Characterization Report

Building A-1 at the U.S. Department of Energy Nevada Operations Office North Las Vegas Facility

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Bechtel Nevada

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ACRONYMS and ABBREVIATIONS

$\mu\text{Ci}/\text{cm}^3$	microcurie per cubic centimeter
BN	Bechtel Nevada
cm^2	square centimeter
CNLV	City of North Las Vegas
DOE	U.S. Department of Energy
DOE/NV	U.S. Department of Energy/Nevada Operations Office
dpm	disintegrations per minute
ft	foot (feet)
HT	tritium gas
HTO	tritium vapor
in.	inch
LLNL	Lawrence Livermore National Laboratory
LVVWD	Las Vegas Valley Water District
$\mu\text{S}/\text{cm}$	microSiemens per centimeter
MDA	Minimum Detectable Activity
mg/L	milligram per liter
mrem	milliroentgen equivalent man
NLVF	North Las Vegas Facility
pCi/L	picocurie per liter
ScT_3	scandium tritide
STNG	Sealed Tube Neutron Generator
TiT_3	titanium tritide
ZrT_3	zirconium tritide

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Executive Summary

Bechtel Nevada discovered water in a source storage well in Room 4862, located in the basement of Building A-1 during a routine weekly radiological survey on October 21, 1999. Building A-1 is located at the U.S. Department of Energy, Nevada Operations Office, North Las Vegas Facility (NLVF), North Las Vegas, Nevada. When first discovered, water was approximately 9 inches deep in the storage well (a volume of approximately 9 gallons). By January 31, 2000, the water was approximately 18 inches deep. Weekly inspections of the sources stored in the storage well have been conducted for approximately four years, with no previously observed intrusions of water. The storage well extends approximately 7 feet below the floor surface.

Daily monitoring of the water level in the source storage well was started on November 4, 1999. A water sample for laboratory analysis was collected on November 8, 1999; the concentration of tritium in the water was $2.45\text{E}+05$ picocuries per liter (pCi/L), approximately ten times the Safe Drinking Water Act Maximum Contaminant Level of $2.0\text{E}+04$ pCi/L.

Two incidents occurred in Building A-1 that resulted in tritium contamination of the first floor and basement (source storage well location) between 1994 and 1995. The contaminated areas were decontaminated during August through September 1995, and October through December 1997.

The origin of the water and the tritium in the source storage well was investigated. A study of the geology and hydrogeology of the NLVF and surrounding area was conducted which included a review of available geologic reports, historical aerial photos, Geoprobe® borings, and installation of temporary monitoring wells. Tritium was not detected in groundwater samples from these borings indicating that significant concentrations of tritium have not been released from the source storage well.

Water was pumped from the source storage well and the recharge was monitored versus time to obtain data on the characteristics of the shallow aquifer. The tritium concentration of the water in the source storage well was also monitored. The tritium concentration generally decreased after each pumping, but increased as the water was allowed to stagnate. These data indicate that residual activity at the base of the well or in the concrete liner of the well is the source of the tritium.

Water below Building A-1 is most likely the near-surface aquifer with water derived from the deeper aquifers. The total dissolved solids concentration is similar to water from the deeper aquifers. Recent elevation of the water level below Building A-1 is best explained, generally in order of importance, by a combination of (1) water in the near-surface aquifer being at or near natural levels, or recovering to natural levels after discontinuation of pumping (although this typically has been a relatively rapid process); (2) pressurization of the valley-fill reservoir from artificial recharge of water; (3) an increase in infiltration of water from the surface; and (4) seasonal reduction in evaporation and plant demand for water.

The concentration of tritium in water in the source storage well exceeds the Safe Drinking Water Act Maximum Contaminant Level of $2.0\text{E}+04$. The water and the room air do not pose a health

risk to employees or the public. Access to the source storage well is restricted and water is not withdrawn from the well for any purpose. Based on current information, contamination is localized around the source storage well; any existing plume of contamination has not been detected beyond the boundaries of Building A-1. Further, near-surface water, either in the shallow aquifer or the near-surface aquifer, is not used for consumption. The dose an individual would receive from drinking 1 liter of water directly from the source storage well, with a water activity of $2.5\text{E}+05$ pCi/L, is about 0.2 mrem (milliroentgen equivalent man). The dose an individual would receive from breathing the air in the source storage room for 40 hours, with an air concentration of $3.92\text{E}-08$ $\mu\text{Ci}/\text{cm}^3$ (microcuries per cubic centimeter) (the highest concentration measured from November 10, 1999, to January 31, 2000), is about 0.2 mrem. In comparison, the U.S. Department of Energy annual occupational dose limit is 5,000 mrem/year.

1.0 INTRODUCTION

1.1 1999 Incident

Building A-1 is located at the U.S. Department of Energy, Nevada Operations Office (DOE/NV) North Las Vegas Facility (NLVF), North Las Vegas, Nevada (Figure 1-1). Room 4862, located in the basement, has a 17-inch-diameter source storage well that is approximately 7 feet deep. The floor of Room 4862 is approximately 17 feet below grade. The source storage well houses a metal rack (hoisted by a small overhead crane) on which sealed radioactive sources are stored. During a routine weekly radiological survey on October 21, 1999, Bechtel Nevada (BN) discovered that the bottom of the metal rack was wet. It was determined that approximately 9 inches of water was present (a volume of approximately 9 gallons). Weekly inspection of the sources stored in the source storage well have been conducted for approximately four years, with no previously observed intrusions of water.

The two sealed sources stored in the source storage well, radium-beryllium and cobalt-60 (both stored in pigs [shielded containers]), were moved to a higher shelf on the rack on discovery of the water. Swipe samples of the storage well and pig surfaces were collected and the two sources were tested for leakage. Testing of the pigs and sources indicated that water had not infiltrated into the pigs and that the sources had not leaked. All swipe samples were negative for tritium, gross alpha, and gross beta. The sources were moved from the rack to another room on November 3, 1999.

After discovery of the water on October 21, 1999, daily monitoring of the water level in the source storage well was started on November 4, 1999. A water sample from the source storage well was collected for laboratory analysis on November 8, 1999; the concentration of tritium in the water was $2.45\text{E}+05$ picocuries per liter (pCi/L). A sample of water collected on November 9, 1999, indicated $2.27\text{E}+05$ pCi/L, confirming the first results. Occurrence Report NVOO-BNLV-BNNLV-1999-0001 was filed on November 10, 1999.

1.2 DOE/NV North Las Vegas Facility

The DOE/NV NLVF, 2621 Losee Road, North Las Vegas, Nevada (Figure 1-2) is located in Clark County where over 1,000,000 people reside, primarily in the cities of Las Vegas, North Las Vegas, Henderson, and Boulder City. The NLVF is located just west of Interstate Highway 15 (I-15) which runs north-northeast through the Las Vegas Valley.

The NLVF includes approximately 80 acres of property, 25 primary fixed structures, and many portable diagnostic trailers. A variety of scientific and technical projects are conducted within these buildings. During the period of DOE/NV's nuclear testing, many of these projects involved developing complex instruments that measured the energy produced by nuclear devices. Currently, teams of scientists, engineers, and technicians work closely to design, assemble, and test sophisticated electronic and electro-optic components.

Figure 1-1 Location of the DOE/NV facility in North Las Vegas, Nevada.

Figure 1-2 Map of the DOE/NV facility in North Las Vegas, Nevada.

1.3 Building A-1, Room 4862

A source range area for calibrating instruments is located in the basement of Building A-1. The source range area consists of a number of rooms, including Room 4862 (Figure 1-3). With the exception of sources stored in the source storage well, this room has been empty since September 1995. Room 4862 measures approximately 10 by 15 feet. The source storage well is 6.95 feet deep from the top of a lip that is raised 0.5 inch above the floor of the room. The source storage well is cased with concrete and below a small step has an inside diameter of 17 inches. The bottom of the source storage well, which is 23.50 feet below ground surface, appears to have a fine gravel base and is open to underlying strata. The elevation of the bottom of the source storage well is 1,922.50 feet and the elevation of the floor of Room 4862 is 1,929.41 feet (the top of the perimeter lip is 0.5 inches [0.04 feet] above this level; elevation 1,929.45 feet).

1.4 Behavior of Tritium

Tritium is a radioactive isotope of hydrogen. It emits a low-energy (18 kiloelectronvolts maximum) beta particle. Tritium has a 12.3-year radiological half-life and biological half-life of about 9.5 days.

Tritium as HT (gas) or HTO (vapor) will react and readily adsorb onto the surface of most metals, plastics, rubbers, and hydrogenous materials. The permeation rate varies with the material and temperature. Over time, the tritium will out-gas (or off-gas) from the material. When this occurs, tritium contamination above regulatory limits may be found during swipe surveys.

The uptake of airborne HTO into the body (by inhalation or ingestion) is extremely efficient (99 percent). In addition, HTO is readily absorbed through the skin (50 percent of that for HTO inhalation).

The surface contamination limit for tritium is outlined in Appendix D of Title 10 Code of Federal Regulations 835, "Occupational Radiation Protection." A limit of 10,000 dpm (disintegrations per minute) per 100 cm² (square centimeters) has been established for removable contamination. Because tritium migrates into material and out-gases over time, no value exists for fixed contamination.

1.5 Previous Incidents

Two incidents occurred in Building A-1 that resulted in tritium contamination of the first floor and basement (source storage well location) between 1994 and 1995: (1) storage of tritium foils in the source storage room and manufacture of components for Sealed Tube Neutron Generators (STNGs) on the first floor of Building A-1 between 1994 and 1995, and (2) opening and swiping of a container that held three tritium foils from Lawrence Livermore National Laboratory (LLNL) on two occasions, one each in June and July 1995.

Figure 1-3 Floor plan of the basement source range area in Building A-1.

The STNGs were manufactured at the NLVF between 1994 and 1995. Construction of the STNGs involved placement of a small tritiated foil on a scandium tritide (ScT_3) target in a machined steel tube, through which an electric current was passed. The current was directed at the target (tritiated foil) and neutrons were produced.

