

ATTACHMENT 3 POST-CLOSURE PLAN, consisting of:

- Section J, Additional Information, of the INTEC Post-Closure Permit for the Volume 21 Waste Calcine Facility and CPP-601/627/640,
- Geologic and Hydrogeologic Characterization of the INEEL, of the INTEC Post-Closure Permit for the Volume 21 Waste Calcine Facility and CPP-601/627/640,
- U.S. Environmental Protection Agency Region 9 Preliminary Remediation Goals (PRGs) User Guide, October 2002.

**HWMA/RCRA INTEC POST-CLOSURE PERMIT
FOR THE
IDAHO NATIONAL LABORATORY**

**Volume 21
Waste Calcining Facility and CPP-601/627/640**

**Attachment 3
Section J, Additional Information**

Revision Date: August 25, 2011

CONTENTS

- J. ADDITIONAL INFORMATION IDAPA 58.01.05.012 [40 CFR 270.14(c)].....J-1
 - J.1 Summary of Groundwater Monitoring Data Collected Under Interim Status.....J-1
 - J.2 Geology, Hydrology, Identification of the Perched Zone, Groundwater Flow Direction, and Rate J-9
 - J.2.1 Area Description J-9
 - J.2.2 Site Geology..... J-10
 - J.2.3 Site Hydrology J-13
 - J.2.3.1 Surface Water. J-13
 - J.2.3.2 Perched Water below INTEC. J-14
 - J.2.3.3 Perched Water in Surficial Alluvium. J-16
 - J.2.3.4 Northern Upper Perched Water. J-16
 - J.2.3.5 Southern Upper Perched Water. J-17
 - J.2.3.6 Hydraulic Conductivities in the Upper Perched Zones J-19
 - J.2.3.7 Lower Perched Water Zone. J-19
 - J.2.3.8 Lower Perched Water Contamination. J-21
 - J.2.4 Snake River Plain Aquifer J-22
 - J.2.4.1 Hydraulic Conductivity in the SRPA. J-24
 - J.2.4.2 Hydraulic Conductivity of the SRPA in the Vicinity of the INTEC J-24
 - J.2.4.3 Contamination in the SRPA. J-25
 - J.2.4.4 Local Flow Velocity in the SRPA. J-26
 - J.2.4.5 Groundwater Pumping Effects on the SRPA..... J-26
 - J.3 Topographic Map Showing Groundwater Monitoring Wells J-27
 - J.4 Description of any Plume Contaminants from a Regulated Unit J-28
 - J.5 Proposed Groundwater Monitoring System J-28
 - J.5.1 Perched Groundwater Monitoring Wells J-29
 - J.5.2 Sampling and Analysis Procedures J-31
 - J.5.2.1 Groundwater Elevations. J-31
 - J.5.2.2 Perched Groundwater Purging..... J-32
 - J.5.2.3 Perched Groundwater Sample Collection..... J-33

J.5.2.4 QA/QC Samples.....J-33

J.5.2.5 Sample Preservation.....J-34

J.5.2.6 Chain-of-Custody Procedures.....J-34

J.5.2.7 Transportation of Samples.....J-35

J.5.2.8 Custody Seals.....J-35

J.5.2.9 On-Site and Off-Site Shipping.....J-36

J.5.2.10 Sample Identification Code.....J-36

J.5.2.11 Sample Designation.....J-36

J.6 Quality Criteria for Measurement Data.....J-37

J.6.1 Evaluation of Initial Characterization Data.....J-37

J.6.2 Quality Assurance/Quality Control.....J-38

J.7 Establishment of a Detection Monitoring Program.....J-40

J.7.1 Detection Monitoring Indicator Parameters.....J-40

J.7.2 Background Values for Detection Monitoring Parameters.....J-42

FIGURES

Figure J-1. Perched water wells at and around the WCF at the INTEC.....J-2

Figure J-2. SRPA wells at and around the INTEC.....J-3

Figure J-3. Results of sampling for HWMA/RCRA-listed constituents in the SRPA monitoring wells from 1987 to 1990.....J-6

Figure J-4. Results of sampling for HWMA/RCRA-listed constituents in the SRPA monitoring wells from 1991 to 1995.....J-7

Figure J-5. Results of sampling for HWMA/RCRA-listed constituents in the SRPA monitoring wells from 1995 to 1999.....J-8

Figure J-6. North to south cross section through INTEC subsurface, illustrating the perched water bodies, lithologies, and water table of the SRPA.....J-12

TABLES

Table J-1. 2001 Unfiltered sample results from monitoring wellsJ-4

Table J-2. 2002 Filtered samples results from monitoring wells.....J-5

Table J-3. Summary of perched groundwater monitoring wellsJ-32

Table J-4. The QA/QC samples for perched groundwater sampling.....J-35

Table J-5. EPA hazardous waste numbers associated with the WCF.....J-41

APPENDICES

Appendix J-1. Statistical Analysis of Perched Groundwater Monitoring Data for the Waste Calcining Facility, (RPT-1013, Rev. 3 – August 2010)

J. ADDITIONAL INFORMATION

IDAPA 58.01.05.012 [40 CFR 270.14(c)]

J.1 Summary of Groundwater Monitoring Data Collected Under Interim Status IDAPA 58.01.05.012 [40 CFR 270.14 (c)(1)]

1 Groundwater monitoring data were not collected under the provisions of IDAPA 58.01.05.009
2 (40 CFR 265 Subpart F) during the interim status period. However, groundwater samples were
3 collected from the perched and SRPA groundwater monitoring wells as part of other investigations
4 and well installation projects. During the 1993 to 1994 WAG 3 perched water investigation, samples
5 were collected from the perched groundwater wells and analyzed for organic contaminants. In 1995,
6 under the continuing WAG 3 investigation, the perched and SRPA groundwater monitoring wells
7 were sampled and analyzed for field parameters, inorganics, and radionuclides. Between 1951 and
8 1998, the USGS sampled numerous SRPA groundwater monitoring wells and analyzed the samples
9 for a variety of organic and inorganic constituents. The locations of the WCF and CPP-601/627/640
10 perched groundwater monitoring wells at and around the INTEC are shown in Figure J-1. The
11 locations of the SRPA wells at and around the WCF at the INTEC are shown in Figure J-2. A well
12 construction summary of the WCF and CPP-601/627/640 perched groundwater monitoring wells is
13 shown in the Permit, Module III, Tables 2 and 2a.

14 Eighteen perched groundwater wells were sampled during the 1993 to 1994 WAG 3
15 investigation. Each sample was analyzed for 35 organic contaminants. Of the 630 reported analytical
16 results (excluding trip blanks), 36 contaminants were reported as detected. However, the analytical
17 data is of unknown quality. Nearly all detections were qualified below the contract laboratory
18 quantification limit, contamination was detected in trip blanks, contaminants were not detected in
19 duplicates with detected contamination, and contaminants were detected in quality control samples.
20 Complicating matters, the original data packages are not available for data validation.

21 In 1995, under the continuing WAG 3 investigation, the perched groundwater monitoring wells
22 were sampled and analyzed for field parameters, inorganics, and radionuclides. HWMA/RCRA
23 inorganics above the toxicity characteristic leaching procedure levels were not detected in the perched
24 groundwater samples taken below the INTEC.

25 Between 1951 and 1998, the USGS sampled numerous SRPA monitoring wells. The samples
26 were analyzed for field parameters, inorganics, a variety of organic constituents, and radionuclides. A
27 visual representation of the 1987 through 1998 organic analyses is shown in Figure J-3, Figure J-4,
28 and Figure J-5. As indicated through the analytical results and figures, HWMA/RCRA inorganics
29 above the toxicity characteristic leaching procedure levels, organic, and characteristic contaminants
30 were not detected in the SRPA groundwater samples below the INTEC facility boundaries.

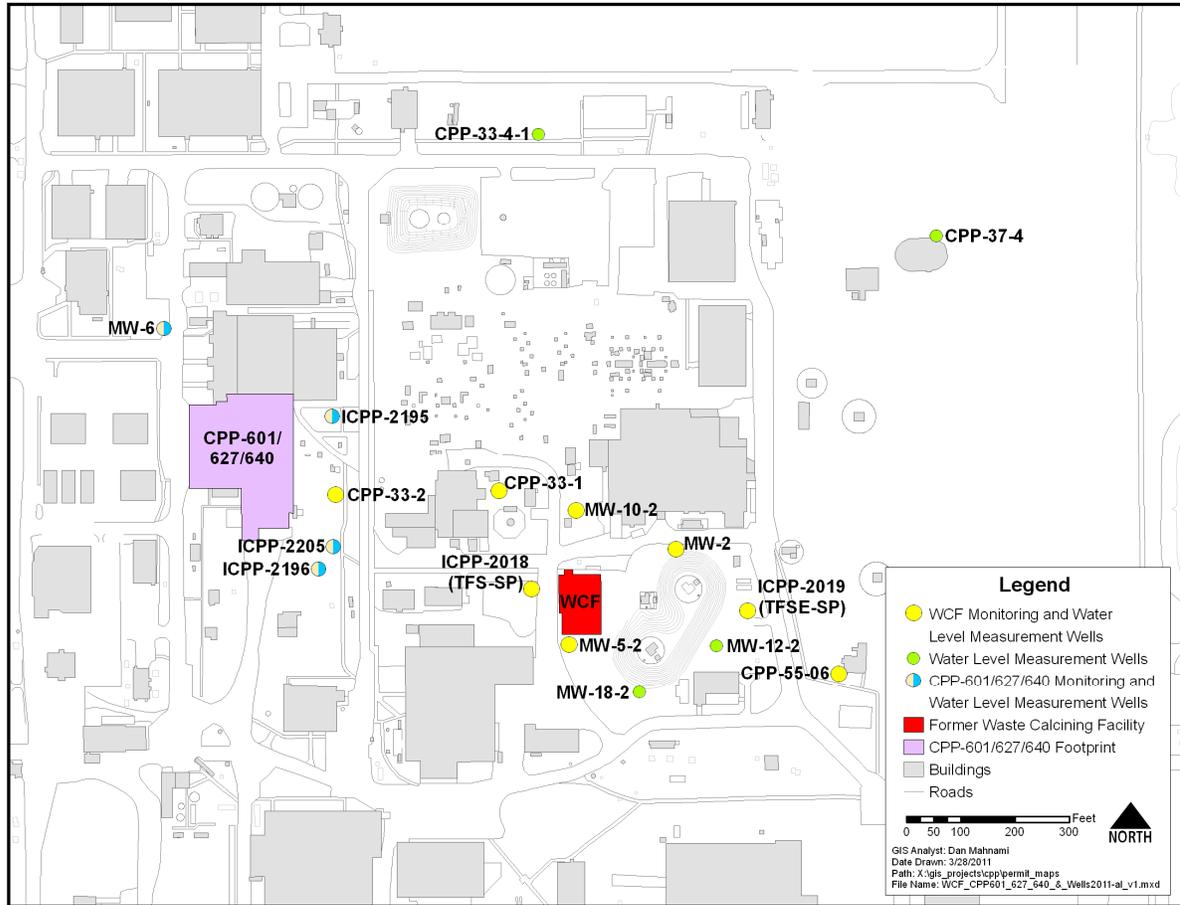


Figure J-1. Perched water wells at and around the WCF and CPP-601/627/640 at the INTEC.

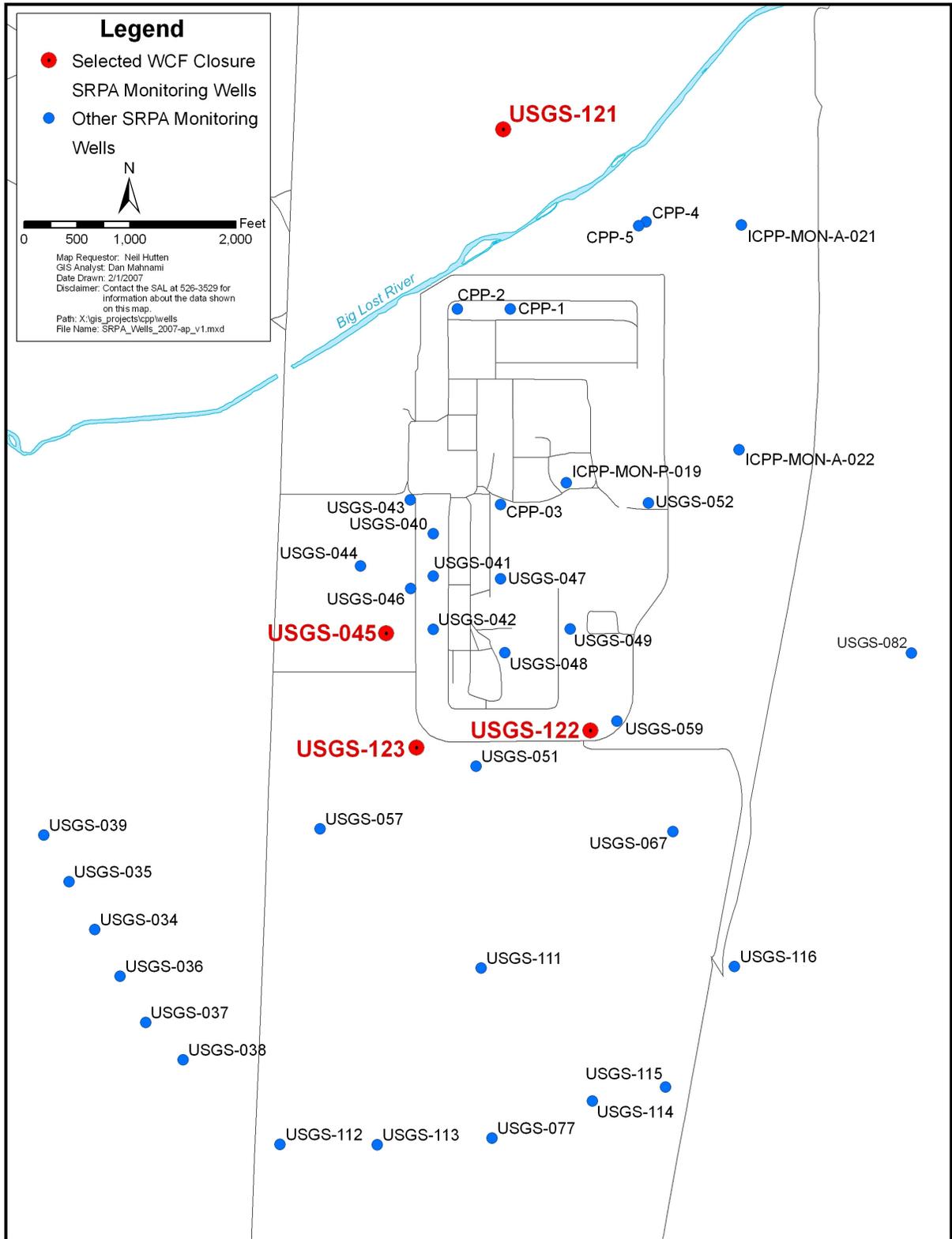


Figure J-2. SRPA wells at and around the INTEC.

1 In 2001, samples were taken from perched groundwater wells MW-2, MW-5, MW-20, and
 2 other wells that are outside the scope of this permit application. The wells were sampled by bailing
 3 due to the low water level of the wells. When bailing, the sediment is suspended in the water that is
 4 being sampled. The samples were not filtered. Since the samples were not filtered the analysis
 5 results included the constituents associated with the sediment not just the water. The analytical
 6 results are given in Table J-1.

7
 8 The following wells were not sampled; therefore, no data is available.

- 9 • CPP-55-06
- 10 • INTEC-MON-P-019

Table J-1. 2001 Unfiltered sample results from monitoring wells.

Analytes	INTEC-MON-P-002 (MW-2)	INTEC-MON-P-005 (MW-5)	INTEC-MON-P-020 (MW-20)	USGS-050
Arsenic µg/L	16.7	5.0/U	6.1/B	5.0/U
Barium µg/L	295	195/B	357	171/B
Cadmium µg/L	5.0/U	5.0/U	5.0/U	5.0/U
Chromium µg/L	2520	11.3	37.6	11.8
Lead µg/L	14,700	3.0U	7.2	3.0/U
Mercury µg/L	0.04	0.31	.20/U	.20/U
Selenium µg/L	5.0/U	5.0/U	5.0/U	5.0/U
Silver µg/L	5.0/U	5.0/U	5.0/U	5.0/U
Toluene µg/L	5.0U	2.0/J	5.0U	5.0U
Tetrachloroethene µg/L	5.0U	5.0U	2.0J	5.0U

B – Analyte Blank Concentration (laboratory or calibration) \geq 20% of sample concentration prior to dilution correction.

J – Indicates an estimated value.

U – Analyte was not detected.

11 In March 2002, wells MW-2, MW-5, and MW-20 were resampled for constituents of concern
 12 based on previous sampling/analytical results. The analytical results are presented in Table J-2.

13
 14 The wells were sampled by bailing due to the low water level of the wells. Once the samples
 15 were collected, they were filtered in the field to eliminate the sediment that becomes suspended in the
 16 water as a result of the sampling method used. If the samples were not filtered, the analysis results
 17 would include the constituents associated with the sediment not just the water. Therefore, filtering
 18 allowed the analysis of just the water.

Table J-2. 2002 Filtered sample results from monitoring wells.

Analytes	INTEC-MON-P-002 (MW-2)	INTEC-MON-P-005 (MW-5)	INTEC-MON-P-020 (MW-20)
Arsenic µg/L	2.6/B	No Data	No Data
Cadmium µg/L	0.60/U	No Data	No Data
Chromium µg/L	115	No Data	No Data
Lead µg/L	2.8/U	No Data	No Data
Toluene µg/L	No Data	5.0/U	5.0/U
Tetrachloroethene µg/L	No Data	5.0/U	3.0/J

B – Analyte Blank Concentration (laboratory or calibration) \geq 20% of sample concentration prior to dilution correction.

J – Indicates an estimated value.

U – Analyte was not detected.

Analysis was not performed for the constituents listed as “No Data”

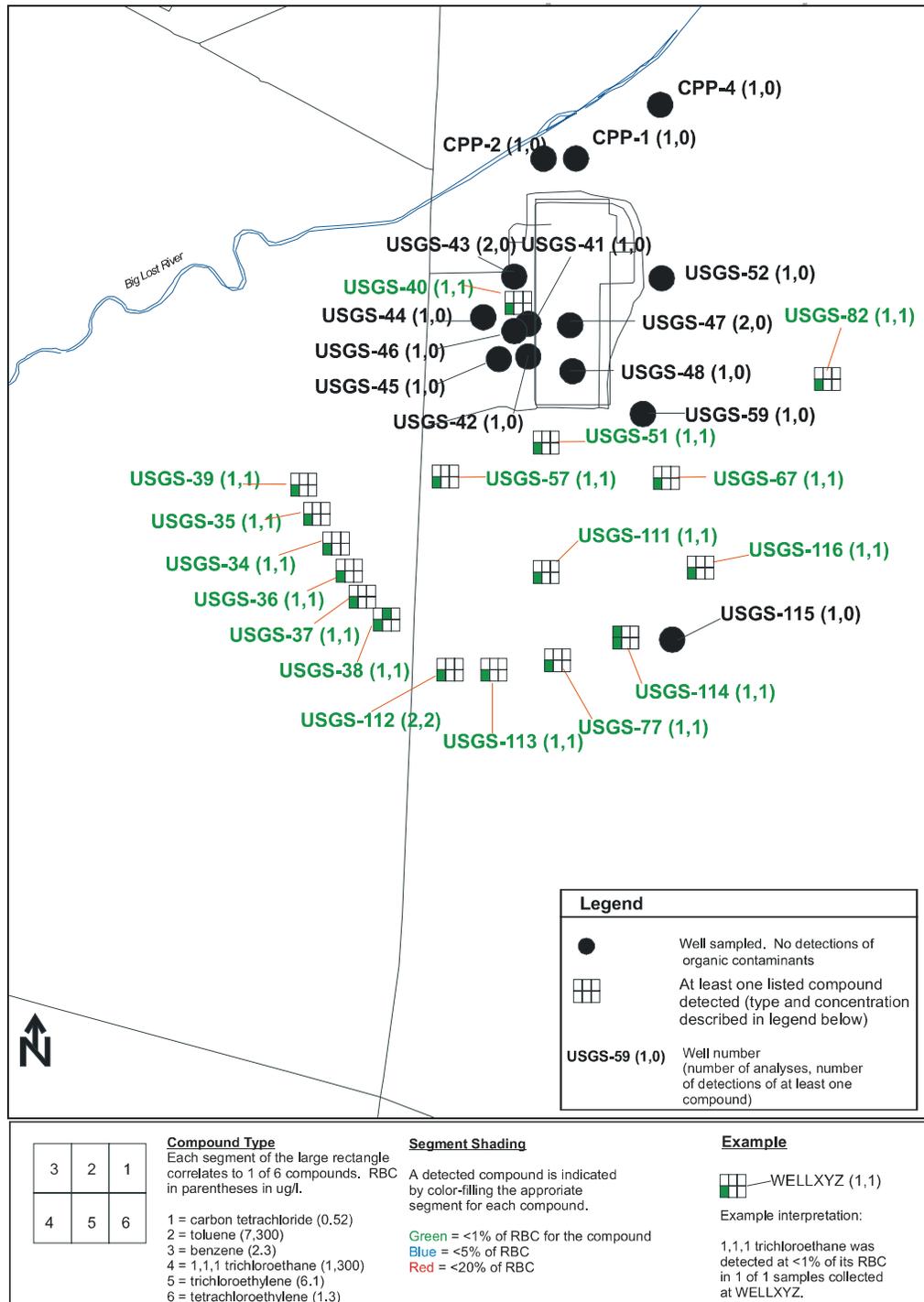


Figure J-3. Results of sampling for HWMA/RCRA-listed constituents in the SRPA monitoring wells from 1987 to 1990.

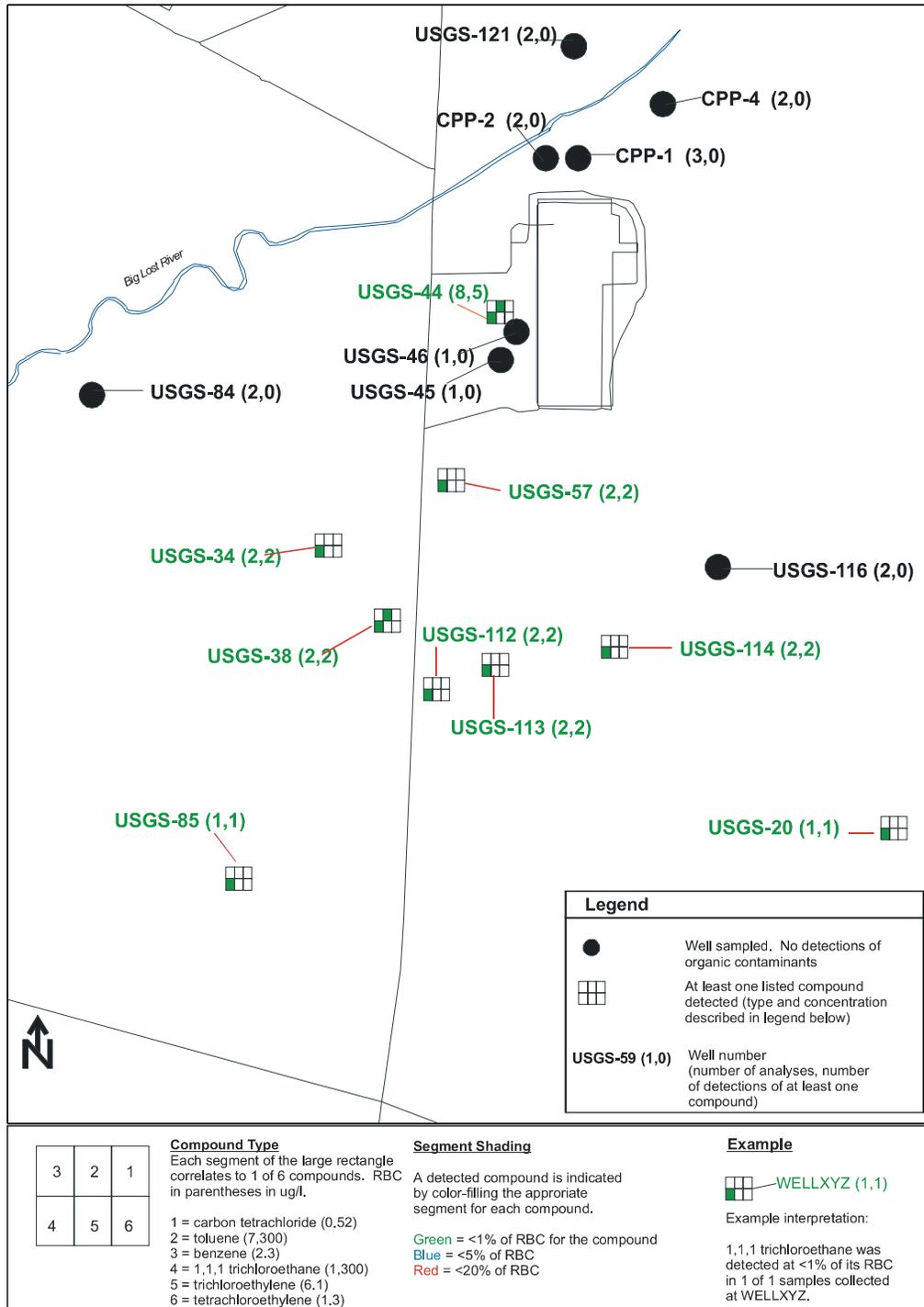


Figure J-4. Results of sampling for HWMA/RCRA-listed constituents in the SRPA monitoring wells from 1991 to 1995.

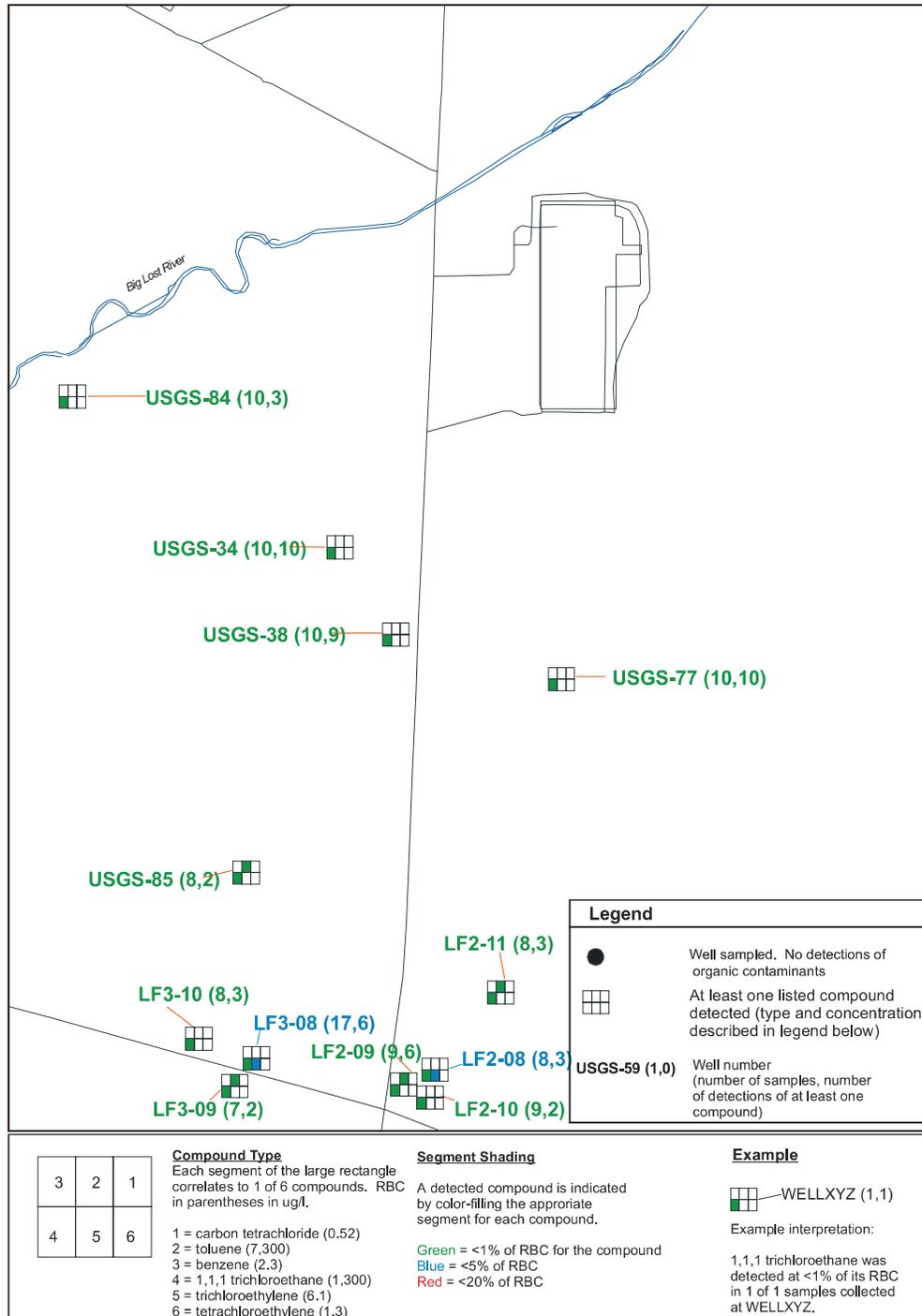


Figure J-5. Results of sampling for HWMA/RCRA-listed constituents in the SRPA monitoring wells from 1995 to 1999.

J.2 Geology, Hydrology, Identification of the Perched Zone, Groundwater Flow Direction, and Rate IDAPA 58.01.05.012 [40 CFR 270.14(c)(2)]

J.2.1 Area Description

1 The INL is located in the Mud Lake–Lost River Basin (also known as the Pioneer Basin.) This
2 closed drainage basin includes three main streams: the Big and Little Lost Rivers and Birch Creek.
3 These three streams drain the mountain areas to the north and west of the INL, although most flow is
4 diverted before it reaches the INL boundaries. Flow that reaches the INL infiltrates the ground surface
5 along the length of the stream beds, in the spreading areas at the southern end of the INL, and, if the
6 stream flow is sufficient, in the ponding areas (playas or sinks) in the northern portion of the INL.
7 During dry years, there is little to no surface water flow on the INL. Because the Mud Lake–Lost
8 River Basin is a closed drainage basin, water either infiltrates the ground surface to recharge the
9 aquifer or is lost to evapotranspiration.

10 The Big Lost River flows southeast from Mackay Dam, past Arco, and onto the ESRP. Near
11 the southwestern boundary of the INL, a diversion dam prevents flooding of downstream areas during
12 periods of heavy runoff by diverting water to a series of natural depressions or spreading areas (DOE
13 1995). During periods of high flow or low irrigation demand, the Big Lost River continues
14 northeastward past the diversion dam, passes within 200 ft (61 m) of the INTEC, and ends in a series
15 of playas 15 to 20 mi (24 to 32 km) northeast of the INTEC, where water infiltrates the ground
16 surface. Flow from Birch Creek and the Little Lost River infrequently reaches the INL, as this water
17 is diverted for irrigation upstream of the INL in the summer months. During periods of unusually
18 high precipitation or rapid snow melt, water from Birch Creek and the Little Lost River may enter
19 INL from the northwest and infiltrate the ground. As with much of the Big Lost River on the INL, the
20 channel is typically dry at the INTEC; however, it should be noted that the Big Lost River flowed
21 during most of 1997 and 1998.

22 The principal surface materials at the INL are basalt, alluvium, lake bed or lacustrine
23 sediments, slope wash sediments, talus, silicic volcanic rocks, and sedimentary rocks. The INTEC is
24 located on an alluvial plain approximately 200 ft (61 m) from the Big Lost River channel near the
25 point the channel intersects with Lincoln Boulevard on the INL. The INTEC is surrounded by a storm
26 water drainage ditch system (DOE-ID 1998). Storm-water runoff from most areas of INTEC flows
27 through ditches to an abandoned gravel pit on the northeast side of the INTEC. From the gravel pit,
28 the runoff infiltrates the ground. The system is designed to handle a 25-yr, 24-hr storm event. Because

1 the land is relatively flat (slopes of generally less than 1%) and annual precipitation is low, storm
2 water runoff volumes are small and are generally spread over large areas where they evaporate or
3 infiltrate the ground surface.

J.2.2 Site Geology

4 The INL is located on the west-central part of the ESRP, a northeast-trending structural basin
5 about 220 mi (322 km) long and 50 to 70 mi (80.5 to 113 km) wide. The INL is underlain by a
6 sequence of Tertiary and Quaternary volcanic rocks and sedimentary interbeds that are more than
7 10,000 ft (3,050 m) thick (Whitehead 1992). The volcanic rocks consist mainly of basalt flows in the
8 upper part of the sequence and rhyolitic ash-flow tuffs in the lower part.

9 Hundreds of basalt flows¹, basalt-flow groups, and sedimentary interbeds underlie the INL.
10 Basalt makes up about 85% of the volume of deposits in most areas. A basalt flow group consists of
11 one or more distinct basalt flows deposited during a single, brief eruptive event. All basalt flows of a
12 group erupted from the same vent or several nearby vents; represent the accumulation of one or more
13 lava fields from the same magma; and have similar geologic ages, paleomagnetic properties,
14 potassium contents, and natural-gamma emissions (Anderson and Bartolomy 1995). The basalt flows
15 consist mainly of medium- to dark-gray vesicular to dense olivine basalt. Individual flows generally
16 range from 10 to 50 ft (3 to 15 m) thick and are locally interbedded with scoria and thin layers of
17 sediment. Sedimentary interbeds are as thick as 50 ft (15 m) and consist of well to poorly sorted
18 deposits of clay, silt, sand, and gravel. In places, the interbeds consist mainly of scoria and basalt
19 rubble. Sedimentary interbeds accumulated on the land surface for hundreds to several hundred-
20 thousand years during periods of volcanic quiescence and are thickest between basalt-flow groups.

21 At least 178 basalt-flow groups and 103 sedimentary interbeds underlie the INL above the
22 effective base of the aquifer (Anderson et al. 1996, 1997). Basalt-flow groups and sedimentary
23 interbeds are informally referred to as A through S5. Basalt-flow groups LM through L and related
24 sediments range in age from about 200,000 to 800,000 years and make up the unsaturated zone and
25 the uppermost areas of the INL. Most wells in the southern and eastern part of the INL are completed
26 in basalt-flow groups AB through I and related sediments. These flow groups and related sediments
27 range in age from about 200,000 to 640,000 years and make up a stratigraphic section characterized
28 by horizontal to slightly inclined layers. Anderson et al (1997) estimated the geologic ages and
29 accumulation rates of basalts and sediments in the unsaturated zone and the SRPA from about

¹ A basalt flow is a solidified body of rock formed by the surficial outpouring of molten lava from a vent or fissure (Bates and Jackson 1980).

1 200,000 to 1.8 M·yr and average accumulation rates are reflective of the subsidence rate of 164 ft (50
2 m)/100,000 years.

3 The nomenclature for the stratigraphy underlying the INTEC facility and the surrounding area
4 is based on work presented by Anderson (1991). At land surface, as much as 60 ft (18.2 m) of
5 surficial alluvium is composed of gravelly, medium- to coarse-grained sediment. This alluvial
6 material overlies a series of basalt/sediment units where the basalt is very transmissive, and the
7 sediment units are relatively thin, much less transmissive, and laterally discontinuous as shown in
8 Figure J-6. The stratigraphy of the aquifer at and near the INTEC is dominated by thick, massive,
9 basalt flows of Flow Group I and thin, overlying flows of Flow Groups B through H. The basalt
10 flows, as interpreted, appear to be relatively uniform in thickness beneath the INTEC.

11 Significant changes in the flow thickness are often related to changes in the lithology of the
12 flow or are caused by the flow margins in which the flow appears as a lobe of basalt. The lithologic
13 changes that may cause a change in the flow thickness are either the existence of pyroclastic deposits
14 on or within a flow or a flow being very vesicular, and thus, more susceptible to the effects of
15 erosion. Based on Anderson (1991) geologic cross section, there are 19 basalt flow groups, 11
16 sedimentary interbeds, and the surficial alluvium that make up the unsaturated zone and upper aquifer
17 underlying the INTEC facility. The sediments, as interpreted, appear to be primarily made up of sands
18 and silts with some small clay lenses. The majority of the sediments are 1 to 5-ft (thick) (0.3 to 1.5-m)
19 layers of silt between the major basalt flows. Sediments were most likely deposited in eolian or
20 fluvial type environment. Two major sediment sequences are shown on the cross sections: the upper
21 sequence associated with the CD, the thick D, and DE2 sands and silts and the lower sediments
22 associated with the DE6, DE7, and DE8 stratigraphic units.

23 The cross sections show a thick sequence of sediments, particularly in the northern end of the
24 south-north section, which are stratigraphically shown as the CD, D, and DE2 units. These sediments
25 appear to be made up of thick layers of sands overlain by silts and clays. The sediments associated
26 with the DE6, DE7, and DE8 stratigraphic units appear to be made up of gravels, silts, and clays.
27 These sediments were most likely deposited in a fluvial environment and may indicate a braided
28 stream deposit. This is the last major sediment deposit above the SRPA.

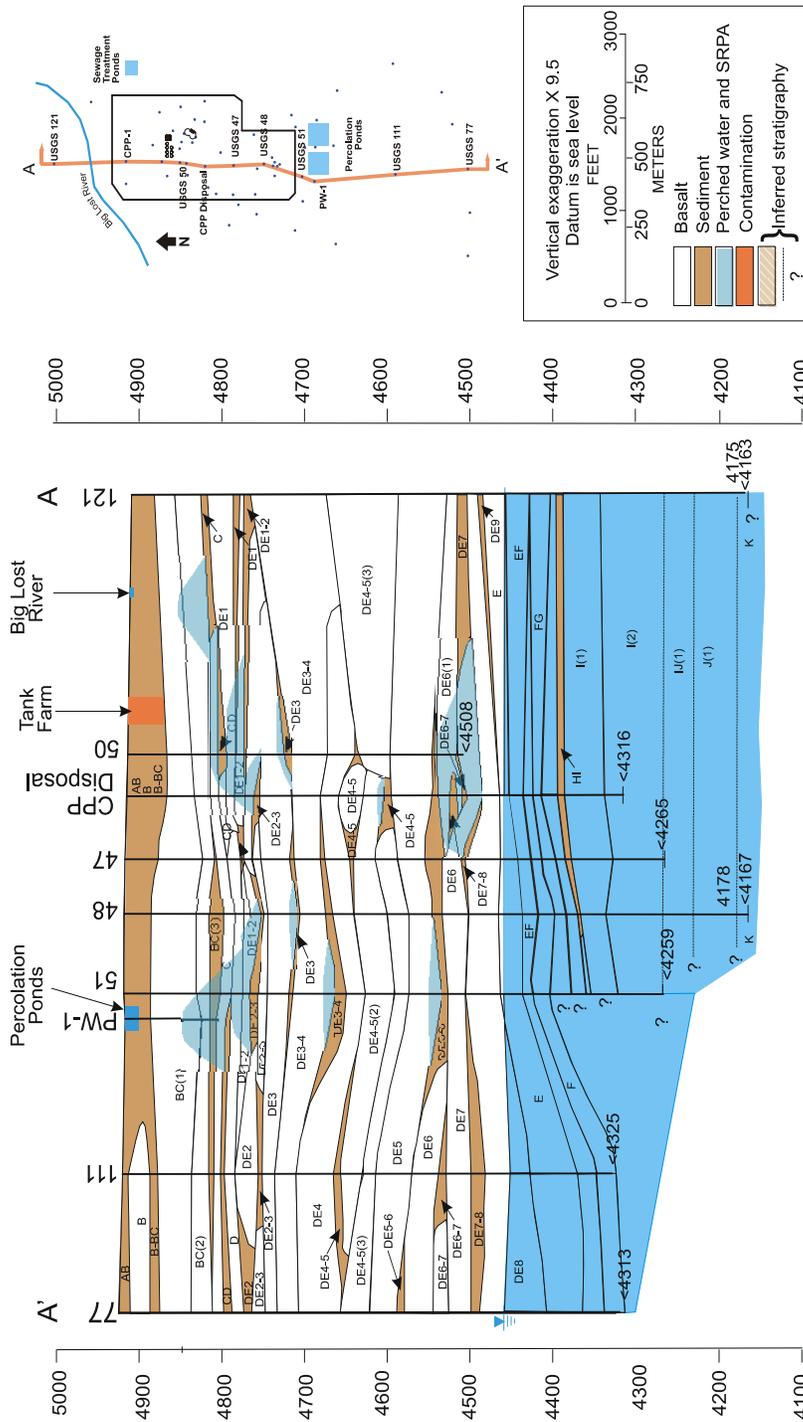


Figure J-6. North to south cross section through INTEC subsurface, illustrating the perched water bodies, lithologies, and water table of the SRPA.

1 Holocene surficial geology and archaeology suggest that fluvial and eolian deposition and
2 tectonic subsidence in the INL area have been in approximate net balance for at least the past 10,000
3 years. A reversal of the long-term, regional pattern of ESRP subsidence, sedimentation, and
4 volcanism into an erosional rather than a depositional regime would require major changes from the
5 Holocene tectonic or climatic configuration of the ESRP. Worldwide geologic evidence indicates that
6 the Quaternary epoch (approximately the past 2 M yr) has been a time of major climatic fluctuations.
7 During colder and wetter periods, glaciers occupied high-elevation areas, and lowland areas such as
8 the ESRP, received thick, widespread loess blankets. Lowland areas were also periodically impacted
9 by local catastrophes such as the large, late-Pleistocene, glacial outburst flood that traveled down the
10 Big Lost River valley, eroded upland surfaces on the ESRP, and deposited sediment in the INTEC
11 area. Additional geologic characterization of the INTEC is provided in Attachment 3 of this permit.

J.2.3 Site Hydrology

J.2.3.1 Surface Water.

12 Most of the INL and all of the INTEC is located in the Pioneer Basin, which is a closed
13 topographic depression on the ESRP that receives intermittent runoff from the Big Lost River, Little
14 Lost River, and Birch Creek Drainage. The Pioneer Basin is not crossed by any perennial streams
15 because of the permeability of alluvium and underlying rock that causes the water to infiltrate the
16 ground. In addition, much of the water from the tributary drainage basins is diverted for irrigation
17 upstream of the INL. The largest stream, the Big Lost River, enters the INL near the southern end
18 from the west and, during exceptionally wet years, flows in a large arc north to the foot of the Lemhi
19 Mountain Range where it ends in a series of playas (sinks). Birch Creek enters INL from the north
20 and the Little Lost River approaches the INL from the northwest, through Howe. As indicated in
21 Subsection J.2.1, flow from these streams infrequently reaches the INL.

22 The Big Lost River is the most important natural element affecting the surface water hydrology
23 of the INL and INTEC. The Big Lost River discharges an average of 211,000 acre-ft/yr
24 ($260.2E+06 \text{ m}^3/\text{y}$) below Mackay Dam, 30 mi (48 km) northwest of Arco. The largest recorded
25 annual flow of the Big Lost River for the entire period of record occurred in 1984 and amounted to
26 476,000 acre-ft/yr ($587.1E+06 \text{ m}^3/\text{yr}$), which was measured below Mackay Dam. The second largest
27 annual flow occurred in 1965 and amounted to roughly three-quarters of the 1984 record.

28 Except for evapotranspiration, most of the water in the Big Lost River, Little Lost River, and
29 Birch Creek is recharged to the ground through irrigation or infiltration. Water from the Big Lost
30 River infiltrates into the material beneath the river and into the SRPA. The volume of this infiltration

1 is significant during wet years. However, the historical record indicated that there are several years in
2 which no flow occurs in the Big Lost River near the INTEC facility. During these years, recharge to
3 the perched zones and ultimately the SRPA is negligible and results in significant changes in the
4 thickness and extent of the perched water zones. Perched water zones have been identified along the
5 Big Lost River when it contains water; however, the extent and volume of these perched water zones
6 is not completely known.

7 Other than these intermittent streams, playas, and the manmade percolation, infiltration, and
8 evaporation ponds, there is little surface water at the INL site. Surface water that reaches the INL is
9 not used for consumptive purposes (e.g., irrigation, manufacturing, or drinking). The Bureau of Land
10 Management has a small water right on INL for stock watering.

J.2.3.2 Perched Water below INTEC.

11 Stratigraphy controls the hydrogeologic characteristics of the subsurface at the INTEC,
12 particularly in the formation and movement of perched groundwater. The formation of perched
13 groundwater may be attributed to lithologic features contributing to contrasts in the vertical hydraulic
14 conductivity of basalt layers and sedimentary interbeds in the unsaturated zone. Cecil et al. (1991)
15 attributed four lithologic features to the formation of perched groundwater at the INTEC. Perched
16 groundwater can form in an area, for example, where (a) there is sedimentary interbed with a reduced
17 vertical hydraulic conductivity underlying a more conductive basalt layer, (b) there are altered baked
18 zones between two basalt flows that reduce hydraulic conductivity, (c) there is a presence of dense
19 unfractured basalt that has low vertical hydraulic conductivity, and (d) where sedimentary and
20 chemical filling of fractures near the upper contact of a basalt flow reduced vertical hydraulic
21 conductivity.

22 Several sources of water contribute to moisture movement and the development of perched
23 water in the INTEC subsurface (DOE-ID 2000a). The two major recharge sources are the historic
24 percolation ponds and the Big Lost River. Historic Service waste percolation pond (SWP-1) was
25 412 by 480 ft and 16 ft deep (126 by 146 m and 4.8 m deep). The pit was excavated in gravelly alluvium
26 that is approximately 20 to 35 ft thick and underlain with basalt rock. The pond was designed to
27 accommodate continuous disposal of 1.5 M·gal (5.7 M·L) of water each day based on 10 gal/day/ft²
28 of area. Service waste percolation pond (SWP-2) was located immediately to the west of SWP-1. It
29 was 498 ft² and 12 to 14 ft deep (46 m² by 3.6 to 4.3 m deep). The pit was excavated in gravelly
30 alluvium, 20 to 35 ft thick and underlain with basalt rock. The pond was designed to accommodate

1 continuous disposal of 3 M·gal (11 M·L) of water each day based on the observed percolation pond
2 rates of SWP-1. Both ponds are fenced to exclude large wildlife. An average of 1.16 M·gal (4.39
3 M·L) of wastewater was discharged to the historic percolation ponds each day. Prior to August 26,
4 2006, this wastewater was discharged to the Old (existing) Percolation Ponds Numbers 1 or 2, located
5 directly south of the INTEC. On August 26, 2002, discharge of the service wastewater to the existing
6 Percolation Ponds ceased and was transferred to the New Percolation Ponds (CPP-1791), located
7 approximately two miles to the southwest of the INTEC.

8 Depending on the depth of the snowpack and volume of precipitation that occurs in a particular
9 year, the Big Lost River may flow all year or cease to flow entirely for several months or years. The
10 mean annual flow in the Big Lost River at a point near the INTEC site is 34,429 acre·ft/mo
11 (42,467,544 m³/mo). Together, these two sources are thought to supply over 98% of the recharge. The
12 wastewater treatment lagoons operational activities, and precipitation account for the remaining
13 recharge. Average annual discharge to the wastewater treatment lagoons is 13.9 M·gal/yr (52.6
14 M·L/yr). Operational losses are variable and not well quantified. The mean annual precipitation at the
15 INL is approximately 8.5 in./yr (21.5 cm/yr). Usually, less than one-half of this amount occurs as
16 snowfall. The collection of precipitation in local basins can supply substantial amounts of focused
17 infiltration (DOE-ID 2000a).

18 Water movement in the basalt units located in the unsaturated zone is poorly understood. These
19 perched water bodies are significant because they increase the opportunity for contaminants to move
20 both laterally and vertically in the vadose zone. This lateral water and contaminant movement in the
21 vadose zone results in vertical migration rates that are spatially nonuniform beneath the INTEC.
22 Infiltration from the surface is assumed to move vertically through the basalt to an interbed. The
23 water and contaminants migrate along the interbed and accumulate at interbed low points because the
24 interbeds are sloped. This results in greater than average vertical water and contaminant fluxes in
25 water accumulation areas and less than average vertical water and contaminant fluxes in the elevated
26 portions of the interbed. The extent to which water moves horizontally while vertically transiting the
27 fractured basalts is uncertain. Water has been shown to move laterally several miles in the subsurface
28 when sufficient water was available to support long lateral spread. Eventually, water infiltrating at the
29 surface of the INTEC will reach the underlying SRPA. Additional information on perched water
30 below the INTEC is provided in Attachment 3 of this permit.

J.2.3.3 Perched Water in Surficial Alluvium.

1 In places with a concentrated source of surface recharge, a perched water zone can develop in
2 the surficial alluvium on top of the first basalt flow. Perched water has been identified in the alluvium
3 at the INTEC beneath surface disposal ponds (the historic Percolation Ponds and the sewage
4 treatment pond). Historically, a small perched water table in alluvium was encountered west of CPP-
5 603. The source for the perched water was assumed to be wastewater that was discharged to a shallow
6 seepage pit (Robertson et al. 1974). The seepage pit was taken out of service in 1966 and it was
7 assumed that the water body dissipated.

8 Perched water in the surficial alluvium requires a concentrated source of recharge that exceeds
9 the normal recharge provided by precipitation. Perched water has not been widely measured at the
10 sediment-basalt interface.

J.2.3.4 Northern Upper Perched Water.

11 Two perched groundwater bodies have been identified in the northern INTEC. The upper
12 perched groundwater body (also divided into upper shallow and lower shallow) is present above the
13 CD and D interbeds, respectively, and the lower perched groundwater body has been identified on the
14 DE3 interbed. According to the lithology, the CD interbed occurs at depths between 113 and 119 ft
15 (34 and 36 m) BGL, the D interbed occurs at depths between 128 and 135 ft (39 and 41m) BGL, and
16 the DE3 interbed occurs at depths between 163 and 170 ft (50 and 52m) BGL. Based on available
17 information, it appears that the perched groundwater between the CD and D interbeds is continuous
18 over much of the northern portion of the INTEC as these interbeds are only separated by 9 ft (3 m).

19 Water-level elevations range from 4,797.3 to 4,845.3 ft (1,462.2 to 1,476.8 m) above mean sea
20 level (AMSL) and represent the average water-table level throughout the monitoring period. Perched
21 groundwater is not known to occur above the CD and D interbeds outside the areas illustrated on
22 Figure J-6. The perched water bodies overlap (i.e., in the vicinity of Wells CPP-33-4-1, CPP-33-4-2,
23 CPP-33-1, and MW-5), the entire region between the CD and D interbeds is likely to be saturated.
24 Otherwise, perched groundwater is only present above the associated interbed.

25 Based on the water-table configuration, it appears that multiple water sources are providing
26 recharge to the upper perched water body in the northern portion of the INTEC. These sources may
27 include recharge from the Big Lost River, the wastewater treatment lagoons, and operational releases.
28 The wastewater treatment lagoons, located northeast of the facility, provide approximately 1.25E+6

1 gal (4.73E+6 L) per month of recharge to the eastern side of this perched water body. This recharge
2 has resulted in a water-table elevation of approximately 4,845 ft (1,477 m) AMSL in the well
3 (ICPP-MON-A-022) completed near the sewage treatment ponds. In the western portion of the
4 perched water body and beneath the main portion of the facility, recharge from an unknown source
5 has produced a water-table elevation of 4,815.2 ft (1,467.7 m) AMSL in Well CPP-33-2. Between the
6 eastern and western portions of the upper perched water body, the groundwater elevation is 4,808.8 ft
7 (1,465.7 m) AMSL in Well CPP-37-4. This water-table configuration indicates that separate sources
8 of water are providing recharge to the eastern and western portions of the perched water body and that
9 the sewage treatment ponds have minimal, if any, impact upon the western portion of this perched
10 water body. Fluctuations in water levels in the upper perched water zone that are observed in response
11 to flow in the river indicate a connection between the northern upper perched water and the river
12 (DOE-ID 2000a).

13 **J.2.3.4.1 Contamination in the Northern Upper Perched Zone**—The highest
14 perched water radioactive contamination occurs beneath the northern portion of the INTEC and is
15 particularly associated with Wells MW-2, MW-5, and CPP 55-06 (see Figure J-1). The maximum
16 gross alpha and gross beta activities measured in the upper perched groundwater were $1,140 \pm$
17 220 pCi/L and $589,000 \pm 2,600$ pCi/L, respectively, in Well MW-2. At a depth of approximately 140
18 ft (42 m), the maximum gross alpha and gross beta concentrations measured in the perched water
19 were 137 ± 9 pCi/L and $65,300 \pm 600$ pCi/L in Wells MW-10 and MW-20. These two wells are
20 completed in water-bearing zones at depths of approximately 140 ft (42 m). Again, only radioactive
21 contamination has been detected in the lower water bearing zones. The maximum concentrations for
22 ^3H , ^{90}Sr , and ^{99}Tc from these wells are $38,000 \pm 50$ pCi/L, $25,800 \pm 30$ pCi/L, and 127 ± 2 pCi/L,
23 respectively.

J.2.3.5 Southern Upper Perched Water.

24 Perched water has been identified beneath two areas of the southern portion of the INTEC.
25 The largest perched water body is the result of discharge to the percolation ponds and is monitored by
26 Wells PW-1 through PW-6 (Figure J-1). Six wells (MW-7, MW-9, and MW-13 through MW-16)
27 were installed to monitor perched water on the upper interbed that is present between 110 and 130 ft
28 (33.5 and 39.6 m) BGL. One triple completion well (MW-17) was installed to monitor for perched
29 water on a deeper interbed occurring approximately 190 ft (57.9 m) BGL.

1 Wells PW-1 through PW-6 were installed adjacent to the historic percolation ponds to monitor
2 the perched groundwater beneath the ponds. The hydrographs for these wells show a similar
3 fluctuation in the water level as observed in Wells PW-1, PW-3, and PW-6 indicating these wells are
4 effective in monitoring infiltration from the western percolation ponds. The water-level fluctuation in
5 Well PW-4 is opposite to the response observed in Wells PW-1, PW-3, and PW-6, indicating this
6 well monitors infiltration from the eastern percolation pond. The water-level fluctuations in Wells
7 PW-2 and PW-5 are fairly consistent and indicate that these wells are influenced by discharge to
8 either pond.

9 The water elevations in the southern perched water zone range between 4,732.4 to 4,790.2 ft
10 (1,442.4 to 1,460.0 m) AMSL north of the percolation ponds and between 4,796.2 to 4,848.9 ft
11 (1,461.9 to 1,477.9 m) AMSL near the percolation ponds. Only two upper perched water wells are
12 located between the northern and southern perched water bodies (Wells MW-11 and MW-14) and
13 neither indicates perched water in these areas.

14 **J.2.3.5.1 Contamination in the Southern Upper Perched Zone**—Wells that
15 monitor the perched water quality in the upper southern perched water zone include Wells MW-7,
16 MW-9, MW-13, MW-14, MW-15, MW-16, and MW-17. As previously indicated, there is no
17 verifiable evidence of HWMA/RCRA-regulated contamination below the INTEC in the southern
18 perched water bodies. From the inorganic analysis, only nitrate/nitrite was detected at a concentration
19 exceeding the maximum contaminate level (MCL) at Well MW-15 (14.7 mg/L). The radionuclides
20 detected in the perched water include ^3H ($3,360 \pm 176$ to $25,700 \pm 400$ pCi/L) and ^{99}Tc (6.4 ± 0.6 to
21 23.7 ± 0.6 pCi/L). In addition, ^{90}Sr and ^{234}U were detected in Well MW-15 at concentrations of
22 $17,200 \pm 200$ pCi/L and 11.8 ± 1.0 pCi/L, respectively (DOE-ID 2000a).

23 The six wells (PW-1 through PW-6) that monitor the perched water body associated with
24 wastewater discharge to the percolation ponds have been monitored by the USGS since 1987. Wells
25 PW-1, PW-2, PW-4, and PW-5 have been sampled for radionuclides on a quarterly basis as part of
26 the INTEC groundwater monitoring program since 1991.

27 Most of the historical radioactivity present in the PW-series wells is from ^3H , with ^{90}Sr
28 providing a secondary activity contribution. According to the USGS monitoring, activities from both
29 ^3H and ^{90}Sr have remained relatively stable with the exception of an increased ^3H activity period in
30 mid-1988. Average ^3H concentrations range from $1,334 \pm 421$ to $4,681 \pm 567$ pCi/L with ^{90}Sr
31 concentrations averaging 3.7 ± 3.4 pCi/L (DOE-ID 2000a).

J.2.3.6 Hydraulic Conductivities in the Upper Perched Zones.

1 Field aquifer tests were performed to determine the hydraulic conductivities for both basalt
2 and sedimentary interbeds. Hydraulic conductivities determined in the field were fairly consistent,
3 varying only over two orders of magnitude. Field hydraulic conductivities ranged from $3.9E-5$ to
4 $2.9E-3$ cm/s with an average of $1.2E-3$ cm/s. Significant differences in hydraulic conductivities were
5 not observed between tests performed on the basalt versus tests performed on the sedimentary
6 interbeds (i.e., interbeds CD, D, and DE2). The depths are approximately 110, 140, and 230 ft (33.5,
7 42.7, and 70.1 m) BGL.

8 The range of hydraulic conductivities determined from the field aquifer tests is within the range
9 of hydraulic conductivities measured in the laboratory. The average hydraulic conductivity
10 determined from the field tests is 3.3 ft/d ($1.2E-3$ cm/s) compared to an average of 1.96 ft/d
11 ($6.9E-4$ cm/s) determined from the laboratory tests. Some of the difference between the two hydraulic
12 conductivities may be attributed to the fact that the field tests measured horizontal hydraulic
13 conductivity whereas the laboratory tests measured vertical hydraulic conductivity. Typically,
14 horizontal hydraulic conductivities are greater than the corresponding vertical hydraulic
15 conductivities.

16 Hydraulic conductivities obtained from both field and laboratory measurements of the
17 boreholes were compared. Results showed that, from the same zone in Well MW-4, the average
18 hydraulic conductivity determined in the laboratory was 0.1 ft/day ($3.8E-5$ m/s) compared to the field
19 determined value of 0.11 ft/day ($3.9E-5$ m/s). Similarly in Well MW-6, the hydraulic conductivity
20 determined in the laboratory was 6.2 ft/d ($2.2E-3$ cm/s) compared to the field determined value of
21 3.7 ft/day ($1.3E-3$ cm/s). These two wells are the only locations where both field and laboratory
22 measurements were performed.

J.2.3.7 Lower Perched Water Zone.

23 A lower perched water zone has been identified in the basalt between 320 and 420 ft (98 and
24 128 m) BGL. This zone was first discovered in 1956 when perched groundwater was encountered at a
25 depth of 348 ft (106 m) while drilling Well USGS-40 (Robertson et al. 1974). Since then, perched
26 water has been encountered in this zone during the drilling of Wells MW-1, MW-17, and MW-18
27 (Figure J-1), USGS-41, USGS-43, USGS-44, USGS-50, USGS-52 (Figure J-2). Borehole neutron
28 logs run from Wells USGS-40, USGS-43, USGS-46, USGS-51, and USGS-52 indicate that in 1993
29 perched water may still have been present in this zone.

1 New well sets have been installed to support post-ROD monitoring of the vadose zone. Prior to
2 these installations, only four wells were completed in the lower perched water zone. Wells MW-1,
3 MW-18, and USGS-50 were completed in the northern portion of the facility, and water has been
4 encountered at approximately 322, 407, and 383 ft (98.1, 124, and 117 m) BGL, respectively. In the
5 southern portion of the INTEC facility, only Well MW-17D was completed in the lower perched
6 water zone in which water is encountered at a depth of approximately 364 ft (111 m) BGL.

7 Similar to the upper perched water zone, it is thought that the lower perched water zone is
8 formed by decreased permeability associated with sedimentary interbed layers. It appears that the
9 lower perched water has formed primarily on the DE7 interbed (see Figure J-6). The top of this
10 interbed occurs beneath the INTEC at depths ranging from 383 to 426 ft (101 to 112.5 m) BGL in the
11 western portion of the INTEC facility. However, the DE6 interbed is responsible for creating perched
12 water associated with Wells USGS-40 and USGS-43. The lower perched water zone is not continuous
13 beneath the entire facility and may actually consist of several individual perched water bodies.
14 Recharge to the southern perched water body is from service wastewater discharged to the historic
15 percolation ponds. The source of recharge to the western portion of the northern perched water body
16 is unknown, though the Big Lost River and facility water leaks are likely contributors.

17 Water levels in the lower perched water zone have been monitored since the early 1960s in
18 Well USGS-50. The water level in this well has been fairly consistent, ranging between 4,530 to
19 4,540 ft (1,381 to 1,384 m) AMSL. In the late 1960s and early 1970s, however, the water level
20 increased by approximately 90 ft (27.4 m) in response to failure of the INTEC injection well, CPP-23.
21 During this period, wastewater was discharged directly to the vadose zone from the INTEC injection
22 well at a reported depth of 226 ft (69 m) BGL (Fromm et al. 1994). Measurements made in 1966
23 showed that the well was intact. Therefore, most of the collapse took place in 1967 or early 1968. The
24 period when the INTEC injection well was plugged and discharged directly into the vadose zone has
25 resulted in a thick zone of contamination underlying the INTEC. This zone serves as a possible source
26 of contamination to the lower perched water zone and complicates any interpretation of
27 contamination in the subsurface.

28 In September 1970, a drilling contractor began to redrill and reline the injection well to its
29 original depth. By October, deepening had progressed to about 500 ft (152.4 m) and the water level in
30 the well had resumed its normal depth at about 455 ft (138.7 m). During the well repair, wastewater
31 was disposed to Well USGS-50. The injection well collapsed again and had to be reopened to the
32 water table in late 1982. At this time, a high-density polyethylene liner 10 in. (25.4 cm) in diameter

1 was placed in the well from ground level to the bottom of the well. The liner was perforated from
2 450 ft (137 m) BGL (approximately 8 ft [2.4 m] above the water table) to the bottom of the well. On
3 February 7, 1984, the injection well was taken out of routine service, and wastewater was pumped to
4 the historic Percolation Ponds.

J.2.3.8 Lower Perched Water Contamination.

5 Contamination in the lower portion of the vadose zone is different in composition from the
6 upper perched zone. The lower vadose zone perched water contamination results from the two INTEC
7 injection well (CPP-23) collapses where service wastewater was released into the vadose zone above
8 the lower sediment and the migration of upper perched water toward the SRPA. Lower perched water
9 is monitored at the INTEC by Wells MW-1, MW-17, MW-18, and USGS-50 that are completed in
10 water-bearing zones occurring at depths between 326 to 336 ft (99.4 to 102.4 m), 360 to 381 ft (110
11 to 116 m), 394 to 414 ft (120 to 126 m), and 360 to 405 ft (110 to 123 m), respectively.

12 Historically, two rounds of perched water samples have been collected from Well MW-1, one
13 round of perched water samples has been collected from Wells MW-17 and MW-18, and a substantial
14 database concerning radioactive contaminants is available about the water quality from Well
15 USGS-50. As previously indicated, there is no verifiable evidence of HWMA/RCRA-regulated
16 contamination below the INTEC in the lower perched water bodies. However, radionuclides have
17 been detected. The radionuclides detected in water samples from Well MW-1 include ^{90}Sr ($4.5 \pm$
18 0.4 pCi/L) and ^3H ($24,700 \pm 400$ pCi/L). Of these contaminants, only ^3H was measured above the
19 federal primary MCL of 20,000 pCi/L. As ^3H concentrations in the lower perched water zone are
20 higher than the ^3H concentrations in the overlying perched water bodies, the source of this
21 contamination is either a historical release where the contaminants have moved through the system, or
22 wastewater disposal to the INTEC injection well.

23 Well MW-18 is completed in the deeper perched water zone near the eastern boundary of the
24 INTEC. From sampling conducted during June 1995, only nitrate/nitrite concentration at 34.4 mg/L
25 exceeded either a federal primary or secondary MCL. The radionuclides detected in the lower perched
26 groundwater at this location include ^3H ($73,000 \pm 700$ pCi/L), ^{90}Sr (207 ± 2 pCi/L), and
27 ^{99}Tc ($736 \pm 6\text{J}^2$ pCi/L). The ^3H and ^{99}Tc concentrations from this well are some of the highest
28 concentrations measured in the perched water beneath the INTEC.

² Results for ^{99}Tc were labeled with a "J" during data validation, which indicates that an intervening factor (or factors) make it probable that the level of uncertainty in the reported value is greater than the uncertainty listed.

1 Well USGS-50 was originally intended to be completed in the SRPA, but was ultimately
2 drilled to a total depth of 405 ft (123 m) to monitor a lower perched water zone. This well is located
3 in the north-central portion of the facility. The highest concentrations of ^3H and ^{90}Sr occurred in 1969
4 and 1970. These elevated concentrations were attributed to the failure of the INTEC disposal well,
5 where the wastewater was injected to the vadose zone rather than directly to the aquifer.

6 From the May 1995 water sampling of Well USGS-50, the concentrations of all chemical
7 contaminants except nitrate/nitrite were below federal primary or secondary MCLs. Nitrate/nitrite
8 concentration was measured at 31.3 mg/L compared to the federal primary MCL of 10 mg/L.
9 Radionuclides in the perched water that were detected include ^3H ($61,900 \pm 700$ pCi/L), ^{90}Sr
10 (151 ± 2 pCi/L), and ^{99}Tc ($63 \pm 1\text{J}$ pCi/L). The concentrations for ^3H and ^{90}Sr are within the expected
11 values based on the historical sampling conducted by the USGS.

12 Well MW-17 is the only lower perched water monitoring well located in the southern portion
13 of the INTEC. This well has been constructed to monitor three perched water bodies: an upper zone
14 from 181.7 to 191.7 ft (55.4 to 58.4 m) BGL, a middle zone from 263.8 to 273.8 ft (80.4 to 83.5 m)
15 BGL, and a lower zone from 360 to 381 ft (110 to 116 m) BGL. During the May 1995 sample
16 collection, water was only present in the upper and lower zones. None of the chemical constituents
17 detected in the perched water exceeded either a federal primary or secondary MCL. Only two
18 radionuclides (^3H and ^{99}Tc) were detected in perched water samples collected from Well MW-17. The
19 concentrations of these two radionuclides were similar between the upper and lower perched water
20 zones. Concentrations of ^3H varied from $25,100 \pm 400$ to $25,700 \pm 400$ pCi/L and ^{99}Tc concentrations
21 varied from 5.9 ± 0.6 to 6.4 ± 0.6 pCi/L.

J.2.4 Snake River Plain Aquifer

22 The SRPA has been designated by the EPA as a sole-source aquifer for the region. The SRPA
23 is about 200 mi (322 km) long and varies between 55 to 70 mi (89 to 113 km) wide. It extends from
24 Ashton, Idaho, and the Big Bend Ridge on the northeast to Hagerman, Idaho, on the southwest and
25 covers about 10,000 mi² (25,900 km²). The aquifer consists of a series of basalt flows with
26 interbedded sedimentary deposits and pyroclastic materials. The boundaries are formed by the
27 contacts of the aquifer with less permeable rock at the margins of the plain (Mundorff et al. 1964).
28 Robertson et al. (1974) estimated that as much as 2 billion acre·ft of water may be in storage in the
29 aquifer, of which about 500 M acre·ft are recoverable (DOE-ID 2000b).

1 Groundwater in the SRPA generally occurs under unconfined conditions, but locally may be
2 quasi-artesian or artesian (Nace et al. 1959). The quasi-artesian or artesian conditions are caused by
3 layers of dense, massive basalt or sediments with relatively low permeability. Nace et al. (1959)
4 described quasi-artesian as the situation in which the groundwater level is first recognized in a
5 borehole during drilling at a depth below the regional water table, and then the level rises
6 significantly (5 to 50 ft [1.5 to 15.2 m]) to the level of the water table. This rise of the water level
7 simulates artesian pressure, but the conditions are not truly artesian. Nace et al. (1959) also noted
8 water levels in some wells in the SRPA respond to fluctuations in barometric pressure similar to wells
9 in confined aquifers, indicating that tight zones in the basalt may impede pressure equalization. True
10 artesian or flowing artesian conditions in the SRPA were identified at Rupert, Idaho, in parts of the
11 Mud Lake Basin, and north of the American Falls Reservoir (Nace et al. 1959).

12 Recharge to the aquifer is primarily by valley underflow from the mountains to the north and
13 northeast of the plain and from infiltration of irrigation water. A small amount of recharge occurs
14 directly from precipitation. Recharge to the aquifer within INL boundaries is primarily by underflow
15 from the northeastern part of the plain and the Big Lost River (Bennett 1990). Significant amounts of
16 recharge from the Big Lost River have caused water levels in some wells at the INL to rise as much
17 as 6 ft (1.8 m) within in a few days after high flows in the river (Barraclough et al. 1982). Locally, the
18 direction of groundwater flow is temporarily changed by recharge from the Big Lost River (Bennett
19 1990).

20 Estimates of the effective thickness of the SRPA at the INL vary. A 10,365-ft (3,159-m) deep
21 geothermal test well (INEL-1) was drilled about 4.5 mi (7.2 km) north of the INTEC in 1979.
22 Subsurface geologic information from INEL-1 indicates at least 2,000 ft (610 m) of basalt underlie
23 the INL (Prestwich and Bowman 1980). Hydrological data from INEL-1 were interpreted by Mann
24 (1986) to indicate that the effective base of the aquifer is located 850 to 1,220 ft (259 to 372 m) BGL.
25 The depth to water at INEL-1 is about 400 ft (122 m) BGL, which suggests an effective aquifer
26 thickness of 450 to 820 ft (137 to 250 m). In earlier studies by Robertson et al. (1974), the effective
27 portion of the SRPA at the Test Reactor Area was assumed to be the upper 250 ft (76 m) of the
28 saturated zone based on lithology and water quality. The aquifer thickness varies at different areas,
29 and the aquifer becomes less productive with depth because of decreasing hydraulic conductivity
30 (Hull 1989). Hydraulic conductivity of the basalt in the upper 800 ft (244 m) of the aquifer generally
31 is 1.0 to 100 ft/d (0.3 to 30.5 m/d); whereas, the hydraulic conductivity of underlying rocks is several
32 orders of magnitude smaller (Orr and Cecil 1991). Fracture filling from sediments and secondary

1 mineralization are the principal reasons for the decreased hydraulic conductivity. Additional INL and
2 INTEC geologic and hydrogeologic characterization is found in Attachment 3 of this permit.

3 The water-table elevations range from 4,590 ft (1,399 m) AMSL in the northern part of INL to
4 about 4,420 ft (1,347 m) AMSL south of the INL; the depth to the water table varies from about
5 200 ft (61.0 m) BGL in the northern part of INL to about 900 ft (274 m) BGL in the southern part.
6 The general direction of groundwater flow is to the south-southwest, and the average gradient is about
7 4 ft/mi (0.8 m/km) (Orr and Cecil 1991). Locally, however, the hydraulic gradient varies significantly
8 and ranges from about 1.0 ft/mi (0.2 m/km) in the northern part of INL to a maximum of 15 ft/mi (2.8
9 m/km).

10 The elevation of the water table and direction of groundwater flow are affected by recharge,
11 groundwater withdrawal, and variations in aquifer transmissivity. The effects of groundwater
12 withdrawal are often localized in contrast to recharge and transmissivity variations that have regional
13 impacts. From July 1985 to July 1988, Orr and Cecil (1991) reported water-level changes in INL
14 wells ranging from a 26-ft (7.9-m) decline near the Radioactive Waste Management Complex to a
15 4-ft (1.2-m) rise north of TAN. Water levels generally declined in the southern two-thirds of the INL
16 during that time and rose in the northern one-third.

J.2.4.1 Hydraulic Conductivity in the SRPA.

17 Hydraulic properties of the SRPA have been determined by pumping tests. The effective
18 hydraulic conductivity of the basalts and interbedded sediments that make up the SRPA at and near
19 the INL ranges from $3E-3$ to $1E+4$ m/d. This six-orders of magnitude range was estimated from
20 single-well aquifer tests in 114 wells, and is mainly attributed to basalt flows and dikes (Anderson et
21 al. 1999). By calculating the geometric mean of transmissivity values, Hull (1989) estimated regional
22 aquifer transmissivity for the southern INL to be $2.94E+5$ ft²/d ($2.7E+5$ m²/d). Estimates of the
23 storage coefficients range from 0.01 to 0.06 and effective porosity from 5 to 15%, with 10% being
24 historically the most accepted value (Robertson et al. 1974), although more recent information
25 indicates that a lower value may be appropriate.

J.2.4.2 Hydraulic Conductivity of the SRPA in the Vicinity of the INTEC.

26 The hydraulic conductivity of the SRPA in the vicinity of INTEC was estimated using the
27 transmissivity values reported by Ackerman (1991) and the saturated thickness of the open interval of
28 the well. The estimation of hydraulic conductivity assumes the wells fully penetrate the saturated

1 thickness of the aquifer. Hydraulic conductivities range five-orders of magnitude with a maximum
2 hydraulic conductivity of $1\text{E}+4$ ft/d ($3\text{E}+3$ m/d) at Well CPP-3 and a minimum hydraulic conductivity
3 of $1\text{E}-1$ ft/d ($3\text{E}-2$ m/d) at Well USGS-114. The average hydraulic conductivity within the immediate
4 vicinity of the INTEC is $1.3\text{E}+3 \pm 2.6\text{E}+3$ ft/d ($4\text{E}+2 \pm 7.9\text{E}+2$ m/d). Using the average hydraulic
5 conductivity, a hydraulic gradient of 6.3 ft/mi (1.2 m/km) (Orr and Cecil 1991), and an effective
6 porosity of 10%, the calculated seepage velocity in the vicinity of the INTEC is approximately 10 ft/d
7 (3 m/d) (DOE-ID 2000a). Additional information on hydraulic conductivity of the INTEC is provided
8 in Attachment 3 of this permit.

J.2.4.3 Contamination in the SRPA.

9 There is no verifiable evidence of HWMA/RCRA contamination below the INTEC in the
10 SRPA. However, the water quality in the SRPA at and downgradient from the INTEC has been
11 adversely impacted from past facility operations. The SRPA (Group 5) is identified under the
12 CERCLA program as containing low-level threat wastes. The COCs identified in the OU 3-13
13 baseline risk assessment are primarily radionuclides and include ^{90}Sr , tritium, ^{137}Cs , ^{129}I , plutonium
14 isotopes (238 , 239 , 240 , and ^{241}Pu), uranium isotopes (234 , 235 , and ^{238}U), ^{237}Np , ^{241}Am , and ^{99}Tc . In addition,
15 mercury was identified through modeling as a COC.

16 Water-level elevations indicate two separate sources of local recharge to the SRPA. One source
17 for recharge is apparently from the historic percolation ponds as indicated by elevated water levels
18 measured in Wells USGS-51, USGS -112, USGS-113, USGS-114, USGS-115, and USGS-116.
19 Water-level response to recharge from these ponds is indicated by a 2-ft (0.6-m) rise in Well USGS-
20 113 and a 1.0-ft (0.3-m) rise in Well USGS-51. The water table in the SRPA downgradient from the
21 historic percolation ponds indicates a preferred flow direction toward the southwest with a secondary
22 flow component to the southeast.

23 Directly south of the historic percolation ponds, water levels in Wells USGS-77 and USGS-111
24 are significantly lower than what would be expected based on the water levels in the adjacent wells.
25 The primary reason suspected for this anomaly is the local variation in the water-bearing
26 characteristics of the SRPA. A second possible source of recharge to the SRPA may be indicated by
27 unusually high water levels measured in Well USGS-47. These levels are consistently 1 to 2 ft (0.3 to
28 0.6 m) higher than corresponding water levels measured from the surrounding wells. The possible
29 causes of this situation include local recharge, local pumping, vertical hydraulic gradient (i.e.,
30 increasing hydraulic head with depth), and well completion characteristics.

1 Groundwater directly beneath the INTEC generally flows to the southwest and southeast, with
2 a minor flow component to the south. The local flow pattern likely results from local recharge (i.e.,
3 percolation ponds and sewage ponds) that creates the mounding in the water table, and possibly from
4 pumping the production wells. As the groundwater progresses beyond the influence of INTEC, it
5 flows toward the southwest. The local hydraulic gradient is low, only 1.2 ft/mi (0.2 m/km) compared
6 to the regional gradient of 4 ft/mi (0.8 m/km). Additional hydrogeologic characterization of the
7 INTEC is provided in Attachment 3.

J.2.4.4 Local Flow Velocity in the SRPA.

8 Tritium from INTEC wastes has been used extensively in tracing groundwater flow velocities
9 and directions (Morris et al. 1964; Hawkins and Schmalz 1965; Barraclough et al. 1967). Peaks of
10 high tritium discharge to the disposal well have been particularly useful in determining the local flow
11 characteristics in the SRPA. One of the most studied peak discharges of tritium occurred in December
12 1961, because it was preceded and followed by relatively long periods of low tritium discharge.

13 The concentration of the tritium peak as it passed each observation well provides an indication
14 of the amount of dispersion the tritium discharge has undergone. The tritium concentration
15 distribution indicates two preferred flow paths from the disposal well probably exist: the predominant
16 path to the southwest and a less clearly defined path to the southeast. Some of the explanation for this
17 phenomenon is provided in the plot of the transmissivity values for the INTEC, where a zone of low
18 transmissivity is located directly to the south. This zone of low transmissivity to the south apparently
19 acts as a barrier and impedes the local groundwater flow. The high degree of anisotropy associated
20 with fractured aquifers is another reason for the large amount of dispersion that occurs in the SRPA.
21 Additional characterization of local flow velocity at the INTEC is provided in Attachment 3.

J.2.4.5 Groundwater Pumping Effects on the SRPA.

22 The INTEC facility uses approximately 2.1 M·gal (7.9 M·L) of water each day. This water is
23 supplied by two raw water wells (CPP-1 and CPP-2) and two potable water wells (CPP-4 and ICPP-
24 POT-012) located in the northern portion of the facility. As part of the WAG 3 remedial investigation,
25 the effect of pumping groundwater from these wells upon the local water table was investigated
26 during July and August 1995. This investigation involved continuous water-level monitoring of
27 several aquifer wells completed in the northern section of the INTEC while metering the pump usage
28 in Production Well CPP-2.

1 Water-level fluctuations in six aquifer wells (MW-18, USGS-40, USGS-43, USGS-47,
2 USGS-52, and USGS -121) were monitored at 5-minute intervals using pressure transducers and data
3 loggers. The National Oceanic and Atmospheric Administration recorded barometric pressure
4 changes at 5-minute intervals at the CFA weather station, which is located approximately 3 mi (5 km)
5 from the INTEC. Pump usage for Well CPP-2 was continuously monitored based on amperage
6 requirements. During the 11 days of the test, the production well pump turned on 17 times with each
7 pump cycle lasting for approximately 9 hours.

8 The water levels in all aquifer wells exhibited a similar response. Daily fluctuations,
9 generally less than 1 in. (3 cm), were observed in all aquifer wells corresponding with pump usage of
10 the production well. In almost all pump cycles, the corresponding water levels in the aquifer wells
11 decreased by an average of 0.75 in. (1.9 cm). Only Pump Cycle No. 11 demonstrated an increase in
12 water levels throughout the pump duration for all wells except Well USGS-40. This water-level
13 increase during this pump cycle may be the result of a local or regional trend and is not related to
14 pumping groundwater. Other than Pump Cycle No. 11, the water levels decreased during the pump
15 cycle in Wells MW-18, USGS-40, USGS-43, and USGS-52 throughout the test.

16 As shown by this test, water levels in the SRPA are affected by pumping groundwater from the
17 production well. Minimal responses (< 1.0 in. [< 2.5 cm]) were observed in these six monitoring
18 wells; however, the wells are located approximately 2,000 ft (610 m) from the production well.
19 Increased drawdown would be expected closer to the production well that could affect the local
20 groundwater flow direction in the northern sections of the INTEC. Additional information on the
21 effects of pumping groundwater at the INTEC is provided in Attachment 3.

J.3 Topographic Map Showing Groundwater Monitoring Wells IDAPA 58.01.05.012 [40 CFR 270.14(c)(3)]

22 The topographic map showing the waste management areas and the groundwater monitoring
23 wells selected for groundwater monitoring is provided in Attachment 1.

J.4 Description of any Plume Contaminants from a Regulated Unit

IDAPA 58.01.05.012 [40 CFR 270.14(c)(4)]

1 As previously stated, there is no verifiable evidence of HWMA/RCRA constituents originating
2 from the WCF or CPP-601/627/640 in the perched groundwater.

J.5 Proposed Groundwater Monitoring System

IDAPA 58.01.05.012 and 008 [40 CFR 270.14(c)(5) and 40 CFR 264.97]

3 Groundwater monitoring of perched water will be conducted to determine (1) whether hazardous
4 waste or hazardous waste constituents associated with the WCF or CPP-601/627/640 have entered the
5 groundwater, (2) the rate and extent of migration of hazardous waste or hazardous waste constituents in the
6 groundwater, and (3) the concentrations of hazardous waste or hazardous waste constituents in the
7 groundwater. If summary statistics determine that significant evidence of contamination is detected above
8 established background levels a PMR would be submitted to the DEQ to include SRPA monitoring.

9 Correlating contaminants, or contaminant concentrations, that may be observed in the perched
10 water to a release from the closed INTEC landfills is extremely complicated because of three
11 significant factors. First, the waste streams that were processed at the WCF and CPP-601/627/640 are
12 not unique to these facilities. The same waste streams were processed at several other major facilities
13 all located in relatively close proximity. These include the Fluorinel Dissolution Process and Fuel
14 Storage Area (Building CPP-666), the HLLW TFF, the PEWE (Building CPP-604/605), and the
15 NWCF (Building CPP-659). In the WAG 3, OU 3-13 ROD, ten release sites were identified at the
16 TFF alone (DOE-ID 1999). Second, approximately 450 ft of vadose zone is present between the land
17 surface and SRPA. The vadose zone beneath the INTEC comprises a highly heterogeneous layering
18 of fractured basalt flows and sedimentary interbeds. Significant sources of groundwater recharge act
19 on the vadose zone, including surface water infiltration due to snowmelt and precipitation over the
20 INTEC facility and anthropogenic sources from leaks in the INTEC water systems. Recharge from
21 these water sources combine to create perched water bodies in the vadose zone and a flow system that
22 mixes contaminants from the numerous surface release sites. Given the layering of the system, where
23 horizontal permeabilities can be several orders of magnitude greater than vertical permeabilities,
24 significant lateral movement of the perched water and associated contaminant may occur, further

1 complicating the ability to track contaminants from land surface to the aquifer. Third, past disposal of
2 service water (including a component from the PEWE) through the former INTEC injection well and
3 the identified presence of soil contamination from old releases under and around the WCF make
4 identification of new releases difficult.

J.5.1 Perched Groundwater Monitoring Wells

5 The WCF monitoring system will consist of wells within the upper perched water zones and
6 lower perched water zones. The perched water zones are noncontiguous bodies of water that are
7 subject to directional change from recharge influences from the Big Lost River, sewage treatment
8 lagoons, and the historic percolation ponds. Within the perched water zones, these factors make it
9 difficult to establish unaffected, hydraulically upgradient background wells for use in detection
10 monitoring. Therefore, perched water monitoring wells have been spatially selected to account for
11 changes in groundwater flow direction, and statistical methods have been proposed to examine
12 significant changes within individual wells and within the entire monitoring well network as a system.

13 To assess contamination from the WCF, perched water samples were collected from five
14 perched groundwater wells. The wells originally selected for detection monitoring are CPP-55-06,
15 ICPP-MON-P-002 (MW-2), ICPP-MON-P-005 (MW-5), ICPP-MON-P-019 (MW-18), and ICPP-
16 MON-P-020 (MW-20) (see Topographic Map in Attachment 1). Well construction details for the
17 perched water monitoring wells are given in Permit Module III, Table 2.

18 As required by Permit Condition III.H.3.a., a Monitoring Well Network Compliance Statement
19 was provided in the fall 2004 semiannual report. The compliance statement assessed whether the
20 monitoring network, as described in the WCF post-closure permit has satisfied the requirements of
21 IDAPA 58.01.05.008 [40 CFR 264.97(a)]. Because monitoring wells MW-12-2, MW-18-2, and CPP-
22 33-1 had not consistently yielded a sufficient volume of water for sampling, the compliance statement
23 proposed revising the monitoring network by adding MW-10-2 and CPP-55-06 for quarterly sampling
24 to provide supplemental information.

25 As required by previous Permit Condition III.I.2., the construction of two additional wells was
26 completed (April 5, 2005). The two wells, identified as ICPP-2018 (alias TFS-SP for tank farm south-
27 shallow perched) and ICPP-2019 (alias TFSE-SP for tank farm southeast-shallow perched), were first
28 sampled during the May 10-12, 2005 sampling event.

1 A HWMA/RCRA Class 2 permit modification request (PMR) to modify the WCF monitoring
2 well network, approved by the DEQ on January 17, 2006, revised the permit to: add wells ICPP-2018,
3 ICPP-2019, and MW-10-2 as monitoring wells; change well CPP-55-06 from a water elevation well
4 to a monitoring well; remove well MW-4-2 as a water elevation well; and change groundwater
5 sampling and analysis procedures and monitoring schedule.

6 Sample results from wells CPP-55-06 and MW-10-2 had been reported as supplemental wells,
7 as proposed in the response to the Comprehensive Ground Water Monitoring Evaluation (CME) for
8 the Waste Calcine Facility. As a result of the HWMA/RCRA Class 2 PMR to modify the WCF
9 monitoring well network, approved by the DEQ on January 17, 2006, wells CPP-55-06 and MW-10-2
10 were no longer considered as supplemental wells but are considered to be part of the permit
11 monitoring network and are considered monitoring wells, not supplemental wells during the 2006
12 WCF quarterly sampling events.

13 The addition of these wells provided a total of thirteen wells in the WCF monitoring network,
14 three of which were background wells and six of which were point-of-compliance wells. Two of the
15 point-of-compliance wells (MW-12-2 and MW-18-2) have been consistently dry and were changed
16 from water monitoring to water elevation only wells via the Class 3 PMR. Water level well MW-8
17 has been consistently dry, and therefore MW-8 was removed from the WCF network via the Class 3
18 PMR. The current WCF monitoring network is expected to continue to satisfy the requirements of
19 IDAPA 58.01.05.008 [40 CFR 264.97(a)].

20 Because of the noncontiguous nature of the perched zones, the water levels in the wells were
21 monitored on a bi-monthly basis for three years to evaluate flow directions in the perched water
22 zones. The five wells were selected to account for possible shifts in flow direction. The interim point
23 of compliance (POC) wells were ICPP-55-06, ICPP-MON-P-002 (MW-2), and ICPP-MON-P-005
24 (MW-5). The direction and rate of flow in the uppermost perched aquifer have been determined as
25 required by Permit Condition III.B.2. This information has been reported in the Fall 2004, 2005, and
26 2006 semiannual reports.

27 The CPP-601/627/640 monitoring well system will consist of five wells: MW-6, CPP-33-2,
28 ICPP-2195, ICPP-2196, and ICPP-2205. Note that the proposed monitoring network initially included
29 only four wells, however during drilling, well ICPP-2196 was dry. Therefore, with DEQ concurrence,
30 well ICPP-2205 was completed to replace well ICPP-2196. The well construction details for these
31 wells are provided in Permit Module III, Table 2a. These wells will be sampled and the data

1 statistically evaluated to determine background levels. The sampling and analysis protocols and
2 compliance requirements are the same as for the WCF sampling.

3 The stated WAG 3 remedial action objective for the INTEC is to eliminate perched water by
4 removing the sources. To accomplish this, the historic service water percolation ponds were moved to
5 a new area west of the INTEC. Other anthropogenic sources of water are being addressed on a case
6 by case basis. The necessity or ability to monitor perched water will be evaluated each year. If a
7 perched water well is dry at the time of sampling, perched water samples will not be collected during
8 that sampling event. All perched monitoring wells proposed for abandonment due to the elimination
9 of perched water must be approved by the Director prior to abandonment and will require a permit
10 modification in accordance with 40 CFR § 270.42.

J.5.2 Sampling and Analysis Procedures

11 Field measurements, sample collection and preservation, and quality assurance/quality control
12 (QA/QC) criteria are defined below for the post-closure sample collection activities.

J.5.2.1 Groundwater Elevations.

13 Prior to initiation of sampling, all groundwater elevations will be measured using an
14 electronic water-level indicator, weighted measuring tape, or continuous recorder method from the
15 reference marker. Measurement of all groundwater levels will be recorded relative to mean sea level
16 and to an accuracy of ± 0.01 ft (0.003 m).

17 The water-level data obtained from the wells in this monitoring program will be combined with
18 water-level measurements obtained from other WAGs or USGS data to determine groundwater flow
19 gradients, direction and rate of annual groundwater flow, and to generate potentiometric maps.

Table J-3. Summary of perched groundwater monitoring wells.

Monitored Zone	Well Designation
Upper Perched Groundwater	CPP-33-1, CPP-33-2, CPP-33-4-1, CPP-37-4, CPP-55-06, ICPP-MON-P-002 (MW-2), ICPP-MON-P-005 (MW-5), ICPP-MON-P-020 (MW-20), MW-10-2, MW-12-2, MW-18-2, ICPP-2018 (TFS), ICPP-2019 (TFSE), MW-6, CPP-33-2, ICPP-2195, ICPP-2196, ICPP-2205

J.5.2.2 Perched Groundwater Purging.

1 All perched water wells will be purged prior to sample collection in an effort to obtain a
 2 representative sample from the perched water zone. Prior to purging, the static water level in each
 3 well scheduled for sampling is measured and a static well casing volume is calculated. Wells that
 4 contain one foot of water column, or less, will be considered to have insufficient water for sampling.
 5 Wells are purged using low-flows at 0.5 to 2 Liters/min to minimize draw down and formation
 6 disruption while obtaining a representative sample from the perched water zone. During purging,
 7 measurements will be made to determine specific conductance and pH. These parameters may be
 8 measured either with probes located downhole or at the ground surface. Purging consists of removing
 9 one to three well volumes while measuring these parameters. Samples for water quality analysis can
 10 be collected after a minimum of one well casing volume of water has been purged from the well, and
 11 as soon as two consecutive measurements of pH and specific conductance fall within the following
 12 limits:

- 13 • pH ± 0.2 standard units
- 14 • Specific conductance $\pm 5\%$ of reading

15 If pH and specific conductance fail to stabilize within the above limits, purging will continue
 16 until a maximum of three well casing volumes of water have been purged from the well, at which
 17 point sampling will begin regardless of parameter stabilization. Water temperature and turbidity will
 18 be measured/recorded during well purging. Stabilization of temperature or turbidity is influenced by
 19 the volume of water in the well and the rate of recharge, thus are not appropriate stability parameters
 20 for these low yielding wells. Stable pH and specific conductance parameters will be used as criterion
 21 for sampling. Purged water from wells completed within the perched water zones will be collected
 22 and managed in accordance with the appropriate HWMA/RCRA and radiological requirements.

J.5.2.3 Perched Groundwater Sample Collection.

1 When purging a well, if insufficient water is available to complete the purging, as described
2 above, the well should be purged to dryness and sampled the next working day at which point, no
3 additional purging or stable parameters are required at the well and the samplers will collect the
4 available water for analysis. Sampling at the well will then be considered complete. The following is
5 the preferred order for sample collection:

- 6 1. Metals (filtered)
- 7 2. Volatile organic compounds (VOCs)
- 8 3. Semivolatile organic compounds.

9 Sample bottles are protected from contamination by the sampler using clean, waterproof
10 gloves. The identification label is placed on the bottle with the appropriate information such as
11 sample ID number, name of project area/well, type of analysis, date, sampler, preservative and
12 collection time. Sufficient water from the well is collected to fill the required number of bottles. The
13 water is transferred from the sampling equipment directly to the sample bottle. The bottle is filled to
14 the neck or for samples that require volatile organic analysis, the bottle is filled until no air bubbles or
15 headspace is left.

16 Following sampling, all non-dedicated equipment that came in contact with the well water will
17 be decontaminated using deionized water. Since the media sampled is suspected of containing RCRA
18 listed hazardous waste, the solution used to decontaminate the equipment is contained, managed, and
19 disposed of in accordance with appropriate HWMA/RCRA and radiological requirements.

J.5.2.4 QA/QC Samples.

20 For perched groundwater monitoring and sampling, collection of QA/QC samples is required.
21 Equipment rinsate samples are required when the same sampling equipment is used to collect samples
22 from multiple wells. Equipment rinsate samples provide an indication of the effectiveness of
23 equipment decontamination between well sampling locations. Equipment rinsate samples are not
24 required for wells that have a dedicated pump or when sampling equipment is limited to sampling of a
25 single well (e.g., disposable bailers that are used to sample one well and then disposed instead of
26 reused to sample a second well).

1 Quality control requirements will be satisfied by collecting QA/QC samples (duplicates, field
2 blanks, and equipment rinsate) during the perched groundwater sampling according to the schedule
3 presented in Table J-4.

J.5.2.5 *Sample Preservation.*

4 Sample preservation is required for many of the chemical constituents and physiochemical
5 parameters that are not chemically stable but are measured or evaluated in a perched groundwater
6 sampling program. Methods of sample preservation are generally intended to retard biological action,
7 retard hydrolysis, and reduce sorption effects. Preservation methods usually include pH control,
8 chemical addition, refrigeration, and protection from light. Appropriate preservation methods will be
9 used.

J.5.2.6 *Chain-of-Custody Procedures.*

10 The purpose of the chain-of-custody procedures is to ensure the possession and handling of
11 samples are traceable at all times. A sample is considered in custody if it falls under one of the
12 following descriptions:

- 13 • In one's possession
- 14 • In one's view after being in one's physical possession
- 15 • In one's physical possession and then locked up to prevent someone from tampering with the
16 sample
- 17 • Kept in a secured area and restricted to authorized and accountable personnel only. A
18 secured area is an area that is locked, such as a room, cooler, or refrigerator. If the area
19 cannot be locked, a current revision of custody seal will be used to secure the area.

