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EVALUATION OF HANFORD SITE WATER-TABLE CHANGES - 1980 TO 1990

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MASTER

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EXECUTIVE SUMMARY

Irrigation applied west of the Hanford Site and wastewater management practices on the Hanford Site resulted in significant changes in the configuration of the water table between December 1979 and December 1989 In the Cold Creek Valley, located in the western part of the Hanford Site, the water table rose more than 3 m (9 ft) between December 1979 and December 1989. Since 1969, the water table in the Cold Creek Valley has been rising, primarily in response to irrigation practices in the Upper Cold Creek Valley. The largest areal changes have occurred in the vicinity of production facilities in the 200 Areas where ground-water mounds have developed since operations began in 1943. During the 1940s and 1950s, two ground-water mounds developed as a result of wastewater management practices in the 200 Areas, one beneath 216-U-10 Pond in the 200-West Area and one beneath 216-B-3 Pond near the 200-East Area. During the 1960s, the ground-water mounds grew moderately before reaching near-equilibrium conditions during the 1970s. During the 1980s (December 1979 to December 1989), stresses imposed on the unconfined aquifer caused recurrence of unsteady state conditions. In the 200-West Area, the water level declined more than 2.5 m (8 ft) between December 1979 and December 1989. Most of the decline occurred after 1984, which correlates with a reduction in wastewater discharge caused by the decommissioning of 216-U-10 Pond in 1984. The decline in the water table occurred mostly in the area between the 200-West Area and the Yakima Ridge basalt, which outcrops above the water table to the south of the 200-West Area.

The change in the water table beneath 216-B-3 Pond and 216-A-25 (Gable Mountain) Pond, which, together, received over 90% of the wastewater from the 200-East Area during the 1980s, can also be correlated with changes in volumes of wastewater released to these ponds. The ground-water mound expanded beneath 216-B-3 Pond during the 1980s, not only because of an increased volume of wastewater produced by startup of operations at the 200-East Area Plutonium Uranium Extraction plant in 1983, but also from redirection of part of that wastewater from Gable Mountain Pond beginning in 1984. Three expansion ponds, 216-B-3A, 216-B-3B, and 216-B-3C were added during the 1980s, increasing the capacity for wastewater discharge. The elevation of the water-table beneath

216-B-3 Pond increased more than 1.5 m (5 ft) between December 1979 and December 1989. The ground-water mound beneath Gable Mountain Pond dissipated as a result of decommissioning activities between 1984 and 1987. The elevation of the water table beneath Gable Mountain Pond declined more than 1 m (3 ft) between December 1979 and December 1989. Wastewater management practices in the 200-East Area, particularly at 216-B-3 Pond, had a wide areal influence on the unconfined aquifer southeast of 216-B-3 Pond. Water levels southeast of 216-B-3 Pond rose approximately 1 m (3 ft) between December 1979 and December 1989.

Water-level changes were also observed in the 100-N Area, the area adjacent to the Columbia River, and in two individual wells. Pulses of wastewater released to the 1325-N Liquid Waste Disposal Facility caused significant changes in the elevation of the water table beneath the 100-N Area between 1985 and 1990, resulting in ground-water mounding. In addition, the water table adjacent to the Columbia River responded to temporal changes in the river stage. Anomalous water-level changes were observed in well 699-59-80B, located south of Gable Butte, and well 699-28-52A, located south of the 200-East Area.

ACKNOWLEDGMENTS

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CONTENTS

EXECUTIVE SUMMARY iii

ACKNOWLEDGMENTS v

INTRODUCTION 1

PRE-1980 OPERATIONAL HISTORY AND WATER-LEVEL RESPONSES 5

WASTEWATER DISCHARGE FACILITIES 6

DATA PREPARATION 11

WATER-LEVEL CHANGES 13

200-WEST AREA 19

200-EAST AREA 28

216-B-3 Pond 29

Gable Mountain Pond 33

100-N AREA 38

IMPACTS FROM IRRIGATION IN UPPER COLD CREEK VALLEY 41

RIVER STAGE INFLUENCES 44

ANOMALOUS WATER-LEVEL CHANGES 46

Well 699-59-80B 46

Well 699-28-52A 46

SUMMARY AND CONCLUSIONS 51

REFERENCES 53

FIGURES

1 Map of the Hanford Site in Southeastern Washington State 2

2 Map of the 200-West Area Showing the Locations of Major Discharge Facilities Active During the 1980s 7

3 Map of the 200-East Area Showing the Locations of Major Discharge Facilities Active During the 1980s 8

4 Contour Map of the Changes in the Elevation of the Water Table for the Hanford Site Between December 1979 and December 1989 15

5 Contour Map of the Changes in the Elevation of the Water Table for the Hanford Site Between December 1979 and December 1984 17

6 Contour Map of the Changes in the Elevation of the Water Table for the Hanford Site Between December 1984 and December 1989 18

7 Water-Table Map of the Hanford Site, December 1979 20

8 Water-Table Map of the Hanford Site, December 1989 21

9 Map of the 200-West Area Showing Designated Areas 1, 2, 3, 4, and 5 22

10 Annual Volume of Wastewater Discharged at the 200-West Area and Vicinity Between 1980 and 1990 23

11 Hydrographs of Wells 299-W10-5, 299-W19-1, 299-W23-4, 699-25-70, 699-35-78A, 699-43-89, 699-45-69A, and 699-49-79 Between December 1979 and December 1989 25

12 Comparison of Annual Volume of Wastewater Discharged at the 200-West Area, Area 2, and U Pond Between 1980 and 1990 26

13 Hydrographs of Wells 299-W14-1, 299-W22-22, 699-32-72, and 699-32-77 Between December 1979 and December 1989 27

14 Hydrograph of Well 299-W18-15 Between December 1979 and December 1989 28

15 Comparison of 200-East Area Annual Discharges and Sum of B Pond and Gable Mountain Pond Annual Discharges Between 1980 and 1990 . 29

16 Map of B Pond Showing the Locations of Wells 299-34-1, 699-39-39, 699-43-42, 699-45-42, and 699-47-35B 30

17 Annual Volume of Wastewater Discharged at B Pond Between 1980 and 1990 31

18 Hydrographs of Wells 299-E34-1, 699-39-39, 699-43-42, 699-45-42, and 699-47-35B Between December 1979 and December 1989 32

19 Hydrographs and Locations of Wells Used to Illustrate the Delayed Response of the Unconfined Aquifer Southeast of B Pond 34

20 Annual Volume of Wastewater Discharged at Gable Mountain Pond Between 1980 and 1990 35

21 Hydrograph of Well 699-53-47A Between December 1979 and December 1989 36

22 Hydrographs and Locations of Wells Used to Illustrate the Areal Influence of Gable Mountain Pond Discharge on the Unconfined Aquifer 37

23 Map of the 100-N Area Showing the Location of Well 199-N-27 . . . 39

24 Monthly Volume of Wastewater Discharged at the 1325-N Liquid Waste Disposal Facility Between September 1985 and January 1990 . 40

25 Hydrograph of Well 199-N-27 Between 1985 and 1990 40

26 Hydrograph of Well 199-N-27 Between February 16, 1988, and March 1, 1988 41

27 Water-Table Map Beneath the 1325-N Liquid Waste Disposal Facility in the 100-N Area for June 1989 42

28 Hydrograph of Well 699-43-104 Between 1957 and 1990 43

29 Map of the Western Part of the Hanford Site in the Cold Creek Valley 45

30 Hydrographs and Locations of Wells Used to Illustrate the Rise in Water Level in Well 699-59-80B 47

31 Hydrographs and Locations of Wells Used to Illustrate the Anomalous Water-Level Changes in Well 699-28-52A 49

TABLE

1 Summary of the Major 200 and 100 Area Discharge Facilities That Operated During the 1980s 9

INTRODUCTION

Water levels in most of the wells open to the unconfined aquifer on the Hanford Site are routinely measured every 6 months as part of the Ground-Water Surveillance Program. These measurements, used to generate water-table maps of the Hanford Site, can also be used to determine water-level changes, which can be correlated spatially and temporally with changes in stresses imposed by artificial recharge and river stage. The primary sources of artificial recharge that cause water-level changes at the Hanford Site are irrigation practices adjacent to the Hanford Site and routine disposal of wastewater. Wastewater is produced by separations processing of spent nuclear fuel at Hanford operating facilities (Serkowski et al. 1988). Natural recharge contributes minimally to the unconfined aquifer (Newcomb et al. 1972; Gee 1987).

The study area is located on the U.S. Department of Energy's (DOE) Hanford Site in southeastern Washington State (Figure 1). The Hanford Site monitoring well network used for this study consists of over 200 wells that are distributed over most of the site. The location and a description of wells on the Hanford Site is provided in McGhan (1989). These wells are perforated or screened in the upper part of the unconfined aquifer. Historically, the wells were designed primarily for radiological and chemical monitoring of ground water, but they have also been used to monitor the elevation of the water table.

The purpose of this report is to evaluate, from a historical perspective, temporal and spatial changes in the Hanford Site water table between 1980 and 1990. This report describes the relationship between stresses caused by the concentrated sum of recharge sources applied to the unconfined aquifer system and the response of the water table to those stresses.

The response of the water table to recharge depends on several factors including the transmittal and storage properties of the aquifer and the strength, duration, and frequency of the recharge events. This study does not attempt to include a description of all areas known to receive recharge, either because 1) the water table responded insignificantly to recharge events or 2) water-level data were lacking in those areas, and hence water-level

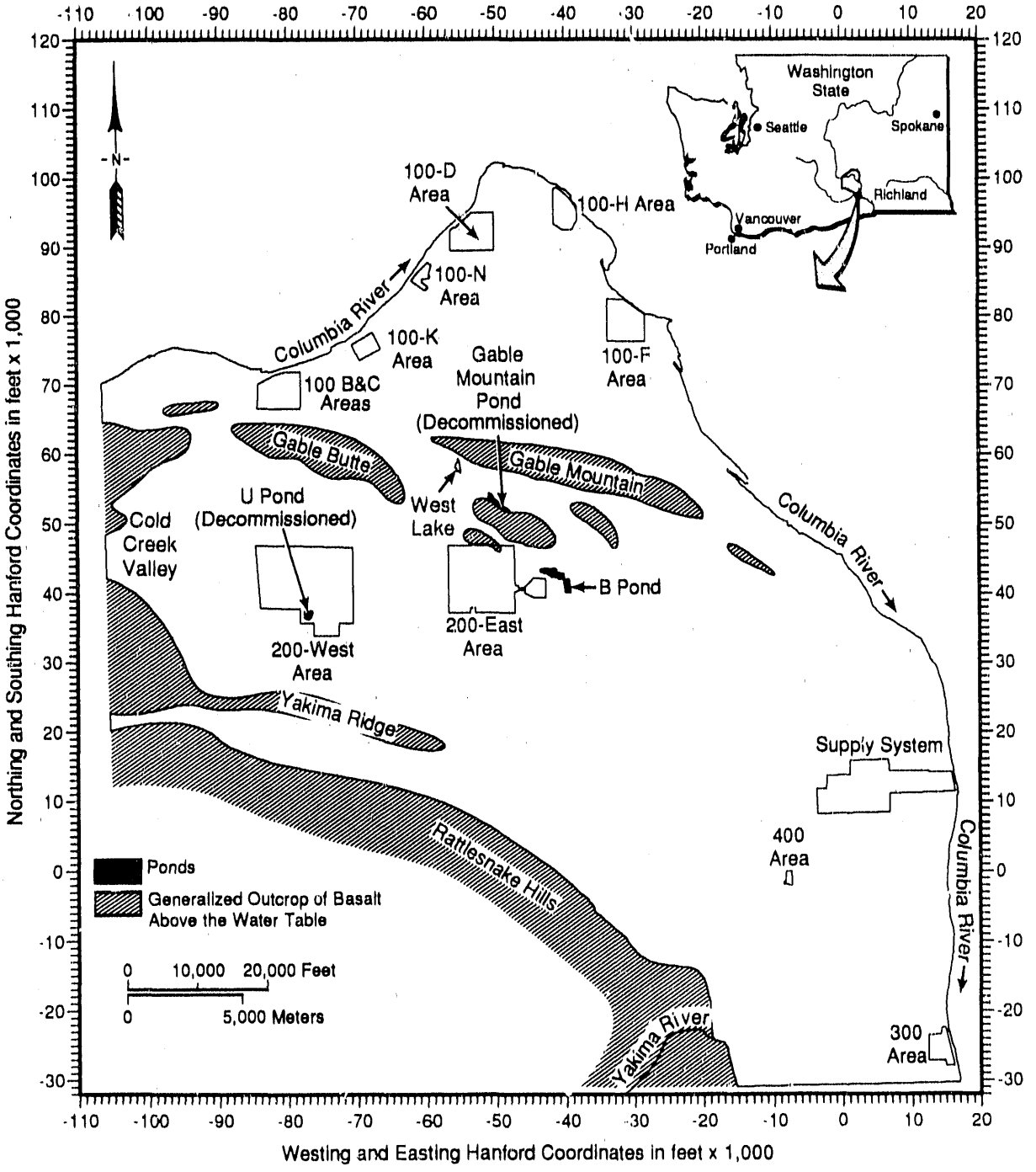

FIGURE 1. Map of the Hanford Site in Southeastern Washington State

changes could not be determined. Examples of such areas include various cribs, trenches, and ponds in the 200, 300 and 400 Areas.

A description of the unconfined aquifer characteristics at the Hanford Site, including changes in the shape of the water table, is found in several studies (Newcomb and Strand 1953; Newcomb, Strand, and Frank 1972; Gephart et al. 1979; and DOE 1988). Well hydrographs of the Hanford Site water table from 1944 through 1973 are provided in Kipp and Mudd (1974). A report by Zimmerman et al. (1986) documented the historical changes of the Hanford Site water table between 1950 and 1980. Hydrographs of selected wells in and around the 200 Areas representing the period between 1983 and 1985 are presented in Last et al. (1990). Between 1980 and 1990, semiannual water-table maps of the Hanford Site were generated and published by Rockwell Hanford Operations (RHO) (1979, 1980a, 1980b, 1981a, 1981b, 1982a, 1982b, 1983a, 1983b, 1984a, 1984b, 1985a, 1985b, 1986a, and 1986b), Westinghouse Hanford Company (WHC) (Schatz et al. 1987), and Pacific Northwest Laboratory (PNL) (Evans et al. 1988; Evans et al. 1989; Newcomer et al. 1989; and Newcomer et al. 1990). Data on the volume of wastewater released to various surface discharge facilities are documented in annual reports by RHO and WHC (Aldrich 1984, 1985, 1986, 1987; Aldrich and Sliger 1981; Cooney, Howe, and Voigt 1988; Cooney and Thomas 1989; Law and Allen 1984; Law and Schatz 1986; Law, Serkowski, Ammerman, and Schatz 1988; Law, Serkowski, and Schatz 1987; Law, Schatz, Fuchs, and Dillon 1986; Sliger 1982, 1983; and Wilbur, Graham, and Lu 1983).

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PRE-1980 OPERATIONAL HISTORY AND WATER-LEVEL RESPONSES

Artificial recharge has caused significant water-level changes in the unconfined aquifer beneath the Hanford Site since operations began in 1943 (Kipp and Mudd 1974; Zimmerman et al. 1986). Between 1943 and 1980, the predominant water-level changes occurred in the form of ground-water mounds that developed under major ponds in and around the 200 Areas. Ground-water mounds beneath the ponds have risen considerably between 1943 and 1980; the greatest of these changes is within 25 m (80 ft) beneath the 200-West Area and 10 m (30 ft) beneath the 200-East Area. The difference in the height of the mounds beneath the 200-West and 200-East Areas reflects the difference in hydraulic properties of the unconfined aquifer. The unconfined aquifer beneath the 200-West Area lies primarily within the Ringold Formation, which has lower transmissive and storage properties than the unconfined aquifer beneath the 200-East Area (DOE 1988). The unconfined aquifer beneath the 200-East Area consists primarily of glaciofluvial deposits of the Hanford formation. The influence of these mounds has also extended laterally, causing water levels to rise throughout the majority of the Hanford Site (Zimmerman 1986). Ground-water levels remained elevated into the 1980s because of continued artificial recharge in and around the 200 Areas.

During the 1940s and 1950s, two ground-water mounds developed beneath major ponds in the 200 Areas, one beneath 200-West Area and one beneath 200-East Area (Newcomb, Strand, and Frank 1972). The mounds grew progressively at various rates above the natural water table, reaching heights of 18 m (60 ft) beneath the 200-West Area and 9 m (30 ft) beneath the 200-East Area. Smaller ground-water mounds developed at various times beneath the 100 Area reactor sites along the Columbia River.

During the 1960s, water-level changes were moderate, the rate of the change increased slowly, as most of the 200-Area plants continued operation. However, water levels rose to the south and east of the 200 Areas as effects from the ground-water mounds beneath the 200 Areas continued to spread outward. Zimmerman et al. (1986) reported that the greatest changes in the configuration of the water table beneath the Hanford Site during the 1960s occurred north of Gable Butte. Water levels north of Gable Butte sharply

decreased as a result of reduced wastewater disposal from shutdown of the 100-B and 100-C reactors. Water levels also decreased in other areas north of Gable Mountain, corresponding to the shutdown of other 100-Area reactors.

Water-level changes throughout the Hanford Site were minor during the 1970s. Zimmerman et al. (1986) concluded that the unconfined aquifer system was nearing equilibrium with the recharge sources during this time throughout most of the site. One exception was increasing water levels at the west end of the Hanford Site. It was hypothesized that the water levels in this area were responding to irrigation practices that occurred in the Upper Cold Creek Valley.

WASTEWATER DISCHARGE FACILITIES

Development of the ground-water mounds corresponds to discharges to wastewater facilities from T Plant, U Plant, Z Plant, and Redox facilities in the 200-West Area and B Plant and the Plutonium Uranium Extraction (PUREX) plant in the 200-East Area. The major ponds used during the 1980s for disposal of wastewater were the 216-B-3 (B) Pond and Gable Mountain Pond near the 200-East Area and the 216-U-10 (U) Pond in 200-West Area. Figures 2 and 3 show the locations of these facilities in and near the 200-West and 200-East Areas, respectively.

Wastewater discharge facilities at the Hanford Site include ponds, trenches, ditches, and cribs. Ponds are shallow, unlined, surface-water facilities that were constructed by excavation and were often diked for containment. Trenches and ditches are open, elongated, earthen structures, which may or may not convey wastewater to other discharge facilities. These surface-water facilities were designed for evaporation as well as percolation of wastewater into the underlying sediments. Cribs are subsurface facilities that typically consists of an elongated, rock-filled trench covered with plastic sheeting and backfill material (Law et al. 1986). A perforated pipe within the rock fill material distributes the wastewater throughout the length of the crib.