The STNG foils were produced at Pinellas and initially shipped in sealed copper tubes to the Special Technologies Laboratory in Santa Barbara, California. From there, the copper tubes were shipped to the Nevada Test Site where they were opened. The foils and opened tubes were placed in poly bags, put in separate steel drums with ring closures, and moved to the NLVF. These drums were stored in the Building A-1 basement source room (Room 4862) during the entire period of STNG manufacturing. Components of the STNGs were manufactured in the NLVF machine shop, and the foils were added to the targets on the first floor of the A-1 Building. At times, the foils were also assembled on the targets in the basement, but not in the source room. When the foils were in place, the STNGs were sealed and evacuated with a vacuum pump.

Reworking of previously used STNGs are suspected of causing higher contamination levels since the open tubes generally had high contamination levels on them. These were, at times, stored in an open condition in the source room, while awaiting or undergoing reassembly. For example, the A-1 machine shop area also became contaminated from welding on tubes that were being reworked. DOE/NV (1995) indicated that during production and rework, contamination levels ranged between $2.2\text{E}+04$ and $1.8\text{E}+07$ dpm/100cm² (swipes).

Each foil contained 1 to 2 curies of tritium. Between 20 and 22 foils were stored and used during production of the STNGs. Wastewater from these activities and from cleanup activities was never discharged to the public sanitary sewer system. Personnel interviewed for this investigation stated that there were no other tritium operations or tritium sources at the NLVF during 1994 to 1995.

A second incident that resulted in tritium contamination in the basement area was opening and swiping of a container that held three tritium foils from LLNL. The foils were originally shipped to the NLVF in 1988; two were 50-Ci zirconium tritide (ZrT_3) foils and the third was a 30-Ci titanium tritide (TiT_3) foil. The foils were swiped for contamination on arrival and the results were 896 dpm/100 cm² for each of the two zirconium tritide foils and 184 dpm/100 cm² for the titanium tritide foil. It was established that the foils could not be used and the foils remained in storage, undisturbed in the source room until June 16, 1995.

The container holding the LLNL foils was opened on June 16, 1995, and again on July 10, 1995. This container was opened and swiped (internally and externally) in the source range area. Subsequent to both openings, bioassay and basement swipes indicated a significant increase in tritium levels than previously reported. The Type B investigation report (DOE/NV, 1995) indicates that the opening of this container added further tritium activity to the basement area of Building A-1.

Personnel occupational radiation exposures were limited to internal uptakes of tritium and tritium skin contamination. Dosimetry evaluations indicated that it was unlikely that any individuals exceeded the U.S. Department of Energy (DOE) Occupational Radiation Annual Limit of 5,000 millirem. Details of the tritium release are in DOE/NV Occurrence Report NVOO-EGGO-NLVO-1995-0001 and in the Type B investigation report (DOE/NV, 1995).

An initial decontamination of the Building A-1 contaminated areas was conducted during August and September 1995. Contaminated equipment, office furniture, and other materials were removed and stored in Sealand® containers. The walls, ceilings, light fixtures, and other accessible hard surfaces were decontaminated. Up to eight coats of wax were applied to the floors to contain the source term while this phase of initial decontamination work was conducted. The remaining source term included the floors, a section of duct work in Room 4860, and an air-handling unit in Room 4520 on the first floor.

Decontamination of tritium was again conducted in October through December 1997. The wax was removed from the floors, the duct work was replaced in the basement source range room office, and the air-handling unit was replaced in the laboratory on the first floor. In addition, walls, ceilings, piping, light fixtures, and equipment were decontaminated as necessary.

1.6 Long-Term Monitoring (Swipe Surveys)

At completion of the October through December 1997 tritium decontamination, all rooms were surveyed for tritium contamination and conditionally free-released. The conditional free-release required that all previously contaminated rooms be monitored weekly for tritium contamination. After about six months, those rooms that did not indicate the return of tritium contamination above 10,000 dpm/100 cm² were free-released for general use. Two rooms have still not been free-released because of the return of tritium contamination above 10,000 dpm/100 cm². One of these rooms is the source storage room (Room 4862). The other room is located on the first floor of Building A-1 where the air-handling unit was replaced in 1997. Monitoring of these rooms is still being conducted weekly, with “hotspots” (areas where swipe surveys indicate tritium contamination levels above 10,000 dpm/100 cm²) being found periodically. The nature of tritium in the environment would allow the isotope to be further released into the local environment with the introduction of water.

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2.0 INVESTIGATION STRATEGY

When tritium activity was identified in the source storage well water, a strategy was developed to investigate the origin of the water and the extent of the tritium activity.

2.1 Migration of Water

To evaluate the origin of the water, pathways for water to flow beneath the building were investigated, including leaks from pipes within the building, surface water percolation, and groundwater flow. Bechtel Nevada gathered information on local surface and groundwater characteristics by reviewing technical reports; interviewing experts from the City of North Las Vegas (CNLV), Clark County, and BN; collecting and analyzing samples; and mapping the shallow subsurface near Building A-1.

2.2 Tritium Concentration

The origin of the tritium was focused primarily on potential sources in and around Building A-1. Swipe surveys were conducted inside Building A-1 to determine if a new source was present, or possibly a source had not been removed during the previous decontamination effort. Tritium was not detected in these surveys. Air samples were also collected in the basement source range room, with the concentration being comparable to surveys taken during the decontamination effort conducted in 1997. A sanitary sewer outfall near the NLVF property line was sampled to determine if tritium was being transported off site via this pathway; the results were negative. Bechtel Nevada reviewed documents from the previous contamination incidents, consulted with tritium experts at other DOE locations, and performed extent-of- contamination studies that included swipes of the source well. Split samples were sent to outside laboratories for confirmation.

2.3 Extent of Tritium Activity

A phased approach was used to assess the extent of tritium activity. Geologic information was collected from a variety of sources including published reports, the local water authorities, and geotechnical investigations conducted for the construction of Building A-1. A subsurface investigation program was developed to collect static groundwater level data and samples for tritium analysis. Monitoring wells were installed to determine if tritium contamination from the source well is being released to groundwater.

Details of these investigations are discussed in the following sections.

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3.0 DETAILED INVESTIGATION

3.1 Geology of the Las Vegas Valley Basin

Discussion of the geology and hydrology of the Las Vegas Valley basin provides the necessary framework for understanding the geology and hydrology of the NLVF and the surrounding area.

Stratigraphy

The Las Vegas Valley basin is filled with several thousands of feet of coarse- and fine-grained fluvial and lacustrine deposits of Miocene and younger age. The oldest of these deposits compose the Horse Spring and Thumb Formations (Longwell *et al.*, 1965). These Miocene formations are overlain by the Pliocene Muddy Creek Formation, which is overlain by Pliocene-Pleistocene deposits termed the “basin fill.” The basin fill deposits are as much as 1,000 feet thick (Bell, 1981). In the area of the NLVF, basin-fill deposits are between 600 and 700 feet thick (Mindling, 1965).

The basin-fill sequence is characterized by three facies: coarse-grained fluvial deposits, fine-grained fluvial and lacustrine deposits, and lacustrine clay (Bell, 1981). The coarse-grained deposits compose piedmonts and alluvial fans that flank the mountains surrounding the basin. The fine-grained deposits compose the central part of the basin. Bingler (1977), Bell (1978), and Dinger (1977) show the dominant, near-surface, fine-grained deposits in the valley to be poorly to moderately indurated silts, sandy silts, silty sands, and sands. Beds of the fine-grained deposits are generally thin, discontinuous, and laterally variable (Bell, 1981). Most of the fine-grained, basin-fill deposits probably derive from marsh or playa environments (Mifflin and Wheat, 1979). The lacustrine clay is characteristically blue, and present only in the subsurface at depths between 480 and 600 feet in the central part of the basin. The blue clay is laterally extensive (Bell, 1981).

Structure

The Pliocene-Pleistocene basin-fill deposits are cut by a series of generally north-south-trending faults (Maxey and Jameson, 1948; Conwell, 1965; Bingler, 1977; Bell, 1978; and Dinger, 1977). The faults form escarpments with displacement down to the east, and many occur in steps. The escarpments are up to 100 feet high and as long as 10 miles. Fissures are common along the scarps (Bell, 1981). Conwell (1965) designated three of the more continuous and higher scarps as Scarp I, II, and III, respectively, from west to east across the valley. The faults extend to at least 500 feet deep, but the total depth is not known (Bell, 1981). Conwell (1965) documents impedance of groundwater by Scarp III. These faults are typically referred to as “compaction” faults, being attributed to differential compaction of the basin sediments (Maxey and Jameson, 1948; Domenico *et al.*, 1964; Mindling, 1965, 1971; Tabor, 1970; Conwell, 1965; and Passmore, 1975). However, more recent studies suggest that the faults are of tectonic origin, or of both tectonic and compaction origin (Bell, 1981; and Bell and DePolo, 1996). Withdrawal of groundwater in the Las Vegas Valley has likely reactivated movement along the faults.

3.2 Hydrology of the Las Vegas Valley Basin

Valley-Fill Reservoir

The Las Vegas Valley groundwater basin is dominantly a shallow intrabasin flow system; evidence that the basin may be part of a regional interbasin flow system is not conclusive (Bell, 1981). The flow system is characterized by recharge in the surrounding mountains, primarily the Spring Mountains on the west and the Sheep Range on the northeast, and discharge in the basin floor. Flow is thought to be downward in the recharge areas, horizontal around the margin of the valley toward the central part of the basin, and generally upward in the central part of the basin (Domenico *et al.*, 1964). Such flow can also be described in terms of imaginary lines that connect points at which water in a well will rise to a given elevation. These lines define the potentiometric surface and are perpendicular to flow (Bell, 1981). Based on a model-derived map of the natural (without the influence of pumping) potentiometric surface (Harrill, 1976), the general flow direction of water in the Las Vegas Valley is from west to east. In the area of the NLVF, the flow direction based on this map is slightly southeast.

Most of the groundwater supply in the Las Vegas Valley is derived from the “valley-fill reservoir,” which consists of the Muddy Creek Formation and the overlying basin-fill deposits (Harrill, 1976). Harrill (1976) presented a model for this reservoir that consists of the “near-surface reservoir” and the “principal aquifers.” The principal aquifers include three zones defined by Maxey and Jameson (1948), and other recognized zones. An upper zone defined by Maxey and Jameson (1948) is immediately below the near-surface reservoir at depths as much as 300 feet and is underlain by the blue lacustrine clay. An intermediate zone lies between the base of the blue clay and the base of the Pliocene-Pleistocene basin-fill deposits, 700 to 1,000 feet below surface. A lower zone is below the Pliocene-Pleistocene basin-fill deposits, presumably in the Muddy Creek Formation. Maxey and Jameson (1948) used the terms shallow, middle, and deep for these zones or principal aquifers; however, these terms are herein avoided because “shallow” is also the term used by researchers since 1978 for low-quality water that is present within a few tens of feet of the surface in the eastern and southeastern parts of Las Vegas Valley (Zikmund, 1996).