20 The following recommended information is recorded as appropriate:

- 21 • Signature of the person maintaining custody
- 22 • Project name or title
- 23 • Sample identification number
- 24 • Sampling date

- 1 • Sampling time
- 2 • Type of sample (e.g., grab or composite)
- 3 • Physical state of sample (e.g., aqueous or solid)
- 4 • Preservation used
- 5 • Sample location
- 6 • Analysis to be performed
- 7 • Number of sample containers

J.5.2.7 Transportation of Samples.

8 Samples will be shipped in accordance with the regulations issued by the U.S. Department of
 9 Transportation (DOT) (49 CFR 171 through 178) and EPA sample handling, packaging, and shipping
 10 methods (40 CFR 262).

J.5.2.8 Custody Seals.

11 Custody seals will be placed on all shipping containers in such a way as to ensure that
 12 tampering or unauthorized opening does not compromise sample integrity. Clear plastic tape will be
 13 placed over the seals to ensure that the seals are not damaged during shipment.

Table J-4. The QA/QC samples for perched groundwater sampling.

Activity	Type	Comment
Perched Groundwater sampling	Duplicate	Field duplicates will be collected at a frequency of 1 per 20 samples per sampling event or 1 per 4 sampling days, whichever is more frequent.
	Field blank	Field blanks will be collected at a frequency of 1 per 20 samples per sampling event or 1 per 4 sampling days, whichever is more frequent.
	Trip blanks	Trip blanks will be collected when VOC samples are taken to include one in every cooler shipped.
	Equipment rinsate	Equipment rinsate samples will be collected if the same sampling equipment is used to sample more than one well. A minimum of 1 rinsate sample will be collected per sampling event, or 1 per 20 samples per sampling event, or 1 per 4 sampling days, whichever is more frequent.

VOC = volatile organic compound

J.5.2.9 On-Site and Off-Site Shipping.

1 An on-Site shipment is any transfer of material within the perimeter of the INL. Site-specific
2 requirements for transporting samples within INL boundaries and those required by the shipping and
3 receiving department will be followed. Shipment within the INL boundaries will conform to DOT
4 requirements as stated in 49 CFR Parts 171–178. Off-Site shipment will be coordinated with INL
5 packaging and transportation personnel, as necessary, and will conform to all applicable DOT
6 requirements.

J.5.2.10 Sample Identification Code.

7 The following lists the sample label information to be used for perched groundwater sampling
8 as applicable:

- 9 • Project name
- 10 • The site/sample identification
- 11 • The analysis to be performed on the sample
- 12 • The date the sample was collected
- 13 • The time the sample was collected
- 14 • The preservative used (if any)
- 15 • Name of sampler

16 The Sampling and Analysis Plan (SAP) tables will be used to record all pertinent information
17 (well designation, media, date, etc.) associated with each sample ID code.

J.5.2.11 Sample Designation.

19 The SAP table format was developed to simplify the presentation of the sampling scheme for
20 project personnel. Examples of SAP tables are presented in Attachment 2.

J.6 Quality Criteria for Measurement Data

J.6.1 Evaluation of Initial Characterization Data

1 There is no verifiable evidence of HWMA/RCRA constituents that have originated from the
2 WCF or CPP-601/627/640 in the perched groundwater (INEEL 2002). Groundwater data were not
3 collected under the provisions of IDAPA 58.01.05.009 (40 CFR 265 Subpart F) during the interim
4 status period at the WCF nor were groundwater data collected for CPP-601/627/640 under either
5 interim status or the HWMA/RCRA permit. However, groundwater samples were collected from the
6 perched and SRPA groundwater monitoring wells as part of other investigations during this period.
7 During the 1993 to 1994 WAG 3, perched water investigation, the perched and SRPA groundwater
8 monitoring wells were sampled and analyzed for field parameters, inorganics, and radionuclides.

9 During the 1993 to 1994 WAG 3 investigation, 18 perched groundwater wells were sampled
10 for 35 organic contaminants. Of the 630 reported analytical results (excluding trip blanks), 36
11 contaminants were reported as detected. These data are of an unknown quality. Nearly all detections
12 were qualified below the contract laboratory quantification limit, contamination was detected in trip
13 blanks, constituents were not detected in duplicate samples where the same constituent was detected
14 in the duplicate pair, and contaminants were detected in quality control samples. Additionally, the
15 original data packages are not available for data validation.

16 Under a continuing WAG 3 investigation in 1995, the perched and SRPA groundwater
17 monitoring wells were sampled and analyzed for field parameters, inorganics, and radionuclides.
18 HWMA/RCRA inorganics above the toxicity characteristic leaching procedure were not detected in
19 the perched or SRPA groundwater samples taken below INTEC.

20 The USGS sampled numerous SRPA monitoring wells between 1951 and 1998 for a variety of
21 organic and inorganic constituents. HWMA/RCRA organic and characteristic contaminants were not
22 detected in the SRPA groundwater samples taken from below INTEC facility boundaries.

23 Samples were taken from the perched groundwater wells MW-2, MW-5, MW-20, USGS-050,
24 and other wells in 2001 and 2002. The 2001 samples were not filtered and results included analytes
25 associated with the water and soil/sediment fractions of the samples. The 2002 samples were filtered
26 prior to analysis, and results include only those analytes associated with the water fraction of the
27 samples. No HWMA/RCRA constituents were detected in the filtered samples.

J.6.2 Quality Assurance/Quality Control

1 QA/QC objectives specify what measurement criteria must be met to produce acceptable data
2 for a project. The technical and statistical qualities of these measurements must be properly
3 documented. Precision, accuracy, and completeness are quantitative parameters that must be specified
4 for physical/chemical measurements. Comparability and representativeness are qualitative
5 parameters.

6 QA/QC objectives for this project will be met through a combination of field and laboratory
7 checks. Field checks will consist of collecting field duplicates, equipment blanks, and field blanks.
8 Laboratory checks consist of initial and continuing calibration samples, laboratory control samples,
9 matrix spikes, and matrix spike duplicates.

J.6.3.1 Field Precision.

10 Field precision is a measure of the variability not due to laboratory or analytical methods. The
11 three types of field variability or heterogeneity are spatially within the data population, between
12 individual samples, and within an individual sample. Although the heterogeneity between and within
13 samples can be evaluated using duplicate and sample splits, overall field precision will be calculated
14 as the relative percent difference between two measurements, or relative standard deviation among
15 three or more measurements. The relative percent difference or relative standard deviation will be
16 calculated during the data validation process or by the laboratory as a requirement of the analytical
17 method used.

18 Duplicate samples to assess precision will be co-located and collected by field personnel at a
19 minimum frequency of one duplicate for at least one of the wells sampled each event. Examples of
20 sample identifications for the duplicate samples are provided in the SAP table presented in
21 Attachment 2. The location for duplicate samples will be rotated over the project life to ensure that at
22 least one duplicate sample will be collected from each well if sufficient water exists.

J.6.3.2 Field Accuracy.

23 Cross-contamination of the samples during collection or shipping could yield incorrect
24 analytical results. To assess the occurrence of any cross-contamination events, equipment and field
25 blanks will be collected to evaluate any potential impacts. The goal of the sampling program is to
26 eliminate any cross-contamination associated with sample collection or shipping.

1 Field personnel will collect equipment rinsate blanks and field blanks during the course of the
2 project. Trip blanks will be collected whenever samples for volatile organic compound analysis are
3 scheduled for collection. The equipment rinsate blanks and field blanks will be collected at a
4 frequency listed in Table J-4. Examples of sample identifications for the blanks are provided in the
5 SAP table presented in Attachment 2.

J.6.3.3 Field Completeness.

6 Field completeness will be assessed by comparing the number of samples collected to the
7 number of planned samples. Field sampling completeness is affected by such factors as equipment
8 and instrument malfunctions, and insufficient sample recovery. Completeness can be assessed
9 following data validation and reduction. The completeness goal for this project is 95%.

J.6.3.4 Comparability.

10 Comparability is a qualitative measure of the confidence with which one data set can be
11 compared to another. These data sets include data generated by different laboratories performing
12 analysis, data generated by laboratories in previous studies, data generated by the same laboratory
13 over a period of several years, or data obtained using different sampling techniques or analytical
14 protocols. Throughout the background concentration determination phase of this project, the same
15 analytical procedures will be used and the same laboratory will analyze the samples in an effort to
16 ensure data comparability. For field aspects of this program, data comparability will be achieved
17 using standard methods of sample collection and handling.

J.6.3.5 Representativeness.

18 Representativeness is evaluated by assessing the accuracy and precision of the sampling
19 program and expressing the degree to which samples represent actual site conditions. In essence,
20 representativeness is a qualitative parameter that addresses whether the sampling program was
21 properly designed to meet the requirements specified. The representativeness criterion is best satisfied
22 by confirming that sampling locations are selected properly, sample collection procedures are
23 consistently followed, and a sufficient number of samples are collected to meet the requirements
24 stated in the final SAP table.

J.7 Establishment of a Detection Monitoring Program

IDAPA 58.01.05.012 and .008

[40 CFR 270.14(c)(6) and 40 CFR 264.98]

1 The WCF and CPP-601/627/640 are closed units located among several identified
2 contaminant release sites currently being managed under the FFA/CO through the CERCLA program.
3 As emphasized earlier, correlating contaminants or contaminant concentrations that may be observed
4 in the perched water to a new release from the WCF will be complicated.

J.7.1 Detection Monitoring Indicator Parameters for WCF

5 Calcination was conducted in the WCF from 1963 until 1981, and then continued in the
6 NWCF until 1998. The *HWMA WCF Closure Plan* provided a list of HWMA/RCRA hazardous waste
7 numbers associated with the WCF. This list was based on an inventory of commercial chemical
8 products that were used at the INTEC and represented a conservative over-filing to allow for potential
9 future operations. A more recent list of HWMA/RCRA hazardous waste numbers that actually
10 entered the calciner systems (via the INTEC liquid waste system) was presented in the February 1999
11 *A Regulatory Analysis and Reassessment of U.S. Environmental Protection Agency Listed Hazardous*
12 *Waste Numbers for Applicability to the INTEC Liquid Waste System* (INEEL 1999). Characteristic
13 hazardous waste numbers associated with the WCF were taken from INL's Part A permit application.

14 The hazardous waste numbers applicable to the WCF and CPP-601/627/640 are shown in
15 Table J-5. The selected indicator parameters for the detection monitoring program are based upon the
16 HWMA/RCRA-listed and characteristic waste constituents as found in the current WCF and CPP-
17 601/627/640 Part A Permit Application (see Attachment 1). These parameters are shown in Table 3a
18 and 3c in Module III of the permit. The organic parameters will provide an indication of whether
19 listed hazardous constituents associated with the WCF and CPP-601/627/640 are present in the
20 groundwater. The characteristic parameters will indicate whether the groundwater exhibits a
21 characteristic of hazardous waste.

22 The approved closure plan for the WCF characteristic and listed hazardous constituents list
23 was based on information in Revision 0 and 1 of the *Regulatory Analysis of INTEC Liquid Waste*
24 *Stream U.S. Environmental Protection Agency Hazardous Waste Numbers*. The report was based on
25 operational information up to and including 1993. This resulted in a lengthy list of constituents in the
26 WCF approved closure plan. Changes incorporated in Revision 2 of the regulatory analysis were a
27 result of operational information acquired after 1993 up to July 1998. The assessment document, *A*

1 *Regulatory Analysis and Reassessment of U.S. Environmental Protection Agency Listed Hazardous*
 2 *Waste Numbers for Applicability to the INTEC Liquid Waste System, Revision 1, provides the*
 3 *applicable hazardous waste numbers as a result of reevaluation of operational information as of*
 4 *February 1999. Between the 1993 list and the 1999 list the number of constituents was greatly*
 5 *reduced as appropriate with supporting data.*

Table J-5. EPA hazardous waste numbers associated with the WCF and CPP-601/627/640.

EPA Hazardous Waste Numbers	Chemical Characteristic/Name
D004	Arsenic
D005	Barium
D006**	Cadmium
D007	Chromium
D008	Lead
D009	Mercury
D010	Selenium
D011	Silver
F001	1,1,1-Trichloroethane, Carbon tetrachloride, Trichloroethylene
F002	1,1,1-Trichloroethane, Carbon tetrachloride, Trichloroethylene, Tetrachloroethylene, Methylene chloride, 1,1,2-Trichloroethane
U134	Hydrogen fluoride*

* These constituents are not listed in 40 CFR264 Appendix IX - Groundwater Monitoring List. Therefore, analysis will not be performed for these constituents.

**This EPA hazardous waste number is only associated with CPP-601/627/640 (not applicable to the WCF)

J.7.2 Background Values for Detection Monitoring Parameters for WCF.

1 Background values were not established during the interim status period for use in the
2 detection monitoring program. In preamble language to the July 26, 1982, “Hazardous Waste
3 Management System; Permitting Requirements for Land Disposal Facilities” (Federal Register 1982),
4 the EPA stated,

5 *“Under the detection monitoring program, the owner or operator determines whether*
6 *contaminants from a regulated unit have entered ground water by comparing levels*
7 *of constituents at the compliance point to background values for those constituents.*
8 *The first step in the process, then, is to establish a background value for each*
9 *monitoring well.”*

10 For newly regulated units, EPA allowed background concentrations to be established from the
11 results of quarterly groundwater sampling conducted during the first year. However, in the case where
12 insufficient data existed to establish background at the time of permit issuance, EPA stated,

13 *“The Regional Administrator may, however, specify in the permit the*
14 *procedures to be used in calculating background and indicate that whatever value*
15 *results from the calculation shall automatically become part of the permit. For*
16 *example, the owner may have only assembled 6 months of background data at the*
17 *time the permit is ready to be issued. Rather than wait for another 6 months until the*
18 *rest of the one year of background data has been assembled, the Regional*
19 *Administrator may simply specify how the additional background data will be used to*
20 *calculate the value.”* (Federal Register 1982)

21 Because the WCF is located among several identified contaminant release sites, and the
22 perched water is subject to recharge fluctuation, establishing background conditions and accounting
23 for the seasonal, temporal, and recharge fluctuation within the groundwater monitoring system is
24 critical.

25 A statistical analysis of all data collected to date to establish background concentrations
26 pursuant to Permit Condition III.D.1. was submitted to DEQ on December 11, 2006 and was
27 approved on January 29, 2007. An updated statistical analysis of WCF data was completed in August
28 2010 (see Appendix J-1.) to support revision of the WCF DMLs in Table 3b in Permit Module III.

J.7.3 Groundwater Monitoring for CPP-601/627/640.

1 Ground water monitoring programs for CPP-601/627/640 have been implemented to meet the
2 requirements of IDAPA 58.01.05.008 (40 CFR 264.97, 264.98, 264.99, and 264.100). A detection
3 monitoring program (DMP) was put into effect upon completion of the monitoring well installation.
4 Detection monitoring limits and groundwater protection standard (GPS) values for CPP-601/627/640
5 are provided in Table 3c in Module III of the permit. These limits are typically established as
6 estimated quantitation limits (EQLs) plus established background concentrations. Groundwater
7 protection standards are typically established as the maximum contaminant levels promulgated under
8 the Safe Drinking Water Act plus established background concentrations. Because background
9 concentrations have not yet been established for CPP-601/627/640 landfill post-closure monitoring,
10 initial DMLs and GPSs were matched to the WCF DMLs that were in effect at the time of the CPP-
11 601/627/640 post-closure plan approval. Samples will be collected quarterly for 2 years to establish
12 background levels, which will be calculated using the statistical requirements set out in Permit
13 Condition III.J. Upon establishment of site-specific background values, the DMLs included in
14 Table 3c will be modified to account for site-specific background values. During the 2-year period in
15 which background levels are being established, exceedence of a DML will not trigger compliance
16 monitoring in the CPP-601/627/640 groundwater monitoring network, because the exceedence may
17 be the result of a higher background concentration.

**APPENDIX J-1. Statistical Analysis of Perched Groundwater
Monitoring Data for the Waste Calcining Facility
(RPT-1013, Rev. 3- August 2010)**

Statistical Analysis of Perched Groundwater Monitoring Data for the Waste Calcining Facility

August 2010



**RPT-1013
Revision 3**

Statistical Analysis of Perched Groundwater Monitoring Data for the Waste Calcining Facility

August 2010

**Portage, Inc.
1075 S. Utah Avenue, Suite 200
Idaho Falls, ID 83402**

**Prepared for
CH2M-WG Idaho, LLC
Contract BMC 500116, Release 30
Portage Project No. 2126.30**

ABSTRACT

The Waste Calcining Facility is located at the Idaho Nuclear Technology and Engineering Center. In 1999, the Waste Calcining Facility was closed under an approved Hazardous Waste Management Act/Resource Conservation and Recovery Act (HWMA/RCRA) Closure Plan. Vessels and spaces were grouted and then covered with a concrete cap. The Idaho Department of Environmental Quality issued a final HWMA/RCRA post-closure permit on September 15, 2003, with an effective date of October 16, 2003. This permit sets forth procedural requirements for groundwater characterization and monitoring, maintenance, and inspections of the Waste Calcining Facility to ensure continued protection of human health and the environment.

Detection monitoring limits were determined in the November 2006 document, *Statistical Analysis of Perched Water Monitoring Data for the Waste Calcining Facility* (Medema 2006). Data obtained from recent sampling events indicate that background concentrations of several constituents have increased in the last few years. These data were analyzed and the results were used to compute new detection monitoring limits to more accurately reflect the current background conditions.

CONTENTS

ABSTRACT.....	ii
ACRONYMS.....	iv
1. INTRODUCTION.....	1
2. METHODS.....	1
3. DATA.....	3
4. ANALYSIS RESULTS AND DETECTION MONITORING LIMITS	6
5. DISCUSSION.....	14
6. PRESENTATION OF FINAL DETECTION MONITORING LIMITS	16
7. CONCLUSIONS	17
8. REFERENCES	17

FIGURES

Figure 1. WCF perched water monitoring wells.....	4
Figure 2. Concentrations by sampling event number for constituents with at least one detected result.....	11

TABLES

Table 1. Number of constituents analyzed at each well for the 22 sampling events.....	5
Table 2. Summary of monitoring results by constituent and well.. ..	7
Table 3. Kruskal-Wallis test results for differences among wells for constituents with at least one detectable result exceeding the EQL.. ..	8
Table 4. Detection monitoring limits for constituents that do not differ among wells and method of determination.....	9
Table 5. Detection monitoring limits ($\mu\text{g/L}$) for constituents that differ among wells and method of determination.....	10
Table 6. Proposed constituent analyte list, associated estimated quantitation limits, groundwater protection standards, and WCF detection monitoring limit.....	16

ACRONYMS

DEQ	Department of Environmental Quality
DML	detection monitoring limit
DOE-ID	Department of Energy, Idaho Operations Office
EPA	Environmental Protection Agency
EQL	estimated quantitation limit
GPS	groundwater protection standard
HWMA	Hazardous Waste Management Act
ICP	Idaho Cleanup Project
INTEC	Idaho Nuclear Technology and Engineering Center
RCRA	Resource Conservation and Recovery Act
UTL	upper tolerance limit
WCF	Waste Calcining Facility

Statistical Analysis of Perched Groundwater Monitoring Data for the Waste Calcining Facility

August 2010

1. INTRODUCTION

Shallow perched groundwater beneath and adjacent to the Waste Calcining Facility (WCF) cap at the Idaho Nuclear Technology and Engineering Center (INTEC) is routinely monitored through a detection monitoring program as outlined in the Resource Conservation and Recovery Act (RCRA) post-closure permit (DEQ 2007). Recent perched groundwater sampling has detected the presence of some constituents in some wells at levels that are higher than the current permit-required detection monitoring limits (DMLs). WCF Permit Condition III.F.4.a.2. requires that when DMLs are exceeded, two verification samples or RCRA Appendix IX samples be collected from each of the affected wells unless the detections can be shown to be due to a source other than the regulated unit (the WCF itself).

The Idaho Cleanup Project (ICP) has investigated these detections above DMLs and believes, with Department of Environmental Quality (DEQ) concurrence, that these detections have resulted from a source or sources other than the WCF. In addition, ICP believes that the recent detections above DMLs are an indication that the perched water in the vicinity of the WCF has changed from the background conditions established by the statistical analysis that was performed in 2006 (Medema 2006). ICP has proposed to DEQ that it may be worthwhile to perform a statistical analysis of all WCF perched groundwater quality data collected to date. Such an analysis would include considerable data collected since the previous statistical analysis was performed, which set the DMLs and was accepted by DEQ. DEQ has encouraged the proposed statistical analysis of all WCF water quality data for the purpose of updating the WCF information (Bullock 2009).

Current WCF DMLs were established as a result of a permit-required statistical analysis of all data collected during twelve quarterly sampling events through August 2006, approved by DEQ on January 29, 2007 (Bullock 2007). The results of the current statistical analysis are intended to document the changes in the perched water in the vicinity of the WCF, will supersede the results of the previous statistical analysis, and will establish new detection monitoring limits upon DEQ approval. The statistical methods used in this analysis to determine DMLs are specified in the WCF post-closure permit (DEQ 2007).

2. METHODS

The methods for development of background levels used for DMLs were in accordance with the WCF Post-Closure Permit. The DMLs were either set at the estimated quantitation limit (EQL) or calculated as the upper tolerance limit (UTL). These methods are summarized and additional analyses are described below.

For hypothesis tests, a significance level (α) of 0.05 was used. For UTLs, 95% confidence and 95% coverage were used (i.e., a 95% confidence limit on the 95th percentile). The analyses were performed for each constituent independently. Analyses were performed for each well separately only when significant differences among wells were identified.

The outline below follows the process prescribed in the Permit augmented by additional analyses:

1. Test for differences among wells using the non-parametric Kruskal-Wallis Rand test.
 - a. Performed for constituents with at least one detectable result greater than the EQL.
 - b. Constituents with all results less than the EQL were assumed to not differ among wells.
 - c. All following analyses were performed for results combined across wells unless the Kruskal-Wallis test was significant.
2. Test for trend using the Mann-Kendall Test.
 - a. Performed for constituents in at least 20% of the data and one annual detectable result greater than the EQL.
 - b. All results less than EQL, detect or nondetect, were replaced with the EQL.
 - c. If a trend existed, another five years of monitoring data would be required before limits could be determined. This would be a stopping point in these analyses for the constituent.
3. Test for normality and log normality using the Shapiro-Wilk Test.
 - a. Performed for constituents detected in at least 85% of the data. Otherwise nonparametric methods as were mandated in the Permit were performed.
 - b. One-half of the EQL was used in place of undetected values for constituents detected in at least 85% of the data overall.
4. Determine UTLs for constituents with at least 85% detects.
 - a. If data are normal (Step 3), use standard normal theory procedures.
 - b. If data are lognormal (Step 3), use the equations in the Permit (established lognormal estimates, see Gibbons [1994] or Gilbert [1987]).
 - c. If data are neither normal nor lognormal, use nonparametric tolerance limits.
5. Determine UTLs for constituents with less than 85% detects.
 - a. Use Poisson tolerance limits for constituents with at least one detectable result greater than the EQL.
 - b. The DML is set to the EQL for constituents with all values not detected or below the EQL.

The details of the hypothesis tests (Kruskal-Wallis, Mann-Kendall and Shapiro-Wilk) are not presented here; the Kruskal-Wallis and Mann-Kendall tests were performed using R software (R Development Core Team 2009). Shapiro-Wilk tests were performed using Analyse-it software (Analyse-it 2008). The UTL methods are described briefly.

The parametric 95% UTL for the 95th percentile, assuming normally distributed data, is $\bar{x} + Ks$, where \bar{x} is the sample mean, s is the sample standard deviation, and K is a constant that depends on the sample size, coverage (percentile), and confidence. K values are tabulated in selected statistical texts (e.g., Gilbert 1987).

The parametric 95% UTL for the 95th percentile, assuming lognormally distributed data, can be calculated using the above formula after calculation of mean and variance of the transformed data and then back transformation, as directed by the Permit:

$$\text{Calculation of transformed data:} \quad \bar{y} = \frac{1}{n} \sum_{i=1}^n \ln(x_i) \quad s_y^2 = \frac{1}{n} \sum_{i=1}^n [\ln(x_i) - \bar{y}]^2$$

$$\text{Back transformation:} \quad \bar{x} = \exp\left(\bar{y} + \frac{s_y^2}{2}\right) \quad s = \sqrt{\exp(2\bar{y} + s_y^2) \times [\exp(s_y^2) - 1]}$$

The Poisson UTL assumes data are comprised of undetected results and a generally few detected values. The limit is calculated in three steps.

$$1. \text{ Calculate} \quad T_n = \frac{1}{2} EQL \times NumND + \sum_{detects} x_i$$

where NumND is the number of nondetects and detects less than the EQL and the summation is over all detects greater than the EQL.

$$2. \text{ Calculate} \quad \lambda_{T_n} = \frac{1}{2n} \chi_{0.05}^2 [2T_n + 2]$$

where $\chi_{0.05}^2 [2T + 2]$ is the 95th percentile of the Chi-square distribution with $[2T + 2]$ degrees of freedom.

$$3. \text{ Find} \quad \chi_{0.05}^2 [2k + 2] \geq 2\lambda_{T_n}$$

and solve for k , which will be set as the UTL.

3. DATA

The WCF Post-Closure Permit monitoring network at one time consisted of nine wells that were sampled for water quality. These wells are CPP-33-1, CPP-55-06, MW-2, MW-5-2, MW-10-2, MW-12-2, MW-18-2, ICPP-2018, and ICPP-2019. Wells MW-12-2 and MW-18-2 had been consistently dry since the effective date of the Permit so these two wells were changed from water quality sampling to water level measurements only via a RCRA Class 3 permit modification request approved by DEQ on June 26, 2007. Thus, there are currently seven wells from which samples are collected for analyses. The seven wells' completion midpoints range from 94-ft bgs to 141 ft bgs. These completions are assumed to occur within one perched water body, allowing combination of sample results. Figure 1 shows the locations of the wells with the size of the point relative to the completion depth midpoint. Well MW-10-2 is the deepest well and is nearest the shallowest well, CPP-33-1. The depth range for well MW-10-2 does not overlap the depth range for any other well. The depth range for well CPP-33-1 overlaps three of the other wells.

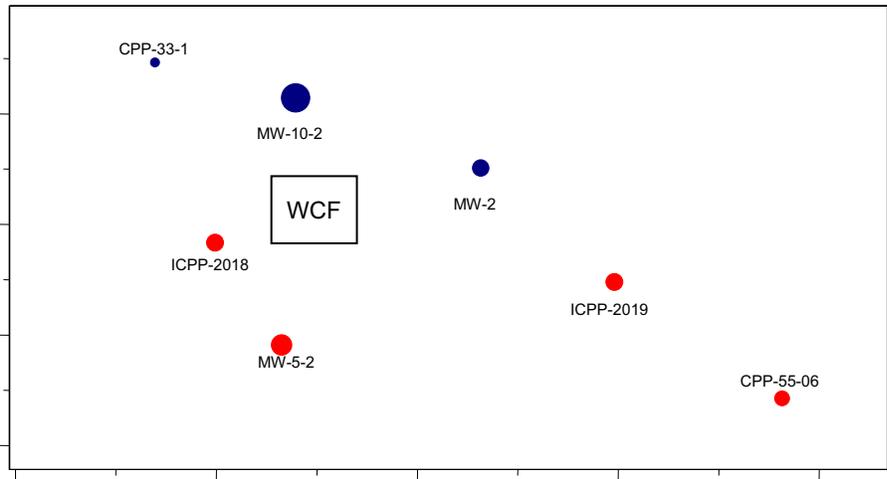


Figure 1. WCF perched water monitoring wells. Upgradient wells are blue and downgradient are red. Increasing size of symbol represents increasing depth of monitoring well sample location.

The upgradient and downgradient wells (Figure 1) were selected from existing wells. Wells ICPP-2018 and MW-5-2 are directly downgradient from the facility while wells ICPP-2019 and CPP-55-06 are farther downgradient.

The number of permit-required constituents to be analyzed from each well has changed through the years that the WCF Post-Closure Permit has been in effect. Thirty-three permit-required constituents for each well (Table 1) were outlined in the original permit (DEQ 2004). However, the list of permit required constituents was reduced to 19 after the 2006 Statistical Report (Medema 2006) via the RCRA Class 3 permit modification request that was approved by DEQ on June 26, 2007 (Monson 2007). Only these 19 permit-required constituents are addressed in this report. The amount of water available from each well has varied occasionally because some monitoring wells have dried up. When this has occurred, less well water was available for sampling, and data from fewer constituents were generated for some wells. An example of this is well MW-10-2. As the water level in this well changed, the entire sample volume could not be collected so some of the constituents could not be analyzed (see footnotes to Table 1). Monitoring wells CPP-55-06 and MW-10-2 were added to the monitoring network via a RCRA Class 2 permit modification request (approved on January 17, 2006), increasing the total number of wells. Thus, the total number of results per constituent has increased due to the increase in the number of wells. Table 1 shows the number of constituents analyzed for each permit prescribed sampling event. Although the data for the October and December 2008 verification and Appendix IX sampling were used to compute the DMLs, these two events are not included in Table 1.

Table 1. Number of constituents analyzed at each well for the 20 sampling events. Thirty-three constituents were required by the WCF Permit prior to August 2007. After August 2007 only 19 constituents were required.

Well	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
CPP-33-1	0	0	0	0	33	0	33	33	33	33	33	33	33	0	0	0	0	0	0	19
CPP-55-06	0	0	0	0	0	33	33	33	33	33	33	33	33	33	33	19	19	19	19	19
ICPP-2018	0	0	0	0	0	0	33	33	33	33	33	33	33	33	33	19	19	19	19	19
ICPP-2019	0	0	0	0	0	0	33	33	33	33	33	33	33	33	33	19	19	19	19	19
MW-2	0	33	33	33	33	33	33	33	33	33	33	33	33	33	33	19	19	19	19	19
MW-5-2	33	33	33	33	33	33	33	33	33	33	33	24 ^c	9 ^b	0	28 ⁱ	0	0	19	0	19
MW-10-2	0	0	0	0	0	27 ^a	9 ^b	24 ^c	30 ^d	20 ^e	23 ^f	27 ^a	30 ^g	25 ^h	26 ^j	19	19	19	19	19

a. Samples not analyzed for 1,4-dioxane, aniline, cyanide, formaldehyde, phenol, or pyridine

b. Only metals were analyzed.

c. Samples not analyzed for metals

d. Samples not analyzed for 1,4-dioxane, cyanide, or formaldehyde.

e. Samples not analyzed for metals, 1,4-dioxane, cyanide, formaldehyde, and isobutyl alcohol.

f. Sample was not analyzed for metals and cyanide.

g. Sample was not analyzed for 1,4-dioxane, formaldehyde, and hydrazine.

h. Sample was not analyzed for 1,4-dioxane, aniline, cyanide, formaldehyde, hydrazine, isobutyl alcohol, phenol, and pyridine.

i. Samples not analyzed for 1,4-dioxane, cyanide, formaldehyde, hydrazine, and isobutyl alcohol.

j. Sample was not analyzed for 1,4-dioxane, aniline, cyanide, formaldehyde, isobutyl alcohol, phenol, and pyridine.

4. ANALYSIS RESULTS AND DETECTION MONITORING LIMITS

The data were pared down to, at most, one observation per well per sampling event. Many duplicates were taken for quality assurance purposes. For each well and sampling event, the primary sample result was retained for data analyses unless only a duplicate value was available. The number of final results used in analyses is provided in Table 2 along with the number of detectable quantities and the number of results exceeding the EQL. Data included in this report were collected from November 2003 through August 2009.

Eleven constituents had detectable results, although only 10 of these constituents have detectable results greater than the EQL (Table 2). Few of the constituents showed a time trend based on the results of the Mann-Kendall test. Figure 2 contains plots of measured concentrations with respect to time for each of the 11 detected constituents.

The 10 constituents with detected results above the EQL were tested for differences among wells using the Kruskal-Wallis non-parametric test (Table 3). Arsenic, barium, chromium, tetrachloroethene, toluene, and 2-butanone (methyl ethyl ketone) concentrations significantly differed among the wells. Lead, mercury, trichloroethene, and carbon disulfide did not significantly differ among wells. The EQLs for the remaining 9 constituents were set as the DMLs.

The Mann-Kendall test was performed on constituents with at least 20% of the results detectable and greater than the EQL. The test was performed by well if the Kruskal-Wallis test was significant for that constituent. The Mann-Kendall test was performed on arsenic (well ICPP-2018), barium for each well, chromium (wells CPP-33-1 and CPP-55-06), tetrachloroethene (well MW-10-2), and toluene (wells CPP-55-06 and MW-10-2). The Mann-Kendall test was significant for barium in well MW-10-2, chromium in well CPP-55-06, and toluene in well CPP-55-06. This means that these analytes in these wells have increased over the past several sampling events. No trends were detected using the Mann-Kendall test in the 2006 statistical analysis (Medema 2006).

The Shapiro-Wilk test for normality was performed on barium for all wells, chromium (wells CPP-33-1, CPP-55-06, ICPP-2019, and MW-2), and tetrachloroethene for well MW-10-2. These were the only constituents with no more than 15% nondetects and with results greater than the EQL. The Shapiro-Wilk test indicated that all of these analytes were normally distributed with the exception of barium for wells ICPP-2018 and MW-5-2, and chromium for wells CPP-55-06, ICPP-2019, and MW-2. Barium was shown to be lognormally distributed in well MW-5-2, as was chromium in well ICPP-2019.

DMLs were determined based on the above results and on permit requirements and are listed in Table 6. Of the 19 constituents, 9 had their DML set as the EQL because all of the values were less than or equal to the EQL. Poisson UTLs were computed for carbon disulfide, lead, mercury, and trichloroethene across all wells (Table 4). Six constituents (arsenic, barium, chromium, tetrachloroethene, toluene, and 2-butanone) required well-specific DMLs. Various statistical methods were employed to generate these DMLs (see Table 5).

Table 2. Summary of monitoring results by constituent and well. The first value in each cell is the number of results. In parentheses are the number of detects followed by the number of detect results greater than the EQL. If none of the data are detected, only a zero is listed in parentheses. The 10 constituents that have at least one detection that exceeds the EQL are in **bold**.

Constituent	CPP-33-1	CPP-55-06	ICPP-2018	ICPP-2019	MW-10-2	MW-2	MW-5-2
1,1,1-Trichloroethane	9 (0)	21 (0)	17 (0)	17 (0)	16 (0)	22 (0)	23 (0)
2-Butanone	9 (0)	21 (0)	17 (1,1)	17 (0)	16 (0)	22 (0)	23 (3,3)
Arsenic	9 (3,1)	19 (0)	20 (8,8)	15 (0)	12 (0)	22 (2,0)	21 (2,1)
Barium	9 (9,9)	19 (19,19)	20 (18,18)	15 (15,15)	12 (12,12)	22 (22,22)	21 (21,21)
Benzene	9 (0)	21 (0)	17 (0)	17 (0)	16 (0)	22 (0)	23 (0)
Cadmium	9 (0)	19 (0)	20 (0)	15 (0)	12 (0)	22 (0)	21 (0)
Carbon Disulfide	9 (1,1)	21 (0)	17 (0)	17 (0)	16 (0)	20 (0)	21 (1,1)
Carbon Tetrachloride	9 (0)	21 (0)	17 (0)	17 (0)	16 (0)	22 (0)	23 (0)
Chloroform	9 (0)	21 (0)	17 (0)	17 (0)	16 (0)	22 (0)	23 (0)
Chromium	9 (9,5)	19 (19,19)	20 (4,0)	15 (15,1)	12 (0)	22 (19,4)	21 (13,2)
Lead	9 (0)	19 (1,0)	20 (0)	15 (0)	12 (0)	22 (1,1)	21 (0)
Mercury	9 (0)	19 (0)	20 (2,0)	15 (0)	12 (0)	22 (2,1)	21 (2,1)
Methylene Chloride	9 (0)	21 (0)	17 (0)	17 (0)	16 (0)	22 (0)	23 (0)
Pyridine	10 (0)	20 (0)	19 (0)	17 (0)	10 (0)	23 (0)	23 (0)
Selenium	9 (4,0)	19 (0)	20 (0)	15 (0)	12 (0)	22 (2,0)	21 (2,0)
Silver	9 (0)	19 (0)	20 (0)	15 (0)	12 (0)	22 (0)	21 (0)
Tetrachloroethene	9 (0)	21 (0)	17 (0)	17 (0)	16 (15,15)	20 (1,0)	21 (0)
Toluene	9 (0)	21 (6,6)	17 (0)	17 (0)	16 (7,7)	22 (1,1)	23 (1,1)
Trichloroethene	9 (1,1)	21 (0)	17 (0)	17 (0)	16 (0)	22 (1,1)	23 (1,1)

Table 3. Kruskal-Wallis test results for differences among wells for constituents with at least one detection exceeding the EQL. If at least 85% of results were detected, then Shapiro-Wilk Test p-value (lognormal p-value in parentheses if non-normal) is given either overall or by well.

Constituent	Kruskal-Wallis Test p-Value	Over All Wells	CPP-33-1	CPP-55-06	ICPP-2018	ICPP-2019	MW-10-2	MW-2	MW-5-2
			>15% NDS ^b	<EQL ^c	>15% NDS ^b	<EQL ^c	<EQL ^c	<EQL ^c	<EQL ^c
Arsenic	0.0184	- ^a	>15% NDS ^b	<EQL ^c	>15% NDS ^b	<EQL ^c	<EQL ^c	<EQL ^c	>15% NDS ^b
Barium	<0.0001	- ^a	0.902	0.066	0.001 (<0.01)	0.622	0.164	0.455	<0.001 (0.067)
Chromium	<0.0001	- ^a	0.552	<0.01 (0.004)	<EQL ^c	0.021 (0.146)	<EQL ^c	<0.001 (0.0002)	>15% NDS ^b
Lead	0.3692	>15% NDS ^b	- ^a	- ^a	- ^a	- ^a	- ^a	- ^a	- ^a
Mercury	0.3478	>15% NDS ^b	- ^a	- ^a	- ^a	- ^a	- ^a	- ^a	- ^a
Trichloroethene	0.4977	>15% NDS ^b	- ^a	- ^a	- ^a	- ^a	- ^a	- ^a	- ^a
Tetrachloroethene	<0.0001	- ^a	<EQL ^c	<EQL ^c	<EQL ^c	<EQL ^c	0.196	<EQL ^c	<EQL ^c
Carbon Disulfide	0.2770	>15% NDS ^b	- ^a	- ^a	- ^a	- ^a	- ^a	- ^a	- ^a
Toluene	0.0005	- ^a	<EQL ^c	>15% NDS ^b	<EQL ^c	<EQL ^c	>15% NDS ^b	>15% NDS ^b	>15% NDS ^b
2-Butanone	<0.0001	- ^a	<EQL ^c	<EQL ^c	>15% NDS ^b	<EQL ^c	<EQL ^c	<EQL ^c	>15% NDS ^b

a. Shapiro-Wilk test not performed for the category (either over all wells or by well) based on results of the Kruskal-Wallis test.

b. No test for distribution was performed for constituents with more than 15% nondetects (NDs).

c. No test for distribution was performed for constituents with all results less than the EQL.

Table 4. Detection monitoring limits for constituents that do not differ among wells and method for determination.

Constituent	Overall DML (µg/L)	Method	Constituent	Overall DML (µg/L)	Method
1,1,1-Trichloroethane	1	EQL	Mercury	1	P
Benzene	1	EQL	Pyridine	5	EQL
Cadmium	1	EQL	Selenium	20	EQL
Carbon Disulfide	2.5	P	Silver	10	EQL
Carbon Tetrachloride	1	EQL	Trichloroethene	2.5	P
Chloroform	1	EQL	Methylene Chloride	1	EQL
Lead	3	P			

P = Poisson upper tolerance limit
 EQL = estimated quantitation limit

Table 5. Detection monitoring limits ($\mu\text{g/L}$) for constituents that differ among wells and method for determination.

	CPP-33-1		CPP-55-06		ICPP-2018		ICPP-2019		MW-10-2		MW-2		MW-5-2	
Arsenic	7.5	P	5	EQL	9	P	5	EQL	5	EQL	5	EQL	6	P
Barium	244	N	269	N	477	NP	237	N	282	N	370	N	778	LN
Chromium	22.3	N	14.7	NP	10	EQL	10 ^a	EQL	10	EQL	41.9	NP	11.5	P
Tetrachloroethene	1	EQL	1	EQL	1	EQL	1	EQL	5.91	N	1	EQL	1	EQL
Toluene	1	EQL	24	P	1	EQL	1	EQL	62	P	2.3	P	2.5	P
2-Butanone	5	EQL	5	EQL	6	P	5	EQL	5	EQL	5	EQL	5.5	P

P = Poisson upper tolerance limit
 N = normal upper tolerance limit
 LN = lognormal upper tolerance limit
 EQL = estimated quantitation limit
 NP = nonparametric upper tolerance limit
 a. Distributional tests indicated that the DML should be computed using lognormal methods. Therefore, the lognormal DML was less than the EQL so the EQL is used as the DML.

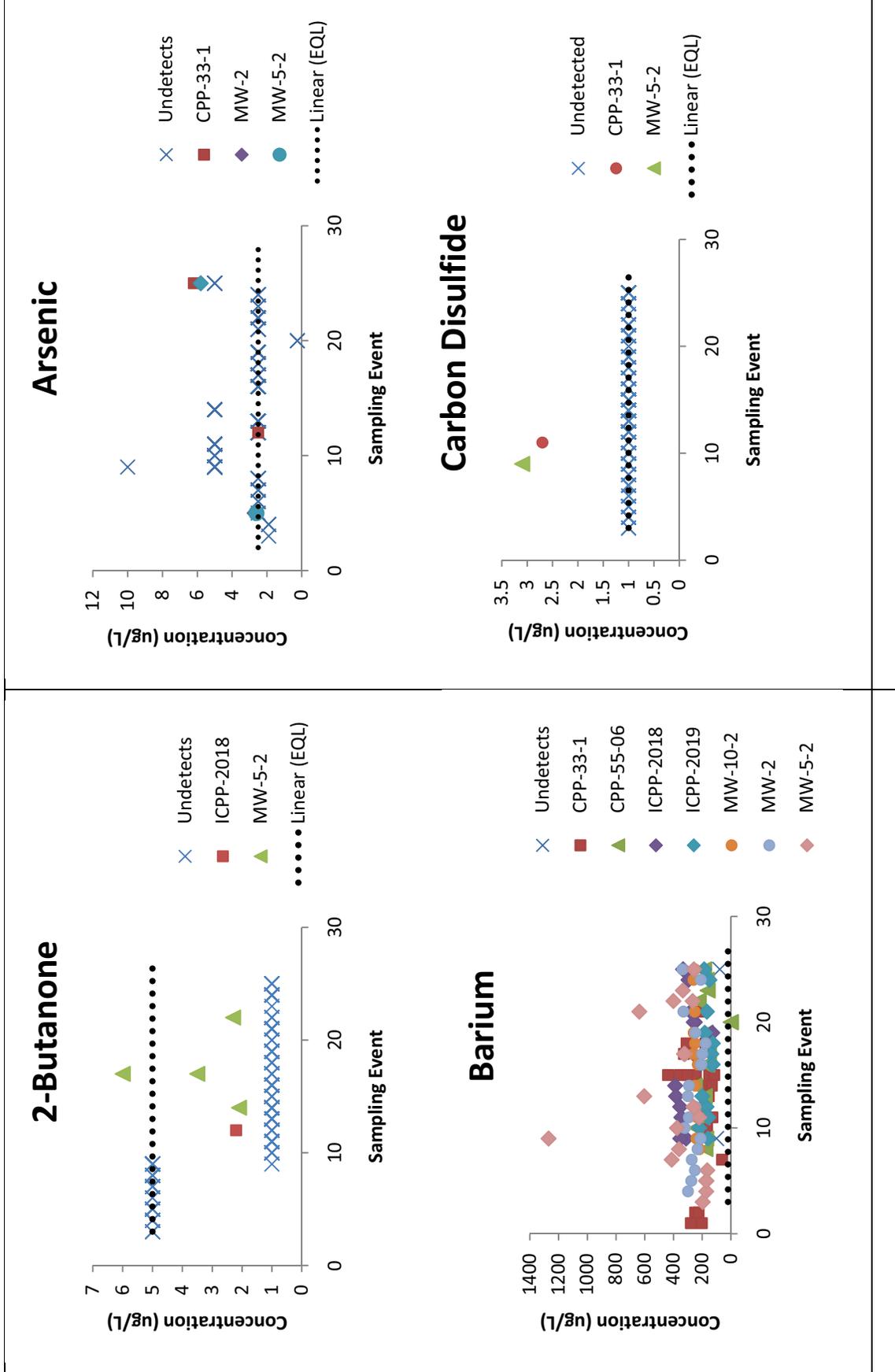
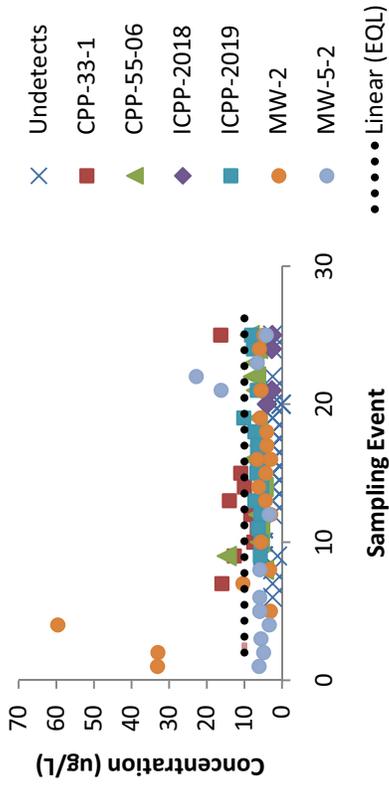
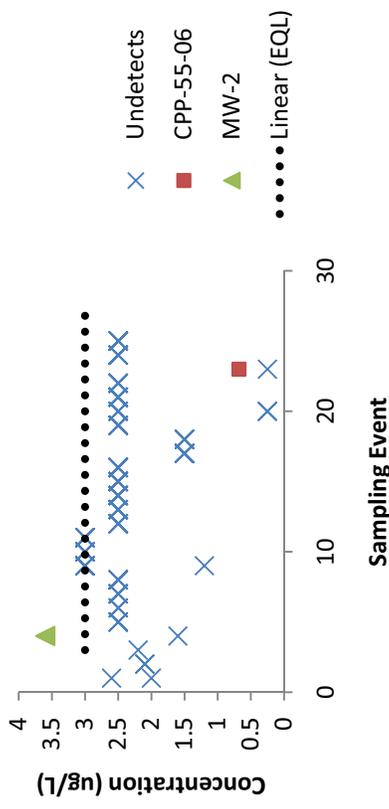


Figure 2. Concentrations by sampling event number for constituents with at least one detected result (even if less than the EQL).

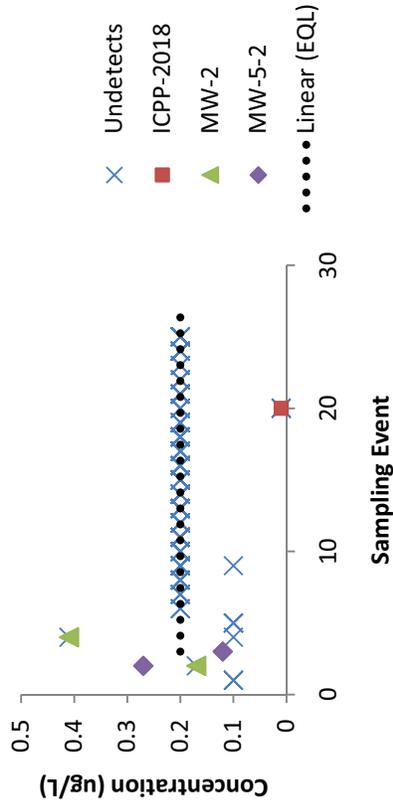
Chromium



Lead



Mercury



Selenium

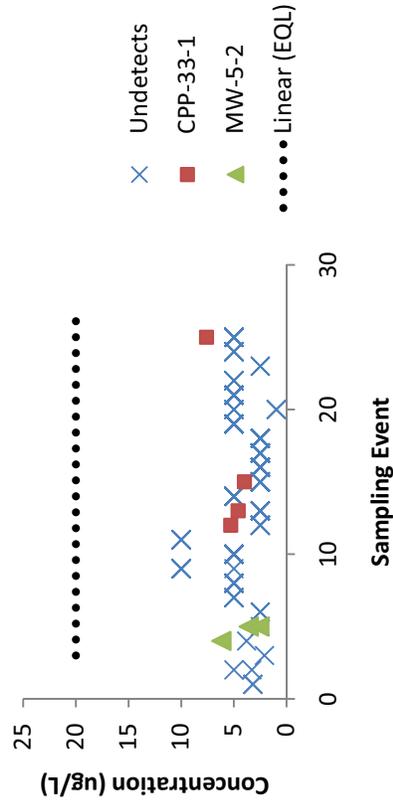
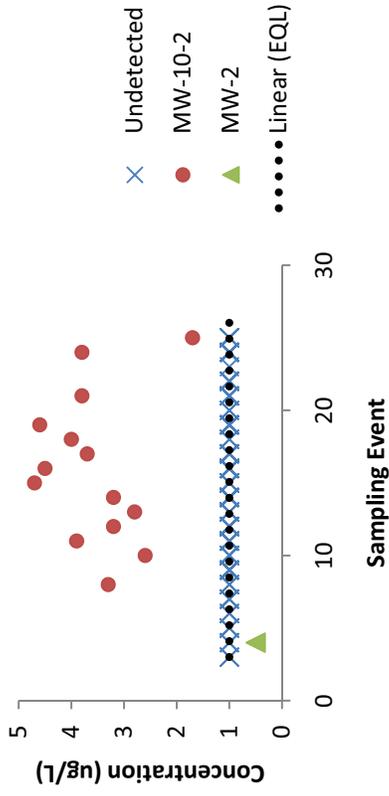
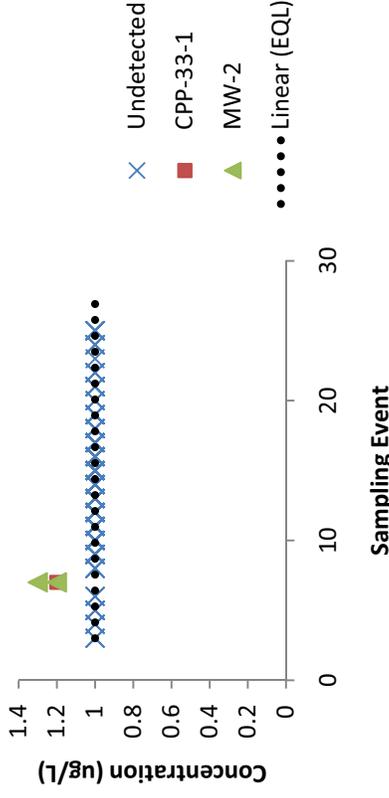


Figure 2 (cont.). Concentrations by sampling event for constituents with at least one detected result (even if less than the EQL).

Tetrachloroethene



Trichloroethene



Toluene

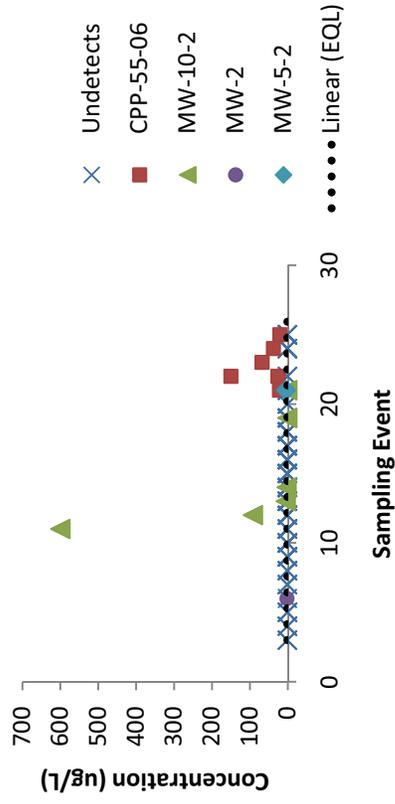


Figure 2 (cont). Concentrations by sampling event for constituents with at least one detected result (even if less than the EQL).

5. DISCUSSION

DMLs were calculated according to Permit requirements. Of the 19 constituents that are required by Permit, 9 have DMLs set at the EQL. Four of the constituents (carbon disulfide, lead, mercury, and trichloroethene) had at least one value detected above the EQL that had a DML computed across all wells. Six constituents (arsenic, barium, chromium, tetrachloroethene, toluene, and 2-butanone) had at least one result above the EQL that had well-specific DMLs calculated.

Three distributions (normal, lognormal, and non-parametric) were used to describe the distribution of the data and to determine the appropriate UTL for each constituent. Barium results are lognormally distributed in well MW-5-2 and are non-parametric in well ICPP-2018. The barium data in all other wells are normally distributed. Chromium data from well CPP-33-1 are normally distributed, chromium data from wells CPP-55-06 and MW-2 are non-parametric, and chromium data from well ICPP-2019 are lognormally distributed. Tetrachloroethene data from well MW-10-2 are normally distributed. Because the normal distribution is symmetric without long flat tails, the UTL will be close to the maximum observed values. The lognormal distribution is skewed toward larger concentrations; it has a long flat tail to the right. This long tail dictates the UTL. Determined distributions were used to determine the correct UTL as outlined in Section 2.

Poisson UTLs were computed for constituents with less than 85% detected values. The Poisson distribution describes rare occurrences; results with positive detections are rare occurrences for many constituents. The UTL is based on the number of nondetect values and the results for the positive detections. For constituents with mostly nondetects or few very large detects, the UTL can be considerably less than the maximum observed results. For toluene in well MW-10-2 the maximum result is 600 µg/L but the calculated DML is 58 µg/L. The reason for the difference is that the maximum concentration is 600 times the EQL of 1 µg/L. Four of the six detected values (68, 150, 26, and 38 µg/L) for the toluene data in well CPP-55-06 exceed the DML listed in Table 5 of 23.5 µg/L. The reason that the computed DML is so much smaller than the maximum is that the 15 nondetects overwhelm the few detected values that are just over the DML.

The DMLs are set to represent the background status of the perched water from the start of sampling in November of 2003 until the present. Although the Poisson distribution is appropriate for constituents with many nondetects, having a DML that is exceeded by the background data is troublesome because it is likely that the DML will often be exceeded when there is no release. An alternative would be to set the DML to the maximum of the calculated DML, using methods from the Permit and the maximum observed result. For this report, the DML for constituents whose maximum values are considerably larger than the computed UTL, the DML is changed to the maximum value. Final proposed DMLs are listed in Table 6.

Increased background concentrations of arsenic, chromium, and toluene prompted the development of new DMLs. Comparison of the previous DMLs (Medema 2006) to the newly computed DMLs shows that the new DMLs for arsenic, chromium, toluene, and 2-butanone have increased. The previous DML for arsenic was set at the EQL. Current calculations indicate that arsenic concentrations differ between wells and the DMLs for wells CPP-33-1, ICPP-2018, and MW-5-2 are greater than the EQL. New data also indicate that chromium concentrations differ between wells. DMLs for chromium have increased in wells CPP-33-1, CPP-55-06, and MW-2. Toluene DMLs were previously specified by well, and statistical analysis indicates that this is still appropriate. The previous DML for 2-butanone was set as the EQL for all wells. The current analysis shows that the data differ between wells. The DML was still set as the EQL for all of the wells except for well MW-5-2 which was computed using a Poisson UTL. DMLs for toluene increased in wells CPP-55-06, MW-10-2, and MW-5-2. These increases indicate that background concentrations of arsenic, chromium, toluene, and 2-butanone have indeed increased in some wells.

6. PRESENTATION OF FINAL DETECTION MONITORING LIMITS

Tables 4 and 5 list the DMLs computed using the methods outlined in Section 2. However, several of the maximum reported values far exceeded the DMLs. It was determined that the maximum reported value should be set as the DML when this occurred to ensure DMLs are not regularly exceeded as a result of natural fluctuations in constituent concentration. Table 6 lists the DMLs that should be used for groundwater monitoring.

Table 6. Proposed constituent analyte list, associated estimated quantitation limits, groundwater protection standards, and WCF detection monitoring limits.

Constituent	EQL (ug/L)	GPS (ug/L)	DML (ug/L)
Arsenic	5	20	*note
Barium	20	4000	*note
Cadmium	1	10	1
Chromium	10	200	*note
Lead	3	30	3
Mercury	0.2	4	1
Selenium	20	100	20
Silver	10	200	10
1,1,1-Trichloroethane	1	400	1
Carbon Tetrachloride	1	10	1
Trichloroethene	1	10	2.5
Tetrachloroethene	1	10	*note
Carbon Disulfide	1	2000	2.5
Toluene	1	2000	*note
Pyridine	5	720	5
2-Butanone (methyl ethyl ketone)	5	38000	*note
Benzene	1	10	1
Chloroform	1	200	1
Methylene Chloride	1	86	1

*Note – Constituent was analyzed by well, and DMLs (ug/L) are listed in the columns below.

Table 6 (cont.)

	CPP-33-1	CPP-55-06	ICPP-2018	ICPP-2019	MW-10-2	MW-2	MW-5-2
Arsenic	7.5	5	9	5	5	5	6
Barium	244	269	477	237	282	370	778
Chromium	22.3	14.7	10	10	10	59.6	22.8
Tetrachloroethene	1	1	1	1	5.91	1	1
Toluene	1	150 ^a	1	1	600 ^a	2.3	4.5 ^a
2-Butanone	5	5	6	5	5	5	5.5

a. DML is the maximum detected value.

7. CONCLUSIONS

The statistical analysis of 20 quarterly and semi-annual sampling events and 2 Appendix IX sampling events of WCF monitoring data combined with an evaluation of constituents present in the INTEC liquid waste management system results in 19 constituents and associated updated detection monitoring limits (Table 6) for which ICP proposes continued monitoring semi-annually.

8. REFERENCES

- Analyse-it, 2008, Analyse-it for Microsoft Excel, Version 2.11, <http://www.analyse-it.com/>: Analyse-it Software, Ltd.
- Bullock, R. E., DEQ, letter to J. E. Medema, DOE-ID, January 29, 2007, "Receipt of the November 17, 2006, Permit Condition III.I.2. (Ground Water Statistical Analysis) Report for the Waste Calcining Facility at INTEC on Idaho National Laboratory (INL-EPA ID No. ID4890008952)," CCN 304311.
- Bullock, R. E., DEQ, letter to N. Brooks, DOE-ID, June 9, 2009, "Receipt of the Semiannual (Permit Conditions III.H. and I. U.) Report for the Waste Calcining Facility at INTEC on Idaho National Laboratory (INL-EPA ID No. ID4890008952)," CCN 308691.
- DEQ (Department of Environmental Quality), 2004, *HWMA/RCRA Post-Closure Permit for the Idaho Nuclear Technology and Engineering Center Waste Calcine Facility at the Idaho National Engineering and Environmental Laboratory*, EPA ID No. ID4890008952, Idaho Department of Environmental Quality, as modified June 10, 2004, and as modified January 17, 2006.
- DEQ, 2007, *HWMA/RCRA Post-Closure Permit for the Idaho Nuclear Technology and Engineering Center Waste Calcine Facility at the Idaho National Engineering and Environmental Laboratory*, EPA ID No. ID4890008952, Idaho Department of Environmental Quality, as modified June 25, 2007.
- Gibbons, R.D., 1994, *Statistical Methods for Groundwater Monitoring*, John Wiley & Sons, New York, 286 pages.

Gilbert, R.O., 1987, *Statistical Method for Environmental Pollution Monitoring*, Van Nostrand Reinhold, New York, 320 pages.

Medema, J. E., DOE, letter to B. R. Monson, DEQ, December 11, 2006, “Permit Condition III.I.2 Report for the Volume 21 HWMA/RCRA Post-Closure Permit for the Waste Calcining Facility at the Idaho Nuclear Technology and Engineering Center, Calculation of Background Data Report (OS-ETSD-06-157),” CCN 304005.

Monson, B. R., DEQ, letter to J. E. Medema, DOE-ID, and K. McNeel, ICP, June 26, 2007, “Approval of a Class 3 Permit Modification Addressing Ground Water Monitoring for the Waste Calcining Facility at INTEC on Idaho National Laboratory (INL EPA ID NO. ID4890008952),” CCN 305128.

R Development Core Team, 2009, R: A language and environment for statistical computing, R Foundation for Statistical Computing, Vienna, Austria, ISBN 3-900051-07-0, URL <http://www.R-project.org>.

**HWMA/RCRA INTEC POST-CLOSURE PERMIT
FOR THE
IDAHO NATIONAL LABORATORY**

**Volume 21
Waste Calcining Facility and
CPP-601/627/640**

**Attachment 3
Geologic and Hydrogeologic Characterization of the
INEEL and INTEC**

Revision Date: August 25, 2011

Geologic and Hydrogeologic Characterization of the INEEL and INTEC

The characterization provided in this appendix is from the *Comprehensive RI/FS for the Idaho Chemical Processing Plant OU 3-13 at the INEEL – Part A, RI/BRA Report*, DOE/ID-10534, U.S. Department of Energy Idaho Operations Office, Idaho Falls, Idaho, November 1997.

2. ENVIRONMENTAL SETTING OF THE ICPP

The INEEL occupies 2,305 km² (890 mi²) on the northern portion of the Eastern Snake River Plain (ESRP) in southeastern Idaho (Figure 1-1). The eastern boundary of the INEEL is located approximately 51 km (32 mi) west of Idaho Falls. The INEEL is bounded on the northwest by the Lost River, Lemhi, and Beaverhead mountain ranges. The remainder of the INEEL is bounded by the ESRP.

The INEEL is located in a topographically closed drainage basin. Three intermittent streams, the Big Lost River, Little Lost River, and Birch Creek flow onto the INEEL. These streams originate in local mountain drainages and much of the water is diverted or stored upstream of the INEEL for use in irrigation. The Big Lost River is the principal surface water feature on the INEEL. Several storage and diversion systems exist on the Big Lost River. The Mackay Reservoir is located about 48-km (30-mi) upstream from Arco, Idaho, and has a storage capacity of 44,500 acre-ft (Van Haften et al., 1984). A flood diversion system was constructed on the INEEL in 1958 to protect INEEL facilities from potential flooding of the Big Lost River. The system uses a low dam to divert river flow into a series of spreading areas located in the southwestern portion of the INEEL. The capacity of the diversion system was expanded in 1984, and the system is capable of accommodating flows of up to 263 m³/sec (9,300 ft³/sec) (Bennett, 1986).

Except for evapotranspiration, most of the water in the Big Lost River, Little Lost River, and Birch Creek is recharged to the ground through irrigation or infiltration. Water from the Big Lost River infiltrates into the material beneath the river and into the SRPA. The volume of this infiltration is significant during wet years. Zones of perched water have been identified along the Big Lost River when it contains water. The extent and volume of these perched water zones is not completely known.

The Snake River Plain Aquifer (SRPA) underlies the INEEL and is a valuable regional resource in southeastern Idaho, extending approximately 320 km (200 mi) from Ashton, Idaho, in the northeast to Hagerman, Idaho, on the southwest. The aquifer consists of a series of basalt flows with interbedded sedimentary deposits and pyroclastic materials. INEEL-wide water-level data compiled in July 1985 indicated the general direction of groundwater flow across the INEEL was toward the south-southwest at an average gradient of about 0.8 m/km (4 ft/mi) (Bartholomay et al., 1997). Horizontal groundwater flow rates in the SRPA have been estimated to vary from 0.3 to 7.6 m/day (1 to 25 ft/day) (Kaminsky et al., 1994; Robertson et al., 1974). The SRPA was designated as a sole source aquifer by the EPA (56 FR 50634, October 7, 1991) because it is the only viable source of drinking water for many communities on the ESRP. The aquifer is the source of all water used at the INEEL.

2.1 Surface Features

The land surface of the INEEL is characterized as rolling to broken, typical of basalt terrain. The predominant relief on the INEEL is the result of volcanic buttes and unevenly surfaced and fissured basalt flows. Elevations on the INEEL range from 1,585 m (5,200 ft) in the northeast to 1,448 m (4,750 ft) in the southwest with the average being approximately 1,520 m (5,000 ft). A broad ridge on the ESRP extends through the Big Southern, Middle, and East Buttes on the southern portion of the INEEL, effectively separating drainage from the mountains in the north from that of the Snake River to the south. The Big Lost River flows onto the INEEL in the southwest and turns north, culminating in a series of playa lakes where it infiltrates, recharging the SRPA. The majority of the land within the boundaries of the INEEL is relatively undisturbed and covered with sagebrush. Three public highways traverse the INEEL.

The ICPP is located in the south-central portion of the INEEL. Elevation at the ICPP is 1,498 m (4,917 ft), and the facility's northwest corner is actually truncated by the current channel of the Big Lost River. Gravelly, medium-to-coarse textured soils derived from alluvial deposits occur in the vicinity of the ICPP. The underlying basalt is covered with as much as 18.2 m (60 ft) of these soils and the land surface is flat and covered with sagebrush.

2.2 Demographic and Land Use

2.2.1 Demography (On-Site and Off-Site Populations)

The nearest INEEL boundaries are 51 km (32 mi) west of Idaho Falls, 37-km (23-mi) northwest of Blackfoot, 71 km (44 mi) northwest of Pocatello, and 11 km (7 mi) east of Arco, Idaho. With a population of approximately 1100, Arco is the largest boundary community in the area surrounding the Site. Approximately 121,500 people reside within a radius of 80 km (50 mi) of the Site's operational center, which is the TRA-ICPP area. There are no residents within 16 km (10 mi) of that center with Atomic City (population 25) being the closest boundary community.

2.2.2 Land Use (Current and Future)

As with virtually all of the sites in the DOE complex, the INEEL is making major changes in the use of its land. Until recent years, land use planning was driven by nuclear energy research and defense-related projects. Presently, however, the shutdown of facilities and environmental restoration of the land play important roles in land use planning.

The primary use of INEEL lands is to support facility operations and act as buffer and safety zones around the facilities. Virtually all of the work at the INEEL is performed within the site's primary facility areas [i.e., Central Facilities Area (CFA), Test Reactor Area (TRA), ICPP]. These areas, however, occupy only about 2% of the total INEEL land area. Other land uses include environmental research, ecological preservation, and socio-cultural preservation. INEEL land is also used for grazing, recreation, and connecting infrastructure, with the remaining land being essentially undisturbed.

Currently the ICPP has a total land area of 200 acres and 106,070 m² (1,141,711 ft²) of facilities. Land at ICPP is used to store spent nuclear fuels and radioactive wastes for the DOE. Other uses include a coal-fired generating plant, Tank Farm waste storage facility, and wastewater treatment/disposal facilities. Before April 1992, spent nuclear fuels were reprocessed at the plant. With the DOE's decision to cease reprocessing operations, however, the need to store greater quantities of these fuels increased.

As the shutdown of INEEL facilities and the environmental restoration of INEEL land play greater roles, environmental studies are increasingly important elements in land use planning. These studies provide INEEL scientists, engineers, and planners with information about how nuclear reactor research has affected the environment and the extent of remediation necessary to restore the land.

To facilitate decisions about environmental restoration activities at the INEEL, DOE-ID conducted analyses in 1994 to project reasonable land use scenarios at the INEEL for the next 100 years. These analyses, conducted with extensive public involvement, resulted in the development of specific issues, assumptions, and constraints that guided the generation of facility and land use scenarios for the next 25, 50,

75, and 100 years, as published in the *Long-Term Land Use Future Scenarios for the Idaho National Engineering Laboratory* (DOE-ID, 1995). Refer to that document for a listing of participating individuals/organizations, comments received, and an explanation of the process for producing future land use scenarios. The INEEL Site Specific Advisory Board reviewed and provided input to the creation of the future use scenarios. EPA and IDHW did not review or comment on the document.

The planning assumptions for the future use scenarios include:

- The INEEL will remain under DOE management and control for at least the next 100 years.
- Advances in DOE and private-sector research will result in the obsolescence of existing facilities. It is further assumed that new facilities will need to be constructed in response to the need to provide state-of-the-art research facilities. Other programs, however, will be discontinued after the facilities become obsolete.
- New construction may include structures in existing facility areas; other new construction may require the development of new facility areas.
- As facilities become obsolete, decontamination and decommissioning will likely be required. Similarly, contaminated areas will require remediation.
- To the extent practical, new development will be encouraged in developed facility areas to take advantage of existing physical and service infrastructures. Such redevelopment will reduce environmental degradation associated with construction activities in previously undeveloped areas.
- The CFA will remain the focal area for support and infrastructure activities.
- The life expectancy of current and new facilities is expected to range between 30 and 50 years. The decontamination and decommissioning process will commence after closure of a facility, assuming no new missions for a facility are articulated.
- Environmental restoration and waste management activities will continue. Cleanup of hazardous, mixed, and low-level waste sites is expected to be completed within 10 years after completion of a record of decision for the activities mandated under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).
- Research and development facilities will be expanded to accommodate "new frontier research" such as fusion, transportation, space exploration, nuclear propulsion, alternative fuels, and advanced cleanup technologies.
- Research at the INEEL will focus increasingly on advances in nuclear medical research and the production of isotopes used in medicine, research, and industry. In addition, other specific research initiatives (i.e., alternative fuels, advanced environmental restoration and waste management technology, transportation) will gain importance at the INEEL. To support such efforts, cooperative partnerships between the public and private sectors will be developed to

achieve mutual goals. This could result in the reuse of INEEL facilities by private sector interests, supplemented with technology support by INEEL personnel.

- The INEEL will continually be prepared to support defense-related operations (i.e., manufacturing, testing, support) in response to the ever-changing military climate throughout the world. Although the INEEL will continue to be used for defense-related research, other nuclear research will receive an increasing emphasis in years to come.
- Regional development trends will be closely related to activities at the INEEL. For example, new housing development will be generated by increases in onsite employment because the INEEL is a major regional employer. Conversely, a major decrease in onsite employment will hamper the regional housing market.
- No residential development (i.e., housing) will occur within INEEL boundaries; however, grazing will be allowed to continue in the buffer area.
- No new, major, private developments (residential or nonresidential) are expected in areas adjacent to the INEEL site. There is uncertainty about the applicability of this assumption to privately held land. Beyond 25 to 50 years, there is less certainty about this assumption.
- An 890 mi² site dedicated to nuclear research, development, testing, and evaluation is irreplaceable. It was therefore assumed that it is extremely unlikely that a similar DOE facility could be sited at any other location.

The ICPP was one of the facilities that had a future use scenario projected. The scenarios are broken down into the present situation, as well as for the next 25, 50, 75, and 100 years.

Present:	Interim storage of SNFs; disposition of fuels; managing waste and improving waste and water management techniques.
25-Year:	Continue use as industrial area; planned new waste treatment facility.
50-Year:	Approaching end of useful life if no new mission identified; D&D with all or selected areas for restricted industrial use.
75-Year:	Standby mode for restricted industrial use; reuse permitted, but no new development outside existing fence line.
100-Year:	Continuation as a restricted industrial area.

These planning assumptions and the constraints just described were used to project the most likely INEEL configuration. Over time, the planning assumptions and resulting long-term scenarios may need to be revised due to unforeseen developments.

2.3 Surface Water Recharge

Surface water recharge to the groundwater beneath the ICPP is provided through natural precipitation, human made sources (i.e., surface percolation ponds, lawn watering, steam injection wells, leaking water pipes), and occasionally during wet years from the Big Lost River. These water sources have resulted in the formation of several perched water zones beneath the ICPP at depths ranging from 12.2 to 115 m (40 to 377 ft) (Thomas, 1988; Chipman, 1989).

2.3.1 Climatology and Meteorology

The INEEL is located on the Snake River Plain, which is a large flat valley surrounded by mountains. Air masses cross this mountain barrier before entering the Snake River Plain. Most of the moisture is lost in crossing the mountain barrier; thus, the INEEL has little annual rainfall and is classified as semiarid.

The arid climate permits intense solar heating of the ground surface during the day and rapid cooling at night, especially during the summer months. In general, the INEEL has a large diurnal variation in temperature at ground level.

Mountain ranges to the north block many of the shallow, intensely cold, air masses moving out of Canada in the winter months. The climate in eastern Idaho is a more moderate climate than the climate in areas at similar latitudes east of the continental divide. The mountains can also serve as a barrier and cold air masses that do enter the valley are frequently held in place for a week or longer.

The surrounding mountains tend to channel the winds in the region. The prevailing winds on the Snake River Plain are from the southwest and windspeeds are frequently greater than 8 km/hr (5 mi/hr). The second most frequent winds are from the northeast.

Meteorological data have been collected at over 40 locations on or near the INEEL since 1949. The weather station at the CFA was the first onsite station and appears on National Climatic Center records as Idaho Falls 46 W. There are 27 active meteorological stations in operation on or near the INEEL. Most of the meteorological monitoring within 80 km (50 mi) of the INEEL is conducted by the National Oceanic and Atmospheric Administration (NOAA) Air Resources Laboratories. A large database has been compiled and analyzed by NOAA (Clawson et al., 1989).

An overview of climatological data is available from summaries of temperatures, precipitation, snowfall and snow depth, windspeed and direction, and moisture content of the air. Much of the summary information comes from the monitoring station at CFA, which is located approximately 5 km (3 mi) south of the ICPP. Differences in climate between the facilities would be small local variations.

Temperatures at the INEEL vary widely over the course of the year. Records for CFA indicate that the highest daily maximum temperature occurring between 1950 and 1988 was 38°C (101°F) and the lowest temperature recorded at CFA was -44°C (-47°F). The highest daily average temperature over the course of a month was 28°C (83°F) and the lowest daily average was -33°C (-28°F). Temperatures also vary greatly over the course of the day and, on average, span a 17°C (30°F) range. The maximum temperature range in 1 day at CFA spanned 50°C (90°F).

Average annual precipitation at the CFA (1950 to 1988 inclusive) is 22.1 cm (8.7 in.). The highest annual precipitation was 36.6 cm (14.4 in.) and the lowest was 11.4 cm (4.5 in.). Over the years, the wettest months have been May and June. However, recorded precipitation amounts of less than 0.3 cm (0.1 in.) have occurred in all months. Individual months have had as much as 11.2 cm (4.4 in.) of precipitation or as little as no precipitation. The greatest amount of precipitation at the CFA in a 1-hr period or a 24-hr period, is 1.3 cm (0.5 in.) and 4.1 cm (1.6 in.), respectively, occurred in June. The monthly precipitation totals for CFA from March 1950 through November, 1995 are provided in Table 2-1.

From 1950 to 1988, the CFA averaged 70.1 cm (27.6 in.) of snow per year. The maximum snowfall in a year was 151.6 cm (59.7 in.). Maximum snowfall occurs in December and January. Little snow falls from May through October. June, July, and August are the only months with no recorded snowfall between 1950 and 1988. The maximum snowfall in a 24-hr period was 21.8 cm (8.6 in.), which occurred in March. A snowfall of 21.6 cm (8.5 in.) in a 24-hr period is recorded for January. The lowest annual snowfall at the CFA was 17.3 cm (6.8 in.). All months have gone without snowfall in at least 1 year during the recording period.

January and February have the highest average maximum snow depth at 10.4 cm (4.1 in.). The highest recorded maximum snow depth was 51 cm (20 in.) and occurred in March. December, January, and February also have had snow depths greater than 28 cm (11 in.).

Average relative humidities at the CFA range from 30 to 70%. Relative humidities typically are higher during the colder months (November through March). The relationship between relative humidity and temperature makes high relative humidities possible from small amounts of moisture when the temperature is low. Consequently, winter months may have high relative humidities from very low moisture contents. Relative humidities on summer afternoons are frequently lower than 15% and can be lower than 5%. Maximum absolute humidities reach 100% in all months except July. Average minimum absolute humidities are below 16% in all months and below 10% from April through October.

From 1955 through 1961, the average air temperature in January (the coldest month) was -8.6°C (16.5°F) and the average dewpoint was -13.7°C (7.4°F). During July, the warmest month, the temperature averaged 20.6°C (69.0°F) and the dewpoint averaged 0.8°C (33.5°F). The annual average temperature was 5.9°C (42.6°F) and the dewpoint was -6.4°C (20.4°F). Low dewpoints and relative humidities indicate the environment at the INEEL is quite arid.

The most frequent winds at the ICPP are southwesterly. Other significant components are westerly and northeasterly. Most windspeeds are less than 5.0 m/sec (11 mph). The peak wind gust at the CFA [6.1 m (20 ft) level] was 126 km/hr (78 mph), which occurred in January. All months have seen wind gusts of 97 km/hr (60 mph) or greater. At 76.2 m (250 ft), the peak wind gust at CFA was 135 km/hr (84 mph) and occurred in March.

Severe weather on the INEEL consists of thunderstorms, tornadoes, and funnel clouds. On the average, two to three thunderstorms occur during each of the summer months. Small hail may accompany the thunderstorms but hail damage has not been reported at the INEEL. Occasionally, rain in excess of the average monthly total precipitation may be recorded at a monitoring station on the INEEL as a result of a single thunderstorm. Nevertheless, precipitation from thunderstorms on the INEEL is generally light and may evaporate before reaching the ground.

Table 2-1. CFA precipitation totals for March 1950 through November 1995 (NOAA database).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1950	—	—	1.05	0.14	0.28	0.98	0.10	1.08	0.28	0.16	0.30	0.55	(4.92)
1951	0.76	0.58	0.60	0.30	0.56	0.15	0.58	2.17	0.00	0.69	0.33	0.72	7.44
1952	0.61	1.04	0.41	0.03	0.80	0.91	0.38	0.29	0.12	0.00	0.37	0.67	5.63
1953	0.45	0.25	0.40	0.64	1.78	0.80	0.00	0.18	0.01	0.41	0.08	0.25	5.25
1954	0.51	0.87	0.55	0.46	0.45	2.74	0.16	0.39	0.15	0.07	0.65	0.40	7.40
1955	0.47	0.21	0.20	0.49	0.81	1.03	0.65	0.19	0.21	0.20	0.24	2.06	6.76
1956	0.80	0.31	0.27	0.35	1.63	0.02	0.17	0.02	0.28	1.53	0.28	0.15	5.81
1957	1.15	1.12	0.82	1.43	4.42	0.83	0.47	0.11	0.06	1.03	0.39	0.47	12.30
1958	0.85	0.87	0.93	1.45	0.79	0.48	0.45	0.20	0.66	0.00	0.43	0.23	7.34
1959	0.52	0.49	0.16	0.04	1.82	1.45	0.05	1.52	0.74	0.05	0.00	1.13	7.97
1960	0.66	1.33	0.71	0.45	0.70	1.38	0.07	1.20	0.29	0.23	1.02	0.12	8.16
1961	0.00	0.80	0.12	0.54	1.55	0.54	0.20	0.96	3.52	0.96	0.31	0.54	10.04
1962	0.80	2.40	0.58	0.23	1.91	1.77	0.72	0.03	1.21	0.29	0.11	0.25	10.30
1963	1.04	0.84	0.74	2.50	2.30	2.84	0.00	0.89	1.39	0.36	0.98	0.52	14.40
1964	0.47	0.22	0.81	1.17	1.05	2.23	0.49	0.26	0.00	0.74	1.53	3.43	12.40
1965	1.56	0.15	0.07	1.54	1.32	1.86	0.07	0.54	0.20	0.03	1.25	0.36	8.95
1966	0.14	0.63	0.24	0.30	0.84	0.12	0.25	0.11	0.47	0.23	0.29	0.88	4.50
1967	1.39	0.01	0.54	0.86	0.69	2.58	0.56	0.18	0.03	0.52	0.37	0.63	8.36
1968	0.55	0.20	0.33	0.11	1.49	3.89	0.05	3.27	0.85	0.34	0.94	1.23	13.25
1969	2.56	0.93	0.08	0.08	0.07	2.39	0.02	0.00	0.29	0.20	1.02	0.50	8.14
1970	0.62	0.05	0.83	1.26	1.28	0.96	0.51	0.50	0.53	0.35	1.53	0.97	9.39
1971	0.56	0.71	0.70	0.43	1.48	1.05	0.11	0.43	2.08	1.07	0.78	1.54	10.94
1972	0.48	0.09	0.25	0.35	0.66	1.41	0.34	0.78	0.48	0.75	0.76	1.08	7.43
1973	0.69	0.76	0.75	0.41	0.50	1.04	1.70	0.15	1.09	0.62	1.30	1.18	10.19
1974	0.66	0.36	1.44	0.35	0.72	0.49	0.03	0.71	0.01	1.34	0.42	1.19	7.72
1975	0.76	0.94	1.20	1.99	0.98	0.89	0.61	0.14	0.00	1.16	0.50	0.16	9.33
1976	0.45	0.88	0.50	1.66	1.00	0.79	0.18	0.82	0.96	0.51	0.00	0.05	7.80
1977	0.60	0.16	0.32	0.00	1.55	1.07	0.45	0.25	0.31	0.00	0.70	0.97	6.38
1978	1.00	1.05	0.66	1.32	0.74	0.26	0.31	0.17	0.96	0.09	0.48	0.44	7.48
1979	0.92	0.80	0.79	0.06	1.41	0.39	1.33	0.90	0.06	0.65	0.60	0.18	8.09

Table 2-1. (continued).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1980	0.91	0.84	0.24	0.48	2.24	1.26	0.59	0.35	1.52	0.52	0.20	0.73	9.88
1981	0.61	0.69	0.94	1.83	1.81	0.25	0.17	0.07	0.14	0.93	1.34	0.67	9.45
1982	0.53	0.28	1.25	0.42	1.03	0.71	0.51	0.76	0.92	0.95	0.66	1.88	9.90
1983	0.20	0.19	1.08	0.42	0.40	1.75	1.31	0.88	1.07	1.67	1.18	0.81	10.96
1984	0.03	0.58	0.75	1.45	0.71	2.86	2.09	0.43	0.25	0.44	1.43	0.26	11.28
1985	0.98	0.50	0.76	0.06	0.91	0.40	2.29	0.02	1.67	0.28	1.07	0.63	9.57
1986	0.31	2.36	1.22	1.25	1.46	0.74	0.48	1.11	1.50	0.67	0.17	0.02	11.29
1987	0.65	0.38	0.18	0.40	1.96	0.76	2.16	0.21	0.00	0.11	0.72	0.42	7.95
1988	0.50	0.00	0.08	1.28	0.56	0.13	0.04	0.04	0.23	0.01	1.74	0.80	5.41
1989	0.31	0.38	0.62	0.31	0.75	1.21	0.32	0.41	1.86	0.29	0.45	0.04	6.95
1990	1.05	0.15	0.19	0.97	1.28	0.86	0.59	0.68	0.05	0.25	0.18	0.23	6.48
1991	0.05	0.00	1.18	0.51	2.03	1.15	0.53	0.78	1.08	0.51	0.73	0.00	8.55
1992	0.01	0.45	0.28	0.06	0.31	1.53	0.25	0.07	0.58	0.33	0.47	1.16	5.50
1993	1.15	1.44	0.57	1.20	1.99	2.73	0.08	0.73	0.12	0.92	0.48	0.21	11.62
1994	0.17	0.72	0.00	1.00	0.80	0.00	0.06	0.33	1.11	0.44	0.69	0.85	6.17
1995	1.03	0.28	2.03	0.72	2.34	4.64	0.59	0.05	0.52	0.07	0.22	—	(12.49)

()—indicates incomplete record.

Since 1949, three small tornadoes, which caused no damage, have occurred within the boundaries of the INEEL. Additionally, 10 confirmed and three unconfirmed funnel clouds have been observed since 1954 (NOAA and Morrison Knudsen, 1983). NOAA records indicate a total of five funnel clouds and no tornadoes on the INEEL since 1950 (Clawson et al., 1989). Discrepancies in these records may be related to different methods of reporting and confirming tornadoes. No INEEL facilities have ever been damaged by a tornado.

Dust devils are also common in the region and can entrain dust and pebbles and transport them over short distances. Dust devils usually occur on warm sunny days with little or no wind. The dust cloud may be several hundred meters (yards) in diameter and extend several hundred meters (feet) in the air.

Vertical temperature and humidity profiles in the atmosphere determine atmospheric stability. Stable atmospheres are characterized by low levels of turbulence and less vertical mixing. Stability parameters at the INEEL range from stable to unstable. Stable conditions occur mostly at night during strong radiational cooling. Unstable conditions can occur during the day when there is strong solar heating of the surface layer or whenever a synoptic scale disturbance passes over the region.

2.3.1.1 Air Quality Monitoring. Air quality monitoring at the INEEL consists of two networks of stations designed to monitor atmospheric transport of radionuclides on particulate matter and ambient concentrations of total suspended particulates. Although the air quality monitoring networks are designed to monitor emissions from the entire INEEL, select low-volume particulate samplers in the vicinity of the ICPP provide detailed data on ambient concentrations of radionuclides and particulates.

Historically, one network has been operated by the contractor and the other network has been operated independently by the DOE. The contractor network consists of low-volume air samplers that operate at 0.14 m³/min (5 ft³/min). Particulate matter is collected on a membrane filter. The air filters are collected and analyzed every 2 weeks for gross alpha and gross beta activity. Filters are also analyzed monthly for selected gamma-emitting radionuclides. Gross beta analyses of the air filters are evaluated to determine if any increases in the sample radioactivity may require more immediate and/or more in-depth analysis by gamma spectrometry or radiochemistry.

The DOE network consists of 23 monitoring stations on and around the INEEL. Each low-volume air sampler contains two filters: a membrane prefilter and charcoal-impregnated paper filter. Filters are collected and analyzed weekly. Gross beta activity for each filter is determined weekly as a screening technique to give timely information in the event of site releases. If unusually high gross beta activity is detected on the filters, gamma spectrometry is conducted to obtain more detailed information. Composites of the membrane prefilters for each location are analyzed for specific radionuclides on a quarterly basis.

2.3.2 Humanmade Surface Water Features

Human made surface water features in the vicinity of the ICPP consist of two percolation ponds used for disposal of water in the service waste system (formerly injected into the aquifer via the ICPP injection well) and sewage treatment lagoons for treated water. In addition, several landscaped areas at the ICPP have historically been watered during the summer months and a network of ditches are used to channel runoff from the plant after precipitation events. Historically, precipitation runoff has been channeled to an old gravel pit (Site CPP-37-1) and both this pit and the unlined ditches may contribute recharge to the perched water bodies at the ICPP. Perched water bodies are known to exist beneath the percolation ponds and the sewage

treatment ponds. In addition, perched water bodies are known to exist beneath the ICPP plant facilities, including the high-level liquid waste (HLLW) Tank Farm and the CPP-603 facility.

The presence of the perched water bodies with no identifiable surface water source, and discrepancies between the reported volume of water pumped from the SRPA and the volume of water disposed at the ICPP, suggest water is being lost from the plant water distribution system and/or the liquid waste collection system. Leaks in municipal water systems are not unusual; however, concerns that this water source could leach and transport contaminants that have been released over the years at the ICPP led to a Water Inventory Study (Richards, 1994).

2.3.2.1 ICPP Water Inventory Study. The Water Inventory Study (Richards, 1994) was undertaken to determine if water was leaking from plant water supply systems and wastewater systems in sufficient quantities to account for seepage into the Tank Farm vaults and support the perched water beneath the plant (which have no readily apparent source, such as the surface infiltration ponds). The study involved a number of tasks and was designed to:

- Evaluate water budget measurements and calculations for plant water systems
- Upgrade plant water metering as necessary to quantify the plant water budget
- Leak-test the plant water supply and wastewater systems in the northern portion of the ICPP
- Estimate natural recharge
- Identify sources of water seeping into the Tank Farm vaults.

The ICPP uses approximately 7.9M L (2.1M gal) of water per day. Water is supplied by two raw water wells and one potable water well. The water is used for process cooling, equipment cooling, steam production, process solutions, decontamination, fuel storage basin makeup, chemical laboratory use, regeneration of ion exchange units, fire protection, and human uses. Piping systems external to facility buildings are either buried or enclosed in utility tunnels. The ICPP water systems that were considered relevant to the water inventory study included the raw water, fire water, treated (softened) water, demineralized water, steam condensate, landscape watering, potable water, service waste (industrial wastewater), and sanitary waste systems. Criteria of low volume, secondary containment, distinct radiological or chemical signature, and close monitoring or visibility were used to eliminate the steam distribution system, HLLW process lines, and pipes used to distribute cooling water to the HLLW storage tanks in the Tank Farm from leak testing during the Water Inventory Study.

The primary water systems at the ICPP include the raw water system, fire water system, water softeners (treated water system), and demineralizer (demineralized water system). The raw water system piping has an approximate length of 1,905 m (6,250 ft) and an average flow of 1,473 L/min (389 gal/min). Raw water is pumped from the aquifer from two production wells to the fire water storage tanks. The raw water feed tanks supply water to three distribution pumps. The fire water piping system has a length of 8.0 km (5 mi), with an average flow of 170 L/min (45 gal/min). This flow in the system is water used for watering lawns, safety showers, cooling of waste tanks and sump pump bearings, and flushing radiation monitor bowls. The treated (softened) water system has a length of 1,219 m (4,000 ft) and an average flow of 3,407 L/min (900 gal/min). Treated water is used for chemical process makeup and in heat exchangers. The

demineralized water system has a length of 1,280 m (4,200 ft) and an average flow of 5.7 L/min (1.5 gal/min). Demineralized water is used for process cooling, steam, and in fuel storage basins.

The steam condensate piping system has a length of 1,280 m (4,200 ft) and an average flow of 280 L/min (74 gal/min) between September and April. Primary steam use occurs between the months of September and March due to seasonal demands such as heating and freeze protection. Most of the steam is condensed and recycled or routed to the service waste system. Approximately 10% of the steam is either released to the atmosphere or discharged to the ground.

The potable water system has a length of 3.2 km (2 mi) with an average flow of 231 L/min (61 gal/min) (Figure 2-1). Potable water is supplied from two wells completed in the SRPA. Water is pumped to a storage tank, and three distribution pumps in building CPP-606 are used to supply potable water to ICPP facilities. The potable water system includes a chlorination system.

The service waste piping system has a length of 3.9 km (2.4 mi) and an average flow of 4,997 L/min (1,320 gal/min) (Figure 2-2). Raw water, treated water, demineralized water, and steam condensate are discharged to the service waste system. Waste streams that might be contaminated with radioactive materials are monitored before discharge to the service waste system, and the water is diverted to a holding tank for processing in the process equipment waste (PEW) Evaporator if contamination is detected. Water in the service waste system is discharged to two percolation ponds located on the south end of the facility.

The sanitary sewer piping system is 2.4 km (1.5 mi) long and has an average flow rate of 110 L/min (29 gal/min) (Figure 2-3). Potable water and sanitary waste from ICPP facilities are discharged to the sanitary sewer system and gravity drained to lift stations, where the waste is pumped to the ICPP Sewage Treatment Plant (STP). The waste is transferred to a series of treatment lagoons located at the northeast corner of the ICPP.

The seven landscape watering systems are all located in the northern ICPP and historically covered a total area of 1.5 acres (Figure 2-4). Approximately 75,710 L/day (20,000 gal/day) from the raw water, fire water, and potable water systems has been used to maintain lawns and landscaping at the ICPP during the summer months. A total volume of 8.90M L (2.35M gal) was used to water ICPP lawns each year. Consumptive use was calculated to require 2,967,760 L (784,000 gal) per growing season. Subtracting the consumption and evapotranspiration from the supplied water yields a net volume of 5.94M L (1.57M gal) available for infiltration and recharge of the perched water bodies.

2.3.2.1.1 Leak Testing—Leak testing was performed as part of the Water Inventory Study and indicated the fire water and potable water systems were leaking. The fire water system was found to have a year-round leak of 15.1 L/min (4 gal/min) and an additional leak of 45.4 L/min (12 gal/min) in a branch connection that is only used periodically. The potential loss from the fire water system was determined to be 14.8M L/yr (3.9M gal/yr). The potable water system was found to have a small leak of 0.57 L/min (0.15 gal/min), which would provide 299,050 L/yr (79,000 gal/yr) of potential recharge. These leaks have been repaired, but have historically provided nearly 15.1M L/yr (4M gal/yr) of potential recharge to the perched water bodies below the ICPP facilities and Tank Farm.

2.3.2.1.2 Tank Farm Vaults—Another purpose of the water inventory study (Richards, 1994) was identification of the source of water infiltrating into the Tank Farm vaults. Seepage into the vaults is a concern because the water could be leaching contaminants released to the soil in the vicinity of the Tank Farm

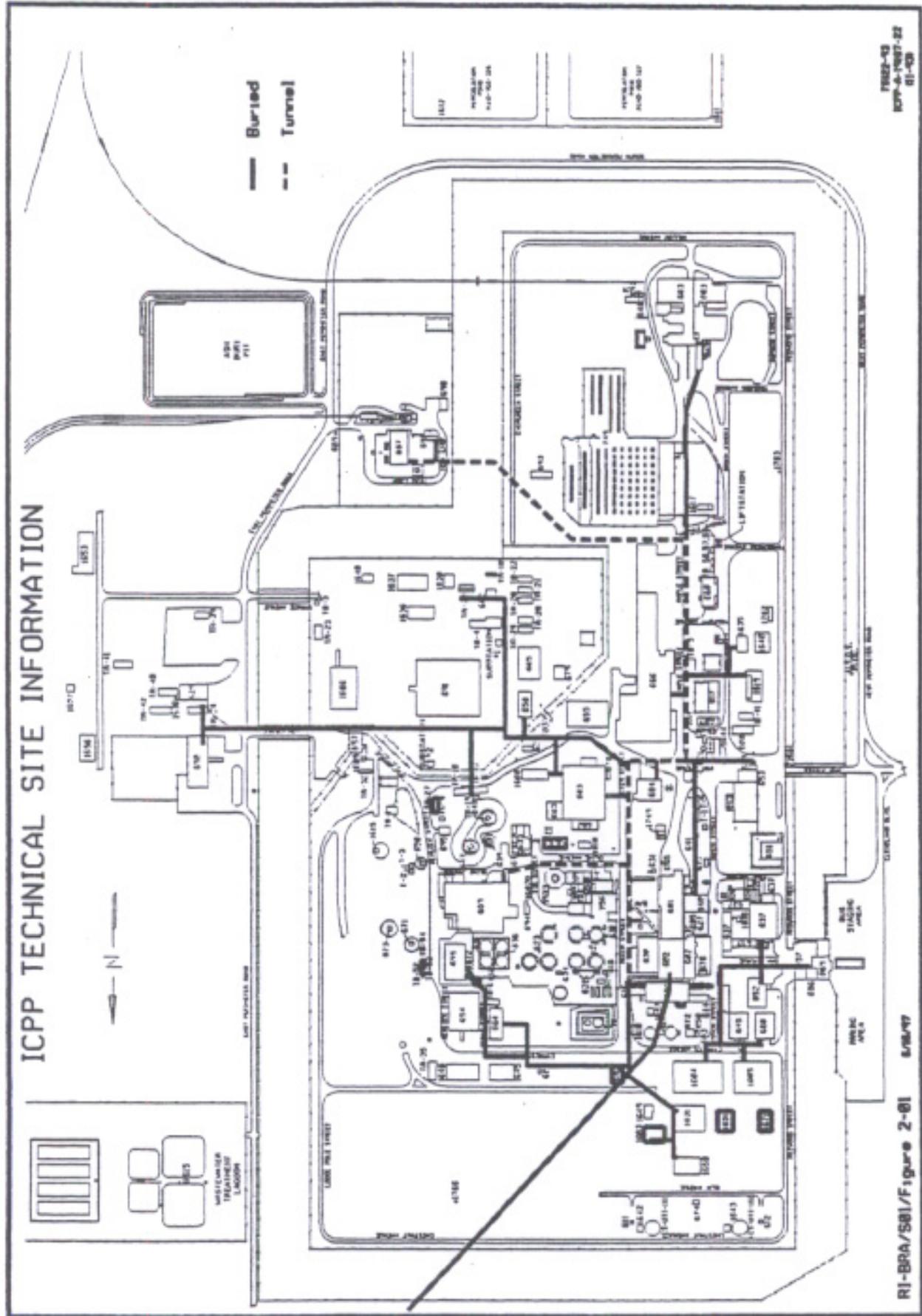


Figure 2-1. Potable water piping system.

