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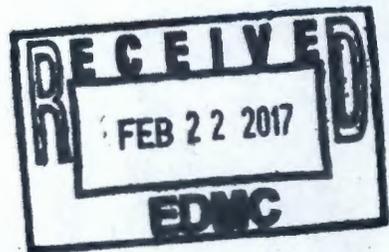
# Historical Changes in Water Table Elevation and Groundwater Flow Direction at Hanford : 1944 to 2014

Prepared for the U.S. Department of Energy  
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy  
under Contract DE-AC06-08RL14788



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**APPROVED**

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## Terms

NAVD88	<i>North American Vertical Datum of 1988</i>
NGVD29	<i>National Geodetic Vertical Datum of 1929</i>
SALDS	State-Approved Disposal Site
TEDF	Treated Effluent Disposal Facility

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## 1 Introduction

Historical changes in the Hanford Site water table over a period of 70 years (1944 to 2014) reflect the hydrologic response to the management of effluent discharged to the soil column and, to a smaller degree, interim remedial actions. Impacts to groundwater in the 200 Areas are observed as increasing and decreasing water table elevations, gradient changes, groundwater mounding (i.e., radial groundwater flow including gradient reversals), and changes in groundwater flow direction. This report provides a basic overview of changes to the water table since operations began on the Hanford Site in 1944.

From 1944 to 1993 effluent was discharge to the ground at hundreds of liquid waste receiving sites. The major areas of artificial recharge in the 200 Areas were 216-S-16D, 216-T-4A, 216-U-10, 216-B-3, and 216-A-25 Ponds. These liquid waste receiving sites accepted the bulk of the effluent volume discharged to the ground in the 200 Areas and produced very significant changes in the elevation of the water table and groundwater flow direction. Facilities currently discharging effluent in the 200 Areas and vicinity are a pump and treat system, a State-Approved Disposal Site (SALDS) and the Treated Effluent Disposal Facility (TEDF). Along with potential irrigation from west of the Hanford Site, artificial recharge from these operations minimize the current declining elevation of the 200 Area water table. SALDS and TEDF began discharging effluent in 1995 and continues to operate to date, along with various pump and treat system designs in use since 1994.

The water table maps presented in this document are based on BNWL-B-360, *Selected Water Table Contour Maps and Well Hydrograph for the Hanford Reservation 1944-1973*, DOE/RL-93-88, *Annual Report for RCRA Groundwater Monitoring Projects at Hanford Site Facilities for 1993*, PNNL-13404, *Hanford Site Groundwater Monitoring for FY 2000*, PNNL-15670, *Hanford Site Groundwater Monitoring for FY 2005*, and DOE/RL-2015-07, *Hanford Site Groundwater Monitoring for 2015*. Each map shows geographical information that includes the 200 East Area, 200 West Area, former areas of major artificial recharge, current areas of artificial recharge, and selected well locations.

Map presentations in this report generated prior to 1998 are based on the *National Geodetic Vertical Datum of 1929* (NGVD29). From 1998 forward, the map presentations are based on the *North American Vertical Datum of 1988* (NAVD88) which is about 1 m (3 ft) higher than the NGVD29 datum. No adjustments have been made on the water table maps in this report for the disparity between each datum. However, the text, hydrographs and tables in the report are based on NAVD88.

## 2 Water Table Elevation Changes

Hydrographs are used to show changes in the elevation of the water table over time. The hydrographs in Figures 1 and 2 show the rise and decline in the elevation of the water table in selected wells across the 200 Areas. Table 1 summarizes the maximum 200 East Area (including 216-A-25 and 216-B-3 Ponds) and 200 West Area water table elevations (adjusted for datum differences), changes in the elevation of the water table over time, and groundwater flow direction.

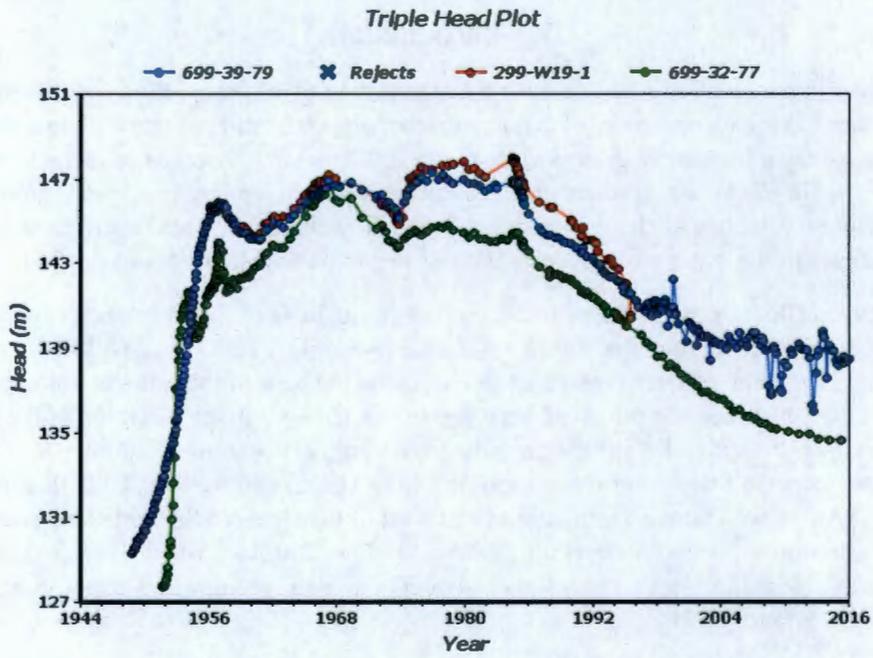


Figure 1. Hydrographs from Selected Wells in the 200 West Area

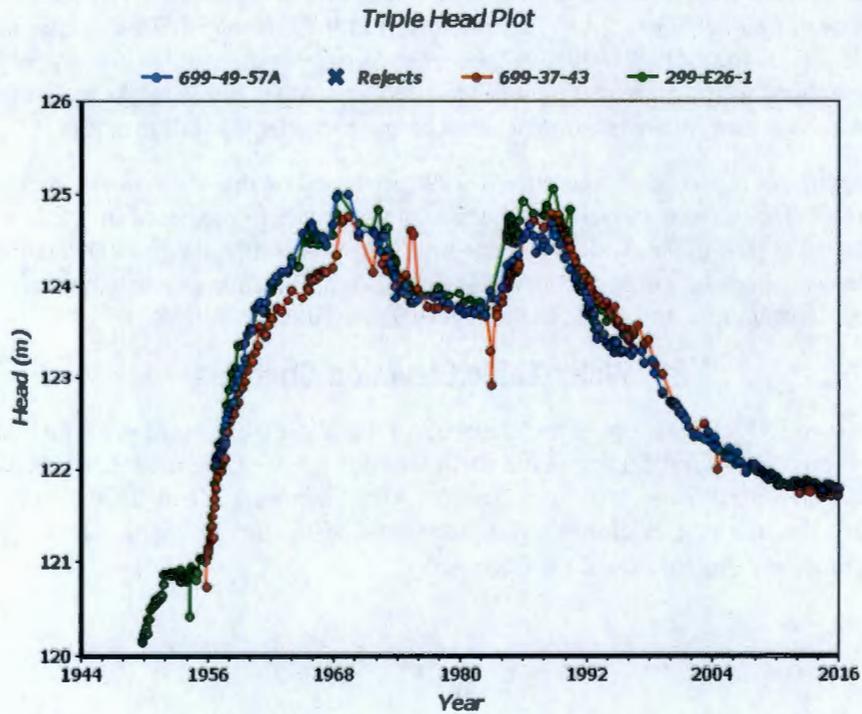


Figure 2. Hydrographs from Selected Wells in the 200 East Area

**Table 1. Maximum Water Table Elevation in the 200 Areas and Change in the Elevation of the Water Table from 1944 to 2014**

Year	200 West Area Elevation m (ft)	200 West Area Difference from 1944 m (ft)	200 East Area Elevation m (ft)	200 East Area Difference from 1944 m (ft)	Predominant flow direction	
					200 West	*200 East
1944	126 (413)	-	120 (394)	-	East	Southeast/East
1948	135 (443)	9 (30)	124 (407)	4 (13)	Radial	Radial
1951	169 (554)	43 (141)	124 (407)	4 (13)	Radial	Radial
1955	147 (482)	21 (69)	123 (404)	3 (10)	Radial	Radial
1960	141 (463)	15 (50)	126 (413)	6 (20)	North/East	Radial
1970	146 (479)	20 (65)	127 (417)	7 (23)	North/East	Radial
1973	146 (479)	20 (65)	153 (502)	33 (108)	North/East	Radial
1993	143 (469)	17 (56)	129 (423)	9 (30)	East	Radial
2000	140 (459)	14 (46)	123 (403)	3 (10)	East	North/East
2005	138 (453)	12 (39)	123 (403)	3 (10)	East	North/East
2014	138 (453)	12 (39)	122 (399)	2 (7)	East	Southeast

Notes:

Elevations are approximate.

