PNNL-12261

Revised Hydrogeology for the Suprabasalt Aquifer System, 200-East Area and Vicinity, Hanford Site, Washington

B. A. Williams R. Schalla
B. N. Bjornstad W. D. Webber

April 2000

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

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Pacific Northwest National Laboratory
Richland, Washington 99352

Executive Summary

The primary objective of this study was to refine the conceptual groundwater flow model for the 200-East Area and vicinity. This area holds the largest inventory of radionuclide and chemical wastes on the Hanford Site. This inventory is located in underground storage tanks, the vadose zone, and the saturated zone. Within the saturated zone groundwater contaminant plumes, originating from past practice activities at facilities within this area are migrating toward the Columbia River where they will be accessible to the public.

This study supports the Hanford Groundwater/Vadose Integration Project objectives, to better understand the risk of groundwater contamination, and potential risk to the public via groundwater flow paths.

The primary components of the conceptual groundwater flow model are 1) the static elements of the subsurface that form the hydrostratigraphic framework and 2) the groundwater that moves through this framework in response to stresses within the aquifer. The previous conceptual model was used as the baseline and was expanded and refined using new data and by re-evaluating existing data and reports from previous investigations to include all the suprabasalt hydrostratigraphy and associated groundwater flow patterns beneath the 200-East Area and vicinity. Earlier work focused on either the 1) basalt confined aquifer system or 2) a single suprabasalt aquifer. This report separated the suprabasalt sediments into two aquifer systems. Most contaminants detected in groundwater are constrained by these two systems.

The results of this study suggest that groundwater monitoring and characterization of the suprabasalt aquifers downgradient of the 200 Areas plateau are inadequate; this area constitutes the preferential groundwater flow path and primary contaminant pathway to the river. Also, characterization of the confined Ringold aquifer beneath the 200 Areas is limited, and more work needs to be done to understand the groundwater flow patterns and magnitude of contamination within this aquifer.

Based on this study the existing groundwater-monitoring network should be revised to provide accurate and realistic tracking of groundwater and existing contamination emanating from the 200 Areas and upgrade the three-dimensional numerical model to incorporate the new conceptual model. New wells should be considered to improve the spatial coverage within these distinct aquifers and test the findings of this study.

Acknowledgments

The authors wish to acknowledge the individuals that contributed to the completion of this report. The technical support and expertise provided by Dr. Steve Reidel, Mickie Chamness, and Brent Barnett are greatly appreciated. Steve Airhart of Basin Environmental provided support for data collection and preparation of cross sections. David Lanigan and Chris Newbill generated computer graphics figures, maps, and cross sections. Their support, creativity, and patience to this project are greatly appreciated.

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1.0 Introduction

The largest inventory of radiochemical wastes on the U.S. Department of Energy (DOE) Hanford Site is stored in the 200 Areas plateau in single- and double-shell tanks and within the soil column above the water table or "vadose zone." The DOE, U.S. Environmental Protection Agency (EPA), and Washington State Department of Ecology (Ecology) have determined that this waste poses a potential hazard to the public and environment.

In addition to the risk of groundwater contamination resulting from future unplanned releases from the inventories described above, past practice activities between 1940 and the mid-1990s disposed of large quantities of contaminated liquid effluent to the ground via cribs, ponds, and ditches (Figure 1.1). A large portion of this effluent has migrated through the vadose zone into the groundwater. It now forms the groundwater plumes being tracked out of the 200 Areas plateau via two, well-established flow paths, one to the southeast of B-Pond and one to the north between Gable Mountain and Gable Butte (Gable Gap). Current groundwater contaminant mapping indicates approximately 100 square miles (or 18%) of groundwater beneath the Hanford Site is contaminated above drinking water standards (Hartman 1999).

To gain a better understanding of potential risk from vadose contamination to the Site and the river via the groundwater flow path, DOE/Ecology initiated an extensive vadose zone characterization project implemented under the Hanford Groundwater/Vadose Zone Integration Project (DOE/RL 98-48, Draft C). In support of the Groundwater/Vadose Zone Integration Project, the Hanford Groundwater Monitoring Project (HGWMP), administered by Pacific Northwest National Laboratory (PNNL), was asked to revise and update the hydrogeology and the existing conceptual groundwater flow model to better explain groundwater conditions and mechanisms within the suprabasalt aquifer system beneath the 200-East Area.

To understand and evaluate the groundwater flow regime, groundwater samples are collected from monitoring wells and analyzed for selected constituents, (i.e., anions, cations, isotopic composition). To make a valid evaluation of groundwater data, it is necessary that the groundwater samples collected be representative of a specific known hydrogeologic unit along the groundwater flow path of interest. The hydrogeologic unit monitored is a function of the local hydrologic conditions, well construction, sampling method, and sampling procedure. It is possible for groundwater samples from adjacent wells to be representative of distinct hydrogeologic units at different depths or a composite of groundwater from multiple hydrogeologic units. Therefore, it is imperative that each sample be evaluated to ensure it is representative of the hydrogeologic unit of interest and is used accordingly.

The suprabasalt aquifer system includes all the saturated geologic units or strata that occur above the basalt bedrock. This aquifer system is the most significant and direct pathway for contaminants disposed to the ground (via cribs, ponds and ditches, leaking single-shell tanks, or through accidental discharge) to migrate off the Hanford Site and impact the public (via the Columbia River).

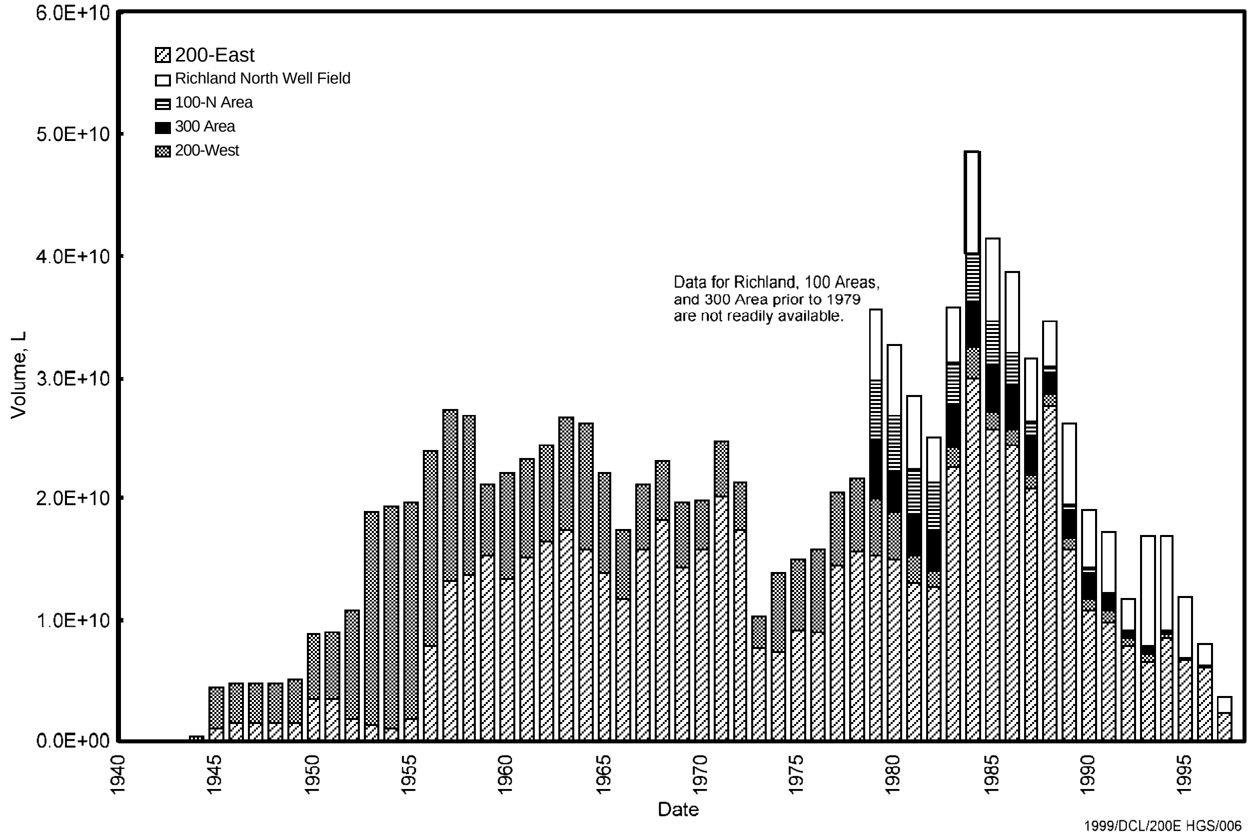


Figure 1.1. Annual Volumes of Major Liquid Effluent Streams Discharged to Hanford Site Soil Column

The geologic units that make up the subsurface environment form the framework or "natural pipeline network" that governs groundwater movement in space and time. The hydraulic properties (i.e., the ability of a geologic unit to transmit groundwater, and the extent or hydraulic continuity, of the units) all relate to define potential groundwater pathways to the river. To understand groundwater movement in the subsurface, laterally extensive geologic units are categorized into hydrostratigraphic units (flow units) consisting of an aquifer, a confining unit, or a combination of aquifers and confining units that define a reasonably distinct hydrologic system.

A detailed and thorough evaluation (and integration) of existing and new data was used to enhance the previous conceptual groundwater flow model to differentiate the multiple hydrogeologic units and the related groundwater flow regimes that exist beneath the 200-East Area. Without this detailed conceptual model, it is difficult to determine where (both vertically and horizontally) the contaminants are, how they are moving, when they will impact the public, and how to track and monitor them.

In the past, groundwater results from most sampled wells were mapped as one continuous aquifer. However, Hanford's groundwater wells are not all completed in the same aquifer flow unit, and equal numbers of wells do not exist in the various hydrogeologic units. The net result are contaminant plumes biased by preferential sampling of the Hanford unconfined aquifer that indicates movement across hydrogeologic barriers that cannot be substantiated by empirical data or inference.

1.1 Study Area Location

The study area includes the 200-East Area and vicinity, and is located in the west-central part of the Hanford Site in south-central Washington (Figure 1.2). The Hanford Site is located within the Pasco Basin, a geographic and structural basin within the Columbia Basin Subprovince of the Columbia Intermontane Province (Lindsey et al. 1992).

The study area boundaries (Figure 1.3) include the natural structural barriers of Gable Mountain to the north and the buried May Junction Fault lineament to the east. The southern and western boundaries are arbitrarily based on where the hydrogeologic units dip deep below the upper unconfined aquifer and do not affect groundwater movement beyond the study area (just west and east of the 200-East Area boundary). For this study, regional geologic interpretations published by Lindsey (1995), where applicable, were used to correlate the hydrogeologic units within the study area.

This study is limited vertically to those units at or below the water table within the study area. It does not attempt to correlate details of the vadose stratigraphy (mostly Hanford formation). See Connelly et al. (1992) and Lindsey et al. (1992) for more-detailed information on the vadose zone.

1.2 Purpose and Objectives

The purpose of this study was to refine the conceptual groundwater flow and contaminant transport model for the 200-East Area and vicinity, so that we can better predict the changes in groundwater flow and contaminant migration patterns and rates. The specific objectives of the project are:

1. Provide a detailed, accurate, and comprehensive 200-East Area hydrostratigraphic conceptual model as the baseline for the HGWMP three-dimensional numerical groundwater model (Wurstner et al. 1995). As requested by DOE, this model will be used to predict and verify present and future groundwater flow conditions and related contaminant pathways, rates of migration, and distribution within the aquifer system. Results from these model forecasts can be strategic in defining those areas where groundwater monitoring needs to be enhanced and areas where monitoring may be reduced. These results also provide valuable input toward defining DOE's groundwater cleanup strategies.

2. Show how groundwater flow and contaminant migration patterns and rates are changing in the 200-East Area as water levels decline. Recent water level declines within the suprabasalt aquifer "system" are receding into more varied hydrogeologic units which warrant a closer, detailed look and may necessitate treating the high- and low-hydraulic conductivity layers as separate units for predicting groundwater and contaminant movement along preferential flow paths. Groundwater contaminant flow paths maybe altered by hydrogeologic conditions within the aquifer system as the water table declines.

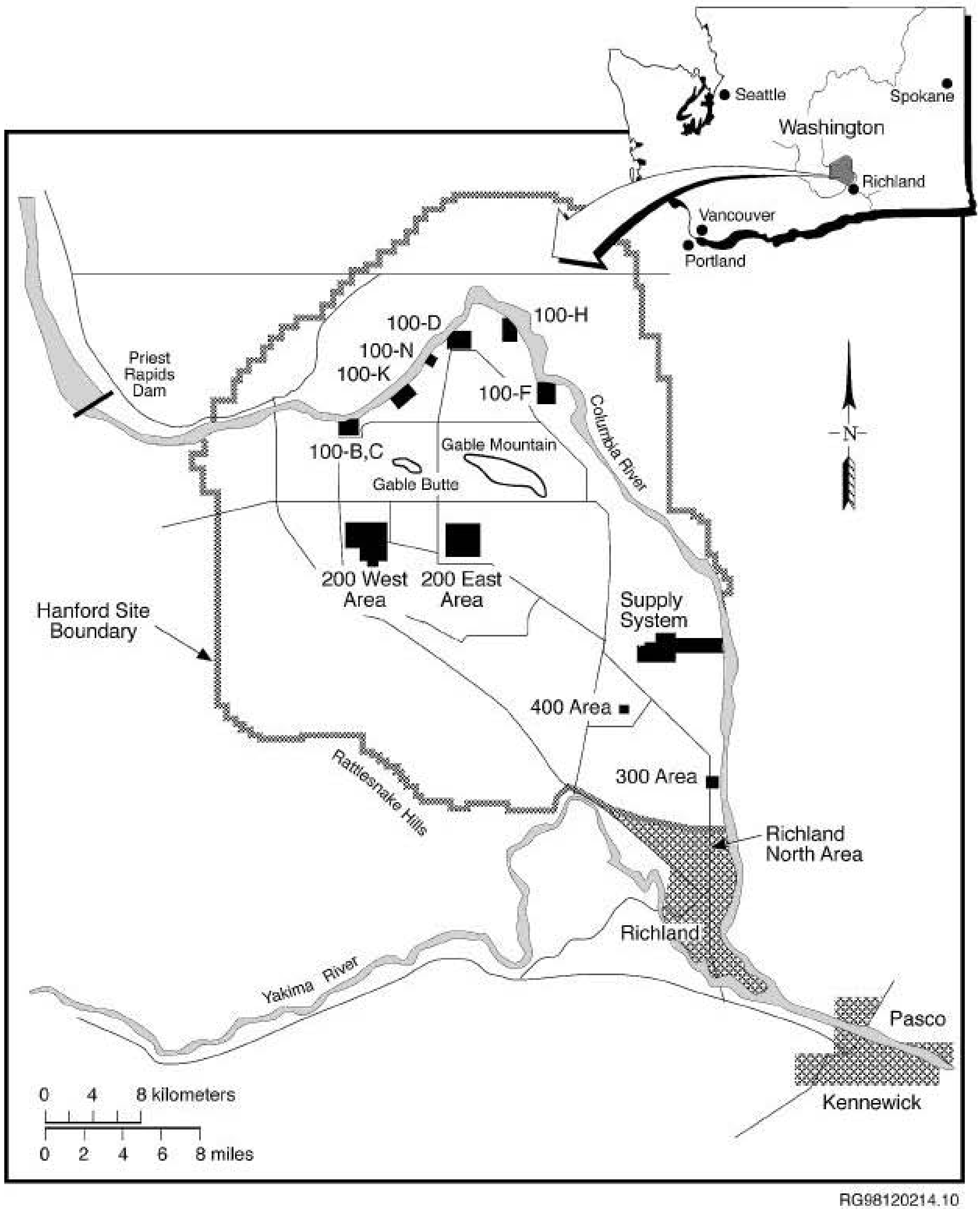


Figure 1.2. 200-East Area Location on the Hanford Site, Washington

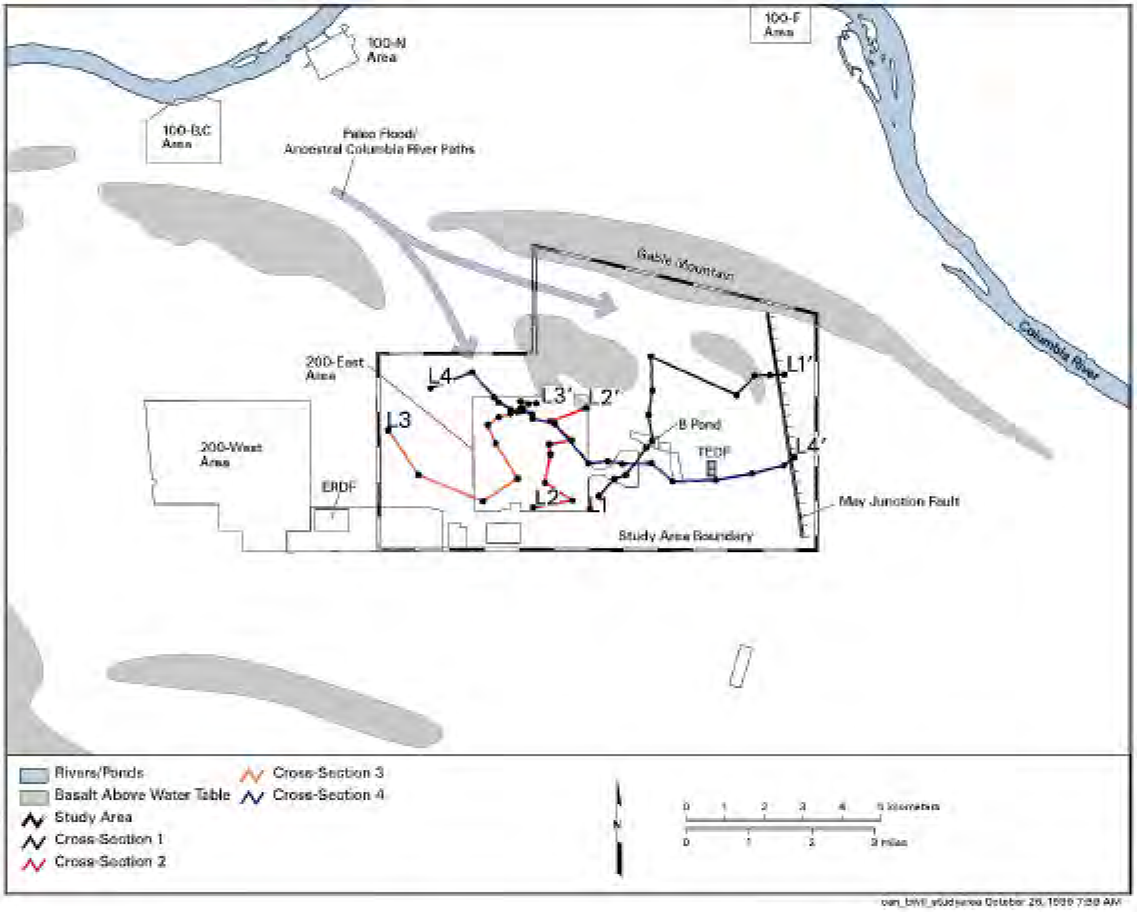


Figure 1.3. 200-East Study Area Boundary

1.3 Report Contents

Previous reports, investigations, and conceptual models pertaining to the geology, hydrology and hydrostratigraphy of the suprabasalt aquifer system were used as a baseline from which to develop the new conceptual groundwater flow model. This information was then expanded, revised, and reinterpreted to provide a comprehensive look at the suprabasalt hydrogeology of the 200-East Area. Section 2.0 of this report describes these previous studies. Section 3.0 describes the hydrogeology of the 200-East Area. Section 4.0 presents the development of the revised conceptual hydrostratigraphic model, a revised water table map, and discusses possible groundwater flow patterns. Study conclusions and recommendations are presented in Section 5.0. References are included as Section 6.0. Appendix A provides hydrogeologic unit data for selected wells within the 200-East study area, Appendix B provides plates of soil samples in selected wells, and Appendix C includes units and open interval data tables for the 200-East Area.

2.0 Previous Studies

The regional geologic setting of the Pasco Basin and the Hanford Site were described by Delaney et al. (1991) and DOE (1988). The geologic setting for the 200 Areas has been investigated and reported by Tallman et al. (1979, 1981), Last et al. (1989), and most recently, by Lindsey et al. (1992) and Lindsey (1995). Lindsey (1995) provides a stratigraphic interpretation for the Ringold Formation based on facies associations and defines the areal extent of these suprabasalt units in the Pasco Basin. For example, Lindsey describes the Ringold Unit A and the Lower Mud Unit as thickening and dipping generally to the south and southwest consistent with the underlying basalt flows and states that the Lower Mud unit is absent in the northern half of the 200-East Area. Lindsey indicates that the mud unit pinches out in some areas against uplifted basalt or is truncated by overlying Ringold E or Hanford gravel but does not address the reason for the absence of the lower mud unit across most of the 200-East Area.

The first detailed hydrologic study of the 200 Areas was presented by Graham et al. (1981) and has been updated and modified by Connelly et al. (1992). Early groundwater monitoring results in the 200 Areas were reported by Wilbur et al. (1983) and currently are reported annually in the Hanford Site groundwater monitoring reports (e.g., Hartman 1999).

The most recent 200-East Area hydrogeologic report published at Hanford was Connelly et al. (1992). They provided a comprehensive hydrogeologic model for the 200-East Area, combining data from both the vadose and saturated zones. Results of Connelly et al. (1992) established the 200-East Area hydrogeologic framework, which is the interpretation most similar to the conceptual model described in this report. The hydrogeologic conceptual model presented by Connelly describes all the saturated units above the basalt (suprabasalt sediments) as the "uppermost aquifer" in the 200-East Area and defines the regionally most extensive uppermost confined aquifer as the Rattlesnake Ridge interbed aquifer.

Connelly et al. (1992) briefly describes the basalt and suprabasalt geology and areal extent of the suprabasalt geologic units including the hydraulic properties of those units within the 200-East Area. The hydrogeologic model describes the relationship between Hanford and Ringold formation sediments as resulting from a combination of both erosional and depositional mechanisms. The erosional area is described as an area of "off-lap" deposition having a northwest-southeast trend through the 200-East Area consistent with the location and direction of the underlying basalt structure, which controlled the direction of floodwaters during Pleistocene cataclysmic flooding.

Connelly et al (1992) also evaluates aquifer intercommunication with the basalt-confined aquifer and briefly describes the uppermost aquifer near B-Pond as a transition zone between unconfined and confined conditions; the aquifer being confined beneath the Lower Mud where it is continuous. Groundwater flow conditions are generally described as flowing from west to east between 200-West and 200-East Areas. Groundwater flow is described as a radial outward flow from around B-Pond and generally north between Gable Mountain and Gable Butte.

Groundwater contaminant plumes for all major chemical and radioactive contaminants detected in the 200-East Area are graphically presented and briefly described for the uppermost aquifer. Connelly et al. (1992) also provides a 3-dimensional graphical interpretation of the major lithologic units within the uppermost aquifer system.

Gephart et al. (1976) and Hartman (1999) discuss the influence of wastewater discharge at the 216-B-3 Pond (B-Pond) and associated lobes. Barnett (1998) discusses the influence of wastewater discharge at the 200-East Areas Treated Effluent Disposal Facility (TEDF).

3.0 Hydrogeologic Setting

The geology of the 200-East Area consists of the Elephant Mountain Member of the Saddle Mountains Basalt, Columbia River Basalt Group, which forms the base of the suprabasalt aquifer system [(bedrock) (Reidel and Fecht 1981)] and the Ringold Formation and Hanford formation (informal name) sedimentary sequences, which overlie the basalt. For a detailed geographic and geologic description of the stratigraphic units present in the 200-East Area, see Lindsey et al. (1992).

In the western half of the study area, erosion associated with post-Ringold fluvial incision and Pleistocene cataclysmic flooding created a scoured surface that was later buried and is often difficult to map. Within most of this buried paleo-channel and scoured area, Ringold-age sediments have been reworked and/or removed and younger, pre-Missoula gravel (PMG) or Hanford formation cataclysmic flood deposits of sand and gravel lie directly on top of basalt. Pre-Missoula gravel in the 200-East Areas appears to represent a post-Ringold/Pre-Ice-Age flood deposit that partially filled channels of the ancestral Columbia River. Given this, the PMG is stratigraphically equivalent to the Plio-Pleistocene unit as defined in Lindsey et al (1994)

3.1 Hydrogeologic Units

Two separate Hanford Site stratigraphic classifications are available (Figure 3.1); one developed by Lindsey (1996) is based on geology alone, and the second, developed by PNNL, subdivides units based on hydrologic properties (hydrogeology). This report uses PNNL's hydrogeologic classification. A hydrogeologic summary of these units is presented below. The basis for selecting this classification is to maintain consistency with the site 3-D computer models that utilize this classification and the need to account for hydraulic separation or isolation of lower Ringold units that are not differentiated by the purely geologic classification. For example, the geologic classification defines the lower mud unit as being stratigraphically above and below other units (i.e., units B and D) which makes differentiating and defining hydrogeologic boundaries and groundwater flow conditions difficult. The hydrostratigraphic column selected provides the best fit for modeling, mapping, and describing the hydrogeologic changes in and around the 200-East Area. Three new units, 9A, 9B, and 9C, are sub-units of Unit 9 (Ringold Unit A of Lindsey [1995]), and are proposed based on the mapping interpretations of this report.

3.1.1 Basalt

The Elephant Mountain Member of the Saddle Mountains Basalt, dated at 10.5 Ma, is a Miocene age medium- to fine-grained tholeiitic continental flood basalt. Beneath the 200 Areas of the Hanford Site, the Elephant Mountain unit consists of two flows and ranges in thickness from 20 to 30 m (Reidel and Fecht 1976).

The uppermost surface of the Elephant Mountain Member (basalt) is considered the base of the suprabasalt aquifer system (bedrock) because of its low permeability relative to the overlying sediments. This surface is interpreted and mapped to be a groundwater no-flow boundary. The basalt surface

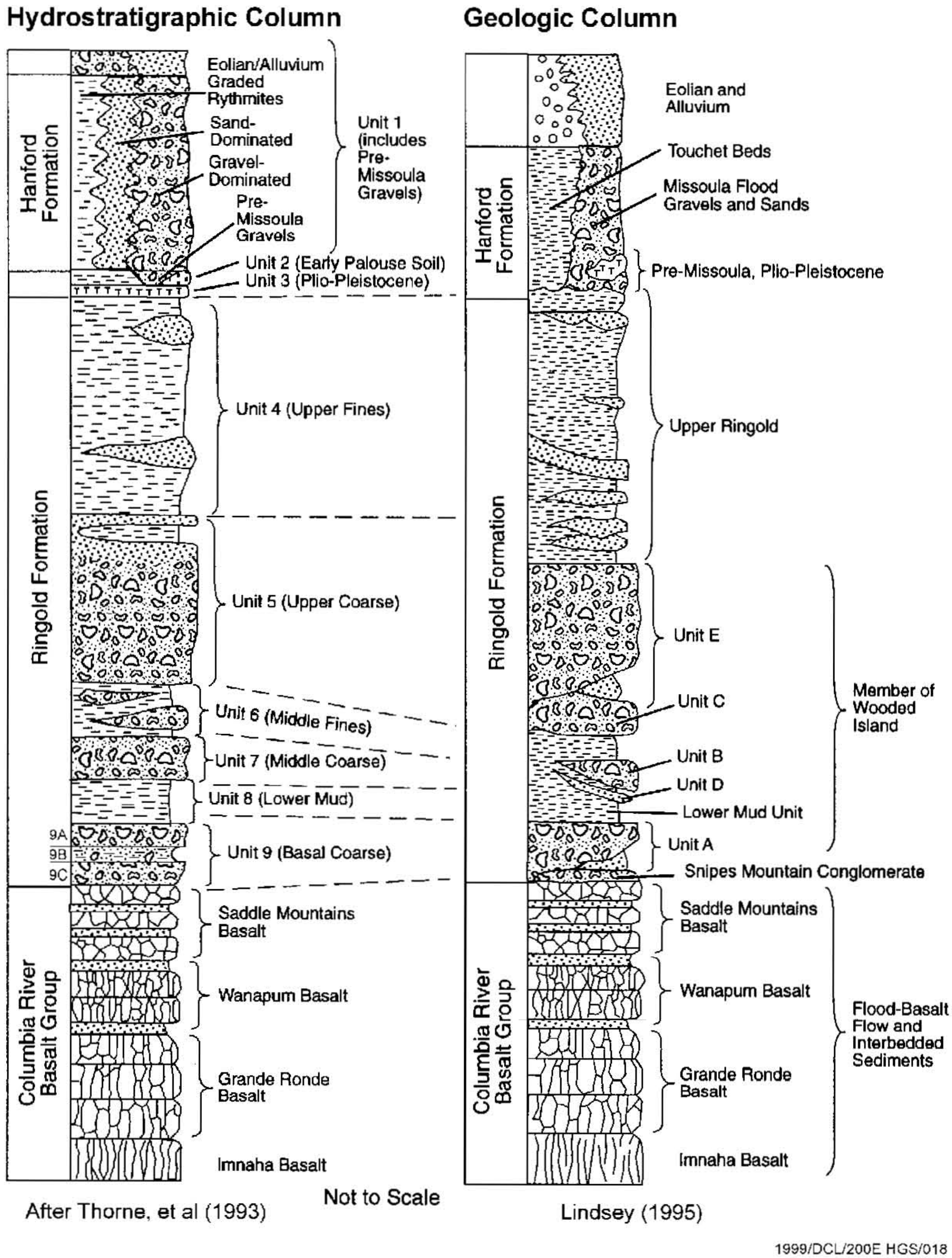


Figure 3.1. Comparison of Hydrostratigraphic and Geologic Classifications

beneath the 200-East Area dips south forming the southern limb of the Gable Mountain anticline (after Fecht et al. [1987]). Two smaller basalt folds or anticlinal ridges trending northwest-southeast extend above the water table and create barriers to groundwater flow just north and east of the 200-East Area (Plate 2 Basalt map). Intercommunication of groundwater between the uppermost basalt-confined aquifer and overlying suprabasalt aquifer system does occur in some areas of the Hanford Site but is not addressed in this report.

3.1.2 Units 4 through 9 (Ringold Formation)

Units 4 through 9 correspond to the Ringold Formation (see Figure 3.1) continental fluvial and lacustrine sediments deposited on the Elephant Mountain basalt by ancestral Columbia and Clearwater-Salmon rivers during late Miocene to middle-Pliocene time (DOE 1988).

Units 4 through 9 consist of intercalated layers of indurated to semi-indurated and/or pedogenically altered sediment, including clay, silt, fine- to coarse-grained sand, and granule-to-cobble gravel. Within the 200-East Area and vicinity, this sequence consists of three distinct stratigraphic intervals designated Units 5, 8, and 9. Units 5, 8, and 9 correspond generally to Lindsey's Ringold Formation fluvial gravel Unit E, lower mud unit and fluvial gravel Unit A, respectively (Figure 3.1). Unit 5 (Lindsey's Ringold Unit E) is only present in the southern and southwestern portion of the 200-East study area (Lindsey et al. 1992). Units 6 and 7, which correspond to Lindsey's Ringold Formation Units B, C, and D, are not present in the study area. From the oldest to youngest (bottom to top of the section), the stratigraphic intervals are Unit 9 (Ringold Formation Unit A) fluvial gravel, Unit 8 (Ringold Formation lower mud unit) paleosol/overbank facies and lacustrine fine-grained facies, and Unit 5 (Ringold Formation Unit E) fluvial gravel.

3.1.2.1 Unit 9 (Ringold Formation Unit A)

In some parts of the study area this report subdivides Unit 9 (Ringold Formation Unit A) into three hydrogeologic units, based on markedly different lithologic descriptions and hydraulic properties. These hydrogeologic units are designated as Units 9A, 9B, and 9C (Figure 3.1). In the southern and eastern portion of the 200-East Areas, Unit 9 can be subdivided by a low permeability poorly characterized silt-to clay rich confining zone (aquiclude) classified as Unit 9B. Units 9A, 9B, and 9C can be differentiated and mapped as separate units based on correlation of Unit 9B where it is laterally continuous using geophysical logs, lithologic logs, and drillers reports. Based on lithology, and limited soil core hydraulic conductivity tests, it is assumed that Units 9A and 9C (9A/C) are more permeable than Unit 9B. In some areas of the study area data was not sufficient to allow the subdivision of unit 9 into the three sub-units. In these areas Unit 9 is undifferentiated.

This new correlation is important because it supports the differentiation of the Ringold unit 8 from the older Ringold 9 units. In previous reports, Unit 9B has been grouped and mapped with Unit 8 as the Ringold Formation lower mud unit. Integrated evaluation of geologic, geophysical, and hydrologic data from new and existing wells has provided the necessary detail to differentiate these units and more accurately correlate them across the study area (Figure 3.2).