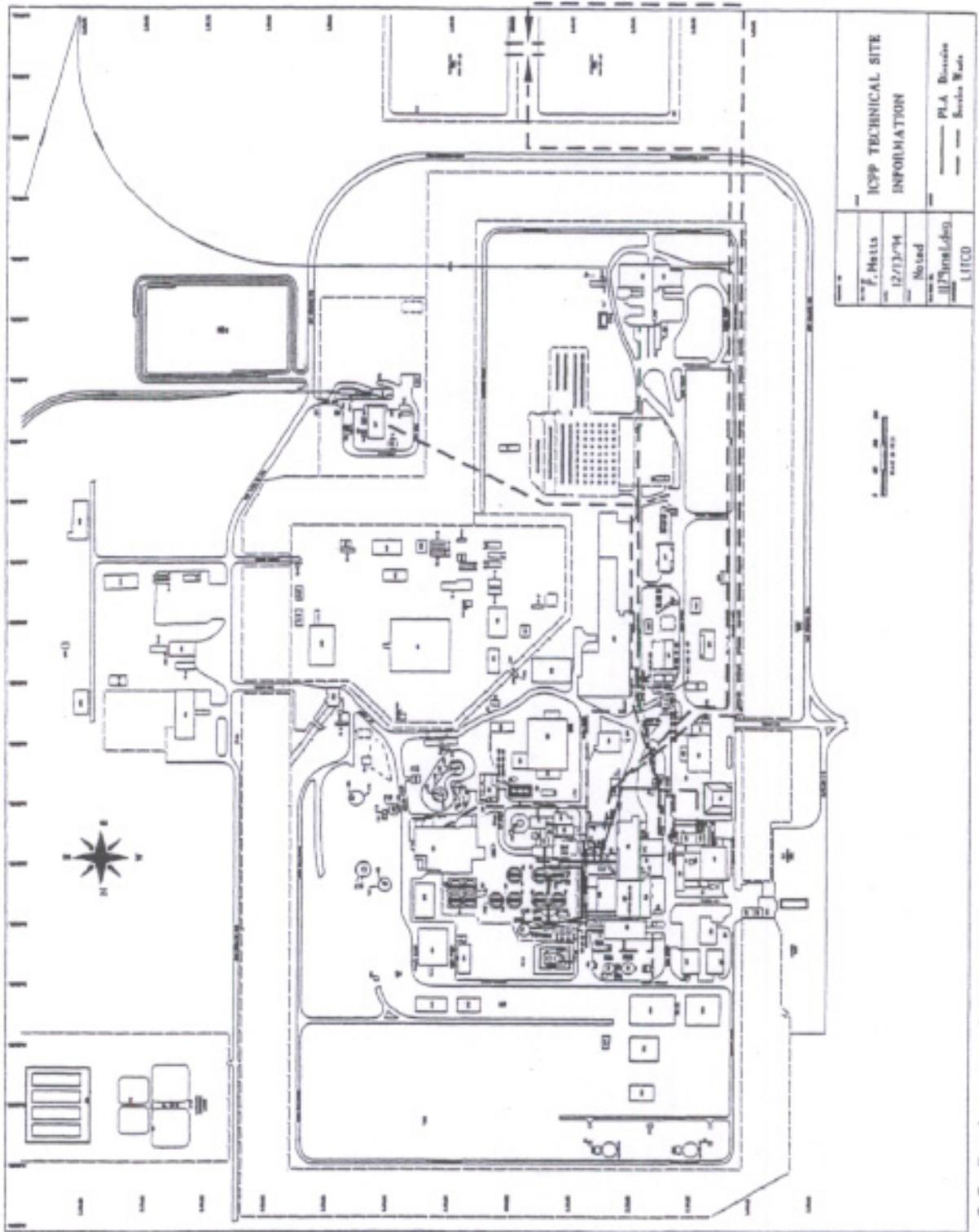


Figure 2-2. Service waste piping system.

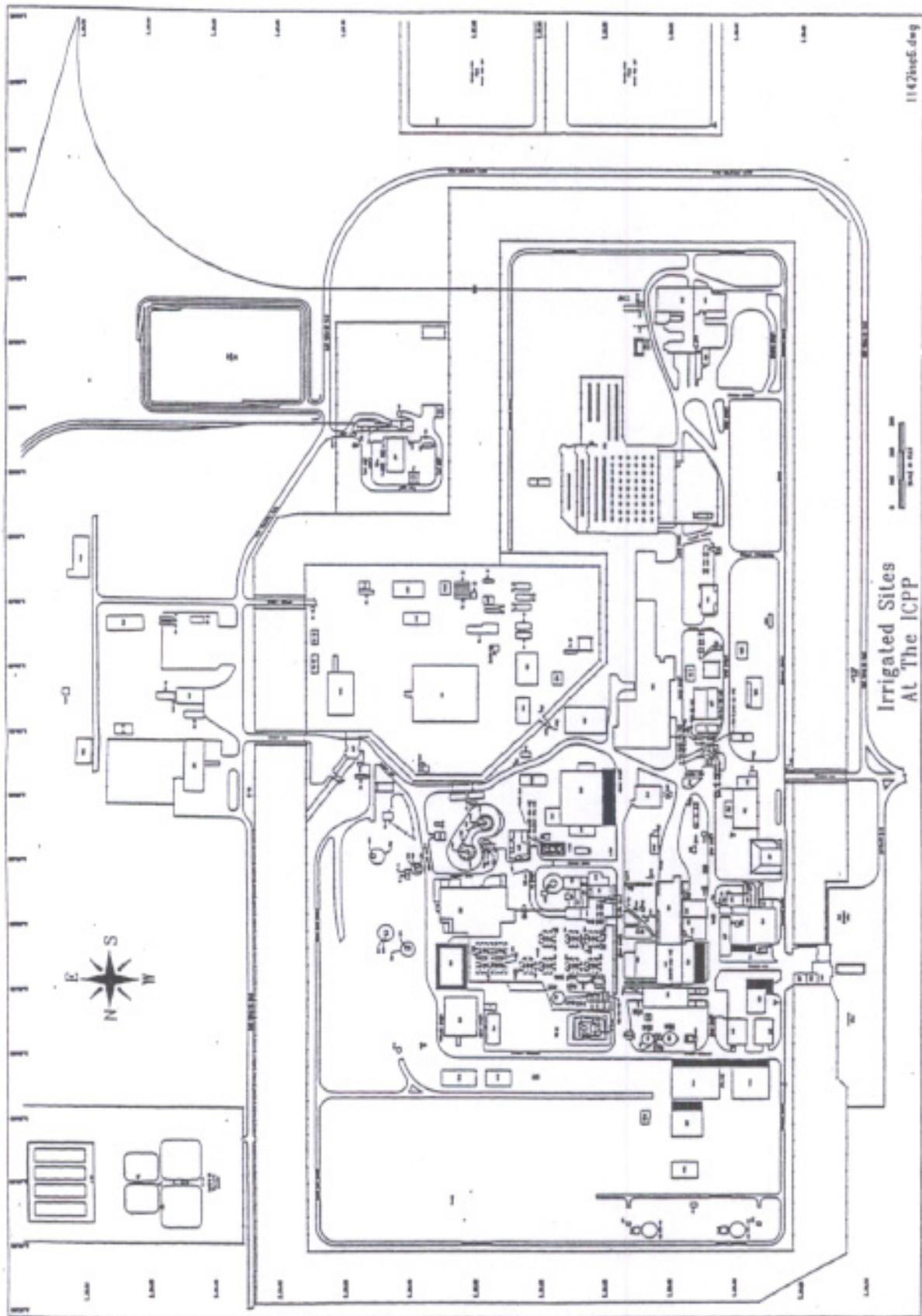


Figure 2-4. Historically irrigated sites at the ICPP.

and transporting those contaminants to the aquifer. The rate of seepage into the vaults is approximately 109,780 L/yr (29,000 gal/yr). Sources of this water were evaluated based on the pattern (constant, precipitation related, seasonal, or random) of seepage, chemistry of the water, location of the sources, and volume of water available for seepage from a particular source. The two most important sources of water for seepage were determined to be infiltration of precipitation and watering the lawn to the west of building CPP-699.

Infiltration of precipitation is a source of seepage for every vault except 781, which showed no seepage during the study period. The volume of water falling on the Tank Farm as precipitation is more than sufficient to provide the necessary volume of water, and the most likely pathway for the water to enter the vaults is seepage through the existing membrane at perforations made for pipes, risers, and valve boxes. Approximately 41% of the water seeping into the vaults comes from this source. The second most important source of seepage for the Tank Farm is watering the lawn. The volume of water from this source is slightly greater than that from precipitation, providing 47% of the seepage. However, this water only affects Vault 713. The pathway for movement of this water was not clearly identified by Richards (1994) because 9.1 to 12.2 m (30 to 40 ft) of lateral movement with only 0.9 to 1.2 m (3 to 4 ft) of vertical movement would be required. Movement of this landscape irrigation water along pipe encasements and drain lines is possible. The remaining 12% of seepage, or 13,476 L/yr (3,560 gal/yr), is from miscellaneous sources, such as leaky steam valves or leaks from valve seals in waste transfer lines. These small sources are not major contributors, but do contribute to seepage periodically.

2.3.2.2 ICPP Steam Condensate System. Subsequent to the Water Inventory Study, a perched groundwater investigation was undertaken in fiscal year (FY)-94. This study was intended to provide additional information about the northern perched groundwater system, including water chemistry and temperature, dissolved contaminant concentrations, depth, and saturated thickness. Temperature measurements in the perched groundwater ranged from 22.2°C (72.1°F) in Well MW-5 to 10.8°C (51.5°F) in Well MW-4. The elevated temperatures in the perched groundwater suggest that hot water sources may be contributing to the perched water system in some areas at the ICPP. Steam condensate drains located throughout the facility (Figure 2-5) are one of the major sources of hot water at the ICPP.

The ICPP steam system consists of two boiler plants (CPP-606 and -687), which supply steam to various buildings and installations throughout the ICPP. Steam condensate traps are located at low portions of the steam lines and these traps allow condensate water to exit the system. The volume of condensate at each trap depends on the length of the steam line the vent services and the heat loss in the steam line. A large portion of this steam distribution system is located in a utility tunnel housing a 30.5-cm (12-in.) steam line connecting CPP-606 to the coal powered generating plant (CPP-687). A total of 48 steam vent condensate drains are located in the utility tunnel. Condensate water drains to the subsurface. Generally, the steam is used in steam heater units, which are used to heat a majority of the buildings onsite. Steam usage is greatest during the heating season beginning in September and ending in April when an average flow rate of 280 L/min (74 gal/min) occurs in the system. Volumes of condensate water generated in the system depend on the heat load of the system, and estimates of the volume of condensate originating at steam heater units were based on 150 days at an ambient temperature of -7°C (20°F). The main steam line in the utility tunnel is active all year and condensate calculations for the steam condensate traps along this line were adjusted to reflect 365 days/yr of operation.

The volume of condensate from the steam heater units and the steam traps were estimated (Table 2-2). The largest contributors of waste steam condensate water to the ground are the steam heater units located in

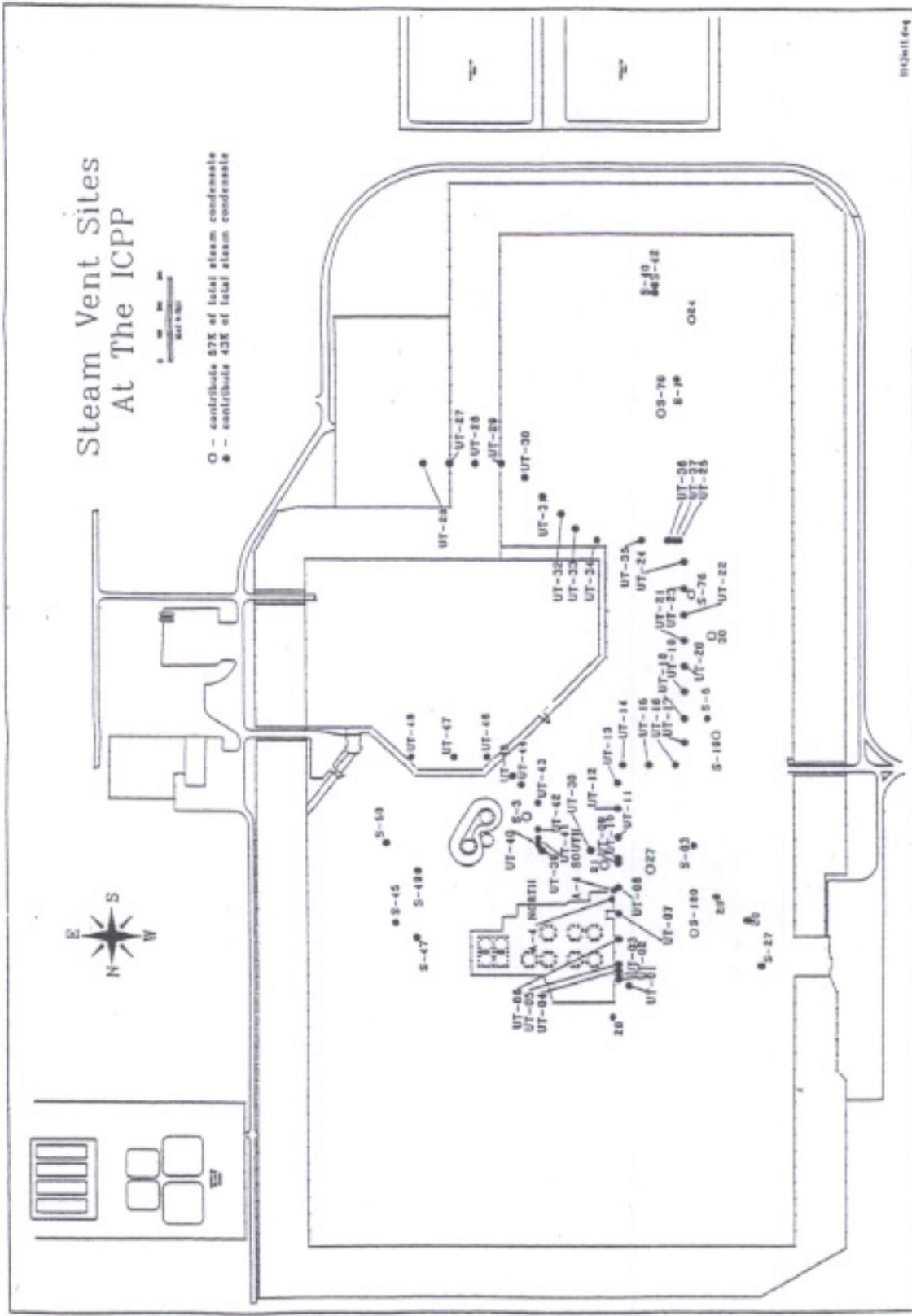


Figure 2-5. Steam condensate drains at the ICPP.

Table 2-2. Approximate discharge from the ICPP condensate drains.

STEAM VENT IDENTIFICATION	NORTHING COORDINATE	EASTING COORDINATE	VOLUME OF WATER IN GALLONS PER DAY	YEARLY VOLUME IN GALLONS
S-1	693405	296474	6	900
S-3	695098	297063	2160	324000
S-5	694707	296359	0	0
S-19	694774	296325	1344	201600
S-27	695682	296160	0	0
S-40	693067	296557	28	4200
S-42	693037	296557	5	750
S-45	695511	297568	8	1200
S-47	695568	297487	8	1200
S-49	695308	297482	8	1200
S-51	695200	297600	8	1200
S-63	695209	296416	15	2250
S-76	694229	296419	288	43200
S-78	693537	296533	144	21600
S-180	695551	296416	432	64800
20	695502	296213	28	4200
21	695286	296761	144	21600
24	693170	296417	1008	151200
26	695411	296330	28	4200
27	695302	296583	144	21600
28	695877	296728	28	4200
30	694389	296342	432	64800
A-4 NORTH	695419	296731	0	0
A-4 SOUTH	695385	296722	0	0
UT-01	695757	296665	35	12775
UT-02	695733	296704	23	8395
UT-03	695723	296704	8	2920
UT-04	695699	296704	10	3630
UT-05	695674	296704	26	9490
UT-06	695574.5	296704	43	15695
UT-07	695474	296704	43	15695
UT-08	695373	296704	42	15330
UT-09	695277.5	296704	25	9125
UT-10	695259	296704	43	15695
UT-11	695178.5	296704	42	15330
UT-12	695066	296704	46	16790
TU-13	694966	296704	42	15330
UT-14	694895	296683	42	15330
UT-15	694895	296584	43	15695
UT-16	694895	296484	47	17155
UT-17	694804	296448	46	16790
UT-18	694708	296448	43	15695
UT-19	694604	296448	44	16060
UT-20	694506	296448	45	16425
UT-21	694406.5	296448	45	16425
UT-22	694307	296448	43	15695
UT-23	694207	296448	43	15695
UT-24	694107	296448	44	16060
UT-25	694025	296466	30	10950
JT-26	693729	297452	52	18980
UT-27	693729	297352	43	15695
UT-28	693729	297252	43	15695
UT-29	693729	297152	43	15695
UT-30	693781	297061	43	15695
UT-31	693854	296992	43	15695
UT-32	693924	296921	39	14235
UT-33	693981	296865	39	14235

Table 2-2. (continued).

STEAM VENT IDENTIFICATION	NORTHING COORDINATE	EASTING COORDINATE	VOLUME OF WATER IN GALLONS PER DAY	YEARLY VOLUME IN GALLONS
UT-34	694025	296782	59	21535
UT-35	694025	296608	59	21535
UT-36	694025	296508	43	15695
UT-37	694025	296485	30	10950
UT-38	695229	296813	51	18615
UT-39	695229	297004	51	18615
UT-40	695208	297017.5	58	21170
UT-41	695181.5	297017.5	16	5840
UT-42	695148	297017.5	33	12045
UT-43	695042.5	297017.5	44	16060
UT-44	694973	297082	31	11315
UT-45	694938	297115	32	11680
UT-46	694863	297212	53	19345
UT-47	694863	297341	61	22265
UT-48	694863	297504	104	37960
TOTALS:			8279	1674645

some of the buildings around the site. These units produce a 3.8-L/min (1-gal/min) flow of condensate water for every 600,000 British thermal units (BTUs) of heat energy generated. The amount of condensate water generated at each steam condensate trap along the line in the utility tunnel is relatively low compared to the volumes generated by the steam heater units, but the number of these traps and drains make this a significant source of steam condensate that is discharged to the subsurface. The total annual volume of steam condensate discharged to the ground was estimated to be 6.32M L (1.67M gal). Of this volume, approximately 4.92M L (1.3M gal) are discharged in an area where the condensate could contribute to the northern perched water body.

2.3.2.3 CPP-603 Basins. CPP-603 consists of three reinforced concrete fuel storage basins connected by a transfer channel. The walls of the basins are 0.6-m (2-ft) thick and the floor is 1.5-m (5-ft) thick. The pools are 6.1-m (20-ft) deep and the water inventory is maintained at approximately 5.7M L (1.5M gal). The basin water treatment system consists of sand filters, a selective cation exchange system, and an ultraviolet sterilizer. Demineralized makeup water is provided from a reverse osmosis unit. The basin water contains a variety of soluble radionuclides and stable constituents. The radionuclides are removed by the basin water treatment system and the primary nonradioactive soluble ions that have accumulated in the basin water are sodium, calcium, chloride, and nitrate. Inspection of the accessible walls and floor of the basin do not indicate any cracking or other physical damage. The basin is unlined and several studies have been undertaken to estimate the quantity of water that may be leaking from the basin. These studies have estimated losses due to evaporation and have evaluated the basin water inventory.

Various methods of estimating water loss from the basin were evaluated. Measurement of the dilution of dissolved solids was used to estimate the basin water inventory because the method is direct and reasonably reliable. This method involves measurement of the dilution of a dissolved solid in the basin water as water is added to the basin to maintain the water level. The dissolved solid selected for measurement must not be removed by the basin ion exchanges system, the filter, or by contact with the basin walls and piping. Chloride was selected as the best candidate dissolved solid for monitoring. Cation concentrations can be affected by the basin ion exchange system and are not useful for determining the basin leak rate. Nitrate is also not useful because the ion is a known nutrient for basin microorganisms. Chloride is not a nutrient and is not affected by the basin water treatment systems. However, small amounts of chloride may be lost from corrosion of aluminum. The sludges on the basin floor are also known to contain undissolved chloride, but chloride in the sludges is likely to be in equilibrium with the water.

Dilution of chloride has been used in two basin water inventory studies. The first study was conducted from July 28, 1986, through August 3, 1987. In this study, the chloride concentration in the makeup water was assumed to be 10 parts per million (ppm) based on measurements of the concentration in ICPP well water. A loss rate of 379 L/day (100 gal/day) in excess of measured losses was estimated. The estimate was determined to have an error of approximately 100%. The second study calculated basin water inventory based on dilution of chloride during the period from May 3, 1993 to October 3, 1993. In this inventory, the total loss rate from the basin was determined to be 874 L/day (231 gal/day). Measured losses were determined to be 363 L/day (96 gal/day), leaving a discrepancy of 511 L/day (135 gal/day) (estimated error has not been calculated). The evaporation rate from the pond was estimated to be 1,173 L/day (310 gal/day), which is consistent with a previous laboratory study estimate of 1,211 L/day (320 gal/day). The 511 L/day (135 gal/day) loss rate can be attributed to permeation through microcracks along the basin surface. Based on the two studies the best estimate for the loss rate is between 500–700 L/day. This loss rate is very small for a simple concrete structure as large as CPP-603 and is an indication the basin surfaces are in excellent condition.

2.3.2.4 Sewage Treatment and Percolation Ponds. The ICPP STP treats sanitary sewage from 31 permanent facilities at the ICPP, primarily consisting of wastewater from restrooms and cafeterias. All sanitary waste from the 31 permanent facilities is collected by gravity-flow lines and piped via lift stations to the STP for treatment. In addition, sanitary waste from nine ICPP buildings is collected and treated separately from the main STP.

The STP facility is located to the northeast of the enclosed ICPP plant area. It consists of two aerated lagoons, two quiescent facultative stabilization lagoons, four infiltration/percolation (I/P) trenches, and six weir boxes. The aerated lagoons are arranged in series and drain into facultative lagoons, which then overflow into the I/P trenches. The weir boxes route the wastewater through the lagoons and trenches. Maximum plant capacity is 454,200 L/day (120,000 gal/day), with an average flow of 159,000 L/day (42,000 gal/day). From 1984 to present, the monthly discharge to the sewage treatment ponds is provided in Table 2-3.

The service waste system collects, monitors, and samples nonradioactive, nonhazardous wastewater used in various plant activities and transfers it to one of the two percolation ponds located south of the ICPP for disposal. Percolation Ponds 1 and 2 are located outside the ICPP southern security fence, southeast of CPP-603. The percolation ponds are unlined ponds that were excavated from the surficial alluvium in 1982 and 1985. Percolation Pond 1 began receiving flow in 1984, but an inadequate percolation rate made it necessary to build Pond 2. The two ponds have been used alternately since then, receiving approximately [5.7 to 9.5M L/day (1.5 to 2.5M gal/day)] of service wastewater. From 1984 to present, the monthly discharge to the percolation ponds is provided in Table 2-4.

2.3.3 Big Lost River

The Big Lost River flows southeast from the Mackay Dam, through the Big Lost River Basin, past Arco, Idaho, and onto the Snake River Plain. The river flows onto the INEEL near the southwest boundary, curves to the northeast, and flows northward to its termination in the Big Lost River playas (Figure 1-1).

The Big Lost River basin includes parts of Custer and Butte Counties in south-central Idaho (Bennett, 1990). The drainage area of the river upstream of the INEEL is approximately 3,626 km² (1,400 mi²). Of the 2,305 km² (890 mi²) within the boundaries of the INEEL, only 181 to 207 km² (70 to 80 mi²) contribute surface runoff of any significance to the Big Lost River. Noncontributing areas of the Big Lost River basin within the INEEL consist of small topographically closed basins 2.6 to 26 km² (1 to 10 mi²) in area. Land surface altitudes of the drainage area range from 1,457 m (4,780 ft) above sea level at the terminal playas to 3,858 m (12,656 ft) at Borah Peak in the Lost River Range. The channel of the Big Lost River is incised about 18.3 m (60 ft) into the basalt of the Snake River Plain at a point 1.6 to 3.2 km (1 to 2 mi) downstream from the gauging station near Arco. After reaching the western boundary of the INEEL, the river emerges from the narrow, 61- to 91-m (200- to 300-ft) wide, canyon into a broad plain where it is incised less than 6.1 m (20 ft). The river is incised less than 3 m (10 ft) near Highway 20 and downstream from the highway, the river enters a broad floodplain that ranges in width from 1.6 to 6.4 km (1 to 4 mi). This floodplain is characterized by remnants of old meander channels. Ultimately, the main channel branches into many small channels and flow spreads across several ponding areas, or playas, known as the Big Lost River Sinks. Playas 1 and 2 have an elevation of 1,459 m (4,788 ft) and surface areas of about 350 and 110 acres, respectively. Playas 3 and 4 are at an altitude of 1,457 m (4,780 ft) and have surface areas of 1,000 and 1,350 acres, respectively.

Table 2-3. Monthly discharge of the sewage treatment ponds (RWMIS database).

	Jan.	Feb.	March	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1984	0.7	0.6	0.5	0.6	0.7	0.5	0.6	0.6	0.6	0.5	0.6	0.6	7.1
1985	0.6	0.6	0.7	0.6	0.6	0.6	0.6	0.5	0.6	0.6	0.6	0.1	6.5
1986	0.8	0.8	0.9	0.9	0.8	0.7	0.9	0.8	0.8	0.7	0.8	0.8	9.6
1987	0.8	0.8	0.8	0.8	0.8	0.7	0.7	0.7	0.6	0.7	0.8	0.8	9.0
1988	0.9	0.8	0.8	0.8	0.8	0.7	0.7	0.7	0.8	0.7	0.7	0.8	9.2
1989	0.8	0.9	0.9	0.8	0.8	0.8	0.7	0.7	0.7	0.9	0.8	0.9	9.7
1990	0.8	1.0	0.9	0.8	0.9	0.9	1.0	1.1	1.1	0.9	0.9	0.9	11.3
1991	1.2	1.1	0.8	0.9	0.8	0.8	0.9	0.7	0.8	0.7	0.9	1.2	10.8
1992	0.9	1.5	1.6	1.5	1.5	1.3	1.3	1.6	1.7	2.0	2.2	1.7	18.7
1993	1.1	1.2	1.1	1.2	1.1	1.2	1.4	0.6	0.8	1.2	1.2	1.1	13.1
1994	3.1	1.4	ND	1.9	4.4	5.9	3.2	2.0	1.4	1.0	1.6	2.0	(27.92)
1995	2.5	1.3	2.3	2.2	3.1	1.3	0.1	1.8	1.3	ND	ND	ND	(15.75)

() - indicates incomplete record.

Discharge in millions of gallons.

Table 2-4. Monthly discharge to percolation ponds (RWMIS database).

	Jnn.	Feb.	March	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1984	ND	ND	42.1	45.4	52.5	53.1	45.0	47.2	41.8	41.3	37.6	38.9	(444.9)
1985	29.9	36.7	36.4	0.6	31.5	41.9	39.3	43.4	60.0	58.5	17.4	57.6	453.23
1986	54.1	46.7	40.8	50.1	45.0	47.3	50.2	50.6	43.7	49.7	49.3	48.1	575.56
1987	51.9	50.7	47.9	50.4	51.8	52.1	51.4	50.8	49.5	49.7	46.6	47.1	599.90
1988	53.3	49.4	47.1	51.4	47.4	50.3	48.2	48.3	42.5	44.9	41.2	41.5	565.50
1989	36.2	40.2	39.0	36.9	29.8	35.9	33.0	33.2	37.9	36.7	37.6	43.4	439.80
1990	46.7	45.1	38.7	51.5	59.9	62.4	57.3	55.7	62.5	50.9	47.4	44.3	622.40
1991	45.6	44.4	38.0	44.6	45.6	44.0	49.3	48.1	52.7	48.6	49.2	46.3	556.43
1992	55.5	58.7	52.6	57.5	48.1	43.6	47.5	54.2	57.8	54.6	58.8	53.6	642.50
1993	58.2	57.1	62.9	60.2	56.1	59.2	53.1	53.9	50.9	48.6	49.8	54.8	664.80
1994	55.5	40.8	54.9	49.6	48.7	40.0	35.2	37.8	40.2	37.3	40.1	39.1	519.20
1995	39.5	40.8	38.0	58.0	46.1	35.9	35.6	45.3	3.8	ND	ND	ND	(342.98)

() - indicates incomplete records.

Discharge in millions of gallons.

Storage and diversion systems on the Big Lost River include the Mackay Dam, several irrigation diversions, and the INEEL flood diversion dam. The Mackay Dam is a 435.9-m (1,430-ft) long, 24.1-m (79-ft) high earthfill dam built for the Big Lost River Irrigation District. The dam was completed in 1918 and is located 6.4-km (4-mi) northwest of the town Mackay. The dam has a storage capacity of $5.49 \times 10^7 \text{ m}^3$ (4.45×10^4 acre-ft) of water. The dam is used to impound water for irrigation in the Big Lost River Irrigation District. Water from the Big Lost River is used to irrigate about 57,500 acres of land downstream from the Mackay Reservoir and another 10,200 acres of land are subirrigated upstream from the reservoir (Harenberg et al., 1987).

The INEEL flood diversion system, located approximately 10.5-km (6.5-mi) downstream from the western INEEL boundary, was built in 1958 to divert high flows on the Big Lost River away from INEEL facilities. During the winter months, most of the flow in the river is diverted to avoid accumulation of ice in the channel, thus reducing the possibility of flooding at downstream INEEL facilities. The system consists of a small earthen diversion dam and headgate that diverts water from the main channel, through a connecting channel, and into a series of four natural depressions, called spreading areas. The capacity of the spreading areas is about $7.2 \times 10^7 \text{ m}^3$ (5.8×10^4 acre-ft) at an elevation of 1,539 m (5,050 ft) mean sea level. An overflow weir in Spreading Area D allows water to drain southwest off the INEEL. Runoff from the Big Lost River has never been sufficient to exceed the capacity of the areas and overflow the weir.

Carrigan (1972) modeled the capacity of the INEEL flood diversion system as it existed in 1972 and concluded the system was inadequate for long period floods. The diversion system was upgraded in 1984 in response to a flood risk that occurred in late 1983 and early 1984 (McKinney, 1985). The present diversion system has a total diversion channel capacity of up to $263.3 \text{ m}^3/\text{s}$ ($9,300 \text{ ft}^3/\text{s}$). The existing diversion channel can carry $203.9 \text{ m}^3/\text{s}$ ($7,200 \text{ ft}^3/\text{s}$). The ICPP area has not been flooded since construction of the diversion system.

Gauging stations are located upstream and downstream of the Mackay Reservoir to monitor discharge. Additional stream gauging stations are maintained on the Big Lost River by the U.S. Geologic Survey (USGS), including a station where the river is crossed by Lincoln Boulevard on the INEEL. Flow in the river is highly variable with peak flows occurring in June and July due to snowmelt (Table 2-5). Generally, there is no flow in the river during the winter months.

The Big Lost River flow is perennial upstream from a point a few miles southeast of Arco. Downstream, the flow is lost by infiltration through the river bottom, and the point where flow ceases depends on discharge and the infiltration conditions of the channel. Infiltration rates are greatest when the channel is initially wetted and the hydraulic head is at a maximum. Flow in the river may not reach the western boundary of the INEEL or may continue as far north as Playa 4. Losses in streamflow also result from evaporation and transpiration. These losses are small by comparison to losses due to infiltration. The intermittent flow of the river does not encourage growth of vegetation along the periphery, which minimizes transpiration. Annual net evaporation from large water surfaces in the ESRP is $84 \text{ cm}/\text{yr}$ ($33 \text{ in.}/\text{yr}$) (Stearns et al., 1938). Using this evaporation rate, Harenberg et al. (1987) calculated the maximum possible evaporation for the 71-km (44-mi) stretch from Arco to the playas would be less than 900 acre-ft/yr. The river is also generally dry during periods of peak evaporation so actual losses are lower. During the period from 1965 to 1987, losses due to evapotranspiration and infiltration in the 18-km (11-mi) stretch between the INEEL diversion dam and Lincoln Boulevard averaged 9,820 acre-ft/yr. During this period there was no flow 28% of the time at the diversion dam and 49% of the time at Lincoln Boulevard. Since 1987, the Big Lost

Table 2-5. Monthly discharge of the Big Lost River at Lincoln Boulevard near the ICPP (acre-feet).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1965*	0	0	2,380	10,300	15,400	29,600	31,100	16,900	10,900	0	0	0	116,580
1966	0	0	0	3,660	981	0	0	0	0	0	0	0	4,641
1967	0	0	0	0	2,030	20,180	18,376	4,400	9,050	8,740	0	0	62,776
1968	0	0	2,280	3,390	16	524	0	1,053	1,130	3,290	4,500	0	16,183
1969	0	0	0	3,960	33,000	33,500	21,800	4,780	9,840	6,710	3,290	0	116,880
1970	0	0	501	1,650	793	13,800	17,700	1,510	6,080	5,280	4,750	8	52,072
1971	0	0	0	10,600	12,300	17,200	20,800	7,760	13,400	14,400	13,100	0	109,560
1972	0	0	1,540	4,920	504	1,710	861	84	2,990	3,520	3,099	0	19,228
1973	0	0	0	2,830	405	0	0	0	0	0	0	0	3,235
1974	0	0	3,240	5,520	6,940	16,200	9,390	1,170	1,160	3,760	4,200	0	51,580
1975	0	0	0	3,180	12,000	12,100	18,700	3,560	6,520	8,210	7,990	0	72,260
1976	0	0	333	1,450	1,660	1,120	0	0	300	620	1,100	76	6,659
1977	0	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	0	0	0	0	0	0	0
1979	0	0	0	0	0	0	0	0	0	0	0	0	0
1980	0	0	0	0	0	0	1,140	0	0	0	0	0	1,140
1981	0	0	0	1,300	5,092	7,560	0	0	0	0	0	0	13,952
1982	0	0	0	5,930	17,200	13,400	15,100	4,820	8,190	10,500	5,740	600	81,480
1983	600	600	900	12,800	15,800	18,900	18,200	9,780	7,320	6,200	5,660	1,200	97,960
1984	1,200	1,200	1,200	2,200	2,320	4,550	3,950	5,790	5,140	5,980	8,710	2,120	44,360
1985	3	0	0	7,170	6,430	0	0	0	9,950	10,707	1,275	0	35,535
1986	0	96	537	8,370	14,825	20,315	2,900	1,016	14,753	8,220	1,190	2	72,224
1987	0	0	531	491	0	0	0	0	0	0	0	0	1,022
1988*	0	0	0	0	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 2-5. (continued).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1992	0	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	5,116	0	0	0	0	0	0	5,116
1994	0	0	0	0	0	0	0	0	0	0	0	0	0
1995	0	11	0	0	0	16,010	22,310	955	0	NA	NA	NA	—

a. Monthly discharge volume for 1965 to 1988 from Bennett 1990, Streamflow Losses and Ground Water Level Changes Along the Big Lost River at the Idaho National Engineering Laboratory, Idaho. USGS Water-Resources Investigations Report 90-4067.

b. Monthly discharge data for 1988 to 1994 from the USGS.

NA—Not available.

River has been dry on the INEEL with the exception of brief periods in 1993, 1995, and 1996. Flows have reached Playa 1 in 24 of the 77 years since the construction of the Mackay Reservoir in 1917.

The ICPP is located on the alluvial plain approximately 61.0 m (200 ft) from the Big Lost River channel near the point where the channel intersects with Lincoln Boulevard on the INEEL. The elevation of the Big Lost River channel immediately northwest of the ICPP is 1,495 m (4,908 ft), and the elevation of the river bank or berm is 1,497.1 m (4,912 ft). The average elevation of the ICPP is 1,498.7 m (4,917 ft).

The INEEL diversion system diverts water from the Big Lost River during periods of high flow. The diversion dam across the Big Lost River permits the passage of less than 900 cubic feet per second during floods (Bennett, 1986), and the river channel near ICPP can accommodate this flow. The maximum diversion capacity of the INEEL diversion system is up to 9,300 cubic feet per second, well above the 100-year flood stage (Bennett, 1986). The Big Lost River poses no flood threat to the ICPP as it flows northeast to its termination in the playas.

2.3.3.1 Aquifer Recharge from the Big Lost River. In 1985, flow in the SRPA at the INEEL was to the southwest and the gradient was about 0.8 m/km (4 ft/mi) (Bartholomay et al., 1997). The direction of flow is locally affected by recharge and discharge. Recharge at the INEEL is primarily the result of underflow from the northeastern part of the plain and the Big Lost River. During periods of high flow, local groundwater levels and the direction of groundwater flow can be temporarily altered by recharge from the river. In periods of low flow in the Big Lost River, local gradients reflect regional flow directions.

The altitude of water levels and configuration of the water table in the SRPA vary in response to changes in the volume and source of recharge. Water levels peaked in the early 1970s during a prolonged period of above average precipitation and high flows in the Big Lost River beginning in 1965. Water levels subsequently declined during a period of average or below average precipitation and stream flow beginning in 1976 and continuing through the early 1980s. No flows were recorded at Lincoln Boulevard on the INEEL during the period from 1977 through 1979 and small flows were recorded in 1 month of 1980 and 3 months of 1981. Measured water levels in USGS monitoring wells rose during the period from 1981 through 1985, corresponding with a period of flow in the Big Lost River Channel.

During the period from 1972 to 1978, water levels declined as much as 3.0 m (10 ft) near the Radioactive Waste Management Complex (RWMC) spreading areas and north of the Naval Reactors Facility (NRF). During the same period, water levels in the eastern part of the INEEL, where water levels are probably influenced least by flows in the Big Lost River and other surface water recharge sources, declined about 1.5 m (5 ft). The net increase in the regional water table during the period from 1981 to 1985 reflected a change in the volume of water available for recharge during a comparatively wet period following 3 years of no flow in the river. The water table in the vicinity of the RWMC rose as much as 4.9 m (16 ft) in response to recharge from water diverted to the spreading areas. Water levels rose as much as 3.7 m (12 ft) in the vicinity of the NRF and about 1.5 m (5 ft) in the eastern INEEL. Water levels at the Test Area North (TAN) declined less than 0.3 m (1 ft) during the first period, but rose as much as 1.2 m (4 ft) during the period of high flow. Between the period 1989 to 1991, water levels declined because there was no stream flow in the Big Lost River below Arco and because of a general decline in recharge to the aquifer. From 1991 to 1995, water levels generally decline throughout the INEEL because of drought conditions that began in 1987. Water level declines ranged from about 8.5 ft in wells in the west-central part of the INEEL to about 2.5 ft in wells in the southern part. The water level decline in the west-central part of the INEEL is attributed to lack of recharge from the Big Lost River.

Changes in water levels in wells in the vicinity of the Big Lost River sinks correlate with flows that were recorded at the gauging station at Lincoln Boulevard. Groundwater levels rose rapidly during periods of high stream flow and declined during periods of decreased or no flow. Groundwater levels in the areas southwest of the RWMC and north of the NRF are significantly affected by recharge from the Big Lost River. These areas correspond with the spreading areas and sinks.

From 1964 through 1994, water levels in USGS monitoring wells near the ICPP rose in response to periods of flow on the Big Lost River (Figure 2-6). Periods of high flow on the river correspond to periods of rising water levels in the monitoring wells. Peak water levels in the wells occurred approximately 1 year after each period of high flow in the river. Although infiltration of precipitation would contribute to water levels in the wells and river flows would be expected to be greater in years with higher precipitation, infiltration of water from the Big Lost River channel appears to be the major cause of increased water table elevation along the channel during periods of high flow.

2.3.4 Summary of Surface Water Recharge

The ICPP uses approximately 7.9M L (2.1M gal) of water per day. Water is supplied by two raw water wells and two potable water wells located in the northern portion of the facility. The primary water systems at the ICPP include raw water, fire water, treated (softened) water, demineralized water, steam condensate, landscape watering, potable water, service waste (industrial wastewater), and sanitary waste systems (Table 2-6). Piping systems external to facility buildings are either buried or enclosed in utility tunnels. Based on the primary water systems, approximately 2.9B L (767M gal) of water are distributed throughout 23 km (14 mi) of piping annually at the ICPP.

A Water Inventory Study (Richards, 1994) was performed at the ICPP to determine whether water was leaking from the plant's water supply and wastewater systems in sufficient quantities to support the perched water bodies beneath the plant (which have no readily apparent source). A thorough evaluation of the primary piping systems was performed and leaks were discovered on the fire water and potable water systems. The fire water system was found to have a year-round leak of 15 L/min (4 gal/min) and an additional leak of 45.4 L/min (12 gal/min) in a branch connection that was only used periodically. The potential loss from the fire water systems was determined to be 14.8M L/yr (3.9M gal/yr). The potable water system was found to have a small leak of 0.57 L/min (0.15 gal/min), which would provide approximately 299,000 L/yr (79,000 gal/yr) of potential recharge to the perched water systems. These leaks have been repaired, but historically provided nearly 15.1M L/yr (4M gal/yr) of potential recharge to the perched water bodies. A potential exists that other unknown leaks are present in the 23 km (14 mi) of piping. For example, even if the metering could measure the flow throughout the plant to a 5% accuracy, an annual loss of 145M L (38.4M gal) could go undetected.

Another source of recharge to the perched water bodies is the subsurface injection of waste steam condensate. The steam condensate piping system has a length of 1,280 m (4,200 ft) and an average flow of 280 L/min (74 gal/min.) between September and April. Primary steam use occurs between these months due to seasonal demands such as heating and freeze protection. The total annual volume of steam condensate discharged to the ground was estimated to be 6.4M L (1.7M gal). Of this volume, it is estimated that 4.9M L (1.3M gal) are discharged in an area where the condensate could contribute to the northern perched water body.

The seven landscape watering systems are all located in the northern ICPP and cover a total area of approximately 1.5 acres. It is estimated 75,710 L/day (20,000 gal/day) of water are used to maintain lawns

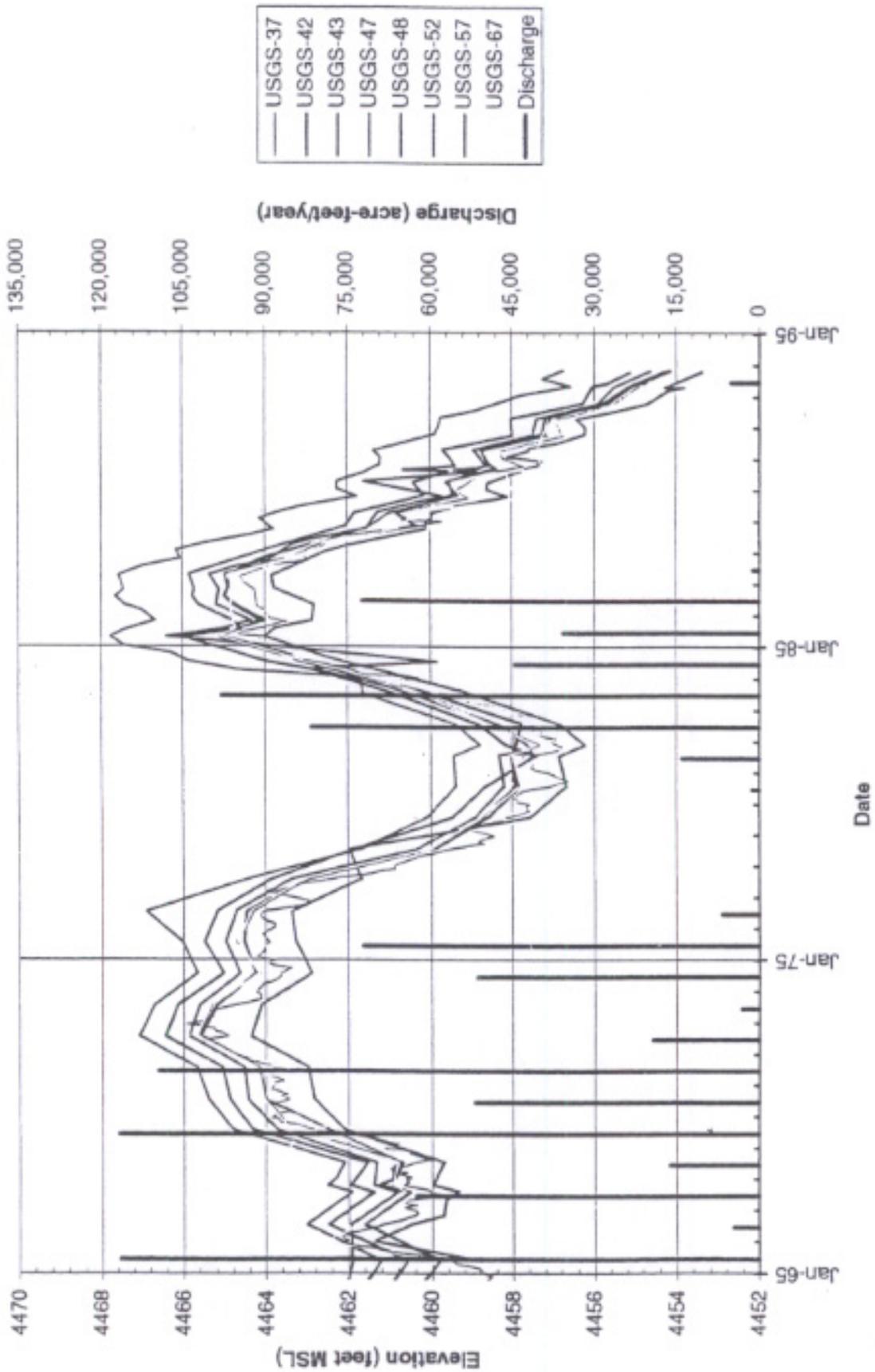


Table 2-6. Primary water systems at ICPP.

System	Estimated annual flow (gallons)	Length of piping
Raw	200,000,000	1,905 m (6,250 ft)
Fire	24,000,000	8,049 m (26,400 ft)
Treated (softened)	470,000,000	1,219 m (4,000 ft)
Demineralized	790,000	1,280 m (4,200 ft)
Steam condensate	39,000,000	1,280 m (4,200 ft)
Potable	32,000,000	3,220 m (10,560 ft)
Service	690,000,000	3,863 m (12,670 ft)
Sanitary	15,000,000	2,415 m (7,920 ft)
Total	1,470,000,000 ^a	20,132 m (76,200 ft) (14.4 mi)

a. Annual flow is approximately twice the estimated 7.9M L (2.1M gal) of water used daily because the annual flow is based on both the process end and the waste disposal (i.e., service and sanitary wastewater).

and landscaping at the ICPP during the summer months. Annually, a total volume of 8.9M L (2.35M gal) is used to water ICPP lawns. Consumptive use was calculated to require 2,967,760 L/growing season (784,000 gal/growing season). Subtracting the consumption and evapotranspiration from the supplied water yields a net volume of approximately 5.94M L (1.57M gal) available for infiltration and recharge of the perched water bodies.

Natural recharge from precipitation is also available to support perched water bodies. Long-term average annual precipitation at the INEEL is 22.1 cm (8.7 in.) and pan evaporation is on the order of 109 cm/yr (43 in./yr). Nevertheless, water from snowmelt or heavy rains may infiltrate to a depth where it cannot be evaporated. Furthermore, many areas within the ICPP are impervious and precipitation runs off to drainage ditches. The ditches are unlined and a significant fraction of infiltration is likely to occur along the ditches. Estimates of net recharge from precipitation range from 2.5 to 10.2 cm (1 to 4 in.) (Miller et al., 1990), with 4.1 cm/yr (1.6 in./yr) being considered to be the best estimate for net infiltration to be used at the ICPP. Infiltration may actually be greater due to the impervious areas, drainage ditches, and infiltration ponds used to collect runoff. Using a net infiltration rate of 4.1 cm/yr (1.6 in./yr) and assuming the recharge area for the entire ICPP to be approximately 184 acres provides an estimate of 30M L (8M gal) of water available for recharge from natural precipitation. For the northern perched water bodies, approximately 14.3M L (3.8M gal) of recharge is available due to precipitation using an area of 87 acres. Approximately 15M gal/yr are discharged into the infiltration galleries of the new sewage treatment plant in the northeastern corner of the facility. Finally, the largest source of recharge to the southern portion of the facility is due to approximately 690M gal/yr of service waste water discharge to the 2 service waste percolation ponds.

A summary of the amount of water available to recharge the perched water bodies at the ICPP is provided in Table 2-7. Historically, approximately 2.73 billion L/yr (720M gal/yr) are known to be providing recharge at the ICPP. This does not include an additional 145M L (38.4M gal) that could be leaking through the facility piping and go undetected by the current metering system.

Table 2-7. Estimated volume of water recharging the perched water bodies at ICPP.

Source	Northern ICPP		Facility-wide	
	Volume (gal/yr)	Percent	Volume (gal/yr)	Percent
Service wastewater	None	0	690,000,000	95.8
Sewage treatment ponds	15,000,000	58	15,000,000	2.1
Water system leaks ^a	3,980,000	16	3,980,000	0.6
Landscape irrigation ^a	1,568,000	6	1,568,000	0.2
Precipitation infiltration	3,800,000	15	8,000,000	1.1
Steam condensate	1,300,000	5	1,700,000	0.2
CPP-603 Basins	None	0.00	49,275	<0.1
Total	25,648,000	100	720,297,275	100

a. Estimate based on past leaks and irrigation practices. Actual loss from piping leaks is unknown.

2.4 Geology

The following geologic description is summarized from *Lithology and Stratigraphy at the Idaho Chemical Processing Plant* [Attachment 2 of LITCO (1995)]. This technical memorandum includes the data used for the interpretation, an explanation of interpretive methods, and lithologic descriptions of each geologic unit.

2.4.1 Regional Geology

The INEEL is located in south-central Idaho on the Snake River Plain. The Snake River Plain is commonly divided into two regions: a western region, which is a northwest trending depositional basin, and an eastern region, which is a northeast trending volcanic plain (Malde, 1991). The INEEL is located in the eastern region of the Snake River Plain. This volcanic plain is comprised of approximately 914 m (3,000 ft) of layered late Cenozoic basalt flows over a rhyolitic basement that is approximately 3,048 m (10,000 ft) deep (Malde, 1991).

The ESRP is approximately 322-km (200-mi) long and ranges between 80 and 113 km (50 and 70 mi) in width (Anderson, 1991). It is bounded on the west by the north flowing reach of the Snake River through the Hagerman Valley and on the east by the Island Park rhyolite deposits. The northern and southern boundaries consist of the basin and range mountains of south central Idaho (Malde, 1991).

2.4.1.1 Origin of the Snake River Plain Volcanics. The crustal structure of the Snake River Plain volcanics, although not completely understood, is believed to include the entire thickness of the crust (Malde, 1991). It is believed the crust beneath the plain was modified by a hotspot (Malde, 1991). This theory is supported by numerous geophysical studies (Malde, 1991).

The geophysical studies suggest the crust beneath the plain is approximately 3.1-km (1.9-mi) thick as opposed to the crust surrounding the plain, which is approximately 20.0 km (12.4-mi) thick (Malde, 1991). There is geophysical evidence that a shallow source of heat exists at approximately 12.1 km (7.5 mi) below the surface (Malde, 1991). Heat flow measurements and volcanic activity suggest either the hotspot has progressed in a northeast direction or the crust has moved in a southwest direction resulting in the hotspot being presently associated with Yellowstone National Park (Malde, 1991). The absence of Paleozoic rocks within the ESRP is explained by Malde (1991), who suggests the hotspot produced mafic intrusions causing the granitic crust to melt from below, which resulted in a thinning of the crust and the formation of silicic magma bodies. These silicic magma bodies would have resulted in the formation of granitic batholiths, which would effectively displace any Paleozoic rock, leaving only the silicic magma and the underlying mafic intrusion as the only source materials for the formation of the ESRP. As the silicic magma erupted to the surface, the rhyolitic rocks found beneath the basalt were deposited. The violent silicic eruptions would have opened passage ways for the mafic magma to move through, eventually resulting in the basalt flows that now make up the ESRP.

2.4.1.2 Basalt Flow Structure. Greeley (1982) proposed the term "basalt plain" to describe the basaltic region of the ESRP. According to Greeley, a basalt plain combines elements of shield volcanoes and flood basalt plateaus.

The ESRP is composed of multiple thin flows erupted from vents aligned on volcanic rift zones. Two types of basalt are commonly erupted on the ESRP: a form known as *pahoehoe*, which is a very fluid, low-viscosity magma that produces thin tongues and lobes, and *aa*, which is a high-viscosity magma that results in blocky angular flows. A third "hybrid" type of basalt is also found among the lava flows of the ESRP. It is suggested it was formed by magma interacting with crustal rocks at depths of about 31 km (19 mi) (Malde, 1991).

As suggested by Greeley (1982), *pahoehoe* is the dominant type of basalt that erupted on the Snake River Plain, which forms the long, low angle flanks of the low shield volcanoes. The eruption of an *aa* lava produces the higher angle slopes surrounding the vents. As the eruption of the basalt continued over time, several low shield volcanoes formed, their flanks overlapping, to produce the complex stratigraphy found within the Snake River Plain.

2.4.1.3 Flows, Flow Units, Flow Groups. A lava flow is generally defined as a solidified body of rock that has been extruded out horizontally across the earth's surface from a fissure or vent. A lava flow may be described as a flow, which refers to the overall body of rock; a lava flow may also be described as a flow unit that is defined as a separate distinct lobe that issues out from a flow, or a lava flow may be described as a flow group, which is a sequence of petrographically similar flows that erupted from the same magma chamber (Anderson and Lewis, 1989). Between lava flows there is a contact that represents a cooling surface between flows. The cooling surface is typically marked by an increase in the number of vesicles and fractures in the rock as well as a significant amount of oxidation. There may also be a layer of sediments between flows. Commonly these sediments are referred to as interbeds.

The sediment or interbed sources may be other volcanic activity or alluvial, lacustrine, and eolian types of sediments. The sediment thickness depends on the location of the deposition, time between eruptions, and type of sediments.

2.4.1.4 Volcanic Features Near the INEEL. Several volcanic features exist on the Snake River Plain in the vicinity of the INEEL; these features make up a series of volcanic rift zones. To the west of the INEEL is the Arco Volcanic Rift Zone, to the south is an arc of volcanic vents and rhyolitic domes, the largest of which is Big Southern Butte, which is dated at about 300,000 years ago (Spear and King, 1982). This arc of volcanic features is called the Axial Volcanic Zone. To the east of the INEEL is the Hells Half Acre Rift Zone, which trends northwest to southeast. These volcanic zones are thought to be the sources of much of the basalt that has flowed out onto the Snake River Plain.

2.4.1.5 Surficial Sediments. A summary of Kuntz et al. (1990) of the surficial sediments deposited on the surface of the Snake River Plain follows:

“The surficial sediments deposited on the surface of the plain in the vicinity of the INEEL are composed of alluvial, lacustrine, and eolian deposits. During the Pleistocene times, streams originating in the mountains north of the plain carried large volumes of sediments and deposited them in the mouths of the stream valleys as huge alluvial fans. Some sediments were carried out into the basins below the mountain ranges to form broad gravel plains. In addition to the sediments deposited by the regular workings of the mountain streams, some sediments were distributed through large floods that moved across the plain. There was also a large lake that formed during the Pleistocene time that covered much of the northeast portion of the INEEL. The lake has been named Lake Terreton. Sediment was also carried out over the plain by strong winds which deposited fine grained sands and silts.”

2.4.2 Subsurface Geology of the ICPP

The subsurface of the ICPP has been extensively drilled and sampled by the USGS in an effort to understand and monitor the movement of groundwater and contaminants beneath the ICPP. The geologic data acquired during the drilling of the wells at the ICPP were used to make the geologic interpretation of the subsurface at the ICPP.

To date, 41 wells have been drilled at and around the ICPP to depths that exceed the upper limits of the SRPA (36 USGS monitoring wells, four production wells, and ICPP monitoring well); 32 wells have been drilled and are completed in the various perched water bodies beneath the ICPP; and numerous holes have been drilled at the ICPP in the surficial sediments to the top of the basalt. Two of the deep aquifer wells and 11 of the shallow perched wells were cored. A significant number of the wells completed in the perched groundwater and SRPA have geophysical logs including natural-gamma, neutron, gamma-gamma, and caliper. In addition, borehole video logs are available for each well. Figure 2-7 is a map of the ICPP showing well locations.

The subsurface geologic interpretation is divided into a section in which the lithology of the basalt flows is discussed and a section in which the basalt flow stratigraphy is discussed. The reason the geologic interpretation is being presented in this manner is because the complex lithology (i.e., fracturing, vesicles, and weathering surfaces) is not continuous within a single flow unit and, therefore, the lithology cannot be correlated between boreholes. However, the stratigraphic relationship of the basalt flows can be correlated

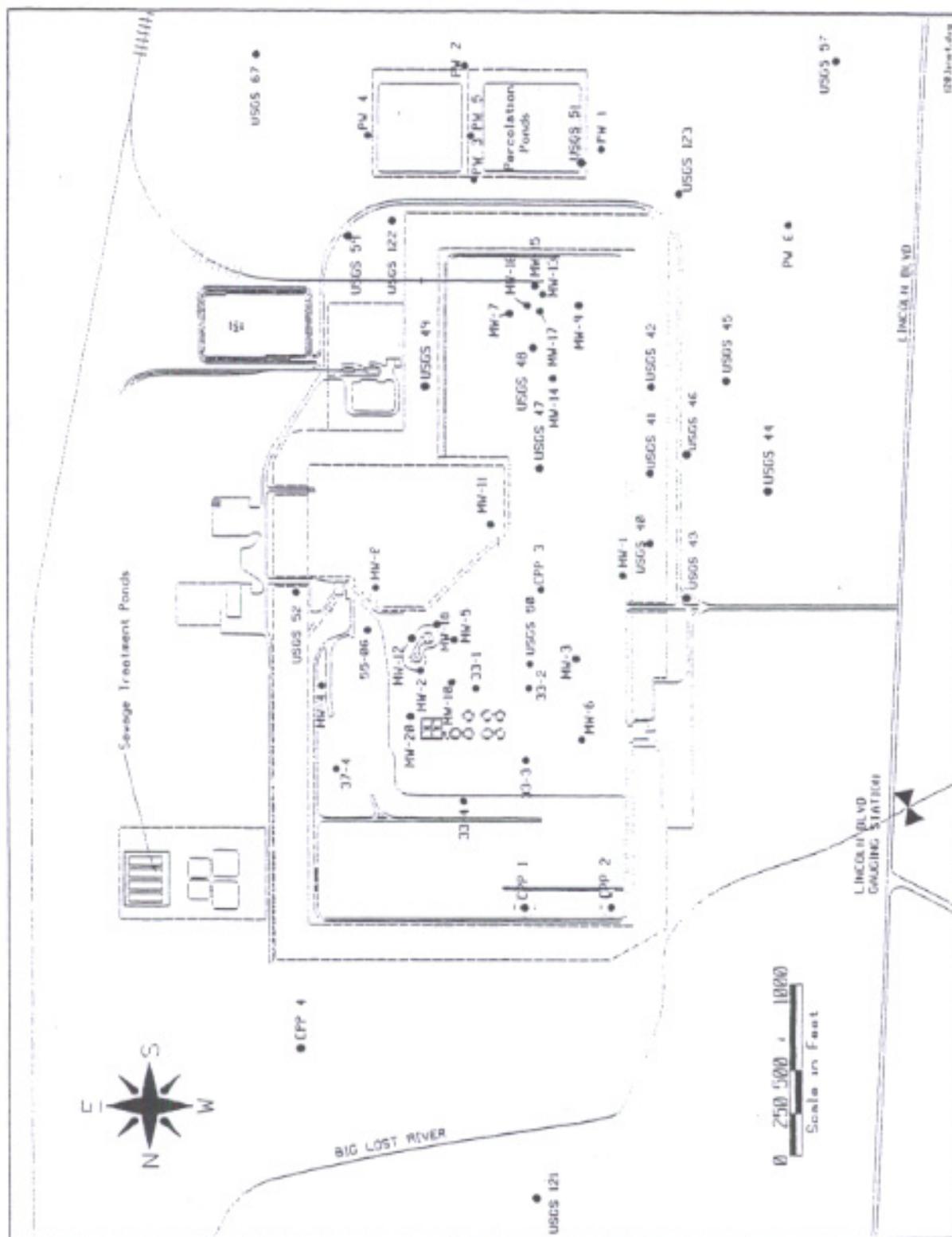


Figure 2-7. Locations of the ICPP monitoring wells.

between boreholes using the stratigraphic position of the flows as indicated by similar geophysical responses measured within the boreholes. This correlation is difficult due to the high degree of similarity between basalt flows.

2.4.2.1 Lithology. Figure 2-8 is a generalized lithologic column showing the basalt flows and sedimentary interbeds beneath the ICPP and the geophysical response associated with each different geologic material as determined by careful examination of core from the ICPP.

The generalized lithologic column (Figure 2-8) shows three typical lithologic sequences found in basalt flows beneath the ICPP. The upper portion of the column indicates a massive dry basalt grading downward into a moist vesicular basalt. The base of the flow rests on a saturated layer of sediments. The sediments cover a weathered fractured vesicular basalt in which the vesicles and fractures have been filled to some extent with sediments from above. A set of horizontal sediment-filled fractures are shown below the upper weathered zone. These horizontal fractures overlay a dry massive basalt, which grades into a saturated basalt vesicular basalt. The bottom of this flow unit overlies a tight, moist sediment layer. The sediments then overlay a moist to dry layer of vesicular fractured basalt, which grades to a massive dry basalt. Below the massive basalt is a basalt vesicular zone followed by a fractured weathered vesicular zone. This is typical of a contact between two flows in which there are no sediments present. There may be some measurable amount of moisture due to the fracturing and vesicular nature of the basalt near the edge of flows. The basalt then grades to a massive dry basalt.

The geophysical logs provided on the generalized column show typical responses to the different lithologies. The gamma log shows a typical low gamma radiation count for the massive portions of the basalt with increasing gamma counts related to zones of increased sediment percentages. The largest gamma counts correspond to those portions of the lithologic column that are entirely sediment. The sediment-filled horizontal fracture produces a small gamma anomaly. The actual gamma count from the sediment may be equal to that of the thicker sediment layer above, but because the fracture is very small, the radiation is attenuated causing a smaller response.

The neutron log indicates a response to moisture in the formation. The dry basalt causes very limited neutron thermalization and, therefore, the neutron count for these zones is much higher than the zones where moisture is present. Zones of either limited porosity or moisture tend to produce a moderate number of neutron collisions, thereby causing the neutron count to decrease slightly. Saturated zones produce the most neutron collisions, which is reflected by the low neutron counts.

The generalized natural-gamma and neutron logs show perching units versus nonperching units and zones where groundwater occurs. A perching unit will have a neutron low above it and exhibit a neutron high. If the perching layer is composed of sediments, there will be a natural-gamma anomaly associated with it. Fractures and other zones of water are indicated by low neutron counts.

2.4.2.2 Lithology of Corehole USGS-121. The lithologic column for Corehole USGS-121 was selected to show the lithology from the ground surface to the SRPA. This corehole penetrates lithology that is typical of the ICPP subsurface, however, the lithology may vary significantly between boreholes at the ICPP.

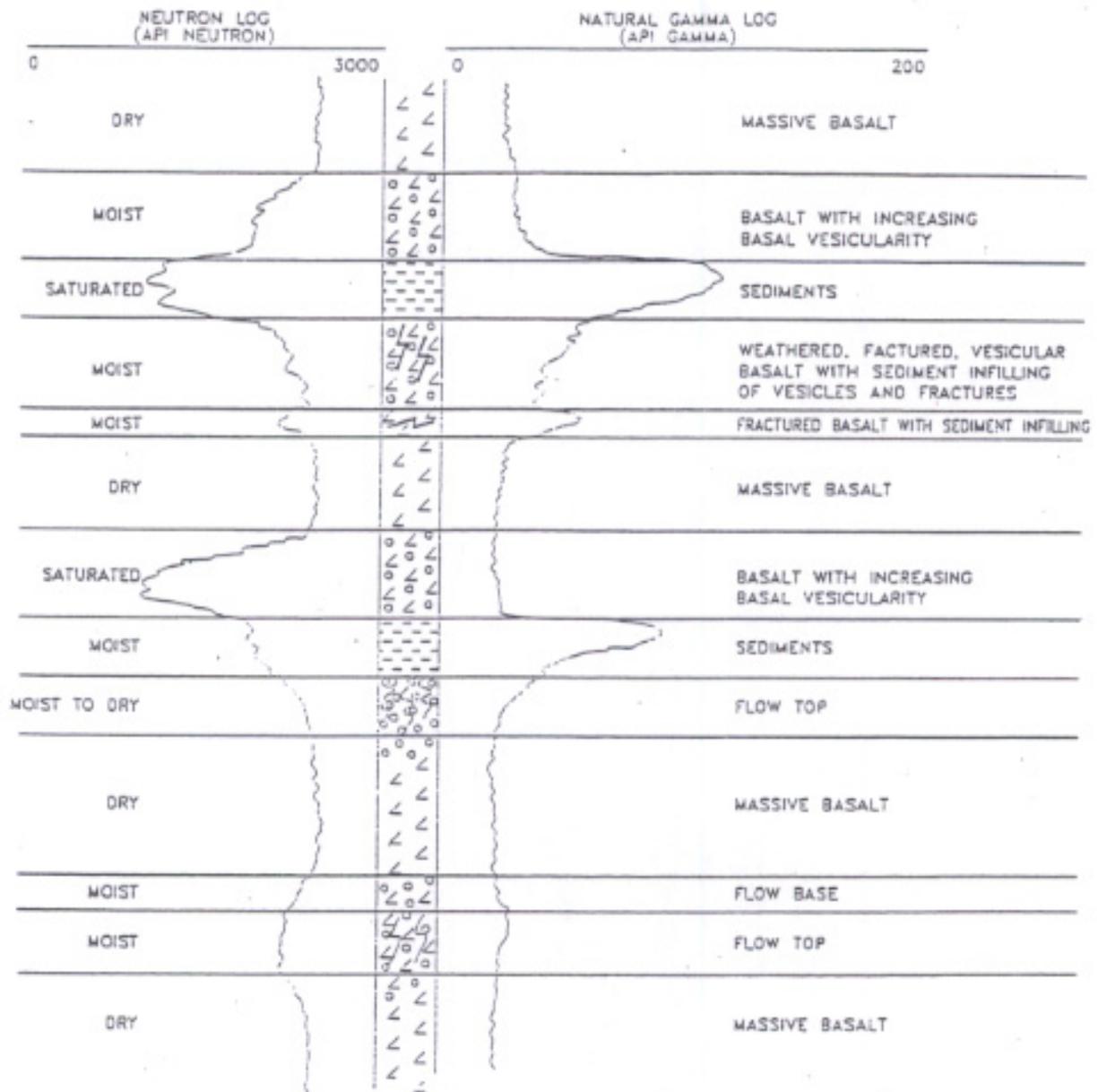


Figure 2-8. Generalized lithologic column and associated geophysical response.

Corehole USGS-121 is located north of the ICPP (Figure 2-7); the total depth of the corehole is 227 m (745.8 ft) below ground surface (bgs). The corehole was drilled in 1989 and 1990 as a monitoring well. Static water level in the SRPA is approximately 139 m (455 ft) bgs. The hole was overreamed to 30.18 cm (11.88 in.) and cased to 131.7 m (432 ft) bgs with a 20-cm (8-in.) carbon steel casing. Stainless steel casing was hung from 125.8 to 136 m (412.6 to 449 ft) bgs having 7.9 m (26 ft) of 0.02 slot stainless screen and an additional 1.5 m (5 ft) of stainless steel casing to a depth of 146 m (480 ft) bgs. A silica sand pack was placed from 146 to 148 m (480 to 485 ft) bgs over a Volclay bentonite plug, which was installed from 148 to 151 m (485 to 495 ft) bgs.

Digital natural-gamma and neutron logs were recorded for Corehole USGS-121 in June, 1993 to a depth of 146 m (480 ft) bgs, which is the top of the silica sand pack. Before the 1993 logging effort, the hole was geophysically logged using an analog natural-gamma, neutron, and gamma-gamma logging system in 1989 and again in 1990. For the lithologic evaluation of the hole, the digital log recorded in 1993 was used. The effects of well construction and the static water level on the neutron log are seen in the interval from 131 to 140 m (430 to 460 ft) bgs.

A detailed lithologic column for Corehole USGS-121 was derived from the core log description and geophysical logs contained in Attachment 2 of LITCO (1995). Top and bottom depths of the lithologic units and descriptions of the lithologic units are also provided in LITCO (1995). Significant lithologic sequences penetrated by Corehole USGS-121 are described as follows:

- The base of the surficial sediments at 10.4 m (34 ft) bgs are indicated by a sharp decrease in the natural gamma count. The neutron log does not show a significant change until the basalt becomes more competent and less fractured and/or vesicular. This delay in the neutron log response was confirmed by inspection of the core.
- A basalt sequence of an unusually high natural gamma radiation is found between 35.4 and 39.6 m (116 and 130 ft) bgs. This was confirmed as a basalt from inspection of the core. It appears to be a single unit with a thin sediment layer above and below, as indicated by the neutron log. The neutron log shows a significant decrease between 34.7 and 35.4 m (114 and 116 ft) bgs and again at 39.6 and 40.5 m (130 and 133 ft) bgs. Core loss in these zones prevented a detailed description of the materials from these intervals, but silty sediments were found on the core above and below these intervals.
- Moist silt is possibly indicated by the natural gamma and neutron logs between 42.7 and 44.2 m (140 and 145 ft) bgs. Inspection of the core from above and below this interval revealed traces of silt, thus supporting the interpretation of the geophysical logs.
- The interval between 79.2 and 85.3 m (260 and 280 ft) bgs is a slightly weathered to fresh dusky red basalt that is highly fractured, as indicated by the neutron log. It overlies a 9.8-m (32-ft) thick interval [85.3 to 95.1 m (280 to 312 ft) bgs] of fresh, minutely vesicular basalt that is relatively unfractured. This interval is characterized by a higher neutron log count than the overlying basalt, while the natural gamma log remains essentially the same. Below this interval is a highly weathered vesicular basalt, which is possibly a pyroclastic flow [97.8 to 98.4 m (321 to 323 ft) bgs]. The neutron log shows a significant decrease in the count rate between 95.7 and 97.5 m (314 and 320 ft) bgs, whereas, the natural gamma log does not show any significant change between this interval and the one above.

- The interval from 122.2 to 125.3 m (401 to 411 ft) bgs is a series of sands, silts, and clays. The sediment descriptions were obtained by inspection of the core. The geophysical responses of the sediments are used to confirm the intervals in which the sediments exist and aid in the identification of the type of sediments.

The sediments between 122.2 and 122.5 m (401 and 402 ft) bgs are described in the core log as silt with basalt gravel. The natural gamma count is beginning to increase in this interval and the neutron log shows a significant low.

From 122.5 to 123.4 m (402 to 405 ft) bgs a reddish brown, massive silty clay is described. The natural gamma count has significantly increased from the interval above and the neutron log also increased in this interval, indicating a decrease in the moisture content in these sediments.

From 123.4 to 124.7 m (405 to 409 ft) bgs there was a significant amount of core loss, but no indication the lithology changed from sediments to basalt. The geophysical data suggest a sand. This is based on the low natural gamma count combined with a decrease in the neutron count indicating the clay mineral content of the sediments decreased and the porosity increased, which is typical of a sand.

From 124.7 to 125.0 m (409 to 410 ft) bgs a pale yellow brown moist silt is described in the core log. This geologic material type is accompanied by a high natural gamma count and an increase in the neutron count.

Based on the above observations, it appears water may be perching on the fine clay like sediments from 122.5 to 123.4 m (402 to 405 ft) bgs. The sediments above this zone may contain some water based on the neutron response while the sediments below appear to be relatively dry.

2.4.2.3 Stratigraphy. Several stratigraphic units based on similar lithology and stratigraphic position have been identified beneath the ICPP. A generalized stratigraphic column is presented in LITCO (1995). This figure shows the stratigraphic units and gives a general description of the units. The unit thicknesses provided on the stratigraphic column are average thicknesses from the wells used to make the stratigraphic interpretation. A complete table of the unit thicknesses are provided in *Lithology and Stratigraphy at the Idaho Chemical Processing Plant* [Attachment 2 of LITCO (1995)]. The names given the stratigraphic units are based on the nomenclature used by Anderson (1991). An attempt was made to stratigraphically associate the sediments found between the basalt flows and as a result, the names of the sediment units are based on their stratigraphic association (i.e., "DE2" Basalt and "DE2" Sands).

South-north and west-east cross sections have been prepared from the available data. A complete description of these cross sections is presented in *Lithology and Stratigraphy at the Idaho Chemical Processing Plant* [Attachment 2 of LITCO (1995)]. The cross sections extend from the ground surface [approximately 1,494 m (4,900 ft) above median sea level (amsl)] to 1,341 m (4,400 ft) amsl. The top of the SRPA is approximately 1,356 m (4,450 ft) amsl in the vicinity of the ICPP. Figure 2-9 shows the location of the east-west cross section and the wells used for correlation. The east-west cross section of the ICPP may be found in Section 2.6.1.2.1 of this report, and additional cross sections are provided in Plate 3 of the Final Work Plan. The wells used for the west-east section include USGS-043, MW-001, CPP-03 (Injection Well), MW-018 (the location of MW-018 is approximate; it was not surveyed in at the time of this Work Plan), MW-008, and USGS-052. MW-001, MW-008, and MW-018 were drilled using an air rotary drill rig with a

tri-cone bit between 1992 and 1994. The remaining wells were drilled using a cable tool rig in the early 1950s and 1960s.

The USGS wells were drilled as monitoring wells for the SRPA. The MW series of wells were drilled to monitor the perched water zones beneath the ICPP. Well CPP-3 was drilled as a deep injection well for the ICPP (it has since been abandoned), and Well CPP-2 was drilled as a production well for the ICPP water supply.

The stratigraphic relations shown on the cross section depict the typical subsurface stratigraphy beneath the ICPP. The basalt flows are characterized as overlapping lobes of basalt intermixed with larger basalt flows of relatively uniform thickness beneath the ICPP. The sediments found between the basalt flows are often discontinuous and characterized by sequences of sands, silt, and clays. These changes in the sediment lithology are distinguished by the geologist records from drilling and/or the responses of the sediments on the geophysical logs.

The basalt flows, as interpreted, appear to be relatively uniform in thickness beneath the ICPP. Significant changes in the flow thickness are often related to changes in the lithology of the flow or are caused by the flow margins in which the flow appears as a lobe of basalt. The lithologic changes that may cause a change in the flow thickness are the existence of pyroclastic deposits on or within a flow, or a flow being very vesicular, and thus, more susceptible to the effects of erosion.

Stratigraphically significant basalt flows beneath the ICPP include the "CD" flow, "DE3" flow, and "DE4" and "DE5" flows. The "CD" flow appears to be a very hard, nonporous flow that is not continuous over the entire ICPP. This could potentially affect the movement of groundwater in the vadose zone. The "DE3" flow is typically uniform in thickness and appears to be relatively flat lying; it is most likely a porous to semiporous basalt. It provides a lower boundary for the thick sediments associated with the "D" and "DE2" stratigraphic units. The "DE4" and "DE5" basalt flow units are often characterized as massive and unfractured, however, portions of the flows are described as pyroclastic cinder-type deposits in which the basalt is highly vesicular and fractured. The boundary between these flows is not clearly defined; there does not appear to be any major sedimentary units separating these basalt flows.

The sediments, as interpreted, appear to be primarily made up of sands and silts with some small clay lenses. The majority of the sediments are thin [0.3- to 1.5-m (1- to 5-ft) thick] layers of silt between the major basalt flows. Sediments were most likely deposited in eolian or fluvial type environments. Two major sediment sequences are shown on the cross sections: the upper sequence associated with the "CD," the thick "D" and "DE2" sands and silts; and the lower sediments associated with the "DE6," "DE7," and "DE8" stratigraphic units.

The cross sections show a very thick sequence of sediments, particularly in the northern end of the south-north section, which are stratigraphically shown as the "CD," "D," and "DE2" units. These sediments appear to be a thick sequence of sands over and underlain by silts and clays. Structure contour maps of the top of the "CD" and "D" interbeds are provided in Figures 2-10 and 2-11, respectively.

The sediments associated with the "DE6," "DE7," and "DE8" stratigraphic units appear to be made up of gravels, silts, and clays. These sediments were most likely deposited in a fluvial environment and may indicate a braided stream deposit. This is the last major sediment deposit above the SRPA. Structure contour map of the top of the "DE8" interbed is provided in Figure 2-12.

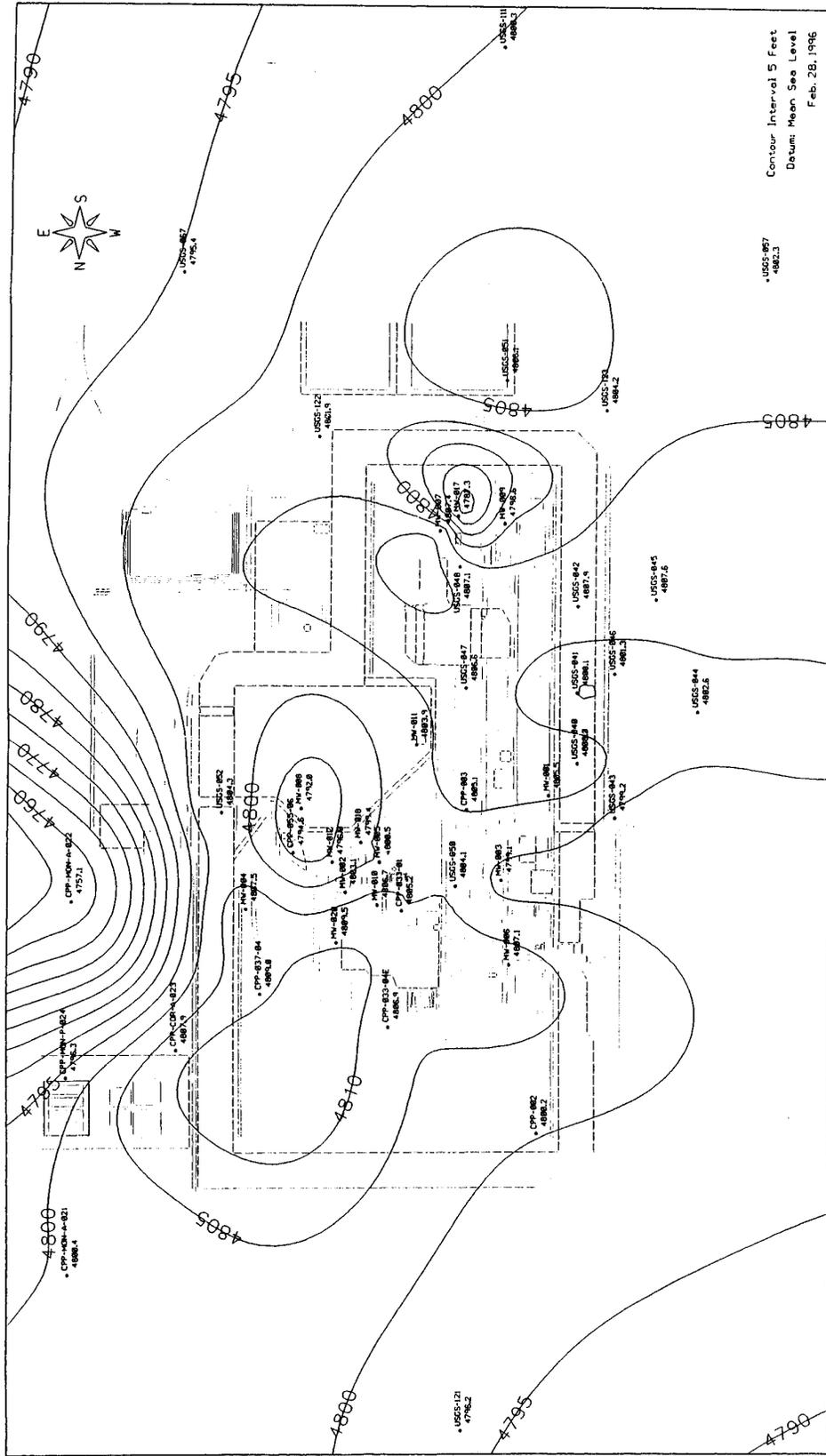


Figure 2-10. Structure contour map of the top of the "CD" interbed.

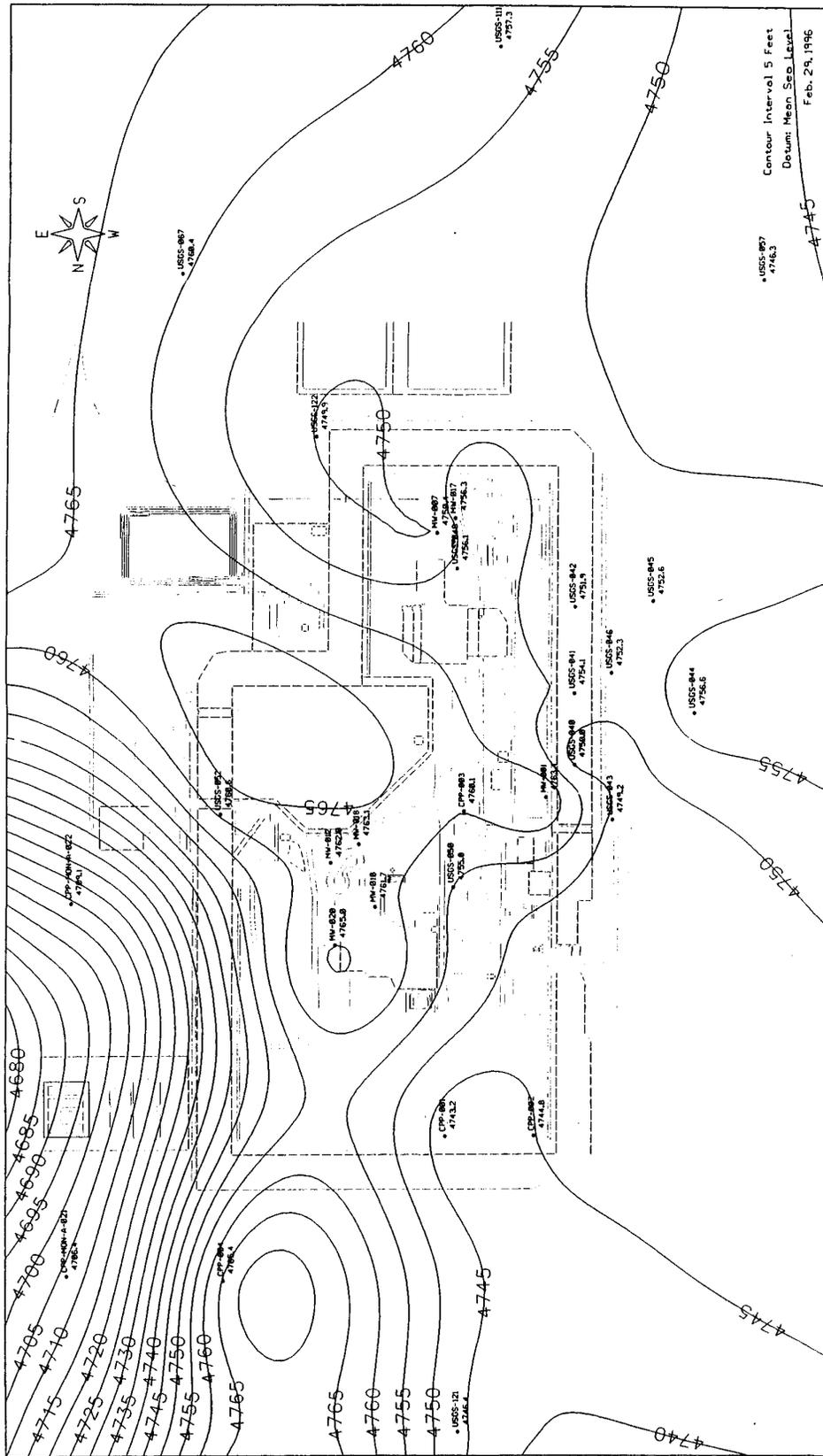


Figure 2-12. Structure contour map of the top of the "DE8" interbed.

2.5 Regional Hydrogeology

The SRPA flows beneath the INEEL and is about 322 km (200 mi) long and 89- to 113-km (55- to 70-mi) wide. It extends from Ashton and the Big Bend Ridge on the northeast to Hagerman on the southwest (Figure 2-13) and covers about 25,900 km² (10,000 mi²). The aquifer consists of a series of basalt flows with interbedded sedimentary deposits and pyroclastic materials. The boundaries are formed by the contacts of the aquifer with less permeable rock at the margins of the plain (Mundorff et al., 1964). Robertson et al. (1974) estimated as much as 2B acre-ft of water may be in storage in the aquifer, of which about 500M acre-ft are recoverable.

Groundwater in the SRPA generally occurs under unconfined conditions, but locally may be quasi-artesian or artesian (Nace et al., 1959). The quasi-artesian or artesian conditions are caused by layers of dense, massive basalt or sediments with relatively low permeability. Nace et al. (1959) described quasi-artesian as the situation in which the groundwater level is first recognized in a borehole during drilling at a depth below the regional water table, and then the level rises significantly [1.5 to 15.2 m (5 to 50 ft)] to the level of the water table. This rise of the water level simulates artesian pressure, but the conditions are not truly artesian. Nace et al. (1959) also noted water levels in some wells in the SRPA respond to fluctuations in barometric pressure similar to wells in confined aquifers, indicating tight zones in the basalt may impede pressure equalization. True artesian or flowing artesian conditions in the SRPA were identified at Rupert, in parts of the Mud Lake Basin, and north of the American Falls Reservoir (Nace et al., 1959).

Recharge to the aquifer is primarily by valley underflow from the mountains to the north and northeast of the plain and from infiltration of irrigation water. A small amount of recharge occurs directly from precipitation. Recharge to the aquifer within INEEL boundaries is primarily by underflow from the northeastern part of the plain and the Big Lost River (Bennett, 1990). Significant amounts of recharge from the Big Lost River have caused water levels in some wells at the INEEL to rise as much as 1.8 m (6 ft) in a few months after high flows in the river (Barracough et al., 1982). Locally, the direction of groundwater flow is temporarily changed by recharge from the Big Lost River (Bennett, 1990).

Estimates of the effective thickness of the SRPA at the INEEL are variable. A 3,159-m (10,365-ft) deep geothermal test well (INEL-1) was drilled about 7.2-km (4.5-mi) north of the ICPP in 1979. Subsurface geologic information from INEL-1 indicates at least 610 m (2,000 ft) of basalt underlie the INEEL (Prestwich and Bowman, 1980). Hydrological data from INEL-1 were interpreted by Mann (1986) to indicate the effective base of the aquifer is 259 to 372 m (850 to 1,220 ft) bgs. The depth to water at INEL-1 is about 122 m (400 ft) bgs, which suggests an effective aquifer thickness of 137 to 250 m (450 to 820 ft). In earlier studies by Robertson et al. (1974), the effective portion of the SRPA at the Test Reactor Area (TRA) was assumed to be the upper 76 m (250 ft) of the saturated zone based on lithology and water quality. The aquifer's thickness varies at different areas, and the aquifer becomes less productive with depth due to decreasing hydraulic conductivity (Hull, 1989). Hydraulic conductivity of the basalt in the upper 244 m (800 ft) of the aquifer generally is 0.3 to 30.5 m/day (1 to 100 ft/day); whereas, the hydraulic conductivity of underlying rocks is several orders of magnitude smaller (Orr and Cecil, 1991). Fracture filling from sediments and secondary mineralization are the principal reasons for the decreased hydraulic conductivity.

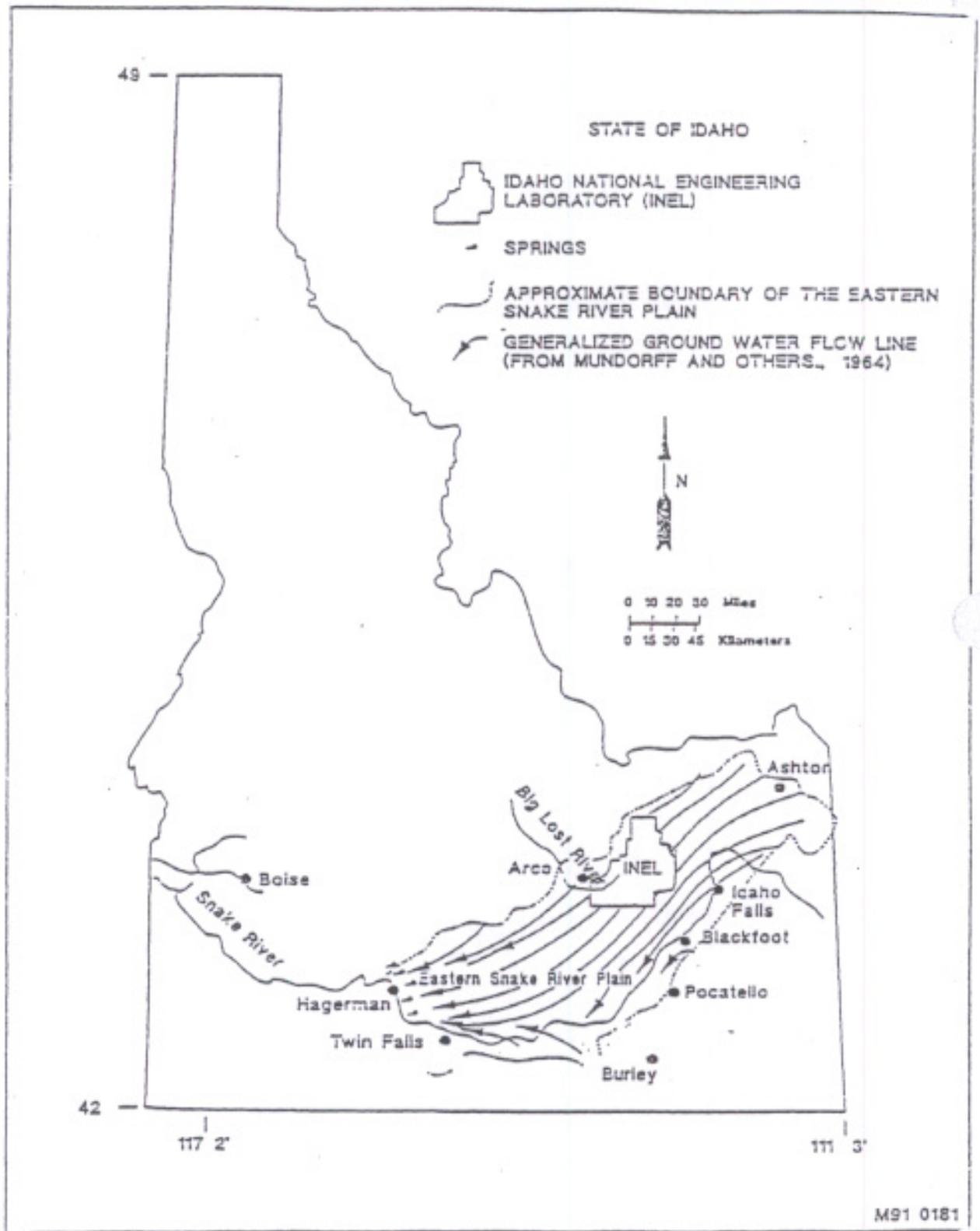


Figure 2-13. Map of Idaho showing location of the INEEL, Snake River Plain, and generalized groundwater flow of the SRPA (Hull, 1989).

Perched groundwater zones occur when downward flow to the aquifer is impeded by fine sediments or dense basalt flows with relatively low permeability. At the INEEL, perched groundwater has been documented beneath the Big Lost River system, and at the NRF, TRA, and ICPP (Morris et al., 1965; Robertson et al. 1974; and Pittman et al., 1988). The occurrence of perched groundwater at the ICPP will be discussed later in this section.

