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REVIEW OF PRESENT GROUNDWATER MONITORING PROGRAMS AT THE NEVADA TEST SITE

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INTRODUCTION

Groundwater monitoring at the Nevada Test Site (NTS) is conducted to detect the presence of radionuclides produced by underground nuclear testing and to verify the quality and safety of groundwater supplies as required by the State of Nevada and federal regulations, and by U.S. Department of Energy (DOE) Orders. Groundwater is monitored at water-supply wells and at other boreholes and wells not specifically designed or located for traditional groundwater monitoring objectives. Different groundwater monitoring programs at the NTS are conducted by several DOE Nevada Operations Office (DOE/NV) contractors. Presently, these individual groundwater monitoring programs have not been assessed or administered under a comprehensive planning approach. Redundancy exists among the programs in both the sampling locations and the constituents analyzed. Also, sampling for certain radionuclides is conducted more frequently than required. The purpose of this report is to review the existing NTS groundwater monitoring programs and make recommendations for modifying the programs so a coordinated, streamlined, and comprehensive monitoring effort may be achieved by DOE/NV.

This review will be accomplished in several steps. These include: summarizing the present knowledge of the hydrogeology of the NTS and the potential radionuclide source areas for groundwater contamination; reviewing the existing groundwater monitoring programs at the NTS; examining the rationale for monitoring and the constituents analyzed; reviewing the analytical methods used to quantify tritium activity; discussing monitoring network design criteria; and synthesizing the information presented and making recommendations based on the synthesis. This scope of work was requested by the DOE/NV Hydrologic Resources Management Program (HRMP) and satisfies the 1993 (fiscal year) HRMP Groundwater Monitoring Program Review task.

HYDROGEOLOGY OF THE NEVADA TEST SITE

The NTS is located in southern Nevada in the Basin and Range physiographic province. The topography of the NTS is composed of four major basins, three large mesas, and a number of north-south-trending mountain ranges (Figure 1). The four major basins, located in the eastern and southern portion of the NTS, are Frenchman Flat, Yucca Flat, Jackass Flats, and Mercury Valley. The minimum elevations of these basins are 1200, 1000, 1100, and 1000 meters above mean sea level, respectively. The three large mesas and their maximum elevations are Pahute Mesa (2256 meters), Buckboard Mesa (1848 meters), and Rainier Mesa (2324 meters). The major mountain ranges and their maximum elevations on the NTS include the Belted Range (2354 meters), Mercury Ridge (1608 meters), and the Halfpint Range (1539 meters). Isolated mountains and their maximum elevations such as Skull Mountain (1828 meters), Shoshone Mountain (2154 meters), and Yucca Mountain (1930 meters) are also present. The locations of these features are shown in Figure 1.

The geology at the NTS can be classified into three major rock types: complexly folded and faulted sedimentary rocks of Paleozoic age; volcanic tuffs and lavas of Tertiary age; and, Tertiary and Quaternary alluvium (Figure 2). The sedimentary rocks of Paleozoic age are hundreds to thousands of meters thick and consist primarily of carbonate rocks in the lower and upper section, separated by a thick sequence of clastic rocks (shale and quartzite). These Paleozoic-age

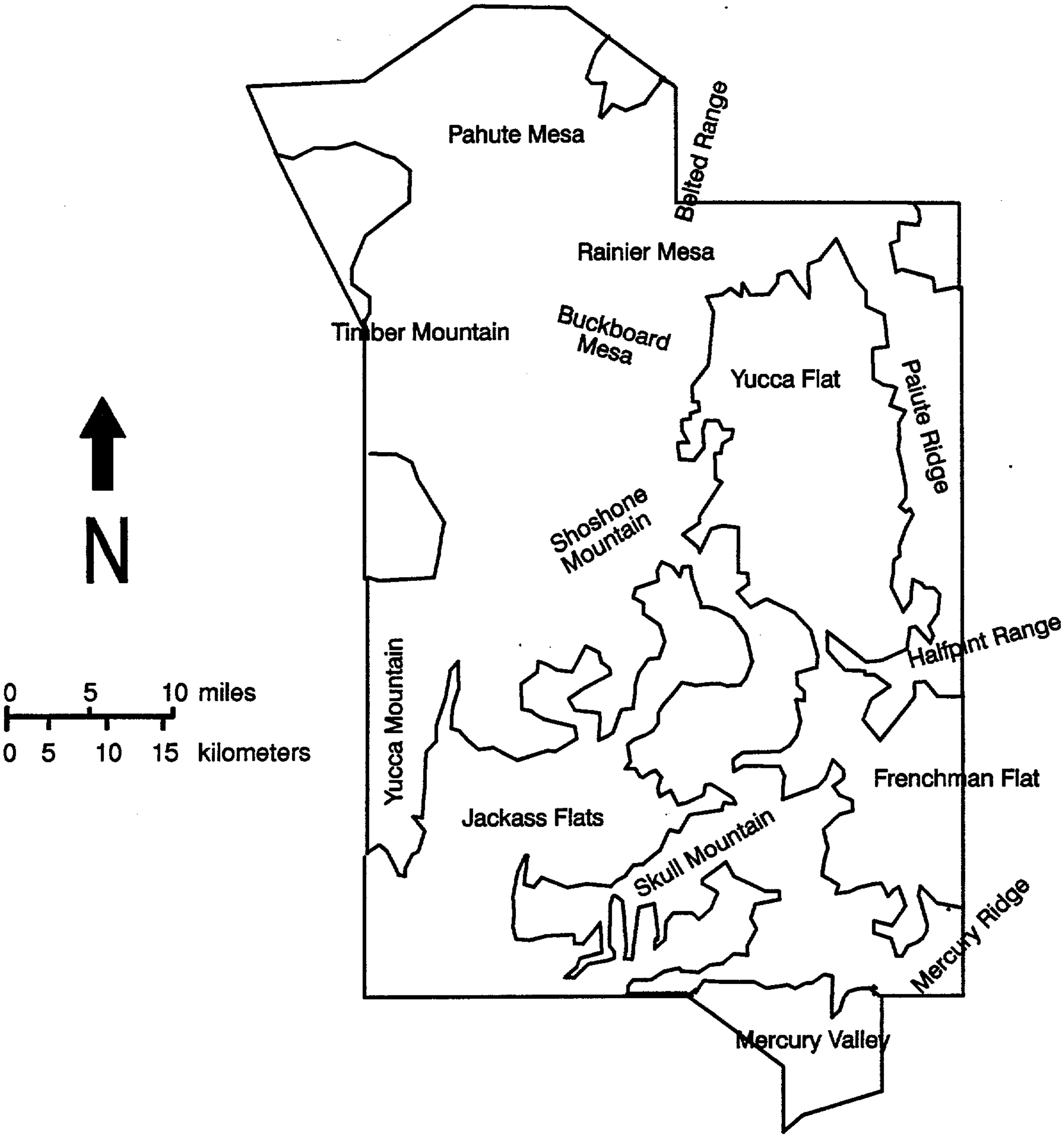


Figure 1. Physiographic features at the Nevada Test Site.

