DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
U.S. DEPARTMENT OF ENERGY

HYDROLOGIC INVESTIGATIONS
ATLAS HA-674 (SHEET 1 OF 2)

INTRODUCTION

The Idaho National Engineering Laboratory (INEL), formerly the National Reactor Testing Station (NRTS), was established in 1949 by the Atomic Energy Commission (AEC) and is now operated by the U.S. Department of Energy (DOE) to build, operate, and test various types of nuclear reactors. Fifty-two reactors have been constructed to date, of which 17 are still operable.

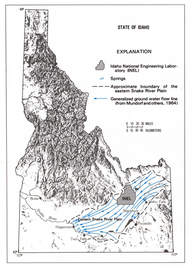

Figure 1.—RELIEF MAP OF IDAHO. Showing the location of the INEL, Snake River Plain, and generalized ground-water flow lines of the Snake River Plain aquifer (from Barraclough, Lewis, and Jensen, 1981)

The INEL site covers about 890 square miles on the eastern Snake River Plain (fig. 1) in southeastern Idaho. The plain is a structural and topographic basin about 200 miles long and 50 to 70 miles wide. Thin basaltic lava flows, rhyolite deposits, and interbedded sediments fill the basin from its present level (land surface) to depths of approximately 2,000 to 10,000 feet. A more detailed description of the geology is found in Robertson, Schoen, and Barraclough (1974). Underlying the plain, and contained in the upper part of this stratigraphic sequence, is a vast body of ground water contained in the Snake River Plain aquifer—the major aquifer in Idaho. The INEL obtains its entire water supply from this aquifer. Aqueous chemical and radioactive wastes are discharged to shallow ponds and to shallow or deep wells on the INEL site. Many of these waste constituents enter the aquifer either directly or indirectly following percolation through the unsaturated zone.

The successful protection of subsurface waste disposal on the regional hydrology requires a knowledge of the hydrogeology of the Snake River Plain aquifer, the locations and quantities of aqueous waste disposal, the methods of disposal, and the geochemistry of the waste solutions and of the ground water in the aquifer. During recent years, the prime concern has been to have the movement of dilute chemical and low-level radioactive wastes in the subsurface and to explain the chemical and radiochemical changes that accompany such movement in terms of the geologic, hydrologic, and geochemical properties.

PURPOSE AND SCOPE

In 1949, the AEC requested the U.S. Geological Survey to investigate and describe the water resources of the INEL and adjacent areas. Information was collected which depicted hydrogeologic conditions prior to any reactor operations at the Laboratory. Current investigations serve to determine natural changes in the hydrology and also to determine changes resulting from activities at the Laboratory.

This atlas presents an analysis of the water-level and water-quality data collected by the U.S.Geological Survey during the calendar years 1979 through 1981. The atlas therefore covers a period following that covered by a previous report by Barraclough, Lewis and Jensen (1981), which summarized the influences of waste disposal from 1974 to 1978. Reports on previous Geological Survey investigations describing geologic and hydrologic studies of the area and related reports by the DOE staff are listed in the references and may be obtained from the INEL library or from the office of the Geological Survey at Central Facilities Area (CFA) (fig. 2).

Figure 2.—LOCATION OF THE INEL AND FACILITIES. (From Barraclough, Lewis, and Jensen, 1981)

ACKNOWLEDGMENTS

These studies have been sponsored and funded by the U.S. Department of Energy. The U.S. Geological Survey project at the INEL is coordinated through the following personnel of the DOE Idaho Operations Office (DOE): J. P. Hamic, Director, Nuclear Fuel Cycle and Waste Management Division; J. B. Whitsett, Chief, Radioactive Waste Programs Branch; and M. M. Williamson, Director, Radiological and Environmental Sciences Laboratory. Considerable assistance has also been obtained from the following DOE-ID personnel: the staff of the Analytical Chemistry Branch, L. Z. Bodnar, Chief, who provided most of the chemical and radiochemical analyses of ground-water samples; and E. W. Chew, Chief, Environmental Sciences Branch.

REGIONAL HYDROLOGY

The eastern Snake River Plain is underlain by a vast ground-water reservoir known as the Snake River Plain aquifer, which may contain more than 1 billion acre-feet of usable water (Lewis, Lewis, and Jensen, 1981). The flow of ground water in the aquifer is principally to the south-southwest (fig. 3) at relatively high velocities of 5–20 feet per day. The transmissivity of the aquifer generally ranges from 1 million to 100 million gallons per day per foot or 134,000 to 13,400,000 feet squared per day (Robertson, Schoen, and Barraclough, 1974).