2.5.1 Depth to Water and Groundwater Flow

The water table contour map shows the configuration of the water table and general lateral direction of groundwater flow across the INEEL in July, 1988 (Figure 2-14). The water level elevations ranged from 1,399 m (4,590 ft) amsl in the northern part of the INEEL to about 1,347 m (4,420 ft) amsl south of the INEEL; the depth to the water table varied from about 61.0 m (200 ft) bgs in the northern part of the INEEL to about 274-m (900-ft) bgs in the southern part. The general direction of groundwater flow was to the south-southwest, and the average gradient was about 0.8 m/km (4 ft/mi) (Orr and Cecil, 1991). Locally, however, the hydraulic gradient varies significantly and ranges from about 0.2 m/km (1 ft/mi) in the northern part of the INEEL to a maximum of 2.8 m/km (15 ft/mi).

The elevation of the water table and direction of groundwater flow are affected by recharge and groundwater withdrawal. From July 1985 to July 1988, Orr and Cecil (1991) reported water level changes in INEEL wells ranging from a 7.9-m (26-ft) decline near the RWMC to a 1.2-m (4-ft) rise north of TAN. Water levels generally declined in the southern two-thirds of the INEEL during that time and rose in the northern one-third.

The Big Lost River flows intermittently on the INEEL. When flowing, the water infiltrates from the river and percolates downward toward the SRPA. Layers of sediment and massive basalt in the vadose zone having relatively low permeability may impede the downward percolation of water and sometimes form perched water bodies beneath the river. A hydrograph of Well USGS-78 located west of the ICPP and corresponding discharge measurements from the Big Lost River at the Lincoln Boulevard Bridge near the ICPP are shown in Figure 2-15. Well USGS-78 is 71.6 m (235 ft) from the river and 61.9 m (203 ft) deep, and is completed approximately 79.2 m (260 ft) above the SRPA.

The water level in Well USGS-78 begins an abrupt rise about 4½ days after flow starts in the Big Lost River. The water level may rise as much as 30.5 m (100 ft) within a few months. The water level in the well is very sensitive to river stage, and as stream flow declines or ceases, the perched water level declines abruptly. Declines of 18.3 to 27.4 m (60 to 90 ft) have been measured within 3 or 4 months (Barraclough and Jensen, 1976). Well USGS-78 is an open borehole from 20.1 to 61.9 m (66- to 203-ft) bgs, and as a result, the transmissive zone cannot be determined to provide an estimate for the vertical flow velocity. The horizontal groundwater velocity from the Big Lost River to Well USGS-78 appears to be as high as 0.9 m/hr (3 ft/hr).

2.5.2 Aquifer Properties

Aquifer permeability is controlled primarily by fractures, fissures, and voids along the upper and lower contacts of basalt flows, interstitial large voids, and intergranular pore spaces. Vesicles contribute little to permeability because most are isolated and do not transmit much water. Locally, the direction of groundwater flow may vary due to the variability of the hydraulic characteristics of the aquifer within a small area.

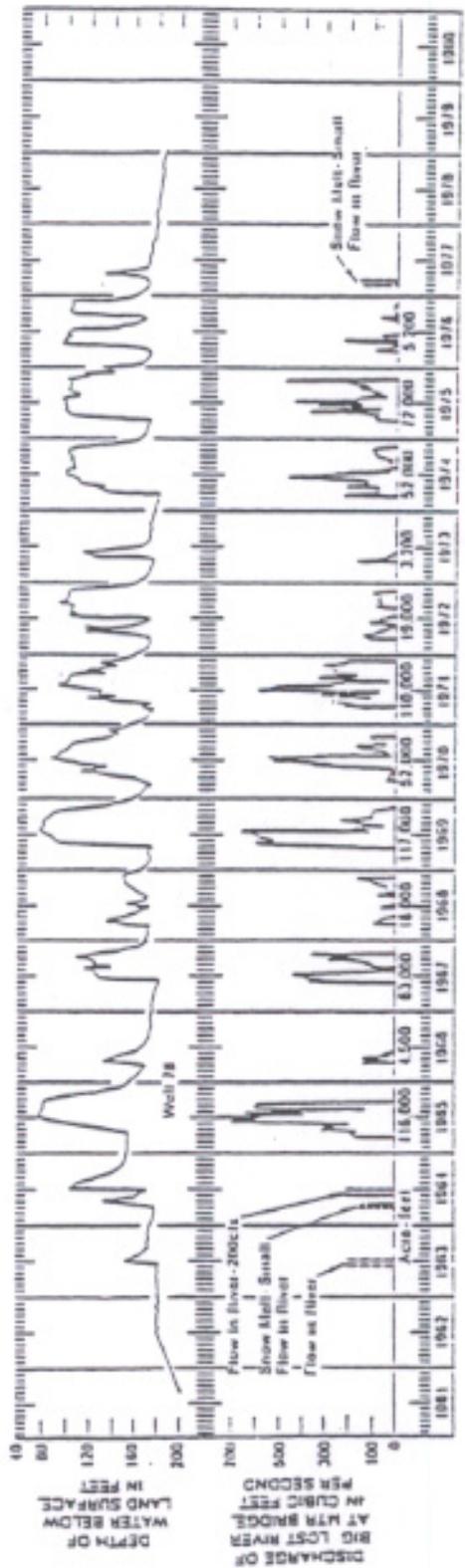


Figure 2-15. USGS-78 water level response vs. Big Lost River discharge at Lincoln Boulevard (Barracough et al., 1982).

Hydraulic properties of the SRPA have been determined by pumping tests. According to Robertson et al. (1974), transmissivities range from 1.24×10^4 to 1.24×10^6 m²/day (1.34×10^5 to 1.3×10^7 ft²/day) with 6.2×10^4 m²/day (6.7×10^5 ft²/day) considered normal. Table 2-8 summarizes transmissivity and storage coefficients calculated from tests conducted at the INEEL. Transmissivities range from 3.7×10^2 to 2.2×10^4 m²/day (4.0×10^4 to 2.4×10^6 ft²/day), with the lowest at TAN and highest at TRA. By calculating the geometric mean of transmissivity values, Hull (1989) estimated regional aquifer transmissivity for the southern INEEL to be 27,000 m²/day (294,000 ft²/day). Estimates of the storage coefficients range from 0.01 to 0.06 and effective porosity from 5 to 15%, with 10% being historically the most accepted value (Robertson et al., 1974), though more recent information indicates that a lower value may be appropriate.

2.6 ICPP Hydrogeology

Sixty-eight wells have been installed at the ICPP to monitor perched water bodies and the SRPA. This monitoring well network consists of 32 wells completed in the perched water zones and 36 wells completed in the SRPA. Several of the perched water monitoring wells are completed in multiple water bearing zones. The location of the wells completed in the perched water zones are shown in Figure 2-16, with the construction specifications provided in Table 2-9.

2.6.1 Perched Water Zones

The uppermost perched water zone identified at the ICPP occurred within the Big Lost River alluvium above the basalt. This shallow perched water was first investigated near the fuel element cutting and storage facility (CPP-603) in the early 1960's. The perched water was primarily attributed to the discharges of wastewater to the shallow seepage pit (CPP-2) located on the west side of the building. This shallow perched water body was investigated by installing 27 observation wells in the alluvium above the basalt. A small zone of perched water was encountered at a depth of 6.7-m (22-ft) bgs, and a larger zone was encountered directly on the basalt surface at a depth of 9.8-m (32-ft) bgs. This perched water body has not been monitored since 1970 and is believed to have dissipated since the construction of the Irradiated Fuel Storage Facility (IFSF) on the western portion of CPP-603 over the seepage pit in the early 1970's. Other than the shallow perched water bodies beneath surface discharge ponds, no other extensive alluvial perched water bodies have been identified at the ICPP.

The upper basalt perched water zone was initially discovered in the late 1950s where Wells USGS-50 and USGS-52 encountered perched water at 38.4 and 53.0 m (126 and 174 ft) bgs, respectively. The occurrence of this perched water was attributed to operational practices based on the presence of radioactive and chemical contaminants. Since then, numerous monitoring wells have been installed in the upper perched water zone to identify the source of recharge, delineate the perched water bodies, and determine the nature and extent of contamination. A discussion of this perched water zone is provided in Section 2.6.1.2.

A lower perched water zone was also identified in the basalt at depths between 104 and 122 m (340 and 400 ft) bgs (Robertson et al., 1974). This water was first discovered in 1956 while drilling Well USGS-40 where perched water was encountered at a depth of 106 m (348 ft). An analysis of this perched water

Table 2-8. Results of aquifer tests conducted to determine transmissivity and storage properties of the SRPA (Walton, 1958 and Walker, 1960).

Well number	Test date	Transmissivity (ft ² /day)	Storage coefficient	Penetration of well below water table (ft)
CFA-2	27-FEB-51	2.1×10^4	—	209
TRA-1	22-JUL-57	1.9×10^6	0.02	114
MTR-TEST	07-JUN-57	2.4×10^6	0.06	134
Fire Station Well	03-NOV-58	4.1×10^5	—	96
SPERT	11-JAN-56	1.6×10^4	—	196
GCRE	20-MAY-59	3.9×10^5	—	747
4N 30E 7ad	29-AUG-50	2.3×10^5	—	367
CPP-1	11-NOV-51	4.4×10^5	0.06	136
STR-1	17-NOV-50	2.0×10^5	—	172
NRF-1	12-NOV-53	1.1×10^4	0.03	157
STR-2	03-AUG-50	4.9×10^5	—	163
NRF-2	19-FEB-57	5.7×10^5	—	
ALW	24-AUG-56	1.5×10^5	—	180
NRF-3	25-MAR-57	6.4×10^4	—	
ANP-1	16-APR-53	9.4×10^4	0.01	157
ANP-2	30-APR-53	1.3×10^4	—	133
ANP-3	20-JUL-53	8.6×10^4	—	112
FET Prod 1	17-APR-58	4.4×10^4	—	139
FET Prod 2	03-MAY-58	9.1×10^4	—	259
LPTF Disposal	20-JUN-57	4.0×10^3	—	109

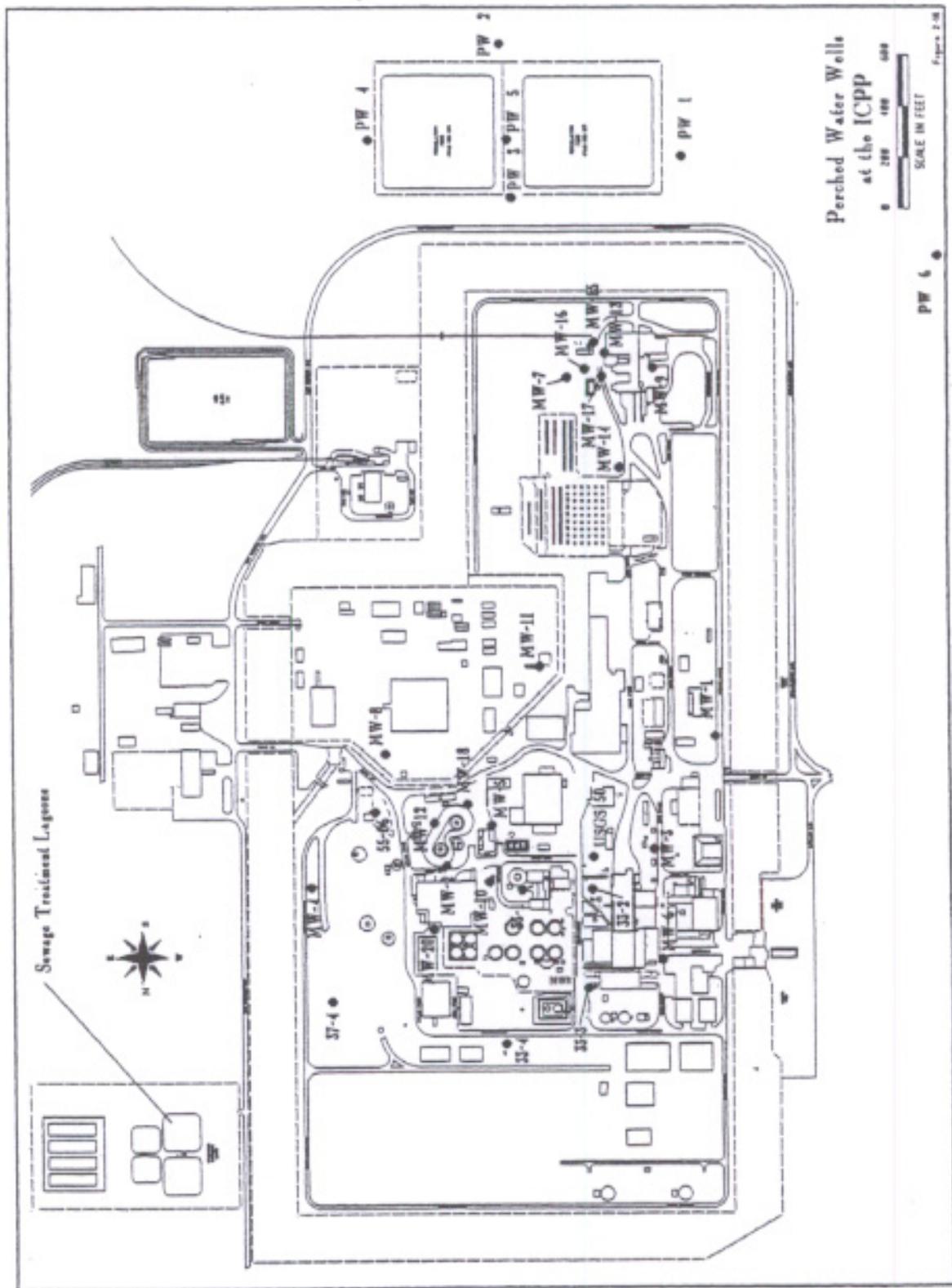


Figure 2-16. Locations of the perched water wells as the ICPP.

Table 2-9. Specifications of the perched water wells.

Well	Type	Northing	Easting	Land Surface		Measuring Point		Total Depth Drilled		Well Screen (footage)		Well Screen (elevation)	
				Elevation	Elevation	Elevation	Footage	Elevation	Top	Bottom	Top	Bottom	
CPP 33-1	2-in. SS Well	695392	296939	4915.2	4917.38	113.6	4801.6	89.0	99.0	4826.2	4816.2		
CPP 33-2	2-in. SS Well	695385	296639	4914.2	4915.42	114.7	4799.5	85.8	105.8	4828.4	4808.4		
CPP 33-3	2-in. SS Well	695806	296659	4913.7	4916.23	126.4	4787.3	111.8	121.8	4801.9	4791.9		
CPP 33-4	2-in. SS Well	696049	297011	4911.9	4914.01	124.0	4787.9	98.2	118.2	4813.7	4793.7		
CPP 37-4	2-in. SS Well	695861	297743	4911.0	4912.66	129.3	4781.7	99.9	109.9	4811.1	4801.1		
CPP 55-06	2-in. SS Well	695057	297563	4911.6	4913.21	122.9	4788.7	93.1	113.1	4818.5	4798.5		
PW-1	6-in. Steel Well	692270	296234	4917.8	4919.13	120.0	4797.8	100.0	120.0	4817.8	4797.8		
PW-2	6-in. Steel Well	691791	297010	4917.0	4918.54	131.0	4786.0	111.0	131.0	4806.0	4786.0		
PW-3	6-in. Steel Well	692447	296961	4916.7	4918.12	123.0	4793.7	103.0	123.0	4813.7	4793.7		
PW-4	6-in. Steel Well	692197	297572	4914.8	4916.30	150.0	4764.8	110.0	150.0	4804.8	4764.8		
PW-5	6-in. Steel Well	692196	296978	4916.4	4918.40	131.0	4785.4	109.0	129.0	4807.4	4787.4		
PW-6	6-in. Steel Well	692696	295150	4920.5	4922.34	135.0	4785.5	105.0	125.0	4815.5	4795.5		
MW-1	4-in. PVC Well	694731	296099	4916.5	4919.25	395.0	4521.5	326.0	336.0	4590.5	4580.5		
MW-1	1-in. PVC Piezo.	694731	296099	4916.5	4919.00	395.0	4521.5	359.0	369.0	4557.5	4547.5		
MW-2	2-in. PVC Well	695285	297262	4913.1	4916.09	127.0	4786.1	102.0	112.0	4811.1	4801.1		
MW-3	2-in. PVC Well	695215	296369	4916.0	4918.50	151.3	4764.7	128.0	138.0	4788.0	4778.0		
MW-3	1-in. PVC Piezo.	695215	296369	4916.0	4918.50	151.3	4764.7	116.3	118.0	4799.7	4798.0		
MW-4	2-in. PVC Well	695376	297828	4911.4	4914.21	131.0	4780.4	100.6	110.6	4810.8	4800.8		
MW-4	1-in. PVC Piezo.	695376	297828	4911.4	4913.77	131.0	4780.4	128.0	129.7	4783.4	4781.7		
MW-5	2-in. PVC Well	695110	297064	4916.4	4919.27	141.0	4775.4	106.5	126.5	4809.9	4789.9		
MW-6	2-in. PVC Well	695690	296320	4916.5	4919.26	161.0	4755.5	117.0	137.0	4799.5	4779.5		
MW-7	2-in. PVC Well	693209	296726	4917.4	4920.13	177.0	4740.4	132.0	142.0	4785.4	4775.4		
MW-7	1-in. PVC Piezo.	693209	296726	4917.4	4920.13	177.0	4740.4	102.3	104.0	4815.1	4813.4		
MW-8	2-in. PVC Well	694806	297514	4911.7	4914.37	141.0	4770.7	115.0	125.0	4796.7	4786.7		
MW-9	2-in. PVC Well	693168	296357	4919.6	4922.33	158.0	4761.6	120.0	130.0	4799.6	4789.6		
MW-9	1-in. PVC Piezo.	693168	296357	4919.6	4922.33	158.0	4761.6	104.2	105.7	4815.4	4813.9		
MW-10	2-in. PVC Well	695356	297078	4914.7	4917.41	181.0	4733.7	141.0	151.0	4773.7	4763.7		
MW-10	1-in. PVC Piezo.	695356	297078	4914.7	4917.41	181.0	4733.7	76.5	78.0	4838.2	4836.7		
MW-11	2-in. PVC Well	694435	296854	4914.9	4917.72	150.5	4764.4	131.0	136.0	4783.9	4778.9		
MW-11	1-in. PVC Piezo.	694435	296854	4914.9	4917.72	150.5	4764.4	112.0	113.5	4802.9	4801.4		
MW-12	2-in. PVC Well	695107	297336	4913.0	4915.99	153.0	4760.0	109.0	119.0	4804.0	4794.0		
MW-12	1-in. PVC Piezo.	695107	297336	4913.0	4915.99	153.0	4760.0	148.6	150.3	4764.4	4762.7		

Table 2-9. (continued).

Well	Type	Northing	Easting	Land Surface Elevation	Measuring Point Elevation	Total Depth Drilled		Well Screen (footage)		Well Screen (elevation)	
						Footage	Elevation	Top	Bottom	Top	Bottom
MW-13	2-in. PVC Well	693106	296561	4919.9	4921.99	128.0	4791.9	100.0	105.0	4819.9	4814.9
MW-14	2-in. PVC Well	693594	296503	4919.1	4921.60	138.0	4781.1	94.0	104.0	4825.1	4815.1
MW-15	2-in. PVC Well	693059	296608	4918.9	4921.25	143.0	4775.9	111.3	131.3	4807.6	4787.6
MW-16	2-in. PVC Well	693173	296648	4919.1	4921.65	126.0	4793.1	97.0	107.0	4822.1	4812.1
MW-17	2-in. PVC Well	693129	296622	4918.3	4921.11	381.0	4537.3	181.7	191.7	4736.6	4726.6
MW-17	1-in. PVC Piezo.	693129	296622	4918.3	4921.11	381.0	4537.3	263.8	273.8	4654.5	4644.5
MW-17	4-in. Steel Well	693129	296622	4918.3	4921.11	381.0	4537.3	360.0	381.0	4558.3	4537.3
MW-18	2-in. PVC Well	695020	297193	4914.0	4917.32	494.0	4420.0	113.5	123.5	4800.5	4790.5
MW-18	1-in. PVC Well	695020	297193	4914.0	4917.33	494.0	4420.0	394.0	414.0	4520.0	4500.0
MW-18	4-in. PVC Well	695020	297193	4914.0	4917.31	494.0	4420.0	458.5	478.5	4455.5	4435.5
MW-20	2-in. PVC Well	695568	297309	4915.0	4918.00	151.5	4763.5	133.2	148.4	4781.8	4766.6
MW-20	1-in. PVC Piezo.	695568	297309	4915.0	4918.00	151.5	4763.5	96.0	106.0	4819.0	4809.0
USGS-50	4-in. Steel Well	695247	296633	4913.5	4918.31	405.0	4508.5	356.0	405.0	4557.5	4508.5

Notes: SS = stainless steel
Piezo. = piezometer.

detected abnormally high total dissolved solids (303 mg/L), sodium (25 mg/L), and chloride (81 mg/L) indicating the water is of waste origin (Olmsted, 1962). According to Robertson et al. (1974), this was a reasonable level for the perched groundwater due to the presence of a clay bed "aquitar" at 113 m (370 ft) bgs.

In the late 1950s, only wells drilled in the northern ICPP encountered the lower perched groundwater zone. Since 1984, a lower perched groundwater zone has also formed in the southern ICPP due to disposal of process waste through the percolation ponds. The location of this lower perched water zone is indicated by Well MW-17 and borehole neutron logs from Well USGS-51. A discussion of the lower basalt perched water zone is described in Section 2.6.1.3.

2.6.1.1 Alluvium Perched Water. The only extensive perched water identified in the alluvium at the ICPP, other than beneath surface disposal ponds (i.e., percolation pond and sewage treatment pond), was encountered west of CPP-603. The source for the perched water was thought to be wastewater discharged to the shallow seepage pit (CPP-02). This disposal pit was in operation from 1952 to 1966 (Robertson et al., 1974). In 1963, 27 observation wells were installed in the alluvium to monitor this perched water body.

From 1962 to 1963, the volume of liquid wastes discharged to the pit averaged 37,850 L/day (10,000 gal/day). Morris et al. (1965) calculated that approximately 37,850 L (10,000 gal) of liquid waste were contained in the alluvium near the pit. Therefore, the shallow perched water body contained approximately 1 day's discharge of waste. Under these conditions, the perched water should quickly reflect short-term variations in the discharge rates or compositions. A comparison of the Sr-90 concentrations on the discharge to the Sr-90 concentration in the perched water confirms the short-term variations in the water quality (Morris et al., 1965).

If the source of recharge to the shallow alluvium perched water was solely due to the discharge pit, cessation in discharge to the pit should result in a dramatic decrease in the shallow perched water. Use of the pit was discontinued in October 1966, however, the shallow perched water body had not reflected the corresponding response by 1970 (Robertson et al., 1974). The configuration of the post-1966 perched water body is very similar to that of the pre-1966 period (Figure 2-17).

Robertson et al. (1974) made a comparison of the Sr-90 and H-3 concentrations in the shallow perched groundwater for 1963 and 1970 (Figure 2-18). The high Sr-90 concentrations in the 1963 perched water were the result of large Sr-90 releases to the disposal pit when more than 33 Ci were discharged. The 1970 concentrations in the perched water were attributed to either continued minor discharges or desorption from sediments of previously discharged and sorbed Sr-90. Tritium concentrations in the perched water indicate a significant decrease during the period from 1963 to 1970. The high concentrations in 1963 reflect the relatively high volumes of waste discharged to the pit during 1962 and 1963. The decline in H-3 concentrations from 1963 to 1970 is too great to be caused solely by radioactive decay. This information, combined with an increase in water levels from 1966 to 1970, indicates a nonradioactive source may have been percolating down and recharging the shallow perched water body, thus diluting the H-3 concentrations.

According to Morris et al. (1965), sewage wastes (nonradioactive) from CPP-603 were discharged to the pit from a nearby septic tank. It is unknown how the volume of sewage discharge compared to the volume

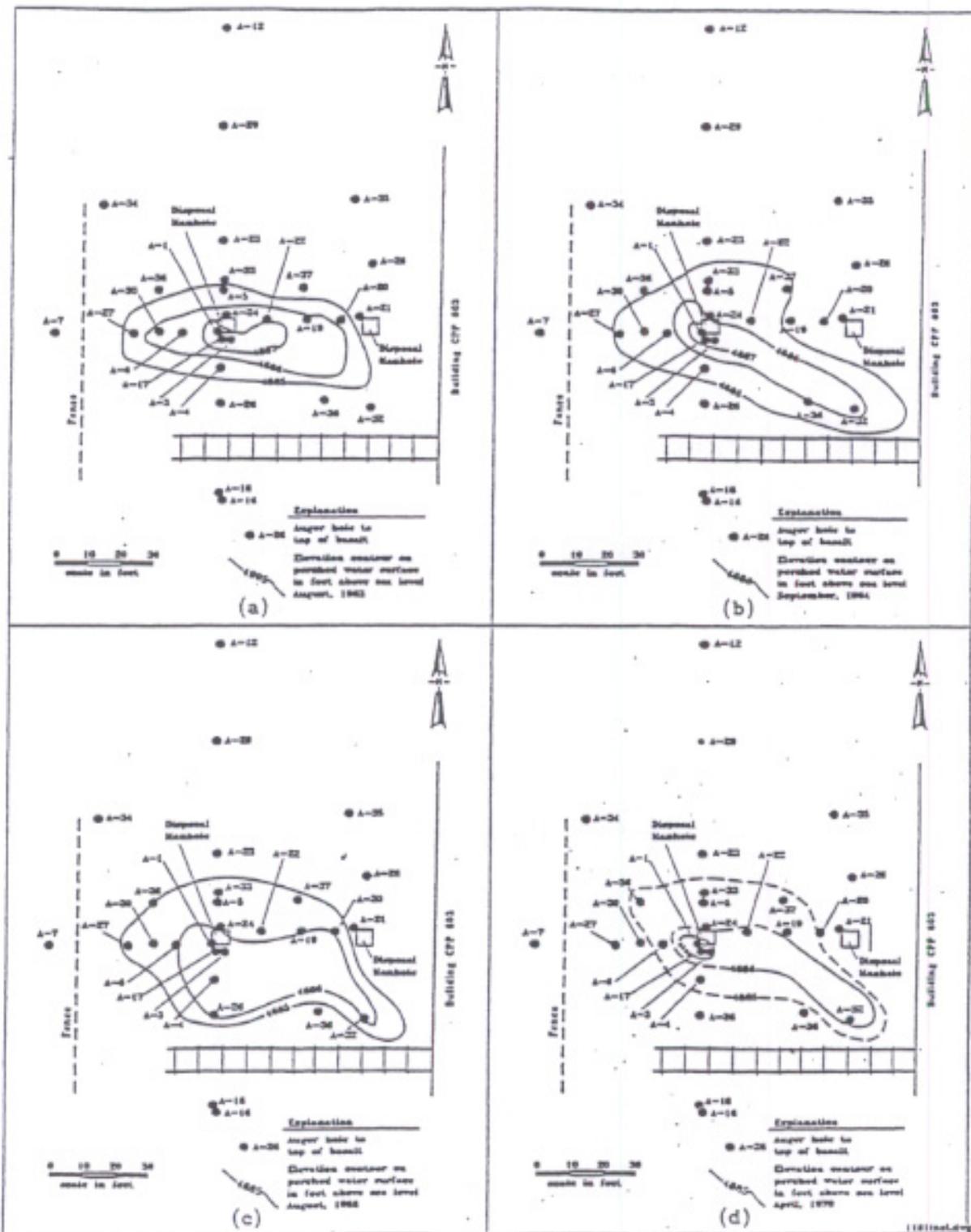


Figure 2-17. Water level contours on the alluvial perched water at the ICPP for 1963, 1966, 1968, and 1970 (Robertson et al., 1974).

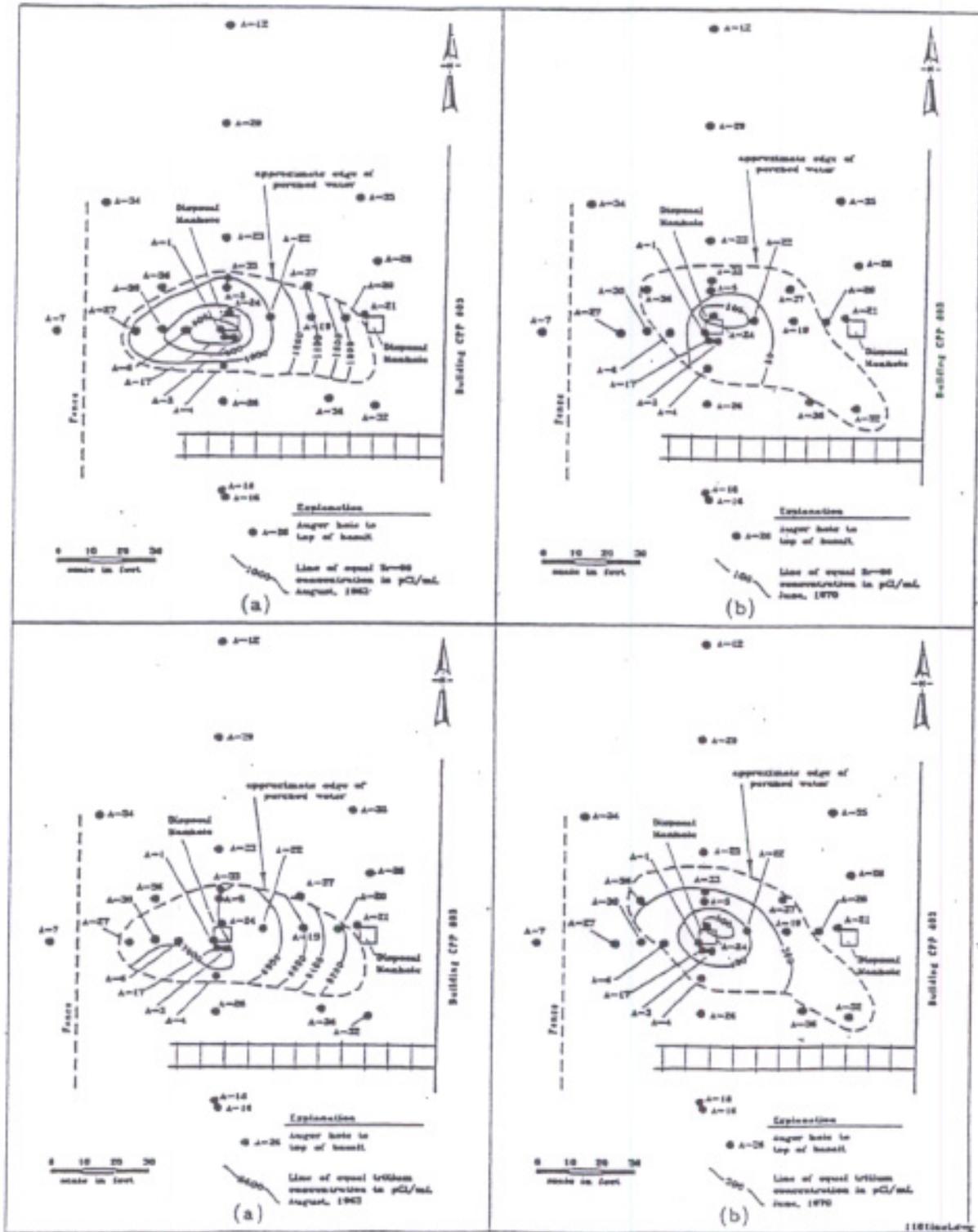


Figure 2-18. Distribution of Sr-90 and H-3 in the alluvial perched groundwater for 1963 and 1970 (Robertson et al., 1974).

of radioactive wastes discharged to the seepage pit. It was postulated that the sewage discharge may be at least partially responsible for the existence of the shallow perched water body in 1970. It was also speculated that piping leaks of nonradioactive water may also be contributing to the perched water body in 1970. Since the construction of the IRFS in 1973, the shallow perched water body has not been monitored and is believed to have dissipated. From the soil borings and monitoring wells installed during 1993 and 1994, only Well MW-13 encountered perched water in the alluvium. The water encountered by Well MW-13 is not believed to be related to the historical perched water body because (a) the well is located to the east of the facility and the historical perched water body was to the west and (b) discharge from the disposal pit ceased in 1966.

2.6.1.2 Upper Basalt Perched Water Zone. Stratigraphy controls the hydrogeologic characteristics of the subsurface at the ICPP, particularly in the formation and movement of perched groundwater. The formation of perched groundwater can be attributed to lithologic features contributing to contrasts in the vertical hydraulic conductivity of basalt layers and sedimentary interbeds in the unsaturated zone. Cecil et al. (1991) attributed four lithologic features to the formation of perched groundwater at the ICPP. Perched groundwater can form where (a) a sedimentary interbed with a reduced vertical hydraulic conductivity underlies a more conductive basalt layer, (b) altered baked zones between two basalt flows reduce the hydraulic conductivity, (c) the presence of dense unfractured basalt having low vertical hydraulic conductivity, and (d) sedimentary and chemical filling of fractures near the upper contact of a basalt flow reduce the vertical hydraulic conductivity.

Based on the perched water data, it appears the upper perched groundwater bodies are formed by the relatively low vertical hydraulic conductivity in the sedimentary interbeds. Of particular importance to the formation of perched groundwater are the "CD," "D," and "DE3" interbeds. Figure 2-19 shows the location of the upper basalt perched water zone that occurs between depths of 30.5 and 58 m (100 to 190 ft).

2.6.1.2.1 Northern ICPP—Twenty-three monitoring wells (including multiple completion wells) have been installed in the northern ICPP to monitor the upper perched groundwater (i.e., groundwater that occurs less than 58 m (190 ft) bgs. Two perched groundwater bodies have been identified in the northern ICPP. The upper perched groundwater body is present above the "CD" and "D" interbeds and the lower perched groundwater body has been identified on the "DE3" interbed. According to the lithology, the "CD" interbed occurs at depths between 34 and 36 m (113- and 119-ft) bgs, the "D" interbed occurs at depths between 39 and 41 m (128- and 135-ft) bgs, and the "DE3" interbed occurs at depths between 50 and 52 m (163- and 170-ft) bgs. Based on available information, it appears that the perched groundwater between the "CD" and "D" interbeds is continuous over much of the northern ICPP since these interbeds are only separated by 9 ft. The perched water body and monitoring well completed above the associated interbed are as follows:

<u>"CD" Interbed</u>	<u>"D" Interbed</u>	<u>"DE3" Interbed</u>
CPP-33-1	CPP-33-3	MW-10 (2-in.)
CPP-33-2	CPP-33-4	MW-12 (1-in.)
CPP-37-4	CPP-37-4	MW-20 (2-in.)
CPP-55-06	MW-3 (2-in.)	
MW-2 (2-in.)	MW-4 (2-in.)	
MW-3 (1-in.)	MW-5 (2-in.)	
MW-8 (2-in.)	MW-6 (2-in.)	
MW-11 (1-in.)	MW-11 (2-in.)	
MW-12 (2-in.)	MW-18 (1-in.)	
MW-20 (1-in.)		

In addition to these wells, well MW-4 (1 in.) is completed at the bottom of the "D" interbed and Well MW-10 (1 in.) is completed in a fracture zone associated with the "BC" interbed. Historically, both of these wells have been dry.

The extent of the upper basalt perched groundwater body is provided in Figure 2-19. These elevations range from 1,462.2 to 1,476.8 m (4,797.3 to 4,845.3 ft) and represent the average water table level throughout the monitoring period as discussed in Section 2.6.1.4. The extent of the perched water above the "CD" and "D" interbeds are illustrated in this figure. Perched groundwater is not known to occur above these interbeds outside the areas illustrated on the map. Where the perched water bodies overlap (i.e., in the vicinity of wells CPP-33-4, CPP-33-1, MW-5), the entire region between the "CD" and "D" interbeds is likely to be saturated. Otherwise, perched groundwater is only present above the associated interbed. The height of the perched groundwater above the "CD" and "D" interbeds is provided in Figures 2-20 and 2-21, respectively. Based upon the input parameters used in the Tetrad groundwater model, and assuming 100% water saturation, it is estimated that the upper perched water zone contains 25.7×10^9 L (6.8×10^9 gal) of water.

An east-west cross section is provided in Figure 2-22 to illustrate the occurrence of the interbeds and the associated perched groundwater. In the eastern part of the section (i.e., in the vicinity of wells MW-4 and CPP 55-06), the "CD" and "D" interbeds form a single stratigraphic unit because the "CD" basalt flow is not present. These interbeds separate toward the west forming two layers to impede the downward migration of water. The average separation between these two interbed is approximately 2.7 m (9 ft).

Based on the water table configuration, it appears that multiple water sources are providing recharge to the upper basalt perched water body in the northern ICPP. The sewage treatment ponds, located east of the facility, provide approximately 4.73×10^6 L (1.25×10^6 gal) per month of recharge to this perched water body. This recharge has resulted in a water table elevation of 1,476.8 m (4,845 ft) in the well (CPP-MON-P-024) completed near the sewage treatment ponds. In the western portion of the perched water body and beneath the main portion of the facility, recharge from an unknown source(s) has produced a maximum water table elevation of 1,468.4 m (4,817.5 ft) in well CPP-33-2. Between the eastern and western portions of the upper perched water body, the average groundwater elevation is 1,465.8 m (4,809.2) ft in Well CPP-37-4. This water table configuration indicates separate sources of water providing recharge to the eastern and western portions of the upper-most perched water body and that the sewage treatment ponds have minimal, if any, impact upon the western portion of this perched water body.

Occurring beneath the upper perched groundwater body, a deeper perched groundwater body has been identified at a depth of approximately 140 ft bgs. This groundwater appears to be the result of the "DE3" interbed, which occurs between 163 and 169 ft bgs in the northern ICPP. Only three wells [MW-10 (2-in.), MW-12 (1-in.), and MW-20 (2-in.)] are completed in this perched groundwater body. Based upon monitoring data, the water table elevation within this perched water zone varies from 1,453.6 to 1,456.6 m (4,769 to 4,779 ft). The estimated extent and water table elevation for this perched water body is provided in Figure 2-23. Based on the input parameters for the Tetrad groundwater model, and assuming 100% water saturation, it is estimated that the middle perched water zone contains 14.8×10^9 L (3.9×10^9 gal) of water.

2.6.1.2.2 Southern ICPP—The upper perched water bodies identified in the southern ICPP are shown in Figure 2-19. The largest perched water body is the result of discharge to the percolation ponds and monitored by wells PW-1 through PW-6. In the vicinity of CPP-603, six wells (MW-7, MW-9, and MW-13

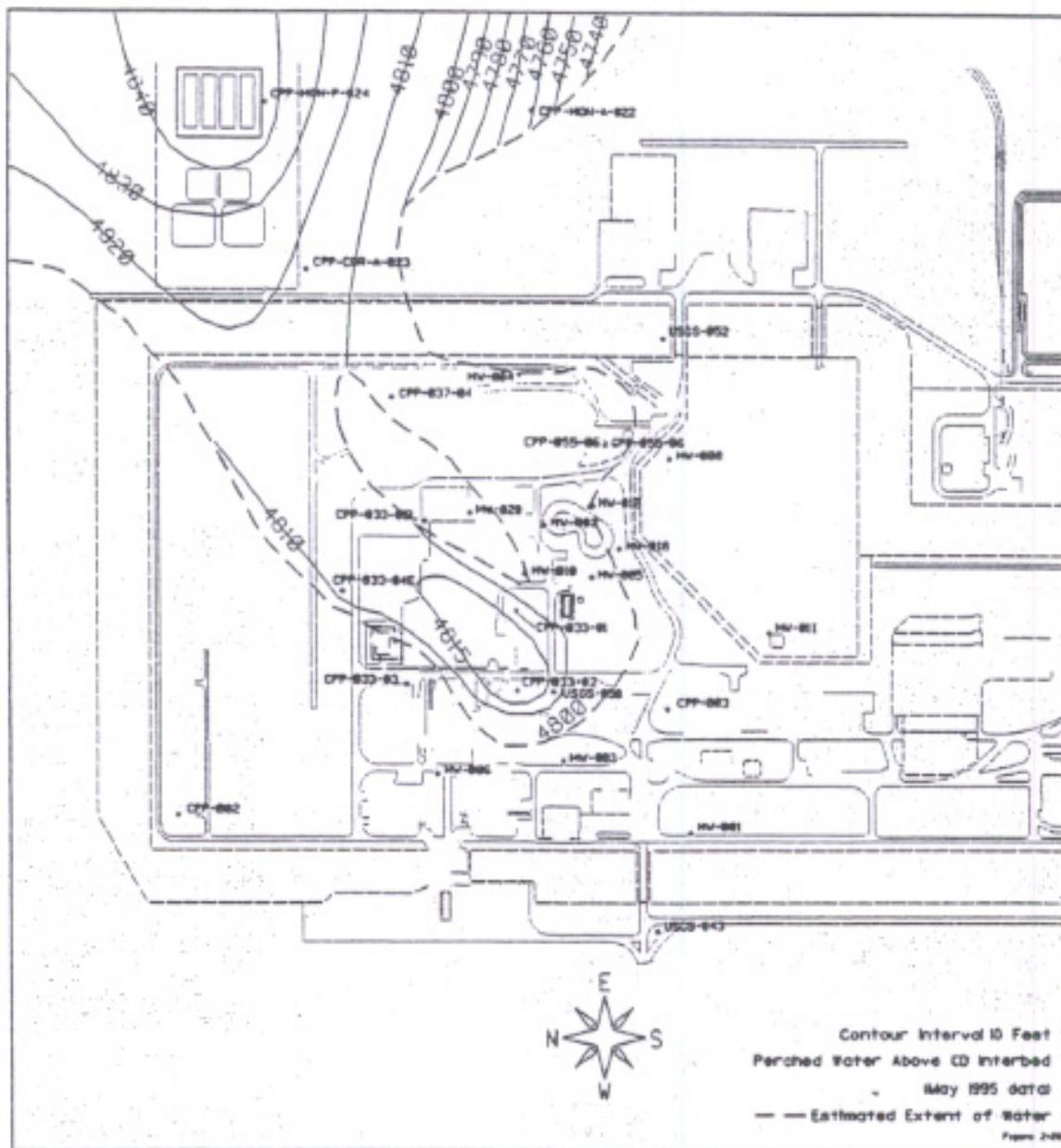


Figure 2-20. Elevation of water above the "CD" interbed in the northern ICPP.

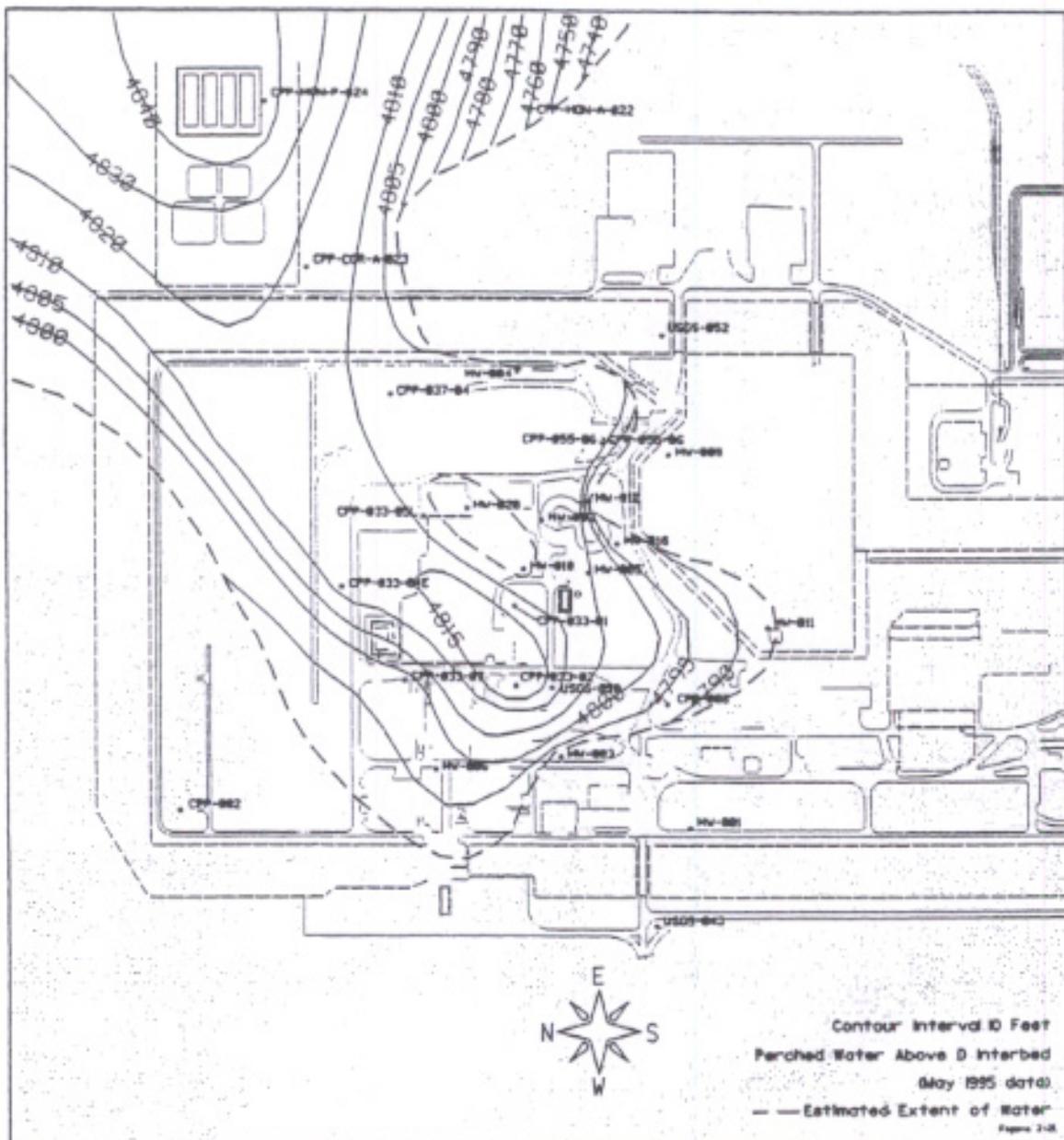


Figure 2-21. Elevation of water above the "D" interbed in the northern ICPP.

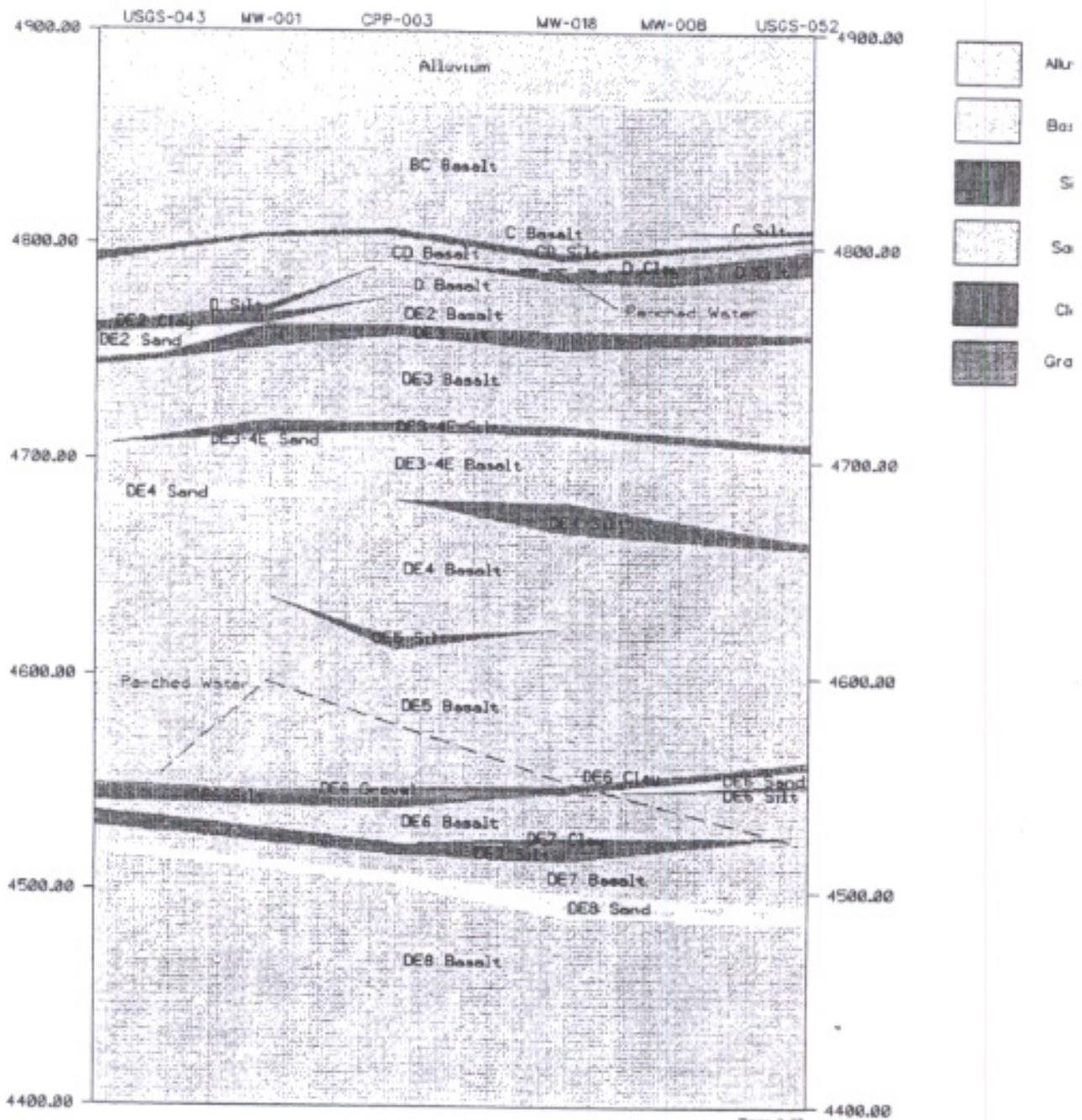


Figure 2-22

Figure 2-22. East-west cross section of the upper basalt perched water zone in the northern ICPP.

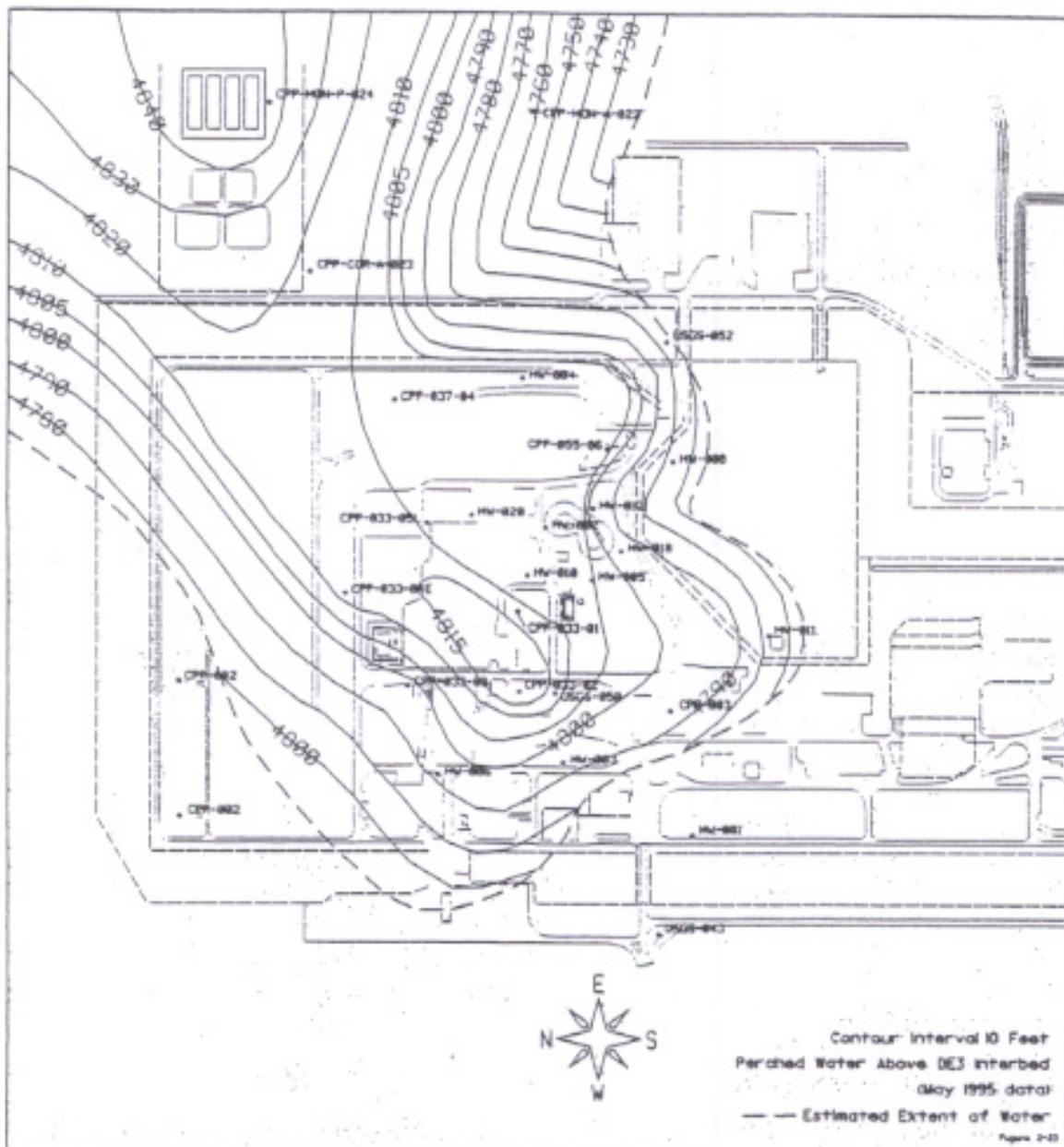


Figure 2-23. Approximate extent of the perched groundwater above the "DE3" interbed.

through MW-16) were installed to monitor perched water on the upper interbed that is present between 33.5- and 39.6-m (110- and 130-ft) bgs. One triple completion well (MW-17) was installed to monitor for perched water on a deeper interbed occurring approximately 57.9 m (190 ft) bgs.

An extensive perched water body on the upper interbed has not been identified in the vicinity of CPP-603. Only three wells (MW-7, MW-9, and MW-15) have detected water on the upper interbed, and the remaining three wells (MW-13, MW-14, and MW-16) are dry. Other than MW-15, only minimal water has been encountered with the height of water above the interbed less than 1.2 m (4 ft) during every measuring event.

Wells PW-1 through PW-6 were installed adjacent to the percolation ponds to monitor the perched groundwater beneath the ponds. Figure 2-24 provides the hydrographs for these wells during the period from September 1986 through early 1994. As shown in this figure, a similar fluctuation in the water level is observed for Wells PW-1, PW-3, and PW-6 indicating these wells are effective in monitoring infiltration from the western percolation pond. The water level fluctuation in Well PW-4 is opposite to the response observed in Wells PW-1, PW-3, and PW-6, indicating this well monitors infiltration from the eastern percolation pond. The water level fluctuations in Wells PW-2 and PW-5 are fairly consistent indicating these wells are influenced by discharge to either pond.

2.6.1.3 Lower Basalt Perched Water Zone. A lower perched groundwater zone has been identified to occur in the basalt between 97.5- and 128-m (320- and 420-ft) bgs. This water was first discovered in 1956 while drilling Well USGS-40 where perched groundwater was encountered at a depth of 106 m (348 ft) (Robertson et al., 1974). Since then, groundwater has been encountered in this zone during the drilling of Wells USGS-41, USGS-43, USGS-44, USGS-50, USGS-52, MW-1, MW-17, and MW-18. Table 2-10 summarizes the available data from the USGS wells concerning the deep perched groundwater zone. Borehole neutron logs run in 1993 indicate perched water may still be present in this zone from Wells USGS-40, USGS-43, USGS-46, USGS-51, and USGS-52.

Only four wells are completed in the lower perched water zone that presently monitor water level changes. Wells MW-1, MW-18, and USGS-50 are completed in the northern portion of the facility having encountered water at approximately 85, 107.5, and 101 m (322, 407, and 383-ft) bgs, respectively. In the southern portion of the facility, only Well MW-17 is completed in the lower perched water zone where water is encountered at a depth of approximately 96-m (364-ft) bgs. Based upon water quality information, the deep perched groundwater encountered by Well MW-17 is the result of discharge to the percolation ponds.

Similar to the upper basalt perched water zone, the lower perched water zone is thought to be formed by decreased permeability associated with sedimentary interbed layers. It appears that the lower perched groundwater has formed primarily on the "DE8" interbed. The top of this interbed occurs beneath the ICPP at depths ranging from 101 to 112.5 m (383 to 426 ft) bgs. In the western portion of the facility, however, the "DE6" interbed is responsible for creating perched groundwater associated with Wells USGS-40 and USGS-43. Table 2-11 provides a summary of the perching layer, depth to water, and water table elevation for the wells that encountered lower perched groundwater. The extent of the lower perched groundwater and approximate elevation of the water table is shown in Figure 2-25. It should be noted that these data contain a high degree of uncertainty since they consist of a combination of original drillers logs (some dating back 40 years), geophysical borehole logs, and monitoring wells that are completed in this zone.

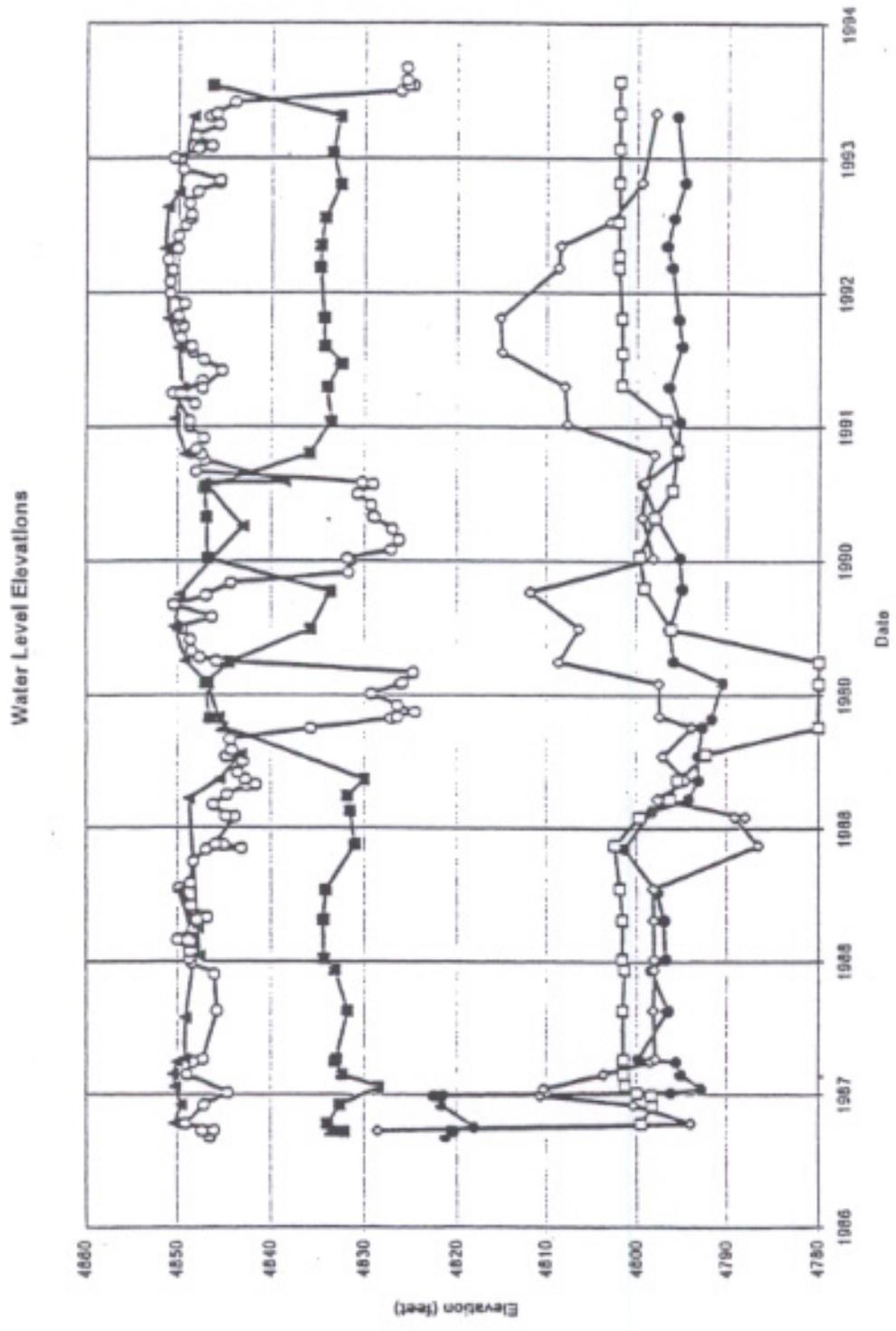


Figure 2-24. Hydrographs for the PW-series wells.

Table 2-10. Depth of perched water zones encountered during the drilling of wells around the ICPP (Robertson et al., 1974).

Well number	Date drilled	Depths to perched water (ft)	Characteristics of the water	Depth of perching clay layer (ft)	
USGS-40	September, 1956	348 (rose to 340)	high Na ⁺ , Cl ⁻	370	
USGS-41	December, 1956	396 (rose to 384)	high Cl ⁻	Unknown	
USGS-43	March, 1957	367 (rose to 362)	background groundwater composition	370	
USGS-44	September, 1957	385	background groundwater composition	Unknown	
USGS-50	September, 1959	84		110 ?	
		126	high sodium, β activity, Ru-106, Rh-106 present	135	
		Deepened to 405 ft October, 1962	390	high H-3	392
USGS-52	December, 1959	174	slightly high Na ⁺ , high β and γ activity, I-131, Ru-106, Rh-106 present	195	
		Deepened to 650 ft October, 1960	320		345
		385	slightly high Na ⁺ , high β activity, Ru-106 present	410	

Table 2-11. Perched layer, depth to water, and water table elevation for the wells encountering water in the lower perched water zone.

Well	Water Level		Perching Layer		Water Table Elevation
	ft bls	Year	Interbed	Depth	(ft AMSL)
USGS-40	340	1956	DE6	368-383	4,576
USGS-41	384	1956	DE8	406-430	4,533
USGS-43	362	1957	DE6	368-376	4,554
USGS-44	385	1957	DE8	410	4,534
USGS-50	383	1995	DE8	396-405	4,535
USGS-51	270	1986	DE6	384-400	4,686
USGS-52	385	1960	DE8	416-425	4,525
MW-1	322	1995	Unknown	Unknown	4,597
MW-17	364	1995	DE8	>381	4,557
MW-18	407	1995	DE8	412.7-423.2	4,553

As shown in Figure 2-25, the lower perched water zone is probably not continuous beneath the entire facility, and may actually consist of several individual perched water bodies. The north-south separation of the lower perched water bodies is based on the lack of perched groundwater (either through drilling or subsequent neutron logging) identified in Wells USGS-42, -45, -47, -48, and -49. Based on input parameters used in the Tetrad groundwater model, and assuming 100% water saturation, it is estimated that the deep perched water zone contains 20.4×10^9 L (5.4×10^9 gal) of water. Recharge to the southern perched water body is from wastewater discharged to the percolation ponds. The source of recharge to the western portion of the northern perched water body is unknown.

Water levels in this lower perched water zone have been monitored since the early 1960's in Well USGS-50 (Figure 2-26). Other than during the late 1960's and early 1970's, the water level in this well has been fairly consistent. The water level during this period generally ranged between 1,381 and 1,384 m (4,530 and 4,540 ft) amsl. In the late 1960's/early 1970's, however, the water level increased by approximately 27.4 m (90 ft) in response to failure of the ICPP injection well. During this period, wastewater was discharged directly to the vadose zone from the ICPP injection well at a reported depth of 68.9 m (226 ft) bgs.

The presence of a deep perched groundwater zone beneath the percolation ponds is indicated by the borehole neutron response from Wells USGS-51 and MW-17. Figure 2-27 shows the natural gamma log, stratigraphy, and epithermal neutron logs ran in 1984, 1985, and 1986 for Well USGS-51. Deflections of the neutron log to the left indicate increases in moisture content. As shown in this figure, two zones illustrate significantly increasing moisture content since the percolation ponds were placed into service on February 1984. These two zones occur from 44.2 to 54.3 m (145 to 178 ft) and 83.5 to 101 m (274- to 332-ft) bgs. The upper perched water zone is currently being monitored by the PW-series wells. Well MW-17 (4-in.) is completed in the lower perched water zone.

2.6.1.4 Water Level Fluctuation. Thirty-two wells have been installed to monitor the water level fluctuations in the perched groundwater beneath the ICPP. Several piezometers have been completed in conjunction with the perched water wells, resulting in 44 different monitoring intervals. If water was present in the well following completion, the well was usually equipped with a pressure transducer and data logger to automatically monitor changes in the water level. Table 2-12 describes the well, monitoring period, number of measurements, and general statistics concerning the water level elevation for the wells being monitored. Concurrent with the automatic monitoring of selected wells, complete rounds of water level measurements have been recorded for all the perched water wells. A summary of the water level data from these measuring events is provided in Table 2-13.

Hydrographs for the nine perched water wells completed in the northern ICPP are provided in Figure 2-28. Figure 2-29 shows the same well hydrographs grouped according to similar water level patterns. Data presented in these hydrographs were collected between January 1993 and October 1995 and represent the majority of perched water monitoring at the ICPP. Individual hydrographs for each of these wells are presented in Appendix B. Several water-level fluctuation patterns are shown in the hydrographs presented in Figure 2-29 and are discussed below:

- Wells CPP-33-4, CPP-37-4, and MW-4 show similar water-level fluctuation patterns. During 1994, water level elevations were highest in March, and decreased during the summer and remained relatively constant for the remainder of the year. Well CPP-33-4 showed a rise in water level during the November and December of 1994. Water levels increased from January 1995 to

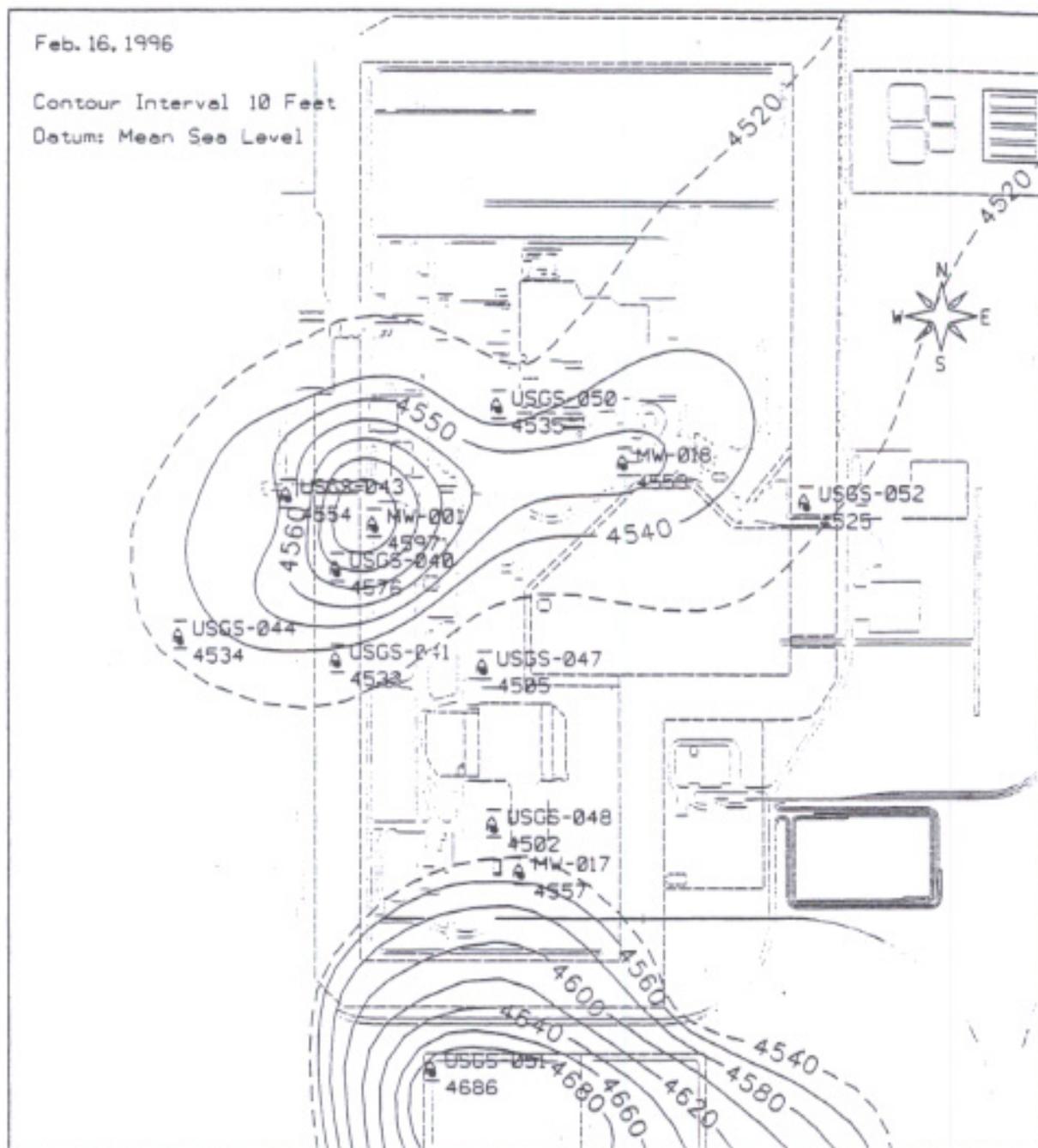


Figure 2-25. Approximate extent of the lower perched groundwater zone.

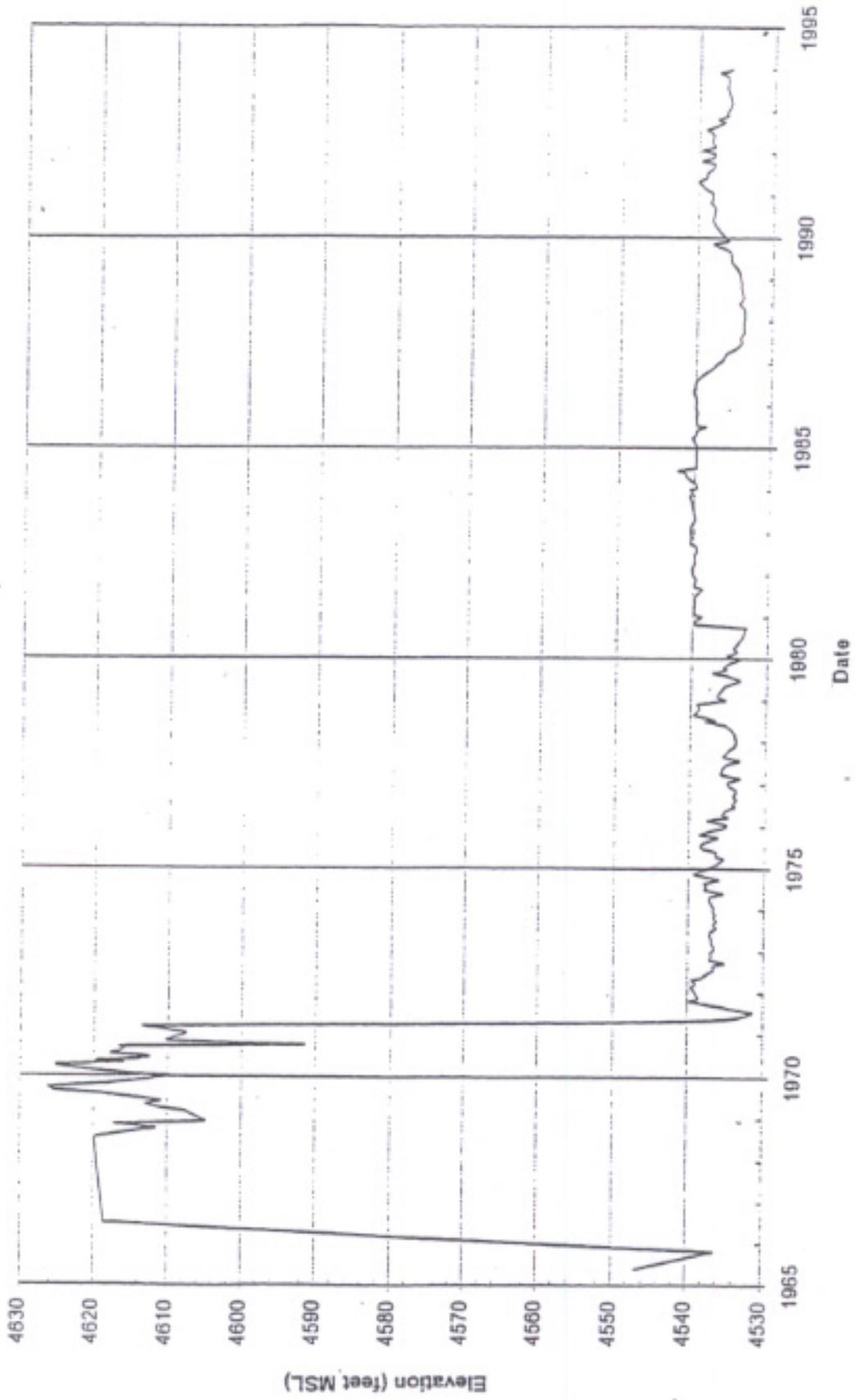


Figure 2-26. Hydrograph for Well USGS-50 (USGS records).

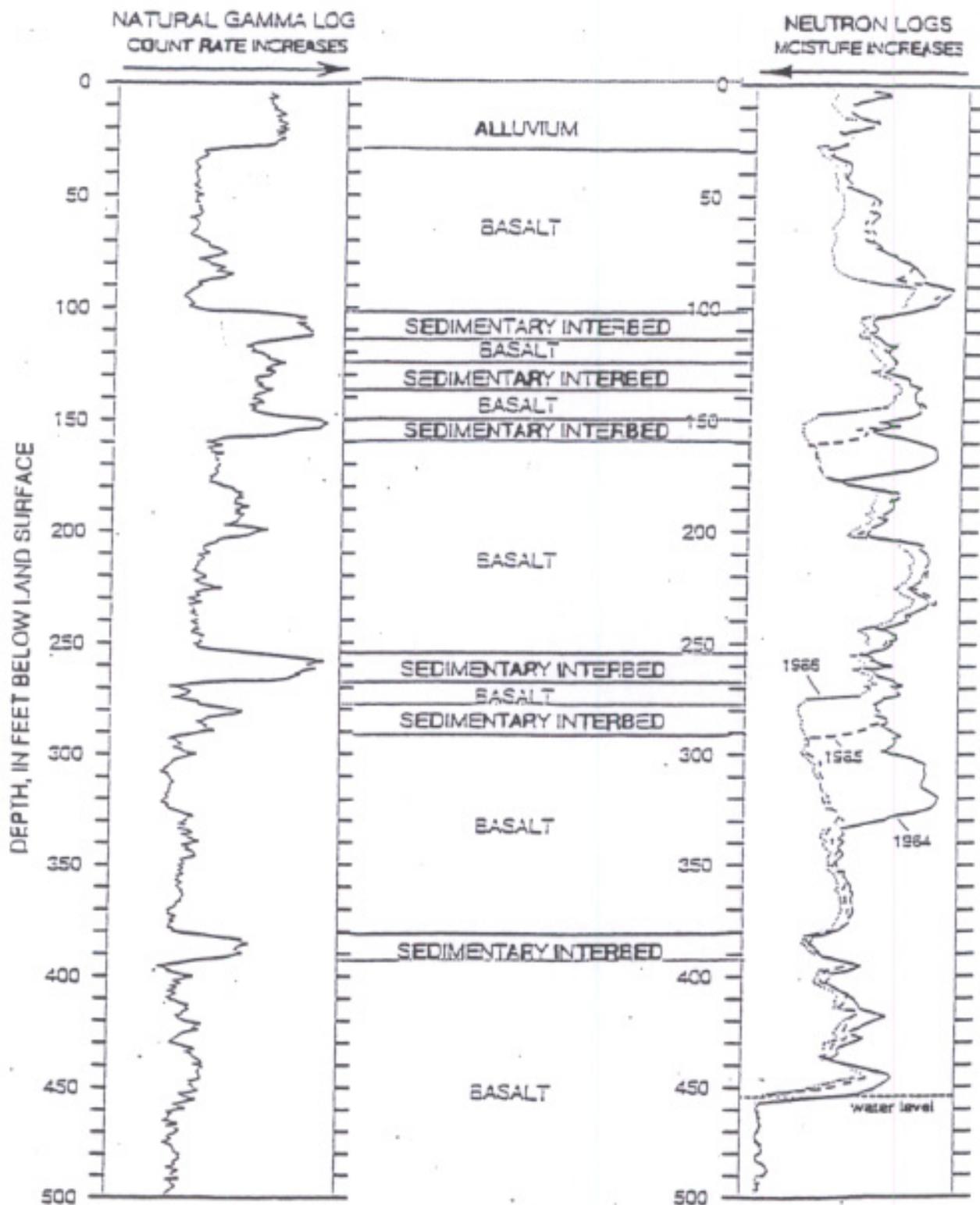


Figure 2-27. Natural gamma log, stratigraphy, and neutron logs for Well USGS-51 (Cecil et al., 1991).

Table 2-12. Summary of the water level monitoring data from the perched water wells equipped with data loggers.

Well	Period of record	Number of measurements	Minimum water level (ft amsl)	Maximum water level (ft amsl)	Average water level (ft amsl)
CPP 33-2	12/92-10/95	973	4,811.14	4,820.68	4,817.53
CPP 33-3	1/93-10/95	962	4,794.02	4,802.25	4,799.05
CPP 33-4	1/93-10/95	672	4,800.11	4,815.51	4,810.83
CPP 37-4	9/92-10/95	481	4,806.52	4,812.82	4,809.21
CPP 55-06	10/92-10/95	1,000	4,802.10	4,810.52	4,806.61
MW-1	6/95-11/95	942	4,595.07	4,602.89	4,598.97
MW-2	2/94-10/95	588	4,804.72	4,809.85	4,807.14
MW-4	2/94-10/95	606	4,804.64	4,810.04	4,806.65
MW-5	3/94-9/95	559	4,803.34	4,808.98	4,805.61
MW-6	2/94-10/95	608	4,792.14	4,804.79	4,797.32
MW-20	6/95-9/95	539	4,779.56	4,781.44	4,780.53
USGS-50	6/95-11/95	943	4,524.02	4,534.80	4,533.05

Table 2-13. Summary of water level data from the perched water wells.

Designation	Construction	January 1994				August 1994				Sept 1994 - Jan 1995				May 1995			
		Pt bts	Elevation	Pt in Well	Pt bts	Elevation	Pt in Well	Pt bts	Elevation	Pt in Well	Pt bts	Elevation	Pt in Well	Pt bts	Elevation	Pt in Well	
CPP 33-1	2-in. SS Well	Dry(1)	NA	NA	Dry(1)	NA	NA	NA	Dry	NA	NA	NA	99.91	4817.47	1.27		
CPP 33-2	2-in. SS Well	101.55	4813.87	5.47	98.90	4816.52	8.12	98.67	98.85	4816.57	8.17	97.50	4817.92	9.52			
CPP 33-3	2-in. SS Well	117.95	4798.28	6.38	117.92	4798.31	6.41	117.85	115.11	4801.12	9.22	118.33	4797.90	6.00			
CPP 33-4	2-in. SS Well	104.88	4809.13	15.43	102.56	4811.45	17.75	106.60	106.83	4807.18	13.48	102.85	4811.16	17.46			
CPP 37-4	2-in. SS Well	104.66	4808.00	6.90	103.60	4807.06	5.96	106.21	106.60	4806.06	4.96	103.89	4808.86	7.76			
CPP 35-06	2-in. SS Well	106.42	4806.79	8.29	108.58	4804.63	6.13	110.48	106.93	4806.28	7.78	106.25	4806.96	8.46			
MW-1	4-in. PVC Well	318.12	4661.13	20.63	322.00	4597.25	16.75	324.23	323.25	4596.00	15.50	322.28	4596.97	16.47			
MW-1	1-in. PVC Piezo.	NR	NA	NA	Dry	NA	NA	Dry	Dry	NA	NA	Dry	NA	NA			
MW-2	2-in. PVC Well	107.87	4808.22	7.12	109.88	4806.21	5.11	Dry	107.70	4808.39	7.29	107.49	4808.60	7.50			
MW-3	2-in. PVC Well	Dry	NA	NA	Dry	NA	NA	Dry	Dry	NA	NA	Dry	NA	NA			
MW-3	1-in. PVC Piezo.	NR	NA	NA	Dry	NA	NA	Dry	Dry	NA	NA	Dry	NA	NA			
MW-4	2-in. PVC Well	Dry	NA	NA	Dry	NA	NA	Dry	Dry	NA	NA	Dry	NA	NA			
MW-4	1-in. PVC Piezo.	NR	NA	NA	NR	NA	NA	Dry	Dry	NA	NA	Dry	NA	NA			
MW-5	2-in. PVC Well	111.92	4807.35	17.45	113.25	4806.02	16.12	115.12	115.36	4803.91	14.01	112.30	4806.97	17.07			
MW-6	2-in. PVC Well	126.34	4792.92	13.42	127.25	4792.01	12.51	116.77	116.60	4802.66	23.16	122.70	4796.56	17.06			
MW-7	2-in. PVC Well	141.85	4778.28	2.88	140.75	4779.38	3.98	140.75	134.31	4785.82	10.42	Dry	NA	NA			
MW-7	1-in. PVC Piezo.	NR	NA	NA	NR	NA	NA	Dry(1)	Dry	NA	NA	Dry	NA	NA			
MW-8	2-in. PVC Well	Dry	NA	NA	Dry	NA	NA	Dry	Dry	NA	NA	Dry	NA	NA			
MW-9	2-in. PVC Well	129.81	4792.52	2.92	Dry(1)	NA	NA	Dry	131.87	4789.98	0.38	Dry	NA	NA			
MW-9	1-in. PVC Piezo.	NR	NA	NA	NR	NA	NA	Dry	Dry	NA	NA	Dry	NA	NA			
MW-10	2-in. PVC Well	Dry	NA	NA	NA	NA	NA	147.29	141.47	4775.94	12.24	Dry	NA	NA			
MW-10	1-in. PVC Piezo.	NR	NA	NA	NR	NA	NA	Dry	Dry	NA	NA	Dry	NA	NA			
MW-11	2-in. PVC Well	138.46	4779.44	0.54	137.72	4780.18	1.28	138.62	Dry	NA	NA	79.12	4838.29	1.59			
MW-11	1-in. PVC Piezo.	NR	NA	NA	NR	NA	NA	Dry	Dry	NA	NA	Dry	NA	NA			
MW-12	2-in. PVC Well	Dry	NA	NA	Dry	NA	NA	Dry	Dry	NA	NA	Dry	NA	NA			
MW-12	1-in. PVC Piezo.	NR	NA	NA	NR	NA	NA	Dry	Dry	NA	NA	Dry	NA	NA			
MW-13	2-in. PVC Well	NR	NA	NA	NR	NA	NA	NR	Dry	NA	NA	Dry	NA	NA			
MW-14	2-in. PVC Well	NR	NA	NA	NR	NA	NA	NR	Dry	NA	NA	Dry	NA	NA			
MW-15	2-in. PVC Well	NR	NA	NA	NR	NA	NA	NR	Dry	NA	NA	Dry	NA	NA			
MW-16	2-in. PVC Well	NR	NA	NA	NR	NA	NA	NR	Dry	NA	NA	Dry	NA	NA			
MW-17	2-in. PVC Well	NR	NA	NA	NR	NA	NA	NR	Dry	NA	NA	Dry	NA	NA			
MW-17	1-in. PVC Piezo.	NR	NA	NA	NR	NA	NA	NR	Dry	NA	NA	Dry	NA	NA			
MW-17	4-in. Sued Well	NR	NA	NA	NR	NA	NA	NR	Dry	NA	NA	Dry	NA	NA			
MW-18	2-in. PVC Well	NR	NA	NA	NR	NA	NA	NR	Dry	NA	NA	Dry	NA	NA			
MW-18	1-in. PVC Well	NR	NA	NA	NR	NA	NA	NR	Dry	NA	NA	Dry	NA	NA			
MW-18	4-in. PVC Well	NR	NA	NA	NR	NA	NA	NR	407.25	4510.08	10.08	407.63	4509.70	9.70			
MW-20	2-in. PVC Well	NR	NA	NA	NR	NA	NA	NR	462.95	4454.36	18.86	464.19	4453.12	17.62			
MW-20	1-in. PVC Piezo.	NR	NA	NA	NR	NA	NA	NR	139.60	4778.40	11.80	137.33	4780.67	14.07			
MW-20	1-in. PVC Piezo.	NR	NA	NA	NR	NA	NA	NR	Dry	NA	NA	109.34	4808.66	0.00			

NR - not reported.
NA - not available.

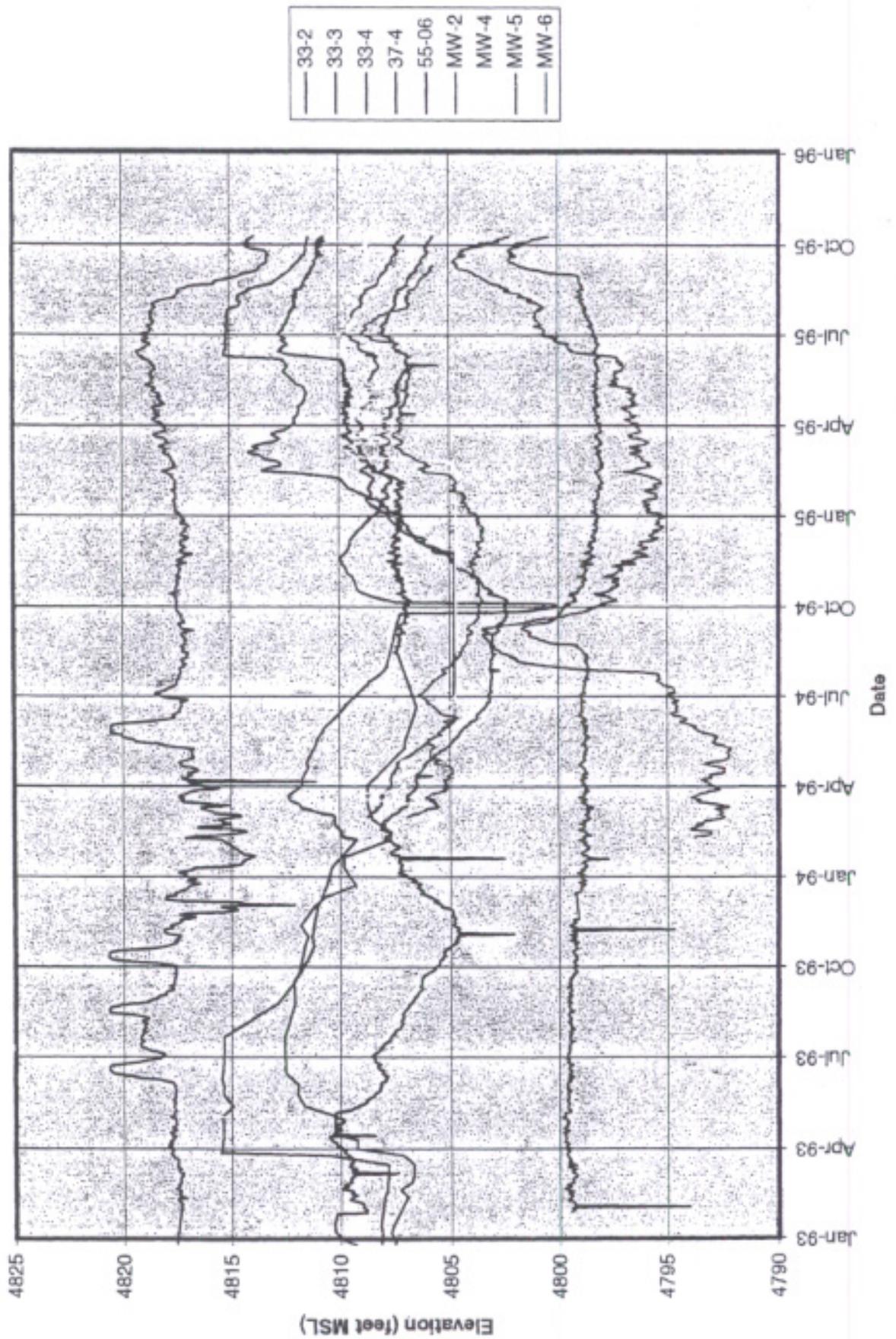


Figure 2-28. Hydrographs for the perched water wells equipped with data loggers

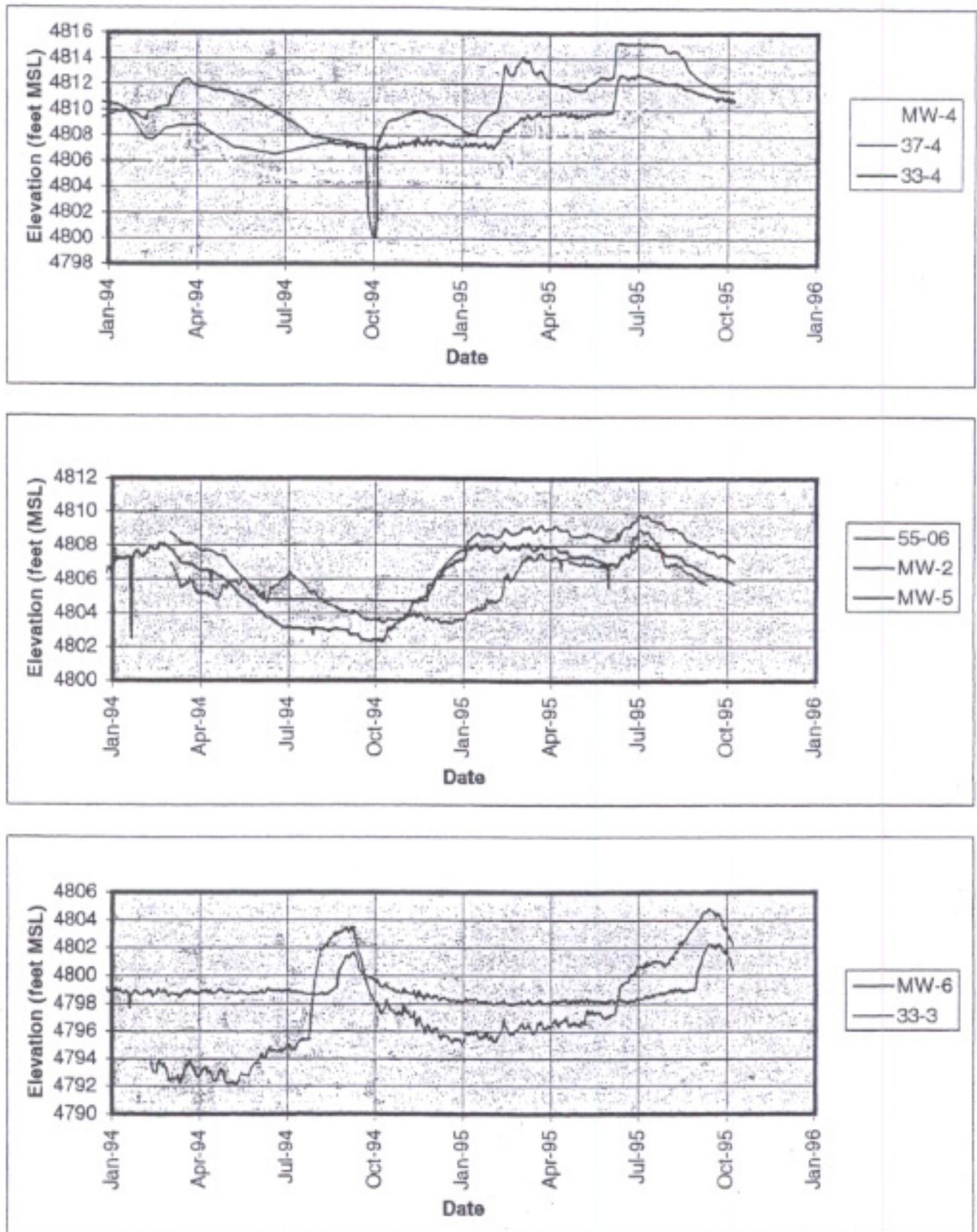


Figure 2-29. Hydrographs for perched water wells from 1994 to October 1995.

the highest level during May 1995. The water level fluctuations at these wells appear to be caused by recharge from both spring snowmelt and increased runoff in the Big Lost River as indicated by the June water level increases. The hydrograph for well MW-2 shows the water-level elevation of about 4805 ft msl between July 1994 and February 1995, which was caused by the water level falling below the transducer.

- Similar water-level responses are shown by wells 55-06, MW-2, and MW-5. Water levels generally are lower during the summer months and increase during the fall, winter, and spring months. These water-level patterns are largely attributed to the steam injection vents, where excess steam is discharged to the subsurface. The hydrograph for well MW-2 shows the water-level elevation of 4,805 ft msl between May and November 1994 which was caused by the water level falling below the transducer.
- Wells MW-6 and CPP-33-3 also exhibit similar water-level fluctuations. Both wells show an apparent seasonal water-level increase and decrease between July and October for each of the years monitored. The water level increase during this period is about 8 feet for well MW-6 and 3 feet for well 33-3. These apparent seasonal responses can not be attributed to any known plant operations. The water-level fluctuations may suggest a local lag in groundwater recharge, resulting from spring snowmelt, to the area where these wells are completed. The permeability of the C interbed at well MW-6 is about two orders of magnitude less than the C-interbed at the adjacent well MW-3 which might account for the apparent lag.
- Water-levels in well CPP 33-2 are not similar to most of the other perched water wells. This well exhibits relatively rapid responses to recharge events as shown in the hydrograph presented in Figure 2-28. The hydrograph presented in Appendix B is difficult to evaluate but appears to show a general pattern of higher water levels during the spring and lower or more constant water levels during the winter. The highest water levels occurred during late spring and summer of 1993 which was a much wetter period than average. About 6 inches of precipitation (Table 2-1) occurred between April and June 1993. The lowest measured water levels occurred during late September 1995, which was also during a period of much lower than average precipitation.

