Evaluations of the Effects of the Columbia River on the Unconfined Aquifer Beneath the 1301-N Liquid Waste Disposal Facility

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May 1990

**Prepared for the U.S. Department of Energy
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EVALUATIONS OF THE EFFECTS OF THE
COLUMBIA RIVER ON THE UNCONFINED
AQUIFER BENEATH THE 1301-N LIQUID
WASTE DISPOSAL FACILITY

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EXECUTIVE SUMMARY

The unconfined ground-water flow system beneath the 1301-N facility in the 100-N Area on the Hanford Site is affected by a number of factors including geologic facies changes, Columbia River stage fluctuations, and artificial recharge from adjacent waste-water disposal facilities. Water-table elevation data indicate that water levels beneath the 1301-N facility have declined approximately 2 ft from October 1989 to February 1990. These data also indicate that a ground-water mound under the adjacent 1325-N facility that existed prior to the "dry layup" status of the N Reactor has largely dissipated. The current dominant water-table feature in the 100-N Area is the ground-water mound under the nearby 1324-N/NA ponds.

Statistical analysis of the water-level data indicate a strong correlation between river stage and the water-table fluctuations in wells located within 480 ft of the river. Wells located between 860 and 2570 ft from the river do not indicate significant association between water-level fluctuations and river stage elevation. The time lag between river stage changes and the corresponding effects in the wells located within 480 ft of the river range from less than 1 h up to 15 h. Attenuation of these responses ranges from 0.13 to 0.51. Generally the time lags and attenuation of response to the river-level fluctuations increase with distance from the river.

Impacts of river stage fluctuations on the ground-water system beneath the 1301-N facility were not evident during the period of study. Water levels in the vicinity of the 1301-N facility were predominantly influenced by the regional gradient and the ground-water mound beneath the 1324-N/NA facility. Other factors, such as barometric effects, do not have a significant influence on the water-table elevations.

CONTENTS

EXECUTIVE SUMMARY	iii
INTRODUCTION	1
PREVIOUS WORK	1
BACKGROUND INFORMATION	1
METHODS OF STUDY	3
Water-Level Monitoring Equipment	6
Data Verification of Water-Level Recorders	8
Columbia River Stage	9
Problems Encountered	9
GEOLOGIC AND HYDROLOGIC SETTING	11
RINGOLD FORMATION	11
GLACIOFLUVIAL SEDIMENTS	12
HYDROLOGY	14
Ground Water	14
Surface Water	17
WATER-TABLE ELEVATIONS	19
STATISTICAL ANALYSIS	25
METHOD	25
RESULTS	26
CONCLUSIONS	29
REFERENCES	31
APPENDIX A - WATER-TABLE MAPS OF THE UNCONFINED AQUIFER BENEATH THE 100-N AREA	A.1
APPENDIX B - GRAPHS OF HOURLY COLUMBIA RIVER STAGE DATA NEAR THE 100-N AREA	B.1
APPENDIX C - WATER-LEVEL HYDROGRAPHS	C.1

FIGURES

1	Map of the Hanford Site	2
2	Locations of Monitoring Wells Near the 1301-N Liquid Waste Disposal Facility	5
3	Water-Stage Recorder	7
4	Location of Cross Section A-A'	13
5	Generalized Cross Section A-A' Near the 1301-N Facility	15
6	Water-Level Elevations Showing the Ground-Water Mound Near the 1325-N Facility, May 30, 1989	20
7	Columbia River 5-Day Average Stage, October 1989- February 1990	22
8	Hourly Water-Level Elevations Versus Hourly Barometric Pressure Data for Well 199-N-34	24

TABLES

1	Waste-Water Discharges to 1324-N/NA Ponds: Elementary Neutralization Unit System Surge Tank Discharges	4
2	Continuous Water-Level Monitoring Points	4
3	Change in Water Levels and 100-N River Stage	21
4	Results of Statistical Parameter Analysis Between the River Stage Fluctuations and the Well Water-Level Fluctuations for January 10 Through January 31, 1989	27

INTRODUCTION

Westinghouse Hanford Company (WHC) requested that Pacific Northwest Laboratory (PNL) perform a study to determine what influence the Columbia River has on the aquifer beneath the 1301-N Liquid Waste Disposal Facility (LWDF) located in the 100-N Area. Because of the change in operational status of the N Reactor to "dry layup" in November 1989, there has been a reduction in the liquid effluent discharge to the ground in the 100-N Area. This reduction in discharge reduces the artificial recharge to the unconfined aquifer, thereby altering ground-water flow in the vicinity of the 1301-N LWDF.

This study addresses these changes and evaluates the effect that the Columbia River has on the unconfined aquifer beneath the 1301-N facility under present ground-water conditions. In addition, information developed by this study will be utilized by the Environmental Division of WHC in their concurrent study entitled "Numerical Simulation of Radionuclide Transport from the 1301-N and 1325-N LWDFs to the Columbia River."

PREVIOUS WORK

Reports on the ground water and its interaction with the disposal facilities at the 100-N Area include Jensen (1987) and Nelson (1964). Newcomer (1988) addresses the effects of bank storage with Columbia River fluctuations. Reports on the hydrogeology have also been included in published reports on two Resource Conservation and Recovery Act (RCRA) ground-water monitoring programs in the 100-N Area including Gilmore (1989) and Gilmore and Jensen (1989), which outline ground-water quality assessment programs at the 1301-N and 1324-N/NA facilities. Quarterly and annual RCRA monitoring program status reports (PNL 1988a, 1988b, 1988c, and 1988d; Fruland et al. 1989a, 1989b; and Smith et al. 1989a, 1989b) included ground-water surface elevation maps of the 100-N Area for each month between January 1988 and February 1990.