The near-surface reservoir occurs under confined and unconfined conditions. Prior to pumping, the near-surface reservoir was primarily supplied by upward leakage from the underlying principal aquifers (Bell, 1981). Maxey and Jameson (1948) (before heavy pumping, which started in 1962) reported that the top of the near-surface reservoir generally occurred between 50 and 100 feet below surface. Water in the near-surface reservoir was discharged to the surface by evaporation and springs (Brothers and Katzer, 1988). Pumping of the principal aquifers has caused the artesian head in the central part of the valley to drop significantly, resulting in reversal of the upward flow of water from the principal aquifers. Bernholtz (1993) reported that the flow of water in the eastern part of the valley is still upward.

In general, water from wells in the valley is good quality. Table 3-1 shows the average chemical composition of water in the principal and near-surface aquifers. Note that the concentration of total dissolved solids is relatively low in intermediate-depth groundwater, and tends to increase toward the surface.

Table 3-1 Average chemical composition of water in the principal and near-surface aquifers in the Las Vegas Valley. Quantities are reported in mg/L (milligrams per liter). Modified from Dinger (1977).

Source	pH	HCO ₃ ⁻	Cl	SO ₄ -2 (SO ₄ :Cl)	NO ₃ ⁻	Na+	K+	Ca ²⁺	Mg+2 (Ca:Mg)	NH ₄ ⁺	TDS	Average Screen Depth (ft)
1	7.6	242	311	1569 (5.00)	13.5	262	34	303	212 (1.42)	0.43	2824	NA
2	NA	120	45	267 (5.88)	3.2	35*		89	55 (1.62)	NA	640	NA
3	NA	237	9	47 (5.26)	2.3	12	2	40	35 (1.14)	NA	295	457
4	NA	219	6	36 (6.25)	1.8	12	2	46	26 (1.77)	NA	265	942
5	8.1	128	88	310 (3.57)	1.6	105*		85	28 (3.03)	0.00	737	NA

1. Shallow to near-surface groundwater (0 to 50 feet); average of 35 samples representing natural groundwater from wells listed in Dinger (1977, Appendix III).
 2. Near-surface to upper-intermediate-depth groundwater (101 to 300 feet); average of 250 samples reported by Kaufmann (1976, Appendix 3).
 3. Upper-intermediate-depth groundwater; average of 3 samples from the screened interval (Dinger, 1977).
 4. Intermediate-depth groundwater; average of 6 samples from the screened interval (in Dinger, 1977).
 5. Colorado River water; average of 4 samples taken by the Las Vegas Valley Water District, 1973 (Dinger, 1977).
- * Reported as the sum of Na+ and K+.

Shallow Aquifer

The decrease in artesian head, an increase in infiltration of surface waters from urbanization, and relatively impermeable near-surface sediments have resulted in accumulation of low-quality water above the near-surface reservoir. This water is termed the shallow aquifer (Kaufmann, 1978). As other aquifers in the Las Vegas Valley, the shallow aquifer is not within a distinct lithologic unit and is separated from other water-bearing units because of the confining characteristics of intermediate units (Bernholtz, 1993). Zikmund (1996) defined the shallow aquifer as “where the water table is within thirty feet of land surface and where total dissolved solids exceed those typically found in the near-surface and principal aquifers.”

About 60 monitoring wells have been installed in the shallow aquifer throughout the Las Vegas Valley by various agencies to monitor water level and water quality. Most of the monitoring wells in the shallow aquifer are south and west of U.S. Highway 95. The approximate boundaries of the shallow aquifer and the locations of monitoring wells are shown in Figure 3-1.

Water in the shallow aquifer generally flows eastward toward the Las Vegas Wash; however, “micro-gradients” can be in any direction, resulting from proximity to channels or from “mounding” of water where infiltration is high, as in areas of heavy irrigation (Converse Consultants, 1985). Monitoring wells in the shallow aquifer show that water levels tend to fluctuate with seasonal water usage (Zikmund, 1996).

Table 3-2 shows the chemical composition of water from selected monitoring wells in the shallow aquifer. The average concentration of total dissolved solids in water in the shallow aquifer (3,638 mg/L [Table 3-2]) is much greater than water from the near-surface and principal aquifers (265 to 737 mg/L [Table 3-1]). The total dissolved solids are typically high in the shallow aquifer because evapotranspiration concentrates natural salts and contaminants introduced by infiltration from the surface (e.g., organic compounds, salts from septic systems, leakage of sewage pipes).

3.3 Geology of the DOE/NV North Las Vegas Facility Area

Much of the area surrounding the NLVF has been developed and, in many cases, undeveloped areas have been disturbed by grading or placement of fill. Such development and disturbance make evaluation of the geology difficult. Evaluation of the geology necessarily was conducted through review of literature, examination of time-series aerial photographs, and limited field investigation.

The facility is approximately coincident with Scarp III of Conwell (1965), which at the facility trends southwest to northeast (Figure 3-2). The elevation changes from roughly 2,010 feet above mean sea level on the west side of the facility to 1,950 feet on the east side of the facility. Building A-1 at the NLVF is located approximately at the base of Scarp III. Undeveloped property north of Building A-1 is bounded on the west by elevated terrain that steps down eastward to a relatively flat surface. The break in slope between the easternmost step (“C” in Figure 3-2) and the low part of the property trends approximately north-south and, if continued south, would pass under the west end of Building A-1 (Figure 3-2). The approximate north-south trend of this fault suggests that it may be a splay of the fault associated with Scarp III. Additional faults are shown by Bell and Price (1991) in the area north of Building A-1 (Figure 3-2); although apparent on pre-development aerial photographs, few of these faults could be verified on the ground because of grading and development.

Fine-grained, basin-fill deposits (predominantly light-green, red-brown, and white sandy silt) are exposed on the undeveloped property north of Building A-1. These deposits demonstrate a large variability in both stratigraphy and structure over relatively short distances. Such variability likely carries southward under the NLVF. The south end of the north-south-trending scarp, and a small topographic high east of the scarp, expose light-green sandy silt over white sandy silt. North along the scarp, the white sandy silt transitions to red-brown sandy silt. This apparent

Table 3-2 Average chemical composition of water from selected wells in the shallow aquifer in the Las Vegas Valley. Concentrations are reported in mg/L. Well locations are shown in Figure 3-1. Modified from Zikmund, 1996 (Appendices A and B).

Well	HCO ₃ ⁻	Cl ⁻	SO ₄ -2	NO ₃ -N	Na ⁺	K ⁺	Ca ⁺²	Mg ⁺²	TDS	Water Level (ft)
C25	NA	NA	NA	NA	NA	NA	NA	NA	4940*	16.4
C27	275	249	3890	2.88	405	41.0	456	610	6340	20.9
C28	308	733	2360	2.56	610	31.0	464	274	4930	7.5
C29	205	500	3050	4.02	460	52.9	518	390	5530	11.7
C32	176	248	2780	7.93	317	19.6	420	380	4650	17.1
C33	NA	NA	NA	NA	NA	NA	NA	NA	3770*	20.2
C36	NA	NA	NA	NA	NA	NA	NA	NA	4750*	9.4
C42	254	351	2390	8.40	335	34.5	513	265	4380	11.3
C43	NA	NA	NA	NA	NA	NA	NA	NA	3550*	7.1
C49	258	270	1640	6.72	286	22.0	314	202	3120	10.3
DROSE	270	286	2030	1.78	336	35.3	338	250	3750	19.2
DROSE10G	306	646	3960	13.6	756	154	437	553	7240	15.2
DROSE11G	314	360	2380	7.21	421	138	424	251	4500	20.0
DROSE13T	262	308	2410	7.04	364	92.3	364	299	4280	15.3
DROSEPS	256	466	2900	17.6	512	58.3	371	428	5380	16.0
JGP	410	252	120	2	55	17.0	100	70	756	12.7
LG048	274	421	2540	0.81	379	61.7	324	400	4580	NA
MDB3	NA	40	214	0.01	33.7	8.7	132	0.3	548	19.1
MDB5	58	14	747	0.22	33.2	39.0	255	21	1185	14.3
MDB6	NA	63	178	0.38	55	22.4	185	0.2	728	16.4
PVP	201	238	1750	8.29	225	17.2	394	203	3230	16.1
USGS 5	321	487	2650	4.67	446	67.2	513	320	4940	8.9
USGS 34	265	132	429	5.53	41	5.3	143	100	990	10.8
USGS 37	563	172	739	13.6	145	22.4	175	165	1855	10.8
USGS 40	250	246	1570	8.16	238	18.5	327	211	3070	8.5
USGS 43	373	208	2760	8.54	222	38.5	433	423	4830	9.2
USGS 47	255	166	1240	1.20	141	14.9	218	211	2360	7.6
USGS 48	NA	NA	NA	NA	NA	NA	NA	NA	1840*	8.4
USGS 56	183	650	2900	NA	340	20.0	610	410	5400	15.3
AVERAGE	274	313	1984	5.79	298	43.0	351	268	3638	13.5

*TDS calculated from Electrical Conductivity (0.66 x EC= TDS)

Figure 3-2 Faults and fissures near the DOE/NV North Las Vegas Facility (from Bell, 1981; Bell and Price, 1991; Patt and Maxey, 1978; and original mapping).

transition from white sandy silt to red-brown sandy silt is also expressed in a west-to-east-trending excavation west of the south end of the scarp. There the beds dip eastward (apparent) at a few degrees. In the excavation, the light-green sandy silt is underlain by red-brown sandy silt. (Another red-brown sandy silt also overlies the light-green sandy silt at that location.) The true stratigraphic relationship between the white sandy silt and the red sandy silt is obscured by erosion, grading, and placement of fill.