Correlation between pairs of water level data was also performed using the Pearson product-moment test. This procedure is used to calculate the strength of a linear relationship between two variables on a scale of -1 to +1. These coefficients correspond to a perfect negative correlation for -1 and a perfect positive correlation for +1. A coefficient near 0 indicates no linear relationship between the variables. The equation used to calculate the coefficients is as follows:

$$r = \frac{S_{xy}}{\sqrt{S_{xx} * S_{yy}}} \quad (2-1)$$

where

r = correlation coefficient

x = variable 1

y = variable 2

S_{xy} = sum of column x multiplied by the sum of column y squared

S_{xx} = sum of column x multiplied by the sum of column x squared

S_{yy} = sum of column y multiplied by the sum of column y squared.

The results of the Pearson product-moment correlation for the perched water wells in the northern ICPP is provided in Table 2-14. The best positive correlation is observed between Wells CPP 55-06 and MW-2 (0.96), followed by Wells CPP 37-4 and MW-4 (0.93). Good positive correlation is also observed between Wells CPP 37-4 and MW-5 (0.88), Wells CPP 33-4 and CPP 37-4 (0.84), Wells CPP 33-4 and MW-4 (0.81), and Wells CPP 33-4 and MW-5 (0.80). These wells are located in the northeastern portion of the facility indicating a similar source of recharge to these wells. Poor correlation is observed from the wells located in the western portion of the facility (CPP 33-2, CPP 33-3, and MW-6) to the wells located to the east. This variation in the water level response indicates two separate sources of recharge to the northern perched water body: one water source providing recharge to the western portion (i.e., in the vicinity of Wells CPP 33-2, CPP 33-3, and MW-6) and the other source providing recharge to the eastern portion (i.e., in the vicinity of Wells CPP 33-4, CPP 37-4, CPP 55-06, MW-2, MW-4, and MW-6).

2.6.1.4.1 Barometric Pressure Effects—Barometric efficiency, which is the response in water level change to change in barometric pressure, was examined in the perched water monitoring wells at ICPP. Barometric efficiency may be as high as 80% (*Ground Water Manual*), and is estimated using the relationship $B=dH/dpA$, where B is the barometric efficiency, dH is the change in water elevation in a monitoring well, and dpA is the change in air pressure expressed as equivalent feet of water. Daily water level and barometric pressure readings in April 1994 were used because the general trend for water levels in each perched water monitoring well was relatively uneventful and appeared to be less affected by influences other than barometric pressure.

Water level fluctuations in several of the wells exhibited good correlation with changes in barometric pressure, while other wells were either insensitive to air pressure variation or the response was masked by other influences. Well CPP 33-3 exhibited an excellent correlation between water fluid level and barometric pressure, indicating local confinement in this area. Water level fluctuations from Well MW-5 displayed good correlation with barometric changes throughout the first several weeks of April, implying some local confinement for the perched water in this area. There was a significant rise in water level during the fourth week of April in Well MW-5 in excess of that due to barometric pressure alone. Well CPP 55-06 also had good correlation during the first several weeks of April, whereas the last 2 weeks of water level fluctuations were not as correlatable to barometric pressure. Wells CPP 33-2 and MW-6 demonstrated significant changes in water levels, frequently in excess of 100% efficiency, indicating something other than barometric pressure may be influencing the local fluid level behavior. Wells CPP 33-4 and MW-2 exhibited considerably lower barometric efficiency than did Wells CPP 33-3 and MW-5, however, the data are in the range normally observed in confined water aquifer systems, suggesting confinement of perched water may also be occurring in the vicinity of these wells.

Figures 2 through 8 in Appendix B display water levels in perched water wells and also barometric pressure expressed in equivalent feet of head. Table 2-15 provides a summary of the estimates of barometric efficiency for the perched water monitoring wells.

Table 2-14. Pearson correlation coefficient for the perched water wells.

	33-2	33-3	33-4	37-4	55-06	MW-2	MW-4	MW-5	MW-6
33-2	X	-0.65	0.15	0.02	0.07	0.08	0.02	0.36	-0.35
33-3	-0.65	X	-0.25	0.04	-0.42	-0.34	0.000	-0.34	0.60
33-4	0.15	-0.25	X	0.84	0.71	0.74	0.81	0.80	0.07
37-4	0.02	0.04	0.84	X	0.54	0.69	0.93	0.88	0.46
55-06	0.07	-0.42	0.71	0.54	X	0.96	0.64	0.57	-0.10
MW-2	0.08	-0.34	0.74	0.69	0.96	X	0.75	0.70	0.02
MW-4	0.02	0.00	0.81	0.93	0.64	0.75	X	0.84	0.32
MW-5	0.36	-0.34	0.80	0.88	0.57	0.70	0.84	X	0.10
MW-6	-0.35	0.60	0.07	0.46	-0.10	0.02	0.32	0.10	X

2.6.1.5 Big Lost River Effects. The Big Lost River is located directly to the north of the ICPP. Surface water flow from the Big Lost River is monitored near the ICPP at the Lincoln Boulevard gauging station located adjacent to the bridge. Typically, no flow is observed in the Big Lost River near the ICPP. During the past 5 years, however, flow was observed at the Lincoln Boulevard gauging station twice. The first time occurred during June, 1993 where flow in the Big Lost River lasted for approximately 3 weeks. No response was observed in any of the upper basalt perched water wells resulting from the 1993 stream flow in the Big Lost River (Figure 2-30).

Flow in the Big Lost River was again observed at the Lincoln Boulevard gauging station from June 6 to August 9, 1995, which is a span of 64 days. During this period flows were 16,010 acre/ft (June), 22,310 acre/ft (July) and 955 acre/ft (August). An evaluation of the water level response in the perched groundwater to the Big Lost River flow is therefore based on the duration of flow rather than the flow measurements at the gauging station. Figure 2-31 provides hydrographs for wells completed in the upper perched water zone and flow duration for the Big Lost River at the Lincoln Boulevard gauging station.

Of the nine wells completed in the upper perched groundwater zone in the northern ICPP, response to flows in the Big Lost River was observed in seven wells (CPP 33-4, CPP 37-4, CPP 55-06, MW-2, MW-4, MW-5, and MW-6). According to the monitoring data, changes in water level were observed to occur between 3 and 9 days following flow in Big Lost River. The average response time was 5.2 days. The maximum increase in water level was observed in Well CPP 33-4 at 0.6 m (2.4 ft). An average increase in the water level for all wells was 0.3 m (1.2 ft). An estimated travel time for the water to move from the Big Lost River to the upper perched groundwater was calculated based upon the distance between the well and the river and the amount of time elapsed until a response was observed in the well. The estimated travel time from the Big Lost River to the upper perched water zone varied between 64.5 to 220 m/day (244 to 834 ft/day) with an average of 121 m/day (459 ft/day). Table 2-16 provides a summary of the water level response attributed to the Big Lost River.

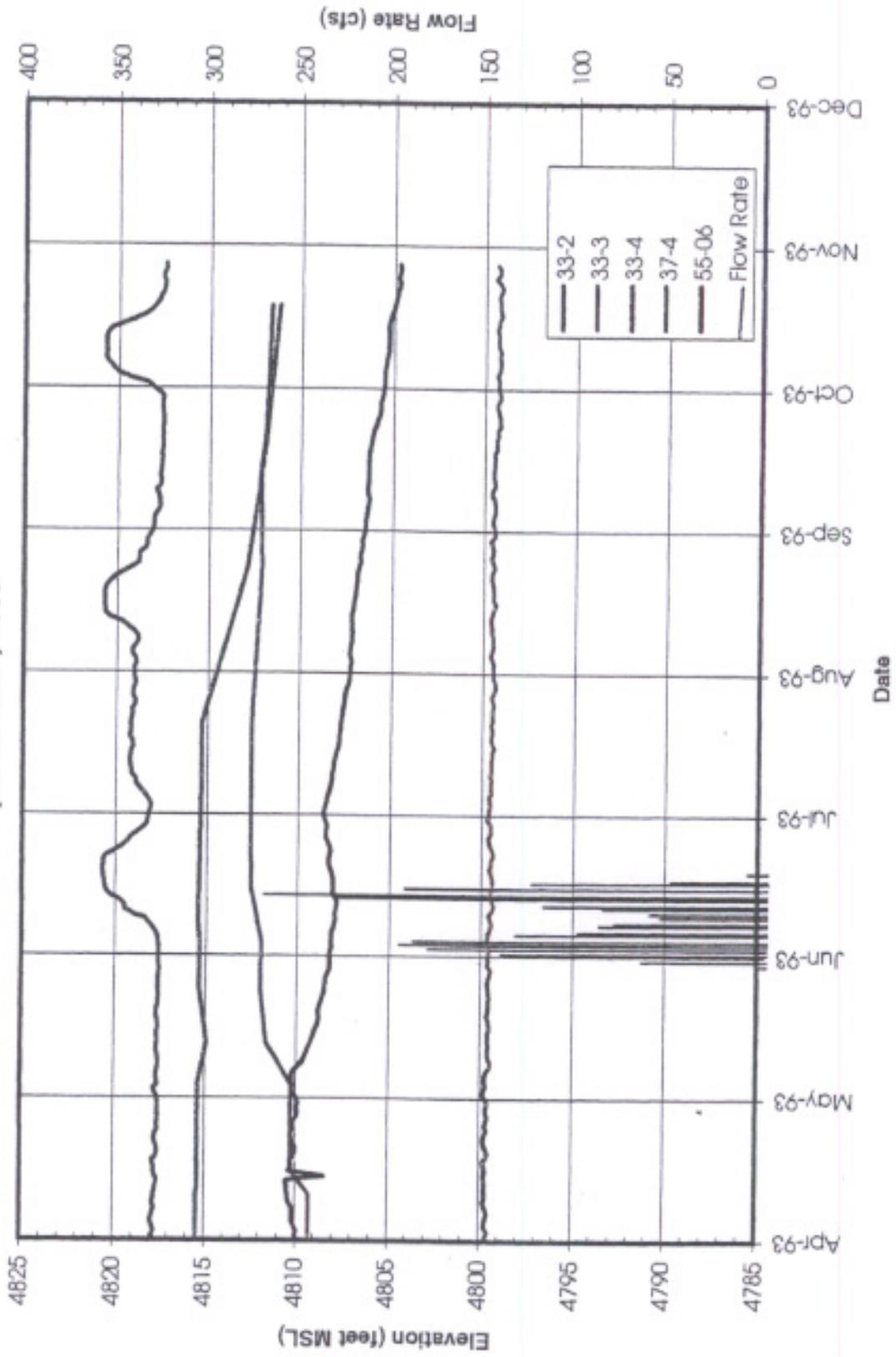
The effects of the Big Lost River were monitored in the lower perched groundwater zone as shown in Figure 2-32. Wells MW-1 and USGS-50 are completed in lower perched groundwater zones at depths of approximately 85 and 100 m (322 and 380 ft), respectively. The water level increased throughout the

Table 2-15. Barometric efficiency estimates for selected perched water monitoring wells at the ICPP.

Change in barometric pressure		Change in water level (ft)															
Interval	dpA, Hg (in.)	dpA, H ₂ O (ft)	Well 55-06 dH	Well 33-2 dH	Well 33-3 dH	Well 33-4 dH	Well MW-2 dH	Well MW-5 dH	Well MW-6 dH	Barometric efficiency							
										B	B						
A-B	0.280	0.317	0.027	0.157	0.202	0.037	0.007	0.178	0.398	8.51%	49.46%						
B-C	0.110	0.125	0.034	0.532	0.088	0.026	0.013	0.112	0.031	27.26%	426.57%*						
C-D	0.240	0.272	0.101	0.309	0.180	0.000	0.043	0.140	0.360	37.12%	113.56%						
D-E	0.420	0.476	0.080	0.389	0.272	0.003	0.074	0.295	0.448	16.80%	81.69%						
E-F	0.280	0.317	0.021	0.469	0.203	0.060	0.009	0.120	0.121	6.61%	147.74%						
F-G	0.350	0.397	0.132	0.361	0.254	0.067	0.125	0.241	0.585	33.26%	90.97%*						
G-H	0.620	0.703	0.221	0.842	0.367	0.159	0.137	0.834	0.790	31.44%	119.78%						
H-I	0.480	0.544	0.269	0.393	0.269	0.006	0.223	0.265	0.844	49.43%	72.21%						
										Well 55-06 B	Well 33-2 B	Well 33-3 B	Well 33-4 B	Well MW-2 B	Well MW-5 B	Well MW-6 B	
A-B			8.51%	49.46%	63.63%	11.66%	2.21%	56.07%	125.37%*								
B-C			27.26%	426.57%*	70.56%	20.85%	10.42%	89.80%	24.86%								
C-D			37.12%	113.56%	66.15%	0.00%	15.80%	51.45%	132.30%*								
D-E			16.80%	81.69%	57.12%	0.63%	15.54%	61.95%	94.08%								
E-F			6.61%	147.74%	63.94%	18.90%	2.84%	37.80%	38.12%								
F-G			33.26%	90.97%*	64.01%	16.88%	31.50%	60.73%	147.42%*								
G-H			31.44%	119.78%	52.21%	22.62%	19.49%	118.64%	112.38%								
H-I			49.43%	72.21%	49.43%	1.10%	40.98%	48.69%	155.09%*								
Average			26.3%	87.9%	60.9%	11.6%	17.4%	66.0%	67.4%								
Std Dev			13.8%	26.3%	6.8%	9.0%	12.5%	26.0%	42.4%								

a. If the barometric efficiency was greater than 120%, it was not included in Average and Standard Deviation calculations.

Water Levels & Big Lost River Flow Rates
April-October, 1993



ICPP Perched Water Wells

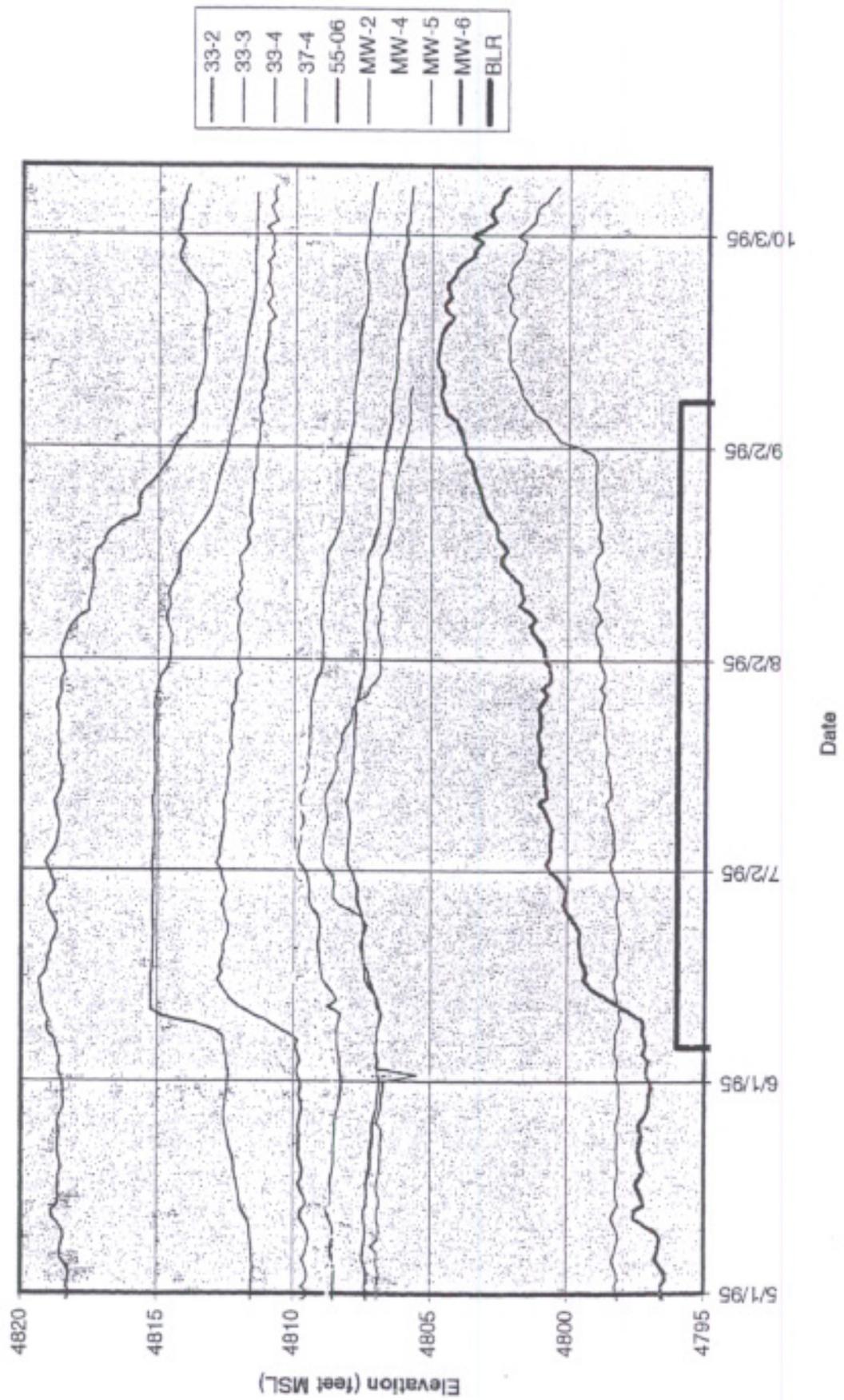


Table 2-16. Summary of upper perched groundwater level response to discharge in the Big Lost River.

Well	Well distance to BLR (feet)	Depth to water (ft bgs)	Water level increase (feet)	Water level response (days)	Estimated travel* (ft/day)
CPP 33-4	1,429	99	2.4	3	477
CPP 37-4	2,286	101	2.3	3	763
CPP 55-06	2,500	104	0.3	9	278
MW-2	2,143	104	0.4	6	358
MW-4	2,500	102	0.9	3	834
MW-5	2,071	109	0.5	8	259
MW-6	1,214	119	1.9	5	244
Average					459

a. Rate assuming straight line.

monitoring period for both of these wells. Since historical data are not available, it is uncertain whether this increase in water level is attributable to the Big Lost River or some other factor.

2.6.1.6 Physical and Hydrologic Properties (Perched Water Zone). Aquifer tests have been performed on nine wells completed in the upper perched water zone. Single well pumping tests using the drawdown and recovery data were performed on Wells CPP 33-2, CPP 33-3, CPP 33-4, and CPP 55-06. Saturated zone hydraulic conductivities were calculated using the Cooper-Jacob analytical technique (Hubbell, 1992 and Bishop, 1992). Slug tests were performed on Wells MW-1, MW-2, MW-4, MW-5, and MW-6. These data were also evaluated using the Cooper-Jacob analytical technique to determine the saturated zone hydraulic conductivities. A 22-hr pumping test was also performed on Well MW-5 to determine the saturated zone hydraulic conductivity and the response from surrounding wells completed in the upper perched groundwater zone.

Field aquifer tests were performed to determine the hydraulic conductivities for both basalts and sedimentary interbeds (Table 2-17). Hydraulic conductivities determined in the field were fairly consistent, varying only over two orders of magnitude. Field hydraulic conductivities ranged from 3.9×10^{-5} to 2.9×10^{-3} cm/s (0.11 to 8.3 ft/day) with an average of 1.2×10^{-3} cm/s (3.3 ft/day). As shown in Table 2-17, significant differences in hydraulic conductivities were not observed between tests performed on basalts versus tests performed on sedimentary interbeds.

Laboratory testing of the interbed samples was performed to determine the physical properties of the various interbeds. During the drilling operation, interbed samples were obtained from Wells MW-3, MW-4, MW-5, MW-6, MW-7, MW-8, MW-9, and MW-10 (Table 2-18). This table presents a summary of the field data and laboratory results including depth, soil type (from logbooks), moisture content, density, porosity, and saturated hydraulic conductivity. Additionally, this information is grouped by depth into three different

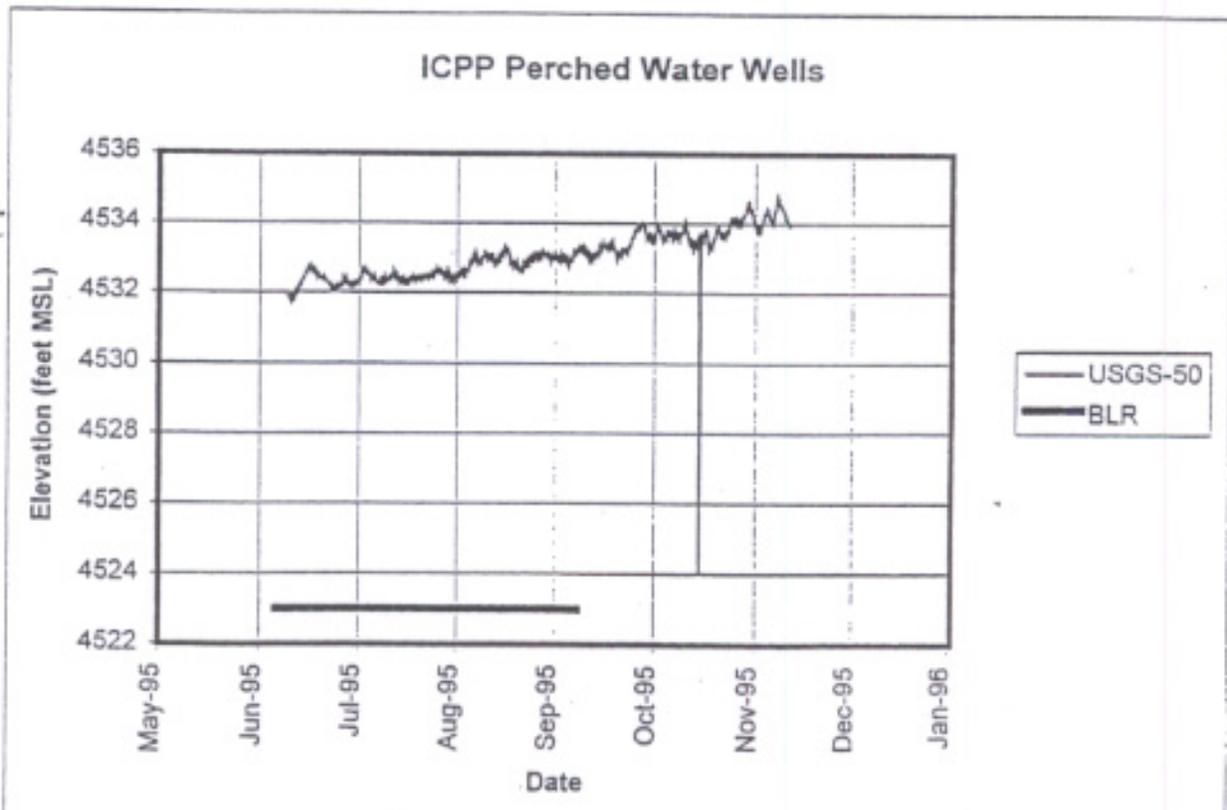
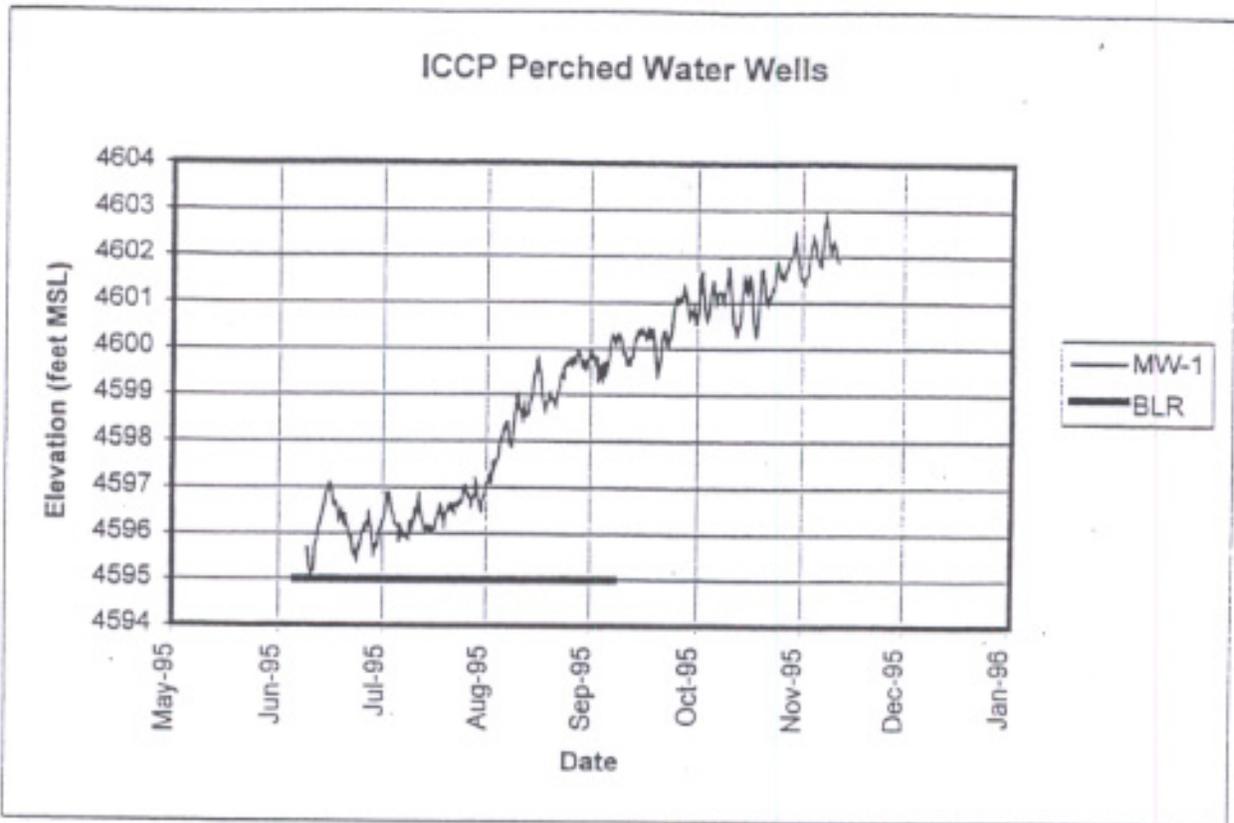


Figure 2-32. Big Lost River discharge vs. lower perched groundwater levels (1995).

Table 2-17. Results of perched water aquifer tests at the ICPP.

Well	Test zone (ft bgs)	Test type	Material	Hydraulic conductivity	
				cm/sec	ft/day
CPP 33-2	97.8-105.8	Pumping/Recovery	Basalt	1.3×10^{-3}	5.0
CPP 33-3	111.2-121.8	Pumping/Recovery	Basalt	9.5×10^{-4}	2.7
CPP 33-4	103.7-118.2	Pumping/Recovery	Basalt	2.9×10^{-3} (average)	6.9 (average)
CPP 55-06	105.2-113.1	Pumping/Recovery	Basalt	4.2×10^{-4}	1.2
MW-1	326-336	Slug	Basalt	2×10^{-4}	0.57
MW-2	107.9-112	Slug	Sandy clay interbed	1.8×10^{-3} (average)	5.1 (average)
MW-4	104.6-110.6	Slug	Silty sand and gravel interbed	3.9×10^{-3}	0.11
MW-5	115-126.5	Slug	Basalt with small sandy clay interbeds	1.1×10^{-3}	3.1
MW-5	110.8-126.5	22-hr Pumping Test	Basalt with small sandy clay interbeds	1.3×10^{-3}	3.6
MW-6	140-151	Slug	Silty sand, fine grained interbed	1.3×10^{-3} (average)	3.7 (average)
			Average (basalts) ^a	1.2×10^{-3}	3.5
			Average (interbeds) ^b	1.0×10^{-3}	3.0
			Average (all tests)	1.3×10^{-3}	3.3

a. Average is based on Wells CPP 33-2, CPP 33-3, CPP 33-4, CPP 55-06, MW-1, and MW-5.

b. Average is based on Wells MW-2, MW-4, and MW-6.

Table 2-18. Laboratory testing results for the ICPP interbed samples.

Well	Depth (feet)	Interbed	Soil type (logbooks)	Initial moisture content		Dry bulk density (g/cc)	Calculated porosity (%)	K _{sat} (cm/sec)
				Gravimetric (%/g/g)	Volumetric (%/cc/cc)			
MW-3	117-119.3	CD	silty clay	32.8	42.5	1.29	52.5	8.9E-05
MW-4	108-109.3	CD	silty sand and gravel	35.9	49.2	1.37	50.2	1.6E-05
MW-7	113.5-114.5	CD	silt with fine gravel	22.7	32.5	1.44	47.0	1.3E-03
MW-8	122.3-123.7	CD	clay with silt	28.0	42.2	1.51	45.0	1.1E-05
MW-10	110.3-111	CD	sandy silt	39.5	50.2	1.27	54.0	1.0E-05
MW-11	113.7-115.3	CD	silty sand	29.5	43.7	1.48	45.9	1.2E-05
MW-4	105.1-105.6	CD	silt	43.8	51.4	1.18	57.6	3.2E-05
MW-4	105.6-106.8	CD	silt	50.8	56.8	1.12	60.9	6.7E-05
MW-6	110-111	CD	clay	33.4	48.3	1.45	47.8	3.0E-07
MW-9	111.6-112.5	CD	clay with silt	28.8	30.1	1.05	61.4	2.1E-03
Average				34.5	44.7	1.33	50.9	3.6E-04
MW-11	135.4-136	D	clay	18.1	33.2	1.83	33.6	5.2E-08
MW-3	138-139	D	silty clay	21.6	30.9	1.43	47.2	8.3E-04
MW-6	142-143	D	silty clay	22.4	30.6	1.36	49.5	2.2E-03
MW-9	148.7-149.4	DE 2	silt with clay	9.5	12.7	1.34	50.3	3.4E-03
Average				17.9	26.9	1.48	44.6	1.6E-03
MW-1	231.7-232.3	DE 4	sand with silt	15.7	24.8	1.59	41.3	3.3E-04

classes (i.e., interbeds "CD," "D," and "DE2"). The depths are approximately 33.5, 42.7, and 70.1 m (110-, 140-, and 230-ft) bgs. A complete discussion of the sample collection and laboratory data package is described in *Interim Data Results From the FY 93/94 Perched Ground Water Investigation* (February 18, 1994).

The range of hydraulic conductivities determined from the field aquifer tests are within the range of hydraulic conductivities measured in the laboratory. The average hydraulic conductivity determined from the field tests is 1.2×10^{-3} cm/s (3.3 ft/day) compared to an average of 6.9×10^{-4} cm/s (1.96 ft/day) determined from the laboratory tests. Some of the difference between the two hydraulic conductivities may be attributed to the fact that the field tests measured horizontal hydraulic conductivity whereas the laboratory tests measured vertical hydraulic conductivity. Typically, horizontal hydraulic conductivities are higher than the corresponding vertical hydraulic conductivities.

Good correlation in the hydraulic conductivity values occurred from the boreholes where both field and laboratory measurements were performed. From the same zone in Well MW-4, the average hydraulic conductivity determined in the laboratory was 3.81×10^{-5} cm/s (0.1 ft/day) compared to the field determined value of 3.9×10^{-5} cm/s (0.11 ft/day). Similarly in Well MW-6, the hydraulic conductivity determined in the laboratory was 2.2×10^{-3} cm/s (6.2 ft/day) compared to the field determined value of 1.3×10^{-3} cm/s (3.7 ft/day). These two wells are the only locations where both field and laboratory measurements were performed.

The physical property data collected from the interbeds at the ICPP were compared to similar data collected at other INEEL facilities (Table 2-19). This table provides minimum, maximum, and average values of saturated hydraulic conductivity, density, porosity, and Van Genuchten parameters for the three ICPP interbeds and interbeds at the TRA and RWMC. A significant range of values is apparent in this table, however, the physical properties data collected on the ICPP interbeds are in good agreement with the data collected at other INEEL facilities.

2.6.1.6.1 MW-5 Pumping Test Results—A constant rate pumping test was performed on Well MW-5, which is completed in the upper perched groundwater zone. The well was pumped at a rate of 11.4 L/min (3 gpm) for 22 hr after which, the pump was turned off and the water level recovery data monitored. Figure 2-33 provides the drawdown and recovery data for the test. In addition to monitoring the pumping well, water levels in wells MW-2, MW-4, MW-6, CPP 33-2, CPP 33-3, CPP 33-4, CPP 37-4, and CPP 55-06 were recorded at 1-min intervals throughout the duration of the test.

For the first 400 min into the test, drawdown in Well MW-5 was similar to an expected "Theis-type" curve where the rate of drawdown decreases exponentially. An increase in drawdown was noted for the next 100 minutes where a maximum drawdown of approximately 3 m (10 ft) was recorded at 500 min into the test. The additional 2 feet of drawdown observed at approximately 500 minutes into the test probably represents a local boundary condition caused by a much lower permeability stratum of interbed material which could not provide sufficient recharge to the well at the constant discharge rate. Water levels in Well MW-5 increased for the next 100 minutes to a drawdown of 2.4 m (8 ft). This level corresponds to the level that would have been expected if the water level response were to follow a "Theis-type" response. Drawdown in the latter portion of the test (600 to 1,300 min) increased more than what would be expected assuming a "Theis-type" response. The increased drawdown in the middle portion of the test may be the result of local boundary effects caused by heterogeneous sedimentary interbed material. The well recovered to approximately 0.2 m (0.5 ft) of the prepumping levels and maintained the constant level for several days.

Table 2-19. Comparison of the physical properties data for the interbeds from ICPP, TRA, and RWMC.

Interbed or INBEL facility	Approx depth (ft)	Ksat (cm/sec)	Dry bulk density (g/cc)	Porosity	Van Genuchten Parameters				r-squared
					Sal. water content	Res. water content	alpha	n	
"CD" interbed (range of values)	110	3.7E-05 (3.0E-07 to 1.3E-03)	1.33 (1.05 to 1.51)	50.9 (45.0 to 61.4)	0.50 (0.43 to 0.64)	0.00	0.0025 (0.00012 to 0.25)	1.43 (1.12 to 2.70)	0.96 (0.88 to 1.00)
D interbed (range of values)	140	1.3E-04 (5.3E-08 to 3.4E-03)	1.48 (1.34 to 1.83)	44.6 (33.6 to 50.3)	0.46 (0.36 to 0.55)	0.0036 (0.00 to 0.82)	0.24 (0.0021 to 0.078)	1.63 (1.20 to 2.71)	0.97 (0.95 to 0.99)
deep interbed (range of values)	230	3.3E-04 —	1.59 —	41.3 —	0.43 —	0.041 —	0.052 —	1.29 —	0.99 —
TRA (range of values)	— ^a	1.4E-06 (1.7E-08 to 1.4E-03)	1.66 (1.24 to 2.13)	38.4 (20.4 to 54.8)	0.42 (0.31 to 0.57)	—	—	—	—
RWMC (range of values)	—	7.6E-05 —	—	—	—	—	—	—	—

a. — = no value.

Drawdown and Recovery (MW-5)

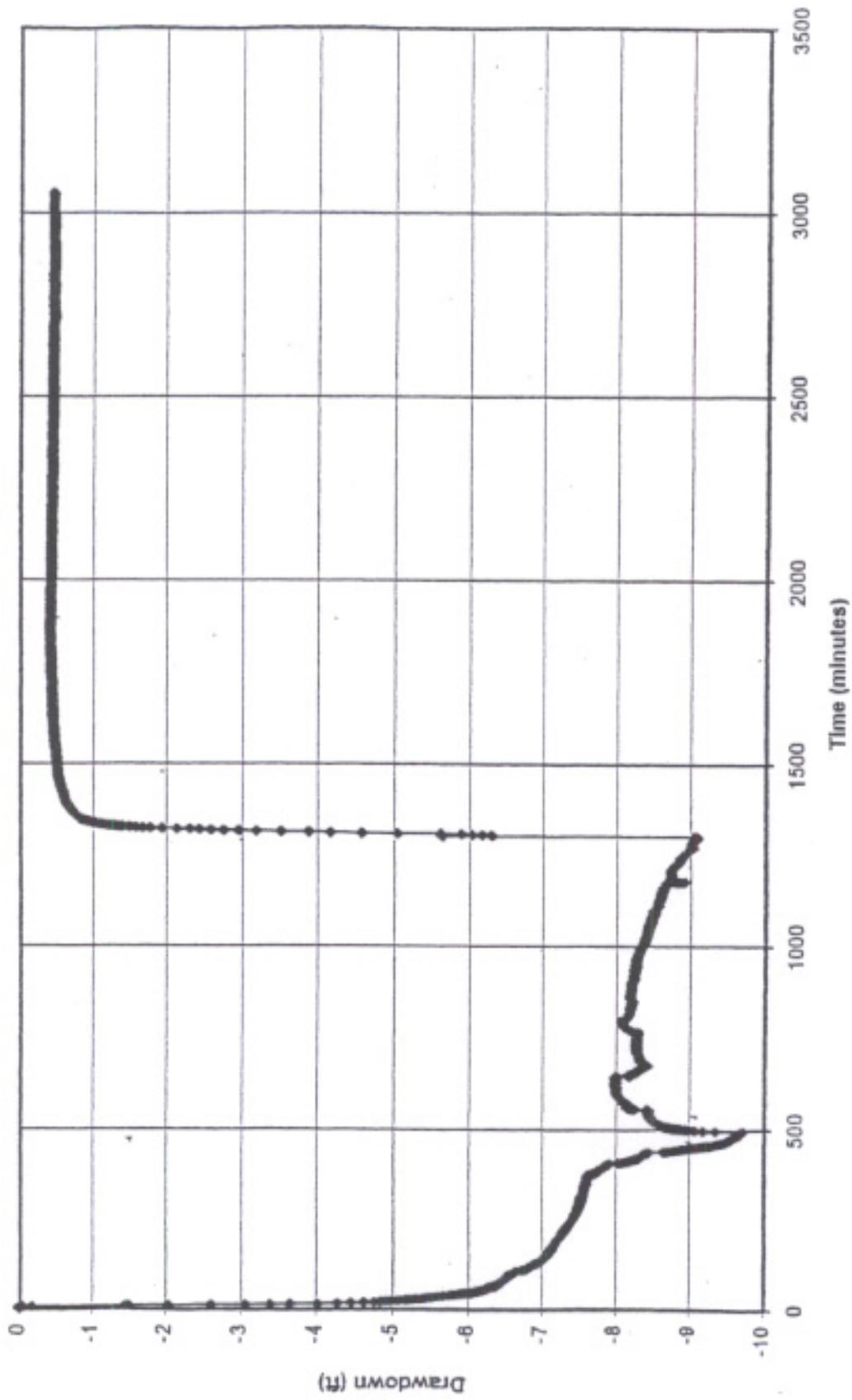


Figure 2-33. Drawdown and recovery data for the Well MW-5 pumping test.

As stated earlier, the water level in eight wells completed in the upper perched groundwater were monitored at 1-minute intervals throughout the duration of the test. The groundwater elevations in these observation wells did not respond to discharge from Well MW-5 as shown in Figure 2-34. Overall, water elevations in the observation wells increased (i.e., negative drawdown) during the first half of the test and then decreased for the remainder of the monitoring period with no correlation to the pumping test.

The drawdown data from the pumping well (MW-5) was evaluated using the Jacob straight line method (Figure 2-35) (Fetter, 1980). The early time data (i.e., under 10 min) were not used in the calculation because of water stored in the casing. Schafer (1978) suggests that in many instances the early pumping test data may not fit Jacob's modification of the nonequilibrium theory, and that calculations based on the early drawdown data will be erroneous. When pumping begins, water in the casing is removed first. As the water level in the casing falls, water begins to enter the well from the surrounding formation. Gradually, a greater percentage of the well's yield will be from the aquifer. Based on the height of water in the well at the time of the test, approximately 79 L (21 gal) of water is contained in the well casing and surrounding sand pack. It would take approximately 7 min to purge this volume of water from the well using a pumping rate of 11.4 L/min (3 gpm). Therefore, it is reasonable to ignore the early time data from this test and base the transmissivity calculation solely on the late-time data.

Transmissivity and hydraulic conductivity were calculated using the following equations:

$$T = \frac{264Q}{\Delta s} \quad (2-2)$$

$$K = T/b \quad (2-3)$$

where

- T = transmissivity (gpd/ft)
- Q = discharge (gpm)
- s = drawdown (ft)
- K = hydraulic conductivity (gpd/ft²)
- b = saturated thickness (ft).

Based on these equations and a saturated thickness of 4.8 m (15.7 ft), the transmissivity and hydraulic conductivity are 419.6 gpd/ft and 1.3×10^{-3} cm/s (3.6 ft/day), respectively. The hydraulic conductivity determined from the pumping test correlates very well with the hydraulic conductivity of 1.1×10^{-3} cm/s (3.1 ft/day) determined from the slug test.

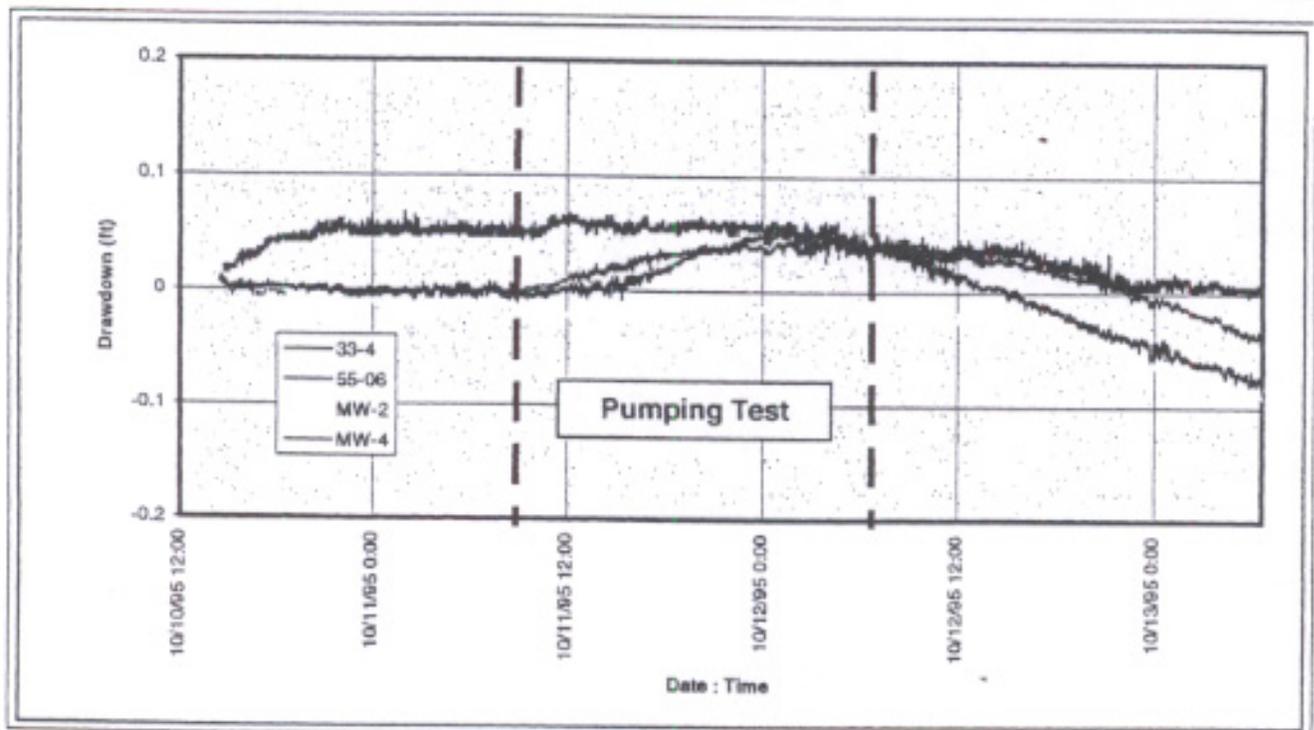
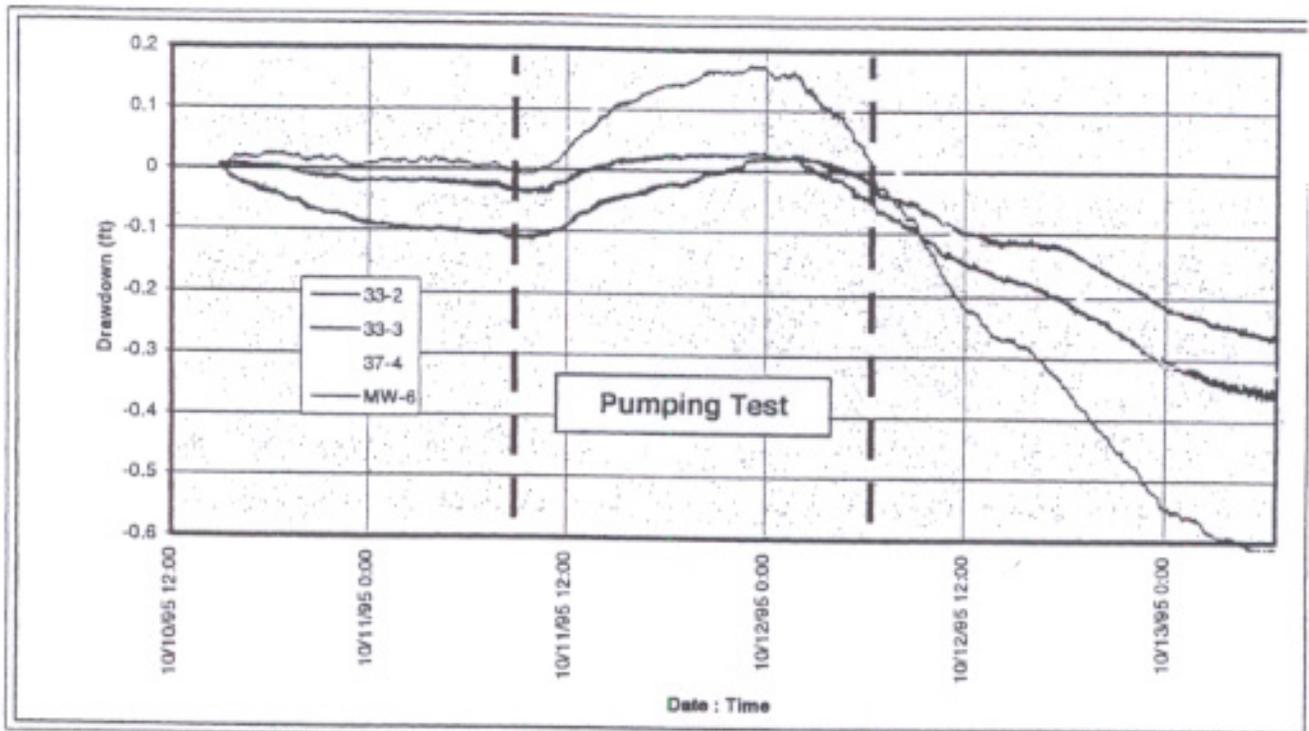


Figure 2-34. Water level response in the perched water wells monitored during the pumping test.

MW-5

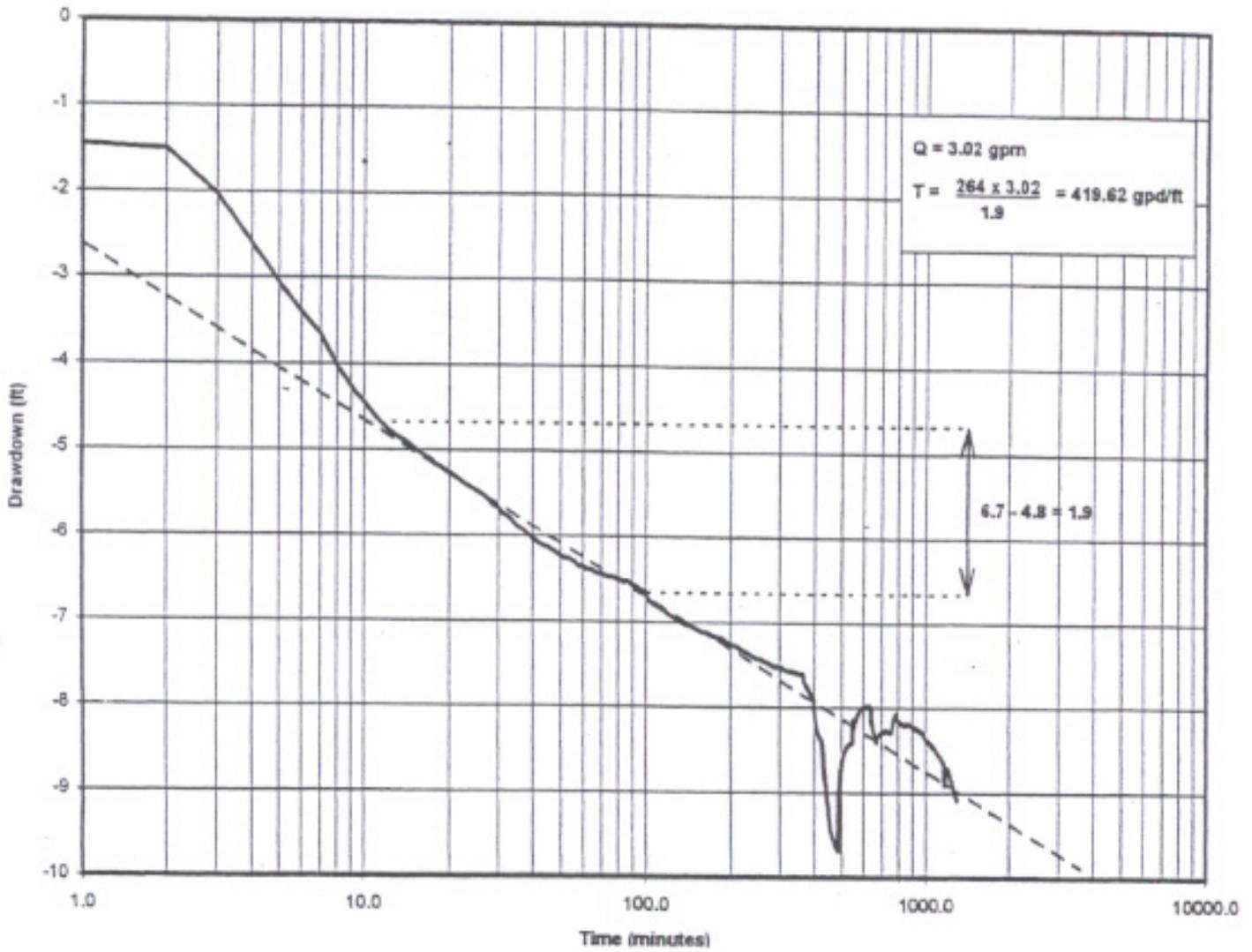


Figure 2-35. Drawdown data from the Well MW-5 pumping test.

2.6.2 Snake River Plain Aquifer

Thirty-three monitoring wells have been installed by the USGS around the ICPP to characterize the occurrence, movement, and quality of water in the SRPA. The monitoring well network was designed to determine hydraulic-gradient changes that influence the rate and direction of groundwater and waste-constituent movement in the SRPA, identify sources of recharge to the aquifer, and measure the effect of recharge (Orr and Cecil, 1991). The location of the observation wells, frequency of water-level measurements, and frequency of water sample collection are shown in Figure 2-36.

2.6.2.1 Groundwater Flow. As part of the WAG 3 RI, a complete round of water level measurements was recorded for the wells completed in the SRPA (Table 2-20). This table includes the measured water depth, borehole deviation information (if available), and a corrected depth to water based upon the borehole deviation. Subsequently, the water level elevations listed in Table 2-20 are corrected for borehole deviation and use the most recent INEEL well survey data. Based on these measurements, the groundwater flow down gradient of the ICPP during May, 1995 is shown in Figure 2-37. Overall, the local groundwater flow is to the south-southwest, consistent with the regional groundwater flow as discussed in Section 2.5.1.

The water level elevations indicate two separate sources of local recharge to the SRPA. One source for recharge is apparently from the percolation ponds as indicated by elevated water levels measured in Wells USGS-51, -112, -113, -114, -115, and -116. Water level response to recharge from these ponds is indicated by a 0.6 m (2 ft) increase in Well USGS-113 and a 0.3 m (1 ft) increase in Well USGS-51. The water table in the SRPA down gradient from the percolation ponds has a bimodal shape, indicating a preferred flow direction toward the southwest with a secondary flow component to the southeast. Directly south of the ponds, water levels in Wells USGS-77 and USGS-111 are significantly lower than what would be expected based on the water levels in the adjacent wells. The reason(s) for the anomalously low water levels in these two wells is not attributed to erroneous wellhead elevations or borehole deviation, but rather to local variations in the water-bearing characteristics of the SRPA (see Section 2.6.2.2, Hydraulic Characteristics).

A second possible source of recharge to the SRPA may be indicated by anomalously high water levels measured in Well USGS-47. The water levels measured in Well USGS-47 are consistently 0.3 to 0.6 m (1 to 2 ft) higher than corresponding water levels measured from the surrounding wells. The possible causes of the anomalously high water levels include local recharge, local pumping, vertical hydraulic gradient (i.e., increasing hydraulic head with depth), and/or well completion characteristics.

The local groundwater flow appears complex and is apparently affected by local recharge, variations in hydraulic conductivity, local pumping, and possibly vertical hydraulic gradients. Groundwater directly beneath the ICPP generally flows to the southwest and southeast, with a minor flow component to the south. The local flow pattern likely results from local recharge (i.e., percolation ponds and sewage ponds) that creates the mounding in the water table and possibly from pumpage of the production wells. As the groundwater progresses beyond the influence of the ICPP, it flows toward the southwest. The local hydraulic gradient is low, only 0.2 m/km (1.2 ft/mi) compared to the regional gradient of 0.8 m/km (4 ft/mi).

2.6.2.2 Hydraulic Characteristics. Hydraulic characteristics of the SRPA have been determined from 16 aquifer tests conducted in the vicinity of the ICPP (Ackerman, 1991). Transmissivity is the rate at which water is transmitted through a unit width of an aquifer under a unit gradient. Since transmissivity is the rate

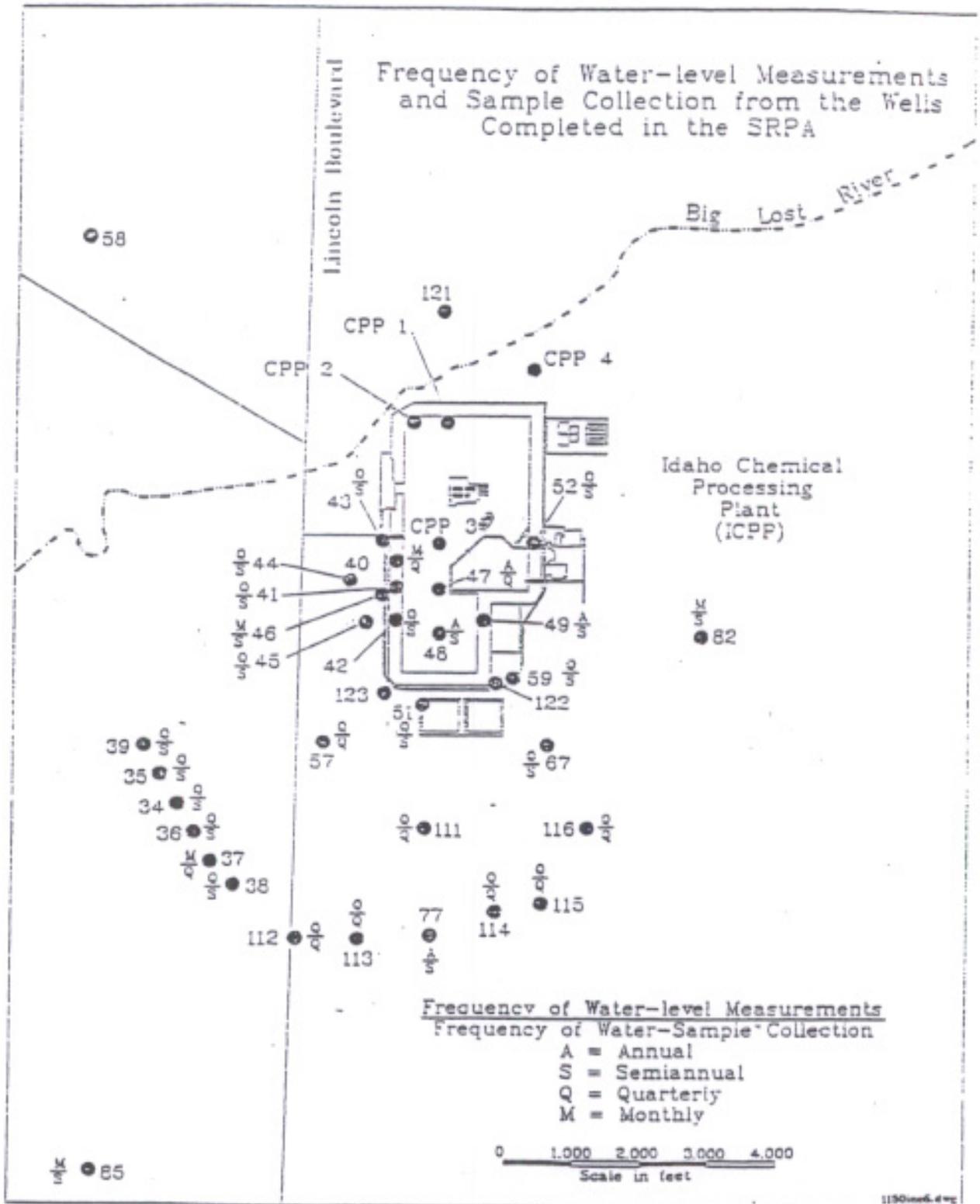


Figure 2-36. Location and frequency of water level measurements, and frequency of water sample collection for the wells completed in the SRPA (USGS).

Table 2-20. Water level measurements in the SRPA (May 1995).

Well	Drilled Depth (ft)	Actual Vertical Depth - Well (ft)	Measured Vertical Depth - Well (ft)	Measured Water Depth (ft)	Actual Water Depth (ft)	Water Level Elevation (ft)
MW-18	479.0	471.96	472.4	464.19	463.75	4453.56
USGS 34	700.0	564.90	565.0	477.33	477.25	4453.02
USGS 35	578.5	479.71	480.0	477.76	477.47	4453.73
USGS 36	567.1	539.94	540.0	477.48	477.42	4453.01
USGS 37	573.0	550.00	550.0	477.61	477.54	4453.07
USGS 38	729.0	599.94	600.0	478.03	477.98	4453.08
USGS 39	571.9	479.89	480.0	479.16	479.05	4453.13
USGS 40	679.0	No borehole deviation survey.		463.58	463.58	4453.67
USGS 41	674.4	No borehole deviation survey.		464.53	464.53	4453.87
USGS 42	678.5	No borehole deviation survey.		464.83	464.83	4453.89
USGS 43	676.0	No borehole deviation survey.		465.58	465.58	4451.25
USGS 44	650.0	No borehole deviation survey.		465.58	465.58	4453.79
USGS 45	651.2	No borehole deviation survey.		467.41	467.41	4452.40
USGS 46	650.9	No borehole deviation survey.		468.10	468.10	4449.53
USGS 47	652.0	Deviation noted as insignificant.		461.34	461.34	4455.11
USGS 48	750.0	No borehole deviation survey.		464.16	464.16	4453.99
USGS 49	656.0	No borehole deviation survey.		NA	NA	NA
USGS 51	659.0	No borehole deviation survey.		466.77	466.77	4454.10
USGS 52	650.0	No borehole deviation survey.		457.75	457.75	4453.92
USGS 57	732.0	No borehole deviation survey.		471.80	471.80	4452.64
USGS 59	657.0	No borehole deviation survey.		461.44	461.44	4453.45
USGS 67	698.0	No borehole deviation survey.		462.34	462.34	4453.42
USGS 77	610.0	No borehole deviation survey.		471.26	471.26	4452.75
USGS 82	700.0	No borehole deviation survey.		454.94	454.94	4451.66
USGS 84	505.0	No borehole deviation survey.		486.56	486.56	4453.03
USGS 85	637.0	No borehole deviation survey.		489.07	489.07	4452.45
USGS 111	595.0	512.75	520.0	475.98	469.35	4453.40
USGS 112	563.0	546.04	550.0	479.67	476.22	4453.91
USGS 113	564.0	541.39	550.0	480.31	472.79	4454.88
USGS 114	562.0	533.70	540.0	474.02	468.49	4453.85
USGS 115	581.0	546.33	550.0	470.27	467.13	4454.00
USGS 116	580.0	559.47	560.0	464.71	464.27	4454.33
USGS 121	745.8	456.49	458.0	459.12	457.61	4453.86
USGS 122	482.8	478.79	479.3	462.62	462.13	4453.57
USGS 123	744.2	480.10	480.2	468.39	468.29	4453.02
LF2-08	495.0	477.04	480.0	485.79	482.80	4450.34
LF2-09	497.0	479.12	485.0	486.30	480.40	4453.06
LF2-10	765.0	707.52	710.0	484.74	483.05	4450.59
LF2-11	499.0	484.90	485.0	477.60	477.50	4452.67
LF2-12	483.0	474.89	475.0	481.85	481.73	4452.53
LF3-08	510.0	489.96	495.0	494.16	489.13	4452.45
LF3-09	500.0	489.87	490.0	490.59	490.46	4452.31
LF3-10	501.0	489.99	490.0	492.14	492.13	4452.49
LF3-11	492.2	479.97	480.0	NA	NA	NA

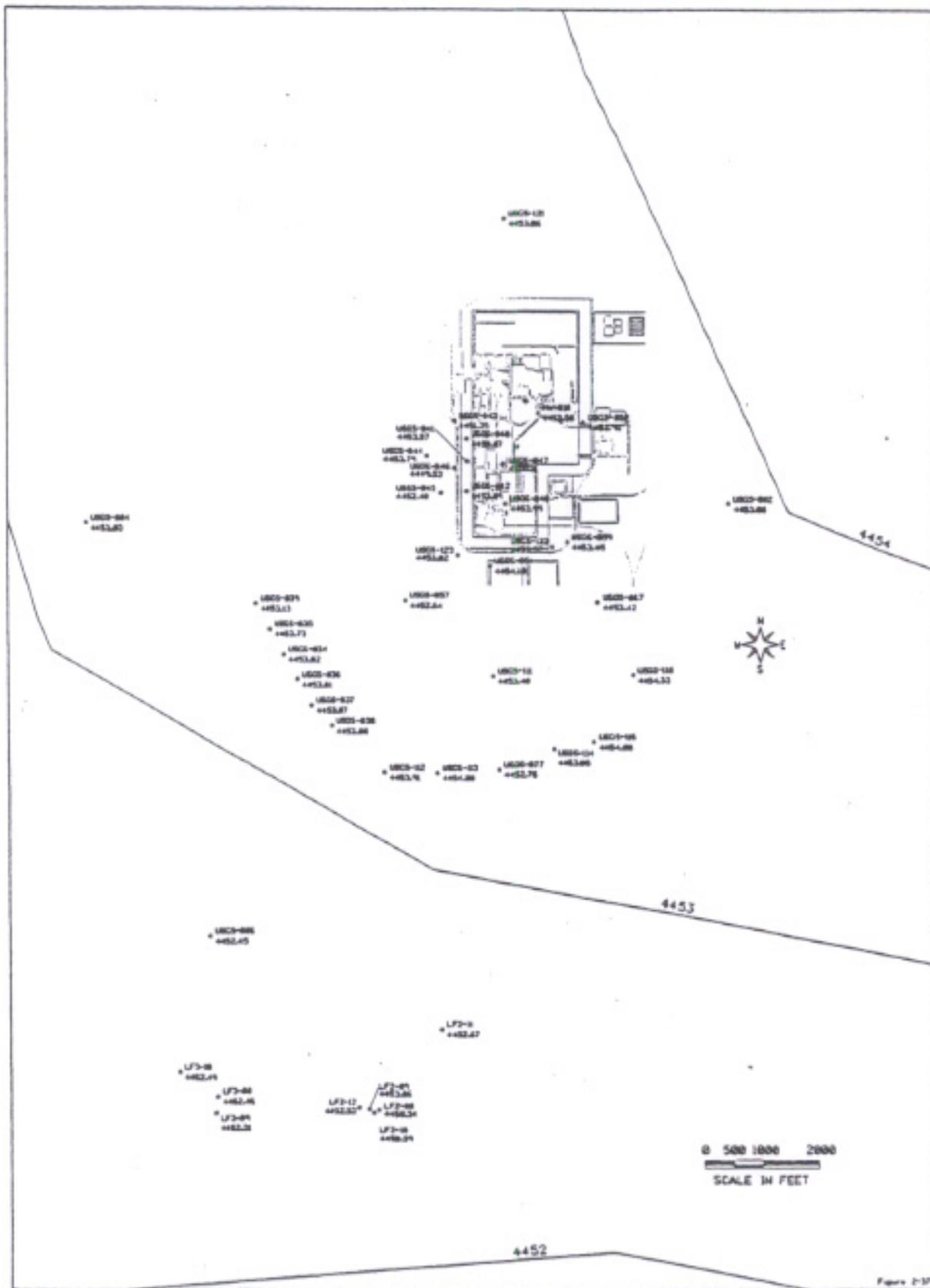


Figure 2-37. Groundwater flow in the SRPA (May 1995).

at which water will be transmitted through a unit width of an aquifer under a unit hydraulic gradient, the values are directly comparable from well to well. The transmissivity values at the ICPP range five orders of magnitude with a maximum transmissivity of $7.0 \times 10^4 \text{ m}^2/\text{day}$ ($7.5 \times 10^5 \text{ ft}^2/\text{day}$) at well CPP-3 and a minimum transmissivity of $0.93 \text{ m}^2/\text{day}$ ($10 \text{ ft}^2/\text{day}$) at well USGS-114 (Table 2-21). The average transmissivity for the SRPA in the vicinity of the ICPP is $8.8 \times 10^3 \pm 1.8 \times 10^4 \text{ m}^2/\text{day}$ ($9.5 \times 10^4 \pm 1.9 \times 10^5 \text{ ft}^2/\text{day}$).

A plot of the SRPA transmissivities at the ICPP is shown in Figure 2-38. This figure indicates two zones of higher transmissivity extend to the southwest and east-southeast of the ICPP Disposal Well. Directly to the south of the ICPP is a region of relative low transmissivities [$<93 \text{ m}^2/\text{day}$ ($<1,000 \text{ ft}^2/\text{day}$)], indicating lower flow rates through this area. This transmissivity pattern apparently has a big impact on the groundwater flow direction from the ICPP as shown in contaminant distribution maps.

Hydraulic conductivity describes the rate at which water can move through permeable medium. Aquifer hydraulic conductivity is estimated by including the aquifer thickness using the following relationship:

$$K = T/b \quad (2-4)$$

where

K = hydraulic conductivity (ft/day)

T = transmissivity (ft^2/day)

b = aquifer thickness (ft).

One problem with estimating hydraulic conductivity by dividing the transmissivity by aquifer thickness for a well in fractured rock aquifers is the hydraulic conductivity could range over several orders of magnitude depending on whether a 0.3-m (1-ft) zone is highly fractured to dense and unfractured. At local scales, the velocity of groundwater movement or the movement of a pollutant is governed by the maximum hydraulic conductivity that would be representative of a fracture or set of fractures in a zone open to a well. Therefore, a calculated velocity using an average hydraulic conductivity can be misleading.

The hydraulic conductivity of the SRPA in the vicinity of the ICPP was estimated using the transmissivity values reported by Ackerman (1991) and the saturated thickness of the open interval of the well (Table 2-21). The estimation of hydraulic conductivity assumes the wells fully penetrate the saturated thickness of the aquifer. Hydraulic conductivities range five orders of magnitude with a maximum hydraulic conductivity of $3.0 \times 10^3 \text{ m/day}$ ($1.0 \times 10^4 \text{ ft/day}$) at Well CPP-3 and a minimum hydraulic conductivity of $3.0 \times 10^{-2} \text{ m/day}$ ($1.0 \times 10^{-1} \text{ ft/day}$) at Well USGS-114. The average hydraulic conductivity within the immediate vicinity of the ICPP is $4.0 \times 10^2 \pm 7.9 \times 10^2 \text{ m/day}$ ($1.3 \times 10^3 \pm 2.6 \times 10^3 \text{ ft/day}$). Using the average hydraulic conductivity, a hydraulic gradient of 1.2 m/km (6.3 ft/mi) (Orr and Cecil, 1991), and an effective porosity of 10%, the calculated seepage velocity in the vicinity of the ICPP is approximately 3 m/day (10 ft/day).

2.6.2.3 Local Flow Velocity. Tritium from the ICPP wastes has been used extensively in tracing groundwater flow velocities and directions (Morris et al., 1964; Hawkins and Schmalz, 1965; and

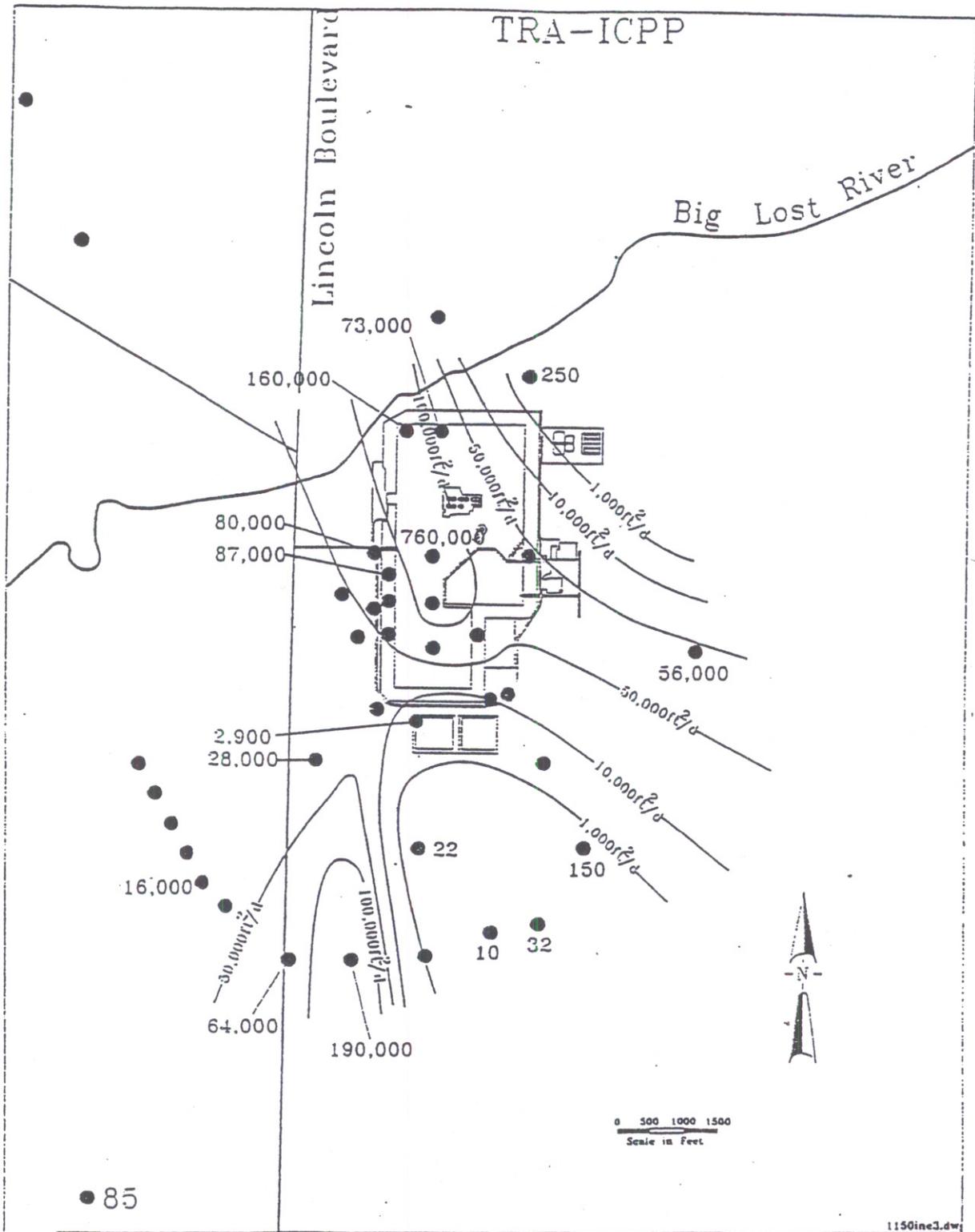


Figure 2-38. Plot of transmissivities in the SRPA near the ICPP.

Table 2-21. Transmissivities in the SRPA near the ICPP (Ackerman, 1991) and estimates of hydraulic conductivity.

Well identifier	Transmissivity (ft ² /day)	Saturated thickness (ft) ^a	Hydraulic conductivity (ft/day)
CPP-1	7.3×10^4	150	4.9×10^2
CPP-2	1.6×10^5	75	2.1×10^3
CPP-3	7.6×10^5	74	1.0×10^4
CPP-4	2.5×10^2	255	9.8×10^{-1}
USGS-37	1.6×10^4	65	2.5×10^2
USGS-40	8.7×10^4	27	3.2×10^3
USGS-43	8.0×10^4	225	3.6×10^2
USGS-51	2.9×10^3	184	1.6×10^1
USGS-57	2.8×10^4	255	1.1×10^2
USGS-82	5.6×10^4	100	5.6×10^2
USGS-111	2.2×10^1	137	1.6×10^{-1}
USGS-112	6.4×10^4	96	6.7×10^2
USGS-113	1.9×10^5	97	2.0×10^3
USGS-114	1.0×10^1	100	1.0×10^{-1}
USGS-115	3.2×10^1	123	2.6×10^{-1}
USGS-116	1.5×10^2	127	1.2×10^0
Maximum	7.6×10^5		1.0×10^4
Minimum	1.0×10^1		1.0×10^{-1}
Average ± standard deviation (SD)	9.5×10^4 $\pm 1.9 \times 10^5$		1.3×10^3 $\pm 2.6 \times 10^3$

a. Saturated thickness values are the total saturated portion of the open well intervals.

Barracough et al., 1967). Peaks of high H-3 discharge to the disposal well have been particularly useful in determining the local flow characteristics in the SRPA. One of the most studied "peak" discharges of H-3 occurred in December 1961 because it was preceded and followed by relatively long periods of low H-3 discharge.

The concentration of the H-3 peak as it passed each observation well provides an indication of the amount of dispersion the slug has undergone. Wells along the most direct line of flow should show the least attenuation in peak concentration. This effect is illustrated in Figure 2-39 where the maximum concentration of the peak from the December, 1961 release was plotted and contoured (Barracough et al., 1967). The most prominent features are the zones of least attenuation to the southwest (Wells USGS-42, USGS-57, USGS-38, and USGS-85) and a second lobe of higher peak concentrations to the southeast. These lobes indicate two preferred flow paths from the disposal well probably exist; the predominant one to the southwest and a less clearly defined path to the southeast. Some of the explanation for this phenomenon is provided in the plot of the transmissivity values for the ICPP where a zone of low transmissivity is located directly to the south. This zone of low transmissivity to the south apparently acts as a barrier to impede the local groundwater flow.

According to Figure 2-39, the most prominent flow path from the disposal well is to the southwest along Wells USGS-42, USGS-57, USGS-38, and USGS-85. Barracough et al. (1967) studied the movement of the December 1961 peak down this line of wells and calculated the groundwater flow velocity from the ICPP. Figure 2-40 shows the H-3 concentration with time for these wells. The December 1961 peak is apparent through Well USGS-57, but becomes obscured in Wells USGS-38 and USGS-85. The arrow on the figure indicates the time of arrival for the December 1961 peak (Barracough et al., 1967).

The behavior of the peak is shown in the following tabulation (Barracough et al., 1967):

Well	Distance from disposal well (ft)	Groundwater velocity (ft/day)
47	705	25
42	1,340	11.5
48	1,400	12.5
57	3,500	20
38	6,300	12
85	10,400	10

The anomalously high value for Well USGS-57 apparently indicates very rapid flow from Wells USGS-42 and USGS-48. The groundwater velocity between Well USGS-47 and Well USGS-42 or USGS-48 would have to be approximately 2.3 m/day (7.5 ft/day), while the average groundwater flow velocity between Well USGS-42 or USGS-48 and Well USGS-57 would have to be approximately 18.3 m/day (60 ft/day). One possible explanation for the extremely high groundwater flow velocity is Wells USGS-42 and USGS-48 are not in the most direct flow path from the disposal well. In this case, the preferred groundwater flow path from the disposal well would occur as a thin band between these two wells.

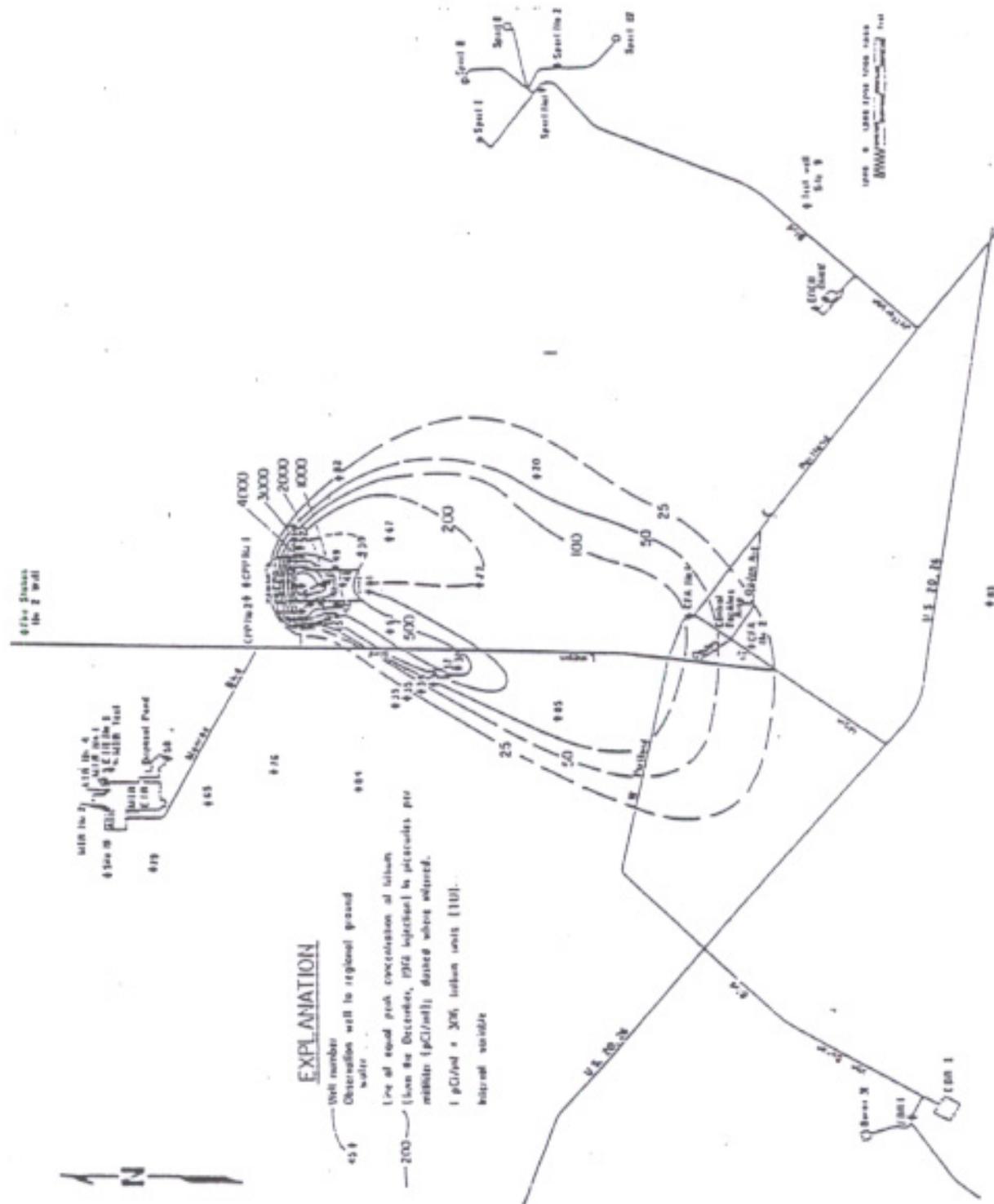


Figure 2-39. Maximum tritium concentrations in the SRPA from the December 1961 release (Barracough et al., 1967).

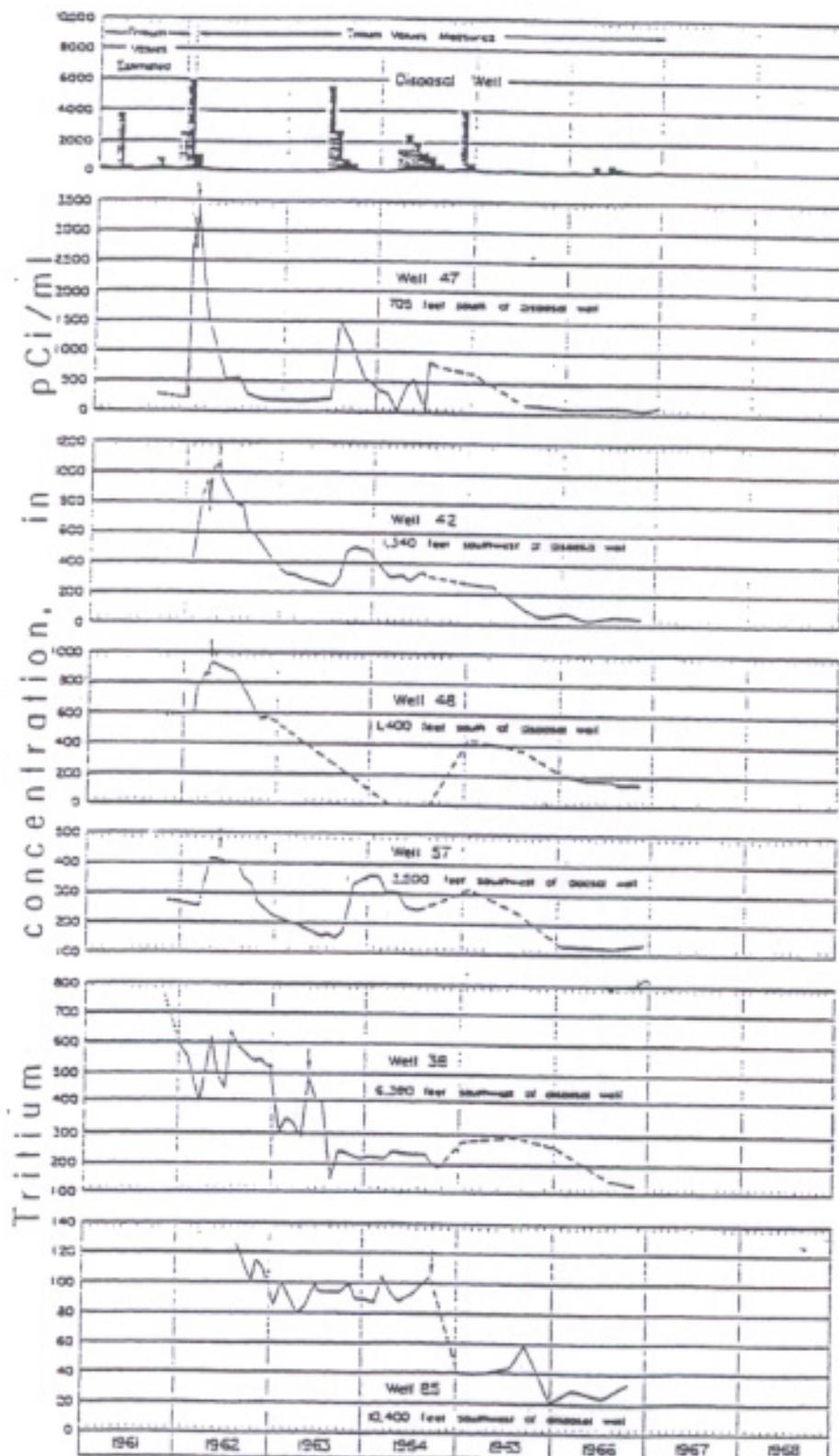


Figure 2-40. Graphs of tritium concentrations in the SRPA Wells USGS-47, -42, -57, -38, and -85 from 1961 through 1966 (Barraclough et al., 1967).

The relatively poor response of Well USGS-38 to the December 1961 peak is probably due to either the well not being located on the most direct flow path or the well being completed in a different portion of the aquifer than the other wells along the line. Most of the other wells are perforated in the upper 76.2 m (250 ft) of the aquifer, whereas, Well USGS-38 is completed in a 15.5-m (51-ft) wide zone between 64 and 79 m (210 and 260 ft) below the water table. This may indicate the majority of the H-3 is being transported in the upper 61 m (200 ft) of the aquifer.

Well USGS-85 also shows a poor response to the December 1961 H-3 peak. It was postulated by Barraclough et al. (1967) that this poor response may be a result of the well not being in the direct flow path and also due to its greater distance from the disposal well.

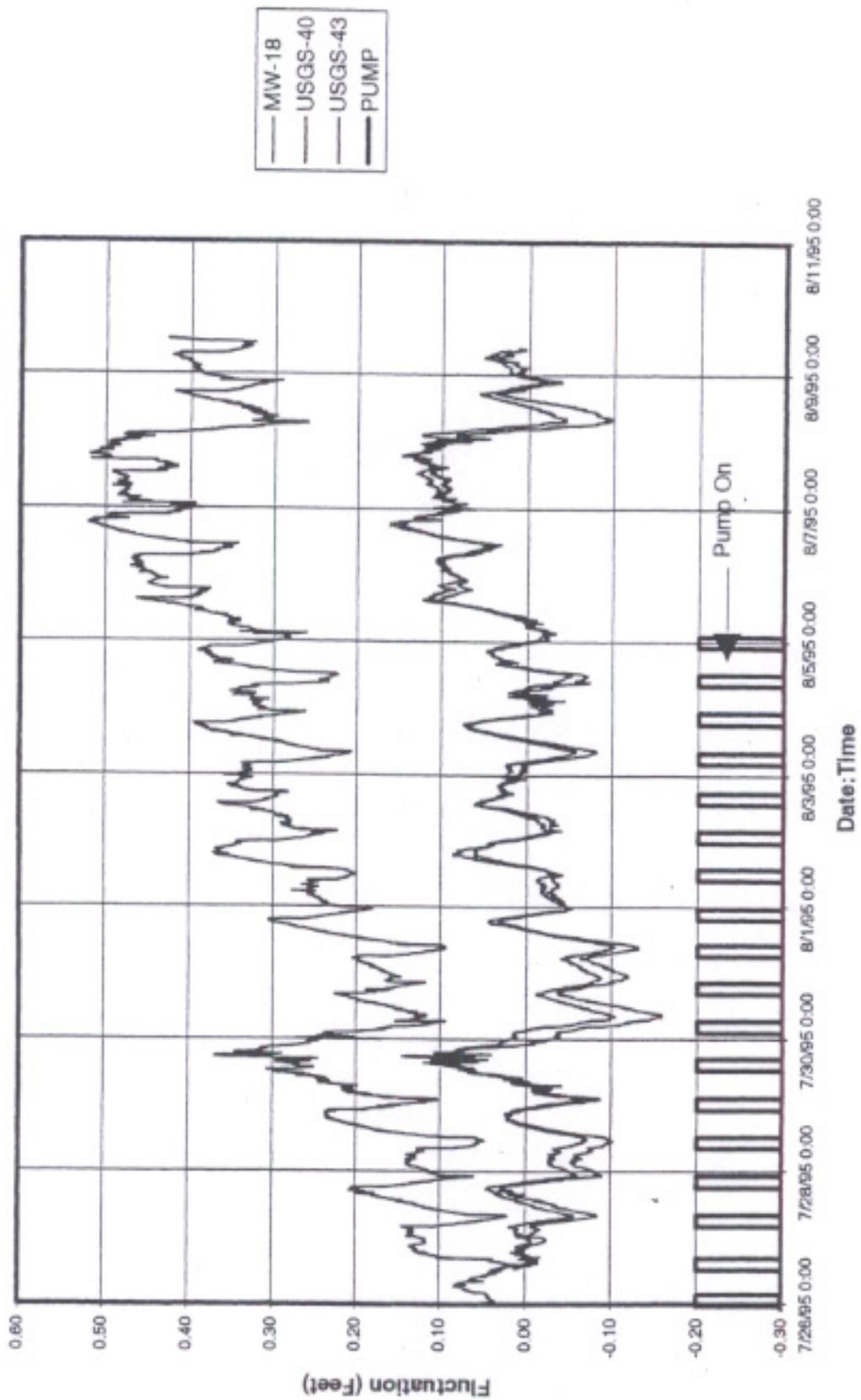
2.6.2.4 Pumping Effects. The ICPP uses approximately 7.9M L (2.1M gal) of water per day. This water is supplied by two raw water wells (CPP-1 and CPP-2) and two potable water wells (CPP-4 and new well) located in the northern portion of the facility. As part of the WAG 3 RI, the effect of groundwater pumpage from these wells upon the local water table was investigated during July and August 1995. This investigation involved continuous water level monitoring of several aquifer wells completed in the northern ICPP while metering the pump usage in Production Well CPP-2.

Water level fluctuations in six aquifer wells (MW-18, USGS-40, -43, -47, -52, and -121) were monitored at 5-min intervals using pressure transducers and data loggers. Barometric pressure changes were recorded at 5-min intervals by NOAA at the CFA weather station, which is located approximately 5 km (3 mi) from the test site. Pump usage for Well CPP-2 was continuously monitored based on amperage requirements. Plots of the water level fluctuation versus pump usage for this test are provided in Figures 2-41 and 2-42. During the 11 days of the test, the production well pump turned on 17 times with each pump cycle lasting for approximately 9 hr.

The water levels in all aquifer wells exhibited a similar response. Daily fluctuations, generally less than 3 cm (1 in.), were observed in all aquifer wells corresponding with pump usage of the production well. The change in water level for each pump cycle is provided in Table 2-22. In almost all pump cycles, the corresponding water levels in the aquifer wells decreased by an average of 1.9 cm (0.75 in.). Only Pump Cycle #11 demonstrated an increase in water levels throughout the pump duration for all wells except Well USGS-40. This water level increase during this pump cycle may be the result of a local or regional trend and not related to groundwater pumpage. Other than Pump Cycle #11, the water levels decreased during the pump cycle in Wells MW-18, USGS-40, -43, and -52 throughout the test.

The SRPA has been described as "quasi-artesian" by Nace et al. (1959) and therefore, the water levels may be affected by changes in barometric pressure. Plots of the change in barometric pressure versus change in water level (standardized to feet of water) for the six aquifer wells are provided in Figure 2-43. The barometric pressure efficiency for each well was then calculated based upon the linear regression line shown in the figure. The barometric pressure efficiency for Wells MW-18, USGS-40, -47, and -121 were calculated to be 54, 77, 66, and 48%, respectively. For two of the wells (USGS-43 and -52), the linear regression line did not intercept the 0-0 point and as a result, the barometric pressure efficiency could not be calculated for these wells.

Water Level Fluctuation & Pump Operation



Water Level Fluctuation & Pump Operation

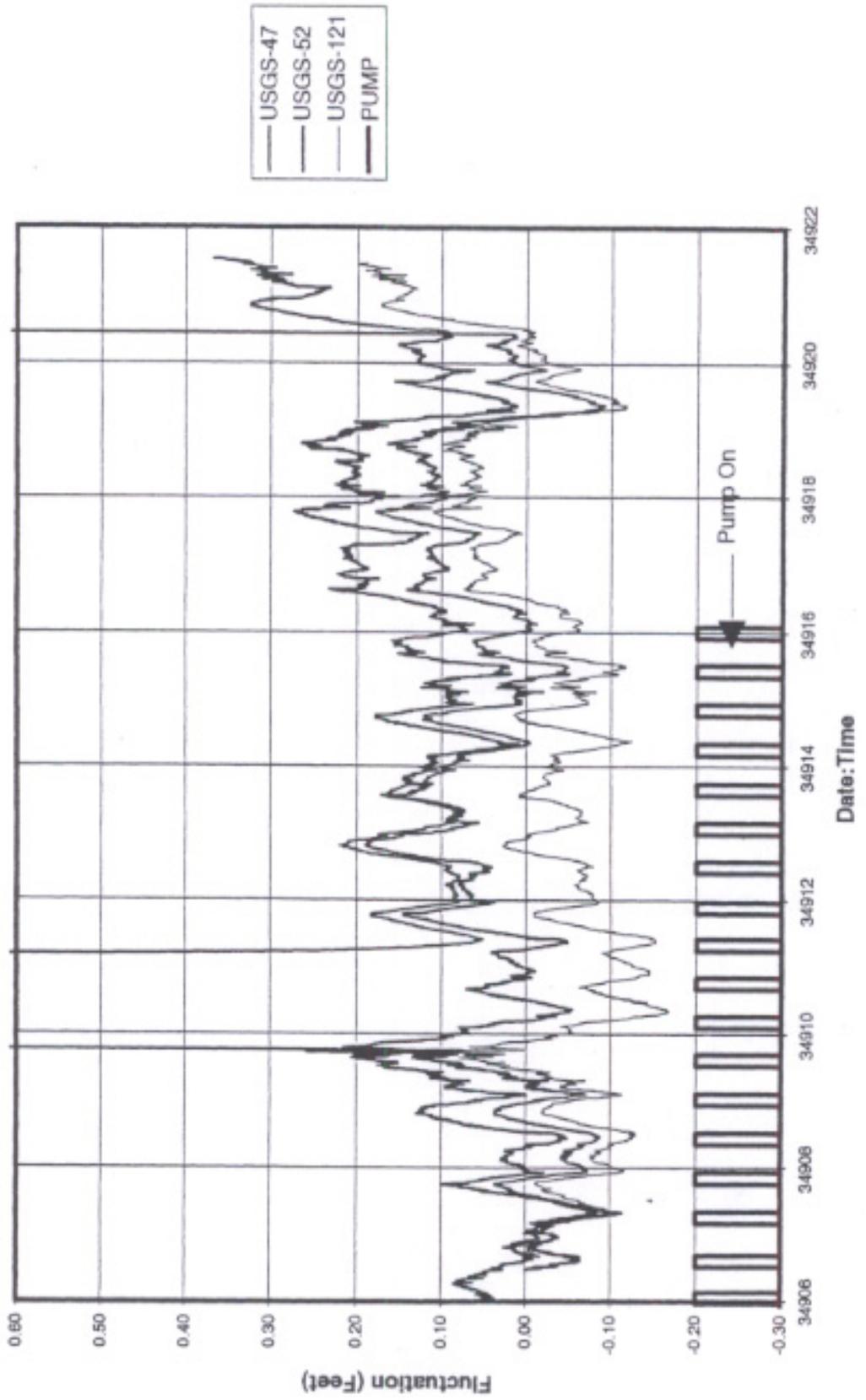


Table 2-22. Summary of water level fluctuation for each pump cycle.