BACKGROUND INFORMATION

The study area is located on the U.S. Department of Energy's (DOE) Hanford Site in southeastern Washington State (Figure 1). The study location encompasses an area within the 100-N Area, in the vicinity of the 1301-N LWDF.

FIGURE 1. Map of the Hanford Site

The 1301-N LWDF was used to dispose of waste streams that were generated in the N Reactor and related facilities, from the startup of the N Reactor in 1963 until September 1985. The 1301-N facility is currently not in use. The 1301-N LWDF is located approximately 800 ft east of the Columbia River. It consists of a 52- by 12-ft concrete-lined ditch connected to a 125- by 250-ft unlined rectangular basin. The basin bottom is covered with a 3-ft-thick layer of large stones. Adjacent to the basin is an unlined ditch 1600 ft long, 50 ft wide, and 12 ft deep, which extends north in a zigzag pattern. The ditch was intended to handle overflow from the basin. Two other facilities of importance to this report are the 1325-N Liquid Waste Disposal Facility (LWDF) and the 1324-N/NA ponds. These facilities have received liquid effluent in the past, and continued to receive reduced volumes of effluent during the course of this study. The amount of discharge to these two facilities has been greatly reduced following the operational status change for the N Reactor in April 1989. The 1325-N LWDF, during the course of this study, received a continuous stream of approximately 300 gal/min. The discharges to the 1324-N/NA Ponds are listed in Table 1.

METHODS OF STUDY

Continuous water-level measurements were collected from 12 wells in the vicinity of the 1301-N LWDF between the end of October 1989 and the beginning of April 1990. The 12 wells monitored are listed in Table 2 and their locations are shown in Figure 2. Water-table maps constructed from these data are located in Appendix A. The continuous water-level monitoring points were located in wells on a line generally parallel to and between the river and the 1301-N facility and on a line that runs through the facility approximately perpendicular to the river. Additional monitoring points were located adjacent to the 1325-N and 1324-N/NA facilities to assess their effect on the ground-water surface elevations. In addition, Columbia River stage data were also obtained from the Hanford Generating Project located approximately 2500 ft upstream of the 1301-N Crib area. Graphs of the Columbia River stage data are presented in Appendix B.

Water-level data were gathered using three types of continuous water-level monitoring equipment: chart-type stage recorders, stage recorders with

TABLE 1. Waste-Water Discharges to 1324-N/NA Ponds: Elementary Neutralization Unit System Surge Tank Discharges

<u>Date</u>	<u>Gallons</u>	<u>Date</u>	<u>Gallons</u>
12/25/89	177,000	1/27/90	175,000
12/28/89	175,000	1/30/90	188,000
12/31/89	238,000	1/31/90	140,000
1/02/90	151,000	1/03/90	158,000
1/04/90	130,000	2/04/90	175,000
1/08/90	216,000	1/08/90	193,000
1/10/90	166,000	2/11/90	182,000
1/14/90	170,000	2/14/90	179,000
1/16/90	166,000	2/19/90	195,000
1/19/90	149,000	2/20/90	216,000
1/23/90	136,000	2/22/90	254,000
Subtotals:	1,874,000	Subtotal:	2,055,000
Total:	3,929,000 gallons	Days:	59
	69,593 gallons/day		46 gpm

TABLE 2. Continuous Water-Level Monitoring Points

<u>Well</u>	<u>Recorder Type</u>	<u>Data Collection Frequency, min</u>	<u>Dates in Service</u>
N-3	SR	60	2/21/90 - 3/31/90
N-8S	LPT	30	1/10/90 - 3/31/90
N-8P	LPT	30	1/10/90 - 3/31/90
N-20	SRL	30	12/28/89 - 3/31/90
N-23	SRL	30	12/20/89 - 3/31/90
N-25	SR	60	12/20/89 - 3/31/90
N-27	SR	60	10/25/89 - 3/31/90
N-34	SR	60	12/20/89 - 3/31/90
N-51	SR	60	12/05/89 - 3/31/90
N-58	LPT	30	12/22/89 - 3/31/90
N-66	LPT	30	2/04/90 - 3/31/90
N-67	LPT	30	10/19/89 - 3/31/90

SR = Stage recorder.

SRL = Stage recorder with logger.

LPT = Logger with pressure transducer.

FIGURE 2. Locations of Monitoring Wells Near the 1301-N Liquid Waste Disposal Facility

attached data loggers, and data loggers with bridge-type pressure transducers. To calibrate the recording equipment, water-level measurements were periodically taken at the well sites using steel tapes. Water-level hydrographs are presented in Appendix C.

Water-Level Monitoring Equipment

Mechanical stage recorders were used in wells 199-N-3, 199-N-25, 199-N-27, 199-N-34, and 199-N-51. These mechanical stage recorders continuously monitor water levels by recording the position of a float, which floats on the surface of the water in the well. The float is attached to a counterweight by means of a beaded cable. The cable is placed over a pulley connected to a drum, the face of which holds a chart (Figure 3). A pen is driven at a constant speed across the drum by either a manual or electronic timer. As the float rises and falls in response to water-level changes in the well, the drum turns proportionally producing a chart that records the water level in relation to time. The charts produced by the mechanical stage recorders were digitized for computer processing. The stage recorders in wells 199-N-20 and 199-N-23 were equipped with an electronic data logger. An optical encoder is used to convert the rotation of the pulley into digital information, which is recorded at discrete periodic intervals. The electronic loggers eliminated the need for digitizing the chart.

These water-level stage recorders were reliable and accurate devices for recording water-level data. Their simple design results in instruments that are relatively free of problems. The accuracy of this equipment is affected by the clock accuracy, freedom of movement of the float, the ratio between water-level change and drum rotation, and thermal expansion/contraction of the float line, (considered to be negligible).