Fissures are present at two locations on relatively flat ground east of the scarp, approximately 120 and 220 feet north of the north boundary of the DOE/NV facility (*Figure 3-2*). One fissure occurs in light-green sandy silt near North 5th Street. This fissure is coincident with a southwest to northeast trend of fissures mapped by Patt and Maxey (1978) that extends across North 5th Street into an area that is now developed (*Figure 3-2*). A group of fissures occurs in the white sandy silt near the scarp. The fissures have been widened by erosion from infiltrating water and range up to 5 feet wide and 5 to 10 feet long. Fine-grained sediments fill the fissures making the observable depth generally between 2 and 3 feet. The group of fissures near the scarp is in an area that periodically floods when flow exceeds the capacity of a natural channel that traverses west to east across the property north of the fissures (*Figure 3-2*). The channel and flood areas are apparent on aerial photographs taken prior to development of the surrounding area. The flood area supports considerably more vegetation than surrounding areas. The natural course of the channel at the top of the scarp is now Mayflower Road, which ends as a cul-de-sac at the scarp. Storm drains in the cul-de-sac convey water through a pipe that discharges into a small water impoundment at the base of the scarp. Overflow from the impoundment drains into the flood area and eastward through the channel to North 5th Street, where a new concrete storm water channel is being constructed to connect with an existing downstream storm water channel system. The small water impoundment apparently exists throughout the year, suggesting that it may be connected to the near-surface or shallow aquifer.

An inspection of an excavation for the storm water channel being constructed east of North 5th Street revealed from top to bottom approximately 2 feet of fill; 4 feet of brown clayey silt; 1.5 feet of white, carbonate-cemented silt; and 4 feet of green and red-brown clay. The beds dip eastward (apparent) at approximately 2 degrees, consistent with the dip of beds exposed in the excavation west of the south end of the scarp on the property north of the NLVF. How deposits exposed in the excavation for the storm channel fit stratigraphically with deposits exposed on the property north of the NLVF is uncertain because of grading and development.

The north-south-trending scarp becomes increasingly obscured northward because of grading, but may intersect another southwest-northeast-trending scarp approximately at Brooks Avenue, where it continues on that trend, transecting City View Park north of Brooks Avenue, approximately 0.3 miles north of the NLVF. Bell (1981) shows a discontinuous trend of fissures that likely marks the trend of the fault (*Figure 3-2*). One area of fissures shown by Bell (1981) is within the park, presumably at the base of the scarp. Such an area could be conducive to infiltration of water used to irrigate the park.

East of City View Park, in an undeveloped area bounded on the south by Brooks Avenue, and on the east by Losee Road, a relatively flat, graded area rises abruptly, exposing from bottom to top,

approximately 10 feet of white sandy silt, 10 feet of brown sandy silt, and 5 feet of caliche. The abrupt rise in topography suggests a fault between the flat ground and the elevated ground (*Figure 3-2*), although differential erosion is certainly an alternative explanation for the change in topography. The caliche is fine-grained, having more the appearance of an impure limestone (marl), and perhaps represents late Pleistocene spring deposits. The caliche forms a resistant cap that dips a few degrees almost due east. This dip angle and direction are consistent with apparent attitudes of beds observed elsewhere in the area.

The Kyle Ranch Historic Area is 0.1 mile south of the west part of the NLVF, at the base of a series of north-south-trending fault scarps (*Figure 3-2*). Deposits here are brown sandy silt. Historically, the Kyle Ranch was the site of a spring and now supports vegetation consistent with wet ground conditions. Numerous fissures have been mapped within the Kyle Ranch area (Patt and Maxey, 1978).

3.4 Hydrology of the DOE/NV North Las Vegas Facility Area

Water Supply Wells

Twenty public water supply wells are present within approximately 1 mile of the NLVF (*Figure 3-3*.) Table 3-3 provides information on these water supply wells. Many of the wells are relatively old and the current status is not known. Several of the wells are known to have been abandoned, and at least one has been converted to a monitoring well. The initial static water level in wells nearest to the NLVF for which information is available – Reservoir 1, Reservoir 2, Galluci, Losee, Federal Park, and Northland Park – ranges between artesian flow (-46 feet) and 23 feet below surface. The elevation of the initial static water level in these wells ranges approximately between 2,046 feet at Reservoir 1 and 1,860 feet at Federal Park, suggesting a southeast gradient. Additionally, three monitoring wells are known to be present at the City of North Las Vegas Civic Center. Data are not available for these monitoring wells.

Four monitoring wells in the shallow aquifer (*Figure 3-1*) are within 2 miles of the NLVF: well ATTC is approximately 1 mile northwest; well KB-1 is approximately 2 miles west-southwest; well MK-1 is approximately 1.5 miles southwest; and well JGP is approximately 2 miles south. In August 1995, the static water level in wells ATTC, KB-1, MK-1, and JGP was 63.1, 33.6, 18.7, and 12.7 feet, respectively.

Groundwater Quality

A water analysis report dated July 1962, from the Losee well located approximately 0.1 mile from the NLVF (*Figure 3-3*; *Table 3-3*), showed the concentration of total dissolved solids to be 252 mg/L. The concentration of total dissolved solids in water collected from the source storage well in Building A-1 at the NLVF is 350 mg/L. The concentrations of total dissolved solids in these two wells are comparable with the average concentration given in *Table 3-1* for intermediate and upper-intermediate-depth water in the principal aquifers. Water quality data for well JGP is presented in *Table 3-2*. The concentration of total dissolved solids in well JGP (756 mg/L) is comparable with the average concentration given in *Table 3-1* for upper intermediate-depth water (640 mg/L). The probable influence of surface-derived water is evident in well JGP,

Figure 3-3 Locations of water supply wells near the DOE/NV North Las Vegas Facility (data from CNLV and LVVWD databases, 1998).

Table 3-3 Water supply wells near the DOE/NV North Las Vegas Facility. Listed north to south. Elevation and depths are in feet. See Figure 3-3 for locations of wells. Data are from well logs provided by CNLV and LVVWD well databases, 1998.

Well Name	Drilled	Log	Elev.	Access. Depth	Water Level		Status
					Date	Depth	
Leavitt	1962	Yes	1905	1040	9/20/62	50	Active
Reservoir 1	1956	NA	2000	1171	3/02/56 1/14/73	-46 71	Abandoned
Reservoir 2	1956	Yes	2003	1925	1/30/56	Artes.	Abandoned
Northland Park	1955	Yes	1895	472	12/55	8	NA
Galluci	1949	Yes Yes	2035	730	4/25/49 8/03/61 2/28/75 3/01/77	8 54 91 74.5	NA
Francis Corp	NA	NA	NA	NA	NA	NA	NA
Boris Terrace	1954	Yes	1859	507	6/10/54	36	NA
Losee	1961/62	Yes	NA	500	1961	23	Abandoned 11/95
North Main	NA	NA	1858	402	NA	NA	NA
Federal Park	1954	Yes	1883	550	7/20/54	20	Abandoned
Valley View	1962	Yes	2019	1000	8/18/62 3/05/74 5/17/99	92 55.4 14.2	Abandoned
N. Fun Center	NA	Yes	1913	853	NA	NA	NA
S. Fun Center	NA	NA	1915	752	NA	NA	NA
Tonopah	NA	NA	1911	1105	3/05/74 4/23/98	29.8 -1.2	Abandoned
Goldfield	NA	NA	NA	NA	NA	NA	Conv. to monitor
Reservoir 2A	1956	Yes	NA	1220	4/03/56	45	NA
Grandview	1954	Yes	1846	450	4/21/54	7	NA
Railroad	NA	NA	1936	740	NA	NA	NA
Sakai	NA	NA	NA	450	NA	NA	NA
Stocker	1969	Yes	1950	450	2/2/69	8	Abandoned 9/96

given the higher concentration of total dissolved solids. The location of well JGP and very shallow depth to groundwater at that location are conducive to infiltration from the surface. Relatively low concentrations of total dissolved solids in groundwater near the NLVF suggest, at least in part, a deeper source. This assertion is consistent with the still upward flow of water reported in the eastern part of the Las Vegas Valley (Bernholtz, 1993).

Effects of Pumping and Recharging Groundwater

Figure 3-4 shows the effect of pumping groundwater in selected wells. Locations of these wells are shown in *Figure 3-3*. The upper limits of the lines show the typical water levels in the wells. Abrupt decreases in the level of the line indicate pumping and abrupt increases indicate cessation of pumping. The degree of drawdown shown in *Figure 3-4*, in some cases as much as approximately 350 feet, is primarily dependent on the rate of pumping and rate of recharge. Water levels in the wells tend to recover to typical levels in relatively short periods of time after cessation of pumping.

Both the Las Vegas Valley Water District and the City of North Las Vegas have groundwater recharge programs; the programs have been active since 1987 and 1989, respectively. The intent is to recharge water to the various aquifers when demand is low, for subsequent use during periods of high demand. Figure 3-5 shows the locations of water recharge wells operated by the Las Vegas Valley Water District (LVVWD, 1998), and selected water recharge wells operated by the City of North Las Vegas (CNLV, 1998). In 1998, the City of North Las Vegas operated six water recharge wells, most of which are in the general vicinity of the North Las Vegas Airport. The closest water recharge wells to the NLVF are the West Cheyenne (WC), Simmons-Mead (SM), and Simmons-Evans (SE), all approximately 2.5 miles west of the NLVF; and the Gowen No.1, approximately 2.6 miles east of the facility (not shown on *Figure 3-5*). Between 1987 and 1999, the Las Vegas Valley Water District has a cumulative net storage of 190,875 acre-feet (LVVWD verbal communication, 1999). Between 1990 and 1998, the City of North Las Vegas has a cumulative net storage of 11,205 acre-feet (CNLV, 1998).

The effect of recharge is generally the opposite of pumping. Water levels, or at least the pressure in the aquifer, tend to increase. Figure 3-6 shows the net change in the potentiometric surface of the principal aquifer between 1990 and 1998. The potentiometric surface has risen approximately 30 feet in the general area of the NLVF (LVVWD, 1998). The static water level in the Valley View and Tonopah wells, both near the NLVF has risen at least this amount between 1974 and recent past years (*Table 3-3*).