Ponds, trenches, ditches and cribs that have received large volumes of wastewater during the 1980s are summarized in Table 1. The summary table

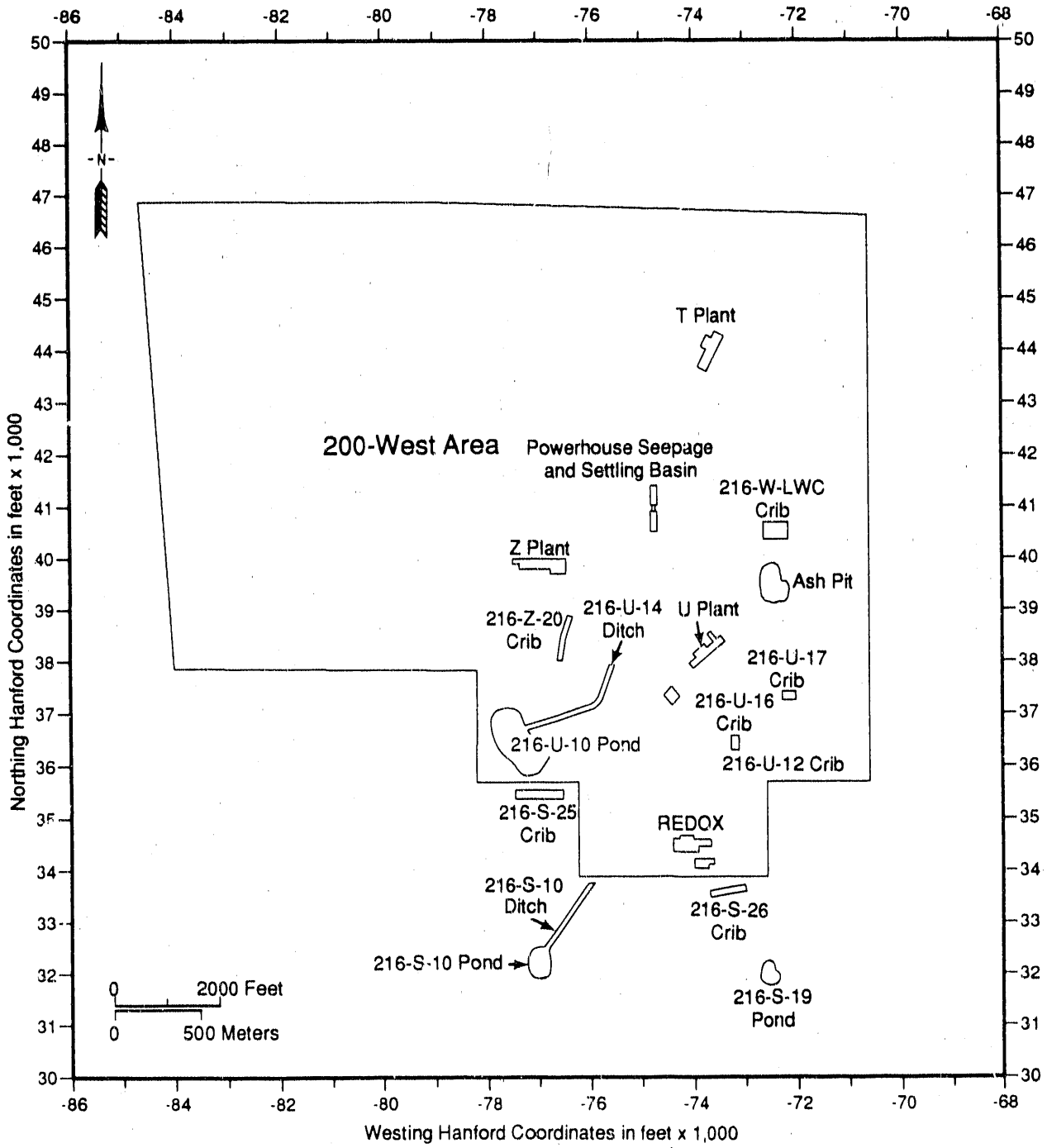

FIGURE 2. Map of the 200-West Area Showing the Locations of Major Discharge Facilities Active During the 1980s

includes the name and location of the various wastewater facilities. The information presented in this table is taken from annual reports. Maps showing the locations of these facilities in the 200-West and 200-East Areas are shown in Figures 2 and 3.

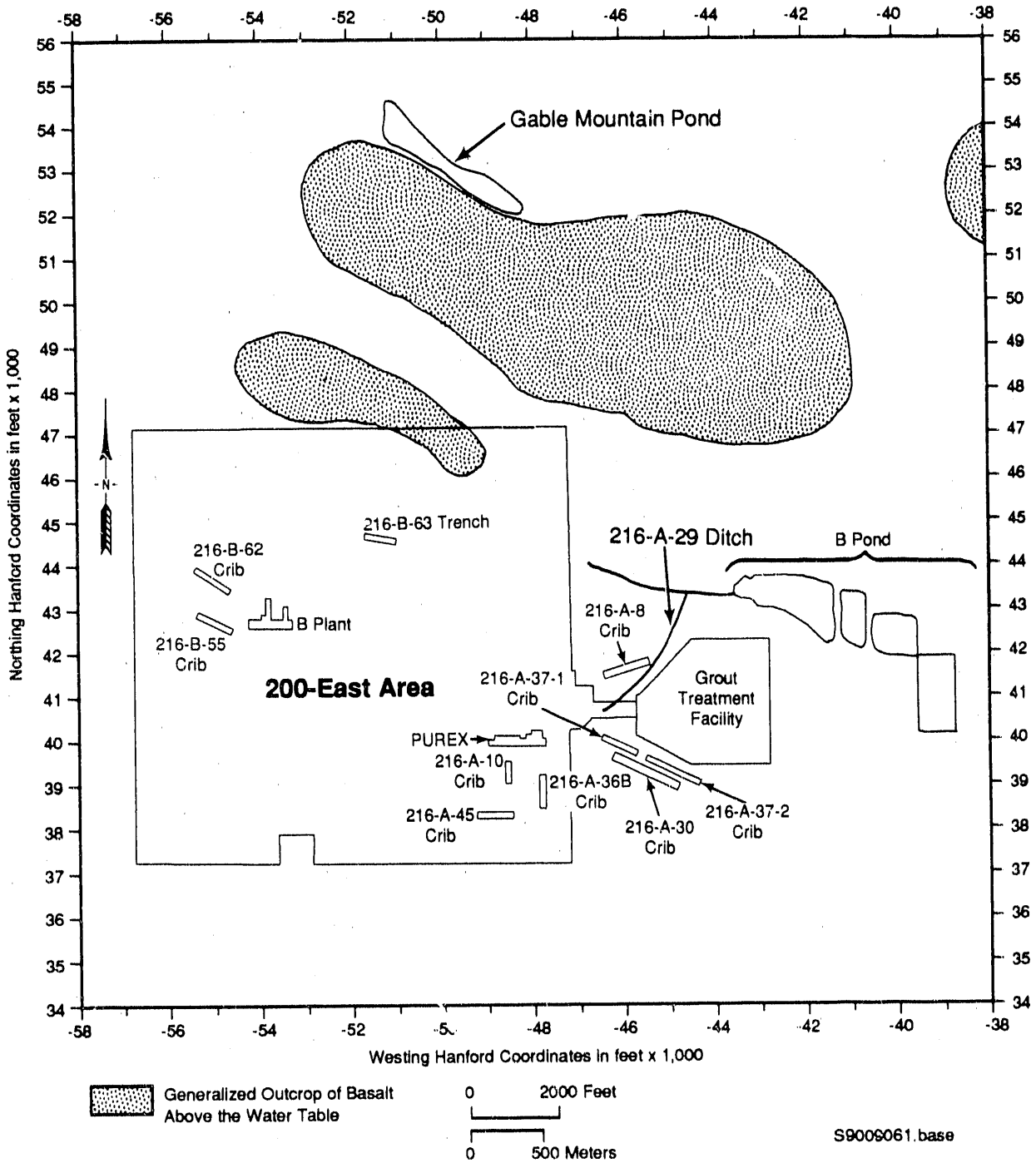

FIGURE 3. Map of the 200-East Area Showing the Locations of Major Discharge Facilities Active During the 1980s

TABLE 1. Summary of the Major 200 and 100 Area Discharge Facilities That Operated During the 1980s

Location	Facility
200-West Area and Vicinity	216-S-10 Ditch
	216-S-10 Pond
	216-S-19 Pond
	216-S-25 Crib
	216-S-26 Crib
	216-U-10 (U Pond)
	216-U-12 Crib
	216-U-14 Ditch
	216-U-17 Crib
	216-W-LWC Crib
	216-Z-20 Crib
	Powerhouse Seepage and Settling Basin
	Ash Pit
200-East Area and Vicinity	216-A-8-Crib
	216-A-10 Crib
	216-A-25 (Gable Mountain Pond)
	216-A-29 Ditch
	216-A-30 Crib
	216-A-37-1 Crib
	216-A-37-2 Cribs
	216-A-36B Crib
	216-A-45 Crib
	216-B-3 Pond (B Pond)
	216-B-55 Crib
	216-B-62 Crib
	216-B-63 Trench
100-N Area	1301-N Liquid Waste Disposal Facility
	1325-N Liquid Waste Disposal Facility

DATA PREPARATION

Water levels are routinely measured in wells that are completed within the unconfined aquifer at the Hanford Site. Water-level data are then stored in a computerized data base, called the Hanford Ground-Water Data Base (HGWDB) PNL (1990). All water-level data used for evaluating the changes in the water table were extracted from this data base. Most of the water-level measurements used to evaluate water-table changes were collected as part of PNL's Ground-Water Surveillance Program. Some of the water-level measurements stored in the data base were collected as part of Resource Conservation and Recovery Act (RCRA) activities.

Documented procedures were followed to measure water levels in wells during the period 1980 to 1990. The first formal written procedure, Procedure No. TP-O&EP-39-1, was issued in late 1985 and can be found in Last et al. (1990). Other water-level measurement procedures were issued in July 1986 and June 1989 (PNL 1989). Although no written PNL water-level measurement procedure was issued prior to late 1985, a procedure similar to Procedure No. TP-O&EP-39-1 was informally followed.

Review of the data base indicated that most of the wells open to the unconfined aquifer were measured biannually (June and December of each year) during the 1980s. The water-level data were examined to determine the elevation change over the 10-year period 1980 to 1990, and 5-year periods 1980 to 1985 and 1985 to 1990. Therefore, to closely approximate the water-level change for these periods and yet maximize the number of wells in which water levels were measured, water-level data common to December 1979, December 1984, and December 1989 were selected to evaluate water-level changes.

The number of data points is slightly reduced because some of the wells were not measured in December 1979, December 1984, or December 1989. For example, if wells were measured for water levels in December 1979 and December 1989, but not in December 1984, then they were not used in both the 5-year and 10-year comparisons. An exception to this restriction is well 699-43-104. The water levels in this well were measured in December 1979 and December 1989, but not in December 1984. However, this well is located at the west end of the Hanford Site in the Cold Creek Valley where fewer monitoring wells

exist, and provides a strategic location for determining water-level changes that may be affected by activities outside the Hanford Site boundary. Therefore, water-level data for this well were used to determine the water-level change over the 10-year period, but not for the two 5-year periods.

Water-level changes attributed to seasonal fluctuations were determined to be insignificant between 1950 and 1980, relative to water-level changes over other 5-year periods (Zimmerman et al. 1986). Zimmerman determined this by calculating the water-level change for the spring and fall data separately. The water-level differences over the 5-year and 10-year periods for the 1980s were, therefore, not corrected for seasonal variations. Except near the river, seasonal changes in the water table (i.e., natural recharge events) are negligible at the Hanford Site compared to changes caused by artificial recharge. Natural recharge rates at the Hanford Site range from less than 0.1 cm/yr to 10 cm/yr or more, depending upon specific site conditions (Gee 1987).

Water-level data in the form of hydrographs for a number of wells at the Hanford Site are presented throughout this report. Some of the wells used for plotting the hydrographs are the same as those presented in Zimmerman et al. (1986) to provide a level of continuity between reports. Hydrographs of other wells are also included to further illustrate the water-level responses in those areas that were affected during the 1980 to 1990 period.

WATER-LEVEL CHANGES

A contour map showing changes in the elevation of the water table for the Hanford Site between December 1979 and December 1989 is presented in Figure 4. Contour maps for the changes over the two 5-year periods between December 1979 and December 1984 and between December 1984 and December 1989 are shown in Figures 5 and 6, respectively.

These maps were contoured by the software package, UNIRAS®, using a linear inverse distance weighting technique. This technique uses the irregularly spaced water-level data to generate interpolated data points on a regularly spaced grid. The interpolated data are used to draw the contours. The technique is based on application of a weighting scheme for all data points within the limits of a specified search radius such that interpolated data points close to measured data points receive greater weight than those farther away.

The portion of the unconfined aquifer between the Yakima Ridge and the Rattlesnake Hills was not contoured because there are no data points within this area from which to interpret the contours. The regularly spaced data points in this region were interpolated primarily from measured data points north of the ridge because the specified search radius extended across the ridge. However, the Yakima Ridge is expected to act as a relatively impermeable barrier to ground-water flow, and therefore, the portion of the unconfined aquifer between the Yakima Ridge and the Rattlesnake Hills may not respond to influences north or east of this barrier.

The contour maps of the water-level changes in Figures 4, 5, and 6 indicate that significant changes in the configuration of the water table occurred beneath the 200-West Area, beneath B Pond, located east of the 200-East Area, beneath Gable Mountain Pond, and beneath the Cold Creek Valley area, located at the west end of the Hanford Site. The maps also indicate that other isolated anomalies in water-level changes were observed in well 699-59-80B, located south of Gable Butte, and well 699-28-52A, located south of the 200-East Area.

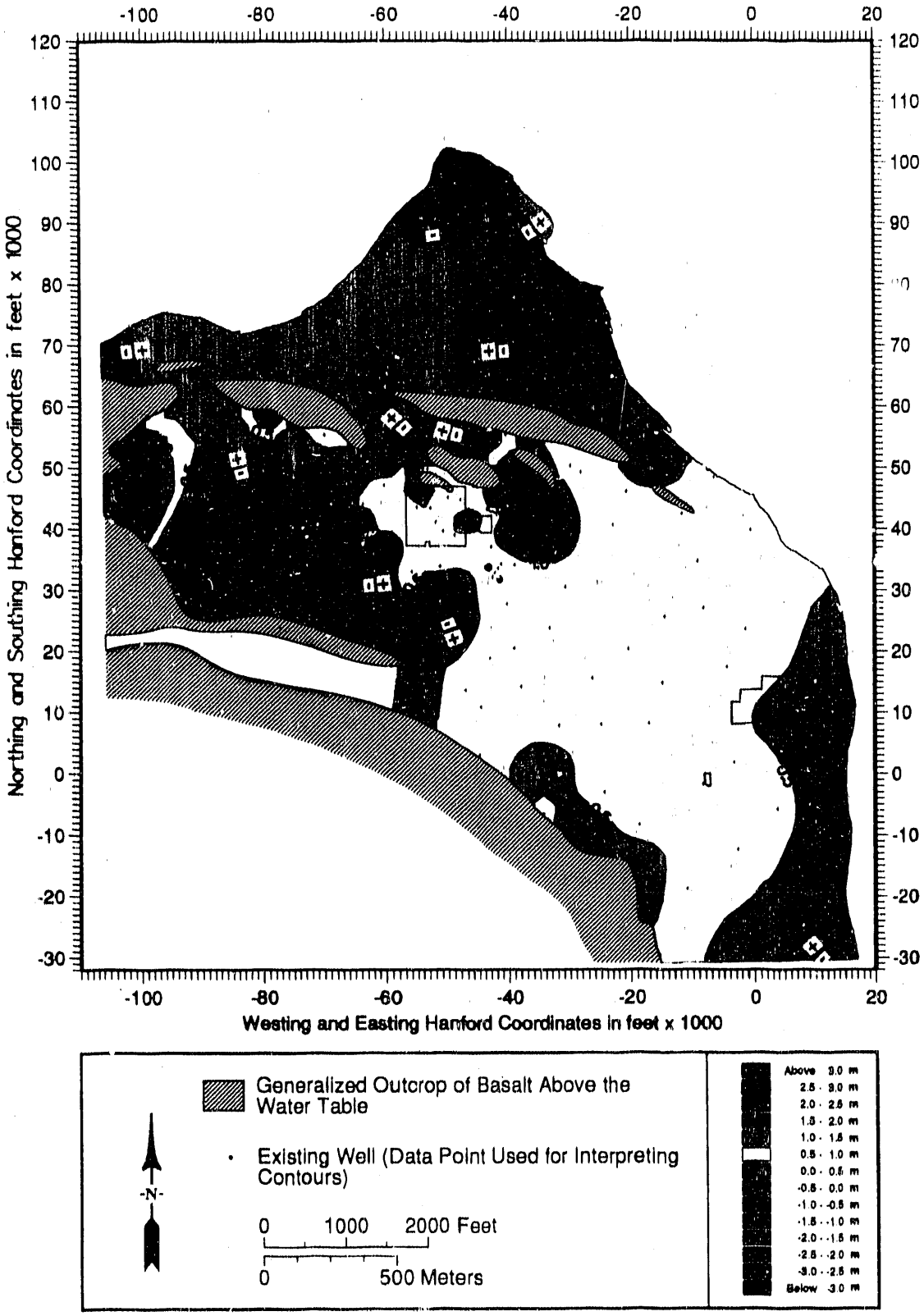

FIGURE 4. Contour Map of the Changes in the Elevation of the Water Table for the Hanford Site Between December 1979 and December 1989