Pump Cycle	Water Level Fluctuation (including barometric pressure effects)					
	MW-18	USGS-40	USGS-43	USGS-47	USGS-52	USGS-121
1	-0.02	NA	NA	-0.27	NA	NA
2	-0.08	-0.07	-0.12	-0.07	-0.07	-0.08
3	-0.12	-0.10	-0.11	-0.11	-0.10	-0.10
4	-0.02	-0.03	-0.06	-0.01	-0.01	0.01
5	-0.09	-0.08	-0.08	-0.08	-0.09	-0.08
6	0.00	-0.01	-0.05	0.00	-0.02	0.00
7	-0.10	-0.09	-0.08	-0.14	-0.08	-0.09
8	-0.06	-0.06	-0.11	0.00	-0.05	-0.06
9	-0.05	-0.05	-0.05	-0.15	-0.03	-0.05
10	-0.09	-0.08	-0.01	-0.10	-0.11	-0.08
11	0.01	-0.01	0.00	0.04	0.02	0.01
12	-0.07	-0.07	-0.11	-0.08	-0.06	-0.06
13	-0.03	-0.04	-0.08	-0.05	-0.02	-0.03
14	-0.09	-0.08	-0.12	-0.08	-0.06	-0.08
15	-0.10	-0.07	-0.13	-0.11	-0.09	-0.08
16	-0.03	-0.04	-0.05	-0.02	0.00	-0.04
17	-0.05	-0.05	-0.09	-0.05	-0.06	-0.04
Maximum	0.01	-0.01	0.00	0.04	0.02	0.01
Minimum	-0.12	-0.10	-0.13	-0.27	-0.11	-0.10
Average	-0.06	-0.06	-0.08	-0.08	-0.05	-0.05

Pump Cycle	Water Level Fluctuation (without barometric pressure effects)					
	MW-18	USGS-40	USGS-43	USGS-47	USGS-52	USGS-121
1	-0.02	0.00	NA	-0.27	NA	0.00
2	-0.10	-0.10	NA	-0.10	NA	-0.10
3	-0.15	-0.16	NA	-0.15	NA	-0.13
4	0.00	0.00	NA	0.02	NA	0.01
5	-0.09	-0.08	NA	-0.08	NA	-0.80
6	-0.07	-0.10	NA	-0.08	NA	-0.05
7	-0.15	-0.17	NA	-0.21	NA	-0.14
8	0.06	0.11	NA	0.15	NA	0.05
9	-0.04	-0.04	NA	-0.14	NA	-0.37
10	-0.10	-0.09	NA	-0.10	NA	-0.08
11	0.06	0.06	NA	0.09	NA	0.05
12	-0.08	-0.82	NA	-0.09	NA	-0.08
13	-0.01	-0.02	NA	-0.03	NA	-0.02
14	-0.11	-0.12	NA	-0.11	NA	-0.10
15	-0.13	-0.11	NA	-0.14	NA	-0.10
16	0.00	0.00	NA	0.17	NA	-0.01
17	-0.05	-0.05	NA	-0.05	NA	-0.04
Maximum	0.06	0.11	NA	0.17	NA	0.05
Minimum	-0.15	-0.82	NA	-0.27	NA	-0.80
Average	-0.06	-0.10	NA	-0.07	NA	-0.11

NA denotes not available

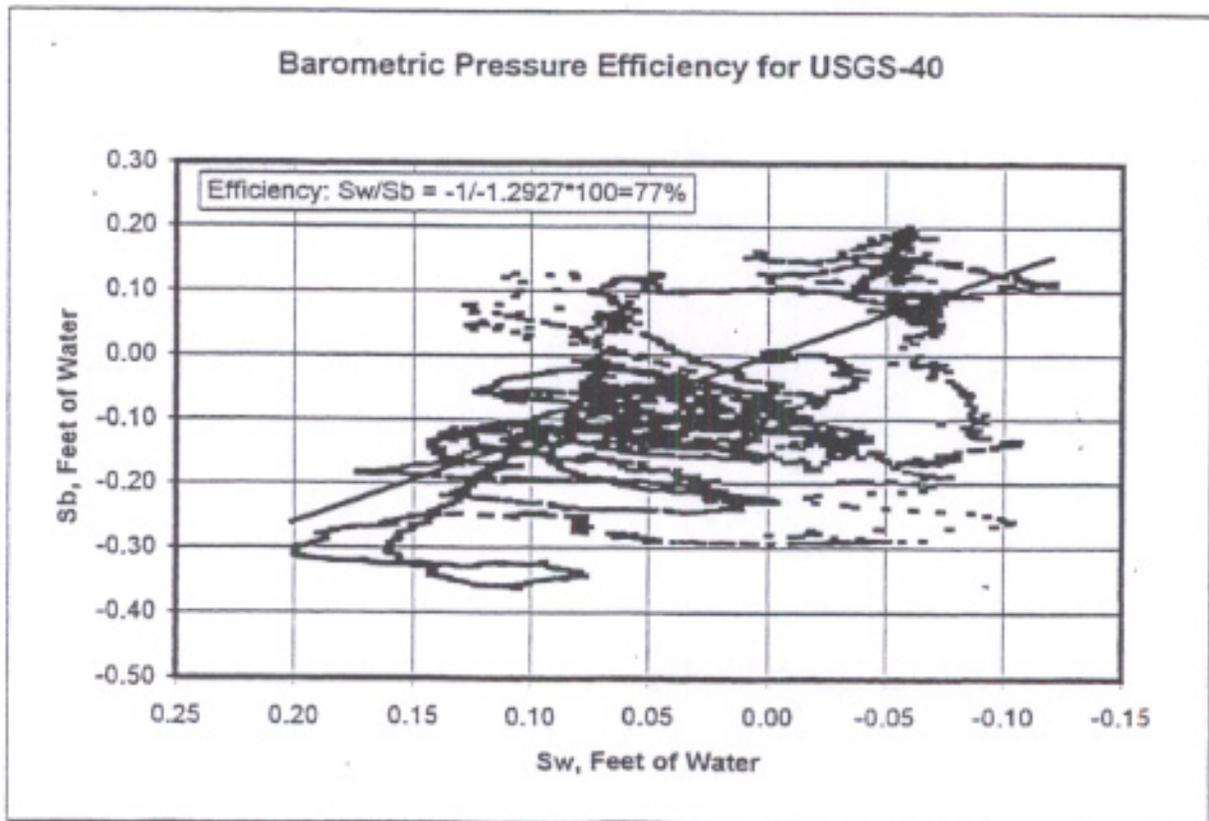
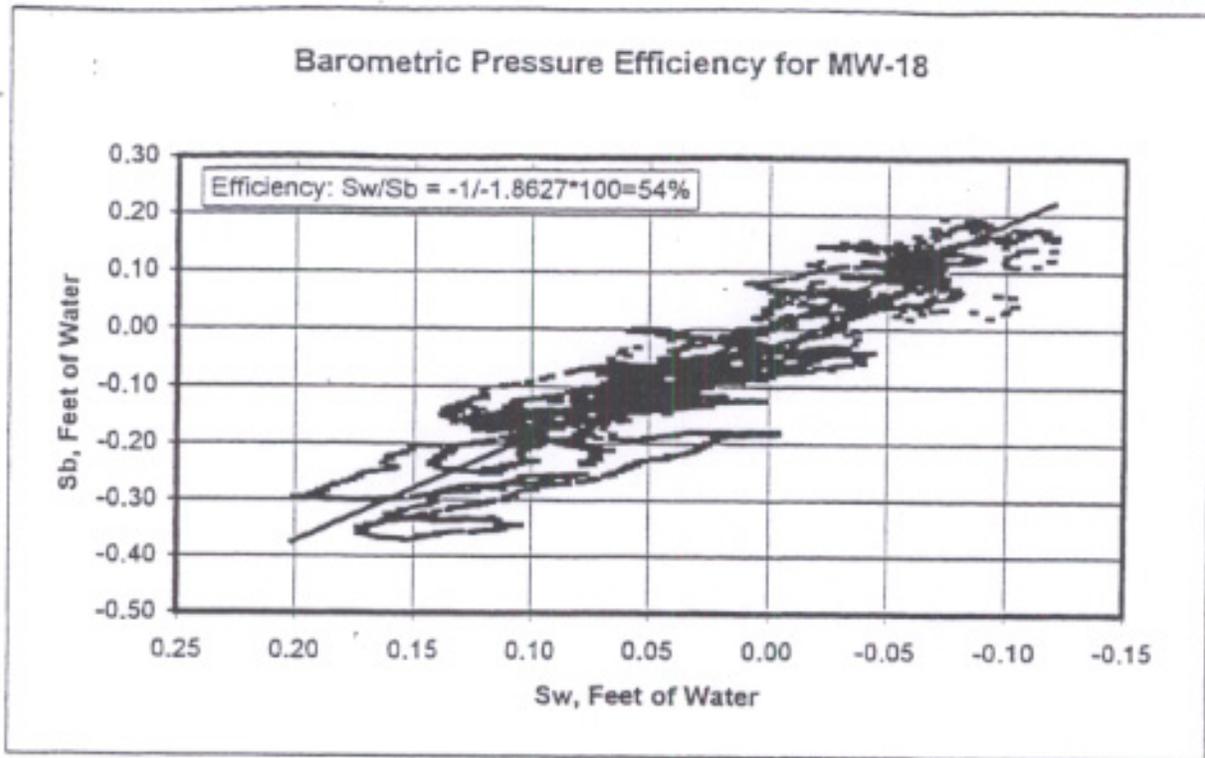


Figure 2-43. Barometric pressure vs. water level fluctuation for Wells MW-18, USGS-40, -43, -47, -52, and -121.

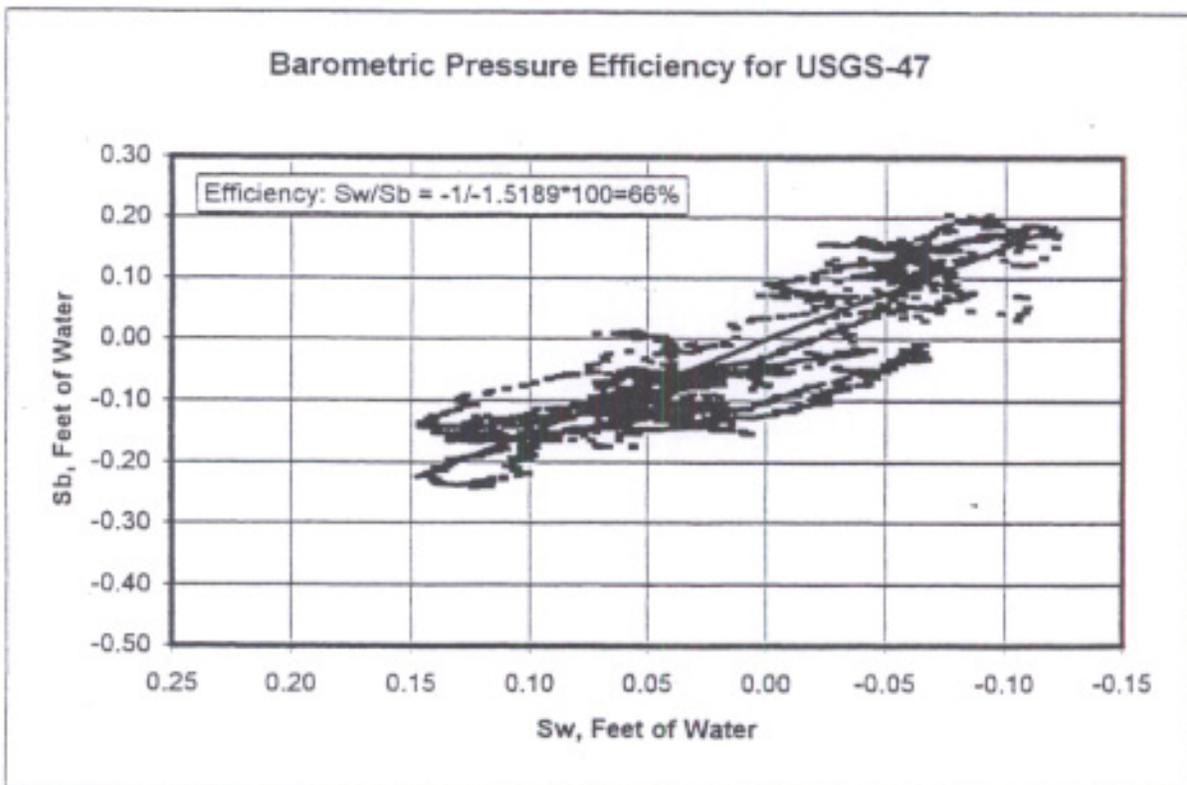
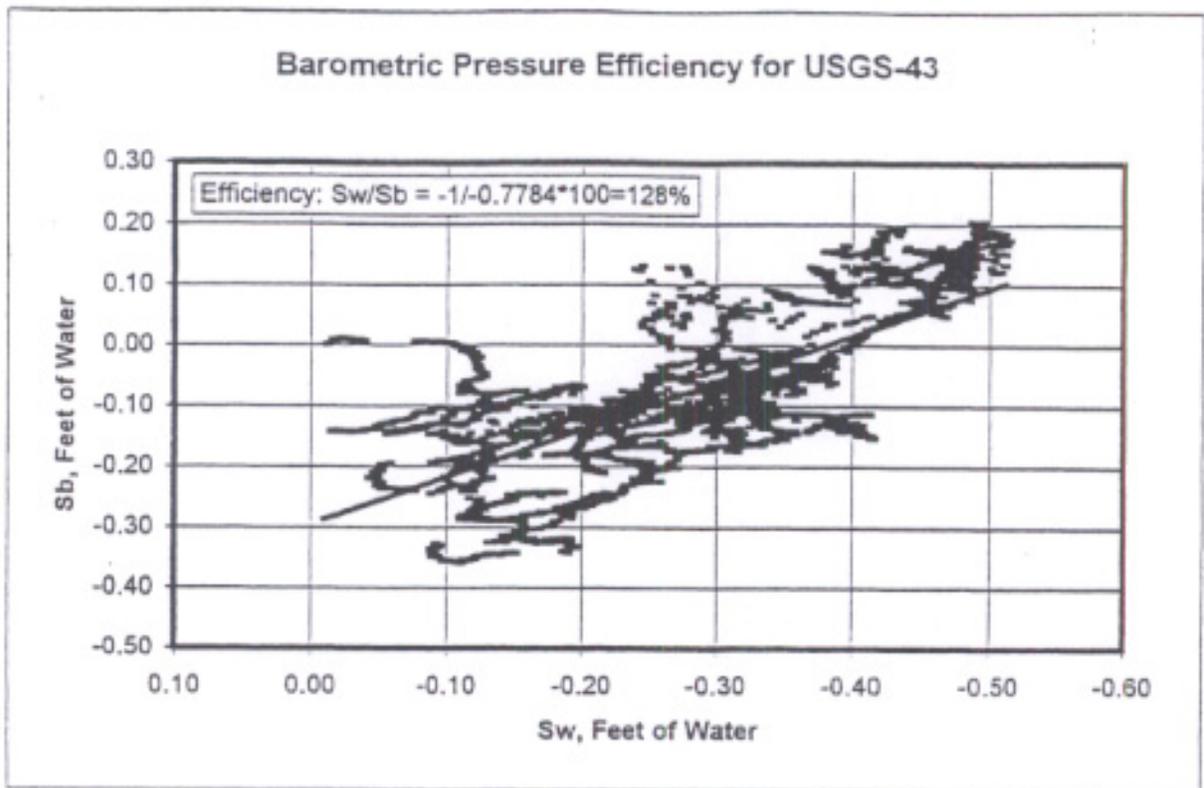


Figure 2-43. (continued).

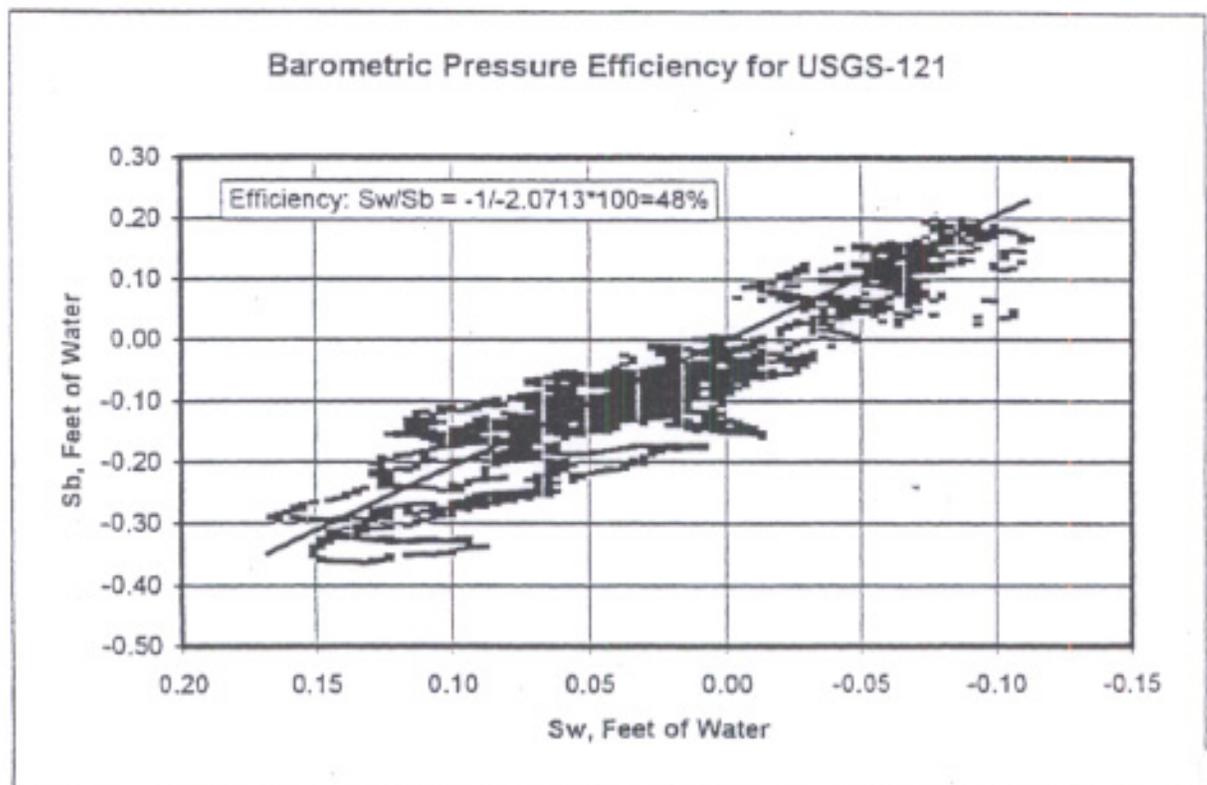
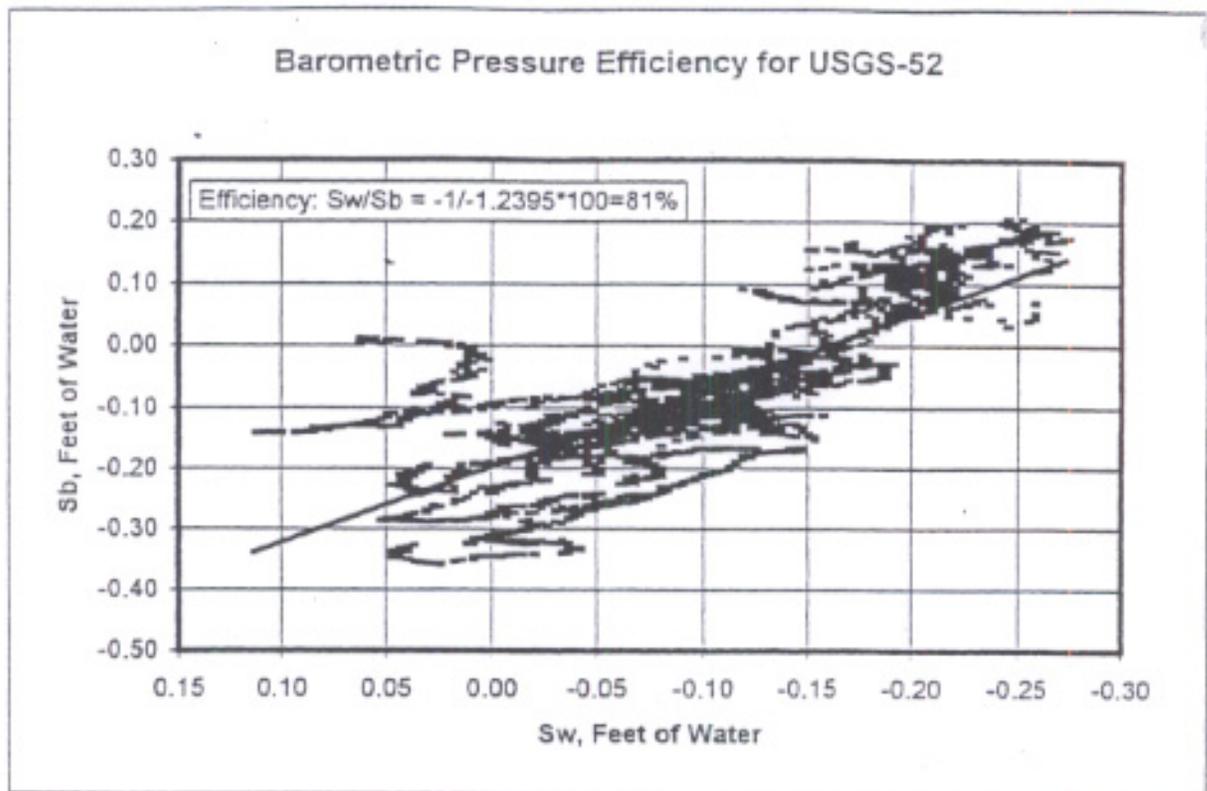


Figure 2-43. (continued).

The effects of barometric pressure upon the water level were eliminated by combining the barometric pressure change during the pump cycle with the barometric pressure efficiency calculated in Figure 2-43. The water level fluctuations without barometric pressure effects for each pump cycle are also provided in Table 2-22. By eliminating barometric pressure effects, water levels in the SRPA decreased during 13 pump cycles, increased during three pump cycles, and demonstrated a mixed response in one pump cycle. Overall, the water level in the SRPA decreased an average of 2.5 cm (1 in.) during each pump cycle.

As shown by this test, water levels in the SRPA are affected by groundwater pumpage from the production well. Minimal responses [<2.5 cm (<1 in.)] were observed in these six monitoring wells, however, the wells are located approximately 610 m (2,000 ft) from the production well. Increased drawdown would be expected closer to the production well that could affect the local groundwater flow direction in the northern ICPP.

2.7 References

- Ackerman, D. J., 1991, *Transmissivity of the Snake River Plain Aquifer at the Idaho National Engineering Laboratory Site, Idaho*, U.S. Geological Survey Water-Resources Investigations Report 91-4058, DOE/ID-22097.
- Anderson, S. R. and B. D. Lewis, 1989, *Stratigraphy of the Unsaturated Zone at the Radioactive Waste Management Complex, Idaho National Engineering Laboratory, Idaho*, USGS Water-Resources Investigations Report 89-4065, IDO-22080.
- Anderson, S. R., 1991, *Stratigraphy of the Unsaturated Zone and Uppermost Part of the Snake River Plain Aquifer at the Idaho Chemical Processing Plant and Test Reactor Area, Idaho National Engineering Laboratory, Idaho*, USGS Water-Resources Investigations Report 91-4010, IDO-22095.
- Barracough, J. T. and R. G. Jensen, 1976, *Hydrologic Data for the Idaho National Engineering Laboratory Site, Idaho 1971 to 1973*, IDO-22055, January.
- Barracough, J. T. et al., 1967, *Hydrology of the National Reactor Testing Station, Idaho, 1966*, U.S. Geological Survey Open-File Report, Waste Disposal and Processing TID-4500, IDO-22049.
- Bennett, C. M., 1990, *Streamflow Losses and Groundwater Level Changes along the Big Lost River at the INEL, Idaho*, USGS Water Resources Investigation Report 86-4204, DOE/ID-22091.
- Bennett, C. M., 1986, *Capacity of the Diversion Channel Below the Flood-Control Dam on the Big Lost River at the Idaho National Engineering Laboratory*, U.S. Geological Survey, Water Resources Investigations Report 86-4204.
- Bishop, C. W., 1992, Interoffice Correspondence, Bishop, C. W. to Wood T. R. and Norrell, G. T. "Pumping Tests Performed at ICPP, September 1992—Perched Water—CWB-29-92."
- Carrigan, P. H., Jr., 1972, *Probability of Exceeding Capacity of Flood-control System at the National Reactor Testing Station, Idaho*, USGS Open-File Report, IDO-22052.

- Cecil, L. D. et al., 1991, *Formation of Perched Ground-water Zones and Concentrations of Selected Chemical Constituents in Water, Idaho National Engineering Laboratory, Idaho 1986-1988*, U.S. Geological Survey Water-Resources Investigations Report 91-4166, DOE/ID-22100.
- Chipman, N. A., 1989, *Potential Near Surface Disposal Concepts for High-Level Radioactive Waste at the Idaho Chemical Processing Plant*, WINCO-1073, December.
- Cholewa, A. F. and D. M. Henderson, 1984, *A Survey and Assessment of the Rare Vascular Plants of the Idaho National Engineering Laboratory*, DOE/ID-12100.
- Clawson, K. L., G. E. Start, and N. R. Ricks, eds., 1989, *Climatology of the Idaho National Engineering Laboratory*, 2nd Edition, DOE/ID-12118.
- Coats, D. W. and R. C. Murray, 1985, *Natural Phenomena Hazards Modelling Project: Extreme Wind/Tornado Hazard Models for Department of Energy Sites*, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-53526, Rev. 1.
- Craig, T. H., E. H. Craig, and L. R. Powers, 1983, Raptor Studies on the Idaho National Engineering Laboratory, O. D. Markham (ed.), Idaho National Engineering Laboratory Radioecology and Ecology Programs, 1983 Progress Report, DOE/ID-12098.
- Ferguson, F. G. and J. Andrews, 1994, *Idaho Chemical Processing Plant Technical Site Information*, WINCO-1200, March.
- Fetter, C. W. Jr., 1980, *Applied Hydrogeology*, Bell and Howell Company, Columbus, Ground Water Manual. A Water Resources Technical Publication. U.S. Department of the Interior Water and Power Resources Service, p. 154-155, John Wiley and Sons.
- Greeley, R., 1982, *The Style of Basaltic Volcanism in the Eastern Snake River Plain, Idaho*, Bonnicksen, B., and Breckenridge, R. M. (eds.), Cenozoic Geology of Idaho; Idaho Bureau of Mines and Geology Bulletin 26, p. 407-421.
- Harenberg, W. A. et al., 1987, *Water Resource Data, Idaho, Water Year 1987*, USGS Water-Data Report ID-87-1.
- Harness, R. O. and N. E. West, 1973, *Vegetation Patterns on the National Reactor Testing Station, Southeastern Idaho*, Northwest Science 47:30-43.
- Hawkins, D. B. and H. L. Schmalz, 1965, *Equations for the Sorption of Cesium and Strontium on Soil and Clinoptilolite*, IDO-12046.
- Hubbell, J. M., 1992, Interoffice Correspondence, Hubbell, J. M. to Wood, T. R. and Norrell, G. T., "Pumping Tests Performed at ICPP," May 5-6, 1992—Perched Water—JMH-29-92.
- Hull, L. C., 1989, *Conceptual Model and Description of the Affected Environment for the TRA Warm Waste Pond (Waste Management Unit TRA-03)*, EGG-ER-8644, October.

- Jeppson, R. J. and K. E. Holte, 1978, *Flora of the Idaho National Engineering Laboratory Site*. In: O. D. Markham ed. 1978, *Ecological Studies on the Idaho National Engineering Laboratory Site 1978 Progress Report*, IDO-12087.
- Kaminsky, J. F. et al., 1994, *Remedial Investigation Final Report with Addendum for Test Area North Groundwater Operable Unit 1-07B at the Idaho National Engineering Laboratory*, EGG-ER-10643.
- Koslow, K. N. and D. H. Van Haaften, 1986, *Flood Routing Analysis for a Failure of Mackay Dam*, EGG-EP-7184.
- Kuntz, M. A. et al., 1990, *Revised Geologic Map of the Idaho National Engineering Laboratory and Adjoining Areas, Idaho*, U.S. Geological Survey Open File Report 90-333.
- Malde, H. E., 1991, *Quaternary Geology and Structural History of the Snake River Plain, Idaho and Oregon*, Morrison, R. B., (ed.), *Quaternary Nonglacial Geology: Conterminous US*. Boulder, CO, Geological Society of America, *The Geology of North*.
- Mann, L. J., 1986, *Hydraulic Properties of Rock Units and Chemical Quality of Water for INEL-1; A 10,365-Foot Deep Test Hole Drilled at the Idaho National Engineering Laboratory, Idaho*, USGS Water-Resources Investigations Report 86-4020, IDO-22070.
- McKinney, J. D., 1985, *Big Lost River 1983-1984 Flood Threat*, EGG-PPD-FPB-002.
- Miller, S. M., J. E. Hammel, and L. F. Hall, 1990, *Characterization of Soil Cover and Estimation of Water Infiltration at Central Facilities Area II, Idaho National Engineering Laboratory*, Research Technical Completion Report for Contract C85-110544, University of Idaho, June.
- Morris, D. A. et al., 1965, *Hydrology of Subsurface Waste Disposal National Reactor Testing Station Idaho Annual Progress Report 1964*, IDO-22047-USGS, May.
- Morris, D. A. et al., 1964, *Hydrology of Subsurface Waste Disposal National Reactor Testing Station Idaho Annual Progress Report 1963*, IDO-22046-USGS, May.
- Mundorff, M. J., E. G. Crosthwaite, and C. Kilburn, 1964, *Ground Water for Irrigation in the Snake River Basin in Idaho*, USGS Water Supply Paper 1654.
- Nace, R. L. et al., 1959, *Geography, Geology, and Water Resources of the National Reactor Testing Station, Idaho, Part 3, Hydrology and Water Resources*, IDO-22034-USGS.
- NOAA and Morrison Knudsen Company, Inc., 1983, *Climatography of the Idaho National Engineering Laboratory (Update of Chapters 1 and 2 through 1983)*, IDO-12048A, (Draft).
- Olmsted, F. H., 1962, *Chemical and Physical Character of Groundwater in the National Reactor Testing Station, Idaho*, IDO-22043.

- Orr, B. R. and L. D. Cecil, 1991, *Hydrologic Conditions and Distribution of Selected Chemical Constituents in Water, Snake River Plain Aquifer, Idaho National Engineering Laboratory, Idaho, 1986 to 1988*, DOE/ID-22096, March.
- Bartholomay, R. C., Tucker, B. J., Ackerman, D. J., and Liszewski, M. J., 1997, *Hydrologic Conditions and Distribution of Selected Radiochemical and Chemical Constituents in Water, Snake River Plain Aquifer, Idaho National Engineering Laboratory, Idaho, 1992 through 1995*; USGS Water Resources Investigations Report 97-4086 (DOE/ID-22137).
- Prestwich, S. M. et al., 1980, *Completion and Testing Report; INEL Geothermal Exploratory Well One (INEL-1)*, U.S. DOE Idaho Operations Office, EG&G Idaho, Inc., IDO-10096.
- Reynolds, T. D. et al., 1986, *Vertebrate Fauna of the Idaho National Environmental Research Park, Great Basin Naturalist* 46:513-527.
- Richards, B. T., 1994, *ICPP Water Inventory Study*, WINCO-1181-1184, January.
- Robertson, J. B., R. Schoen, and J. T. Barraclough, 1974, *The Influence of Liquid Waste Disposal on the Geochemistry of Water at the National Reactor Testing Station, 1952-1970*, USGS Open File Report. IDP-22053, TID-4500, February.
- Spear, D. B. and King, J. S., 1982, *The Geology of Big Southern Butte, Idaho, Cenozoic Geology of Idaho: Idaho Bureau of Mines and Geology Bulletin* 26, B., Bonnicksen and Breckenridge, R., M. (eds.), p. 395-403.
- Stafford, M. P., 1984, *Surface-Dwelling Coleoptera Inhabiting Sagebrush Communities in Southeastern Idaho*, M.S. Thesis, University of Idaho, Moscow.
- Stearns, H. T., L. Crandall, and W. G. Steward, 1938, *Geology and Ground-water Resources of the Snake River Plain in Southeastern Idaho*, USGS Water Supply Paper 774.
- Thomas, T. R., 1988, *Modeling Hypothetical Groundwater Transport of Nitrates, Chromium, and Cadmium at the Idaho Chemical Processing Plant*, WINCO-1060.
- Van Haaften, D. H., K. N. Koslow, and C. J. Naretto, 1984, *Hydrologic Analysis of a Mackay Dam Failure During a Probable Maximum Flood on the Big Lost River, Idaho*, EG&G Idaho, Inc., Internal Technical Report No. SE-A-84-018, May.
- Walker, E. H., 1960, *Analysis of Aquifer Tests, January 1958-June 1959, at the National Reactor Testing Station, Idaho*, Atomic Energy Commission.
- Walton, W. C., 1958, *Analysis of Aquifer Tests at the National Reactor Testing Station, Idaho, 1949-1957*, Prepared for the U.S. Atomic Energy Commission.
- Interim Data Results From the FY 93/94 Perched Ground Water Investigation* (February 18, 1994).

4. NATURE AND EXTENT OF CONTAMINATION

During more than 40 years of operations, radioactive and hazardous materials have been released to the environment at the ICPP. Releases, which are not unusual at industrial facilities, have occurred as the result of spills, leaks in waste transfer lines, and through previous waste management practices. To date, 94 potentially contaminated sites have been identified. Most of these sites were identified before finalization of the FFA/CO and are grouped in OUs based on similar waste streams or conditions. Some release sites were cleaned up at the time of the release and most have been sampled and characterized. The objective of this section is to describe the major sources of contamination that have led to adverse soil and groundwater impacts and subsequently describe the extent of contamination to groundwater. This section will also discuss efforts taken to verify the completeness of the data collected.

To this end, Section 4.1 will describe the nature of contamination in terms of the major sources and Sections 4.2 and 4.3 will describe the resulting extent of contamination in the perched water and aquifer. It should be noted that Section 4.1.3 briefly discusses soil contamination however, the nature and extent of soil contamination will be described in detail on a site basis in Sections 8 through 26. The completeness of the field investigations in terms of the inventory of radioactive contaminants expected given the spent nuclear fuel reprocessing mission of the ICPP is discussed in Section 4.4.

4.1 Sources and Source Inventory

Based on a review of the generation process and existing artifacts, the primary sources of contamination at the ICPP include (a) historical waste discharge to the ICPP disposal well (Section 4.1.1), (b) leakage from the concrete holding tanks in building CPP-603 (Section 4.1.2), and (c) accidental releases to the environment as identified in the FFA/CO. For all sources except the CPP-603 concrete holding tanks, the release of contamination to the environment is from historical events. Wastewater is currently being discharged to two active surface impoundments, the percolation ponds and sewage treatment ponds. According to existing characterization data on the ponds sediments and the quality of the waste stream, these two sources do not contribute significantly to the groundwater contamination. However, water movement from these ponds may affect the migration of contaminants in other areas of the ICPP such as the tank farm. Depending upon the location of the water source with respect to the contaminated areas, this discharge may contribute to contaminant migration in the subsurface.

4.1.1 ICPP Injection Well, CPP-23

Since 1952, ICPP processes have generated large volumes of plant cooling waters and condensates. These service waste waters contained small quantities of radioactive and inorganic contaminants. The ICPP injection well (MEH-FE-PL-304), located north of building CPP-666, was used to discharge these low-level radioactive and chemical wastes to the aquifer from 1952 to February 1984. The ICPP injection well was drilled in 1950 to a depth of 64.6 m (212 ft) and deepened in 1951 to 182 m (597 ft). A 61-cm (24-in.) diameter borehole was drilled and cased using 41-cm (16-in.) nominal diameter carbon steel casing. The annular space between the borehole and casing was filled with gravel. The well casing was perforated from 125.6 to 137.8 m (412- to 452-ft) and 149.4- to 180.7-m (490- to 593-ft) bls. The average discharge to the well during this period was about 1.4B L/yr (363M gal./yr) or about 3.8 ML/day (1M gal/day). Figure 4-1

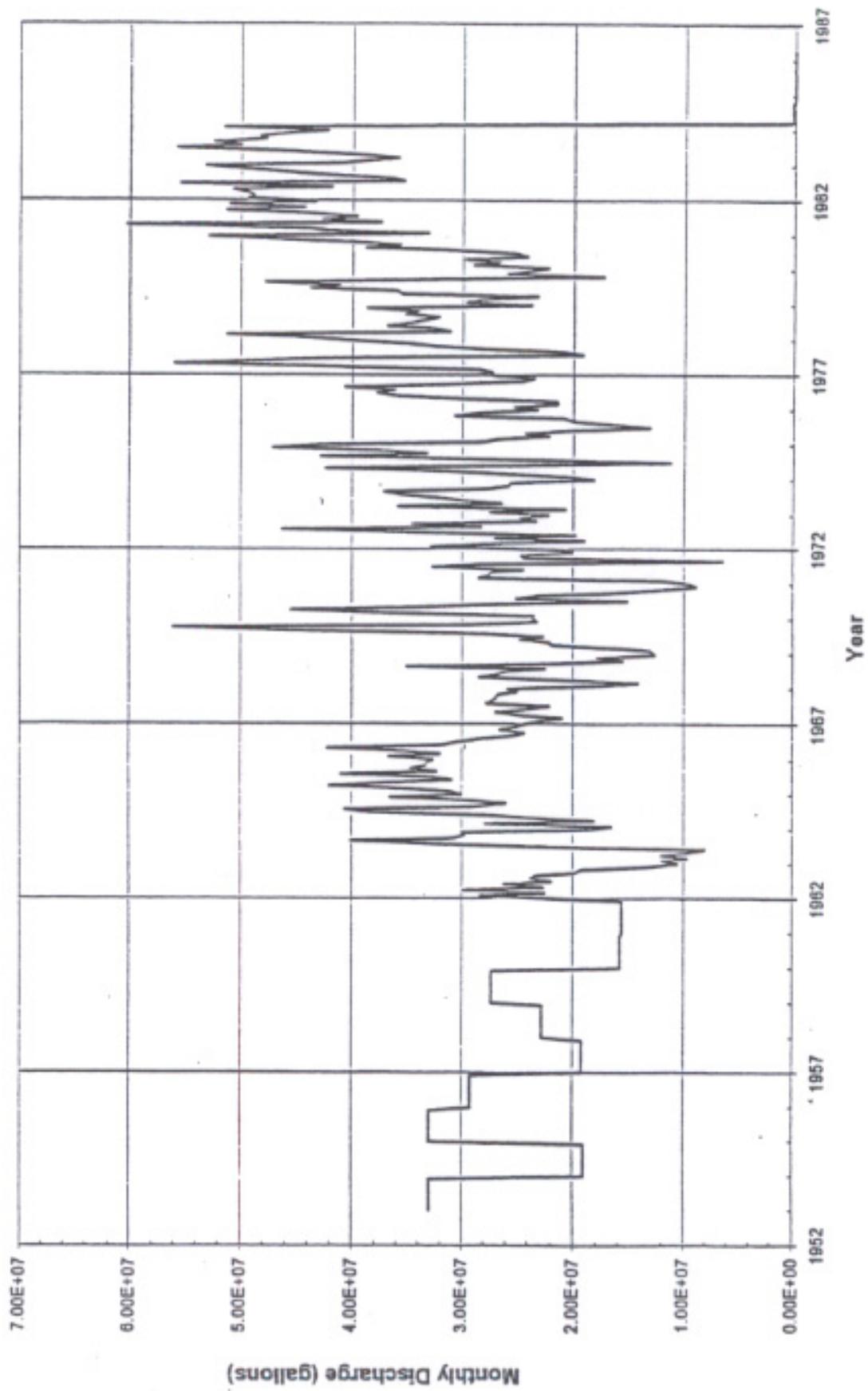


Figure 4-1. Monthly waste water discharge to the ICPP injection well (RWMIS records).

presents the monthly volume of wastewater discharged to the ICPP injection well. The available data for 1953 to 1961 are yearly totals and are plotted by assuming equal volumes discharged every month.

In June 1970, an attempt was made to replace a defective measuring line in the disposal well. It was discovered the well had collapsed and was plugged at a depth of 68.9 m (226 ft). Consequently, waste water was being injected into the unsaturated zone above 68.9 m (226 ft) (WINCO, 1990). The waste water discharged to the disposal well was warm (65° to 70°F) and salty (chloride content averaging approximately 200 to 250 mg/L). The salty, aerated waste water apparently corroded the casing until it collapsed, allowing the gravel pack and intruding sediment to fill the well up to the 68.9-m (226-ft) depth. Only fragmentary corroded pieces of the original 41-cm (16-in.) casing were left as indicated by caliper logs and first attempts at cleaning the well. Measurements made in 1966 showed the well was still intact. Therefore, most of the collapse took place in 1967 or early 1968. Additional evidence supporting this time frame are levels of H-3 and Sr-90 in USGS-50 which occurred in 1969 and 1990 (see Section 4.2.4).

In September 1970, a drilling contractor began to redrill and reline the injection well to its original depth. By October, deepening had progressed to about 152.4 m (500 ft) and the water level in the well had resumed its normal depth at about 138.7 m (455 ft). During this period of well rehabilitation, waste water was disposed to USGS-50. It is assumed during or after these well rehabilitation operations, the well collapsed again and was reopened to the water table in late 1982. At this time, a 2.5-cm (1-in.) thick high-density polyethylene line was placed in the well from ground level to the bottom of the well. The liner was perforated from 137 m (450 ft) bls [approximately 2.4 m (8 ft) above the water table] to the bottom of the well (WINCO Installation Assessment Report, 1986).

On February 7, 1984, the injection well was taken out of routine service and waste water has been pumped from two parallel collection vaults to Percolation Ponds 1 and 2. Disposal of waste water decreased in 1985 and 1986. The injection well also served as an emergency overflow protection for buildings CPP-709, -734, and -797, which contain the vaults from which the service waste water is monitored and pumped. The overflow protection was only required on a temporary basis if the operating and standby pumps from one of the parallel streams failed simultaneously. All the lines have been plugged and can no longer be used to route service waste water overflow from the vaults in the buildings.

In 1986, modifications were made to the injection well entry, which further decreased use of the well resulting in a decrease to approximately 12,200 L (3,220 gal.) to the injection well in 1986. No releases have occurred to the well since 1986.

In October and November 1989, the injection well was sealed by perforating the casing throughout and pumping in cement. The well was sealed from the basalt silt layer [145 m (475 ft) bls] to land surface to prevent hydraulic communication between the land surface, perched water, and SRPA.

4.1.1.1 Waste Disposal. From 1952 to 1984, the injection well was used for the disposal of waste water. According to the RWMIS database, it is estimated a total of 22,200 Ci (approximately 96% consisting of H-3) have been released in 4.2×10^{10} L (1.1×10^{10} gal.) of water. This database provides a qualitative estimate of the activity and volume of waste water discharged to the injection well. Table 4-1 presents a summary of the total curies discharged to the injection well for each radionuclide and includes the curies remaining after radioactive decay. Based on drinking water standards, the major radionuclides of concern

Table 4-1. Activity of radionuclides discharged to the ICPP injection well (RWMIS Database).

Radionuclide	Half Life (years)	Total Activity Injected (Ci)	Total Activity Remaining* (Ci)	Percent of the Injected Activity Remaining (after decay)	Percent of the Current Activity
Ag-110m	6.80E-01	8.36E-05	1.34E-12	0.0	0.00
Am-241	4.32E+02	3.17E-04	3.08E-04	97.2	0.00
Ba-140	3.49E-02	5.05E-04	8.86E-156	0.0	0.00
C-14	5.73E+03	1.27E-01	1.27E-01	99.8	0.00
Ce-141	8.90E-02	1.58E-04	3.19E-61	0.0	0.00
Ce-141/144	7.80E-01	1.16E-01	2.42E-14	0.0	0.00
Ce-144	7.80E-01	1.75E+01	2.07E-06	0.0	0.00
Co-57	7.40E-01	6.54E-03	8.91E-09	0.0	0.00
Co-60	5.27E+00	1.49E-01	8.77E-03	5.9	0.00
Cr-51	7.59E-02	5.37E-03	2.91E-67	0.0	0.00
Ca-134	2.06E+00	1.50E+00	2.03E-03	0.1	0.00
Ca-137	3.02E+01	2.05E+01	1.19E+01	57.8	0.30
Ca-138	6.10E-05	2.50E-01	0.00E+00	0.0	0.00
Eu-152	1.36E+01	8.12E-02	4.36E-02	53.7	0.00
Eu-154	8.80E+00	8.38E-02	2.95E-02	35.2	0.00
Eu-155	4.96E+00	2.22E-02	3.43E-03	15.5	0.00
H-3	1.23E+01	2.13E+04	3.89E+03	18.2	99.44
Hg-203	1.28E-01	7.33E-05	3.10E-42	0.0	0.00
I-129	1.57E+07	2.78E-01	2.78E-01	100.0	0.01
I-130	2.21E-02	2.98E+01	4.38E-152	0.0	0.00
K-40	1.28E+09	2.81E-12	2.81E-12	100.0	0.00
La-140	4.60E-05	6.22E-04	0.00E+00	0.0	0.00
Mn-54	8.30E-01	6.15E-03	7.02E-08	0.0	0.00
Nb-95	9.53E-02	4.63E-01	4.17E-35	0.0	0.00
Np-237	2.14E+06	5.48E-03	5.48E-03	100.0	0.00
Pt-144	3.29E-05	4.47E-01	0.00E+00	0.0	0.00
Po-218	8.78E-01	1.32E-01	1.15E-01	87.1	0.00
Po-219	2.44E+04	1.05E-02	1.04E-02	99.9	0.00
Po-219/240	2.44E+04	3.74E-02	3.74E-02	99.9	0.00
Po-240	6.57E+03	1.14E-03	1.14E-03	99.8	0.00
Rb-106	9.48E-07	4.81E+00	0.00E+00	0.0	0.00
Ra-103	1.10E-01	1.45E-01	4.99E-37	0.0	0.00
Ra-106	1.00E+00	1.70E+01	6.85E-04	0.0	0.00
Sb-124	1.65E-01	2.41E-04	5.02E-36	0.0	0.00
Sb-125	2.77E+00	1.86E+00	1.22E-02	0.7	0.00
Sr-85	1.78E-01	9.14E-05	1.78E-23	0.0	0.00
Sr-89	1.40E-01	5.99E+00	4.51E-27	0.0	0.00
Sr-89/90	2.36E-01	1.31E+00	6.40E-01	48.8	0.02
Sr-90	2.36E+01	1.50E-01	8.75E+00	54.8	0.22
U-234	2.45E+05	2.28E-02	2.28E-02	100.0	0.00
U-235	7.04E+08	1.94E-03	1.94E-03	100.0	0.00
U-236	2.34E+07	4.09E-04	4.09E-04	100.0	0.00
U-238	4.47E+09	6.81E-03	6.81E-03	100.0	0.00
Y-90	7.32E-03	1.32E+00	0.00E+00	0.0	0.00
Zn-65	6.68E-01	4.65E-04	1.39E-11	0.0	0.00
Zr-95	1.78E-01	2.34E-01	2.53E-23	0.0	0.00
Zr/Nb-95	1.78E-01	2.06E+01	1.38E-43	0.0	0.00
Unidentified Alpha	--	6.36E-01	--	--	--
Unidentified Beta-Gamma	--	5.82E+01	--	--	--
Others**		6.33E+02	--	--	--
Total		2.22E+04	3.92E+03	--	196.9

* Decayed to January 1, 1995

** Estimate of radionuclides other than H-3 from 1957 to 1962 (assuming 95.5% of the total curies is H-3, Barnackough (1966))

disposed to the injection well were H-3 and Sr-90 with Cs-137 exhibiting the second highest remaining activity. Figures 4-2 and 4-3 provides plots of the disposal history of H-3 and Sr-90 to the ICPP injection well, respectively. The waste water also contained low concentrations of various chemicals. Since well closure in February 7, 1984, the well was used only for emergencies such as loss of pump power and overflow protection for buildings CPP-709, -734, and -797, which contain vaults from which service waste water was monitored and pumped.

Since the percolation ponds were placed in service, the volumes of service waste effluents transferred to the injection well during emergencies decreased to about 2.96×10^8 L (7.8×10^7 gal.) in 1984, 185,490 L (49,000 gal.) in 1985, and 12,190 L (3,220 gal.) in 1986. Emergency releases to the injection well decreased from 1984 to 1986 because the percolation ponds were placed in service and volumes of service waste effluents transferred to the injection well decreased. No discharges to the injection well occurred after 1986.

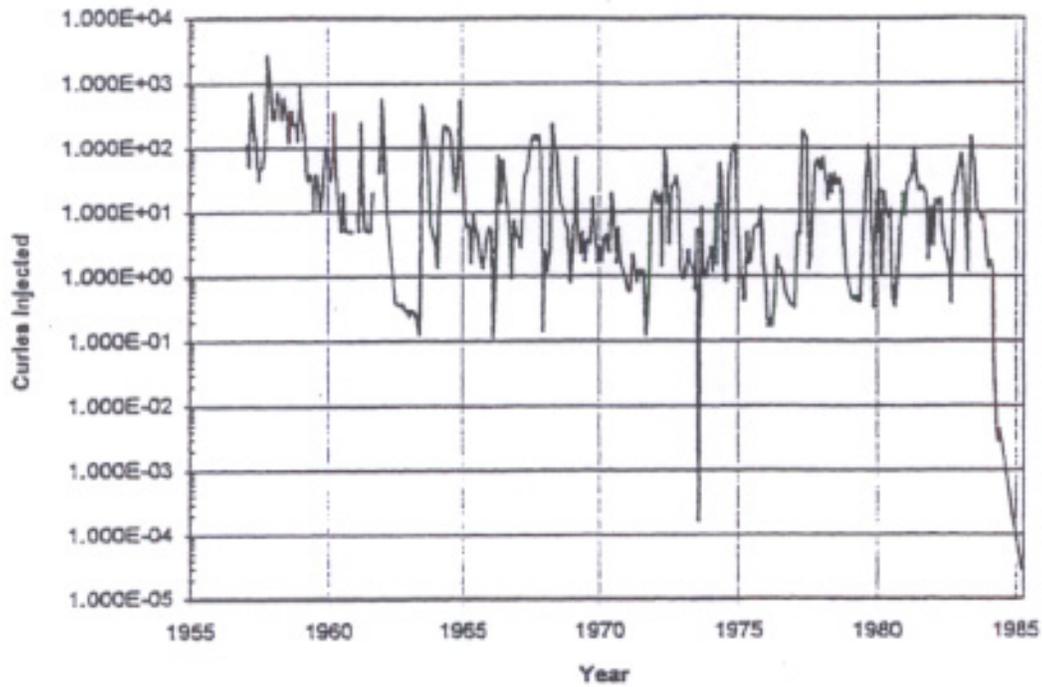
During the ICPP operational life, known accidental discharges to the injection well occurred and are described below (WINCO, 1992).

1. July 1953: The contents of a tank discharged to the waste water flowing to the well. A post discharge analysis showed that 51 mCi of radioactive contaminants were released in 923,640 L (244,000 gal.) of water.
2. December 1958: About 29 Ci of radioactive contaminants, including 7 Ci of Sr-90 were released to the well.
3. September 1969: Two separate releases resulted in 19 Ci of fission products released to the well. Releases included Cs-137, Cs-134, cerium (Ce)-144, and antimony (Sb)-125 in 12.4×10^6 L (3.28×10^6) of waste water.
4. December 1969: Two releases occurred in which the quantity of Sr-90 released was higher than expected. About 1 Ci, including 30% Sr-90 was released.
5. March 1981: mercury was detected during routine monitoring of the ICPP Service Waste System. Mercury in the form of mercuric nitrate was released from CPP-601, through the ICPP Service Waste System to the ICPP injection well. An estimated 0.207 mg/L of mercury was detected in service waste (RCRA EP Toxicity limit for mercury is 0.2 mg/L).

Soluble mercury, as mercuric nitrate, is used as a catalyst in certain ICPP fuel dissolution processes. These operations are the only ones in which significant quantities of soluble mercury have been used at the ICPP. In March 1981, a batch of catalyst was mixed, then found to contain solids. The solution was discarded and it is assumed it was drained to the waste system. Assuming the worst case scenario of draining one batch of catalyst, the maximum catalyst lost would be 250 L (66.0 gal) of solution containing 15 kg of mercury. This is the only contaminant release to the well identified as a RCRA concern.

4.1.1.2 Monitoring. Eight monitoring wells within 0.40 km (0.25 mi) and downgradient of the injection well have been established by the USGS. Although there is typical dispersion of waste plumes laterally and

Monthly Activity of H-3 Discharged into the ICPP Injection Well



Annual Activity of H-3 Discharged into the ICPP Injection Well

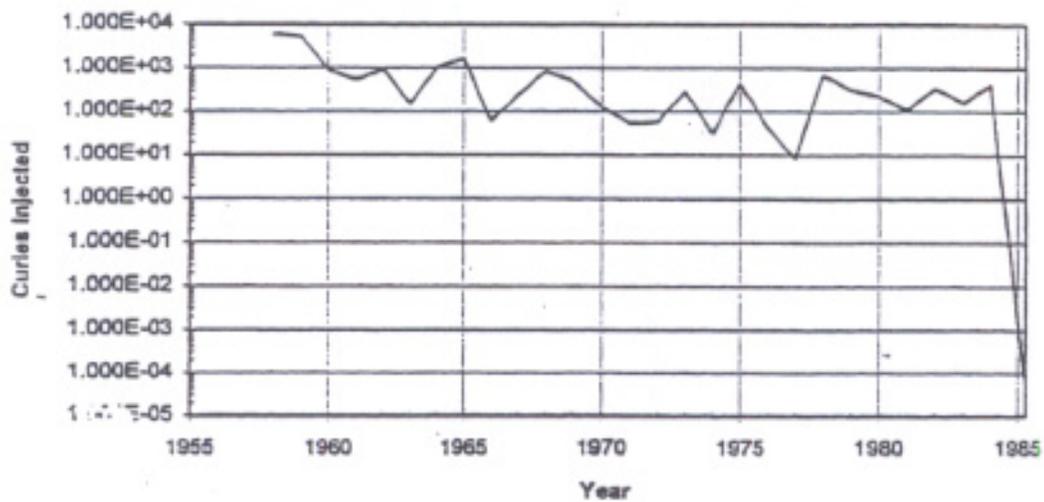
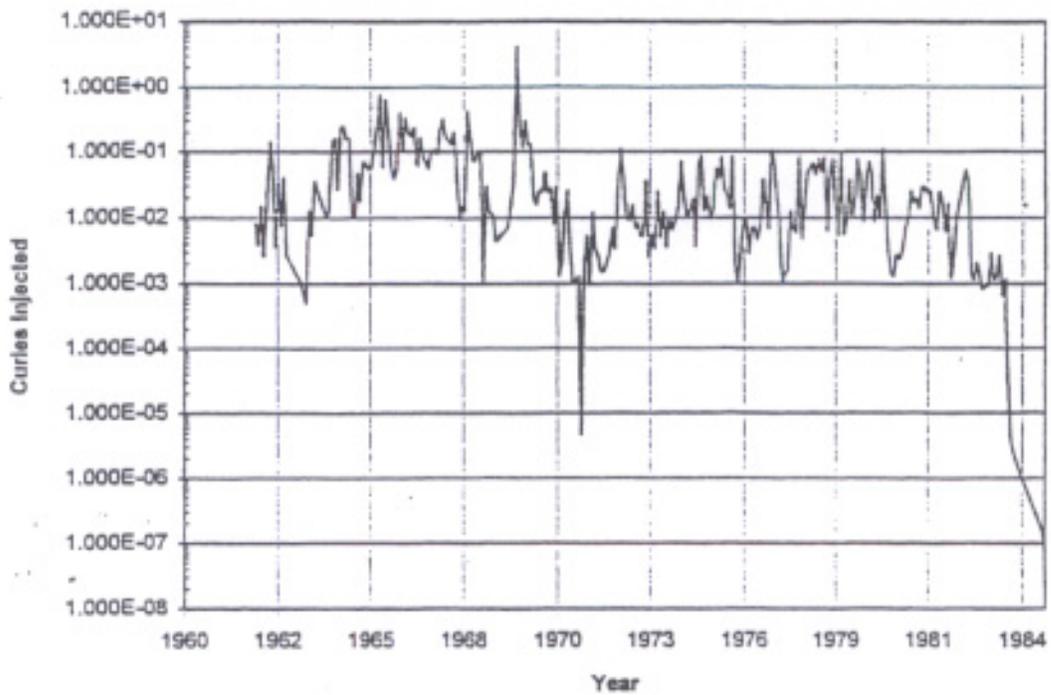


Figure 4-2. Monthly and annual activity of H-3 discharged to the ICPP injection well (RWMIS Records).

Monthly Activity of Sr-90 Discharged into the ICPP Injection Well



Annual Activity of Sr-90 Discharged into the ICPP Injection Well

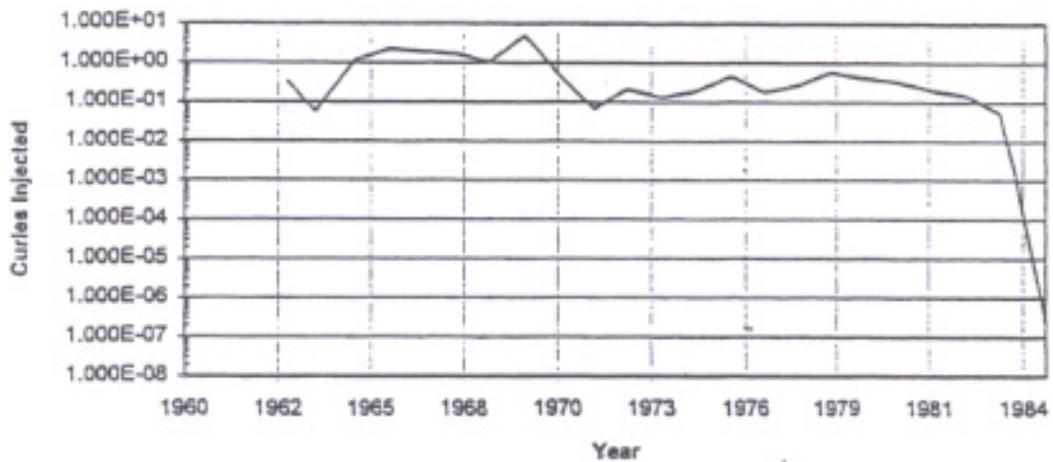


Figure 4-3. Monthly and annual activity of Sr-90 discharged to the ICPP injection well (RWMIS Records).

longitudinally, there appears to be little vertically because of relatively low vertical permeability and apparent lower permeability at depths greater than about 76.2 m (250 ft) below the water table. Analyses of water samples collected from the USGS wells downgradient of the ICPP indicated detectable mercury concentrations (0.2 µg/L) in three USGS wells (36, 37, and 41). Because heavy metal analysis is not conducted by the USGS on a regular frequency, it is not certain if these analyses indicate detectable mercury because of the March 1981 injection well release.

A sample of the sediment within the injection well was collected on August 31, 1989. PCB 1260 (Arochlor) was the only organic compound detected above method detection limit (MDL) in this sediment sample; however, the sample was collected from the top of the sediment column in the injection well and may not be representative of contaminants and concentrations at deeper intervals of the column. Arochlor was detected at a concentration of 10 µg/kg; the minimum detectable limit is 8.3 µg/kg. Downgradient monitoring wells were sampled and PCB was not indicated. Radionuclide analyses of sediments taken from the injection well measured indicate beta activity at 150 pCi/g and three radionuclides: Cs-137 at 100 pCi/g; Eu-152 at 3.8 pCi/g; and Eu-154 at 2.5 pCi/g.

4.1.2 CPP-603 Basins

CPP-603 fuel storage basin has been operational since 1952 and is utilized to store spent fuel assemblies until such time a sufficient amount of fuel was accumulated for a processing run. CPP-603 consists of three reinforced concrete fuel storage basins connected by a transfer channel. The basins are 6.1 m (20 ft) thick and the water inventory is maintained at approximately 5.7M L (1.5M/gal). Based on two studies performed in 1986/87 and 1993 the estimated loss rates from the basins are between 500–700 L/day.

Limited basin water quality data collected by plant operations is available over the period from 1976 to 1996. Water quality parameters analyzed for during this period included pH, chlorides, conductivity, nitrate, and total activity. During this period pH has ranged from 7.2 and 8.3 (1977–1996 data), chlorides 382 mg/L (1977 data) to 35 mg/L (1995 data), conductivity 592.5 to 511 uS/cm (1995–1996 data), and nitrate 682 mg/L (1981 data) to 149 mg/L (1995 data). The total activity for the period 1976 to 1996 has ranged from 0.12 uCi/mL (1976 data) to 3.3 E-05 uCi/mL (1987 data). The major contributor to total activity over this period was Cs-137.

4.1.3 Soil Contamination

Based on the WAG 3 RI/FS Work Plan (INEL-95/0056, Rev. 2), 73 different contaminants have been identified at the ICPP including 13 metals, 25 organic compounds, 32 radionuclides, and 3 other (fluoride, nitrate, and oil and grease) contaminants. Results from the Track 1 and Track 2 investigations indicate that radionuclides are the most significant contaminants at the ICPP. Most if not all field investigations to define the nature of contamination within the soil release areas and groundwater were scoped during the Track 1 and 2 process. Of course, the more recent investigations in 1995 were scoped during the RI Report work plan phase. The sampling programs were designed with the use of process history to the extent that it was available and therefore, the analysis suite was in large part defined by what was known to have been released at a particular site. For example, the soil samples taken within the releases associated with the operation of the HLW tank farm were analyzed for contaminants known to be present in the HLW inside the 11 tanks.

The soil sample results are located in Appendix G and are summarized on a site by site basis in Sections 8 through 26 of this document.

4.2 Perched Groundwater

Perched groundwater zones have been identified to occur in the basalts beneath the ICPP at depths ranging from 30.5 to 42.7 m (100 to 140 ft) bls and 110 to 128 m (360 to 420 ft) bls. Within the upper perched water zone, one perched water body is being monitored beneath the sewage treatment pond, two perched water bodies are being monitored beneath the Tank Farm, one perched water body is being monitored in the vicinity of building CPP-603, and one perched water body is being monitored beneath the percolation ponds. The extent of the lower perched water body(s) is less well defined, being monitored by only three wells in the northern portion of the plant and only one well in the southern portion.

As part of the WAG 3 RI, a complete round of groundwater samples were collected during May and June 1995 from all perched water wells having sufficient water for sample collection. The results from this sampling effort are provided in Table 4-2 and described in the following subsections. The results from previous groundwater sampling efforts have been described in the WAG 3 RI/FS Work Plan (INEL-95/0056, Rev. 2).

4.2.1 Northern Perched Groundwater

Wells that monitor the groundwater quality in the upper perched water zone in the northern ICPP include CPP 33-2, CPP 33-3, CPP 33-4, CPP 37-4, CPP 55-06, MW-2, MW-3, MW-4, MW-5, MW-6, MW-8, MW-10, MW-11, MW-12, MW-18, and MW-20. In addition, well ICPP-Mon-A-024 was installed to monitor the perched water beneath the sewage treatment plan. In addition, well ICPP-Mon-A-024 was installed to monitor the perched water beneath the sewage treatment plant. During the WAG 3 RI, sufficient water was available for the collection of groundwater samples for analysis in all wells except MW-3, MW-8, MW-11, MW-12, and in the 113.5 to 123.5-ft completion zone of MW-18.

4.2.1.1 Chemical Contaminants. The only chemical constituent in the upper perched groundwater zone that was detected above either a Federal primary or secondary maximum contaminant level (MCL) was nitrate. Nitrate/nitrite was detected above the Federal primary MCL of 10 mg/L in wells CPP 33-4, CPP 37-4, CPP 55-06, MW-2, MW-4, MW-5, MW-10, and MW-20 (Figure 4-4). The highest nitrate/nitrite concentrations (35.4 mg/L in well CPP 55-06 and 26.8 mg/L in well MW-10) were measured in the southeastern portion of the perched groundwater body. As shown in Figure 4-4, Nitrate/nitrite concentrations decrease toward the northeastern portion of the perched water body.

4.2.1.2 Radionuclides. The distribution of radionuclide contamination in the upper perched water zones is illustrated by plots of gross alpha and gross beta concentrations (Figures 4-5 and 4-6, respectively). These plots indicate the highest radioactive contamination occurs within the southeastern portion of the perched water body, particularly associated with wells MW-2, MW-5, and CPP 55-06. The maximum gross alpha and gross beta activity measured in the upper perched groundwater were $1,140 \pm 220$ pCi/L and $589,000 \pm 2,600$ pCi/L, respectively, in well MW-2. At a depth of approximately 42 m (140 ft), the maximum gross alpha and gross beta concentrations measured in the perched groundwater were 137 ± 9 pCi/L and $65,300 \pm 600$ pCi/L in wells MW-10 and MW-20.

Table 4-2. Water quality results from the perched water wells (May-June 1995).

Well	MW-17 May-95 190.18 to 195.2 3122101	MW-17 May-95 364.8 to 381 3122201	MW-18 June-95 487.0 to 414 3122301	MW-20 June-95 177.33 to 144.4 3122401	UNCG-30 May-95 384-405 3122501	MW-5 Oct-95 START 3122601	MW-5 Oct-95 END 31227101	MW-5 MIDDLE 3122801	MW-5 MIDDLE 3122901	UNCG-10 Duplicate 384-405 3123001	CP7 31-4 Duplicate 102.85 to 118.2 3123401
Field Parameters											
Total Solids	17.85	19.96	18.4	15.48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total Hardness	7.77	9.60	8.81	7.72	N/A	N/A	N/A	N/A	N/A	N/A	N/A
pH	8.84	8.615	8.53	8.747	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Metals, Inorganics											
Aluminum	137	61.2	143	284	129	ND	ND	ND	ND	170	216
Boron	132	33.9	143	284	129	ND	ND	ND	ND	190	216
Calcium	21.5	78.6	78.6	28.3	2 U	ND	ND	ND	ND	2 U	2 U
Chloride	0.3	0.28	0.31	0.36	0.36	ND	ND	ND	ND	0.3	0.3
Fluoride	28.1	33.5	35.6	49.3	44.8	ND	ND	ND	ND	4.5	6.1
Sulfate	0.1	0.22	0.11	0.13	0.11	ND	ND	ND	ND	0.1 U	0.1 U
TICN	0.1	0.1	0.1	0.1	0.1	ND	ND	ND	ND	0.1 U	0.1 U
NOSANOS2-N	4.9	4.6	34.4	15.1	31.3	ND	ND	ND	ND	31.2	12.7
Trace Metals											
Antimony	68.9 BU	26.8 U	69.7 BU	26.8 U	26.8 U	ND	ND	ND	ND	26.8 U	26.8 U
Asbestos	1.9 U	4 U	1.9 U	4 U	1.9 U	ND	ND	ND	ND	1.9 U	4 U
Barium	4 U	4 U	4 U	4 U	4 U	ND	ND	ND	ND	4 U	4 U
Beryllium	72.1 B	196 B	84.8 B	194 B	167 B	ND	ND	ND	ND	105 BU	284
Cadmium	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	ND	ND	ND	ND	0.1 U	0.1 U
Cobalt	0.4 U	0.4 U	0.3 U	0.4 U	0.4 U	ND	ND	ND	ND	0.4 U	0.4 U
Chromium	40000	22100	49100	87900	73300	ND	ND	ND	ND	47100	100000
Copper	4.1 U	4.1 U	11.1	4.2 B	4.2 B	ND	ND	ND	ND	4.1 U	4.1 U
Iron	179	149 B	32 U	21 B	24.8 B	ND	ND	ND	ND	12 B	63.2 B
Lead	2 U	2 U	2 U	2 U	2 U	ND	ND	ND	ND	2 U	2 U
Magnesium	18400	9250	18900	23400	20000	ND	ND	ND	ND	18400	27000
Manganese	31.7	6.8 U	1.3 BU	6.8 U	1.8 B	ND	ND	ND	ND	2.2 B	0.8 U
Mercury	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	ND	ND	ND	ND	0.1 U	0.1 U
Nickel	2.4 U	2.4 U	2.4 U	2.4 U	2.4 U	ND	ND	ND	ND	2.4 U	2.4 U
Selenium	51.8 BU	34.2 BU	80.2 BU	37.7 BU	37.7 BU	ND	ND	ND	ND	37.9 BU	3918 BU
Silver	3.2 BU	3.2 BU	3.2 BU	3.2 BU	3.2 BU	ND	ND	ND	ND	3.2 BU	3.2 BU
Sodium	8.6 MCU	8.6 U	1.4 B	8.6 U	8.6 U	ND	ND	ND	ND	8.6 U	8.6 MCU
Sulfur	33300	75400	73200	47200	62200	ND	ND	ND	ND	33000	30300
Thallium	4.6 U	4.6 U	3.2 U	4.6 U	4.6 U	ND	ND	ND	ND	4.6 U	4.6 U
Vanadium	1.3 BU	6.7 B	3.4 BU	3.3 BU	4.3 B	ND	ND	ND	ND	6 B	1.1 BU
Zinc	3.4 BU	4.2 BU	27.1 BU	12.6 BU	10.8 BU	ND	ND	ND	ND	10.8 BU	13.7 B
Zirconium	ND	31.2 U	ND	31.2 U	31.2 U	ND	ND	ND	ND	31.2 U	ND
Radionuclides											
Chloride	2.34	841.1 U	3.241.7 U	16419 U	8341.7 U	ND	ND	ND	ND	2.6e-8 U	8.462.6
Chromium	1141	4562	7667	63700e000	4562	ND	ND	ND	ND	47157	47157
Thoron	25700e000	23100e000	72000e000	11500e000	61900e000	ND	ND	ND	ND	9715443	9715443
Strontium	1.641.4 U	6.7462.4 U	39752	23900e000	13142	104000e000	104000e000	104000e000	104000e000	17343	17343
Polonium-210	ND	ND	ND	644.12 U	ND	ND	ND	ND	ND	6.06e07 U	6.06e07 U
Polonium-214	ND	ND	ND	0.07e008 U	ND	ND	ND	ND	ND	0.07e008 U	0.07e008 U
Radon-222	ND	ND	ND	0.00e004 U	ND	ND	ND	ND	ND	0.00e004 U	0.00e004 U
Radon-220	ND	ND	ND	0.00e004 U	ND	ND	ND	ND	ND	0.00e004 U	0.00e004 U
Radon-226	ND	ND	ND	0.00e004 U	ND	ND	ND	ND	ND	0.00e004 U	0.00e004 U
Radon-228	ND	ND	ND	0.00e004 U	ND	ND	ND	ND	ND	0.00e004 U	0.00e004 U
Radon-230	ND	ND	ND	0.00e004 U	ND	ND	ND	ND	ND	0.00e004 U	0.00e004 U
Radon-232	ND	ND	ND	0.00e004 U	ND	ND	ND	ND	ND	0.00e004 U	0.00e004 U
Radon-234	ND	ND	ND	0.00e004 U	ND	ND	ND	ND	ND	0.00e004 U	0.00e004 U
Radon-235	ND	ND	ND	0.00e004 U	ND	ND	ND	ND	ND	0.00e004 U	0.00e004 U
Radon-238	ND	ND	ND	0.00e004 U	ND	ND	ND	ND	ND	0.00e004 U	0.00e004 U

NA = not analyzed
 ND = not detected
 BU = below useful
 U = uncertain
 B = concentration in associated blank
 R = concentration reported in remarks
 J = estimated concentration

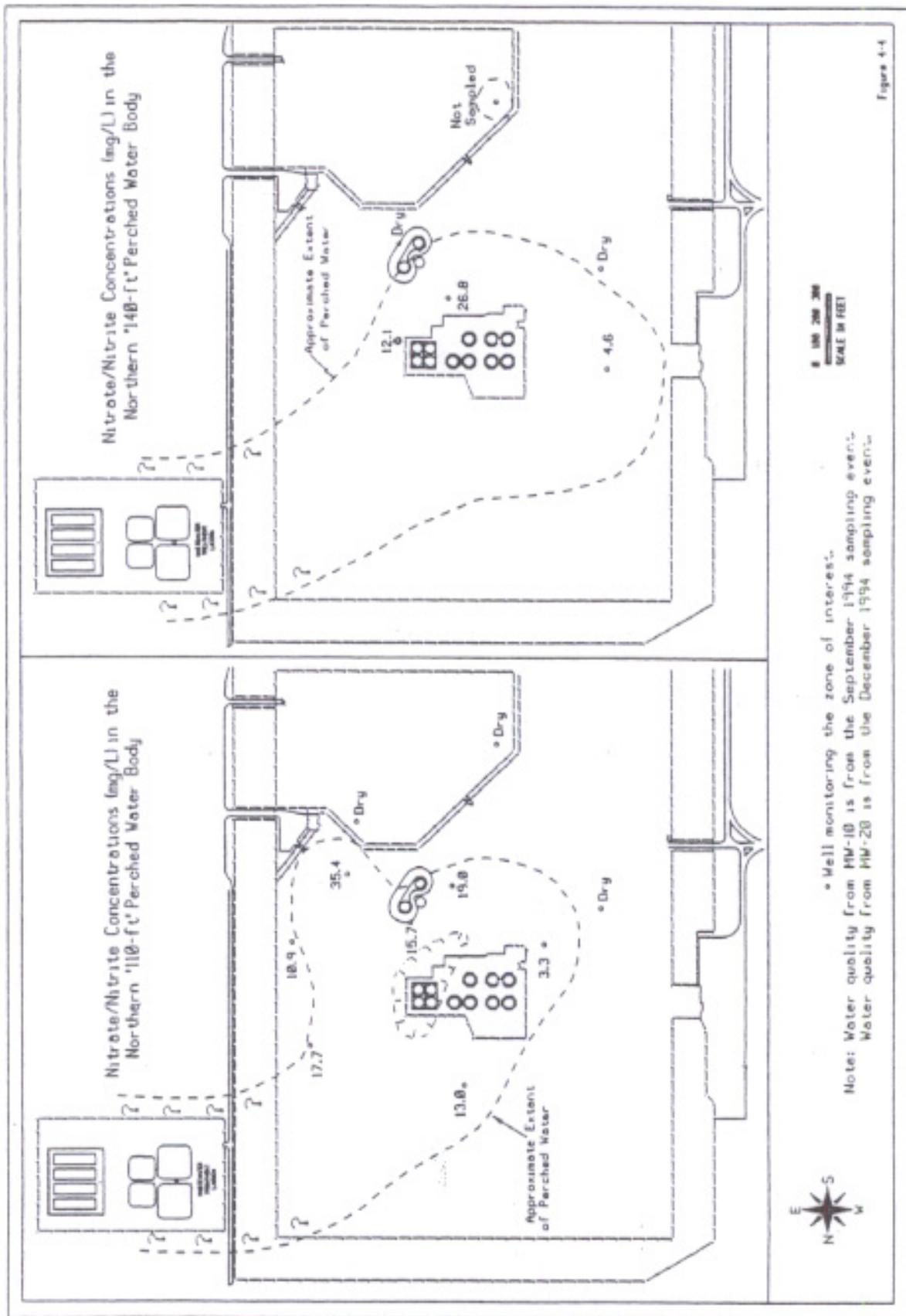


Figure 4-4. Nitrate/Nitrite concentrations in the upper perched water body (May-June 1995).

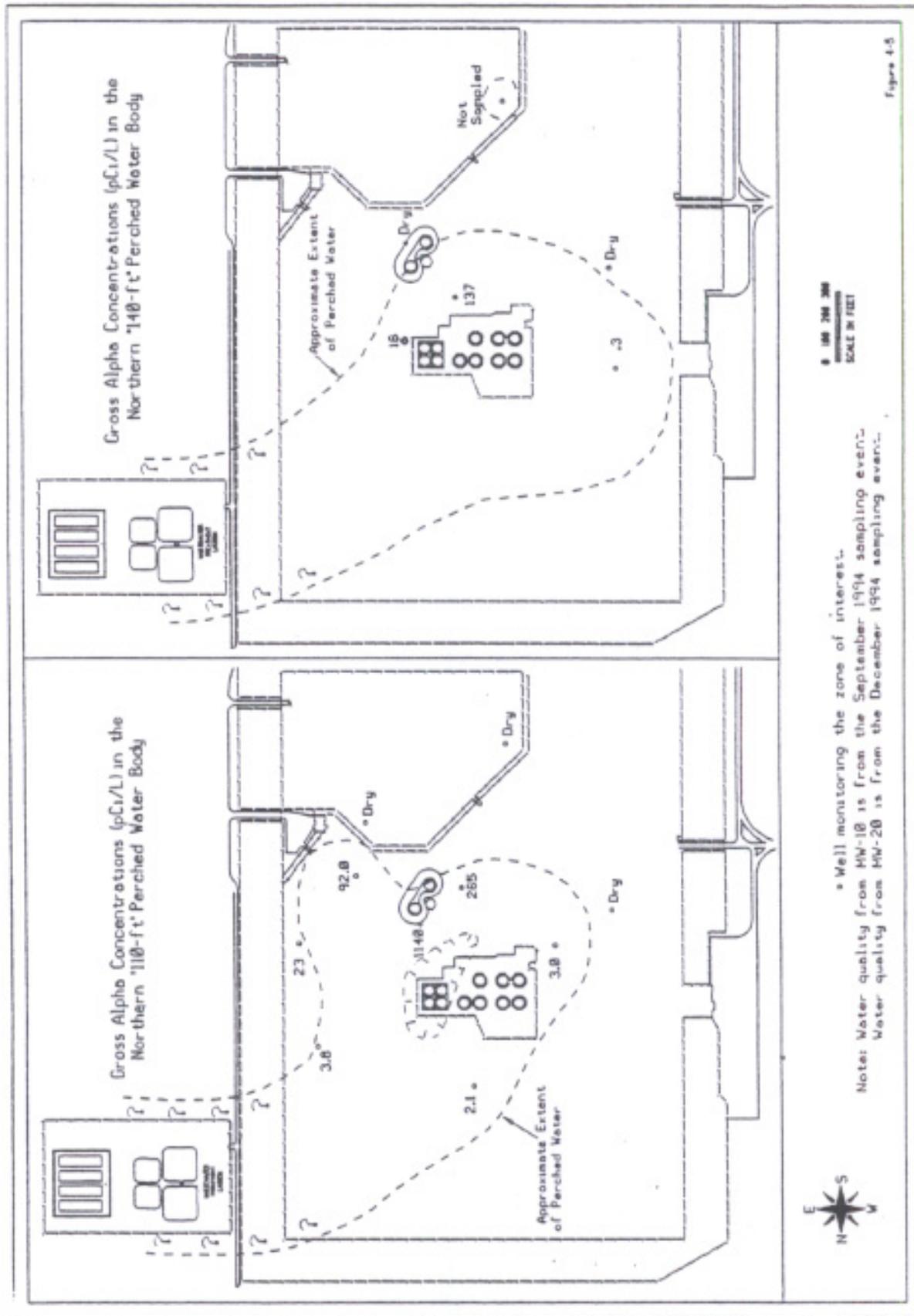


Figure 4-5. Gross alpha activities in the upper perched groundwater (May-June 1995).

The most significant radionuclides in the upper perched water body are Sr-90 and Tc-99. Low levels of H-3 were also detected in the upper perched water zone, however, none of the water samples exceeded the Federal primary MCL of 20,000 pCi/L. The low H-3 concentrations in the upper perched water zone significantly contrast the waste stream that was directed to the ICPP disposal well where the vast majority of the associated radioactivity consisted of H-3.

Radioactivity from fission products is due almost equally from Sr-90 and two Cs isotopes (Cs-134 and Cs-137) with minor contributions from several other intermediate term radionuclides. Cesium isotopes have not been detected in the groundwater, probably as a result of the high sorption capacity of Cs, which makes it relatively immobile in the environment. Strontium-90 was detected in all wells completed in the upper perched water zone with the distribution shown in Figure 4-7. The maximum Sr-90 concentration detected in the upper perched water zone was $320,000 \pm 3,000$ pCi/L (well MW-2) followed by $104,000 \pm 1,000$ pCi/L (well MW-5) and $66,300 \pm 600$ pCi/L (well CPP 55-06).

The only other fission product detected in the upper perched groundwater is Tc-99. This radionuclide has been detected in all wells except CPP 33-4 and MW-6 with the distribution provided in Figure 4-8. The maximum Tc-99 concentration detected in the upper perched groundwater zone was 105 ± 2 pCi/L in well MW-5.

Two wells (MW-10 and MW-20) are completed in water-bearing zones at depths of approximately 42 m (140 ft). The maximum concentrations for H-3, Sr-90, and Tc-99 from these wells are $38,000 \pm 50$ pCi/L, $25,800 \pm 30$ pCi/L, and 127 ± 2 pCi/L, respectively. A comparison of the water quality from the wells completed in the upper perched groundwater body [i.e., at approximately 33 m (110 ft)] to this deeper zone indicates an increase in both H-3 and Tc-99 concentrations and a decrease in the Sr-90 concentrations.

4.2.2 Southern Perched Groundwater

Two perched water bodies have been identified in the southern ICPP. A small perched water body has been identified in the vicinity of building CPP-603 and a larger perched water body has developed from the discharge of waste water to the percolation ponds.

Wells that monitor the groundwater quality in the upper perched groundwater zone around CPP-603 include MW-7, MW-9, MW-13, MW-14, MW-15, MW-16, and MW-17. Of these seven wells, wells MW-7, MW-9, MW-15, and MW-17 have historically had sufficient water for sample collection. During the WAG 3 RI, sufficient water was only available in wells MW-15 and MW-17.

Water samples were collected from wells MW-15 and MW-17 and analyzed for miscellaneous inorganics, target analyte list (TAL) inorganics, and radionuclides. From the inorganic analysis, only nitrate/nitrite was detected at a concentration exceeding either a Federal primary or secondary MCL. The nitrate/nitrite concentration in well MW-15 was 14.7 mg/L, compared to the Federal primary MCL of 10 mg/L. The nitrate/nitrite concentration in well MW-17 was 4.9 mg/L.

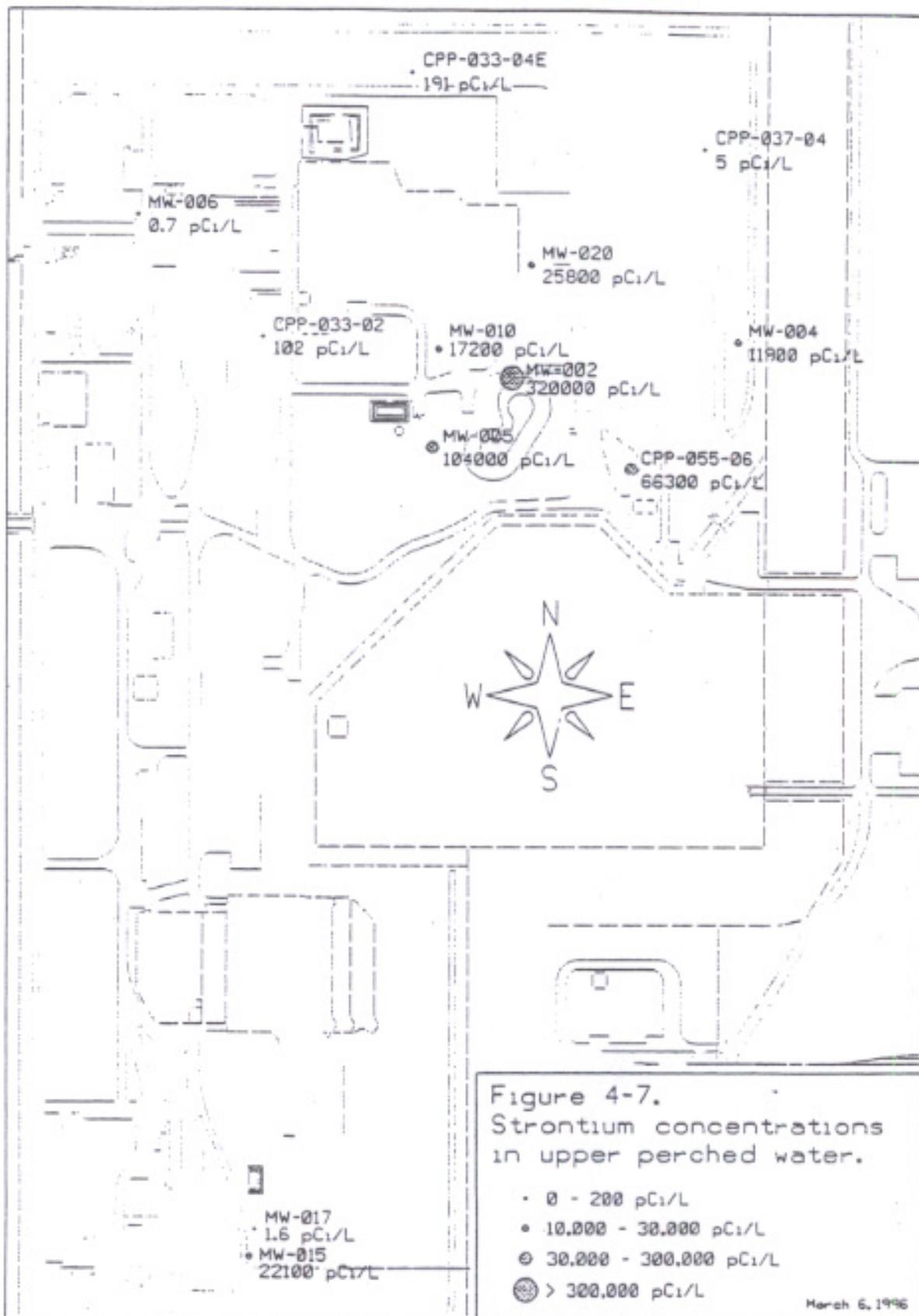


Figure 4-7. Sr-90 concentrations in the upper perched groundwater (May-June 1995).

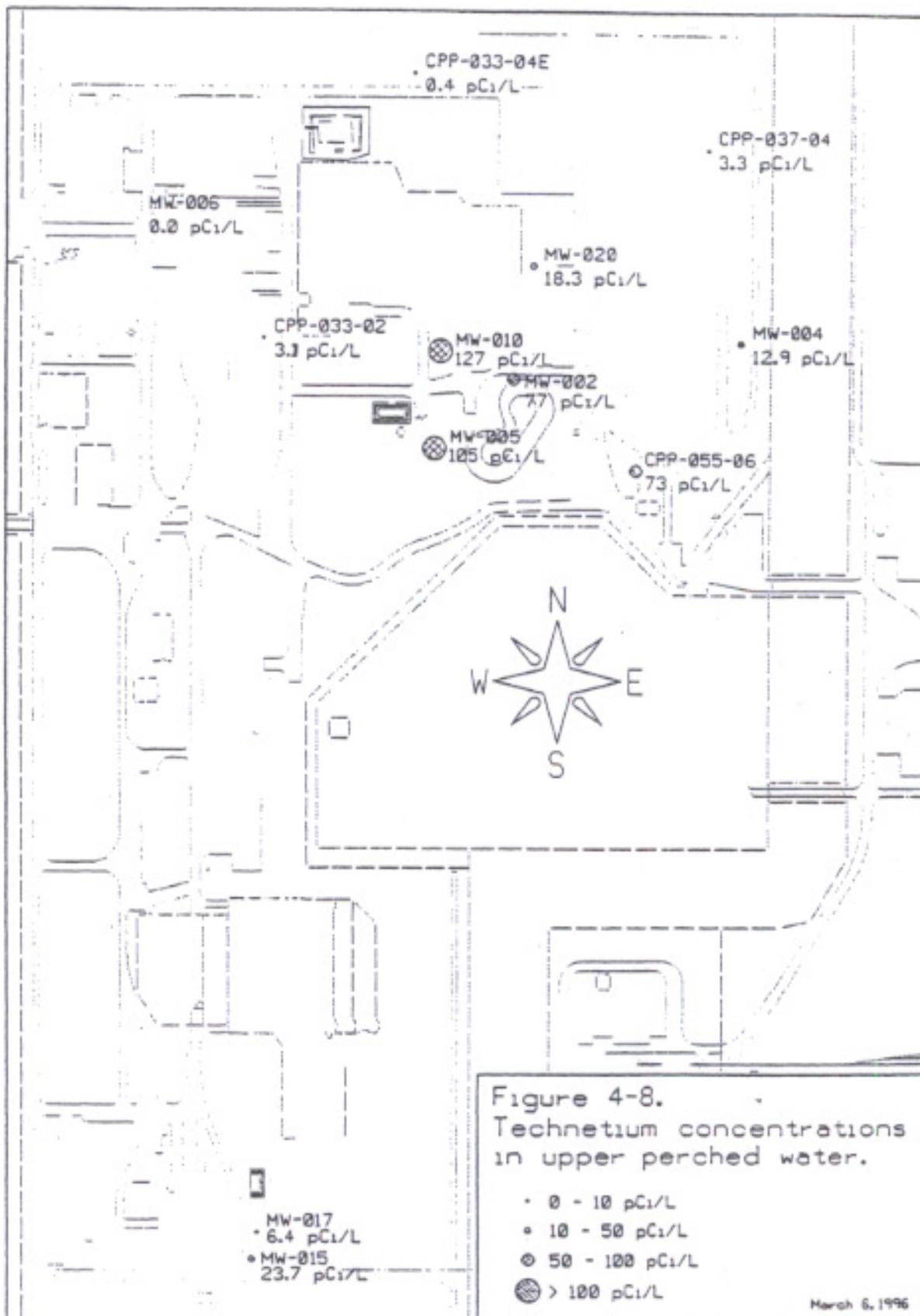


Figure 4-8. Tc-99 concentrations in the upper perched groundwater (May-June 1995).

The radionuclides detected in the groundwater from both wells include H-3 ($3,360 \pm 176$ to $25,700 \pm 400$ pCi/L) and Tc-99 (6.4 ± 0.6 to 23.7 ± 0.6 pCi/L). In addition, Sr-90 and U-234 were detected in MW-15 at concentrations of $17,200 \pm 200$ pCi/L and 11.8 ± 1 pCi/L, respectively.

4.2.3 Percolation Pond Perched Groundwater

Six wells, designated as PW-1 through PW-6, were installed in 1986 to monitor the upper-most perched groundwater body associated with waste water discharge to the percolation ponds. These wells have been monitored by the USGS since 1987. Wells PW-1, PW-2, PW-4, and PW-5 have been sampled on a quarterly basis as part of the ICPP groundwater monitoring program since 1991 (INEL-95/0056, Rev. 2). They were not sampled however, as part of the OU 3-13 RI.

Since the waste stream to the percolation ponds is virtually the same as the waste stream formerly sent to the disposal well (with somewhat better contaminant removal than in the past), the contamination in these wells should not differ significantly from that observed downgradient from the disposal well. As would be expected, most of the historical radioactivity present in the PW-series wells is from H-3, with Sr-90 providing a secondary activity contribution. According to the USGS monitoring, activities from both H-3 and Sr-90 have remained relatively stable with the exception of an increased H-3 activity period in mid-1988 (Figure 4-9).

According to the results from the ICPP groundwater monitoring program, the constituents detected in the upper perched water zone that exceeded either a Federal primary or secondary MCL include chloride, nitrate, manganese, iron, and Sr-90. Chloride concentrations generally exceeded the Federal secondary MCL of 250 mg/L in all wells. Nitrate concentrations exceeded the Federal primary MCL of 10 mg/L in a single sample collected from well PW-4 (14.11 mg/L from the October 1993 sample). Manganese concentrations exceeded the Federal secondary MCL of 50 μ g/L in two samples collected from well PW-2 (165 μ g/L from the October 1991 sample and 60.2 μ g/L from the August 1993 sample). Iron concentrations exceeded the Federal secondary MCL of 300 μ g/L in one sample collected from PW-1 (324 μ g/L from the April 1993 sample) and the first three samples collected from PW-2 (i.e., prior to September 1992). Strontium-90 concentrations exceeded the Federal primary MCL of 8 pCi/L in samples collected from PW-1, PW-4, and PW-5 with the maximum concentration measured during October 1991 sampling event at PW-1 (15.7 pCi/L).

4.2.4 Deep Perched Groundwater

Four wells at the ICPP monitor deeper perched groundwater zones. These wells include MW-1, MW-17, MW-18, and USGS-50 that are completed in water-bearing zones occurring at depths between 99.4 to 102.4 m (326 to 336 ft), 109.7 to 116.1 m (360 to 381 ft), 120.1 to 126.2 m (394 to 414 ft), and 109.7 to 123.4 m (360 to 405 ft), respectively. Historically, two rounds of groundwater samples have been collected from MW-1, one round of groundwater samples have been collected from MW-17 and MW-18, and a substantial database concerning radioactive contaminants is available for the water quality from USGS-50. Results from these water sampling events are described in the WAG 3 RI/FS Work Plan (INEL-95/0056, Rev. 2).