Electronic data loggers and bridge-type pressure transducers were used in wells 199-N-8s, 199-N-8p, 199-N-58, 199-N-66, and 199-N-67. These transducers employ a diaphragm that deforms under pressure and correspondingly affects the electrical resistance through a group of resistors (Wheatstone bridge) attached or linked to the diaphragm. The corresponding change in resistance across the bridge is converted to the change in feet of water.

FIGURE 3. Water-Stage Recorder (Modified after Jensen 1987)

This reading is then stored along with the time of the measurement in the data logger's Random Access Memory (RAM) for later downloading to a computer for processing.

The accuracy of pressure transducer measurements is affected by the specific design of the transducer and data logger, the response of the equipment to environmental conditions and the stability of the transducer's position in the well. The data loggers used were designed with either a 10- or 12-bit processing capacity. The 12-bit machines used on this study were capable of providing a resolution of 0.01 ft; however, the 10-bit machine used in well 199-N-67 rounded its data for a resolution of 0.035 ft. When possible, the transducers were installed 24 h or more before the start of data collection. This allowed the equipment to equilibrate to environmental conditions and for the cable to stretch to an equilibrium point, thus stabilizing the transducer at a specific depth.

The logger clocks and recorder timers used in this study were standardized with a field watch set to 8 hr behind Coordinated Universal Time (from radio station WWV, Colorado) yielding Pacific Standard Time (PST) and is traceable to the National Institute of Standards and Technology (NIST). The chart data were digitized for computer processing using the value at the "top of each hour." This yielded data frequency of every 60 min. The loggers were programmed for data collection frequency of 30 min and set to record their measurements simultaneously at each half-hour mark.

Data Verification of Water-Level Recorders

Water-level measurements using steel tapes were taken at the beginning of each data collection period to calibrate the loggers to a known level and to index the charts with respect to time on the stage recorders. Calibration measurements were also taken periodically during data collection periods to correct for drift of the recording equipment. When steel-tape measurements did not correspond to the instrument's recording, the instrument was reset. The tapes used in this study were compared to a standard tape that is calibrated annually by the Westinghouse Standards Laboratory, and traceable to the NIST. The steel-tape measurements are indicated on the hydrographs in Appendix C.

Columbia River Stage

Stage data for the Columbia River are recorded by the Hanford Generating Project, which is operated by the Washington Public Power Supply System (WPPSS). These measurements are taken at a point approximately 2500 ft upstream of the 1301-N Crib area (Figure 2). The data are collected with an air bubbler system and are continuously recorded on a strip chart. Copies of these data were obtained and digitized for computer processing.

Problems Encountered

The overall quality of the data set is good with a few exceptions. Complete and/or verified data sets from wells 199-N-67 and 199-N-3 were unobtainable. A logger/transducer had been installed in well 199-N-67 in the middle of October 1989. These two wells are inside a radiation zone surrounding 1301-N Crib area. At the end of October, new procedures for working in radiation zones were implemented that denied field personnel access to these two wells. As a result of implementing the new procedures, field personnel received additional training so they could service the equipment. The recorder in 199-N-67 had to be left unattended for a period of 4 months. During this time, the equipment experienced an instrument drift problem. When the data were collected in February, the transducer readings were 0.78 ft lower than the actual water level. The data logger in well 199-N-67 later failed for an unknown reason, resulting in a loss of data between early February and April. The data set for well 199-N-3 is incomplete, missing October through February 17, also as a result of the access requirements into the radiation zone.

The logger/transducer installed at well 199-N-8P experienced an instrument shift. In this case, the error seems to have occurred suddenly. The transducer readings corresponded well with the steel-tape measurements, then were higher by approximately 0.21 ft beginning in early February. The logger was reset when the problem was discovered.

Of the six chart recorders used on this study, five were driven by electronic timers and one was driven by a manual timer. The electronic timers proved accurate; however, the manual timer was slow by 1/2 to 1 hr per week toward the end of the study. This recorder was installed at well 199-N-27,

which did not produce rapid or large water-level changes, thus the timer inaccuracy did not affect the interpretation of the data.

In wells 199-N-25, 199-N-34, 199-N-27 and 199-N-3, the recorder floats occasionally encountered obstructions, such as pump columns and wiring, as they responded to water-level changes. This resulted in chart data that "jumped" rather than recording in a smooth curve. At wells 199-N-25, 199-N-34, and 199-N-27, the maximum jump in data was 0.13 ft as a result of float obstruction. Water-level data from well 199-N-3 were affected to a greater degree. The maximum shift was 0.30 ft and one period of 6 days occurred when the float did not move at all.

Loss of data occurred at some of the well sites because of hydrochemical sampling activities. Three of the stage recorders were disturbed by sampling personnel, resulting in a loss of data of several hours at wells 199-N-20, 199-N-23, and 199-N-27. At well 199-N-25, a sample bailer was stuck downhole, resulting in a loss of data from February 6 through 16.

GEOLOGIC AND HYDROLOGIC SETTING

There are approximately 70 wells that have been drilled in the 100-N Area since 1962. Many of these wells provide the basis for the geologic interpretation for this report. The sample descriptions from the majority of these wells have been logged by drillers and do not have the detail or the consistency from which to draw more than generalized interpretations. The newer wells drilled under the RCRA programs have been logged by geologists and yield more detailed descriptions. In addition to these newer wells, there are natural gamma logs for many of the wells that can be used collectively with the sample descriptions to determine lithologies in the older wells.

The stratigraphy of the suprabasalt sediments in the 100-N Area and around the 1301-N LWDF include the Ringold Formation and the overlying glacio-fluvial sediments informally referred to as the Hanford formation.