sedimentary rocks have undergone several deformational events, resulting in a series of north-south-oriented thrust faults associated with complex folding and normal faulting. The volcanic rocks of Tertiary age are predominantly rhyolitic tuffs ejected from the Silent Canyon and Timber Mountain calderas, located in the northwest portion of the NTS (Figure 2). The aggregate thickness of these volcanic rocks is several thousand meters; however, extremely variable thickness of individual sections result from erosion and non-deposition. Tertiary rocks are deformed much less than the Paleozoic rocks. Tertiary rocks are down-dropped in the valleys and tilted along steeply dipping late Tertiary faults. Alluvial sediments are composed of Paleozoic and Tertiary rock fragments, and fill the valleys to a maximum thickness of 600 to 900 meters. Alluvial sediments

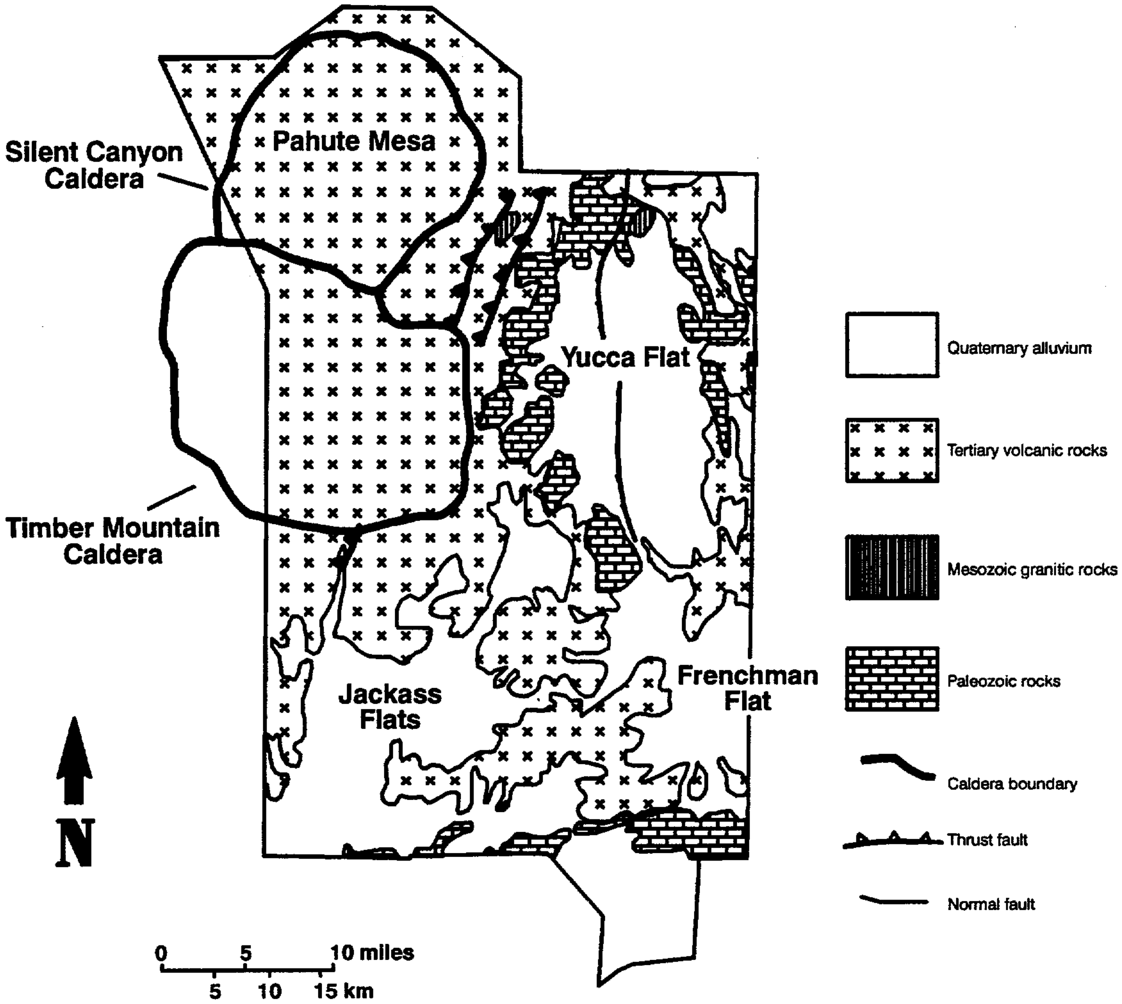


Figure 2. Major rock types at the Nevada Test Site.

appear to be relatively undeformed except for offsets formed by recent faulting as seen along the north-south-trending Yucca Fault in central Yucca Flat.

Table 1 presents a hydrostratigraphic classification of the principal lithologic units at the NTS as modified from Winograd and Thordarson (1975). This hydrostratigraphic classification applies specifically to Yucca Flat, the only area where the areal extent of saturated hydrostratigraphic units have been defined (Winograd and Thordarson, 1975); however, generalizations can be extended to other portions of the NTS. The unconsolidated valley-fill aquifers transmit groundwater via intergranular primary porosity interstices. Tertiary volcanic aquifers consist of lava flows, welded tuffs, and bedded tuffs, and Tertiary volcanic aquitards consist of non-welded zeolitized tuffs. In general, groundwater flow in Tertiary volcanic aquifers occurs in Paleozoic upper and lower carbonate aquifers consist of fractured carbonate rocks and Paleozoic clastic aquitards consist of interbedded clastic shales and quartzites.

TABLE 1. HYDROSTRATIGRAPHIC CLASSIFICATION OF PRINCIPAL LITHOLOGIC UNITS AT THE NEVADA TEST SITE.