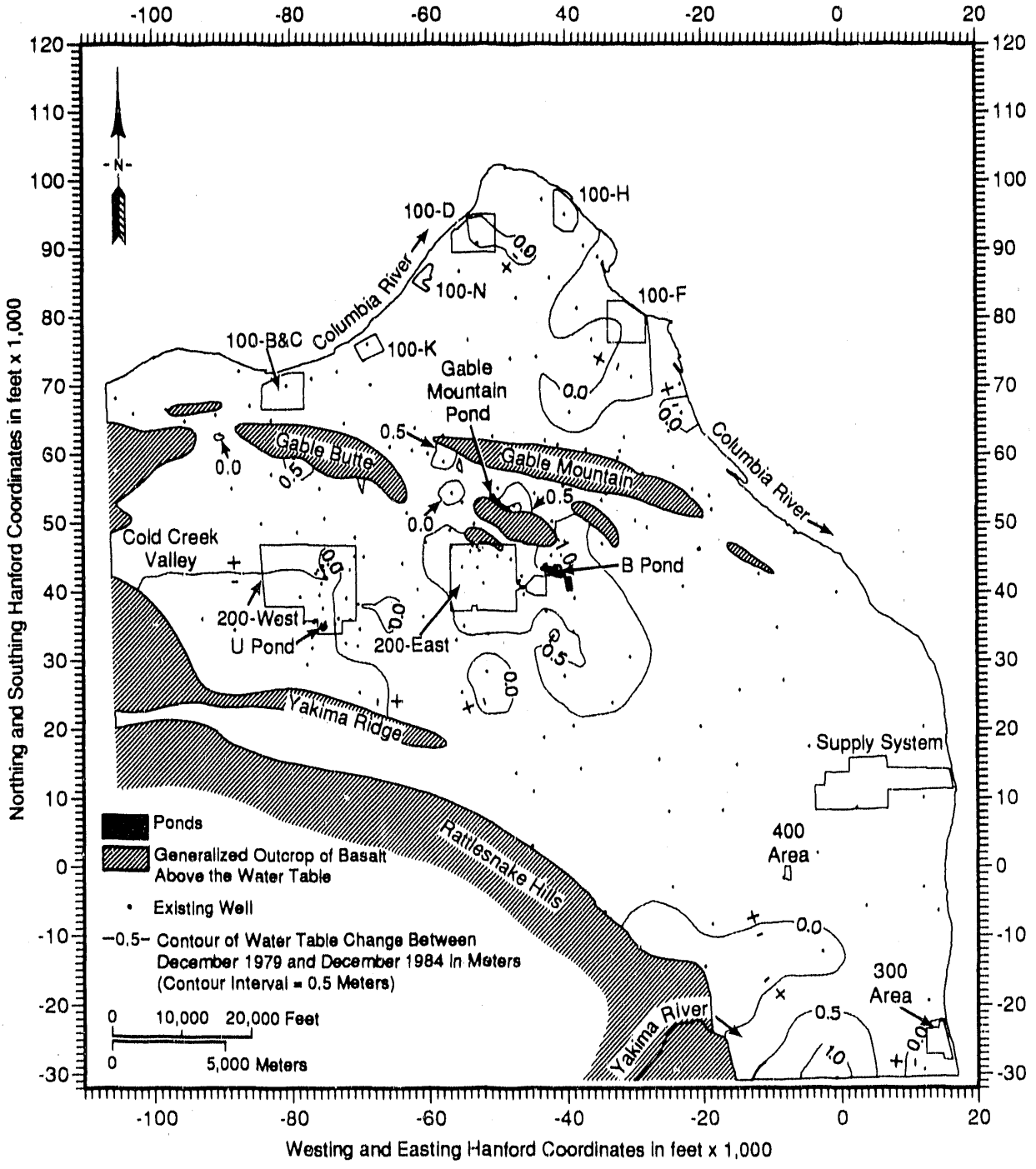

FIGURE 5. Contour Map of the Changes in the Elevation of the Water Table for the Hanford Site Between December 1979 and December 1984

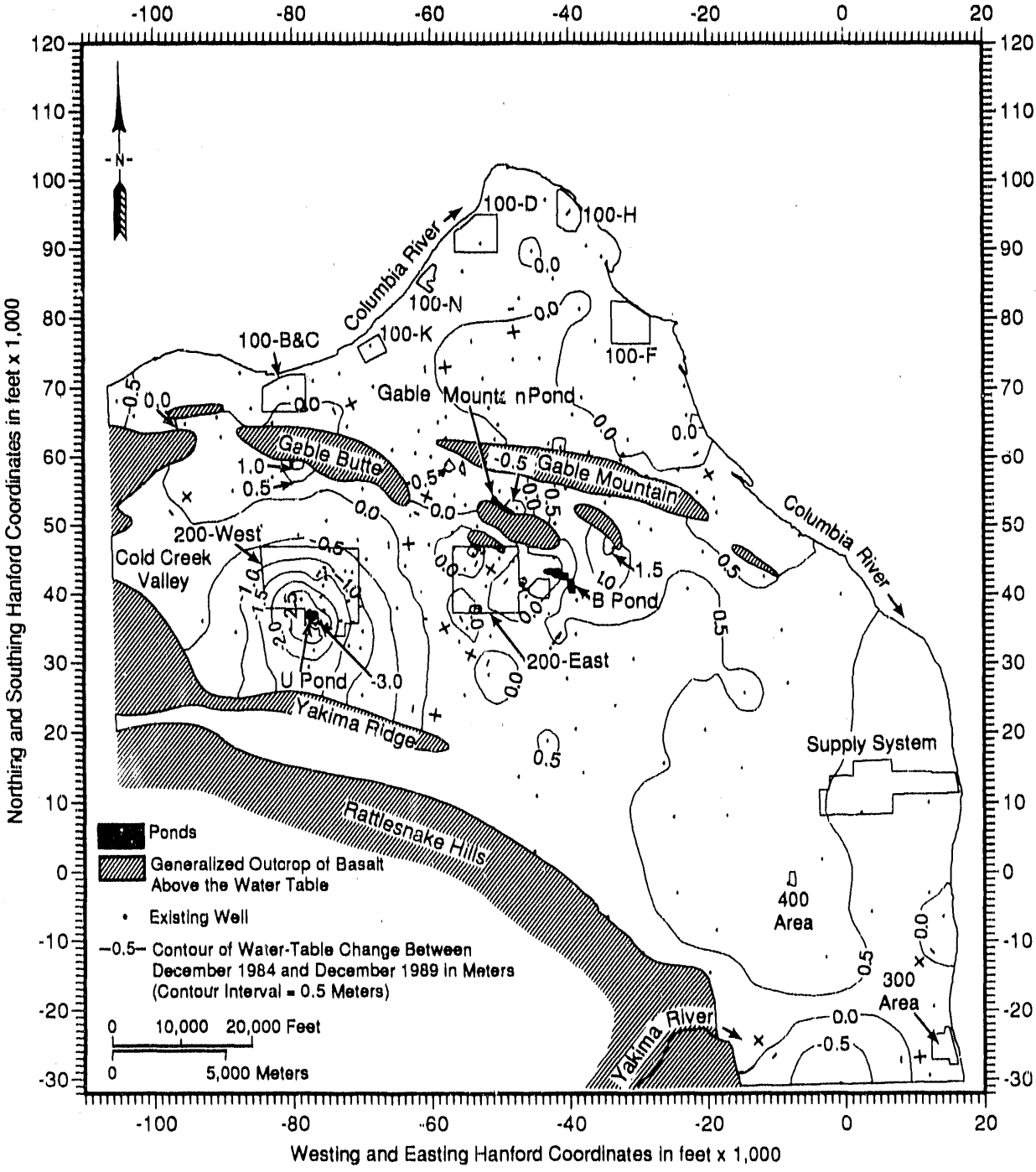

FIGURE 6. Contour Map of the Changes in the Elevation of the Water Table for the Hanford Site Between December 1984 and December 1989

The water table adjacent to the Columbia River changes in response to cyclical river stage fluctuations ranging between hourly and annually. These changes may not be indicative of any long-term trend because the water levels

used to determine the change over a long period (e.g., 5 or 10 years) may have occurred during different amplitudes during different cyclical periods. Therefore, the 5-year or 10-year water-level changes adjacent to the river on the contour maps must be interpreted with caution.

Water level changes that have been observed at the 100-N Area are not apparent on the contour maps. Water levels in the 100-N Area were not measured in December 1979 nor December 1984, therefore, water-level changes over the 5-year and 10-year periods could not be determined. However, water-level measurements collected between 1985 and 1990 indicate that the water table responded significantly to pulses of recharge from wastewater released to facilities in the 100-N Area.

The water-table changes for each of the above mentioned areas are discussed individually below.

200 WEST AREA

Since the mid-1940s, the water table rose approximately 26 m (85 ft) beneath the 200-West Area, which caused ground-water mounding to develop (DOE 1988). Throughout the 1980s, the ground-water mound beneath the 200-West Area declined, although it continues to be a prominent feature of the Hanford Site water table. This mound is caused by liquid wastes recharging the unconfined aquifer at or near the 200-West Area. Water-table maps of the Hanford Site for December 1979 and December 1989 show the configuration of the ground-water mound beneath the 200-West Area (Figures 7 and 8).

For the purposes of this report, wastewater facilities in and around the 200-West Area were grouped together as Areas 1, 2, 3, 4, and 5 (Figure 9) to correlate areas of concentrated discharge to the unconfined aquifer with changes in water level. Area 1 includes 216-W-LWC Crib, the Powerhouse Seepage and Settling Basin, and Ash Pit; Area 2 includes 216-U-10 Pond and the ditches feeding it (e.g., 216-U-14 Ditch), and cribs 216-S-25 and 216-Z-20; Area 3 includes 216-S-10 Pond and Ditch; Area 4 includes cribs 216-S-19 and 216-S-26; and Area 5 includes cribs 216-U-12, 216-U-16, and 216-U-17.

Figure 10 is a bar graph showing the annual discharge of wastewater between 1980 and 1990 at the 200-West Area, including ponds and ditches

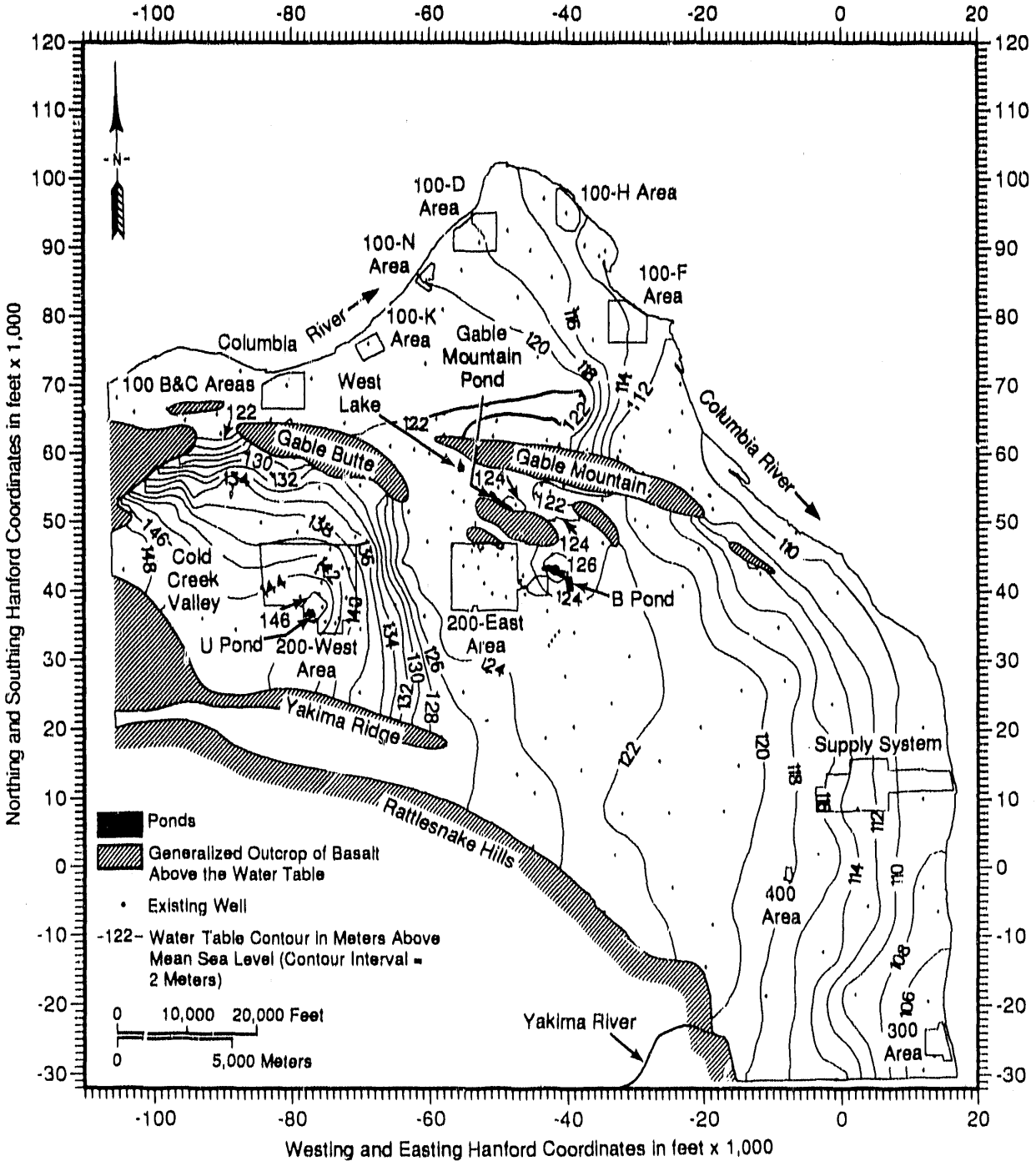

FIGURE 7. Water-Table Map of the Hanford Site, December 1979 (After RHO 1979)

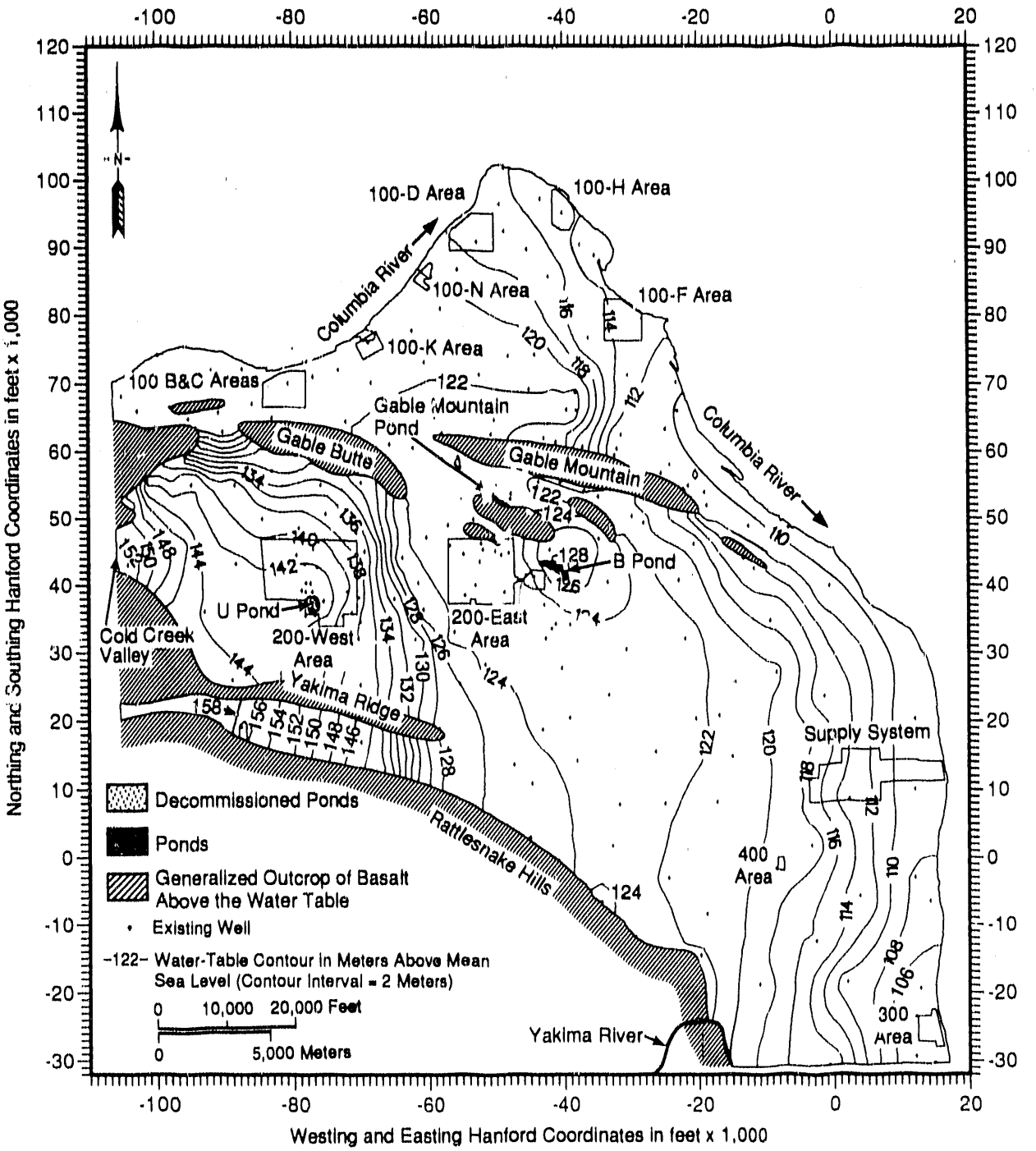

FIGURE 8. Water-Table Map of the Hanford Site, December 1989 (After Newcomer and McDonald 1990)

