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7 Abstract This work plan was written to identify and guide the data collection and analysis needed to evaluate a site tentatively chosen to dispose of treated effluents from the 200 Areas of the Hanford Site (Project W-049H). The plan summarizes currently available information for the candidate site, identifies what additional information is needed, describes the work to collect and analyze the additional information, and estimates the work's cost and duration.

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Site Characterization Work Plan

-- 200 Areas Treated Effluent Disposal Facility -- Project W-049H

J.D. Davis - C.D. Delaney

Synopsis

This work plan was written to identify and guide the data collection and analysis needed to evaluate a site tentatively chosen to dispose of treated effluents from the 200 Areas of the Hanford Site (Project W-049H). If found to be suitable, the site will be used to construct and operate a facility designed to infiltrate the effluent into the land's surface.

This plan summarizes information currently available for the candidate site, identifies what additional information is needed, describes the work to collect and analyze the additional information, and estimates the work's cost and duration. Wells will be drilled to determine the elevation of the water table, the direction and magnitude of the hydraulic gradient, and how the site's stratigraphy influences the hydrology. These wells will also be used to sample the saturated and unsaturated sediments overlying the basalt bedrock and the water of the unconfined aquifer. These samples will be analyzed and the results of the analyses used in numerical simulations of the effects of effluent infiltration at the site.

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Acknowledgments

The authors wish to credit K. A. Lindsey for the information upon which most of Section 2.1 is based. J. W. Lindberg provided the information for Section 2.3. W. J. McMahon made the numerical simulations that form the basis for Section 2.6.

1.0 INTRODUCTION

This report identifies the work needed to evaluate the suitability of the site tentatively selected to construct an infiltration basin [hereafter referred to as the 200 Areas Treated Effluent Disposal Basin (TEDB) of Project W-049H] for disposal of treated effluent from the 200 Areas of the Hanford Site (Figure 1). The evaluation is needed to support the findings of the engineering report required by Washington Administrative Code (WAC) 173-240. The candidate site is bounded by Hanford Site coordinates N40119, N41595, W35726, W37202. First, currently available information that was used to select the candidate site is summarized. Then, the report identifies what additional information is needed. Next are detailed descriptions of the work to collect and analyze the information. Finally, the cost and schedule for completing the site characterization are estimated. Additional details are provided in appendixes and the cited references.

Samples from unsaturated and saturated sediments overlying the basalt bedrock at the site will be retrieved during the drilling of ground water monitoring wells. The wells will be geologically and geophysically logged to provide information on the sediments from the surface to the top of the basalt bedrock. Samples of the sediments encountered will be evaluated to verify that no contaminants are present. Physical testing of samples from the unsaturated zone will provide information on matric potential and relative hydraulic conductivity as a function of volumetric water content.

Depths to the water table will be measured for use in assessing hydraulic gradients. Hydraulic tests will be conducted to determine saturated hydraulic conductivities, transmissivities, and specific yields. Samples of ground water from the unconfined aquifer will be analyzed to assess water quality. Temperature, pH, electrical conductivity, and major cations and anions will be determined.

Based on information obtained from drilling, the site will be described in terms of the effects that the stratigraphy and lithology have on the hydrogeology. This description will be used by a computer-encoded numerical model to simulate the hydrologic effects at the site from the infiltration of treated effluent from the 200 Areas TEDB. Site-specific information obtained for use in the hydrologic simulations will include saturated hydraulic conductivity, transmissivity, saturated and residual volumetric water contents, and van Genuchten curve-fitting parameters "N" and "M." If the site is found to be suitable, a ground water monitoring program using the site characterization wells will be established to provide water quality and hydraulic gradient data on an on-going basis.

1.1 Background

Past waste disposal practices at the Hanford Site included discharge of untreated liquid effluents directly to ponds and trenches that infiltrated the effluents into thick, unconsolidated sediments overlying basalt bedrock. This practice was accepted at the

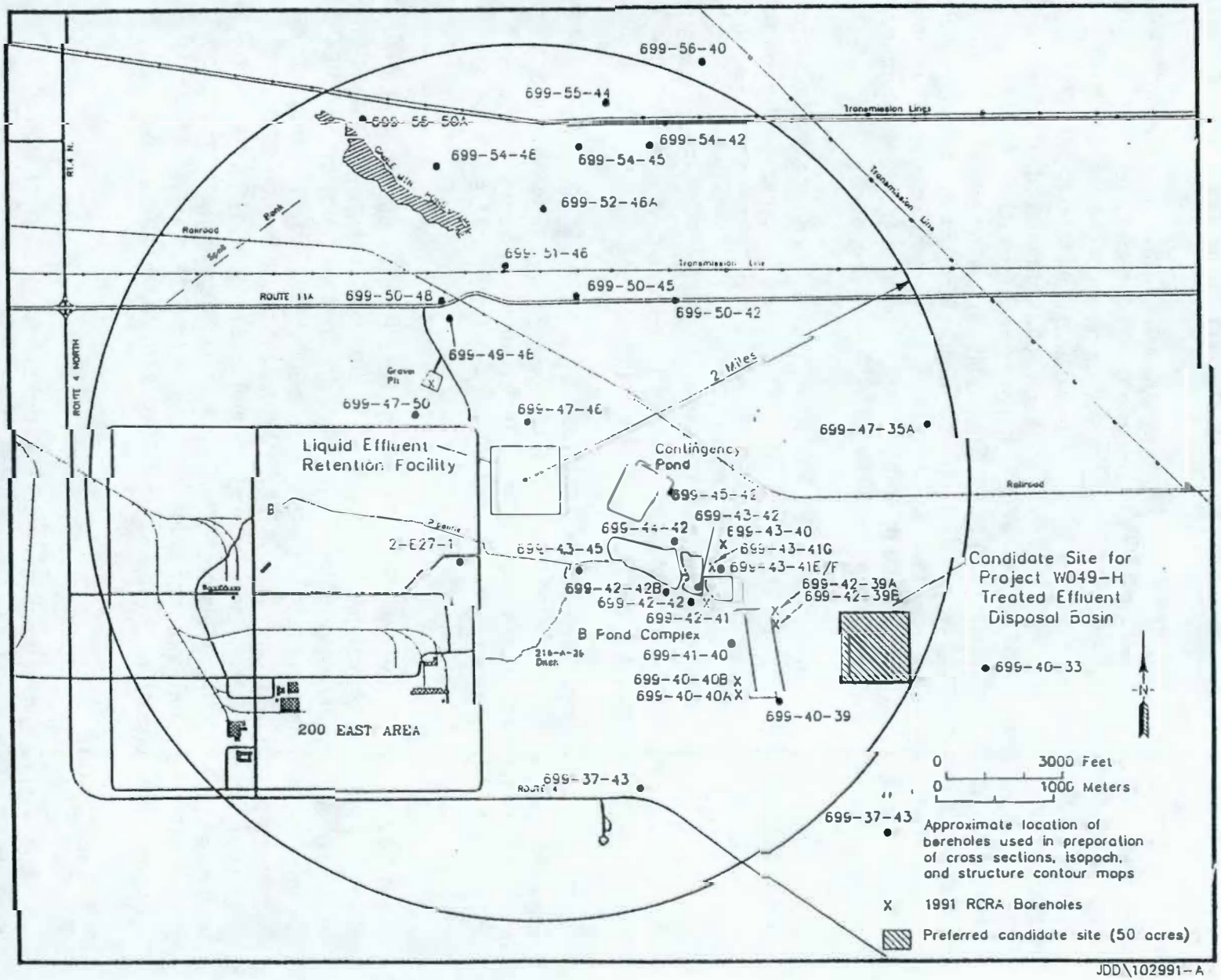


Figure 1. Location of the Preferred Site for Construction of the 200 Areas Treated Effluent Disposal Basin (Davis 1991).

time because the area was isolated from major population centers and had low average annual precipitation, a deep water table, and favorable ion-exchange properties of the sediments.

In March 1987, the U.S. Department of Energy's (DOE) Richland Field Office (RL), published a report (DOE 1987) stating that the DOE would end its discharge of untreated effluents. The *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology et al. 1989a; as amended 1990) established a schedule and performance milestones either to treat the effluents prior to their discharge or to eliminate the discharge. Current plans are for treated effluent to be discharged to the surface of the land via the facility to be constructed by Project W-049H in compliance with Washington State Department of Ecology (Ecology) WAC 173-216 (Ecology 1988), or to the Columbia River in compliance with a *National Pollutant Discharge Elimination System* (NPDES) permit. An engineering report as per WAC 173-240 and a permit application pursuant to WAC 173-216 must be approved by Ecology to obtain a WAC 173-216 permit. Compliance with NEPA has been demonstrated through the preparation of the Hanford Environmental Compliance Environmental Assessment. This document covers impacts from construction and operation of Projects W-049H, C-018H, and L-045H.

Before their discharge, the effluents will be sampled, analyzed, and verified as complying with the WAC 173-200 allowable discharge criteria. The actual compliance limits will be negotiated with Ecology during the definitive design phase of the project and will be part of the permit conditions for the 200 Areas TEDB. No dangerous waste as per WAC 173-303 will be discharged. Data on current ground water quality in the candidate site area is provided in Appendix A.

1.2 Scope of Work Plan

This plan addresses only the work needed to characterize the site tentatively selected for disposal of treated effluent to the land surface. The basis for tentatively selecting the site for disposal of the effluent in this manner is described by Davis (1991). Site selection criteria were developed from guidelines published in DOE-RL Order 4320.2C, *Site Selection* (DOE 1990), and DOE Order 6430.1A, *General Design Criteria* (DOE 1989; Section 200-1, Facility Siting). Identification, evaluation, and ranking of options for disposal of the treated effluent are provided by Bovay Northwest (1992).

The work described by this plan is subject to the requirements of DOE-RL Order 5700.6c, *Quality Assurance* (DOE 1991a). This order establishes broadly applicable quality assurance program requirements. The planned work is also subject to compliance with all quality assurance requirements of the Tri-Party Agreement, as amended (Ecology et al. 1989a). All field activities and laboratory analyses performed as part of this work plan are subject to compliance with the *Quality Assurance Project Plan for RCRA Ground*

Water Monitoring Activities (Jackson 1990). All laboratory analyses of sediments for hydrology-affecting physical properties are to comply with the *Geotechnical Engineering Procedures Manual* (WHC 1990). All numerical analyses of ground water movement are to be compatible with DOE/RL-91-44 (DOE 1991b). The quality assurance plan specific to the scope of this work plan is provided in Appendix B.

1.3 Objective of Work Plan

The objective of this plan is to define and guide work needed to adequately determine the suitability of the site tentatively selected for construction of the 200 Areas TEDB (see Figure 1). To achieve this objective, the work is defined and will be conducted to provide the site characterization information required by WAC 173-240.

1.4 Objective of Site Characterization

The principal objectives of the site characterization work for the 200 Areas TEDB of Project W-049H are to (1) obtain data required to judge the suitability of the candidate site for the 200 Areas TEDB, (2) apply this data to complete the evaluation begun by Davis (1991), and (3) use the information to contribute to the preparation of the WAC 173-240 *Engineering Report* and the WAC 173-216 permit application. These objectives will be accomplished by:

- Evaluating the adequacy of existing data and identifying data deficiencies
- Drilling wells to provide access to additional subsurface data
- Geophysical and geologic logging of the wells
- Sampling and analyzing unsaturated and saturated sediments from the land surface to the bottom of the regionally unconfined aquifer
- Sampling and analyzing ground water of the unconfined aquifer
- Evaluating ground water quality, gradients and flow directions
- Hydraulic testing of the regionally unconfined aquifer.

2.0 RESULTS OF INITIAL SITE EVALUATION

The criteria and process by which a site was tentatively chosen for disposal of Project W049-H treated effluent are identified by Davis (1991). The appendixes of that report describe what was known of the preferred site as of September 1991. The choice of a site

for detailed characterization was based on information derived from nearby wells (see Figure 1) and ground-based surveys of cultural and wildlife resources. This information includes:

- Geology -- Projections of the lithology, stratigraphy, and structural geology
- Hydrology -- Estimates of the hydraulic properties of the sediments; estimates of the current and projected elevations of the water table; regional hydraulic gradient and hydraulic gradient expected in the candidate site area and its immediate vicinity
- Ground Water Quality -- Evaluation of available information on the installation and sampling techniques used in nearby wells and the water quality data from those wells
- Air Quality -- Evaluation of air quality in the area of interest based on currently available information
- Endangered, Threatened, or Sensitive Species -- A ground-based survey of the areas under consideration as candidate sites
- Cultural Resources -- A search of previously published reports on the general areas of interest and a ground-based search for archaeologic sites at the candidate location.

The following sections summarize the information in the appendixes of Davis (1991), cited references, and as-yet-unpublished geologic and hydrologic information from recently drilled RCRA wells (see Figure 1).

2.1 Regional Geology

The Hanford Site is located within the Pasco Basin (Figure 2). The candidate site is in the west-central part of the Hanford Site in south-central Washington. The geologic setting of the Hanford Site has been discussed in Myers et al. (1979), DOE (1988), and Delaney et al. (1991). The following summary is based on the most recently published discussion of Hanford Site geology (Delaney et al. 1991).

2.1.1 Stratigraphy of the Pasco Basin

Basalt of Miocene age (the Columbia River Basalt Group) and late-Miocene-to-Pleistocene age sediments underlie the Hanford Site (Figures 3 and 4). The basalts and sediments thicken toward the center of the Pasco Basin and generally reach their maximum thicknesses in the Cold Creek syncline. Older Cenozoic sedimentary and

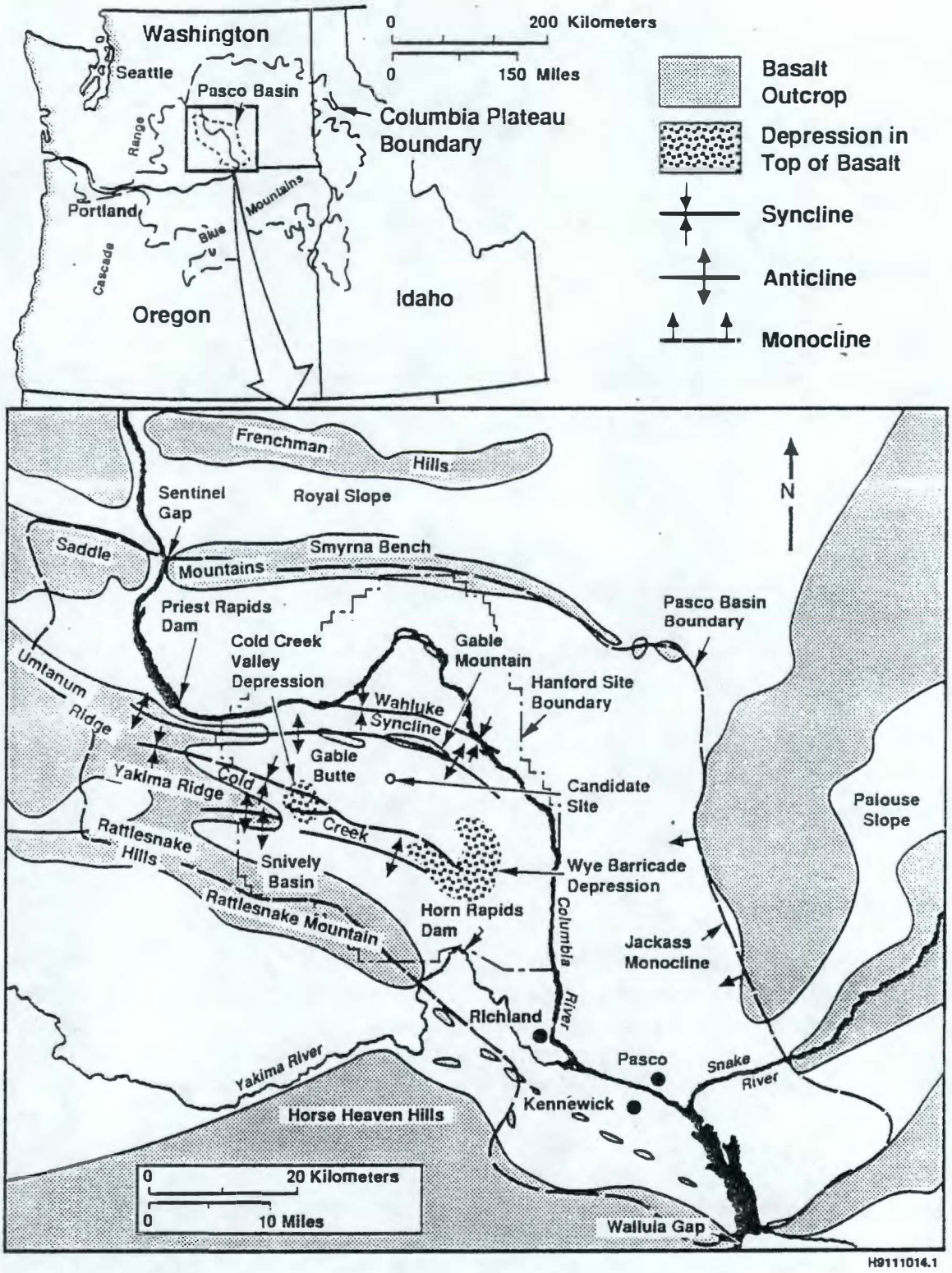
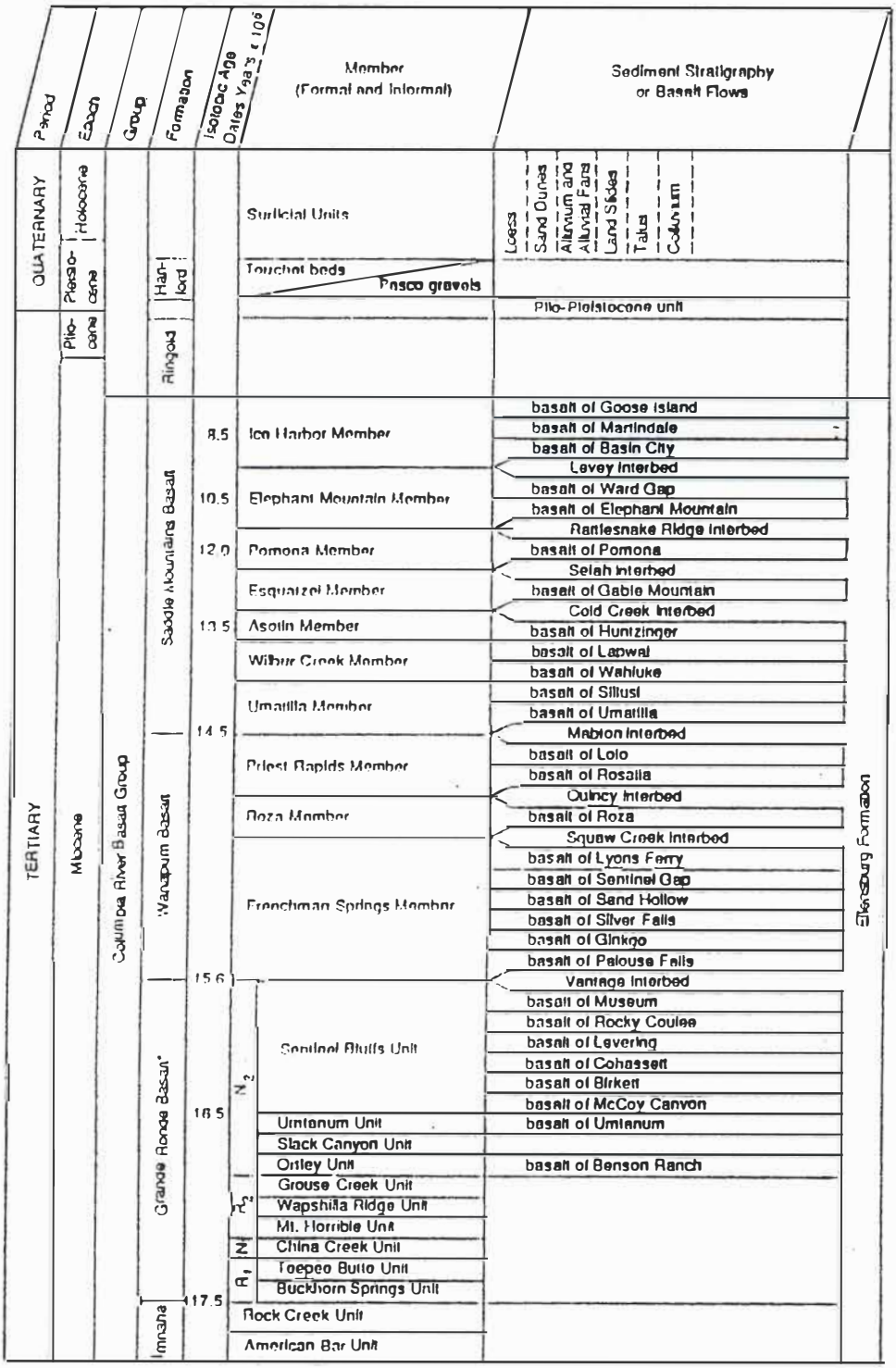


Figure 2. Geologic and Geographic Setting of the Hanford Site.



*The Grande Ronde Basalt consists of at least 120 major basalt flows. Only a few flows have been named.
N_2, R_2, N_1 and R_1 are magnetostratigraphic units.

Figure 3. Generalized Stratigraphy of the Hanford Site.

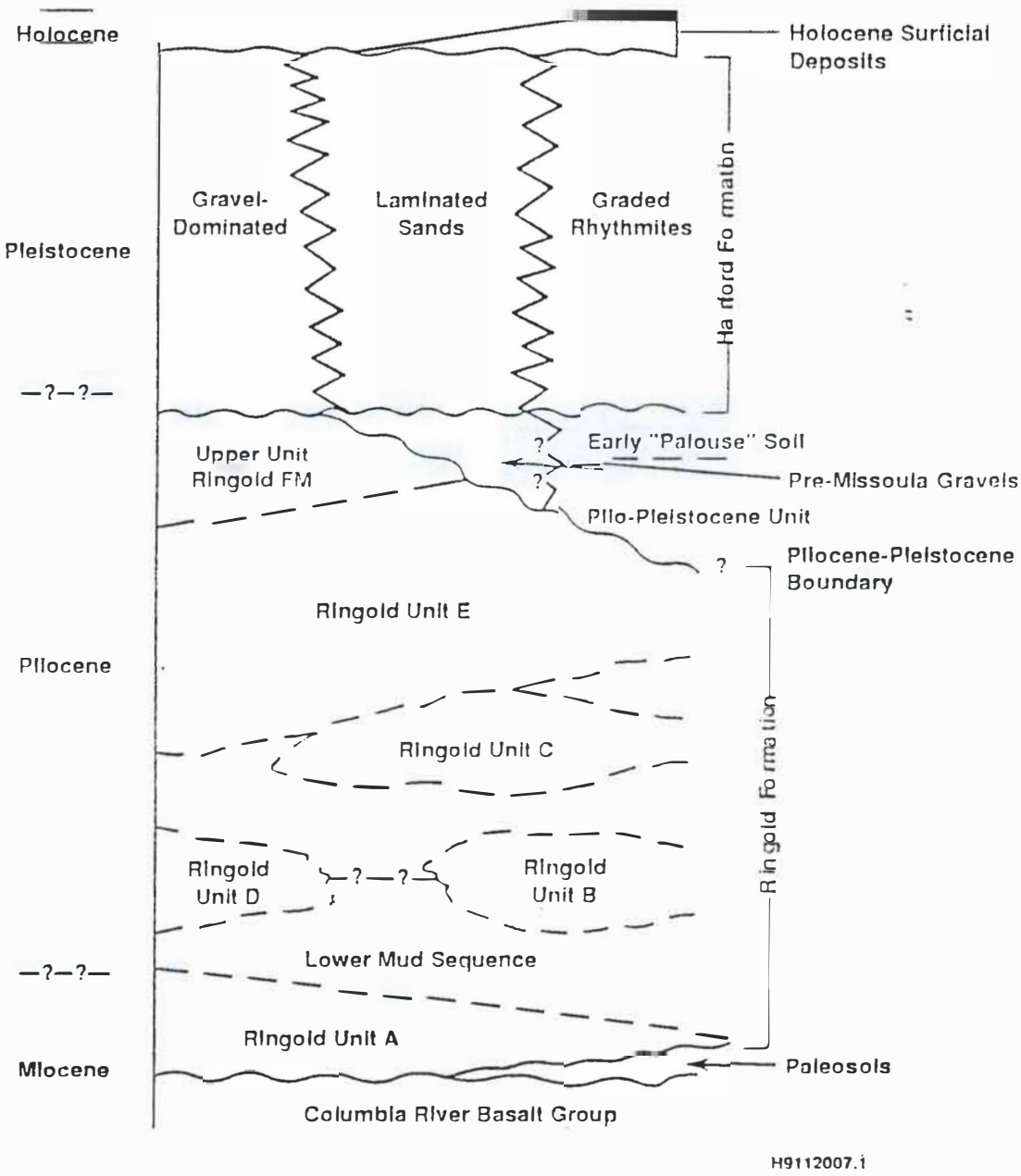


Figure 4. Generalized Stratigraphy of the Sediments above the Basalts at the Hanford Site.

volcaniclastic rocks underlying the basalts are not exposed at the surface in the vicinity of the Hanford Site.

2.1.1.1 Columbia River Basalt Group. The Columbia River Basalt Group is an assemblage of tholeiitic, continental flood basalts of Miocene age. These flows cover an area of more than 63,000 mi^2 (163,700 km^2) in Washington, Oregon, and Idaho, and have an estimated volume of about 40,800 mi^3 (174,356 km^3) (Tolan et al. 1989). Isotopic age determinations indicate that the basalt flows were erupted approximately 17 to 6 Ma, with more than 98% erupted in a 2.5 M-yr period from 17-14.5 Ma (Reidel et al. 1989).

Columbia River basalt flows were erupted from north- to northwest-trending fissures or linear vents in north-central and northeastern Oregon, eastern Washington, and western Idaho (Swanson et al. 1979). The Columbia River Basalt Group is subdivided into five formations (from oldest to youngest): Imnaha Basalt, Picture Gorge Basalt, Grande Ronde Basalt, Wanapum Basalt, and Saddle Mountains Basalt. Of these, only the Picture Gorge Basalt is not known to be present in the Pasco Basin. The Saddle Mountains Basalt (subdivided into the Ice Harbor, Elephant Mountain, Pomona, Esquatzel, Asotin, Wilbur Creek, and Umatilla Members) is generally the uppermost basalt formation throughout the Pasco Basin and the Hanford Site (see Figure 3). The Elephant Mountain Member is the uppermost flow of the Saddle Mountains Basalt in the central part of the Hanford Site. However, the Elephant Mountain Member is not the uppermost unit in the northern part of the 200 Area plateau of the Hanford Site. In parts of this area, the upper basalt flows have been eroded away, exposing the Umatilla Member. In the 300 Area, it is overlain by the Ice Harbor Member. On the anticlinal ridges bounding the Pasco Basin, erosion has locally removed the Saddle Mountains Basalt, exposing the Wanapum and Grand Ronde Basalts.

2.1.1.2 Ellensburg Formation. The Ellensburg Formation consists of all sedimentary units that occur between the basalt flows of the Columbia River Basalt Group in the central part of the Columbia Basin (see Figure 3). Two lithologies generally comprise the Ellensburg Formation, volcaniclastics and siliciclastics (DOE 1988). The volcaniclastics are generally primary, pyroclastic air-fall deposits and reworked epiclastics derived from volcanic terrains west of the Columbia Plateau. The siliciclastics are reworked clastic, plutonic, and metamorphic detritus derived from the Rocky Mountains. At the Hanford Site, the three uppermost units of the Ellensburg Formation are the Levey interbed, the Rattlesnake Ridge interbed, and the Selah interbed. A detailed discussion of the Ellensburg Formation in the Hanford Site area is given by Reidel and Fecht (1981). Smith et al. (1989) discuss age-equivalent units adjacent to the Columbia Plateau.

2.1.1.3 Sediments Overlying the Basalts. The sediments at the Hanford Site (see Figure 4) are up to ~230 m thick in the west-central Cold Creek syncline and pinch out against the Saddle Mountains, Gable Mountain/Umtanum Ridge, Yakima Ridge, and Rattlesnake Hills anticlines (see Figure 2). The sediments are dominated by the laterally

extensive Ringold and Hanford formations. Locally occurring strata that separate the Ringold Formation from the Hanford formation are assigned to the informally defined Plio-Pleistocene unit, early "Palouse" soil, and pre-Missoula gravels.

Ringold Formation - The Ringold Formation at the Hanford Site is up to 185 m thick in the deepest part of the Cold Creek syncline south of the 200 West Area and 170 m thick in the western Wahluke syncline near the 100 B Area. It is generally absent in the northern and northeastern parts of the 200 East Area and adjacent areas to the north. The Ringold Formation is of late Miocene to Pliocene age (Fecht et al. 1987, DOE 1988).

Recent studies of the Ringold Formation (Lindsey and Gaylord 1989, Lindsey 1991) indicate that it is best described and subdivided on the basis of lithofacies associations and their distributions. Facies associations in the Ringold Formation are defined by lithology, petrology, stratification, and pedogenic alteration. These facies are fluvial gravel, fluvial sand, overbank deposits, lacustrine deposits, and alluvial fans.

1. *Fluvial gravel* - Clast-supported granule to cobble gravel with a sandy matrix dominates the facies. Interstratified sands and muds are also present. Clast lithology is variable, with basalt, quartzite, porphyritic volcanics, and greenstone the most common. Silicic plutonic rocks, gneisses, and volcanic breccias are also present. Sands in this facies are generally quartzo-feldspathic; basalt sand is generally between 5% and 25%. Low-angle to planar stratification, massive bedding, wide, shallow channels, and large-scale cross-bedding are evident. This facies was deposited in wide, shallow, shifting, braided fluvial channels.

2. *Fluvial sand* - Cross-bedded, laminated, quartzo-feldspathic sands dominate this facies. This facies usually contains <15% basalt, although basalt contents as high as 50% can occur. Interstratified lithologies consist of lenticular sands and clays up to 3 m thick and gravels <0.5 m thick. Sands <1 m thick that become more fine-grained upwards are common in the facies. The facies was deposited in wide, shallow channels.

3. *Overbank deposits* - This facies is dominated by laminated to massive silt, silty, fine-grained sand, and paleosols containing variable amounts of pedogenic calcium carbonate. Overbank deposits occur as thin (<0.5 to 2 m), lenticular interbeds in the fluvial gravel and fluvial sand facies and as thick (up to 10 m), laterally continuous sequences. These sediments record deposition in areas that are proximal to distal from flood plain levees.

4. *Lacustrine deposits* - This facies is characterized by plane-laminated to massive clay with thin silt and silty sand interbeds that locally display soft-sediment deformation. The lacustrine deposits commonly are <1 m to 10 m thick and become more coarse-grained upwards. Sediments comprising this facies were

deposited in a lake under stagnant- to deltaic-water conditions.

5. *Alluvial fan* - Massive to crudely stratified, weathered to unweathered basalt detritus dominates this facies. These basaltic deposits generally are found at the periphery of the Pasco Basin. Deposition occurred by debris flows in alluvial fans, and in side streams draining into the Pasco Basin.

The lower half of the Ringold Formation contains five distinguishable stratigraphic intervals dominated by fluvial gravels. These gravels, designated units A, B, C, D, and E (see Figure 4), are separated by deposits typical of the overbank and lacustrine facies associations (Lindsey 1991). The lowest of the fine-grained sequences overlying unit A is termed the lower mud sequence (see Figure 4). The uppermost gravel unit, unit E, grades upwards into interbedded fluvial sand and overbank deposits that, in turn, are overlain by lacustrine-dominated sediments.

Fluvial gravel units A and E correspond to the lower basal and middle Ringold units (DOE 1988), respectively. Gravel units B, C, and D do not correlate to any previously defined units (Lindsey 1991). The lower mud sequence corresponds to the upper basal unit and lower Ringold units as defined by DOE (1988). The upper basal and lower Ringold units are not differentiated in this work plan. The sequence of fluvial sands, overbank deposits, and lacustrine sediments overlying unit E corresponds to the upper Ringold unit, as originally defined by Newcomb (1958) at the White Bluffs in the eastern Pasco Basin.

Plio-Pleistocene unit - The Plio-Pleistocene unit is laterally discontinuous, up to 25-m thick, and subdivided into two facies: (1) side-stream alluvium and (2) calcic paleosol (Bjornstad 1984, DOE 1988). The calcic paleosol facies consists of massive, calcium carbonate-cemented (caliche) silt, sand, and gravel with interbedded caliche-rich and caliche-poor silts and sands. The caliche is moderately to highly fractured. Weathered and unweathered basaltic gravels dominate the detritus of the side-stream alluvium facies. The Plio-Pleistocene unit appears to correlate to side-stream alluvial and pedogenic deposits at the periphery of the Pasco Basin. These side-stream alluvial and pedogenic deposits are inferred to be of late Pliocene to early Pleistocene age based on their stratigraphic position and the magnetic polarity of inter-fingering loess. The Plio-Pleistocene unit unconformably overlies the Ringold Formation in the western Cold Creek syncline in the vicinity of the 200 West Area (see Figure 4) (DOE 1988).

Pre-Missoula gravels - Deposits typical of the pre-Missoula gravels (PSPL 1982) are dominated by quartzose to gneissic, clast-supported pebble to cobble gravel with a quartzo-feldspathic sand matrix. The pre-Missoula gravels occur in the east-central Cold Creek syncline and at the east end of the Gable Mountain anticline, east and south of the 200 East Area. The gravels are up to 25m thick, contain less basalt than the underlying Ringold gravels and overlying Hanford formation, commonly have a distinctive white or

bleached color, and sharply truncate underlying strata. The nature of the contact between the pre-Missoula gravels and the overlying Hanford formation is not clear. It is additionally unclear whether the pre-Missoula gravels overlie, or interfinger with, the early "Palouse" soil and Plio-Pleistocene unit (see Figure 4). Magnetic polarity data indicate that the unit is no younger than early Pleistocene (>0.74 Ma).

Early "Palouse" soil - The early "Palouse" soil consists of up to 20 m of massive, brownish-yellow, compact, loess-like silt and minor fine-grained sand (Tallman et al. 1979, 1981; DOE 1988). Granules consisting primarily of basalt occur in this unit. These deposits overlie the Plio-Pleistocene unit (see Figure 4) in the western Cold Creek syncline near the 200 West Area. The unit is differentiated from overlying graded rhythmites of the Hanford formation by a higher content of calcium carbonate, massive structure in core samples, and high natural-gamma response in geophysical logs (DOE 1988). The upper contact of the unit is poorly defined; the lithology may grade upwards into the silty sediments commonly found in the lower part of the Hanford formation. Based on a predominantly reversed polarity, the unit is inferred to be early Pleistocene in age.

Hanford formation - The Hanford formation consists of pebble to boulder gravel, fine- to coarse-grained sand, and silt. These deposits are divided into three facies: (1) gravel-dominated, (2) sand-dominated, and (3) slackwater. These facies are termed coarse-grained, plane-laminated, and rhythmite, respectively (Bjornstad et al. 1987; Bjornstad 1984). The slackwater deposits have also been termed the "Touchet Beds." The pebble to boulder gravel has also been called the "Pasco Gravels." The Hanford formation is thickest in the vicinity of the 200 West and 200 East Areas, where it is up to 65 m thick. The Hanford formation is absent at elevations of 385 m above sea level, the highest level of cataclysmic flooding in the Pasco Basin (Bjornstad et al. 1987).

The gravel-dominated facies generally consists of coarse-grained basaltic sand and granule to boulder gravel. These deposits have massive bedding, plane- to low-angle bedding, and large-scale planar cross-bedding. These gravels usually are matrix-poor and have an open-framework texture. Lenticular sand and silt beds are interstratified throughout the facies. The gravel generally consists dominantly of basalt (50% to 80%), with subordinate reworked Ringold and Plio-Pleistocene granite, quartzite, and gneiss. The gravel facies dominates the Hanford formation in the 100 Areas north of Gable Mountain, the northern part of the 200 East and West Areas, and the eastern part of the Hanford Site, including the 300 Area. The gravel-dominated facies was deposited by high-energy flood waters in, or immediately adjacent to, the main flood channels.

The sand-dominated facies consists of fine- to coarse-grained sand and granule-sized gravel with plane lamination and bedding, and less commonly, plane bedding and channel-fill sequences. These sands may contain small pebbles and reworked clasts in addition to pebble-gravel interbeds and silty interbeds <1 m thick. The silt content of these sands is variable, but where it is low, a well-sorted and open-framework texture is

common. These sands typically are basaltic and are black, grey, or salt-and-pepper in appearance. This facies is most common in the central Cold Creek Syncline, in the central to southern parts of the 200 East and 200 West Areas, and in the vicinity of the Washington Public Power Supply facilities. The laminated sand facies was deposited adjacent to the main flood channels by water spilled over the channel banks during the waning stages of flooding. The facies is transitional between the gravel-dominated facies and the rhythmite facies.

The slackwater facies consists of thinly bedded, plane-laminated and ripple cross-laminated silt and fine- to coarse-grained sands that commonly consist of normally graded rhythmites a few centimeters to several tens of centimeters thick. This facies occurs throughout the central, southern, and western Cold Creek syncline within and south of the 200 East and 200 West Areas. These sediments were deposited by stagnant waters in flooded areas (DOE 1988).