The basaltic volcanic rocks and interbedded sediments composing the aquifer are all included within the Snake River Group of Quaternary age. The Snake River Group is probably composed of older volcanic and sedimentary rocks in addition to the younger underlying rhyolite rocks. The basalt is the principal aquifer. Water-bearing openings in the basalt are distributed throughout the rock system in the form of intercrystalline and intergranular porosity, fractures, cavities, interstitial voids, interflow zones, and lava tubes. The variety and degree of interconnection of these openings control the direction of flow of ground-water movement locally throughout the aquifer.

Ground-water recharge to the aquifer is primarily by underflow from the northeastern part of the plain and also from adjacent drainages on the west and north. Most of the ground water underlying the INEL enters the ground in the uplands to the north, northeast, and northwest of the site, moves southward or southwestward through the aquifer, and discharges at springs along the valley of the Snake River near Hagerman (fig. 1). Lesser amounts of the water are derived from local precipitation on the plain. Part of the precipitation evaporates, but part infiltrates the ground surface and percolates through the subsurface to the regional water table. Significant recharge is also derived from occasional flow in the Big Lost River.

WATER-TABLE DATA

The water-table observation well program was designed to determine the changes in gradient that influence the rate and direction of ground water and radionuclide movement, to identify sources of recharge to the aquifer, and to measure the areal extent of the effects of recharge. Water levels were measured in both the regional aquifer and perched aquifers. Taken continuous water-level recorders were operated from 1979 to 1981; water levels were measured monthly to 56 wells, and annually in 53, in order to study the regional water table. To study perched water bodies, two wells were equipped with continuous water-level recorders; and water levels in 24 wells were measured monthly, 60 were measured quarterly, and 97 were measured annually. A total of 3,400 water-level measurements were made from 1979 to 1981, for an average of 1,133 measurements per year.

Figures 3 and 4 show the locations of wells in the observation wells and the frequency of water-level measurements. Data are on file in the office of the U.S. Geological Survey at the INEL.

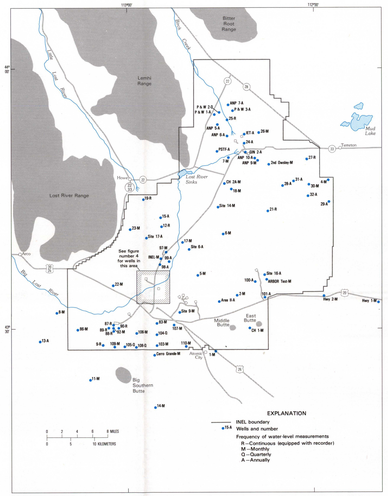

Figure 3.—LOCATIONS OF WELLS AND THE FREQUENCY OF WATER-LEVEL MEASUREMENTS AT THE INEL AND VICINITY

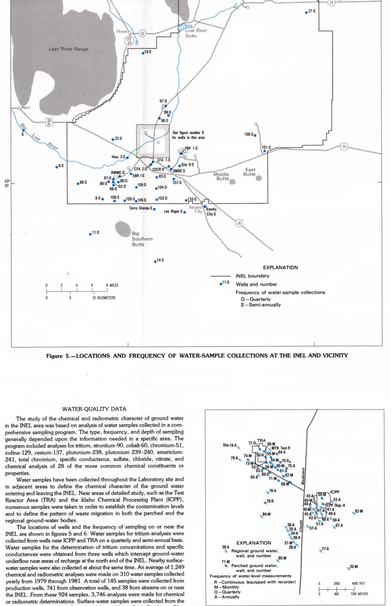

Figure 4.—LOCATIONS OF WELLS AND THE FREQUENCY OF WATER-LEVEL MEASUREMENTS IN THE TRA-ICPP AREA

WATER-QUALITY DATA

The study of the chemical and radiochemical character of ground water in the INEL area was based on analysis of water samples collected in a comprehensive sampling program. The type, frequency, and depth of sampling generally depended upon the information needed in a specific area. The program included analyses for tritium, strontium-90, cobalt-60, chromium-51, iodine-129, cesium-137, plutonium-238, plutonium 239–240, americium-241, total chromium, specific conductance, sodium, chloride, nitrate, and chemical analysis of 28 of the more common chemical constituents or properties.