RINGOLD FORMATION

The Ringold Formation has been variously divided into the basal, lower, middle, and upper units based on sediment texture in the central portion of the Hanford Site (Brown 1959; Tallman et al. 1979; Routson and Fecht 1979; and Bjornstad 1984, 1985). These designations, however, may not be correlative to the sediments in the 100-N Area; therefore, the sediment descriptions in this report will be in general lithologic terms.

The Ringold Formation in the 100-N Area is composed of three distinct lithologic units that include, in ascending order, an indurated sandy gravel unit, a mud unit, and a sandy gravel unit. The indurated sandy gravel unit rests unconformably on basalt at approximately 520 ft below land surface (bls) (-78 ft below sea level). This indurated sandy gravel unit is approximately 35 ft thick and is overlain by a caliche layer. The indurated sandy gravel unit was penetrated by the now abandoned well, 699-86-60, under the 1312 Liquid Effluent Retention Facility (LERF). Overlying the indurated sandy gravel unit is a mud unit that extends to approximately 100 ft bls (360 ft above sea level). This unit is predominantly an olive brown color and composed of 75% mud (undifferentiated silts and clays) with 10% fine sands and 15% gravel. It appears from the logs that these lithologic fractions occur as

a mixture rather than discrete horizons. It is generally recognized that the top of this mud unit forms the base of the unconfined aquifer.

Near the 1301-N LWDF, the contact of the Ringold Formation and the overlying glaciofluvial sediments occurs at approximately 60 ft bls (410 ft above sea level). The Ringold is differentiated from the glaciofluvial sediments by an increase in calcium carbonate with a zone of increased consolidation and cementing, a decrease in the percentages of basalt clasts, and an increase in the quartz/silica-rich materials. These changes are reflected in a distinct color change from the olive gray of the glaciofluvial sediments to a dark grayish brown of the Ringold. This sandy gravel unit of the Ringold is heterogenous, varying in texture both laterally and vertically.

GLACIOFLUVIAL SEDIMENTS

Overlying the Ringold Formation are flood deposits that were deposited when ice-dammed lakes within the Columbia River drainage were periodically breached during Pleistocene glaciation (Bretz 1959; Baker 1973; Waitt 1980). Deposits of glaciofluvial sediments from these floods have been informally referred to as the Hanford formation. These deposits are highly variable both laterally and vertically, reflecting the dynamic nature of deposition. These cataclysmic flood deposits have been divided into two facies: a coarse-grained channel facies (the pasco gravels) and a fine-grained slackwater facies (the touchet beds) (DOE 1988). The pasco gravels predominate at the 100-N Area. These gravels are composed of poorly sorted coarse sand and gravel that were deposited in flood bars along high-energy flood channels (DOE 1988).

Near the 1301-N LWDF the upper 15 ft of the sediments contain 5 to 20% cobbles and boulders in a generally coarse-grained matrix. From 15 ft bls to the top of the Ringold Formation, the sediments are variable silty sandy gravel with an occasional boulder. The upper 55 ft vary in texture laterally north of the facility to a coarser grained facies with decreasing fine-grained sediments near well 199-N-51.

A generalized cross section (location shown in Figure 4) constructed from drillers' and geologists' logs indicates a lithology or facies change

FIGURE 4. Location of Cross Section A-A'

occurring within the study area (Figure 5). The sediments in the saturated zone that include the sandy gravel unit in the Ringold Formation increase in silts, clays, and finer grained material in the area around and south of the 1301-N facility relative to the areas north of the facility near wells 199-N-14 and 199-N-51 (Figure 2). (This cross section does not include wells that penetrate lower than the sandy gravel unit within the Ringold Formation discussed earlier in this section.) The lithologic or facies changes that are inferred from this cross section can control in part the hydrological responses of this area.

HYDROLOGY

The Hanford Site occupies approximately one-third of the land area within the Pasco Basin. The Pasco Basin encompasses approximately 1.2 million acres (Gephart et al. 1979; DOE 1988). The climate for the region is characterized by semi-arid conditions and receives on average of about 6.25 in. of precipitation annually. While most of this precipitation is evaporated or transpired back to the atmosphere, evidence suggests that some ground-water recharge from precipitation does occur at the Hanford Site (Gee and Heller 1985). The Hanford Site is bordered by the Columbia River to the north and east, by the Yakima River to the south, and by Rattlesnake Mountain, Yakima Ridge, and Umtanum Ridge to the west. Flow along the reach of the Columbia River near the 1301-N facility is regulated by the Priest Rapids Dam.

Ground Water

Ground water beneath the Hanford Site occurs under both unconfined and confined conditions. The confined aquifers beneath the Hanford Site have been divided into upper and lower flow systems (Gephart et al. 1979; DOE 1988). The upper confined flow system includes the interflow contacts and sedimentary interbed within the Saddle Mountain Basalts. Partially confining conditions may also exist in the lower Ringold Formation (DOE 1988). The lower confined flow system is contained within the flow contacts or brecciated interflow zones within the Wanapum and Grande Ronde Basalts. The unconfined aquifer is of primary interest in this report because it is directly affected by the river stage of the Columbia and by disposal practices at the Liquid Waste

FIGURE 5. Generalized Cross Section A-A' Near the 1301-N Facility

Disposal Facilities. To a lesser extent, water levels in the unconfined aquifer are also affected by precipitation, atmospheric pressures, and planetary effects.

A shallow unconfined aquifer is contained primarily within the sandy gravel unit of the Ringold Formation and extends into the glaciofluvial sediments in some areas (Gephart et al. 1979). The base of the unconfined aquifer is the surface of the Columbia River Basalt Group, or where present, the clay/mud zones of the Ringold deposits. The saturated thickness of the unconfined aquifer beneath the Hanford Site ranges from zero along the flanks of the basalt anticlines to a maximum of 200 ft (Gephart et al. 1979).