Holocene surficial deposits - These sediments consist of silt, sand, and gravel that form a thin (<10 m thick) veneer over much of the Hanford Site. These sediments were deposited by a combination of aeolian and alluvial processes.

2.1.2 Structural Geology

The Columbia Plateau is informally subdivided into three structural provinces: the Blue Mountains, Palouse, and Yakima Fold Belt (Reidel et al. 1989) (Figure 5). The Hanford Site is near the juncture of the Yakima Fold Belt and the Palouse subprovinces. Unlike physiographic provinces, which are defined on the basis of a commonality of landforms, these structural subprovinces are delineated based on their commonality of geologic structure.

The Yakima Fold Belt is characterized by a series of segmented, narrow, asymmetric, east-west trending anticlines with wave lengths between 5 and 32 km, and amplitudes commonly <1 km (Reidel et al. 1989). The northern limbs of these anticlines generally dip steeply to the north, are vertical, or even overturned. The southern limbs generally dip at relatively shallow angles to the south. Thrust or high-angle reverse faults with fault planes that generally parallel fold-axis trends commonly occur on the north sides of the anticlines. The amount of vertical stratigraphic offset associated with these faults varies but commonly exceeds hundreds of meters. The anticlinal ridges are separated by broad synclines or basins that, in many cases, contain thick accumulations of Neogene- to Quaternary-age sediments. The Pasco Basin is one of the larger structural basins in the fold belt.

The Pasco Basin, in which the Hanford Site is located, is a structural depression bounded to the north by the Saddle Mountains anticline, to the west by the Umtanum Ridge, Yakima Ridge, and Rattlesnake Hills anticlines, and to the south by the Rattlesnake

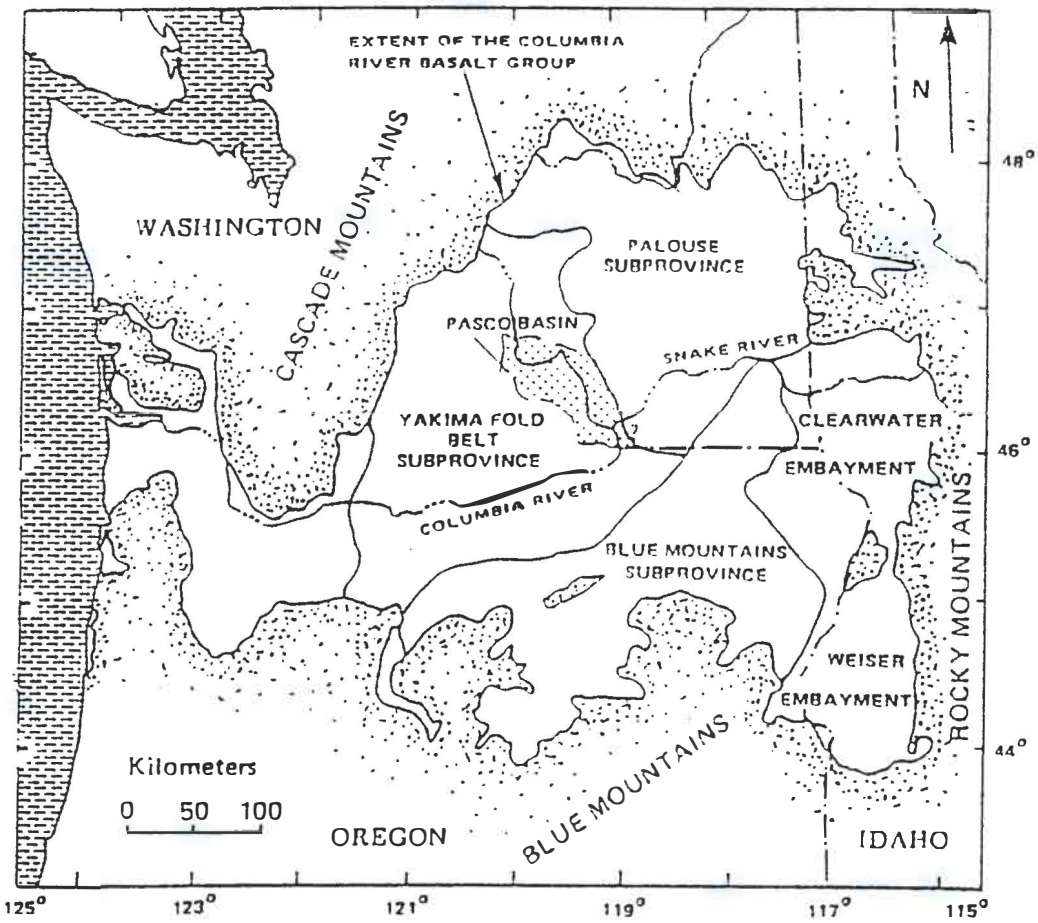


Figure 5. Major Structural Subdivisions of the Columbia Plateau (from Reidel et al. 1989).

Mountain anticline. The Palouse slope, a west-dipping monocline, bounds the Pasco Basin to the east (see Figure 2).

The Pasco Basin is divided by the Gable Mountain anticline (the eastern-most extension of the Umtanum Ridge anticline) into the Wahluke syncline to the north and the Cold Creek syncline to the south (see Figure 2). Both synclines are asymmetric and relatively flat-bottomed structures. The north limbs of both synclines dip gently (~ 5 degrees) to the south; the south limbs deep steeply to the north. The deepest parts of the Cold Creek syncline, the Wye Barricade depression and the Cold Creek depression, are respectively ~7.5 mi (~2.3 km) southeast of the 200 Areas and immediately west-southwest of the 200 West Area. The deepest part of the Wahluke syncline is north of the 200 East and West Areas.

2.2 Regional Hydrology

Four hydrogeologic units comprise the multi-aquifer system of the Pasco Basin. The system consists of the upper three formations of the Columbia River Basalt Group (Grande Ronde Basalt, Wanapum Basalt, and Saddle Mountains Basalt) and the sediments overlying the basalts (see Figure 3). The basalts are tholeiitic flood basalts of Miocene age. Confined aquifers occur within some of the flow tops and bottoms and in sediments of the Ellensburg Formation. The Ellensburg Formation occurs between basalt flows in the upper part of the basaltic sequence. The principal water-bearing parts of the basalt flows are networks of interconnected vesicles and fractures in the flow tops and bottoms (DOE 1988).

A regionally unconfined aquifer occurs within the late Miocene- to Pleistocene-age fluvial, lacustrine, and glaciofluvial sediments of the Hanford and Ringold formations that overlie the basalts. The water table is at depths ranging from the surface at West Lake and the Columbia and Yakima Rivers to more than 350 ft (107 m) below the surface in the center of the Hanford Site.

Local recharge to some of the relatively shallow confined aquifers results from infiltration of precipitation and runoff at the margins of the Pasco Basin, and in areas of artificial recharge where there is a downward gradient from the regionally unconfined aquifer to the uppermost confined aquifer. Regional recharge of the deep confined aquifers is inferred to result from inter-basin ground water movement originating northeast and northwest of the Pasco Basin in areas where the Wanapum and Grande Ronde Basalts are extensively exposed at the surface (DOE 1988). Discharge of ground water from the relatively shallow confined aquifers is probably to overlying aquifers and to the Columbia River. The locations of discharge from the deeper confined aquifers are uncertain, but are inferred to be south to southeast of the Hanford Site (DOE 1988).

Erosional "windows" through the relatively impervious interiors of basalt flows (e.g., through the Elephant Mountain Member of the Saddle Mountains Basalt) permit direct interconnection between the regionally unconfined aquifer and the uppermost confined aquifer. Graham et al. (1984) reported that contamination was present in the uppermost confined aquifer (the Rattlesnake Ridge interbed) south and east of the former site of the Gable Mountain Pond. Their evaluation of the hydraulic relationships between the Rattlesnake Ridge interbed aquifer and the overlying unconfined aquifer suggests an area of potential inter-aquifer communication beneath the northeast corner of the 200 East Area. In the Gable Gap area, erosional windows have exposed the Umatilla Member and younger basalts and interbeds (Figure 15, page 48, Graham et al. 1984). Below the Rattlesnake Ridge interbed, no contamination of confined aquifers is known.

Recent studies of the Ringold Formation in the Pasco Basin and Hanford Site have resulted in recognition of five distinct lithofacies: (1) fluvial gravel, (2) fluvial sand, (3) overbank deposits consisting of silt and sand, (4) lacustrine muds, and (5) basaltic debris-flow gravels (see Figure 4) (Lindsey and Gaylord 1989; Lindsey 1991). The lower half of the Ringold Formation contains five distinctive stratigraphic intervals dominated by fluvial gravels. These gravels are separated by intervals containing finer grained sediments typical of overbank and lacustrine deposition.

The water table beneath the Hanford Site is generally within fluvially deposited gravels near the top of the Ringold Formation. In the northern and eastern Pasco Basin, the water table is generally within the Hanford formation. Hydraulic conductivities of the Hanford formation typically range from 2,000 to 10,000 ft/d (610 to 3048 m/d) and are much larger than the 610 to 3,050 ft/d (186 to 930 m/d) hydraulic conductivities of the gravel facies of the Ringold Formation (Graham et al. 1981).

The base of the unconfined aquifer is generally defined as the top of the uppermost basalt flow. However, fine-grained overbank and lacustrine sediments in the Ringold Formation locally may confine ground water within the gravels. The unconfined aquifer is laterally bounded by anticlinal ridges of basalt. In the center of the Pasco Basin, the unconfined aquifer is more than 500 ft (152 m) thick.

Sources of natural recharge to the unconfined aquifer are rainfall and runoff from higher elevations bordering the basin, water infiltration from small ephemeral streams such as Cold Creek and Dry Creek, and river water from influent sections of the Columbia and Yakima Rivers. The movement of precipitation through the unsaturated zone has been studied at several locations on the Hanford Site (Gee 1987; Routson and Johnson 1990; Rockhold et al. 1990). Gee (1987) and Routson and Johnson (1990) concluded that precipitation moves no deeper than the root zone in the 200 Areas, where the sediments are well stratified and texturally varied. However, Rockhold et al. (1990) concluded that precipitation has infiltrated to depths below the root zone in the 300 Area, where the sediments are coarse-textured and precipitation has been above normal.

Artificial recharge of the regionally unconfined aquifer is from the disposal of large volumes of effluent, mostly within the 200 Areas of the Hanford Site, and from extensive irrigated agriculture near the site's boundaries. Artificial recharge to the regionally unconfined aquifer within the Hanford Site has been estimated by Graham et al. (1981) to be10 times natural recharge. The major sources of artificial recharge in the 200 Areas have been three effluent discharge ponds: U Pond, Gable Mountain Pond, and B Pond (Figure 6). The U Pond and Gable Mountain Pond were decommissioned in 1984 and 1987, respectively. Part of the B Pond complex is scheduled for closure in 1995.

Effluent disposal at the Hanford Site has appreciably altered hydraulic gradients and flow directions. Comparison of the water table beneath the Hanford Site in 1944 (Figure 7) with June 1989 (Figure 8) indicates that the direction of regional ground water flow was originally towards the east; the natural hydraulic gradient was on the order of 1 ft/1,000 ft (0.3 m/305 m) in the 200 West Area. Currently, the regional hydraulic gradient is interrupted by the water table mounds in the 200 Areas and ground water locally flows to the north between Gable Butte and Gable Mountain (Figure 9).

2.3 Candidate Site Geology

Because outcrops of subsurface strata are absent in vicinity of the candidate site, the best source of geologic data are wells. Unfortunately, no wells are adjacent to the candidate site. The nearest well (699-42-39B) is more than 2,300 ft (700 m) to the west, near C lobe of the B Pond complex (Figure 10). However, because of its relative proximity to the candidate site, this well and well 699-40-33C, located ~2,400 ft (732 m) east of the candidate site, were used with three other wells to predict the stratigraphy at the site.

The location of the geologic cross section based on data from these five wells is shown in Figure 10; the cross section is Figure 11. As shown in Figure 10, the southeast end of the cross section intersects the candidate site. The northwest end intersects the A, B, and C lobes of the B Pond complex. Three of the wells were drilled sufficiently deep to completely penetrate the Ringold Formation. The other two wells only partially penetrate the Ringold Formation but are included because of their proximity to the candidate site.

2.3.1 Stratigraphy

Listed in ascending order, the sediments at the candidate site that are projected to be above the Elephant Mountain Member of the Saddle Mountains Basalt are as follows:

- Ringold Formation -- Unit A; Lower mud sequence (each ~70 ft; ~21 m)
- Undifferentiated Hanford formation (~120 ft; ~37 m).

Details of the local stratigraphy below the Ringold formation are unknown because wells in the vicinity of the candidate site do not penetrate more than a few feet of Columbia

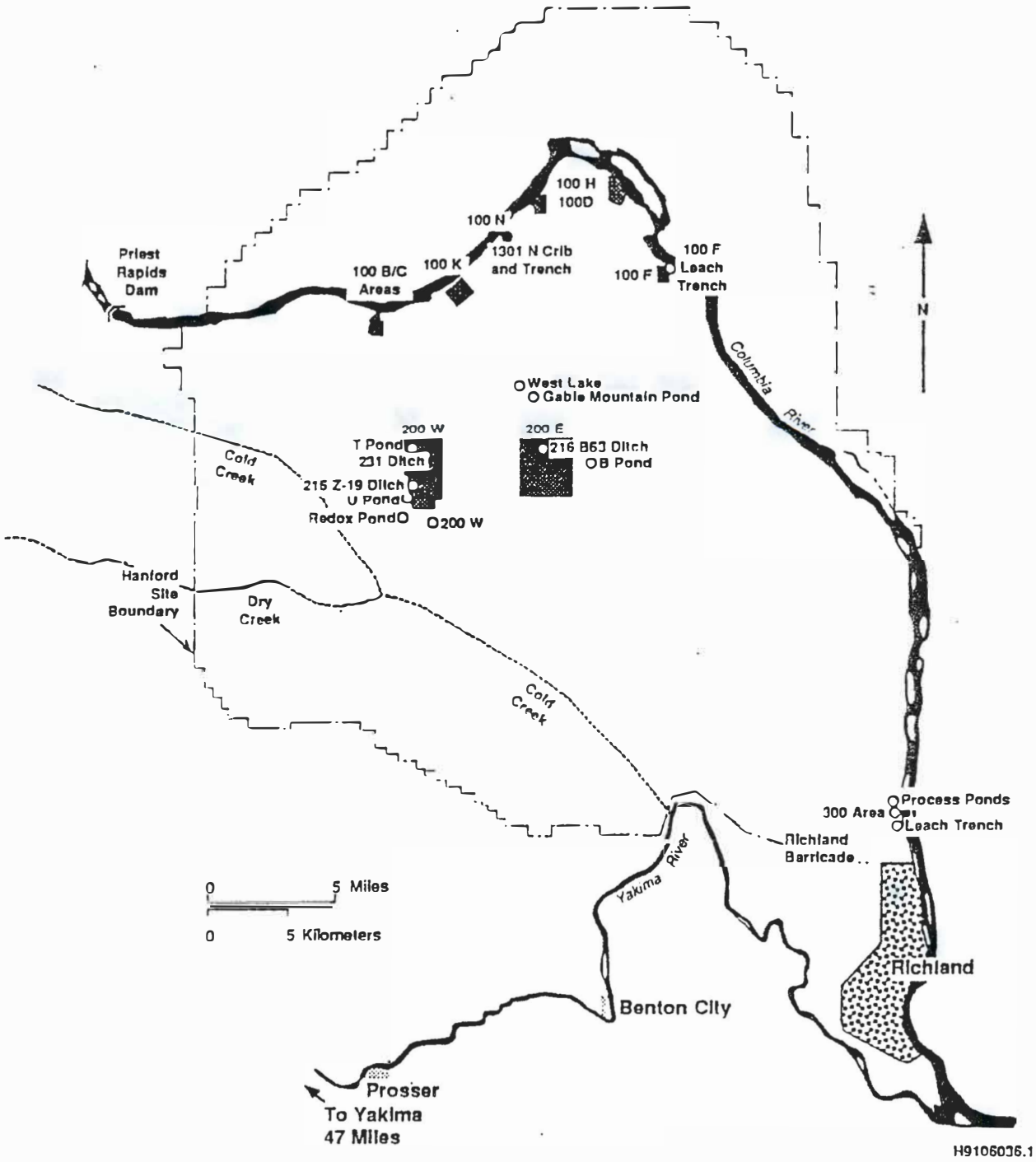


Figure 6. Location of Effluent Disposal Ponds on the Hanford Site.

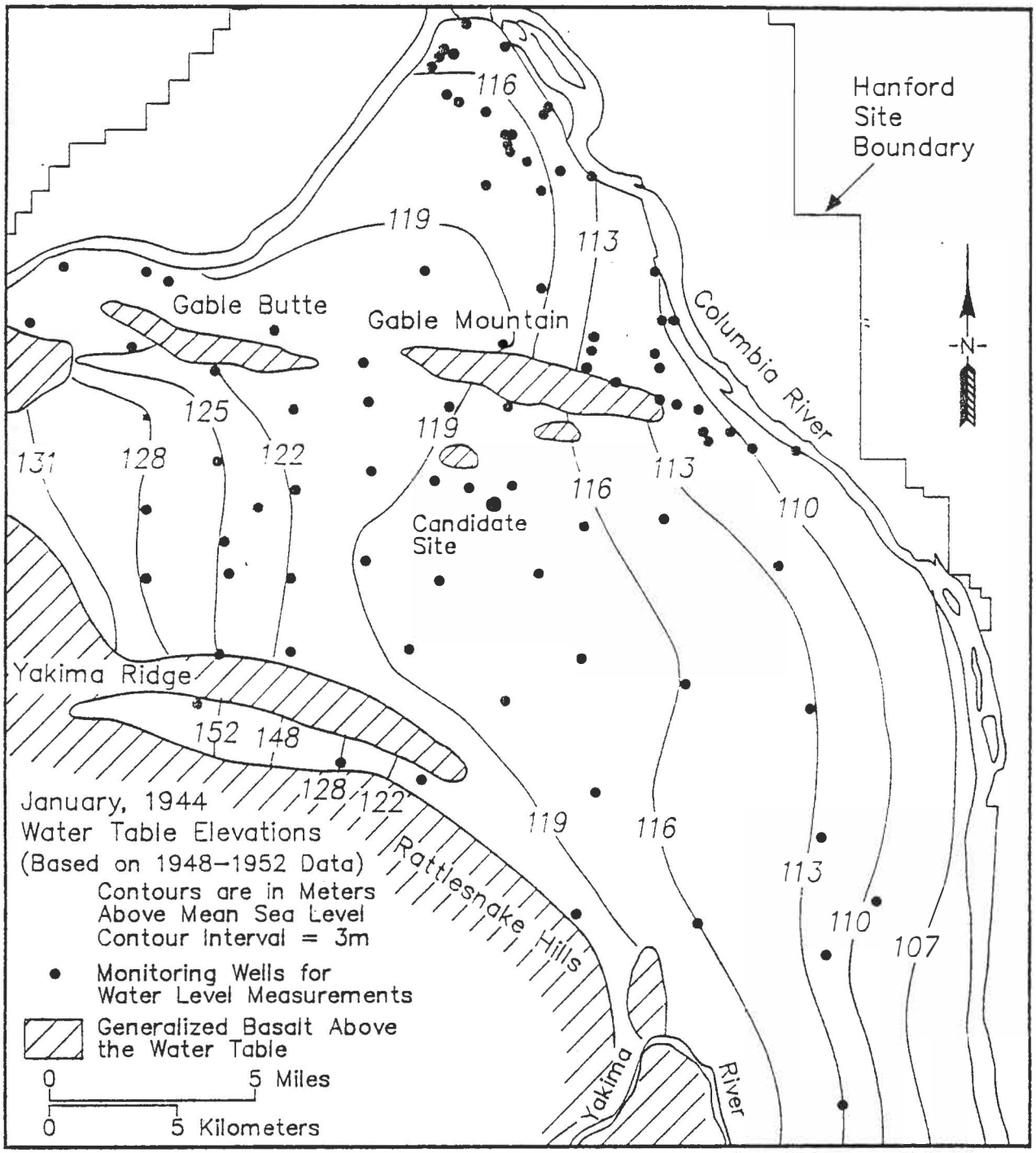


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Figure 7. Map of the Hanford Site Water Table in 1944.

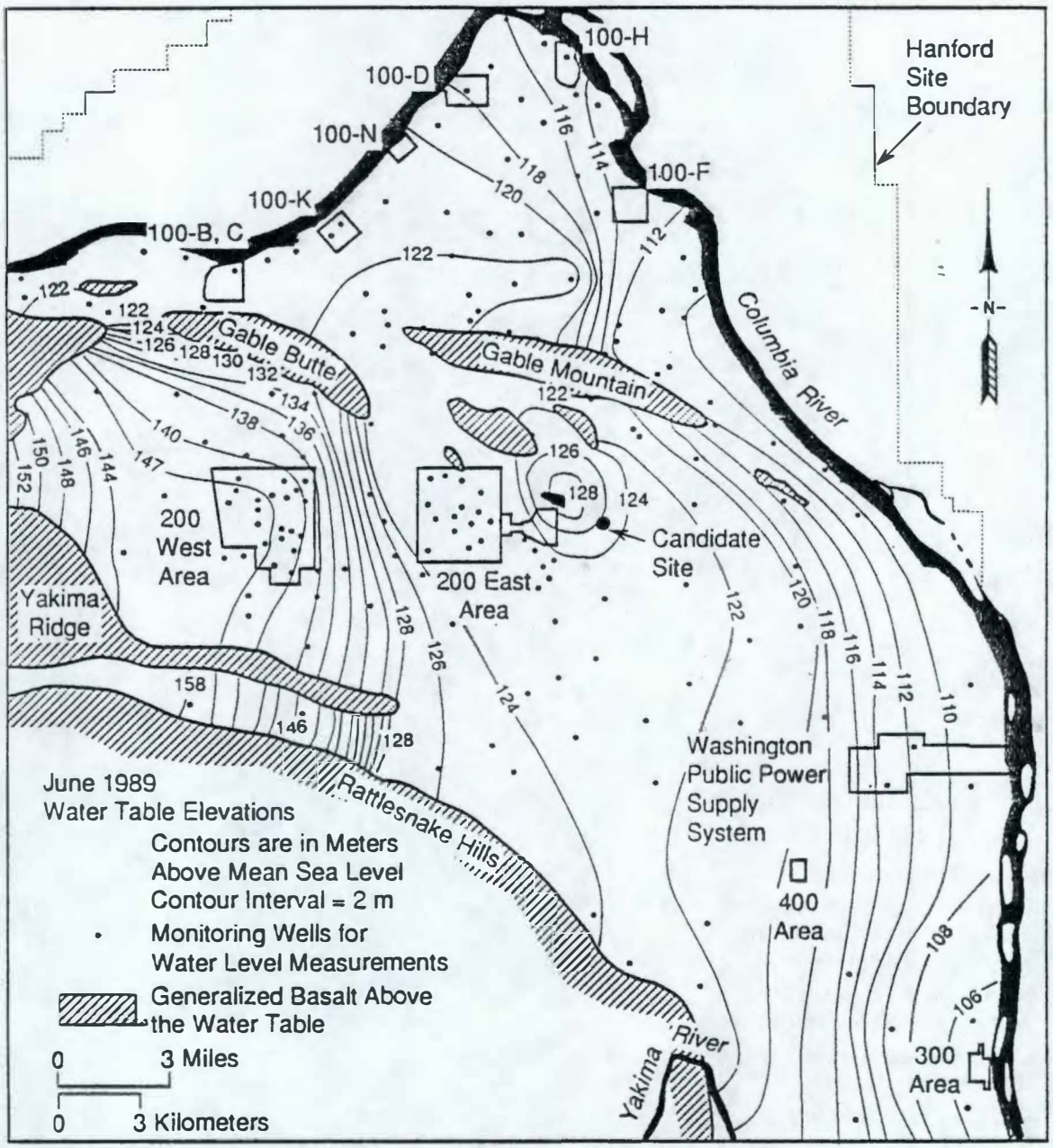
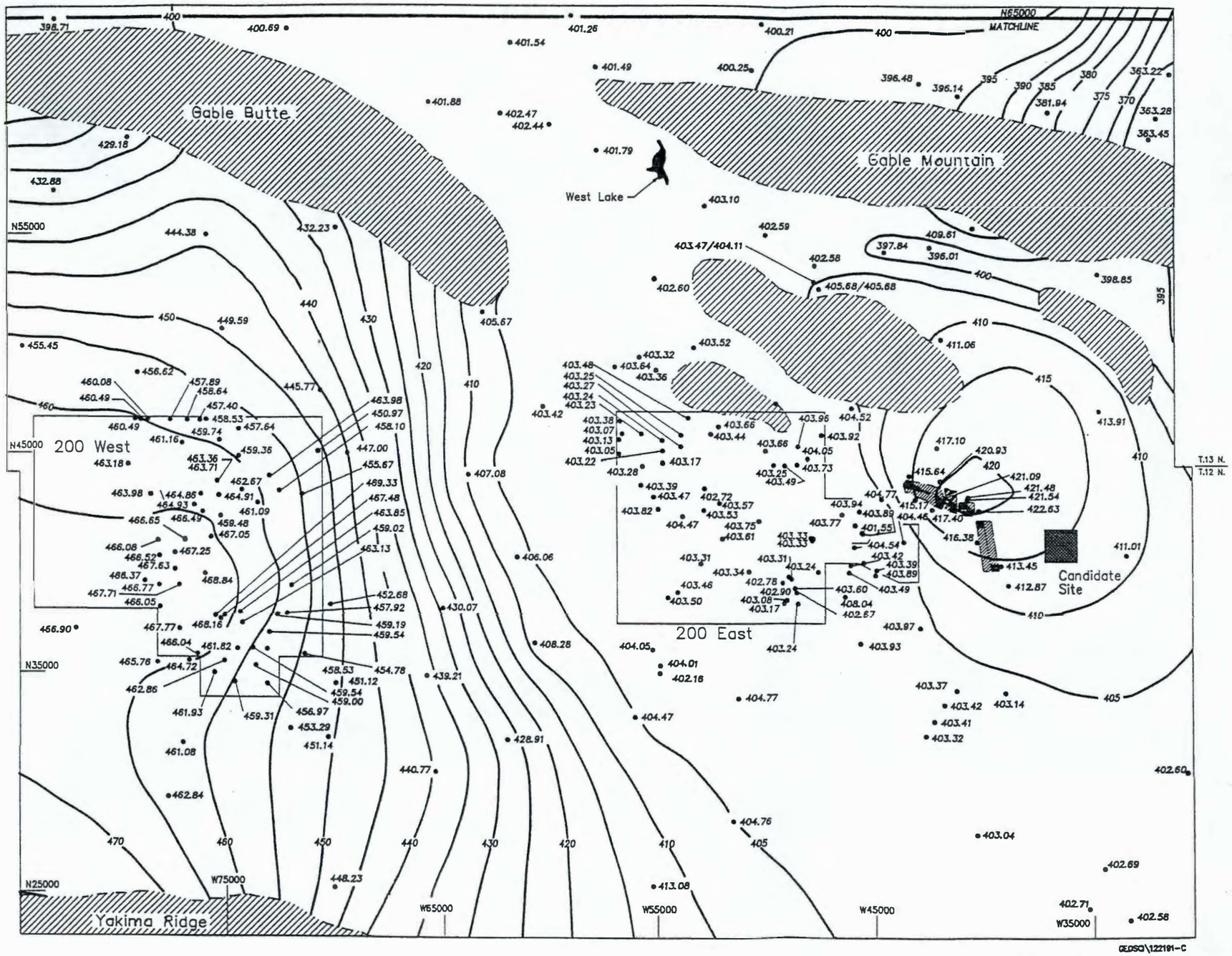


Figure 8. Map of the Hanford Site Water Table in June 1989.



200 Areas Water Table Elevation June 1991

411.49 Water table elevation (feet above mean sea level)

410 Water table contours in feet above mean sea level Contour interval ~ 5 ft

Ponds

Areas where the basalt surface is generally above the water table

The 200 Areas water table elevation map has been prepared by the Geosciences Group, Environmental Division, of Westinghouse Hanford Company.

Note: To convert to metric, multiply elevation (ft) by 0.3048 to obtain elevation (m).

From: Kasza, et al., 1991

0 1 Mile

0 1 Kilometer

-N-

Figure 9. Water Table in the 200 Areas in December 1990 (Kasza et al. 1991).

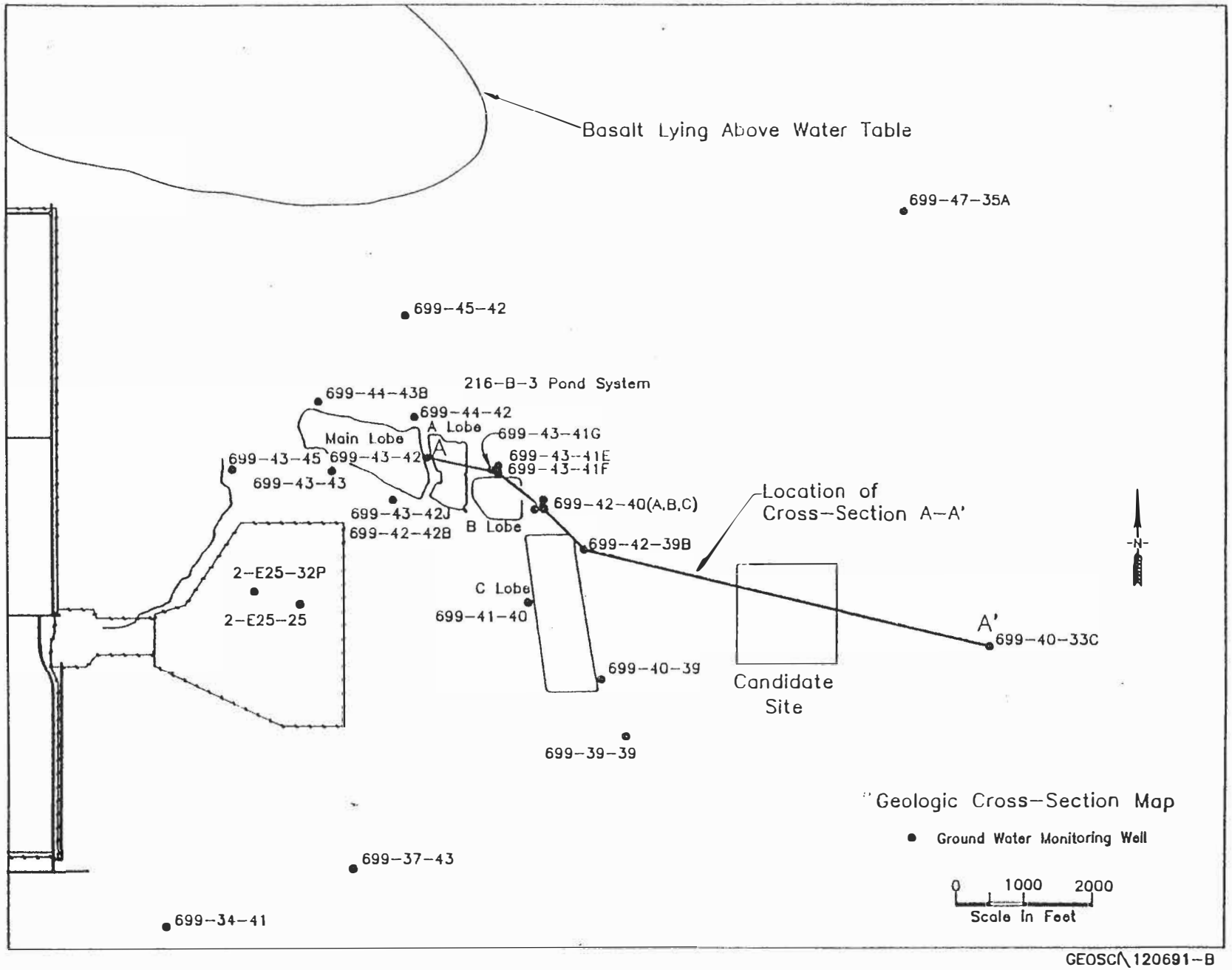


Figure 10. Location of Geologic Cross Section A-A'.

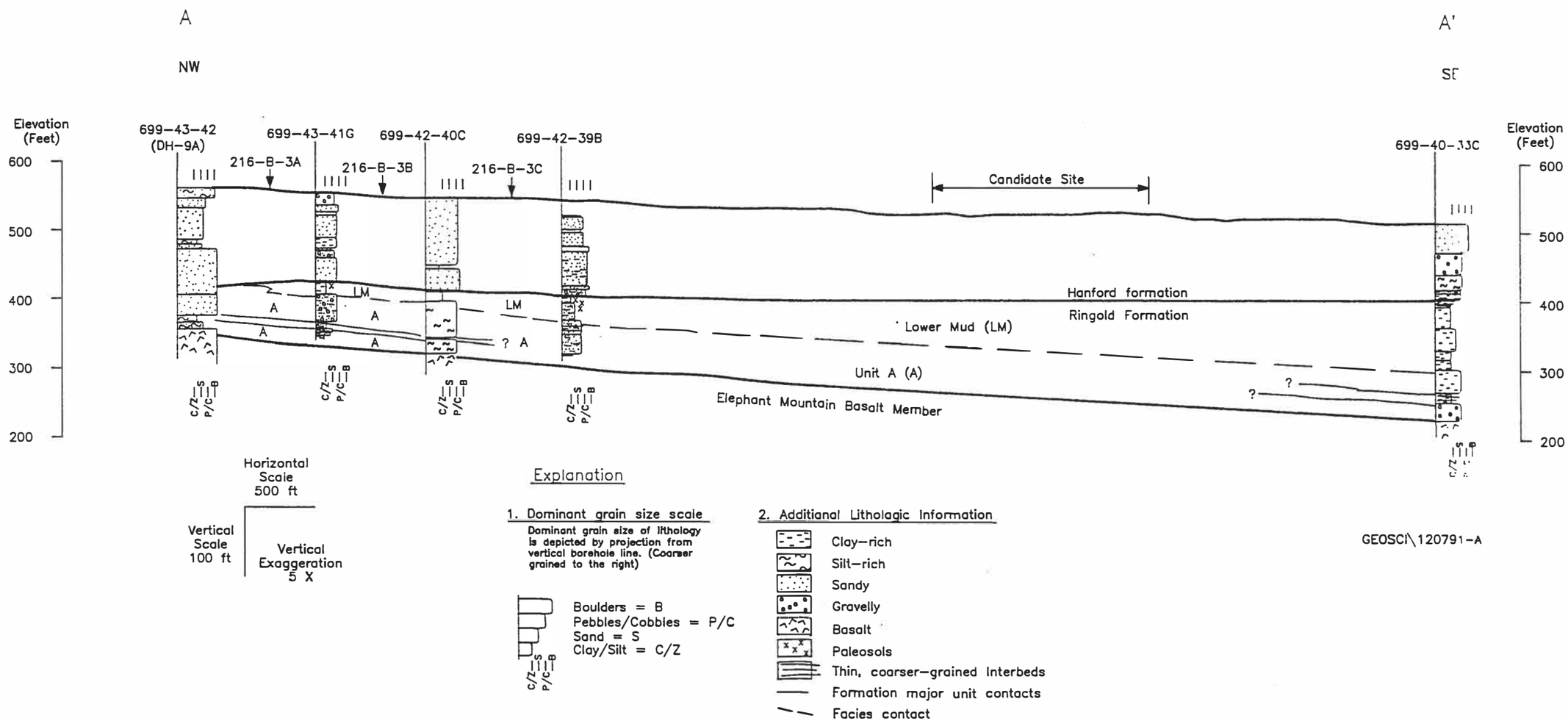


Figure 11. Geologic Cross Section A-A'.

River Basalt. However, the inference based on the regional stratigraphy (see Section 2.1) is that the Elephant Mountain Member is ~75 to 100 ft (~23 m to 30 m) thick and the underlying Rattlesnake Ridge interbed is ~57 ft (~17 m) thick.

2.3.1.1 Ringold Formation -- Unit A. The A unit of the Ringold Formation is locally composed of ~70 ft (~21 m) of sandy gravel of fluvial origin. The gravel is generally clast-supported with a sandy or muddy matrix. However, thin beds of silt or sand are occasionally interbedded with gravel, as observed in wells 699-43-42, 699-43-41G, and 699-42-40C (see Figure 11).

Unit A grades upward into the overlying lower mud sequence. The upper contact of unit A is characterized by beds of sandy or muddy gravel that, with increasing frequency in an upward direction, are interbedded with mud until the unit becomes composed predominantly of mud (i.e., grades into the lower mud sequence).

2.3.1.2 Ringold Formation -- Lower Mud Sequence. The lower mud sequence is ~70 ft (~21 m) thick and commonly is composed of overbank and lacustrine sediments. Overbank sediments consist of laminated to massive silt or sandy silt, or of paleosols containing $CaCO_3$. As noted in Section 2.1, these sediments record deposition in low-energy environments that occur in the areas behind natural levees during periods of flooding. The calcic paleosols indicate subaerial exposure. Lacustrine sediments are laminated to massive clays with thin, silty or sandy layers deposited in lakes with stagnant-water to deltaic conditions.