Water samples have been collected throughout the Laboratory site and in adjacent areas to define the chemical character of the ground water entering and leaving the INEL. Near areas of detailed study, such as the Test Reactor Area (TRA) and the Idaho Chemical Processing Plant (ICPP), numerous samples were taken in order to establish the contamination levels and to define the path of waste migration in both the perched and the regional ground-water bodies.

The frequency of both and the frequency of sampling on or near the INEL are shown in figures 5 and 6. Water samples for tritium analyses were collected monthly from ICPP and TRA on a quarterly and semi-annual basis. Water samples for the determination of tritium concentrations and specific conductances were obtained from those wells which intercept ground-water underflow near areas of recharge at the north end of the INEL. Nearby surface-water samples were also collected at about the same time. An average of 1,249 chemical and radiometric analyses were made on 310 water samples collected yearly from 1979 through 1981. A total of 145 samples were collected from production wells, 741 from observation wells, and 38 from streams or near the INEL. From these 924 samples, 3,746 analyses were made for chemical or radiometric determinations. Surface-water samples were collected from the following stations: Big Lost River near Moore, Idaho; Birch Creek near Blue Dome, Idaho; Little Lost River near Howe, Idaho; and Mud Lake near Terreton, Idaho.

Figure 5.—LOCATIONS AND FREQUENCY OF WATER-SAMPLE COLLECTIONS AT THE INEL AND VICINITY

Figure 6.—LOCATIONS AND FREQUENCY OF WATER-SAMPLE COLLECTIONS IN THE TRA-ICPP AREA

CONFIGURATION OF THE REGIONAL WATER TABLE

Figure 7 is a map of the INEL site and adjacent areas showing altitude contours on the water table of the Snake River Plain aquifer for July 1981 and the inferred directions of ground-water movement. The altitude of the water table ranges from 4,582 feet above the National Geodetic Vertical Datum of 1929 (NGVD of 1929) in the northern part of the site to 4,427 feet near the southwestern boundary of the site. The general direction of regional ground-water movement is southwestward (fig. 7). The regional gradient of the water surface east of the water table is about 4 feet per mile. In the northern part of the INEL, near the Birch Creek valley, the water-table gradient is relatively flat, sloping southward about 1 foot per mile (fig. 7).

The configuration of the regional water table varies with the recharge received by the system over some period prior to the measurement of water levels. From 1979 through 1981, recharge was considerably less than discharge, as was the case in the prior four-year period (Barraclough, Lewis, and Jensen, 1981), and collected data show that the relative vertical position of the water table has fallen. Figure 8 shows this decline from July 1972 to July 1981. Near the northern boundary of the INEL, where recharge from the Birch Creek and Mud Lake area has been characterized by long-term consistency, the decline has been as little as 2 feet. In many parts of the INEL declines have been greater than 10 feet in observation wells that are sensitive to changes in recharge from the Big Lost River as it traverses the site. Big Lost River flow on the INEL has been abnormally low for the past five years (1977–1981). In addition, pumping from production wells at a few facilities has increased over the same period and may have contributed slightly to the declines.

SURFACE WATER

Surface water is found mainly in streams draining the mountains and valleys to the west and north of the INEL (see fig. 1). Locally, snowmelt and rain also contribute to surface water, especially in the spring. The Big Lost River is the INEL's most important source of surface-water recharge. Recharge to the Snake River Plain aquifer from streamflow during wet years is significant. All streamflow that enters the INEL is recharged to the aquifer, except for evaporation and transpiration losses. During dry periods, streamflow does not reach the INEL.

The Big Lost River flows southeastward in its valley past Arco, onto the Snake River Plain, and then turns northeastward through the INEL to its termination in playas, called the Lost River Sinks (fig. 2). The river loses water by infiltration through the channel bottom as it flows on the plain. As it approaches the terminal playas, the channel branches into many distributaries and spreads out over several flooding and ponding areas (Barraclough and others, 1967).