Geologic Time Period	Stratigraphic Unit	Hydrogeologic Unit
Cenozoic	Valley Fill	Valley-Fill Aquifer
	Basalt of Kiwi Mesa Rhyolite of Shoshone Mountain Basalt of Skull Mountain	Lava-Flow Aquifer
	Timber Mountain Tuff Paintbrush Tuff	Welded Tuff Aquifer
	Informal Bedded Tuff	Bedded Tuff Aquifer
	Wahmonie Formation	Lava-Flow Aquitard/ Tuff Aquitard
	Salyer Formation Belted Range Tuff Local Informal Units Rhyolite Flows and Tuffaceous Beds of Calico Hills Tuff of Crater Flat Lithic Ridge Tuff Rocks of Pavits Spring Horse Spring Formation	Tuff Aquitard
Mesozoic	Granitic Stocks	Minor Aquitard
Paleozoic	Tippipah Limestone	Upper Carbonate Aquifer
	Eleana Formation	Upper Clastic Aquitard
	Devil's Gate Limestone Nevada Formation Undifferentiated Dolomite Ely Springs Dolomite Eureka Quartzite Pogonip Group Nopah Formation Bonanza King Formation Carrera Formation	Lower Carbonate Aquifer
Precambrian	Zabriskie Quartzite Wood Canyon Formation Stirling Quartzite Johnnie Formation	Lower Clastic Aquitard

The NTS has been divided into three hydrographic subbasins (Figure 3), all considered part of the larger Death Valley groundwater basin (Waddell *et al.*, 1984). Groundwater within the Ash Meadows subbasin flows from areas north and east of the NTS, southwestward toward springs at Ash Meadows (Winograd and Thordarson, 1975). Groundwater within this subbasin is thought to flow primarily in the lower carbonate aquifer. The distribution of hydraulic heads and the direction

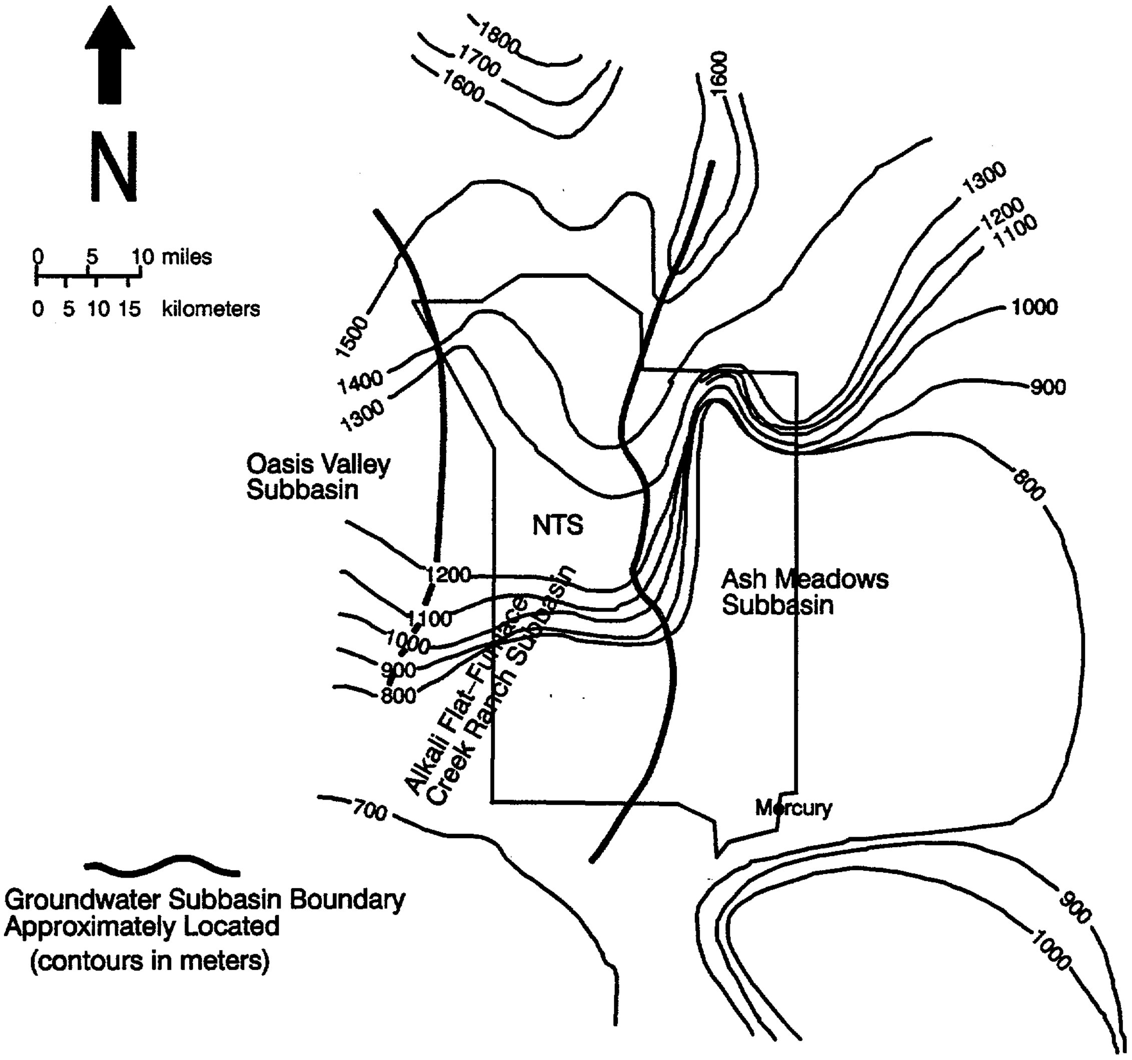


Figure 3. Composite potentiometric surface and hydrographic subbasins at the Nevada Test Site (after Waddell *et al.*, 1984).

of flow within the subbasin are greatly affected by the presence of low permeability rocks of the lower clastic aquitard (Winograd and Thordarson, 1975). Groundwater from the majority of the western portion of the NTS flows from Pahute Mesa (and possibly other northern areas), southward toward Alkali Flat in the central Amargosa Desert. Groundwater flows through the valley-fill, volcanic, and lower carbonate aquifers. Groundwater discharges at Alkali Flat by evapotranspiration with possibly some groundwater underflow continuing to Death Valley (Winograd and Thordarson, 1975). The remaining portion of groundwater from western Pahute Mesa and areas further north is thought to flow southward, through the western portion of the NTS, within the Oasis Valley subbasin. Groundwater from this flow system discharges primarily by evapotranspiration at Oasis Valley and with underflow to the Alkali Flat-Furnace Creek Ranch subbasin (White, 1979). Groundwater in Pahute Mesa flows primarily through interbedded volcanic rocks with extreme vertical and horizontal hydraulic conductivity contrasts (Blankennagel and Weir, 1973). The boundaries of the subbasins are poorly defined and have been placed at different locations by different authors. Data are sparse; the average density of wells at the NTS is less than 0.05 per square kilometer (excluding device emplacement and post-shot holes. The paucity of wells inhibit the determination of vital hydrologic information that is needed to develop detailed local scale flow models. Hydrologic characteristics such as the rate and direction of interaquifer flux, the perturbations created by localized geologic structures and nuclear testing, and the delineation of permeable and impermeable zones within individual hydrologic units have not been adequately determined.