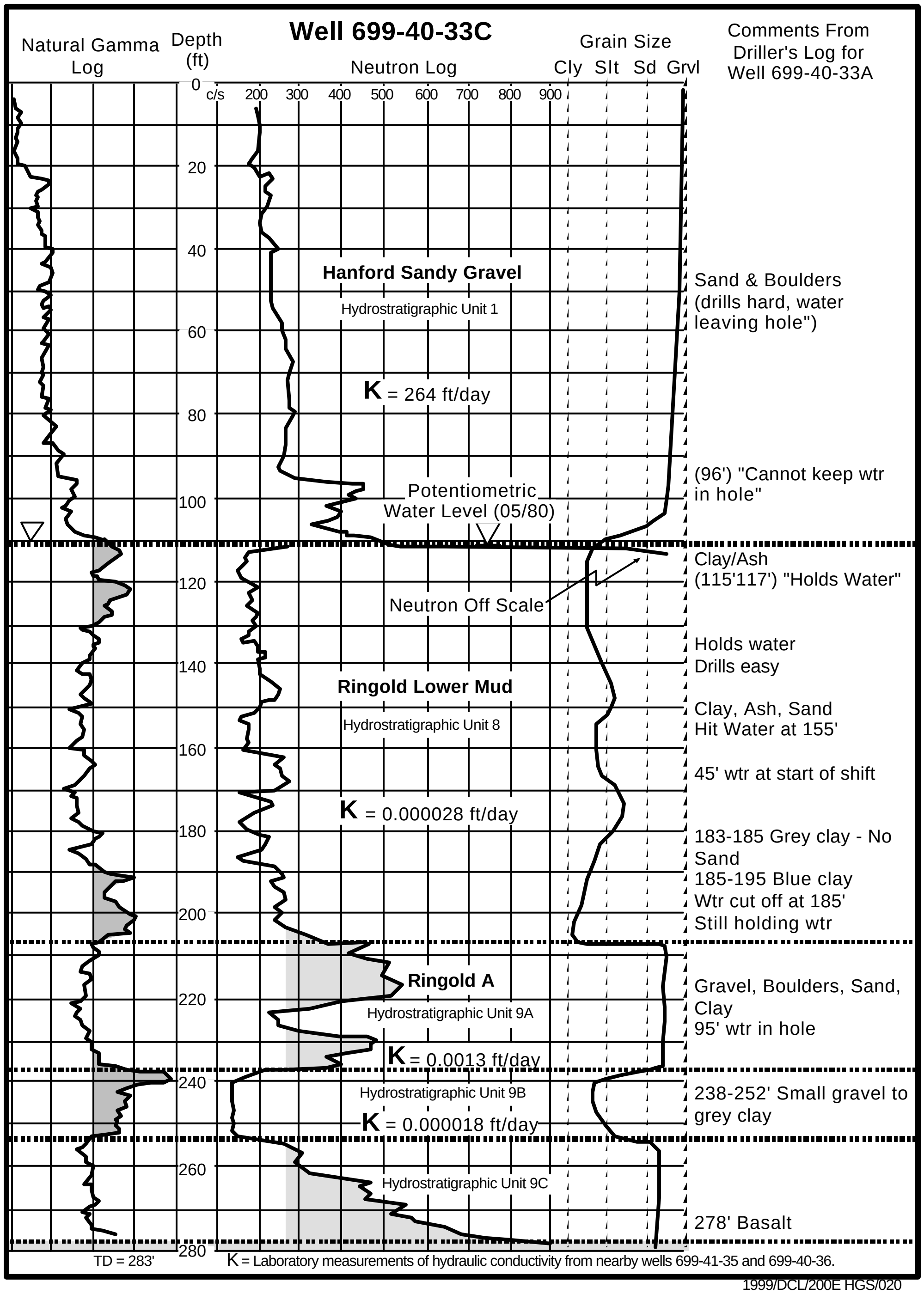


Figure 3.2. Example of Borehole Data Evaluation for Hydrostratigraphic Classification. Shaded areas on the gamma log are interpreted to denote areas consisting of significantly finer grained (i.e., higher percentages of clay sized particles) particles than non-shaded areas. Shaded area on Neutron log is interpreted to highlight areas with higher overall water saturation than non-shaded areas.

Units 9A, 9B, and 9C dip consistently to the south, roughly paralleling the basalt structure (see Plates 2, 3, 4, and 5). These units increase in thickness from north to south into the Cold Creek syncline, suggesting progressive growth of this structure during the Ringold time.

The northern edge of Units 9A/C and 9B is approximate, and is delineated as the erosional limit of post-Ringold fluvial incision and cataclysmic flooding that traversed across the uplifted anticlinal area (see Plates 3, 4, and 5). In the scoured area, interpreted to be north of the erosional unit boundary, Units 8 and 9A/B/C are all or partially removed and/or reworked.

Evaluation of data north and east of B-Pond, suggest that only portions of Units 9A/C and 9B are preserved on the lee side and between the smaller anticlinal ridges within the erosional area.

Aquifer testing, primarily in Unit 9A, reveals that this unit has a lower hydraulic conductivity than the uppermost unconfined aquifer system, which is composed of Unit 1 (Hanford formation gravel and sand/ PMG [undiff.]) and Unit 5 (Ringold Formation Unit E).

3.1.2.2 Unit 8 (Ringold Formation Lower Mud Unit)

Unit 8 correlates with the lowermost fine-grained sequence of the Wooded Island Member of the Ringold Formation designated the "Lower Mud Unit" (Figure 3.1). Unit 8 is composed of a thick sequence of fluvial overbank, paleosol, and lacustrine silts and clay with minor sand and gravel. More detailed descriptions of Unit 8 (the lower mud unit) can be found in Lindsey (1995).

This study indicates that Unit 8 is the most significant aquiclude (confining unit) within the suprabasalt aquifer system at the Hanford Site. Unit 8 separates the saturated sediments of the suprabasalt aquifer system into an uppermost unconfined aquifer system, often referred to as the Hanford unconfined aquifer, and a lower confined aquifer system referred to as the confined Ringold aquifer system. In the 200-East study area, this study shows the confined Ringold aquifer system is composed of Unit 9A/C gravels separated by Unit 9B. The uppermost unconfined aquifer system includes saturated sediments above Unit 8 (the Ringold lower mud unit) or the top of Unit 9B in the areas where Unit 8 is missing, or the top of basalt in the area where Unit 8 is missing.

Work by Lindsey (1995) indicates that east of B-Pond and south of the study area boundary Unit 8 is regionally continuous throughout the Pasco Basin. However, as Lindsey and others describe Unit 8 is not present on the Gable Mountain anticline including Gable Gap and the region to the south extending to the northern boundary of the 200-West Area and including most of the 200-East Area. Lindsey suggests the absence of Unit 8 (Ringold lower mud unit) is due to either depositional thinning onto the basalt structure or because of truncation by Ringold Unit E or Hanford formation sediments. Connelly mentions the erosional trends across the gap and the 200-East Area and suggests an "off-lap" relationship between the Hanford formation and the Ringold Unit E as being erosional. Geologic, geophysical, and hydraulic data evaluated for this report indicate that where channeling occurs within the study area, erosion appears to have scoured into and completely removed all of Unit 8 (the Ringold lower mud unit) and Unit 5 (Ringold Unit E), with the possible exception of small, localized remnants. This report proposes an erosional limit for the Ringold Unit 8 (Ringold lower mud unit).

Where it is present in the 200-East Area, Unit 8 is up to 96 ft thick and dips south into the Cold Creek syncline roughly paralleling the basalt structure. The revised structure map of Unit 8 illustrates that it is elevated above the groundwater surface east and south of B-Pond (Plate 6). In these areas, where Unit 8 is at or above the water table, it is mapped as a hydraulic barrier similar to the basalt surface (see Section 3.1.1). According to Wurstner et al. (1995) hydraulic conductivity measured in Unit 8 (the Ringold lower mud unit) ranges from 3×10^{-4} to 9×10^{-2} m/d, which is several orders of magnitude lower than measured in the Hanford unconfined aquifer (Unit 1 through Unit 5; e.g., 1×10^{-1} to 1,000,000 m/d) and average over two orders of magnitude lower than the confined Ringold aquifer system (Unit 9A/C; i.e., 1×10^{-1} to 2×10^{2} m/d).[a]

Interpretations presented in this report, using hydrochemistry and hydrologic data, the given hydrogeologic continuity and thickness of Unit 8, indicate that groundwater within the Hanford unconfined aquifer and confined Ringold aquifer system does not flow vertically through Unit 8. However, along the lateral boundary of Unit 8 where it has been removed by erosion, groundwater from the confined Ringold aquifer system may be in communication with groundwater from the uppermost unconfined aquifer. Also, along the May Junction Fault where uplift has juxtaposed Unit 8 adjacent to the unconfined aquifer, intercommunication may occur.

3.1.2.3 Unit 5 (Ringold Formation Unit E)

Within the study area, Unit 5 (the Ringold Formation Unit E) is the uppermost Ringold unit in the 200-East Area (Figure 3.1) and is composed primarily of fluvial gravel that grades upward into interbedded fluvial sand and silt (Lindsey 1995). Unit 5 overlies Unit 8 (the Ringold lower mud unit) and is present only in the southern portion of the study area; in the southwester portion of the study area its updip limit is interpreted to be the same as the Unit 8 (the Ringold lower mud unit) limit as defined by the channel boundary (Plate 7). This interpretation is slightly different from previous work and suggests that Unit 5 (Ringold Unit E) was also eroded and/or reworked in this area during post-Ringold fluvial incision or Pleistocene flooding events.

Unit 5 (Ringold Unit E) has been removed from Gable Gap and most of the 200-East Area to approximately the May Junction Fault. Unit 5 (Ringold Unit E) was not removed from the downthrown side of the fault because of the structural displacement into the basin and distance away from the highest forces of the floods. The Unit 5 (Ringold Unit E) structure map in this report is based primarily on work by Lindsey (1995).

As described by previous authors, Unit 5 (Ringold Unit E) comprises the uppermost unconfined aquifer south and west of the 200-East Area. Most known contaminant plumes that emanate from the 200-West Area migrate east through this unit and into the adjacent and overlying Unit 1 (Hanford formation) sand and gravel near the 200-East Area.

(a) Results are values reported by Wurstner et al. (1995) and are reported here for trending purposes only.

3.1.3 Unit 3 (Plio-Pleistocene Unit)

Unit 3 (Plio-Pleistocene unit) is present to the west, as a strong calcic horizon or sidestream alluvium overlying the Ringold Formation. Elsewhere, in the Pasco Basin, a quartzo-feldspathic sandy gravel overlying the Ringold Formation has been identified above the Ringold Formation and below the more basaltic Hanford formation. This intermediate gravel is referred to as the PMG (DOE 1982) and appears to be laterally equivalent to the Plio-Pleistocene unit. Because the PMG is mineralogically similar to the Ringold Formation, it is difficult to decipher the contact. They are best differentiated on the basis of their saturated hydraulic conductivity, which is 1 to 2 orders of magnitude greater for the PMG.

Unit 2, the "early Palouse" soil unit, is not present in the study area having been eroded or never deposited in this area. Part or all of the PMG could be equivalent to Unit 2, as well. For the purpose of this report, Units 1-3 are grouped together on cross sections and maps, since no attempt was made to differentiate these units at this time.

3.1.4 Unit 1 (Hanford formation/PMG [undiff.])

Unit 1 (Hanford formation/PMG [undiff.]) consists of post-Ringold fluvial deposits from the ancestral Columbia River (PMG) and glaciofluvial sediments deposited during cataclysmic flooding. It is continuous over the entire study area except on the Gable Mountain basalt outcrop and locally on the basalt high northeast of B-Pond. Unit 1 (Hanford formation/PMG [undiff.]) sediments were deposited between ≥3 Ma and 13 Ka and are composed of relatively unconsolidated pebble-to-boulder gravel, fine-to-coarse-grained sand, and silt-to-clayey silt. The Hanford formation is subdivided into three facies (Figure 3.1; Baker et al. 1991). In the northern portion of the study area, Unit 1 (Hanford formation/PMG [undiff.]) sediments are deposited unconformably on top of basalt and form part or all the sediments in the Hanford unconfined aquifer. Farther south, Unit 1 (Hanford formation/PMG [undiff.]) sediments overlie Units 5, 8, and 9 (Ringold Formation). As reported in Connelly, Thorne, and others, the Hanford formation hydraulic conductivity (K) values are highest of all the hydrogeologic units present (5-9) (Table 3.1, modified from Cole et al. 1997). PMG have a hydraulic conductivity (K) one- to two-orders-of-magnitude less than the Hanford formation.

In the study area, the Hanford unconfined aquifer system is composed mostly of Unit 1 (Hanford formation/PMG [undiff.]) and Unit 5 (Ringold Unit E) gravel.

Within the study area, the vadose zone is composed primarily of Unit 1 (Hanford formation/PMG [undiff.]) sediments. This report does not attempt to map or subdivide the vadose interval. Lindsey et al. (1992) and Connelly et al. (1992) provide detailed descriptions of the Hanford facies and vadose zone in the 200-East Area.

Table 3.1. Hydraulic Conductivities for Major Hydrogeologic Units

Hydrogeologic Unit	Estimated Range of Saturated Hydraulic Conductivities (m/d)	Reference(s)
Unit 1 (Hanford formation)	1 to 1,000,000	Wurstner et al. (1995): Thorne and Newcomer (1992)
Unit 5 (Ringold Formation Unit E)	0.1 to 200	Wurstner et al. (1995): Thorne and Newcomer (1992)
Unit 8 (Ringold Formation Lower Mud Unit)	0.0003 to 0.09	Wurstner et al. (1995): Thorne and Newcomer (1992)
Unit 9 undifferentiated Ringold Formation Unit A	0.1 to 200	Wurstner et al. (1995): Thorne and Newcomer (1992)
Note: This table is modified from Cole et al. (1997).		

4.0 Conceptual Groundwater Model

The primary objective of this study was to refine the conceptual groundwater flow model for the 200-East Area and vicinity. The primary components of the model are the 1) static elements of the subsurface that form the hydrostratigraphic framework, and 2) groundwater that moves through this framework in response to stresses within the aquifer. The previous conceptual model was used as the baseline and was expanded and refined to include all the suprabasalt hydrostratigraphy and associated groundwater flow patterns beneath the 200-East Area and vicinity, using new data and by re-evaluating existing data and reports from previous investigations.

4.1 Hydrostratigraphic Framework

In some areas, the hydrostratigraphic interpretation described in this report differs from previous conceptual models. These differences generally are associated with the depositional setting of specific hydrogeologic units and subsequent mapping options. Every attempt was made to make the interpretation as comprehensive as possible.

Because the focus of this study is to define the hydrostratigraphy of the suprabasalt aquifer system, only units saturated within the study area are delineated. Stratigraphic sequences within the vadose zone have not been included in this study except in a few instances where a semi-regional marker is easily defined or where geophysical anomalies (gamma log, radioactive contamination) are discernible and distinguish the natural from manmade log signature. If not evaluated, these anomalies can create complications in interpreting the subsurface stratigraphy. Contaminant anomalies can also provide valuable data for determining the nature and extent of vadose contamination and migration through the vadose into the uppermost aquifer system.

4.1.1 Data Integration

The new conceptual groundwater flow model presented here incorporates the latest hydrogeologic and hydrostratigraphic information available within the study area. Appendix A provides a partial listing of wells used for this study. Existing information files for many older wells were also used as part of this study. Where available, the following data and information were used for this interpretation:

- Geologic and borehole geophysical data were integrated with a review of soil samples archived in the Hanford Geotechnical Sample Library (2101-M Building, 200-East Area) to confirm data sets and ensure consistent correlations (see Figure 3.1).

- Driller's logs and well-construction information were used to identify the hydrogeologic interval monitored by each well used in this investigation. This was necessary to ensure that groundwater data used were correctly associated with the position along the respective groundwater flow path from which each sample was taken.

- Hydrographs (water-level trend plots) and other water-level data were used to delineate areas with rapid groundwater change (e.g., drainage and outflow) from those areas that appear more stable (e.g., less groundwater decline, steady state, and equilibrium). Water-level information was correlated with the hydrostratigraphy to identify aquifer boundaries, flow barriers, and preferential flow paths.

- Spatial distribution of groundwater major ion composition is represented on maps using STIFF diagrams (Stiff 1951); groundwater isotope composition (tritium) and contaminant concentrations are also plotted spatially to delineate groundwater flow patterns and aid in identifying separate aquifer zones and their related hydrostratigraphic units. The STIFF diagrams provide geochemical corroboration for the selection of aquifer boundaries presented here; isotope (i.e., tritium) differences in groundwater aid in determining groundwater residence time, which also facilitates evaluation of groundwater flow patterns.

- Hydraulic parameters (e.g., aquifer test results) determined by Wurstner et al (1995) from slug and pumping tests deemed to be valid for estimating hydraulic conductivity, and where possible storativity, were used to identify preferential flow paths and barriers.

- Spatial data were used to geographically correlate surface and subsurface features on maps. These data include information from the Computer-Automated Mapping Information System (CAMIS), the Hanford Geographical Information System (HGIS), and the PNNL Geographical Information System (PNLGIS).

  An evaluation of geologic sample results, drill cuttings, and geophysical logs aid in the accurate correlation of hydrogeologic units from one well to the next. Borehole geophysical data sometimes provide the means to correlate between wells that have little or no reliable geologic data. In older wells, a driller's log description is often the only geologic information available. For some wells, geophysical logs were used to aid in correlation of hydrogeologic units between wells. The correlation of Units 8, 9A/C, 9B, and basalt between wells 699-37-47A and 299-E16-1 is an example of the use of geophysical logs in the absence of geologic data (Plate 8). Specifically, confined Unit 9B is composed of a clayey to silty-sandy gravel, which is not always recognized or recorded as a distinct unit by the driller or field geologist (depending on drilling methodology) but can be easily identifiable from geophysical logs (see also Figure 3.2).

Drilling information sometimes provides qualitative evidence about the geologic formation encountered. For example, descriptive terms recorded during drilling, such as "loses water," "no cementation," and "no recovery," may indicate a younger, less consolidated or reworked Hanford-age sand and gravel. Terms like "indurated," "cemented," "oxidized," or "clayey" could indicate an older more compacted and cemented material and are often characteristic of Ringold Formation sediments. Hydrologic descriptions, such as "loses water" and "won't hold water" may indicate a relatively permeable formation. Terms like "water shuts off," "clay binders," "drills easy," "hole stays open," and "changing water level measurements" may indicate units that are relatively lower in permeability or hydraulic conductivity.

Many older wells did not have borehole geophysical logs, and driller's logs were the only data available for cross-well correlation. An attempt was made to obtain downhole geophysical logs (re-log) from several such older wells that were key to understanding the hydrostratigraphy of the study area. For example, the driller's log and archived sediment samples were the only data available for well 299-E17-6. Geophysical logs obtained for this well greatly improved the accuracy and confidence of the interpretation and correlation of the hydrostratigraphy (Plate 8).

4.1.2 Maps and Cross Sections

The PNNL's extensive Well Log Library and the PNLGIS were used to prepare structure maps showing the elevation of the top of each hydrostratigraphic unit and four cross sections as visual representations of the subsurface hydrogeology and hydrostratigraphy. These four structural cross sections, Lines 1-4, are enclosed as plates 8 and 9 and represented schematically in Figures 4.1, 4.2, 4.3, and 4.4. These cross sections are oriented roughly perpendicular to the regional structural trends and depositional axes of the geologic units (Plate 1). It is intended that these visual aids help illustrate the revised interpretation of the lateral and vertical extent and variability of the principal hydrogeologic unit within the geologic framework and their relationship to groundwater movement through the area.

The hydrostratigraphic nomenclature used in these four cross sections and maps is illustrated in Figure 3.1. All measurements are reported in English (feet) rather than metric (meter) units because most well logs and driller's records are recorded using the "foot" as the standard unit of measurement. Elevations used are rounded to the nearest foot and represent the most recent Hanford well survey results with respect to the North American Vertical Datum of 1988 (NAVD88).

The salient features associated with each of the four cross section lines (see Figure 1.2 and Plate 1) are discussed in the following subsections. Changes from previous work are also discussed, and justifications supporting the changes are presented.

4.1.2.1 Line 1

Cross section 1 (Figure 4.1, Plate 1 and Plate 8) introduces the groundwater conceptual model for the suprabasalt aquifer system near B-Pond. The southern portion of cross section 1 illustrates the entire hydrostratigraphic sequence in the 200-East Area and vicinity from basalt through Ringold and Hanford formations.

Line 1 illustrates the hydrostratigraphy roughly perpendicular to the ancestral Columbia River and Pleistocene flood paths and subsequent channel development (Figure 4.1, Plate 8). Salient hydrostratigraphic features include the relative stratigraphic position and thickness of the confining lower mud, Unit 8, with respect to the basalt structure; the continuity of Unit 8 up onto the structure (only minor depositional thinning); and the isolated areas where Unit 8, and portions of 9A/C and 9B are abruptly absent or have been removed. The thickness and relative position (vertical separation) of the units is maintained up onto the structure on both sides of the channel scour, which suggests the erosional removal of the units rather than depositional thinning.

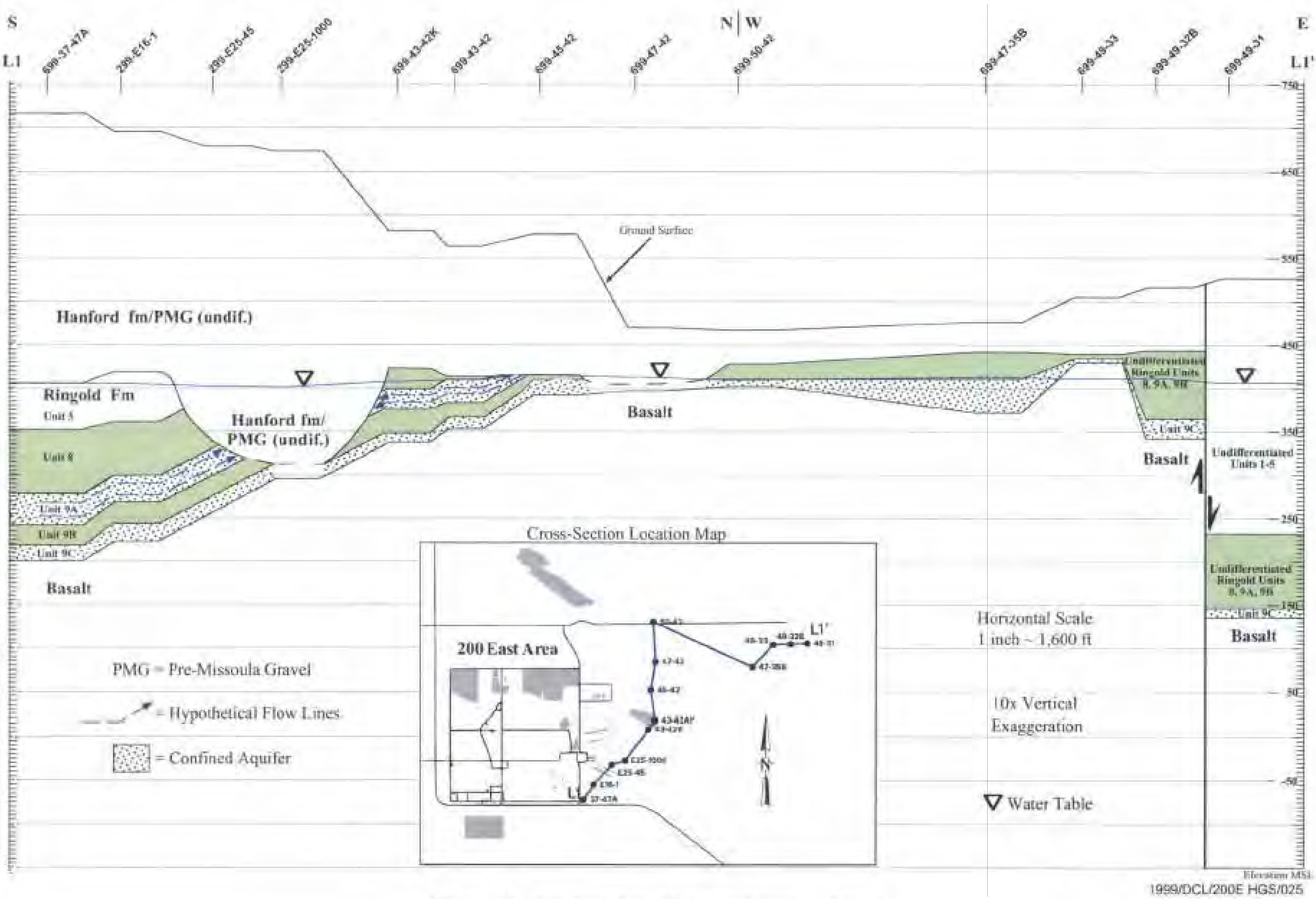


Figure 4.1. 200 East Area Hydrostratigraphy - Line 1

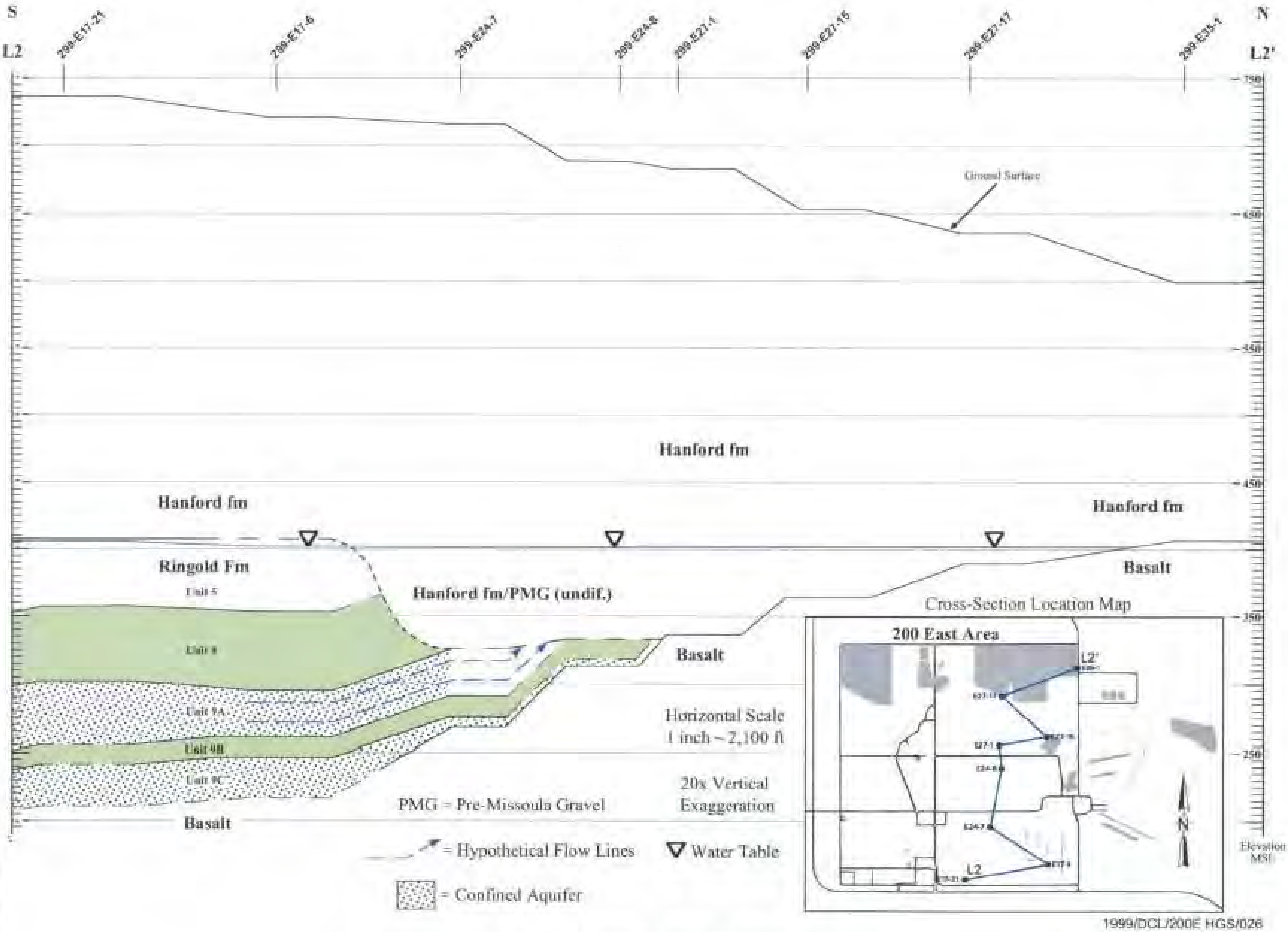


Figure 4.2. 200 East Area Hydrostratigraphy - Line 2

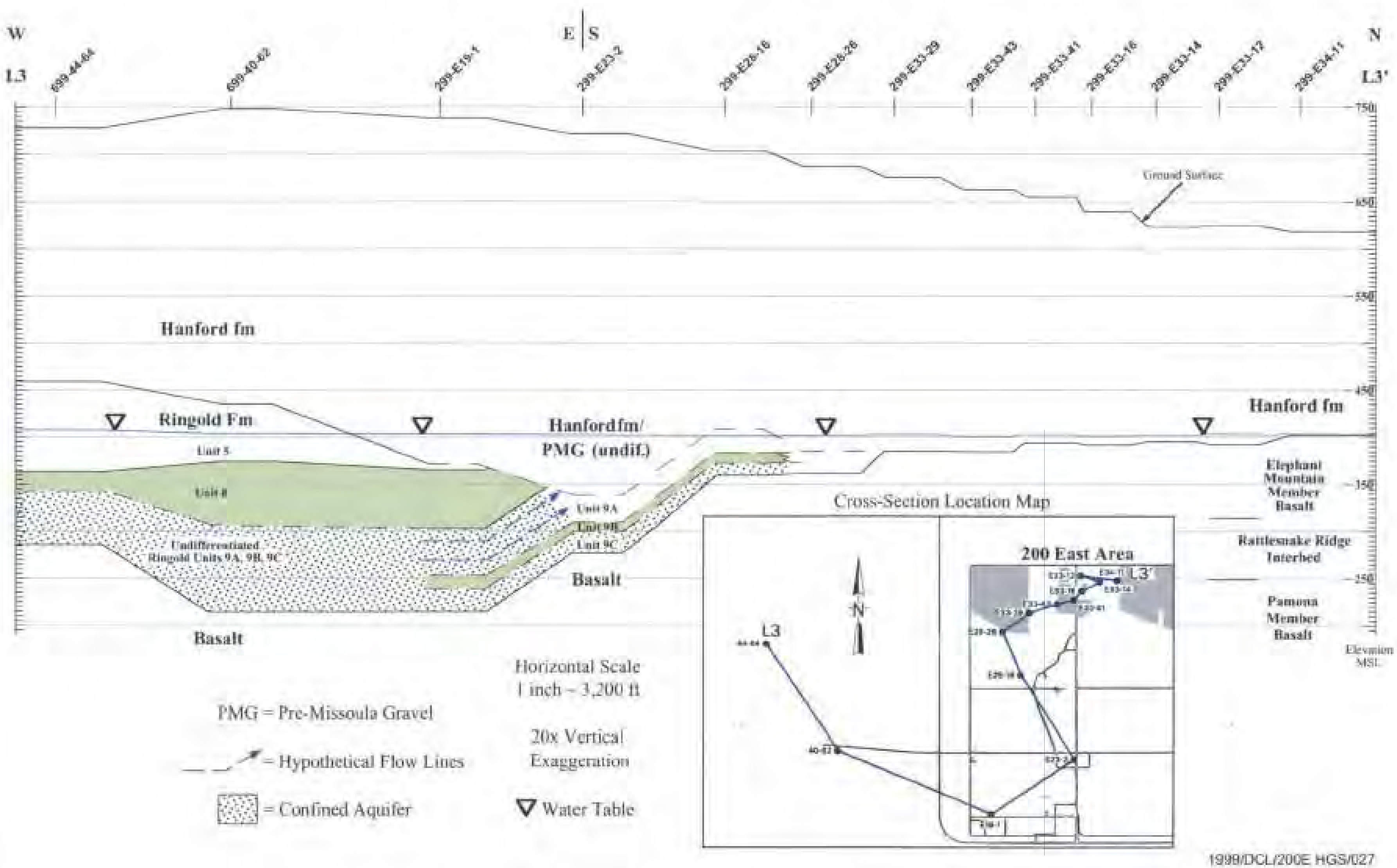


Figure 4.3. 200 East Area Hydrostratigraphy - Line 3

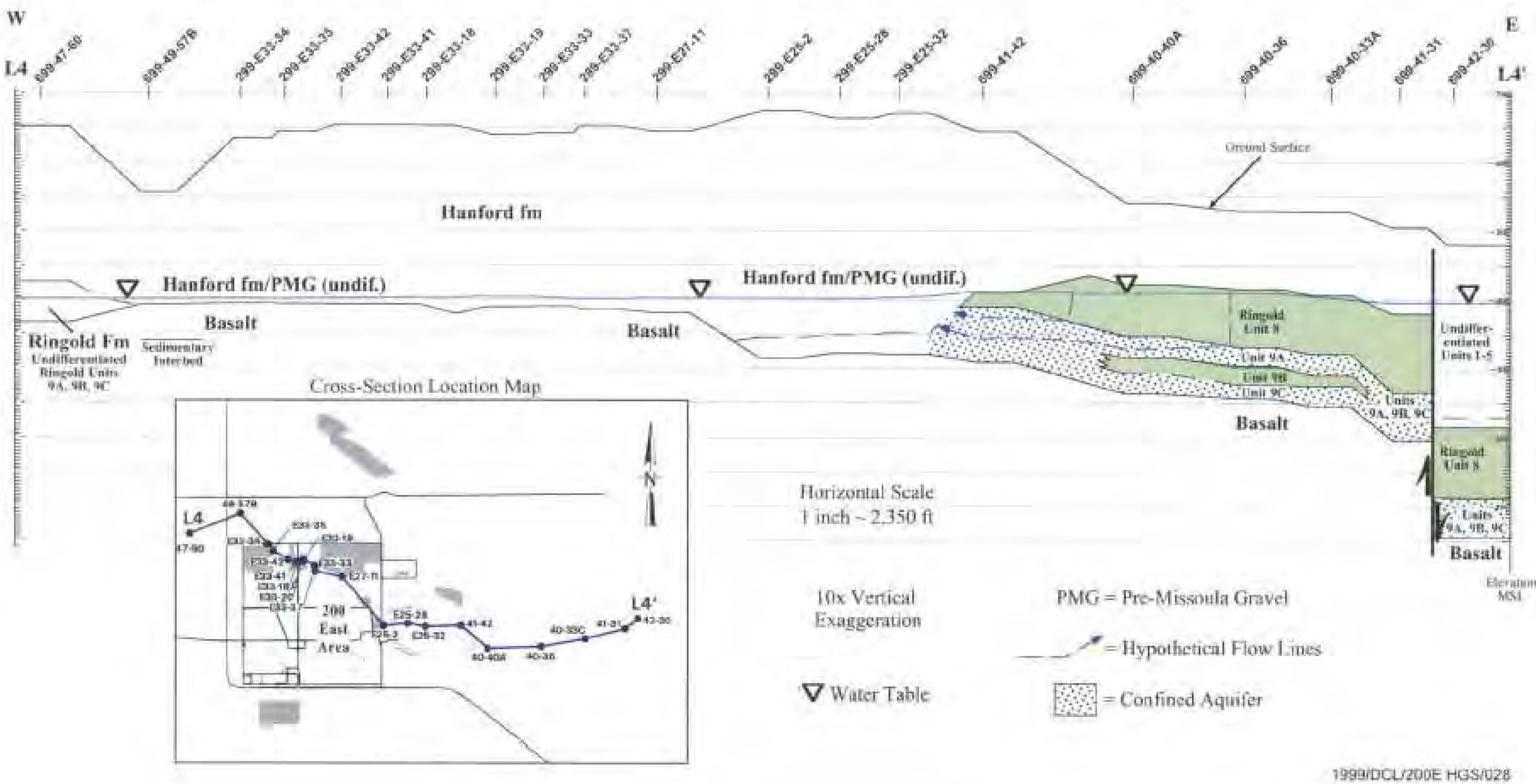


Figure 4.4. 200 East Area Hydrostratigraphy - Line 4

The eastern end of line 1 crosses the May Junction Fault and illustrates the relative thickness of Units 8 through 9 (undifferentiated) on both sides of the fault. The vertical displacement of the top of basalt and the Ringold units across the fault is roughly the same, approximately 185-ft. Because this sequence (Units 8 through 9 undifferentiated) maintains a near uniform thickness across the fault boundary, it is assumed that most of the fault displacement occurred after the deposition of these older Ringold units. This is supported by the relatively thick sequence of Ringold- to Hanford-age sediments overlying Unit 8 on the downthrown side of the fault. This fault-related depositional ("growth") feature suggests that the major movement likely occurred after the Ringold Unit 8 deposition. This structural activity suggests a time when increased basin movement (tectonic deformation) may have occurred. It is the hypothesis of this report that the basalt uplift and formation of the anticlinal ridges in the 200-East Area occurred mostly after the Ringold Unit 8 deposition. This would place the Ringold sediments higher on the uplifted structure than those in the surrounding Basin area, consequently exposing them to the brunt of the erosional force associated with post-Ringold fluvial incision and the flood front moving through and over Gable Gap.