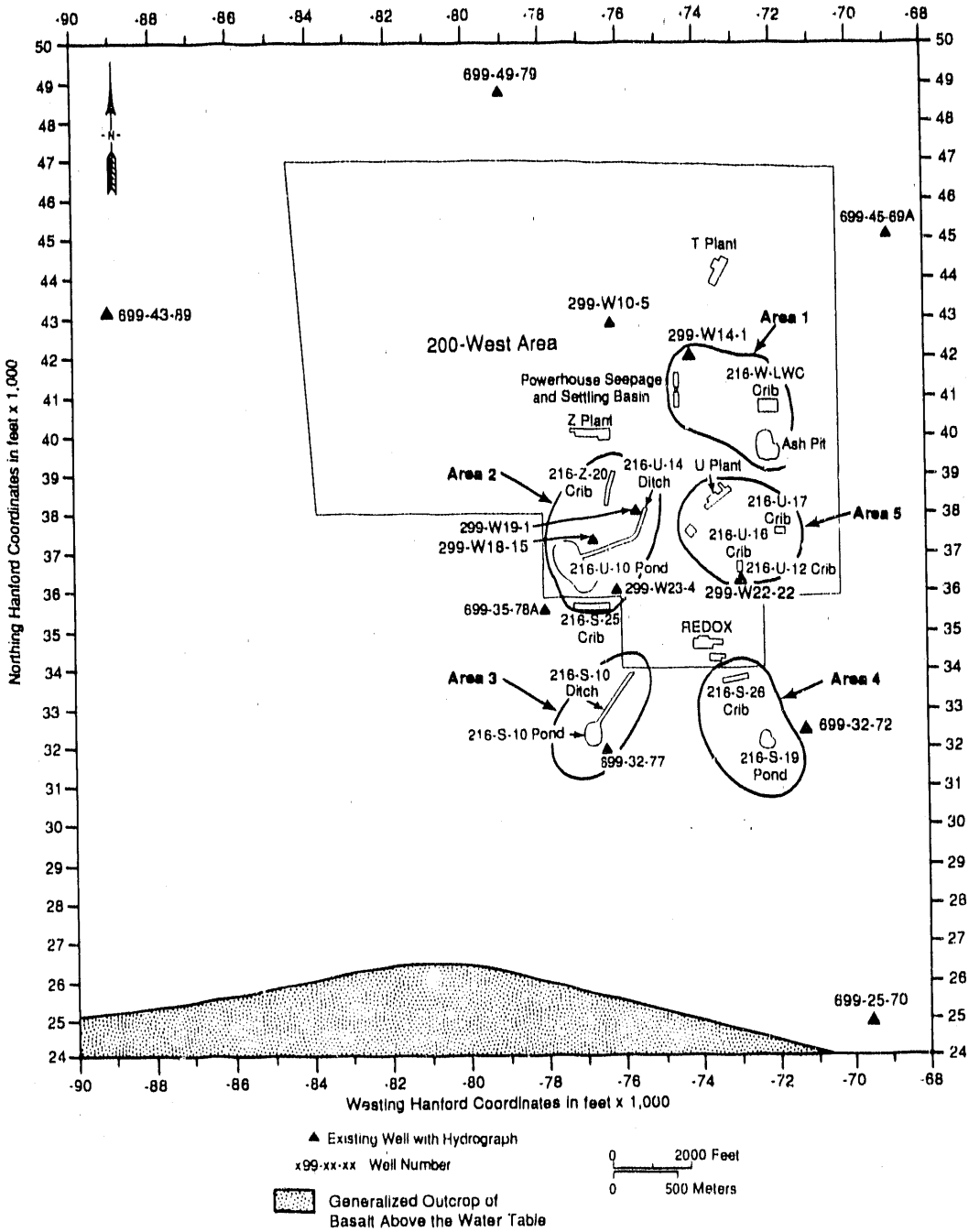

FIGURE 9. Map of the 200-West Area Showing Designated Areas 1, 2, 3, 4, and 5

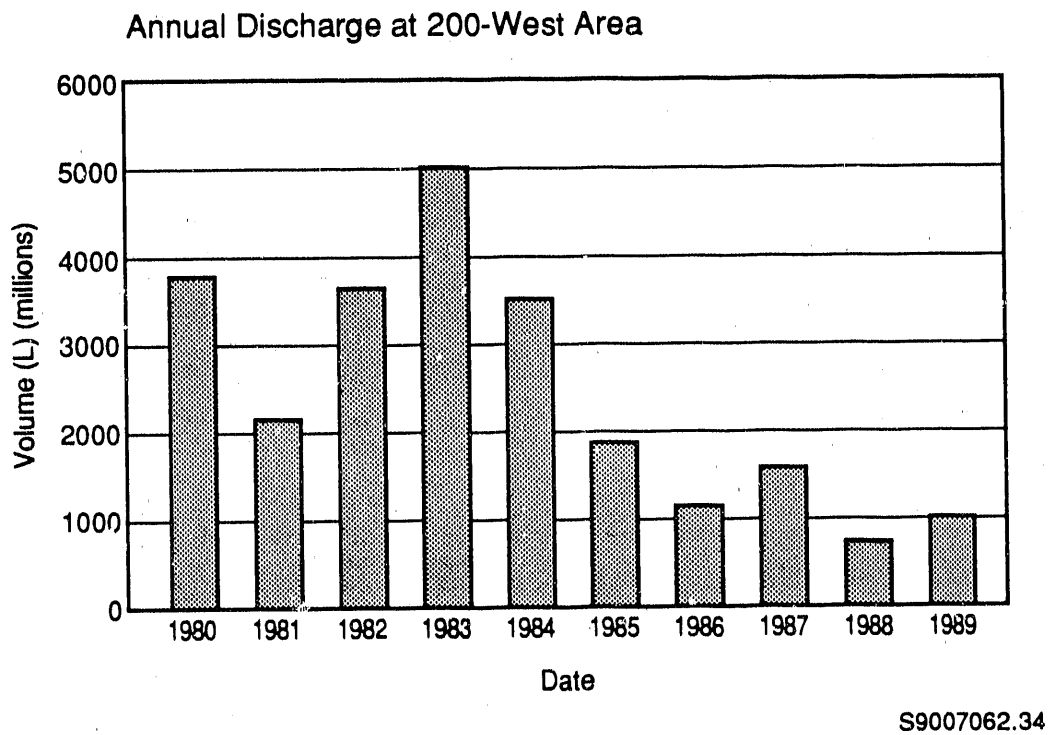

FIGURE 10. Annual Volume of Wastewater Discharged at the 200-West Area and Vicinity Between 1980 and 1990

located just south of the 200-West Area geographic boundary. The total volume of wastewater decreased between 1980 and 1981, increased between 1981 and 1983, and then decreased significantly between 1983 and 1989.

Figure 4 indicates that the elevation of the water table declined significantly beneath the 200-West Area between December 1979 and December 1989. During the last half of the 1980s, the water table declined in excess of 3 m (9.8 ft), primarily the result of decommissioning U Pond in the fall of 1984. The greatest change is centered in the vicinity of the decommissioned U Pond, as shown in Figure 6.

Figure 4 also indicates that the unconfined aquifer south of the 200-West Area was more responsive to wastewater management practices than the unconfined aquifer north of the 200-West Area. The unconfined aquifer south of the 200-West Area is less extensive because of the basalt ridge (Yakima Ridge) and, therefore, may be holding less water in storage. Also, application of irrigation water in the Upper Cold Creek Valley has caused water

levels to rise at the west end of the Hanford Site and may be responsible for maintaining elevated water levels north of 200-West Area as well.

Figure 11 includes a hydrograph of well 699-49-79 that indicates water levels declined very little between December 1979 and December 1989. The location of this well, shown in Figure 9, is north of the 200-West Area.

Hydrograph of several wells in and around the 200-West Area representing the period December 1979 to December 1989 are presented in Figure 11. Plots of water levels for wells near the decommissioned U Pond (699-32-77, 699-35-78A, 299-W19-1, and 299-W23-4) indicate that the water table generally declined between 1980 and 1982, rose between 1982 and 1984 approximately to its 1980 level, and fell steeply thereafter. Hydrographs of these wells exhibit a similar pattern as the bar graph presented in Figure 10. Hydrographs of wells 699-25-70, 699-45-69A, 699-43-87, and 299-W10-5, also shown in Figure 9, display the water-level pattern farther from the decommissioned U Pond.

Prior to decommissioning U Pond in 1984, approximately 60% of the total volume released to 200-West Area facilities went to the U Pond complex, which includes U Pond and the ditches (e.g., 216-U-14 Ditch) feeding it. Figure 12 illustrates that most of the wastewater discharged to facilities within Area 2 went to U Pond, thereby contributing to the ground-water mound beneath U Pond. Furthermore, the highest elevation of the mound beneath the 200-West Area is under U Pond.

Between 1980 and 1985, wastewater was rerouted from the U Pond complex to other 200-West Area facilities (e.g., 216-W-LWC and 216-Z-20 cribs). This rerouting of wastewater reduced the total volume discharged to U Pond between 1980 and 1982. Reduction in released wastewater to U Pond correlates with the decline of the water table between 1980 and 1982.

Between 1982 and 1984, the volume of wastewater discharged to U Pond increased, primarily because the discharge of make-up water (nonwastewater) to U Pond increased. Addition of make-up water was necessary to maintain the level of the pond to keep contaminated sediments on the bottom of the pond wetted before U Pond could be decommissioned (Law et al. 1986). The increased release of water to U Pond correlates with the rise in the water table between 1982 and 1984.

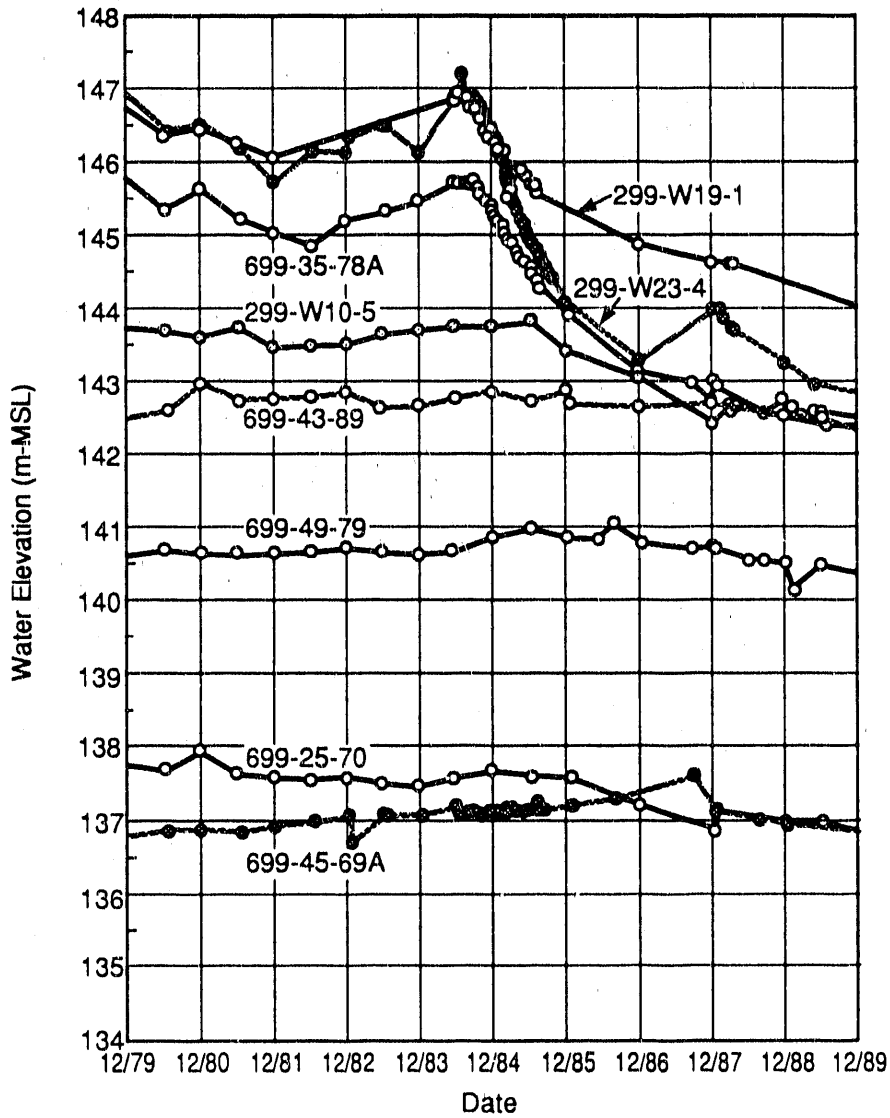

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FIGURE 11. Hydrographs of Wells 299-W10-5, 299-W19-1, 299-W23-4, 699-25-70, 699-35-78A, 699-43-89, 699-45-69A, and 699-49-79 Between December 1979 and December 1989

The abrupt change in the water table after 1984 is the result of decommissioning of U Pond in the fall of 1984 when discharges were stopped and the pond was covered over. After 1984, process wastewater continued to be routed to the 216-U-14 Ditch; however, the load on the unconfined aquifer in the area of U Pond was significantly reduced. This reduction was primarily because make-up water was no longer added to U Pond. After 1984, only 40% of the total volume of wastewater released to all 200-West Area discharge facilities went to the U Pond complex (Figure 12).

The effect of discharges to Areas 1, 3, 4, and 5 on the water table has been masked by the effect of discharges to U Pond in Area 2. This is evident in Figure 13, which shows a hydrograph of a well in or near each of the Areas 1, 3, 4, and 5. The locations of these wells are shown in Figure 9.

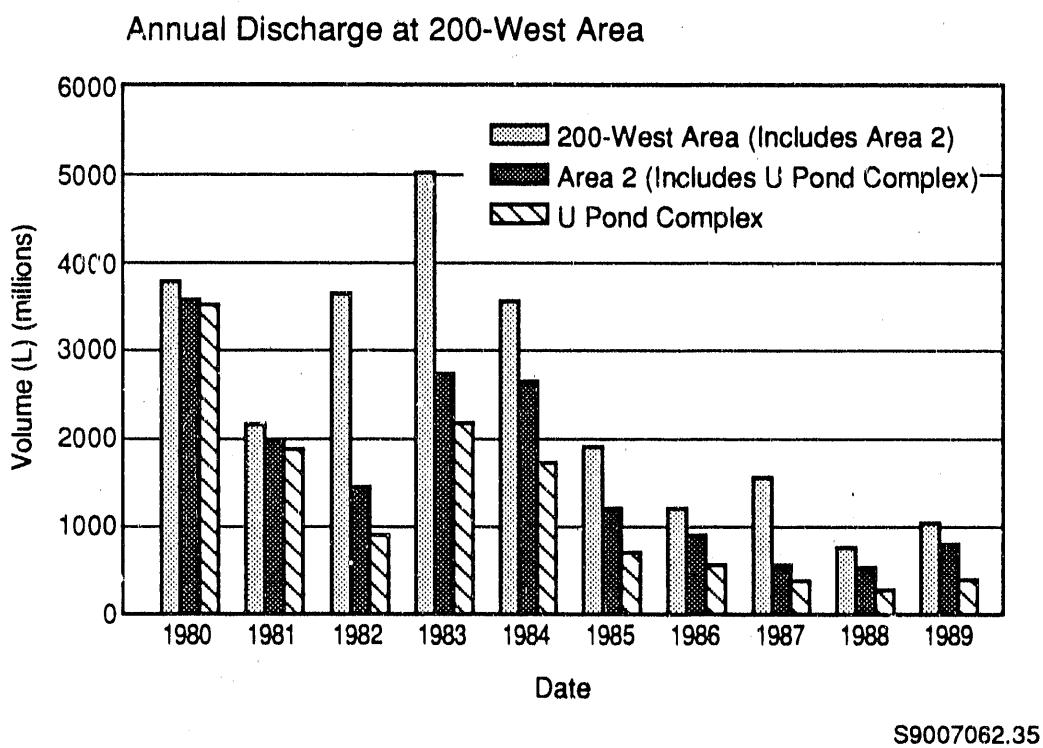

FIGURE 12. Comparison of Annual Volume of Wastewater Discharged at the 200-West Area, Area 2. and U Pond Between 1980 and 1990 (Aldrich and Sliger 1981; Sliger 1982; Wilbur et al. 1983; Law et al. 1984; Law et al. 1986; Law 1986; Aldrich 1986; Aldrich 1987; Law et al. 1987; Serkowski et al. 1988; Cooney et al. 1988; Cooney 1989)

Hydrographs of these wells exhibit a similar pattern as the hydrographs of wells near U Pond (299-W19-1, 299-W23-4, and 699-35-78A) presented in Figure 11 and the bar graph in Figure 10.

Hydrographs of several wells in the 200-West Area, shown in Figure 11 and 13, exhibit an approximate exponential decay curve, reflecting decommissioning of U Pond in 1984. These hydrographs indicate that the ground-water mound beneath U Pond diminished abruptly between 1984 and 1986, but diminished slowly thereafter. The hydrograph for well 299-W18-15, located adjacent to the decommissioned U Pond on the northeast side, shows the greatest water-table change after 1984, falling approximately 5 m (16 ft) between June 1984 and December 1989 (Figure 14).

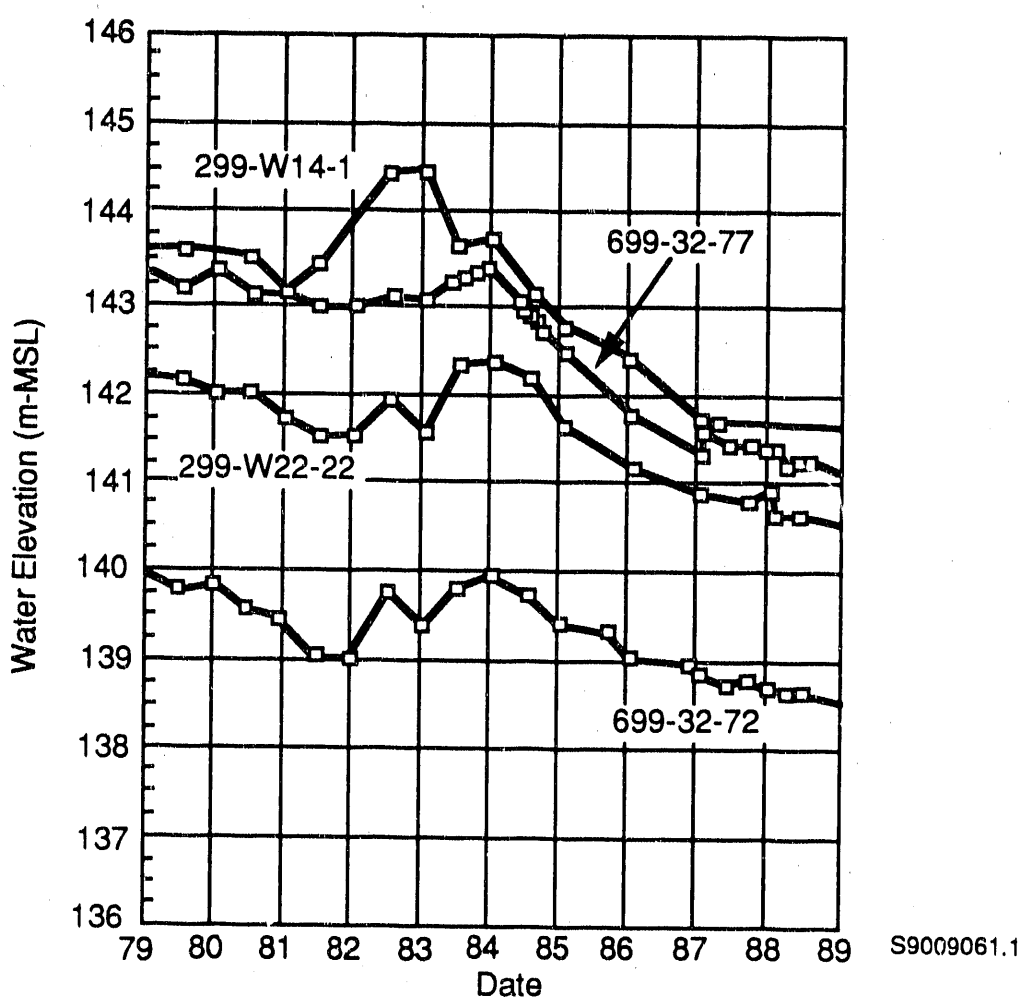

FIGURE 13. Hydrographs of Wells 299-W14-1, 299-W22-22, 699-32-72, and 699-32-77 Between December 1979 and December 1989

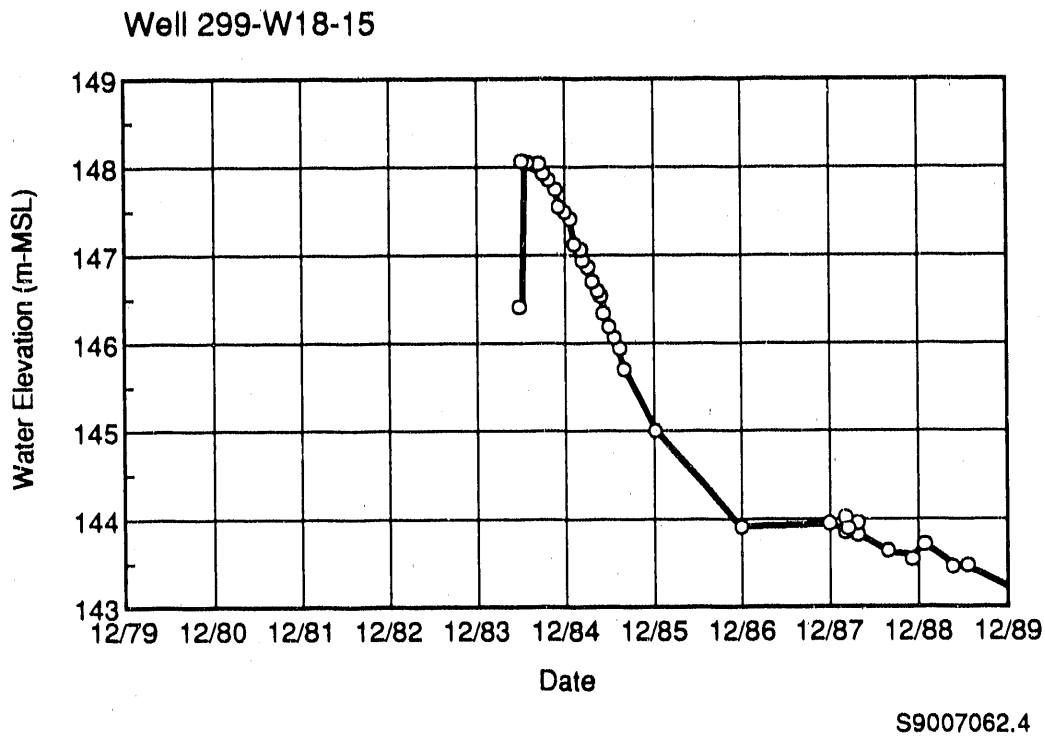

FIGURE 14. Hydrograph of Well 299-W18-15 Between December 1979 and December 1989

A water-table map of the 200-West Area for 1989 (Figure 8) indicates that, although the ground-water mound has diminished since U Pond was decommissioned in 1984, mounding continues to exist beneath the U Pond area. The highest elevation of the ground-water mound, previously beneath U Pond, shifted slightly to the northeast beneath the 216-U-14 Ditch between 1984 and 1989 (Newcomer et al. 1990). This shift is reflected by the majority of the water disposed to the 216-U-14 Ditch after U Pond was decommissioned.