In addition to irrigation diversions, two major artificial controls affect flow in the river. These are the Mackay Dam, 30 miles upstream from Arco, and INEL flood-control diversion system in the southwestern part of the site (fig. 2). The INEL flood-control diversion system was constructed in 1958 to reduce the threat of floods from the Big Lost River on that part of the site. The diversion dam can divert flow out of the main channel to diversion areas A, B, C, and D (see Lamke, 1969, for discussion of flood control). During winter months, nearly all flow is diverted to avoid accumulation of ice in the main channel and to reduce the possibility of flooding INEL facilities.

The period of highest average flow of the Big Lost River below Mackay Reservoir for the entire historical record (fig. 9) was from 1965 through 1976, with 1965, 1969, 1967, 1974, 1975, and 1971 recording the six highest flows of record in order of decreasing magnitude. The total discharge decreased during 1977 to 160,300 acre-feet, much less than normal. During the 1978 water year the discharge was measured at 225,900 acre-feet, slightly above average. In 1979 the discharge declined to 202,400 acre-feet. In 1980 the discharge rose to an above-average 249,500 acre-feet. During 1981 the discharge fell slightly to 240,100 acre-feet but depicted on fig. 9) but remained significantly above the 64-year discharge average of 215,000 acre-feet.

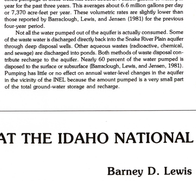

Figure 9.—DISCHARGE OF THE BIG LOST RIVER BELOW THE MACKAY RESERVOIR. (From Lewis and Goldstein, 1982)

Continuous flow of the Big Lost River was recorded at the INEL diversion gaging station for at least three years prior to 1977 (Barraclough, Lewis, and Jensen, 1981). However, since 1977, very little or no water has flowed past the diversion, reflecting the dry period that began in 1977. The above-average flow of the Big Lost River below Mackay Reservoir for 1980 (fig. 9) was located for irrigation in the Big Lost River valley (see fig. 1) and only a small amount reached the diversion area (Lewis and Goldstein, 1982).

GROUND WATER

Water infiltrates from the Big Lost River during periods of flow and percolates to the Snake River Plain aquifer. Significant amounts of this recharge have caused a regional rise of the ground-water level over much of the INEL following several flow events. The water levels in some wells have risen as much as 6 feet in a few months following high flows in the river (Barraclough, Lewis, and Jensen, 1981). Water-level changes in four regional aquifer wells (fig. 10) in the southwestern part of the INEL illustrate the influence of recharge from the Big Lost River. In wells 17, 23, and 12 (see fig. 3 for well locations), the lowest water levels on record occurred in 1964 following four years of below-average discharge in the river. The highest water levels occurred in 1965 following the wet year of 1965 to 1971.

The water level in well 32, which taps the Snake River Plain aquifer, rose 21.5 feet in 8 years from 1964 to 1972. This is the largest measured fluctuation of water level in any INEL well. The water level in well 23 rose about 18 feet during this same period, which is the second largest water-level rise that has been measured.

Figure 8.—GENERALIZED NET DECLINE OF THE WATER TABLE, SNAKE RIVER PLAIN AQUIFER, INEL AND VICINITY, FROM JULY 1972 TO JULY 1981

Figure 10.—HYDROGRAPHS OF FOUR WELLS IN THE SOUTHWESTERN PART OF THE INEL. (From Lewis and Goldstein, 1982)

FACTORS FOR CONVERTING INCH-POUND UNITS TO METRIC (SI) UNITS

The following factors can be used to convert inch-pound units published herein to the International System of units (SI).

Multiply inch-pound units	By	To obtain SI units
inches (in)	2.54	centimeters (cm)
feet (ft)	0.3048	meters (m)
miles (mi)	1.609	kilometers (km)
square feet (ft²)	0.0929	square meters (m²)
acres	0.4047	square hectometers (hm²)
square miles (mi²)	2.590	square kilometers (km²)
gallons (gal)	3.785	liters (L)
gallons (gal)	3.785 x 10⁻³	cubic meters (m³)
million gallons (102 gal or Mgal)	3,785	cubic meters (m³)
acre-feet (acre-ft)	1,233	cubic meters (m³)
pounds (lb)	0.4536	kilograms (kg)
feet per mile (ft/mi)	0.1894	meters per kilometer (m/km)
curies (C)	3.70 x 10¹⁰	becquerel (Bq)
micromhos (mho)	1.00	microsiemens (S)
temperature, degrees Celsius (°C)	t=0.556 (°F–32)	

The water level in well 20 (see fig. 4 for well location) rose only about 6 feet from 1964 to 1972 and had declined by nearly 8 feet to a record low by the end of 1980 (fig. 10). The more stable position of this water level may indicate that well 20 is not as greatly influenced by recharge from the Big Lost River and represents that the changes in water level for the Snake River aquifer on a more regional basis (Lewis and Goldstein, 1982). The water level remained nearly constant at the record low level during the 1981 water year and may indicate that the aquifer has reached a discharge-recharge balance on a regional basis.