3.5 Geology Under Building A-1, DOE/NV North Las Vegas Facility

Canister Pits

Building A-1 is near the northeast corner of the NLVF. The entire area around the building has been paved, precluding direct observation of the underlying deposits. A geotechnical investigation conducted in 1975 (Converse, Davis, and Associates, 1975), prior to construction of Building A-1 later that year, provides information on the subsurface stratigraphy. Although a

Figure 3-4 The effect of pumping groundwater in wells near the DOE/NV North Las Vegas Facility (from CNLV, 1998).

Figure 3-5 Locations of water recharge wells operated by the Las Vegas Valley Water District, and selected water recharge wells operated by the City of North Las Vegas (data from CNLV and LVVWD, 1998).

Figure 3-6 Net change in the potentiometric surface in the Las Vegas Valley between 1990 and 1998 (modified from LVVWD, 1998).

number of boreholes and trenches were drilled or excavated as part of the investigation, the available report included the logs of only five boreholes (Figure 3-7). One borehole log (BH-8) mentioned in the report, but not available, was drilled at the site of what is now referred to as the “north canister pit.” The drilling log for the north canister pit is available (Fenix and Scisson, 1975). Canister pits are cased, large-diameter holes, approximately 120 feet deep, used for checking the alignment of test diagnostic equipment. Three canister pits were eventually drilled. The “south canister pit” is approximately 40 feet south of the north canister pit under the “twin towers” at the east end of Building A-1. The “west canister pit” is outside, approximately 125 feet west of Building A-1 (Figure 3-7).

The canister pits provide the stratigraphy of deposits underlying Building A-1 to approximately 120 feet below surface (Figure 3-8). Converse Consultants (1984a and 1984b) describe the stratigraphy of the south and west canister pits, respectively (the south canister pit is referred to as the “east site” in the 1984a report). Fenix and Scisson (1975) describes the stratigraphy of the north canister pit. Although the distance between the west canister pit and the north and south canister pits is only about 600 feet, the documented stratigraphy of the west canister pit is remarkably different than the stratigraphy in the two canister pits on the east side of Building A-1. Differences between the stratigraphy in the north and south canister pits may simply be a function of description of texture, color, and thickness of beds; alternatively, some differences may be real, or both real and a function of description.

The upper 60 feet in the west canister pit is primarily alternating silty clay, clayey silt, and sandy silt, with low to moderate plasticity; silty sand and clayey sand are also present. (Plasticity is the degree to which a wetted sediment can be molded.) Converse Consultants (1984b) described 5- and 20-foot layers of dense silty sand to clayey sand at depths of 10 and 16 feet (18 feet on the log), respectively. These sandy beds may be significant in terms of describing the shallow and near-surface aquifers. Discounting a thin clay between these sandy units, the associated top and bottom elevations are 1,937 feet and approximately 1,909 feet, respectively. Also noted were partially cemented sediments throughout the entire depth of boring. The stratigraphy in the west canister pit below 60 feet (elevation 1,887 feet) is clay with high plasticity. The dominant colors of beds encountered in the borehole are shades of gray and brown, although shades of green are also present. During drilling, the sequence of beds was noted to be very moist between 25 and 69 feet, and wet between 69 and 120 feet. The groundwater level at 69 feet below surface corresponds roughly to an elevation of 1,878 feet. Converse Consultants (1984b) believed the long-term static groundwater level would be higher.

The entire depth of the south canister pit encountered primarily silty clay and sandy clay, with low to high plasticity. Sand, clayey sand, sandy gravel, and caliche beds were also encountered. Partially cemented sediments were encountered throughout the entire depth of boring (Converse Consultants, 1984a). The caliche beds are present between 7.5 and 9.0 feet below surface (elevations 1,938.5 and 1,937 feet), and between 28.5 and 34.5 feet below surface (elevations 1,917.5 and 1,911.5 feet). A noted loss of drilling mud during drilling was attributed to a sandy gravel bed between 67 and 75 feet below surface (elevations 1,878.5 and 1,870.5 feet). The dominant colors of beds encountered in the borehole are shades of brown, although white, gray, and green are also present. Brown beds are more common in the approximately upper 50 feet of

Figure 3-7 Locations of canister pits, geotechnical boreholes, and Geoprobe® holes.

Figure 3-8

Figure 3-8 Stratigraphic sections of the west, north, and south canister pits (data from Converse Consultants, 1984a,b; Fenix and Scisson, 1975).

section, whereas gray and green beds are more common below this approximate depth. Groundwater was encountered at 56 feet below surface (elevation 1,890 feet) shortly after drilling. Eight days after drilling, the water level had risen to 51 feet below surface (elevation 1,895 feet).

The borehole log of the north canister pit (Fenix and Scisson, 1975) shows primarily sandy clay the entire depth of boring, 109 feet below surface. Sand, clay, and caliche beds were also encountered. The dominant reported colors of beds encountered in the north canister pit are red and white, although shades of green are also reported. Converse, Davis, and Associates (1975) encountered groundwater at 70.5 feet below surface in their borehole BH-8, which was drilled at the approximate location of the north canister pit.

A thick bed of caliche encountered between 19 and 23 feet below surface (elevations 1,927 and 1,923 feet) in the north canister pit likely correlates with the caliche bed encountered in the south canister pit between 28.5 and 34.5 feet below surface (elevations 1,917.5 and 1,911.5 feet). Sandy gravel encountered between 60 and 69 feet below surface (elevations 1,886 and 1,877) in the north canister pit likely correlates with sandy gravel encountered between 67 and 75 feet below surface (elevations 1,878.5 and 1,870.5 feet) in the south canister pit. These correlations indicate that over a relatively short distance (less than 40 feet), beds in the top part of the south canister pit are about 11 feet lower than beds in the top part of the north canister pit, and beds in the bottom part of the south canister pit are about 6 feet lower than beds in the bottom part of the south canister pit. These differences indicate approximately a 12-degree angle between corresponding beds in the top part of the section, and approximately a 7-degree angle between corresponding beds in the bottom part of the section.

The angle between corresponding beds in the north and south canister pits may represent the dip of beds between the two canister pits. However, these angles seem excessive, considering the more shallow dips observed in undeveloped areas north of the NLVF. Further, the generally observed dip direction in the area is more east than south. The presence of a fault between the two canister pits is an alternative interpretation. The remarkable difference between the stratigraphy in the west canister pit and the stratigraphy in the north and south canister pits may also be best explained by the presence of an approximately north-south-trending fault between these end points, perhaps the scarp observed on the undeveloped property north of the NLVF.

Geotechnical Boreholes

The locations of geotechnical boreholes drilled near or under Building A-1 as part of the preconstruction geotechnical investigation (Converse, Davis, and Associates, 1975) are shown on *Figure 3-7* with the prefix "BH." These boreholes typically extend to between 20 and 30 feet below surface. Fill, sand, clayey sand, and clay are the primary deposits underlying the building. Also present are sandy clay and caliche. The beds are typically shades of brown, green, and white. *Figure 3-9* shows boreholes BH-1, BH-5 and BH-4, providing an approximate northwest to southeast section of the stratigraphy under the building. *Figure 3-10* shows boreholes BH-2, BH-5, and BH-3, providing an approximate southwest-to-northeast section of the stratigraphy under Building A-1.

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Beds between the boreholes in both sections do not correlate well. Difficulty in correlating the beds may simply be a function of description of texture, color, and thickness of beds; alternatively, some differences may be real, or both real and a function of description. Correlation is further hampered because boreholes BH-5 and BH-3 have fill from the surface to 14.5 feet and approximately 11 feet, respectively. One possible tie between boreholes BH-1, BH-2, and BH-4 might be a clay-sand-clay sequence that lies between 8 and 17 feet in borehole BH-1, between 9 and 13.5 feet in borehole BH-2, and between 12 and 18 feet in borehole BH-4. Although the top and bottom clay beds in the sequence are different thicknesses, and a different color in borehole BH-1, the intermediate sand in all boreholes is between 1 and 1.5 feet thick, and white. Assuming this correlation to be valid, a three-point solution determines the strike of the sand to be N14°W, and the dip angle and direction to be 32°N76°E, respectively. Although the strike and dip direction of the sand bed are reasonable based on field observations in the area, such a steep dip is not consistent with observed dip angles. Rather than a steep dip angle, however, the sand bed could be offset down to the east by a fault. This interpretation is consistent with (1) the trend of the roughly north-south scarp present on the property north of the NLVF (*Figure 3-2*), (2) the apparent stratigraphic differences between the west canister pit and the north and south canister pits, and (3) the fact that considerable fill was placed in the vicinity of boreholes BH-5 and BH 3 to bring the topography roughly to an even grade.

One notable bed in borehole BH 4 at the southeast corner of the main part of Building A-1 is a 4.5-foot thick, white caliche bed between 2 and 6.5 feet below surface (elevations 1,941.5 and 1,937.0 feet). This bed is not present in the other boreholes; however, it could have been present in borehole BH-3 in the place of fill.

3.6 Hydrology Under Building A-1, DOE/NV North Las Vegas Facility

Source Storage Well Water Levels

Water was discovered in the source storage well on October 21, 1999. Between November 4, 1999, and mid-December 1999, the water level was checked several times each week and expressed in inches above the bottom of the storage well. Since mid-December 1999, the water level has generally been checked weekly. Figure 3-11 shows water levels recorded for the months of November and December 1999 and January 2000. Since measurement of the water levels was started, the water level has generally steadily risen. The lowest level recorded is 9.5 inches on November 6, 1999 (1,923.29 feet), and the highest level recorded is 17.8 inches on January 31, 2000 (1,923.98 feet). The corresponding volumes of water in the source storage well are approximately 9.3 gallons and 17.5 gallons, respectively.