200-EAST AREA

Over 90% of all wastewater from the 200-East Area production facilities was discharged to either Gable Mountain Pond or B Pond during the 1980s (Figure 15). The impact of wastewater released to other 200-East Area discharge facilities on water level has always been influenced by discharges to Gable Mountain Pond or B Pond. This is due largely to the ability of the aquifer to

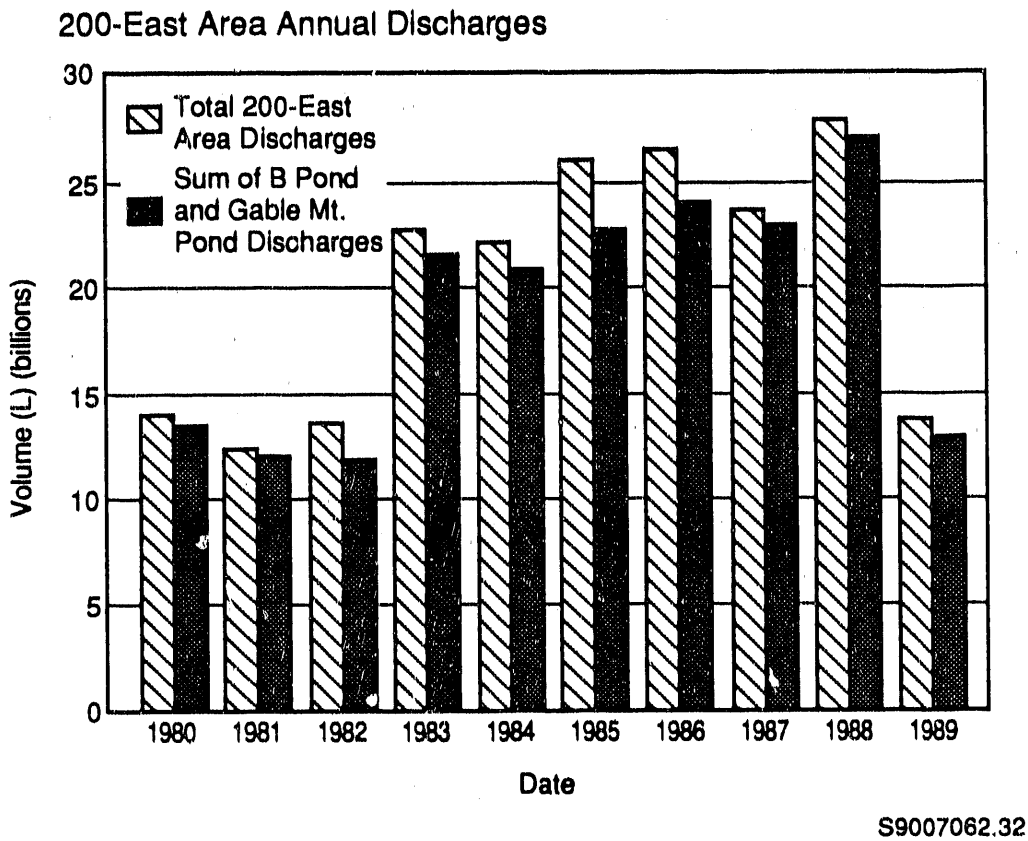

FIGURE 15. Comparison of 200-East Area Annual Discharges and Sum of B Pond and Gable Mountain Pond Annual Discharges Between 1980 and 1990 (Aldrich and Sliger 1981; Sliger 1982; Wilbur et al. 1983; Law et al. 1984; Law et al. 1986; Law and Schatz 1986; Law et al. 1987; Serkowski et al. 1988; Cooney and Thomas 1989)

transmit large volumes of water. Water-level changes during the 1980s, if any, could not be correlated to recharge events caused by discharges to other 200-East Area discharge facilities because the water-level measurements were not frequent enough to record the change or because water-level changes were masked by influences from the two ponds. Most of the discussion will, therefore, be focused on the recharge effects from wastewater released to Gable Mountain Pond and B Pond.

216-B-3 Pond (B Pond)

Since the mid-1940s, the water table rose in excess of 6 m (20 ft) beneath B Pond, which caused ground-water mounding to develop (Gephart et al. 1979). Throughout the 1980s, a ground-water mound was present beneath B Pond

and continues to be a prominent feature of the Hanford Site water table. This mound is caused by liquid waste recharging the aquifer at B Pond. Water-table maps of the Hanford Site for December 1979 and December 1989 show the configuration of the ground-water mound under B Pond (Figures 7 and 8).

The 216-B-3 Pond is located east of the 200-East Area (Figure 1). This pond began receiving wastewater in 1945. Two expansion ponds (216-B-3A and 216-B-3B) were added in 1984, adding 50% more capacity. A third basin (216-B-3C) was added in 1985 (Serkowski et al. 1988). The location of B Pond is shown in Figure 16. Wastewater previously discharged to Gable Mountain Pond was rerouted to B Pond in the 1980s. Together, Gable Mountain Pond and B Pond received wastewater from the 242-A Evaporator, A Tank Farm, AR Vault, B Plant, and PUREX (Serkowski et al. 1988).

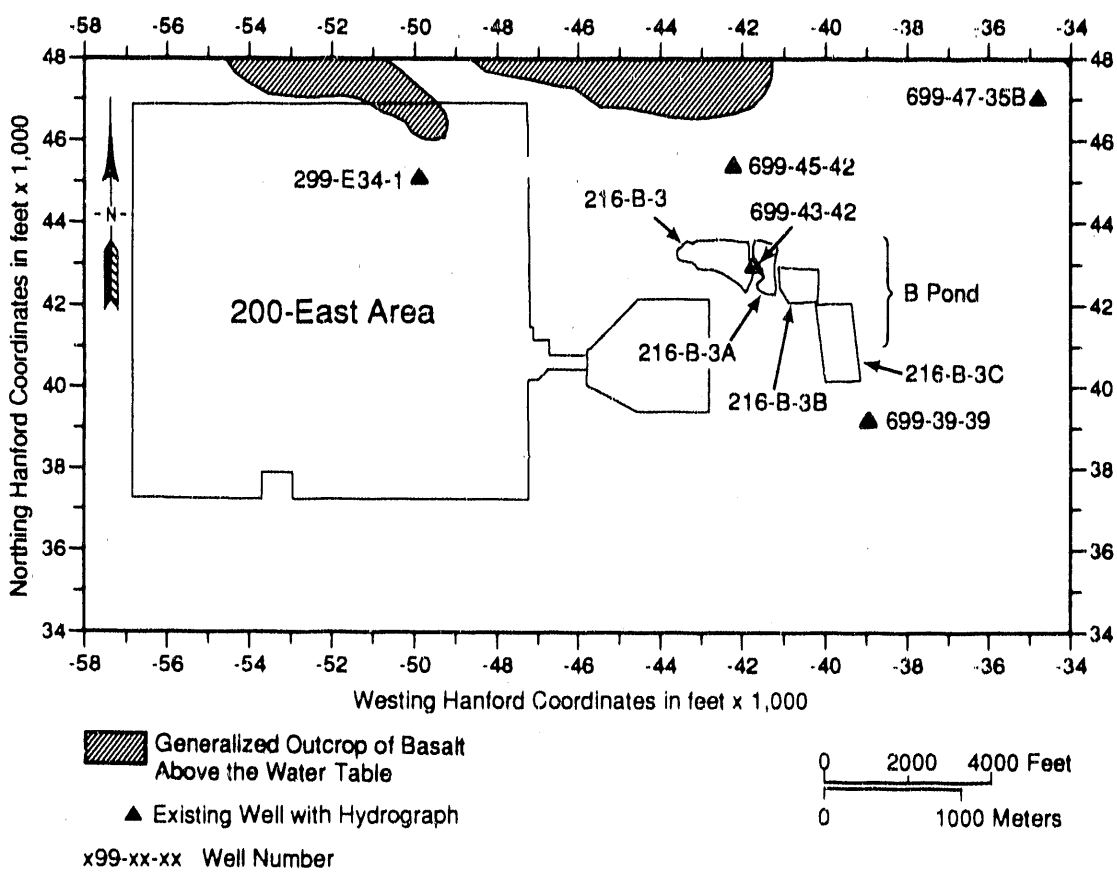

FIGURE 16. Map of B Pond Showing the Locations of Wells 299-34-1, 699-39-39, 699-43-42, 699-45-42, and 699-47-35B

The map of water-table changes in Figure 4 indicates that the water levels rose over 1.5 m (5 ft) beneath B Pond between December 1979 and December 1989. The majority of this rise in water level occurred between 1983 and 1986, during which time the annual discharge of wastewater to B Pond increased. This increase was attributed to decommissioning of Gable Mountain Pond between 1984 and 1987 and to greater volumes of wastewater produced by the restart of PUREX in 1983. Annual volumes of wastewater discharged to B Pond between 1980 and 1990 are plotted as a bar graph in Figure 17. The bar graph indicates that the annual volume of wastewater discharged to B Pond increased from 5.17E+09 L in 1982 to 2.29E+10 L in 1986.

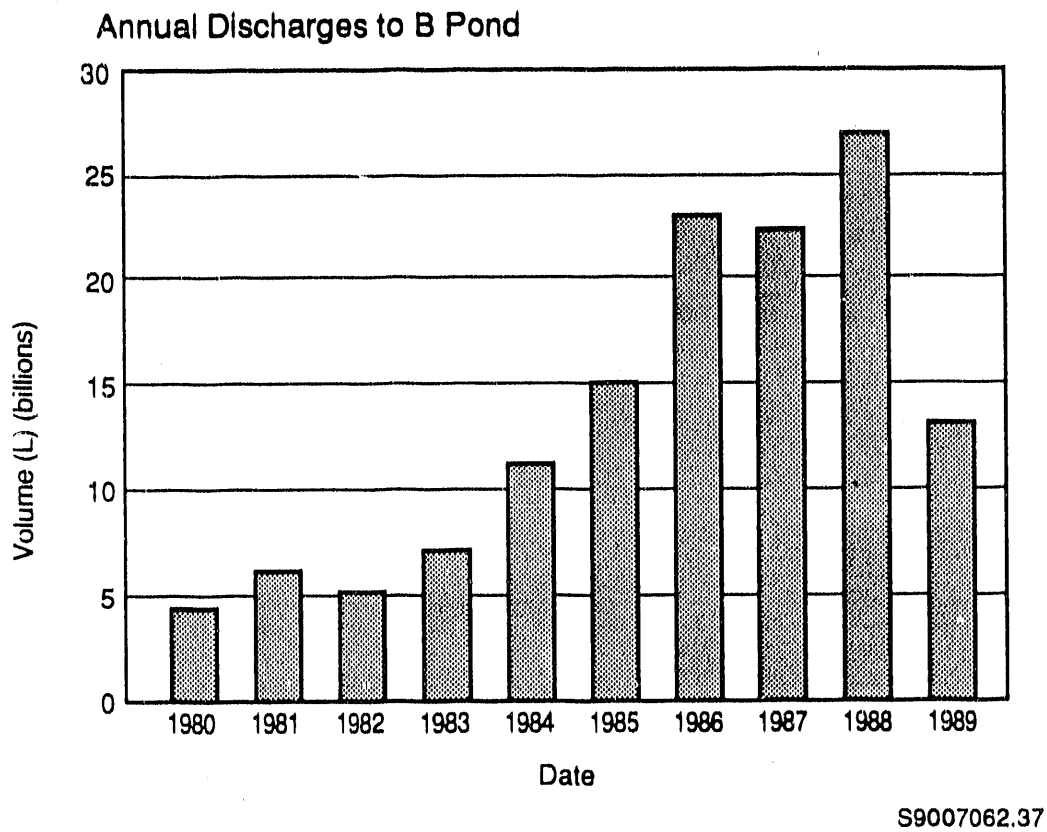

FIGURE 17. Annual Volume of Wastewater Discharged at B Pond Between 1980 and 1990 (Aldrich and Sliger 1981; Sliger 1982; Wilbur et al. 1983; Law et al. 1984; Law et al. 1986; Law and Schatz 1986; Law et al. 1987; Serkowski et al. 1988; Cooney and Thomas 1989)

Hydrographs of wells 299-E34-1, 699-39-39, 699-43-42, 699-45-42, and 699-47-35B, located in the vicinity of B Pond, representing the period December 1979 through December 1989, are shown in Figure 18. The locations of these well are shown in Figure 16. These hydrographs show that the water-level responded primarily to increased discharge to B Pond between 1983 and 1986 (see Figure 17). Figure 16 indicates that the water levels rose 1 m (3 ft) to 1.5 m (5 ft) between 1983 and 1986.

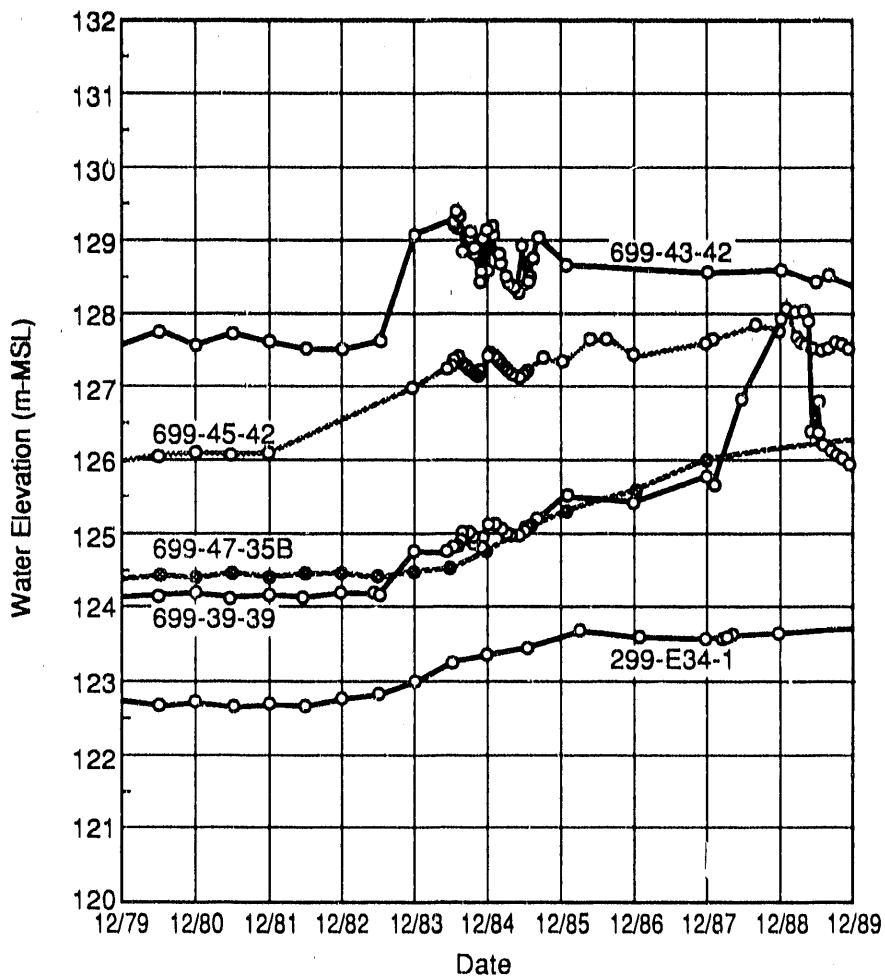

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FIGURE 18. Hydrographs of Wells 299-E34-1, 699-39-39, 699-43-42, 699-45-42, and 699-47-35B Between December 1979 and December 1989

The greatest net change in water levels between December 1979 and December 1989 was observed at well 699-39-39, where the water level rose 1.99 m (6.5 ft). During 1988, the water level increased over 2 m (7 ft) and then, in early 1989, it dropped approximately 1.5 m (5 ft). This large pulse, not observed in other wells in the vicinity of B Pond, was probably due to the increase in discharge to B Pond in 1988 (see Figure 17).

The maps of the water-level changes from December 1979 to December 1984 and from December 1984 to December 1989 (Figures 5 and 6, respectively) show a delayed response of the unconfined aquifer southeast of B Pond. The water table rose approximately 1 m (3 ft) near B Pond over the 5-year period between December 1979 and December 1984 (Figure 5). The water table southeast of B Pond exhibits an increase between 0.5 m (1.5 ft) and 1 m (3 ft) during the period of December 1984 to December 1989 (Figure 6).