The 1944 to 1993 elevations above are adjusted for the 1 m (3 ft) difference between NGVD29 and NAVD88. Elevations on the 1944 to 1993 water table maps are 1 m (3 ft) lower (NGVD29).

North/East denotes a northward and eastward component of the groundwater flow direction.

\*Across most of the 200 East Area proper, groundwater flow direction was assumed to be to the northwest toward Gable Gap and southeast because the hydraulic gradient is very flat. On the 2014 groundwater map groundwater flow was confirmed to be to the southeast (SGW-58828, *Water Table Maps for the Hanford Site 200 East Area 2013 and 2014*).

### 3 Hanford Site Water Table

This section describes the Hanford Site water table.

#### 3.1 1944 Hanford Site Water Table

The 1944 Hanford Site Water Table Map (Figure 3) shows baseline conditions prior to Hanford Site Operations. The 1944 water table map is uncertain because no actual water level measurements are available. The map is based on back trending of water level measurements from wells constructed later.

**200 West Area** – The maximum elevation of the water table in the 200 West Area was about 126 m (413 ft) in 1944 adjusted to NAVD88. Groundwater flowed predominately to the east towards the Columbia River.

**200 East Area (inclusive of the 216-A-25 and 216-B-3 Ponds)** – The maximum elevation of the water table in the vicinity of the 200 East Area was approximately 120 m (394 ft) in 1944 adjusted to NAVD88. Groundwater flowed to the southeast and east towards the Columbia River.

#### 3.2 1948 Hanford Site Water Table

The 1948 Hanford Site Water Table Map (Figure 4) is characterized by substantial increases in the elevation of the water table, steeper gradients, and groundwater mounding.

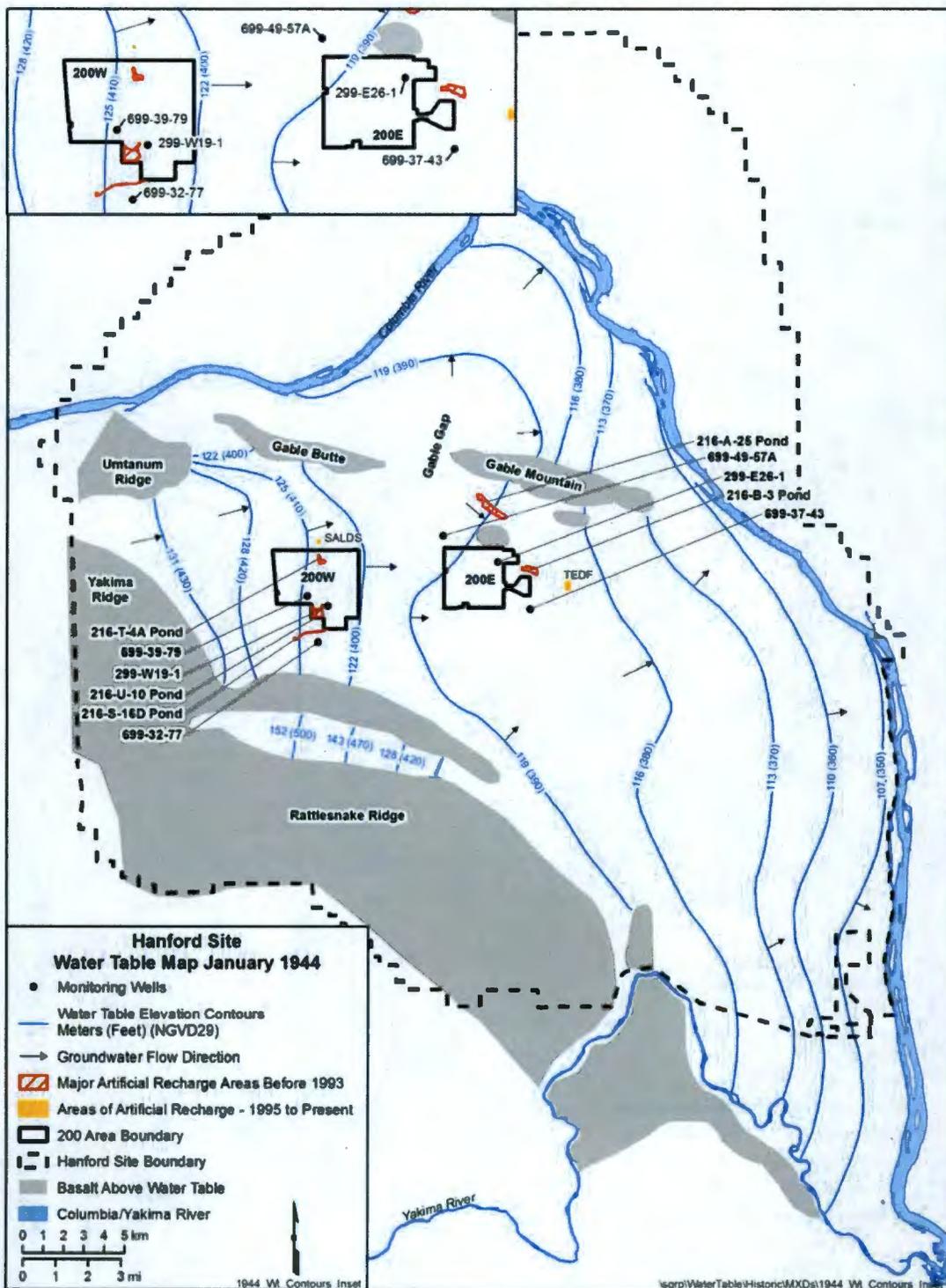
**200 West Area** – Adjusted to NAVD88, the maximum elevation of the water table in the 200 West Area was about 135 m (443 ft) and 9 m (30 ft) higher than the baseline elevation on the 1944 map. Groundwater flow was radial from a groundwater mound in the northeast half of the 200 West Area beneath 216-T-4A Pond and the groundwater gradient was steeper than baseline. The position of the groundwater mound indicates that 216-T-4A was the main area of artificial recharge in 1948. 216-T-4A Pond was in use from 1944 to 1976 and received 42 billion L (11 billion gallons) of effluent.

**200 East Area (inclusive of the 216-A-25 and 216-B-3 Ponds)** – Adjusted to NAVD88, the maximum elevation of the 1948 water table in the 200 East Area was approximately 124 m (407 ft) and about 4 m (13 ft) higher than baseline. Groundwater flow was radial from a groundwater mound. The groundwater mound was mainly from discharges to 216-B-3 Pond (1945 to 1993). By 1948, 5.15 billion L (1.4 billion gallons) of effluent were discharged to the 216-B-3 Pond system. The size, shape, and location of the mound reflects the volumes of effluent discharged and the movement of the water table into the highly transmissive Hanford formation (contact at 120 m [393 ft]). The 1948 water table map indicates that groundwater flow direction in the central portion of the 200 East Area was mainly to the south.