Areas of recharge to the unconfined aquifer at the Hanford Site include areas of high relief to the north and west, two ephemeral streams along the western boundary of the Hanford Site, Cold Creek and Dry Creek, and the Columbia and Yakima Rivers during high river stage (Gephart et al. 1979). A small amount of natural recharge occurs from precipitation (Gee and Heller 1985). Liquid waste disposal from activities on the Hanford Site also have been a major source of artificial recharge. Discharge from the unconfined aquifer on the Hanford Site is predominantly to the Columbia River (Gephart et al. 1979).

Ground Water at 100-N Area

The unconfined aquifer in the 100-N Area is contained in the sand/gravel unit of the Ringold Formation. Its lower boundary is the mud unit within the Ringold Formation. The water-table occurs about 20 ft below the contact with the glaciofluvial sediments. The thickness of the unconfined aquifer in the 100-N Area averages 65 ft around the 1301-N facility. The general groundwater flow direction is northwest, toward the Columbia River, based on interpretation of ground-water gradients. The elevation of the water table at the site is affected by the level of the nearby Columbia River, to which the unconfined aquifer is hydraulically connected, by groundwater entering the 100-N Area from other parts of the Hanford Site, and by discharge of waste water to the disposal facilities. Near the 1301-N facility during high river levels, bank storage along the river is increased, and in response groundwater levels near the river also rise (Newcomer 1988).

Surface Water

The primary surface-water features associated with the Hanford Site are the Columbia and Yakima Rivers. Several surface ponds and ditches are present on site, and are generally associated with fuel and waste processing activities.

The average annual river flow along the Hanford reach of the Columbia, based on 65 years of record, is about 120,000 ft³/sec. Large-scale flooding of the Columbia River has occurred in the past, but the likelihood of such flooding recurring has been reduced by the construction of several flood control/water storage dams upstream from the Hanford Site. Normal Columbia River elevations within the site range from 394 ft above mean sea level (MSL) at the northwestern boundary near Vernita, to 341 ft at the southeastern boundary near the 300 Area.

The fluctuations of the river are regulated immediately upstream of the Hanford Site by the Priest Rapids Dam, which is a part of the Columbia Basin Water Project. The primary driving force in the utilization of the water supply for the Columbia Reservoir System is hydropower production (COE 1984). In addition to hydropower production, there are numerous other concerns of the Columbia Reservoir System that are ranked on a priority basis including flood control, municipal and industrial use, irrigation, fish and wildlife, and recreation use. Each year prior to June 30, an operational utilization plan is developed for the following year, which controls the water releases and river levels in the system.

River-level fluctuations are reflective of a number of cyclical factors including daily, weekly, seasonal, and annual cycles. Daily cycles with river fluctuations of several feet are related to hydroelectric energy needs. Weekly cycles are also attributed to hydroelectric needs, these cycles show a decrease in river levels during weekend periods, which reflect a lower energy demand. Seasonal cycles, which are considered to have the greatest effect on the ground-water flow around the 1301-N facility, are influenced largely by the spring runoff, along with fish and wildlife management activities. In January and February, in preparation for the runoff, the reservoir system is lowered, creating higher river levels. In mid-April, there is another large

release of water, which lasts over a month, to facilitate the salmon migration downstream. The largest release of water from the system occurs from May to the end of June, which represents the release of spring runoff (COE 1984).

WATER-TABLE ELEVATIONS

Water levels in wells open to the unconfined aquifer beneath the 1301-N facility are influenced predominantly by river stage fluctuations and waste-water discharges to nearby facilities.

Water-table maps of the unconfined aquifer underlying the 100-N Area show a decline in the water table beneath the 1301-N facility from October 31, 1989, through January 25, 1990 (Appendix A). The amount of decline for this period is about 2 ft. Water levels measured with a steel tape from well 199-N-67 confirm the areal decline shown on water-table maps. A measurement taken on October 19, 1989, was 391.11 ft above MSL and a measurement taken on February 14, 1990, was 389.56 ft above MSL, yielding a decline in water level of 1.55 ft.

Water-table maps constructed for the 100-N Area indicate the influences of facilities on the ground-water system. A ground-water mound is present under the 1324-N/NA facility. The mound rose about 2 ft in elevation from October to November 1989, as indicated by a water-level rise in well 199-N-61 located approximately 50 ft east of the 1324-N/NA facility (Appendix A). A decline in the mound of about 4 ft occurred during the period from November 1989 to January 1990. The steepest gradient of the 1324-N/NA mound is northwest toward the Columbia River (Appendix A).

The 1325-N facility also had an influence on the water-table elevations in the 100-N Area. Prior to the waste-water discharge reduction to the 1325-N facility in about July 1989, a ground-water mound was present beneath the facility (Figure 6). This mound has dissipated since the reduction of waste-water flow from 1500-2000 gal/min. during operation of N Reactor to approximately 350 gal/min. currently. Jensen (1987) noted that when the 1325-N facility was not in operation, the ground-water mound beneath the facility dissipated outward in all directions. The maximum elevation of the water table beneath the 1325-N facility was approximately 413 ft MSL in May 1989. The elevation of the water table beneath this facility in January 1990, was about 393 ft MSL. The mound declined at an average rate of 0.08 ft/day. The waste-water discharge to 1325-N, however, still appears to be influencing the water table beneath the facility based on the water-table maps.