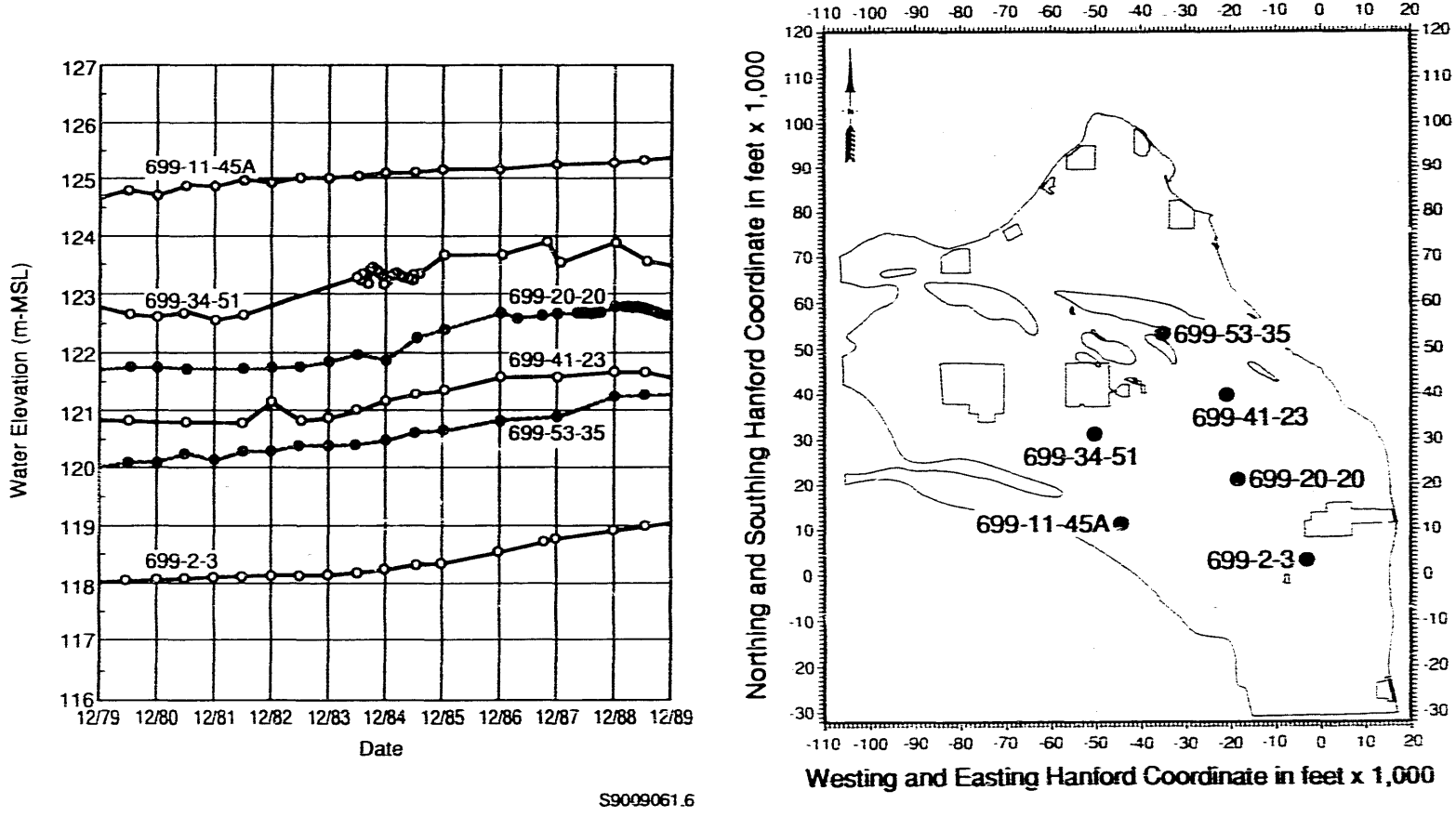
To graphically illustrate the delayed response of the unconfined aquifer southeast of B Pond, hydrographs (and their locations) of six wells are presented in Figure 19. Hydrographs of four of these wells, 699-2-3, 699-20-20, 699-34-51, and 699-41-23, indicate that a distinct increase in water levels did not begin until 1984 to 1985. The water level in well 699-2-3, located farthest from B Pond, continued to rise as late as 1989 while water levels in wells 699-20-20, 699-41-23, and 699-34-51, located closer to B Pond, began to decline by 1989.

The hydrographs in Figure 19 show that the water levels increased as much as 1.5 m (5 ft) between December 1979 and December 1989. These water levels correlate with total 200-East Area discharges (Figure 15) as well as B Pond discharges (Figure 17). These data indicate the wide areal influence that wastewater management practices in the 200-East Area, particularly at B Pond, have on the unconfined aquifer.

Gable Mountain Pond

Gable Mountain Pond (216-A-25 Pond) is located north of the 200-East Area near Gable Mountain (Figure 1).

During the early 1980s, a distinct ground-water mound was present beneath Gable Mountain Pond; however, it was not laterally extensive (RHO 1980b, 1981b, 1982b, 1983b, 1984b). The mound began to dissipate following



a) b)

FIGURE 19. Hydrographs and Locations of Wells Used to Illustrate the Delayed Response of the Unconfined Aquifer Southeast of B Pond. a) Hydrographs of Wells 699-2-3, 699-11-45A, 699-20-20, 699-34-51, 699-41-23, and 699-53-35 Between December 1979 and December 1989. b) Locations of Wells Used for Hydrographs.

the start of decommissioning activities in 1984, after which, Gable Mountain Pond continued to receive reduced discharges until deactivation was complete in the fall of 1987 (Serkowski et al. 1988).

Annual volumes of wastewater discharged to Gable Mountain Pond between 1980 and 1990 are plotted as a bar graph in Figure 20. The bar graph indicates that discharge increased in 1983, probably as a result of the startup of PUREX, and then decreased thereafter. With the diversion of wastewater from Gable Mountain Pond to B Pond in 1986, the volume of water discharged to Gable Mountain Pond was 1.36E+09 L, an 80% reduction from the effluent disposed there in 1985 (Law et al. 1987).

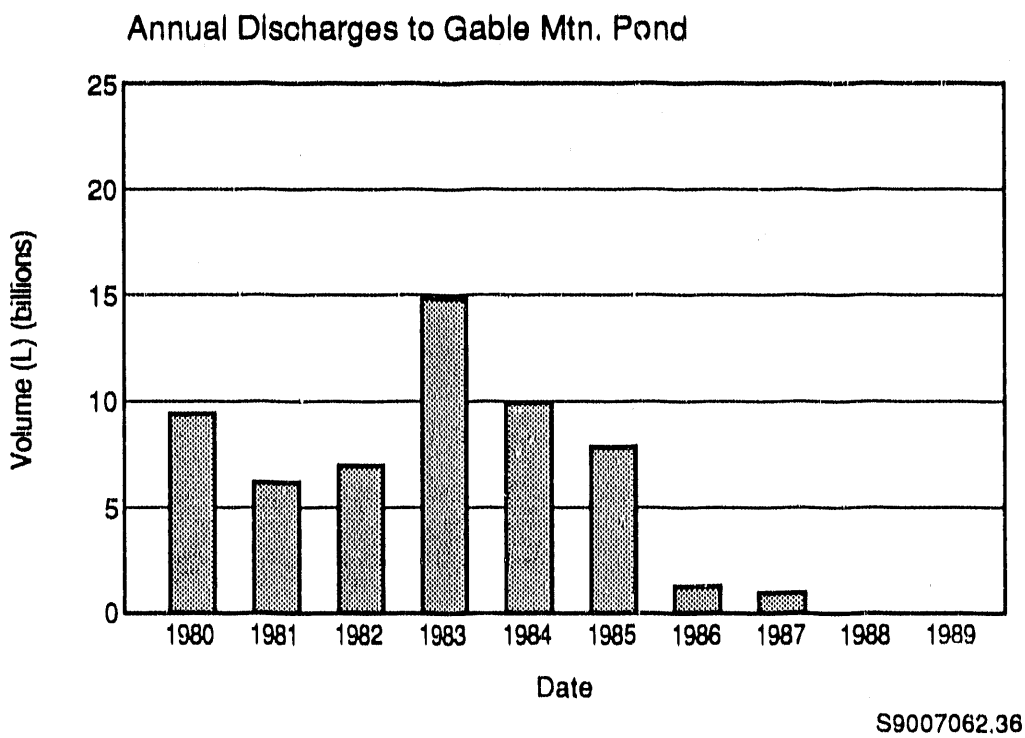


FIGURE 20. Annual Volume of Wastewater Discharged at Gable Mountain Pond Between 1980 and 1990 (Aldrich and Sliger 1981; Sliger 1982; Wilbur et al. 1983; Law et al. 1984; Law et al. 1986; Law and Schatz 1986; Law et al. 1987; Serkowski et al. 1988; Cooney and Thomas 1989)

Figure 4 shows that the water level declined over 1.5 m (5.0 ft) between December 1979 and December 1989. Figure 6 shows that the water level declined over 0.5 m (1.5 ft) between December 1984 and December 1989. A hydrograph of well 699-53-47A, shown in Figure 21, indicates that this decline occurred after mid-1984. This well is located along the northeast perimeter of Gable Mountain Pond.

To illustrate the areal influence of Gable Mountain Pond discharge on the unconfined aquifer, hydrographs of wells (and their locations) in the vicinity of Gable Mountain Pond are presented in Figure 22.

The hydrographs indicate that water levels in the vicinity of Gable Mountain Pond peaked in early 1985. The greatest responses, as much as 0.6 m (2 ft), were observed in wells located nearest Gable Mountain Pond. Responses were also observed in wells located hydraulically downgradient from the pond to the northwest in the gap between Gable Mountain and Gable Butte, but, as expected, appeared to diminish with greater distance from the pond.

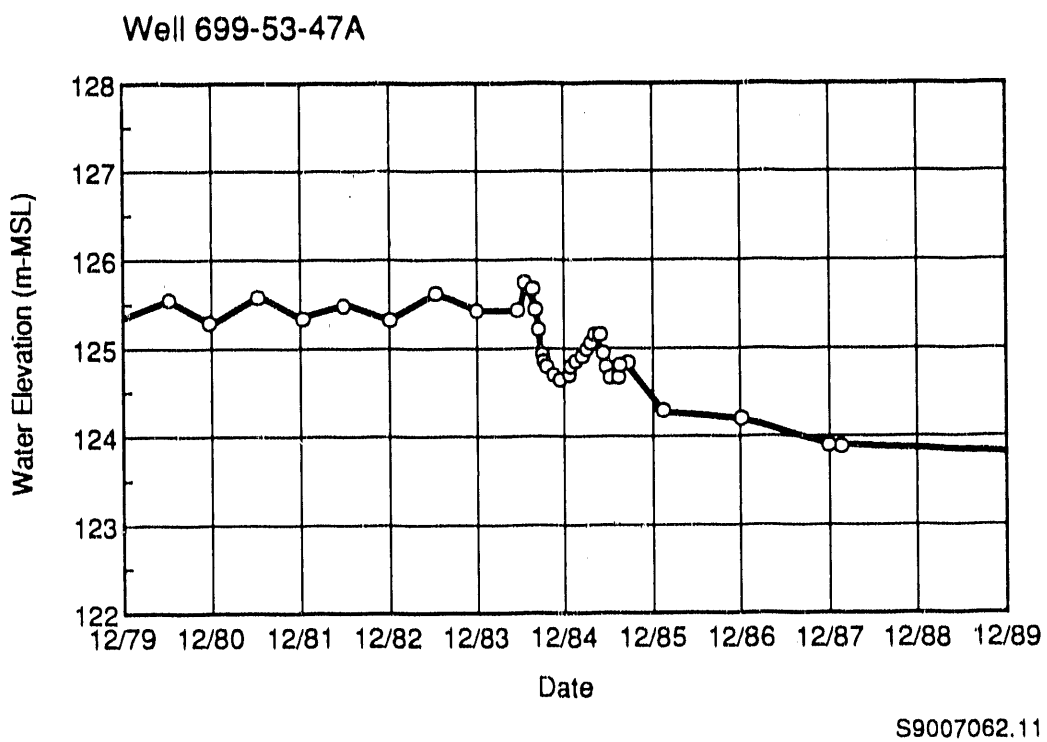


FIGURE 21. Hydrograph of Well 699-53-47A Between December 1979 and December 1989

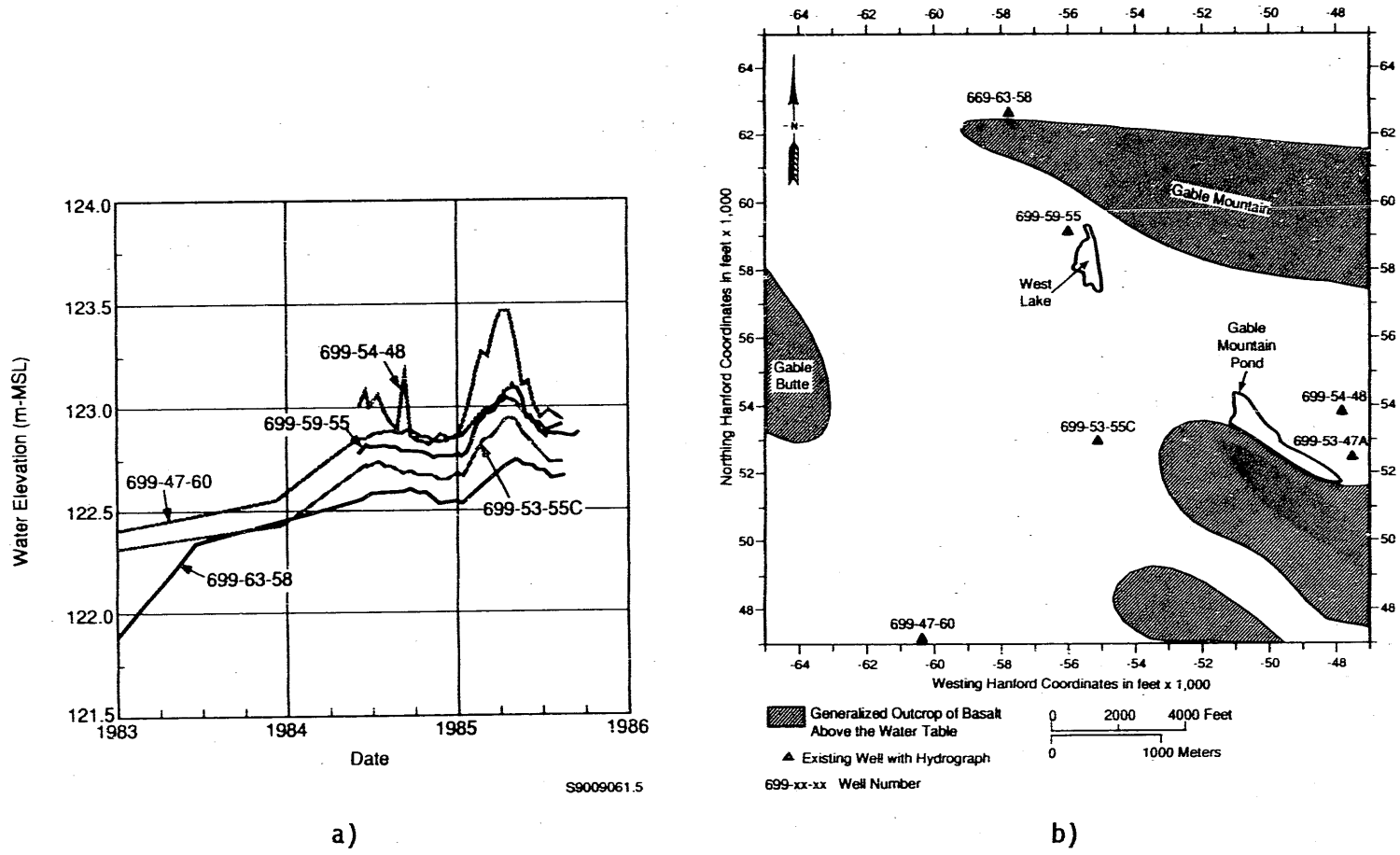


FIGURE 22. Hydrographs and Locations of Wells Used to Illustrate the Areal Influence of Gable Mountain Pond Discharge on the Unconfined Aquifer. a) Hydrographs of Wells 699-47-60, 699-53-55C, 699-54-48, 699-59-55, and 699-63-58 Between 1983 and 1986 (after Last et al. 1990). b) Locations of Wells Used for Hydrographs.

100-N AREA

The 100-N Area is located along the Columbia River north of Gable Mountain (Figure 1). The 1301-N Liquid Waste Disposal Facility (LWDF) and 1325-N LWDF were the primary waste disposal facilities for the N Reactor in the 100-N Area during the 1980s. The location of these facilities are shown in Figure 23.

The 1301-N LWDF operated until 1985 before it was shutdown (Smith and Gorst 1990). The 1325-N LWDF began receiving wastewater via pipeline in September 1985 (Jensen 1987). The volume of liquid wastewater disposed to the facility, and consequently, the rise and fall of the water table beneath the 1301-N and 1325-N LWDFs, were dependent on the operational status of the N Reactor. The N Reactor went back into operation in October 1985 and then on cold standby in January 1988 (Fruland and Lundgren 1989).

No water-level data exist for the period the 1301-N LDWF was operating (1980 and 1985). Therefore, discharges to the 1301-N LDWF will not be presented here. Monthly volumes of wastewater discharged to the 1325-N LWDF between September 1985 and December 1989 are plotted as a bar graph in Figure 24. Large volumes of wastewater released to the 1325-N LWDF between September 1985 and September 1986 are indicative of the operational status of the N Reactor. Water-level data, however, are not complete during this period.

The bar graph in Figure 24 indicates that after September 1986 monthly volumes of wastewater discharged to the 1325-N facility were significantly reduced. As a result, the water levels beneath the 1325-N LWDF declined. A hydrograph of well 199-N-27, located near the 1325-N facility (see Figure 23), is shown in Figure 25.

Following cold standby of the N Reactor in January 1988, 3.7E+7 L (9.9E+6 gal) of wastewater were disposed to the 1325-N facility in approximately 3.5 days in February 1988 (PNL 1988). This rate resulted in a water-table rise in February 1988, as indicated by the spike in the hydrograph shown in Figure 25.