In many of the wells drilled in the B pond area, the facies of the Ringold Formation that is first encountered is clay with relatively minor amounts of admixed sand or gravel (see Figure 11). This upper, lacustrine facies of the Ringold Formation contains more clay than is present in the lower part of the lower mud sequence, where silt interbedded with lenses of sand (more typical of overbank deposition) is more common.

2.3.1.3 Hanford Formation. The ~120 ft (~37 m) of Hanford formation in the vicinity of the candidate site is dominated by sandy gravel, as observed in the wells that are nearest the site (e.g., in well 699-40-33). In these wells, beds of fine-grained sand and silt are not present, in contrast to their presence in the area at the northwest end of cross section A-A'. Consequently, detailed correlation of the stratigraphy between these two areas is difficult, and the Hanford formation currently is undifferentiated in the vicinity of the candidate site.

The sandy gravels of the Hanford formation were deposited by catastrophic floods in, or immediately adjacent to, the main flood channels when water spilled over the banks of the main channels or during the waning stages of flooding. This facies is characteristic of a high-energy environment of deposition. The sandy gravels are dominated by medium- to coarse-grained basaltic sand and gravel with occasional boulders.

In some areas of the Hanford Site, the Hanford formation consists of sediments that indicate a relatively lower energy environment of deposition -- the sand-dominated facies. This lower energy facies occurs in areas adjacent to the main flood channels. The wells nearest to the candidate site have not intersected these sands. However, their presence cannot be precluded because they are found in wells northwest of the candidate site (699-43-42, 699-43-41G, and 699-42-40C). Where present, the sand-dominated facies consists of fine- to coarse-grained, black sand, with minor granule- to pebble-sized fractions. Silty interbeds that rarely exceed 3 ft (1 m) thick are also common in the sand-dominated facies.

2.3.2 Structural Geology

The candidate site is south of a subsurface topographic high in the basalt bedrock that is centered ~2.5 mi (4 km) to the northwest of the candidate site. Uplift continued on this structural high after (and perhaps during) the deposition of the Ringold Formation. This is evidenced by a few degrees of tilting of the Ringold Formation on the southeast flank of the structure. Prior to, or during, the late Pleistocene flooding, the area was beveled by erosion, resulting in the nearly flat surface on which the Hanford Formation was deposited. Consequently, the Hanford-Ringold contact in this area is an angular unconformity.

The tilting by uplift of the basalt high and later erosional planation of the Ringold Formation caused the uppermost unit of the Ringold Formation (the lower mud sequence) to pinch out to the northwest of the candidate site. As can be seen on cross section A-A' (see Figure 11), the lower mud sequence pinches out between wells 699-43-41G and 699-43-42. The A unit is generally 70 ft (21 m) thick beneath the lower mud sequence and does not pinch out in this area because, although also subjected to tilting, it was not eroded except to the northeast of well 699-43-41G.

2.3.3 Lithologic Properties

Table 1 lists the results of laboratory tests of the physical properties of sediment samples that were collected from RCRA ground water monitoring wells. These RCRA wells were drilled in 1991 at the B pond complex and include wells 699-40-40A, 699-40-40B, 699-42-39A, 699-42-39B, 699-43-40, and 699-43-41G (see Figure 1). All samples were obtained by the split-spoon method. Based on their appearance when withdrawn from the drill holes, the samples of fine-grained sediments are judged generally to be representative of in situ conditions. In contrast, the samples of coarse-grained sediments may not reflect in situ conditions because of compaction during the sampling process. Consequently, the results of the tests for these samples must be used with caution.

Table 1. Physical Properties of the Ringold Formation beneath the B Pond Complex.

PHYSICAL PROPERTIES DATA SHEET 216-B-3 POND FY91 RCRA BOREHOLES								
Lab Sample #	Stratigraphic Unit	Sample Depth (ft)	Specific Gravity (g/cm^3)	Moisture (%)	Moisture Retention	Sieve Analysis	Hydraulic Cond. (cm/sec)	Porosity (%)
699-40-40A								
1-2137	Ringold Lower Mud	165.5-166	2.61	24.19	test not requested	silty sand	2.3 E-7	38.18
1-2195	Ringold Lower Mud	171-172	2.60	22.02	test not requested	silty clay	1.5 E-9	37.76
1-2196	Ringold Lower Mud	178-179.5	2.64	23.08	test not requested	silty sand	9.2 E-6	38.35
1-2241	Ringold Unit A	225.5-226.5	2.63	14.89	test not requested	fine sand	1.0 E-7	33.64
699-40-40B								
1-1894	Ringold Lower Mud	124.8-126.8	2.66	19.73	curve data available	sandy clay sieve data available	1.0 E-8	34.90
1-1899	Ringold Lower Mud	150-150.25	2.60	53.90	test not requested	clay sieve data available	test not run	test not run
1-1898	Ringold Lower Mud	150.25-150.9	2.61	24.86	test not requested	silt sieve data available	test not run	test not run
1-1897	Ringold Lower Mud	150.9-151	2.70	10.75	test not requested	clay sieve data available	3.5 E-7	37.92
1-1901	Ringold Lower Mud	182-184	2.67	22.85	test not requested	clay sieve data available	4 E-8	37.74
1-2242	Ringold Unit A	193-195	test not requested	test not requested	test not requested	sandy gravel sieve data available	test not requested	test not requested
699-42-39A								
1-1895	Ringold Lower Mud	138-140	2.66	20.46	test not requested	sandy clay sieve data available	8.6 E-8	35.86
699-42-39B								
1-2138	Ringold Lower Mud	156.5-157	2.62	20.29	test not requested	silt sieve data available	test not requested	test not requested
1-2139	Ringold Lower Mud	157-157.5	2.62	test not requested	test not requested	test not requested	1.1 E-7	36.87
1-2240	Ringold Lower Mud	215-216	2.66	44.99	test not requested	silt (cemented) sieve data available	1.0 E-7	56.15
699-43-40								
1-2004	Ringold Unit A	130-131.5	2.73	7.63	curve data available	Sandy gravel /sand, sieve data available	1.9 E-4	22.45
699-43-41G								
1-1930	Ringold Lower Mud	127.8-129.8	2.70	23.79	test not requested	clay sieve data available	1.5 E-5	42.54
1-1931	Ringold Unit A	147.2-148.1	2.68	5.47	curve data available	sandy gravel sieve data available	no test	19.89
1-2003	Ringold Unit A	166.2-167.2	2.68	8.95	curve data available	sandy gravel sieve data available	1.9 E-6	17.65
1-2135	Ringold Unit A	181.5-182.5	2.58	41.30	curve data available	silty sand sieve data available	4.0 E-9	51.09

Table 2 is a statistical summary of the data shown in Table 1; the mean (x), standard deviation (s), and number of samples (n) are subdivided based on Ringold Formation facies (i.e., lower mud sequence and unit A).

Table 2. Summary of Physical Property Test Results Reported in Table 1.

Physical Property Test	Ringold Formation	
	Lower Mud Sequence	Unit A
Specific Gravity (g/cm³)	$\bar{x}$ = 2.64 s = 0.04 n = 13	$\bar{x}$ = 2.66 s = 0.05 n = 6
Moisture (vol. %)	$\bar{x}$ = 25.91 s = 11.75 n = 12	$\bar{x}$ = 14.23 s = 13.65 n = 6
Porosity (%)	$\bar{x}$ = 39.63 s = 6.14 n = 10	$\bar{x}$ = 26.78 s = 13.46 n = 6
Hydraulic Conductivity (cm/sec)		
Arithmetic	$\bar{x}$ = 2.51E-6 s = 5.24E-6 n = 10	$\bar{x}$ = 3.93E-5 s = 8.42E-5 n = 5
Natural Logarithm	$\bar{x}$ = -15.70 s = 2.79	$\bar{x}$ = -12.91 s = 2.80
Antilog of Log Mean	1.52E-7	2.47E-6

The physical properties tests included specific gravity, moisture content, sieve analysis, hydraulic conductivity, and porosity. There is little difference between samples of the lower mud sequence and unit A with respect to specific gravity (see Table 2). Both units average about 2.65 g/cm^3. However, test results for moisture content, porosity, and hydraulic conductivity vary significantly between the two units. Average moisture content and porosity are higher for the lower mud sequence; hydraulic conductivity is higher for unit A. These moisture-content results are expected; the hydraulic conductivity for unit A is less than that which is typical of Ringold Formation gravels. The reason for this may be due to a higher percentage of interstitial mud in the gravels compared to that which is typical of Ringold Formation gravels elsewhere on the Hanford Site.

2.4 Candidate Site Hydrostratigraphy

The stratigraphic units of interest at the candidate site are the (1) Rattlesnake Ridge interbed, (2) Elephant Mountain Basalt Member, (3) Ringold Formation, and (4) Hanford Formation (Figure 12). Although little is known about stratigraphic units below the Rattlesnake Ridge interbed in the candidate area, deeper zones are not of interest in the context of Project W049-H because significant water-bearing intervals are generally closer to the surface. The hydrogeologic designations were determined by examination of well logs and integration of these data with published stratigraphic correlations.

The Rattlesnake Ridge interbed, the overlying flow bottom of the Elephant Mountain Member, and the underlying flow top of the Pomona Member, in combination, form the uppermost regionally extensive, confined aquifer beneath the candidate site. The interbed consists of a clayey basalt conglomerate, an epiclastic fluvial floodplain unit, an air-fall tuff, and a tuffite derived from fluvial reworking of the air-fall tuff and detrital sediments (Graham et. al 1984). The interbed is 50 to 82 ft (15 to 25 m) thick beneath the 200 Areas and generally thickens to the west (Graham et al. 1981, 1984). Recharge to the interbed occurs in the higher elevations surrounding the Pasco Basin to the west, north, and northeast. The flow of ground water in the aquifer is generally toward the northeast beneath the 200 West Area and west to west-northwest beneath the 200 East Area. Graham et al. (1981, 1984) report transmissivities that vary from 8 to 1,165 ft^2/d (2.4 to 355.1 m^2/d) over the entire thickness of the Rattlesnake Ridge aquifer.

Beneath the 200 Areas, the Rattlesnake Ridge confined aquifer is generally separated from the overlying, unconfined aquifer by the Elephant Mountain Member. The Elephant Mountain Member is up to 115 ft (35 m) thick and consists of two flow units separated by a ~3 ft (0.9 m) thick interflow zone of interconnected vesicles and rubble (Graham et al. 1984, Gephart et al. 1979). The interflow zone has a higher transmissivity (7.5 to 6,120 ft^2/d; 0.7 to 569 m^2/d) than its bounding flows (Graham et al. 1984). This interflow zone is found south and west of the 200 East Area and in the vicinity of B Pond. In the northeast corner of the 200 East Area, the upper flow and the interflow zone of the Elephant Mountain Member have been removed by erosion (Graham et al. 1984).

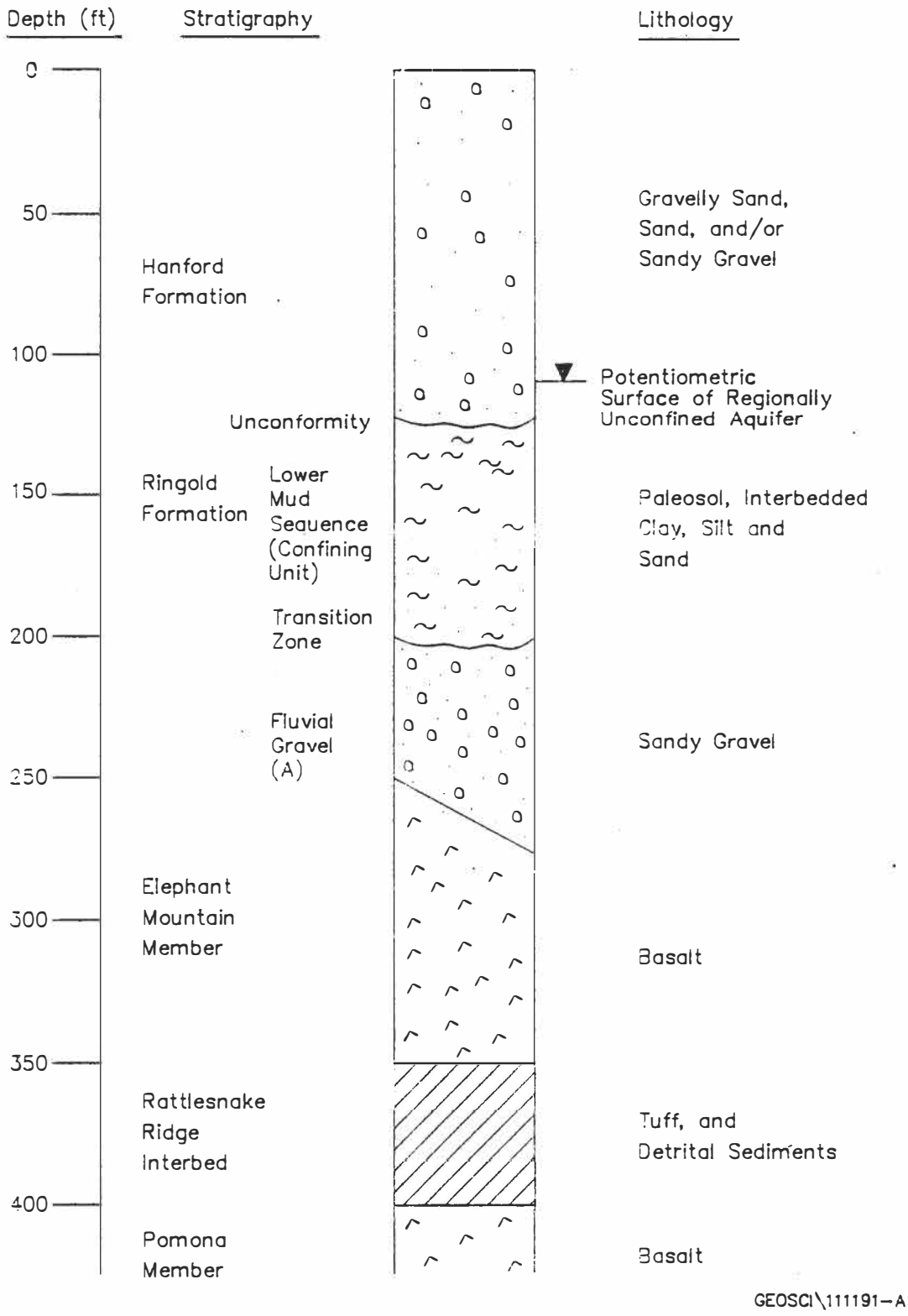


Figure 12. Generalized Stratigraphic Column for the Candidate Site.

The regionally unconfined aquifer in the 200 Areas occurs primarily within the sediments of the Ringold and Hanford Formations. East of the 200 East Area, the unconfined aquifer occurs principally in the Ringold Formation. The depth to the potentiometric surface at the candidate site ranges from approximately 105 to 108 ft (32 to 33 m). The hydraulic gradient in this area decreases to the southeast because of mounding of the water table to the west under the B Pond complex. The saturated thickness of the unconfined aquifer increases to the southeast because of the south-southeast dip of the basalt bedrock and southeasterly thickening of the Ringold Formation. The saturated thickness ranges from approximately 100 to 170 ft (30 to 52 m).

The regionally unconfined aquifer in the vicinity of the candidate site is dominated by the fluvial gravels (A unit) and the lower mud (LM) sequence of the Ringold Formation. The A unit generally is about 70 ft (21 m) thick under the candidate site and overlies the basalt of the Elephant Mountain Member. Hydraulic conductivities generally range from 6.0×10^{-7} cm/sec to 7.0×10^{-2} cm/sec. Transmissivities ranging from 60 to 130 ft^2/day and storativities ranging from 1×10^{-6} to 3.3×10^{3} have been reported. Stratigraphically above the A unit, a ~70 ft (~21 m) thick LM sequence of silts and clays occurs in the vicinity of B Pond and to the east of B Pond (see Figure 12). These fine-grained sediments confine or partially confine the saturated A unit. The confining zone pinches out to the west, beneath the A lobe of B Pond. A mean hydraulic conductivity of 2.5×10^{-6} cm/sec was measured for these fine-grained sediments based on permeameter tests of split-spoon samples from the top of the unit. In the B Pond Area, the LM sequence appears to have little moisture; water generally is not encountered until drilling reaches the saturated gravels. The hydraulic head then rises to approximately the top of the LM sequence because of locally confining conditions.

Aquifer tests and laboratory analyses have previously been made to estimate hydraulic properties at the B Pond. Results of these tests and analyses are shown in Table 3. The locations of wells listed in the table are shown in Figure 1.

The unsaturated zone beneath the candidate site ranges from ~120 to ~140 ft thick (37 to 42 m). Unsaturated sediments consist of the Pasco Gravels facies of the Hanford formation. At this location, the Hanford formation is predominantly sandy gravel, with the gravel fraction ranging up to boulder size. Up to 7 ft (2 m) of perched water has been found immediately above the LM sequence in wells drilled near the C lobe of B Pond. The moisture content of unsaturated Hanford formation sediments beneath the 200 Areas generally ranges from 2% to slightly more than 6% (Last et al. 1989).

2.5 Candidate Site Hydraulic Gradients

In the area of the candidate site, regional ground water flow is generally from the west. Because of the mounding of the water table beneath the B Pond complex, ground water in the unconfined aquifer locally has diverged from its natural flow path. One

Table 3. Summary of Aquifer Test Results for the B Pond Area.

Well Number	Formation	Type of Test	Analysis Method	Transmissivity (ft^2/d)	Hydraulic Conductivity (ft/d)	Date Tested
699-44-42	Hanford/ Ringold	constant discharge	Cooper and Jacob (1946)	76,000	4,200	09/22/88
699-43-43	Hanford/ Ringold	constant discharge	Cooper and Jacob (1946)	37,000	2,100	09/09/88
699-42-42B	Ringold-Lower Mud Sequence	falling-head permeameter	Klute and Dirksen (1986)	---	0.07[a]	06/28/89
699-42-42B	Ringold-Lower Mud Sequence	constant-head permeameter	Klute and Dirksen (1986)	---	0.002[a]	06/29/89
699-42-42B	Ringold-A Unit	constant discharge	Cooper and Jacob (1946)	140	6	10/18/88
699-42-40A	Ringold	constant discharge	Cooper and Jacob (1946)	310	4	01/18/82
699-42-40B	Ringold	constant discharge	Cooper and Jacob (1946)	360	5	01/18/82
699-42-40C	Elephant Mountain Member	constant discharge	Cooper and Jacob (1946)	8	---	04/15/82
699-42-40C	Rattlesnake Ridge	constant discharge	Cooper and Jacob (1946)	300	12	05/19 to 05/21/82

[a] vertical hydraulic conductivity

component of the flow is northward between Gable Butte and Gable Mountain; a second component is to the southeast, toward the Columbia River (see Figure 9).

June 1991 ground water elevations and representative flow paths for the unconfined aquifer in the candidate site area are shown in Figure 13. Ground water flow directions and hydraulic gradients are generally controlled by the mounding of the water table from effluent discharge at the B Pond complex. The water table map indicates that the hydraulic gradient in the vicinity of the candidate site is on the order of 1 ft/1,000 ft (0.3 m/305 m) and that the direction of ground water flow is to the southeast.

Current ground water flow directions may change because of changes in the rates of effluent discharge to the B Pond complex and the effect that changes in the mound have on the relatively flat gradients beyond the mound. Consequently, it is difficult to accurately predict ground water flow directions beneath the candidate site based on the water table maps of the 200 East Area. Nevertheless, contaminant plume maps of the 200 Areas can be used to predict long-term trends in ground water flow directions (Serkowski and Johnson 1989). These plume maps indicate a north-northwest direction of flow in the

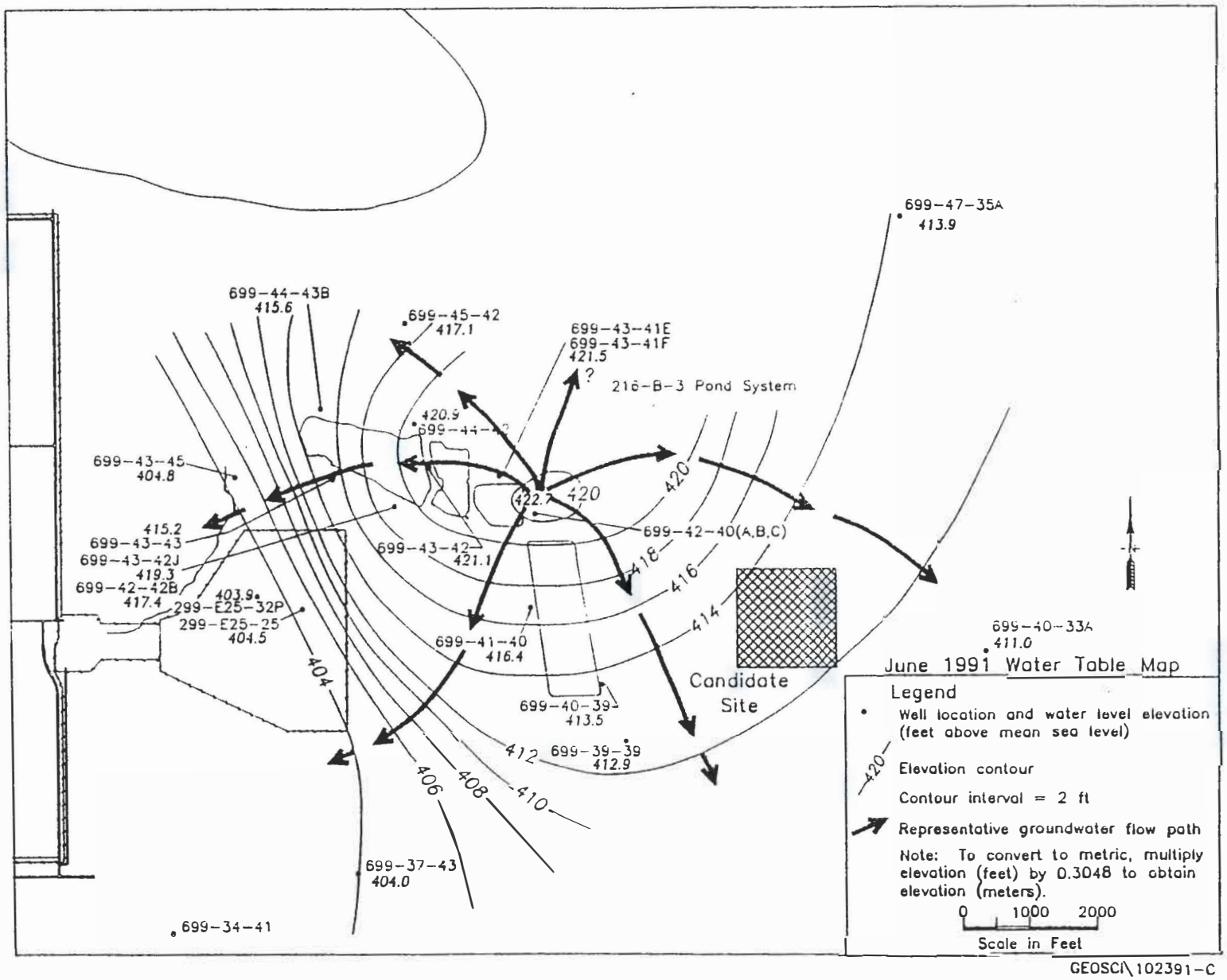


Figure 13. June 1991 Water Table Elevations for the Candidate Site.

extreme north-central part of the 200 East Area and a south to southeast direction of flow in the southeast part of the 200 East Area.

2.6 Results of Numerical Analysis

Using hydrogeologic information inferred from nearby wells (see Figure 10), the MODFLOW software developed by the U.S. Geological Survey (McDonald and Harbaugh 1988) was used to simulate the effects on the regionally unconfined aquifer that could be expected to result from operation of the 200 Areas TEDB at the candidate site (Davis, Appendix A 1991).

The simulation was performed in two steps. The first step was a sensitivity analysis. This analysis evaluated the importance of stratigraphic and lithologic changes in affecting the size and configuration of the water table mound resulting from operation of the TEDB. The second step predicted the effect that infiltration of the effluent would have on the preexisting water table at the candidate site.

The results of the sensitivity analysis indicated that changing the value of any parameter except for the hydraulic conductivity of the Hanford formation resulted in little or no change in MODFLOW results. Even changing the specific yield value for the Hanford formation (where all of the mounding was assumed to occur) caused changes only in the fifth or sixth significant digit of the calculated elevation of the water table mound.

The initial elevation of the water table, stratigraphy, and other pertinent hydrogeologic data were represented as accurately as the input structure and computational technique would allow, but were adjusted as required to operate MODFLOW. Limitations imposed by MODFLOW required oversimplification of the stratigraphy and initial position of the water table; the simulations did not account for progressive mounding of the water table in the Ringold Formation prior to its rising into the overlying Hanford formation.

The grid that was simulated consisted of 70 by 70 cells, with the TEDB located over the 16 center-most cells of the grid. The cells were square, with each side representing 369 ft (112 m); hence, the area simulated was 24 mi^2 (~15,300 acres). The area of TEDB infiltration was assumed to be 50 acres. The distance from the edge of the TEDB to the grid boundary was approximately 2.3 mi (0.7 km). The perimeter cells of the model domain were assigned constant-head status based on an assumption that the water level in those cells was beyond the direct influence of the mound.

Three stratigraphic units were simulated for the candidate site based on geologic projections from nearby wells (see Section 2.1). The Hanford formation was treated as a single unit. The Ringold Formation was subdivided into two units; one was assumed to be clayey, silty sands, and the other was assumed to be coarse-grained pebbly sand.

Hydraulic data used in MODFLOW included hydraulic conductivity, specific yield, and storativity. To account for the movement of water between stratigraphic units, vertical hydraulic conductivity was calculated independently of MODFLOW and included as input data. Physical properties data for each stratum were the initial hydraulic head, whether the aquifer was confined or unconfined, and the elevations (except for the top of the uppermost unit) of the top and bottom of the model domain. All input data were assumed to remain constant throughout the duration simulated.

Estimates of parameter values were based on the data in Gephart et al. (1979). MODFLOW was run using two bracketing values of hydraulic conductivity for the Hanford formation (1,000 and 10,000 ft/day) and two bracketing values for the finer grained unit of the Ringold Formation (0.1 and 1.0 ft/day). The hydraulic conductivity assigned to the coarse-grained unit of the Ringold Formation was 5 ft/day. The specific yield values used for the Hanford, coarse-grained Ringold, and fine-grained Ringold were 0.22, 0.17, and 0.10, respectively. The storativity used for all three units was 0.001.

Recharge from the TEDB was assumed to be the only source of water to the model domain, and flow through the model boundaries was assumed to be the only water loss. The time simulated was divided into 1-year time steps. The hydrologic system was assumed to have homogeneous and isotropic hydraulic properties for each stratum simulated.

The size of the water table mound was shown to be highly dependent on the hydraulic conductivity of the Hanford formation and the flux from the proposed 200 Areas TEDB. The results were insensitive to other input parameters. Based on MODFLOW results, the water table beneath the proposed TEDB is likely to rise on the order of 4 to 14 ft (~1 to 4 m) for a discharge rate of 1,500 gpm, or 14 to 50 ft (~4 to 15 m) for a discharge rate of 15,000 gpm, depending on the hydraulic conductivity (10,000 and 1,000 ft/day, respectively) assigned to the Hanford formation. A 10-fold increase in the hydraulic conductivity of the fine-grained unit of the Ringold Formation decreased the size of the water table mound by ≤0.3 ft (~0.1 m), an insignificant amount considering the uncertainties in the input data and the simplifications of the conceptual model. Furthermore, the absence of both the fine-grained and coarse-grained units of the Ringold Formation have no noticeable effect on the size of the simulated water table mound.

Stratigraphic Effects. Extrapolations from nearby sources of geologic data (see Section 2.1) suggested the following stratigraphic thicknesses at the candidate site: Hanford formation -- 122 ft (~37 m); fine-grained Ringold Formation -- 70 ft (~21 m); and coarse-grained Ringold Formation -- 70 ft (~21 m). For the conceptual model, the Hanford-Ringold contact was at an elevation of 412 ft (~126 m) (all elevations are above mean sea level), the coarse grained-fine grained Ringold contact at an elevation of 320 ft (~98 m), and the Ringold-basalt contact at 283 ft (~86 m). According to the water table map for the area (see Figure 13), the water table currently is slightly above the Hanford-Ringold

formational contact; the initial condition used in MODFLOW for the elevation of the water table was 413 ft (~126 m). The results of the simulation are shown in Figure 14. The maximum distance from the proposed TEDB (12,177 ft) was to the cell adjacent to the grid boundary. At the boundary, the initial elevation of the water table was fixed at 413 ft (~126 m), as noted in the table in brackets.

Water Table Mound Development. Because the results from the first step of the analysis showed essentially no sensitivity to the presence of the Ringold Formation, only one unit (the Hanford formation) was used in the second step of the analysis. By considering only one, the initial water level datum could be input more accurately without causing the program to malfunction because of the inclusion of dry cells. As an additional step to prevent this kind of malfunction, the bottom of the model domain was arbitrarily defined as 5 ft below the lowest elevation of effluent water entering the water table.

Four simulations were made for the candidate site; two for each assigned discharge rate (1,500 and 15,000 gpm) and two for each assigned hydraulic conductivity of the Hanford formation (1,000 and 10,000 ft^2/d). The value assigned to the specific yield was 0.22. The data set used for the initial elevation of the water table was determined from Figure 13. The grid that was simulated was again 70 by 70 cells, but the length of the edge of each cell was reduced to 250 ft (~76 m) to permit better resolution of the results in immediate proximity to the candidate site. The total area simulated was approximately 11 mi^2 (7,000 acres). The effluent entering the water table from the proposed TEDB was equally distributed through the 36 center-most cells, representing an area of about 52 acres. The distance from the edge of the TEDB to the grid boundary was 8,000 ft (~2,439 m). The cells for these simulations were assigned no-flow or constant-head status only if available hydrologic data indicated that this was appropriate.

The cells representing the two subsurface basalt topographic highs north and northwest of the candidate site (see Figure 9) were assigned no-flow status for two reasons. The first was that the hydraulic conductivity through the basalt is negligible compared to that of the Hanford formation. The second is that a no-flow condition best describes the behavior of the water table in the two areas of near-surface basalt. The rise in the water table beneath the candidate site predicted by MODFLOW is shown in Figures 15 through 18. The results indicate that a mound in the water table would develop directly beneath and to the north of the candidate site if the proposed 200 Areas TEDB were constructed there. The mound that currently results from effluent disposal at the B Pond complex is elongated toward the northeast, and would continue to be elongated northeasterly, between the two basalt subcrops, as it gradually decays.

The predicted rise in the water table beneath the candidate site due to simulated infiltration of 200 Areas TEDB effluent produces the highest hydraulic gradients to the south and southwest. This mound would block flow to the east (toward the Columbia River) from the B Pond complex. Acceleration of flow to the south would rapidly attenuate

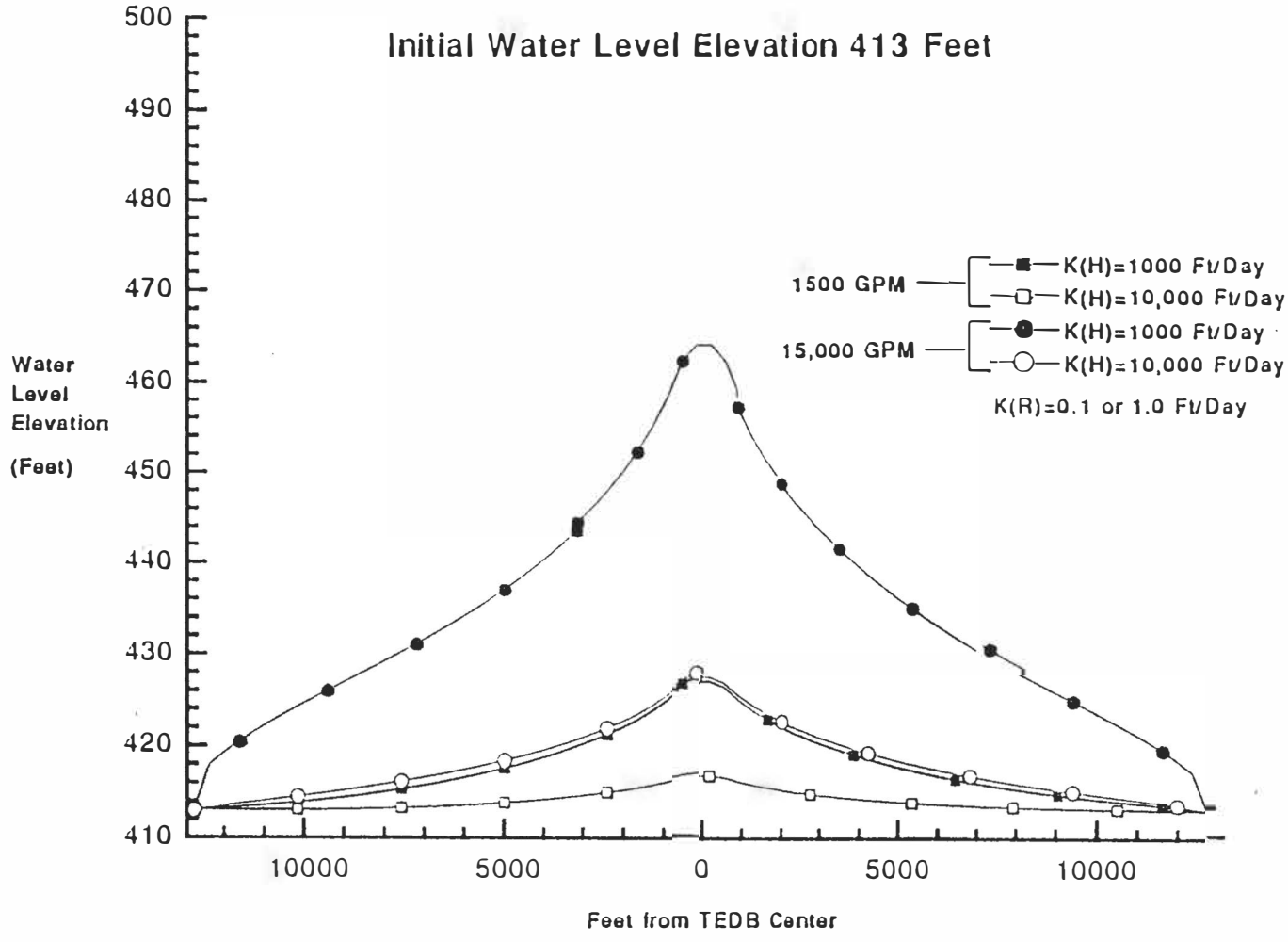


Figure 14. Profile of Water Table Elevations Simulated for the Candidate Site.

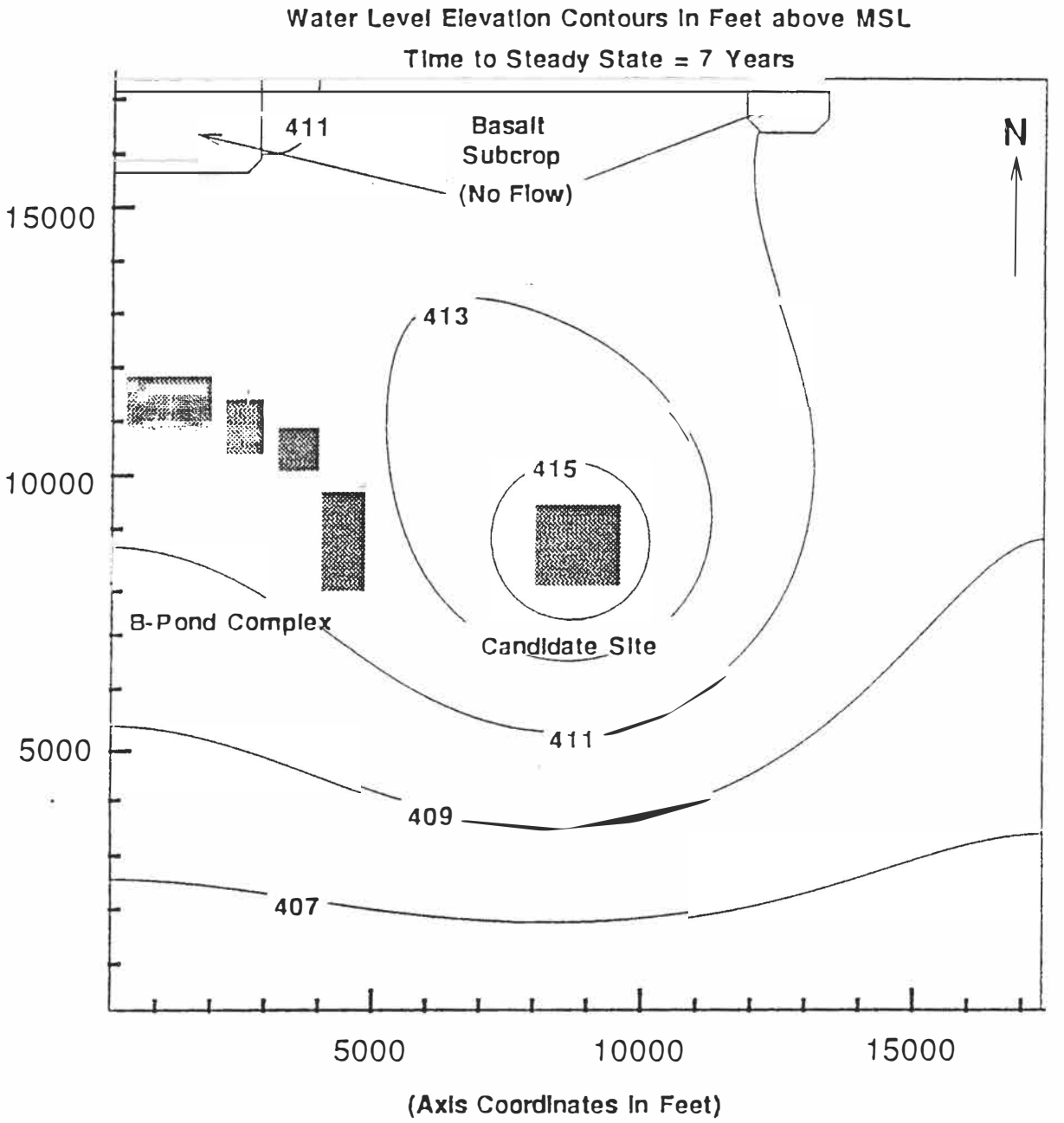


Figure 15. Mounding of the Water Table Beneath the Candidate Site with a Discharge Rate of 1500 gpm and a Hydraulic Conductivity of 1000 ft/d.