Source Storage Well Pump Tests

Water in the source storage well was pumped on four occasions between November 23, 1999, and January 18, 2000, for the purposes of testing for tritium and determining a representative hydraulic conductivity of the water-bearing formation surrounding the storage well. The rate of water recovery into the well versus time was recorded for the first three pumping events. The Hvorslev method for piezometers was used to determine the hydraulic conductivity (Hvorslev, 1951). This method relates the flow at any time at a piezometer (in this case, the source

Figure 3-11 Plot of water levels in the Building A-1 source storage well.

storage well) to the hydraulic conductivity, and the unrecovered head distance after the source storage well is drained, given that the radius and the length of the piezometer intake are known. By assuming the length and the radius, various estimates of conductivity can be made from the test data. Because the actual pumping conditions only approximately match the Hvorslev test conditions, the results of the analysis are only reasonable approximations of conductivity. Furthermore, because the media properties immediately below the floor at the well are not known, the estimated conductivity can be interpreted as an equivalent conductivity of the media surrounding the well, regardless of whether the media is fractured or porous. Head and time measurements are recorded while the source storage well is recovering water from the formation. Table 3-4 shows the data and results for the three pump tests. Figure 3-12 is a plot of the results for each of the three pump tests. Results of each test are remarkably similar. The average hydraulic conductivity is $7.3\text{E-}04$ centimeters per second, which is about 2 feet per day. Geotechnical borehole BH-5 (*Figures 3-9 and 3-10*), the borehole closest to the storage well, shows a well-sorted (poorly graded), dense sand at the depth of the bottom of the source storage well. The lateral extent and stratigraphic relationships of the sand with other beds are not known.

Prior to the first pump test, samples of water in the source storage well were collected for analysis of the tritium concentration. Samples were also collected after each pump test, when sufficient water had entered the source storage well to facilitate collection, and again after the water had nearly fully recovered or had fully recovered. Samples have also been collected and analyzed on a weekly basis since the last pump test. Results of these analyses are presented in Table 3-5 and shown on Figure 3-13. Generally, recovered water after each pump test had a progressively smaller concentration of tritium. However, if the water was allowed to sit for a period of time in the storage well, the concentration of tritium increased.

Geoprobe® Boreholes

Boreholes were drilled using the Geoprobe® direct-push system. The Geoprobe® pushes a string of 1.25-inch (outside diameter) pipe into the ground for the purpose of determining geotechnical properties of the subsurface beds. For this investigation, the Geoprobe® was configured to advance a hole to approximately 30 feet below surface, expose a screened interval at the end of the string of pipe, and recover a sample of any encountered water. The static water level of encountered water could also be determined by lowering a water-level probe down the center of the string of pipe. In this report, these borings are referred to as Geoprobe® boreholes. The system as configured did not provide information on the subsurface stratigraphy, except that which could be surmised through the degree of difficulty in pushing through the subsurface beds. The locations of Geoprobe® boreholes are shown on *Figure 3-7* with the prefix “GP.” Eight Geoprobe® boreholes were completed. Numbers assigned to the Geoprobe® boreholes are not sequential; several proposed holes were abandoned because of their proximity to underground utilities, and the retained boreholes were not renumbered.

Two Geoprobe® boreholes did not reach the total desired depth of 30 feet below surface. Geoprobe® borehole GP-11, near the northeast corner of the main part of Building A-1, was terminated at approximately 25 feet after encountering an exceptionally hard bed. The hard bed likely is the thick caliche bed noted in the north canister pit at 19 feet below surface (*Figure 3-8*).

Table 3-4 Data and results of pump tests in the source storage well in Building A-1.

Test 1 - 11/21/1999

H = 20.12 cm

T_o = 1.0 @ recovery = 0.37

for all tests

H₀ = 0 cm

radius = 21.59 cm

Time (min)	Time (hr)	ΔT (min)	Change in water level (ft)	Change in water level (cm)	Cumulative Recovery (cm)	(H-h) / (H-H ₀)	L (assumed) cm	K cm/hr	K cm/sec
0	0.00	0				1	10	N/A	N/A
31	0.52	31	0.27	8.23	8.23	0.591	20	N/A	N/A
62	1.03	31	0.15	4.57	12.80	0.364	30	2.56	0.00071
94	1.57	32	0.11	3.35	16.15	0.197	40	3.59	0.00100
125	2.08	31	0.06	1.83	17.98	0.106	50	3.91	0.00109
155	2.58	30	0.04	1.22	19.20	0.046	100	3.57	0.00099
171	2.85	16	0.03	0.91	20.12	0.000	200	2.59	0.00072
							300	2.04	0.00057
							1000	0.89	0.00025

min = 0.00025

max = 0.00109

avg = 0.00076

Test 2 - 11/30/1999

H = 26.21 cm

T_o = 1.5 @ recovery = 0.37

Time (min)	Time (hr)	ΔT (min)	Change in water level (ft)	Change in water level (cm)	Cumulative Recovery (cm)	(H-h) / (H-H ₀)	L (assumed) cm	K cm/hr	K cm/sec
0	0					1	10	N/A	N/A
8	0.13	8	0.06	1.83	1.83	0.93	20	N/A	N/A
20	0.33	12	0.1	3.05	4.88	0.81	30	1.70	0.00047
28	0.47	8	0.06	1.83	6.71	0.74	40	2.40	0.00067
46	0.77	18	0.11	3.35	10.06	0.62	50	2.61	0.00072
61	1.02	15	0.08	2.44	12.50	0.52	75	2.58	0.00072
75	1.25	14	0.08	2.44	14.94	0.43	100	2.38	0.00066
90	1.50	15	0.05	1.52	16.46	0.37	150	2.01	0.00056
105	1.75	15	0.05	1.52	17.98	0.31	250	1.52	0.00042
120	2.00	15	0.03	0.91	18.90	0.28	350	1.24	0.00034
190	3.17	70	0.14	4.27	23.16	0.12	500	0.98	0.00027
260	4.33	70	0.09	2.74	25.91	0.01	750	0.73	0.00020
275	4.58	15	0.01	0.30	26.21		1000	0.60	0.00017

min = 0.00017

max = 0.00072

avg = 0.00047

Test 3 - 12/7/1999

H = 25.908 cm

T_o = 0.9 @ recovery = 0.37

Time (min)	Time (hr)	ΔT (min)	Change in water level (ft)	Change in water level (cm)	Cumulative Recovery (cm)	(H-h) / (H-H ₀)	L (assumed) cm	K cm/hr	K cm/sec
0	0					1	10	N/A	N/A
8	0.13	22	0.21	6.40	6.40	0.75	20	N/A	N/A
26	0.43	18	0.14	4.27	10.67	0.59	30	2.84	0.00079
39	0.65	13	0.07	2.13	12.80	0.51	40	3.99	0.00111
54	0.90	15	0.08	2.44	15.24	0.41	50	4.35	0.00121
69	1.15	15	0.08	2.44	17.68	0.32	75	4.30	0.00119
84	1.40	15	0.08	2.44	20.12	0.22	100	3.97	0.00110
99	1.65	15	0.04	1.22	21.34	0.18	150	3.35	0.00093
164	2.73	65	0.1	3.05	24.38	0.06	250	2.54	0.00070
190	3.17	26	0.05	1.52	25.91		350	2.06	0.00057

min = 0.00057

max = 0.00121

avg = 0.00095

Test Average = 0.00073 cm/sec

Figure 3-12 Plot of results of pump tests in the source storage well in Building A-1

Table 3-5 Tritium concentrations in water from the source storage well in Building A-1.

Date	Sample Number	Sample Description	Tritium Concentration (pCi/L)
11/08/1999	HP00000001	Initial sample	2.45E+05
11/08/1999	NA	Recount of initial sample	2.40E+05
11/08/1999	NA	Duplicate of initial sample	2.46E+05
11/09/1999	RM 4862-1	Confirmation sample	2.27E+05
11/09/1999	RM 4862-2	Confirmation sample	2.38E+05
11/10/1999	NA	Independent lab	2.50E+05
11/23/1999	99TPS11-23-3	First recharge - initial	3.40E+04
11/24/1999	99TPS11-24-1	First recharge - completion	2.84E+04
11/30/1999	HP00000005	Second recharge - initial	7.92E+03
12/06/1999	HP00000006	Second recharge -completion	8.49E+03
12/06/1999	HP00000007	Third recharge - initial	5.94E+03
12/06/1999	HP00000008	Third recharge - completion	5.07E+03
12/07/1999	125ml Water Sample	Third recharge - 12 hours	9.00E+03
12/13/1999	RM 4862 WELL	Confirmation sample	4.11E+04
12/20/1999	RM 4862 WELL	Confirmation sample	6.86E+04
12/28/1999	RM 4862 WELL	Confirmation sample	9.90E+04
01/03/2000	RM 4862 WELL	Confirmation sample	1.11E+05
01/10/2000	RM 4862 WELL	Confirmation sample	1.14E+05
01/18/2000	RM 4862 WELL	Confirmation sample	1.27E+05
01/19/2000	00SER01-19-1	Initial sample - after recharge	1.00E+04
01/20/2000	00SER01-20-1	Second sample - ~ 14 hrs after recharge	1.08E+04
01/24/2000	RM 4862 WELL	Confirmation sample	3.25E+04
01/31/2000	RM 4862 WELL	Confirmation sample	6.32E+04

Figure 3-13 Tritium concentrations in water from the source storage well in Building A-1.

Geoprobe® borehole GP-12, punched near the center of the main part of Building A-1 (the concrete floor was augered), was terminated at approximately 21 feet after entering an exceptionally resistant bed. The resistant bed may be the stiff clay noted in geotechnical borehole BH-5 at 15.5 feet below the floor (14.5 feet below grade when drilled) (*Figures 3-9 and 3-10*).

Groundwater Levels

Water levels encountered as part of the Geoprobe® borehole investigation are given in Table 3-6, and also noted on the geotechnical borehole sections closest to the Geoprobe® boreholes; the water level in the source storage well is noted on borehole BH-5 (*Figures 3-9 and 3-10*). The probable water-bearing bed in Geoprobe® boreholes GP-1A and GP-9 (based on the nearest geotechnical borehole) is clayey sand and sandy clay, respectively.

Initial measures shown in Table 3-6 are those taken immediately after the boreholes were advanced to total depth. Geoprobe® boreholes GP-2 on the south side of Building A-1 and GP-6 near the northwest corner of Building A-1 were dry immediately after the boreholes were completed. Geoprobe® boreholes GP-11 and GP-12 were terminated as discussed above. Final measures shown in Table 3-6 are those taken after water levels were assumed to have approached a near static level.

Figure 3-14 is a contour map of the surface of the water underlying Building A-1. Figure 3-14 shows a southeast gradient of about 0.03 (1.8 degrees), and thus flow direction of water underlying Building A-1. Contours are based on interpolation of water levels between known points, and the maps do not consider potential variations in the surface of the water due to variations in the subsurface geology, which appears to be relatively complex. Beds under Building A-1 likely thicken or thin, pinch out, or are truncated. Faults may be responsible for apparent truncations or offsets of beds, which could account for the apparent relatively steep gradient.