The Snake River Plain aquifer is the only source of water utilized at the INEL. Twenty-five of the 29 production wells are generally in use. A total of 3 billion pumpage of these wells has been about 2.4 billion gallons of water per year for the past three years. This averages about 6.6 million gallons per day or 7,370 acre-feet per year. These volumetric rates are slightly lower than those reported by Barraclough, Lewis, and Jensen (1981) for the previous four-year period.

Most of the water pumped out of the aquifer is actually consumed. Some of the waste water is discharged to ponds, back into the Snake River aquifer through deep disposal wells. Other aqueous wastes inadioactive, chemical, and sewage are discharged to ponds. Both methods of waste disposal contribute recharge to the aquifer. Nearly 60 percent of the water pumped is disposed to the surface or subsurface (Barraclough, Lewis, and Jensen, 1981). Pumping has little or no effect on annual water-level changes in the aquifer in the vicinity of the INEL because the amount pumped is a very small part of the total ground-water storage and recharge.

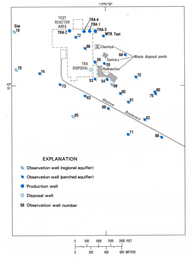

Figure 11.—LOCATION OF OBSERVATION WELLS, PRODUCTION WELLS, WASTE-DISPOSAL PONDS, AND THE DISPOSAL WELL AT THE TRA

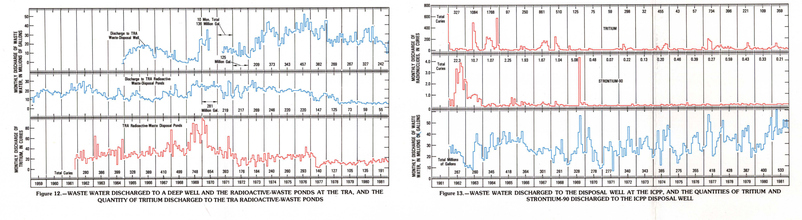

Figure 12.—WASTE WATER DISCHARGED TO A DEEP WELL AND THE RADIOACTIVE-WASTE PONDS AT THE TRA, AND THE QUANTITY OF TRITIUM DISCHARGED TO THE TRA RADIOACTIVE-WASTE PONDS

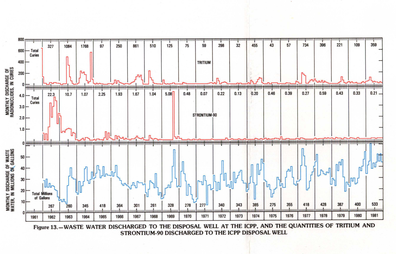

Figure 13.—WASTE WATER DISCHARGED TO THE DISPOSAL WELL AT THE ICPP, AND THE QUANTITIES OF TRITIUM AND STRONTIUM-90 DISCHARGED TO THE ICPP DISPOSAL WELL

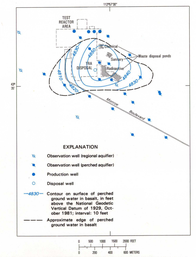

Figure 14.—WATER-LEVEL CONTOURS ON THE SURFACE OF THE PERCHED GROUND WATER IN THE BASALT AT THE TRA, OCTOBER 1981

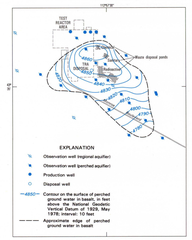

Figure 15.—WATER-LEVEL CONTOURS ON THE SURFACE OF THE PERCHED GROUND WATER IN THE BASALT AT THE TRA, MAY 1978. (From Barraclough, Lewis, and Jensen, 1981)