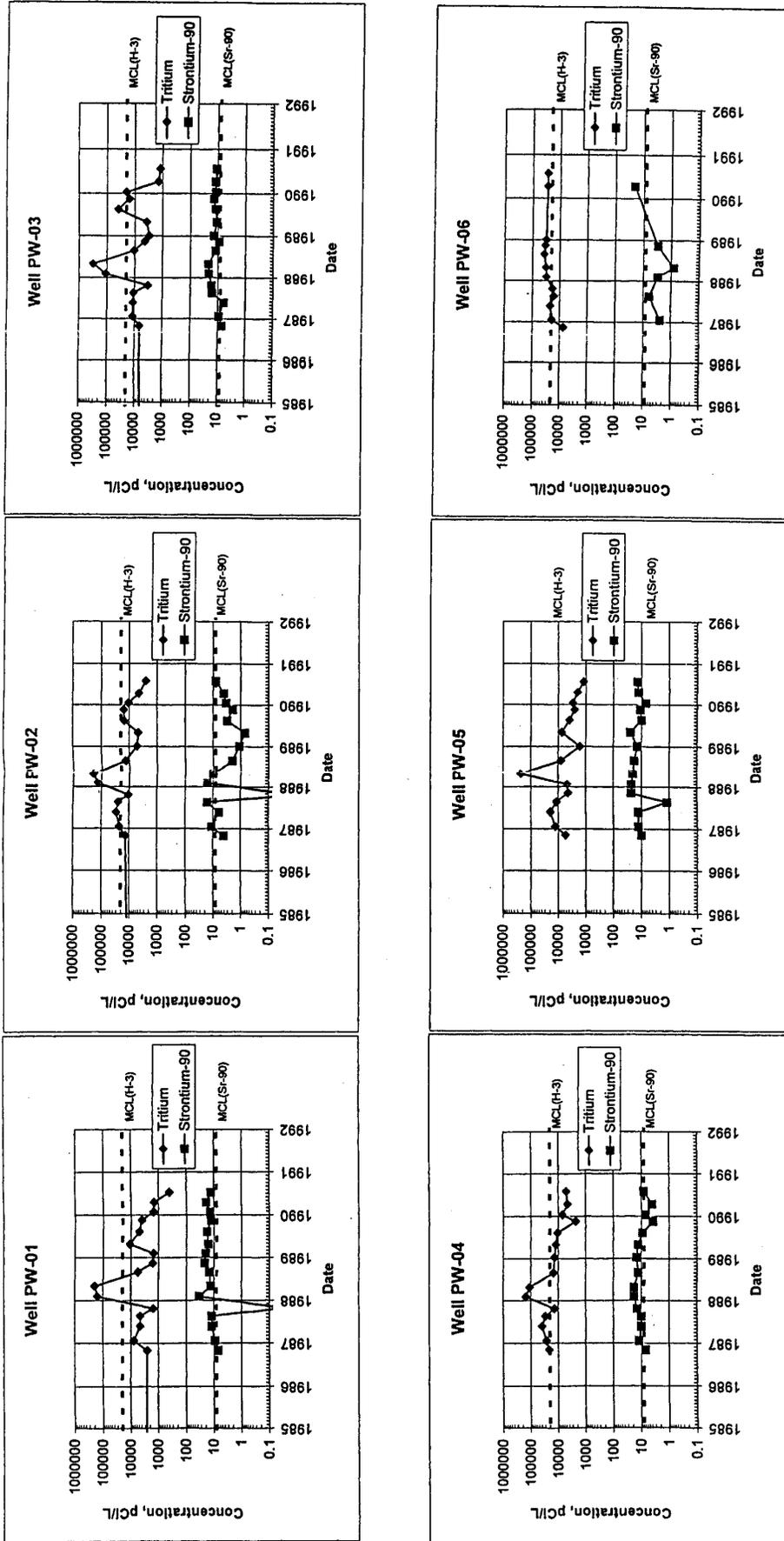


Figure 4-9. Historical H-3 and Sr-90 concentrations in the PW-series wells (USGS records).

Well MW-1 is located in the northern ICPP along the southwestern edge of the deeper perched water body. The only chemical contaminant to exceed either a Federal primary or secondary MCL was nitrate/nitrite. Nitrate/nitrite was detected above the Federal primary MCL of 10 mg/L at a concentration of 69.6 mg/L. The radionuclides detected in water samples from well MW-1 include Sr-90 (4.5 ± 0.4 pCi/L) and H-3 ($24,700 \pm 400$ pCi/L). Of these contaminants, only H-3 was measured above the Federal primary MCL of 20,000 pCi/L. Since H-3 concentrations in the deep perched water zone are higher than the H-3 concentrations in the overlying perched water bodies, the source of this contamination is either from a historical release where the contaminants have moved through the system or waste water disposal to the ICPP injection well.

Well MW-18 is completed in the deeper perched water zone near the eastern boundary of the ICPP. From the June 1995 sampling event, only nitrate/nitrite concentration at 34.4 mg/L exceeded either a Federal primary or secondary MCL. The radionuclides detected in the deep perched groundwater at this location include H-3 ($73,000 \pm 700$ pCi/L), Sr-90 (207 ± 2 pCi/L), and Tc-99 (736 ± 6 pCi/L). The H-3 and Tc-99 concentrations from this well are some of the highest concentrations measured in the perched groundwater beneath the ICPP.

USGS-50 was originally intended to be completed in the aquifer, but was ultimately drilled to a total depth of 123 m (405 ft) to monitor a deep perched water zone. This well is located in the north central portion of the facility, to the south of the northern perched water zone and upgradient from the former ICPP disposal well. According to the historical water quality, the highest concentrations of H-3 and Sr-90 occurred in 1969 and 1970 (Figure 4-10). These elevated concentrations were attributed to the failure of the ICPP disposal well where the waste water was injected into the vadose zone rather than directly to the aquifer. The relationship between the ICPP disposal well discharge and the water level and H-3 concentrations in well USGS-50 is shown in Figure 4-11. Based on the response observed in well USGS-50 and the ICPP disposal well records, it appears the well failed in mid-1967 and allowed approximately 3.41×10^9 L (9.0×10^8 gal.) of waste water to be injected into the basalt above the 69-m (226-ft) plug (Robertson et al., 1974). The ICPP disposal well was repaired by early 1971. It again failed in the 1970s and was repaired in 1982.

Since 1970, H-3 and Sr-90 concentrations have varied little between sampling events, indicating an overall slight decrease with time. Two periods of slight increase are noted with the first period occurring from the late 1970s until 1982 and the second period from late 1986 to early 1988. The first period of increase (from approximately 1978 to 1982) was probably the result of the ICPP disposal well failing and injecting waste water directly into the vadose zone. It is uncertain exactly when the ICPP disposal well failed the second time, however, it was reportedly repaired by 1982. The second period of increase, from late 1986 to early 1988, is after the ICPP disposal well was taken out of service. The increase in Sr-90 concentrations during this period suggests either (1) a local, post-disposal well source or (2) a delay in the migration of contamination from a near surface source. It should also be noted water from overlying perched water has been observed leaking into the wellbore through the annular space. This mixing of water from two perched water zones places additional uncertainty on the representativeness of the water quality from USGS-50. The leaky borehole annulus was repaired during the FY-94 field season.

From the May 1995 water sampling of USGS-50, the concentrations of all chemical contaminants except nitrate/nitrite were below Federal primary or secondary MCLs. Nitrate/nitrite concentration was measured at 31.3 mg/L, compared to the Federal primary MCL of 10 mg/L. Radionuclides in the

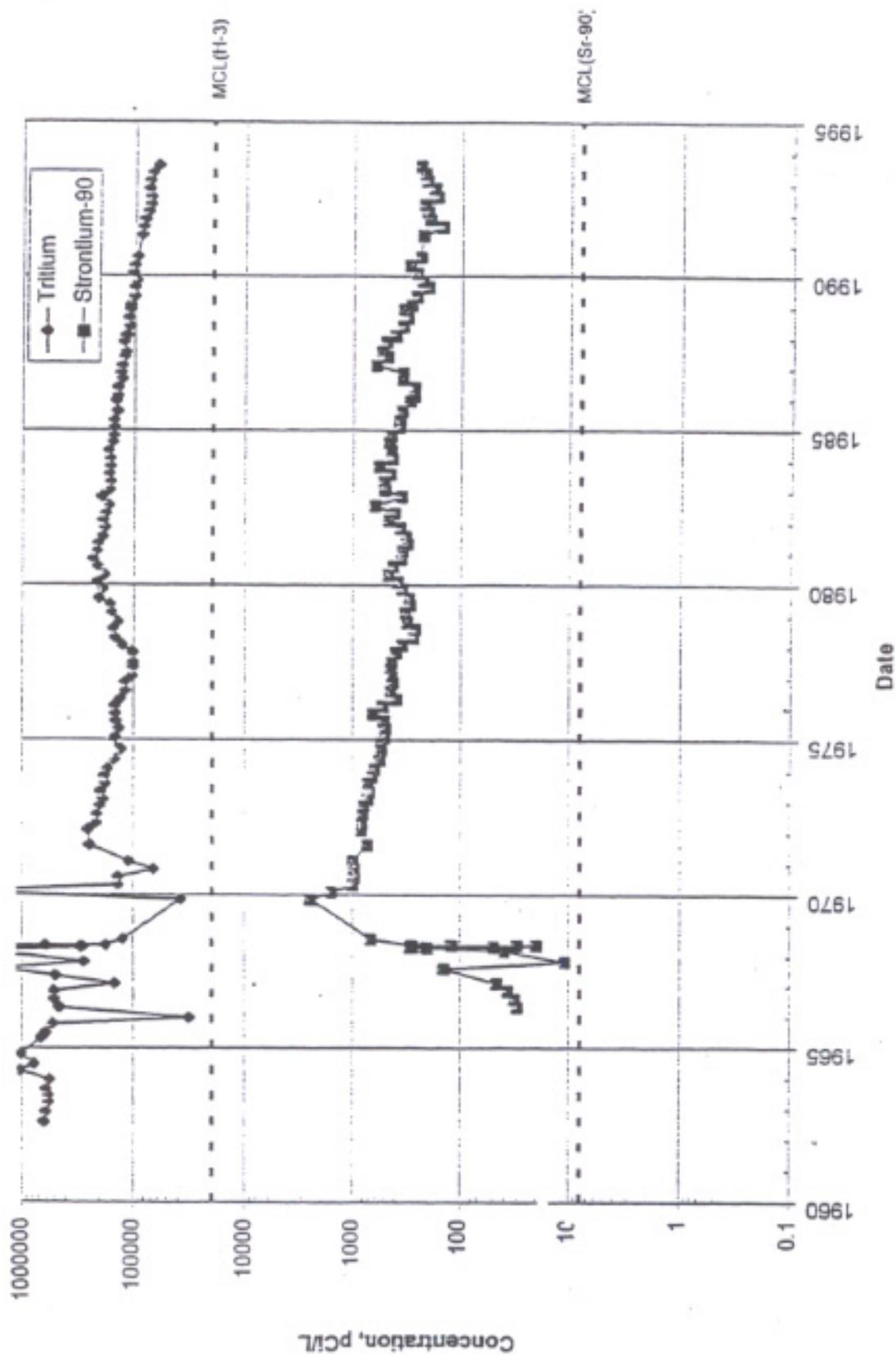


Figure 4-10. Historical H-3 and Sr-90 concentrations in well USGS-50 (USGS records).

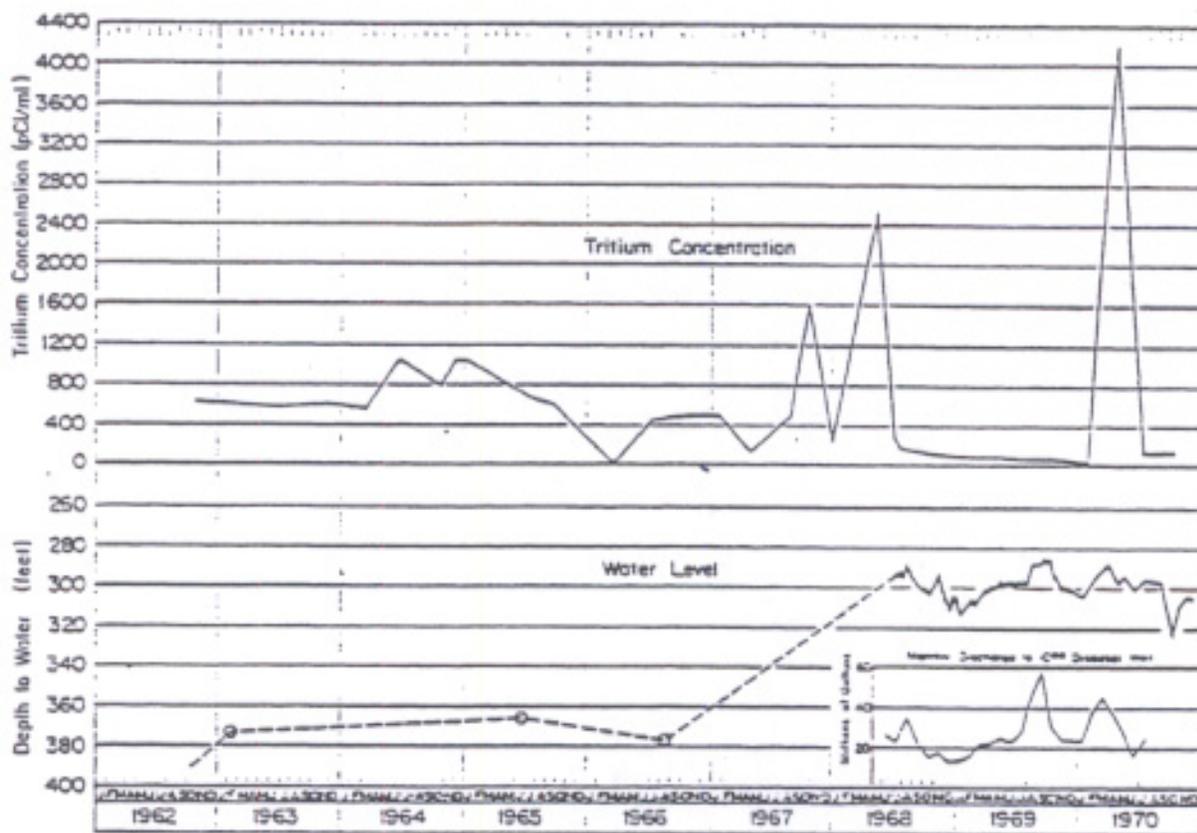


Figure 4-11. Relationship between discharge to the ICPP injection well and water level and H-3 concentrations in USGS-50 (Robertson et al., 1974).

groundwater that were detected include H-3 ($61,900 \pm 700$ pCi/L), Sr-90 (151 ± 2 pCi/L), and Tc-99 (63 ± 1 pCi/L). The concentrations for H-3 and Sr-90 are within the expected values based on the historical sampling conducted by the USGS.

Well MW-17 is the only deep perched water monitoring well located in the southern portion of the ICPP. This well has been constructed to monitor three perched water bodies: an upper zone from 55.4 to 58.4 m (181.7 to 191.7 ft) bls, a middle zone from 80.4 to 83.5 m (263.8 to 273.8 ft) bls, and a lower zone from 110 to 116 m (360 to 381 ft) bls. During the May 1995 sampling event, water was only present in the upper and lower zones. None of the chemical constituents detected in the groundwater exceeded either a Federal primary or secondary MCL. Only two radionuclides (H-3 and Tc-99) were detected in groundwater samples collected from MW-17. The concentrations of these two radionuclides were similar between the upper and lower perched water zones. H-3 concentrations varied from $25,100 \pm 400$ to $25,700 \pm 400$ pCi/L and Tc-99 concentrations varied from 5.9 ± 0.6 to 6.4 ± 0.6 pCi/L.

4.2.5 Sedimentary Interbed Results

Twelve perched water wells were drilled and installed in 1993 and 1994 during the perched water investigation at the ICPP. Sedimentary interbed samples were collected and analyzed. The results of this analysis are summarized in Table 4-3. A review of the data indicates a large presence of gross beta activity at the MW-2 location, most of which is due to Sr-90. This confirms that Sr-90 has migrated to the 110 ft interbed from a number of possible sources that include the release areas within the tank farm or possibly from the old calcine bin storage located next to MW-2.

4.3 Snake River Plain Aquifer

The water quality in the SRPA at and downgradient from the ICPP has been adversely impacted due to past facility operations, primarily related to the disposal of wastes through the ICPP injection well. This well was the primary source for waste disposal from 1952 through February 1984 and used intermittently for emergency situations until 1986. It has been estimated a total of 22,000 Ci of radioactive contaminants have been released in 4.2×10^{10} L (1.1×10^{10} gal.) of water (WINCO, 1994). The vast majority of radioactivity is being attributed to H-3 (approximately 96%) with minor components of Am-241, Tc-99, Sr-90, Cs-137, Co-60, iodine (I)-129, and Pu. During the last 2 yrs of operation (1984 to 1986) when it was only used for emergency situations, the injection well discharged 0.002 Ci in 15.2×10^6 L (4×10^6 gal.) of water. A discussion of the waste discharge to the ICPP injection well is provided in Section 4.1.1.

Since the 1950's, the USGS has installed 33 monitoring wells around the ICPP to characterize the occurrence, movement, and quality of the water in the SRPA. The radioactive and chemical character of the water in the SRPA is determined from analyses of water samples collected as part of a comprehensive sampling program to identify contaminant concentrations and define the pattern of waste migration in the aquifer (Orr and Cecil, 1991). This sampling program has been in place since the early 1960s and provides an excellent database to evaluate the impact of facility operations on the SRPA. The location of the wells completed in the SRPA and the frequency of groundwater sample collection by the USGS are provided in Figure 4-12.

Table 4-3. Summary of radiological results from sedimentary interbed samples at the ICPP (pCi/g).

Sample Number	Well	Depth(ft)	Gross Alpha	Gross Beta	Am-241	Ce-144	Co-60	Cs-134	Cs-137	Eu-154	Eu-155
3PG10101BG	MW-1	231-232.5	13 ± 3	23 ± 2	ND	ND	ND	ND	ND	ND	ND
3PG10201BG	MW-1	375-378.1	13 ± 3	26 ± 3	ND	ND	ND	ND	ND	ND	ND
3PG10501BG	MW-2	111.6-112	140 ± 10	76000 ± 100	.09 ± .07	ND	ND	ND	ND	ND	ND
3PG10301BG	MW-2	94.2-94.5	26 ± 4	4300 ± 20	.06 ± .06	ND	ND	ND	ND	ND	ND
3PG10401BG	MW-2	109-110.5	520 ± 15	74000 ± 100	.06 ± .06	ND	ND	ND	ND	ND	ND
3PG10701BG	MW-3	118-118.3	15 ± 3	27 ± 3	ND	ND	ND	ND	ND	ND	ND
3PG10801BG	MW-3	138-139	16 ± 3	28 ± 3	ND	ND	ND	ND	ND	ND	ND
3PG11001BG	MW-4	106.8-108	16 ± 3	75 ± 3	ND	ND	ND	ND	ND	ND	ND
3PG11301BG	MW-5	119.5-120	8.1 ± 2.4	520 ± 5	ND	ND	ND	ND	ND	ND	ND
3PG11601BG	MW-6	106.2-106.8	8 ± 2.4	15 ± 2	ND	ND	ND	ND	ND	ND	ND
3PG11701BG	MW-6	141-141.5	19 ± 3	30 ± 3	0 ± .02	ND	ND	ND	ND	ND	ND
3PG11901BG	MW-7	103.6-104	9.5 ± 2.4	25 ± 2	ND	ND	ND	ND	ND	ND	ND
3PG12201BG	MW-8	123.7-124	17 ± 3	36 ± 3	0 ± .02	ND	ND	ND	ND	ND	ND
3PG12601BG	MW-9	145.6-148.4	11 ± 3	23 ± 3	0 ± .02	ND	ND	ND	ND	ND	ND
3PG12501BG	MW-9	105.8-106.1	24 ± 4	1390 ± 10	ND	ND	ND	ND	ND	ND	ND
3PG12801BG	MW-10	109-109.5	18 ± 3	87 ± 3	ND	ND	ND	ND	ND	ND	ND
3PG12901BG	MW-10	154.0-154.3	12 ± 3	75 ± 3	ND	ND	ND	ND	ND	ND	2 ± .05
3PG13101BG	MW-11	113.7-115.3	18 ± 3	25 ± 3	.11 ± .05	ND	ND	ND	ND	ND	ND
3PG13201BG	MW-11	134.135.4	13 ± 3	22 ± 2	ND	ND	ND	ND	ND	ND	ND
3PG13301BG	MW-12	117.8-118.1	9.5 ± 2.4	61 ± 3	ND	ND	ND	ND	ND	ND	ND
3PG13401BG	MW-12	152.0-152.5	20 ± 3	28 ± 3	.08 ± .03	ND	ND	ND	ND	ND	.21 ± .05
3131101E9	MW-17	208-210.5	14 ± 4	14 ± 2	.03 ± .03	ND	ND	ND	ND	ND	ND
3131010E9	MW-18	196-196.5	9.4 ± 1.7	544 ± 6	ND	ND	ND	ND	ND	ND	ND
3131020E9	MW-18	397.6-398	12 ± 2	23 ± 2	ND	ND	ND	ND	ND	ND	ND
3131160E9	MW-18	397.6-398	11 ± 2	27 ± 2	ND	ND	ND	ND	ND	ND	ND
3131030E9	MW-18	420.75-421	17 ± 2	33 ± 2	ND	ND	ND	ND	ND	ND	ND
3131150E9	MW-20	108	29 ± 5	30 ± 3	.03 ± .03	ND	ND	ND	ND	ND	ND

ND - Not Detected.

Table 4-3. (continued).

Sample Number	Well	Depth(ft)	Nb-95	Pu-238	Pu-239/240	Ru-103	Ru-106	Sb-125	Sr-90	U-234	U-235	U-238
3PG10101BG	MW-1	231-232.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
3PG10201BG	MW-1	375-378.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
3PG10501BG	MW-2	111.6-112	ND	0 ± 0.03	0 ± 0.04	ND	ND	ND	40400 ± 10	1 ± 0.10	0 ± 0.10	9 ± 0.10
3PG10301BG	MW-2	94.2-94.5	ND	0 ± 0.03	0 ± 0.05	ND	ND	ND	38900 ± 10	9 ± 0.10	0 ± 0.10	9 ± 0.10
3PG10401BG	MW-2	109-110.5	ND	0 ± 0.03	.04 ± 0.06	ND	ND	ND	2390 ± 3	.8 ± 0.10	0 ± 0.10	.8 ± 0.10
3PG10701BG	MW-3	118-118.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
3PG10801BG	MW-3	138-139	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
3PG11001BG	MW-4	106.8-108	ND	ND	ND	ND	ND	ND	32.8 ± .50	ND	ND	ND
3PG11301BG	MW-5	119.5-120	ND	ND	ND	ND	ND	ND	321 ± 2	ND	ND	ND
3PG11601BG	MW-6	106.2-106.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
3PG11701BG	MW-6	141-141.5	ND	0 ± 0.02	0 ± 0.03	ND	ND	ND	3.7 ± .5	9 ± 0.10	0 ± 0.10	9 ± 0.10
3PG11901BG	MW-7	103.6-104	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
3PG12201BG	MW-8	123.7-124	ND	0 ± 0.02	0 ± 0.03	ND	ND	ND	4 ± .20	1.1 ± 0.10	0 ± 0.10	1.1 ± 0.10
3PG12601BG	MW-9	145.6-148.4	ND	0 ± 0.02	0 ± 0.02	ND	ND	ND	819 ± 2	1.3 ± 0.10	0 ± 0.10	1.4 ± 0.10
3PG12501BG	MW-9	105.8-106.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
3PG12801BG	MW-10	109-109.5	ND	ND	ND	ND	ND	ND	32.2 ± .50	ND	ND	ND
3PG12901BG	MW-10	154.0-154.3	ND	ND	ND	ND	ND	ND	24.5 ± .70	ND	ND	ND
3PG13101BG	MW-11	113.7-115.3	ND	0 ± 0.02	.03 ± 0.04	ND	ND	ND	ND	1 ± 0.10	0 ± 0.10	1.1 ± 0.10
3PG13201BG	MW-11	134.135.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
3PG13301BG	MW-12	117.8-118.1	ND	ND	ND	ND	ND	ND	29 ± 1.00	ND	ND	ND
3PG13401BG	MW-12	152.0-152.5	ND	0 ± 0.01	0 ± 0.02	ND	ND	ND	ND	1.6 ± 0.10	.06 ± 0.05	1.4 ± 0.10
3131101E9	MW-17	208-210.5	ND	.01 ± 0.02	0 ± 0.02	ND	ND	ND	0 ± .20	.67 ± .06	.01 ± .05	.68 ± .06
3131010E9	MW-18	196-196.5	ND	ND	ND	ND	ND	ND	321 ± 200	ND	ND	ND
3131020E9	MW-18	397.6-398	ND	ND	ND	ND	ND	ND	.6 ± .20	ND	ND	ND
31311601E9	MW-18	397.6-398	ND	ND	ND	ND	ND	ND	.3 ± .10	ND	ND	ND
31310301E9	MW-18	420.75-421	ND	ND	ND	ND	ND	ND	.3 ± .20	ND	ND	ND
31311501E9	MW-20	108	ND	0 ± 0.01	0 ± 0.02	ND	ND	ND	0 ± .40	.74 ± .07	.02 ± 0.05	.74 ± .07

ND = Not Detected.

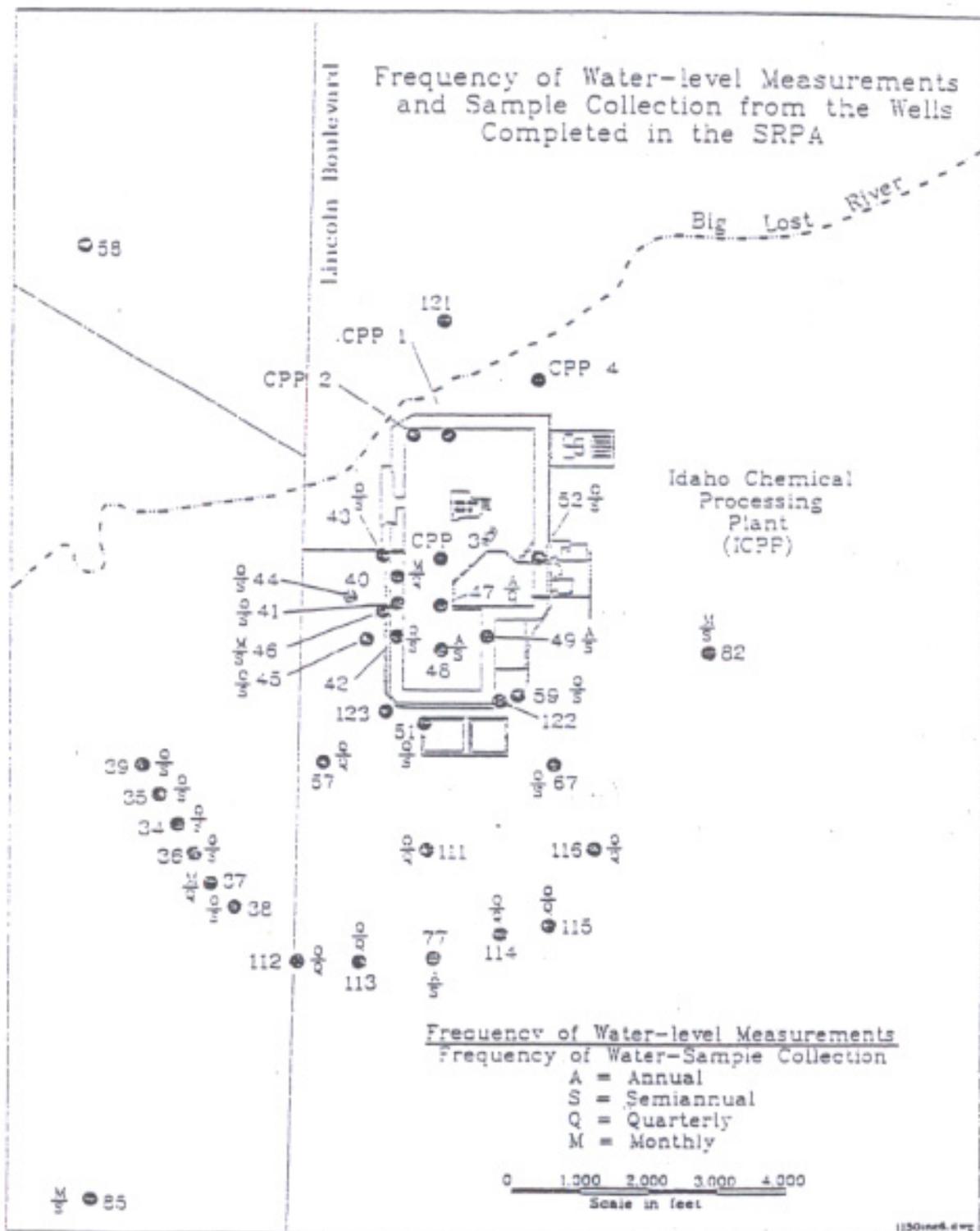


Figure 4-12. Locations of wells completed in the SRPA.

According to the latest USGS report describing SRPA water quality (Bartholomay, 1997), detectable concentrations of H-3, Sr-90, Co-60, Cs-137, Pu-238, Pu-239/-240 (undivided), and americium (Am)-241 from samples taken from wells in the SRPA at INEEL decreased or remained constant during 1992-1995. Decreased concentrations are attributed to reduced rates of radioactive-waste disposal, sorption processes, radioactive decay, and changes in waste disposal practices. Chemical constituents detected in SRPA at the INEEL include total chromium, sodium, chloride, and nitrate. Purgeable organic compounds were detected in samples from wells at the INEEL. This report provides information concerning the distribution of chemical and radionuclide constituents in the SRPA and covers the period from 1992 to 1995. Of the 14 purgeable organic compounds detected at the INEEL, only 1,1,1-trichloroethane was detected in the vicinity of the ICPP at concentrations well below the federal drinking water standard (MCL) of 200 $\mu\text{g/L}$.

The ICPP has a groundwater sampling program of selected SRPA wells to satisfy the groundwater monitoring requirements for the RCRA and DOE Order 5400.1. This sampling program, implemented in October 1991, uses selected USGS wells and collects samples on a quarterly basis to be analyzed for the RCRA groundwater contamination parameters, RCRA drinking water parameters, RCRA groundwater quality parameters, and selected radionuclides. The results from this sampling program are provided in the WAG 3 RI/FS Work Plan (INEL-95/0056, Rev. 2). Also, wells ICPP-Mon-A-021 and -022 were installed to monitor the SRPA water quality beneath the sewage treatment plant.

In May and June 1995, a complete round of groundwater samples were collected from the aquifer wells located near and downgradient from the ICPP (see Figure 4-12). The results from this sampling effort are provided in Table 4-4, and described in the following subsections.

4.3.1 Contaminant Distribution

4.3.1.1 Cesium-137. According to Bartholomay (1997), Cs-137 has been detected above reporting levels through 1985 in wells USGS-40 and USGS-47 at the ICPP due to liquid-waste discharge to the ICPP injection well. During 1982 to 1985, maximum concentrations in wells USGS-40 and USGS-47 were 237 ± 45 and 200 ± 50 pCi/L, respectively. During 1986 to 1988, Cs-137 was not detected in these wells (Orr and Cecil, 1991). Since 1988, cesium-137 was detected in one sample from well USGS-40 (70 ± 30 pCi/L on January 15, 1990) and one sample from well USGS-47 (70 ± 30 pCi/L on April 29, 1992). Cs-137 was not detected in any of the aquifer wells sampled during the WAG 3 RI. The half-life for Cs-137 is 30.17 yrs.

4.3.1.2 Plutonium. Monitoring the quantities of Pu-238 and Pu-239/-240 (undivided) discharged to the ICPP disposal well began in 1974. Prior to that time, alpha activity from plutonium disintegration was not separable from the monitored, undifferentiated alpha activity. During 1974 through 1985, about 0.15 Ci of Pu-238 and 0.05 Ci of Pu-239/-240 (undivided) were discharged to the ICPP injection well. During the period from 1986 to 1988, approximately 0.06 Ci of plutonium isotopes were discharged to the infiltration ponds at the ICPP. The half-lives of Pu-238, -239, and -240 are 87.7, 24 100, and 6,560 years, respectively.

According to Orr and Cecil (1991), plutonium has been detected in the SRPA near the ICPP in wells USGS-40 and USGS-47. Both of these wells are located near the ICPP injection well. In well USGS-40, Pu-238 and Pu-239/-240 (undivided) were last detected in January 1987 at concentrations of 0.47 ± 0.16 pCi/L and 5.5 ± 0.4 pCi/L, respectively. In well USGS-47, Pu-238 was last detected in October 1983 at a concentration of 0.5 ± 0.06 pCi/L. Since the 1986 to 1988 period reported by Orr and Cecil (1991),

Table 4-4. Water quality from the wells completed in the SRPA (May-June 1995).

Well		MW-18	USGS 34	USGS 35	USGS 36
Date		Jun-95	May-95	May-95	May-95
Sample Depth		464.19 to 479	477.33 to 700	477.76 to 580.5	477.48 to 567.1
Sample ID	Units	31330101	31330201	31330301	31330401
Field Parameters					
Temperature	(celsius)	13.2	12.31	12.08	12.75
pH		7.88	7.67	7.73	7.81
Conductivity	(micromen)	0.73	0.468	0.454	0.486
TAL Inorganics					
Aluminum	(ug/L)	26.8 U	49.9 BU	53.4 BU	26.8 U
Antimony	(ug/L)	1.9 U	42.2 U	42.2 U	1.9 U
Arsenic	(ug/L)	4 U	1.8 U	1.8 U	4 U
Barium	(ug/L)	122 B	95.1 B	98.1 B	109 B
Beryllium	(ug/L)	0.1 U	0.1 U	0.1 U	0.1 U
Cadmium	(ug/L)	0.4 U	2.9 U	2.9 U	0.4 U
Calcium	(ug/L)	62300	57000	57400	57200
Chromium	(ug/L)	4.1 U	21.6	29.2	13.5
Cobalt	(ug/L)	0.5 U	4.9 U	4.9 U	0.5 U
Copper	(ug/L)	2.8 B	7.1 U	7.1 U	2 BU
Iron	(ug/L)	21.5 U	7.1 U	20.3 B	21.5 U
Lead	(ug/L)	2 U	2.3 BWJ	1.5 UW	2 U
Magnesium	(ug/L)	18700	14300	14900	14700
Manganese	(ug/L)	2 B	1.2 U	1.2 U	0.8 U
Mercury	(ug/L)	0.1 U	0.1 U	0.1 U	0.1 U
Nickel	(ug/L)	3.4 U	12.4 U	12.4 U	3.4 U
Potassium	(ug/L)	4650 B	2640 B	3110 B	2770 BEJ
Selenium	(ug/L)	2.7 U	1.2 U	1.2 U	2.7 U
Silver	(ug/L)	0.6 U	5.2 BNR	6.5 BNR	0.6 UN
Sodium	(ug/L)	30800	10100	9950	16600
Thallium	(ug/L)	4.6 U	2.3 UW	2.3 UW	4.6 U
Vanadium	(ug/L)	3.2 B	6.9 B	4 U	3.7 BU
Zinc	(ug/L)	14.2 BU	2.6 B	3.5 B	2 BEUJ
Zirconium	(ug/L)	31.2 U	31.3 U	31.3 U	31.3 U
Radionuclides					
Gross Alpha	(pCi/L)	10±2	2±1.2 U	2.4±1.2	4.4±1.4
Gross Beta	(pCi/L)	469±6	13±1	14±1	32±2
Tritium	(pCi/L)	26400±400	4530±217	6630±250	6560±240
Sr-90	(pCi/L)	84±1	2.4±0.3	2.6±0.3	9±0.5
Pu-238	(pCi/L)	0±0.07 U	ND	ND	ND
Pu-239/240	(pCi/L)	0.03±0.05 U	ND	ND	ND
Am-241	(pCi/L)	0.05±0.07 U	ND	ND	ND
Np-237	(pCi/L)	3.1±0.3 U	ND	ND	ND
I-129	(pCi/L)	0±0.3 U	0±0.3 U	0±0.3 U	0±0.3 U
Tc-99	(pCi/L)	448±4 J	0.9±0.6 U	0.9±0.8 U	4.1±0.5
U-234	(pCi/L)	0.7±0.3	ND	ND	ND
U-235	(pCi/L)	0±0.2 U	ND	ND	ND
U-238	(pCi/L)	0.9±0.3	ND	ND	ND

NA - not analyzed.

ND - not detected.

NS - not sampled.

U - analyzed, not detected.

B - contaminant in blank.

R - concentration is unusable.

J - estimated concentration.

Table 4-4. (continued).

Well		USGS 37	USGS 38	USGS 39	USGS 40
Date		May-95	May-95	May-95	May-95
Sample Depth		477.61 to 573	478.03 to 729	479.16 to 573.9	463.58 to 679
Sample ID	Units	31330501	31330601	31330701	31330801
Field Parameters					
Temperature	(celsius)	13.46	14.41	12.1	14.31
pH		7.76	7.69	7.73	7.46
Conductivity	(micromen)	0.751	0.737	0.436	0.524
TAL Inorganics					
Aluminum	(ug/L)	26.8 U	26.8 U	42.9 U	26.8 U
Antimony	(ug/L)	1.9 U	1.9 U	42.2 U	1.9 U
Arsenic	(ug/L)	4 U	4 U	1.8 U	4 U
Barium	(ug/L)	170 B	197 B	104 B	98.3 B
Beryllium	(ug/L)	0.1 U	0.1 U	0.1 U	0.1 U
Cadmium	(ug/L)	0.4 U	0.4 U	3 B	0.4 U
Calcium	(ug/L)	71200	66900	58000	62100
Chromium	(ug/L)	7.1 B	5.6 B	38.8	5.3 B
Cobalt	(ug/L)	0.5 U	0.5 U	4.9 U	0.5 U
Copper	(ug/L)	1.3 U	1.3 U	7.1 U	1.3 U
Iron	(ug/L)	21.5 U	21.5 U	9.4 B	21.5 U
Lead	(ug/L)	3.9 B	2 U	1.5 UW	2 U
Magnesium	(ug/L)	18900	18300	15700	17000
Manganese	(ug/L)	0.8 U	0.84 B	1.4 BU	0.8 U
Mercury	(ug/L)	0.1 U	0.1 U	0.1 U	0.1 U
Nickel	(ug/L)	3.4 U	3.4 U	12.4 U	3.4 U
Potassium	(ug/L)	4220 BEJ	4500 BEJ	2250 B	2510 BEJ
Selenium	(ug/L)	2.7 U	2.7 U	1.2 U	2.7 U
Silver	(ug/L)	0.6 UN	0.6 UN	5.1 UN	0.6 UN
Sodium	(ug/L)	41900	52000	8460	16100
Thallium	(ug/L)	4.6 U	4.6 U	2.3 UW	4.6 U
Vanadium	(ug/L)	3.8 BU	3.8 BU	6.3 B	3.5 BU
Zinc	(ug/L)	179 EJ	18.6 BEJ	3.9 B	216 EJ
Zirconium	(ug/L)	31.3 U	31.3 U	31.3 U	31.3 U
Radionuclides					
Gross Alpha	(pCi/L)	1.7±1.6 U	4.9±2	1.6±1 U	3±1.3
Gross Beta	(pCi/L)	38±2	63±3	3.2±1.2	81±2
Tritium	(pCi/L)	17700±400	17300±400	7620±260	9850±280
Se-90	(pCi/L)	7.6±0.5	19±0.7	0±0.3	17.4±0.6 J
Po-238	(pCi/L)	ND	ND	ND	ND
Po-239/240	(pCi/L)	ND	ND	ND	ND
Am-241	(pCi/L)	ND	ND	ND	ND
Np-237	(pCi/L)	ND	ND	ND	ND
I-129	(pCi/L)	0±0.3 U	0±0.3 U	0±0.4	0±0.4 U
Tc-99	(pCi/L)	7.3±0.5	14±1	39±1	3.9±0.5
U-234	(pCi/L)	ND	ND	ND	ND
U-235	(pCi/L)	ND	ND	ND	ND
U-238	(pCi/L)	ND	ND	ND	ND

NA - not analyzed.

ND - not detected.

NS - not sampled.

U - analyzed, not detected.

B - contaminant in blank.

R - concentration is unusable.

J - estimated concentration.

Table 4-4. (continued).

Well		USGS 41	USGS 42	USGS 44	USGS 45
Date		May-95	May-95	May-95	May-95
Sample Depth		646.53 to 674.4	464.83 to 678.5	465.58 to 650	467.41 to 651.2
Sample ID	Units	31330901	31334301	31331101	31331201
Field Parameters					
Temperature	(celsius)	13.05	13.29	12.18	12.55
pH		7.41	7.37	7.69	7.56
Conductivity	(micromen)	0.484	0.468	0.397	0.441
TAL Inorganics					
Aluminum	(ug/L)	26.8 U	26.8 U	42.9 U	27.2 BU
Antimony	(ug/L)	1.9 U	1.9 U	42.2 U	1.9 U
Arsenic	(ug/L)	4 U	4 U	1.8 U	4 U
Barium	(ug/L)	94.2 B	91.8 B	89.9 B	82 B
Beryllium	(ug/L)	0.1 U	0.1 U	0.1 U	0.1 U
Cadmium	(ug/L)	0.4 U	0.4 U	2.9 U	0.4 U
Calcium	(ug/L)	60800	58800	56300	54400
Chromium	(ug/L)	5.3 B	5.4 B	5.5 U	5.1 B
Cobalt	(ug/L)	0.5 U	0.5 U	4.9 U	0.5 U
Copper	(ug/L)	1.3 U	1.8 BU	7.1 U	1.3 UJ
Iron	(ug/L)	21.5 U	21.5 U	7.1 U	21.5 U
Lead	(ug/L)	2 U	2 U	1.5 UW	2 U
Magnesium	(ug/L)	16700	16200	14600	14700
Manganese	(ug/L)	0.8 U	0.8 U	1.2 BU	0.8 U
Mercury	(ug/L)	0.1 B	0.1 U	0.1 U	0.1 U
Nickel	(ug/L)	3.4 U	3.4 U	12.4 U	3.4 U
Potassium	(ug/L)	2410 BEJ	2350 BEJ	2550 B	2510 BEJ
Selenium	(ug/L)	2.7 U	2.7 U	1.2 U	2.7 U
Silver	(ug/L)	0.6 UN	0.6 UN	5.1 UN	0.6 NUJ
Sodium	(ug/L)	13200	10500	8,60	10300
Thallium	(ug/L)	4.6 U	4.6 U	2.3 U	4.6 U
Vanadium	(ug/L)	4.1 BU	4.1 BU	4.2 B	3.5 BJ
Zinc	(ug/L)	10.8 BEUJ	11.1 BEUJ	3.2 B	4.5 BU
Zirconium	(ug/L)	31.3 U	31.3 U	31.3 U	ND
Radionuclides					
Gross Alpha	(pCi/L)	4.1±1.4	2.6±1.2	3.6±1.3	2.3±1.2 U
Gross Beta	(pCi/L)	52.4±2.2	33±2	14±1	14±1
Tritium	(pCi/L)	7770±250	3880±200	581±138	2540±180
Sr-90	(pCi/L)	15.8±0.6	9.7±0.6	3.6±0.3	3.8±0.4
Pu-238	(pCi/L)	ND	0.03±0.04 U	ND	ND
Pu-239/240	(pCi/L)	ND	0±0.03 U	ND	ND
Am-241	(pCi/L)	ND	0.54±0.14	ND	ND
Np-237	(pCi/L)	ND	0±0.11 U	ND	ND
I-129	(pCi/L)	0±0.3 U	0±0.3 U	0±0.3 U	0±0.3 U
Tc-99	(pCi/L)	8.2±0.6	8±0.8	0.4±0.6 U	0.4±0.5 U
U-234	(pCi/L)	ND	1.8±0.4	ND	ND
U-235	(pCi/L)	ND	0±0.2 U	ND	ND
U-238	(pCi/L)	ND	0.9±0.3	ND	ND

NA - not analyzed.

ND - not detected.

NS - not sampled.

U - analyzed, not detected.

B - co-contaminant in blank.

R - concentration is unusable.

J - estimated concentration.

Table 4-4. (continued).

Well		USGS 46	USGS 47	USGS 48	USGS 51
Date		May-95	Jun-95	May-95	May-95
Sample Depth		468.1 to 654.9	460.35 to 652	464.16 to 752	466.77 to 659
Sample ID	Units	31331301	31334401	31331401	31331601
Field Parameters					
Temperature	(celsius)	13.52	16.2	14.77	13.73
pH		7.55	7.75	7.42	7.69
Conductivity	(micromen)	0.61	0.54	0.59	0.623
TAL Inorganics					
Aluminum	(ug/L)	120 BU	25.2 BU	47.5 BU	26.8 U
Antimony	(ug/L)	1.9 U	2.7 U	42.2 U	1.9 U
Arsenic	(ug/L)	4 U	2.4 U	1.8 U	4 U
Barium	(ug/L)	107 B	98.3 B	85 B	101 B
Beryllium	(ug/L)	0.1 U	0.1 U	0.1 U	0.1 U
Cadmium	(ug/L)	0.4 U	0.3 U	2.9 U	0.4 U
Calcium	(ug/L)	64500	64800	57400	59400
Chromium	(ug/L)	4.7 B	6.7 B	5.5 U	8.9 B
Cobalt	(ug/L)	0.93 B	0.6 U	4.9 U	0.5 U
Copper	(ug/L)	1.3 U	2.2 U	7.1 U	1.6 BU
Iron	(ug/L)	119	3 B	7.1 U	21.5 U
Lead	(ug/L)	2 U	2 U	1.5 UW	2.9 B
Magnesium	(ug/L)	17100	17200	15700	20000
Manganese	(ug/L)	1.3 B	0.8 U	1.7 BU	0.8 U
Mercury	(ug/L)	0.1 U	0.32	0.11 B	0.1 U
Nickel	(ug/L)	3.4 U	1.8 U	12.4 U	3.4 U
Potassium	(ug/L)	2740 B	2290 B	2550 B	5000 EJ
Selenium	(ug/L)	2.7 U	2.8 B	1.5 B	2.7 U
Silver	(ug/L)	0.6 U	0.8 UN	5.5 BNR	0.6 UN
Sodium	(ug/L)	16000	20000	14500	23700
Thallium	(ug/L)	4.6 U	3.2 U	2.3 U	4.6 U
Vanadium	(ug/L)	4 B	3.8 B	4.1 B	5.7 BU
Zinc	(ug/L)	7.6 BU	380	5.5 B	166 EJ
Zirconium	(ug/L)	31.2 U	11.6 U	31.3 U	31.3 U
Radionuclides					
Gross Alpha	(pCi/L)	2.8±1.3 J	3.8±1.5 U	2.3±1.2 U	0.2±1.2 U
Gross Beta	(pCi/L)	140±3 J	233±3	81±2	5.7±1.4
Tritium	(pCi/L)	10200±300	15800±400 U	6820±252	23900±400
Sr-90	(pCi/L)	23.4±0.8	67±1 J	18.4±0.5	0.4±0.3 U
Pu-238	(pCi/L)	ND	ND	0±0.03 U	ND
Pu-239/240	(pCi/L)	ND	ND	0±0.04 U	ND
Am-241	(pCi/L)	ND	ND	0±0.05 U	ND
Np-237	(pCi/L)	ND	ND	0±0.11 U	ND
I-129	(pCi/L)	0±0.4 U	0.1±0.3 U	0±0.3 U	0±0.4 U
Tc-99	(pCi/L)	9.7±0.7	174±2	2±0.7	0.8±0.5 U
U-234	(pCi/L)	ND	2.6±0.8	1.9±0.4	ND
U-235	(pCi/L)	ND	0±0.3 U	0±0.2 U	ND
U-238	(pCi/L)	ND	0.4±0.5 U	0.8±0.3	ND

NA - not analyzed.

ND - not detected.

NS - not sampled.

U - analyzed, not detected.

B - contaminant in blank.

R - concentration is unusable.

J - estimated concentration.

Table 4-4. (continued).

Well		USGS 52	USGS 57	USGS 59	USGS 67
Date		May-95	May-95	May-95	May-95
Sample Depth		457.75 to 650	471.8 to 732	470 to 657	462 to 699
Sample ID	Units	31331701	31331801	31331901	31332001
Field Parameters					
Temperature	(celsius)	13.69	13.77	14.89	14.03
pH		7.48	7.7	7.51	7.48
Conductivity	(micromm)	0.475	0.811	0.897	0.875
TAL Inorganics					
Aluminum	(ug/L)	26.8 U	26.8 U	36.4 BU	56.7 BU
Antimony	(ug/L)	1.9 U	1.9 U	3.1 B	1.9 U
Arsenic	(ug/L)	4 U	4 U	10.8 B	4 U
Barium	(ug/L)	99.5 B	90.9 B	188 B	185 B
Beryllium	(ug/L)	0.1 U	0.1 U	0.1 U	0.1 U
Cadmium	(ug/L)	0.4 U	0.4 U	0.4 U	0.4 U
Calcium	(ug/L)	48700	30000	62500	77200
Chromium	(ug/L)	6.2 B	4.1 U	5.8 B	5.6 B
Cobalt	(ug/L)	0.5 U	0.5 U	0.5 U	0.5 U
Copper	(ug/L)	1.7 BU	1.3 U	1.6 BU	1.3 U
Iron	(ug/L)	21.5 U	21.5 U	21.5 U	21.5 U
Lead	(ug/L)	2 U	2 U	2 U	5 BU
Magnesium	(ug/L)	14100	8250	16800	21700
Manganese	(ug/L)	0.8 U	0.8 U	0.8 U	0.8 U
Mercury	(ug/L)	0.1 U	0.18 B	0.1 U	0.1 U
Nickel	(ug/L)	3.4 U	3.4 U	3.4 U	3.4 U
Potassium	(ug/L)	3280 BEJ	1960 BEJ	5140 EJ	5340 EJ
Selenium	(ug/L)	2.7 U	2.7 U	4.5 BU	5 BU
Silver	(ug/L)	0.6 UN	0.6 UN	0.6 NUJ	0.6 NUJ
Sodium	(ug/L)	22400	24400	76700	44700
Thallium	(ug/L)	4.6 U	4.6 U	4.6 U	4.6 U
Vanadium	(ug/L)	4.9 BU	1.8 BU	3.1 BU	3.1 BU
Zinc	(ug/L)	5.9 BEUJ	4.4 BEUJ	296	329
Zirconium	(ug/L)	31.3 U	31.3 U	ND	ND
Radionuclides					
Gross Alpha	(pCi/L)	2.8±1.3 U	2±1.8 U	1±1.7 U	1.6±1.6 U
Gross Beta	(pCi/L)	183±3	83±3	43±3	45±3
Tritium	(pCi/L)	10700±300	18400±400	17900±400	21200±400
Sr-90	(pCi/L)	12.1±0.6	22.7±0.7	12±0.5	10.3±0.5
Pu-238	(pCi/L)	ND	0±0.07 U	ND	ND
Pu-239/240	(pCi/L)	ND	0±0.02 U	ND	ND
Am-241	(pCi/L)	ND	0.09±0.07 U	ND	ND
Np-237	(pCi/L)	ND	0±0.14 U	ND	ND
I-129	(pCi/L)	0±0.3 U	0.1±0.3 U	0±0.3 U	1±0.3
To-99	(pCi/L)	235±3	28±1	20±1	13±1
U-234	(pCi/L)	ND	2±0.4	ND	ND
U-235	(pCi/L)	ND	0±0.2 U	ND	ND
U-238	(pCi/L)	ND	0.9±0.3 U	ND	ND

NA - not analyzed.

ND - not detected.

NS - not sampled.

U - analyzed, not detected.

B - contaminant in blank.

R - concentration is unusable.

J - estimated concentration.

Table 4-4. (continued).

Well		USGS 77	USGS 82	USGS 84	USGS 85
Date		May-95	May-95	May-95	May-95
Sample Depth		471.26 to 610	454.94 to 700	486.56 to 505	489.07 to 637
Sample ID	Units	31332101	31332201	31334201	31332301
Field Parameters					
Temperature	(celsius)	13.05	12.48	12.28	12.7
pH		7.7	7.78	7.91	7.54
Conductivity	(microsiemen)	0.704	0.31	0.454	0.508
TAL Inorganics					
Aluminum	(ug/L)	26.8 U	43.4 BU	26.8 U	38.4 BU
Antimony	(ug/L)	1.9 U	42.2 U	1.9 U	1.9 U
Arsenic	(ug/L)	4 U	3.1 B	4 U	4 U
Barium	(ug/L)	147 B	50 B	92.6 B	127 B
Beryllium	(ug/L)	0.1 U	0.1 U	0.1 U	0.1 U
Cadmium	(ug/L)	0.4 U	2.9 U	0.4 U	0.4 U
Calcium	(ug/L)	68000	35300	55500	63400
Chromium	(ug/L)	11.4	5.5 U	19.9	16.2
Cobalt	(ug/L)	0.5 U	4.9 U	0.5 U	0.55 B
Copper	(ug/L)	2.3 BU	7.1 U	5.7 BU	1.3 UJ
Iron	(ug/L)	21.5 U	8.8 B	29.1 B	21.5 U
Lead	(ug/L)	2 U	1.5 UW	17.5 B	2 U
Magnesium	(ug/L)	20000	13000	17700	16200
Manganese	(ug/L)	0.8 U	1.4 BU	0.8 U	1.9 B
Mercury	(ug/L)	0.1 U	0.1 U	0.1 U	0.1 U
Nickel	(ug/L)	3.4 U	12.4 U	3.4 U	3.4 U
Potassium	(ug/L)	4430 BEJ	3460 B	2030 BEJ	3530 BEJ
Selenium	(ug/L)	2.7 U	1.2 U	2.7 U	2.7 U
Silver	(ug/L)	0.73 BNJ	5.8 BNR	0.6 UN	0.63 RNJ
Sodium	(ug/L)	30800	10400	8980	25600
Thallium	(ug/L)	4.6 U	2.3 U	4.6 U	4.6 U
Vanadium	(ug/L)	3.7 BU	9.9 B	3.2 BU	3.2 BJ
Zinc	(ug/L)	5.3 BEUJ	106	428 EJ	8.6 B
Zirconium	(ug/L)	31.3 U	31.3 U	31.3 U	ND
Radionuclides					
Gross Alpha	(pCi/L)	4.6±1.7	2.9±1.1	1±1.2 U	3±1.4
Gross Beta	(pCi/L)	13±2	4.1±1.3	2.4±1.2	16±2
Tritium	(pCi/L)	30700±500	67±122 U	4790±210	11800±300
Sr-90	(pCi/L)	1.3±0.3	0.1±0.3 U	0±0.3 U	4±0.4
Pu-238	(pCi/L)	ND	ND	ND	ND
Pu-239/240	(pCi/L)	ND	ND	ND	ND
Am-241	(pCi/L)	ND	ND	ND	ND
Np-237	(pCi/L)	ND	ND	ND	ND
I-129	(pCi/L)	0±0.3 U	0±0.3 U	0±0.3 U	0±0.3 U
To-99	(pCi/L)	7.5±0.7	0.1±0.6 U	0.8±0.6 U	6.4±0.6
U-234	(pCi/L)	ND	ND	ND	ND
U-235	(pCi/L)	ND	ND	ND	ND
U-238	(pCi/L)	ND	ND	ND	ND

NA - not analyzed.

ND - not detected.

NS - not sampled.

U - analyzed, not detected.

B - co-contaminant in blank.

R - concentration is unusable.

J - estimated concentration.

Table 4-4. (continued).

Well		USGS 111	USGS 112	USGS 113	USGS 114
Date		May-95	May-95	May-95	May-95
Sample Depth		475.98 to 597	479.67 to 563	480.31 to 564	474.02 to 564
Sample ID	Units	31332401	31332501	31332601	31332701
Field Parameters					
Temperature	(celsius)	13.46	13.94	13.37	13.55
pH		9.02	7.6	7.71	7.72
Conductivity	(microsiemen)	0.608	0.18	0.945	0.531
TAL Inorganics					
Aluminum	(ug/L)	57.6 BU	44.1 BU	26.8 U	26.8 U
Antimony	(ug/L)	42.2 U	1.9 U	1.9 U	1.9 U
Arsenic	(ug/L)	1.8 U	4 U	4 U	4 U
Barium	(ug/L)	105 B	205	107 B	102 B
Beryllium	(ug/L)	0.1 U	0.1 U	0.1 U	0.1 U
Cadmium	(ug/L)	2.9 U	0.4 U	0.4 U	0.4 U
Calcium	(ug/L)	58100	71500	32000	55600
Chromium	(ug/L)	29.6	6 B	4.1 U	9.3 B
Cobalt	(ug/L)	4.9 U	0.5 U	0.5 U	0.5 U
Copper	(ug/L)	7.1 U	1.3 UJ	1.7 BU	3.9 BU
Iron	(ug/L)	86.8 B	21.5 U	21.5 U	21.5 U
Lead	(ug/L)	1.5 UW	2 U	2 U	2 U
Magnesium	(ug/L)	16900	19000	9060	17700
Manganese	(ug/L)	1.2 U	0.8 U	0.8 U	0.8 U
Mercury	(ug/L)	0.1 U	0.1 B	0.1 U	0.1 U
Nickel	(ug/L)	12.4 U	3.4 U	3.4 U	3.4 U
Potassium	(ug/L)	3600 B	4920 BEJ	2520 BEJ	3850 BEJ
Selenium	(ug/L)	1.4 B	2.7 U	2.7 U	2.7 U
Silver	(ug/L)	5.1 UN	0.6 NUJ	0.88 BNJ	0.6 UN
Sodium	(ug/L)	23700	57000	33500	19800
Thallium	(ug/L)	2.3 WUJ	4.6 U	4.6 U	4.6 U
Vanadium	(ug/L)	6.1 B	3.6 BJ	1.9 BU	3.6 BU
Zinc	(ug/L)	200	169	90.7 EJ	261 EJ
Zirconium	(ug/L)	31.3 U	ND	31.3 U	31.3 U
Radionuclides					
Gross Alpha	(pCi/L)	0.2±1.2 U	2.3±1.7 U	0±1.8 U	0.4±1.1 U
Gross Beta	(pCi/L)	3.5±1.3	78±3	38±3	11±1
Tritium	(pCi/L)	10900±300	17900±400	15500±300	27000±400
Sr-90	(pCi/L)	0.2±0.3 U	21.5±0.7	12±0.5	0.1±0.4 U
Po-238	(pCi/L)	ND	0±0.02 U	ND	ND
Po-239/240	(pCi/L)	ND	0±0.04 U	ND	ND
Am-241	(pCi/L)	ND	0.09±0.07 U	ND	ND
Np-237	(pCi/L)	ND	0.02±0.14 U	ND	ND
I-129	(pCi/L)	0±0.3 U	0.1±0.4 U	0.1±0.3 U	0±0.3 U
To-99	(pCi/L)	1.5±0.8 U	18±1	9.6±0.7	12.6±0.9
U-234	(pCi/L)	ND	1.3±0.4	ND	ND
U-235	(pCi/L)	ND	0±0.2 U	ND	ND
U-238	(pCi/L)	ND	0.6±0.3 U	ND	ND

NA - not analyzed.

ND - not detected.

NS - not sampled.

U - analyzed, not detected.

B - contaminant in blank.

R - concentration is unusable.

J - estimated concentration.

Table 4-4. (continued).

Well		USGS 115	USGS 116	USGS 121	USGS 122
Date		May-95	May-95	May-95	May-95
Sample Depth		470.27 to 581	464.71 to 580	459.12 to 475	465 to 476
Sample ID	Units	31332801	31332901	31333001	31333101
Field Parameters					
Temperature	(celsius)	13.31	12.99	12.6	15.39
pH		7.85	7.71	7.58	7.65
Conductivity	(micromen)	0.385	0.69	0.424	0.59
TAL Inorganics					
Aluminum	(ug/L)	26.8 U	26.8 U	36.6 BU	26.8 U
Antimony	(ug/L)	1.9 U	1.9 U	1.9 B	1.9 U
Arsenic	(ug/L)	4 U	4 U	7.5 B	4 U
Barium	(ug/L)	57.6 B	137 B	88.6 B	114 B
Beryllium	(ug/L)	0.1 U	0.1 U	0.1 U	0.1 U
Cadmium	(ug/L)	0.4 U	0.4 U	0.4 U	0.4 U
Calcium	(ug/L)	40100	59000	52800	46000
Chromium	(ug/L)	7.7 B	7.8 B	4.2 B	4.1 U
Cobalt	(ug/L)	0.5 U	0.5 U	0.5 U	0.5 U
Copper	(ug/L)	1.7 BU	2 BU	1.3 UJ	1.3 U
Iron	(ug/L)	21.5 U	21.5 U	21.5 U	21.5 U
Lead	(ug/L)	3 B	2.9 B	2 U	2 U
Magnesium	(ug/L)	12600	17000	14100	11900
Manganese	(ug/L)	0.8 U	0.8 U	0.8 U	44
Mercury	(ug/L)	0.1 U	0.1 U	0.1 U	0.1 U
Nickel	(ug/L)	3.4 U	3.4 U	3.4 U	4.3 B
Potassium	(ug/L)	3300 BEJ	4950 BEJ	2350 BEJ	6800
Selenium	(ug/L)	2.7 U	2.7 U	3 BU	2.7 U
Silver	(ug/L)	0.6 UN	0.6 UN	0.6 NUJ	0.6 U
Sodium	(ug/L)	13100	32200	7340	30600
Thallium	(ug/L)	4.6 U	4.6 U	4.6 U	4.6 U
Vanadium	(ug/L)	4.1 BU	4.4 BU	3.4 BJ	3.2 B
Zinc	(ug/L)	454 EJ	197 EJ	6.8 BU	46.8
Zirconium	(ug/L)	31.3 U	31.3 U	ND	31.2 U
Radionuclides					
Gross Alpha	(pCi/L)	2.3±1	3.5±1.6	2.6±1.1	1.6±1.1 U
Gross Beta	(pCi/L)	8.4±1.3	5.8±1.6	2.7±1.1	13±1
Tritium	(pCi/L)	5340±220	8020±260	168±123 U	19300±300
Sr-90	(pCi/L)	0.6±0.3 U	0.8±0.3	0.3±0.3 U	2.2±0.3
Pu-238	(pCi/L)	ND	ND	ND	ND
Pu-239/240	(pCi/L)	ND	ND	ND	ND
Am-241	(pCi/L)	ND	ND	ND	ND
Np-237	(pCi/L)	ND	ND	ND	ND
I-129	(pCi/L)	0±0.4 U	0±0.3 U	0±0.4 U	0±0.2 U
To-99	(pCi/L)	4±0.7	3.4±0.6	0.1±0.5 U	2±0.5 J
U-234	(pCi/L)	ND	ND	ND	ND
U-235	(pCi/L)	ND	ND	ND	ND
U-238	(pCi/L)	ND	ND	ND	ND

NA - not analyzed.

ND - not detected.

NS - not sampled.

U - analyzed, not detected.

B - contaminant in blank.

R - concentration is unusable.

J - estimated concentration.

Table 4-4. (continued).

Well		USGS 123	CPP-1	CPP-2	LF2-08
Date		May-95	Jun-95	May-95	May-95
Sample Depth		468.39 to 475	595	595	495
Sample ID	Units	31333201	31334501	31334601	31333301
Field Parameters					
Temperature	(celsius)	14.61	16.6	15.2	12.84
pH		8.26	7	7.7	7.87
Conductivity	(misiemen)	0.662	0.547	0.534	0.748
TAL Inorganics					
Aluminum	(ug/L)	69.1 BU	26.8 U	43.9 BU	26.8 U
Antimony	(ug/L)	1.9 U	1.9 U	1.9 U	1.9 U
Arsenic	(ug/L)	4 U	4 U	4 U	4 U
Barium	(ug/L)	173 B	96.2 B	186 B	159 B
Beryllium	(ug/L)	0.1 U	0.1 U	0.1 U	0.1 U
Cadmium	(ug/L)	0.4 U	0.4 U	0.4 U	2.1 B
Calcium	(ug/L)	70400	58100	77500	74900
Chromium	(ug/L)	8.6 B	4.1 U	5.9 B	9.1 B
Cobalt	(ug/L)	0.79 B	0.5 U	0.5 U	0.5 U
Copper	(ug/L)	1.8 B	1.3 U	1.3 UJ	2.1 B
Iron	(ug/L)	129	21.5 U	21.5 U	21.5 U
Lead	(ug/L)	2 U	2 U	2.1 BU	37.7
Magnesium	(ug/L)	18900	17000	21600	20400
Manganese	(ug/L)	3 B	0.8 U	0.8 U	0.8 U
Mercury	(ug/L)	0.14 B	0.1 U	0.1 U	0.1 U
Nickel	(ug/L)	4.7 B	3.4 U	3.4 U	3.4 U
Potassium	(ug/L)	4570 B	2980 B	5330 EJ	6100
Selenium	(ug/L)	2.7 U	2.7 U	2.7 U	2.7 U
Silver	(ug/L)	0.6 U	0.6 U	0.6 NUJ	0.6 U
Sodium	(ug/L)	46100	9110	44500	40600
Thallium	(ug/L)	4.6 U	4.6 U	4.6 U	4.6 U
Vanadium	(ug/L)	3.9 B	4.9 B	3.4 BJ	3.1 B
Zinc	(ug/L)	7.3 BU	1.3 BU	339	5.7 BU
Zirconium	(ug/L)	31.2 U	31.2 U	ND	31.2 U
Radionuclides					
Gross Alpha	(pCi/L)	1.7±1.5 U	1.9±1.1 U	ND	2±1.6 U
Gross Beta	(pCi/L)	123±3	25±2	ND	38±2
Tritium	(pCi/L)	25900±400	754±173	ND	21000±400
Sr-90	(pCi/L)	30±1	0.9±0.3 U	ND	0.6±0.3 U
Pu-238	(pCi/L)	0.08±0.06 U	ND	ND	ND
Pu-239/240	(pCi/L)	0±0.03 U	ND	ND	ND
Am-241	(pCi/L)	0.03±0.06 U	ND	ND	ND
Np-237	(pCi/L)	0±0.12 U	ND	ND	ND
I-129	(pCi/L)	0±0.2 U	0±0.3 U	ND	0.4±0.4 U
To-99	(pCi/L)	48±1	31±1 J	ND	4.7±0.4
U-234	(pCi/L)	1.3±0.4	ND	ND	ND
U-235	(pCi/L)	0±0.2 U	ND	ND	ND
U-238	(pCi/L)	1.1±0.4	ND	ND	ND

NA - not analyzed.

ND - not detected.

NS - not sampled.

U - analyzed, not detected.

B - contaminant in blank.

R - concentration is unusable.

J - estimated concentration.

Table 4-4. (continued).

Well		LF2-10	LF2-11	LF2-12	LF3-08
Date		May-95	Aug-95	Jun-95	May-95
Sample Depth		765	499	489	510
Sample ID	Units	31333501	31333601	31333701	31333801
Field Parameters					
Temperature	(celsius)	12.79	12.77	13.73	12.85
pH		8.58	8.11	7.59	7.79
Conductivity	(micromen)	0.515	1.035	0.724	0.705
TAL Inorganics					
Aluminum	(ug/L)	26.8 U	76.3 BU	26.8 U	26.8 U
Antimony	(ug/L)	1.9 U	4.6 B	1.9 U	1.9 U
Arsenic	(ug/L)	4 U	2.4 U	4 U	4 U
Barium	(ug/L)	92.1 B	127 B	177 B	139 B
Beryllium	(ug/L)	0.1 U	0.1 U	0.1 U	0.1 U
Cadmium	(ug/L)	0.4 U	1 BU	2.7 B	0.4 U
Calcium	(ug/L)	64800	66200	77000	69900
Chromium	(ug/L)	8.9 B	1.8 B	4.1 U	4.1 U
Cobalt	(ug/L)	0.5 U	1.4 B	0.74 B	1 B
Copper	(ug/L)	1.8 B	18.5 BU	1.3 U	3.2 B
Iron	(ug/L)	21.5 U	6.3 BU	21.5 U	21.5 U
Lead	(ug/L)	2 U	2 U	12.2	2 U
Magnesium	(ug/L)	18100	19600	20300	20100
Manganese	(ug/L)	0.8 U	62.8	6.7 B	0.8 U
Mercury	(ug/L)	0.1 UJ	0.1 U	0.44	0.1 U
Nickel	(ug/L)	3.4 U	206	23.3 B	3.4 U
Potassium	(ug/L)	2840 B	1490 EJ	5340	5950
Selenium	(ug/L)	2.7 U	3.7 B	2.7 B	2.8 B
Silver	(ug/L)	0.6 U	0.8 U	0.6 U	0.6 U
Sodium	(ug/L)	11700	54500	46700	42700
Thallium	(ug/L)	4.6 U	3.4 BU	4.6 U	4.6 U
Vanadium	(ug/L)	4 B	0.7 U	2.3 B	3.7 B
Zinc	(ug/L)	18.3 BU	11.2 BEUJ	30.8	46
Zirconium	(ug/L)	31.2 U	11.6 U	31.2 U	31.2 U
Radionuclides					
Gross Alpha	(pCi/L)	2.5±1.3 U	0±1.7 U	2.6±1.6 U	4±1.8
Gross Beta	(pCi/L)	3.4±1.3	18±2	12±2	17±2
Tritium	(pCi/L)	7700±300	24000±400	25200±400	25200±400
Sr-90	(pCi/L)	0.7±0.3	0.4±0.3 U	0.3±0.3 U	0.2±0.3 U
Pa-238	(pCi/L)	ND	ND	ND	ND
Pa-239/240	(pCi/L)	ND	ND	ND	ND
Am-241	(pCi/L)	ND	ND	ND	ND
Np-237	(pCi/L)	ND	ND	ND	ND
I-129	(pCi/L)	0±0.3 U	0.3±0.3 U	1.2±0.3	0.3±0.3 U
To-99	(pCi/L)	0.6±0.5 U	3.1±0.5	8.5±0.6	9.4±0.6
U-234	(pCi/L)	ND	ND	ND	ND
U-235	(pCi/L)	ND	ND	ND	ND
U-238	(pCi/L)	ND	ND	ND	ND

NA - not analyzed.

ND - not detected.

NS - not sampled.

U - analyzed, not detected.

B - contaminant in blank.

R - concentration is unusable.

J - estimated concentration.

Table 4-4. (continued).

Well		LF3-09	LF3-10	USGS 36	USGS 67
Date		May-95	Aug-95	Duplicate	Duplicate
Sample Depth		500	501	477.48 to 567.1	462.34 to 698
Sample ID	Units	31333901	31334001	31334801	31335001
Field Parameters					
Temperature	(celsius)	12.83	12.96	12.75	14.03
pH		7.6	8.33	7.81	7.48
Conductivity	(micromen)	0.681	0.771	0.486	0.875
TAL Inorganics					
Aluminum	(ug/L)	26.8 U	96.4 BU	26.8 U	NA
Antimony	(ug/L)	1.9 U	2.7 U	1.9 U	NA
Arsenic	(ug/L)	4 U	2.4 U	4 U	NA
Barium	(ug/L)	132 B	152 B	108 B	NA
Beryllium	(ug/L)	0.1 U	0.1 U	0.1 U	NA
Cadmium	(ug/L)	0.48 B	0.94 BU	0.4 U	NA
Calcium	(ug/L)	68500	65700	56000	NA
Chromium	(ug/L)	4.1 U	5.1 B	12.9	NA
Cobalt	(ug/L)	0.52 B	0.69 B	0.5 U	NA
Copper	(ug/L)	1.8 B	16.2 BU	1.8 BU	NA
Iron	(ug/L)	36.6 B	6.3 BU	21.5 U	NA
Lead	(ug/L)	13.9	2.6 B	2 U	NA
Magnesium	(ug/L)	20300	18700	14500	NA
Manganese	(ug/L)	1.8 B	10.4 B	0.8 U	NA
Mercury	(ug/L)	0.1 U	0.1 U	0.1 U	NA
Nickel	(ug/L)	24.7 B	7 B	3.4 U	NA
Potassium	(ug/L)	5030	4810 BEJ	2810 BEJ	NA
Selenium	(ug/L)	2.7 U	3.2 B	2.7 U	NA
Silver	(ug/L)	0.6 U	0.8 U	0.6 UN	NA
Sodium	(ug/L)	36500	40800	16200	NA
Thallium	(ug/L)	4.6 U	7.6 BU	4.6 U	NA
Vanadium	(ug/L)	3 B	2.5 BU	3.3 BU	NA
Zinc	(ug/L)	168	109 EJ	6.2 BEUJ	NA
Zirconium	(ug/L)	31.2 U	11.6 U	31.3 U	NA
Radionuclides					
Gross Alpha	(pCi/L)	1.8±1.4 U	2.3±1.6 U	2.9±1.3	0±1.5 U
Gross Beta	(pCi/L)	31±2	13±2	31±2	47±3
Tritium	(pCi/L)	26900±400	17600±400	6110±230	21000±400
Sr-90	(pCi/L)	0.2±0.3 U	0.7±0.3	8.6±0.5	12.8±0.5
Pu-238	(pCi/L)	ND	ND	ND	ND
Pu-239/240	(pCi/L)	ND	ND	ND	ND
Am-241	(pCi/L)	ND	ND	ND	ND
Np-237	(pCi/L)	ND	ND	ND	ND
I-129	(pCi/L)	0.9±0.3	0.2±0.3 U	0±0.3 U	0±0.3 U
To-99	(pCi/L)	9.4±0.6	1.8±0.5	4.8±0.8	12±1
U-234	(pCi/L)	ND	ND	ND	ND
U-235	(pCi/L)	ND	ND	ND	ND
U-238	(pCi/L)	ND	ND	ND	ND

NA - not analyzed.

ND - not detected.

NS - not sampled.

U - analyzed, not detected.

B - cocontaminant in blank.

R - concentration is unusable.

J - estimated concentration.

Table 4-4. (continued).

Well		USGS 121	CPP-2	USGS 47	USGS 47
Date		Duplicate	Duplicate	Jun-95	Jun-95
Sample Depth		459.12 to 475	595	462 to 470.8	483 to 491.8
Sample ID	Units	31334901	31334601	31340601	31340701
Field Parameters					
Temperature	(celsius)	12.6	15.2	16.2	16.2
pH		7.58	7.7	7.75	7.75
Conductivity	(micromen)	0.424	0.534	0.54	0.54
TAL Inorganics					
Aluminum	(ug/L)	38.7 BU	26.8 U	NA	NA
Antimony	(ug/L)	1.9 U	1.9 U	NA	NA
Arsenic	(ug/L)	4 U	4 U	NA	NA
Barium	(ug/L)	90.7 B	96.6 B	NA	NA
Beryllium	(ug/L)	0.1 U	0.1 U	NA	NA
Cadmium	(ug/L)	0.4 U	0.4 U	NA	NA
Calcium	(ug/L)	53900	55100	NA	NA
Chromium	(ug/L)	5.1 B	4.1 U	NA	NA
Cobalt	(ug/L)	0.5 U	0.5 U	NA	NA
Copper	(ug/L)	1.3 UJ	13.5 B	NA	NA
Iron	(ug/L)	21.5 U	21.5 U	NA	NA
Lead	(ug/L)	2 U	2 U	NA	NA
Magnesium	(ug/L)	14300	16300	NA	NA
Manganese	(ug/L)	0.8 U	0.8 U	NA	NA
Mercury	(ug/L)	0.1 U	0.1 U	NA	NA
Nickel	(ug/L)	3.4 U	3.4 U	NA	NA
Potassium	(ug/L)	2380 BEJ	2890 B	NA	NA
Selenium	(ug/L)	5.5 BU	2.7 U	NA	NA
Silver	(ug/L)	0.6 NUJ	0.6 U	NA	NA
Sodium	(ug/L)	7480	8180	NA	NA
Thallium	(ug/L)	4.6 U	4.6 U	NA	NA
Vanadium	(ug/L)	3.8 BJ	4.9 B	NA	NA
Zinc	(ug/L)	9.5 B	3.6 BU	NA	NA
Zirconium	(ug/L)	ND	31.2 U	NA	NA
Radionuclides					
Gross Alpha	(pCi/L)	4.7±1.2	1.6±1 U	1.4±0.8 U	4.3±1.6
Gross Beta	(pCi/L)	3.8±1.2	3.8±1.2	105±2	267±4
Tritium	(pCi/L)	240±123 U	136±156 U	10300±300	15600±400
Sr-90	(pCi/L)	0±0.4 U	0.7±0.3 U	31±1	44±1 U
Pu-238	(pCi/L)	ND	ND	ND	ND
Pu-239/240	(pCi/L)	ND	ND	ND	ND
Am-241	(pCi/L)	ND	ND	ND	ND
Np-237	(pCi/L)	ND	ND	ND	ND
I-129	(pCi/L)	0±0.3 U	0±0.3 U	0±0.3 U	0.2±0.3 U
Tc-99	(pCi/L)	0.1±0.5 U	1.1±0.5	119±2	17±1
U-234	(pCi/L)	ND	ND	ND	ND
U-235	(pCi/L)	ND	ND	ND	ND
U-238	(pCi/L)	ND	ND	ND	ND

NA - not analyzed.

ND - not detected.

NS - not sampled.

U - analyzed, not detected.

B - contaminant in blank.

R - concentration is unreasonable.

J - estimated concentration.

Table 4-4. (continued).

Well		USGS 47	USGS 47	USGS 47	USGS 47
Date		Jun-95	Jun-95	Jun-95	Jun-95
Sample Depth		511.5 to 520.8	558 to 566.8	576 to 584.8	483 to 491.8
Sample ID	Units	31340801	31340901	31341001	31341101
Field Parameters					
Temperature	(celsius)	16.2	16.2	16.2	16.2
pH		7.75	7.75	7.75	7.75
Conductivity	(micromen)	0.54	0.54	0.54	0.54
TAL Inorganics					
Aluminum	(ug/L)	NA	NA	NA	NA
Antimony	(ug/L)	NA	NA	NA	NA
Arsenic	(ug/L)	NA	NA	NA	NA
Barium	(ug/L)	NA	NA	NA	NA
Beryllium	(ug/L)	NA	NA	NA	NA
Cadmium	(ug/L)	NA	NA	NA	NA
Calcium	(ug/L)	NA	NA	NA	NA
Chromium	(ug/L)	NA	NA	NA	NA
Cobalt	(ug/L)	NA	NA	NA	NA
Copper	(ug/L)	NA	NA	NA	NA
Iron	(ug/L)	NA	NA	NA	NA
Lead	(ug/L)	NA	NA	NA	NA
Magnesium	(ug/L)	NA	NA	NA	NA
Manganese	(ug/L)	NA	NA	NA	NA
Mercury	(ug/L)	NA	NA	NA	NA
Nickel	(ug/L)	NA	NA	NA	NA
Potassium	(ug/L)	NA	NA	NA	NA
Selenium	(ug/L)	NA	NA	NA	NA
Silver	(ug/L)	NA	NA	NA	NA
Sodium	(ug/L)	NA	NA	NA	NA
Thallium	(ug/L)	NA	NA	NA	NA
Vanadium	(ug/L)	NA	NA	NA	NA
Zinc	(ug/L)	NA	NA	NA	NA
Zirconium	(ug/L)	NA	NA	NA	NA
Radionuclides					
Gross Alpha	(pCi/L)	2.3±1.2 J	2.5±1.2	4.6±1.4	1.4±1.3 U
Gross Beta	(pCi/L)	148±3	158±3	151±3	268±4
Tritium	(pCi/L)	5310±260	6130±270	7570±280	15800±400
Sr-90	(pCi/L)	40±1	41±1	42±1	44±1 U
Pu-238	(pCi/L)	ND	ND	ND	ND
Pu-239/240	(pCi/L)	ND	ND	ND	ND
Am-241	(pCi/L)	ND	ND	ND	ND
Np-237	(pCi/L)	ND	ND	ND	ND
I-129	(pCi/L)	0±0.3 U	0±0.3 U	0±0.3 U	0.8±0.3
To-99	(pCi/L)	62±1	23±1	63±1	18±1
U-234	(pCi/L)	ND	ND	ND	ND
U-235	(pCi/L)	ND	ND	ND	ND
U-238	(pCi/L)	ND	ND	ND	ND

NA - not analyzed.

ND - not detected.

NS - not sampled.

U - analyzed, not detected.

B - contaminant in blank.

R - concentration is unusable.

J - estimated concentration.

Table 4-4. (continued).

Well		USGS 47
Date		Jun-95
Sample Depth		596 to 604.8
Sample ID	Units	31341401
Field Parameters		
Temperature	(celsius)	N/A
pH		N/A
Conductivity	(misiemen)	N/A
TAL Inorganics		
Aluminum	(ug/L)	NA
Antimony	(ug/L)	NA
Arsenic	(ug/L)	NA
Barium	(ug/L)	NA
Beryllium	(ug/L)	NA
Cadmium	(ug/L)	NA
Calcium	(ug/L)	NA
Chromium	(ug/L)	NA
Cobalt	(ug/L)	NA
Copper	(ug/L)	NA
Iron	(ug/L)	NA
Lead	(ug/L)	NA
Magnesium	(ug/L)	NA
Manganese	(ug/L)	NA
Mercury	(ug/L)	NA
Nickel	(ug/L)	NA
Potassium	(ug/L)	NA
Selenium	(ug/L)	NA
Silver	(ug/L)	NA
Sodium	(ug/L)	NA
Thallium	(ug/L)	NA
Vanadium	(ug/L)	NA
Zinc	(ug/L)	NA
Zirconium	(ug/L)	NA
Radionuclides		
Gross Alpha	(pCi/L)	4±1.3 U
Gross Beta	(pCi/L)	80±2
Tritium	(pCi/L)	3280±220
Sr-90	(pCi/L)	29±1
Pu-238	(pCi/L)	ND
Pu-239/240	(pCi/L)	ND
Am-241	(pCi/L)	ND
Np-237	(pCi/L)	ND
I-129	(pCi/L)	0±0.3 U
To-99	(pCi/L)	3±1
U-234	(pCi/L)	ND
U-235	(pCi/L)	ND
U-238	(pCi/L)	ND

NA - not analyzed.

ND - not detected.

NS - not sampled.

U - analyzed, not detected.

B - co-contaminant in blank.

R - concentration is unusable.

J - estimated concentration.

Pu-238 was only detected in a single water sample collected from well USGS-48. The sample was collected in October 1990 and had a concentration near the MDL at 0.05 ± 0.02 pCi/L. During 1992–1995, all plutonium measurements at the INEEL were below the reporting level (Bartholomay, 1997). Plutonium was not detected in any of the aquifer wells sampled during the WAG 3 RI field investigation of 1995.

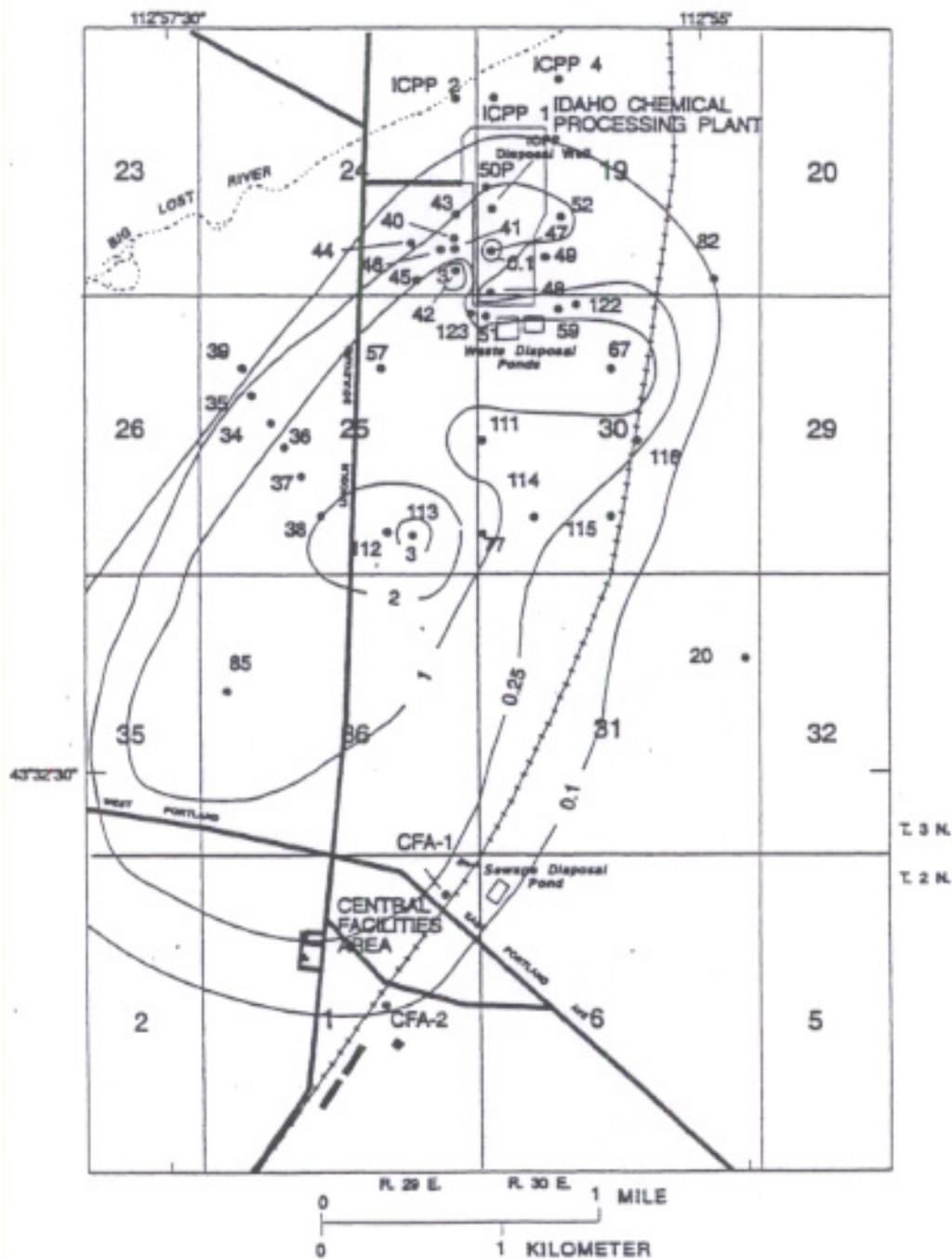
4.3.1.3 Americium-241. Americium-241 is a decay product of Pu-241 and has a half-life of 432.7 years. According to Orr and Cecil (1991), Am-241 has only been detected in the SRPA near the RWMC and TAN. Since 1988, however, Am-241 was detected in well USGS-44 during July 1992 at concentrations of 0.07 ± 0.03 and 0.08 ± 0.03 pCi/L, in well USGS-37 during October 1992 at a concentration of 0.09 ± 0.03 pCi/L, and in well USGS-85 during June 1991 at concentrations of 0.08 ± 0.03 pCi/L. During 1992–1995, all other plutonium measurements were below the reporting level (Bartholomay, 1997). During the WAG 3 RI field investigation in 1995, Am-241 was detected in well USGS-42 at a concentration of 0.54 ± 0.14 pCi/L.

4.3.1.4 Iodine-129. From 1953 to 1983, an estimated 0.01 to 0.136 Ci/yr (0.56 to 1.18 Ci) of I-129 were contained in the waste water discharged to the disposal well (Mann et al., 1988). For 1984 to 1986, the annual amount of I-129 in the waste water discharged to the ICPP percolation ponds ranged from 0.0064 to 0.039 Ci.

Four rounds of groundwater samples (1977, 1981, 1986, and 1990–1991) have been collected by the USGS from the SRPA at the ICPP (Mann and Beasley, 1994). During 1990 through 1991, samples were collected from 50 aquifer wells. Figure 4-13 displays approximate areal extent of groundwater containing greater than 0.1 pCi/L I-129 based on the 1990–1991 sampling results. According to Mann and Beasley (1994), "In 1990–1991 concentrations of I-129 in water samples from wells that obtain water from the Snake River Plain aquifer ranged from 0.0000006 ± 0.0000002 to 3.82 ± 0.19 picocuries per liter (pCi/L). The mean concentration in water from 18 wells was 0.81 ± 0.19 as compared to 1.3 ± 0.26 in 1986." Mann et al. (1988) reported a similar decrease in I-129 groundwater concentrations between the 1981 and 1986 sampling events. Decreases in the I-129 concentration in groundwater at the ICPP are attributed to (1) the decrease in the amount of I-129 disposed annually, (2) a change in the disposal techniques from the disposal well to the percolation ponds, and (3) dilution by infiltration of stream flow from the Big Lost River.

During the WAG 3 RI, I-129 was detected in wells USGS-67, LF2-12, and LF3-08 at concentrations of 1 ± 0.3 pCi/L, 1.2 ± 0.3 pCi/L, and 0.9 ± 0.3 pCi/L, respectively. Two of these wells are located several miles downgradient from the ICPP indicating the contamination is from a historical release rather than an on-going source. The limited amount of I-129 contamination in the aquifer is consistent with the observations made by Mann et al. (1988) where decreasing I-129 concentrations were attributed to decreasing I-129 disposal and the change in disposal techniques. The half-life of I-129 is $1.57E+07$ years.

4.3.1.5 Tritium. A H-3 plume has developed in the SRPA since the 1950s from disposal of liquid wastes at the INEL. The principle sources of H-3 in the aquifer have been through injection of liquid wastes through the disposal well at the ICPP and discharge of waste water to the infiltration ponds at the ICPP and the TRA. It is estimated approximately 30,900 Ci of H-3 have been discharged to the SRPA at the ICPP since 1952 (Orr and Cecil, 1991). Of this amount, approximately 22,200 Ci were discharged via the disposal well at the ICPP. The remainder of the H-3 was discharged to the aquifer via the ICPP percolation ponds.



EXPLANATION

- 1— LINE OF EQUAL IODINE-129 CONCENTRATION—Interval, in picocuries per liter, is variable
- 57 • WELL FROM WHICH WATER SAMPLE FOR IODINE-129 WAS COLLECTED IN 1990-91—Number, 57, is local well identifier; P indicates well obtains water from a perched ground-water zone. See table 2 for iodine-129 concentrations in specific wells

Figure 4-13. I-129 distribution in the SRPA during 1990-1991 (taken from Mann and Beasley, 1994).

According to Orr and Cecil (page 30, 1991), "Tritium concentrations in water from the Snake River Plain aquifer decreased by as much as 39,000 pCi/L during 1986–88. By October 1988, tritium concentrations ranged from 700 ± 200 pCi/L to $61,600 \pm 1,100$ pCi/L and the tritium plume extended southwestward in the general direction of ground-water flow. The size of the plume in which tritium concentrations exceeded 0.5 pCi/mL decreased from about 51 mi² in October 1985 to about 45 mi² in October 1988. The area of the plume containing tritium concentrations in excess of the maximum contaminant level (MCL) of 20,000 pCi/L (EPA 1989, p. 551) decreased from 4.4 to 2.8 mi²." They attributed the reduced concentrations of H-3 and decreased size of the plume to radioactive decay processes, overall reduction in H-3 disposal rates, dilution from recharge, and changes in the disposal methods. Long term radioactive decay processes and an overall decrease in tritium disposal rates have contributed to decreased concentrations and a decrease in the area of the tritium plume at the INEEL during 1992–1995 (Figure 4-14).

The distribution of H-3 in the SRPA for May 1995 is shown in Figure 4-15. The size of the plume that exceeds the federal drinking water standard of 20,000 pCi/L is approximately 3.3 km² (1.3 mi²), significantly smaller than the 7.3 km² (2.8 mi²) reported in October 1988. Using these areas, the distribution of H-3 in May 1995, an aquifer thickness of 76.2 m (250 ft), and an effective porosity of 10% yields approximately 706 Ci of H-3 currently present in the SRPA. This is a rough approximation of high uncertainty due to the assumptions that were necessary for this estimate. Of the 44 aquifer monitoring wells sampled during the WAG 3 RI, water samples from 11 wells exceeded the federal MCL for H-3 of 20,000 pCi/L. H-3 concentrations from these 11 wells was a maximum of 30,700 pCi/L in well USGS-77. Historical H-3 concentrations for the USGS and CPP aquifer wells were provided in the WAG 3 RI/FS Work Plan (INEL-95/0056, Rev. 2).

4.3.1.6 Strontium-90. A plume of Sr-90 has formed downgradient from the ICPP primarily in response to the ICPP disposal well. According to Orr and Cecil (page 32, 1991), "in October 1985, the size of the strontium-90 plume where concentration exceeded 6 pCi/L was about 2 mi² (Pittman et al., 1988, p. 53); the concentrations of strontium-90 in wells 57 and 47 were 74 ± 5 and 63 ± 5 pCi/L, respectively. Strontium concentrations decreased as much as 33 pCi/L during 1986–88. By October 1988, strontium-90 concentrations ranged from 8 ± 2 to 48 ± 3 pCi/L, and the area of the strontium-90 plume had decreased to approximately 0.8 mi². The strontium-90 concentrations in wells 57 and 47, both within the plume, decreased to 41 ± 3 and 48 ± 3 pCi/L, respectively." They attributed the reduced areal extent and concentration of Sr-90 to the diversion of liquid radioactive wastes from the disposal well to the infiltration ponds in addition to radioactive decay, diffusion, dispersion, and dilution from natural recharge. Since 1989, concentrations of Sr-90 in water samples from most wells have remained relatively constant. Figure 4-17 depicts the plume extent for 2, 8, 40 and 70 pCi/L based on the most recent data.