Uplift of Ringold-age sediments adjacent to the May Junction Fault and subsequent erosion by Pleistocene cataclysmic flooding is supported by the presence of Units 8 and 9A/C and 9B on the lee sides of the basalt ridges relative to the flood front (e.g., well 699-49-32B on line 1, and areas southeast of B-Pond). The northern portion of line 1 near B-Pond illustrates that most or all of the Ringold Units 5-9 could have been removed as a result of the relative uplift and subsequent erosion by flooding and/or fluvial incision by the ancestral Columbia River. The Rattlesnake Ridge basalt interbed is also illustrated on line 1 (Plate 8), and reveals the structural continuity and uniformity of thickness in the underlying Elephant Mountain basalt.

Hypothetically, the energy and volume of an individual flood event would have controlled the depth of sediment removal and channel erosion. In structurally high areas, this energy could scour down to and perhaps into the basalt (e.g., north and northwest of the 200-East Area at Gable Gap). Farther out into the basin, away from the Gable Gap, where the basalt dips away from the flood front, the energy would be reduced, only capable of removing the less resistant, smaller grain-size, younger Ringold sediments. This outer area also would be a potential site for depositing the reworked materials eroded from the elevated areas.

The channel depicted in cross section 1 contains mostly Hanford-age sediments but may be partially filled with PMG (Plio-Pleistocene-age ancestral Columbia River deposits), which may have preceded filling of the channel with cataclysmic flood deposits. Delineating the basal limit or contact of the channel(s) is difficult due to this variable, but similar, lithology (i.e., depositional framework). Borehole geophysics, geological and drilling information, and hydrologic results have been used together as corroborative evidence for delineation of this paleo-channel.

Borehole geophysical logs were used to illustrate the absence or presence of the lower mud signature (character type fit) that can be seen in nearby wells inside and outside the channel, respectively.

4.1.2.2 Line 2

Line 2 (Figure 4.2, Plate 1 and Plate 8) is a north to south oriented structural cross section across the eastern 200-East Area. This line is perpendicular to the suspected erosional channel that cut through and removed the Unit 8 lower mud and older Ringold sediments near the crest of the basalt anticline (north end) (Figure 4.2).

The first well on the south end of the section is a new well, 299-E17-21, drilled for the Immobilized Low-Activity Waste Site (ILAW) in 1998 (Reidel et al. 1998). The geophysical log and geologic data illustrate the Unit 8 type curve (note overall thickness) and hydrostratigraphic continuity to well 299-E17-6.

Wells 299-E17-6 and 299-E24-7 are located northeast and north of well 299-E17-21 along Line 2 respectively. Well 299-E17-6 is located south of the paleochannel, and well 299-E24-7 is located within the flood or river paleochannel. Reliable geophysical data were not available for well 299-E24-7, but samples from both wells are available from the archive sample library (Appendix B). A side-by-side comparison of samples from these two wells was used to correlate stratigraphic units. In some cases, the gravel appears the same in both wells. The presence of fine-grained silt and clay from Unit 8 is clearly visible in samples from well 299-E17-6 as clayey silt coatings from 350 or 300 ft elevation (Appendix B). By visual comparison, the Unit 8 lower mud interval is not present at structurally or stratigraphically equivalent depths in the adjacent well, 299-E24-7. Instead, the interval is composed of coarse-grained pebbles and large cobbles with little to no fine-grained sediments (Appendix B - note the complete absence of dried clay rinds on the samples and jars from well 299-E24-7 compared to those from well 299-E17-6). The gravel in well 299-E24-7 from this interval does not exhibit cementation and is composed of younger and much coarser grained PMG or Hanford formation- gravel, which is indicative of high-energy fluvial or glacio-fluvial deposition. Underlying the Hanford formation gravel in well 299-E24-7 is the Unit 9A gravel of the Ringold Formation. This is consistent with Connelly et al. (1992), who reported that Unit 9 (Ringold Unit A gravel) sediments exist at this depth in well 299-E24-7.

This is one area where the geologic correlation (Lindsey et al. 1992) deviates from the hydrostratigraphic correlation. Although the lithology appears to consist of Ringold-age sediments, the depositional environment and related hydraulic properties of this channel-fill interval are different than the hydrostratigraphic unit from the adjacent well, 299-E17-6.

Another criterion used to differentiate the channel-fill gravel from older Ringold hydrostratigraphic units is aquifer test results from wells completed within this unit. Hydraulic conductivities for wells screened in the channel are extremely high (water-table map), similar to Unit 1 (Hanford formation/PMG [undiff.]) gravel, and are much greater than measured values within the Units 8 and 9A/C (Ringold Formation) gravel (e.g., B-Pond). Connelly (1992) first mapped the hydraulic conductivities to illustrate differences in groundwater flow rates in the suprabasalt aquifer system. These and other hydraulic data were used to support the interpretation of the hydrostratigraphic boundaries within the suprabasalt aquifer system. Still, additional data are needed to conclusively determine the age and origin of this so-called "channel-fill unit." For this report, it is designated as undifferentiated Unit 1 (Hanford formation/PMG [undiff.]). The PMG as defined by Lindsey et al (1994) is post-Ringold ancestral Columbia River deposits laid down prior to cataclysmic flooding.

As noted in Section 4.2.1, it is difficult to determine the base or bottom of this channel where PMG or Hanford formation gravel overlies older Ringold-age gravel. Sample correlation from the basalt upward between wells 299-E17-6 and 299-E24-7 reveals that the lower gravel Units 9A/C and clayey gravel Unit 9B are present in well 299-E24-7, but correlation becomes difficult in the upper or younger part of the Unit 9A gravel. The major change between the two wells is in the lack of fines and clay in well 299-E24-7 and lithologic differences (Appendix B) within the gravel. This is interpreted to represent the base of the channel.

The same process was used to continue the correlation north. It is hypothesized that the elevated basalt structure to the north exposed more of the Ringold sediments to the down cutting and erosional impacts of the ancestral Columbia River and cataclysmic floods. Evaluation of geologic samples indicates that no Ringold sediments are present in well 299-E27-1 (Appendix B, photos of E27-1 sediments) and is consistent with results reported by Lindsey (1992). This interpretation provides an updip limit for Ringold sediments and indicates the area where Plio-Pleistocene fluvial incision and Pleistocene flood events completely eroded down to the basalt bedrock. On all lines and maps, the upper surface (unit contacts) of the Ringold Formation is dashed where data are not available to resolve the exact unit boundary.

Correlation of the top of the Ringold Unit 5 (Ringold E) gravel within the 200-East Area and vicinity is the same as that reported in Lindsey (1995) with the exception of a few changes to the updip limit of the Unit 5. The Ringold Unit 5 is missing beneath most of the 200-East Area. The north end of Line 2 illustrates the younger Hanford formation-age gravel deposited on basalt and the pinching out of the upper unconfined aquifer where the water table intersects the basalt near the Liquid Effluent Retention Facility (LERF). The intersection of the water table and basalt represents the northern limit of the uppermost unconfined aquifer in the 200-East Area. The unconfined aquifer at the south end of Line 2 lies within the Unit 5 Ringold gravel, overlying the Unit 8 Ringold, which is juxtaposed by the undifferentiated channel fill gravel of Units 1 and 5.

The geophysical log used for correlating well 299-E24-8 on Line 2 has two anomalous intervals, at 12 ft and below 310 ft depth. These anomalous intervals are most likely due to gamma-emitting contaminants associated with 216-C-3, -4, and -5 crib effluent disposal operations. Geophysical anomalies on the other lines are also denoted where data are available.

4.1.2.3 Line 3

Line 3 (Figure 4.3, Plate 1 and Plate 9) extends from the southwestern boundary of the study area near the 200-West Area to the north-central 200-East Area, roughly perpendicular to the axis of the Pleistocene flood path, where the uppermost unconfined aquifer pinches out against the basalt high (Figure 1.3) just northeast of single-shell tank farm B-BX-BY. The west end of Line 3 includes three wells that contact or extend through Unit 5 (Ringold E) into Unit 8 (Ringold lower mud). These wells illustrate the continuity and stratigraphic position of Unit 8 to the west of the 200-East Area. Well 299-E19-1 (DH-17) penetrated the lower Units 8, 9A/C, 9B (Ringold formation lower mud unit and Unit A) and basalt.

Geophysical comparisons and drilling log descriptions from wells 299-E19-1 and 299-E23-2 place the southern limit of the ancestral Columbia River/flood channel scour between these wells (Figure 4.3 and Plate 9). This interpretation places the northern limit of Unit 8 (Ringold lower mud unit) approximately 1,640 to 3,280 ft farther south than previously described by Connelly et al. (1992) and Lindsey (1995).

The base of the channel scour in this area is interpreted from limited data. The channel scour is believed to be within the Unit 9 (Ringold A) given that the Unit 8 (lower mud) is completely removed and an equivalent Unit 9A/C and 9B stratigraphic sequence can be correlated from nearby wells.

The channel scour surface is more difficult to define north of well 299-E23-2. The various techniques mentioned above, including evaluating existing geologic descriptions (Last et al. 1989) were applied to this interpretation. Based on these results, the northern-most extent of the Ringold-age sediments is between wells 299-E28-26 and 299-E33-29. Wells in Section 3 north of this area encounter only Unit 1 Hanford formation/PMG (undiff.) gravel and sand deposited directly on basalt.

The structure map of the Unit 8 mud (Plate 6) depicts a revised structural surface and proposed limits of the erosional channel(s). Two possible scouring scenarios are proposed as explanations for the various structural interpretations presented by various authors. Figure 4.5 (option 1) illustrates the effect of a single erosional event of sufficient magnitude to remove all the Ringold sediments at once. Figure 4.6 (option 2) illustrates the effect of a series of erosional events, scouring out some areas and leaving remnant mounds of Ringold sediments in other areas. Option 2 is preferred based on data discrepancies from well to well within the flood scoured area of the 200-East Area (e.g., see localized Ringold high in well 299-E28-16) and on stratigraphy of Hanford formation-age sediments in structurally deeper parts of the basin.

The northeastern portion of line 3 reveals the highly conductive but very thin uppermost unconfined aquifer system beneath the B-BX-BY single-shell tank farm. Old geophysical logs for many wells in this area (e.g., well 299-E33-16, line 3) reveal vadose zone and groundwater contamination, which has been attributed to discharge of waste water to reverse wells and disposal cribs. In some logs, the geophysical anomalies extend from the water table to the basalt, indicating that, at some previous time, groundwater contamination extended over the entire saturated interval. The vadose contamination is most likely from 216-B-8 and 216-B-12 crib operations.

4.1.2.4 Line 4

Line 4 is the longest section and traverses from northwest to southeast, roughly parallel to the paleo-flow direction of the ancestral Columbia River and flood channel (Plate 1 and 9). For this area, this section illustrates the upstream removal (i.e., absence) of Ringold sediments and suggests the downstream limit of the post-Ringold fluvial and flood-channel scouring into the Ringold sediments (Figure 4.4 and Plate 9). The topographic expression of the Cold Creek bar is illustrated on Figure 4.7. This remnant geographic feature suggests a southern erosional boundary of the paleo-flood path near the 200 Areas. The bar also suggests a downstream limit of flood-related deposition where the energy of the floodwaters waned. Over time, younger flood events and river channels cut new paths through these flood sediments

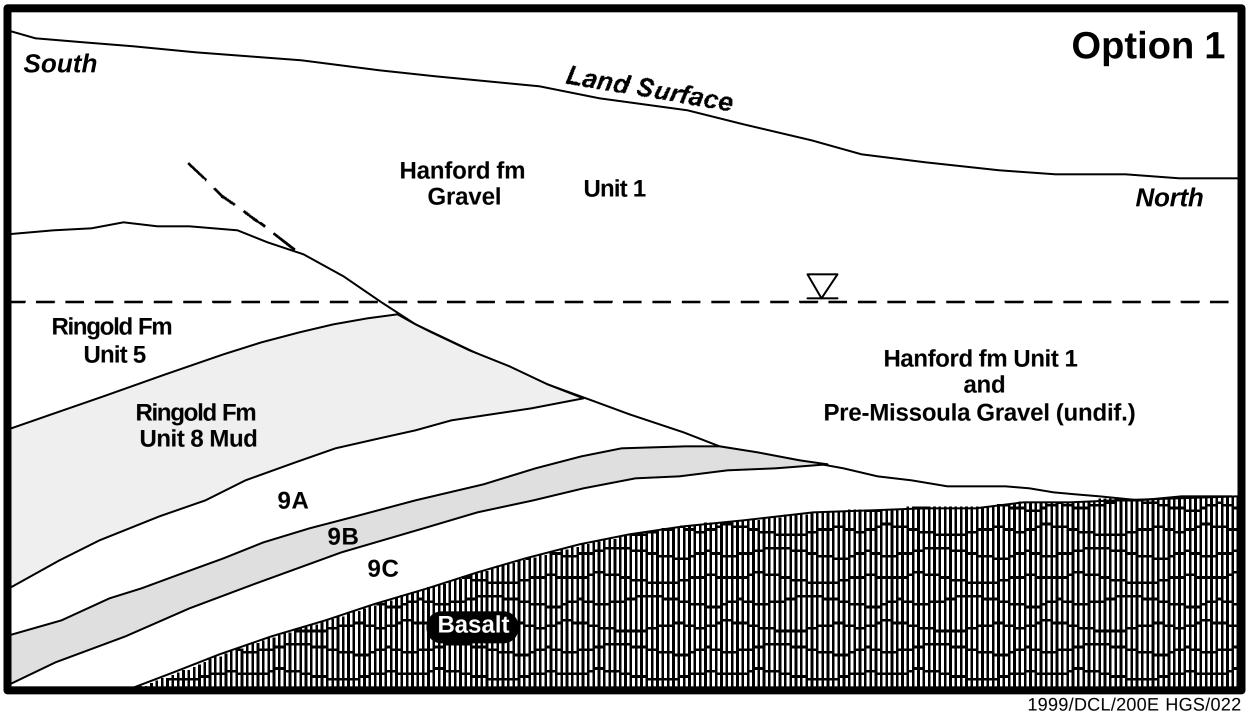


Figure 4.5. Option 1: Single Flood/River Channel

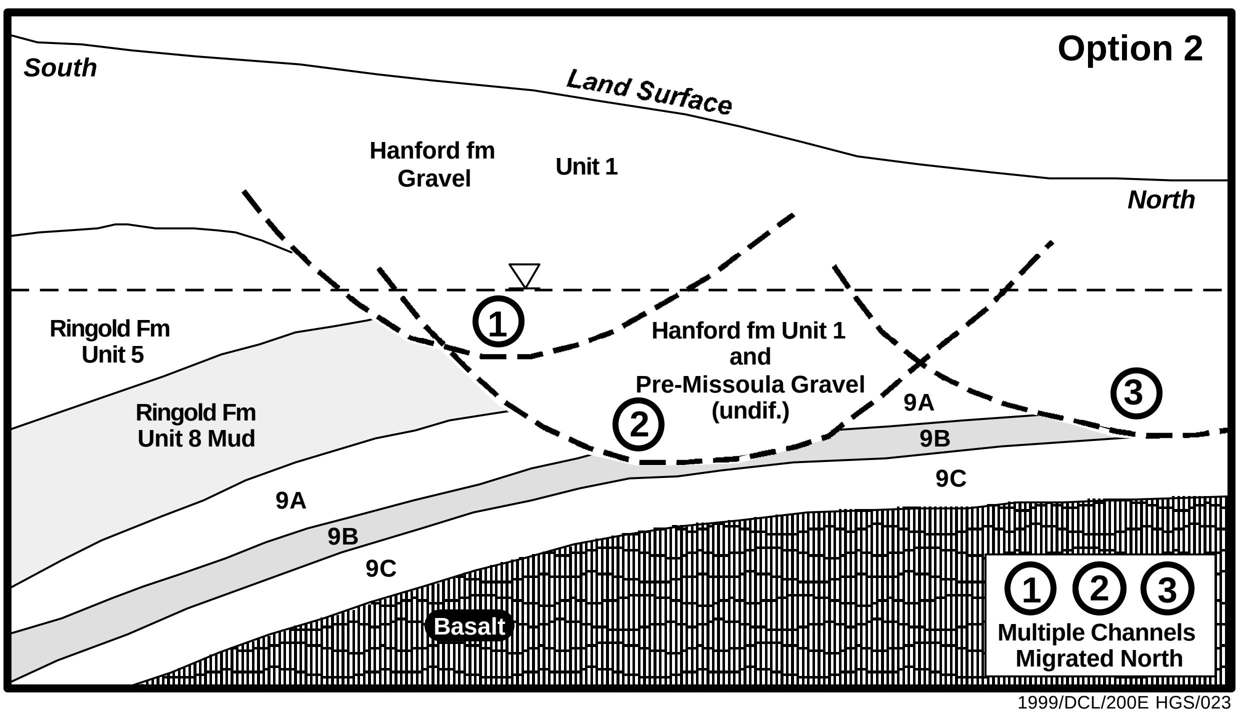


Figure 4.6. Option 2: Multiple Migrating Channels

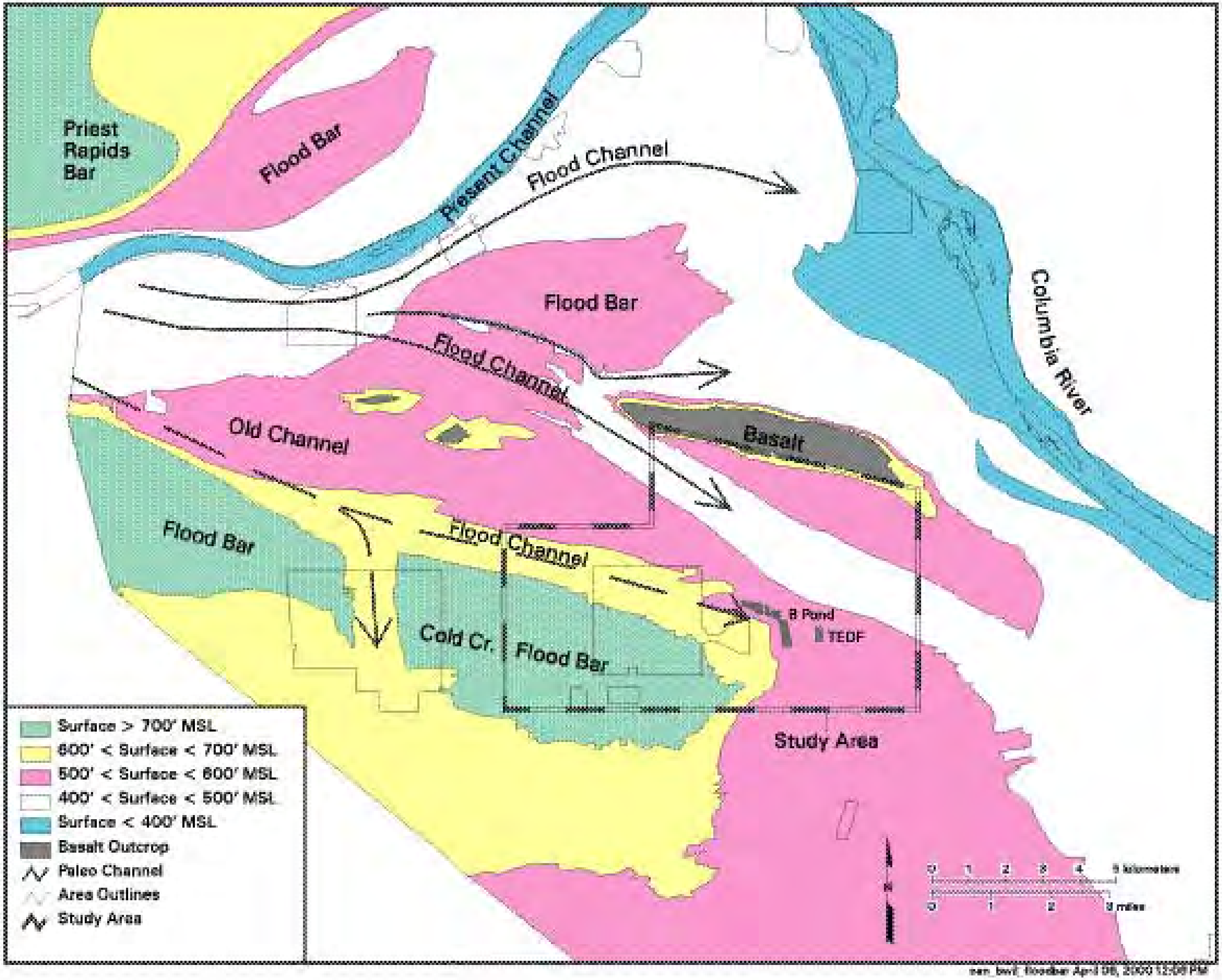


Figure 4.7. Topographic Illustration of Pleistocene Flood-Channels and the Present Day Columbia River Channel Pathways, Hanford Site, Washington

(Fecht 1987). Line 4 also illustrates the western limit of the Ringold units within the study area based on changes in lithology and geophysical correlation. The lithology of the suprabasalt sediments at well 699-47-60 is composed mostly of Unit 1 Hanford-age/PMG (undiff.) silty sandy gravel, which overlies a thin sequence of Unit 9 Ringold silt, sand, and gravel.

The unconfined aquifer directly north and east of well 699-47-60 is composed of Unit 1 (Hanford formation/PMG [undiff.]) sand and silts overlying the Unit 1 (Hanford formation/PMG [undiff.]) gravel. In the vadose zone, a thin silt zone, indicative of separate depositional events, lies on top of the gravel and differentiates the gravel from the overlying sand (this can be seen in Figure 4.8). This silt "marker interval" can be geophysically correlated east across the study area for some distance before it loses character near the eastern end of the Cold Creek flood bar.

The central portion of Line 4 illustrates the relatively thin uppermost unconfined aquifer that is primarily within the Unit 1 (Hanford formation/PMG [undiff.]) gravel. This unit exhibits very high conductivity; geophysical logs indicate that in the past the entire saturated interval has been contaminated by effluent disposal activities (Figure 4.8).

The east end of Line 4 is approximately parallel to the paleo-flow path of the ancestral Columbia River and illustrates the pattern and extent of channel development into the older Ringold units (Units 8 and 9) that resulted from cataclysmic flooding. The Unit 8 Ringold can be correlated continuously from the break in slope of the basalt structure all the way east and across the May Junction Fault using geophysical and geologic data. Units 8, 9A/C, and 9B (Ringold Formation) are easily correlated (illustrated in wells 699-40-40A, 699-40-36, and 699-40-33C) with good geophysical and geologic data. Some older wells (i.e., 699-41-31 and 699-42-30), however, did not provide the data necessary to identify these units, so they were left undifferentiated. The east end of Line 4 also shows the surface of Unit 8 at or above the unconfined water table, which creates a flow barrier in the uppermost unconfined aquifer. Farther east, the structure dips into the Pasco Basin (Cold Creek syncline), and the May Junction Fault interrupts the continuity of Unit 8. Based on work by Lindsey (1995), groundwater flow in the unconfined aquifer east of the May Junction Fault is primarily within the high conductivity Units 1-5.

Confined groundwater occurs in the suprabasalt sediments along the east end of Line 4. This confined aquifer is composed of Unit 9A/C (Ringold Formation) where it occurs below the Unit 8 mud and is referred to as the confined Ringold aquifer system.

4.1.3 Observations

This study suggests that two distinct aquifer systems exist in the suprabasalt sediments. These aquifers are vertically separated by Unit 8 except in the northern and central parts of the study area where it is missing.

Post-Ringold fluvial and flood-related erosion appears to have removed and/or reworked (PMG [undiff.]) the Ringold-age sediments from much of the 200-East Area and vicinity. Abundant information is available to support this interpretation. Prior to the floods, fluvial incision from the ancestral Columbia River scoured a channel in the Ringold Formation across the 200-East Area. This ancestral channel might

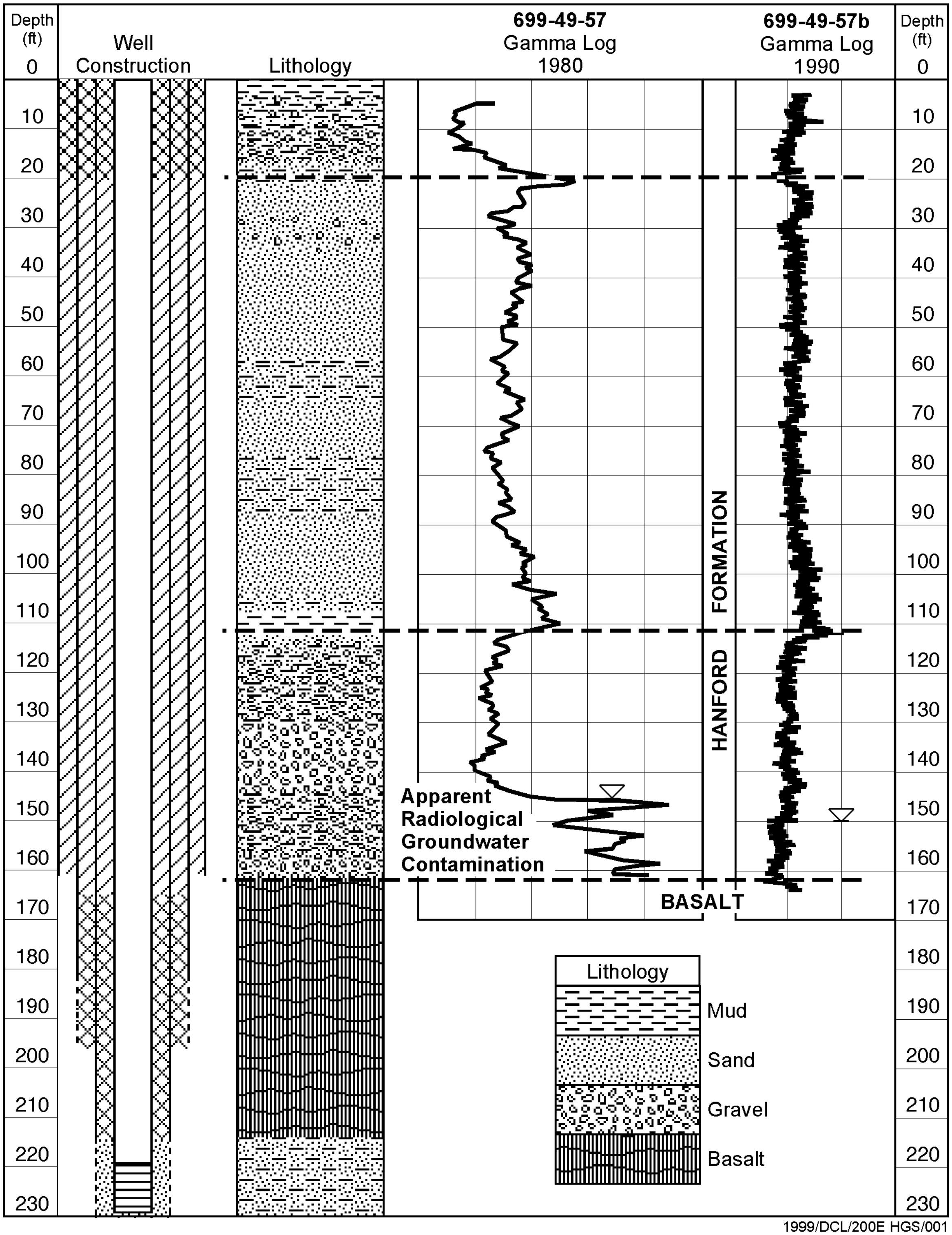


Figure 4.8. Comparison of Geophysical Logs for Twin Wells Revealing Apparent Groundwater Contamination From Past-Practice Effluent Disposal Activities

have been widened across the area by early Pleistocene ice-age floods. Topographic and enhanced surface maps (Figures 4.7 and 4.9) show remnant and overlapping flood channels and help illustrate how large scale erosional forces exploded into the Pasco Basin from the northwest during the Pleistocene (Fecht et al. 1987). The presence of localized basalt highs (ridges) in this uplifted area probably constrained, guided, and directed the incoming floodwaters into channels between the ridges and across the anticlinal high area along a generally narrow flow path. This action focused the flood energy, causing it to scour out the overlying Ringold sediments, in some cases eroding down to and possibly into basalt bedrock. The energy of the floodwaters was sufficient to suspend and carry the sediments out into the basin. As the floodwaters moved south to southeast away from the basalt ridges, the flood channels became less constrained and spread laterally, losing much of their velocity and carrying capacity. Subsequently, the bedload and suspended material would have been deposited in the structurally low portion of the basin.

The topography shown on Figure 4.7 supports the subsurface erosional interpretation and indicates that floods passed through the Gable Mountain/Gap area. Eventually, these remnant channels were filled in with much younger Pleistocene Unit 1 (Hanford formation/PMG [undiff.]) sand and gravel. At the margins of these erosional channels, where the Unit 8 (Ringold Formation lower mud) is present, it is adjacent to the more permeable Unit 1 (Hanford formation/PMG [undiff.]) sand and gravel that make up the unconfined aquifer. The ancestral Columbia River probably shifted course to flow north of Gable Mountain during early Pleistocene time with the accumulation of cataclysmic flood deposits, which plugged the former river channel through Gable Gap (see also Fecht [1987] and Reidel et al. [1994]).

4.2 Groundwater Flow Patterns

Two distinct aquifers were identified within the suprabasalt sediments beneath the 200-East Area. These aquifers have separate and distinct flow regimes that are delineated based on evaluation of new well data and re-evaluation of existing data, including descriptions from driller's logs, hydraulic head, groundwater chemistry, and isotope composition. Previous interpretations do not differentiate these aquifer systems and do not attempt to separate groundwater results (i.e., plume mapping and potentiometer surfaces) for the separate aquifers.