The depth to water below Building A-1 varies from approximately 18 feet at the northwest corner to approximately 27 feet along the south wall, about midway between the southwest and southeast corners. These depths are consistent with depths reported for the shallow aquifer (Zikmund, 1996). Water in the shallow aquifer, however, by definition has a relatively high concentration of total dissolved solids (Zikmund, 1996). An analysis conducted to determine the quality of water in the source storage well showed a relatively low concentration of total dissolved solids (350 mg/L). This low concentration of total dissolved solids suggests a deep source or a short resident time in the ground following infiltration, or both. However, even with a short resident time, infiltrated water should have a concentration of total dissolved solids of at least that in Colorado River water (737 mg/L, Table 3-1). The Colorado River is the primary source of domestic water used in the Las Vegas Valley. Historically, the top of the near-surface aquifer in the vicinity of the NLVF has been relatively close to the surface (see Section 3.4). Water below Building A-1 is most likely the near-surface aquifer with water derived from deeper aquifers. Comparison of SO₄:Cl and Ca:Mg ratios indicate that upward movement of groundwater from deeper aquifer zones is the major source of recharge to near-surface ground water (Dinger, 1977).

Table 3-6 Water levels measured in the Geoprobe boreholes. Datum is the north end of the threshold for the rail-track bay door. Set at 1,946.00 feet (finished floor elevation).

Hole	Grnd. Elev.	Depth	Date 1	Time 1	WL 1 Depth	WL 1 Elev	Date 2	Time 2	WL 2 Depth	WL 2 Elev.
GP-1A	1944.95	30	12/15/1999	1448	26.74	1918.21	12/16/1999	1230	26.32	1918.63
GP-2	1945.37	30	12/20/1999	1730	NA	NA	12/21/1999	0743	27.26	1818.12
GP-3	1945.67	30	12/21/1999	1055	28.15	1917.52	12/21/1999	1342	23.79	1921.88
GP-4	1945.83	30	12/20/1999	1155	26.27	1919.56	12/20/1999	1400	21.93	1923.90
GP-6	1945.69	30	12/21/1999	1157	NA	NA	12/22/1999	0830	17.90	1927.79
GP-9	1945.60	30	12/14/1999	1628	22.27	1923.33	12/15/1999	0807	20.78	1924.82
GP-11	1945.68	25	12/20/1999	1633	NA	NA	12/21/1999	0855	NA	NA
GP-12	1945.89	21	12/22/1999	1255	NA	NA	12/22/1999	1430	NA	NA

Figure 3-14 Contour map of the surface water underlying Building A-1.

The shallow depth of water below Building A-1 is conducive to mixing of infiltrated water with water of the near-surface aquifer. Any infiltrated water would have to be from sources relatively close to the NLVF to maintain the observed low concentration of total dissolved solids in the source storage well. The southeast flow direction of water below Building A-1 suggests that any recharge from the surface is from approximately north of the NLVF. If the gradient of the water surface below Building A-1 is hypothetically continued northwest, it intersects the ground surface approximately 880 feet from Geoprobe® borehole GP-2. An arc turned this distance north from Geoprobe® borehole GP-2 includes the area of undeveloped property north of the NLVF that periodically floods and has ground fissures (see Section 3.3). Recharge could result from infiltration of (1) runoff water from increased development north of the NLVF, (2) irrigation water at City View Park, (3) direct and accumulated precipitation (perhaps through recognized fissures north of the NLVF), (4) sewage from a leaking pipe (a sewer pipe is present near the water impoundment north of the NLVF), or (5) a combination of these possibilities. Increased runoff and irrigation, in part enhanced by reduced seasonal evaporation and plant demand, are the two most probable contributing factors to increased infiltration.

Recent elevation of the water level below Building A-1 is best explained, generally in order of importance, by a combination of (1) water in the near-surface aquifer being at or near natural levels, or recovering to natural levels after discontinuation of pumping (although this typically has been a relatively rapid process); (2) pressurization of the valley-fill reservoir from artificial recharge of water; (3) an increase in infiltration of water from the surface; and (4) seasonal reduction in evaporation and plant demand for water.

Temporary Monitoring Wells

The concentration of tritium in water from the Geoprobe® boreholes is shown in Table 3-7. The tritium concentration in all samples was less than the minimum detectable activity (MDA) which ranged from 7.70E+02 to 8.00E+02 pCi/L. For comparison, tap water from a faucet on the first floor of Building A-1 had a tritium concentration of 6.00E+01 pCi/L, and water from a nearby sanitary sewer outfall at the NLVF had a tritium concentration of 1.61E+02 pCi/L. Dinger (1977) reported the average concentration of tritium in near-surface groundwater in the Las Vegas Valley, resulting from interaction with natural and nuclear-weapon-produced tritium in the atmosphere, to be 8.00E+01 pCi/L (expected to be less now because almost two half-lives for tritium have since passed).

One upgradient temporary monitoring well and three downgradient temporary monitoring wells have been installed on the north and south sides of Building A-1, respectively (*Figure 3-7*), to periodically check the water level and concentration of tritium. Data from these temporary monitoring wells are forthcoming.

Table 3-7 Tritium concentrations in water from the Geoprobe® boreholes around Building A-1.

Sample Date	Sample Number	Geoprobe® Borehole	Tritium Concentration (pCi/L)
12/15/1999	99JMF12-15-3	GP-9	-6.36E+02
12/15/1999	99JMF12-15-4	GP-9	-2.48E+02
12/16/1999	99SER12-16-2	GP-1A	-2.10E+02
12/20/1999	99SER12-20-2	GP-4	-2.91E+02
12/20/1999	99SER12-20-3	GP-4	-1.05E+02
12/21/1999	99SER12-21-2	GP-2	-2.17E+02
12/21/1999	99SER12-21-4	GP-3	-4.40E+02
12/21/1999	99SER12-21-6	GP-6	-2.17E+02

Note: MDA ranged from 7.70E+02 to 8.00E+02 pCi/L. Negative concentration values indicate the concentration is less than the instrument background.

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4.0 SAMPLING ACTIVITIES AND RESULTS

Water samples from locations in and around the NLVF were tested for tritium and other potential contaminants to determine whether they were potential sources of the water present in the source storage well in Building A-1 (Table 4-1).

4.1 Water Impoundment

A small water impoundment on undeveloped property north of the NLVF (see Section 3.3) is reportedly part of the Regional Flood Control system. The impoundment is fed primarily by a large pipe bringing storm water and runoff from an industrial area northwest of the NLVF. The pipe is covered with several feet of riprap apparently designed to accept and direct excess surface runoff into the pond. The surrounding area shows numerous large fissures and channels which are left in their natural state. The pond itself was reinforced with riprap, presumably to prevent erosion during storms. The standing water in the pond had a gray color and fetid odor. Samples were collected using a clean plastic scoop.

Samples were analyzed for tritium, oil and grease, nitrate, water quality parameters (alkalinity, conductivity, chlorides, sulfate, total dissolved solids, and total suspended solids), and metals. The tritium concentration was below the laboratory MDA. The other analytes were within the expected ranges for this type of stagnant surface water. The primary purpose of the parameters was to obtain data for comparison with the concentration of the same analytes in the source storage well.

4.2 Waste Water

A water sample for tritium analysis was collected from the Atlas Gate sanitary sewer outfall located near the east side of the NLVF. The purpose of the sample was to determine if tritium-contaminated water was being discharged to the North Las Vegas public wastewater treatment system. Tritium was below the MDA.

4.3 Potable Water

A sample of potable water was collected from a faucet on the first floor of Building A-1 to confirm that this was not the source of the tritium. Tritium was below the MDA.

4.4 Canister Pits

Water was measured in the west canister pit at 74.6 feet from ground surface, with a total depth of 101.8 feet. The canister pit is cased and has a cement plug in the bottom. The water in this pit is believed to be primarily from surface runoff from the parking lot. Water in the south canister pit was measured at 112 feet and the total depth at 115 feet. This pit is also cased and has a

Table 4-1 Summary of Water Sample Analyses(all results in mg/L unless otherwise indicated).

Analyte	Source Well	Pond	¹ SDWA MCL	Lake Mead (untreated)	Lake Mead (treated)	NLV Groundwater
Tritium (pCi/L)	8500	background	4 mrem/yr (20,000 pCi/L)	² ND	<461	NA
Volatile organics	ND	NA	varies	³ THM only	ND	NA
Semivolatile organics	ND	NA	varies	ND	ND	NA
Nitrate (as N)	3.1	ND	10	370	0.37	2.7
Oil and grease	5.9	23	none	NA	NA	NA
Alkalinity - total	75	213	none	130	130.5	208
Chloride	58	240	400	71	71.7	5
Conductivity (μS/cm)	590	1910	none	907	919	NA
Sulfate	110	260	500	223	222.5	41
TDS ⁴	350	1190	1000	612	NA	252
TSS ⁵	24	24	none	NA	NA	NA
Metals	⁶ BRL	⁷ NA	varies	BRL	BRL	BRL

¹ Safe Drinking Water Act Maximum Contaminant Level

² ND = not detected

³ THM = trihalomethanes (disinfection by-products resulting from the reaction of chlorine with organic material in the water)

⁴ TDS = total dissolved solids

⁵ TSS = total suspended solids

⁶ BRL = below regulatory limits

⁷ NA = not analyzed for this parameter or not available from published source

cement bottom plug. The water in this pit is probably groundwater that has seeped through small cracks in the liner or bottom plug. The water in these pits was sampled using a hand bailer. Tritium was not detected in either pit. Water was not detected in the north canister pit.

4.5 Source Storage Well

Sampling of the source storage well is discussed in Section 3.6.

4.6 Swipe Surveys of Borehole Equipment

During the Geoprobe® sampling on December 15, 1999, swipe survey samples were taken on the direct-push rods and on the surface of the pavement. Fourteen alpha-beta and tritium swipe surveys were taken on the direct-push rods and associated equipment as they were removed from Geoprobe® borehole GP-9. These results were background. One tritium swipe was taken from the surface of the asphalt around the Geoprobe® borehole, with a result of 2,183 dpm. Another swipe collected from soil immediately below the pavement had 9,700 dpm tritium. Surveys were then taken from the surface and approximately 2 inches below the surface of Geoprobe® boreholes GP-1 and GP-1A on the south side of the building. The results were 4,574 and 8,041 dpm tritium, respectively. The swipe surveys were recounted several times, with the activity generally decreasing with each count. A “Stop Work” was issued and a plan was developed to investigate the source of the tritium.