The distribution of Sr-90 in the SRPA for May 1995 is provided in Figure 4-17. The areal extent of the Sr-90 plume has decreased between October 1988 and May 1995, consistent with the previous years' trend. The size of the plume exceeding the federal drinking water standard is approximately 1.6 km² (0.6 mi²). Using the distribution of Sr-90 in May 1995, an aquifer thickness of 76.2 m (250 ft), and an effective porosity of 10% yields approximately 0.27 Ci of Sr-90 currently present in the SRPA. This is a rough approximation of high uncertainty due to the assumptions that were necessary for this estimate. Of the 44 aquifer monitoring wells, water samples from 16 wells exceeded the federal drinking water standard during May 1995 of 8 pCi/L. The maximum Sr-90 concentration detected in the aquifer was 84 pCi/L in well

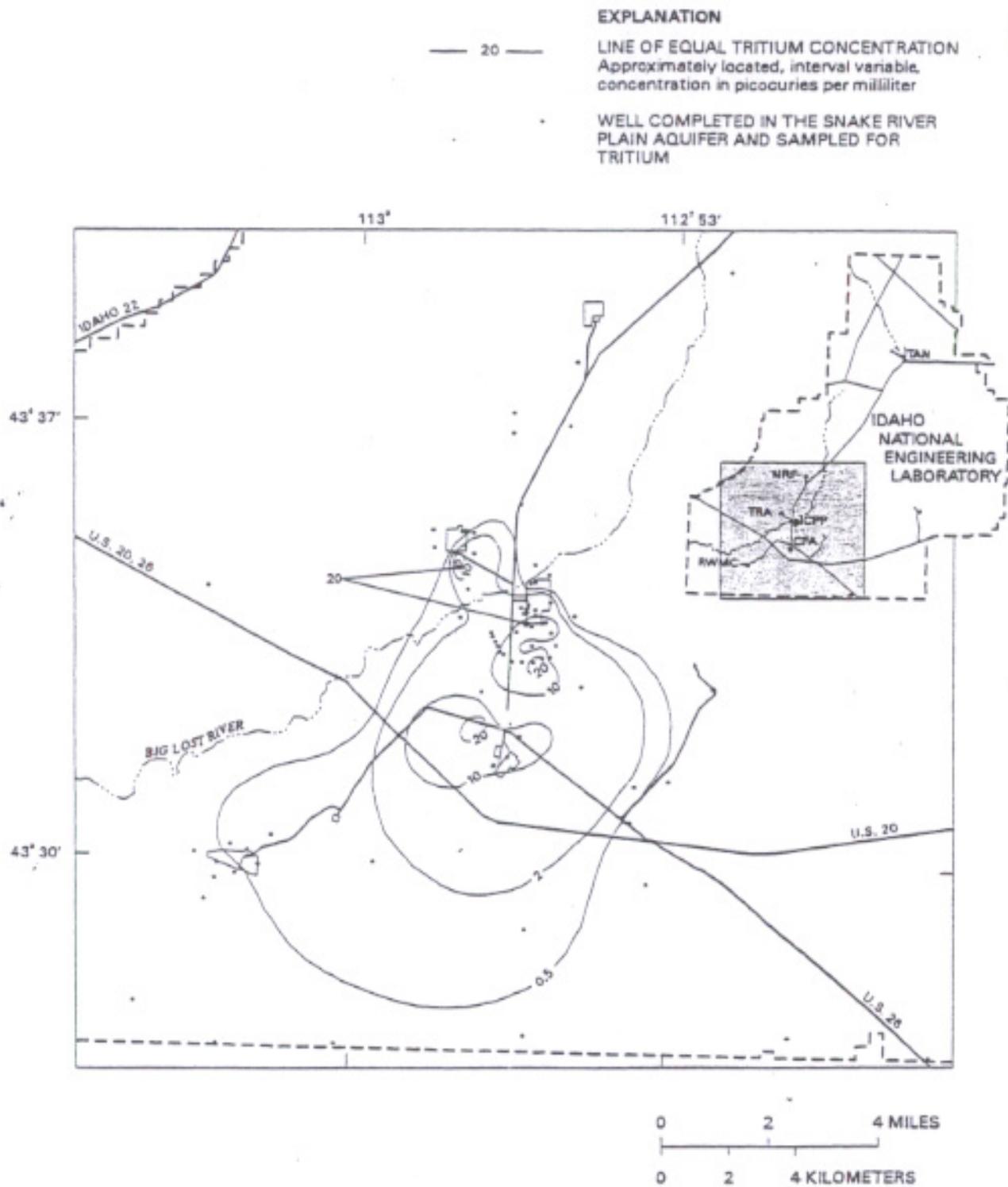


Figure 4-14. H-3 distribution in the SRPA during October 1995 (Bartholomay, 1997).

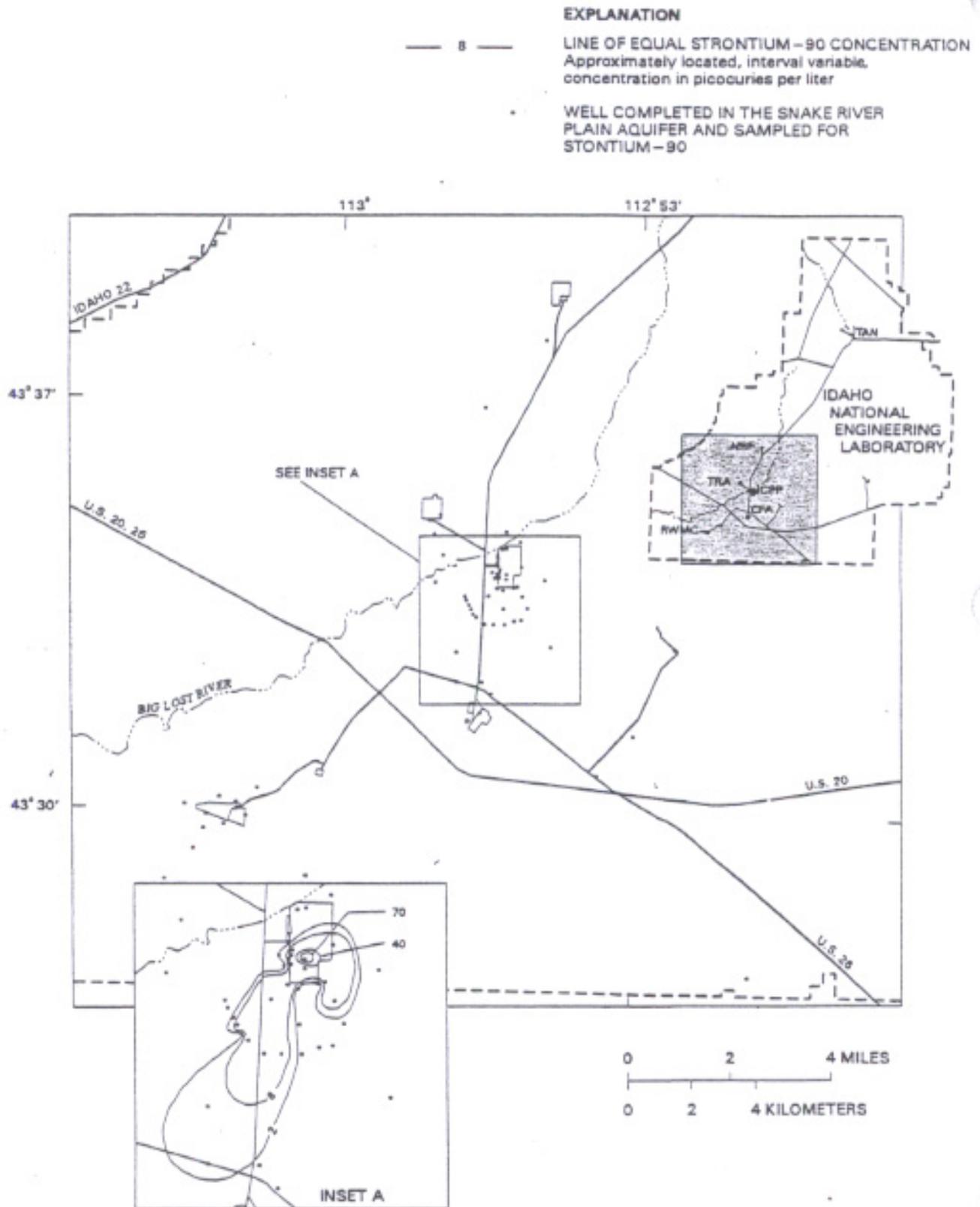


Figure 4-16. Sr-90 distribution in the SRPA during October 1995 (Bartholomay, 1997).

MW-18. Historical Sr-90 concentrations for the USGS and CPP aquifer wells were provided in the WAG 3 RI/FS Work Plan (INEL-95/0056, Rev. 2).

4.3.1.7 Technetium-99. Tc-99 was identified in 32 of the 44 wells sampled during the WAG 3 RI (Figure 4-18). The highest concentration of Tc-99 were identified in the north central portion of the ICPP in wells MW-18, USGS-47, and USGS-52 having concentrations of 448 ± 4 pCi/L, 235 ± 3 pCi/L, and 174 ± 2 pCi/L, respectively. The Tc-99 plume extends to the southwest of the ICPP and includes wells USGS-123, USGS-57, and USGS-39. The maximum Tc-99 concentration outside the ICPP security perimeter fence is 49 pCi/L in well USGS-123.

4.3.1.8 Inorganics. During the WAG 3 RI, water samples were collected from all aquifer wells and analyzed for CLP metals plus zirconium. From the 44 wells tested, only the water sample from well LF2-11 exceeded a federal primary or secondary MCL. The magnesium concentration in LF2-11 was measured at $62.8 \mu\text{g/L}$, compared to a federal secondary MCL of $50 \mu\text{g/L}$. This well is located approximately three miles downgradient from ICPP and since magnesium was not measured in other wells above the federal secondary MCL, this contamination is not likely associated with the ICPP.

4.3.2 Background Concentrations and Regulatory Limits

The established Federal Primary and Secondary Maximum contaminant Levels (MCLs) and background water quality for the SRPA are included in Table 4-5 for inorganic, organic and radionuclides. The background inorganic concentration reported by the USGS in Orr et al. (1991) are for filtered groundwater samples. The Primary MCLs are the maximum permissible levels of contaminants in water delivered from a public water system. The EPA uses MCLs under the Safe Drinking Water Act as reference points for water resource protection efforts when groundwater in question is a potential source of drinking water. The Secondary MCLs control contaminants in drinking water that primarily affect the aesthetic qualities. The Secondary regulations are not Federally enforceable, but are intended as guidelines for the States.

A report by Orr et al. (1991) describes the background concentrations of selected radionuclides, organic compounds, and inorganic chemical constituents in the groundwater from the SRPA in the vicinity of INEL. This report statistically presents the median and mean concentrations for various constituents in the groundwater. This statistical interpretation is based only on sample analyses having reportable concentrations based on the instrument/method detection level. Any analyses that resulted in non-detects for a given constituent were not used for the determination of background concentrations.

4.4 Verification of Source Inventory

At the time of this writing, a number of issues were raised regarding the inventory of contaminants considered in this RI/BRA Report. Specifically, the concern focused on radioactive contaminants that, given the nature of the former reprocessing mission at the ICPP, should be present in areas where HLW solutions have been released to the soil. The presumption is that raffinates produced by the reprocessing of spent U.S. Navy nuclear fuel contains more actinides and activation and fission products than have actually been measured during recent and past field investigations. To help address this concern, the computer code

Table 4-5. Federal drinking water standards and background concentrations for inorganic constituents, organic constituents, and radionuclides.

Inorganic	Federal Primary Drinking Water Standard 40 CFR 141.11 ($\mu\text{g/L}$)	Federal Secondary Drinking Water Standard 40 CFR 143.3 ($\mu\text{g/L}$)	Background ^a ($\mu\text{g/L}$)
Arsenic	50	—	2–3
Barium	1,000	—	50–70
Beryllium	2,000	—	—
Cadmium	10	—	<1
Chromium	50	—	2–3
Chloride	—	250,000	—
Copper	—	1,000	—
Fluoride	4,000	2,000	400–500
Iron	—	300	—
Lead	50	—	5
Manganese	—	50	—
Mercury	2	—	<0.1
Nitrate	10,000	—	<1,400
pH	—	6.5–8.5	—
Selenium	5	—	<1
Silver	—	—	<1
Sulfate	—	250,000	—
TDS	—	500,000	—
Thallium	200	—	—
Zinc	—	5,000	—

a. Background for Snake River Plain Aquifer in the vicinity of INEL. (From Orr et al., 1991)

Table 4-5. (continued).

Organic	Federal Primary Drinking Water Standard 40 CFR 141.12	
	40 CFR 141.61 ($\mu\text{g/L}$)	Background ^a ($\mu\text{g/L}$)
<u>Volatile Organic</u>		
Benzene	5	<0.2
Carbon Tetrachloride	5	<0.2
1,1-Dichloroethylene	7	<0.2
1,2-Dichloroethylene	5	<0.2
para- Dichlorobenzene	75	<0.2
Total trihalomethanes	100 ^b	<0.2
1,1,1- Trichloroethane	200	<0.2
Trichloroethylene	5	<0.2
Vinyl chloride	2	<0.2
<u>Pesticides/Herbicides</u>		
Endrin	0.2	<0.01
Lindane	4	<0.01
Methoxychlor	100	<0.01
Toxaphene	5	<1
2,4-D	100	<0.01
2,4,5-TP Silvex	10	<0.01

a. Background for Snake River Plain Aquifer in the vicinity of INEL (Orr et al., 1991).

b. Sum of the concentrations of bromodichloromethane, Dibromochloromethane, bromoform, and chloroform.

Table 4-5. (continued).

Radionuclide	Federal Primary Drinking Water Standard	
	40 CFR 141.15	Background ^a
	40 CFR 141.16	(pCi/mL)
	(pCi/mL)	
Total Uranium ^b	—	0–0.009
Radium 226 & 228	0.005	<0.005
Radon 222	—	0–0.25
Plutonium 238	—	0
Plutonium 239,240	—	0
Americium 241	—	0
Tritium	20	0.75–0.15
Strontium 90	0.008	0
Iodine 129	—	0–0.00005
Gross alpha ^c	0.015	0–0.005
Man-made beta	Concentration causing 4 mrem/yr total body or organ dose	0–0.008
Cesium 137	—	0
Cobalt 60	—	0

a. Background for Snake River Plain Aquifer in the vicinity of INEL (Orr et al., 1991).

b. Total uranium is the sum of U-234, U-235, and U-238.

c. Gross alpha particle activity excluding radon and uranium.

ORIGEN was used to evaluate the inventory of radioactive contaminants that could be expected in the waste solutions released within several areas at the ICPP. The computer code simulates the activation, actinide, and fission product yields for the fissioning of U-235. Ideally, the composition of the nuclear fuel, cladding material, reactor time, and other information about the Navy spent fuel would need to be known to estimate the inventory and quantities of radionuclides present in the spent fuel. However, this information is sensitive and could not be obtained. The approach used to help address the issue of missing contaminants was to compare the screened results of the ORIGEN code against soil contaminant field measurements and/or assumptions used to estimate sources for use in the groundwater model. As a result, any contaminants identified as potentially missing from source estimates can be explained as uncertainty and the impact it could have on the results of the RI/BRA.

Results from two ORIGEN runs were used to provide a benchmark of the radionuclides that could be present in areas where these waste solutions were released. One of the ORIGEN runs was based on a high enrichment fuel configuration used by Oak Ridge National Laboratory (ORNL) to conduct irradiation and material studies. This ORIGEN run was already available and was developed with assumptions of 93% U-235 fuel enrichment (i.e., 285 grams of U-235 per element), aluminum cladding, 49% fissionable yield (or U-235 "burn-up"), a fissionable period of 234 days, followed by a decay period of 10.8 years. The other ORIGEN run was prepared by personnel familiar with the reprocessing history at the ICPP, especially during the November 1972 release of HLW during a transfer between tanks WM-181 and WM-180, now known as site CPP-31. The assumptions for this run are described in Appendix N of the RI/BRA but include the type of fuel and extraction chemistry being used at that time.

The raw results from both ORIGEN runs each included over 150 different radionuclides. These were reduced to a more manageable number by separately placing the results of each ORIGEN run through a screening step. The technique used is that recommended by EPA in the Risk Assessment Guidance that consists of a toxicity-concentration screen whereby risk factors are calculated for each contaminant, and those having a factor of less than 0.01 can be screened out from further consideration. Since site risks are expected to be high, the factor used in this screen was lowered to 0.0001 or 0.01%. Approximately 25 radionuclides did not have health criteria and could not be evaluated. Normally, these would not screen out; however, their activity relative abundance were very small, ranging between 0.001 to 1E-10% and are not expected to contribute significantly. The contaminants contributing to a relative risk of 99.99% for both ORIGEN runs are shown on Table 4-6. Many of these radioactive contaminants have a half-life of 5 years or less and will decay by a factor of about 1E+06 or more by the year 2095. These are flagged in Table 4-6. Based on the screened results of both ORIGEN runs, the most significant radionuclides at the ICPP would be Sr-90, Cs-137, Eu-154, Am-241, Pu-238, Pu-239, Pu-240, and Pu-241.

The next step in the use of these results was to compare this inventory against what has been measured in the soil, perched water, aquifer, and the source estimates used for the tank farm releases. The purpose of this comparison is to help identify potential data gaps. The results are shown in Table 4-7. For the perched water and SRPA, they indicate that the sampling programs have included those contaminants shown by the screened ORIGEN runs to be of concern. The results of the comparisons with regard to the soil measurements at each site are further discussed in each site-specific section of this document.

Table 4-6. Summary of the results for both ORIGEN simulations.

Simulated Radionuclide Having Risk Factor > 0.01%	Half-Life (years)	Potential Problem	Reason
ORNL Fuel			
Sr-90+D	29.1	Y	
Cs-137+D	30.0	Y	
Cs-134	2.06	N	Half-Life < 5 years
Eu-154	8.6	Y	
Eu-155	4.96	N	Half-Life < 5 years
Ce-144+D	0.8	N	Half-Life < 5 years
Ru-106+D	1.01	N	Half-Life < 5 years
Sb-125+D	2.77	N	Half-Life < 5 years
Pm-147	2.62	N	Half-Life < 5 years
Am-241	432	Y	
Pu-238	87.8	Y	
Pu-239	24,100	Y	
Pu-240	6,570	Y	
Pu-241	14.4	Y	
CPP-31 Release			
Co-60	5.27	N	Half life is within 5% of the screening criteria.
Cs-134	2.06	N	Half-Life < 5 years
Cs-137	30.0	Y	
Eu-154	8.6	Y	
Sb-125+D	2.77	N	Half-Life < 5 years
Sr-90+D	29.1	Y	
Pm-147	2.62	N	Half-Life < 5 years
Am-241	432	Y	
Pu-238	87.8	Y	
Pu-239	24,100	Y	
Pu-240	6,570	Y	
Pu-241	14.4	Y	

Table 4-7. Summary of which nuclides were sampled for in the aquifer, perched water, and contaminated soil sites.

Site	Am-241	Cs-137	Eu-154	Pu-238	Pu-239	Pu-240	Pu-241	Sr-90
Aquifer	X	X	X	X	X	X	X	X
Perched Water	X	X	X	X	X	X	X	X
Soil Sites								
Tank Farm								
CPP-20/-25	X	X	X	X	X	X		X
CPP-26	X	X	X	X	X			X
CPP-28*		X	X		X	X	X	X
CPP-31*	X	X	X		X	X	X	X
CPP-32E/W		X	X					X
CPP-79		X	X		X	X	X	X
Tank Farm South								
CPP-15 - zone 1W	X	X	X	X	X	X		
CPP-15 - zone 1E								
CPP-15 - zone 2								
CPP-27/-33	X	X	X	X	X	X		X
CPP-58E/W	X	X	X	X	X	X		X
WCF								
CPP-35	X	X	X	X	X	X		X
CPP-36/-91 - zone 1	X	X	X	X	X	X		X
CPP-36/-91 - zone 2								
CPP-85		X	X					X
Old Storage Pool								
CPP-01/-04/-05	X	X	X		X	X		X
CPP-08/09		X	X					X
CPP-10		X	X					X
CPP-11	X	X	X	X	X	X		X
Storage Yard East								
CPP-03		X						X
CPP-17A		X	X					X
CPP-17B		X						

Table 4-7. (continued).

Site	Am-241	Cs-137	Eu-154	Pu-238	Pu-239	Pu-240	Pu-241	Sr-90
WAG 3 individual sites								
CPP-06		X						X
CPP-13		X	X					X
CPP-14 Imhoff	X	X		X	X	X		X
CPP-14 Plant	X	X		X	X	X		X
CPP-14 Drain	X	X		X	X	X		X
CPP-19	X	X	X		X	X		X
CPP-22		X	X					X
CPP-34		X		X				X
CPP-37A	X	X		X				X
CPP-37B	X	X		X				X
CPP-67	X	X		X	X	X		X
CPP-89	X	X		X	X	X		X
CPP-90		X	X					X

Notes: "X"s indicate radioactive contaminants that were analyzed for in the various environmental medium. Spaces are blank in this table to indicate radioactive contaminants that have not been part of the sampling program.

a. The CPP-28 (and CPP-79) release estimate for groundwater modeling use was based on release history and not soil data therefore the "X" denotes contaminants included in the gw release. This estimate did not include Am-241 or Pu-238. See Section 9 of Appendix F for a discussion of uncertainty and/or impacts to the simulations from not including these COCs. The same comment applies to only Pu-238 at CPP-31.

4.5 References

- Bartholomay, R. C. et al., 1997, *Hydrologic Conditions and Distribution of Selected Radiochemical and Chemical Constituents in Water, SRPA, INEL, Idaho, 1992 Through 1995*, U. S. Geological Survey, Water-Resources Investigations Report 97-4086, April.
- EPA, 1989, *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A)*, EPA/540/1-1-89/002, December.
- LITCO, 1995, *WAG 3 Comprehensive RI/FS Workplan, Vol. 2*, INEL-95/0056, August.
- Mann, L. J. and T. M. Beasley, 1994, *Iodine-129 in the Snake River Plain Aquifer At and Near the Idaho National Engineering Laboratory, Idaho 1990-91*, U.S. Geological Survey Water-Resources Investigations Report 94-4053, DOE/ID-22115, April.
- Mann, L. et al., 1988, *Iodine-129 in the Snake River Plain Aquifer at the Idaho National Engineering Laboratory*, U.S. Geological Survey Water-Resources Investigations Report 88-4165.
- Mann, L. J. and L. L. Knobel, 1987, *Purgeable Organic Compounds in Ground Water at the Idaho National Engineering Laboratory*, U.S. Geological Survey Open-File Report 87-766.
- Mann, L. J., 1986, *Hydraulic Properties of Rock Units and Chemical Quality of Water for INEL-1; A 10, 365-Foot Deep Test Hole Drilled at the Idaho National Engineering Laboratory, Idaho*, USGS Water-Resources Investigations Report 86-4020, IDO-22070.
- Orr, B. R. and L. D. Cecil, 1991, *Hydrologic Conditions and Distribution of Selected chemical Constituents in Water, Snake River Plain Aquifer, Idaho National Engineering Laboratory, Idaho, 1986 to 1988*, DOE/ID-22096, March.
- Pittman J. R., R. G. Jensen, and P. R. Fischer, 1988, *Hydrologic Conditions at the Idaho National Engineering Laboratory, 1982 to 1985*, DOE/ID-22078, December.
- Robertson, J. B., Robert Schoen, and J. T. Barraclough, 1974, *The Influence of Liquid Waste Disposal on the Geochemistry of Water at the National Reactor Testing Station, 1952-1970*, USGS Open File Report. IDP-22053, TID-4500, February.
- WINCO, 1994, *INEL Integrated Spent Fuel Consolidation Task Team Report*, WINCO-1217.
- WINCO, 1992, *Track 1 Decision Documentation Package, Waste Area Group 3, Operable Unit 2, Site CPP-23, ICPP Injection Well (MAH-FE-PL-304)*, April.
- WINCO, 1990, *Closure Plan for LDU CPP-23 Injection Well*, Report number MAH-FE-PL-304, Document Control Number 000900, March 6.

**HWMA/RCRA INTEC POST-CLOSURE PERMIT
FOR THE
IDAHO NATIONAL LABORATORY**

**Volume 21
Waste Calcining Facility and
CPP-601/627/640**

**Attachment 3
U.S. EPA Region 9
Preliminary Remediation Goals User Guide
October 2002**

Revision Date: August 25, 2011



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105

October 1, 2002

Subject: Region 9 PRGs Table 2002 Update

From: Stanford J. Smucker, Ph.D.
Regional Toxicologist (SFD-8-B)
Technical Support Team

To: PRGs Table Users

With this cover letter, we announce the update to the Region 9 PRGs table for 2002. The PRGs table contains over 600 preliminary remediation goals (PRGs) for contaminants in soil, air, and tap water. Region 9 PRGs are risk-based concentrations that are intended to assist risk assessors and others in initial screening-level evaluations of environmental measurements.

As their name implies, Region 9 PRGs may also be viewed as preliminary cleanup goals for an individual chemical, but in this context, they are best viewed as dynamic and subject to change because they are generic and based on direct contact exposures which may not address site-specific conditions and/or indirect exposure pathways at sites (See Exhibit 1-1 in "Region 9 PRGs Table Users Guide/Technical Background Document"). Also for planning purposes, these human health based PRGs should always be considered in conjunction with ARAR-based PRGs (e.g. MCLs), ecological benchmarks, and "background" conditions before establishing a final cleanup level for a particular site.

You can find the PRGs 2002 table, InterCalc tables, "Region 9 PRGs Table Users Guide/Technical Background Document", and additional helpful toxicological and risk assessment information at:

<http://www.epa.gov/region09/waste/sfund/prg/> .

We view risk-based PRGs as "evergreen". Ongoing changes to the PRGs reflect continuing improvements in our scientific knowledge base and state-of-the-art approaches to risk assessment. In the new *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites* (Supplemental SSL Guidance, EPA 2001a), two different soil ingestion rates are assumed for non-construction workers: 100 mg/day is assumed for outdoor workers whereas 50 mg/day is assumed for indoor workers. The default value of 100 mg/day for outdoor workers is also recommended by EPA's Technical Review Workgroup for Lead (TRW), and it reflects increased exposures to soils for outdoor workers relative to their indoor counterparts. For more on this, please see Section 4.1 of the "Region 9 PRGs Table Users Guide/Technical Background Document" or refer to the Supplemental SSL Guidance available at the following website:

<http://www.epa.gov/superfund/resources/soil/index.htm>

Because the Region 9 PRGs are generic and intended for screening sites early in the investigation process (often before site-specific information is available), we have chosen to use the 100 mg/day soil ingestion (i.e. outdoor worker) assumption to calculate industrial soil PRGs. Please note that previous issues of the Region 9 PRGs table assumed 50 mg/day soil ingestion rate for workers. This change in soil ingestion rates is reflected in a somewhat lower (more stringent) industrial soils PRG for many contaminants. The appropriateness of this assumption for a particular site may be evaluated when additional information becomes available regarding site conditions or site development.

In addition to changes in exposure factor assumptions, several chemicals have new or revised toxicity values that results in changes to the PRG calculations. To facilitate the users review, chemicals with new and revised toxicological criteria are presented in bold in the 2002 table and also listed here for convenience: **acetonitrile, benzyl chloride, boron, bromate, 1,3-butadiene, 1-butanol, butylbenzenes, cacodylic acid, cadmium (California State value), chloroform, chloronitrobenzenes, chrysene (California State value), cobalt, 1,2-dibromo-3-chloropropane (California State value), 1,1-dichloroethylene, diethylene glycol ethers, diethylformamide, dinitrobenzenes, di-n-octyl phthalate, diphenyl sulfone, ethylbenzene, HCH, hexachlorocyclopentadiene, kepone, lead (California State value), MTBE, 2-nitroaniline, carcinogenic PAHs, perchlorate, polychlorinated terphenyls, benzo(k)fluoranthene (California State value), propylbenzene, propylene glycol, quinoline, tetrachloroethylene, tetrahydrofuran, thiocyanate, 1,1,1-trichloroethane, trichloroethylene, 2,4,6-trichlorophenol, 1,2,3-trichloropropane, triphenylphosphine oxide, tris(2-chloroethyl) phosphate, vinyl chloride, and xylene.**

Also in this update to the “Region 9 PRGs Table User’s Guide/Technical Background Document”, we have added a brief discussion of special case chemicals for which an alternate approach was applied in the derivation of the Region 9 PRGs (Section 2.3). Increasingly, chemical-specific approaches are being used that do not lend themselves to a single PRG model. Special case chemicals that are discussed include: cadmium, chromium 6, lead, manganese, nitrate/nitrite, thallium, and vinyl chloride.

Finally it should be recognized by all that use the PRGs table that not all PRG values in the table are “created equal”. For some chemicals, a robust data set exists upon which the toxicological criteria are based whereas for others, there may be relatively few studies that form the basis of the PRG calculation. Also, PRGs for some chemicals are based on withdrawn toxicity values or route-extrapolated values. Withdrawn and route-extrapolated numbers are shown in the table because we still need to deal with these contaminants during the long delays before replacement numbers are ready. Please consult with your toxicologist or agency risk assessor to best address potential uncertainties associated with chemical-specific PRGs, especially if the chemical is a risk driver at your site.

As with any risk-based tool, there exists the potential for misuse. We try to highlight potential problems in Section 3.8. However, it should be noted that the use of PRGs at a particular site becomes the responsibility of the user. It is recommended that the user verify the numbers with an agency toxicologist or risk assessor because the toxicity / exposure information in the table may contain errors or default assumptions that need to be refined based on further evaluation. If you find an error please send me a note via email at smucker.stan@epa.gov.

DISCLAIMER

Preliminary remediation goals (PRGs) focus on common exposure pathways and may not consider all exposure pathways encountered at CERCLA / RCRA sites (Exhibit 1-1). PRGs do not consider impact to groundwater or address ecological concerns. The PRG table is specifically not intended as a (1) stand-alone decision-making tool, (2) as a substitute for EPA guidance for preparing baseline risk assessments, (3) a rule to determine if a waste is hazardous under RCRA, or (4) set of final cleanup or action levels to be applied at contaminated sites.

The guidance set out in this document is not final Agency action. It is not intended, nor can it be relied upon to create any rights enforceable by any party in litigation with the United States. EPA officials may decide to follow the guidance provided herein, or act at variance with the guidance, based on an analysis of specific circumstances. The Agency also reserves the right to change this guidance at any time without public notice.

1.0 INTRODUCTION

Region 9 Preliminary Remediation Goals (PRGs) are risk-based tools for evaluating and cleaning up contaminated sites. They are being used to streamline and standardize all stages of the risk decision-making process.

The Region 9 PRG table combines current EPA toxicity values with "standard" exposure factors to estimate contaminant concentrations in environmental media (soil, air, and water) that the agency considers protective of humans (including sensitive groups), over a lifetime. Chemical concentrations above these levels would not automatically designate a site as "dirty" or trigger a response action. However, exceeding a PRG suggests that further evaluation of the potential risks that may be posed by site contaminants is appropriate. Further evaluation may include additional sampling, consideration of ambient levels in the environment, or a reassessment of the assumptions contained in these screening-level estimates (e.g. appropriateness of route-to-route extrapolations, appropriateness of using chronic toxicity values to evaluate childhood exposures, appropriateness of generic exposure factors for a specific site etc.).

The PRG concentrations presented in the table can be used to screen pollutants in environmental media, trigger further investigation, and provide an initial cleanup goal if applicable. When considering PRGs as cleanup goals, residential concentrations should be used for maximum beneficial uses of a property. Industrial concentrations are included in the table as an alternative cleanup goal for soils. **In general, it recommended that industrial PRGs not be used for screening sites unless they are used in conjunction with residential values.**

Before applying PRGs as screening tools or initial goals, the user of the table should consider whether the exposure pathways and exposure scenarios at the site are fully accounted for in the PRG calculations. Region 9 PRG concentrations are based on direct contact pathways for which generally accepted methods, models, and assumptions have been developed (i.e. ingestion, dermal contact, and inhalation) for specific land-use conditions and do not consider impact to groundwater or ecological receptors (see Developing a Conceptual Site Model below).

**EXHIBIT 1-1
TYPICAL EXPOSURE PATHWAYS BY MEDIUM
FOR RESIDENTIAL AND INDUSTRIAL LAND USES^a**

EXPOSURE PATHWAYS, ASSUMING:		
MEDIUM	RESIDENTIAL LAND USE	INDUSTRIAL LAND USE
Ground Water	<i>Ingestion from drinking</i>	Ingestion from drinking
	<i>Inhalation of volatiles</i>	Inhalation of volatiles
	Dermal absorption from bathing	Dermal absorption
Surface Water	<i>Ingestion from drinking</i>	Ingestion from drinking
	<i>Inhalation of volatiles</i>	Inhalation of volatiles
	Dermal absorption from bathing	Dermal absorption
	Ingestion during swimming	
	Ingestion of contaminated fish	
Soil	<i>Ingestion</i>	<i>Ingestion</i>
	<i>Inhalation of particulates</i>	<i>Inhalation of particulates</i>
	<i>Inhalation of volatiles</i>	<i>Inhalation of volatiles</i>
	Exposure to indoor air from soil gas	Exposure to indoor air from soil gas
	Exposure to ground water contaminated by soil leachate	Exposure to ground water contaminated by soil leachate
	Ingestion via plant, meat, or dairy products	Inhalation of particulates from trucks and heavy equipment
	<i>Dermal absorption</i>	<i>Dermal absorption</i>

Footnote:

^aExposure pathways considered in the PRG calculations are indicated in boldface italics.

2.0 READING THE PRG TABLE

2.1 General Considerations

With the exceptions described below, PRGs are chemical concentrations that correspond to fixed levels of risk (i.e. either a one-in-one million [10^{-6}] cancer risk or a noncarcinogenic hazard quotient of 1) in soil, air, and water. In most cases, where a substance causes both cancer and noncancer (systemic) effects, the 10^{-6} cancer risk will result in a more stringent criteria and consequently this value is presented in the printed copy of the table. PRG concentrations that equate to a 10^{-6} cancer risk are indicated by "ca". PRG concentrations that equate to a hazard quotient of 1 for noncarcinogenic concerns are indicated by "nc".

If the risk-based concentrations are to be used for site screening, it is recommended that both cancer and noncancer-based PRGs be used. Both carcinogenic and noncarcinogenic values may be obtained at the Region 9 PRG homepage at:

<http://www.epa.gov/region09/waste/sfund/prg/>

It has come to my attention that some users have been multiplying the cancer PRG concentrations by 10 or 100 to set "action levels" for triggering remediation or to set less stringent cleanup levels for a specific site after considering non-risk-based factors such as ambient levels, detection limits, or technological feasibility. This risk management practice recognizes that there may be a range of values that may be "acceptable" for carcinogenic risk (EPA's risk management range is one-in-a-million [10^{-6}] to one-in-ten thousand [10^{-4}]). However, this practice could lead one to overlook serious noncancer health threats and it is strongly recommended that the user consult with a toxicologist or regional risk assessor before doing this. For carcinogens, I have indicated by asterisk ("ca*") in the PRG table where the noncancer PRGs would be exceeded if the cancer value that is displayed is multiplied by 100. Two stars ("ca**") indicate that the noncancer values would be exceeded if the cancer PRG were multiplied by 10. There is no range of "acceptable" noncarcinogenic "risk" so that under no circumstances should noncancer PRGs be multiplied by 10 or 100, when setting final cleanup criteria. In the rare case where noncancer PRGs are more stringent than cancer PRGs set at one-in-one-million risk, a similar approach has been applied (e.g. "nc**").

In general, PRG concentrations in the printed table are risk-based but for soil there are two important exceptions: (1) for several volatile chemicals, PRGs are based on the soil saturation equation ("sat") and (2) for relatively less toxic inorganic and semivolatile contaminants, a non-risk based "ceiling limit" concentration is given as 10^{+5} mg/kg ("max"). At the Region 9 PRG website, the risk-based calculations for these same chemicals are also available in the "InterCalc Tables" if the user wants to view the risk-based concentrations prior to the application of "sat" or "max". For more information on why the "sat" value and not a risk-based value is presented for several volatile chemicals in the PRGs table, please see the discussion in Section 4.5.

With respect to applying a "ceiling limit" for chemicals other than volatiles, it is recognized that this is not a universally accepted approach. Some within the agency argue that all values should be risk-based to allow for scaling (for example, if the risk-based PRG is set at a hazard quotient = 1.0, and the user would like to set the hazard quotient to 0.1 to take into account multiple chemicals, then this is as simple as multiplying the risk-based PRG by 1/10th). If scaling is necessary, PRG users can do

this simply by referring to the “InterCalc Tables” at our website where risk-based soil concentrations are presented for all chemicals (see soil calculations, “combined” pathways column).

In spite of the fact that applying a ceiling limit is not a universally accepted approach, we have opted to continue applying a “max” soil concentration to the PRGs table for the following reasons:

- Risk-based PRGs for some chemicals in soil exceed unity (>1,000,000 mg/kg) which is not possible.
- The ceiling limit of 10^{+5} mg/kg is equivalent to a chemical representing 10% by weight of the soil sample. At this contaminant concentration (and higher), the assumptions for soil contact may be violated (for example, soil adherence and windborne dispersion assumptions) due to the presence of the foreign substance itself.
- PRGs currently do not address short-term exposures (e.g. pica children and construction workers). Although extremely high soil PRGs are likely to represent relatively non-toxic chemicals, such high values may not be justified if in fact more toxicological data were available for evaluating short-term and/or acute exposures.

In addition to Region 9 PRG values, the PRGs table also includes California EPA PRGs ("CAL-Modified PRGs") for specific chemicals where CAL-EPA screening values may be “significantly” more restrictive than the federal values (see Section 2.4) and EPA OSWER soil screening levels (SSLs) for protection of groundwater (see Section 2.5).

2.2 Toxicity Values

Hierarchy of Toxicity Values

EPA toxicity values, known as noncarcinogenic reference doses (RfD) and carcinogenic slope factors (SF) were obtained from IRIS, NCEA through September 2002, and HEAST (1997). The priority among sources of toxicological constants in order of preference is as follows: (1) IRIS (indicated by "i"), (2) NCEA ("n"), (3) HEAST ("h"), (4) withdrawn from IRIS or HEAST and under review ("x") or obtained from other EPA documents (“o”). This hierarchy is subject to change once the HEAST tables are updated.

Inhalation Conversion Factors

As of January 1991, IRIS and NCEA databases no longer present RfDs or SFs for the inhalation route. These criteria have been replaced with reference concentrations (RfC) for noncarcinogenic effects and unit risk factors (URF) for carcinogenic effects. However, for purposes of estimating risk and calculating risk-based concentrations, inhalation reference doses (RfDi) and inhalation slope factors (SF_i) are preferred. This is not a problem for most chemicals because the inhalation toxicity criteria are easily converted. To calculate an RfDi from an RfC, the following equation and assumptions may be used for most chemicals:

$$\text{RfDi} \frac{\text{mg}}{(\text{kg} \cdot \text{day})} = \text{RfC} (\text{mg} / \text{m}^3) \times \frac{20\text{m}^3}{\text{day}} \times \frac{1}{70\text{kg}}$$

Likewise, to calculate an SF_i from an inhalation URF, the following equation and assumptions may be used:

$$SF_i \frac{(\text{kg} \cdot \text{day})}{(\text{mg})} = \text{URF} (\text{m}^3 / \text{ug}) \times \frac{\text{day}}{20\text{m}^3} \times 70\text{kg} \times \frac{10^3 \text{ ug}}{\text{mg}}$$

Substances with New or Withdrawn Toxicity Values

To help users rapidly identify substances with new or revised toxicity values, these chemicals are listed in boldface type in the PRGs table. This issue of the table contains new or revised toxicity values for: **acetonitrile, benzyl chloride, boron, bromate, 1,3-butadiene, 1-butanol, butylbenzenes, cacodylic acid, cadmium (California State value), chloroform, chloronitrobenzenes, chrysene (California State value), cobalt, 1,2-dibromo-3-chloropropane (California State value), 1,1-dichloroethylene, diethylene glycol ethers, diethylformamide, dinitrobenzenes, di-n-octyl phthalate, diphenyl sulfone, ethylbenzene, HCH, hexachlorocyclopentadiene, kepone, lead (California State value), MTBE, 2-nitroaniline, carcinogenic PAHs, perchlorate, polychlorinated terphenyls, benzo(k)fluoranthene (California State value), propylbenzene, propylene glycol, quinoline, tetrachloroethylene, tetrahydrofuran, thiocyanate, 1,1,1-trichloroethane, trichloroethylene, 2,4,6-trichlorophenol, 1,2,3-trichloropropane, triphenylphosphine oxide, tris(2-chloroethyl) phosphate, vinyl chloride, and xylene.**

Chemicals that have been delisted because they are outdated, undocumented, or derived from a data base other than IRIS, HEAST or NCEA include: acifluorfen, 4-bromophenyl phenyl ether, chloroacetaldehyde, 2-chloroethyl vinyl ether, hexachlorodibenzo-p-dioxin mixture (HxCDD), maneb, methyl chlorocarbonate, nitrapyrin, nitric oxide, and 4-nitrophenol.

Route-to-Route Methods

Route-to-route extrapolations ("r") were frequently used when there were no toxicity values available for a given route of exposure. Oral cancer slope factors ("SFo") and reference doses ("RfDo") were used for both oral and inhaled exposures for organic compounds lacking inhalation values. Inhalation slope factors ("SF_i") and inhalation reference doses ("RfDi") were used for both inhaled and oral exposures for organic compounds lacking oral values. Route extrapolations were not performed for inorganics due to portal of entry effects and known differences in absorption efficiency for the two routes of exposure.

An additional route extrapolation is the use of oral toxicity values for evaluating dermal exposures. For many chemicals, a scientifically defensible data base does not exist for making an adjustment to the oral slope factor/RfD to estimate a dermal toxicity value. Based on the current guidance (USEPA 2001b), the only chemical for which an adjustment is recommended is cadmium. An oral absorption efficiency of 5% is assumed for cadmium which leads to an estimated dermal reference dose (RfDd) of 2.5E-05 that was used in the soil PRG calculations for cadmium.

Although route-to-route methods may be a useful screening procedure, the appropriateness of these default assumptions for specific contaminants should be verified by a toxicologist or regional risk assessor. Please note that whenever route-extrapolated values are used to calculate risk-based PRGs, additional uncertainties are introduced in the calculation.

2.3 Region 9 PRGs Derived with Special Considerations

Most of the Region 9 PRGs are readily derived by referring to Equations 4-1 thru 4-8 contained in this “User’s Guide/Technical Background Document” to the Region 9 PRGs. However, there are some chemicals for which the standard equations do not apply and/or adjustments to the toxicity values are recommended. These special case chemicals are discussed below.

Cadmium The PRGs for Cadmium are based on the oral RfD for water which is slightly more conservative (by a factor of 2) than the RfD for food. Because the PRGs are considered screening values, we elected to use the more conservative RfD for cadmium. However, reasonable arguments could be made for applying an RfD for food (instead of the oral RfD for water) for some media such as soils.

The water RfD for cadmium assumes a 5% oral absorption factor. The assumption of an oral absorption efficiency of 5% for Cadmium leads to an estimated dermal RfD of 2.5E-05. The PRG calculations incorporate these adjustments per recent guidance (USEPA 2001b).

Chromium 6 For Chromium 6 (Cr6), IRIS shows an air unit risk of 1.2E-2 per (ug/cu.m) or expressed as an inhalation cancer slope factor (adjusting for inhalation/body weight) of 42 (mg/kg-day)⁻¹. However, the supporting documentation in the IRIS file states that these toxicity values are based on an assumed 1:6 ratio of Cr6:Cr3. Because of this assumption, we in Region 9 prefer to present PRGs based on these cancer toxicity values as “total chromium” numbers.

In the PRG tables, we also include a Cr6 specific value (assuming 100% Cr6) that is derived by multiplying the “total chromium” value by 7, yielding a cancer potency factor of 290 (mg/kg-day)⁻¹. This is considered to be an overly conservative assumption by some within the Agency. However, this calculation is also consistent with the State of California's interpretation of the Mancuso study that forms the basis of Cr6's toxicity values.

If you are working on a project outside of California (and outside of Region 9), you may want to contact the appropriate regulatory officials to determine what their position is on this issue. As mentioned, Region 9 also includes PRGs for “total chromium” which is based on the same ratio (1:6 ratio Cr6:Cr3) that forms the basis of the cancer slope factor of 42 (mg/kg-day)⁻¹ presented in IRIS.

Lead Residential PRGs for Lead (Region 9 EPA and California EPA) are derived based on pharmacokinetic models. Both EPA’s Integrated Exposure Uptake Biokinetic (IEUBK) Model and California’s LeadSpread model are designed to predict the probable blood lead concentrations for children between six months and seven years of age who have been exposed to lead through various sources (air, water, soil, dust, diet and *in utero* contributions from the mother). Run in the reverse, these models also allow the user to calculate lead PRGs that are considered “acceptable” by EPA or the State of California.

The California LeadSpread model can also estimate PRGs for non-residential exposures (e.g. worker) whereas EPA uses a second Adult Lead Model to estimate PRGs for an industrial setting.

For more information on EPA’s Lead models used to estimate residential and industrial PRGs, please refer to the following website:

<http://www.epa.gov/oerrpage/superfund/programs/lead/>

For more information on California's LeadSpread Model and Cal-Modified PRGs for lead, please go to:

<http://www.dtsc.ca.gov/ScienceTechnology/ledspred.html>

Manganese The IRIS RfD (0.14 mg/kg-day) includes manganese from all sources, including diet. The author of the IRIS assessment for manganese recommends that the dietary contribution from the normal U.S. diet (an upper limit of 5 mg/day) be subtracted when evaluating non-food (e.g. drinking water or soil) exposures to manganese, leading to a RfD of 0.071 mg/kg-day for non-food items. The explanatory text in IRIS further recommends using a modifying factor of 3 when calculating risks associated with non-food sources due to a number of uncertainties that are discussed in the IRIS file for manganese, leading to a RfD of 0.024 mg/kg-day. This modified RfD is applied in the derivation of the Region 9 PRGs for soil and water. For more information regarding the Manganese RfD, you may want to contact Dr. Bob Benson at (303) 312-7070.

Nitrates/Nitrites Tap water PRGs for Nitrates/Nitrites are based on the MCL as there is no available RfD for these compounds. For more information, please see IRIS at:

<http://www.epa.gov/iriswebp/iris/index.html>

Thallium IRIS has many values for the different salts of thallium. However, our analytical data packages typically report "thallium". Therefore, as a practical matter it makes more sense to report a PRG for plain thallium. We have done this by making the adjustment contained in the IRIS file for thallium sulfate based on the molecular weight of the thallium in the thallium salt. The adjusted oral RfD for plain thallium is 6.6 E-05 mg/kg-day which we use to calculate a thallium PRG.

Vinyl Chloride In EPA's recent reassessment of vinyl chloride toxicity, IRIS presents two cancer slope factors for vinyl chloride (VC): one that is intended to be applied towards evaluating adult risks and a second more protective slope factor that takes into account the unique susceptibility of developing infants and young children. For residential PRGs, the Region 9 PRGs table applies the more conservative cancer potency factor that addresses exposures to both children and adults whereas for the industrial soils PRG, the adult only cancer slope factor is applied.

Because of the age-dependent vulnerability associated with vinyl chloride exposures, and due to the method that is applied in deriving the cancer slope factor for VC, an assumption of a 70 year exposure over the lifetime is assumed, consistent with the way that the toxicity value for VC was derived. Therefore, instead of the usual exposure assumption of 6 years as a child and 24 years as an adult that is assumed for carcinogenic substances, we have revised the exposure assumption for VC to 6 years as a child and 64 years as adult. Since most of the cancer risk is associated with the first 30 years of exposure to VC, there is actually little difference between a 30 year exposure assumption (typically assumed for Superfund risk assessments) and the 70 year exposure assumption that is assumed in calculating the PRG for VC.

2.4 "Cal-Modified PRGs"

When EPA Region 9 first came out with a Draft of the PRGs table in 1992, there was concern expressed by California EPA's Department of Toxic Substances and Control (DTSC) that for some chemicals the risk-based concentrations calculated using Cal-EPA toxicity values were "significantly" more protective than the risk-based PRGs calculated by Region 9. At an interagency meeting

comprised of mostly toxicologists, it was agreed that PRG values are at best order-of-magnitude estimates, so that if we assume a logarithmic scale, then a difference greater than 3.3 ($\frac{1}{2}$ log above or below) would be considered a significant difference. Therefore, for individual chemicals where California PRG values are significantly more protective than Region 9 EPA PRGs, Cal-Modified PRGs are included in the Region 9 PRGs table. For more information on Cal-Modified PRGs, the reader may want to contact Dr. Michael Wade in Cal-EPA's Department of Toxic Substances (DTSC) at (916) 255-6653.

Please note that in the State of California, Cal-Modified PRGs should be used as screening levels for contaminated sites because they are more stringent than the Federal numbers.

2.5 Soil Screening Levels

Generic, soil screening levels (SSLs) for the protection of groundwater have been included in the PRG table for 100 of the most common contaminants at Superfund sites. Generic SSLs are derived using default values in standardized equations presented in EPA OSWER's *Soil Screening Guidance* series, available on the web at <http://www.epa.gov/superfund/resources/soil/index.htm>.

The SSLs were developed using a default dilution-attenuation factor (DAF) of 20 to account for natural processes that reduce contaminant concentrations in the subsurface. Also included are generic SSLs that assume no dilution or attenuation between the source and the receptor well (i.e., a DAF of 1). These values can be used at sites where little or no dilution or attenuation of soil leachate concentrations is expected at a site (e.g., sites with shallow water tables, fractured media, karst topography, or source size greater than 30 acres).

In general, if an SSL is not exceeded for the migration to groundwater pathway, the user may eliminate this pathway from further investigation.

It should be noted that in the State of California, the California Regional Water Quality Control Board has derived "California SSLs" for a number of pathways including migration to groundwater. These are not included in the Region 9 PRGs table, but may be accessed at the following website:

<http://www.swrcb.ca.gov/rwqcb2/rbsl.htm>

Or, for more information on the "California SSLs", please contact Dr Roger Brewer at: (510) 622-2374.

2.6 Miscellaneous

Volatile organic compounds (VOCs) are indicated by "1" in the VOC column of the table and in general, are defined as those chemicals having a Henry's Law constant greater than 10^{-5} (atm-m³/mol) and a molecular weight less than 200 g/mole). Three borderline chemicals (dibromochloromethane, 1,2-dibromochloropropane, and pyrene) which do not strictly meet these criteria of volatility have also been included based upon discussions with other state and federal agencies and after a consideration of vapor pressure characteristics etc. Volatile organic chemicals are evaluated for potential volatilization from soil/water to air using volatilization factors (see Section 4.1).

Chemical-specific dermal absorption values for contaminants in soil and dust are presented for arsenic, cadmium, chlordane, 2,4-D, DDT, lindane, TCDD, PAHs, PCBs, and pentachlorophenols as recommended in the “Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Interim Guidance” (USEPA 2001b). Otherwise, default skin absorption fractions are assumed to be 0.10 for nonvolatile organics. Please note that previous defaults of 0.01 and 0.10 for inorganics and VOCs respectively, have been withdrawn per new guidance.

3.0 USING THE PRG TABLE

The decision to use PRGs at a site will be driven by the potential benefits of having generic risk-based concentrations in the absence of site-specific risk assessments. The original intended use of PRGs was to provide initial cleanup goals for individual chemicals given specific medium and land-use combinations (see RAGS Part B, 1991), however risk-based concentrations have several applications. They can also be used for:

- Setting health-based detection limits for chemicals of potential concern
- Screening sites to determine whether further evaluation is appropriate
- Calculating cumulative risks associated with multiple contaminants

A few basic procedures are recommended for using PRGs properly. These are briefly described below. Potential problems with the use of PRGs are also identified.

3.1 Developing a Conceptual Site Model

The primary condition for use of PRGs is that exposure pathways of concern and conditions at the site match those taken into account by the PRG framework. Thus, it is always necessary to develop a conceptual site model (CSM) to identify likely contaminant source areas, exposure pathways, and potential receptors. This information can be used to determine the applicability of PRGs at the site and the need for additional information. For those pathways not covered by PRGs, a risk assessment specific to these additional pathways may be necessary. Nonetheless, the PRG lookup values will still be useful in such situations for focusing further investigative efforts on the exposure pathways not addressed.

To develop a site-specific CSM, perform an extensive records search and compile existing data (e.g. available site sampling data, historical records, aerial photographs, and hydrogeologic information). Once this information is obtained, CSM worksheets such as those provided in ASTM's *Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites* (1995) can be used to tailor the generic worksheet model to a site-specific CSM. The final CSM diagram represents linkages among contaminant sources, release mechanisms, exposure pathways and routes and receptors. It summarizes our understanding of the contamination problem.

As a final check, the CSM should answer the following questions:

- Are there potential ecological concerns?
- Is there potential for land use other than those covered by the PRGs (that is, residential and industrial)?

- Are there other likely human exposure pathways that were not considered in development of the PRGs (e.g. impact to groundwater, local fish consumption, raising beef, dairy, or other livestock)?
- Are there unusual site conditions (e.g. large areas of contamination, high fugitive dust levels, potential for indoor air contamination)?

If any of these four conditions exist, the PRG may need to be adjusted to reflect this new information. Suggested websites for the evaluation of pathways not currently addressed by Region 9 PRG's are presented in Exhibit 3-1.

**EXHIBIT 3-1
SUGGESTED WEBSITES FOR EVALUATING EXPOSURE
PATHWAYS NOT CURRENTLY ADDRESSED BY REGION 9 PRGs**

EXPOSURE PATHWAY	WEBSITE
Migration of contaminants to an underlying potable aquifer	EPA Soil Screening Guidance: http://www.epa.gov/superfund/resources/soil/index.htm California Water Board Guidance: http://www.swrcb.ca.gov/rwqcb2/rbsl.htm
Ingestion via plant uptake	EPA Soil Screening Guidance: http://www.epa.gov/superfund/resources/soil/index.htm EPA Fertilizer Risk Assessment: http://www.epa.gov/epaoswer/hazwaste/recycle/fertiliz/risk/
Ingestion via meat, dairy products, human milk	EPA Protocol for Combustion Facilities: http://www.epa.gov/epaoswer/hazwaste/combust/riskvol.htm#volume1 California "Hot Spots" Risk Guidelines: http://www.oehha.ca.gov/air/hot_spots/HRSguide.html
Inhalation of volatiles that have migrated into basements or other enclosed spaces.	EPA's Version of Johnson & Ettinger Model: http://www.epa.gov/oerrpage/superfund/programs/risk/airmodel/johnson_ettinger.htm
Ecological pathways	EPA Ecological Soil Screening Guidance: http://www.epa.gov/superfund/programs/risk/ecorisk/ecossl.htm NOAA Sediment Screening Table: http://response.restoration.noaa.gov/cpr/sediment/squirt/squirt.html

3.2 Background Levels Evaluation

A necessary step in determining the applicability of Region 9 risk-based PRGs is the consideration of background contaminant concentrations. There is new EPA guidance on determining background at sites. *Guidance for Characterizing Background Chemicals in Soil at Superfund Sites* (USEPA 2001c) is available on the web at: <http://www.epa.gov/superfund/programs/risk/background.pdf>.

EPA may be concerned with two types of background at sites: naturally occurring and anthropogenic. Natural background is usually limited to metals whereas anthropogenic (i.e. human-made) “background” includes both organic and inorganic contaminants. Before embarking on an extensive sampling and analysis program to determine local background concentrations in the area, one should first compile existing data on the subject. Far too often there is pertinent information in the literature that gets ignored, resulting in needless expenditures of time and money.

Generally EPA does not clean up below natural background. In some cases, the predictive risk-based models generate PRG levels that lie within or even below typical background. If natural background concentrations are higher than the risk-based PRGs, an adjustment of the PRG is probably needed. Exhibit 3-2 presents summary statistics for selected elements in soils that have background levels that may exceed risk-based PRGs. An illustrative example of this is naturally occurring arsenic in soils which frequently is higher than the risk-based concentration set at a one-in-one-million cancer risk (the PRG for residential soils is 0.39 mg/kg). After considering background concentrations in a local area, EPA Region 9 has at times used the non-cancer PRG (22 mg/kg) to evaluate sites recognizing that this value tends to be above background levels yet still falls within the range of soil concentrations (0.39-39 mg/kg) that equates to EPA’s “acceptable” cancer risk range of 10E-6 to 10E-4.

Where anthropogenic “background” levels exceed PRGs and EPA has determined that a response action is necessary and feasible, EPA's goal will be to develop a comprehensive response to the widespread contamination. This will often require coordination with different authorities that have jurisdiction over the sources of contamination in the area.

**EXHIBIT 3-2
BACKGROUND CONCENTRATIONS OF SELECTED ELEMENTS IN SOILS**

TRACE ELEMENT	U.S. STUDY DATA ¹			CALIFORNIA DATA ²		
	Range	GeoMean	ArMean	Range	GeoMean	ArMean
Arsenic	<.1-97	5.2 mg/kg	7.2 mg/kg	0.59-11	2.75 mg/kg	3.54 mg/kg
Beryllium	<1-15	0.63 “	0.92 “	0.10-2.7	1.14 “	1.28 “
Cadmium	<1-10	--	<1	0.05-1.7	0.26	0.36
Chromium	1-2000	37	54	23-1579	76.25	122.08
Nickel	<5-700	13	19	9.0-509	35.75	56.60

¹Shacklette and Hansford, “Element Concentrations in Soils and Other Surficial Materials of the Conterminous United States”, USGS Professional Paper 1270, 1984.

²Bradford et. al, “Background Concentrations of Trace and Major Elements in California Soils”, Kearney Foundation Special Report, UC-Riverside and CAL-EPA DTSC, March 1996.

3.3 Screening Sites with Multiple Pollutants

A suggested stepwise approach for PRG-screening of sites with multiple pollutants is as follows:

- Perform an extensive records search and compile existing data.
- Identify site contaminants in the PRG table. Record the PRG concentrations for various media and note whether PRG is based on cancer risk (indicated by "ca") or noncancer hazard (indicated by "nc"). Segregate cancer PRGs from non-cancer PRGs and exclude (but don't eliminate) non-risk based PRGs ("sat" or "max").
- For cancer risk estimates, take the site-specific concentration (maximum or 95 UCL) and divide by the PRG concentrations that are designated for cancer evaluation ("ca"). Multiply this ratio by 10^{-6} to estimate chemical-specific risk for a reasonable maximum exposure (RME). For multiple pollutants, simply add the risk for each chemical:

$$Risk = \left[\left(\frac{conc_x}{PRG_x} \right) + \left(\frac{conc_y}{PRG_y} \right) + \left(\frac{conc_z}{PRG_z} \right) \right] \times 10^{-6}$$

- For non-cancer hazard estimates. Divide the concentration term by its respective non-cancer PRG designated as "nc" and sum the ratios for multiple contaminants. The cumulative ratio represents a non-carcinogenic hazard index (HI). A hazard index of 1 or less is generally considered "safe". A ratio greater than 1 suggests further evaluation. **[Note that carcinogens may also have an associated non-cancer PRG that is not listed in the printed copy of the table sent to folks on the mailing list. To obtain these values, the user should view or download the PRG table at our website and display the appropriate sections.]**

$$Hazard\ Index = \left[\left(\frac{conc_x}{PRG_x} \right) + \left(\frac{conc_y}{PRG_y} \right) + \left(\frac{conc_z}{PRG_z} \right) \right]$$

For more information on screening site risks, the reader should contact EPA Region 9's Technical Support Team.

3.4 Potential Problems

As with any risk-based tool, the potential exists for misapplication. In most cases the root cause will be a lack of understanding of the intended use of Region 9 PRGs. In order to prevent misuse of PRGs, the following should be avoided:

- Applying PRGs to a site without adequately developing a conceptual site model that identifies relevant exposure pathways and exposure scenarios,
- Not considering background concentrations when choosing PRGs as cleanup goals,
- Use of PRGs as cleanup levels without the nine-criteria analysis specified in the

National Contingency Plan (or, comparable analysis for programs outside of Superfund),

- Use of PRGs as cleanup levels without verifying numbers with a toxicologist or regional risk assessor,

Use of antiquated PRG tables that have been superseded by more recent publications,

- Not considering the effects of additivity when screening multiple chemicals, and
- Adjusting PRGs upward by factors of 10 or 100 without consulting a toxicologist or regional risk assessor.

4.0 TECHNICAL SUPPORT DOCUMENTATION

Region 9 PRGs consider human exposure hazards to chemicals from contact with contaminated soils, air, and water. The emphasis of the PRG equations and technical discussion are aimed at developing screening criteria for soils, since this is an area where few standards exist. For air and water, additional reference concentrations or standards are available for many chemicals (e.g. MCLs, non-zero MCLGs, AWQC, and NAAQS) and consequently the discussion of these media are brief.

4.1 Soils - Direct Ingestion

Calculation of risk-based PRGs for direct ingestion of soil is based on methods presented in RAGS HHEM, Part B (USEPA 1991a) and *Soil Screening Guidance* (USEPA 1996a,b, USEPA 2001a). Briefly, these methods backcalculate a soil concentration level from a target risk (for carcinogens) or hazard quotient (for noncarcinogens).

Residential Soil PRGs

A number of studies have shown that inadvertent ingestion of soil is common among children 6 years old and younger (Calabrese et al. 1989, Davis et al. 1990, Van Wijnen et al. 1990). To take into account the higher soil intake rate for children, two different approaches are used to estimate PRGs, depending on whether the adverse health effect is cancer or some effect other than cancer.

For carcinogens, the method for calculating PRGs uses an age-adjusted soil ingestion factor that takes into account the difference in daily soil ingestion rates, body weights, and exposure duration for children from 1 to 6 years old and others from 7 to 31 years old. This health-protective approach is chosen to take into account the higher daily rates of soil ingestion in children as well as the longer duration of exposure that is anticipated for a long-term resident. For more on this method, see USEPA RAGs Part B (1991a).

For noncarcinogenic concerns, the more protective method of calculating a soil PRG is to evaluate childhood exposures separately from adult exposures. In other words, an age-adjustment factor is not applied as was done for carcinogens. This approach is considered conservative because it combines the higher 6-year exposure for children with chronic toxicity criteria. In their analysis of the method, the Science Advisory Board (SAB) indicated that, for most chemicals, the approach may be overly

protective. However, they noted that there are specific instances when the chronic RfD may be based on endpoints of toxicity that are specific to children (e.g. fluoride and nitrates) or when the dose-response is steep (i.e., the dosage difference between the no-observed-adverse-effects level [NOAEL] and an adverse effects level is small). Thus, for the purposes of screening, EPA Region 9 has adopted this approach for calculating soil PRGs for noncarcinogenic health concerns.

Industrial Soil PRGs

In the new *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites* (Supplemental SSL Guidance, EPA 2001a), two different soil ingestion rates are assumed for non-construction workers: 100 mg/day is assumed for outdoor workers whereas 50 mg/day is assumed for indoor workers. The default value of 100 mg/day for outdoor workers is also recommended by EPA's Technical Review Workgroup for Lead (TRW), and it reflects increased exposures to soils for outdoor workers relative to their indoor counterparts. For more on this, please see the Supplemental SSL Guidance available at the following website:

<http://www.epa.gov/superfund/resources/soil/index.htm>

Because the Region 9 PRGs are generic and intended for screening sites early in the investigation process (often before site-specific information is available), we have chosen to use the 100 mg/day soil ingestion (i.e. outdoor worker) assumption to calculate industrial soil PRGs. Please note that previous issues of the Region 9 PRGs table assumed 50 mg/day soil ingestion rate for workers. This change in soil ingestion rates is reflected in a somewhat lower (more stringent) industrial soils PRG for many contaminants. The appropriateness of this assumption for a particular site may be evaluated when additional information becomes available regarding site conditions or site development.

4.2 Soils - Vapor and Particulate Inhalation

Agency toxicity criteria indicate that risks from exposure to some chemicals via inhalation far outweigh the risk via ingestion; therefore soil PRGs have been designed to address this pathway as well. The models used to calculate PRGs for inhalation of volatiles/particulates are updates of risk assessment methods presented in RAGS Part B (USEPA 1991a) and are identical to the *Soil Screening Guidance: User's Guide and Technical Background Document* (USEPA 1996a,b).

It should be noted that the soil-to-air pathway that is evaluated in the PRGs calculations is based on direct inhalation exposures that result from the volatilization or particulate emissions of chemicals from soil to outdoor air. The soil PRG calculations currently do not evaluate potential for volatile contaminants in soil to migrate indoors. For this evaluation, a site-specific assessment is required because the applicable model, the Johnson and Ettinger model, is extremely sensitive to a number of model parameters that do not lend themselves to standardization on a national basis. For more information on the indoor air model and/or to download a copy, please go to:

http://www.epa.gov/oerrpage/superfund/programs/risk/airmodel/johnson_ettinger.htm

To address the soil-to-outdoor air pathways, the PRG calculations incorporate volatilization factors (VF_s) for volatile contaminants and particulate emission factors (PEF) for nonvolatile contaminants. These factors relate soil contaminant concentrations to air contaminant concentrations that may be inhaled on-site. The VF_s and PEF equations can be broken into two separate models: an emission model to estimate emissions of the contaminant from the soil and a dispersion model to simulate the dispersion of the contaminant in the atmosphere.

The box model in RAGS Part B has been replaced with a dispersion term (Q/C) derived from a modeling exercise using meteorological data from 29 locations across the United States because the box model may not be applicable to a broad range of site types and meteorology and does not utilize state-of-the-art techniques developed for regulatory dispersion modeling. The dispersion model for both volatiles and particulates is the AREA-ST, an updated version of the Office of Air Quality Planning and Standards, Industrial Source Complex Model, ISC2. However, different Q/C terms are used in the VF and PEF equations. Los Angeles was selected as the 90th percentile data set for volatiles and Minneapolis was selected as the 90th percentile data set for fugitive dusts (USEPA 1996 a,b). A default source size of 0.5 acres was chosen for the PRG calculations. This is consistent with the default exposure area over which Region 9 typically averages contaminant concentrations in soils. If unusual site conditions exist such that the area source is substantially larger than the default source size assumed here, an alternative Q/C could be applied (see USEPA 1996a,b).

Volatilization Factor for Soils

Volatile chemicals, defined as those chemicals having a Henry's Law constant greater than 10^{-5} (atm-m³/mol) and a molecular weight less than 200 g/mole, were screened for inhalation exposures using a volatilization factor for soils (VF_s). Please note that VF_s 's are available at our website.

The emission terms used in the VF_s are chemical-specific and were calculated from physical-chemical information obtained from several sources. The priority of these sources were as follows: *Soil Screening Guidance* (USEPA 1996a,b), *Superfund Chemical Data Matrix* (USEPA 1996c), *Fate and Exposure Data* (Howard 1991), *Subsurface Contamination Reference Guide* (EPA 1990a), and *Superfund Exposure Assessment Manual* (SEAM, EPA 1988). When there was a choice between a measured or a modeled value (e.g. Koc), we went with modeled values. In those cases where Diffusivity Coefficients (D_i) were not provided in existing literature, D_i 's were calculated using Fuller's Method described in SEAM. A surrogate term was required for some chemicals that lacked physico-chemical information. In these cases, a proxy chemical of similar structure was used that may over- or under-estimate the PRG for soils.

Equation 4-9 forms the basis for deriving generic soil PRGs for the inhalation pathway. The following parameters in the standardized equation can be replaced with specific site data to develop a simple site-specific PRG

- Source area
- Average soil moisture content
- Average fraction organic carbon content
- Dry soil bulk density

The basic principle of the VF_s model (Henry's law) is applicable only if the soil contaminant concentration is at or below soil saturation "sat". Above the soil saturation limit, the model cannot predict an accurate VF-based PRG. How these particular cases are handled, depends on whether the contaminant is liquid or solid at ambient soil temperatures (see Section 4.5).

Particulate Emission Factor for Soils

Inhalation of chemicals adsorbed to respirable particles (PM_{10}) were assessed using a default PEF equal to $1.316 \times 10^9 \text{ m}^3/\text{kg}$ that relates the contaminant concentration in soil with the concentration of respirable particles in the air due to fugitive dust emissions from contaminated soils. The generic PEF was derived using default values in Equation 4-11, which corresponds to a receptor point concentration of approximately $0.76 \text{ ug}/\text{m}^3$. The relationship is derived by Cowherd (1985) for a rapid assessment procedure applicable to a typical hazardous waste site where the surface contamination provides a relatively continuous and constant potential for emission over an extended period of time (e.g. years). This represents an annual average emission rate based on wind erosion that should be compared with chronic health criteria; it is not appropriate for evaluating the potential for more acute exposures.

The impact of the PEF on the resultant PRG concentration (that combines soil exposure pathways for ingestion, skin contact, and inhalation) can be assessed by accessing the Region 9 PRG website and viewing the pathway-specific soil concentrations. Equation 4-11 forms the basis for deriving a generic PEF for the inhalation pathway. For more details regarding specific parameters used in the PEF model, the reader is referred to *Soil Screening Guidance: Technical Background Document* (USEPA 1996a).

Note: the generic PEF evaluates windborne emissions and does not consider dust emissions from traffic or other forms of mechanical disturbance that could lead to greater emissions than assumed here.

4.3 Soils - Dermal Exposure

Dermal Contact Assumptions

Exposure factors for dermal contact with soil are based on recommendations in "Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Interim Guidance" (USEPA 2001b). Recommended RME (reasonable maximum exposure) defaults for adult workers' skin surface areas ($3300 \text{ cm}^2/\text{day}$) and soil adherence factors ($0.2 \text{ mg}/\text{cm}^2$) now differ from the defaults recommended for adult residents ($5700 \text{ cm}^2/\text{day}$, $0.07 \text{ mg}/\text{cm}^2$) as noted in Exhibit 4-1. This is due to differences in the range of activities experienced by workers versus residents.

Dermal Absorption

Chemical-specific skin absorption values recommended by the Superfund Dermal Workgroup were applied when available. Chemical-specific values are included for the following chemicals: arsenic, cadmium, chlordane, 2,4-D, DDT, lindane, TCDD, PAHs, PCBs, and pentachlorophenols.

The “Supplemental Guidance for Dermal Risk Assessment” (USEPA 2001b) recommends a default dermal absorption factor for semivolatile organic compounds of 10% as a screening method for the majority of SVOCs without dermal absorption factors. Default dermal absorption values for other chemicals (VOCs and inorganics) are not recommended in this new guidance. Therefore, the assumption of 1% for inorganics and 10% for volatiles is no longer included in the Region 9 PRG table. This change has minimal impact on the final risk-based calculations because human exposure to VOCs and inorganics in soils is generally driven by other pathways of exposure.

4.4 Soils - Migration to Groundwater

The methodology for calculating SSLs for the migration to groundwater was developed to identify chemical concentrations in soil that have the potential to contaminate groundwater. Migration of contaminants from soil to groundwater can be envisioned as a two-stage process: (1) release of contaminant in soil leachate and (2) transport of the contaminant through the underlying soil and aquifer to a receptor well. The SSL methodology considers both of these fate and transport mechanisms.

SSLs are backcalculated from acceptable ground water concentrations (i.e. nonzero MCLGs, MCLs, or risk-based PRGs). First, the acceptable groundwater concentration is multiplied by a dilution factor to obtain a target leachate concentration. For example, if the dilution factor is 10 and the acceptable ground water concentration is 0.05 mg/L, the target soil leachate concentration would be 0.5 mg/L. The partition equation (presented in the *Soil Screening Guidance* document) is then used to calculate the total soil concentration (i.e. SSL) corresponding to this soil leachate concentration.

The SSL methodology was designed for use during the early stages of a site evaluation when information about subsurface conditions may be limited. Because of this constraint, the methodology is based on conservative, simplifying assumptions about the release and transport of contaminants in the subsurface. For more on SSLs, and how to calculate site-specific SSLs versus generic SSLs presented in the PRG table, the reader is referred to the *Soil Screening Guidance* document (USEPA 1996a,b).

4.5 Soil Saturation Limit

The soil saturation concentration “sat” corresponds to the contaminant concentration in soil at which the absorptive limits of the soil particles, the solubility limits of the soil pore water, and saturation of soil pore air have been reached. Above this concentration, the soil contaminant may be present in free phase, i.e., nonaqueous phase liquids (NAPLs) for contaminants that are liquid at ambient soil temperatures and pure solid phases for compounds that are solid at ambient soil temperatures.

Equation 4-10 is used to calculate “sat” for each volatile contaminant. As an update to RAGS HHEM, Part B (USEPA 1991a), this equation takes into account the amount of contaminant that is in the vapor phase in soil in addition to the amount dissolved in the soil’s pore water and sorbed to soil particles.

Chemical-specific “sat” concentrations must be compared with each VF-based PRG because a basic principle of the PRG volatilization model is not applicable when free-phase contaminants are present. How these cases are handled depends on whether the contaminant is liquid or solid at ambient

temperatures. Liquid contaminant that have a VF-based PRG that exceeds the “sat” concentration are set equal to “sat” whereas for solids (e.g., PAHs), soil screening decisions are based on the appropriate PRGs for other pathways of concern at the site (e.g., ingestion).

4.6 Tap Water - Ingestion and Inhalation

Calculation of PRGs for ingestion and inhalation of contaminants in domestic water is based on the methodology presented in RAGS HHEM, Part B (USEPA 1991a). Ingestion of drinking water is an appropriate pathway for all chemicals. For the purposes of this guidance, however, inhalation of volatile chemicals from water is considered routinely only for chemicals with a Henry’s Law constant of 1×10^{-5} atm-m³/mole or greater and with a molecular weight of less than 200 g/mole.

For volatile chemicals, an upperbound volatilization constant (VF_w) is used that is based on all uses of household water (e.g showering, laundering, and dish washing). Certain assumptions were made. For example, it is assumed that the volume of water used in a residence for a family of four is 720 L/day, the volume of the dwelling is 150,000 L and the air exchange rate is 0.25 air changes/hour (Andelman in RAGS Part B). Furthermore, it is assumed that the average transfer efficiency weighted by water use is 50 percent (i.e. half of the concentration of each chemical in water will be transferred into air by all water uses). Note: the range of transfer efficiencies extends from 30% for toilets to 90% for dishwashers.

4.7 Default Exposure Factors

Default exposure factors were obtained primarily from RAGS Supplemental Guidance Standard Default *Exposure Factors* (OSWER Directive, 9285.6-03) dated March 25, 1991 and more recent information from U.S. EPA's Office of Solid Waste and Emergency Response, U.S. EPA's Office of Research and Development, and California EPA's Department of Toxic Substances Control (see Exhibit 4-1).

Because contact rates may be different for children and adults, carcinogenic risks during the first 30 years of life were calculated using age-adjusted factors ("adj"). Use of age-adjusted factors are especially important for soil ingestion exposures, which are higher during childhood and decrease with age. However, for purposes of combining exposures across pathways, additional age-adjusted factors are used for inhalation and dermal exposures. These factors approximate the integrated exposure from birth until age 30 combining contact rates, body weights, and exposure durations for two age groups - small children and adults. Age-adjusted factors were obtained from RAGS PART B or developed by analogy (see derivations next page).

For soils only, noncarcinogenic contaminants are evaluated in children separately from adults. No age-adjustment factor is used in this case. The focus on children is considered protective of the higher daily intake rates of soil by children and their lower body weight. For maintaining consistency when evaluating soils, dermal and inhalation exposures are also based on childhood contact rates.

(1) ingestion([mg-yr]/[kg-d]):

$$IFS_{adj} = \frac{ED_c \times IRS_c}{BW_c} + \frac{(ED_r - ED_c) \times IRS_a}{BW_a}$$

(2) skin contact([mg-yr]/[kg-d]):

$$SFS_{adj} = \frac{ED_c \times AF \times SA_c}{BW_c} + \frac{(ED_r - ED_c) \times AF \times SA_a}{BW_a}$$

(3) inhalation ([m³-yr]/[kg-d]):

$$InhF_{adj} = \frac{ED_c \times IRA_c}{BW_c} + \frac{(ED_r - ED_c) \times IRA_a}{BW_a}$$

EXHIBIT 4-1 STANDARD DEFAULT FACTORS

<u>Symbol</u>	<u>Definition (units)</u>	<u>Default</u>	<u>Reference</u>
CSFo	Cancer slope factor oral (mg/kg-d)-1	--	IRIS, HEAST, or NCEA
CSFi	Cancer slope factor inhaled (mg/kg-d)-1	--	IRIS, HEAST, or NCEA
RfDo	Reference dose oral (mg/kg-d)	--	IRIS, HEAST, or NCEA
RfDi	Reference dose inhaled (mg/kg-d)	--	IRIS, HEAST, or NCEA
TR	Target cancer risk	10 ⁻⁶	--
THQ	Target hazard quotient	1	--
BW _a	Body weight, adult (kg)	70	RAGS (Part A), EPA 1989 (EPA/540/1-89/002)
BW _c	Body weight, child (kg)	15	Exposure Factors, EPA 1991 (OSWER No. 9285.6-03)
AT _c	Averaging time - carcinogens (days)	25550	RAGS(Part A), EPA 1989 (EPA/540/1-89/002)
AT _n	Averaging time - noncarcinogens (days)	ED*365	
SA _a	Exposed surface area for soil/dust (cm ² /day) – adult resident	5700	Dermal Assessment, EPA 2000 (EPA/540/R-99/005)
	– adult worker	3300	
SA _c	Exposed surface area, child in soil (cm ² /day)	2800	Dermal Assessment, EPA 2000 (EPA/540/R-99/005)
AF _a	Adherence factor, soils (mg/cm ²) – adult resident	0.07	Dermal Assessment, EPA 2000 (EPA/540/R-99/005)
	– adult worker	0.2	
AF _c	Adherence factor, child (mg/cm ²)	0.2	Dermal Assessment, EPA 2000 (EPA/540/R-99/005)
ABS	Skin absorption defaults (unitless):		
	– semi-volatile organics	0.1	Dermal Assessment, EPA 2000 (EPA/540/R-99/005)
	– volatile organics	--	Dermal Assessment, EPA 2000 (EPA/540/R-99/005)
	– inorganics	--	Dermal Assessment, EPA 2000 (EPA/540/R-99/005)
IRA _a	Inhalation rate - adult (m ³ /day)	20	Exposure Factors, EPA 1991 (OSWER No. 9285.6-03)
IRA _c	Inhalation rate - child (m ³ /day)	10	Exposure Factors, EPA 1997 (EPA/600/P-95/002Fa)
IRW _a	Drinking water ingestion - adult (L/day)	2	RAGS(Part A), EPA 1989 (EPA/540/1-89/002)
IRW _c	Drinking water ingestion - child (L/day)	1	PEA, Cal-EPA (DTSC, 1994)
IRSA	Soil ingestion - adult (mg/day)	100	Exposure Factors, EPA 1991 (OSWER No. 9285.6-03)
IRSc	Soil ingestion - child (mg/day),	200	Exposure Factors, EPA 1991 (OSWER No. 9285.6-03)
IRSo	Soil ingestion - occupational (mg/day)	100	Soil Screening Guidance (EPA 2001a)
EFr	Exposure frequency - residential (d/y)	350	Exposure Factors, EPA 1991 (OSWER No. 9285.6-03)
EFO	Exposure frequency - occupational (d/y)	250	Exposure Factors, EPA 1991 (OSWER No. 9285.6-03)
EDr	Exposure duration - residential (years)	30 ^a	Exposure Factors, EPA 1991 (OSWER No. 9285.6-03)
EDc	Exposure duration - child (years)	6	Exposure Factors, EPA 1991 (OSWER No. 9285.6-03)
EDo	Exposure duration - occupational (years)	25	Exposure Factors, EPA 1991 (OSWER No. 9285.6-03)
	Age-adjusted factors for carcinogens:		
IFS _{adj}	Ingestion factor, soils ([mg-yr]/[kg-d])	114	RAGS(Part B), EPA 1991 (OSWER No. 9285.7-01B)
SFS _{adj}	Dermal factor, soils ([mg-yr]/[kg-d])	361	By analogy to RAGS (Part B)
InhF _{adj}	Inhalation factor, air ([m ³ -yr]/[kg-d])	11	By analogy to RAGS (Part B)
IFW _{adj}	Ingestion factor, water ([L-yr]/[kg-d])	1.1	By analogy to RAGS (Part B)
VFw	Volatilization factor for water (L/m ³)	0.5	RAGS(Part B), EPA 1991 (OSWER No. 9285.7-01B)
PEF	Particulate emission factor (m ³ /kg)	See below	Soil Screening Guidance (EPA 1996a,b)
VF _s	Volatilization factor for soil (m ³ /kg)	See below	Soil Screening Guidance (EPA 1996a,b)
sat	Soil saturation concentration (mg/kg)	See below	Soil Screening Guidance (EPA 1996a,b)

Footnote:

^aExposure duration for lifetime residents is assumed to be 30 years total. For carcinogens, exposures are combined for children (6 years) and adults (24 years) .

4.8 Standardized Equations

The equations used to calculate the PRGs for carcinogenic and noncarcinogenic contaminants are presented in Equations 4-1 through 4-8. The PRG equations update RAGS Part B equations. The methodology backcalculates a soil, air, or water concentration level from a target risk (for carcinogens) or hazard quotient (for noncarcinogens). For completeness, the soil equations combine risks from ingestion, skin contact, and inhalation simultaneously. **Note: the electronic version of the table also includes pathway-specific PRGs, should the user decide against combining specific exposure pathways; or, the user wants to identify the relative contribution of each pathway to exposure.**

To calculate PRGs for volatile chemicals in soil, a chemical-specific volatilization factor is calculated per Equation 4-9. Because of its reliance on Henry's law, the VF_s model is applicable only when the contaminant concentration in soil is at or below saturation (i.e. there is no free-phase contaminant present). Soil saturation ("sat") corresponds to the contaminant concentration in soil at which the adsorptive limits of the soil particles and the solubility limits of the available soil moisture have been reached. Above this point, pure liquid-phase contaminant is expected in the soil. If the PRG calculated using VF_s was greater than the calculated sat, the PRG was set equal to sat, in accordance with *Soil Screening Guidance* (USEPA 1996 a,b). The equation for deriving sat is presented in Equation 4-10.

PRG EQUATIONS

Soil Equations: For soils, equations were based on three exposure routes (ingestion, skin contact, and inhalation).

Equation 4-1: Combined Exposures to Carcinogenic Contaminants in Residential Soil

$$C(\text{mg/kg}) = \frac{TR \times AT_c}{EF_r \left[\left(\frac{IFS_{adj} \times CSF_o}{10^6 \text{mg/kg}} \right) + \left(\frac{SFS_{adj} \times ABS \times CSF_o}{10^6 \text{mg/kg}} \right) + \left(\frac{InhF_{adj} \times CSF_i}{VF_s^a} \right) \right]}$$

Equation 4-2: Combined Exposures to Noncarcinogenic Contaminants in Residential Soil

$$C(\text{mg/kg}) = \frac{THQ \times BW_c \times AT_n}{EF_r \times ED_c \left[\left(\frac{1}{RfD_o} \times \frac{IRS_c}{10^6 \text{mg/kg}} \right) + \left(\frac{1}{RfD_o} \times \frac{SA_c \times AF \times ABS}{10^6 \text{mg/kg}} \right) + \left(\frac{1}{RfD_i} \times \frac{IRA_c}{VF_s^a} \right) \right]}$$

Equation 4-3: Combined Exposures to Carcinogenic Contaminants in Industrial Soil

$$C(\text{mg/kg}) = \frac{TR \times BW_a \times AT_c}{EF_o \times ED_o \left[\left(\frac{IRS_o \times CSF_o}{10^6 \text{mg/kg}} \right) + \left(\frac{SA_a \times AF \times ABS \times CSF_o}{10^6 \text{mg/kg}} \right) + \left(\frac{IRA_a \times CSF_i}{VF_s^a} \right) \right]}$$

Footnote:

^aUse VF_s for volatile chemicals (defined as having a Henry's Law Constant [atm-m³/mol] greater than 10⁻⁵ and a molecular weight less than 200 grams/mol) or PEF for non-volatile chemicals.

Equation 4-4: Combined Exposures to Noncarcinogenic Contaminants in Industrial Soil

$$C(\text{mg/kg}) = \frac{THQ \times BW_a \times AT_n}{EF_o \times ED_o \left[\left(\frac{1}{RfD_o} \times \frac{IRS_o}{10^6 \text{mg/kg}} \right) + \left(\frac{1}{RfD_o} \times \frac{SA_a \times AF \times ABS}{10^6 \text{mg/kg}} \right) + \left(\frac{1}{RfD_i} \times \frac{IRA_a}{VF_s^a} \right) \right]}$$

Tap Water Equations:

Equation 4-5: Ingestion and Inhalation Exposures to Carcinogenic Contaminants in Water

$$C(\text{ug/L}) = \frac{TR \times AT_c \times 1000 \text{ug/mg}}{EF_r \left[(IFW_{adj} \times CSF_o) + (VF_w \times InhF_{adj} \times CSF_i) \right]}$$

Equation 4-6: Ingestion and Inhalation Exposures to Noncarcinogenic Contaminants in Water

$$C(\text{ug/L}) = \frac{THQ \times BW_a \times AT_n \times 1000 \text{ug/mg}}{EF_r \times ED_r \left[\left(\frac{IRW_a}{RfD_o} \right) + \left(\frac{VF_w \times IRA_a}{RfD_i} \right) \right]}$$

Air Equations:

Equation 4-7: Inhalation Exposures to Carcinogenic Contaminants in Air

$$C(\text{ug/m}^3) = \frac{TR \times AT_c \times 1000 \text{ug/mg}}{EF_r \times InhF_{adj} \times CSF_i}$$

Equation 4-8: Inhalation Exposures to Noncarcinogenic Contaminants in Air

$$C(\text{ug/m}^3) = \frac{THQ \times RfD_i \times BW_a \times AT_n \times 1000 \text{ug/mg}}{EF_r \times ED_r \times IRA_a}$$

Footnote:

^aUse VF_s for volatile chemicals (defined as having a Henry's Law Constant [atm-m³/mol] greater than 10⁻⁵ and a molecular weight less than 200 grams/mol) or PEF for non-volatile chemicals.

SOIL-TO-AIR VOLATILIZATION FACTOR (VF_s)

Equation 4-9: Derivation of the Volatilization Factor

$$VF_s (m^3/kg) = (Q/C) \times \frac{(3.14 \times D_A \times T)^{1/2}}{(2 \times \rho_b \times D_A)} \times 10^{-4} (m^2/cm^2)$$

where:

$$D_A = \frac{[(\Theta_a^{10/3} D_i H' + \Theta_w^{10/3} D_w) / n^2]}{\rho_B K_d + \Theta_w + \Theta_a H'}$$

<u>Parameter</u>	<u>Definition (units)</u>	<u>Default</u>
VF _s	Volatilization factor (m ³ /kg)	--
D _A	Apparent diffusivity (cm ² /s)	--
Q/C	Inverse of the mean conc. at the center of a 0.5-acre square source (g/M ² -s per kg/m ³)	68.81
T	Exposure interval (s)	9.5 x 10 ⁸
ρ _b	Dry soil bulk density (g/cm ³)	1.5
Θ _a	Air filled soil porosity (L _{air} /L _{soil})	0.28 or n-Θ _w
n	Total soil porosity (L _{pore} /L _{soil})	0.43 or 1 - (ρ _b /ρ _s)
Θ _w	Water-filled soil porosity (L _{water} /L _{soil})	0.15
ρ _s	Soil particle density (g/cm ³)	2.65
D _i	Diffusivity in air (cm ² /s)	Chemical-specific
H	Henry's Law constant (atm-m ³ /mol)	Chemical-specific
H'	Dimensionless Henry's Law constant	Calculated from H by multiplying by 41 (USEPA 1991a)
D _w	Diffusivity in water (cm ² /s)	Chemical-specific
K _d	Soil-water partition coefficient (cm ³ /g) = K _{oc} f _{oc}	Chemical-specific
K _{oc}	Soil organic carbon-water partition coefficient (cm ³ /g)	Chemical-specific
f _{oc}	Fraction organic carbon in soil (g/g)	0.006 (0.6%)

SOIL SATURATION CONCENTRATION (sat)

Equation 4-10: Derivation of the Soil Saturation Limit

$$sat = \frac{S}{\rho_b} (K_d \rho_b + \Theta_w + H' \Theta_a)$$

<u>Parameter</u>	<u>Definition (units)</u>	<u>Default</u>
sat	Soil saturation concentration (mg/kg)	--
S	Solubility in water (mg/L-water)	Chemical-specific
ρ_b	Dry soil bulk density (kg/L)	1.5
n	Total soil porosity (L_{pore}/L_{soil})	0.43 or $1 - (\rho_b/\rho_s)$
ρ_s	Soil particle density (kg/L)	2.65
K_d	Soil-water partition coefficient (L/kg)	$K_{oc} \times f_{oc}$ (chemical-specific)
k_{oc}	Soil organic carbon/water partition coefficient (L/kg)	Chemical-specific
f_{oc}	Fraction organic carbon content of soil (g/g)	0.006 or site-specific
Θ_w	Water-filled soil porosity (L_{water}/L_{soil})	0.15
Θ_a	Air filled soil porosity (L_{air}/L_{soil})	0.28 or $n - \Theta_w$
w	Average soil moisture content (kg_{water}/kg_{soil} or L_{water}/kg_{soil})	0.1
H	Henry's Law constant (atm-m ³ /mol)	Chemical-specific
H'	Dimensionless Henry's Law constant	$H \times 41$, where 41 is a units conversion factor

SOIL-TO-AIR PARTICULATE EMISSION FACTOR (PEF)

Equation 4-11: Derivation of the Particulate Emission Factor

$$PEF(m^3/kg) = Q/C \times \frac{3600s/h}{0.036 \times (1-V) \times (U_m/U_t)^3 \times F(x)}$$

<u>Parameter</u>	<u>Definition (units)</u>	<u>Default</u>
PEF	Particulate emission factor (m ³ /kg)	1.316 x 10 ⁹
Q/C	Inverse of the mean concentration at the center of a 0.5-acre-square source (g/M ² -s per kg/m ³)	90.80
V	Fraction of vegetative cover (unitless)	0.5
U _m	Mean annual windspeed (m/s)	4.69
U _t	Equivalent threshold value of windspeed at 7 m (m/s)	11.32
F(x)	Function dependent on U _m /U _t derived using Cowherd (1985) (unitless)	0.194

REFERENCES

- ASTM. 1995. *Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites*. Designation E 1739 - 95. Philadelphia, Pennsylvania.
- Calabrese, E.J., H. Pastides, R. Barnes, et al. 1989. How much soil do young children ingest: an epidemiologic study. In: *Petroleum Contaminated Soils*, Vol. 2. E.J. Calabrese and P.T. Kostecki, eds. pp. 363-417. Chelsea, MI, Lewis Publishers.
- California EPA. 1994. *Preliminary Endangerment Assessment Guidance Manual*. (PEA) Department of Toxic Substances Control, Sacramento, California.
- California EPA. 1996. *Guidance for Ecological Risk Assessment at Hazardous Waste Sites and Permitted Facilities, Part A: Overview*. Department of Toxic Substances Control, Sacramento, California.
- Cowherd, C., G. Muleski, P. Engelhart, and D. Gillette. 1985. *Rapid Assessment of Exposure to Particulate Emission from Surface Contamination*. EPA/600/8-85/002. Prepared for Office of Health and Environmental Assessment, U.S. Environmental Protection Agency, Washington, DC. NTIS PB85-1922197AS.
- Davis, S., P. Waller, R. Buschom, J. Ballou, and P. White. 1990. Quantitative estimates of soil ingestion in normal children between the ages of 2 and 7 years: population-based estimates using Al, Si, and Ti as soil tracer elements. *Archives of Environmental Health* 45:112-122.
- Howard, P.H. 1990. *Handbook of Environmental Fate and Exposure Data for Organic Chemicals*. Lewis Publishers, Chelsea Michigan.
- U.S. EPA. 1988. *Superfund Exposure Assessment Manual*. EPA/540/1-88/001. Office of Emergency and Remedial Response, Washington, DC.
- U.S. EPA. 1990a. *Subsurface Contamination Reference Guide*. EPA/540/2-90/011. Office of Emergency and Remedial Response, Washington, DC.
- U.S. EPA 1990b. *Exposure Factors Handbook*. EPA/600/8089/043. Office of Health and Environmental Assessment, Washington, DC.
- U.S. EPA. 1991a. *Risk Assessment Guidance for Superfund Volume 1: Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Remediation Goals)*. Publication 9285.7-01B. Office of Emergency and Remedial Response, Washington, DC. NTIS PB92-963333.
- U.S. EPA. 1991b. *Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors*. Publication 9285.6-03. Office of Emergency and Remedial Response, Washington, DC. NTIS PB91-921314.
- U.S. EPA. 1992a *Technical Support Document for Land Application of Sewage Sludge; Volumes I and II*. Office of Water, Washington, DC. 822/R-93-001a,b.
- U.S. EPA. 1992b *Dermal Exposure Assessment: Principles and Applications*. EPA/600/8-91/011B. Office of Health and Environmental Assessment, Washington, DC.
- U.S. EPA 1994a. *Estimating Exposure to Dioxin-Like Compounds*. U.S. EPA Office of Research and Development, EPA/600/6-88/005B.
- U.S. EPA 1994b. *Role of Ecological Assessment in the Baseline Risk Assessment*. OSWER Directive No. 9285.7-17. Office of Solid Waste and Emergency Response, Washington, DC.
- U.S. EPA. 1996a. *Soil Screening Guidance: Technical Background Document*. EPA/540/R-95/128. Office of Emergency and Remedial Response, Washington, DC. PB96-963502.
- U.S. EPA. 1996b. *Soil Screening Guidance: User's Guide*. EPA/540/R-96/018. Office of Emergency and Remedial Response, Washington, DC. PB96-963505.

U.S. EPA 1996c. *Superfund Chemical Data Matrix*. EPA/540/R-96/028. Office of Solid Waste and Emergency Response, Washington, DC. PB94-963506.

U.S. EPA. 1997a. *Health Effects Assessment Summary Tables (HEAST): Annual Update, FY 1997*. National Center For Environmental Assessment (NCEA), Office of Research and Development and Office of Emergency and Remedial Response, Washington, DC.

U.S. EPA. 1997b. *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments, Interim Final*. EPA/540/R-97/006. Office of Solid Waste and Emergency Response, Washington, DC. PB97-963211.

U.S. EPA. 2001a. *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites, Interim Guidance*. OSWER 9355.4-24.

U.S. EPA. 2001b. *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment), Interim Guidance*. EPA/540/R-99/005. Office of Solid Waste and Emergency Response, Washington, DC. PB99-963312.

U.S. EPA. 2001c. *Guidance for Characterizing Background Chemicals in Soil at Superfund Sites (Draft)* June 2001, EPA/540/R-01/003. Office of Solid Waste and Emergency Response, Washington, DC.

U.S. EPA. 2002. *Integrated Risk Information System (IRIS)*. Duluth, MN.

Van Wijnen, J.H., P. Clausing and B. Brunekreef. 1990. Estimated soil ingestion by children. *Environmental Research*, 51:147-162.