The uppermost suprabasalt aquifer is unconfined (uppermost unconfined aquifer) and consists primarily of Unit 1 (Hanford formation/PMG [undiff.]) and Unit 5 (Ringold Formation Unit E) sediments. The uppermost unconfined aquifer consists primarily of Unit 5 (Ringold Formation Unit E) sediments in the 200-West Area and Unit 1 (Hanford formation/PMG [undiff.]) sediments in the 200-East Area. Where Unit 8 (Ringold lower mud unit) sediment has been removed by erosion, this aquifer also may include some reworked and/or intact Unit 9 (Ringold Formation Unit A) sediments. This aquifer has often been referred to as the Hanford unconfined aquifer. In most areas of the Hanford Site, Unit 8 underlies the uppermost unconfined aquifer, isolating it from the older underlying Unit 9 (Ringold Formation Unit A) suprabasalt sediments. Where Unit 9 sediments (Units 9A, 9B, and 9C) are isolated from the uppermost unconfined aquifer by Unit 8, they form an independent suprabasalt aquifer system which will be called the confined Ringold aquifer. Previous studies have often included portions of the confined Ringold aquifer (i.e., Unit 8 and the underlying Unit 9) when describing and mapping the uppermost unconfined aquifer and associated water table surface.

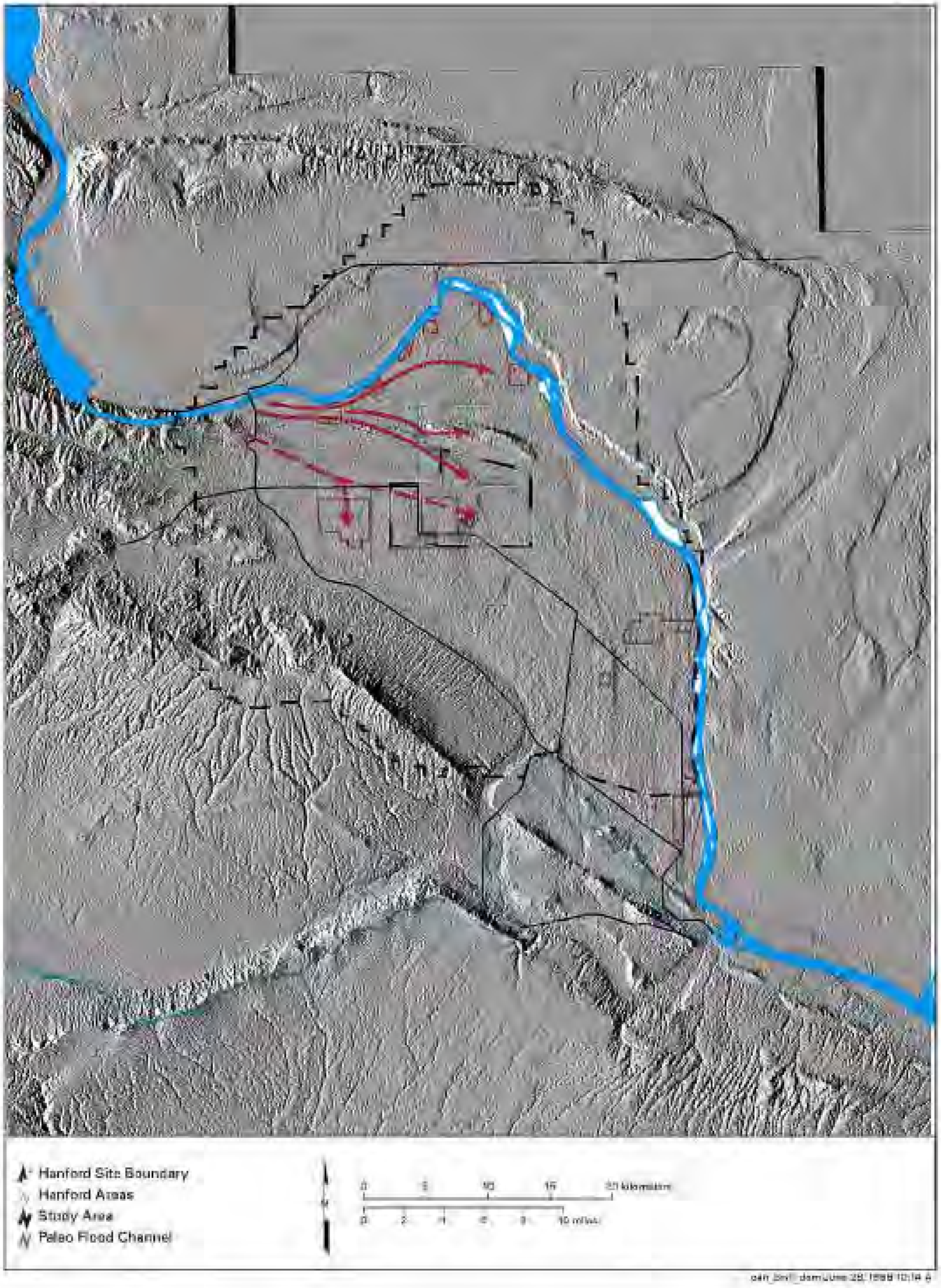


Figure 4.9. Computer-Enhanced Surface Map of the Central Pasco Basin Outlining the Paleo-Flood Channels from Cataclysmic Flooding Near the 200 Areas Plateau

This study suggests that the uppermost unconfined aquifer and the confined Ringold aquifers are in hydraulic communication in the 200-East Area where they are juxtaposed along the juncture of the buried paleo-channel. The confined Ringold aquifer may also be in communication with the uppermost unconfined aquifer along the May Junction Fault (refer to Figures 4.1 and 4.4) where displacement has juxtaposed the confined Ringold aquifer (Unit 9) on the upthrown side of the fault next to the Unit 1 on the downthrown side of the fault.

Wells in the study area were evaluated and categorized based on the hydrostratigraphic unit within which they were completed (Appendix C). A revised water table map is presented that recognizes Unit 8 as the primary suprabasalt flow boundary for groundwater and contaminants migrating east out of 200-East Area. Groundwater within Units 1-5 is categorized as part of the uppermost unconfined aquifer. Groundwater within and below Unit 8 is categorized as the confined Ringold aquifer system. The revised water table map does not reveal the old B-Pond hydraulic mound. The water table for the uppermost unconfined aquifer and the potentiometric surface for the confined Ringold aquifer system are illustrated in Figure 4.10.

4.2.1 Recharge

Previous liquid waste disposal practices at 216-B-3 B-Pond (B-Pond), PUREX cribs, and other facilities established localized water table mounds that elevated the water table throughout the 200-East Area. An artificial groundwater mound east of the 200-East Area that was created by past effluent disposal activities at the B-Pond complex (DOE/RL 1996) has persisted for many years. B-Pond disposal practices have significantly influenced groundwater movement in the 200-East Area and the surrounding region (Gephart et al. 1976; Hartman 1999). Groundwater mounding beneath B-Pond has resulted in more than 10 m (35 ft) of increase in hydraulic head at the water table. Locally, this resulted in a downward vertical gradient, and a radial flow pattern that reversed the natural flow of groundwater in the 200-East Area from its previous west-to-east direction toward the Columbia River to a more east-to-west direction. This observation was reported in Graham et al. (1981). The reversal of groundwater flow has altered the migration of groundwater out of the 200 areas plateau, creating a longer flow path to the Columbia River and has probably increased groundwater flow northwest through the Gable Gap area and diverted groundwater flow farther south of the 200-East Area.

The B-Pond and associated lobes are situated over the juncture (the erosional limit of the Unit 8 [Ringold Formation lower mud unit]) between the uppermost unconfined aquifer (Hanford formation) and the confined Ringold aquifer (Ringold Units 8 and 9A/B/C; Plate 6). The eastern and southern lobes of B-Pond (and the TEDF) are situated where the Unit 8 (Ringold Formation lower mud unit) is structurally higher than the surrounding upper unconfined aquifer water table surface. This structurally elevated area is believed to extend east to the May Junction Fault (Plate 6).

Two scenarios (Figure 4.10) have been proposed to account for groundwater movement and mound development associated with B-Pond operation. In scenario 1, B-Pond effluent disposal created an artificial groundwater mound and driving force (increased head and vertical downward gradient) in the uppermost unconfined aquifer (Unit 1), which was transmitted downward to the confined aquifer at the juncture along the erosional unconfirmity, increasing the potentiometric head and driving contaminants

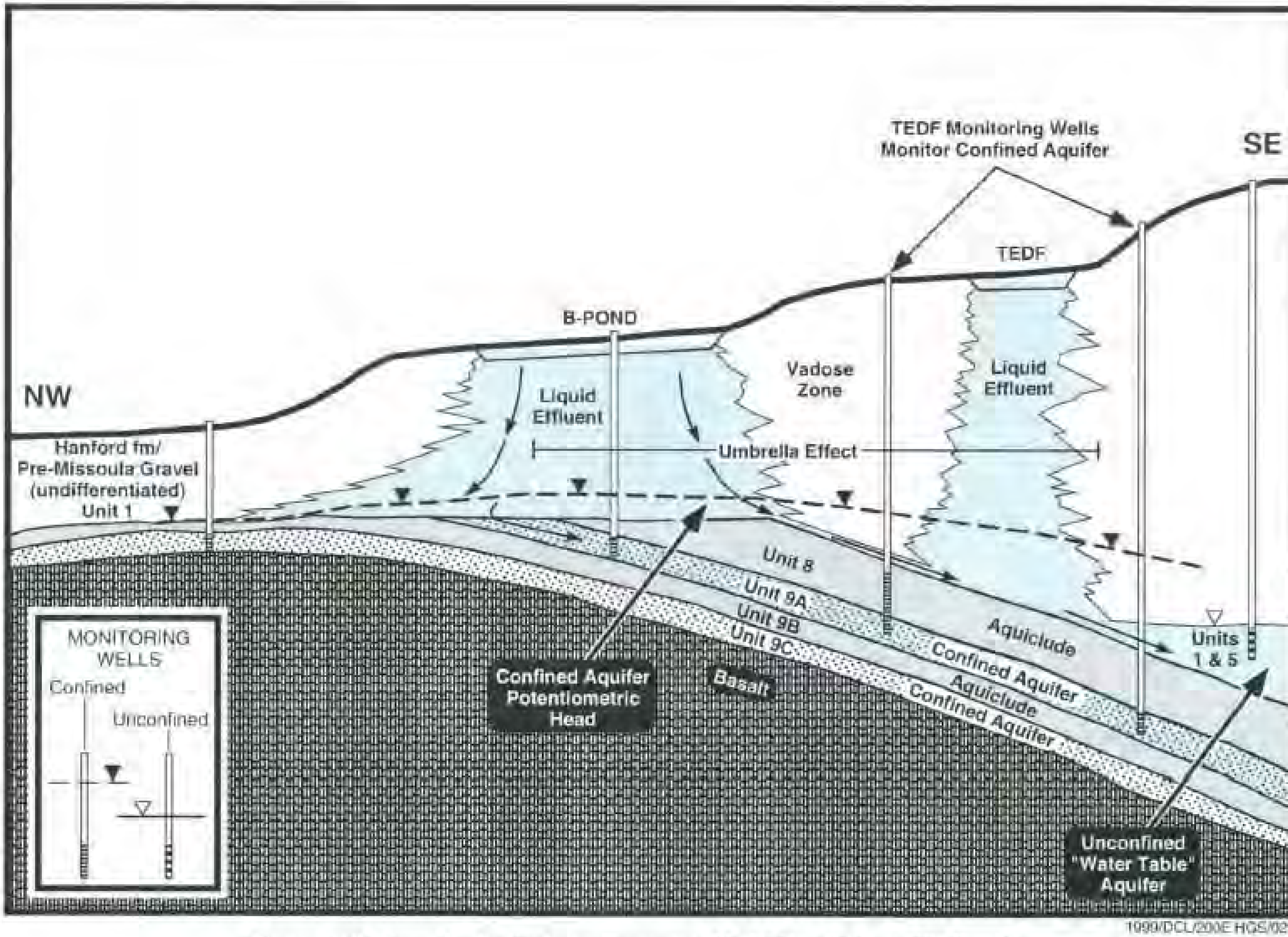


Figure 4.10. Groundwater Recharge Conceptual Model Near B-Pond, 200 East Area

into the confined aquifer below Unit 8. Scenario 2 proposes that the artificial recharge that encountered the impermeable upper surface of Unit 8 was diverted laterally, down dip, through the overlying, highly conductive Unit 1 (Hanford formation/PMG [undiff.]) gravel toward the east and southeast (umbrella effect).

Artificial recharge associated with B-Pond had several effects on both the uppermost unconfined and the confined Ringold aquifers. Groundwater mounding of the upper unconfined aquifer beneath B-Pond created a westerly groundwater flow, increasing the water table elevation throughout the 200-East Area. B-Pond disposal maintained a downward vertical head on the uppermost unconfined aquifer, which pressurized (increased the head) and moved groundwater into the confined Ringold aquifer along the erosional unconformity where the two aquifers are juxtaposed. Some of the B-Pond effluent that infiltrated to the upper surface of the Unit 8 likely moved down the structural slope of Unit 8 (Ringold Formation lower mud unit) within the highly permeable Unit 1 (Hanford formation/PMG [undiff.]). Groundwater flow (perched) along the top of this relatively impermeable surface (umbrella affect) would have been toward the east and southeast to the water table of the uppermost unconfined aquifer.

Liquid effluent discharges to the 200-East Area and B-Pond facilities began to decrease in the mid-1980s. The DOE required that the use of soil columns to treat and retain suspended or dissolved contaminants from liquid waste streams be discontinued (DOE-RL 1987). The Tri-Party Agreement (TPA) milestone M-17-00A defined the schedule to discontinue disposal of contaminated liquids into the soil column and cease all liquid discharges to hazardous waste land disposal units (ponds, cribs, and ditches) at the Hanford Site by 1995 (Ecology et al. 1989). By 1997, all discharge to the B-Pond disposal had ceased, and some of the former B-Pond effluent streams were rerouted to the TEDF (Barnett 1998). Concurrent with the decreased waste-water discharge in the 200-East Area and B-Pond facility since the late 1980s, the water table (and the potentiometric surface) near B-Pond has declined. The decline has occurred at an increased rate since about 1996 (Figure 4.11), which is the result of discontinued discharges to the B-Pond facility. Today, B-Pond and the extensive recharge mound have drained and are essentially nonexistent.

The TEDF is located east of B-Pond where the Unit 8 (Ringold Formation lower mud unit) occurs at an elevation above the regional water table; therefore the uppermost unconfined aquifer does not exist beneath TEDF. Recent hydrochemistry indicates that wastewater discharge to the TEDF does not impact water quality of the uppermost unconfined aquifer within the 200-East Area, but no wells currently monitor the uppermost unconfined aquifer downgradient of the TEDF.

Near the May Junction Fault, declines in groundwater levels and subsequent changes in groundwater flow direction have occurred within the uppermost unconfined and confined Ringold aquifers as a result of a sitewide cessation of contaminated effluent disposal to the ground.

A study (Spane and Webber 1995) has shown that the upper basalt-confined aquifer also may contribute groundwater to the confined Ringold aquifer system (Unit 9). Recharge to the confined Ringold aquifer from the upper basalt-confined aquifer could also produce and maintain higher heads than the surrounding uppermost unconfined aquifer.

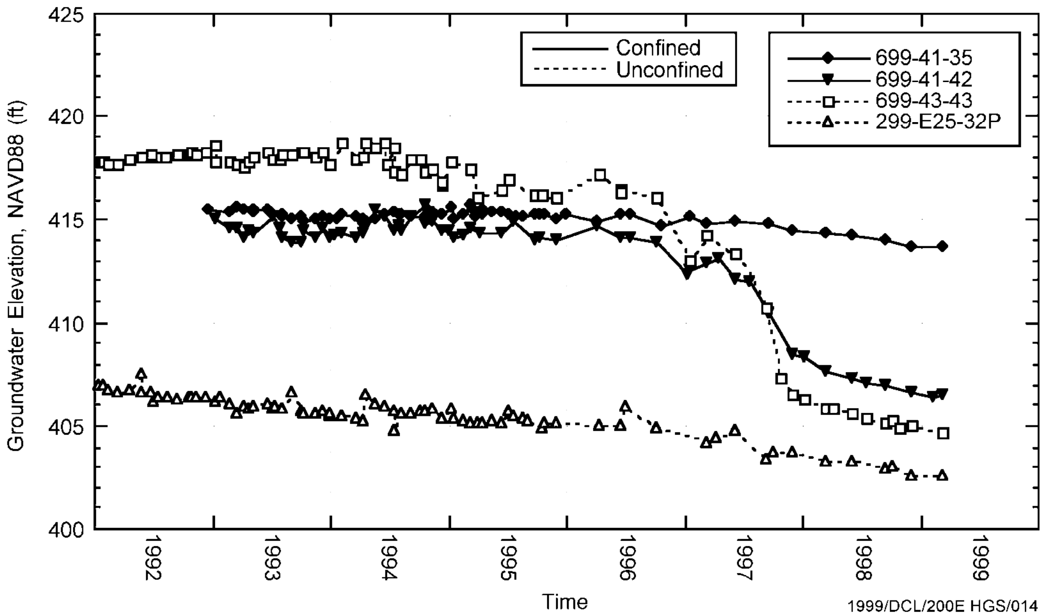


Figure 4.11. Water Level Decline in Groundwater in Wells Near B-Pond

4.2.2 Groundwater Flow in the Hanford Unconfined Aquifer

Previous water table interpretations (e.g., Graham et al. 1982 and Hartman 1999) have used wells that were believed to be completed within the uppermost unconfined aquifer, but are actually completed in the confined Ringold aquifer (Unit 9A/C). Potentiometric head values from these wells are not applicable for use in preparation of water table maps for the uppermost unconfined aquifer. Consequently, new water table and potentiometric maps were prepared for the uppermost unconfined and confined Ringold aquifers for this report.

The revised water table map prepared for the uppermost unconfined aquifer used only selected wells screened above the Unit 8 mud and within the Unit 1 (Hanford formation/PMG [undiff.]) and Ringold Unit 5 unconfined aquifer (Plate 10). Units 8 and 9B are considered no-flow zones similar to basalt where they are above the water table. Occurrence of these units above the water table defines the flow boundary for the uppermost unconfined aquifer near B-Pond. Elsewhere, Unit 8 (Ringold Formation lower mud unit) plunges with the basin structure into the Cold Creek syncline and is too far below the water table to constrain movement of groundwater in the uppermost unconfined aquifer, and thus, most of the contaminant flow out of the 200-East Area.

Exclusion of water level data from wells screened in or below the Ringold Unit 8 mud results in a new interpretation of the water table surface and groundwater flow patterns in the uppermost unconfined aquifer in the vicinity of B-Pond. The resulting groundwater flow directions indicated by this new interpretation suggest that the groundwater flow path for the uppermost unconfined aquifer in the eastern portion of the study area is more easterly, resulting in a more direct flow path from the 200-East Area toward the river (Plate 10). This revised groundwater flow direction could be a significant preferential flow path for groundwater and contaminant transport east out of the 200 Areas and should be investigated further.

Regional groundwater flow in the 200 Areas plateau is generally from the 200-West Area toward the 200-East Area and the Columbia River. Groundwater within the uppermost unconfined aquifer from the 200-West Area flows through Unit 5 sediments, which are juxtaposed to Unit 1 (Hanford formation/PMG [undiff.]) sediments in the erosional channel(s) near the 200-East Area. Groundwaters from the 200-West Area mix with artificial-recharge water disposed in the 200-East Area (e.g., BP-5, PUREX cribs, and B-Pond) along the southern boundary of the buried paleo-channel.

In the vicinity of the 200-East Area, groundwater in the uppermost unconfined aquifer flows in the highly permeable Unit 1 (Hanford formation/PMG [undiff.]) within the buried paleo-channel. This groundwater flows either northwest through the Gable Gap or southeast through the corridor of saturated Units 1-5 southeast of B-Pond.

In the northwest portion of the study area, groundwater flows through the uppermost unconfined aquifer within the Unit 1 (Hanford formation/PMG [undiff.]) sediments at Gable Gap. This is supported by drilling and development activities for well 699-47-60, which indicate that Unit 9 (Ringold gravel) has low hydraulic conductivity relative to adjacent well(s) completed in Unit 1 (Hanford gravel/PMG [undiff.]). It is presumed that the hydraulic contrast between Unit 1 and Unit 9 in the upper unconfined aquifer system results in flow along a preferential path in Unit 1 (Hanford formation/PMG [undiff.]) north through Gable Gap (Plate 11). This interpretation is reinforced by historical groundwater plume maps and water-table maps (DOE/RL 1995, 1996). Within the uppermost unconfined aquifer, groundwater flow is also influenced by the steep water-table gradient west of the geologic boundary (Unit 5 and Unit 1 interface), where the gradient flattens as groundwater flows from Unit 5 (Ringold Formation) into the more permeable Unit 1 (Hanford formation/PMG [undiff.]) (Plate 10).

Historically, groundwater in this area has followed the preferential flow path along buried paleo-channel(s) north to northwest through Gable Gap. However the direction of groundwater flow may be changing in response to recent water level declines. The unconfined aquifer along this northern flow path is the thinnest in the study area and may be cut off as the water table continues to decline. If this occurs, it would create a natural flow barrier restricting the migration of contaminants north toward the 100 Areas. This would result in all groundwater flowing to the south and east of the 200-East Area.

4.2.3 Groundwater Flow in the Confined Ringold Aquifer System

Regionally, groundwater in the confined Ringold aquifer system flows from west to east similar to groundwater in the uppermost unconfined aquifer. Locally, near the 200-East Area, it is more difficult to determine flow direction because of the limited number of wells completed within the confined Ringold aquifer. Groundwater head measured in wells completed within the confined Ringold aquifer is higher than the head measured in nearby wells completed in the uppermost unconfined aquifer, indicating an upward vertical gradient. Hydrographs (histograms) reveal a temporal variation in the pattern of groundwater movement between the confined Ringold aquifer and the uppermost unconfined aquifer along the erosional unconformity where the two aquifers are juxtaposed (Plate 12).

A separate potentiometric map, was prepared for the confined Ringold aquifer in the eastern part of the study area using selected wells screened only within or below the Unit 8 mud and within Ringold Unit 9 (undifferentiated) (Plate 12). Water-level histograms (Figure 4.12) from selected wells screened in the Unit 1 (Hanford formation/PMG [undiff.]) and Unit 5 Ringold of the uppermost unconfined aquifer and the Unit 9A Ringold of the confined Ringold aquifer illustrate the separation of the two systems, which are vertically isolated throughout much of the study area. Comparison of the potentiometric surface for the confined Ringold aquifer with the water table surface for the unconfined aquifer, reveals an upward gradient where these aquifers are vertically separated by Ringold Unit 8 mud.

One possible flow path for groundwater in the confined Ringold aquifer (Unit 9A/C) is into the uppermost unconfined aquifer system east of B-Pond where the May Junction Fault interrupts the continuity of the Unit 8 mud. The fault plane could create a vertical preferential flow path for groundwater in the uplifted confined Ringold aquifer (Unit 9) into the adjacent uppermost unconfined aquifer system across the fault. Hydraulic head data for wells completed near the fault within the confined

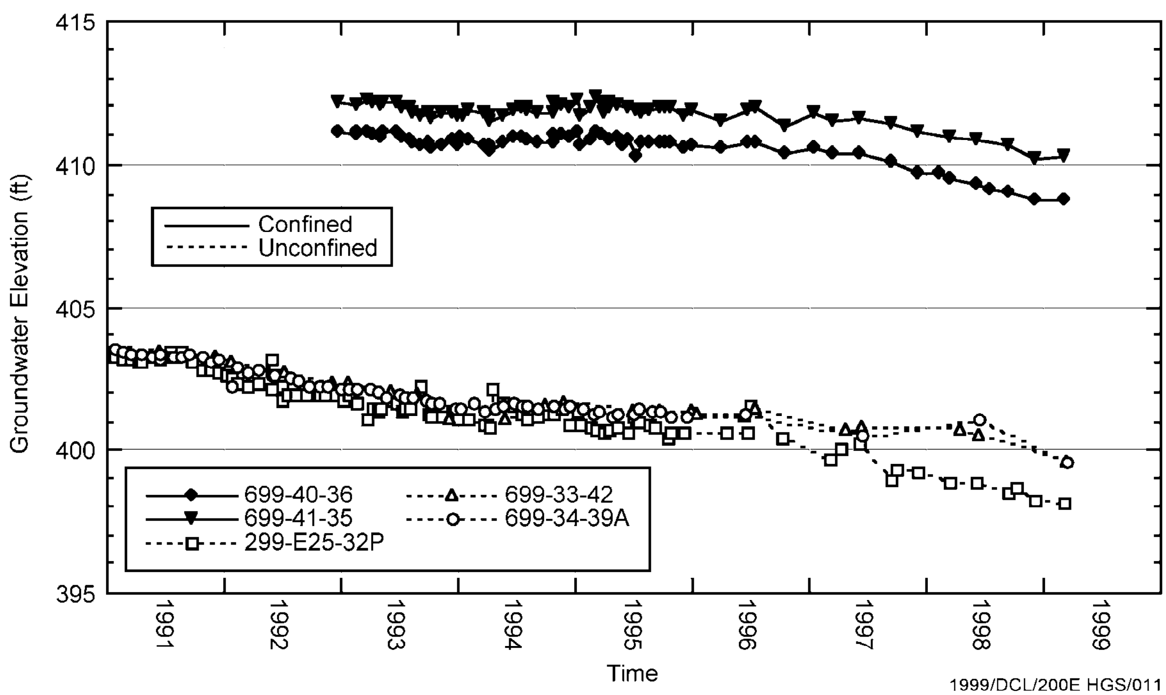


Figure 4.12. Head Difference Between the Confined and Unconfined Aquifers

Ringold aquifer are higher (up to 13 ft of head difference) than the surrounding wells completed in the uppermost unconfined aquifer, indicating a possible upward groundwater flow path. However, comparison of hydrochemistry data does not support the easterly movement of groundwater in the confined Ringold aquifer in the eastern part of the study area and on the upthrown side of the fault.

Groundwater in the confined Ringold aquifer is interpreted to flow laterally through the Unit 9A/C gravel into the juxtaposed uppermost unconfined aquifer along the buried paleo-channel margins. This concept is illustrated with hypothetical flow lines on Line 4 (Plate 9) and on the confined Ringold aquifer potentiometric surface map (Plate 12). Due to the thickness and relatively low vertical hydraulic conductivity of the overlying Unit 8, a lateral flow path is the avenue of least resistance over a vertical flow path. Groundwater in the confined Ringold aquifer likely moves laterally through Unit 9A/C toward the buried paleo-channel where it mixes with the groundwater from the uppermost unconfined aquifer within the Unit 1 (Hanford formation/PMG [undiff.]) sediments and is quickly transported toward the river through the highly conductive uppermost unconfined aquifer system. This is illustrated by comparing the relative difference in heads between the confined Ringold and uppermost unconfined aquifers as both decline (Figure 4.13). Notice that the confined Ringold aquifer system did not begin to respond to decline in the uppermost unconfined aquifer until after 1995.

These current groundwater flow conditions, i.e., confined groundwater movement into the adjacent unconfined aquifer, are the result of the cessation of B-Pond (and other facility) effluent disposal and represent a reversal of groundwater flow patterns created during disposal. This interpretation indicates

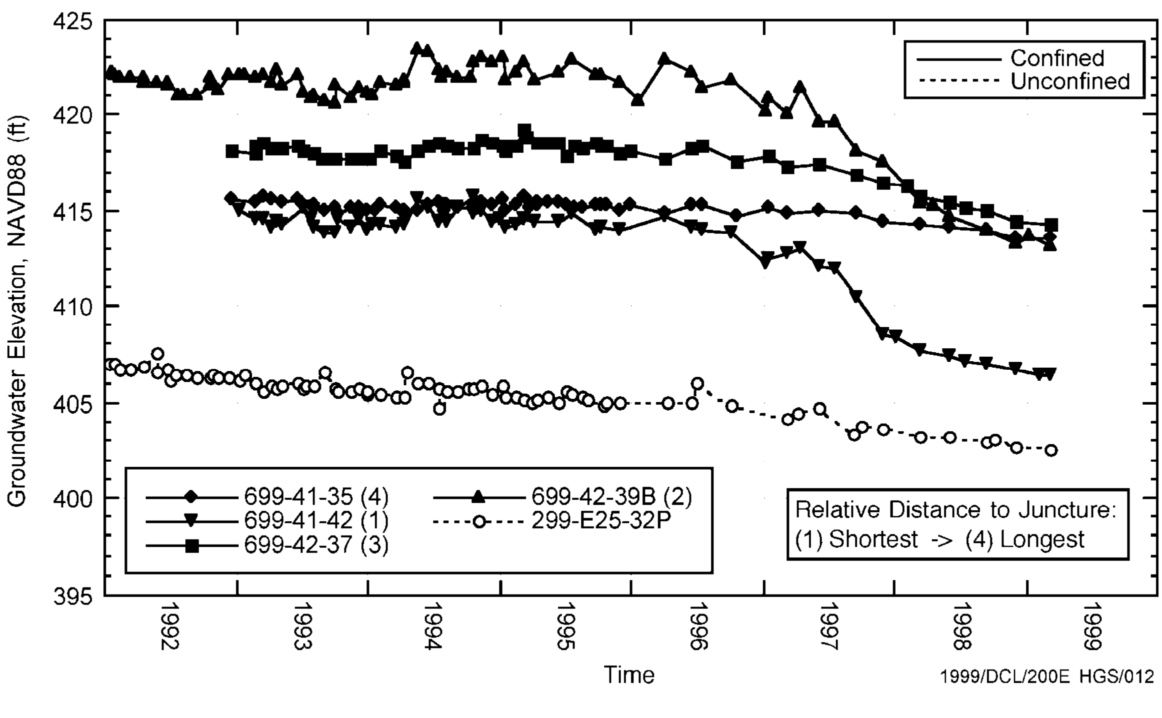


Figure 4.13. Head Difference Between the Confined and Unconfined Aquifers

that, during B-Pond disposal, the increased head and driving force simultaneously impacted the two adjacent aquifers; groundwater recharge was primarily to the uppermost unconfined aquifer and only had a local impact (near the buried paleo-channel/erosional limit) on the confined Ringold aquifer system. The confined Ringold aquifer responded over time to the increased head and the potentiometric surface rose to a level near or equivalent to the perched water table (created by B-Pond) above the Unit 8 (Ringold Formation lower mud unit).

The confined aquifer is fairly well characterized around the B-Pond and TEDF areas, but little is known about other areas near the unconfined/confined aquifer juncture (Plate 12) that may have been impacted by past contaminant disposal to the groundwater, i.e., near the PUREX cribs, ILAW, and north of the BC cribs farther west.

To explain why the potentiometric surface of the confined Ringold aquifer is still significantly higher than the unconfined aquifer, the flow dynamics of the aquifer systems must be considered. Current groundwater flow dynamics have created a hydraulic imbalance (head differential) from the equilibrium established during B-Pond operations. Since B-Pond ceased operations in 1997, the groundwater mound and the associated driving force have dissipated. No groundwater mound currently exists above the erosional unconformity that forms the juncture between the uppermost unconfined and confined Ringold aquifers (except probable perched conditions near the 200 Areas TEDF). Currently, the water table elevation in the uppermost unconfined aquifer is declining rapidly near this juncture. This has resulted in an increased rate of decline in the highly conductive uppermost unconfined aquifer relative to the less conductive confined Ringold aquifer. As a result, differential head between the two aquifers has increased (i.e., creating an over-pressured confined aquifer).

The histogram in Figure 4.11 illustrates how the potentiometric head in wells completed within the confined Ringold aquifer is declining and will eventually approach a new equilibrium potential close to that of the uppermost unconfined aquifer water table. Note also that the confined aquifer monitoring wells farthest from the Unit 8 juncture (i.e., paleo-channel) exhibit the slowest response to these declines (Figure 4.13). This response is consistent with the flow of groundwater in the confined Ringold aquifer toward the juncture. The delay in head decay or decline is due to the lower conductivity of Unit 9A/C and is also partially due to the wells being screened across the less transmissive Unit 8 interval. For example, well 699-41-42, located nearest the unconfined/confined aquifer juncture, has exhibited the fastest drop in potential since 1995, when compared to confined interval wells farther from this aquifer junction (Figure 4.13). Notice how the slope of the water level decline curve in well 699-41-42 flattens as the water level in that portion of the confined aquifer approaches equilibrium, that point where the confined aquifer head equals the water level of the unconfined aquifer.

4.2.4 Intercommunication of Suprabasalt Aquifers

Throughout most of the Hanford Site, groundwater in the uppermost unconfined aquifer is isolated from groundwater in the confined Ringold aquifer system by Unit 8 (Ringold lower mud unit). However, an erosional window exists along the margins of the buried paleo-channel, the confined Ringold aquifer system is in direct contact with the Unit 1 (Hanford formation/PMG [undiff.]) of the uppermost unconfined aquifer (see Plates 3-6 and Figures 4.1, 4.2, 4.3, and 4.4). Because the hydraulic conductivity of the channel fill is generally much higher than for Unit 9, and there is an upward gradient in this region, groundwater from the confined Ringold aquifer system likely discharges into the highly transmissive channel-fill sediments where it mixes with groundwater of the uppermost unconfined aquifer.