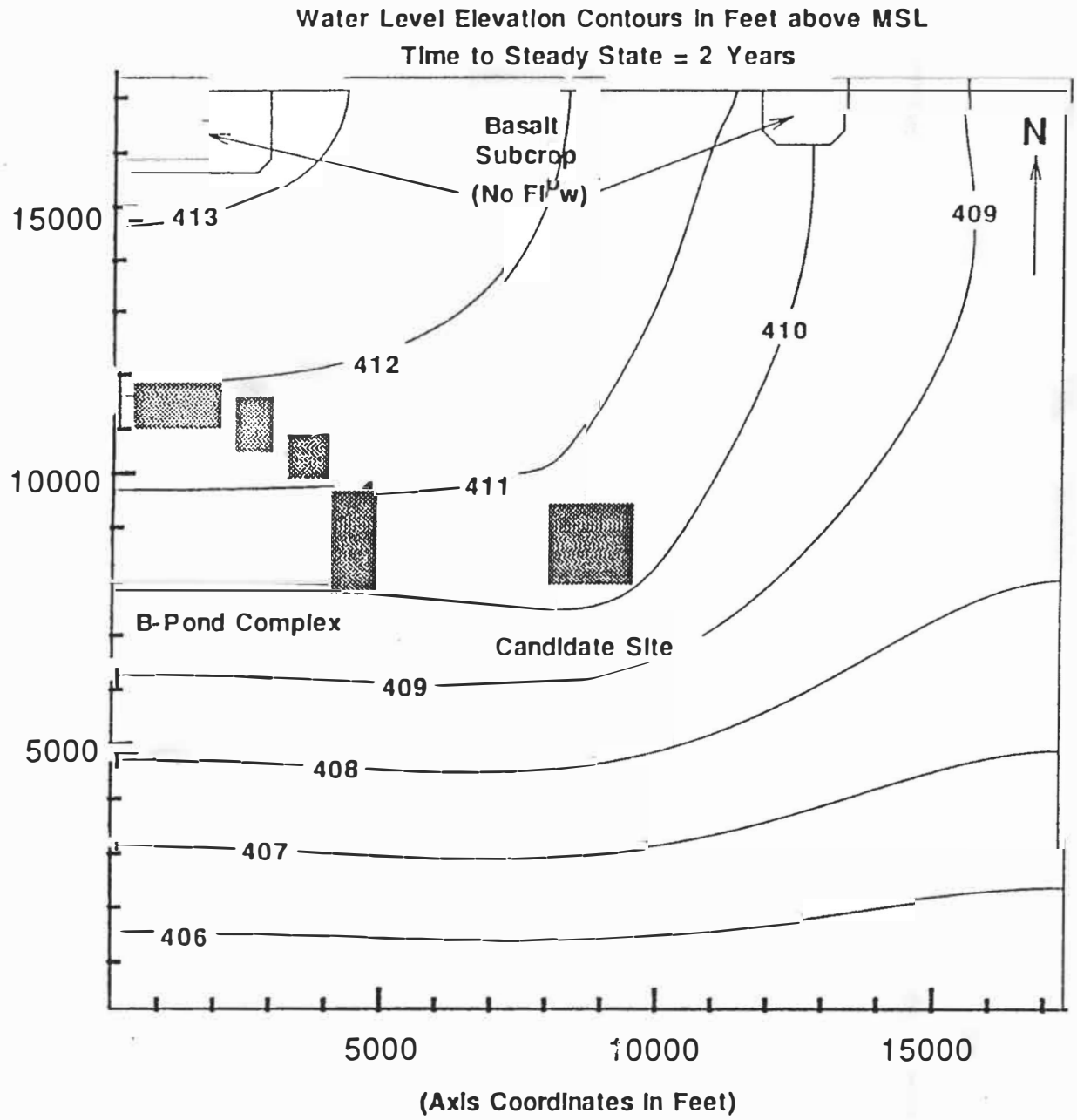


Figure 16. Mounding of the Water Table Beneath the Candidate Site with a Discharge Rate of 1500 gpm and a Hydraulic Conductitvity of 10,000 ft/d.

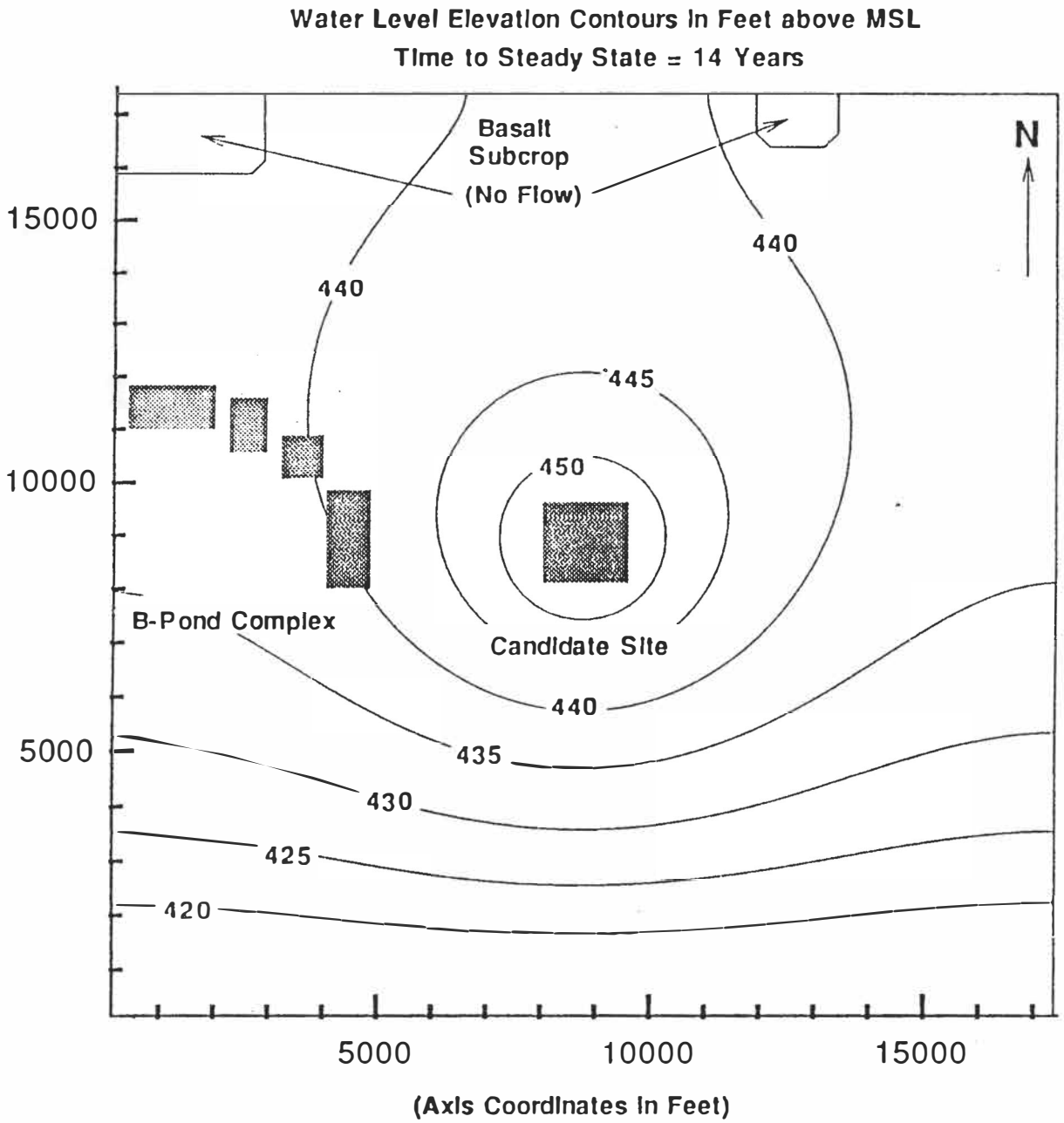


Figure 17. Mounding of the Water Table Beneath the Candidate Site with a Discharge Rate of 15,000 gpm and a Hydraulic Conductivity of 1000 ft/d.

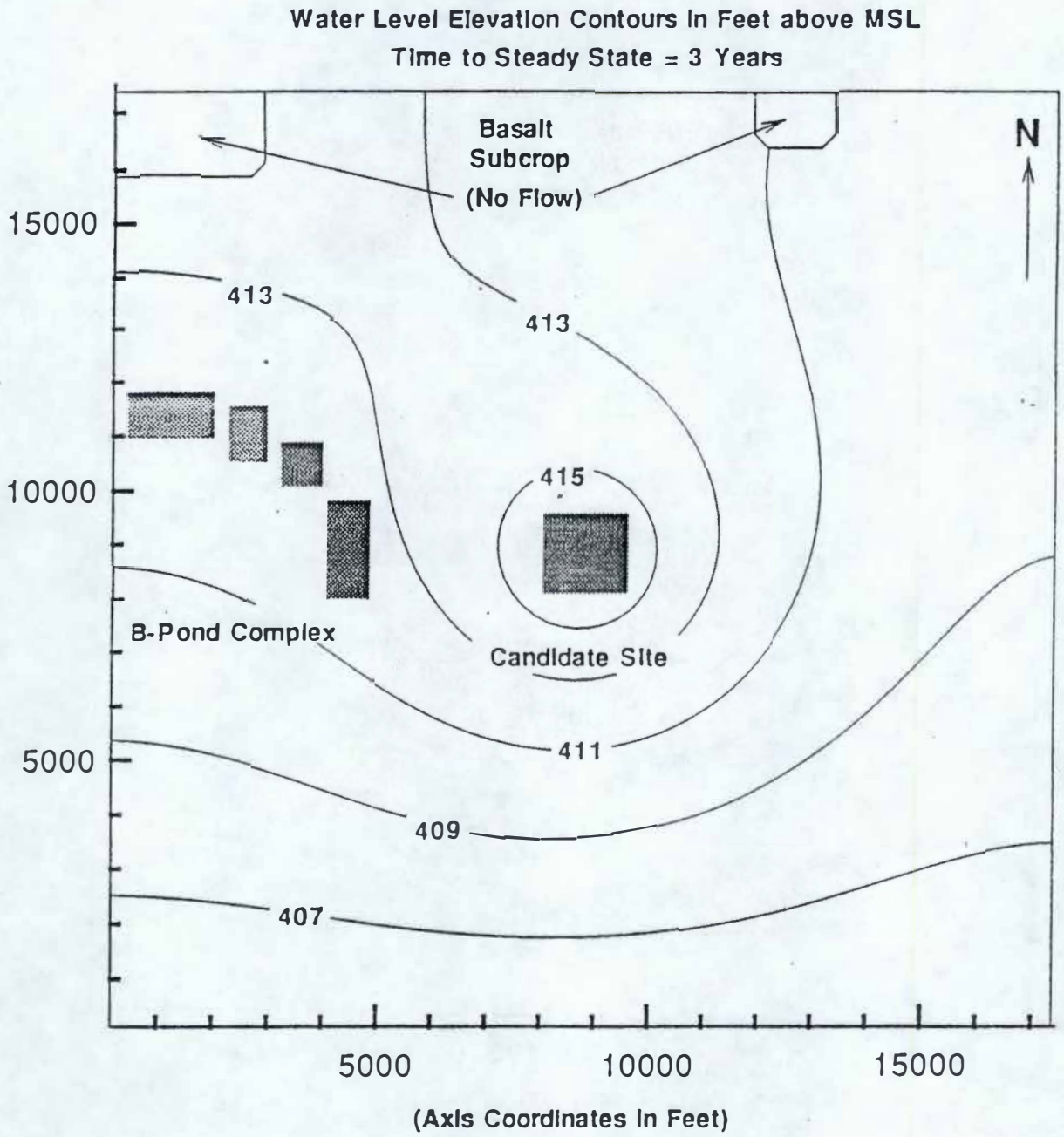


Figure 18. Mounding of the Water Table Beneath the Candidate Site with a Discharge Rate of 15,000 gpm and a Hydraulic Conductivity of 10,000 ft/d.

beyond the immediate influence of the mound resulting from the proposed TEDB; the flow would lose most of its artificially elevated hydraulic gradient and then would gradually be pushed eastward by the natural gradient.

2.7 Candidate Site Ground Water Quality

Currently available published and unpublished technical data were used to evaluate expected ground water quality at the candidate site. In completing the evaluation, existing ground water monitoring wells in the vicinity of the candidate site were evaluated to determine their suitability for obtaining site characterization data. Ground water quality and the extent of ground water contamination in the vicinity of the candidate site were then evaluated. A detailed description of water quality in the B Pond area, the nearest upgradient source of potential contamination to the candidate site, is given in Appendix A.

2.7.1 Evaluation of Existing Ground Water Monitoring Wells and Sampling Techniques

The construction and completion records of existing ground water monitoring wells in the vicinity of the candidate site were evaluated to determine the suitability of the wells for analysis of ground water quality. The construction and completion of a ground water monitoring well and the technique used to collect water samples are important because the reliability of chemistry and water-level data depend on these factors. If a monitoring well is improperly designed or constructed, the data collected from the well may not be reliable or representative of the ground water.

Initially, all ground water monitoring wells within a 2 mi radius of the candidate site were identified for subsequent evaluation. This list was then refined to include only the wells judged to be most useful for characterization of ground water quality in the vicinity of the candidate site. The wells in this select group were chosen based on their proximity to the candidate site and their location relative to the site and the direction of ground water flow. Ground water wells immediately up gradient from the candidate site were considered to be the most useful for estimating ground water quality at the candidate site. Well selection was also based on ability to indicate the effects of past or present waste disposal activities on ground water quality (see Appendix A).

Twenty-one wells were chosen for detailed evaluation. Data from these wells were analyzed by evaluating well construction and sampling information critical to determining the reliability and representativeness of data derived from the well. This information included documentation of the use of adequate well-construction materials and installation procedures, monitoring the proper interval, and adequate purging prior to sampling. Previous work by Golder Associates (Golder 1989) was used in the assessment. For a complete discussion of ground water well design and construction, see National Water Well Association (NWWA) (1989), EPA (1986a), and Liikala et al. (1988).

To evaluate well data for their usefulness in assessing ground water quality for this report, the compatibility of the well construction materials with the geochemical environment were judged; i.e., chemically inert and nonreactive with the ground water or sediments penetrated by the well. Currently, stainless steel is used at the Hanford Site for construction of RCRA and CERCLA wells. Carbon steel was used in many of the older wells.

Proper completion of a well in the desired sampling zone(s) depends on obtaining discrete monitoring intervals by using appropriate screen lengths and sealing the annulus immediately above and below the screened interval. The ground water monitoring program for the Hanford Site currently samples the upper, most locally contaminated part of the unconfined aquifer (Eddy et al. 1978). To minimize the potential for dilution, screen lengths of 20 ft or less are considered appropriate for wells that monitor the unconfined aquifer.

Because water can migrate vertically through the annulus between the well casing and the walls of the well, grout and/or bentonite sealing of the annulus is needed if samples are to be obtained that are representative of the interval to be evaluated. In addition, chemical additives commonly used in drilling must be restricted or eliminated. Because RCRA and CERCLA wells are installed using cable-tool drilling with a minimum of fluids added during drilling, these wells are preferred as sources of water quality data. Preference was also given to wells for which records indicated that all equipment that came in contact with the well was cleaned and decontaminated before drilling. Although many of the wells installed at the Hanford Site comply with some or all of the criteria identified in the preceding discussion, only the recently installed RCRA and CERCLA ground water monitoring wells have the records needed to document their compliance with requirements.

Ground water sampling devices and the correlation between sampling technique and data bias are described by the NWWA (1989), Barcelona (1985), and Gillham et al. (1983). Ground water monitoring wells at the Hanford Site generally have been sampled either by a bailer or a pump. Bailed samples are not considered to be as reliable as pumped samples because they commonly have been collected without first properly purging the well. Improper well purging can seriously bias chemical analyses of major and minor ground water constituents. Consequently, samples of stagnant well-storage water are less likely to be representative of actual water quality than are samples taken immediately after purging. Samples obtained using a dedicated pump system or a submersible pump are judged most likely to produce unbiased analyses.

2.7.2 Results of Ground Water Monitoring Well Evaluation

The 21 wells selected for detailed evaluation were grouped into three categories based on the criteria discussed in the previous section. Wells classified as Category 1

are RCRA/CERCLA wells or equivalents; consequently, they are cased with stainless steel, have a screened, filter-packed interval of 20 ft (~6 m) or less, and have documentation of proper well completion. These wells were recently installed and most use a submersible pump to sample the unconfined aquifer. The wells are used to monitor the elevation of the water table and collect water samples from the unconfined aquifer for chemical analyses in support of RCRA and CERCLA activities. The highest available quality of ground water chemistry data are from these wells.

Category 2 wells have a known screened or perforated interval of 30 ft (~9 m) or less, are sampled by pump, and monitor the unconfined aquifer. The wells may or may not be constructed of stainless steel, have a filter pack, or documentation of proper well completion. Data from these wells on the elevation of the water table are considered in most cases to be representative, but are not of RCRA or CERCLA quality because of screen lengths in excess of 20 ft (~6 m), construction deficiencies, and/or lack of documentation.

Category 3 wells have perforated intervals that either are in excess of 30 ft or are of unknown length, and/or have been sampled by a bailer. These wells are used for measurement of water table elevation if the monitoring interval is known and appropriate. These wells may provide representative water chemistry data, but the data cannot be proven to be unbiased and may represent water quality averaged over a large vertical distance in the aquifer.

Figure 19 depicts the locations of all ground water monitoring wells used in this study. Well categories are differentiated by the use of three map symbols. Table 4 summarizes well construction and sampling information for the 21 wells in the vicinity of the candidate site. The table includes the date of well construction, the length of the screened or perforated interval, and the sampling method used. All wells are screened in the Ringold A unit, except where the entry "RRI confined well" in the comments column of the table indicates completion in the Rattlesnake Ridge interbed. Additional entries in the comment column note whether the well monitors the unconfined aquifer or a lower, locally confined aquifer below the LM sequence.

The candidate site is downgradient from the 216-B-3 Pond (B Pond) complex east of the 200 East Area (see Figure 9). For this reason, data from ground water monitoring wells in the vicinity of the B Pond complex were judged to be essential for determining the extent of ground water contamination that could move downgradient to the candidate site. During 1989-1991, numerous RCRA wells were installed to monitor contamination from the B Pond complex. A description of the B Pond facility, effluent disposal practices at that facility, and water quality data from the area immediately surrounding the B Pond complex is given in Appendix A.

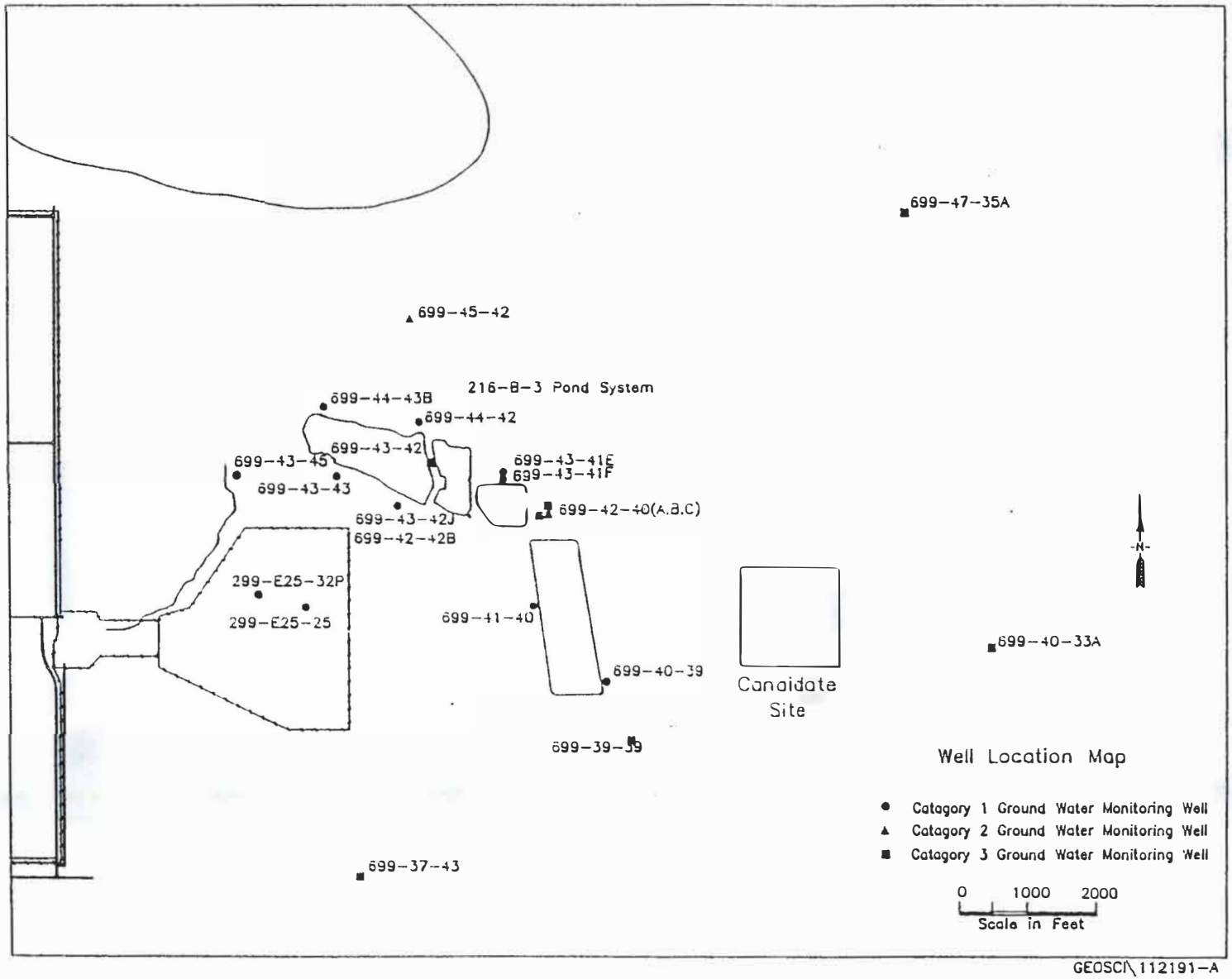


Figure 19. Locations of Ground Water Monitoring Wells Used to Evaluate Water Quality at the Candidate Site.

Table 4. Ground Water Monitoring Wells Used to Evaluate Water Quality at the Candidate Site.

Well #	Category	Date Drilled	Screened or perforated interval	Sampling method	Comments
299-E25-25	1	4/30/85	20	Hydrostar	Water table well
299-E25-32P	1	12/12/88	20	Hydrostar	Water table well
699-37-43	3	11/30/55	18	Submersible	Confined well
699-39-39	3	12/31/70	84	Submersible	Water table well
699-40-33A	3	2/28/49	79	Submersible	Water table well
699-40-39	1	7/31/89	11	Hydrostar	Confined well
699-41-40	1	9/28/89	10	Hydrostar	Confined well
699-42-40A	2	7/31/81	32	Submersible	Confined well
699-42-40B	3	9/30/81	20	Bailer	Water table well
699-42-40C	3	4/30/82	84	Bailer	RRI Confined well
699-42-42B	1	10/15/88	12	Hydrostar	Confined well
699-43-41E	1	9/28/89	10	Hydrostar	Confined well
699-43-41F	1	9/28/89	10	Hydrostar	Confined well
699-43-42	3	2/28/66	69	Bailer	Open hole water table well
699-43-42J	1	9/30/88	20	Hydrostar	Water table well
699-43-43	1	9/30/88	21	Hydrostar	Water table well
699-43-45	1	9/28/89	20	Hydrostar	Water table well
699-44-42	1	9/30/88	20	Hydrostar	Water table well
699-44-43B	1	9/28/89	20	Hydrostar	Water table well
699-45-42	2	6/30/48	22	Submersible	Water table well
699-47-35A	3	8/31/55	37	Submersible	Water table well

Twenty-one monitoring wells in the vicinity of the candidate site were evaluated. Of these wells, 12 are Category 1, 2 are Category 2, and 7 are Category 3 wells. All Category 1 wells in this area are RCRA ground water monitoring wells associated with a specific facility. The other wells are either up or downgradient from the candidate site. Ideally, only Category 1 wells would be used as data sources to help ensure that the data are unbiased and representative. However, because of the need for data from areas not covered by the RCRA wells, chemistry data from other wells have been used with caution. Table 4 lists the category of each of the 21 wells used to evaluate ground water quality at the candidate site.

2.7.3 Groundwater Quality

Ground water data from the vicinity of the candidate site were investigated for (1) evidence of past or present waste disposal practices that may have affected ground water quality, and (2) ground water constituents listed in WAC 173-200 that are present in the vicinity of the candidate site. Water chemistry data from 1990 and 1991 were examined in detail; older data were reviewed for additional information.

Historically, most wells have been sampled for only a few contaminants, principally radionuclides known to be byproducts of nearby facility operations. Currently, ground water monitoring at the Hanford Site is conducted for several programs, including RCRA, CERCLA, and facilities operations. Each of these programs requires the analysis of a different set of constituents. Consequently, chemical data varies from well to well, depending on which program required the sampling, and not all constituents of interest were analyzed for each well. The indicator parameters, Total Organic Carbon (TOC) and Total Organic Halogen (TOX), are well represented but analyses were not made for metals on a routine basis. Analyses are available for tritium, strontium, gross alpha and beta activities, and nitrate, but few, if any, of the organic chemicals or metals listed in WAC-173-200. Nevertheless, the data do provide a general indication of groundwater quality at the candidate site.

To investigate the effects of Hanford Site operations on ground water at the candidate site, the Geosciences Ground Water Data Base was used to provide a list of all available chemistry data from each of the 21 wells. These data were then reviewed to determine which contaminants appear in the wells in concentrations above their detection limits. A site-specific list was then compiled that listed all of these constituents. The constituents evaluated for the candidate site are those typically found in effluent discharged from such 200 East Area facilities as PUREX and B Plant to cribs and the B Pond complex, and known to be present in ground water beneath those facilities. Information compiled in Evans et al. (1990) was also used to develop the site-specific list of ground water contaminants. Appendix A lists all constituents identified in the wells from 1990 through 1991.

After information on ground water quality at the candidate site has been obtained, the water quality is depicted by maps of contaminant concentrations. Unless otherwise noted, data currently available (averaged values for all analyses of samples taken from a well during an 18-month period from January 1990 through June 1991) have been posted for that well.

Two sources of effluent disposal may have affected ground water quality in the vicinity of the candidate site -- the B Pond complex and cribs of the 200 East Area. The relative effects of effluent disposal in these areas on the candidate site depend primarily on the ground water flow paths and gradients. In general, areas downgradient from the

candidate site would have little effect on the site's ground water quality whereas areas directly upgradient could potentially strongly influence ground water quality at the site.

Current ground water flow conditions near the candidate site were depicted in Figure 13. The elevation of the water table has locally risen beneath the B Pond complex, forming a local high in the water table that controls flow directions and gradients over a large part of the Hanford Site. Representative ground water flow paths associated with the mound were also shown in Figure 13. Ground water flow in the unconfined aquifer originates in the vicinity of the candidate site at the crest of the B Pond mound and moves down gradient from the mound. Based on the directions of flow paths from the mound, ground water quality in the unconfined aquifer beneath the candidate site is likely to have a direct influence on the water quality in the B Pond mound.

A variety of effluent disposal activities have taken place within, and adjacent to, the 200 East Area during the past 50 years. Currently, the 200 East Area is downgradient from the candidate site and, consequently, likely has little effect on water quality at the candidate site. However, because the volume of effluent discharged to the B Pond complex has decreased in recent years and the mound appears to be diminishing in size and elevation, ground water flow directions will in the future change and portions of the 200 East Area and the area to the north of the 200 East Area will likely influence the quality of ground water at the candidate site.

Aluminum, barium, chromium, iron, manganese, nitrate, TOC, TOX, and tritium have routinely been identified in ground water from many of the wells to the west of the candidate site; these contaminants are known byproducts of current or past activities in the 200 East Area. Their presence in the ground water in elevated concentrations indicates contamination attributable to effluent disposal in and near the B Pond complex. Of these contaminants, chromium, iron, manganese, nitrate, and tritium are on the WAC 173-200 list.

The discussion of ground water quality in the following sections is organized according to the WAC 173-200 and 40 CFR 173 contaminants identified in the vicinity of the candidate site. The discussion makes use of data collected since 1990 from all three categories of wells. Appendix A lists all available data for these contaminants from 1990 through 1991.

2.7.3.1 Tritium. Tritium is present in many Hanford Site effluents discharged to the land surface and is the most mobile radionuclide at the site. Consequently, tritium provides an indication of the maximum extent of ground water contamination resulting from Hanford Site activities and is the most frequently monitored radionuclide at the site. Figure 20 shows the extent of tritium contamination present in the unconfined aquifer in the vicinity of the candidate site in 1988. Figure 21 shows tritium concentrations in the same area from January through July 1991. The allowable limit for tritium specified by

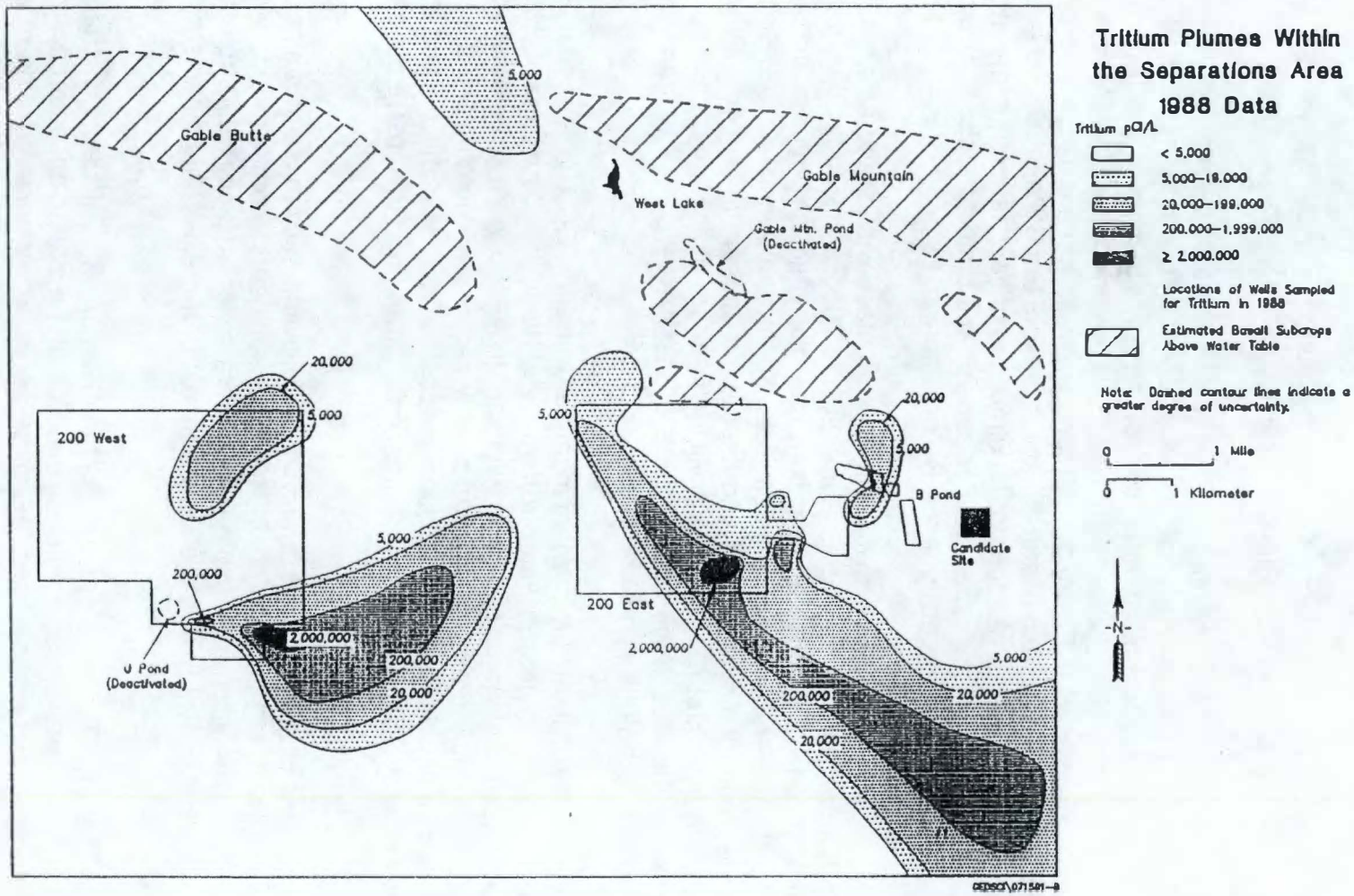


Figure 20. Tritium Contamination of the Unconfined Aquifer Near the Candidate Site in 1988.

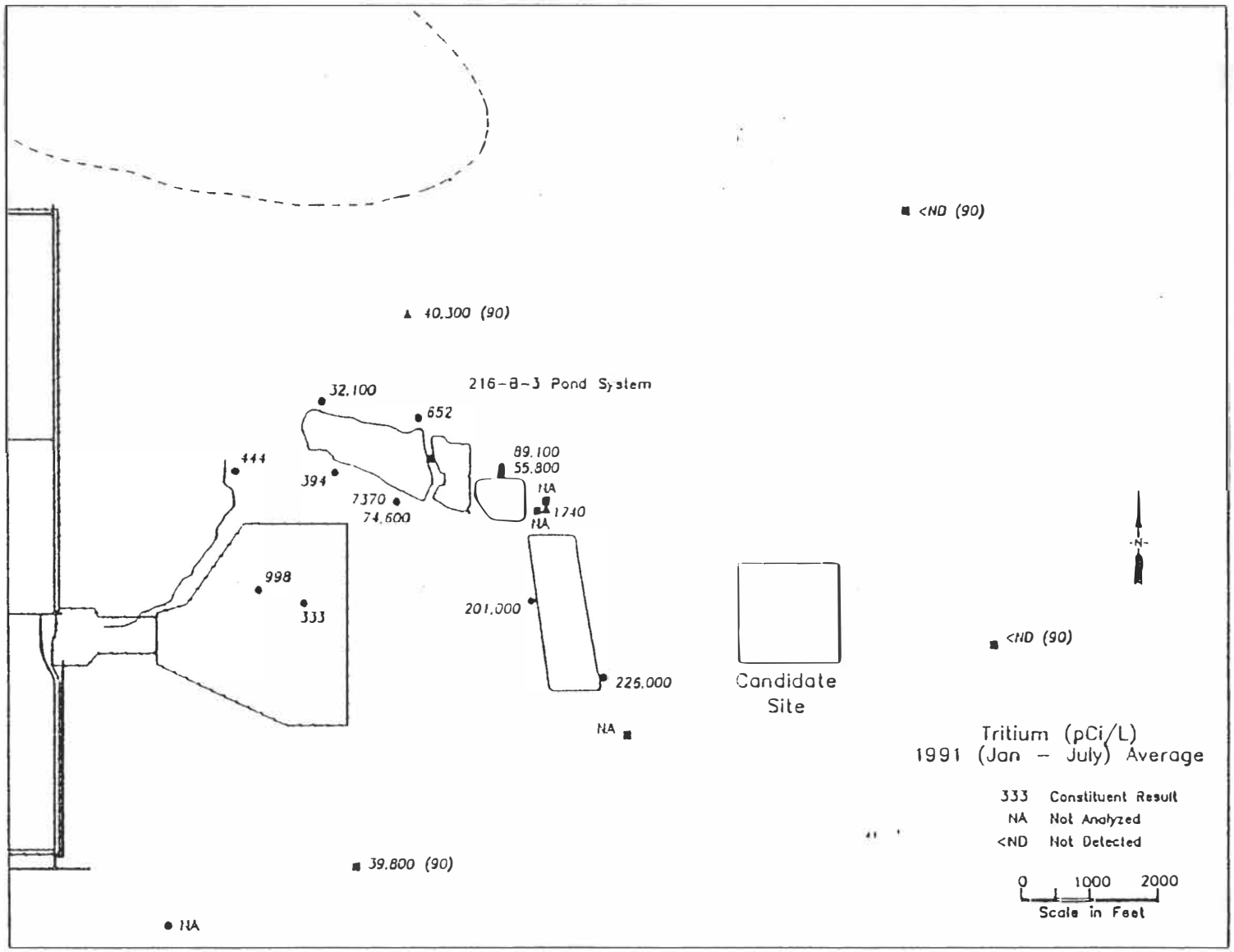


Figure 21. Tritium Concentrations in the Unconfined Aquifer Near the Candidate Site in January-July 1991.