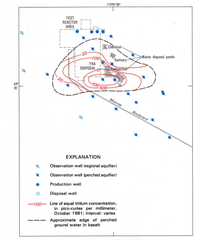

Figure 16.—CONCENTRATION OF TRITIUM IN THE PERCHED GROUND WATER IN THE BASALT AT THE TRA, OCTOBER 1981

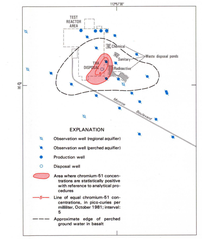

Figure 17.—CONCENTRATION OF CHROMIUM-51 IN THE PERCHED GROUND WATER IN THE BASALT AT THE TRA, OCTOBER 1981

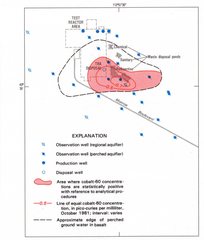

Figure 18.—CONCENTRATION OF COBALT-60 IN THE PERCHED GROUND WATER IN THE BASALT AT THE TRA, OCTOBER 1981

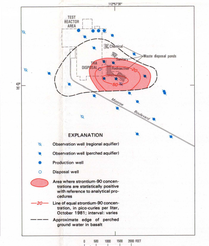

Figure 19.—CONCENTRATION OF STRONTIUM-90 IN THE PERCHED GROUND WATER IN THE BASALT AT THE TRA, OCTOBER 1981

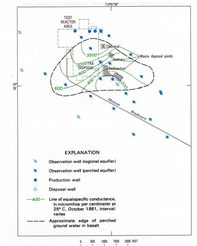

Figure 20.—SPECIFIC CONDUCTANCE OF PERCHED GROUND WATER IN THE BASALT AT THE TRA, OCTOBER 1981

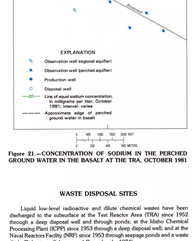

Figure 21.—CONCENTRATION OF SODIUM IN THE PERCHED GROUND WATER IN THE BASALT AT THE TRA, OCTOBER 1981

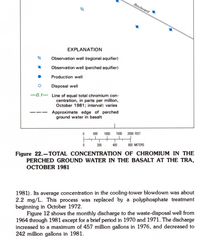

Figure 22.—TOTAL CONCENTRATION OF CHROMIUM IN THE PERCHED GROUND WATER IN THE BASALT AT THE TRA, OCTOBER 1981

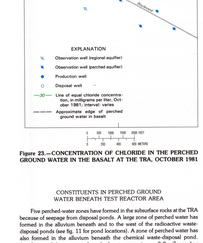

Figure 23.—CONCENTRATION OF CHLORIDE IN THE PERCHED GROUND WATER IN THE BASALT AT THE TRA, OCTOBER 1981

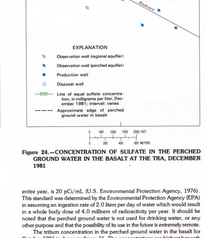

Figure 24.—CONCENTRATION OF SULFATE IN THE PERCHED GROUND WATER IN THE BASALT AT THE TRA, DECEMBER 1981

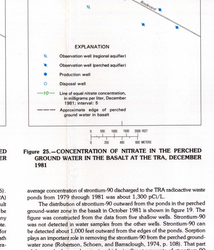

Figure 25.—CONCENTRATION OF NITRATE IN THE PERCHED GROUND WATER IN THE BASALT AT THE TRA, DECEMBER 1981

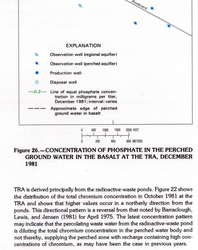

Figure 26.—CONCENTRATION OF PHOSPHATE IN THE PERCHED GROUND WATER IN THE BASALT AT THE TRA, DECEMBER 1981

WASTE DISPOSAL SITES

Liquid low-level radioactive and dilute chemical wastes have been discharged to the subsurface at the Test Reactor Area (TRA) since 1952 through a system of shallow wells and ponds. A large part of the Idaho Chemical Processing Plant (ICPP) since 1953 through a deep disposal well; and at the Naval Reactors Facility (NRF) since 1953 through seepage ponds and a waste ditch (Robertson, Schoen, and Barraclough, 1974).