A more detailed hydrograph showing the water-level response in well 199-N-27 during February 1988 is illustrated in Figure 26. Water levels were

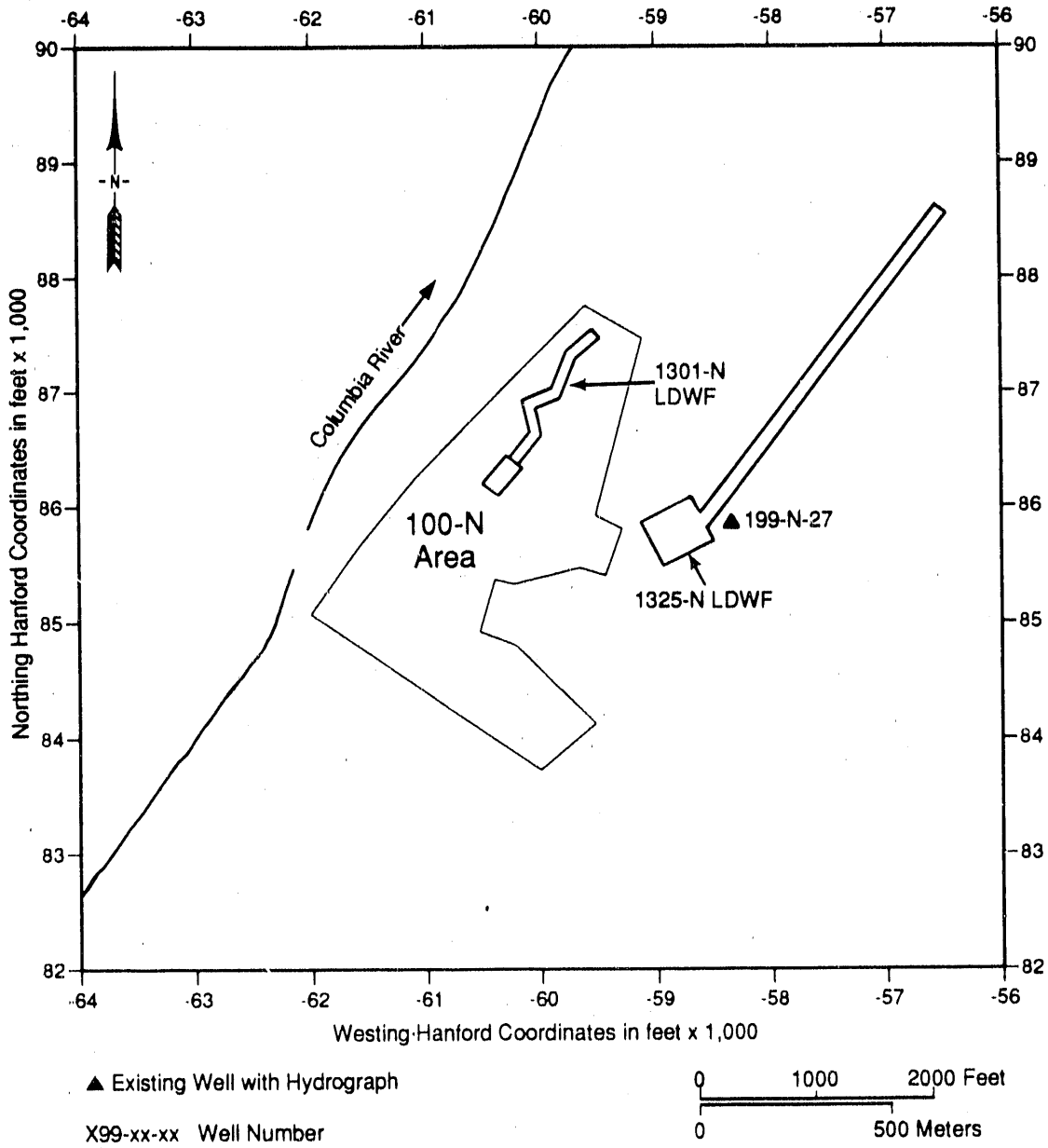


FIGURE 23. Map of the 100-N Area Showing the Location of Well 199-N-27

recorded by a continuous recorder in well 199-N-27 during the February 1988 discharge pulse. This hydrograph indicates that the water table rose sharply, as much as 3.5 m (11.5 ft) in 3.5 days between February 22 and 26, 1988. After disposal was terminated, the elevation of the water level in this well began to decay.

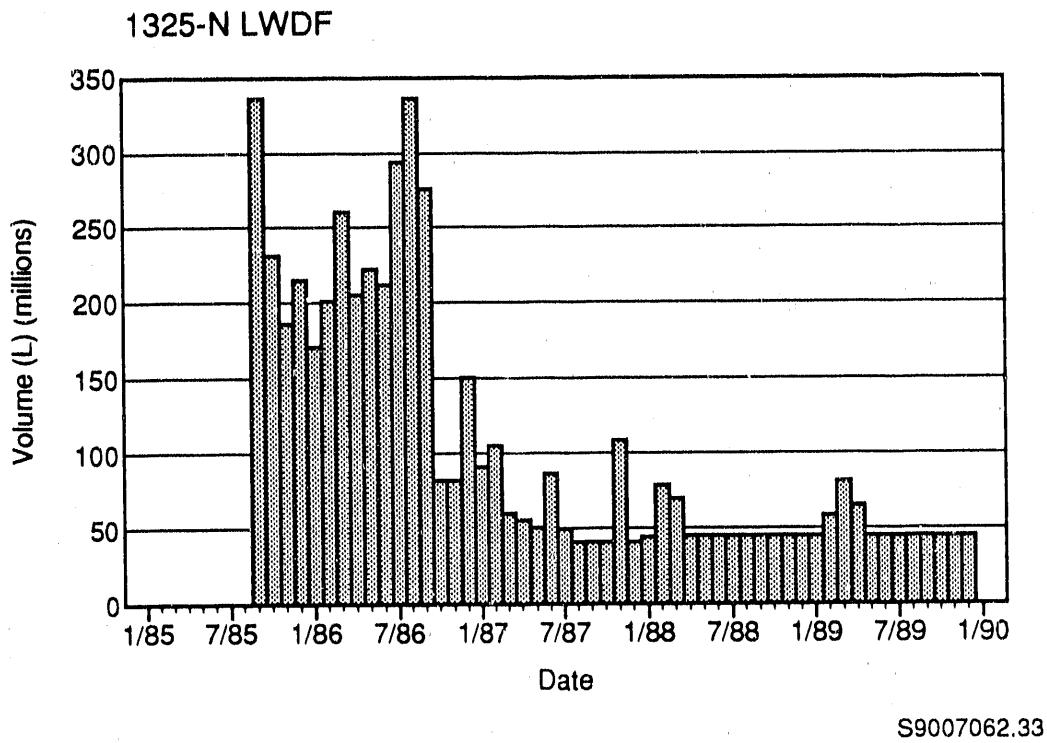


FIGURE 24. Monthly Volume of Wastewater Discharged at the 1325-N Liquid Waste Disposal Facility Between September 1985 and January 1990

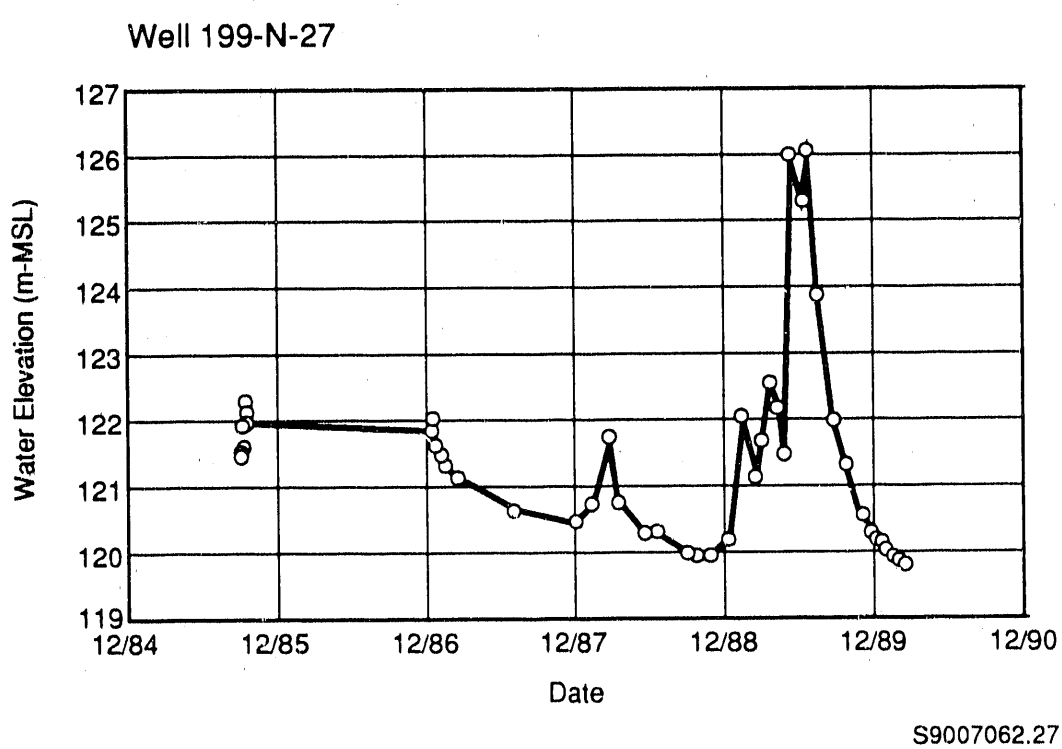


FIGURE 25. Hydrograph of Well 199-N-27 Between 1985 and 1990

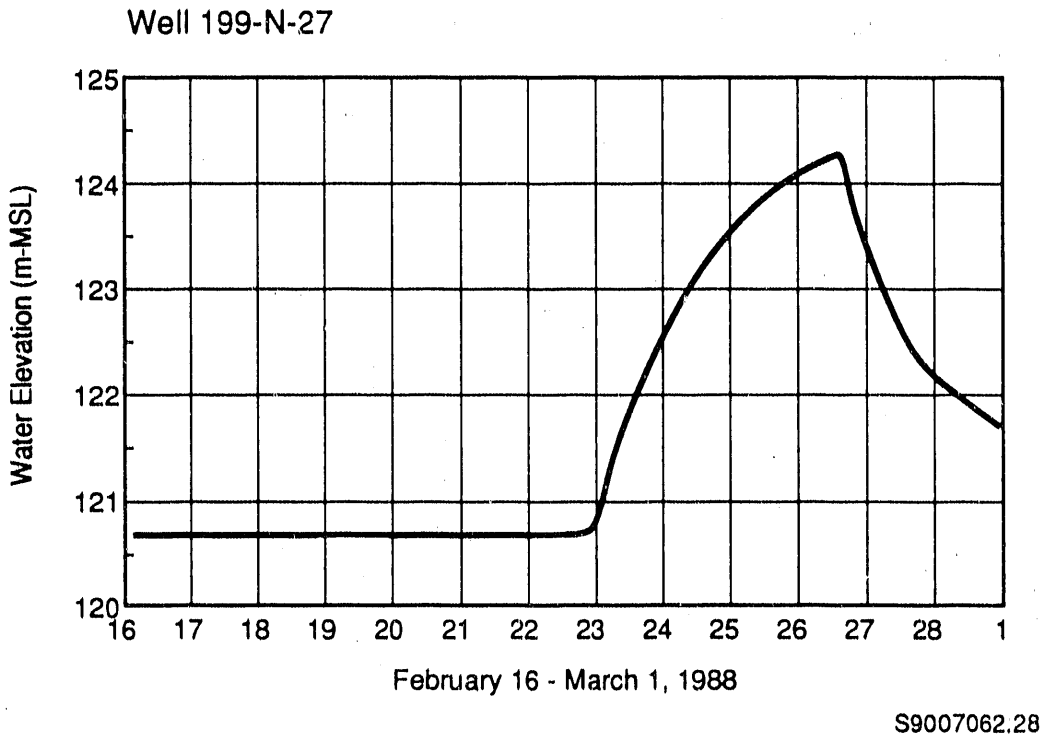
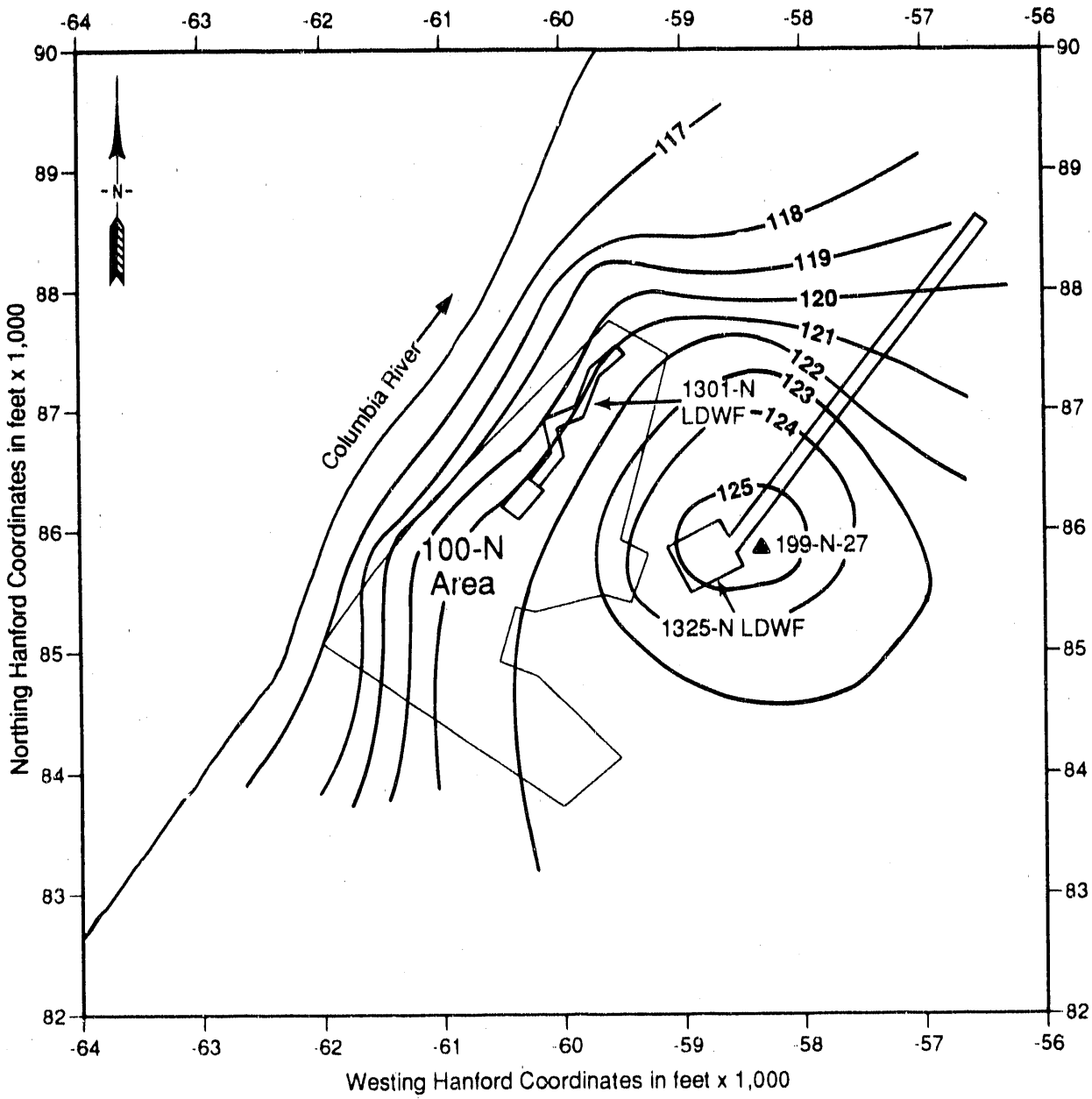


FIGURE 26. Hydrograph of Well 199-N-27 Between Feburary 16, 1988, and March 1, 1988

In January 1989, the N Reactor began defueling operations, which resulted in increased rates of discharge to the 1325-N facility. Beginning in May 1989, a large pulse of wastewater was known to have been released to the 1325-N facility. The hydrograph in Figure 25 also indicates that the water table rose significantly, as much as 4.5 m (14.9 ft) in May 1989. Although minimum detection levels of the flowmeter were measured and reported for the monthly discharge volume, the spike on the hydrograph is probably attributed to recharge from the 1325-N facility. A water-table map in Figure 27 adapted from Smith et al. (1989), shows the configuration of the ground-water mound beneath the 1325-N facility for June 1989.

IMPACTS FROM IRRIGATION IN UPPER COLD CREEK VALLEY

The water-level changes contour map in Figure 4 indicates that the water levels rose over 3 m (10 ft) between December 1979 and December 1989 in the Cold Creek Valley at the west end of the Hanford Site. Zimmerman et al. (1986) postulated that, after 1969, the water table rose as a result of



▲ Existing Well with Hydrograph

X99-xx-xx Well Number

—122— Water-Table Coutour in Meters Above Mean Sea Level (Contour Interval = 1 Meter)

0 1000 2000 Feet

0 500 Meters

FIGURE 27. Water-Table Map Beneath the 1325-N Liquid Waste Disposal Facility in the 100-N Area for June 1989 (modified from Smith et al. 1989)

irrigation activities in the Upper Cold Creek Valley west of the Hanford Site. A hydrograph of well 699-43-104 in Figure 28 indicates that the water table at the west end of the Hanford Site rose during the 1970s and continued to rise through the 1980s. The location of well 699-43-104 is shown in Figure 29. During the 1980s, the net water-level rise was 3.24 m (10.63 ft) between December 1979 and December 1989, and peaked in December 1987.

The water-level measurement in well 699-43-104 for December 1985 does not fit with the trend in the rest of the water-level data and may be an "outlier." This measurement appears to be on the order of 3 m (10 ft) to 4 m (13 ft) below the trend of the data (see Figure 28). One possible explanation for this nontrending measurement is that a small-diameter piezometer, designated "P," inside the well may have been mistakenly measured. The water level in this piezometer, open to a deeper interval, is currently over 3.2 m (10.5 ft) lower than the water level in the well.

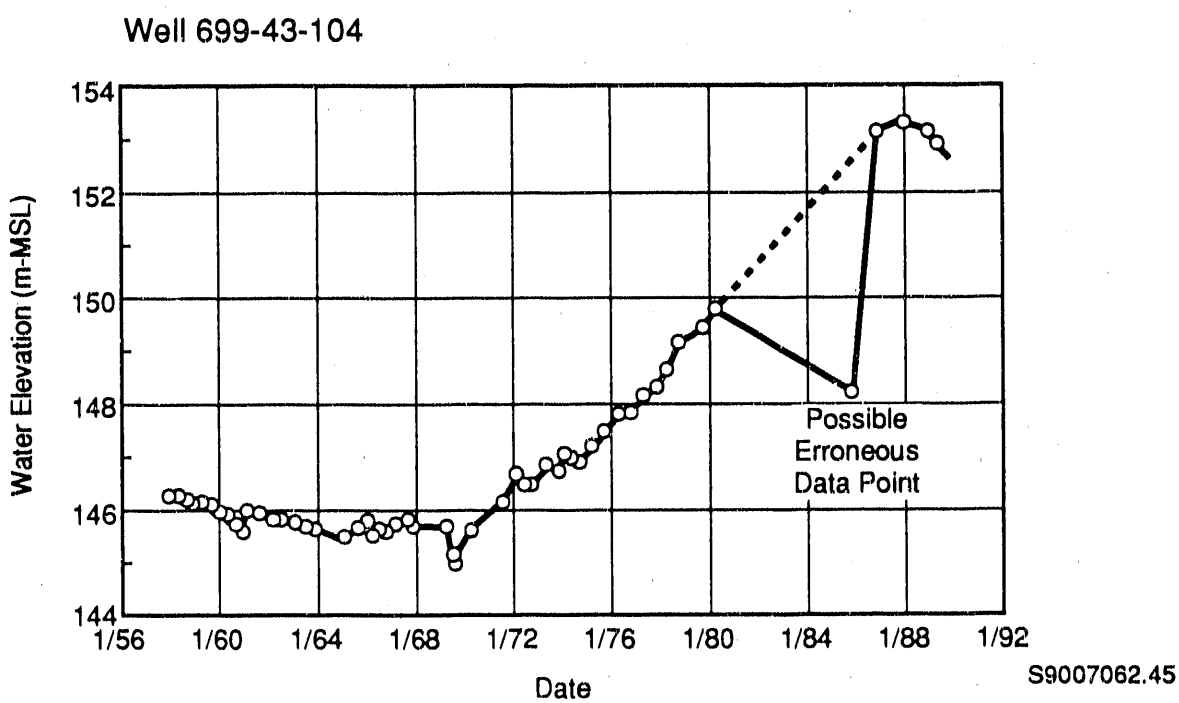


FIGURE 28. Hydrograph of Well 699-43-104 Between 1957 and 1990

The major irrigation users in the upper Cold Creek Valley currently are St. Michelle Vineyards and Sportfisher Orchard Company. The location of these irrigation users with respect to the west end of the Hanford Site is shown in Figure 29. The sources of irrigation for these operations are deeper, confined aquifers. Irrigation water applied in excess of evapotranspiration recharges the unconfined aquifer.