The interpretation of groundwater chemical analyses has been extremely valuable in further developing conceptual models of regional groundwater flow. Schoff and Moore (1964) performed the first comprehensive study of the chemical quality of NTS groundwater. They classified groundwater at the NTS into three broad categories: a sodium and potassium bicarbonate type; a calcium and magnesium bicarbonate type; and, a mixed type consisting of the first two in varying proportions. The sodium and potassium bicarbonate type is found in the tuff aquifers and aquitards. The calcium and magnesium bicarbonate type is found in Paleozoic carbonate aquifers and valley-fill aquifers that are composed primarily of carbonate rock detritus. Mixed type waters are found throughout the NTS and are thought to form in several ways: by movement of sodium and potassium bicarbonate type water from tuffaceous rocks into carbonate rocks or alluvium; by movement of calcium and magnesium bicarbonate type water from carbonates into tuffaceous rocks; or, by mixing. Chapman and Lyles (1993) examined groundwater chemical analyses from 81 wells collected from 1957 to 1990. They verified the existence of Schoff and Moore's three basic groundwater quality categories or types (also called hydrochemical facies). Chapman and Lyles also suggested a dominance of vertical flow within basins between the overlying volcanic aquifers and the underlying carbonate aquifers.

POTENTIAL GROUNDWATER CONTAMINATION SOURCES

A preliminary assessment of underground and surface contamination at the NTS was conducted by the DOE's Environmental, Safety, and Health Office of Environmental Audit in 1987 (U.S. DOE, 1988). The assessment delineated known and potential sources of groundwater contamination including underground testing sites and surface facilities. Because of the great depth to groundwater (from 112 meters at UE-16f to 672 meters at U-20be; Wood, 1992) and the arid climate at the NTS, it is assumed that the potential for mobilization of surface and shallow subsurface contamination is minimal. Therefore, the main source of possible groundwater contamination considered for this report is from underground nuclear testing. To date, there have been 828 underground nuclear tests conducted in five general locations at the NTS (U.S. DOE, 1993b). The principal by-products from nuclear testing are heavy metals (Bryant and Fabryka-Martin, 1991) and a wide variety of radionuclides with differing half-lives and decay products. Underground testing locations are identified on Figure 4 as shaded circles of 1000 meter radius around individual underground test sites. These shaded circles are located primarily in Yucca Flat, Frenchman Flat, Rainier Mesa, Pahute Mesa, and Shoshone Mountain. The majority of underground testing has been

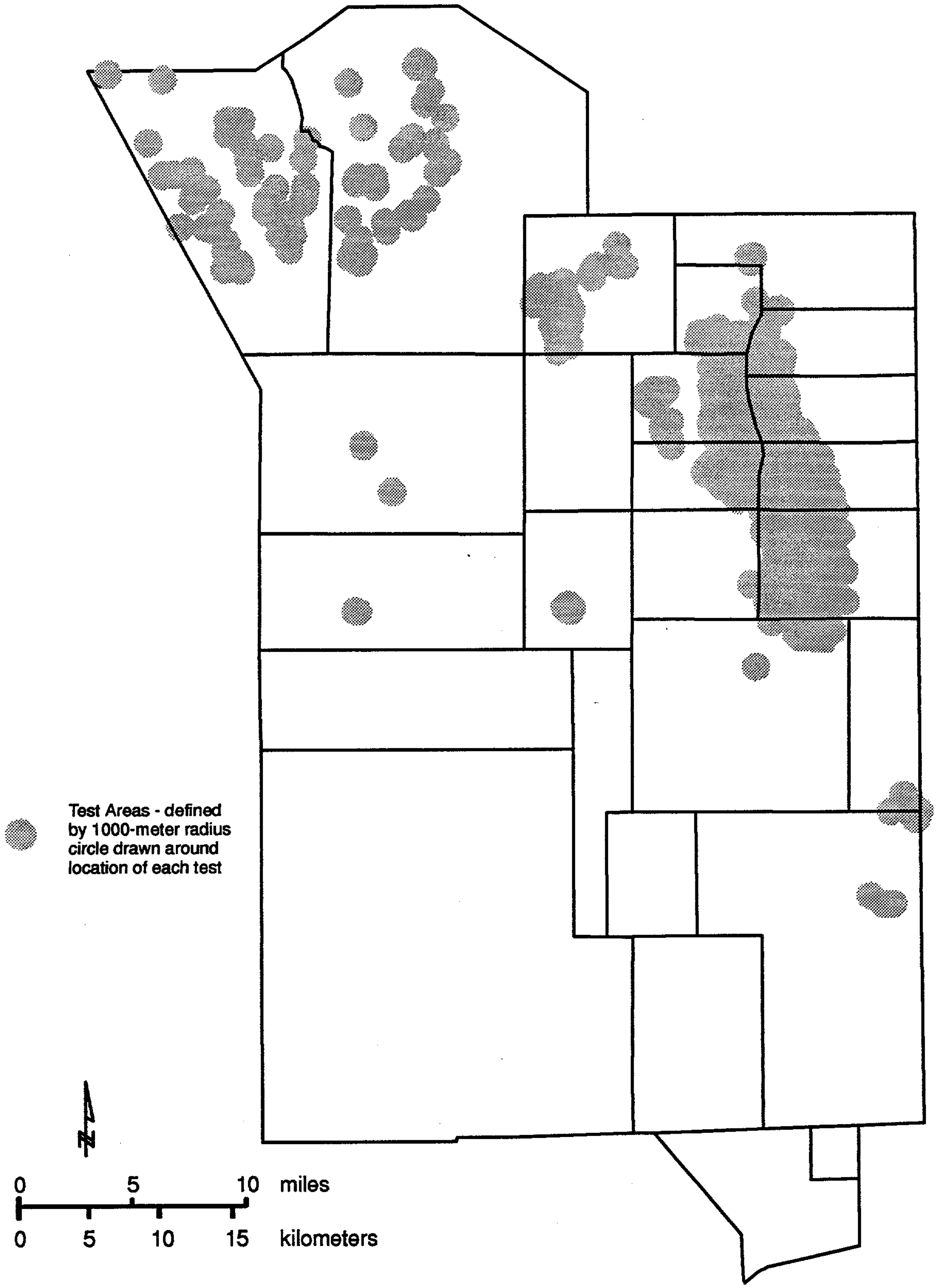


Figure 4. Underground nuclear testing locations at the Nevada Test Site.

conducted in unsaturated alluvium and Tertiary volcanic rocks. However, some tests have been conducted below or near the groundwater table. Marsh (1992) listed approximately 150 tests from June 1957 through August 1988 that were detonated below or within 25 meters of the groundwater table (Appendix A).