TEST REACTOR AREA

The TRA utilized four disposal systems (fig. 11) to dispose of nearly 354 million gallons of waste water annually for the period 1979 through 1981. This is a much reduced disposal rate from the nearly 470 million gallons annually recorded in previous years (Barraclough, Lewis, and Jensen, 1981). Low-level radioactive wastes are discharged to three seepage ponds. A part of the waste passes into the Snake River Plain aquifer, 450 feet below the land surface. Chemical wastes are discharged to another seepage pond. Two shallow wells are used to dispose of sanitary wastes. Cooling-tower blowdown wastes are discharged to a fifth seepage through a deep disposal well.

Radioactive-Waste Ponds

The average annual discharge to the TRA radioactive-waste ponds has been about 180 million gallons for the past twelve years. Figure 12 shows a graph of the annual discharge to the ponds. The annual discharge drops and several yearly discharge totals are shown in the graph. The discharge to the ponds has varied widely over several flooding and ponding areas (Barraclough and others, 1967).

In addition to irrigation diversions, two major artificial controls affect flow in the river. These are the Mackay Dam, 30 miles upstream from Arco, and INEL flood-control diversion system in the southwestern part of the site (fig. 2). The INEL flood-control diversion system was constructed in 1958 to reduce the threat of floods from the Big Lost River on that part of the site. The diversion dam can divert flow out of the main channel to diversion areas A, B, C, and D (see Lamke, 1969, for discussion of flood control). During winter months, nearly all flow is diverted to avoid accumulation of ice in the main channel and to reduce the possibility of flooding INEL facilities.

The period of highest average flow of the Big Lost River below Mackay Reservoir for the entire historical record (fig. 9) was from 1965 through 1976, with 1965, 1969, 1967, 1974, 1975, and 1971 recording the six highest flows of record in order of decreasing magnitude. The total discharge decreased during 1977 to 160,300 acre-feet, much less than normal. During the 1978 water year the discharge was measured at 225,900 acre-feet, slightly above average. In 1979 the discharge declined to 202,400 acre-feet. In 1980 the discharge rose to an above-average 249,500 acre-feet. During 1981 the discharge fell slightly to 240,100 acre-feet but depicted on fig. 9) but remained significantly above the 64-year discharge average of 215,000 acre-feet.

NAVAL REACTORS FACILITY

The NRF utilizes a ditch to dispose of waste water. Nearly 125 million gallons of waste water were discharged to the ditch during the 1981 disposal time period. A part of the discharged waste percolates to the Snake River Plain aquifer, about 400 feet below land surface. The major chemical constituents in this waste water have been sodium, chloride, and sulfate for the past three years (1979–1981). Specific conductance has been about 168,000, 217,000, and 366,000 lb, respectively. These discharge rates and concentrations have resulted in accumulations of about 0.001, 0.002, and 0.003 lb per gallon (about 120, 240, and 360 mg/L) for sodium, chloride, and sulfate, respectively. It should be noted that the sodium and some chloride has decreased significantly over the latest three-year period. For example, about 189 million gallons of waste water was discharged in 1969, and it decreased to about 69 million gallons in 1981; sodium discharge decreased about from 1,000 lbs in 1979 to 127,000 lbs in 1981; chloride discharge decreased from nearly 369,000 lbs in 1979 to less than 134,000 lbs in 1981; and the disposal of sulfate decreased from nearly 910,000 lbs in 1979 to about 207,000 lbs in 1981. During each year, minor amounts of other chemical constituents make up the remainder of the waste water effluent. Seepage ponds are used at the NRF for sewage disposal.

DISTRIBUTION OF WASTE

About 87 percent of the total waste discharged at the INEL since 1952 has been disposed at the TRA, ICPP, and NRF facilities. The effects of this disposal have been intensively studied and are discussed in detail in the following sections.

CONSTITUENTS IN PERCHED GROUND WATER BENEATH TEST REACTOR AREA

Five perched-water zones have formed in the subsurface rocks at the TRA because of seepage from disposal ponds. A large part of the water that is discharged in the alluvium beneath and to the west of the radioactive waste-disposal ponds (see fig. 11 for well locations). A zone of perched water has also formed in the alluvium beneath the chemical waste-disposal pond. Another much larger zone of perched water, covering an 0.2 sq mi, has formed in the basalt beneath the perched zone in the surficial alluvium (fig. 14). This saturated zone in the basalt is perched by a sediment bed approximately 150 feet below land surface.

The water that seeps from the radioactive waste ponds percolates through the surface alluvium and is perched on fine-grained sediment at the base of the alluvium at the top of the basalt surface, about 50 feet below the