Groundwater flow lines shown on line 3 (Figure 4.3, Plate 9) reveal how confined Ringold aquifer groundwater from the 200-West Area migrates within the Ringold Unit 9 to where Unit 9 is juxtaposed against the highly conductive Unit 1 (Hanford formation/PMG [undiff.]) sediments of the uppermost unconfined aquifer. Within the paleo-channel, the uppermost unconfined aquifer system is composed of Unit 1 (Hanford formation/PMG [undiff.]).

This hydrostratigraphic boundary between the Ringold Unit 9 and the adjacent and overlapping Unit 1 (Hanford formation/PMG [undiff.]) is relatively broad and flat, and allows confined Ringold aquifer groundwater from the 200-West Area to mix with groundwater within the uppermost unconfined aquifer within the paleo-channel over a wide area (Plate 12). This interpretation is based on an identical process that occurs in the uppermost unconfined aquifer above the Unit 8 (Figure 4.3, Plate 9) sediments. In the uppermost unconfined aquifer, contaminated groundwater emanates from the 200-West Area within Ringold Unit 5 and flows into the juxtaposed Unit 1 (Hanford formation/PMG [undiff.]) along the erosional channel boundary. This transition zone is partially discernible on the water-table map where the water table gradient from the 200-West Area flattens near the 200-East Area (Plate 10). The dramatic change in gradient results from the low hydraulic transmissivity of the Ringold Units 5 or 9 relative to the high transmissivity of the Unit 1 (Hanford formation/PMG [undiff.]), which comprises the uppermost unconfined aquifer within the paleo-channel (Bryce et al. 1991).

The portion of the study area north of the 200-East Area was identified as an area where intercommunication between the upper basalt aquifer and suprabasalt aquifer system was likely by Gephart et al. (1979), DOE (1982, 1988), Graham et al. (1984), Jensen (1987), and Spane et al. (1995). Spane et al. (1995) found evidence that groundwater mounding associated with past waste water discharges at B-Pond and the decommissioned Gable Mountain Pond have locally formed a downward driving force from the contaminated suprabasalt aquifer system to the underlying upper basalt confined aquifer system. Since waste-water discharge in this area has been reduced, hydraulic head in the uppermost unconfined aquifer has been declining at a higher rate than head in the confined Ringold and the upper basalt-confined aquifers. Section 4.2.3 explains this apparent reversal of the vertical gradient from a downward to an upward gradient in the area southeast of B-Pond. Reversal of vertical gradients in this area has resulted in the westerly flow of groundwater in the confined Ringold aquifer toward the juncture with the uppermost unconfined aquifer along the buried paleo-channel. More data are needed to determine if this reversal of gradients, and thus groundwater flow, is also occurring along the juncture near the B/C Cribs and PUREX. PUREX well characterization data from 1994 measured the confined Unit 9A potentiometric head approximately 4 feet higher than the upper unconfined aquifer head (Lindberg 1994).

4.3 Groundwater Chemistry

The primary factors contributing to the spatial distribution of groundwater chemistry, including contamination associated with operations, are the hydrostratigraphic framework and groundwater flow patterns. The spatial distribution of groundwater chemistry and tritium activities corroborates the interpretation of groundwater flow described in previous sections. Because groundwater flow in the uppermost unconfined aquifer is isolated from flow in the confined Ringold aquifer (except within the erosional unconformity), the distribution of groundwater chemistry and contaminants must be evaluated for each aquifer system independently.

Major ion chemistry of groundwater and tritium activity depicted using STIFF diagrams (Stiff 1951; Plate 11) illustrates that chemical regimes correlate with proposed groundwater flow paths in the uppermost unconfined aquifer, and the confined Ringold aquifer.

4.3.1 Uppermost Unconfined Aquifer

Major ion chemistry of groundwater (STIFF diagrams), water-table elevations, groundwater flow paths, and hydrogeologic units relative to the water table are shown for the uppermost unconfined aquifer in Plate 11. Three hydrochemical zones can be identified in the uppermost unconfined aquifer within the study area. These zones correspond to groundwater flow patterns that exist within the hydrostratigraphic framework described in Section 4.1.

Zone 1 is located in the southwestern portion of the study area where groundwater in the uppermost unconfined aquifer flows primarily in Unit 5 (Ringold Formation Unit E) from the 200-West Area toward the paleo-channel unconformity. Groundwater flowing along this pathway is Ca^{2+}-HCO_3^--type water. In Zone 2, within the central and northwestern portion of the study area, groundwater in the uppermost unconfined aquifer flows primarily in Unit 1 (Hanford formation/PMG [undiff.]) sediments within the paleo-channel. At least two distinct types of groundwater can be identified in the uppermost unconfined aquifer within the paleo-flood channels. Zone 2 is located within the buried paleo-channel and extends from LERF and the 216-A-37-1 crib to well 699-49-57A northwest of the 200-East Area boundary. Groundwater in this part of the uppermost unconfined aquifer is of the Ca^{2+}-HCO_3^--SO_4^{2-} type. The source of the increased SO_4^{2-} is not known, but is likely associated with either the source of recharge or local lithology. Zone 3 is located in the southcentral portion of the study area near B-Pond at the southeastern extent of the paleo-channel. Locally, groundwater in this part of the uppermost unconfined aquifer has the lowest TDS content of anywhere in the study area and is of the Ca^{2+}-HCO_3^- type.

Groundwater in Zone 1 generally flows from Unit 5 (Ringold Formation Unit E) into the Unit 1 (Hanford formation/PMG [undiff.]) sediments that fill the paleo-channel unconformity. Groundwater plume maps for FY 1998 (Hartman 1999) indicate that contaminant plumes from 200-West Area flowing through the uppermost unconfined aquifer in Zone 1 are encroaching on the buried paleo-channel (Plate 11).

Groundwater in Zone 2 appears to originate from artificial recharge within the 200-East Area and/or at the B-Pond facility. Contaminant plumes for various constituents have been mapped throughout much of the paleo-channel area and can generally be correlated to past practices at disposal facilities (Hartman 1999). At specific locations within the paleo-channel, the direction of groundwater flow is uncertain and has likely changed over time in response to changing waste-water discharge practices. A groundwater divide trending from southwest to northeast likely exists within the paleo-channel in the vicinity of the

200-East Area. Groundwater contamination in the uppermost unconfined aquifer lies along the northwest-southeast trend of the buried paleo-channel and indicates two preferential groundwater flow pathways, one northwest toward Gable Gap and the other southeast toward PUREX and toward the southeast corner of the study area. As the groundwater mound associated with waste-water discharge (primarily B-Pond) in the 200-East Area dissipates, the groundwater divide will likely move to the northwest resulting a flow reversal (toward the southeast) for groundwaters along most parts of the paleo-channel.

Groundwater in Zone 3 is believed to have originated primarily as artificial recharge at B-Pond. Groundwater flow in the uppermost unconfined aquifer near the southcentral portion of the study area is to the southeast along a corridor of saturated Unit 1 (Hanford formation/PMG [undiff.]) sediments, extending southeast from the 216-A-30 and 216-A-37-2 cribs (PUREX). B-Pond groundwater flowing along this pathway has low contaminant levels relative to waste water discharged to cribs in the vicinity of the PUREX facility, which also flow to the southeast through the Unit 1 (Hanford formation/PMG [undiff.]) corridor. It is possible that, during B-Pond operations, artificial recharge moved downstructure on top of the Unit 8 (Ringold lower mud unit) (described as umbrella effect in Section 4.2.1). This perched water would have flowed down the Unit 8 mud surface within the highly conductive overlying Unit 1 (Hanford formation/PMG [undiff.]) and flowed into the uppermost unconfined aquifer south of the lower mud subcrop and moved east across the May Junction Fault and toward the river (Figure 4.10).

Currently, there are very few wells along the Unit 1 (Hanford formation/PMG [undiff.]) corridor, that portion of the upper unconfined aquifer immediately south of B-Pond (Plate 10). Without monitoring well control in this region, it is impossible to determine the quantity and distribution of contamination moving through the area based on what is currently being monitored. This new interpretation indicates that this unmonitored region may be an easterly groundwater preferential flow path. A groundwater preferential flow path through this area appears shorter than current models predict and could explain why contaminants have arrived faster than expected at the river. This suggests that contaminants may have gone and may still be moving undetected north of the current monitoring well network (as depicted by the modeled flow paths). This interpretation also suggests that contamination associated with effluent disposal near PUREX may have been constrained to the southwest margin of the corridor by the large recharge flux from B-Pond.

4.3.2 Confined Ringold Aquifer System

Within the study area, the major ion chemistry of groundwater in the confined Ringold aquifer is available for several wells in the vicinity of B-Pond and the TEDF. Confined Ringold aquifer groundwater from this area, adjacent to the flood channel unconformity, is of the Ca^{2+}-HCO_3^--type and has elevated tritium activities similar to groundwater from nearby wells completed in the uppermost unconfined aquifer (Figure 4.14). Moving south and east from B-Pond toward the May Junction Fault, groundwater in the confined Ringold aquifer has tritium activities much lower (<300 pCi/L) than those near the residual B-Pond mound and is of the Na^+-HCO_3^- type. Tritium activity less than <100 pCi/L would not likely occur as a result of decay from activities observed in unconfined aquifer waters in the region since the onset of B-Pond operations. This in conjunction with the distinct major ion composition of groundwater in the confined Ringold aquifer near the fault indicate that these waters predate and have not been displaced or diluted by waste water associated with 200-East Area operations (Figure 4.14). These waters are similar to groundwater from nearby wells completed in the upper basalt-confined aquifer and may also be the result of upwelling.

The confined Ringold aquifer is fairly well characterized in the vicinity of B-Pond and the TEDF, but is not as well characterized in other parts of the study area. Of particular interest are locations near the buried paleo-channel unconformity where the uppermost unconfined and confined Ringold aquifers are in communication, that may have been impacted by past contaminant disposal to the groundwater, i.e., near the PUREX cribs, ILAW, and north of the BC cribs farther west.

There is also a lack of groundwater data (i.e., no wells)in the confined Ringold aquifer to the west and southwest of the 200-East Area where contamination from the 200-West Area may enter the study area. This study suggests that contaminants from the 200-West Area may be moving through the confined Ringold aquifer (Unit 9C), which discharges into Unit 1 (Hanford formation/PMG [undiff.]) within the paleo-channel and continues on in the uppermost unconfined aquifer to the Columbia River (illustrated by flow lines on line 3). Carbon tetrachloride as high as 590 µg/L was detected in two new (1998) deep boreholes drilled below Unit 8 (Hodges et al. 1999a, 1999b), downgradient from the primary contaminant source. These detections support this hypothesis. (The U.S. Environmental Protection Agency drinking water standard maximum contaminant level is 5 µg/L.)

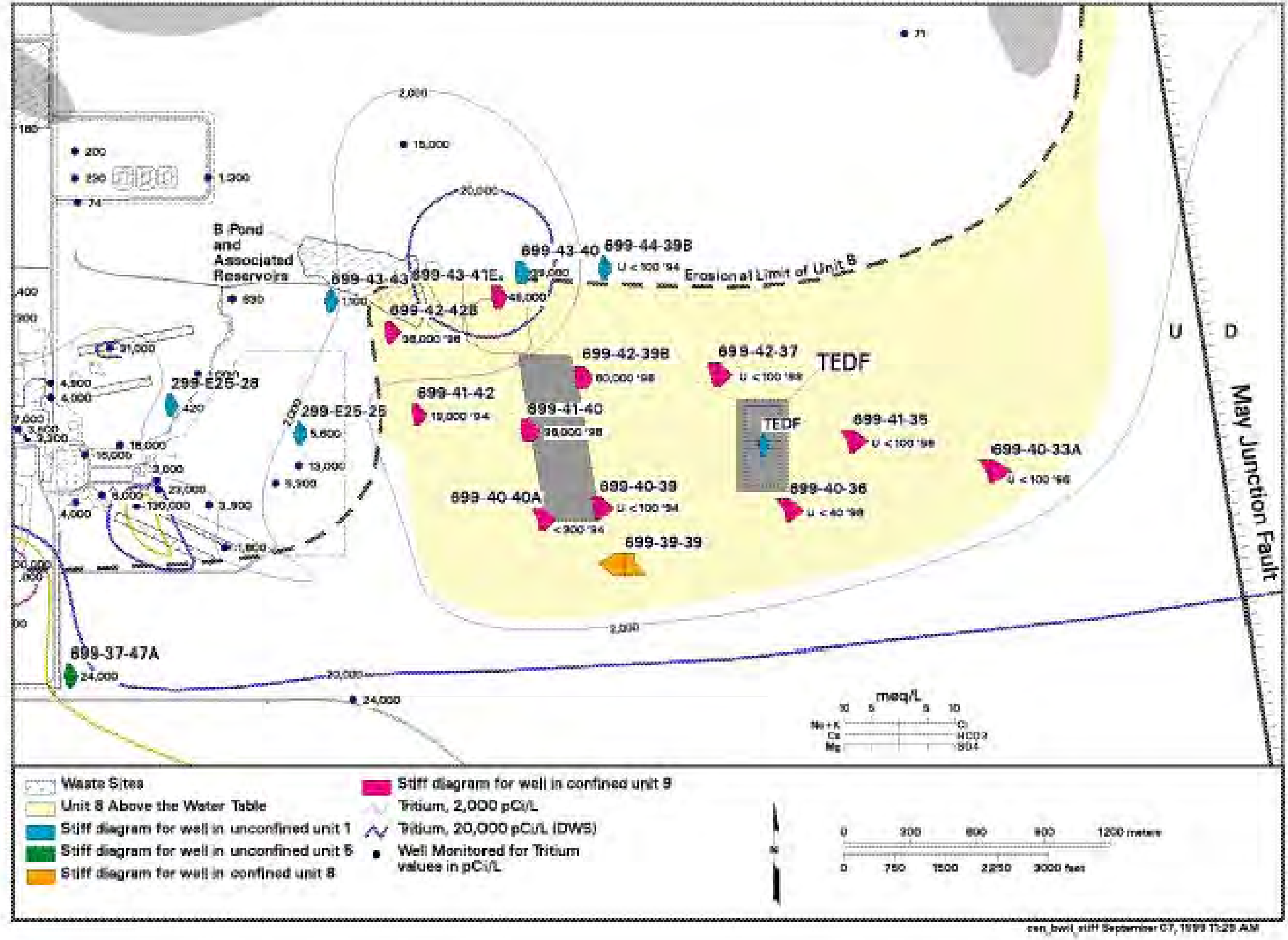


Figure 4.14. Major Ion Chemistry and Tritium Activity for Groundwater Near B-Pond and the TEDF

5.0 Conclusions and Recommendations

5.1 Conclusions

Previous work focused on either the 1) basalt confined aquifer system, or 2) a single suprabasalt aquifer. The results of this report, however, recommend that more emphasis be placed on separation of the suprabasalt aquifer into two systems. Most contaminants detected in groundwater are constrained by these two systems. When applied in the three-dimensional groundwater numerical flow model and preparation of contaminant and water table maps, this new conceptual groundwater flow model will result in more realistic determinations of the groundwater flow and contaminant migration patterns and rates. The results predicted using this new conceptual model will differ from predictions based on previous conceptual groundwater flow models, which reflect composite results from the entire suprabasalt aquifer system.

Conclusions of this report are as follow

- Hydrostratigraphic mapping indicates that the Ringold Unit 8 (comparable to Lindsey's Ringold Formation Lower Mud sequence) is the most significant basin-wide confining unit (aquiclude) within the suprabasalt hydrostratigraphy.

- A buried paleo-channel(s), eroded into the Ringold Formation, trends northwest to southeast (and east) through the 200-East Area. Groundwater and contaminants from 200-East and portions of 200-West preferentially flow along this erosional channel. The revised structure map of the Ringold Unit 8 defines the erosional limits of this channel within the Ringold sediments.

- Based on the revised hydrostratigraphy, the suprabasalt aquifer system is composed of at least two distinct and separate aquifers: 1) the upper unconfined aquifer within the Unit 1 (Hanford formation/ PMG [undiff.]) and Unit 5 (Ringold Formation Unit E) gravel, and 2) the confined Ringold aquifer where the Unit 9A/C (Ringold Unit A) gravel exists below Unit 8 (lower mud unit).

- Water level decline in the 200 Areas plateau is resulting in changes of the contaminant and groundwater preferential flow paths from the 200 Areas plateau toward the river. In addition, groundwater flow conditions and chemistry in the upper unconfined aquifer maybe increasingly impacted by discharges from the Ringold confined aquifer.

- Based on the revised hydrogeologic conceptual model, groundwater monitoring and characterization of the suprabasalt aquifers is inadequate downgradient of the 200 Areas plateau. The existing groundwater well network is limited and does not provide strategic monitoring of the primary or preferential groundwater and plume flow path within the upper unconfined aquifer and confined aquifer. The conclusions of this report indicate that hydrogeologic influences created by the structural May Junction Fault offset control groundwater movement from the 200-East Area. The revised hydrogeology defines those areas where strategically placed wells can be installed to provide monitoring to track groundwater and associated contaminants moving downgradient from the

200 Area plateau east toward the river. Strategic well locations also can provide better characterization, along with addressing potential data gaps and providing information that supports/confirms the accuracy of this new hydrostratigraphic model.

- Characterization of the confined Ringold aquifer (Units 9A/C and 9B) beneath the 200-West Area and east to the buried paleo-channel (near the west side of the 200-East Area) is limited, and more work needs to be done to understand the groundwater flow patterns and magnitude of contamination within this aquifer.

- Several existing wells need to be remediated or decommissioned because current well conditions cannot support any monitoring purpose. These wells are located in areas critical to improving the understanding of the suprabasalt aquifer system. These older wells were drilled into basalt, do not have annular seals, and potentially create cross flow between the aquifers, including the upper basalt interbed aquifer; it is currently not possible to accurately determine which aquifer is being monitored.

5.2 Recommendations

The following recommendations are based on the suggested revisions to the conceptual model of the 200-East Area in this report

- The suprabasalt aquifer is believed to comprise two aquifers; an upper unconfined aquifer, and a lower confined aquifer (Ringold Units 9A/C). Future mapping of the potentiometric surfaces and evaluation of groundwater chemistry for these two aquifers should be separated based on well data results from the revised hydrogeology and used to evaluate this concept. The water table and hydrochemistry of the unconfined aquifer should be mapped using only wells that are completed in the uppermost unconfined aquifer as defined by the revised hydrogeology. This will require revising the current monitoring network to include only those wells that are monitoring the appropriate hydrogeologic units(s). The potentiometric surface and groundwater chemistry of the confined Unit 9 Ringold aquifer also needs to be mapped separately to determine the nature and extent of contamination near the juncture of the two aquifers. This will provide better understanding of groundwater flow paths and contaminant plume mapping/tracking.

- Re-evaluate groundwater flow paths in the 200 Areas and surrounding region based on the proposed revised hydrostratigraphy. For example, this study has suggested that the current B-Pond mound identified as part of the unconfined aquifer (Units 1 & 5) is actually the result of head measurements in a separate confined aquifer system (Units 9A/C) and should not be reflected as a mound at the water table.

- Using the concepts developed in this study, run the three-dimensional numerical model to evaluate their effect on understanding groundwater flow paths and contaminant transport. Remaining contaminants migrating from the 200 Areas through the uppermost unconfined aquifer may reach the Columbia River faster than previously calculated because the perceived effect of the groundwater mound is no longer a major barrier or boundary within the unconfined aquifer flow system.

- Consider additional monitoring and characterization of the proposed confined suprabasalt aquifer system (Unit 9A/C) because this aquifer has known contamination and a higher hydraulic head than the adjacent unconfined aquifer, creating the potential for contaminant discharge to the unconfined aquifer (Units 1 & 5) in the future.

- Consider additional hydrostratigraphic work north through Gable Gap to better characterize groundwater flow paths and aquifer boundaries that influence contaminant and groundwater migration through this area.

- Re-evaluate the hydrostratigraphic conceptual model for the 200-West Area based on insights provided by this study.

- Re-evaluate the 200-East Area hydrostratigraphic conceptual model on an annual or biennial basis to incorporate new data.

6.0 References

Baker, V. R., B. N. Bjornstad, A. J. Busacca, K. R. Fecht, E. P. Kiver, U. L. Moddy, J. G. Rigby, O. F. Stradling, and A. M. Tallman. 1991. "Quaternary Geology of the Columbia Plateau," In *Quaternary Nonglacial Geology; Conterminous United States: The Geology of North America.* R. B. Morrison (ed.), Geological Society of America, Vol. K-2.

Barnett, D. B. 1998. *Evaluation of Groundwater Monitoring Results at the Hanford Site 200 Area Treated Effluent Disposal Facility*. PNNL-11986, Pacific Northwest National Laboratory, Richland, Washington.

Cole, C. R., S. K. Wurstner, M. P. Bergeron, M. D. Williams, and P. D. Thorne. 1997. *Three–Dimensional Analysis of Future Groundwater Flow Conditions and Contaminant Plume Transport in the Hanford Site Unconfined Aquifer System: FY 1996 and 1997 Status Report.* PNNL-11801, Pacific Northwest National Laboratory, Richland, Washington.

Connelly, M. P., J. V. Borghese, C. D. Delaney, B. H. Ford, J. W. Lindberg, and S. J. Trent. 1992. *Hydrogeologic Model for the 200-East Groundwater Aggregate Area*. WHC-SD-EN-TI-019, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Delaney, C. D., K. A. Lindsey, and S. P. Reidel. 1991. *Geology and Hydrology of Hanford Site: A Standardized Text for Use in Westinghouse Hanford Company Document and Reports*. WHC-SD-ER-TI-0003, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Fecht, K. R., S. P. Reidel, and A. M. Tallman. 1987. *Paleodrainage of the Columbia River System on the Columbia Plateau of Washington State–A Summary,* in *Washington Division of Geology and Earth Resources Bulletin 77.* Basalt Waste Isolation Project, Westinghouse Hanford Company, Richland, Washington.

Gephart, R. E., P. A. Eddy, R. C. Arnett, and G. A. Robinson. 1976. *Geohydrologic Study of the West Lake Basin*. ARH-CD-775, Atlantic Richfield Hanford Company, Richland, Washington.

Gephart, R. E., F. A. Spane, Jr., L. S. Leonhart, D. A. Palombo, and S. R. Strait. 1979. *Pasco Basin Hydrology.* In *Hydrologic Studies Within the Columbia Plateau, Washington: An Integration of Current Knowledge*, pp. III-1 to III-236. RHO-BWI-ST-5, Rockwell Hanford Operations, Richland, Washington.

Graham, M. J., M. D. Hall, S. R. Strait, and W. R. Brown. 1981. *Hydrology of the Separations Area*. RHO-ST-42, Rockwell International, Richland, Washington.

Graham, M. J., G. V. Last, and K. R. Fecht. 1984. *An Assessment of Aquifer Intercommunication in the B-Pond-Gable Mountain Pond Area of the Hanford Site*. RHO-RE-ST-12P, Rockwell Hanford Operations, Richland, Washington.

Hartman, M. J. 1999. *Hanford Site Groundwater Monitoring for Fiscal Year 1998*. PNNL-12086, Pacific Northwest National Laboratory, Richland, Washington.

Hartman, M. J., and P. E. Dresel. 1998. *Hanford Site Groundwater Monitoring for Fiscal Year 1997*. PNNL-11793, Pacific Northwest National Laboratory, Richland, Washington.

Hodges, F. N., and D. G. Horton. 1999a. *Borehole Data Package for 1998 Wells Installed at Single-Shell Tank Waste Management Area TX-TY*. PNNL-12124, Pacific Northwest National Laboratory, Richland, Washington.

Hodges, F. N., and D. G. Horton. 1999b. *Borehole Data Package for 1998 Wells Installed at Single-Shell Tank Waste Management Area T.* PNNL-12125, Pacific Northwest National Laboratory, Richland, Washington.

Jensen, E. J. 1987. *An Evaluation of Aquifer Intercommunication Between the Unconfined and Rattlesnake Ridge Aquifers on the Hanford Site.* PNL-6313, Pacific Northwest Laboratory, Richland, Washington.

Last, G. V., B. N. Bjornstad, M. P. Bergeron, D. W. Wallace, D. R. Newcomer, J. A. Schramke, M. A. Chamness, C. S. Cline, S. P. Airhart, and J. S. Wilbur. 1989. *Hydrogeology of the 200 Areas Low-Level Burial Grounds–An Interim Report, Volume 2: Appendixes*. PNL-6820, Vol. 2, Pacific Northwest Laboratory, Richland, Washington.

Lindberg, J. W., F. A. Spane, and B. A. Williams. 1997. *Borehole Data Package for Well 699-36-70A, PUREX Plant Cribs, CY 1996.* PNNL-11515, Pacific Northwest National Laboratory, Richland, Washington.

Lindsey, K. A., B. N. Bjornstad, J. W. Lindberg, and K. M. Hoffman. 1992. *Geologic Setting of the 200-East Area: An Update*. WHC-SD-EN-TI-012, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Lindsey, K. A., S. P. Reidel, K. R. Fecht, J. L. Slate, A. G. Law, and A. M. Tallman, 1994. *Geo-hydrologic Setting of the Hanford Site, South-Central Washington,* in *Geologic Field Trips of the Pacific Northwest*, D. A. Swanson and Haugerud (eds.), 1994 Geological Society of America Annual Meeting, Department of Geological Sciences, University of Washington, Seattle, Washington, p. K-1-K-16.

Lindsey, K. A. 1995. *Miocene- to Pliocene-Aged Suprabasalt Sediments of the Hanford Site, South-Central Washington*. BHI-00184, Bechtel Hanford Inc., Richland, Washington.

Lindsey, K. A. 1996. "The Miocene to Pliocene Ringold Formation and Associated Deposits of the Ancestral Columbia River System, South-Central Washington and North-Central Oregon," Open File Report 96-8, Washington Division of Geology and Earth Resources, Washington State Department of Natural Resources.

Reidel, S. P., and K. R. Fecht. 1976. "Wanapum and Saddle Mountains Basalts of the Cold Creek Syncline Area." In: C. W. Myers and S. M. Price (eds). *Subsurface Geology of the Cold Creek Syncline.* RHO-BWI-ST-14, Rockwell Hanford Operations, Richland, Washington.

Reidel, S. P., N. P. Campbell, K. R. Fecht, and K. A. Lindsey. 1994. *Late Cenozoic Structure and Stratigraphy of South-Central Washington*. Bulletin 80, Washington Division of Geology and Earth Resources, Olympia, Washington.

Reidel, S. P., and K. R. Fecht. 1981. *Wanapum and Saddle Mountains Basalt in the Cold Creek Syncline Area,* In *Subsurface Geology of the Cold Creek Syncline*. RHO-BWI-ST-14, Rockwell Hanford Operations, Richland, Washington.

Reidel, S. P., K. D. Reynolds, and D. G. Horton. 1998. *Immobilized Low-Activity Waste Site Borehole 299-E17-21*. PNNL-11957, Pacific Northwest National Laboratory, Richland, Washington.

Spane, F. A., Jr., and W. D. Webber. 1995. *Hydrochemistry and Hydrogeologic Conditions Within the Hanford Site Upper Basalt Confined Aquifer System.* PNL-10817, Pacific Northwest Laboratory, Richland, Washington.

Stiff, H. A., Jr. 1951. "The Interpretation of Chemical Water Analyses by Means of Patterns." *J. Petrol. Tech.* 3:15-17.

Tallman, A. M., K. R. Fecht, M. C. Marratt, and G. V. Last. 1979. *Geology of the Separation Areas, Hanford Site, South-Central Washington.* RHO-ST-23, Earth Sciences Group Research Department, Rockwell International, Richland, Washington.

Tallman, A. M., J. T. Lillie, and K. R. Fecht. 1981. "Chapter 2.0, Suprabasalt Sediments of the Cold Creek Syncline Area." In *Subsurface Geology of the Cold Creek Syncline*, C. W. Meyers and S. M. Price (eds.), RHO-BWI-ST-14, Rockwell Hanford Operations, Richland, Washington.

Thorne, P. D., and D. R. Newcomer. 1992. *Summary and Evaluation of Available Hydraulic Property Data for the Hanford Site Unconfined Aquifer System.* PNL-8337, Pacific Northwest Laboratory, Richland, Washington.

Thorne, P. D., M. A. Chamness, F. A. Spane, Jr., V. R. Vermeul, and W. D. Webber. 1993. *Three-Dimensional Conceptual Model for the Hanford Site Unconfined Aquifer System, FY 93 Status Report*. PNL-8971, Pacific Northwest Laboratory, Richland, Washington.

U.S. Department of Energy (DOE). 1982. *Site Characterization Report for the Basalt Waste Isolation Project*. DOE/RL 82-3, 3, U.S. Department of Energy, Richland, Washington.

U.S. Department of Energy (DOE). 1988. *Consultation Draft, Site Characterization Plan, Reference Repository Location, Hanford Site, Washington.* DOE/RW-0164, Vols. 1 and 2, U.S. Department of Energy, Office of Civilian Radioactive Waste Management, Washington, D.C.

U.S. Department of Energy, Richland Operations Office (DOE/RL). 1987. *Plan and Schedule to Discontinue Disposal of Contaminated Liquids into the Soil Column at the Hanford Site*. U.S. Department of Energy, Richland, Washington.

U.S. Department of Energy, Richland Operations Office (DOE/RL). 1995. *Annual Report for RCRA Groundwater Monitoring Projects at Hanford Site Facilities for 1994*. DOE/RL-94-136, Rev. 0, U.S. Department of Energy, Richland, Washington.

U.S. Department of Energy, Richland Operations Office (DOE/RL). 1996. *Annual Report for RCRA Groundwater Monitoring Projects at Hanford Site Facilities for 1995*. DOE/RL-96-1, Rev. 0, U.S. Department of Energy, Richland, Washington.

U.S. Department of Energy, Richland Operations Office (DOE/RL). 1998. *Groundwater/Vadose Zone Integration Project Specification*. DOE/RL-98-48, Draft C, U.S. Department of Energy, Richland, Washington.

Washington State Department of Ecology (Ecology), U.S. Environmental Protection Agency, and U.S. Department of Energy (Ecology). 1989. *Hanford Federal Facility Agreement and Consent Order Between the U.S. Environmental Protection Agency, the U.S. Department of Energy, and the State of Washington Department of Ecology*, May 15, 1989, as amended, Olympia, Seattle, and Richland, Washington.

Wilbur, J. S., M. J. Graham, and A. H. Lu. 1983. *Results of the Separations Area Ground-Water Monitoring Network for 1982*. RHO-RE-SR-83-24 P, Rockwell International, Richland, Washington.

Wurstner, S. K., P. D. Thorne, M. A. Chamness, M. D. Freshley, and M. D. Williams. 1995. *Development of a Three-Dimensional Ground-Water Model of the Hanford Site Unconfined Aquifer System: FY 1995 Status Report*. PNL-10886, Pacific Northwest Laboratory, Richland, Washington.

Appendix A

Hydrogeologic Units Data Table for Selected Wells Within the 200-East Study Area

Appendix A

Hydrogeologic Units Data Table for Selected Wells Within the 200-East Study Area

A.1 200-East Area Hydrogeology Database

This appendix presents Table A.1 that denotes the subsurface elevations (structural top) and thickness (isopach) for the hydrogeologic units defined in wells and boreholes within the study area (Figure 3.1). The following section defines the column headings in the table and what they represent.

A.2 Contents of Table A.1

Table A.1 is a listing of the hydrogeologic units identified in selected wells and/or boreholes within the study area. Each well is identified under the *Well Number* column and further subdivided in this column based on the four study area cross sections (e.g., **Line 1**). Near the end of the table are other selected wells used in the study. The values in this table are denoted in feet and are rounded to the nearest foot. All values, except the *Total Depth* column are reported in feet of elevation. *Total Depth* is the total depth drilled in the borehole below ground surface.

Surface elev. is the surveyed ground surface elevation in feet using the North American Vertical Datum of 1988 (NAVD88) or a conversion of the older NAVD29 using a software package called Corpson (Version 5.11, U.S. Army Corps of Engineers 1997). Corpson makes use of the VERTCON software program (version 2.0) developed by the National Geodetic Survey. This datum is the basis of the vertical control network that is part of the National Geodetic Reference System (NGRS) and is maintained by the National Geodetic Survey (NGS). Both the 1929 and 1988 data are defined by the observed heights of mean sea level at 26 tide gages and by the set of elevations of all benchmarks resulting from the adjustment. The vertical datum is not mean sea level, the geoid, or any other equi-potential surface (Schalla et al. 1992). Unlike the NAVD88, the global positioning system (GPS) measures the *height above (a geocentric) ellipsoid* (HAE); however, the NAVD88 is consistent with the GPS (Hartman 1999; Lange 1992) via the conversion. The actual ground surface is not used as the reference elevation, but rather the top surface of the brass survey marker cemented in the concrete pad around the well casing or protective outer casing. The concrete pads average about 0.5 ft thick and are set in the ground. The brass marker is nearly level with the top of the concrete pad, which typically extends about 0.1 to 0.4 ft above the adjacent ground surface.