EXISTING GROUNDWATER MONITORING ACTIVITIES

Regulatory and DOE Order driven groundwater monitoring at the NTS is conducted by Reynolds Electrical & Engineering Co., Inc. (REECo) and the U.S. Environmental Protection Agency's (EPA) Environmental Monitoring Systems Laboratory in Las Vegas, Nevada (EMSL-LV). Groundwater monitoring for site characterization is also conducted at the NTS by the HRMP participants, the Underground Test Area Remedial Investigation and Feasibility Study (UGTA/RIFS) contractors, and the Area 5 Radioactive Waste Management Site (RWMS) contractors. Existing groundwater monitoring activities at the NTS are described below.

REECo's Environmental Monitoring Program

REECo's on-site radiological surveillance network includes seven springs, nine potable water-supply wells, four non-potable water-supply wells, and nine drinking-water consumption points (U.S. DOE, 1993a). In 1992, water from on-site groundwater supply wells (Figure 5) was sampled and analyzed for radiological substances according to the schedule presented in Table 2. Radiological analyses are conducted by REECo. Non-radiological drinking-water sampling is also conducted; however, analyses are performed by off-site contract laboratories.

Monthly samples are collected from seven springs and analyzed for gamma activity, gross beta activity, and tritium activity (conventional method). Quarterly spring samples are collected and analyzed for ^{238}Plutonium and $^{239+240}$Plutonium. Annual spring samples are collected and analyzed for ^{90}Strontium. Springs are not used for human drinking-water supply at the NTS but are a source of water for feral birds and animals.

Monthly groundwater samples are collected from nine potable water-supply wells and analyzed for gamma activity, gross beta activity, and tritium activity (conventional method). Quarterly samples of groundwater are collected and analyzed for ^{238}Plutonium, $^{239+240}$Plutonium, gross alpha activity, ^{226}Radium, ^{228}Radium, and tritium activity (enrichment method). Annual groundwater samples are collected and analyzed for ^{90}Strontium.

Monthly groundwater samples are collected from four non-potable water-supply wells and analyzed for gamma activity, gross beta activity, and tritium activity (conventional method). Quarterly samples of groundwater are collected and analyzed for ^{238}Plutonium and $^{239+240}$Plutonium. Annual groundwater samples are collected and analyzed for ^{90}Strontium.

The NTS has five drinking-water supply systems that are fed by the nine potable supply wells (Table 3). Weekly drinking-water samples are collected from nine consumption points distributed between the five water-supply systems, and are collected from bottled water supplied by a Las Vegas vendor to Area 6. These weekly drinking-water samples are analyzed for gamma activity, gross beta

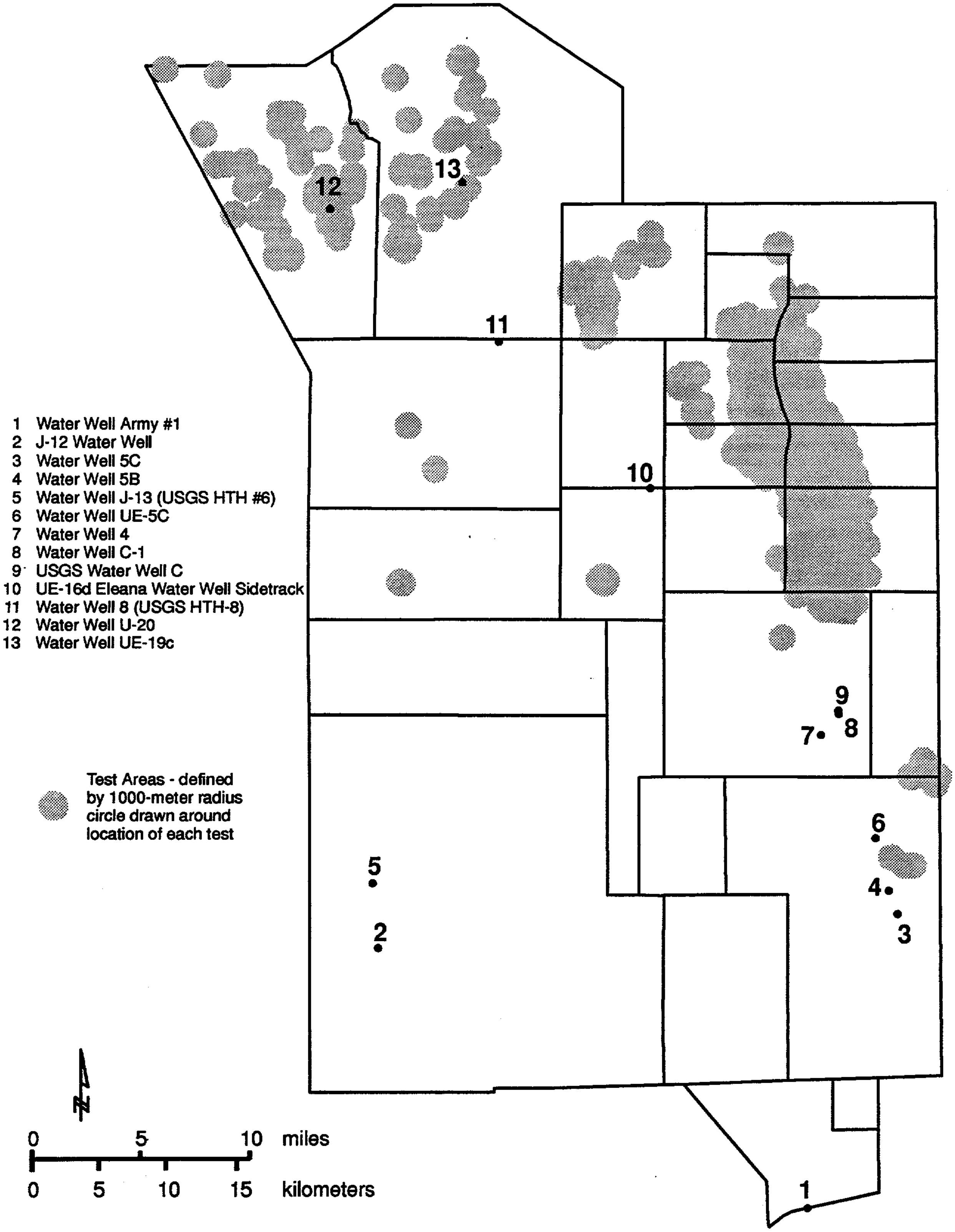


Figure 5. Groundwater supply wells sampled in 1992 by REECo's Environmental Monitoring Program at the Nevada Test Site.

activity, and tritium activity. Quarterly drinking-water samples are collected from consumption points and bottled water, and are analyzed for gross alpha activity, ^{238}Plutonium, and $^{239+240}$Plutonium.