FIGURE 6. Water-Level Elevations Showing the Ground-Water Mound Near the 1325-N Facility, May 30, 1989

The stage of the Columbia River regulated at the Priest Rapids Dam may fluctuate as much as 4 to 6 ft daily (Appendix 8). A dampened daily change is seen in wells 199-N-8S, 199-N-8P, 199-N-20, 199-N-23, 199-N-25, and 199-N-51 (Appendix C). Table 3 shows the change in the water level in the wells responding to a decrease in river stage on January 21, 1990. Well 199-N-25 shows the greatest change.

The river stage generally increased from October 1989 through February 1990 (Figure 7). Water levels in wells 199-N-20, 199-N-23, 199-N-25, and 199-N-51 (Appendix C) also show an associated general increase. Wells 199-N-27, 199-N-34, 199-N-67, and 199-N-51, however, show a general decline in water level. Wells 199-N-34 and 199-N-58 show a decline in water level through January 1990. The declines in these wells may reflect the dissipation of the remnant ground-water mound under the 1325-N facility.

The water-level in well 199-N-58 peaked in early February and water-level for well 199-N-34 peaked in mid-February. The shapes of the hydrographs for water-levels in these wells are similar; however, the peak in 199-N-34 is relatively dampened. These peaks in February may be in response to an increase in waste-water discharge to the 1324-N/NA ponds (see Table 1). Well 199-N-58 is located adjacent to the 1324-N/NA facility. Well 199-N-34 is

TABLE 3. Change in Water Levels and 100-N River Stage

Approximate Columbia River Stage Change, ft		Date
-1.0		1/21/90
Well Number	Water Level Change, ft	Date
199-N-8S	-0.7	1/21/90
199-N-8P	-0.5	1/21/90
199-N-20	-0.4	1/21-22/90
199-N-23	-0.4	1/22/90
199-N-25	-0.9	1/21-22/90
199-N-51	-0.8	1/21/90

FIGURE 7. Columbia River 5-Day Average Stage, October 1989-February 1990

located approximately 2000 feet away from the 1324-N/NA facility. Wells 199-N-3, 199-N-8S, and 199-N-8P do not have enough data to determine long-term rise or fall in water level.

Barometric effects can also affect the water-table fluctuations. These effects may, however, be masked by the influence of river stage fluctuations and waste water discharges. Changes in barometric pressure can cause small fluctuations in the water table in unconfined aquifers (Peck 1960). Figure 8 shows hourly water-level elevations at well 199-N-34 versus hourly barometric pressure data from the Hanford meteorology station in the 200 West Area. As indicated, there is no apparent correlation between water-level fluctuations and changes in barometric pressure. All wells screened in the same strata in the 100-N Area would also be expected to respond similarly to barometric pressure changes.

FIGURE 8. Hourly Water-Level Elevations Versus Hourly Barometric Pressure Data for Well 199-N-34

STATISTICAL ANALYSIS

A statistical analysis was applied to the water-level data to correlate the water-level fluctuations observed in the wells with the river stage fluctuations recorded at the gaging station. The purpose of the statistical analysis was to quantify the relationship between these water-level fluctuations, which can be used to evaluate the influence of the river stage on the water table.

METHOD

The statistical procedure used to evaluate the river stage and well water-level fluctuations is a fast Fourier transform (FFT) algorithm using a verified program taken from Press et al. (1986). This algorithm allows for rapid digital processing on a microcomputer (Brigham 1974). The FFT procedure applies a transformation to the data by separating the waveforms into a sum of sinusoids of different frequencies.

The transformed data (the river stage data and the water-level data from each of the wells for the same discrete time period) are cross-correlated to determine the time lag and dampening effects as a result of river stage fluctuations propagating into the unconfined aquifer inland from the river. The data are cross-correlated by shifting one of the data sets relative to the other data set in discrete time steps and calculating the covariance for each shift using the FFT procedure. The time lag is equal to the number of time steps at which the maximum covariance occurs multiplied by the water-level time interval. The dampening effect, referred to by Bendat and Piersol (1986) as the attenuation factor, α , is related to the maximum covariance by the equation

$$\alpha = \text{Cov}_m / \sigma_x^2 \quad (1)$$

where Cov_m = maximum covariance

σ_x = standard deviation of the first data set (river stage data).

Prior to data transformation, the data were normalized by subtracting the mean for the entire time period from the data. Basic statistics were applied to the normalized data to determine the standard deviation, covariance, and correlation. The correlation is related to the covariance and standard deviation of the two data sets by the equation

$$\text{Corr} = \text{Cov} / \sigma_x \sigma_y \quad (2)$$

where Cov = covariance

σ_x = standard deviation of the first data set (river stage data)

σ_y = standard deviation of the second data set (well water-level data).

The covariance is defined as follows:

$$\text{Cov} = (n * \Sigma xy - \Sigma x * \Sigma y) / (n(n-1)) \quad (3)$$

where n = number of samples

x = data values for the first data set (river stage data)

y = data values for the second data set (well water-level data).

RESULTS

Statistical analysis was applied to water-level data obtained for the period January 10 through January 31, 1989. This period was chosen because the river stage fluctuations observed between January 10 and January 31, 1989, are typical of short-term river stage fluctuations commonly observed along the Hanford reach. Also, the program requires the number of values for each data set to be a power of 2. A sampling frequency of 1 hour over a period of approximately 21 days yields 512 (2^9) data values. This number of data over the 21-day period is sufficient for the statistical analysis. The results of the statistical parameter analysis are tabulated in Table 4.