#### 3.3 1951 Hanford Site Water Table

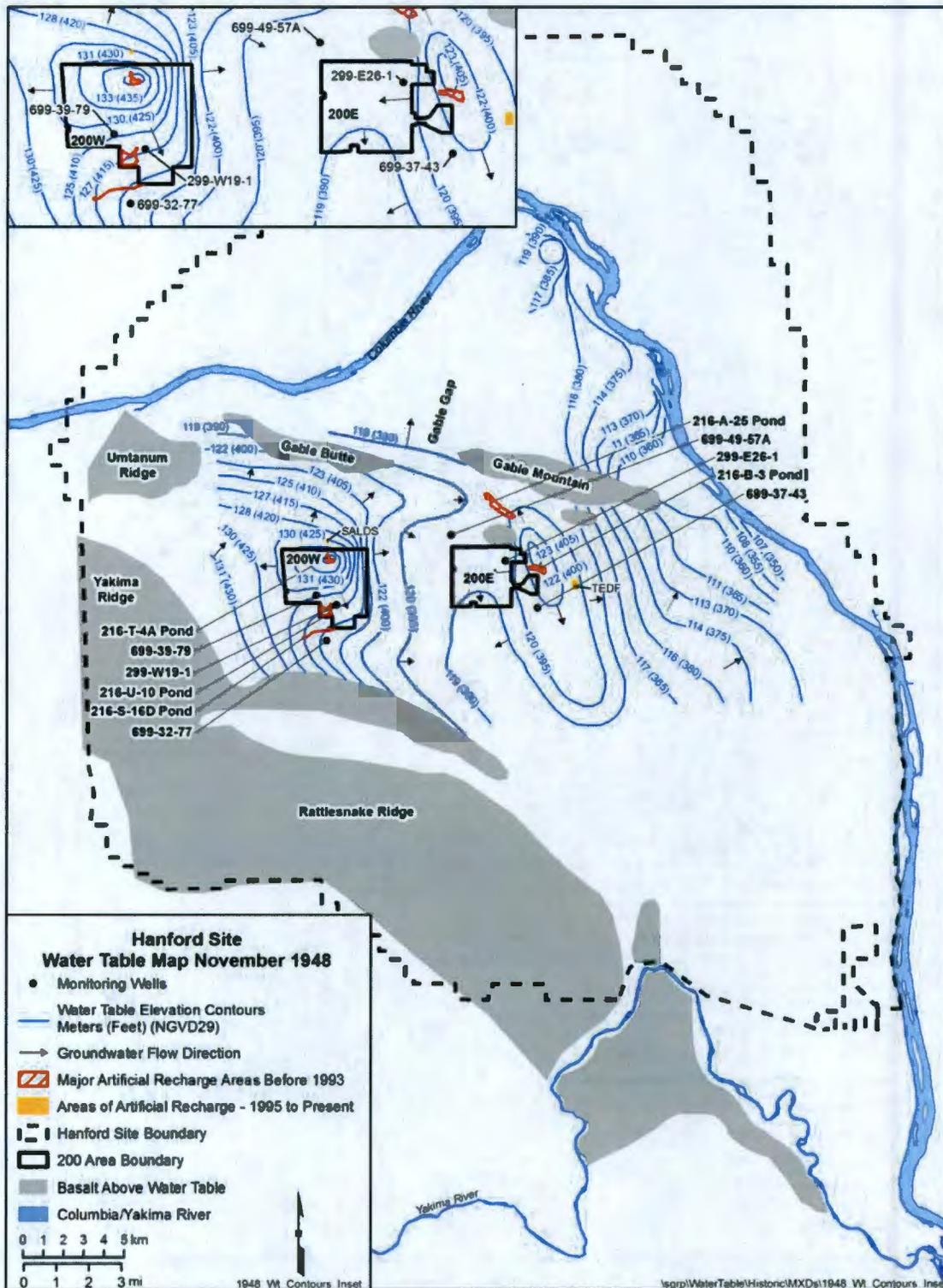
The 1951 Hanford Site Water Table Map (Figure 5) is characterized by the continued rise in the elevation of the water table in the 200 West Area. The maximum water table elevation in the 200 East Area was the same as in 1948.

**200 West Area** – Adjusted to NAVD88, the maximum elevation of the water table in the 200 West Area was about 169 m (554 ft) and about 43 m (141 ft) higher than baseline. Groundwater flow was radial from the groundwater mound at 216-T-4A Pond and the groundwater gradient was steep.



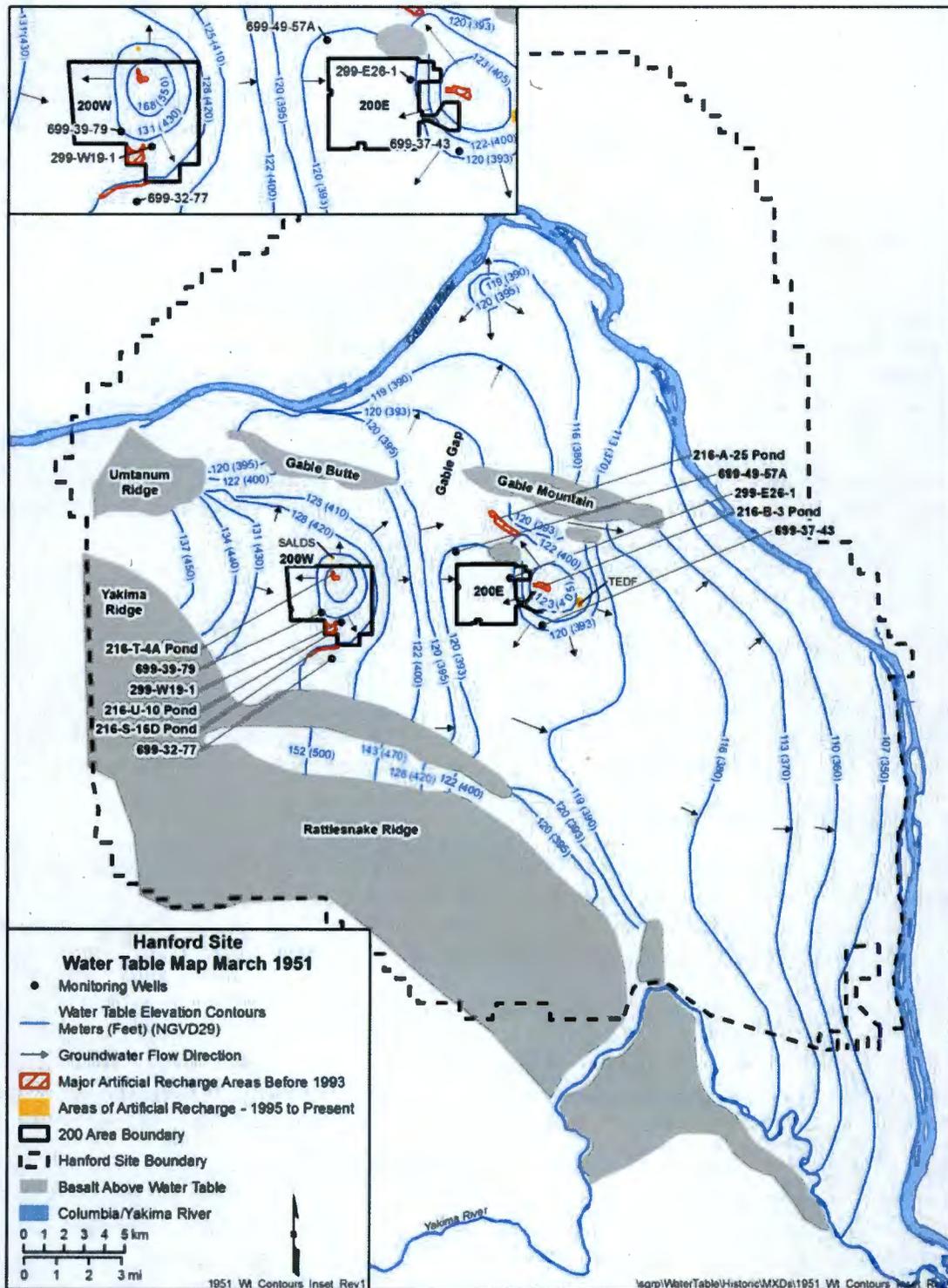
Modified from BNWL-B-360, *Selected Water Table Contour Maps and Well Hydrograph for the Hanford Reservation 1944-1973*.

Figure 3. 1944 Hanford Site Water Table Map



Modified from BNWL-B-360, *Selected Water Table Contour Maps and Well Hydrograph for the Hanford Reservation 1944-1973*.

Figure 4. 1948 Hanford Site Water Table Map



Modified from BNWL-B-360, *Selected Water Table Contour Maps and Well Hydrograph for the Hanford Reservation 1944-1973*.

Figure 5. 1951 Hanford Site Water Table Map

**200 East Area (inclusive of the 216-A-25 and 216-B-325 Ponds)** – Adjusted to NAVD88, the maximum elevation of the water table in the 200 East Area in 1951 was approximately 124 m (407 ft) and about 4 m (13 ft) higher than baseline. Groundwater flow was radial from the groundwater mound at 216-B-3 Pond and groundwater gradients were steep. The size, shape, and location of the mound reflected changes in the discharge volumes in the 200 East Area. The water table map indicates that groundwater flow was mainly to the south within the central portion of the 200 East Area where the gradient was very flat.

### 3.4 1955 Hanford Site Water Table

The 1955 Hanford Site Water Table Map (Figure 6) shows that the elevation of the water table was declining in the 200 West and 200 East Areas. This reflected the reduction in the amount of effluent discharged to the ground in the 200 East Area at 216-B-3 Pond and migration of the 200 West Area groundwater mound to the south toward 216-U-10 Pond. 216-U-10 Pond received effluent from 1944 to 1984. By 1984, 160 billion L (42 billion gallons) of effluent were discharged to the 216-U-10 Pond system.

**200 West Area** – Adjusted to NAVD88, the maximum elevation of the water table in the 200 West Area in 1955 was about 147 m (482 ft) and about 21 m (69 ft) higher than baseline in 1944. Groundwater flow was radial from a groundwater mound and gradients remained steep. Comparison of the 1951 and 1955 water table maps indicates that the groundwater mound was substantially larger and migrating to the south toward 216-U-10 Pond.