TABLE 2. REECO'S 1992 ENVIRONMENTAL MONITORING PROGRAM SAMPLING SCHEDULE OF POTABLE AND NON-POTABLE WATER-SUPPLY WELLS AND SPRINGS AT THE NEVADA TEST SITE.

Area	Sample Location	Radiological	Nonradiological	Comments
5	Water Well 5C	a,b,c	d	
5	Water Well UE-5C	a,c,e		
5	Water Well 5B	a,c,e		Well shut down (U.S. DOE, 1992)
5	Cane Spring	a,c,e		
6	Water Well 4	a,b,c	d	
6	USGS Water Well C	a,b,c	d	
6	Water Well C-1	a,b,c	d	
7	Reitmann Seep	a,c,e		
12	Captain Jack Spring	a,c,e		
12	Gold Meadows	a,c,e		
12	White Rock Spring	a,c,e		
15	Water Well UE-15d	a,b,c	d	Well no longer operated (U.S. DOE, 1993)
16	Tippipah Spring	a,c,e		
18	Water Well 8	a,b,c	d	
19	Water Well UE-19c	a,c,e		
20	Water Well U-20	a,c,e		
22	Water Well Army #1	a,b,c	d	
25	J-12 Water Well	a,b,c	d	
25	Water Well J-13	a,b,c	d	
29	Topopah Spring	a,c,e		

Sampling Schedule

a. Monthly
*Tritium Activity, conventional
*Gross Beta Activity
*Gamma Activity

b. Quarterly
*Gross Alpha Activity
*Plutonium 238, 239 + 240
*Radium 226, 228
*Tritium Activity, enriched

c. Annually
*Strontium 90

d. Annually
*Volatile Organic Compounds
*Inorganics & Metals

e. Quarterly
*Plutonium 238, 239, + 240

TABLE 3. 1992 WATER-SUPPLY WELLS, POPULATION, AND COMMUNITY/ NONCOMMUNITY STATUS OF PUBLIC DRINKING WATER SYSTEMS AT THE NEVADA TEST SITE.

Permit No.	Area(s)	Population	Status	Water Wells
360-12C	22, 23	1500	Community	5C, Army #1
4097-12NC[1]	3	200	Noncommunity	C, C-1, 4 (hauled water)
5000-12NC	6, 27	1000	Noncommunity	C, C-1, 4
4098-12NC	25	200	Noncommunity	J12, J13
4099-12C	2, 12	1000	Community	8
5024-12NC	1	200	Noncommunity	UE-16d Eleana

[1] This permit has been allowed to expire as personnel in the Area 3 camp have been relocated to Area 6.

Non-radiological monitoring of drinking water is also conducted by REECo at the NTS. All NTS drinking-water distribution systems are sampled monthly at various consumption points for coliform bacteria. Samples are sent off-site for analysis. Monthly residual chlorine using colorimetric methods and pH measurements are made at drinking-water consumption points. Annual drinking-water samples are collected from consumption points and analyzed for inorganic constituents and water-quality parameters. Samples are sent off-site for analysis. Annual groundwater samples are collected from potable water-supply wells and analyzed for volatile organic compounds. Samples are sent off-site for analysis. Occasionally, the State of Nevada will collect and analyze groundwater samples from NTS potable water-supply wells for inorganic constituents. In 1992, the State of Nevada collected and analyzed groundwater from Water Well 4A.

EMSL-LV's Long-Term Hydrologic Monitoring Program

The EMSL-LV conducts the Long-Term Hydrologic Monitoring Program (LTHMP). The LTHMP is a radiological groundwater monitoring network on and around the NTS, and at other U.S. locations where nuclear weapons tests have been conducted (U.S. DOE, 1993a). This discussion is limited to the on-site and NTS vicinity network. In 1992, groundwater from wells shown in Figure 6 was sampled for radiological substances according to the schedule presented in Table 4.

In 1992, monthly groundwater samples were collected from 14 wells and biannual samples were collected from 17 others. All samples are analyzed for gamma and tritium activity. All samples are analyzed using the conventional tritium method. When sample results are close to the minimum detectable concentration (MDC) of the method (400 to 700 pCi/L), the sample is re-analyzed using the tritium enrichment method (MDC of 5 to 7 pCi/L). Tritium analysis of biannual samples is alternated between the conventional method and the enrichment method from one sample to the next. Three springs (Crystal Pool, Fairbanks Springs, and Spring 17S-50E-14cac) and one well (Well 18s-51E-7db) located in Ash Meadows are sampled monthly and analyzed for gamma activity and are also sampled biannually for tritium activity. When a new sampling location is added to the network, first time samples are collected and analyzed for ^{238}Plutonium, $^{239+240}$Plutonium, ^{89}Strontium, ^{90}Strontium, and uranium isotopes.