St. Michelle Vineyards has 665 acres of vineyards in production that have been irrigated since they replanted in 1979. The sources of irrigation are two wells that produce from underlying confined aquifers, one (designated well #1) yielding approximately 2500 gpm and the other (designated well #2) yielding approximately 1800 gpm. Between 1982 and 1983, St. Michelle Vineyards converted their irrigation system from a sprinkler system to drip irrigation, which reduced consumptive use by 40% to 50%. Consequently, use of well #2 was stopped and only well #1 was utilized as a source of irrigation water. Well #1 continued to pump at a flow rate of approximately 2500 gpm.

Sportfisher Orchard Company began operating in 1987 with 120 acres of orchards, which were irrigated by a sprinkler system during the summer months. Their holdings have since increased to a current 420 acres. The source of the irrigation water is a single well open to an underlying confined aquifer between 60 m (190 ft) and 80 m (270 ft) below land surface. This well is currently being pumped at a flow rate of approximately 2800 gpm.

RIVER STAGE INFLUENCES

The primary surface-water feature at the Hanford Site is the Columbia River. The river is hydraulically connected to the unconfined aquifer system and changes in river stage strongly influence the elevation of the water table in adjacent areas. The Columbia River stage, which varies cyclically, is controlled primarily by the Priest Rapids Dam upstream of the Hanford Site and by seasonal changes as a result of spring runoff. The frequency of the river-level cycles ranges from hourly to annually.

Hydrographs that illustrate the influence of the river stage on the unconfined aquifer are presented by several authors. Prior to 1980, the effects of river stage on the unconfined aquifer at the Hanford Site was

s ·'ied by Newcomb and Brown (1961). Hydrographs showing the influence of the riv .. stage on the unconfined aquifer in the 100-N Area, 100-H Area, and 300 Area during the 1980s are presented in Jensen (1987), Liikalla et al. (1988), Schalla et al. (1988), and Fruland and Lundgren (1989), respectively.

ANOMALOUS WATER-LEVEL CHANGES

Anomalous water-level changes for December 1979 to December 1989 were observed in two wells, 699-59-80B and 699-28-52A. These are discussed in detail below.

Well 699-59-80B

The water-level changes contour map in Figure 4 shows that the water level in the vicinity of well 699-59-80B rose as much as 2 m (6.6 ft) between December 1979 and December 1989. Figure 30 shows a hydrograph and the location of well 699-59-80B. The hydrograph indicates that this rise in water level is much greater than water-level rises in four neighboring wells, numbered 699-55-70, 699-55-76, 699-55-89, and 699-57-83A. The hydrographs and locations of these four wells are also shown in Figure 30. The water-level rise in these neighboring wells ranged between 0.4 m (1.3 ft) and 0.6 m (2.0 ft).

The hydrographs in Figure 30 indicate that the water levels in the four neighboring wells have been rising since Hanford operations began in the 1940s. However, the water level in well 699-59-80B has continued to rise steadily into the 1980s, but at a greater rate than the water-level rises in the four neighboring wells. Examination of geologic and well construction logs indicates that well 699-59-80B is partially completed in a low-permeability zone while the four nearby wells are completed in higher-permeability zones. A possible explanation for the dissimilar trends observed in the hydrographs between well 699-59-80B and its four neighboring wells is that the low-permeability zone present at well 699-59-80B may cause a delay in propagating areal water-table changes to this well.

Well 699-28-52A

Figure 4 shows that the water level in the vicinity of well 699-28-52A declined as much as 1 m (3.3 ft) between December 1979 and December 1989.

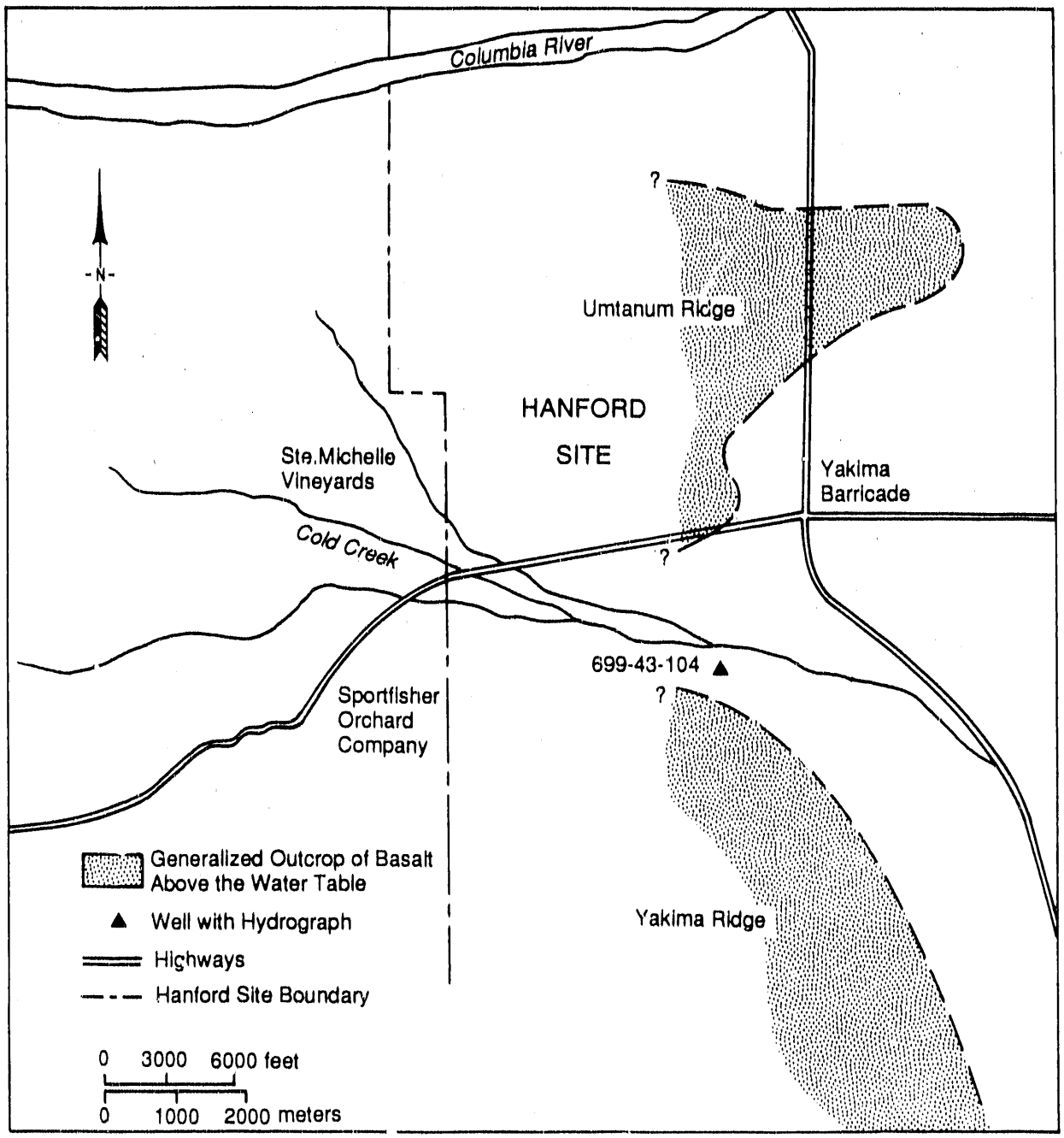
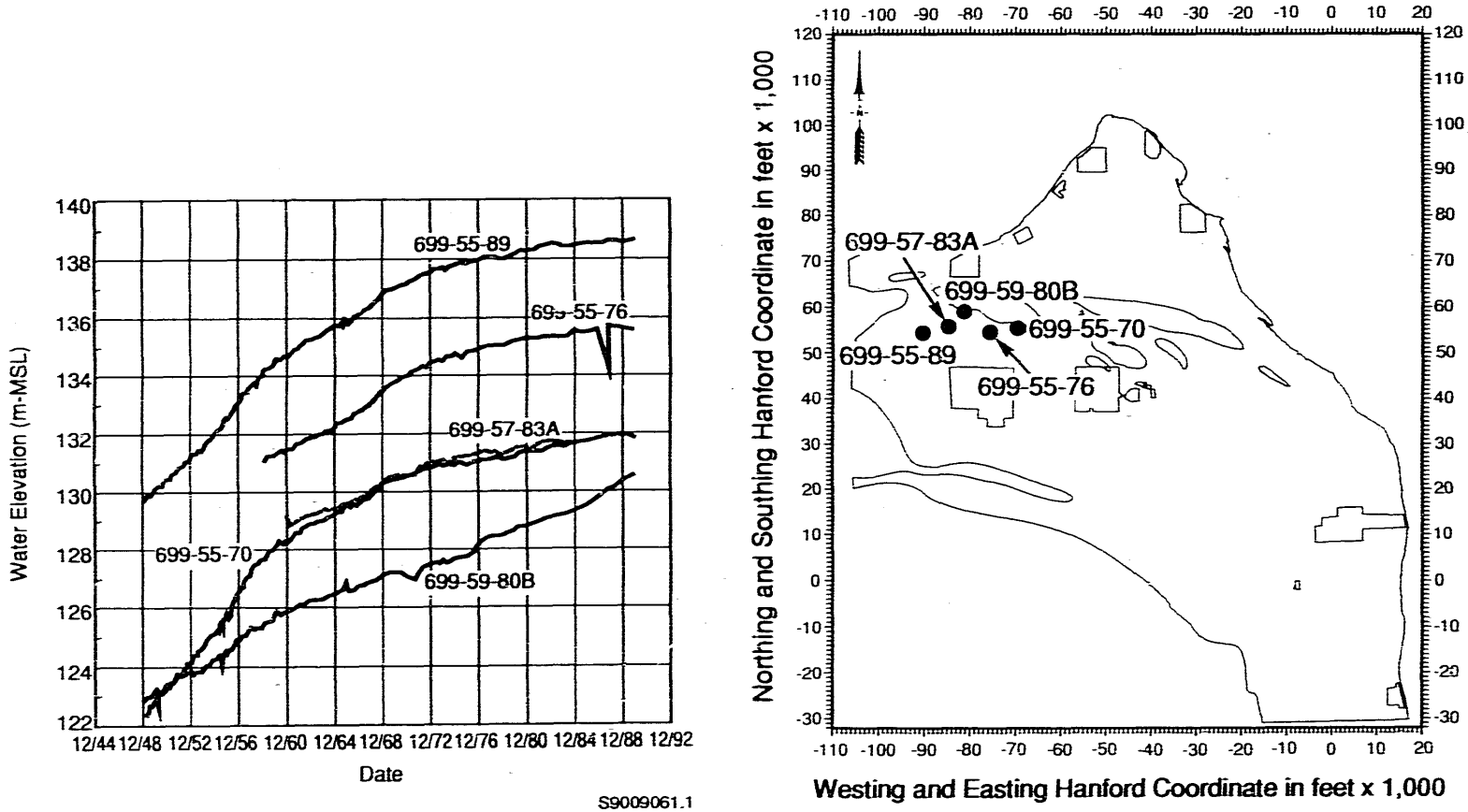


FIGURE 29. Map of the Western Part of the Hanford Site in the Cold Creek Valley



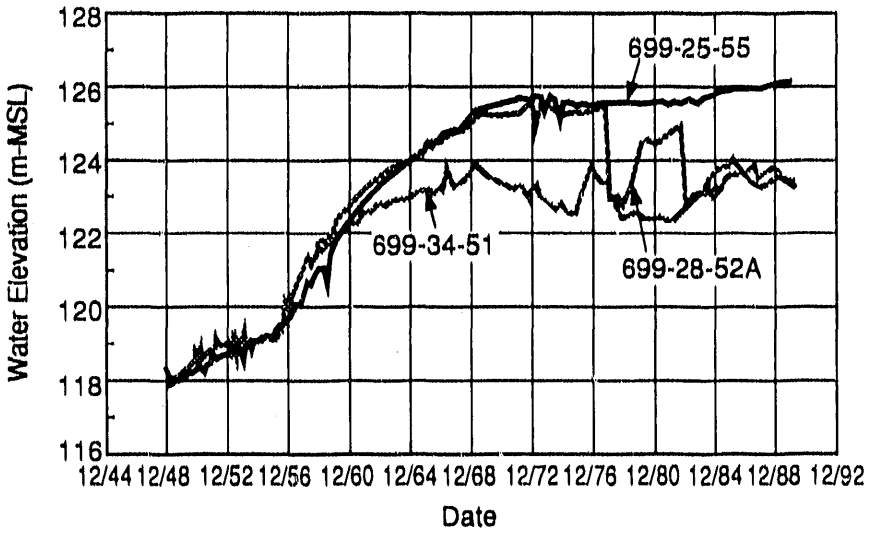
a) b)

FIGURE 30. Hydrographs and Locations of Wells Used to Illustrate the Rise in Water Level in Well 699-59-80B. a) Hydrographs of Wells 699-55-70, 699-55-76, 699-55-89, 699-57-83A, and 699-59-80B. b) Locations of Wells Used for Hydrographs.

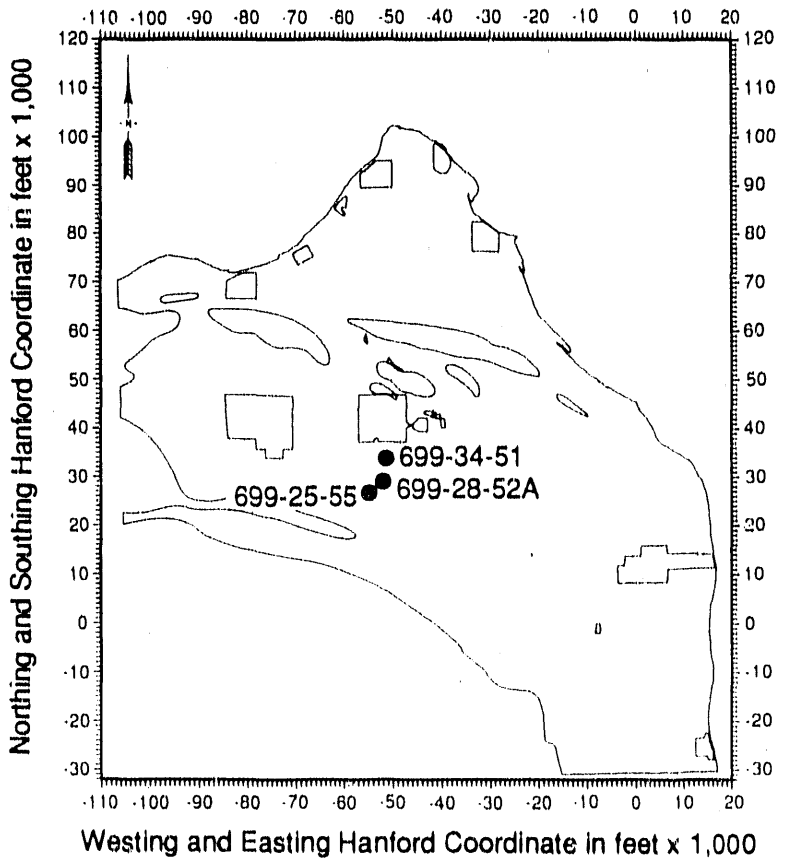
Figure 31 shows hydrographs and locations of wells 699-28-52A, 699-25-55, and 699-34-51. The hydrograph in Figure 31 indicates that the water level in well 699-28-52A declined during the 1980s, while the water levels in two neighboring wells, numbered 699-25-55, and 699-34-51, rose. The water-level rise in these neighboring wells was 0.5 m (1.6 ft) and 0.7 m (2.3 ft), respectively.

Historically, the water-level trend in well 699-28-52A was similar to the water-level trends of the two neighboring wells until about 1977 (Figure 65). Beginning in 1977, the water level in this well changed on three different occasions on the order of 1.5 m (5 ft) to 2 m (7 ft) over a period of 1 year or less (Figure 31).

The significant water-level changes observed in well 699-28-52A are related to well-completion activities and does not reflect actual water-level changes in the aquifer.



a)



b)

FIGURE 31. Hydrographs and Locations of Wells Used to Illustrate the Anomalous Water-Level Changes in Well 699-28-52A. a) Hydrographs of Wells 699-25-55, 699-28-52A, and 699-34-51 Between 1949 and 1989. b) Locations of Wells Used for Hydrographs.

SUMMARY AND CONCLUSIONS

During the 1980s, wastewater discharge and irrigation practices caused significant changes in the configuration of the water table at the Hanford Site. The near-equilibrium conditions observed during the 1970s were disrupted by stresses primarily imposed on the unconfined aquifer system during the 1980s. This disruption, associated with changes in magnitudes of recharge, caused unsteady state water-level conditions. The greatest change in the water level was observed in the western part of the Hanford Site. Water levels rose more than 3 m (10 ft) in response to irrigation practices west of the Hanford Site in the Upper Cold Creek Valley.

The major ground-water mounds that developed because of wastewater discharge practices prior to 1980, either diminished or grew in the 1980s. The total annual discharge of wastewater in the 200 Areas can be correlated with changes in water level. The ground-water mound beneath the 200-West Area began to dissipate in 1984, primarily in response to decommissioning at U Pond. The water table beneath the 200-West Area declined more than 2.5 m (8 ft) during the 1980s. Decommissioning at U Pond also caused the water table to decline between the 200-West Area and the Yakima Ridge basalt, which outcrops above the water table to the south of the 200-West Area. The ground-water mound beneath B Pond, however, grew after the startup of PUREX in 1983. The height of the ground-water mound beneath B Pond increased more than 1.5 m (5 ft) during the 1980s. The mound grew primarily in response to changes in wastewater discharge practices in the 200-East Area, particularly at B Pond. Wastewater discharge practices in the 200-East Area also influenced the unconfined aquifer southeast of B Pond during the 1980s, causing water levels to rise approximately 1 m (3 ft).

The ground-water mound beneath Gable Mountain Pond completely dissipated in response to decommissioning activities at Gable Mountain Pond. The water level declined more than 1 m (3 ft) in the vicinity of Gable Mountain Pond during the 1980s. The total monthly discharge of wastewater at the 100-N Area can also be correlated with changes in water level. The water table beneath the 100-N Area responded significantly to temporal wastewater activities at the 1325-N LWDF. Water levels in the unconfined aquifer adjacent to the Columbia River responded, as expected, to river stage fluctuations.

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