Geophysical log evaluations were used extensively in correlating and selecting the hydrogeologic unit boundaries, i.e., unit tops. The *Geophysics* column defines, by either a "yes," "no," or "Partial, if geophysical logs were available for the correlation. The following columns present either the unit elevation (top) or the units total (gross) thickness (isopach) if the unit could be defined in the borehole (well) hydrogeologic data evaluation. These units correspond to the hydrogeologic units depicted in Figure 3.1 and throughout the study. The *Ring Top* column represents the top of the Ringold Formation. The *E Gravel (5) Top* represents the top of the Ringold Formation Unit 5 gravel. The *(5) Isopach* column represents the thickness of Unit 5. The *Rmud (8) Top* represents the top of the Ringold Formation Unit 8 (lower mud) unit. *(8) Isopach* represents the thickness of the unit 8. *Ring A (9A) Top* represents the top of the Ringold Formation Unit 9A. *Rmud (9B) Top* represents the top of the Ringold Formation Unit 9B. *(9B) Isopach* represents the thickness of the Unit 9B. *(9A) Isopach* represents the thickness of the Unit 9A. *(9)C Top* represents the top of the Ringold Unit 9C. *(9C) Isopach* represents the thickness of the Unit 9C. *Basalt Top* represents the top of the Elephant Mountain Member Basalt. *Comments* present the authors notes about an individual well.

A.3 References

Hartman, M. J. (ed). 1999. *Hanford Site Groundwater Monitoring for Fiscal Year 1998*. PNNL-12086, Pacific Northwest National Laboratory, Richland, Washington.

Lange, A. F. 1992. *Geographic Information Systems (GIS) and Mapping*, "An Overview of the Global Positioning System and Its Use in Geographic Information Systems." *ASTM Special Technical Publication* 1126, eds. A. I. Johnson, C. B. Pettersson, and J. L. Fulton, pp. 106-111, Philadelphia, Pennsylvania.

Schalla, R., A. K. Lewis, and D. J. Bates. 1992. *Geographic Information Systems (GIS) and Mapping*, "Accuracy and Precision of Well Casing Surveys and Water-Level Measurements and Their Impact on Water-Level Contour Maps." *ASTM Special Technical Publication* 1126, eds. A. I. Johnson, C. B. Pettersson, and J. L. Fulton, pp. 295-309, Philadelphia, Pennsylvania.

U.S. Army Corps of Engineers. 1997. *Corpson, Version 5.x, Technical Documentation and Operating Instructions*. Geodetic Applications Division, Topographic Applications Laboratory, U.S. Army Topographic Engineering Center, Alexandria, Virginia.

Table A.1. 200-East Area Hydrogeology Database

Well Number	Surface Elev.	Geophysics	Ring Top	Gravel (E) Top	(5) Isopach	Rmud (8) Top	(8) Isopach	Ring A (9A) Top	Rmud (9B) Top	(9B) Isopach	(9A) Isopach	(9C) Top	(9C) Isopcah	Basalt Top	Total Depth	Comments
Line 1																
699-37-47A	717	Yes	432	407	55	352	74	278	243	24	35	219	19	200	526	
299-E16-1	696	No	422	422	60	362	64	298	268	24	30	244	20	224	510	
299-E25-45	679	Yes	0	0	0	NDE	NDE	NDE	NDE	NDE	NDE	NDE	NDE	NDE	298	
299-E25-1000	674	Yes	311	0	0	0	0	0	0	0	0	311	19	292	392	
699-43-42K	582	Yes	424	0	0	424	24	400	377	29	23	348	16	332	262	
699-43-42A	564	Yes	414	0	0	414	4	410	384	17	26	367	14	353	223	
699-45-42	578	Yes	416	0	0	0	0	0	416	6	0	410	22	388	195	
699-47-42	470	Yes	416	0	0	0	0	0	0	0	0	405	8	397	470	
699-50-42	467	No	429	0	0	0	0	0	429	18	0	411	9	402	125	
699-47-35B	477	Yes	443	0	0	0	0	0	443	32	0	411	34	377	108	
699-49-33	505	Yes	441	0	0	0	0	0	441	5	0	436	7	429	356	
699-49-32B	517	Yes	444	0	0	444	81	undiff	undiff	undiff	undiff	363	20	343	340	
699-49-31	527	Yes	232	0	0	232	92	undiff	undiff	undiff	undiff	150	15	135	675	
Line 2																
299-E17-21	736	Yes	438	408	48	360	59	301	NDE	NDE	NDE	NDE	NDE	NDE	481	
299-E17-6	721	Yes	400	408	54	354	58	296	259	18	37	241	NDE	NDE	500	
299-E24-7	716	No	326	0	0	0	0	326	296	10	30	286	15	271	450	Limited data on unit 9
299-E24-8	689	Yes	332	0	0	0	0	0	332	8	0	324	10	314	382	Limited data on unit 9
299-E27-1	683	Yes	0	0	0	0	0	0	0	0	0	0	0	336	332	
299-E27-15	653	Yes	0	0	0	0	0	0	NDE	NDE	NDE	NDE	NDE	NDE	263	
299-E27-17	635	Yes	0	0	0	0	0	0	0	0	0	0	0	390	246	
299-E35-1	599	Yes	0	0	0	0	0	0	0	0	0	0	0	407	194	
Line 3																
699-44-64	728	Partial	458	458	93	365	22	343	ND	ND	ND	ND	ND	286	452	
699-40-62	748	Partial	434	434	60	374	NDE	NDE	NDE	NDE	NDE	NDE	NDE	NDE	384	
299-E19-1	738	Yes	372	372	10	362	60	302	254	ND	48	ND	ND	314	536	Limited data on unit 9
299-E23-2	721	Yes	337	0	0	0	0	337	309	8	28	301	12	289	456	
299-E28-16	703	Yes	410	0	0	0	0	410	378	NDE	32	NDE	NDE	NDE	325	Need to check samples and data
299-E28-26	688	Yes	388	0	0	0	0	0	0	0	0	388	26	362	329	Need to check samples and data
299-E33-29	675	Yes	0	0	0	0	0	0	0	0	0	0	0	385	290	
299-E33-43	662	Yes	0	0	0	0	0	0	0	0	0	0	0	382	276	
299-E33-41	655	Yes	0	0	0	0	0	0	0	0	0	0	0	392	263	
299-E33-16	639	Yes	0	0	0	0	0	0	0	0	0	0	0	387	258	
299-E33-14	623	Yes	0	0	0	0	0	0	0	0	0	0	0	395	230	
299-E33-12	624	Yes	0	0	0	0	0	0	0	0	0	0	0	392	415	
299-E34-11	618	Yes	0	0	0	0	0	0	0	0	0	0	0	402	219	

Table A.1. (contd)

Well Number	Surface Elev.	Geophysics	Ring Top	Gravel (E) Top	(5) Isopach	Rmud (8) Top	(8) Isopach	Ring A (9A) Top	Rmud (9B) Top	(9B) Isopach	(9A) Isopach	(9C) Top	(9C) Isopcah	Basalt Top	Total Depth	Comments
Line 4																
699-47-60	652	Yes	426	0	0	0	0	0	426	22	0	404	36	368	287	
699-49-57B	556	Yes	0	0	0	0	0	0	0	0	0	0	0	392	230	
299-E33-34	634	Yes	0	0	0	0	0	0	0	0	0	0	0	396	239	
299-E33-35	643	Yes	0	0	0	0	0	0	0	0	0	0	0	393	349	
299-E33-42	654	Yes	0	0	0	0	0	0	0	0	0	0	0	390	260	
299-E33-41	655	Yes	0	0	0	0	0	0	0	0	0	0	0	392	263	
299-E33-18	653	Yes	0	0	0	0	0	0	0	0	0	0	0	388	278	
299-E33-20	649	Yes	0	0	0	0	0	0	0	0	0	0	0	397	254	
299-E33-19	651	Yes	0	0	0	0	0	0	0	0	0	0	0	402	252	
299-E33-33	641	Yes	0	0	0	0	0	0	0	0	0	0	0	389	252	
299-E33-37	653	Yes	0	0	0	0	0	0	0	0	0	0	0	385	268	
299-E27-11	644	Yes	0	0	0	0	0	0	0	0	0	0	0	382	265	
299-E25-2	675	?	367	0	0	0	0	0	0	0	0	367	52	315	375	
299-E25-28	663	No	370	0	0	0	0	0	0	0	0	370	48	322	348	No decent gp logs
299-E25-32	671	No	365	0	0	0	0	0	0	0	0	365	44	321	354	No gp logs
699-41-42	644	Yes	416	0	0	416	24	392	0	0	83	0	0	309	343	Note: No clay indicated in unit 9B
699-40-40A	541	Yes	424	0	0	424	75	349	316	NDE	33	NDE	NDE	NDE	227	
699-40-36	529	Yes	416	0	0	416	84	332	304	29	28	275	16	259	280	
699-40-33C	520	Yes	410	0	0	410	96	314	284	18	30	266	26	240	283	
699-41-31	505	PARTIAL	379	0	0	379	114	265	undiff	undiff	70	undiff	undiff	195	335	
699-42-30	481	No	231	231	13	218	106	undiff	undiff	undiff	undiff	112	56	56	464	
Wells Not on Section but Used in the Mapping																
299-E29-1	710	No	NDE	NDE	NDE	NDE	NDE	NDE	NDE	NDE	NDE	NDE	NDE	NDE	262	
699-43-41G	551	Yes	429	0	0	429	20	409	373	10	36	363	NDE	NDE	201	
699-44-39B	513	Yes	388	0	0	0	0	388	375	9	13	366	25	341	182	
699-42-39A	558	Yes	420	0	0	420	35	385	NDE	NDE	NDE	NDE	NDE	NDE	181	
699-42-39B	558	Yes	424	0	0	424	40	384	343	NDE	41	NDE	NDE	NDE	216	
699-43-43	579	Yes	406	0	0	0	0	406	NDE	NDE	NDE	NDE	NDE	NDE	180	
699-42-42A	604	Yes	417	0	0	417	21	396	347	14	49	333	33	300	314	
699-42-42B	583	Yes	426	0	0	426	25	401	377	28	24	349	NDE	NDE	250	
699-40-39	542	Yes	417	0	0	417	75	342	NDE	NDE	NDE	NDE	NDE	NDE	212	
699-41-40	546	Yes	424	0	0	424	43	381	NDE	NDE	NDE	NDE	NDE	NDE	176	
699-42-41B	?	Yes	NDE	NDE	NDE	NDE	NDE	NDE	NDE	NDE	NDE	NDE	NDE	NDE	125	
699-42-41A	564	Yes	0	0	0	NDE	NDE	NDE	NDE	NDE	NDE	NDE	NDE	NDE	155	
699-42-37	519	Yes	425	0	0	425	36	389	347	17	42	330	60	270	268	

Table A.1. (contd)

Well Number	Surface Elev.	Geophysics	Ring Top	Gravel (E) Top	(5) Isopach	Rmud (8) Top	(8) Isopach	Ring A (9A) Top	Rmud (9B) Top	(9B) Isopach	(9A) Isopach	(9C) Top	(9C) Isopcah	Basalt Top	Total Depth	Comments
699-41-35	521	Yes	420	0	0	420	72	348	320	22	28	298	24	274	260	
699-40-32	525	No	390	0	0	390	120	undiff	undiff	undiff	undiff	270	68	202	370	
699-37-36	544	No	344	0	0	344	104	undiff	undiff	undiff	undiff	240	116	124	430	
699-46-31	479	No	244	0	0	244	90	undiff	undiff	undiff	undiff	154	60	94	573	
699-46-32	474	No	389	0	0	389	92	undiff	undiff	undiff	undiff	297	24	273	425	
699-46-33	472	No	448	0	0	0	0	0	448	10	0	438	26	412	273	
299-E24-18	720	Yes	454	NDE	NDE	NDE	NDE	NDE	NDE	NDE	NDE	NDE	NDE	NDE	330	
699-38-61	745	?	433	433	NDE	NDE	NDE	NDE	NDE	NDE	NDE	NDE	NDE	NDE	358	
699-39-39	537	Yes	418	0	0	418	82	NDE	NDE	NDE	NDE	NDE	NDE	NDE	200	
699-38-65	753	No	359	0	0	359	50	undiff	undiff	undiff	undiff	309	82	227	536	
699-44-43B	580	Yes	420	0	0	0	0	0	0	0	0	420?	NDE	NDE	177	
699-44-42	579	?	416	0	0	0	0	0	?	?	?	?	NDE	NDE	173	

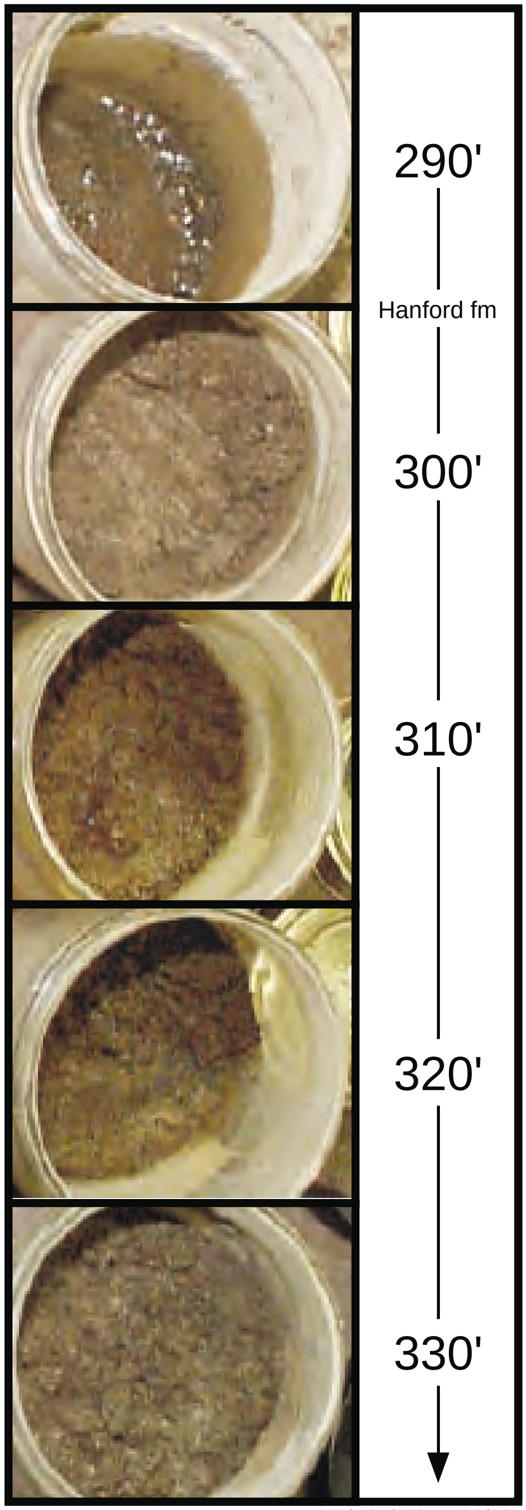
Notes after some wells indicate interpretational problems or issues for that well.
Surface elevations reflect brass cap or ground surface elevations rounded to the nearest foot; NAVD 1988 results.
If Geophysics is indicated then the lithology has been depth corrected based on the geophysics and may vary from depths provided on well logs.
All values in feet; elevations are above mean sea level; total depth in feet below ground surface.
NDE = Borehole not drilled deep enough.
ND = Not enough data to make an interpretation.
Undiff = Unit was not separately mapped because data was not available to separate the unit.
? = Data were not available to determine if unit is present or not.

Appendix B

Photos of Soil Samples in Selected Wells


Horizontal Distance Between Wells ~3,000 ft
299-E17-6
Lithologic Samples
collected in mason jars
(~3-in dia.)
Elevation (ft)
299-E24-7
Lithologic Samples
collected in mason jars
(~3-in dia.)
420'
415'
410'
405'
400'
395'
390'
385'
380'
375'
370'
365'
360'
355'
350'
345'
340'
335'
330'
325'
320'
315'
310'
305'
300'
295'
290'
285'
280'
275'
270'
265'
260'
255'
250'
245'
240'
235'
230'
225'
220'
215'
Hanford formation Unit 1
Ringold Formation Unit 5
Ringold Formation Unit 8
Ringold Formation Unit 9A
Ringold Formation Unit 9B
Ringold Formation Unit 9C
Basalt
No Photographs Available
Water Level (06/96)
No Sample Available
Hanford formation Channel Fill Gravel Units 1-5 (reworked)
Channel Fill
Hanford formation and Pre-Missoula Gravel (undifferentiated)
Ringold Formation Unit 9A
Ringold Formation Unit 9B
Ringold Formation Unit 9C
Basalt
1999/DCL/200E HGS/019
For Area Lithologic Stratigraphy, see "200 East Area Hydrostratigraphy - Line 2"

299-E27-1



Appendix C

Units and Open Interval Data Tables for 200-East Area

Appendix C

Units and Open Interval Data Tables for 200-East Area

C.1 Assignment of Units and Update of Data Tables

This appendix presents Table C.1, which denotes hydrogeologic unit assignments for each well. The assignment of a primary and if applicable secondary unit(s) to each well is based on the open interval and screened interval of the well. The following section addresses the contents and column headings in the table and what they mean. The second section describes how primary and secondary units were assigned to each well.

C.1.1 Contents of Table C.1

Table C.1 contains specific well construction information and correlates these data with unit designations for hydrogeologic units identified at the Hanford Site. This information is from the PNNL Groundwater Monitoring Project (GMP) database. Figure 3.1 shows the stratigraphic units underlying the Hanford Site. The hydrogeologic and geologic stratigraphic columns in Figure 3.1 show differences in stratigraphy, primarily within the Hanford and Ringold Formations. Not all these units are present in the 200-East Area, and additional subdivisions (a, b, and c) were created for Unit 9. The details of assignment of units is discussed in the main text and summarized in the following section of this appendix.

The headings shown in Table C.1 from left to right are: well name, primary unit, primary unit isolated, all units, unit comments, reference elevation, stickup, OI top bgs (open interval top in feet below ground surface), OI below bgs (open internal bottom in feet below ground surface), screen top bgs (top of the well screen in feet below ground surface), screen bottom bgs (bottom of the well screen in feet below ground surface). *Well name* is the Hanford designation number that consists of three parts separated by hyphens. Part one is the area. In this case, all well names are either 200-East Area or 600-Area wells just outside the 200-East Area. Part 2 is a subsection within the area, and part 3 of the name is the well number within that subsection. Part 3 of the well-numbering system refers to chronological sequence with respect to the time the well was completed and entered into the Hanford well system.

Primary unit refers to the primary unit, which is based on the hydrogeologic interpretations in PNNL-10886 (Figure 3.1). Units used in this system in descending order are: unit 1 for the Hanford formation/ pre-Missoula gravel (PMG) (undiff.), unit 5 for Ringold Formation's uppermost unit E in the Wooded Island member, unit 8 for Ringold Formations Lower Mud unit, unit 9, and basalt units of the Columbia River Basalt Group.

Primary unit isolated is a question that is answered as Yes or as No with comments. If yes is the answer entered, it means that the well obtains water from just one unit mentioned above. If the answer entered is No, a qualifying notation will follow consisting of the units that are included with the primary water-bearing unit listed first. *All units* is a list of the units encountered during well drilling and under certain circumstances may contribute water if the well was not isolated adequately during well construction. *Unit comments* are additional comments that may include, but are not limited to, the proximity to the underlying basalt, a unit's depth, well screen issues, well plugging, or abandonment.

Reference elevation is the surveyed ground surface elevation in feet using the North American Vertical Datum of 1988 (NAVD88) or a conversion of the older NGVD29 using Corpson (Version 5.11, U.S. Army Corps of Engineers 1997).

Stick up refers to the height in feet from the brass marker (*reference elevation*) to the top of the pump support plate that rests generally on the outer well casing or protective outer well housing. In a small percentage of monitoring wells, the pump support plate is inside and below the outer casing. All water level measurements and pump depths are measured from the pump support plate, whereas all the well construction information is measured from the reference elevation.

The *OI* includes the vertical extent of the filter pack and, if present, the outer well screen or perforated casing. The well screen interval is always equal to or less than the open interval; that is, the top of the OI is always shallower than the top of the well screen. Likewise, the bottom of the OI is always equal to or deeper than the well screen bottom except if the backfill at the base of the screen overlaps the screen. This is done to alert the user of the data that the permeability characteristics of the backfill are unspecified or unknown. Well screen applies to actual wire wrap well screen or channel pack with dual well screens; it does not include perforated steel casing. That is why some wells in the table do not have a screened interval listed just open interval top and bottom.

C.1.2 Assignment of Unit Designations

Assignment of unit designations to each well was guided primarily by hydrogeologic units intercepted by the OI. Secondarily, a map of STIFF diagrams for each well showing time comparable analytical results were used to help determine horizontal, and more importantly, vertical hydraulic interconnections that may exist as a result of pathways created during well construction. The designations were part of the new conceptual model described in this report. The conceptual model, including Table C.1, incorporates newly acquired data and updated hydrogeologic interpretations that enables identification of aquifer system boundaries based on hydraulic separation or isolation created by large differences between the hydraulic conductivity of the hydrogeologic units.

Hydrogeologic units in the uppermost unconfined or Ringold confined aquifer systems in stratigraphic descending order are Unit 1 for the Hanford formation/PMG (undiff.), Unit 5 for the uppermost Unit E in the Wooded Island Member, unit 8 (lower mud unit), and Unit 9 for the Ringold Formation. Unit 8 is composed primarily of silt and clay is the primary isolation layer between Unit 5 and Unit 9. Unit 9 may be a single undifferentiated permeable layer in some areas, but frequently can be differentiated into permeable Units 9a and c that are separated by a low permeability layer 9b. Underneath the suprabasalt sedimentary units are the basalt units of the Columbia River Basalt Group. Layers of sedimentary material of varying permeability are sometimes sandwiched in between basalt flows in addition to permeable interflow zones common between some basalt flows. *Primary unit* (same as hydrogeologic unit) assignments in Table C.1 are based on the nomenclature developed by Chamness in PNNL-10886 (see Figure 3.1).

Assignment to specific units was first done using four structural cross-sections used in this report. They are called Lines 1 through 4. Well logs (includes borehole logs) from PNNL's Well Log Library and geophysical logs were used in conjunction with the four cross-section lines of wells to assign unit(s) to each of these 60 wells and a few boreholes. The stratigraphic interpretations and assigned units of the 60 wells were expanded laterally to more than 100 additional wells, and served as the primary basis for assigning the primary and secondary hydrogeologic units shown in Table C.1. Each well log record was reviewed to confirm if the assigned units were reasonable and consistent with the insights provided by the original 60 wells.

C.2 References

Lindsey, K. A. 1995. *Miocene- to Pliocene-Aged Suprabasalt Sediments of the Hanford Site, South Central Washington.* BHI-00184, Bechtel Hanford, Inc., Richland, Washington.

Thorne, P. D., M. A. Chamness, F. A. Spane, Jr., V. R. Vermeul, and W. D. Webber. 1993. *Three-Dimensional Conceptual Model for the Hanford Site Unconfined Aquifer System, FY93 Status Report*. PNNL-8971, Pacific Northwest National Laboratory, Richland, Washington.

U.S. Army Corps of Engineers. 1997. *Corpson, Version 5.x, Technical Documentation and Operating Instructions*. Geodetic Applications Division, Topographic Applications Laboratory, U.S. Army Topographic Engineering Center, Alexandria, Virginia.

Wurstner, S. K., P. D. Thorne, M. A. Chamness, M. D. Freshley, and M. D. Williams. 1995. *Development of a Three-Dimensional Ground-Water Model of the Hanford Site Unconfined Aquifer System: FY 1995 Status Report*. PNL-10886, Pacific Northwest Laboratory, Richland, Washington.

Table C.1.

Well Name	Primary Unit	Primary Unit Isolated	All Units	Unit Comment	Ref Elev.	Stickup	OI Top Bgs	OI Bot Bgs	Screen Top Bgs	Screen Bot Bgs
299-E13-14	5	Y	5	8;9 below	745.15	2.95	320.00	345.00		
299-E13-5	5	Y	5	8;9 below	743.06	1.10	330.00	365.00		
299-E16-1	9A	No, basalt confined present	5,8,9ABC basalt	upper units seal	696.44	1.80	468.00	510.00	468.00	510.00
299-E16-2	1	Yes	1		681.09	2.50	265.00	336.00		
299-E17-1	1	Yes	1		719.17	2.50	303.00	333.00		
299-E17-10	5	Yes	5		714.74		305.00	320.00		
299-E17-12	5	Yes	5		721.70	2.70	313.00	334.00		
299-E17-13	5	Yes	5		719.25	1.90	317.00	337.00		
299-E17-14	5	Yes	5		722.18	3.08	311.60	331.50	309.50	330.10
299-E17-15	5	Yes	5		721.78	3.08	309.50	329.60	310.50	330.00
299-E17-16	5	Yes	5		720.58	2.80	310.00	330.00	309.00	330.00
299-E17-17	1	Yes	1		719.92	2.95	310.90	331.40	309.00	331.40
299-E17-18	5	Yes	5		720.65	3.00	311.20	331.50	308.70	329.30
299-E17-19	1	Yes	1		719.33	2.95	306.30	326.60	304.00	326.60
299-E17-2	5	Yes	5		716.07	2.00	303.00	343.00		
299-E17-20	1	Yes	1		719.23	2.99	303.60	323.60	303.60	323.80
299-E17-3	5	Yes	5; 8 at base		715.47	2.00	303.00	398.00		
299-E17-4	5	Yes	5		717.05		298.00	379.00		
299-E17-5	5	Yes	5		718.69	1.40	298.00	330.00		
299-E17-6	9	No, 5 at 315 ft to 367	5, 8, 9	9 at 425 to 500 ft	720.10	2.90	300.00	460.00		
299-E17-7	5	Yes	5		719.19	2.00	300.00	374.00		
299-E17-8	5	Yes	5		718.38	1.70	303.00	342.00		
299-E17-9	5	Yes	5		717.64	1.70	310.00	320.00		
299-E18-1	1	Yes, but 8, & 9 below	1	screen shallow	720.24	3.80	311.20	331.50	308.50	329.00
299-E18-2	1	Yes, but 8, & 9 below	1	screen shallow	721.21	2.90	309.20	329.50	309.10	329.70
299-E18-3	1	Yes, but 8, & 9 below	1	screen shallow	722.04	3.55	309.70	329.90	309.40	329.90
299-E18-4	1	Yes, but 8, & 9 below	1	screen shallow	721.57	3.20	309.00	329.20	307.90	328.40
299-E19-1	na	No, but 1,5,8,& 9 present	NA	Well plugged	734.46					

Table C.1. (contd)

Well Name	Primary Unit	Primary Unit Isolated	All Units	Unit Comment	Ref Elev.	Stickup	OI Top Bgs	OI Bot Bgs	Screen Top Bgs	Screen Bot Bgs
299-E23-1	1	Yes, but 9 present below		screen shallow	713.10	3.70	310.00	340.00		
299-E23-2	1	No, 9A at 392 ft & 9C at 420 ft	1;9A,B, C	basalt at bottom	720.64		304.00	435.00		
299-E24-1	5	Yes	5		716.22	1.70	300.00	341.00		
299-E24-10	5	Yes	5		715.94		278.50	320.00		
299-E24-11	1	Yes	1		718.39	2.40	308.00	362.00		
299-E24-12	1	Yes	1		716.28	1.70	310.00	320.00		
299-E24-13	1	Yes	1		691.32	0.40	270.00	338.00		
299-E24-14	1	Yes	1		691.31	0.40	270.00	338.00		
299-E24-16	1	Yes	1		718.27	3.00	304.40	324.40		
299-E24-17	1	Yes	1		718.69	3.00	308.80	329.00		
299-E24-18	1	Yes	1		719.28	3.00	306.50	327.50		
299-E24-19	1	Yes	1		693.65	2.80	279.60	300.00		
299-E24-2	1	Yes	1		717.47	2.10	295.00	348.00		
299-E24-20	1	Yes	1		689.28	3.43	279.20	299.70		
299-E24-3	1	Yes	1		698.69	1.70	277.00	331.00		
299-E24-4	1	Yes	1		696.69	1.90	272.00	298.00		
299-E24-5	1	Yes	1		696.61	1.80	274.00	327.00		
299-E24-7	1	Yes	1		716.01	2.20	305.00	350.00		
299-E24-8	1	No, screened 9 from 362-TD	1, 8, 9		688.81	1.20	280.00	372.00		
299-E25-1	1	Yes	1		690.57	0.36	280.00	310.00		
299-E25-10	1	Yes	1		655.84	1.90	226.00	291.00		
299-E25-11	1	Yes	1		681.31	1.60	265.00	335.00		
299-E25-12	1	Yes	1		680.95		265.00	338.00		
299-E25-13	1	Yes	1		682.43	0.30	256.00	315.00		
299-E25-15	1	Yes	1		689.73	0.43	270.00	338.00		
299-E25-16	1	Yes	1		691.17	0.30	270.00	338.00		
299-E25-17	1	Yes	1		690.00	1.90	273.00	295.00		
299-E25-18	1	Yes	1		679.27		269.00	294.00		
299-E25-19	1	Yes	1		677.20		270.00	295.00		
299-E25-2	1	Yes	1		675.45	1.90	276.00	316.00		
299-E25-20	1	Yes	1		676.30		269.00	294.00		
299-E25-21	1	Yes	1		677.27	2.60	270.00	293.00		

Table C.1. (contd)

Well Name	Primary Unit	Primary Unit |Isolated	All Units	Unit Comment	Ref Elev.	Stickup	OI Top Bgs	OI Bot Bgs	Screen Top Bgs	Screen Bot Bgs
299-E25-22	1	Yes	1		674.02	2.40	265.00	295.00		
299-E25-23	1	Yes	1		680.13	2.40	273.00	304.00		
299-E25-24	1	Yes	1		679.55		270.00	290.00		
299-E25-25	1	Yes	1		669.42		269.00	289.00		
299-E25-26	8	No, 1 present, 9 below screen	1, 8	8 very sandy	668.55	0.04	269.00	289.00		
299-E25-27	1	Yes	1		676.08	2.00	274.00	294.00		
299-E25-28	9	Yes, but may contact basalt	9	218 ft of casing above screen has no seal.	662.44	2.10	320.00	348.00	320.00	340.00
299-E25-29P	1	Y	1		673.06	0.77	252.00	297.00	256.60	276.50
299-E25-29Q	1	Y	1		673.06	0.77	321.00	330.00	325.00	330.00
299-E25-3	1	Yes	1		693.02	5.75	270.00	312.00		
299-E25-30P	1	Yes	1		678.15	0.30	260.00	290.00	263.50	283.50
299-E25-30Q	1	Yes	1		678.15	0.30	321.00	330.00	325.00	330.00
299-E25-31	1	Yes	1		672.76	2.10	259.00	279.00		
299-E25-32P	1	Y	1		670.38	2.30	253.00	284.80	259.40	279.40
299-E25-32Q	9A	Y	9A	9B & C below	670.38	2.30	310.50	338.00	320.00	330.60
299-E25-33	1	Yes	1		650.03		261.90	282.20		
299-E25-34	1	Y	1		662.87	2.25	251.00	276.00	251.60	271.60
299-E25-35	1	Yes	1		674.39	3.40	260.50	281.00		
299-E25-36	1	No, 9 present at screen base	1;8;9		707.39	3.00	296.70	317.60		
299-E25-37	1	Yes	1		673.29	3.00	260.00	280.70		
299-E25-38	1	Yes	1		673.52	3.00	258.60	279.60		
299-E25-39	1	Yes	1		671.23	2.78	257.50	277.80		
299-E25-4	1	Yes	1		675.04	2.40	234.00	281.00		
299-E25-40	1	Yes	1		665.71	2.90	252.00	273.00		
299-E25-41	1	Yes	1		671.26	3.20	255.30	276.30		
299-E25-42	1	Yes	1		683.06	3.85	267.60	288.90		
299-E25-43	1	Yes	1		649.89	3.37	238.40	259.40		
299-E25-44	1	Yes	1		675.29	2.39	265.80	285.90		

Table C.1. (contd)

Well Name	Primary Unit	Primary Unit Isolated	All Units	Unit Comment	Ref Elev.	Stickup	OI Top Bgs	OI Bot Bgs	Screen Top Bgs	Screen Bot Bgs
299-E25-45	1	Yes	1		678.45	2.71	265.80	297.60	269.40	289.60
299-E25-46	1	Yes	1		694.81	3.02	286.00	306.30		
299-E25-47	1	Yes	1		673.77	3.36	263.00	283.20		
299-E25-48	1	Yes	1		682.31	2.63	274.30	294.60		
299-E25-5	1	Yes	1		657.71		235.00	291.00		
299-E25-6	1	Yes	1		658.31	1.80	234.00	288.00		
299-E25-7	1	Yes	1		657.15	2.50	235.00	290.00		
299-E25-8	1	Yes	1		658.31		244.00	284.00		
299-E25-9	1	Yes	1		654.86	1.50	233.00	288.00		
299-E26-1	1	Yes, but in contact w/basalt	1		617.25	1.90	217.00	227.00		
299-E26-10	1	Yes	1		601.47	2.98	190.50	206.10		
299-E26-11	1	Yes	1		599.68	2.96	200.00	205.80		
299-E26-12	1	Yes	1		630.74	3.47	217.60	238.60		
299-E26-13	1	Yes	1		605.02	3.47	191.70	212.30		
299-E26-2	1	Yes	1		635.30	2.10	220.00	265.00		
299-E26-3	1	Yes	1		641.18		222.00	272.00		
299-E26-4	1	Yes	1		647.76	2.00	225.00	281.00		
299-E26-5	1	Yes	1		651.07		237.00	290.00		
299-E26-6	1	Yes	1		644.78		250.00	290.00		
299-E26-8	basalt	Y, but may connect to 1	basalt, 1		619.83	2.70	326.00	396.00		
299-E26-9	1	Yes	1		602.89	3.00	190.30	200.90		
299-E27-1	1	Yes	1		682.55	2.53	262.00	331.00		
299-E27-10	1	Yes	1		624.47	2.05	212.10	232.40		
299-E27-11	1	Yes	1		643.29	2.95	230.40	251.40		
299-E27-12	1	Yes	1		660.96	3.30	246.50	267.60		
299-E27-13	1	Yes	1		668.99	3.00	253.60	274.70		
299-E27-14	1	Yes	1		658.34	3.00	245.80	266.80		
299-E27-15	1	Yes	1		652.67	2.80	238.00	259.00		
299-E27-16	1	Yes	1		652.13	2.90	238.70	259.70		
299-E27-17	1	Yes	1		634.72	3.47	223.20	244.20		
299-E27-18	1	Yes	1		650.15	3.01	241.40	261.50		
299-E27-19	1	Yes	1		650.88	3.05	242.00	262.10		
299-E27-2	1	Yes	1							