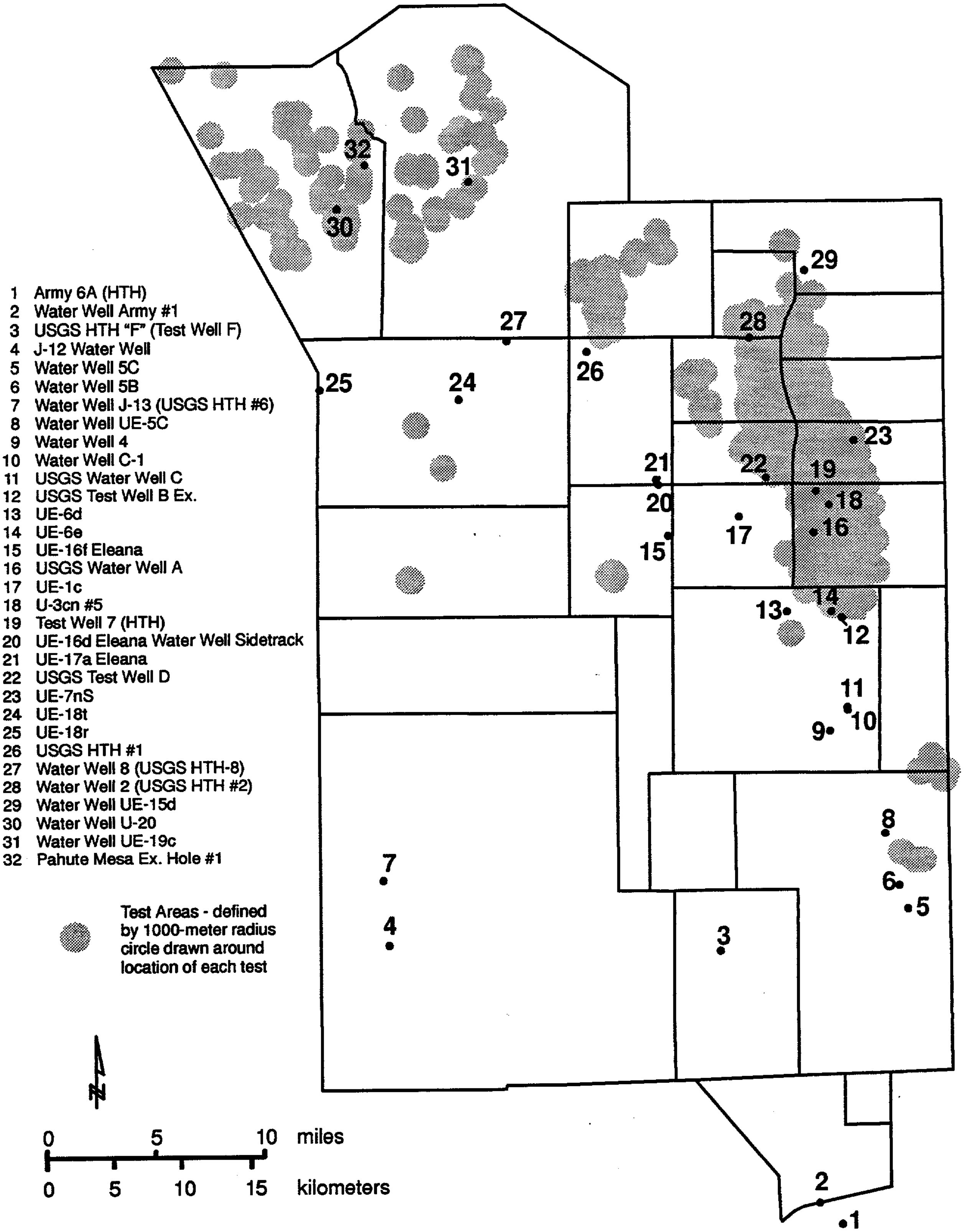


Figure 6. Groundwater wells sampled in 1992 by EMSL-LV at the Nevada Test Site.

TABLE 4. EMSL-LV'S 1992 LTHMP SAMPLING SCHEDULE OF WELLS AT THE NEVADA TEST SITE.

Area	Sample Location	Radiological	Comments
1	UE-1c	b	
2	Water Well 2	b	Well shut down throughout 1991
3	USGS Water Well A	b	
3	Test Well #7	b	
3	U-3cn #5	b	Well shut down throughout 1991
4	USGS Test Well D	b	
5	Water Well 5C	a	
5	Water Well UE-5C	b	
5	Water Well 5B	b	Well shut down (U.S. DOE, 1992)
6	Water Well 4	a	
6	USGS Water Well C	a	
6	Water Well C-1	b	
6	UE-6d	b	
6	UE-6e	b	
6	USGS Test Well B Ex.	b	
7	UE-7nS	b	Last sampled Sept. 1987
7	UE-4t #1	b	
15	Water Well UE-15d	b	
16	UE-16d Eleana Sidetrack	b	
16	UE-16f Eleana	b	
17	USGS HTH #1	b	
17	UE-17a Eleana	b	
18	Water Well 8	a	
18	UE-18r	b	
18	UE-18t	b	
19	Water Well UE-19c	b	
20	Water Well U-20	b	
20	Pahute Mesa Ex. Hole #1	b	
22	Water Well Army #1	a	
25	J-12 Water Well	a	
25	Water Well J-13	a	
27	USGS HTH "F"	b	
offsite	Army 6A	b	
offsite	Ash Meadows: Crystal Pool	c,d	
offsite	Ash Meadows: Fairbanks Spring	c,d	
offsite	Ash Meadows: Spring 17S-50E-14cac	c,d	
offsite	Ash Meadows: Well 18S-51E-7db	c,d	

Sampling Schedule

a. Monthly	b. Semi-Annually	c. Monthly	d. Semi-Annually
*Tritium Activity, enriched *Gamma Activity	*Tritium Activity, enriched *Gamma Activity	*Gamma Activity	*Tritium Activity, enriched once *Tritium Once

U.S. Geological Survey's Water-level Monitoring Program

The U.S. Geological Survey (USGS) in support of the HRMP collects and compiles hydrologic data to aid in characterizing the local and regional groundwater flow systems underlying the NTS (Wood, 1992). Depth-to-water measurements are made in approximately 72 wells and test holes at and in the vicinity of the NTS (Figure 7). Occasionally, groundwater samples are collected for tritium analysis. Samples are analyzed by EMSL-LV using the enrichment method.

Historical depth-to-water measurements are used to indicate long-term depth-to-water fluctuations and to provide a record of all reported completion depths or open intervals for associated wells and test holes. Measurements are obtained by either wire-line, steel-tape, or iron-horse methods. The network consists of short-term test holes and long-term observation wells and test holes. Depth to water is measured intermittently in all accessible test holes that penetrate the saturated zone. These measurements are made frequently until the measured depth to water stabilizes, or until the hole is destroyed or becomes inaccessible. The majority of test holes are short-term holes and the opportunity to measure depth to water is limited to a few weeks or a few months. Other observation wells and test holes are available for long-term depth-to-water measurements. Wells or test holes that exhibit minor fluctuations in depth to water are measured annually. Wells or test holes that exhibit large fluctuations in depth-to-water are measured weekly, quarterly, or continuously.