TABLE 4. Results of Statistical Parameter Analysis Between the River Stage Fluctuations and the Well Water-Level Fluctuations for January 10 Through January 31, 1989

<u>Well Name</u>	<u>Distance to River, ft</u>	<u>Correlation</u>	<u>Approximate Time Lag, hr</u>	<u>Attenuation Factor</u>
199-N-8S	80	0.98	<1	0.51
199-N-8P	80	0.94	1	0.24
199-N-51	380	0.85	2	0.29
199-N-25	310	0.77	3	0.34
199-N-20	430	0.64	7	0.19
199-N-23	410	0.48	15	0.13
199-N-27	5280	-0.50	--	--
199-N-34	2690	-0.50	--	--
199-N-58	2480	0.06	--	--
199-N-67	1450	-0.50	--	--

As expected, the results in Table 4 indicate strong correlation between the river stage fluctuations with the water-level fluctuations observed in piezometers 199-N-8S and 199-N-8P (located approximately 80 ft from the river) and wells 199-N-20, 199-N-23, 199-N-25, and 199-N-51 (located between 130 ft and 480 ft from the river) (i.e., prior to data transformation). The highest correlation is exhibited for wells 199-N-8S, 199-N-8P, and 199-N-51. Correlations ranged between 0.48 and 0.98 on a scale normalized between 0, which represents no correlation, and 1, which represents perfect correlation. The correlations determined for wells 199-N-27, 199-N-34, 199-N-58, and 199-N-67, located between 860 ft and 2570 ft from the river, indicate that the water-level fluctuations observed in these wells do not correlate with the river stage fluctuations. The correlation for those wells ranges between -0.50 and 0.06.

The approximate time lag at which maximum covariance occurs and the attenuation factor associated with each of the wells exhibiting a strong correlation between water-level and river stage fluctuations is also listed in Table 4. Time lags ranged from less than 1 h to as much as 15 h with the attenuation factors (a dimensionless parameter) ranging between 0.13 and 0.51. The time lag is the time after which the water level in the well responds to a

corresponding change in the river stage. The value for the attenuation factor becomes smaller with greater attenuation and ranges between 0 and 1. A value of 1 represents no attenuation and a value of 0 represents complete attenuation.

Waveform characteristics of the observed water-level fluctuations at various distances from the river indicate that the medium through which the river flood waves are propagated is not homogeneous. The results in Table 4 indicate that the water-level fluctuations observed in well 199-N-51, located approximately 50 ft farther from the river than well 199-N-20, are much more responsive to the river stage fluctuations as indicated by a smaller time lag, greater attenuation factor, and higher correlation. Strong correlation exhibited for well 199-N-51 suggests that river stage fluctuations propagate farther inland from well 199-N-51 (greater than 480 ft). The results in Table 4 also indicate that the water-level fluctuations observed in well 199-N-23, located closer to the river than wells 199-N-20 and 199-N-51, are less responsive to the river stage fluctuations as indicated by a greater time lag, smaller attenuation factor, and weaker correlation. The lack of correlation with well 199-N-27 supports Jensen's (1987) conclusion that river stage has little effect on the ground-water levels close to the 1325-N facility.

CONCLUSIONS

The unconfined ground-water flow system beneath the 1301-N facility and the 100-N Area is affected by a number of factors including geologic facies changes, Columbia River stage fluctuations, and artificial recharge from adjacent waste-water disposal facilities. Water-table elevation data indicate that water-levels beneath the 1301-N facility have declined approximately 2 ft from October 1989 to January 1990 and that the ground-water mound under the 1325-N facility that existed prior to the "dry layup" status of the N Reactor has largely dissipated. The current dominant water-table feature in the 100-N Area is the ground-water mound under the 1324-N/NA ponds. Ground-water flow is strongly influenced by this mound. The steepest gradients in the water-table elevations are from the 1324-N/NA facilities to the river.

Statistical analysis of the water-level data contained in this report indicates that strong correlation between river stage and the water-table fluctuations are exhibited in wells located between 130 and 480 ft from the river. Wells located between 860 and 2570 feet from the river do not indicate significant association between water-level fluctuations and river stage elevation. The time lag between river stage changes and the corresponding effects in the wells located 130 to 480 ft from the river range from less than 1 h up to 15 h. Attenuation of these responses range from 0.13 to 0.51. Generally the time lags and attenuation increase with distance from the river with the exception of well 199-N-51. The correlation coefficients of responses to the river in well 199-N-51, which is 480 feet from the river, are similar to wells that are located much closer to the river but several thousand feet south of well 199-N-51. This response suggests other factors such as hydrogeological properties of the aquifer are controlling the behavior of the wave propagation induced by river stage fluctuations. Lithologic sample descriptions indicate that relatively finer grained sediments occur between the river and the 1301-N facility than those occurring north of the facility near well 199-N-51. These finer-grained sediments result in lower transmissivities near the 1301-N facility than in the area to the north.

Impacts of river stage fluctuations on the ground-water system beneath the 1301-N facility were not evident during the period of study. Water levels

in the vicinity of the 1301-N facility are predominantly influenced by the regional gradient and the ground-water mound beneath 1324-N/NA facility. Other factors, such as barometric effects, do not have a significant influence on the water-table elevations.

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APPENDIX A

WATER-TABLE MAPS OF THE UNCONFINED AQUIFER
BENEATH THE 100-N AREA

APPENDIX A

WATER-TABLE MAPS OF THE UNCONFINED AQUIFER BENEATH THE 100-N AREA

This appendix contains water-level maps of the unconfined aquifer beneath the 100-N Area. Included are five maps for the dates October 31, November 30, December 28, 1989, January 25, 1990, and February 26, 1990, and a well location diagram showing the wells used for the water-level maps. Also included are water-table data for the dates October, November, and December 1989, and January 1990.