WAC 173-200 is 20,000 pCi/L. This limit has been exceeded in several wells monitoring the B Pond complex. Maximum concentrations of 226,000 pCi/L were measured in that area. Because the B Pond complex is upgradient of the candidate site, ground water moving towards the candidate site from the B Pond mound could contain tritium in concentrations that exceed the regulatory limit.

Figure 22 shows tritium concentrations measured in water from wells 699-40-39 and 699-41-40 as a function of time. Both wells were constructed in 1989; consequently, the data are for only a short period of time. The highest observed concentration of tritium near the candidate site was in water from well 699-40-39, with an apparent concentration of 226,000 pCi/L in April 1991. However, this concentration decreased to less than detectable in July 1991. Water from well 699-41-40 also had a tritium concentration of 226,000 pCi/L in April 1991, but appeared to maintain a high concentration of 189,000 pCi/L in July 1991. Tritium concentrations in water from these two wells varied from less than detectable to more than 200,000 pCi/L during a 1-year period. Because of the inconsistency of the concentrations in these two wells, true tritium concentrations have not been determined with any confidence.

Water from two other wells upgradient of the candidate site also had anomalous tritium concentrations in 1990, but the concentrations measured in 1991 are more consistent. Figure 23 shows tritium concentrations measured in wells 699-43-41E and 699-43-41F as a function of time. Tritium concentration in well 699-43-41E was 100,000 pCi/L in April 1991; the concentration in water from this well decreased to 83,650 pCi/L in June 1991. A tritium concentration of 60,400 pCi/L was measured in water from well 699-43-41F in April 1991; this decreased to 51,200 pCi/L in July 1991. Tritium concentrations in ground water from these two wells upgradient from the candidate site are above the WAC 173-200 regulatory limit; hence, the potential exists for tritium contamination of the unconfined aquifer beneath the candidate site.

2.7.3.2 Nitrate. Figure 24 shows the extent of nitrate contamination of the unconfined aquifer in the 200 Areas in 1988. Nitrate concentrations that could affect the candidate site are associated with the B Pond water table mound. Within the mound, concentrations are below the WAC 173-200 limit of 10 mg/L N (45,000 ppb NO_3). Figure 25 shows the average nitrate concentrations in the unconfined aquifer from January 1990 through June 1991 near the candidate area. The highest nitrate concentration near the candidate site was in ground water from well 699-41-40, with 22,500 ppb measured in January 1990. Elevated levels of nitrate are also present in well 699-43-41E, with 10,400 ppb measured in May 1990. Water from well 699-43-41F had a nitrate concentration of 11,700 ppb in April 1990. Nitrate concentrations in these wells are well below the regulatory limit of 10 mg/L N (45,000 ppb NO_3). Nitrate was not detected in ground water from wells nearest to the candidate site (699-40-39 and 699-40-33A).

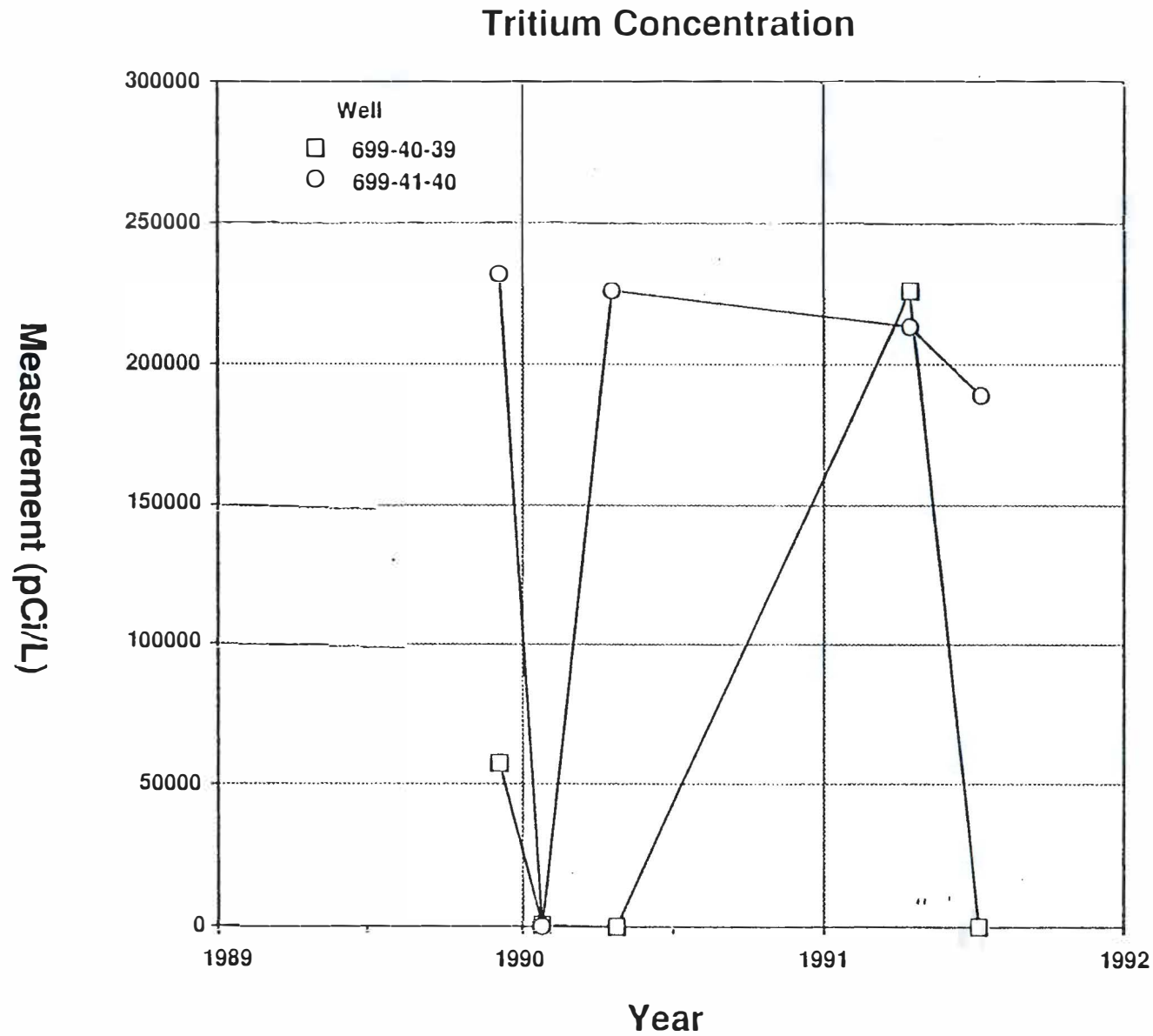


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Figure 22. Tritium Concentrations Measured in Wells 699-41-39 and 699-41-40 as a Function of Time.

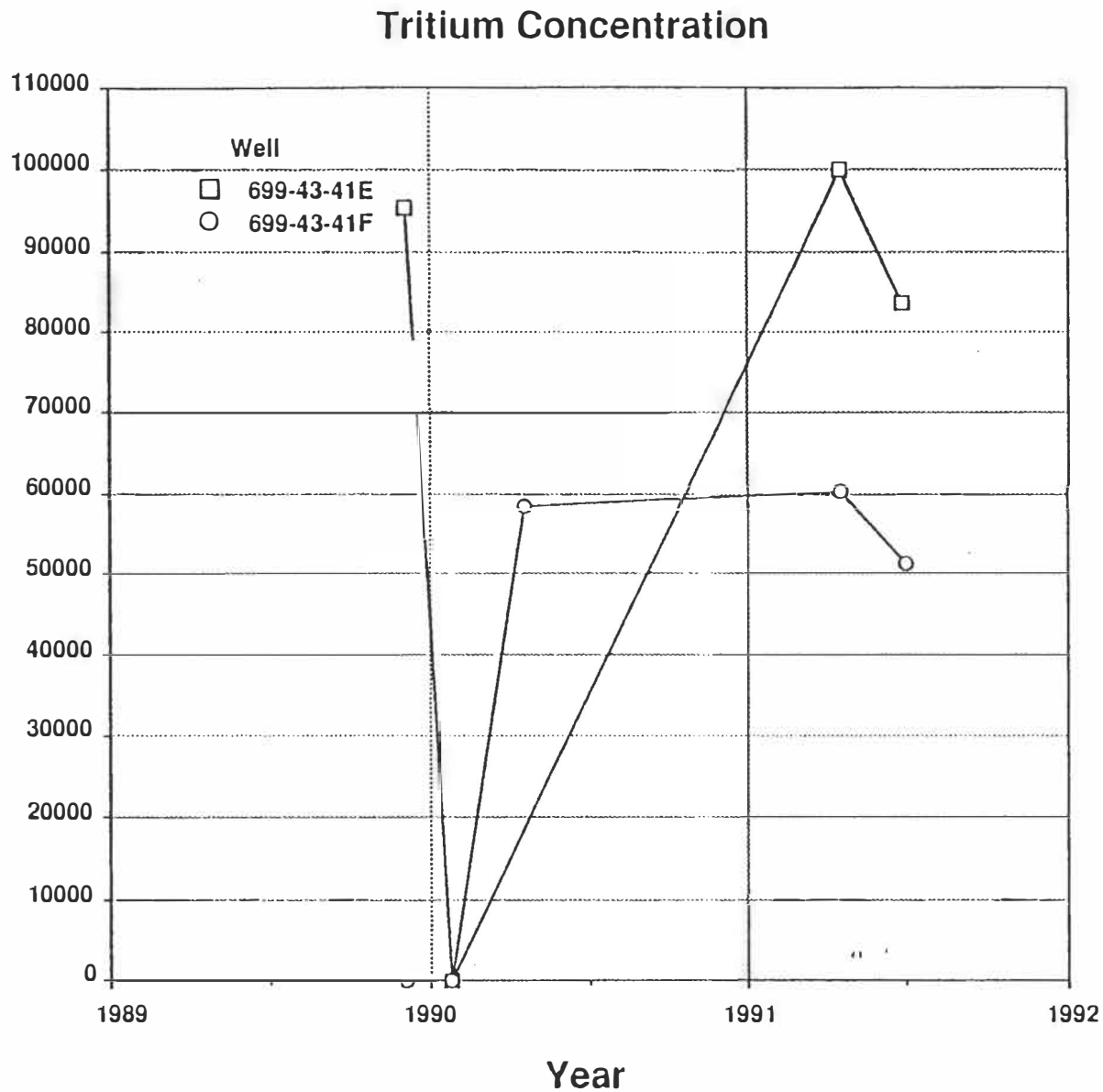

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Figure 23. Tritium Concentrations Measured in Wells 699-43-41E and 699-43-41F as a Function of Time.

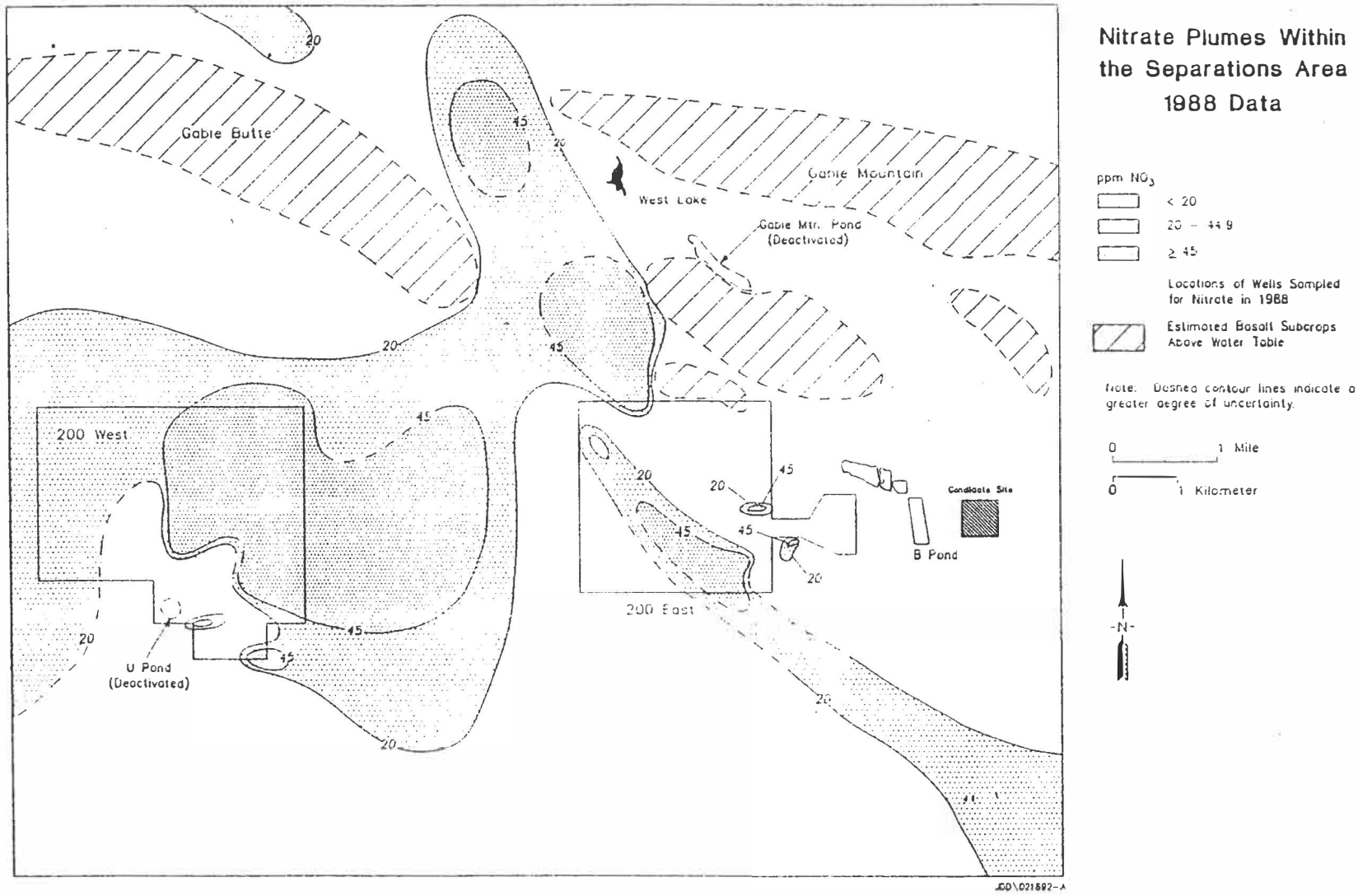

Figure 24. Nitrate Contamination of the Unconfined Aquifer Near the Candidate Site in 1988.

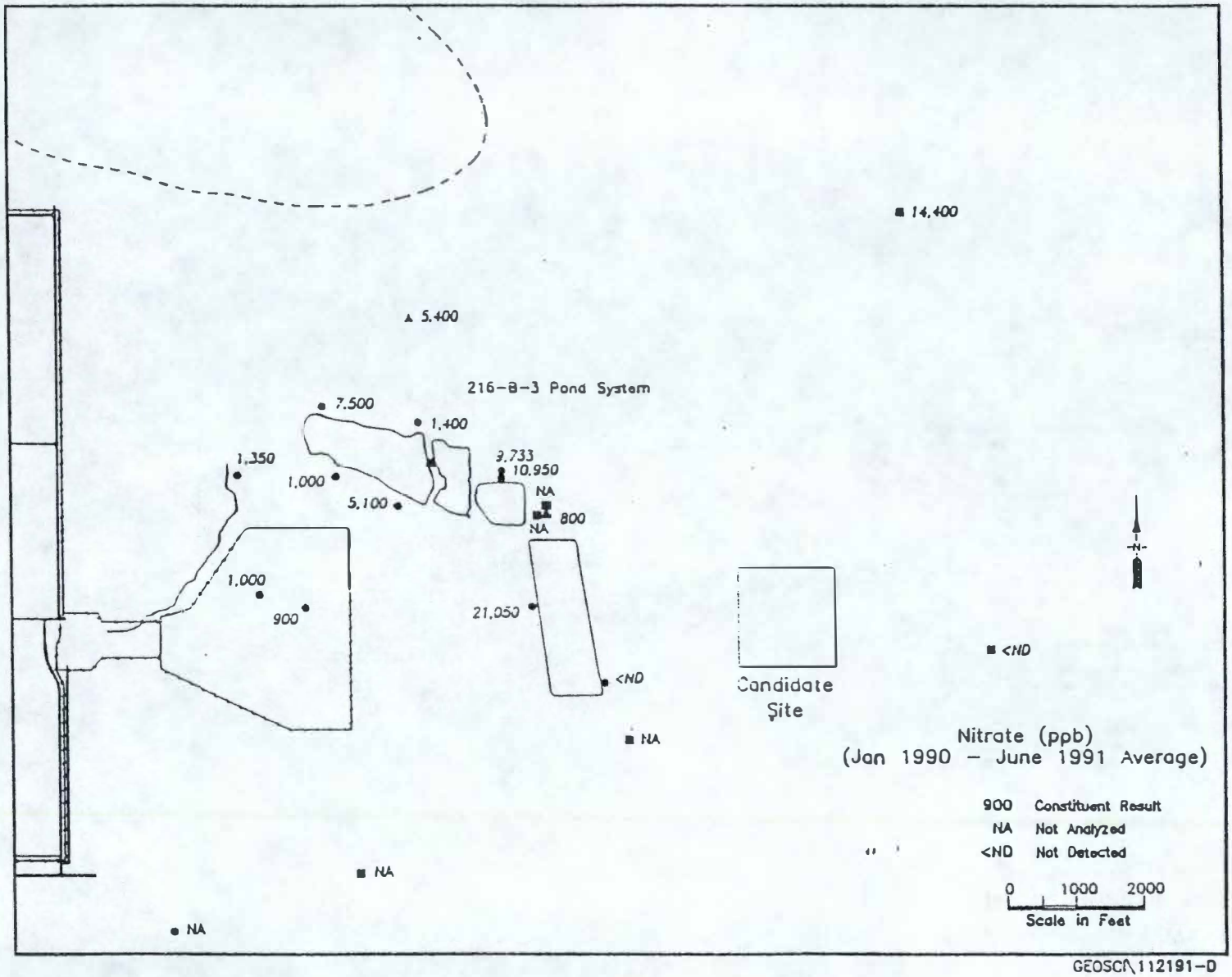

Figure 25. Nitrate Concentrations in the Unconfined Aquifer Near the Candidate Site (January 1990 - June 1991 Average).

2.7.3.3 Manganese. Concentrations of manganese were above the detection limit in water from 7 of the 14 wells analyzed in the vicinity of the candidate site and were above the WAC-173-200 limit of 0.05 mg/L (50 ppb) in 3 wells (Figure 26). The highest detected concentration of manganese near the candidate site is in ground water from well 699-40-39, with 231 ppb in January 1990. The manganese concentration in this well decreased to 93 ppb in April 1991. Ground water in well 699-41-40 had a manganese concentration of 75 ppb in January 1990, but only 35 ppb in April 1990. Based on these data, manganese concentrations in the vicinity of the candidate site appear to be decreasing.

2.7.3.4 Other Metals. Four other metals occurred at concentrations in the ground water that are above their detection limits. Aluminum, barium, and iron were detected both in wells that are upgradient from the candidate site and in wells with the same potentiometric elevation as the candidate site. Chromium was detected only in water wells upgradient from the candidate site.

Aluminum concentrations did not exceed the allowable level of 0.50 mg/L (500 ppb) specified in 40 CFR 143, the *National Secondary Drinking Water Regulations* (EPA 1990). Ground water in well 699-40-33A had an aluminum concentration of 485 ppb in February 1990. More recent analyses from this well are not available. The aluminum concentration in water from well 699-43-41F was 300 ppb in April 1990 but decreased to below the detection limit in April 1991.

Iron occurred in concentrations that exceed the WAC 173-200 allowable limit of 0.30 mg/L (300 ppb) in 2 of the 15 wells analyzed. Ground water from well 699-40-33A had an iron concentration of 548 ppb in February 1990. More recent analyses are not available. Iron concentration in water from well 699-43-41F was 747 ppb in April 1990 but decreased to below the detection limit in April 1991.

Concentrations in ground water from the 14 wells analyzed for barium are generally within the range of the barium background level of 42 ± 20 ppb (Evans et al. 1990). Ground water from one well (699-40-39) had a barium concentration of 126 ppb, slightly higher than the background level.

Chromium was above the detection limit in water from one well in the vicinity of the candidate site. Water from well 699-41-40 had a chromium concentration of 21 ppb in April 1991 that subsequently decreased to 11 ppb in April 1991. These concentrations are well below the allowable limit of 0.05 mg/L (50 ppb) in WAC 173-200.

The presence of elevated concentrations of metals in ground water may be due to well construction materials and completion practices. Casing materials used to construct ground water monitoring wells at the Hanford Site can increase metal concentrations in the ground water. Consequently, the elevated concentrations in ground water of metals

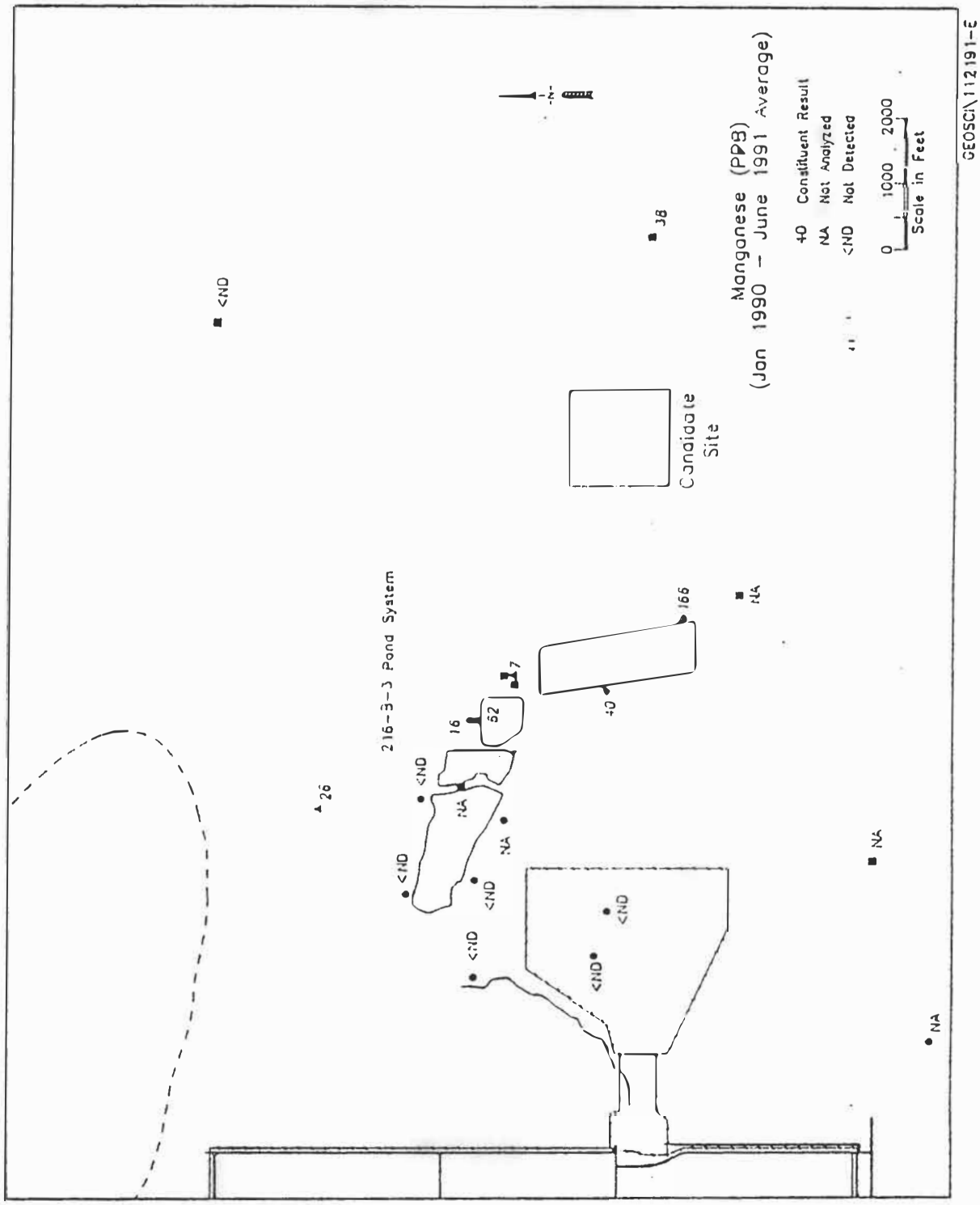

Figure 26. Manganese Concentrations in the Unconfined Aquifer Near the Candidate Site (January 1990 - June 1991 Average).

commonly used in well casings may be a consequence of the well, rather than another source.

2.7.3.5 Total Organic Halogen and Total Organic Carbon. TOX was detected in ground water from two wells upgradient from the candidate site. Figure 27 shows the TOX measured in ground water from wells 699-43-41E and 699-43-41F as a function of time. Water from well 699-43-41E had a TOX concentration of about 1,200 ppb in May 1990 that decreased to 130 ppb in June 1991. Water from well 699-43-41F had a TOX concentration of about 1,250 ppb in April 1990 that decreased to 23 ppb in July 1991. The statistically calculated limit of quantification for TOX in the vicinity of the B Pond complex is about 15 ppb.

TOC was detected in four wells upgradient from the candidate site. Figure 28 shows the TOC measured in ground water wells 699-41-40, 699-42-40A, 699-43-41E, and 699-43-41F as a function of time. Well 699-41-40 had a TOC of 1,400 ppb in April 1990 that decreased to below the detection limit (1,000 ppb) in July 1991. Well 699-42-40A had a TOC concentration of 1,400 ppb in July 1991. Well 699-43-41E had a TOC concentration of about 1,150 ppb in May 1990 that decreased to below the detection limit in June 1991. Well 699-43-41F had a TOC concentration of about 1,100 ppb that decreased to below the detection limit in July 1991. The statistically calculated limit of quantification for TOC in the vicinity of the B Pond complex is 812 ppb.

RCRA ground water monitoring at the B Pond complex was upgraded from detection monitoring to assessment monitoring in June 1990 because of elevated levels of TOX and TOC in ground water at the B Pond complex. Ground water moving towards the candidate site from the B Pond mound may contain elevated levels of TOX and TOC.

2.7.4 Summary of Ground Water Quality Information

Ground water flow toward the candidate site originates at the water table mound associated with effluent discharge at the B Pond complex. Consequently, any contaminants detected in the mound area are likely to influence the quality of the ground water at the candidate site. Data on ground water quality in the vicinity of the candidate site are summarized in Table 5. Well data are in the appendix. Both nitrate and tritium occur in ground water in the southeastern part of the B Pond mound. The concentration of nitrate in water from the mound is below the WAC 173-200 allowable limit; the concentration of tritium is above the limit. Both contaminants result from effluent discharged to the B Pond complex and vicinity since 1945. These contaminants are in ground water currently moving towards the candidate site. Considering the effects of diffusion and dispersion, their concentrations are likely to rapidly decrease radially outward from the apex of the mound, along the flow paths that were shown in Figure 13.

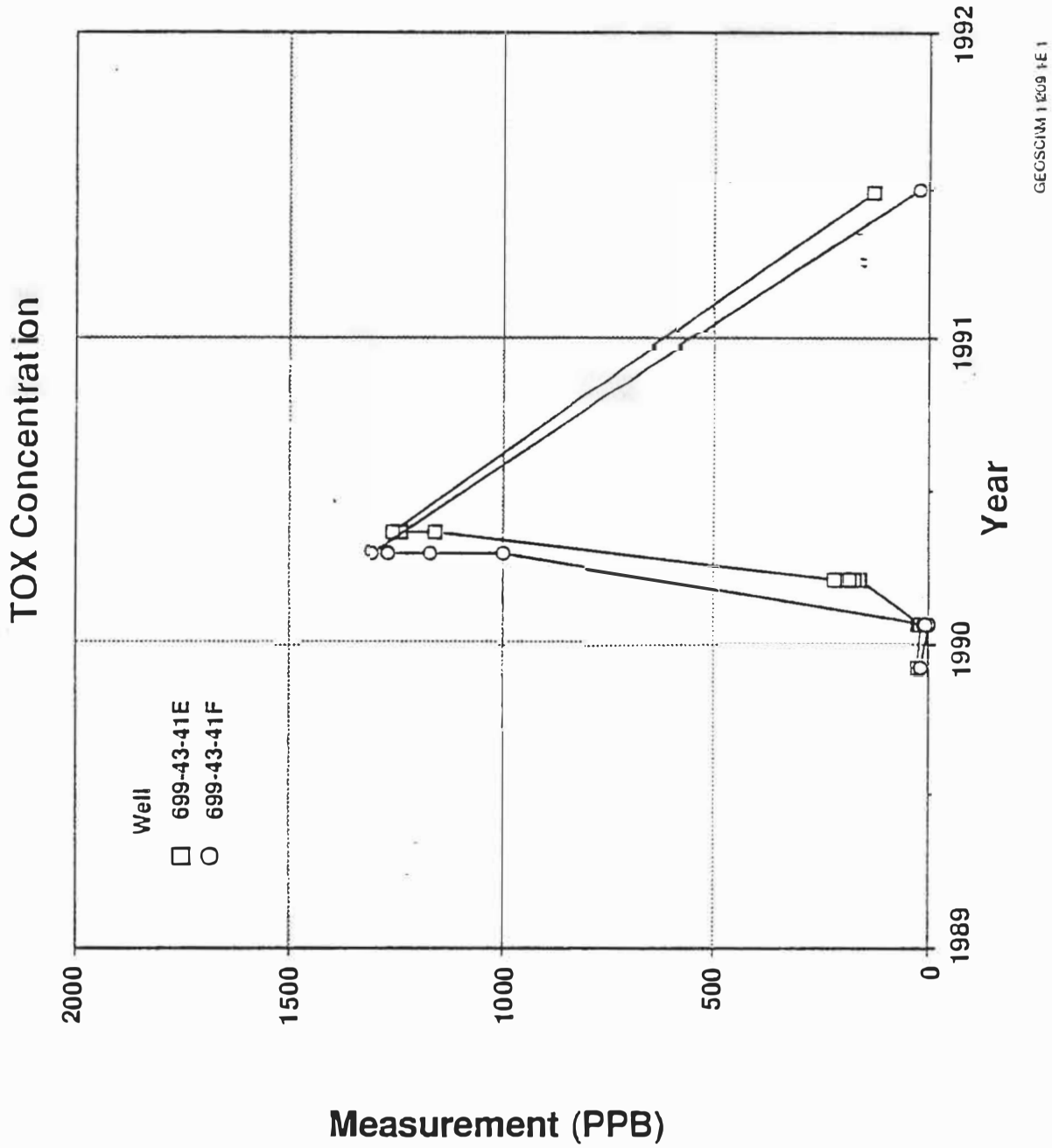

Figure 27. Total Organic Halogen Concentration in Wells 699-43-41E and 699-43-41F as a Function of Time.

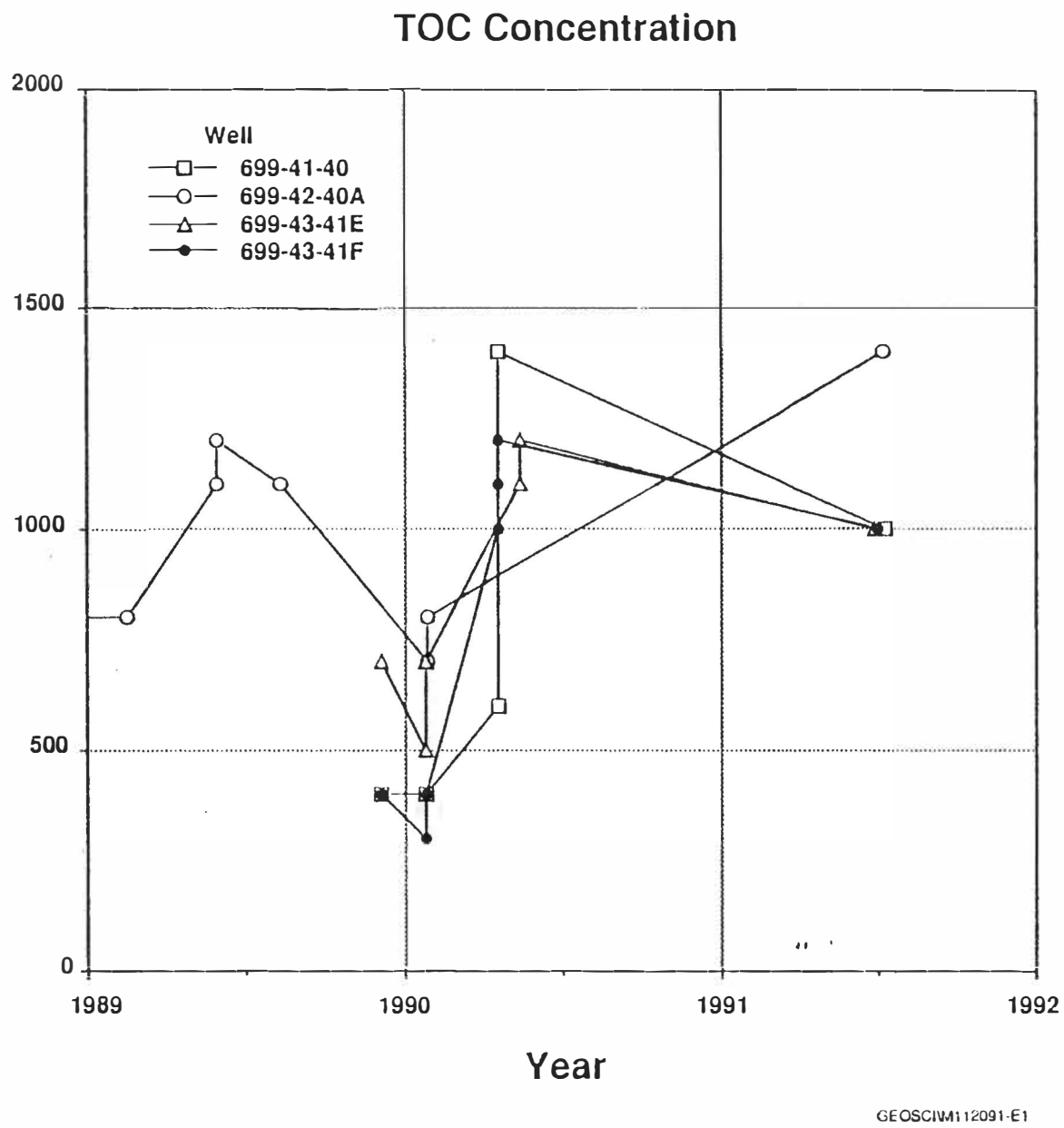

Figure 28. Total Organic Carbon Concentration in Wells 699-41-40, 699-42-40A, 699-43-41E, and 699-43-41F as a Function of Time.

Table 5. Summary of Ground Water Quality Data for Wells in the Vicinity of the Candidate Site Area.

CONSTITUENT	WELL WITH DETECTED CONSTITUENT	CONCENTRATION IN WELL	ABOVE REGULATORY LIMIT?	FEET FROM SITE
Aluminum	699-40-33A	485 ppb	yes	2,000
Barium	699-40-39	126 ppb	no	2,000
Chromium	699-41-40	11 ppb	no	3,000
Iron	699-40-33A	548 ppb	yes	2,000
Manganese	699-40-39	231 ppb	yes	2,000
Nitrate	699-41-40	22,500 ppb	no	3,000
TOX	699-43-41E	130 ppb	yes	4,000
TOC	699-42-40A	1400 ppb	yes	3,000
Tritium	699-41-40	189,000	yes	3,000

Several additional contaminants have likely migrated toward the candidate site. Based on evidence of elevated concentrations in wells upgradient from or at the same potentiometric elevation as the candidate site, elevated concentrations of barium and manganese may be present in the vicinity of the candidate site; manganese may be present in concentrations above the allowable limit. TOX and TOC have been detected in wells upgradient from the candidate site. The contaminants appear to be migrating towards the candidate site, but currently are below detection limits in the vicinity of the site. With the cessation of effluent disposal to the B Pond complex, the gradient forcing flow toward the candidate site will likely decrease.

2.8 Air Quality

The maximum effect on air quality of the effluent disposal facility (estimated by using 40 CFR 61 Appendix D methods) will be less than 1% of the 10 mrem/yr standard. Consequently, pursuant to 40 CFR 61.94, no permit will be required, but a brief description of Project W-049H construction will be included in the annual report to the EPA in the calendar year in which construction is completed.

The EPA regulations to prevent significant deterioration of air quality are published in 40 CFR 52. However, Title III of the 1990 Amendments to the Clean Air Act exclude radionuclides and several other hazardous air pollutants from the 40 CFR 52 regulations. Washington State implements the federal requirements through WAC 173-400. The pollutants currently subject to 40 CFR 52 (as amended) that may be released from Project

W-049H effluents include PM-10 (aerosols) and volatile organic compounds (VOCs). If projected releases of aerosols exceed 25 tons/year and releases of VOCs are expected to exceed 40 tons/year, approval by the state is required prior to construction. Current estimates for Project W-049H are that PM-10 and VOC releases will not exceed these rates.