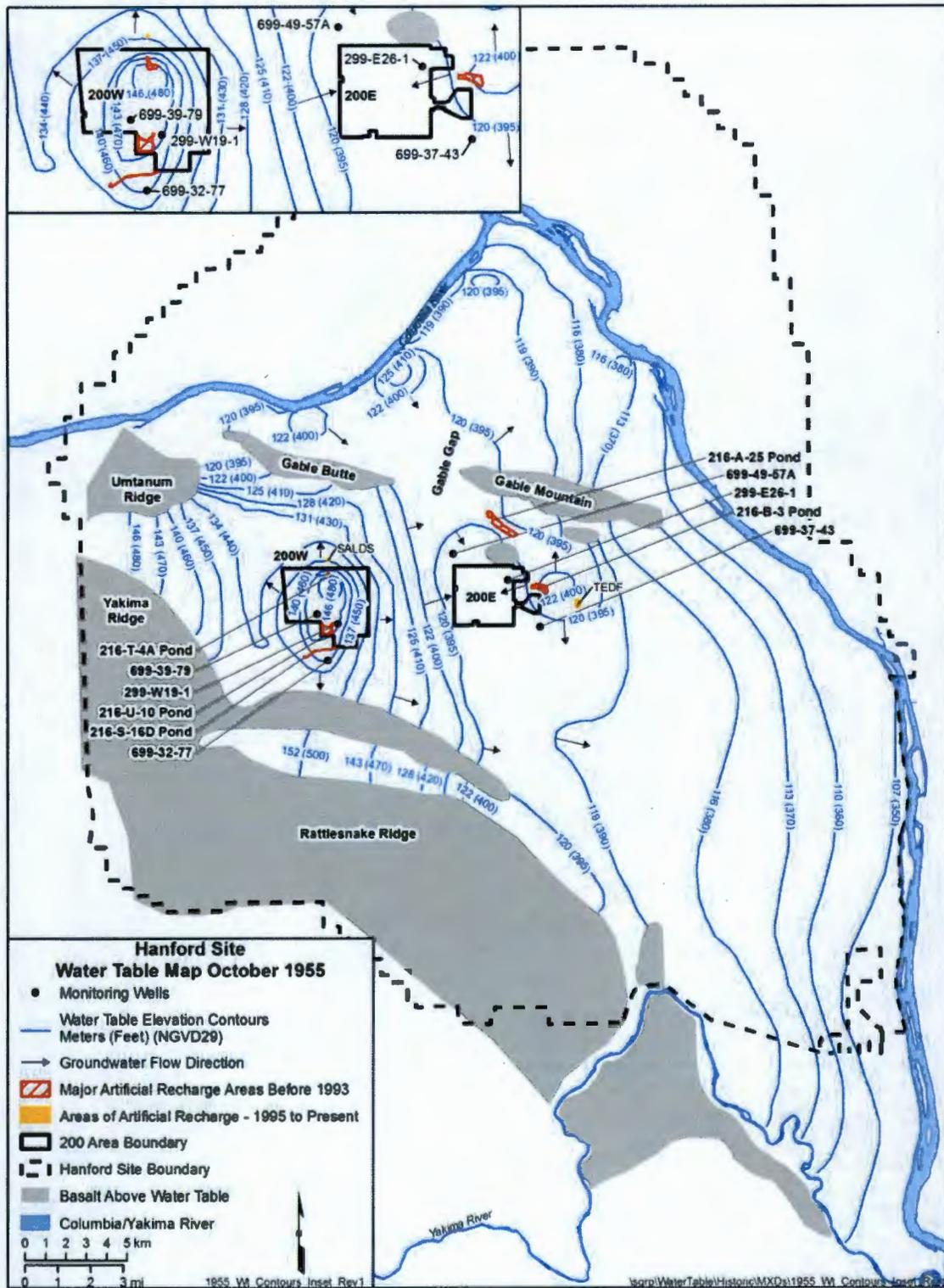
**200 East Area (inclusive of the 216-A-25 and 216-B-3 Ponds)** – Adjusted to NAVD88, the maximum elevation of the water table in the 200 East Area was approximately 123 m (404 ft) and about 3 m (10 ft) higher than baseline in 1944. Groundwater flow was radial from the groundwater mound at 216-B-3 Pond. Along the central portion of the 200 East Area the gradient was very flat. The water table map indicates that groundwater flow was mainly to the south in the central portion of the 200 East Area.

### 3.5 1960 Hanford Site Water Table

Comparison of the 1960 Hanford Site Water Table Map (Figure 7) and the 1955 groundwater map (Figure 6) shows that the elevation of the water table declined in the 200 West Area. Water table elevations in the 200 East Area were increasing due to the continued operation of the 216-B-3 Pond and new discharges to 216-A-25 Pond. Use of the 216-A-25 Pond began in 1957.

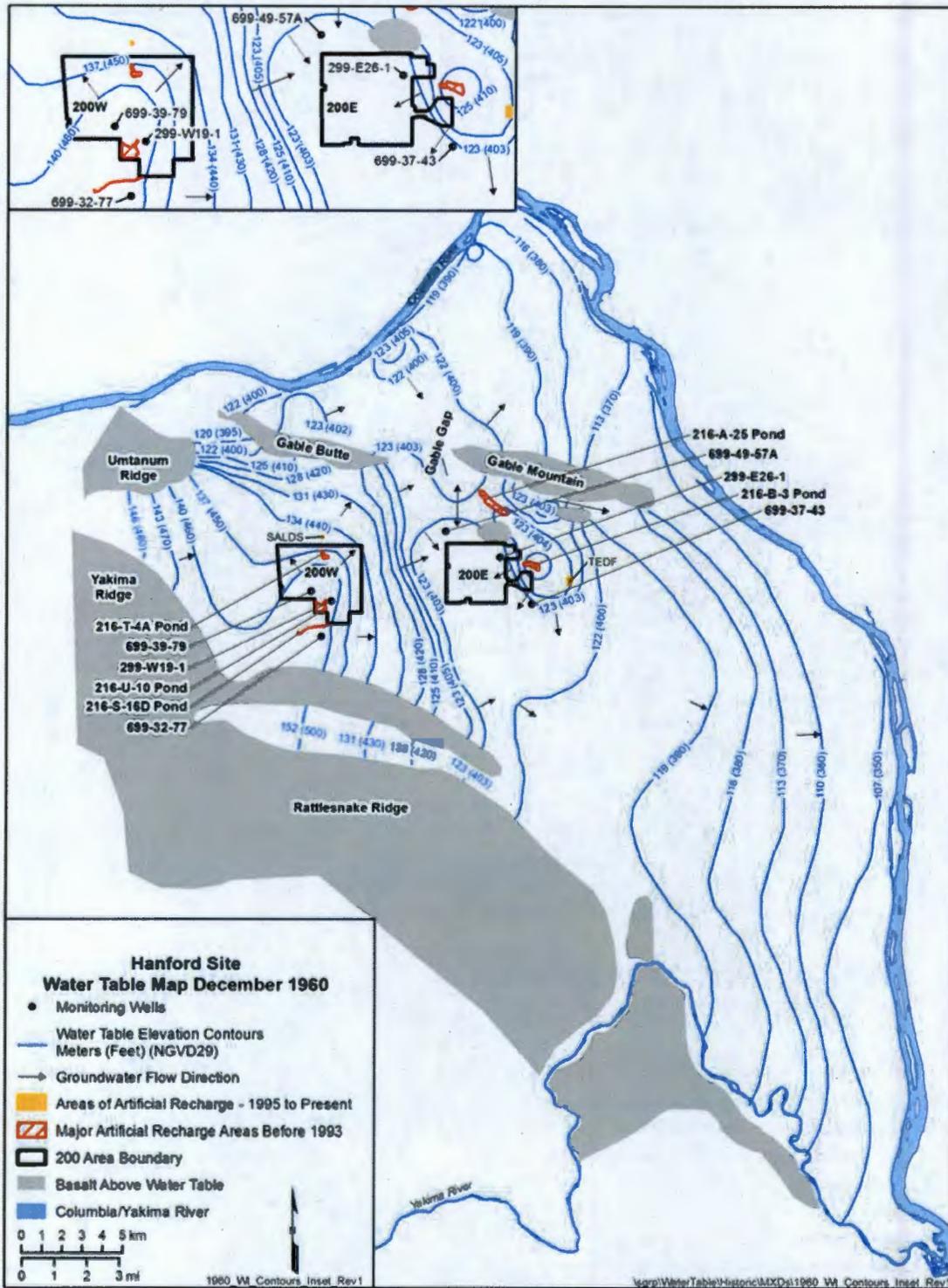
**200 West Area** – Adjusted to NAVD88, the maximum elevation of the water table in the 200 West Area was about 141 m (463 ft) and about 15 m (50 ft) higher than baseline. On the 1960 map, the groundwater mound (i.e., radial flow) does not appear to be maintained by effluent discharges, but its influence on groundwater flow is still apparent. The groundwater flow direction was mainly to the northwest, north, northeast, and east and influenced mainly by discharges from 216-T-4A and 216-U-10 Ponds.