WATER-LEVELS 100 N AREA - OCTOBER 31, 1989

WATER-LEVELS 100 N AREA - NOVEMBER 30, 1989

WATER-LEVELS 100 N AREA - DECEMBER 28, 1989

WATER-LEVELS 100 N AREA - JANUARY 25, 1990

WATER-LEVELS 100 N AREA - FEBRUARY 26, 1990

WELLS USED FOR WATER-LEVEL MAPS

A.7

TABLE A.1. Water-Table Data for October 1989

<u>Water Table Elevation</u>	<u>Well Number (all wells prefixed by 199-)</u>
390.44	N2
389.38	N3
393.93	N4
395.69	N6
383.83	N8s
387.00	N14
392.04	N16
389.30	N17
387.71	N18
387.39	N19
388.51	N20
388.20	N21
386.87	N23
385.31	N24
384.45	N25
395.36	N27
396.22	N28
396.08	N29
395.11	N31
395.10	N32
394.74	N33
395.25	N34
394.73	N36
394.25	N37
393.32	N39
392.44	N40
389.42	N41
390.42	N42
393.94	N44
390.47	N49
384.09	N51
395.97	N52
392.66	N53
392.64	N54
392.56	N55
391.42	N56
393.67	N57
395.29	N58
395.36	N59
395.48	N60
399.20	N61
395.84	N62
395.13	N63
394.41	N64
394.06	N65
394.56	N66
383.80	River

TABLE A.2. Water-Table Data for November 1989

<u>Water Table Elevation</u>	<u>Well Number (all wells prefixed by 199-)</u>
385.78	N8s
387.03	N14
392.97	N16
389.48	N17
388.10	N18
388.19	N19
389.26	N20
389.06	N21
387.87	N23
386.56	N24
386.13	N25
394.33	N27
395.27	N28
395.17	N29
394.14	N31
393.11	N32
393.79	N33
394.35	N34
393.72	N36
393.27	N37
392.49	N39
391.39	N40
388.75	N41
389.38	N42
392.83	N44
389.62	N49
385.17	N51
394.76	N52
391.72	N53
392.43	N54
392.45	N55
391.09	N56
393.46	N57
389.62	N58
398.66	N59
398.78	N60
402.10	N61
395.06	N62
394.49	N63
385.20	River

TABLE A.3. Water-Table Data for December 1989

<u>Water Table Elevation</u>	<u>Well Number (all wells prefixed by 199-)</u>
385.90	N8s
386.88	N14
392.23	N16
389.29	N17
388.00	N18
388.01	N19
388.98	N20
388.79	N21
387.72	N23
386.47	N24
386.07	N25
393.66	N27
394.57	N28
394.49	N29
393.46	N32
393.23	N33
393.75	N34
393.11	N36
392.70	N37
391.90	N39
390.89	N40
388.49	N41
389.26	N42
392.21	N44
389.28	N49
385.28	N51
394.08	N52
391.23	N53
392.06	N54
392.07	N55
390.82	N56
392.98	N57
395.66	N58
395.86	N59
395.89	N60
398.25	N61
394.43	N62
393.92	N63
385.50	River

TABLE A.4. Water-Table Data for January 1990

<u>Water Table Elevation</u>	<u>Well Number (all wells prefixed by 199-)</u>
386.04	N8s
387.12	N14
393.45	N16
389.23	N17
388.12	N18
388.14	N19
388.99	N20
388.83	N21
388.04	N23
387.05	N24
386.60	N25
393.03	N27
393.87	N28
393.78	N29
392.82	N32
392.59	N33
393.11	N34
392.52	N36
392.12	N37
391.38	N39
390.46	N40
388.36	N41
389.05	N42
391.34	N44
389.01	N49
385.58	N51
393.52	N52
388.99	N53
391.59	N54
391.62	N55
390.45	N56
392.50	N57
394.88	N58
394.93	N59
395.07	N60
397.29	N61
393.79	N62
393.34	N63
386.00	River

APPENDIX B

GRAPHS OF HOURLY COLUMBIA RIVER STAGE DATA
NEAR THE 100-N AREA

APPENDIX B

GRAPHS OF HOURLY COLUMBIA RIVER STAGE DATA NEAR THE 100-N AREA

This appendix contains graphs of hourly Columbia River stage data collected near the 100-N Area for the period October 19, 1989, through February 1990. A 5-day moving average is also plotted on the graph.

COLUMBIA RIVER STAGE NEAR 100-N
OCTOBER 1989

COLUMBIA RIVER STAGE NEAR 100-N
NOVEMBER 1989

COLUMBIA RIVER STAGE NEAR 100-N
FEBRUARY 1990

APPENDIX C

WATER-LEVEL HYDROGRAPHS

APPENDIX C

WATER-LEVEL HYDROGRAPHS

This appendix contains water-level hydrographs for the wells listed below. The well number is abbreviated on the graphs. The prefix 199 is omitted.

Well Number

N-03
N-8P
N-8S
N-20
N-23
N-25
N-27
N-34
N-51
N-58
N-66
N-67

WELL N-8P
JANUARY 1990

— CONTINUOUS FIELD RECORDER MEASUREMENTS
oooo PERIODIC STEEL TAPE MEASUREMENTS

WELL N-8S
FEBRUARY 1990

WELL N-23
DECEMBER 1989

— CONTINUOUS FIELD RECORDER MEASUREMENTS
○○○○○ PERIODIC STEEL TAPE MEASUREMENTS

WELL N-51
JANUARY 1990

— CONTINUOUS FIELD RECORDER MEASUREMENTS
○○○○○ PERIODIC STEEL TAPE MEASUREMENTS

C.30

WELL N-66
FEBRUARY 1990

— CONTINUOUS FIELD RECORDER MEASUREMENTS
oooo PERIODIC STEEL TAPE MEASUREMENTS

C.31

WELL N-67
DECEMBER 1989

— CONTINUOUS FIELD RECORDER MEASUREMENTS

C.34

WELL N-67
FEBRUARY 1990

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