Compliance of Project W-049H with the federal and state Clean Air Act and WAC Chapter 246-247, *Radiation Protection -- Air Emissions*, is evaluated through WAC 173-480-050 (3). This administrative code requires that emissions of radionuclides to the air comply with the most stringent limits specified by any other federal or state standard. The most restrictive standard is 40 CFR 61, Subpart H (61.92). This federal regulation requires that the emission of radionuclides to the ambient air from DOE facilities not exceed an effective dose equivalent of 10 mrem/year. In addition, compliance of Project W-049H requires that a Notice of Construction (NOC) be submitted to the Washington State Department of Health and approved prior to initiation of construction, and that the project utilize the Best Available Radionuclide Control Technology (BARCT).

Schmidt et al. (1990) report the results of environmental surveillances of ambient air quality in 1989 for the 200 and 600 Areas of the Hanford Site. Sampling was conducted to determine baseline concentrations of radionuclides in the air and to assess the effect of Hanford Site operations on the local environment. Fifty-two permanent sampling stations that operate on a continuous basis are located about 3 ft (1 m) above the surface of the ground. The stations were located in consideration of prevailing wind directions and likely sources of pollutants. Figure 29 shows the locations of the air samplers that are nearest the candidate site.

The measured concentrations of airborne radionuclides immediately up-wind from the candidate site for the 200 Areas TEDB were many times less than the derived concentration guidelines (Schmidt et al. 1990). Results of a trend analysis using data collected since 1979 demonstrated a continued overall decline at all monitoring stations of airborne radionuclides.

2.9 Survey of Threatened and Endangered Species

A ground-based survey of plant and animal life on candidate sites for the 200 Areas TEDB was made during a period of about 6 weeks in the spring of 1991 (from late April through early June). This is the time of year during which most plant species found on the Hanford Site are at an identifiable stage in their annual life cycle and most resident and migratory animal species are present and active. The survey was made by walking across the areas of interest while identifying and listing each different plant and animal species as it was encountered during the traverse.

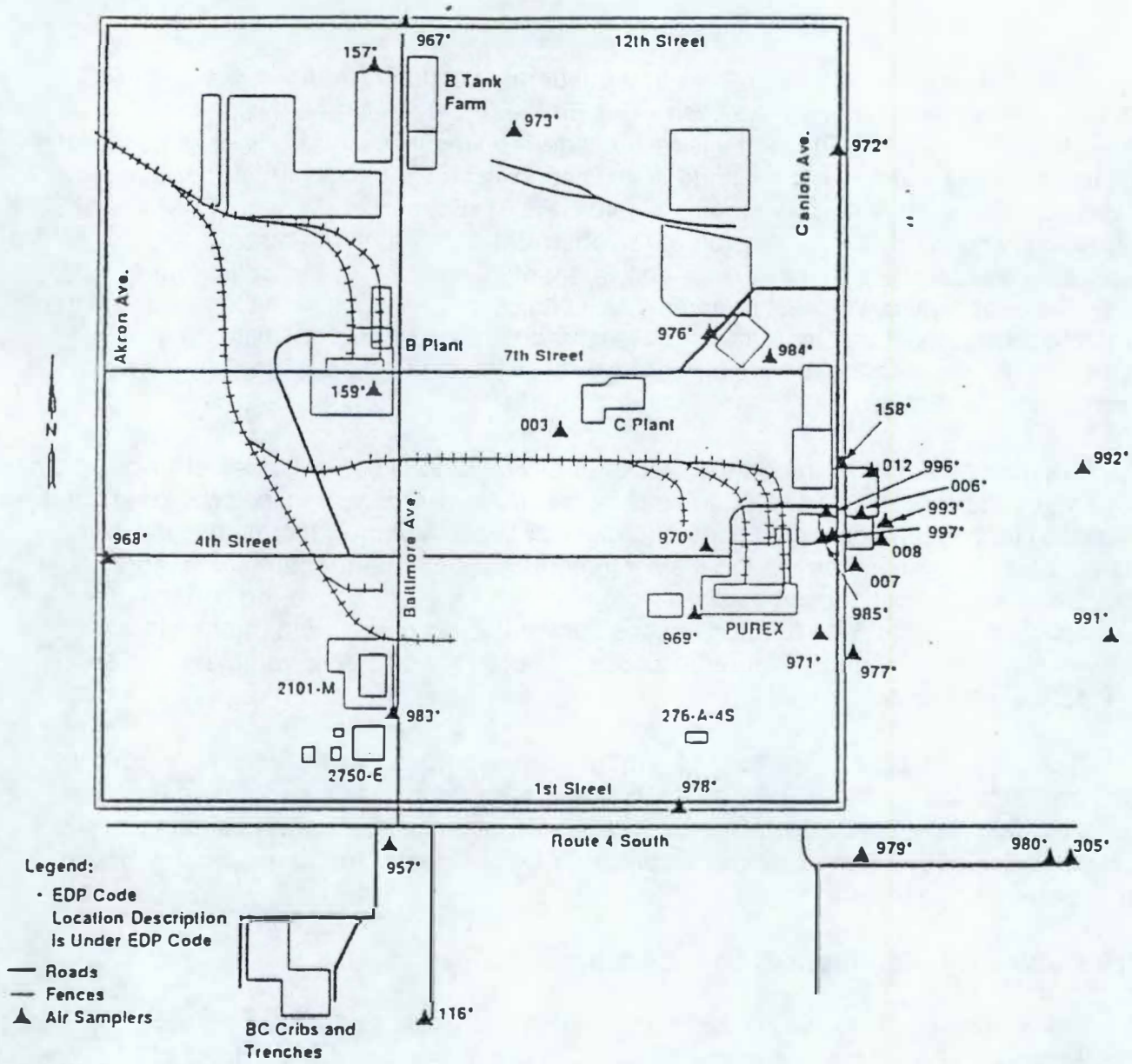

Figure 29. The Location of Air Samplers in the Vicinity of the 200 East Area.

No endangered, threatened, or sensitive plant or animal species were found that would be adversely affected by construction and operation of the 200 Areas TEDB at the site shown in Figure 1. However, because each species became identifiable at different times during the 6-week period, some species could have been overlooked. Consequently, an intensive follow-up survey focused on the area shown in Figure 1, as well as of the projected routes of the associated effluent pipeline and access road, will be made in the spring of 1992. This follow-up survey will be conducted in accordance with the methods described in Appendix C of Davis (1991). The results will be reported as an addendum to this report.

2.10 Survey of Cultural Resources

The Hanford Cultural Resources Laboratory (HCRL) surveyed the preferred candidate site in August 1991. The site shown in Figure 1 was traversed along north-south lines spaced 20 m apart. No cultural resources were found within the candidate site, nor were geomorphic indicators present that suggested the presence of buried materials of archaeologic interest. Details of the survey are given in Appendix B of Davis (1991).

3.0 IDENTIFICATION OF INFORMATION NEEDS

The additional site characterization data needed for the WAC-173-240 engineering report and the WAC 173-216 permit application can be defined based on current knowledge of the candidate site (see Section 2) and regulatory requirements and guidance (see Section 1). Once the data needs are known, the methods to be employed for data collection can be identified, the analyses needed to interpret the data can be defined, and the analytical methods specified.

The discussion that follows (1) provides the rationale for the type and amount of data needed, (2) identifies the data to be obtained by the site characterization activities described in Section 5, and (3) provides an overview of the data collection and analysis methods to be employed.

3.1 Data Needs

Past efforts to collect hydrogeologic data focused on the 100, 200, 300, and 1100 areas of the Hanford Site. Consequently, there are few data currently available and relevant to evaluating the suitability of the candidate site for disposal of Project W-049H treated effluent. This section identifies the remaining questions regarding the suitability of the candidate site, the basis of the data needs, the justifications for acquiring the additional information, and the data to be collected.

The basis for tentatively selecting the candidate site from a group of alternative sites based on available information is discussed in detail by Davis (1991). The basis for choosing to dispose of Project W-049H treated effluent to the land surface rather than by alternative methods is provided by Bovay (1992). What remain are a series of questions that result from inadequate knowledge of the subsurface conditions at the candidate site. These questions must adequately be answered by the work described in Section 5 before the suitability of the candidate site can be demonstrated. The questions are:

(1) Are stratigraphic or lithologic features present that could cause the infiltration of treated effluent to adversely affect ground water quality at, or downgradient from, the proposed site after the facility is in operation?

(2) Is the ground water of the unconfined aquifer and in the sediments above the water table at, or downgradient from, the candidate site sufficiently free of hazardous contaminants that operation of the facility at the site would not adversely affect ground water quality?

(3) What effect will the TEDB have on the current elevation of the water table and the distribution and travel times of known contaminant plumes?

Regulatory guidance on the information required for WAC-173-240 engineering reports specifies that the following site-specific information be provided for facilities proposed to dispose of effluent to the land surface:

- A discussion of the suitability of the proposed site for the facility, including an evaluation of disposal alternatives and descriptions of the following:
  - The stratigraphy and lithologies from the land surface to the water table
  - The stratigraphy and lithologies of the unconfined aquifer
- Pertinent site maps and facility layout sketches
- Description of the effluent composition, location of the point of discharge, and applicable water quality standards
- Hydrogeologic evaluation of the depth to ground water and ground water movement during different times of the year
- A water balance analysis of the proposed discharge area
- Analysis of the effects of the proposed facility on ground water in conjunction with the effects on ground water of other facilities that discharge effluent to the land

surface in the vicinity of the proposed site, including:

- Current ground water quality at the proposed site (pH, temperature, conductivity, and major cations and anions)

- The effect of the facility on existing contamination of the sediments above the water table and in the unconfined aquifer.

Site-specific knowledge of the following is needed to answer the remaining questions of the site's suitability for disposal of treated effluent from Project W049-H.

- Three-dimensional knowledge of the stratigraphic units and their characteristics that affect ground water movement

  Acquisition of this knowledge requires:

  (1) Determination of the presence or absence, configurations, and dimensions of low-permeability hydrologic units in the unsaturated or saturated zones that may impede downward movement and cause lateral movement of infiltrating effluent

  (2) Determination of the presence or absence and configurations of buried paleostream channels or other features which may provide high-permeability pathways in the unsaturated or saturated zones that facilitate rapid migration of treated effluent in preferred directions

  (3) Determination of whether the presence of extensive erosion of the basalt overlying the uppermost confined aquifer permits hydraulic communication between the unconfined and confined aquifers.

- Determination of water quality and chemical and/or radioactive contamination of the unsaturated zone and the unconfined aquifer

  Aquisition of this knowledge requires:

  (1) Physical examination and geophysical logging of the sediments that comprise the unsaturated zone and the zone saturated by the unconfined aquifer

  (2) Analysis of water from the unconfined aquifer for the presence or absence of contaminants known to be present elsewhere at the Hanford Site.

  (3) Chemical analysis of near-surface sediments.

- Estimation of the local rates of effluent movement through the principal stratigraphic units of the unsaturated and saturated zones

  Aquisition of this knowledge requires:

  (1) Determination of moisture characteristic curves for the principal geologic units of the unsaturated zones based on laboratory delimitation of matric potentials and relative hydraulic conductivities as functions of volumetric water contents

  (2) Hydraulic testing to determine hydraulic conductivities, transmissivities, and specific yields of the principal geologic units of the saturated zone

  (3) Measurement of depths to the water table to determine hydraulic gradients

  (4) Simulation of ground water flow vectors and water table elevations in the vicinity of the candidate site for the duration of interest using a computer-encoded numerical model.

3.2 Methods of Site Characterization

The needs for additional data outlined in Section 3.1 will be satisfied by the drilling and completion of wells through the sediments overlying the basalt bedrock at the candidate site. The principal geologic units will be characterized by taking chip samples from the well cuttings and core samples from selected stratigraphic intervals. Chip samples will be collected from the well cuttings at 5-ft intervals, geologically logged, and stored in the Hanford Geologic Sample Library for potential future use. Core samples will selectively be taken to provide material for laboratory determination of the physical properties pertinent to assessing ground water movement in the principal stratigraphic units. The cores will also be stored in the Hanford Geologic Sample Library for potential future use.

The wells will be geophysically logged. Gamma, gamma-gamma, and neutron logs will be made. After well installation, development, and completion, the elevations of the water table will be measured to determine the hydraulic gradient. The temperature and pH of the ground water will be measured. Samples of water from the upper part of the unconfined aquifer will be collected and chemically analyzed for major cation and anion contents, and potential contaminants.

The aquisition of data relates to data needs as follows:

<u>Data Need</u> -- Three-dimensional knowledge of the stratigraphic units and their physical properties that affect ground water movement

Characterization Method --

- Description of chip samples of well cuttings
- Description of core samples from selected strata
- Geologic and geophysical logs
- Analysis of physical properties of samples from selected strata.

Data Need -- Determination of water quality and verification of the presence or absence of chemical and/or radioactive contamination of the unsaturated zone and the unconfined aquifer

Characterization Method --

- Physical examination and geophysical logging of unsaturated and saturated zone sediments
- Chemical analysis of sediments from the top (most likely to be contaminated) 20 ft (~6 m) of the unsaturated zone and of water from the unconfined aquifer
- Measurement of water temperature and pH.

Data Need -- Estimates of the local rates of effluent movement through the principal stratigraphic units of the unsaturated and saturated zones.

Characterization Method --

- Laboratory determination of matric potentials and relative hydraulic conductivities as functions of volumetric water contents
- Aquifer testing to determine hydraulic conductivities, transmissivities, and specific yields
- Measurement of water table elevations to determine the local hydraulic gradients
- Simulation of ground water movement using a numerical model.

The subsurface investigations performed to characterize the candidate site do not constitute a ground water monitoring program. If the results of the site characterization

work confirm the site's suitability, a ground water monitoring plan will be prepared to identify and define monitoring requirements needed to ensure regulatory compliance.

3.3 Analyses and Analytical Methods

Samples of the principal stratigraphic units will be analyzed in the laboratory for physical properties pertinent to the movement of ground water in the unsaturated zone. Bulk chemistry analyses will be made of near-surface sediment samples to determine if the sediments are free of contamination by hazardous chemicals. Ground water of the unconfined aquifer will be chemically analyzed for major ions and potential contaminants.

3.3.1 Chemical Analysis of Bulk Sediment Samples

The bulk analysis of sediments will provide information on concentrations of specific constituents in each sample. These analyses are to be in accordance with procedures specified in Table 6. Details on the analytic methods to be employed are in EPA (1986b; SW 846 methods 6010, 8240, and 8270) and EPA (1989; Method 300). In addition, radionuclide-specific analyses are to be made if the gross alpha and beta or gamma-ray data from the geophysical logs suggest the presence of above-background radioactivity.

The concentrations of the constituents listed in Table 6 are to be determined for the following reasons.

Cations. Cations that are potentially of most environmental concern at the Hanford Site are those of heavy metals. Other cations may not be of direct interest, but are important constituents of the sediments and, hence, are important to understanding the chemical characteristics of the sediments. Moreover, these constituents are normally determined along with the heavy metals in analyses using the SW-6010 method and, consequently, results for them can be obtained at little or no additional cost.

Hexavalent Chromium. Chromium is toxic when present in the hexavalent oxidation state (dichromate or chromate). Hexavalent chromium has locally been identified as a contaminant in parts of the unconfined aquifer beneath the Hanford Site.

Mercury. Mercury is to be determined because of its relatively high toxicity and its known use at the Hanford Site. Mercury concentrations in the soils will be determined by the cold vapor technique because the results provided by method 6010 may not be sufficiently accurate to verify the presence or absence of mercury in concentrations above regulatory guidelines.

Anions. Many anions can be determined simultaneously by ion chromatography (EPA method 300). Among these anions, nitrate and fluoride have previously been identified as contaminants in the unconfined aquifer beneath the Hanford Site.

Determination of other anions is useful in interpreting ground water quality data because the ionic content contributes to the concentration of dissolved solids in water of the unsaturated and saturated zones.

Table 6. Constituents and Analytical Methods for Bulk Sediment-Sample Analysis.

Constituent	Method
Cations	SW-846 method 3050 and 6010
Hexavalent chromium	SW-846 method 7196 (ion extraction)
Mercury	SW-846 method 7471 (cold vapor technique)
Anions	EPA method 300 -- batch leach anions from sample with water and analyze leachate
Cyanide	SW-846 method 9010A
$CaCO_3$	ASTM method D-4373
pH	SW-846 method 9045
Volatile organics	SW-846 method 8240
Semivolatile organics	SW-846 method 3540, or 3550 and 8270
Radiation	
Gross alpha	SW-846 method 9310
Gross beta	SW-846 method 9310
Gamma	Gamma-ray scan

Cyanide. Cyanide is to be determined because it has been identified as a contaminant in parts of the unconfined aquifer beneath the Hanford Site.

Carbonate. Total carbonate (reported as calcium carbonate) of Hanford Site sediments is significant. Carbonate content can influence both hydrologic and chemical characteristics of the unsaturated zone.

pH of Sediments. The pH of near-surface sediment samples will be measured because abnormally high or low pH can indicate the presence of hazardous chemicals.

Volatile and Semivolatile Organics. The presence of abnormally high values for organics is an indicator of the presence of organics; e.g., halogenated solvents known to be present as a contaminant in parts of the unsaturated zone and the unconfined aquifer beneath the Hanford Site.

Radionuclides. Large inventories of radionuclides have been generated by Hanford Site activities and, consequently, are a potential source of contamination above and below the water table.

3.3.2 Determination of Physical Properties

Testing of the physical properties of the principal stratigraphic units is to be in accordance with the procedures identified in Table 7 and the *Geotechnical Engineering Procedures Manual* (WHC 1990).

3.3.3 Chemical Analysis of Ground Water

Although the extent of regional ground water quality has been evaluated at the Hanford Site, water quality data specific to the candidate site are not available. To determine the ground water quality at the candidate site, samples of water from the regionally unconfined aquifer are to be collected from each well drilled to characterize the site. The samples are to be analyzed for the constituents listed in Table 8. Analytical methods to be used for each constituent are also listed in Table 8. Temperature, pH, and electrical conductivity are also to be measured to provide the information likely to be required by the WAC-173-216 permit application. Ammonium and total organics, which are not included in WAC 173-200-040, are also to be analyzed.

A review of the history of effluents discharged to the B Pond complex was made to define a RCRA ground water sampling program for closure/post-closure plans for that facility (DOE 1990b). Four constituents specific to the B Pond complex -- hydrazine, ammonium, tritium, and total organics -- were chosen for analysis based on the historical review and are included in the list of constituents to be analyzed for in ground water at the candidate site. Results of these analyses have been published in quarterly and annual reports (DOE 1991c, d, and e, 1992).

Table 7. Physical Properties to be Determined and Test Methods.

Property	Method
Porosity	ASTM D-698 and D-1557
Bulk Density	ASTM D-698 and D-1557
Particle Size Distribution	ASTM D-422
Soil Moisture	ASTM D-2216
Hydraulic Conductivity	ASTM D-2434
Soil Moisture Characteristic Curves	ASTM D-2325 and D-3152
Particle Fineness	ASTM D-422
Cation Exchange Capacity	American Society of Agronomy (1982)

All ground water samples obtained for site characterization are to be collected, handled, analyzed, and the results reported in accordance with the pertinent provisions of the *Quality Assurance Plan for RCRA Ground Water Monitoring Activities* (Jackson 1990). An initial sample is to be analyzed from each site characterization well. If the results suggest that an anomalous concentration or a concentration that exceeds the regulatory limits for that constituent are present, a second sample is to be collected and analyzed to confirm the results of the first analysis. Samples are to be analyzed in accordance with the methods and procedures specified in Table 8.

3.4 Numerical Simulations

The initial step in the analytical approach for simulating the effects of the proposed effluent disposal facility is to formulate a site-specific conceptual model of the shallow ground water system. The site characterization well data will provide three-dimensional information on the stratigraphic units and their characteristics that affect ground water movement (see Section 3.1) and contaminant transport. Hence, this information is to be used to formulate the model.

The three-dimensional model of the hydrostratigraphy and hydrologic characteristics of the unsaturated zone and the unconfined aquifer is to be numerically simulated using PORFLO-3© or similarly tested and documented software that is compatible with DOE guidance (1991b). The work is to be performed in accordance with *Standard Engineering Practices* (WHC 1988).

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Table 8. Constituents and Analytical Methods for Ground Water Analyses.

CONSTITUENT	ANALYTICAL GROUP	ANALYTICAL METHOD
1,1 Dichloroethane	Volatile Organics	SW-846 Method 8010
1,1,1-Trichloroethane	Volatile Organics	SW-846 Method 8010
1,2-Dichloroethane	Volatile Organics	SW-846 Method 8010
Aluminum	ICP Metals	SW-846 Method 6010
Americium-241	Gross Alpha	Laboratory Method
Arsenic	AA Metals	SW-846 Method 7060
Barium	ICP Metals	SW-846 Method 6010
Bis(2-ethylhexyl) phthalate	Semi-volatile organics	SW-846 Method 7060
Cadmium	ICP Metals	SW-846 Method 6010
Cesium-137	Gross Beta	Laboratory Method
Chloride	Anions	ASTM Method D4327-88
Chloroform	Volatile Organics	SW-846 Method 8010
Chromium	ICP Metals	SW-846 Method 6010
Cobalt-60	Gross Beta	Laboratory Method
Coliform Bacteria	Coliform	SW-846 Method 9131/9132
Copper	ICP Metals	SW-846 Method 6010
Cyanide	Cyanide	SW 846 Method 9010
DDT	Pesticides	SW-846 Method 8080
Fluoride	Anions	ASTM Method D4327-88
Gross Alpha	Gross Alpha	Laboratory Method
Gross Beta	Gross Beta	Laboratory Method
Hydrazine	Hydrazine	ASTM Method D1385
Iodine-129	Iodine-129	Laboratory Method
Iron	ICP Metals	SW-846 Method 6010
Lead	AA Metals	SW-846 Method 7421
Manganese	ICP Metals	SW-846 Method 6010
Mercury	AA Metals	SW-846 Method 7470
N-nitrosodimethylamine	Semi-Volatile Organics	SW-846 Method 7060
Nitrate	Anions	ASTM Method D4327-88

Table 8. (Continued).

CONSTITUENT	ANALYTICAL GROUP	ANALYTICAL METHOD
Plutonium 239/40	Gross Alpha	Laboratory Method
Radium	GrossAlpha	Laboratory Method
Selenium	AA Metals	SW-846 Method 7740
Silver	ICP Metals	SW-846 Method 6010
Strontium-90	Gross Beta	Laboratory Method
Sulfate	Anions	ASTM Method D4327-88
Technetium-99	Gross Beta	Laboratory Method
Tetrachloroethylene	Volatile Organics	SW-846 Method 8010
Toluene	Volatile Organics	SW-846 Method 8010
Trichloroethylene	Volatile Organics	SW-846 Method 8010
Tritium	Tritium	Laboratory Method
Xylene-o,p	Volatile Organics	SW-846 Method 8010
Zinc	ICP Metals	SW-846 Method 6010
Trans-1,2 Dichloroethylene	Volatile Organics	SW-846 Method 8010
PH	Alkalinity	ASTM D1067 A/B
Conductivity	Conductivity	SM 214 A

Laboratory data on the hydrology-affecting physical properties of sediment samples and test data on the characteristics of the regionally unconfined aquifer are to be used to calibrate the numerical model to site-specific conditions. The results of the calibration are to closely match the well test data. After a reasonable match is achieved and the numerical model can reasonably be interpreted to approximate current hydrologic conditions at the site, the duration of the simulation is to be extended to cover the 30-year period assumed to be the operating life of the facility plus a 10-year post-operation period. The effects of effluent discharge at rates of 1,500 and 15,000 gpm are to be evaluated for the projected duration of the facility's operating life.

The results of the three-dimensional baseline and predictive simulations are to be reported in terms of two-dimensional profiles and three-dimensional isometric views of the mounding of the water table beneath the candidate site. This portrayal is to include flow paths and flow vectors. In conjunction with these simulations, the predicted rate of dissipation of the B Pond mound will be simulated because the main lobe of the B Pond complex is scheduled for closure by 1995. The interaction of the growing mound in the water table associated with the 200 Areas TEDB and the dissipating mound associated with the B Pond complex will be evaluated to predict the future hydraulic gradients at the candidate site.

4.0 GENERAL REQUIREMENTS AND PROJECT MANAGEMENT

The responsibilities for completing specific site characterization activities are identified in Figure 30. Work authorization approvals are required before beginning any field, laboratory, or numerical simulation work. During the performance of field activities, periodic monitoring is to be conducted to detect potential health hazards. All sampling and analyses are to be performed in accordance with the sampling and analysis plans, and quality assurance plans specified in Sections 1 through 3 of this report, and the approved procedures of the organizations performing the work.

4.1 Records Management

All records of the site characterization work identified by this plan are to be established and maintained in accordance with procedures defined by the Westinghouse Hanford Company *Environmental Investigations and Site Characterization Manual* (EII) (WHC 1989a). Applicable procedures include EII 1.5, "Field Logbooks"; EII 1.6, "Records Management"; EII 6.1, "Activity Reports of Field Operations;" and EII 14.1, "Analytical Laboratory Data Management". Drilling records are to be documented on the "Drilling Planning Form" (A-6000-422).

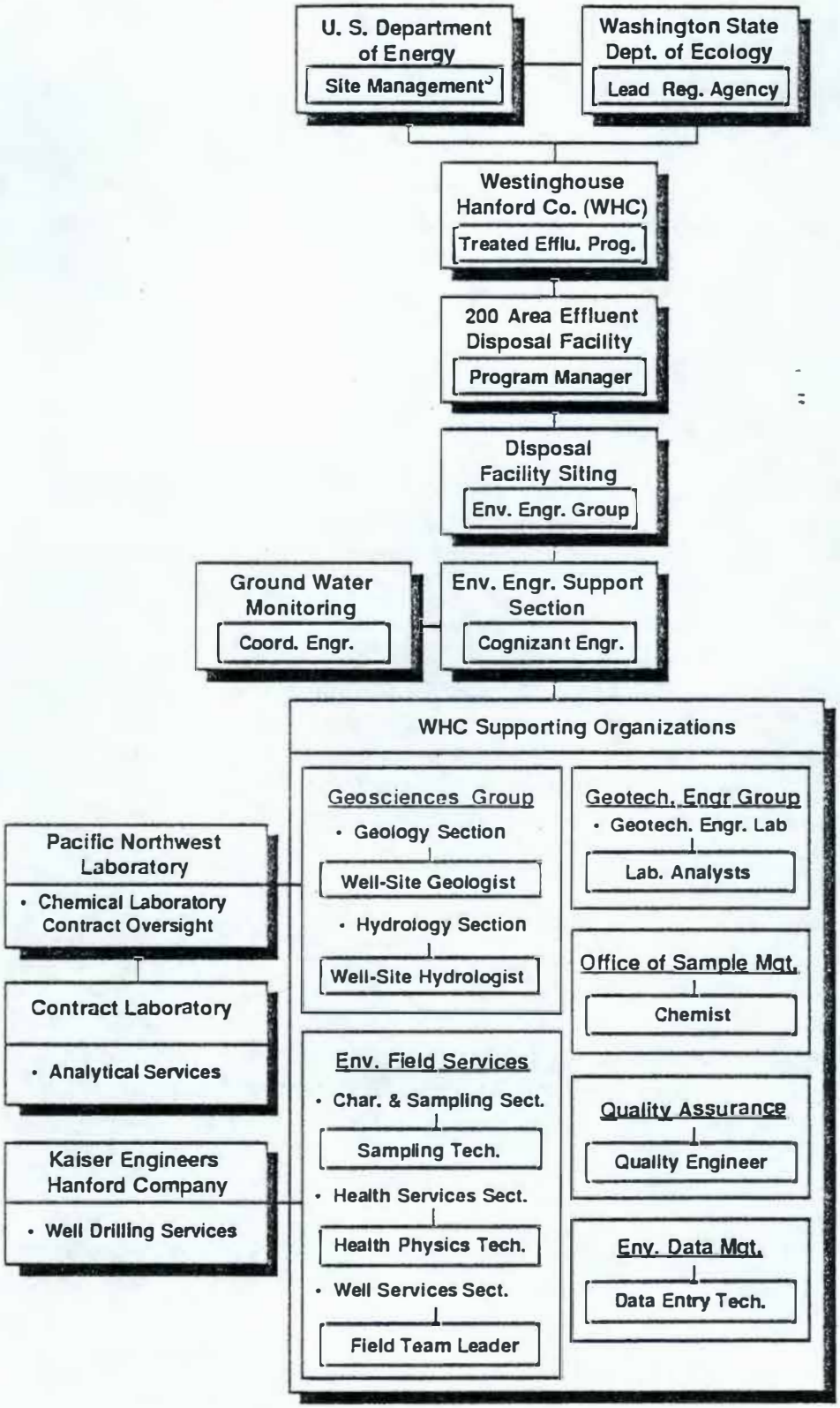

Figure 30. Matrix of Responsibilities for Chararacterization of the Site.

4.2 Drilling

Construction requirements for all site characterization wells drilled to evaluate the candidate site are to be prepared in accordance with Westinghouse specification WHC-S-014 (WHC 1991). The wells are to be constructed in accordance with the requirements of EII 6.4, "Resource Protection Well Services," and EII 6.7, "Resource Protection Well and Test Borehole Drilling." Wells are to be completed and developed as described by EII 6.8, "Well Completion," and EII 10.4, "Well Development Activities." Determination of fitness for use in site characterization of wells constructed before October 1, 1987 is to be in accordance with the instructions of EII 6.6, "Resource Protection Well Characterization and Evaluation."

4.3 Equipment Decontamination

Before commencing drilling to characterize the proposed site for construction of the proposed 200 Areas TEDB and during demobilization, all drilling rigs and associated equipment are to be decontaminated in accordance with EII 5.4, "Field Decontamination of Drilling, Well Development, and Sampling Equipment" (WHC 1989a) and, if appropriate, as directed by a health physics technician.

All non-dedicated equipment that comes into contact with samples (e.g., split-barrel sampler, catch pans) is to be cleaned before and between sample collections. Sampling equipment used only for collecting sediment samples to be analyzed for physical properties must be decontaminated in accordance with the requirements of EII 5.4, "Field Decontamination of Drilling, Well Development, and Sampling Equipment" (WHC 1989a).

4.4 Drill Cuttings and Purge Water

Drill cuttings are to be handled in accordance with EII 4.2, "Interim Control of Unknown, Suspected Hazardous and Mixed Waste" (WHC 1989a). Ground water recovered as a result of sampling, aquifer testing, and well development is to be handled in accordance with the "Strategy for Handling and Disposing of Purge Water at the Hanford Site, Washington" (WHC 1989b) and EII 10.3, "Purge Water Management."

4.5 Sampling

Samples of the sediments retrieved from the wells are to be collected and handled in accordance with EII 5.2, "Soil and Sediment Sampling," and EII 5.8, "Ground Water Sampling" (WHC 1989a).

4.6 Logging

Logs of all wells drilled to characterize the candidate site are to be made as per EII 9.1, "Geologic Logging," and EII 11.1 and 11.2, "Geophysical Logging and Geophysical Survey Work," respectively (WHC 1989a).

4.7 Hydrologic Testing

Hydrologic testing of the wells drilled to characterize the candidate site is to be conducted in accordance with EII 10.1, "Aquifer Testing" and EII 10.2, "Measurement of Groundwater Levels" (WHC 1989a).

4.8 Work Plan Changes

Ecology is to be informed of any substantial changes to this work plan. Modifications may become necessary because of unforseen field conditions or changes mandated by the DOE. Changes and their circumstances are to be recorded in the pertinent field or laboratory log book on the day the change occurs, or as soon as practicable thereafter. If the change causes any deviation from the EII, the deviation is to be documented as per EII 1.4, "Instruction Change Authorization" (WHC 1989a).

5.0 DESCRIPTION OF SITE CHARACTERIZATION TASKS

Section 2 provided a summary of current knowledge of the geology and hydrology of the site tentatively chosen for disposal of the 200 Areas treated effluent. That discussion provided the basis for identifying the additional data needed to evaluate the suitability of the candidate site (see Section 3). Eight tasks must be completed to obtain and analyze the information judged as needed to adequately characterize the candidate site:

- Drilling of site characterization wells
- Geologic logging
- Geophysical logging
- Sampling and analysis of sediments
- Sampling and analysis of ground water from the regionally unconfined aquifer
- Determination of unsaturated zone infiltration rates

- Hydraulic testing of the regionally unconfined aquifer
- Numerical analysis of hydrologic effects.

5.1 Well Locations and Drilling

Three RCRA-compliant wells are to be drilled to evaluate the hydrology of the candidate site. Each well is to serve three purposes: (1) characterization of the subsurface stratigraphy and hydrogeology, (2) physical and chemical analysis of the sediments in the unsaturated and saturated zones, and (3) determination of current ground water quality and monitoring of future ground water quality in the regionally unconfined aquifer. One well is to be drilled upgradient of the candidate site; two wells are to be drilled downgradient.

Three wells are to be drilled at sites located to avoid interference with the proposed effluent disposal facility, yet provide site-specific information. One well is to be located 250 ft (~76 m) upgradient; two wells are to be located 250 ft downgradient from the candidate site (Figure 31). If conditions indicated by data from the three wells merit the collection of additional data, other wells may be sited. These conditions could, for example, include discovery of a relatively impermeable, laterally continuous stratum in the unsaturated zone. The Hanford Site coordinates and identifiers for the three wells to be drilled are as follows:

Identifier	Location	Coordinates
BPE-1	Upgradient	N41845 W37452
BPE-2	Downgradient	N39869 W36464
BPE-3	Downgradient	N40857 W35476

The temporary identifiers assigned above are to be used until the actual well numbers are assigned after the wells have been drilled and their locations surveyed. The permanent well numbers will take the form: 699-North Coordinate-West Coordinate.

The wells are to be constructed in accordance with WHC-S-014 (WHC 1991) and are to be drilled to the top of basalt; i.e., to a depth of approximately 250 ft for the well upgradient from the candidate site and 280 ft for both of the wells downgradient. If sonic or another new drilling method or modification is determined to be superior to the cable-tool drilling method currently used at the Hanford Site to drill RCRA-quality wells, it is

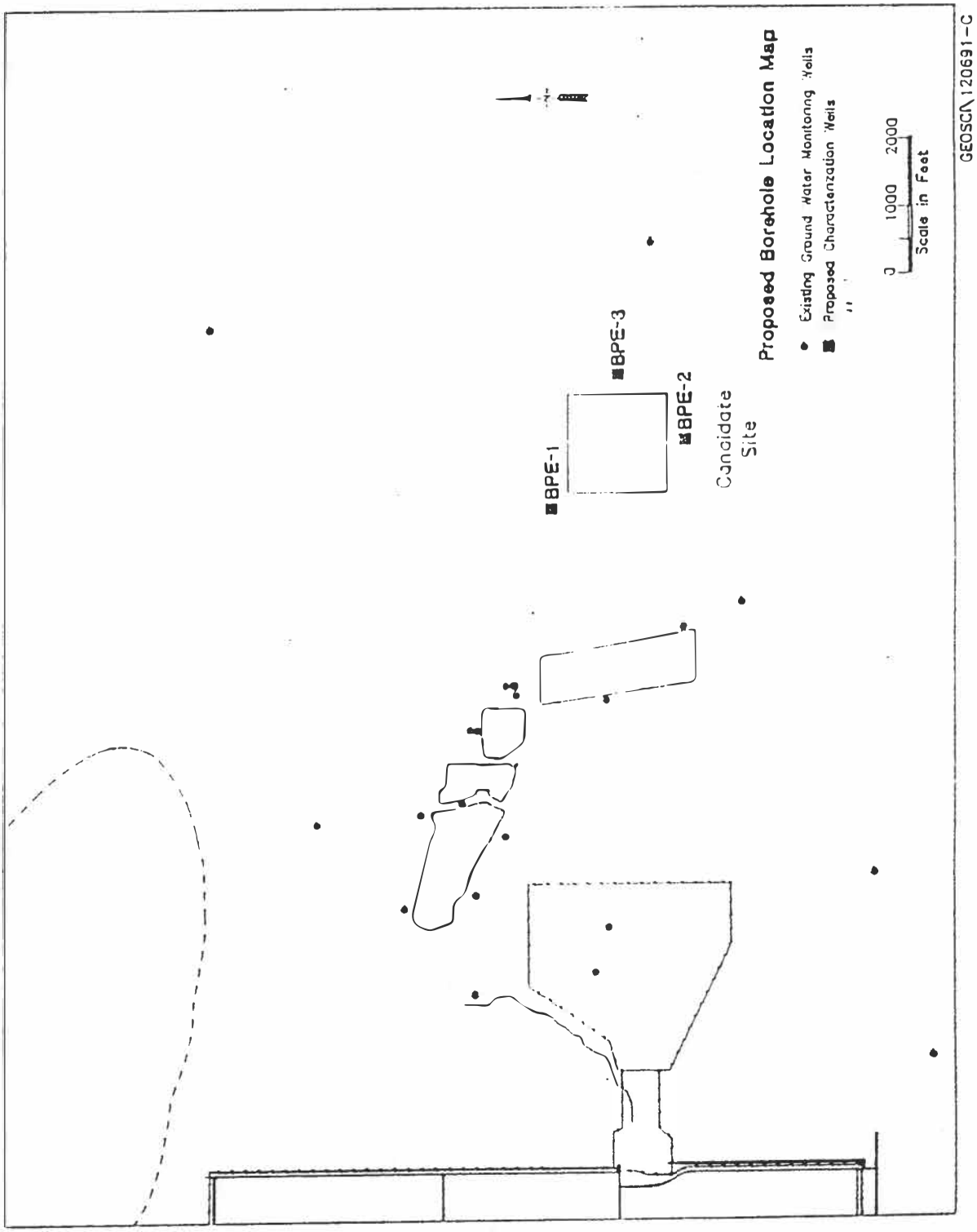

Figure 31. Locations of Site Characterization Wells.

to be used in accordance with the applicable procedures. Casings for the wells are to be constructed in compliance with procedures specified by WHC-S-014, Section 4.1 (WHC 1991). How the as-built casings are to be constructed is depicted in Figure 32.