**200 East Area (inclusive of the 216-A-25 and 216-B-3 Ponds)** – Adjusted to NAVD88, the maximum elevation of the water table in the 200 East Area was approximately 126 m (413 ft) and observed as two groundwater mounds. The maximum water table elevation was about 6 m (20 ft) higher than baseline. Groundwater flow was radial from the two groundwater mounds. The size, shape, and location of the mounds reflects the discharge volumes collectively at 216-A-25 Pond 216-B-3 Pond. Along the central portion of the 200 East Area the water table gradient was very flat. A water table divide formed north of 200 East Area. Groundwater flow is assumed to have been mainly to the northwest towards Gable Gap and south in the 200 East Area.



Modified from BNWL-B-360, *Selected Water Table Contour Maps and Well Hydrograph for the Hanford Reservation 1944-1973*.

Figure 6. 1955 Hanford Site Water Table Map



Modified from BNWL-B-360, *Selected Water Table Contour Maps and Well Hydrograph for the Hanford Reservation 1944-1973*.

Figure 7. 1960 Hanford Site Water Table Map

### 3.6 1970 Hanford Site Water Table

The 1970 Hanford Site Water Table Map (Figure 8) shows that the elevation of the water table was increasing in the 200 West Area. The increase in the elevation on the water table reflected the volume of effluent discharged mainly to the 216-U-10 Pond, and to a smaller degree, 216-T-4A Pond and 216-S-16D Pond. Water table elevations in the 200 East Area were increasing due to the continued operation of 216-B-3 Pond and 216-A-25 Pond. The impact of discharging effluent to the soil column was observed mainly as mounding in the 200 East Area.

**200 West Area** – Adjusted to NAVD88, the maximum elevation of the water table in the 200 West Area was about 146 m (479 ft) and 20 m (65 ft) higher than baseline. Groundwater flow direction was mainly to the northwest, north, northeast, east, and southeast. Migration of the maximum water level elevation to the south from 216-T-4A suggest that 216-U-10 Pond was the predominant area of artificial recharge.

**200 East Area (inclusive of the 216-A-25 and 216-B-3 Ponds)** – Adjusted to NAVD88, the maximum elevation of the water table in the 200 East Area was approximately 127 m (417 ft) and about 7 m (23 ft) higher than baseline. Groundwater flow was radial from the groundwater mound at 216-B-3 Pond. The size, shape and location of the mounds reflects the discharge volumes collectively at 216-A-25 Pond and 216-B-3 Pond. In the central portion of the 200 East Area, the gradient was very flat. Groundwater flow converged in the central 200 East Area from the west (200 West Area) and the east (216-B-3 Pond mound) and flowed mainly to the south and southeast. Some groundwater probably also flowed north toward Gable Gap.

### 3.7 1973 Hanford Site Water Table

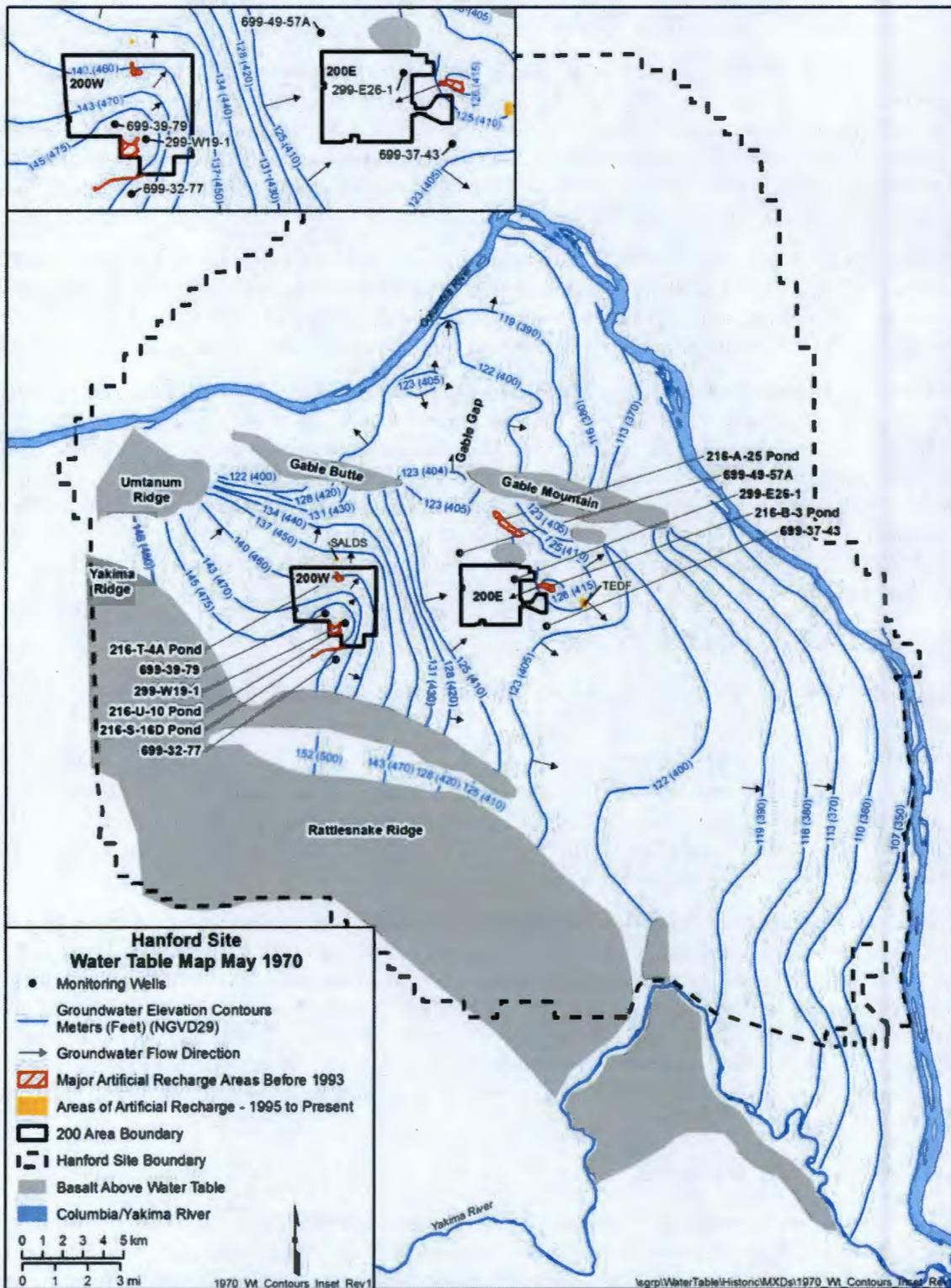
The elevation of the 1973 Hanford Site Water Table (Figure 9) is similar to the 1970 water table in the 200 West Area.

**200 West Area** – Adjusted to NAVD88, the maximum elevation of the water table in the 200 West Area was about 146 m (479 ft) and 20 m (65 ft) higher than baseline. The elevation of the water table in 1973 reflects the discharge of larger volumes of effluent in the southern half of the 200 West Area at 216-U-10 Pond and 216-S-16D Pond and migration of maximum groundwater elevation to the south. Groundwater flowed mainly to the northwest, north, northeast, east and southeast.

**200 East Area (inclusive of the 216-A-25 and 216-B-3 Ponds)** – Adjusted to NAVD88, the maximum elevation of the water table in the 200 East Area was approximately 153 m (502 ft) and observed as a large groundwater mound. The maximum elevation of the mound was about 33 m (108 ft) higher than baseline. Groundwater flow was radial from the groundwater mounds. The size, shape and location of the mounds reflects the discharge volumes collectively at 216-A-25 Pond and 216-B-3 Pond. In the central portion of the 200 East Area the groundwater gradient was very flat. A water table divide was present in the northwest corner of 200 East Area, with some groundwater flowing to the south and some to the north toward Gable Gap.