Table C.1. (contd)

Well Name	Primary Unit	Primary Unit Isolated	All Units	Unit Comment	Ref Elev.	Stickup	OI Top Bgs	OI Bot Bgs	Screen Top Bgs	Screen Bot Bgs
299-E27-3	1	Yes, but 8 & 9 may be below	1, 8?, 9?		683.27		265.00	348.00		
299-E27-5	1	Yes, but 8 & 9 may be below	1, 8?, 9?		685.01		262.00	333.00		
299-E27-7	1	Yes	1		634.67	1.30	241.00	281.00		
299-E27-8	1	Yes	1		637.83	3.20	225.50	245.50		
299-E27-9	1	Yes	1		629.21	1.90	219.80	239.10		
299-E28-1	1	Y, but in contact with basalt	1		685.20	2.70	277.00	324.00		
299-E28-10	1	Y, but in contact with basalt	1		677.67		257.00	309.00		
299-E28-11	9	N probably in contact with 1	1;9		701.00	3.20	340.00	347.00		
299-E28-12	9	N probably in contact with 1	1;9		708.60	2.40	306.00	349.00		
299-E28-13	9	N probably in contact with 1	1;9		706.00	2.90	304.30	368.00		
299-E28-14	1	Y	1		694.74		294.47	352.00		
299-E28-16	1	Yes	1		703.12	2.75	270.00	323.00		
299-E28-17	1	Y	1		708.56	2.00	289.00	335.00		
299-E28-18	1	Y	1		692.58	2.70	260.00	325.00		
299-E28-19	1	Y	1		697.49	2.45	260.00	325.00		
299-E28-2	1	Y, but in contact with basalt	1		680.91	1.60	288.00	318.00		
299-E28-20	1	Y	1		690.29	3.20	260.00	325.00		
299-E28-21	1	Y	1		688.75	2.25	257.00	325.00		
299-E28-22	1	Y, but in contact with basalt	1	functional well?	700.40	1.00				

Table C.1. (contd)

Well Name	Primary Unit	Primary Unit Isolated	All Units	Unit Comment	Ref Elev.	Stickup	OI Top Bgs	OI Bot Bgs	Screen Top Bgs	Screen Bot Bgs
299-E28-23	1	Y, but in contact with basalt	1				278.00	328.00		
299-E28-24	1	Y, but in contact with basalt	1				277.00	327.00		
299-E28-25	1	Y, but in contact with basalt	1			1.90	279.00	329.00		
299-E28-26	1	Y, but in contact with basalt	1		687.26	2.40	276.20	328.50	278.80	298.80
299-E28-27	1	Y	1		680.37	2.20	263.80	301.50	269.80	289.80
299-E28-28	1	Y	1		686.55	3.00	271.50	294.80	275.00	295.00
299-E28-3	1	Y	1		692.86		314.00	324.00		
299-E28-4	1	Y	1		691.55	2.00	295.00	321.00		
299-E28-5	1	Y, but in contact with basalt	1		672.32	1.70	259.00	304.00		
299-E28-6	1	Y	1		700.11	2.30	310.00	339.00		
299-E28-7	1	Y, but in contact with basalt	1		685.91	2.00	270.00	335.00		
299-E28-8	1	Y, but in contact with basalt	1		668.52	1.50	250.00	294.00		
299-E28-9	1	Y	1		700.77	1.80	290.00	340.00		
299-E32-1	1	Y, but in contact with basalt	1		656.17	1.40	241.00	271.00		
299-E32-10	1	Y, but in contact with basalt	1		637.93	3.05	220.80	245.80	225.00	245.30
299-E32-2	1	Y, but in contact with basalt	1		670.06	2.20	251.90	289.20	257.80	277.80
299-E32-3	1	Y	1		676.51	1.20	262.00	304.00	266.20	286.20
299-E32-4	5	Y	5		685.88	1.20	272.00	311.00	278.10	298.10
299-E32-5	1	Y	1		682.14	3.02	265.60	291.20	270.80	291.80
299-E32-6	1	Y	1		667.45	3.51	250.00	278.30	254.50	275.50

Table C.1. (contd)

Well Name	Primary Unit	Primary Unit Isolated	All Units	Unit Comment	Ref Elev.	Stickup	OI Top Bgs	OI Bot Bgs	Screen Top Bgs	Screen Bot Bgs
299-E32-7	1	Y	1		658.42	3.53	242.30	270.60	245.60	266.60
299-E32-8	1	Y	1		645.59	3.46	230.50	256.70	234.70	255.30
299-E32-9	1	Y	1		643.33	3.53	227.20	254.60	230.70	251.30
299-E33-10	1	Y, but in contact with basalt	1		671.18	2.86	259.00	285.00	259.00	285.00
299-E33-12	basalt interbed	Y	interbed upper		623.45	2.40	305.00	385.00	305.00	385.00
299-E33-13	1	Y, but in contact with basalt	1		628.39	2.47	210.00	235.00		
299-E33-14	1	Y, but in contact with basalt	1		622.05	2.50	212.00	227.00		
299-E33-15	1	Y, but in contact with basalt	1		627.29	2.51	222.00	237.00		
299-E33-16	1	Y, but in contact with basalt	1		632.53	0.50	231.00	246.00		
299-E33-17	1	Y, but in contact with basalt	1		631.65	1.75	220.00	242.50		
299-E33-18	1	Y, but in contact with basalt	1		651.86	2.52	240.00	266.00		
299-E33-19	1	Y, but in contact with basalt	1		638.72	2.00	217.00	248.00		
299-E33-1A	1	Y	1		632.11	2.59	215.00	233.40		
299-E33-2	1	Y, but in contact with basalt	1		630.62	2.60	220.00	233.00		
299-E33-20	1	Y, but in contact with basalt	1		640.08	1.25	225.00	254.00	239.00	254.00
299-E33-21	1	Y, but in contact with basalt	1		668.13	4.60	235.00	275.00		

Table C.1. (contd)

Well Name	Primary Unit	Primary Unit Isolated	All Units	Unit Comment	Ref Elev.	Stickup	OI Top Bgs	OI Bot Bgs	Screen Top Bgs	Screen Bot Bgs
299-E33-22	1	Y	1		629.20	2.60	217.00	231.00		
299-E33-23	1	Y	1		628.44	3.10	218.00	230.00		
299-E33-24	1	Y, but in contact with basalt	1		637.97	2.00	219.00	241.00		
299-E33-25	1	Y, but in contact with basalt	1		631.02	3.17	199.00	233.00		
299-E33-26	1	Y, but in contact with basalt	1		632.77	2.43	199.00	220.00		
299-E33-27	5	Y	5		656.17	0.30	240.00	255.00		
299-E33-28	1	Y	1		664.23	1.60	247.80	278.30	255.70	275.70
299-E33-29	5	Y, but in contact with basalt	5		673.77	2.20	257.00	290.50	262.80	282.80
299-E33-3	1	Y	1		630.62	2.60	219.00	231.00		
299-E33-30	1	Y, but in contact with basalt	1		663.70	1.80	251.50	280.10	255.00	275.00
299-E33-31	1	Y, but in contact with basalt	1		647.50	3.06	231.20	255.90	234.90	255.90
299-E33-32	1	Y, but in contact with basalt	1		660.05	3.09	243.20	267.40	246.40	267.40
299-E33-33	1	Y, but in contact with basalt	1		640.17	2.99	224.20	246.80	227.30	248.30
299-E33-34	1	Y, but in contact with basalt	1		633.33	2.94	216.60	239.30	219.00	239.30
299-E33-35	1	Y, but in contact with basalt	1		643.01	2.96	224.80	249.20	228.30	249.30
299-E33-36	1	Y, but in contact with basalt	1		646.67	3.00	230.40	259.00	234.40	255.40

Table C.1. (contd)

Well Name	Primary Unit	Primary Unit Isolated	All Units	Unit Comment	Ref Elev.	Stickup	OI Top Bgs	OI Bot Bgs	Screen Top Bgs	Screen Bot Bgs
299-E33-37	1	Y, but in contact with basalt	1		653.01	3.09	237.60	264.30	240.30	261.10
299-E33-38	1	Y, but in contact with basalt	1		631.95	2.00	212.50	239.60	218.60	239.60
299-E33-39	1	Y, but in contact with basalt	1		623.32	2.90	203.10	230.10	208.20	229.20
299-E33-4	1	Y, but in contact with basalt	1		629.84	2.66	215.00	231.00		
299-E33-40	basalt interflow	Y	bottom 1st flow		624.58	3.32	286.10	308.10	293.90	304.90
299-E33-41	1	Y, but in contact with basalt	1		654.95	3.42	243.10	262.00	244.90	261.00
299-E33-42	1	Y, but in contact with basalt	1		654.30	3.42	233.00	256.80	238.50	259.50
299-E33-43	1	Y, but in contact with basalt	1		662.68	3.50	246.90	273.70	250.20	271.30
299-E33-5	1	Y, but in contact with basalt	1		634.72	2.56	218.00	235.50		
299-E33-6	1	Y, but in contact with basalt	1		628.18	2.90	214.00	229.00		
299-E33-7	1	Y, but in contact with basalt	1		626.58	4.00	215.00	231.00		
299-E33-8	1	Y, but in contact with basalt	1		650.73	3.60	230.00	257.00		
299-E33-9	1	Y, but in contact with basalt	1		650.40	0.60	252.00	262.00		

Table C.1. (contd)

Well Name	Primary Unit	Primary Unit Isolated	All Units	Unit Comment	Ref Elev.	Stickup	OI Top Bgs	OI Bot Bgs	Screen Top Bgs	Screen Bot Bgs
299-E34-1	1	Y, but in contact with basalt	1		629.45	2.45	215.00	230.00		
299-E34-10	1	Y, but in contact with basalt	1		639.77	2.76	222.10	249.00	225.30	246.40
299-E34-11	1	Y, but in contact with basalt	1		617.95	3.16	202.10	219.30	207.50	217.90
299-E34-12	1	Y, but in contact with basalt	1		638.83	2.97	220.80	245.30	223.90	244.50
299-E34-2	1	Y, but in contact with basalt	1		630.80	1.80	212.80	241.50	219.90	239.90
299-E34-3	1	Y, but in contact with basalt	1		611.52	2.04	184.00	213.90	193.00	213.00
299-E34-5	1	Y, but in contact with basalt	1		590.79	1.80	158.00	192.00	170.50	190.50
299-E34-6	1	Y, but in contact with basalt	1		597.83	1.27	163.00	195.00	175.00	195.00
299-E34-7	1	Y, but in contact with basalt	1		604.25	3.11	189.30	204.10	193.90	204.60
299-E34-8	1	Y	1		640.52	3.00	224.20	249.40	227.90	247.90
299-E34-9	1	Y, but in contact with basalt	1		628.69	2.72	205.10	234.50	212.60	233.70
299-E35-2	1	Y, but in contact with basalt	1		602.10	2.95	186.90	201.50	190.90	201.50
699-32-43	1	Y	1		516.62	3.00	110.00	120.00		
699-32-62	5	Y	5;8;9	Two piezometer	707.09	1.90	365.00	375.00		
699-32-62P	9	Y	5;8;9		707.09	1.90	485.00	501.00	490.00	500.00
699-33-56	5	Y	5;8		717.03	1.55	315.00	409.00		

Table C.1. (contd)

Well Name	Primary Unit	Primary Unit Isolated	All Units	Unit Comment	Ref Elev.	Stickup	OI Top Bgs	OI Bot Bgs	Screen Top Bgs	Screen Bot Bgs
699-34-42	1	Y	1		540.20	3.00	123.00	145.00		
699-34-51	5	Y	5	8 below screen	736.76	3.95	340.00	381.00		
699-36-61A	5	Y	5		748.11	1.60	330.00	363.00		
699-37-47A	5	Y	5			?	304.50	340.80	307.50	?
699-38-61	5	Y	5							
699-38-65	9	Y, but may connect to 5	5;8;9		753.33	2.30	460.00	536.00	500.00	510.00
699-39-39	8	N, 9A now vadose	8;9A,B, C	9B,C below	536.65	2.60	110.00	1807.00		
699-40-33A	5	N	5;8		518.05	1.48	106.00	160.00		
699-40-33B	9A	N	8;9A,B, C		518.00	1.86	233.00	283.00	233.00	273.00
699-40-33C	8	Yes, but 9A, B & C below	8;9A,B, C		518.00	2.00	160.00	160.00		
699-40-36	9A	Yes, but 9 C below	9B;9C	8 very thick	528.92	3.10	203.60	223.20	209.20	219.50
699-40-39	9A	Yes, but 9 B & C below	9A,B,C		541.84	2.89	198.00	212.20	201.00	211.50
699-40-40A	9A	Y	9A,B,C	unit 9B, 224-226 ft	541.21	3.46	208.50	226.10	215.10	225.87
699-40-40B	9A	Y	9A,B,C		541.96	3.50	183.00	199.60	187.80	198.60
699-40-62	5	Y, isolated from 9 by 8 below	5;8;9A, B, C		747.78	0.13	335.00	369.00		
699-41-35	9A	Y	9A,B,C	9A & 9C saturated	520.38	3.00	183.50	201.90	189.80	200.10
699-41-40	9A	Y, but 9B & 9C maybe below	9A,B,C		545.94	2.94	158.00	175.50	163.90	174.30
699-41-42	9	Y, 9B not present	9	9B missing	643.91	3.61	262.10	285.30	270.30	280.60
699-42-37	9A	Y	8;9A,B, C	9 saturated	519.40	3.22	139.60	159.90	144.20	154.50
699-42-39A	9A	Y, but 5 and 8 saturated	5;8;9A, B,C	5 saturated	558.14	3.47	162.60	179.90	169.40	180.10

Table C.1. (contd)

Well Name	Primary Unit	Primary Unit Isolated	All Units	Unit Comment	Ref Elev.	Stickup	OI Top Bgs	OI Bot Bgs	Screen Top Bgs	Screen Bot Bgs
699-42-39B	9A	Y, but 8 and 9B saturated	8;9A,B	9C may be below	558.32	3.46	194.20	214.20	203.00	213.80
699-42-40A	9A	Y, but in contact with basalt	5;8;9A, B,C	5 saturated	545.53	2.00	140.00	171.00		
699-42-40B	9A	Y, but 5 and 8 saturated	5;8;9A, B,C	5 saturated	546.46	2.00	130.00	150.00		
699-42-40C	basalt	Y	8;9A,B, C	9ABC saturated	546.16	2.00	307.00	390.00		
699-42-41	1	N, in contact with 2 feet of 5	1;5;8	8;9 are below	567.30	3.27	130.30	154.80	134.20	155.20
699-42-42B	9A	Y	8;9A,B, C	9ABC saturated	583.23	4.00	184.90	207.20	192.90	203.50
699-43-40	1	Y	1	8;9 may be below	542.20	3.44	109.50	134.40	114.30	135.30
699-43-41E	9A	Y	8;9A,B, C	9ABC saturated	550.86	2.97	135.20	145.80		
699-43-41F	9A	Y, lower part of unit 9A	8;9A,B, C	9B&C are below	551.01	2.95	160.70	176.20	165.00	175.70
699-43-41G	9A	Y	8;9A,B, C		551.34	3.38	181.80	198.70	188.30	198.60
699-43-43	1	Y	1	8;9 may be below	579.37	3.40	156.80	177.40	159.50	179.50
699-43-45	1	Y	1	9 maybe below	597.68	3.00	179.20	203.60	183.00	203.30
699-44-39B	1	Y	1	9 below screen	513.40	3.78	98.90	118.90	93.90	121.40
699-44-42	1	Y, but may connect to 9	1;9	9 below screen?	579.22	3.30	152.30	172.50	151.00	171.60
699-44-43B	1	Y, but may connect to 9	1;9	9 below screen?	580.12	2.90	149.90	176.20	155.60	176.20
699-44-64	5	Y, but may connect to 9A,C	5;8;9A, B,C		725.60	2.25	316.00	360.00		
699-45-42	9	Y, but in contact with basalt	1		577.33	1.70	158.00	180.00		

Table C.1. (contd)

Well Name	Primary Unit	Primary Unit Isolated	All Units	Unit Comment	Ref Elev.	Stickup	OI Top Bgs	OI Bot Bgs	Screen Top Bgs	Screen Bot Bgs
699-47-35B	9	Y, but in contact with basalt	1		476.36	2.15	65.00	102.00		
699-47-46A	1	Y, but in contact with basalt	1		580.14	2.00	168.00	181.00		
699-47-50	basalt	Y, but maybe contact with 1	1; basalt		584.22	2.50	260.00	295.00		
699-47-60	9	Y, but near basalt surface	1		651.52	2.50	235.00	277.00		
699-48-50	1	Y, but in contact w/ basalt	1; basalt		574.06	2.76	156.30	184.00	159.40	179.70
699-49-55A	1	Y, but in contact with basalt	1		531.03	2.56	124.00	139.00		
699-49-57A	1	Y, but in contact with basalt	1		553.52	2.60	144.00	161.00		
699-49-57B	basalt	Y, upper confined interbed	upper confined	silty sand	555.99	2.77	215.10	230.40	219.30	229.70
699-50-45	basalt	Y	1; basalt		451.41	2.27	133.00	178.00		
699-50-48B	basalt	Y	1; basalt		550.39	1.75	213.00	250.00		
699-50-53A	1	Y, but in contact with basalt	1		557.46	2.50	142.00	156.00		
699-50-53B	basalt	Y	1; basalt		557.62	2.59	208.80	225.00	214.70	224.70

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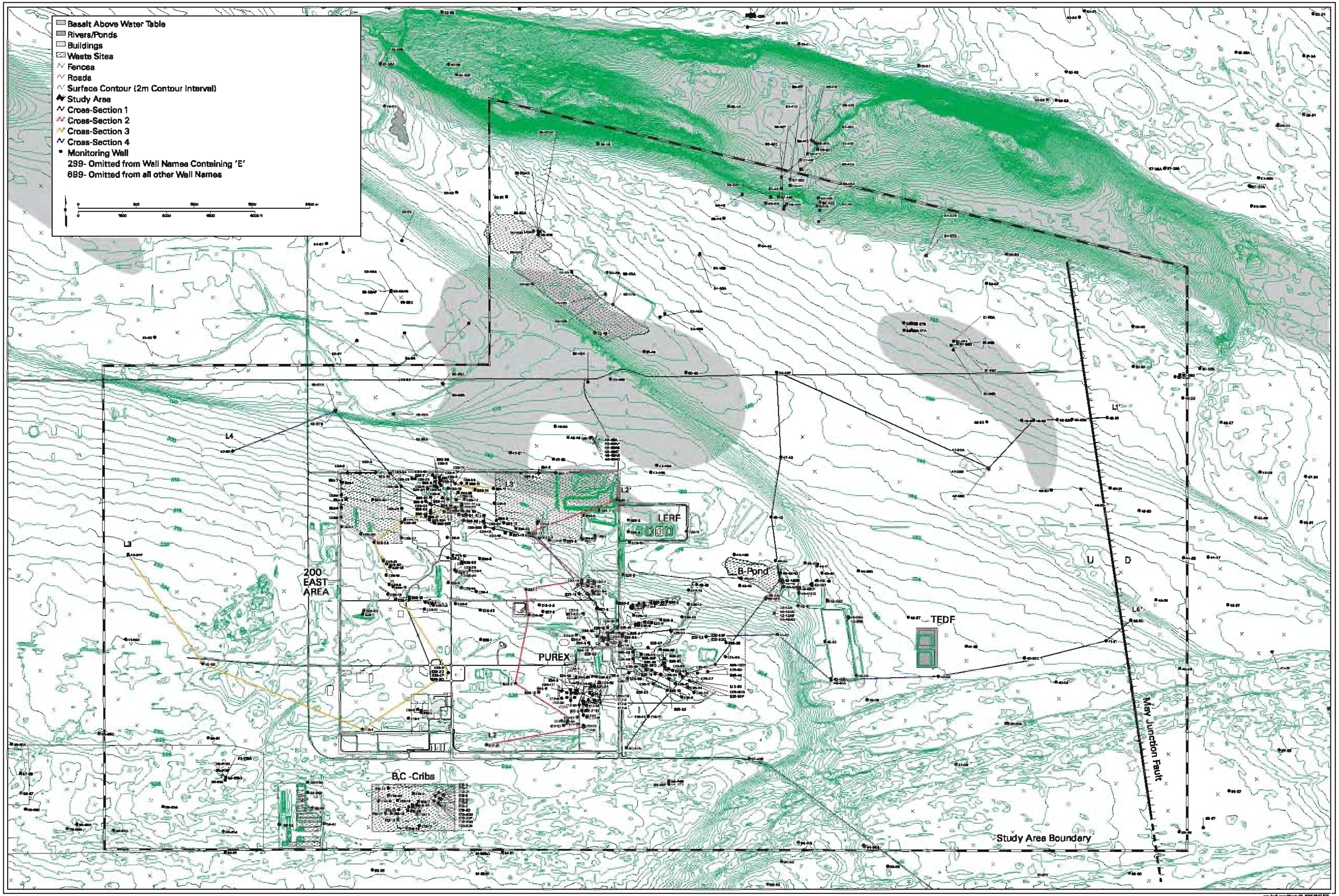