All wells drilled to characterize the candidate site are also to be used as ground water monitoring wells. However, if warranted, the wells are to be abandoned. If the well is to be abandoned, all steel casing is to be removed from the hole and the hole is to be grouted or otherwise sealed to the depth and other specifications required by WAC 173-160 (Ecology 1989b).

5.2 Geological Logging

Chip samples (from well cuttings) are to be collected at 5-ft (~1.5-m) intervals for geologic logging and stored in the Hanford Geologic Sample Library to provide a permanent record of the stratigraphy at the well location. Chip samples of the top of the basalt flow at the total depth of each well are to be analyzed by x-ray fluorescence to identify the flow. The identity of the basalt flow will indicate whether erosion of the confining flow above the uppermost confined aquifer permits its hydraulic communication with the regionally unconfined aquifer.

Each sample is to be labeled as to its geologic characteristics in accordance with EII 5.10. Samples are to be identified as to well number, geologic description, and depth (feet). Geologic descriptors to be used are as follows: SG = sandy gravel, GS = gravelly sand, S = sand, and SL = silt. For example, the descriptor 699-xxx-yyy-SG-110 denotes a sample taken from the 600 Area at coordinates xxxx North and yyyy West. The sample is sandy gravel and was collected at a depth of 110 ft (33.5 m)

5.3 Geophysical Logging

The site characterization wells are to be geophysically logged to provide two kinds of geologic information, (1) stratigraphic and (2) density (porosity). However, the principal use of the geophysical logs will be to determine the presence or absence of specific gamma-emitting radionuclides, determine their concentrations, if present, and estimate the relative moisture content of the sediments. The wells are to be geophysically logged as per EII 11.1. The geophysical logging is to include, but not necessarily be limited to, high-resolution spectral gamma, gamma density, and neutron-neutron. The spectral gamma logging is to be conducted such that spectra will be produced every 1 to 2 in. (2.5 to 5 cm) throughout the logged zone. The need to obtain other types of geophysical logs is to be determined by the nature of results from these three logs and the results of chemical analyses of sediments from the uppermost 20 ft of the well. Only those techniques with demonstrated utility for Hanford Site conditions, and with procedures adequate to ensure the quality of data, are to be used.

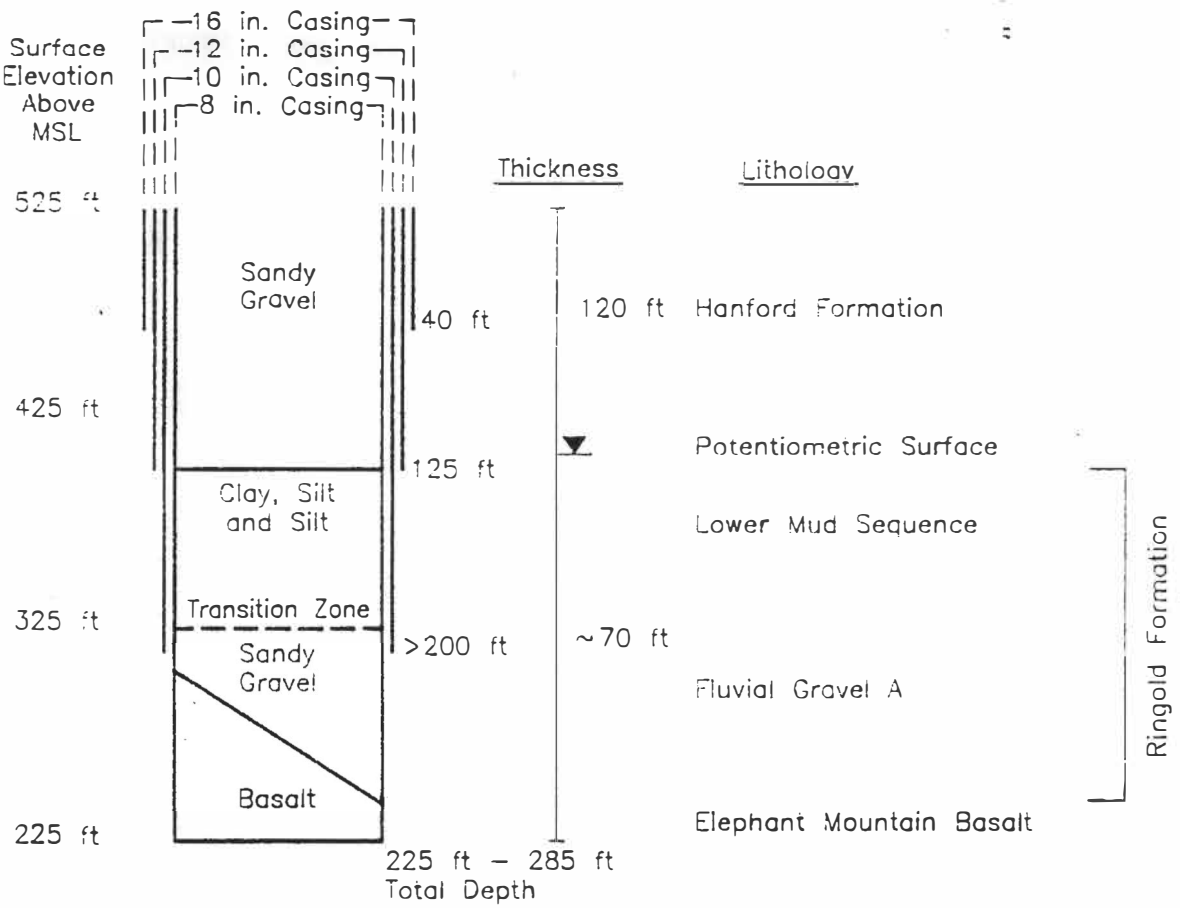

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Figure 32. Schematic of As-Built Casing for Site Characterization Work.

Because optimal logging conditions require that only one thickness of casing be present, the geophysical logging is to be done in stages before smaller diameter casing is emplaced (see Figure 32). The starter casing is to be exempt from this requirement unless the well-site geologist requests that it be logged.

5.4 Sampling of Sediments

Samples taken to determine physical properties are to be obtained with a 2-ft-long (~0.6 m) drive-tube sampler that incorporates a 2.36-in. (6-cm) (minimum) inside-diameter stainless steel liner. The samples are to be taken after the well casing has been bailed clean to the depth of the drive shoe. Samples taken for chemical analysis are to be obtained by the split-spoon method. The stainless steel split-spoon sampler is to have a minimum internal diameter of 4 in. (~10 cm) and is to incorporate four stainless steel liners, each 6-in. (~15 cm) long.

A minimum of one split-spoon sample per sediment lithology encountered in each well is to be collected for physical and/or chemical testing. In addition, one split-spoon sample of each 5-ft (~1.5-m) interval of the first 20 ft of sediments encountered in each well is to be collected for analysis for potential contaminants.

Cores and samples are to be screened, as appropriate, by scintillation detector and by organic-vapor flame-ionization device. Specific requirements and procedures for screening are to be specified by the Radiation Work Permit and Hazardous Work Operations Plan. Sampling activities are to be administered in accordance with applicable procedures in WHC-CM-7-7, *Environmental Investigations and Site Characterization Manual* (WHC 1989a).

5.4.1 Sampling Locations and Frequency

Chip samples are to be monitored by the well-site geologist to ensure that all lithologies are sampled. Samples for physical properties tests (Section 3.3.2) are to be obtained from a split-spoon sample of each lithology encountered. The principal criterion to be used in determining the depths of sampling is change in lithology. Based on current knowledge of the sediments in the candidate site area (see Figure 32), a minimum of three samples from each well are expected to be needed for physical properties testing.

If a sufficiently large volume of sediment is retrieved, the sample is to be used for both physical and chemical tests. Otherwise, two split-spoon samples per lithology will be taken. If samples cannot be retrieved from a specific lithology, the circumstances are to be entered in the log book and drilling is to continue. The first 20 ft (~6 m) of the Hanford formation penetrated by each well is to be sampled at 5-ft (~1.5-m) intervals by split-spoon methods. These four samples are to be chemically analyzed for the constituents identified in Section 3.3.1.

Based on the nature of the sediments encountered during drilling, the well-site geologist may select additional split-spoon samples for analysis of any chemical or hydrogeologic parameter of interest. For example, if a stratum that could perch or otherwise preferentially direct the movement of infiltrating effluents is encountered, a split-spoon sample of the contact between the confining stratum and the overlying sediments may be collected for testing. After drilling has been completed, the well-site geologist may select more samples from those in the Hanford Geologic Sample Library to provide specific additional information or to resolve uncertainties.

5.4.2 Sample Handling

Various types of analyses require special sample-handling procedures. Regulatory requirements for the type of analysis or the procedures of the laboratory making the analysis may require special sample handling. In general, samples are to be transferred to a temporary sample handling and evaluation area at the well site. In this area, the samples are to be geologically logged. Samples for analyses are to be double wrapped in plastic, labeled, and stored in an ice chest. From these samples, samples for chemical analysis are then to be packaged and shipped to the appropriate laboratory in accordance with EII 5.11, "Sample Packaging and Shipping," and EII 5.1, "Chain of Custody".

5.4.3 Sample Archive

The purpose of placing samples in an archive is to provide material for future verification or contingency testing or analysis. Additional samples may be placed in the archive at the direction of the well-site geologist. A minimum of 1 split-spoon sample per sediment lithology encountered in each well is to be collected for storage in the sample archive, resulting in archive storage of approximately 12 split-spoon samples from the 3 holes.

All samples that are to be placed in the archive are to be retained in the original stainless steel liner. The ends of the liner are to be sealed by Teflon™ caps or equivalent Teflon™- tape-sealed plastic caps that are taped to the liners to achieve a tight, secure seal. The sample is then to be transferred with documentation of the chain of custody to the Hanford Geological Sample Library.

5.5 Ground Water Sampling

The objective of this task is to obtain samples that are adequate for determining ground water quality of the regionally unconfined aquifer at the candidate site. This objective is to be achieved by installing ground water monitoring wells, collecting samples of water from at least the top 20 ft (~6 m) (and potentially from deeper zones) of the

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regionally unconfined aquifer and analyzing the water samples for the constituents specified in Section 3.3.3.

5.5.1 Ground Water Monitoring Well Locations

Three ground water monitoring wells are to be installed in the vicinity of the candidate site (see Figure 31). These wells are to be the same wells that were used to characterize the hydrogeology of the site.

5.5.2 Well Drilling and Installation

The cable-tool method is to be used to drill the site characterization wells unless another, more rapid drilling method is determined to be superior for the site characterization needs of Project W049-H. This method is preferred for drilling RCRA-compliant wells at the Hanford Site for the following reasons:

- Drill cuttings are easily contained
- Representative geologic samples can be collected from drive barrels
- Moisture-content samples from above the water table can be collected using drive barrels
- Disturbance of the walls of the hole is minimized
- A straight and plumb hole is produced
- No circulation media is required to maintain an open hole or to remove drill cuttings.

5.5.2.1 Well Construction. Construction of the three site characterization wells is to be in accordance with the specifications in WHC-S-014 (WHC 1990). In turn, these specifications are based on WAC-173-160 (Ecology 1989b) These specifications include the following:

- Site preparation
- Drilling
- Collection of sediment samples
- Installation and removal of temporary well casing

- Disposition of purge water
- Completion of final monitoring configuration
- Development of monitoring intervals
- Installation of the sampling pump
- Surveying the completed well for location and elevation.

Quality assurance requirements of the Tri-Party Agreement (Ecology et. al. 1989a) and WHC-SD-EN-QAPP-001 (Jackson 1990) also apply. If contamination is encountered that requires changes in this project plan, Ecology is to be immediately notified.

5.5.2.2 Well Development. The three site characterization wells are to be developed following their completion. The wells are to be developed by the surge-and-bail technique in preference to pumping, or by any other technique deemed necessary by the well-site hydrologist to reduce turbidity to less than 5 nephelometric turbidity units (NTU) and sediment content to less than 8 mg/L. If the water cannot be developed to a turbidity of less than 5 NTU, the reason is to be documented by a qualified hydrogeologist. Other hydrochemical indicators, such as amount of total iron and drilling fluid tracers, may be monitored to assess the adequacy of development pumping for trace constituent sampling. Water is to be pumped from the well only after current, approved requirements for handling purge water (WHC 1989b) have been complied with.

5.5.2.3 Well Surveying. After well installation has been completed, the wells are to be surveyed for location and elevation by a qualified surveyor per WHC-S-014 (WHC 1990b). The elevation of the top of the stainless steel well casing and a brass marker in the concrete well-head pad are to be determined to within 0.01 ft (0.1 m). A permanent mark is to be placed on the casing to indicate the location that was surveyed. The areal location of the centerline of the well is to be determined to the nearest 0.01 ft (0.1 m). All measurements are to be referenced to a common datum and reported in meters as Washington State Plane Coordinates (Southzone) of the NAD 83. Documentation of the survey results is to be reviewed by a licensed surveyor other than the surveyor who performed the survey.

5.5.3 Ground Water Sampling

After well completion, water from the regionally unconfined aquifer is to be sampled and analyzed for the constituents listed in Table 8. To provide information for a WAC-173-216 permit application, water from the wells will also be analyzed for major cations, anions, pH, temperature, and conductivity. Additional sampling and analyses are to be done as needed, based on the results from the initial samples and analyses.

Hydrostar™ or equivalent sampling pumps are to be installed in the new wells soon after completion of well construction and development. The depth to the water table is to be measured before the wells are purged. The wells are then to be purged and samples of water collected after at least three well-storage volumes of water have been removed, when specific conductance and pH have stabilized or, in the case of wells completed in very low permeability materials, after the well has recharged.

All sampling activities to be performed by PNL under contract to Westinghouse are to comply with procedures for ground water sample collection, water-level measurement, and field measurement in EII 5.8, "Ground Water Sampling" (WHC 1989a).

5.6 Determination of Initial Infiltration Rates

To provide an initial estimate of effluent disposal facility performance, the initial rate of effluent infiltration into the sediments is to be determined. Based on past Hanford Site experience with similar facilities, the highest rate of infiltration typically occurs at the beginning of facility operations and then gradually decreases by 50% or more due to clogging of the pore space at the land surface by wind-blown silt and/or algae. The projected initial infiltration rate is to be determined at the candidate site to provide baseline initial-conditions data for use in numerical simulations.

Infiltration measurements are to be made to predict infiltration rates for ponded conditions. The Guelph permeameter testing method (Reynolds and Elrick 1985) is to be used to measure the steady-state rate of water intake from a cylindrical auger hole in which a constant depth of water is maintained. The field-saturated hydraulic conductivity and matric flux potential can be calculated from steady-state recharge rates by simultaneous solution of equations using the Richards analysis method (Reynolds et al. 1985).

The Guelph permeameter measurements are to use the procedure outlined in WHC-IP-0635 (WHC 1989a). The number, location, and depth of measurements are to be determined after an initial field examination of the general appearance of the sediment at the surface of the candidate site.

5.7 Aquifer Testing

After completion of the three ground water monitoring wells, aquifer testing is to be conducted to estimate values of hydraulic parameters for the regionally unconfined aquifer. Constant-discharge aquifer tests in each well are to be made to provide drawdown and discharge data from which site-specific values of hydraulic conductivity, transmissivity, and specific yield can be estimated. If significant concentrations of

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contaminants are found in ground water at the candidate site, slug injection/withdrawal tests are to be used instead of the constant-discharge tests. After drilling and prior to conducting the aquifer tests, a test plan is to be written to describe the specific design and implementation requirements. This aquifer test plan is to include the following:

- An overview of the hydrogeology of the test site
- Well construction and design
- Test design, conduct, equipment and data collection requirements for both constant discharge or, as needed, slug injection/withdrawal tests
- A predicted response of the regionally unconfined aquifer
- Applicable procedures and quality assurance requirements
- Means for handling large volumes of purgewater from constant-discharge tests.

5.8 Numerical Analysis Using Site-Specific Data and Issuance of Site Characterization Report

The site characterization data resulting from completion of Tasks 1 through 7 are to be used to refine the previously developed conceptual and numerical models (see Section 3.4 and Davis 1991) of the shallow ground water system at the candidate site. These refined models are to be used to predict the effects on the regionally unconfined aquifer of operating the effluent disposal facility at the candidate site for a period of 30 years and for a 10-year post-operation period of aquifer readjustment following cessation of effluent discharge. The simulations are to reflect minimum and maximum discharges of 1500 and 15,000 gpm, respectively. Results are to be shown as contours of water-table elevation, flow paths, and flow vectors, and incorporated into a site characterization report.

6.0 COST AND SCHEDULE

The schedule for completing the 7 tasks to evaluate the suitability of candidate site for the 200 Areas TEDB of Project W-049H is shown in Figure 33. Estimates of the durations to complete each task depend on the timely availability of the following:

- Concurrence with work plan by Ecology
- Drilling, logging, sampling, and analytic equipment
- Personnel

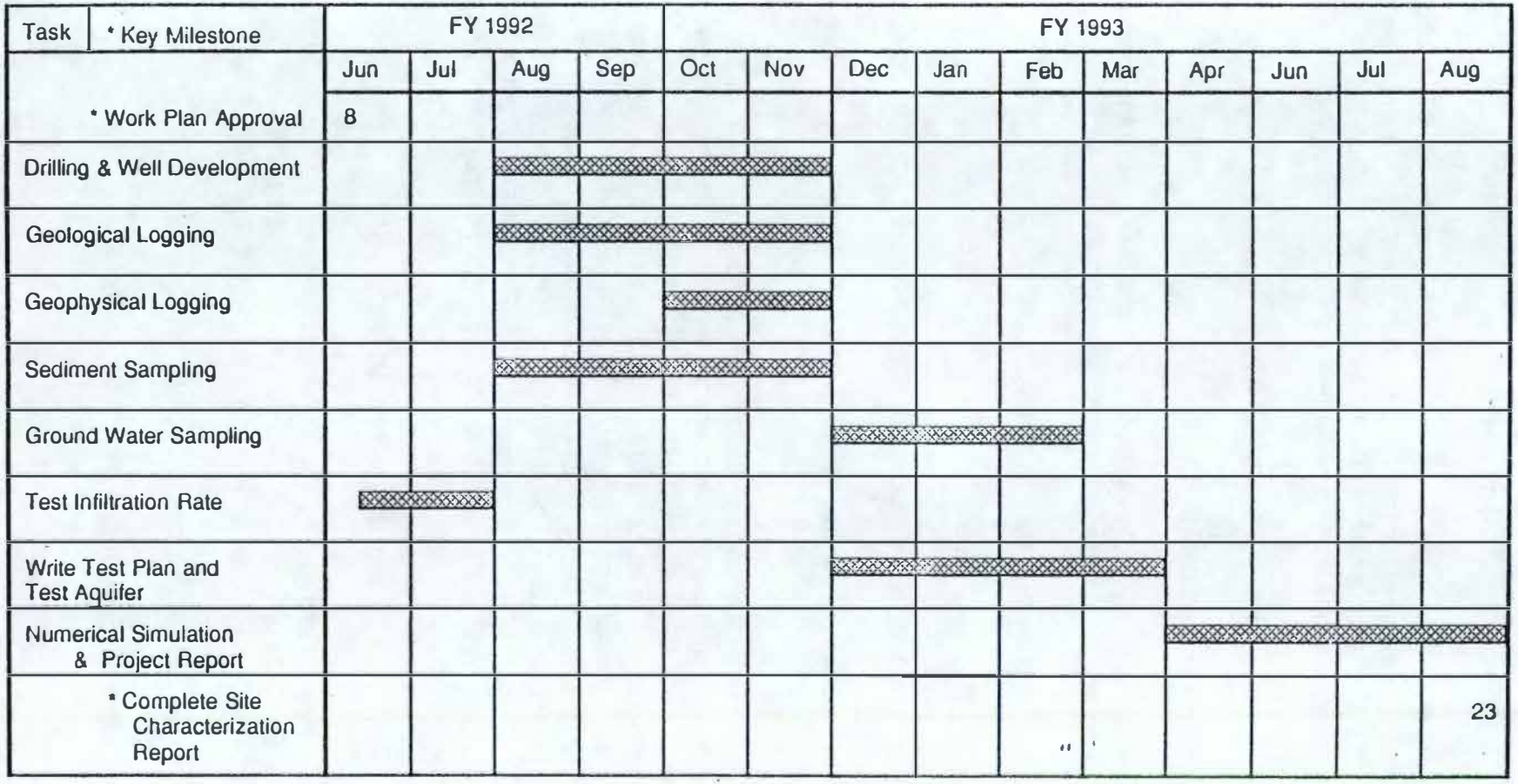

Figure 33. 1992-1993 Schedule for Completion of Tasks to Characterize the Candidate Site.

- Approval of the implementation of adequate quality assurance, quality control, and safety precautions

- The on-time placement of analytic laboratory and other contracts.

Although some tasks can be performed in parallel, most require that one or more preceding tasks be completed before the task at hand can be initiated. The task completion schedule shown in Figure 33 assumes the availability of key personnel at the times needed, and that necessary preceding administrative and technical tasks have been completed on schedule.

The schedule for completing Project W-049H has been determined by the milestones of the Tri-Party Agreement (Ecology et al. 1989; as amended 1990). Compliance with the schedules of the Tri-Party Agreement require that the 200 Areas TEDB be completed by June 1995. Consequently, the schedules for completing the site characterization tasks identified by this plan are constrained by the requirements of the larger, overall project schedule. Those requirements that are pertinent to the site characterization schedule are also shown in Figure 33 as the start and finish dates for the first and last items.

Projected costs for completing each of the eight tasks that were identified and described in Section 5 are shown in Figure 34. Included in the costs shown are the project management and other overhead costs. Also shown are the additive, cumulative costs of all tasks. The total cost of completing all eight tasks is estimated to be on the order of $1,120,000.

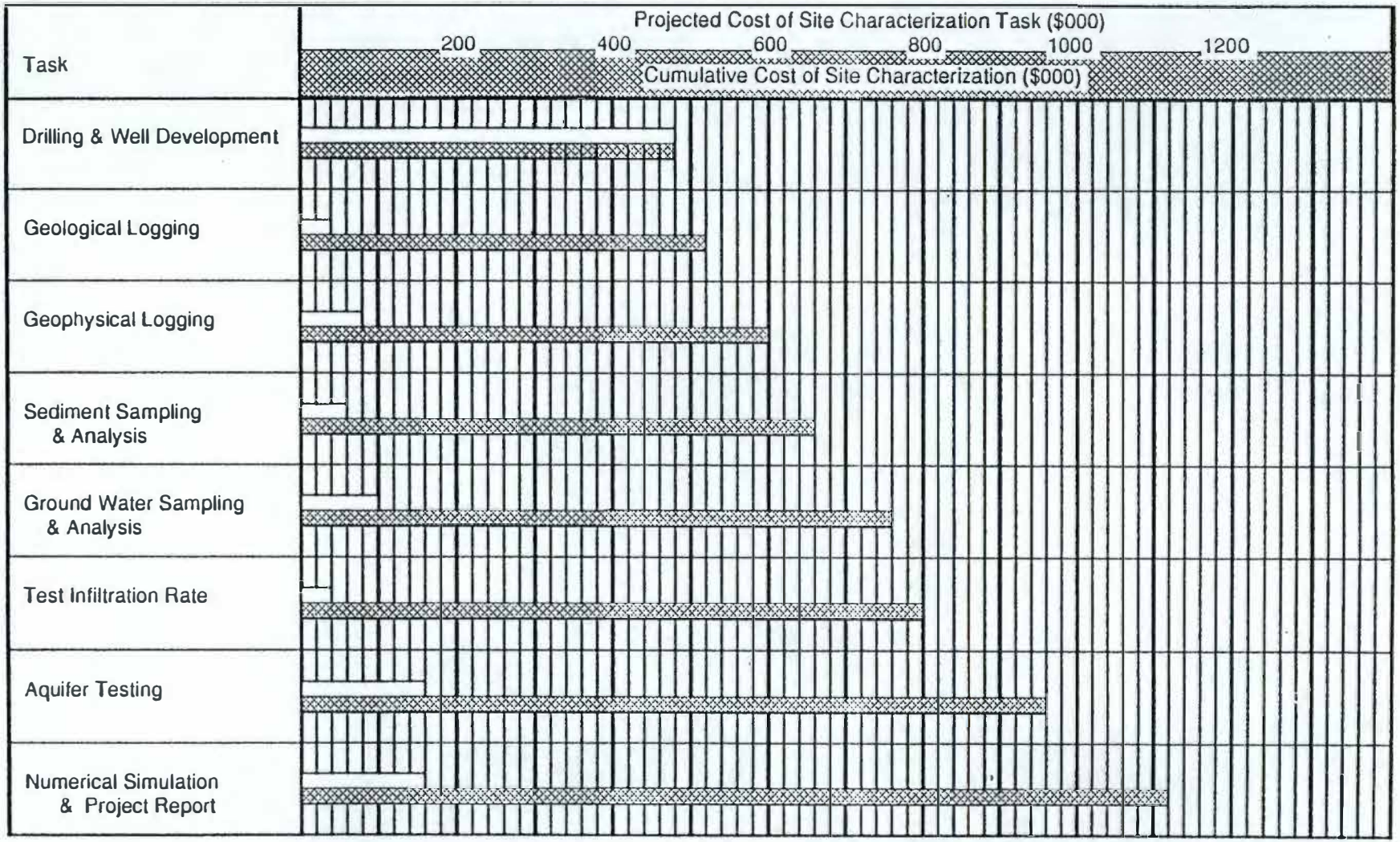

Figure 34. Projected Costs of Site Characterization.

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APPENDIX A

-- Ground Water Quality Data --

This appendix describes the B Pond complex and effluent disposal practices at that site, and contains ground water quality data from the area surrounding the B Pond complex and the vicinity of the candidate site.

Description of the B Pond Complex

The B Pond complex is a series of unlined, interconnected effluent disposal ponds that are east of the 200 East Area (Figure A-1). Detailed information on the facility and its effluent characteristics is in the B Pond closure plan (DOE 1990) and in Roos and Woodworth (1989). The following components comprise the B Pond RCRA unit:

216-B-3 Pond
216-B-3A, 3B, and 3C Ponds or Lobes
216-B-3-3 Ditch
Part of an inactive overflow area.

The B Pond is located in a natural topographic depression and is enclosed by a dike at its eastern margin. It covers ~35 acres, with a maximum depth of ~20 ft. The three expansion ponds, 3A, 3B, and 3C, were placed into service in 1983, 1984, and 1985, respectively. The 3A and 3B ponds are each ~11 acres; the 3C pond is ~41 acres. The 3B pond currently is not in use.

Throughout its operational history, B Pond has received effluent through various unlined, uncovered ditches (see Figure A-1). The 216-B-3-1 Ditch was placed in service in 1945 and was backfilled with soil in 1964. The 216-B-3-2 Ditch was used from 1964 through 1970, when it was also backfilled. Both of these ditches carried dangerous wastes; however, they are not part of the B Pond RCRA unit. The 216-A-29 Ditch also carried RCRA-regulated wastes, but is considered to be a separate RCRA unit. The 216-A-29 Ditch was backfilled in July 1991, and effluent was rerouted to the Cooling Water Line (see Figure A-1).

Immediately west of the 216-B-3 Pond was an overflow area that was deactivated and backfilled in 1985. Part of the overflow area is believed to have received RCRA-regulated waste and is considered to be part of the B Pond RCRA unit.

Waste Disposal Practices

The B Pond began receiving effluent in 1945. The B Pond complex receives effluent that is primarily from the Plutonium-Uranium Extraction (PUREX) and B Plants.

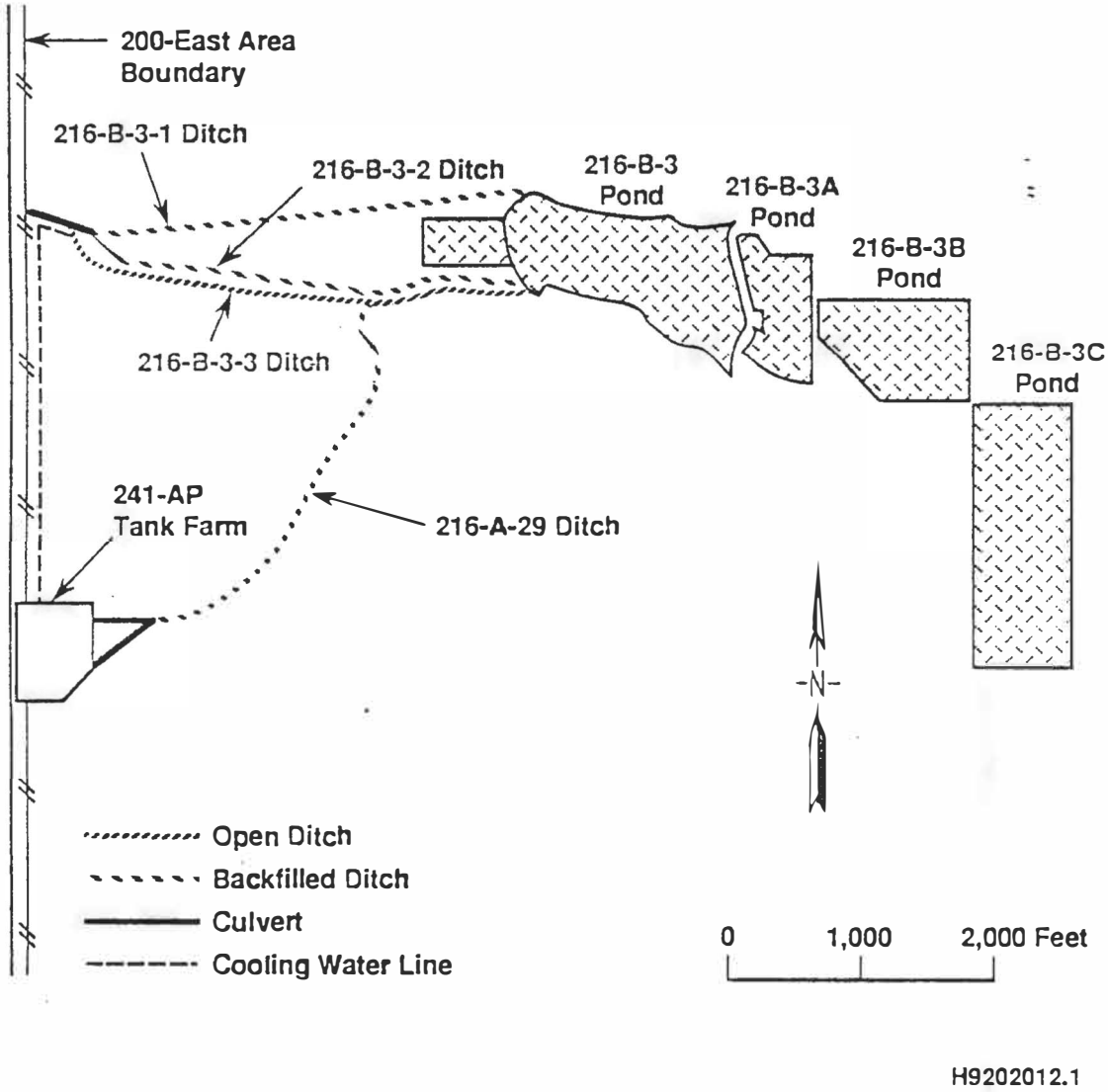

Figure A-1. Location of the 216-B-3 Pond Complex.

Specifically, these effluents are B Plant cooling water, the PUREX Plant chemical sewer, and PUREX Plant steam condensate. In the past, the B Pond also received effluents from the B Plant steam condensate and chemical sewer. Additional sources of effluent routed to the B Pond are the 242-A Evaporator, 244-AR Vault, 241-BY Tank Farm (inactive), 244-CR Vault (inactive), 241-A-702 Vessel Ventilation System, 283-E Water Treatment Facility, and the 284-E Powerhouse.

The B Pond has occasionally received spilled or off-specification chemicals and has routinely received corrosive effluent from a demineralizer regeneration system; these effluents were transported via the 216-A-29 Ditch. The most frequent hazardous discharge was the demineralizer effluent. Discharges of sodium hydroxide and sulfuric acid solutions occurred on a daily basis until February 1986. Quarterly analyses of samples of waste streams discharged to the B Pond later in 1986 through 1987 indicated that these discharges were not regulated dangerous wastes as per WAC 173-303 (WDOE 1987, Jungfleisch 1988).

Radioactively contaminated water occasionally has been released to the B Pond complex. The radionuclide inventory estimated for the B Pond complex, corrected for radioactive decay through 1987, is provided in Table A-1. Cesium-131, strontium-90, and tritium account for nearly all of the activity (WHC 1989). The volumes of effluent recently discharged to the B Pond complex are summarized in Table A-2.

Table A-1. Decayed Radionuclide Inventory in the B Pond Complex as of December 31, 1988.

RADIONUCLIDES	INVENTORY (CI)
Total Alpha	$<1.60 \times 10^{1}$
Total beta	$<3.93 \times 10^{2}$
Tritium	8.29×10^{2}
Strontium-90	$<1.03 \times 10^{2}$
Ruthenium-106	$<1.34 \times 10^{-4}$
Cesium-137	$<9.49 \times 10^{1}$
Promethium-147	<1.03
Uranium (gross)	<2.07
Plutonium-239	$<5.52 \times 10^{-1}$
Americium-241	<3.52

Table A-2. Volume of Effluent Discharged to the B Pond Complex, 1985 through 1989.

YEAR	VOLUME OF DISCHARGE
1985	3.90 x 109 gal (1.50 x 10^{10} L)
1986	6.06 x 109 gal (2.29 x 10^{10} L)
1987	5.86 x 109 gal (2.22 x 10^{10} L)
1988	5.86 x 109 gal (2.22 x 10^{10} L)
1989	3.5 x 109 gal (1.3 x 10^{10} L)

Ground Water Quality

Ground water quality data from 21 monitoring wells in the vicinity of the candidate site are provided in the listing that follows. The first three digits of well numbers are abbreviated (i.e., 699- is shortened to 6-). The analysis results are presented in terms of their relationships to the detection limits and the drinking water standard. Values which are below the detection limits in the listing that follows cannot be quantified. Undetected is indicated by "U"; the symbol "<" indicates present in amounts less than the detection limit. Analytical results are reported for the time period since January 1990 for the following constituents: aluminum, barium, chromium, iron, manganese, nitrate, total organic carbon, total organic halogen, and tritium.