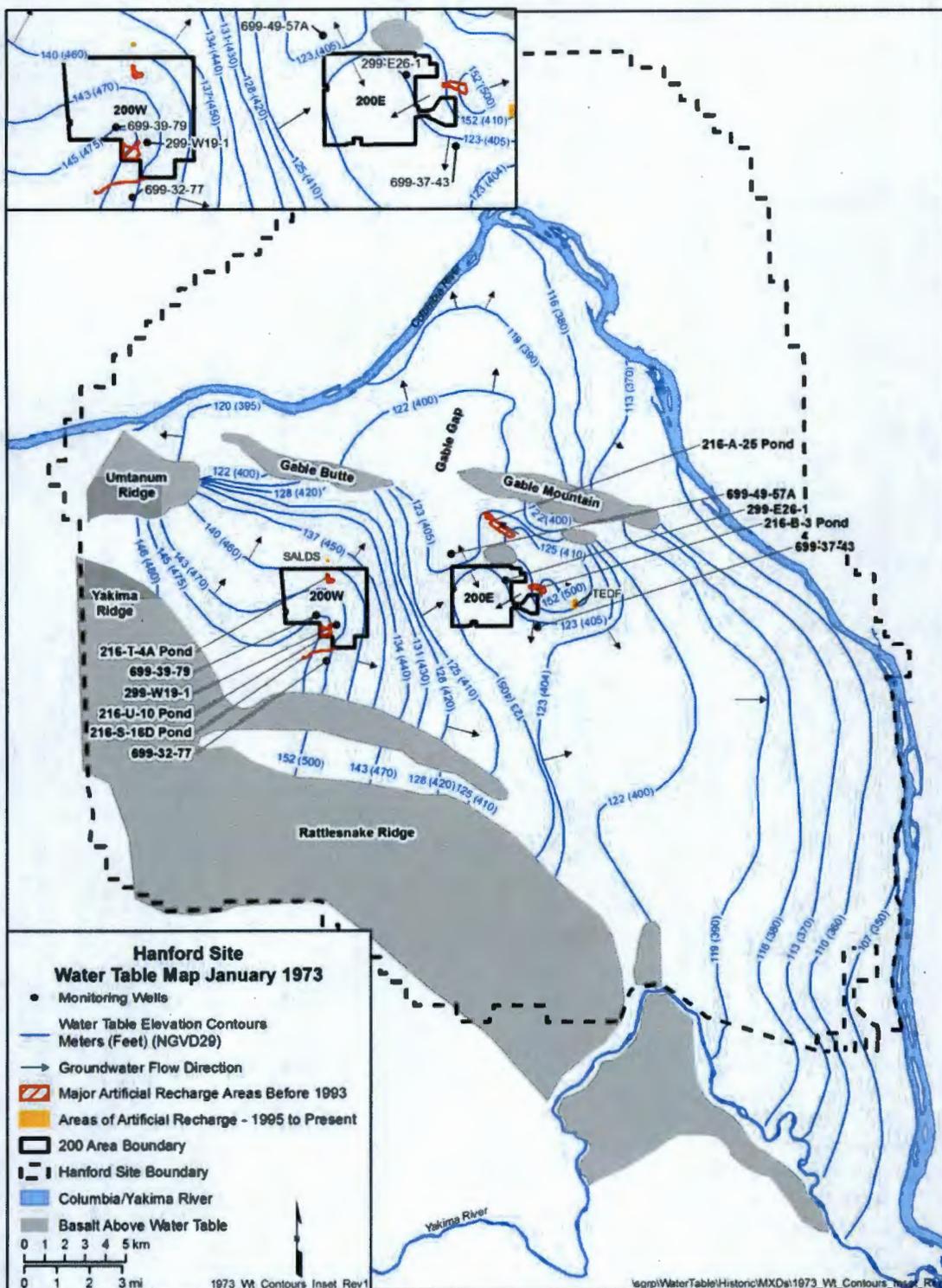
### 3.8 1993 Hanford Site Water Table

The elevation of the water table was declining in the 200 Areas in 1993 (Figure 10). Most of the major liquid waste sites (i.e., ponds) were no longer receiving effluent. Discharges to the 216-U-10 Pond and 216-A-25 Pond ceased about 1985. The 216-B-3 Pond was in its last year of use in 1993. Groundwater flow direction was to the northeast and east and similar to baselines conditions in the 200 West Area. In the 200 East Area, groundwater mounding dominated in the vicinity of the 216-B-3 Pond.



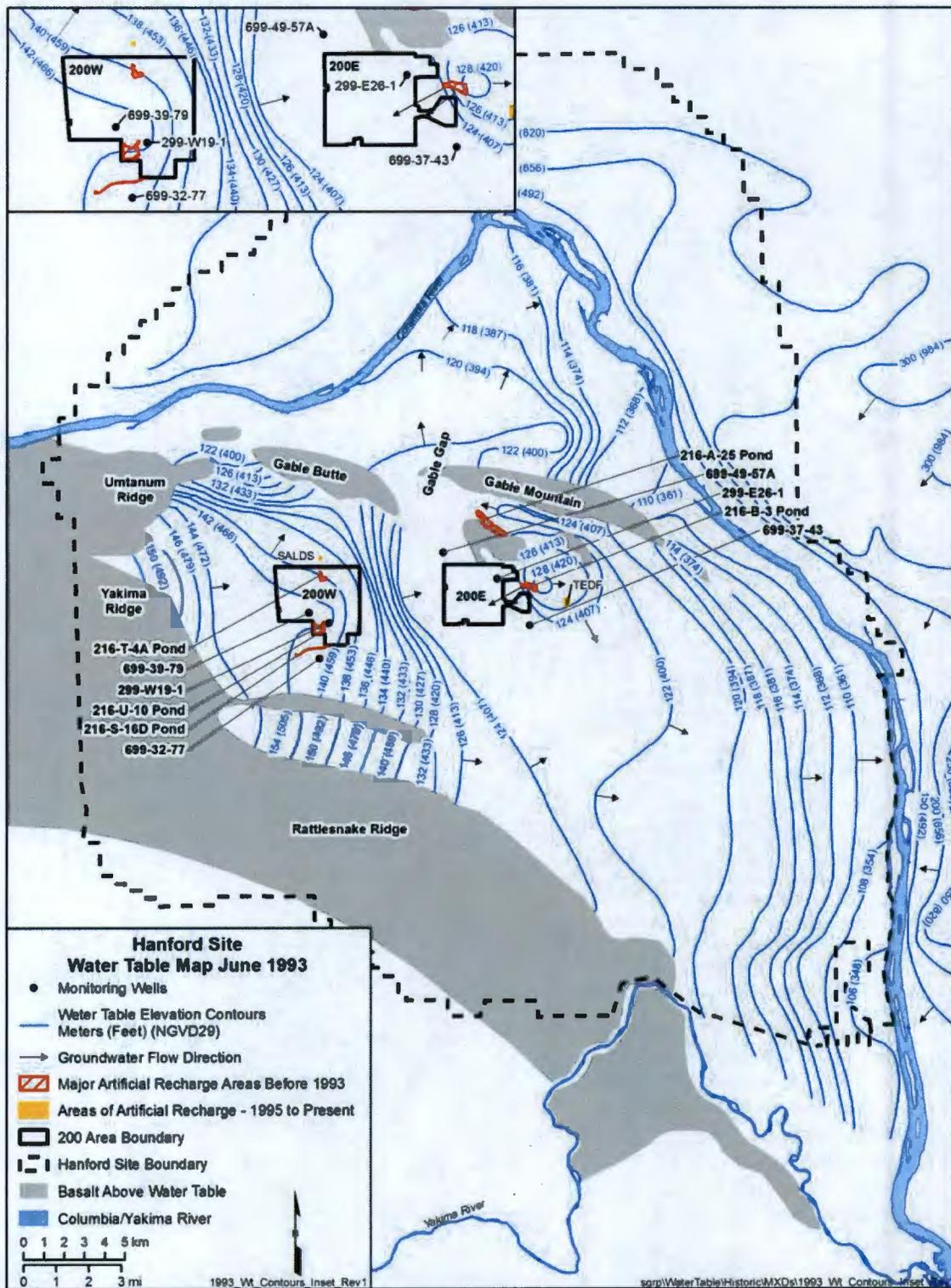
Modified from BNWL-B-360, *Selected Water Table Contour Maps and Well Hydrograph for the Hanford Reservation 1944-1973*.

Figure 8. 1970 Hanford Site Water Table Map



Modified from BNWL-B-360, *Selected Water Table Contour Maps and Well Hydrograph for the Hanford Reservation 1944-1973*.

Figure 9. 1973 Hanford Site Water Table Map



Modified from DOE/RL-93-88, Annual Report for RCRA Groundwater Monitoring Projects at Hanford Site Facilities for 1993.

Figure 10. 1993 Hanford Site Water Table Map

**200 West Area** - Adjusted to NAVD88, the maximum elevation of the water table in the 200 West Area in 1993 was about 143 m (469 ft) and 17 m (56 ft) higher than baseline. A remnant of the groundwater mound was still evident in southern 200 West near 216-U-10 Pond. The groundwater flow direction was to the northeast and east and similar to baseline.

**200 East Area (inclusive of the 216-A-25 and 216-B-3 Ponds)** – Adjusted to NAVD88, the maximum elevation of the water table in the 200 East Area was approximately 129 m (423 ft) and 9 m (30 ft) higher than baseline. Groundwater flow was radial from 216-B-3 Pond. Across most of the 200 East Area the gradient was very flat. Groundwater flow is assumed to be mainly to the southeast and northwest towards Gable Gap across the 200 East Area.