Plate 1. 200 East Study Area and Base Map

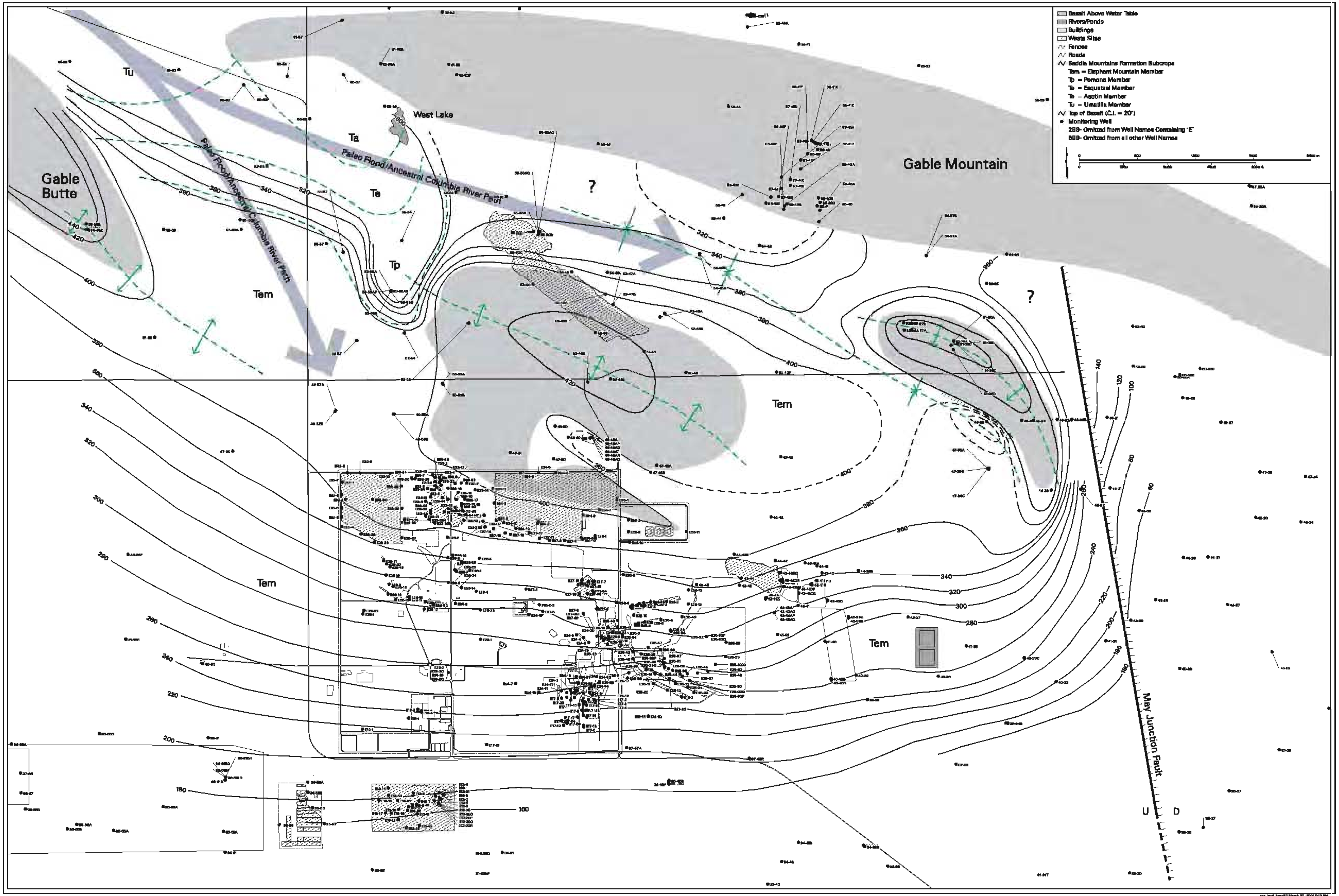


Plate 2. Structure Map of Basalt

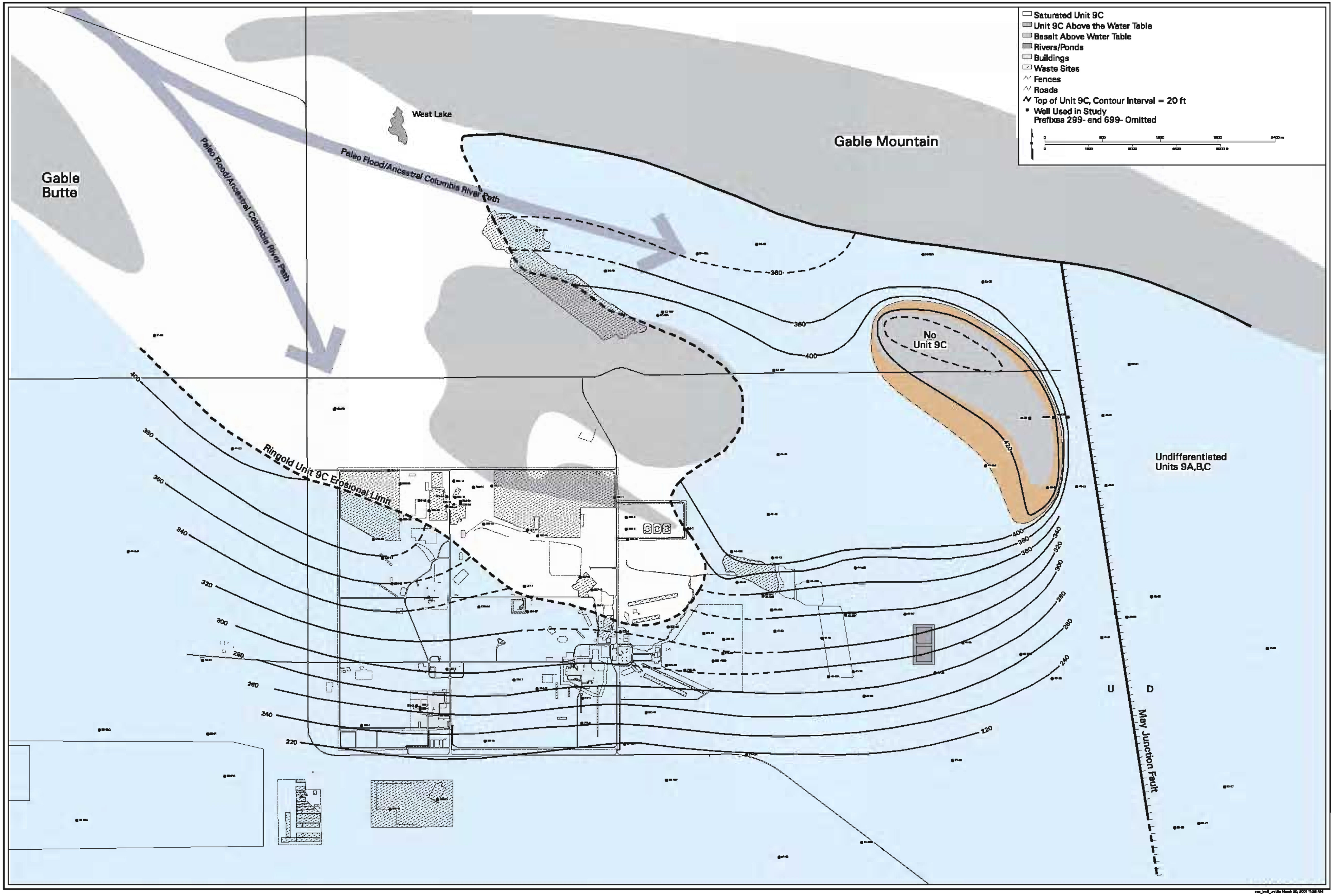


Plate 3. Structure Map of Ringold Formation, Unit 9C, Confined Aquifer

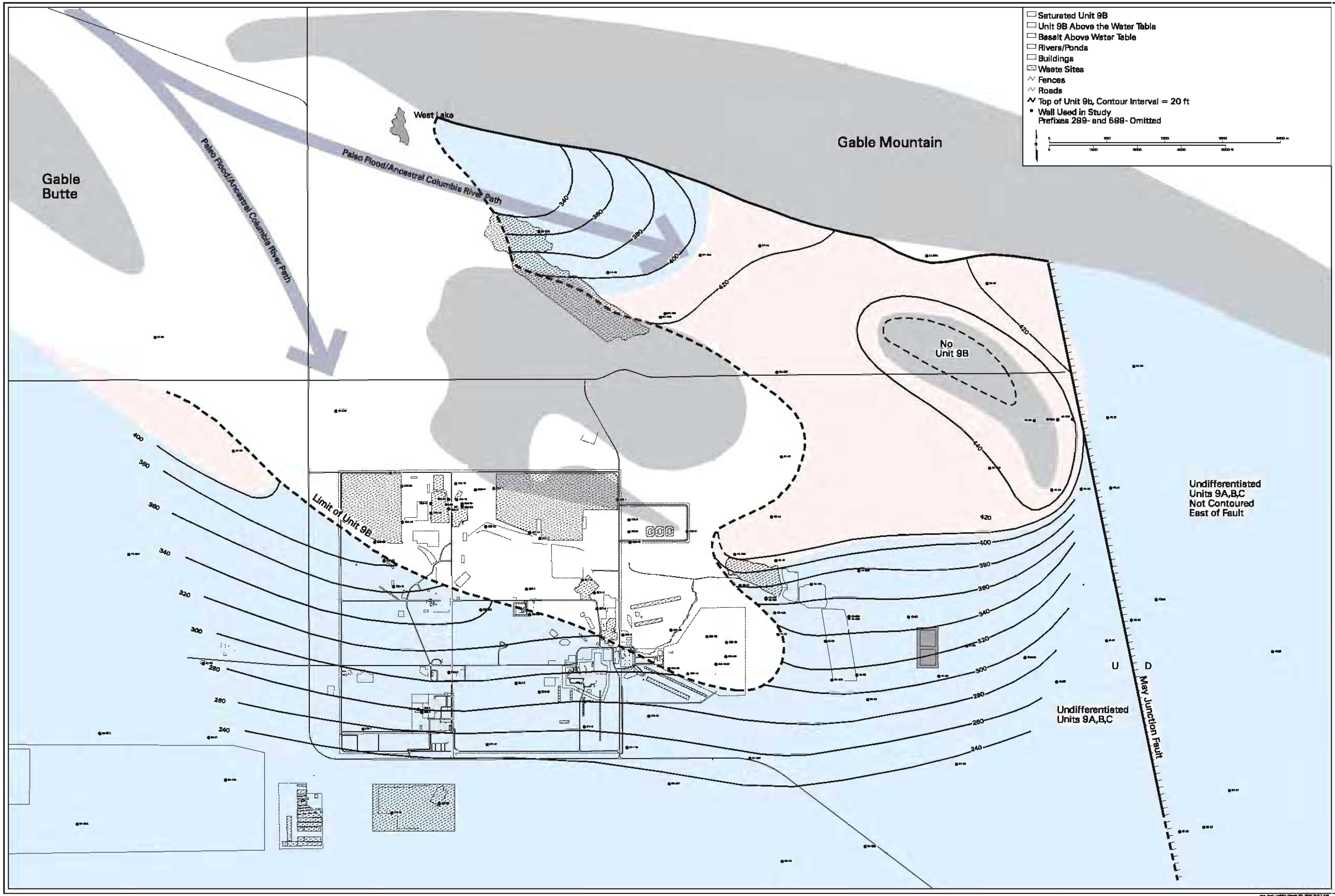


Plate 4. Structure Map of Ringold Formation, Unit 9B, Confining Unit

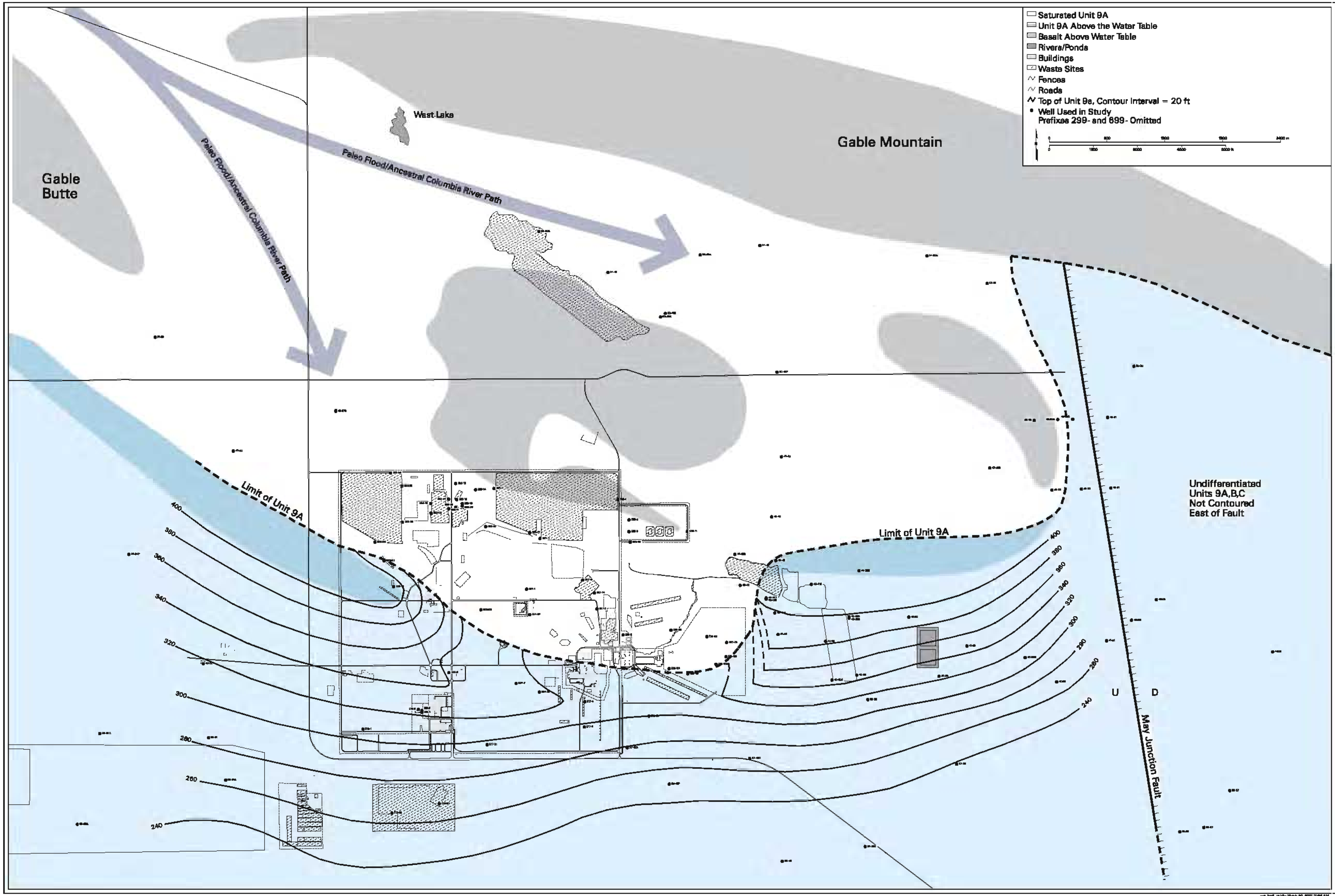


Plate 5. Structure Map of Ringold Formation, Unit 9A

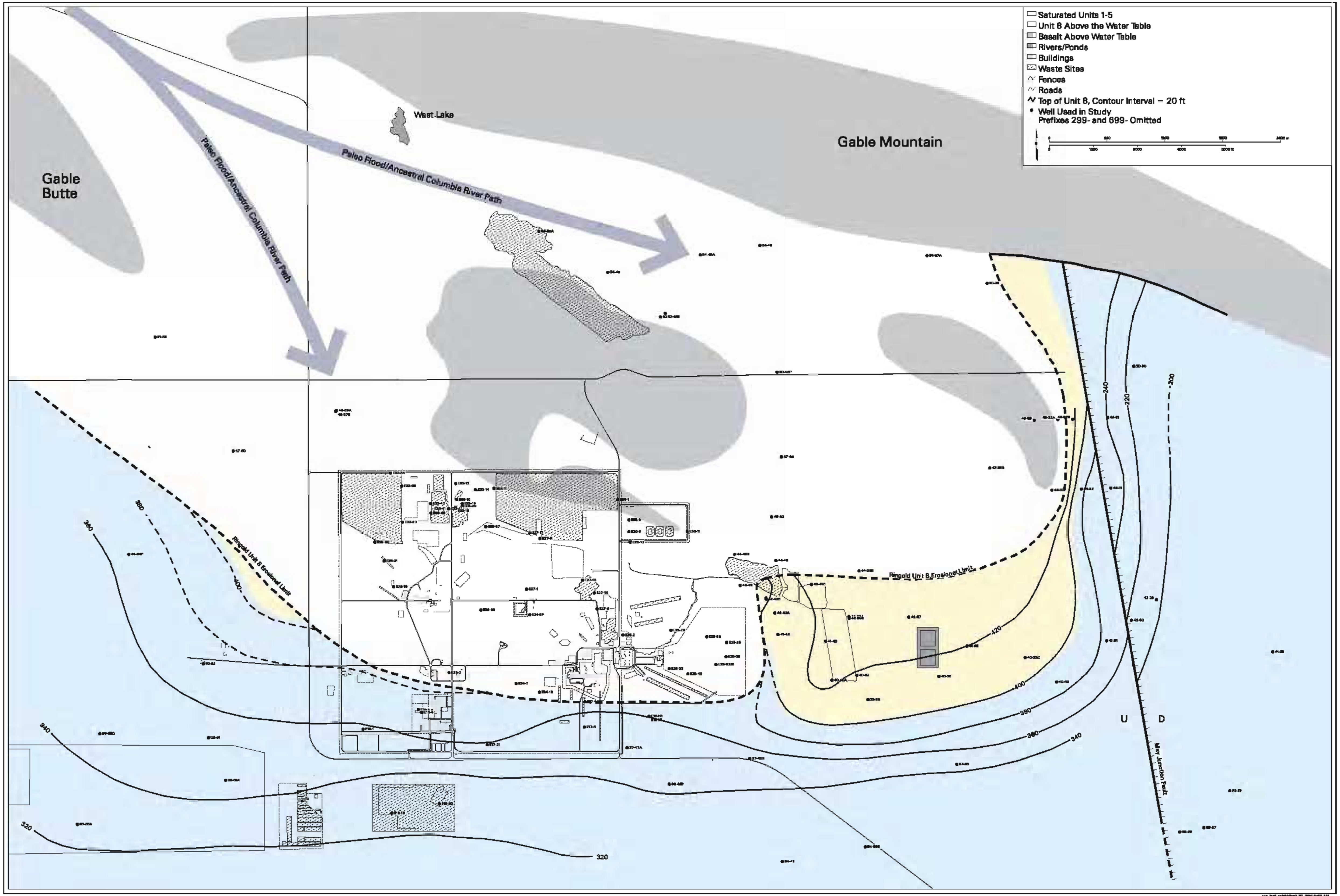


Plate 6. Structure Map of Ringold Formation, Unit 8, Aquifer Confining Unit

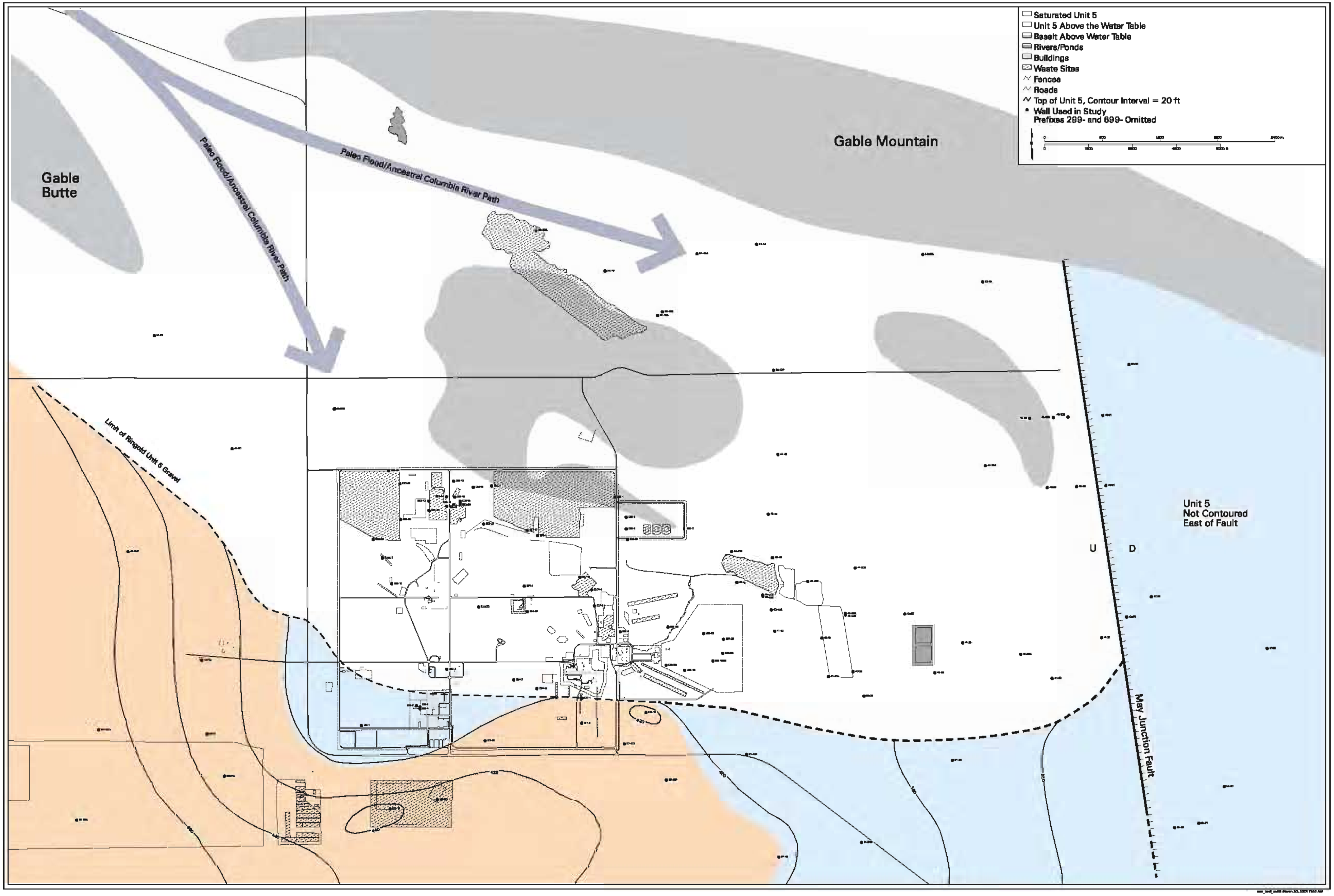
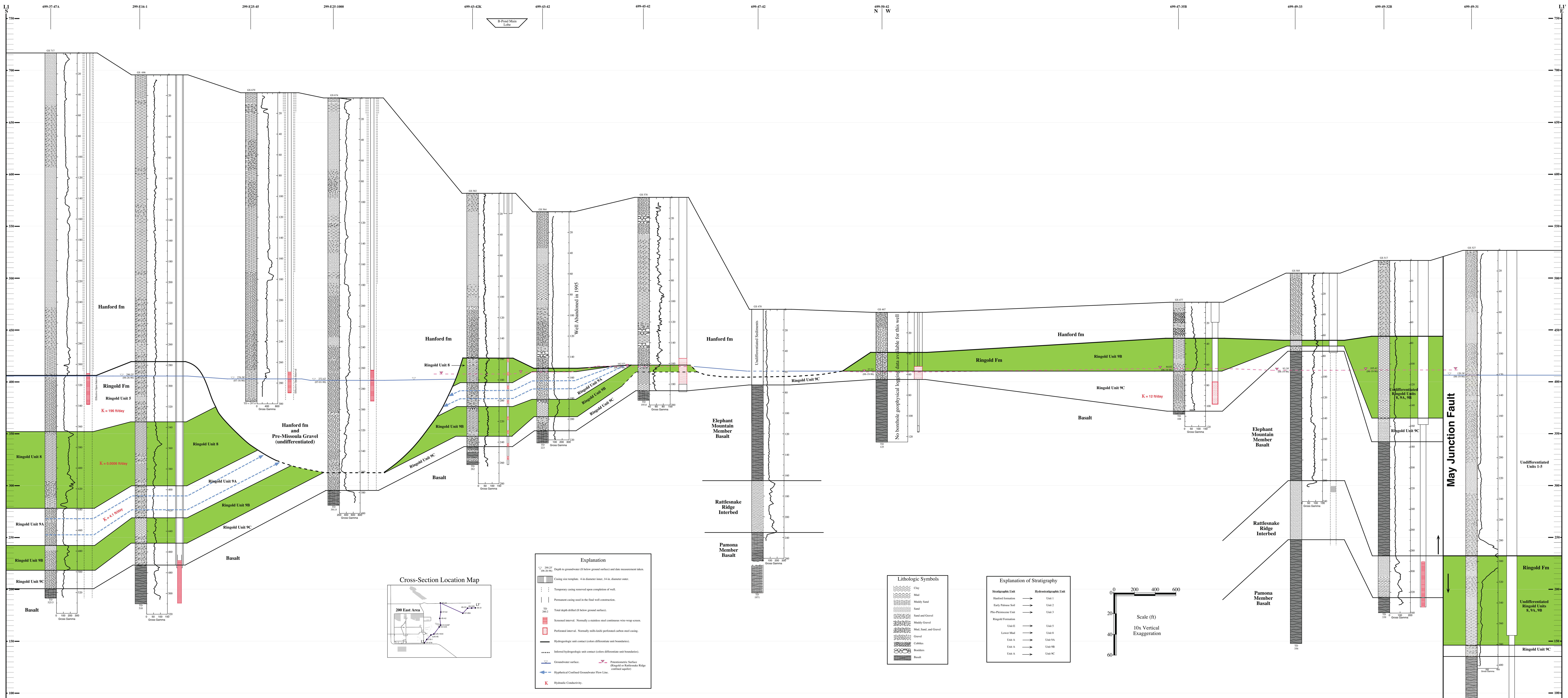
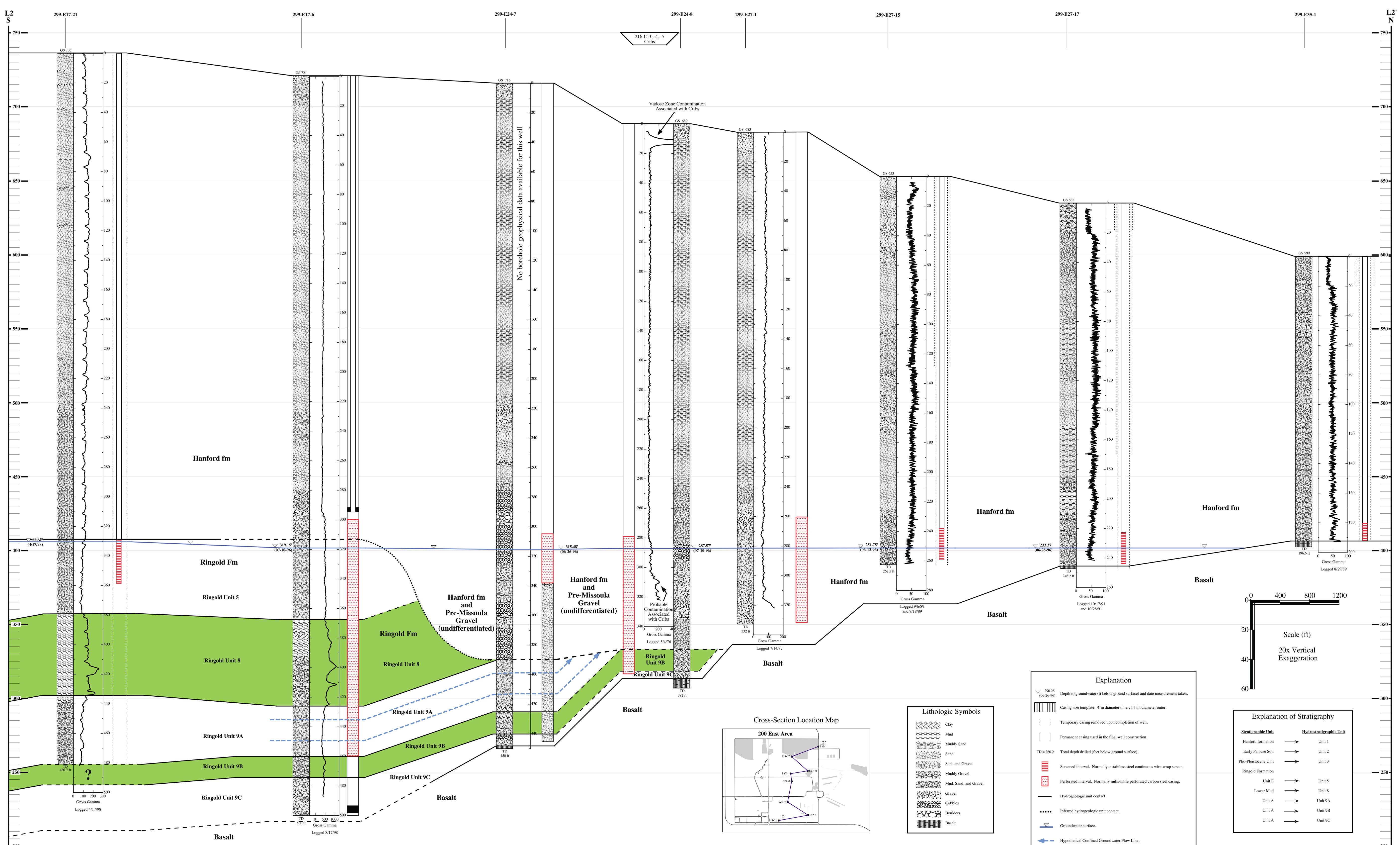


Plate 7. Structure Map of Ringold Formation, Unit 5, Upper Unconfined Aquifer



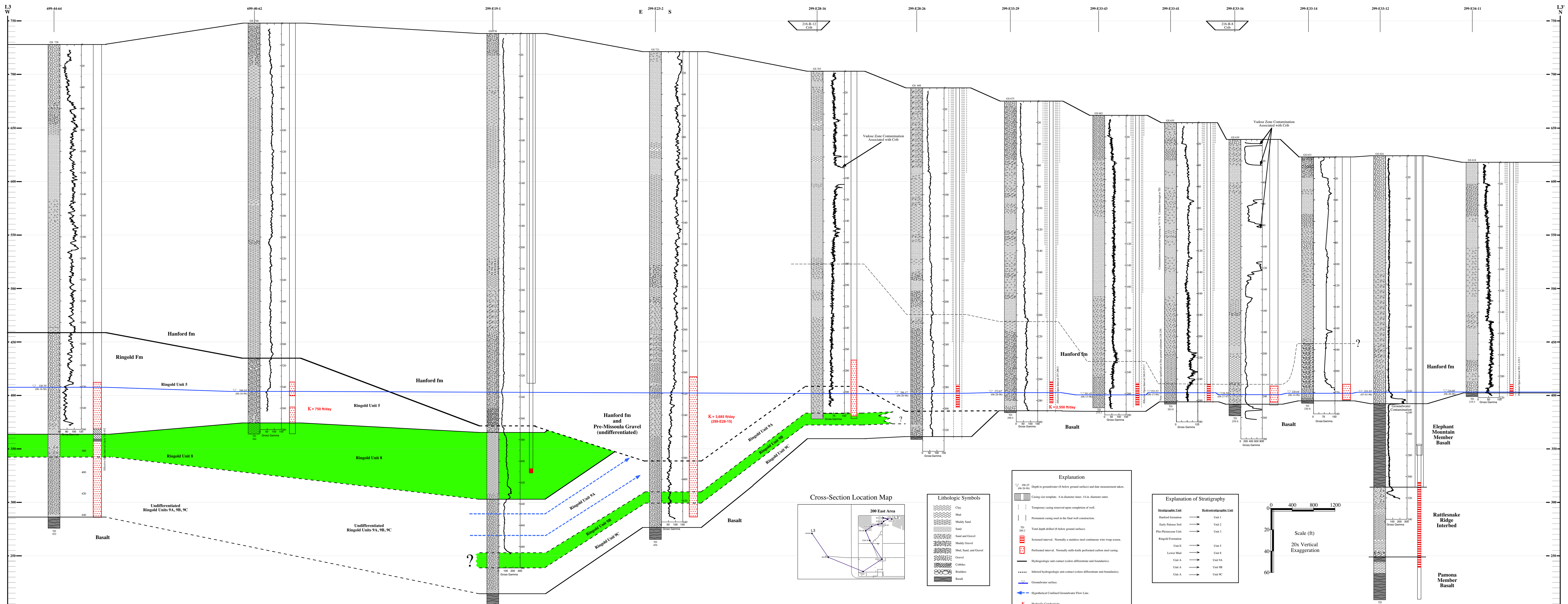
200 East Area Hydrostratigraphy - Line 1



200 East Area Hydrostratigraphy - Line 2

PLATE 8

PLATE 9



200 East Area Hydrostratigraphy - Line 3

200 East Area Hydrostratigraphy - Line 4

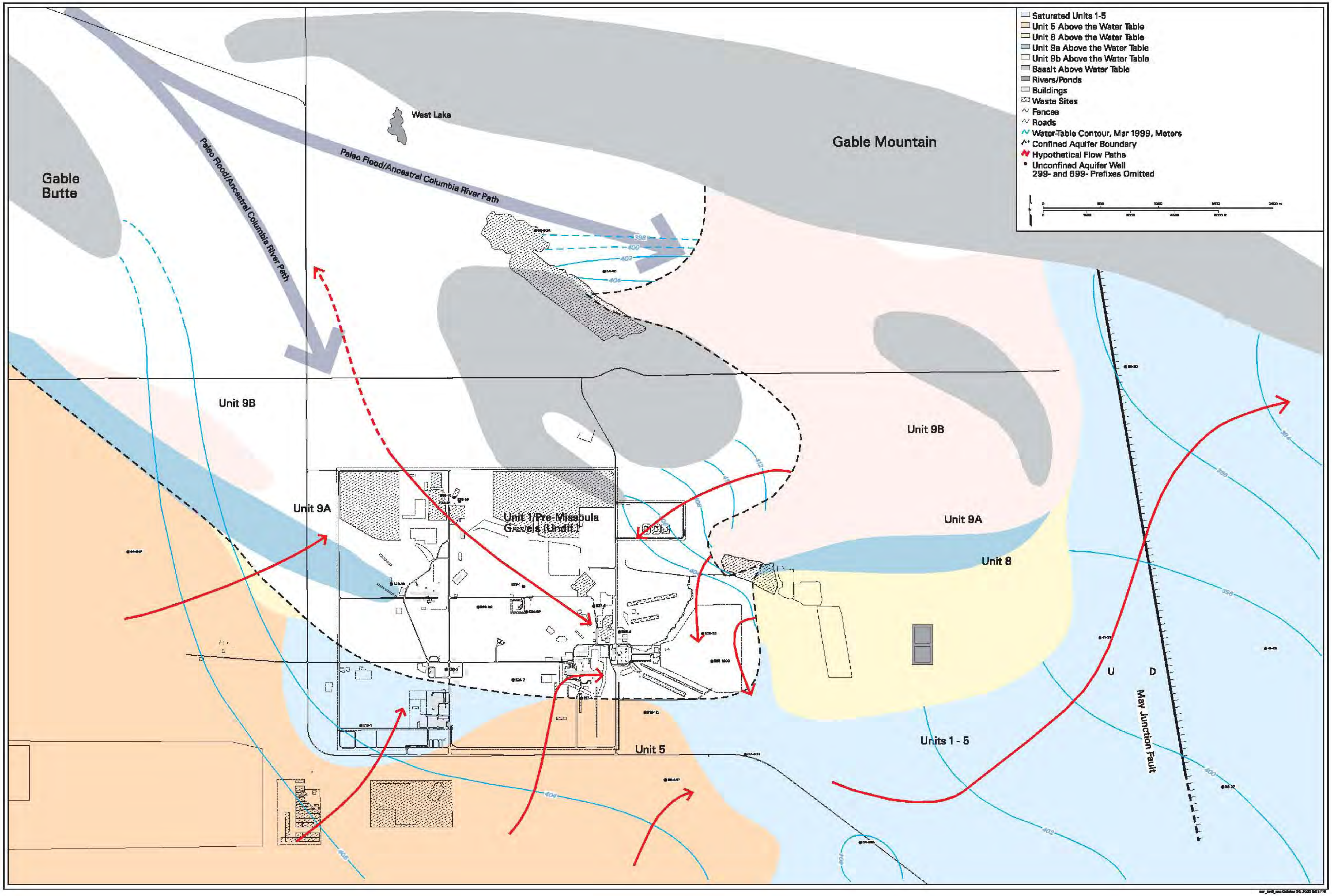


Plate 10. 1999 Revised Water Table, Upper Unconfined Aquifer

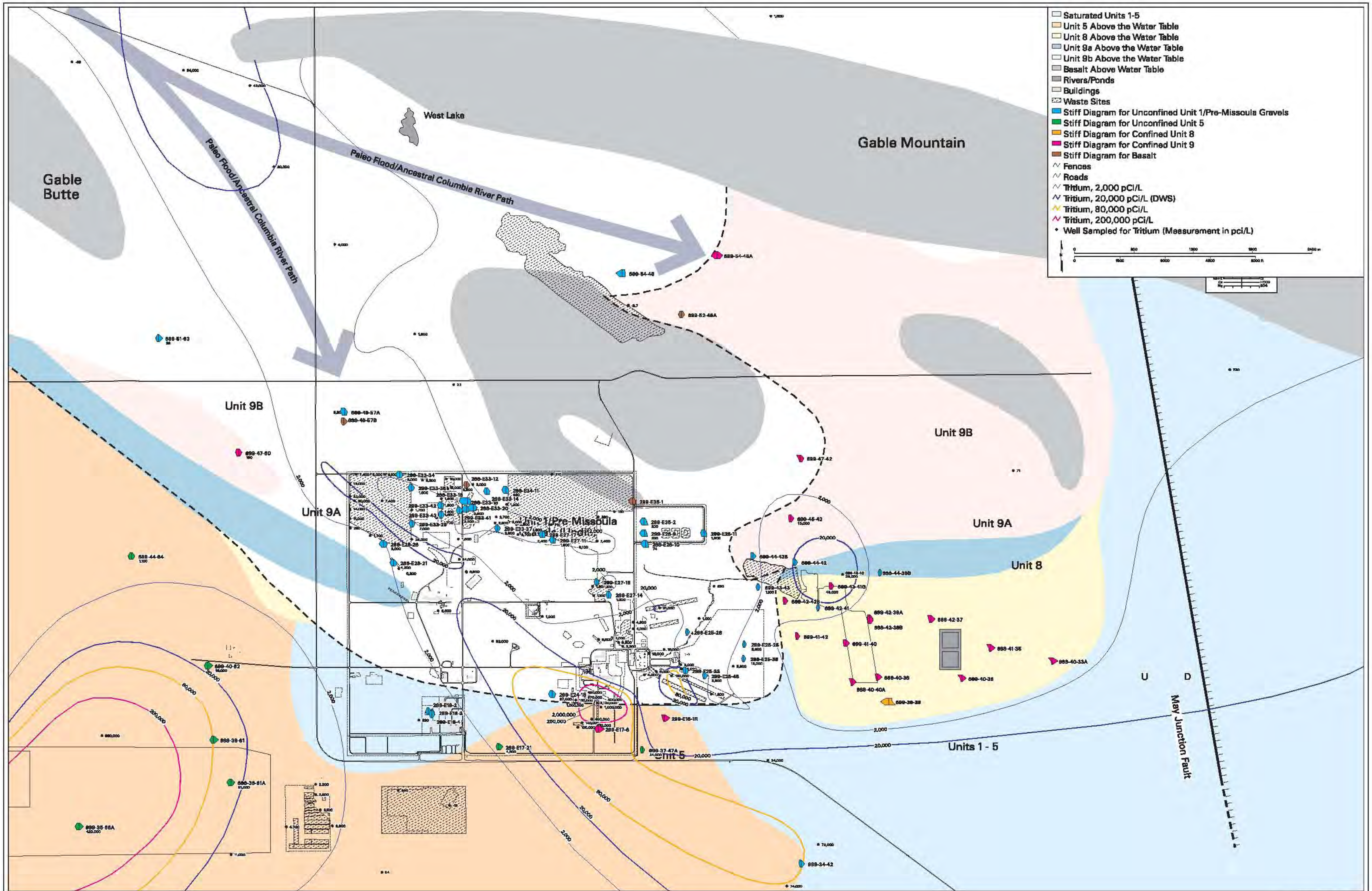


Plate 11. STIFF Diagrams and Upper Unconfined Tritium Contours

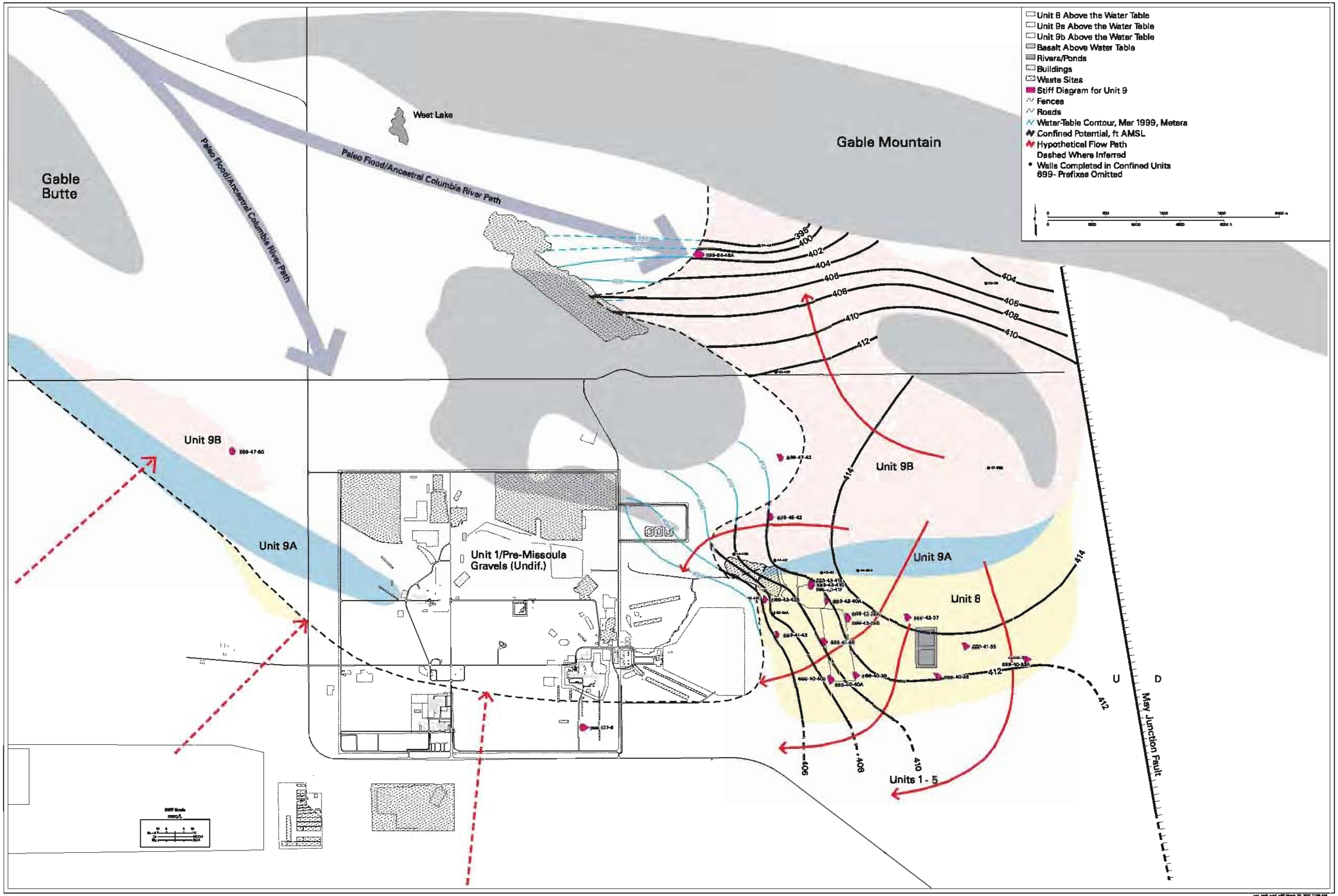


Plate 12. 1999 Potentiometric Surface Map, Ringold Confined Aquifer

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