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Constituent Result Report

W-049 Constituent Information Jan 1990 - July 1991

CONSTITUENT				RESULT			
Name	Units	Drinking Water Std	Detection Limit	Monitoring Well	Sample Date		Analysis Value
Aluminum, filtered	PPB	50.00	150.0	2-E25-25	3/14/90	<	150.0
					3/14/90	<	150.0
					3/14/90	<	150.0
					3/14/90	<	150.0
				2-E25-32P	4/04/90	<	150.0
					4/04/90	<	150.0
					4/04/90	<	150.0
					4/04/90	<	150.0
				6-40-33A	2/21/90		485.0
				6-40-39	1/25/90	<	150.0
					4/25/90	<	150.0
				6-41-40	1/25/90	<	150.0
					4/19/90	<	150.0
				6-42-40A	1/26/90	<	150.0
				6-43-41E	1/25/90	<	150.0
				6-43-41F	1/25/90	<	150.0
					4/18/90		300.0
				6-43-43	1/26/90	<	150.0
				6-43-45	1/26/90	<	150.0
					4/18/90	<	150.0
				6-44-42	1/31/90	<	150.0
				6-44-43B	1/26/90	<	150.0
					1/26/90	<	150.0
					4/18/90	<	150.0
				6-45-42	4/30/90	<	150.0
				6-47-35A	4/26/90	<	150.0
Barium, filtered	PPB	1000.00	6.0	2-E25-25	3/14/90		15.0
					3/14/90		15.0
					3/14/90		16.0
					3/14/90		16.0
				2-E25-32P	4/04/90		15.0
					4/04/90		15.0
					4/04/90		15.0
					4/04/90		16.0
				6-40-33A	2/21/90		104.0
				6-40-39	1/25/90		110.0
					4/25/90		118.0
				6-41-40	1/25/90		75.0
					4/19/90		69.0
				6-42-40A	1/26/90	<	6.0
				6-43-41E	1/25/90		54.0
				6-43-41F	1/25/90		42.0
					4/18/90		44.0

Note: Data are unofficial and should not be referenced without permission from the Geosciences Group

Geosciences Group PARADOX Database

12/03/91

Constituent Result Report

W-049 Constituent Information Jan 1990 - July 1991

CONSTITUENT				RESULT			
Name	Units	Drinking Water Std	Detection Limit	Monitoring Well	Sample Date		Analysis Value
Barium, filtered	PPB	1000.00	6.0	6-43-43	1/26/90		15.0
				6-43-45	1/26/90		38.0
					4/18/90		39.0
				6-44-42	1/31/90		13.0
				6-44-43B	1/26/90		49.0
					1/26/90		49.0
					4/18/90		47.0
				6-45-42	4/30/90		30.0
				6-47-35A	4/26/90		71.0
Chromium, filtered	PPB	50.00	10.0	2-E25-25	3/14/90	<	10.0
					3/14/90	<	10.0
					3/14/90	<	10.0
					3/14/90	<	10.0
				2-E25-32P	4/04/90	<	10.0
					4/04/90	<	10.0
					4/04/90	<	10.0
					4/04/90	<	10.0
				6-40-33A	2/21/90	<	10.0
				6-40-39	1/25/90	<	10.0
					4/25/90	<	10.0
				6-41-40	1/25/90	<	10.0
					4/19/90		21.0
				6-42-40A	1/26/90	<	10.0
				6-43-41E	1/25/90	<	10.0
				6-43-41F	1/25/90	<	10.0
					4/18/90	<	10.0
				6-43-43	1/26/90	<	10.0
				6-43-45	1/26/90	<	10.0
					4/18/90	<	10.0
				6-44-42	1/31/90	<	10.0
				6-44-43B	1/26/90	<	10.0
					1/26/90	<	10.0
					4/18/90	<	10.0
				6-45-42	4/30/90	<	10.0
				6-47-35A	4/26/90	<	10.0
Iron, filtered	PPB	300.00	30.0	2-E25-25	3/14/90	<	30.0
					3/14/90	<	30.0
					3/14/90	<	30.0
					3/14/90	<	30.0
				2-E25-32P	4/04/90	<	30.0
					4/04/90	<	30.0
					4/04/90	<	30.0

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Constituent Result Report

W-049 Constituent Information Jan 1990 - July 1991

CONSTITUENT				RESULT			
Name	Units	Drinking Water Std	Detection Limit	Monitoring Well	Sample Date		Analysis Value
Iron, filtered	PPB	300.00	30.0	2-E25-32P	4/04/90	<	30.0
				6-40-33A	2/21/90		548.0
				6-40-39	1/25/90		51.0
					4/25/90		39.0
				6-41-40	1/25/90		47.0
					4/19/90		164.0
				6-42-40A	1/26/90		49.0
				6-43-41E	1/25/90		37.0
				6-43-41F	1/25/90		63.0
					4/18/90		747.0
				6-43-43	1/26/90	<	30.0
				6-43-45	1/26/90	<	30.0
					4/18/90	<	30.0
				6-44-42	1/31/90	<	30.0
				6-44-43B	1/26/90	<	30.0
					1/26/90		64.0
					4/18/90	<	30.0
				6-45-42	4/30/90		195.0
				6-47-35A	4/26/90	<	30.0
Manganese, filtered	PPB	50.00	5.0	2-E25-25	3/14/90	<	5.0
					3/14/90	<	5.0
					3/14/90	<	5.0
					3/14/90	<	5.0
				2-E25-32P	4/04/90	<	5.0
					4/04/90	<	5.0
					4/04/90	<	5.0
					4/04/90	<	5.0
				6-40-33A	2/21/90		38.0
				6-40-39	1/25/90		231.0
					4/25/90		175.0
				6-41-40	1/25/90		75.0
					4/19/90		35.0
				6-42-40A	1/26/90		7.0
				6-43-41E	1/25/90		16.0
				6-43-41F	1/25/90		79.0
					4/18/90		89.0
				6-43-43	1/26/90	<	5.0
				6-43-45	1/26/90	<	5.0
					4/18/90	<	5.0
				6-44-42	1/31/90	<	5.0
				6-44-43B	1/26/90	<	5.0
					1/26/90	<	5.0
					4/18/90	<	5.0

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Geosciences Group PARADOX Database

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Constituent Result Report

W-049 Constituent Information Jan 1990 - July 1991

CONSTITUENT				RESULT			
Name	Units	Drinking Water Std	Detection Limit	Monitoring Well	Sample Date		Analysis Value
Manganese, filtered	PPB	50.00	5.0	6-45-42	4/30/90		26.0
				6-47-35A	4/26/90	<	5.0
Nitrate	PPB	45000.00	500.0	2-E25-25	3/14/90		900.0
				2-E25-32P	4/04/90		1000.0
				6-40-33A	2/21/90	<	500.0
				6-40-39	1/25/90	<	500.0
					4/25/90	<	500.0
				6-41-40	1/25/90		22500.0
					4/19/90		19600.0
				6-42-40A	1/26/90		800.0
				6-43-41E	1/25/90		8700.0
					5/15/90		10100.0
					5/15/90		10400.0
				6-43-41F	1/25/90		10200.0
					4/18/90		11700.0
				6-43-42J	1/31/90		5100.0
				6-43-43	1/26/90		1000.0
				6-43-45	1/26/90		1200.0
					4/18/90		1500.0
				6-44-42	1/31/90		1400.0
				6-44-43B	1/26/90		7600.0
					1/26/90		8300.0
					4/18/90		6600.0
				6-45-42	4/30/90		5400.0
				6-47-35A	4/26/90		14400.0
Total Organic Halogen, Low Det	PPB		10.0	2-E25-25	3/14/90	<	6.0
					3/14/90	<	6.0
					3/14/90	<	8.0
					3/14/90	<	8.0
					6/25/91	U	10.0
					6/25/91	U	10.0
					6/25/91	U	10.0
					6/25/91	U	10.0
				2-E25-32P	1/29/90		153.0
					1/29/90		166.0
					1/29/90		182.0
					1/29/90		199.0
					2/20/90		182.0
					2/20/90		278.0
					2/20/90		297.0
					2/20/90		329.0
					3/25/90	<	2.0

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Constituent Result Report

W-049 Constituent Information Jan 1990 - July 1991

CONSTITUENT				RESULT			
Name	Units	Drinking Water Std	Detection Limit	Monitoring Well	Sample Date		Analysis Value
Total Organic Halogen, Low Det	PPB		10.0	2-E25-32P	3/25/90	<	5.0
					3/25/90	<	5.0
					3/25/90	<	6.0
					4/04/90		16.0
					4/04/90		17.0
					4/04/90		21.0
					4/04/90		22.0
					7/19/91	U	10.0
					7/19/91	U	10.0
					7/19/91	U	10.0
					7/19/91	U	10.0
					7/19/91	U	10.0
				6-40-39	1/25/90	<	4.0
					1/25/90	<	6.0
					1/25/90	<	6.0
					1/25/90	<	9.0
					4/25/90	<	1.0
					4/25/90	<	2.0
					4/25/90	<	2.0
					4/25/90	<	4.0
					7/08/91	U	10.0
				6-41-40	1/25/90	<	3.0
					1/25/90	<	4.0
					1/25/90	<	7.0
					1/25/90	<	9.0
					4/19/90	<	1.0
					4/19/90	<	1.0
					4/19/90	<	2.0
					4/19/90	<	3.0
					7/10/91	U	10.0
				6-42-40A	1/26/90	<	3.0
					1/26/90	<	3.0
					1/26/90	<	4.0
					1/26/90	<	6.0
					7/08/91	U	10.0
				6-42-42B	1/26/90	<	4.0
					1/26/90	<	4.0
					1/26/90	<	4.0
					1/26/90	<	8.0
					7/08/91	U	10.0
				6-43-41E	1/25/90		21.0
					1/25/90		21.0
					1/25/90		22.0
					1/25/90		28.0

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Constituent Result Report

W-049 Constituent Information Jan 1990 - July 1991

CONSTITUENT				RESULT			
Name	Units	Drinking Water Std	Detection Limit	Monitoring Well	Sample Date		Analysis Value
Total Organic Halogen, Low Det	PPB		10.0	6-43-41E	3/19/90		162.0
					3/19/90		173.0
					3/19/90		184.0
					3/19/90		217.0
					5/15/90		1160.0
					5/15/90		1160.0
					5/15/90		1240.0
					5/15/90		1260.0
					6/28/91		130.0
					6/28/91		130.0
				6-43-41F	1/25/90	<	1.0
					1/25/90	<	7.0
					1/25/90	<	8.0
					1/25/90		11.0
					4/18/90		998.0
					4/18/90		1170.0
					4/18/90		1270.0
					4/18/90		1310.0
					7/02/91		23.0
				6-43-42J	1/31/90	<	2.0
					1/31/90	<	3.0
					1/31/90		11.0
					1/31/90		13.0
					7/02/91	U	10.0
				6-43-43	1/26/90	<	3.0
					1/26/90	<	5.0
					1/26/90	<	6.0
					1/26/90		14.0
					7/08/91	U	10.0
				6-43-45	1/26/90	<	2.0
					1/26/90	<	3.0
					1/26/90	<	6.0
					1/26/90		10.0
					4/18/90	<	2.0
					4/18/90	<	2.0
					4/18/90	<	3.0
					4/18/90	<	4.0
					7/08/91	U	10.0
				6-44-42	1/31/90	<	2.0
					1/31/90	<	2.0
					1/31/90	<	4.0
					1/31/90	<	7.0
					7/10/91	U	10.0
				6-44-43B	1/26/90	<	1.0

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Constituent Result Report

W-049 Constituent Information Jan 1990 - July 1991

CONSTITUENT				RESULT			
Name	Units	Drinking Water Std	Detection Limit	Monitoring Well	Sample Date		Analysis Value
Total Organic Halogen, Low Det	PPB		10.0	6-44-43B	1/26/90	<	2.0
					1/26/90	<	3.0
					1/26/90		15.0
					4/18/90	<	1.0
					4/18/90	<	2.0
					4/18/90	<	3.0
					4/18/90	<	4.0
					7/08/91	U	10.0
Total organic carbon	PPB		1000.0	2-E25-25	3/14/90	<	500.0
					3/14/90	<	600.0
					3/14/90	<	600.0
					3/14/90	<	700.0
					6/25/91	U	1000.0
					6/25/91	U	1000.0
					6/25/91	U	1000.0
					6/25/91	U	1000.0
				2-E25-32P	1/29/90	<	600.0
					1/29/90	<	600.0
					1/29/90	<	700.0
					1/29/90	<	700.0
					4/04/90	<	500.0
					4/04/90	<	500.0
					4/04/90	<	500.0
					4/04/90	<	600.0
					7/19/91	U	1000.0
					7/19/91	U	1000.0
					7/19/91	U	1000.0
					7/19/91	U	1000.0
					7/19/91	U	1000.0
				6-40-39	1/25/90	<	200.0
					1/25/90	<	200.0
					1/25/90	<	200.0
					1/25/90	<	200.0
					4/25/90	<	200.0
					4/25/90	<	200.0
					4/25/90	<	300.0
					4/25/90	<	300.0
					7/08/91	U	1000.0
				6-41-40	1/25/90	<	400.0
					1/25/90	<	400.0
					1/25/90	<	400.0
					1/25/90	<	400.0
					4/19/90	<	600.0

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Constituent Result Report

W-049 Constituent Information Jan 1990 - July 1991

CONSTITUENT				RESULT			
Name	Units	Drinking Water Std	Detection Limit	Monitoring Well	Sample Date		Analysis Value
Total organic carbon	PPB		1000.0	6-41-40	4/19/90	<	600.0
					4/19/90	<	600.0
					4/19/90		1400.0
					7/10/91	U	1000.0
				6-42-40A	1/26/90	<	700.0
					1/26/90	<	700.0
					1/26/90	<	700.0
					1/26/90	<	800.0
					7/08/91		1400.0
				6-42-42B	1/26/90	<	300.0
					1/26/90	<	300.0
					1/26/90	<	300.0
					1/26/90	<	300.0
					7/08/91	U	1000.0
				6-43-41E	1/25/90	<	500.0
					1/25/90	<	700.0
					1/25/90	<	700.0
					1/25/90	<	700.0
					5/15/90		1100.0
					5/15/90		1100.0
					5/15/90		1100.0
					5/15/90		1200.0
					6/28/91	U	1000.0
					6/28/91	U	1000.0
				6-43-41F	1/25/90	<	300.0
					1/25/90	<	300.0
					1/25/90	<	300.0
					1/25/90	<	400.0
					4/18/90		1000.0
					4/18/90		1100.0
					4/18/90		1200.0
					4/18/90		1200.0
					7/02/91	U	1000.0
				6-43-42J	1/31/90	<	300.0
					1/31/90	<	300.0
					1/31/90	<	400.0
					1/31/90	<	400.0
					7/02/91		1075.0
				6-43-43	1/26/90	<	500.0
					1/26/90	<	500.0
					1/26/90	<	500.0
					1/26/90	<	500.0
					7/08/91		1025.0
				6-43-45	1/26/90	<	400.0

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12/03/91

Constituent Result Report

W-049 Constituent Information Jan 1990 - July 1991

CONSTITUENT				RESULT			
Name	Units	Drinking Water Std	Detection Limit	Monitoring Well	Sample Date		Analysis Value
Total organic carbon	PPB		1000.0	6-43-45	1/26/90	<	400.0
					1/26/90	<	500.0
					1/26/90	<	500.0
					4/18/90	<	400.0
					4/18/90	<	400.0
					4/18/90	<	400.0
					4/18/90	<	500.0
					7/08/91	U	1000.0
				6-44-42	1/31/90	<	500.0
					1/31/90	<	500.0
					1/31/90	<	500.0
					1/31/90	<	500.0
					7/10/91	U	1000.0
				6-44-43B	1/26/90	<	300.0
					1/26/90	<	300.0
					1/26/90	<	300.0
					1/26/90	<	300.0
					4/18/90	<	300.0
					4/18/90	<	300.0
					4/18/90	<	400.0
					4/18/90	<	500.0
					7/08/91	U	1000.0
Tritium	PCI/L	20000.00	500.0	2-E25-25	6/25/91		290.0
					6/25/91		376.0
				2-E25-32P	4/11/91		1130.0
					7/19/91		865.0
				6-37-43	5/01/90		39800.0
				6-39-39	12/03/90		114.0
				6-40-33A	2/21/90	<	82.6
					4/15/91		-47.6
					6/20/91		-208.0
				6-40-39	1/25/90		334.0
					4/25/90	<	20.2
					4/15/91		226000.0
					7/08/91		-51.6
				6-41-40	1/25/90	<	17.3
					4/19/90		226000.0
					4/15/91		213000.0
					7/10/91		189000.0
				6-42-40A	1/26/90	<	-44.2
					7/08/91		1740.0
				6-42-40B	12/03/90		-7.9
				6-42-42B	7/08/91		74600.0

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Constituent Result Report

W-049 Constituent Information Jan 1990 - July 1991

CONSTITUENT				RESULT			
Name	Units	Drinking Water Std	Detection Limit	Monitoring Well	Sample Date		Analysis Value
Tritium	PCI/L	20000.00	500.0	6-43-41E	1/25/90	<	64.4
					4/18/91		100000.0
					6/28/91		83600.0
					6/28/91		83700.0
				6-43-41F	1/25/90	<	-65.3
					4/18/90		58500.0
					4/18/91		60400.0
					7/02/91		51200.0
				6-43-42J	1/31/90		13000.0
					7/02/91		7370.0
				6-43-43	1/26/90		349.0
					7/08/91		394.0
				6-43-45	1/26/90		392.0
					4/18/90		506.0
					7/08/91		444.0
				6-44-42	1/31/90		1040.0
					7/10/91		652.0
				6-44-43B	1/26/90		44000.0
					1/26/90		45000.0
					4/18/90		37300.0
					7/08/91		32100.0
				6-45-42	4/30/90		40300.0
				6-47-35A	4/26/90	<	-53.9

Note: Data are unofficial and should not be referenced without permission from the Geosciences Group

Appendix A References

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Jungfleisch, F.L., 1988, Preliminary Evaluation of Hanford Liquid Discharges to Ground, WHC-EP-0052, Westinghouse Hanford Company, Richland, Washington.

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WDOE, 1987, Dangerous Waste Regulations, Washington Administrative Code, Washington Department of Ecology, Olympia, Washington.

WHC, 1989, Effluent Discharges and Solid Waste Management Report for 1988: 200/600 Areas, WHC-EP-0141-1, Westinghouse Hanford Company, Richland, Washington.

Appendix B

Quality Assurance Plan for Project W-049H Effluent Disposal Site Characterization

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1.0 BACKGROUND INFORMATION

The candidate site addressed in this work plan is the site chosen for characterization using the criteria and selection process discussed by Davis (1991). This quality assurance plan is an integral part of the work plan for characterizing that candidate site and is subordinate to the Westinghouse Hanford Company (Westinghouse) *Quality Assurance Manual* (WHC 1989a).

This quality assurance plan applies specifically to the work to characterize the site proposed for disposal of Project W-049H treated effluents. Its objective is to help ensure that all site characterization work is compliant with the requirements of the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology et al., 1989; as amended in 1990).

The eight tasks that must be completed to characterize the site are described in Section 5.0 of the work plan. The eight tasks and the subsections in which they are described are as follow:

Subsection	Task
5.1	Well Locations and Drilling
5.2	Geological Logging
5.3	Geophysical Logging
5.4	Sampling of Sediments
5.5	Ground Water Sampling
5.6	Determination of Initial Infiltration Rates
5.7	Aquifer Testing
5.8	Numerical Analysis and Issuance of Site Characterization Report.

2.0 PROJECT ORGANIZATION AND RESPONSIBILITIES

The responsibilities and interrelationships of individuals working on the various site characterization tasks are depicted in Figure B-1 and are briefly described in the subsections that follow.

2.1 Technical Lead

The responsibilities of the Technical Lead are to plan, authorize, and control work so that it can be completed on schedule and within budget. It is the responsibility of the Technical Lead to ensure that the planning and performance of all site characterization work are technically sound, sufficient to provide the information needed, and within the scope of this work plan.

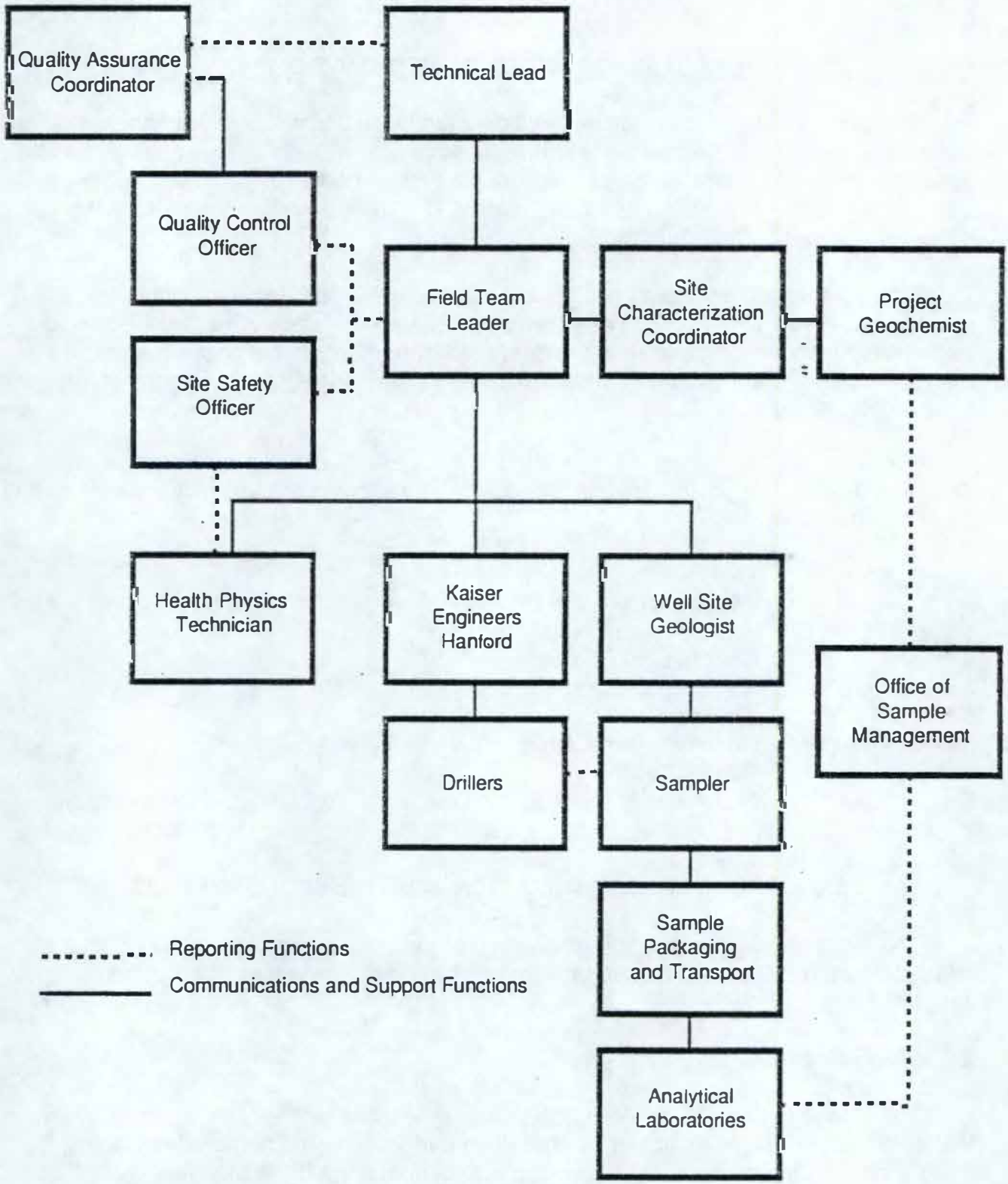

Figure B-1. Responsibilities and Reporting Relationships of Site Characterization Participants.

2.2 Quality Assurance Coordinator and Quality Control Officer

Sufficient organizational independence and authority are to be vested in the Quality Assurance Coordinator to facilitate identification of conditions adverse to quality and to recommend to the Technical Lead a course of corrective action. The Quality Control Officer is responsible for ensuring that the tasks of this work plan are performed in accordance with the requirements of this quality assurance plan and to inform the Technical Lead of any deviations. Consequently, the Quality Control Officer is empowered to conduct internal quality audits and surveillances to determine whether the quality assurance requirements are being complied with.

2.3 Site Characterization Coordinator

The Site Characterization Coordinator is responsible for coordinating data collection, analysis, and reporting tasks to ensure that the objectives of these tasks are being met in a timely and cost-effective manner.

2.4 Project Geochemist

The Project Geochemist is responsible for defining the procedures used for all project-related chemical analyses, the direction of the analytical work, and evaluation of the analytical results.

2.5 Site Safety Officer

The Site Safety Officer has the overall responsibility for ensuring that health and safety procedures and precautions are adequate and are being practiced by all personnel at the field site. The Site Safety Officer has the authority to halt field activities until hazardous conditions or practices are remedied or corrected.

2.6 Field Team Leader

The Field Team Leader is responsible for directing and controlling the activities of field personnel in completing the well-site tasks associated with the site characterization.

2.7 Well-Site Geologist

The Well-Site Geologist is responsible for all geologic logging and sampling activities associated with the site characterization.

2.8 Health Physics Technician

Westinghouse Hanford Health Physics is to provide a health physics technician to support the field work. The Health Physics Technician is to be responsible for screening well-site samples.

2.9 Kaiser Engineers Hanford

Kaiser Engineers Hanford (KEH) is responsible for the conduct of drilling activities and is to provide the site safety officer. KEH is to provide other well-site services in accordance with the Letter of Instruction for Project W049-H effluent disposal site characterization work.

2.10 Sample Management and Analysis

The Office of Sample Management (OSM) has the responsibility to coordinate environmental laboratory work, excluding independent oversight and audit responsibilities. The OSM is responsible for ensuring compliance of laboratory performance with applicable environmental regulations.

The Westinghouse Hanford Physical Properties Testing Laboratory is to analyze the sediment samples provided by the well-site geologist. Chemical analyses of sediment and ground water samples are to be provided by an offsite contract laboratory. All analyses are to be performed in compliance with Westinghouse Hanford-approved laboratory quality assurance plans and the analytical procedures specified in this work plan.

2.11 Transportation Logistics

Transportation Logistics is responsible for providing instructions for the transport of sediment samples, including the required marking, labeling, and packaging, and the necessary sample-shipping paperwork. No samples are expected to be hazardous or radioactive.

2.12 Contract Laboratories

Offsite contract laboratories are to analyze samples provided by Westinghouse Hanfoard in accordance with the laboratory's quality assurance plan. All analytical procedures are to be approved in advance of their use by the Project Geochemist, and are subject to Westinghouse Hanford quality assurance surveillances and quality control audits by the OSM.

2.13 Other Technical Support Resources

Procurement of other technical support resources is to be in compliance with applicable procurement requirements. All statements of work, task orders, or work orders are to require compliance with Westinghouse Hanford-approved quality assurance plans and procedures.

3.0 QUALITY ASSURANCE OBJECTIVES

Compliance with objectives related to precision, accuracy, representativeness, completeness, and comparability is required to ensure that the site characterization data are of acceptable quality for their intended use. The sampling locations, intervals, and procedures must provide assurance that the sample data are representative of site conditions. Compliance with comparability objectives is to be achieved by using standardized sampling, analytical, and reporting protocols.

Five levels of increasing analytical precision and accuracy have been defined by the U. S. Environmental Protection Agency (EPA 1987). The levels applicable for the site characterization work of this work plan are specified as follow:

• Geologic logging of lithologies	Level I
• Determination of Physical Properties	Level III
• Chemical Analyses of Ground Water Samples	Level III
• Chemical Analyses of Sediment Samples	Level III
• Geophysical Logging and Radiological Analyses	Level III.

4.0 WELL DRILLING PROCEDURES

All well drilling activities are to be performed in accordance with EII of WHC CM-7-7, "Environmental Investigations and Site Characterization Manual" (WHC 1989b), EII 6.7, "Ground Water Well and Borehole Drilling," and EII 6.8, "Well Completion." Specifications for the site characterization wells are to be in accordance with WHC-S-014,"Generic Specifications -- Ground Water Monitoring Wells" (WHC 1990).

5.0 SAMPLING PROCEDURES

All sediment and ground water sampling is to be in compliance with currently Westinghouse Hanford-approved procedures.

5.1 Sediment

All sediment sampling is to be done in accordance with EII 5.2, "Soil and Sediment Sampling." All drill holes are to be logged in compliance with EII 9.1, "Geologic Logging," and EII 11.1, "Geophysical Logging." The numbers, types, and locations of samples are defined in the appropriate sections of this work plan. Documentation requirements are specified in the applicable EIIs. The selection of the type of sample container to be used is to comply with EII 5.2, "Soil and Sediment Sampling".

5.2 Ground Water

All ground water sampling is to be in accordance with the *RCRA Ground Water Monitoring Project Quality Assurance Plan* (PNL 1989a). All ground water sampling, water level measurements, and field measurements are to comply with *Procedures for Ground Water Investigations* (PNL 1989b).

5.3 Presence of Radioactivity

Radiological Engineering has established criteria applicable to well drilling activities. For purposes of sampling and analysis, the following constraints apply:

- <10 mrem/hr -- open field extraction
- >10 mrem/hr, <1000 mrem/hr -- extraction in field glovebox or other containment
- >1000 mrem/hr -- hot cell extraction.

5.4 Procedure Changes

If deviations from established, specified procedures are required to accommodate unforseen field conditions, they may be authorized by the Field Team Leader in accordance with the requirements of EII 1.4, "Instruction Change Authorization." Documentation, review, and disposition of instruction change authorization forms are defined by EII 1.4. Other types of procedure change requests are to be documented as per applicable Westinghouse Hanford requirements.

5.5 Sample Custody

Chain-of-custody procedures ensure the maintenance of sample integrity and identification throughout the sampling and analysis process. Chain-of-custody forms are to accompany all samples. Results of all analyses are to be traceable to the original samples through a unique identifier. Documentation of all analytical results is to be controlled as permanent project quality assurance records.

The OSM is responsible for validating the chain-of-custody records for all ground water and sediment samples submitted for chemical analysis. All sediment samples obtained during the course of the site investigation are to be controlled from the point of origin to the analytical laboratory as per EII 5.1, "Chain-of Custody." All ground water samples obtained during the course of this investigation are to be controlled as per procedure AD-2, "Ground Water Sample Chain-of-Custody in Procedures for Ground Water Investigations" (PNL 1989b). The history of the custody of each sample is to be documented in accordance with this procedure.

No sediment or ground water samples from the site to be characterized are expected to contain hazardous or radioactive materials. However, samples are to be screened in accordance with approved radiological protection and Health Physics procedures. If elevated levels of radiation are observed, the inner core barrels are to be sealed at the drilling site and transported to T Plant or 222S Laboratory for sample extraction in a hot cell.

6.0 CALIBRATION PROCEDURES

Calibration of all Westinghouse Hanford measuring and test equipment, whether in existing inventory or purchased for the work described by this report, is to be performed as required by applicable Westinghouse Hanford calibration procedures. Equipment that requires user calibration or field adjustment is to be calibrated as required by the operator manual.

All calibrations resulting from the requirements of this work plan are to comply with the minimum requirements of *Laboratory Data Validation Functional Guidelines for Evaluating Inorganics Analyses* (EPA 1988a, Section II), *Laboratory Data Validation Functional Guidelines for Evaluating Organics Analyses* (EPA 1988b, Section III), and EPA (1986). Such requirements are to be invoked through Westinghouse Hanford procurement control procedures. Laboratory quality assurance plans are to specify the laboratory equipment to be calibrated and the respective calibration schedules.

7.0 ANALYTICAL PROCEDURES

In Section 3.3.1 of this work plan, Table 6, "Constituents and Analytical Methods for Bulk Sediment-Sample Analysis," specifies the analytes and analytical methods to be used for the sediment samples. In Section 3.3.2, Table 7, "Physical Properties to be Determined and Test Methods," specifies the analytical methods to be used in determining the physical properties of the sediments. In Section 3.3.3, Table 8, "Constituents and Analytical Methods for Ground Water Analyses," specifies the analytes and analytical methods for ground water. Unless otherwise defined, precision and

accuracy required for each analyte of potential interest in the sediment samples are to be ±20% (relative percentage difference) and ±25%, respectively. All chemical analyses of ground water are to be performed to the standards specified in the *RCRA Ground Water Monitoring Projects Quality Assurance Project Plan* (PNL 1989a).

8.0 DATA REDUCTION, VALIDATION, AND REPORTING

Analytical data from site characterization sampling activities are to be used primarily to determine the presence and quantities of analytes of interest for the sampled locations and intervals. The OSM is responsible for the examination and validation of analytical results. The requirements of the OSM are to apply to procurements for analytical services. Results from all analyses are to be summarized in a validation report and documented in terms of such measures as recovery percentages; equipment calibration records; and precision, accuracy, and the results of other quality control checks.

All validation reports and supporting information are to be subject to a detailed technical review by personnel designated by the Technical Lead. All validation reports, technical reviews, and supporting data are to be retained as permanent project quality assurance records in compliance with referenced procedures.

9.0 INTERNAL QUALITY CONTROL

The quality of analytical samples is to be subject to in-process quality control checks in the field and in the laboratory. Unless otherwise specified, the following are to be used to check quality.

- Field duplicate samples. A minimum of 5% of the total samples collected are to be duplicated or 1 duplicate is to be collected per 20 samples, whichever is greater. Submittals of duplicate samples are to be evenly distributed throughout the entire duration of sampling and analysis.

- Field blanks. Field blanks are to be submitted at the same frequency and for the same duration as field duplicate samples.

- Equipment blanks. Equipment blanks are to be submitted at the same frequency and for the same duration as field duplicate samples.

- Trip blanks. A minimum of one trip blank is to be taken per day of sampling.

10.0 PERFORMANCE AND SYSTEM AUDITS

Acceptable performance for the work described by this work plan is defined as compliance with the requirements of this quality assurance plan, its implementing procedures, and other applicable Westinghouse Hanford quality assurance program plans. All activities addressed by this quality assurance plan are subject to surveillance of project performance and systems adequacy. Surveillances are to be conducted in accordance with applicable Westinghouse Hanford procedures and are to be performed at the discretion of the Quality Assurance Coordinator or Technical Lead.

11.0 PREVENTIVE MAINTENANCE

All measurement and testing equipment used in the field and laboratory that directly affect the quality of the analytical data are required to have preventive maintenance to ensure minimization of measurement and analysis downtime. For the work described in this work plan, such maintence includes geophysical logging and analytical laboratory equipment. Contract laboratories are responsible for the maintenance of their equipment; maintenance requirements, spare parts lists, and maintenance procedures are to be included in contract laboratory quality assurance plans that are subject to Westinghouse Hanford review and approval.

12.0 DATA ASSESSMENT PROCEDURES

As discussed in Section 8 of this quality assurance plan, a data validation report is to be prepared by each analytical laboratory performing the work described herein. The data validation report is to summarize the precision, accuracy, and completeness of the analysis. The report is to compare actual analytical results with the objectives stated in the laboratory analysis plan. If the stated objectives for a specified parameter are not met, the reasons are to be determined, and limitations or restrictions on the uses of such data are to be identified. The validation report is to be reviewed and approved by the Project Geochemist, who may require additional sampling if quality assurance objectives have not been met. The approved report is to be routed to the project quality records and included within the reports submitted to regulatory agencies.

13.0 CORRECTIVE ACTIONS

Corrective actions required as a result of surveillance findings are to be documented and dispositioned as required by Westinghouse Hanford corrective action procedures. Primary responsibilities for corrective action documentation are assigned to the Technical Lead and the Quality Assurance Coordinator. Documentation of all surveillance findings

and corrective actions are to be included in the project quality assurance records.

14.0 GLOSSARY OF TERMS

Accuracy: The measure of the bias in a system.

Bias: Bias represents a systematic error that contributes to the difference between a population mean of a set of measurements and an accepted reference or true value.

Coefficient of Variation: The standard deviation divided by the mean; multiplied by 100 if expressed as a percentage.

Comparability: An expression of the relative confidence with which one data set may be compared with another.

Completeness: A qualitative parameter expressing the confidence with which one data set can be compared with another.

Deviation: A planned departure from established criteria that may be required as a result of unforeseen field situations or that may be required to correct ambiguities in procedures that may arise during practical applications.

Equipment Blanks: Pure deionized, distilled water washed through decontaminated sampling equipment and placed in containers identical to those used for actual field samples; they are used to verify the adequacy of sampling equipment decontamination procedures.

Field Blanks: Pure deionized, distilled water, transferred to a sample container at the site and preserved with the reagent specified for the analytes of interest; they are used to check for possible contamination originating with the reagent or the sampling equipment.

Field Duplicate Sample: Samples retrieved from the same sampling location using the same equipment and sampling technique, placed in separate, identically prepared and preserved containers, and analyzed independently. Field duplicate samples are generally used to verify the repeatability or reproduceability of analytical data.

Precision: A measure of the repeatability or reproduceability of specific measurements for a given set of conditions. Specifically, it is a quantitative measure of the variability of a group of measurements compared to their average value. Precision is normally expressed in terms of standard deviation, but may also be expressed as the coefficient of variation (i.e., relative standard deviation) and range (i.e., maximum value minus minimum value). Precision is assessed by means of duplicate or replicate sample analysis.

Quality Assurance: The fully integrated quality planning, quality control, quality assessment, and corrective action activities that collectively ensure that the data from monitoring and analysis meet all requirements of the users.

Quality Control: The routine application of procedures and defined methods to the performance of sampling, measurement, and analytical processes.

Range: The difference between the largest and smallest reported values in a sample; a statistic for describing the spread in a set of data.

Replicate Sample: Two aliquots removed from the same sample container in the laboratory and analyzed independently.

Representativeness: The degree to which data accurately and precisely represent the characteristics of a population parameter, variations at a sampling point, or an environmental condition. Representativeness is a qualitative parameter that is most concerned with the proper design of a sampling program.

Standard Deviation Estimate: The standard deviation estimate is the positive square root of the variance.

Trip Blanks: A type of field quality control sample, consisting of pure, deionized, distilled water in a clean, sealed sample container, accompanying each batch of containers shipped to the sampling site and returned unopened to the laboratory. Trip blanks are used to identify any possible contamination originating from container preparation methods, shipment, handling, storage, or site conditions.

Validation: A systematic process of reviewing a body of data against a set of criteria to provide assurance that the data are acceptable for their intended use. Validation methods may include review of verification activities, editing, screening, cross checking, or technical review.

Variance: A measure of the dispersion of a set of measurements; it is further defined as the sum of the squares of the individual deviations from the sample mean divided by one less than the number of results involved.

Verification: The process of determining whether procedures, processes, data, or documentation conform to specified requirements. Verification activities may include inspections, audits, surveillances, or technical review.

15.0 APPENDIX B REFERENCES

Davis, J. D., 1991, Site Evaluation Report -- Site Screening, Evaluation, and Selection; Project W-049H, 200 Areas Treated Effluent Disposal Basin, WHC-SD-W049H-SE-004 Rev. 0, Westinghouse Hanford Company, Richland, Washington.

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WHC, 1989b, Environmental Investigations and Site Characterization Manual, WHC-CM-7-7, Westinghouse Hanford Company, Richland, Washington.

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References: WHC-CM-3-4

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