### 3.9 2000 Hanford Site Water Table

The elevation of the water table was declining in the 200 Areas in 2000 (Figure 11) as most liquid waste sites were no longer receiving effluent. However, in 1995 operations of the 200 Area TEDF commenced. This operation continues to discharge effluent to the ground and may influence groundwater flow direction in the 200 East Area. Groundwater flow direction was to the northeast and east in the 200 West Area. In the 200 East Area, the groundwater mound had dissipated and groundwater flow direction was assumed to be the northwest towards Gable Gap and southeast.

**200 West Area** – The maximum elevation of the water table in the 200 West Area was about 140 m (459 ft) and 14 m (46 ft) above baseline. Groundwater flow direction was to the northeast and east and similar to baseline.

**200 East Area (inclusive of the 216-A-25 and 216-B-3 Ponds)** – The maximum elevation of the water table in the 200 East Area was approximately 123 m (403 ft) and 3 m (10 ft) above baseline. The apparent groundwater flow direction was to the northwest towards Gable Gap and southeast.

### 3.10 2005 Hanford Site Water Table

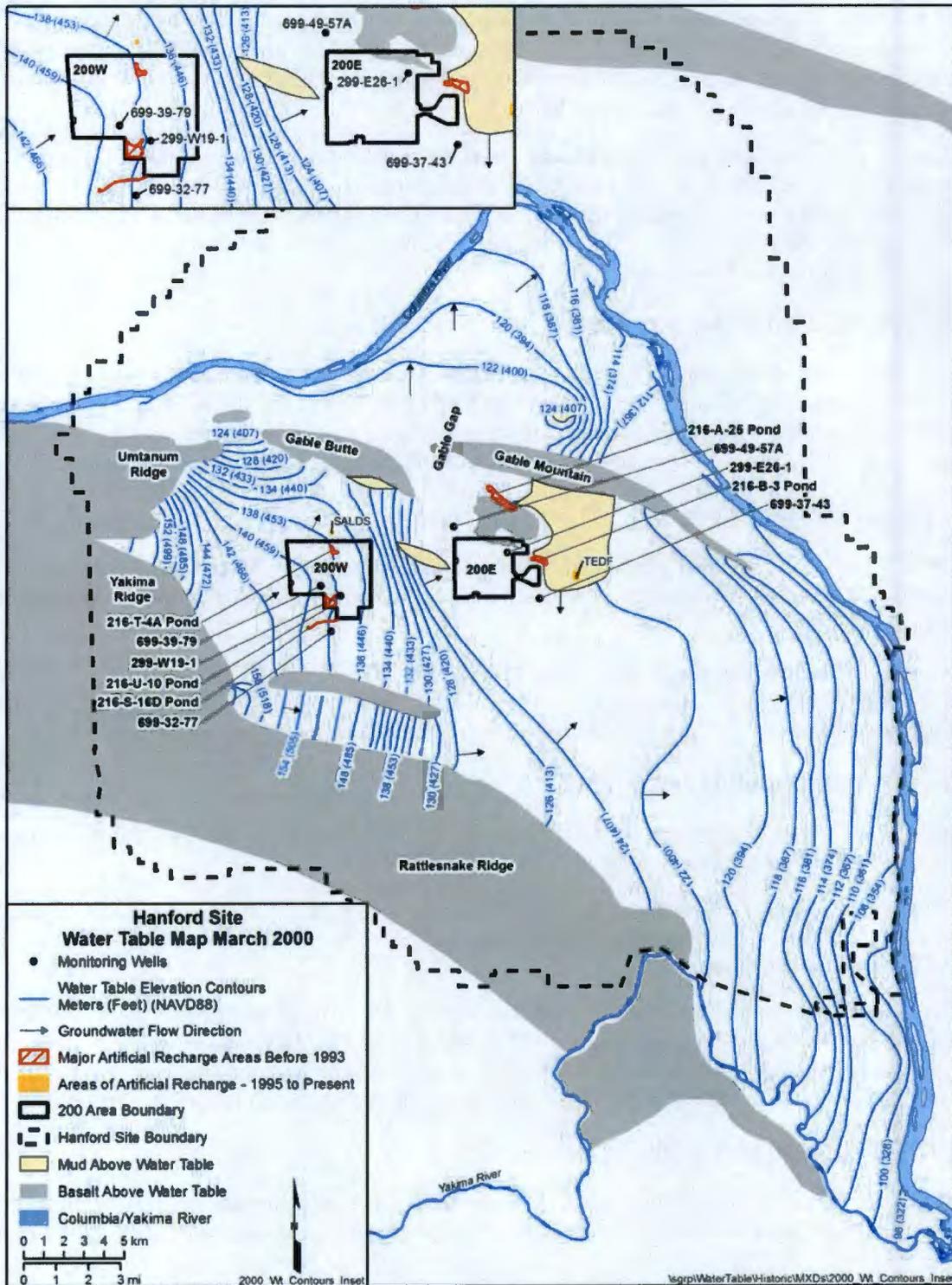
The elevation of water table was no longer rising in the 200 Areas in 2005 (Figure 12). Liquid waste sites were no longer receiving effluent, except at SALDS and TEDF.

**200 West Area** – The maximum elevation of the water table in the 200 West Area was about 138 m (453 ft) and 12 m (39 ft) above baseline. Groundwater flow direction was to the northeast and east and similar to baselines conditions.

**200 East Area (inclusive of the 216-A-25 and 216-B-3 Ponds)** – The maximum elevation of the water table in the 200 East Area was approximately 123 m (403 ft) and 3 m (10 ft) above baseline. In the 200 East Area, groundwater flow direction was difficult to discern because the gradient was very flat. The apparent groundwater flow direction was to the southeast and northwest towards Gable Gap.

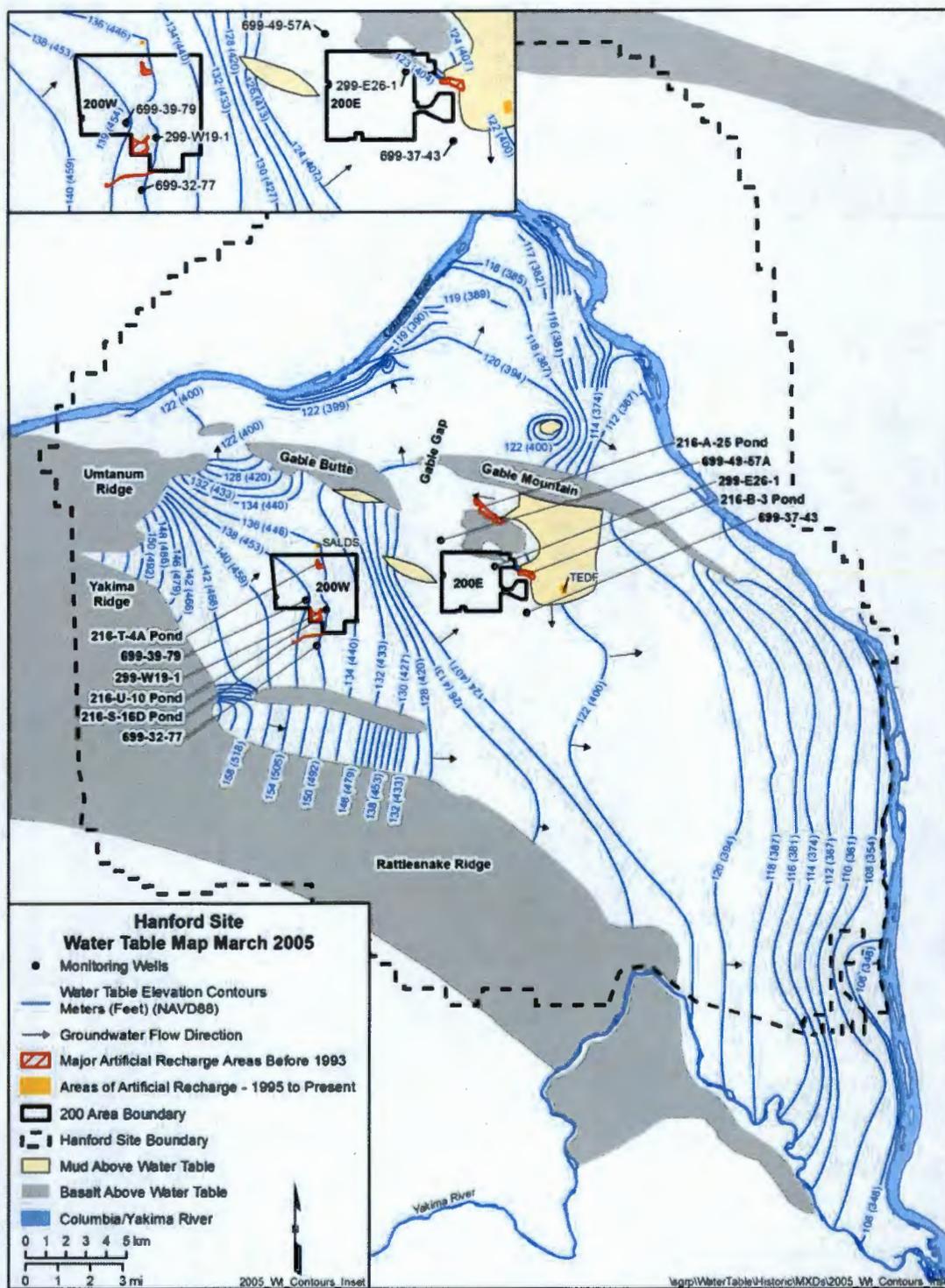
### 3.11 2014 Hanford Site Water Table

The maximum elevation of water table in 2014 (Figure 13) was equal to the maximum elevation of the water in 2005 in the 200 West Area. The elevation of the water table continued to decline in the 200 East Area.