A Packard® scintillation counter is used to count the swipe surveys. It was determined that approximately 90 percent of the fluorescence counted by the Packard® instrument was chemical luminescence. Another indication that the counts were false-positives was that the apparent tritium concentration decreased with subsequent recounts of the samples.

To confirm that the apparent tritium concentration resulted from chemical luminescence, four 9-inch-deep cores of the asphalt and underlying soil were taken at locations around Building A-1. Two cores were taken within a few feet of Geoprobe® boreholes GP-9 and GP-1A, and two were taken at locations several hundred feet away from these boreholes. Swipe surveys were taken from the asphalt surface, a fresh surface in the middle of the asphalt, the asphalt/soil interface, and the underlying soil. These swipes were counted by analysis of a distilled aliquot of the water in which the swipe filter was placed. This is an approved laboratory method which removes chemicals that might cause a false-positive from chemical luminescence. Sixteen swipes (four from each core hole) were counted using this method. All swipes were below the laboratory MDA except two from Core Hole 1 (adjacent to Geoprobe® borehole GP-1A). At this location, a swipe of the asphalt/soil interface had 29.6 dpm/100 cm² tritium, and a swipe of the interior of the asphalt had 190 dpm/100 cm² tritium (material can be free-released with less than 10,000 dpm/100 cm² tritium).

Samples of the asphalt, asphalt/soil interface, and the soil at each of the four core holes were also analyzed for tritium using the distillation method. All samples were below the MDA except a soil sample at Core Hole 1A, which had 2.42 pCi/g tritium, an extremely low concentration.

Based on this data, the apparent tritium concentration detected when swiping the asphalt and the soil within the borings resulted from a chemical luminescence. The “Stop Work” was rescinded and the Geoprobe® sampling continued on December 20, 1999.

4.7 Air Monitoring

Ambient air in Room 4862 has been monitored for tritium since November 10, 1999, and in Room 4860 since December 1, 1999 (Table 4-2). From December 1, 1999, to February 2, 2000,

Table 4-2 Tritium concentration in ambient air in Rooms 4860 and 4862, Building A-1.

Tritium Concentration ($\mu\text{Ci}/\text{cm}^3$)		
Date	Room 4860	Room 4862
11/10/1999-11/17/1999	NA	3.92E-08
11/17/1999-11/24/1999	NA	3.59E-08
11/24/1999-12/01/1999	NA	1.60E-08
12/01/1999-12/08/1999	1.26E-09	2.85E-08
12/08/1999-12/15/1999	1.22E-09	3.07E-08
12/15/1999-12/22/1999	1.24E-09	3.20E-08
12/22/1999-12/29/1999	1.34E-09	3.38E-08
12/29/1999-01/05/2000	1.21E-09	3.33E-08
01/05/2000-01/12/2000	1.38E-09	3.09E-08
01/12/2000-01/19/2000	9.40E-10	3.57E-08
01/19/2000-01/26/2000	2.38E-09	4.76E-08
01/26/2000-02/02/2000	1.60E-09	4.80E-08

NA = not measured.

the tritium concentration in Room 4860 has varied between $9.40\text{E-}10$ and $2.38\text{E-}09 \mu\text{Ci}/\text{cm}^3$. This is comparable to the concentration during the decontamination activities of this room conducted from October to November 1997.

From November 10, 1999, to February 2, 2000, the tritium concentration in Room 4862 has varied between $1.6\text{E-}08 \mu\text{Ci}/\text{cm}^3$ to $4.80\text{E-}08 \mu\text{Ci}/\text{cm}^3$. An air monitor was not installed in this room during the 1997 decontamination activities, so no historical data are available for comparison. The higher tritium concentration occurs because there is less air flow through the room as the door to the room is kept closed, and evaporation of the water in the source well is occurring.

4.8 Discussion of Analytical Data

The source well water is believed to be groundwater, although there are no distinguishing analytical characteristics that conclusively indicate the source of the water. The water is generally good quality, with a low concentration of suspended solids, precluding raw sewage as

the source. The low concentration of total dissolved solids suggests that the water is intermediate-depth groundwater. It is not potable water from Lake Mead, which has a high concentration of total dissolved solids. A lack of disinfection by-products is also another indication that the water is groundwater.

Water in the source well contains no detectable organic compounds, and water pumped from the well did not require management as hazardous waste.

The water from the water impoundment north of the NLVF had a high concentration of dissolved solids, chloride, oil and grease, and sulfate typically expected from industrial runoff and evaporation. Tritium was not detected. This water did not have any distinguishing characteristics indicating that it was the source of the water in the source storage well.

4.9 Risk to Personnel

Although the concentration of tritium in water in the source storage well exceeds the Safe Drinking Water Act Maximum Contaminant Level of $2.0\text{E}+04$, the water and the room air do not pose a health risk to employees or the public. Access to the source storage well is restricted and water is not withdrawn from the well for either potable or nonpotable uses. Based on current information, contamination is local around the source storage well; any existing plume of contamination has not been detected beyond the boundaries of Building A-1. Further, near-surface water, either in the shallow aquifer or the near-surface aquifer, is not used for consumption.

The dose an individual would receive from drinking one liter of water directly from the source storage well, with a water activity of $2.5\text{E}+05$ pCi/L, is about 0.2 mrem. The dose an individual would receive from breathing the air in the source storage room for 40 hours, with an air concentration of $3.92\text{E}-08$ $\mu\text{Ci}/\text{cm}^3$ (the highest concentration measured from November 10, 1999, to January 31, 2000), is about 0.2 mrem. In comparison, the DOE annual occupational dose limit is 5,000 mrem/year.

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5.0 POTENTIAL SOURCES OF TRITIUM CONTAMINATION

Two incidents occurred in Building A-1 that resulted in tritium contamination of the first floor and basement (source storage well location) between 1994 and 1995: (1) storage of tritium foils in the source storage room and manufacture of components for STNGs on the first floor of Building A-1 between 1994 and 1995, and (2) opening and swiping of a container that held three tritium foils from LLNL on two occasions, one each in June and July 1995. These incidents may have left residual levels of tritium in the basement area capable of producing the levels seen in the analysis of water from the source storage well.

Other sources of tritium activity pre-dating 1994-1995 cannot be ruled out, but are believed to be unlikely. Key personnel knowledgeable in the history of activities at the NLVF were interviewed. Those interviewed included personnel associated with manufacturing STNGs, and some of those who had conducted the Type B investigation. The interviews concluded that STNG manufacturing was the only potential source for tritium contamination. These personnel also confirmed that wastewater from STNG manufacture was not discharged to the sewer system nor was wastewater from the decontamination activities discharged.

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6.0 CONCLUSIONS

Water below Building A-1 is most likely the near-surface aquifer with water derived from deeper aquifers. Recent elevation of the water level below Building A-1 is best explained, generally in order of importance, by a combination of (1) water in the near-surface aquifer being at or near natural levels, or recovering to natural levels after discontinuation of pumping (although this typically has been a relatively rapid process); (2) pressurization of the valley-fill reservoir from artificial recharge of water; (3) an increase in infiltration of water from the surface; and (4) seasonal reduction in evaporation and plant demand for water.

The shallow depth of water below Building A-1 is conducive to mixing of infiltrated water with water of the near-surface aquifer. Any infiltrated water would have to be from sources relatively close to the NLVF to maintain the observed low concentration of total dissolved solids in the source storage well. The southeast flow direction of water below Building A-1 suggests that any recharge from the surface is from approximately north of the NLVF. Recharge could result from infiltration of (1) runoff water from increased development north of the NLVF, (2) irrigation water at City View Park, (3) direct and accumulated precipitation (perhaps through recognized fissures north of the NLVF), (4) sewage from a leaking pipe (a sewer pipe is present near the water impoundment north of the NLVF), or (5) a combination of these possibilities. Increased runoff and irrigation, in part enhanced by reduced seasonal evaporation and plant demand, are the two most probable contributing factors to increased infiltration.

The most likely sources of the Building A-1 tritium contamination are the two 50-Ci ZrT_3 and 30-Ci TiT_3 accelerator foils stored in the source storage room from 1988 to 1995, and an unknown quantity of scandium tritide (ScT_3) foils in STNGs manufactured and reworked during 1994 and 1995. Tritium activity at the base of the source storage well is residual activity from these previous activities.

Tritium activity is not present in the water that infiltrates the source storage well. The source of the activity is probably within the base of the well or the concrete lining of the well. The activity diffuses into the infiltrated water as the water stagnates. Release of tritium to the groundwater has not been detected.

The tritium contamination detected in this investigation does not present any risk to the workers, the public, or the environment.

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7.0 RECOMMENDATIONS

7.1 Water Level Monitoring

The water level in the source well should continue to be monitored weekly until September 30, 2000. The data will be evaluated monthly and appropriate action, if any, will be initiated.

7.2 Tritium Monitoring

Groundwater below Building A-1 should be monitored via the temporary monitoring wells to determine whether tritium is migrating away from the source storage well. Because the groundwater is estimated to be flowing to the southeast at approximately 2 feet per day, any contamination that resulted from the initial rise of water into the source well could be expected to pass the downgradient monitoring wells approximately in February 2000. The four temporary monitoring wells should be sampled weekly for the first month after installation, biweekly during the second month, and monthly thereafter until June 2000.

The water in the source storage well should be monitored weekly for the first month after the soil in the bottom of the well is removed, then monthly thereafter. If the concentration decreases to below 20,000 pCi/L (the Safe Drinking Water Act standard) for three consecutive months, monitoring should be stopped. If the concentration does not decrease below 20,000 pCi/L, investigate methods for maintaining the concentration below this level. This may include periodically pumping water from the source storage well.

7.3 Soil Samples

The soil around and beneath the building may not be contaminated with tritium. Tritium is very mobile and should have migrated to the temporary monitoring wells. However, tritium has not been detected in these wells. To confirm this conclusion, soil samples from discrete locations will be taken for tritium analysis.

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