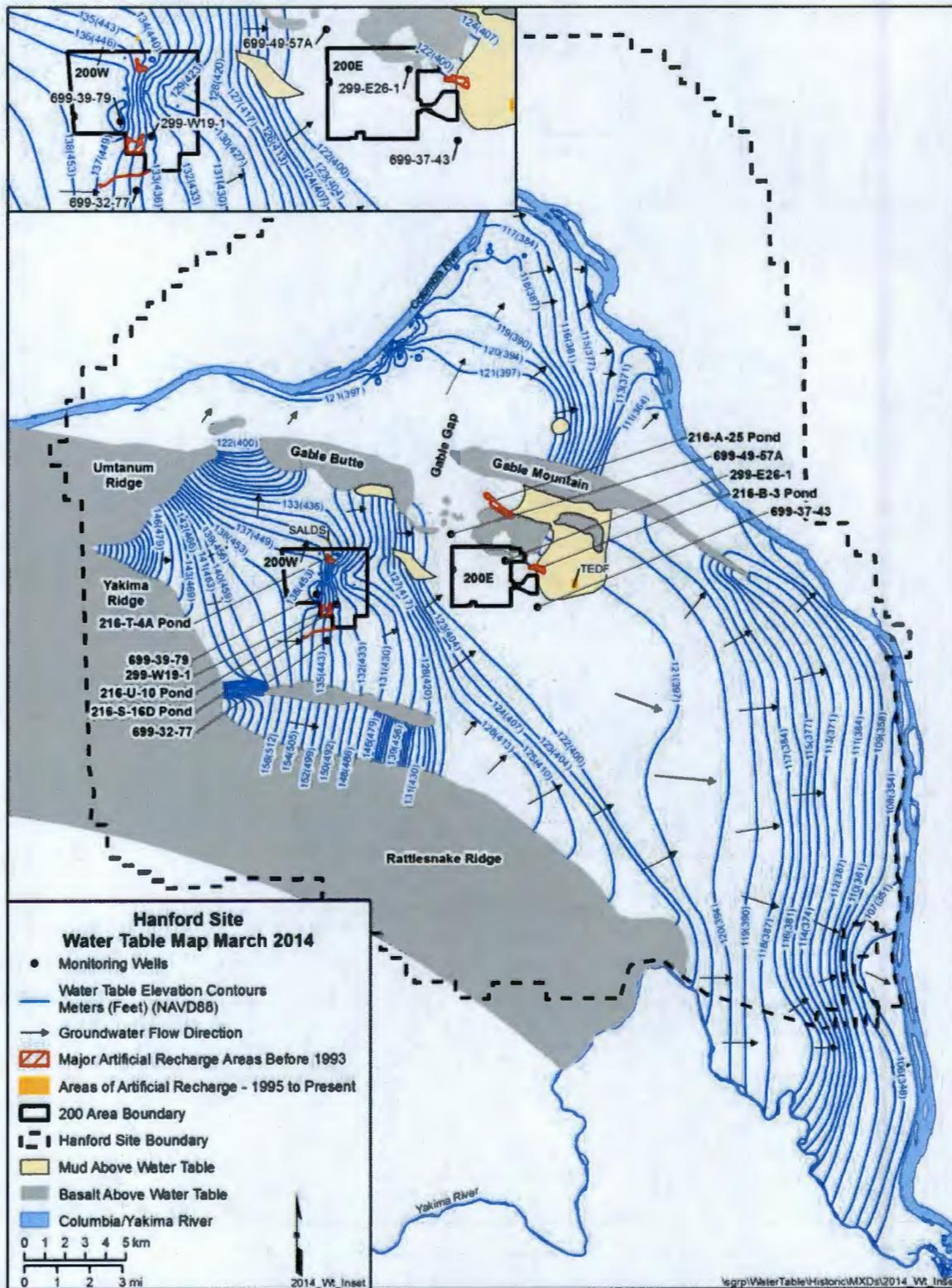
Modified from PNNL-13404, *Hanford Site Groundwater Monitoring for FY 2000*.

Figure 11. 2000 Hanford Site Water Table Map



Modified from PNNL-15670, Hanford Site Groundwater Monitoring for Fiscal Year 2005.

Figure 12. 2005 Hanford Site Water Table Map



Modified from DOE/RL-2015-07, Hanford Site Groundwater Monitoring Report for 2014.

Figure 13. 2014 Hanford Site Water Table Map

**200 West Area** – The water table in 200 West Area in 2014 showed the influence of the expanded pump and treat system that began to operate in 2012. Groundwater mounds were present around injection wells, most notably in the central portion of the 200 West Area. Groundwater flow was radial from the mounds. Extraction wells created cones of depression, evident on the map as concave contours in eastern 200 West Area. The general direction of flow across the 200 West Area was towards the east. The maximum elevation of the water table in the 200 West Area was about 138 m (453 ft) and 12 m (39 ft) above baseline.

**200 East Area (inclusive of the 216-B-3 Pond)** – Across most of the 200 East Area, the maximum elevation of the water table was between 121 m (397 ft) and 122 m (400 ft) and about 2 m (7 ft) higher than baseline. In the 200 East Area, groundwater flow direction is difficult to discern because the gradient is very flat. SGW-58828, *Water Table Maps for the Hanford Site 200 East Area 2013 and 2014*, estimates the average gradient across the 200 East area during 2014 was approximately 0.0000061. Groundwater flowed to the southeast (SGW-58828).

## 4 Conclusions

Eleven Hanford Site water table maps and six hydrographs were presented in this report. The illustrations show historical changes to the Hanford Site water table over a period of 70 years (1944 to 2014). Historical changes to the water table reflect the hydrologic response to the management of effluent discharged to the soil column at the major liquid waste receiving sites (i.e., 216-B-3 Pond, 216-U-10 Pond) and, to a smaller degree, interim remedial actions. Impacts to groundwater are observed as increasing and decreasing water table elevations, gradient changes, groundwater mounding (i.e., radial groundwater flow including gradient reversals), and changes in groundwater flow direction.

The pre-Hanford Site water table map establishes baseline of conditions prior to Hanford Site Operation. The 1944 Hanford Site water map shows the maximum elevation of the water table in the 200 East and 200 West areas of 120 m (394 ft) and 126 m (413 ft), respectively. In the 200 West Area, groundwater flowed predominately to the east towards the Columbia River. In the 200 East Area, groundwater flowed to the southeast/east towards the Columbia River.

After 1944, the Hanford Site water table showed substantial changes in the elevation, gradient, and shape of the water table. The maximum rise in the elevation of the water table (169 m [554 ft]) was observed in 1951 in the 200 West Area. The maximum rise in the elevation of the water table (153 m [502 ft]) was observed in 1973 in the 200 East Area. Groundwater mounding was common in both the 200 East and West Areas from 1948 to about 1955. Groundwater mounding dissipated in the 200 East Area after 1993. With reductions and eventual cessation of discharges to the soil column at the liquid waste receiving site in the early 1990s, the elevation of the water table declined. In 2014, the water table was about 12 m (39 ft) above baseline in the 200 West Area and 2 m (7 ft) above baseline in the 200 East Area. Groundwater flow direction across the 200 West Area in 2014 was mainly to the east and northeast. In the 200 East Area, groundwater flow direction is difficult to discern because the gradient is very flat. The gradient of the water table is estimated to be about 0.003 to 0.007 in the 200 West Area (DOE/RL-2016-12, *Hanford Site RCRA Groundwater Monitoring for 2015*). SGW-58828 estimates the average gradient across the 200 East area during 2014 was approximately 0.0000061. Groundwater flowed to the southeast.

## 5 References

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