Other Groundwater Sampling Programs

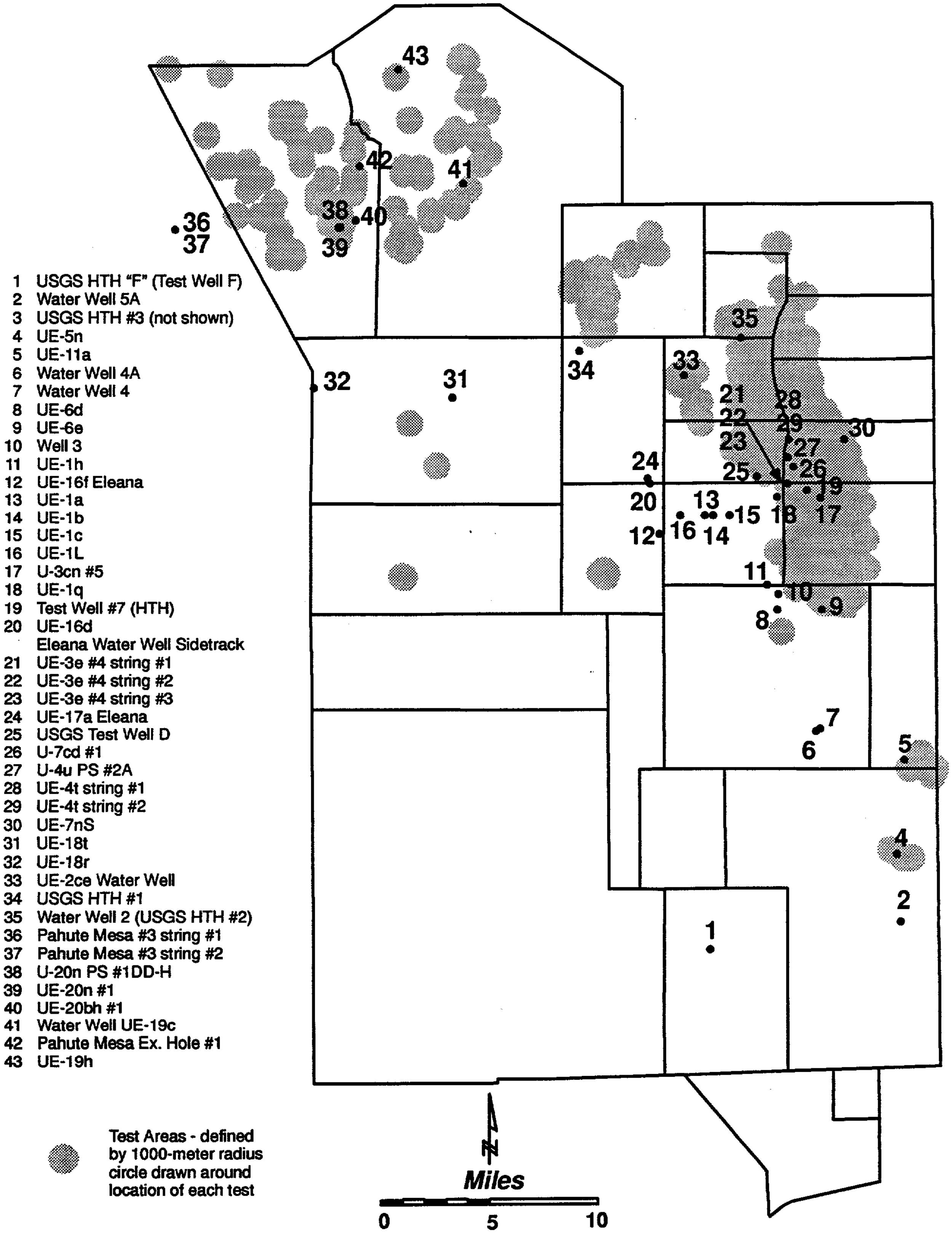
Some non-routine groundwater sampling is conducted by HRMP participants to accomplish the program goals to protect groundwater, support NTS operations, and conduct long-range hydrologic investigations. Groundwater monitoring activities consist primarily of non-routine sampling for radiological and non-radiological constituents to answer specific hydrologic questions. UGTA/RIFS participants are drilling new wells to obtain information to characterize the hydrogeology on the NTS. That program's specific goal is to obtain data to support Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) driven site characterization and risk assessment. Groundwater samples are collected from new wells for radiological and non-radiological analysis. Groundwater samples are also being collected to characterize the hydrogeology of the Area 5 RWMS as required for a Resource Conservation and Recovery Act (RCRA) Part B permit needed to operate the waste management facility.

RATIONALE FOR SPECIFIC CONSTITUENT MONITORING

Groundwater monitoring activities at the NTS are conducted for several reasons. These reasons include the detection of radioactive constituents produced by nuclear testing, monitoring to satisfy State of Nevada and federal regulatory requirements, and monitoring to satisfy DOE Order requirements.

Detection of Radioactive Constituents

Underground nuclear detonations produce radioactivity from three different sources: original device materials that have not undergone the fission or thermonuclear reaction (e.g., ^{239}Plutonium),



1	USGS HTH "F" (Test Well F)
2	Water Well 5A
3	USGS HTH #3 (not shown)
4	UE-5n
5	UE-11a
6	Water Well 4A
7	Water Well 4
8	UE-6d
9	UE-6e
10	Well 3
11	UE-1h
12	UE-16f Eleana
13	UE-1a
14	UE-1b
15	UE-1c
16	UE-1L
17	U-3cn #5
18	UE-1q
19	Test Well #7 (HTH)
20	UE-16d Eleana Water Well Sidetrack
21	UE-3e #4 string #1
22	UE-3e #4 string #2
23	UE-3e #4 string #3
24	UE-17a Eleana
25	USGS Test Well D
26	U-7cd #1
27	U-4u PS #2A
28	UE-4t string #1
29	UE-4t string #2
30	UE-7nS
31	UE-18t
32	UE-18r
33	UE-2ce Water Well
34	USGS HTH #1
35	Water Well 2 (USGS HTH #2)
36	Pahute Mesa #3 string #1
37	Pahute Mesa #3 string #2
38	U-20n PS #1DD-H
39	UE-20n #1
40	UE-20bh #1
41	Water Well UE-19c
42	Pahute Mesa Ex. Hole #1
43	UE-19h

●	Test Areas - defined by 1000-meter radius circle drawn around location of each test

Figure 7. Groundwater wells where depth-to-water is measured by the USGS at the Nevada Test Site.

nuclear reaction products (e.g., ^{90}Strontium), and radionuclides produced from neutron activation (e.g., ^{14}Carbon). As described in Borg *et al.* (1976), all device materials and much of the surrounding rock are vaporized at detonation and some of the resulting gaseous radionuclides are injected into fractures. As heat starts to dissipate, radionuclides separate according to their boiling points, the refractory or high boiling point radionuclides are concentrated in the solidifying puddle glass and the volatile or low boiling point radionuclides are distributed through the forming rubble chimney.

Radionuclides produced from detonations below, at, or near the water table begin to react with the groundwater. Chemical reactions between groundwater and radionuclides injected into fractures, incorporated in the puddle glass, or distributed in the chimney are poorly understood; however, limited research suggests that several processes are important when considering the mobility of radionuclides with groundwater. First, the rate of radioactive decay or the half-life of individual radionuclides is important. Many weapons-produced radionuclides have short half-lives resulting in a rapid decrease of concentration with time. Because groundwater at the NTS moves slowly, only radionuclides with half-lives of one year or more are considered significant (Borg, *et al.*, 1976). Second, leaching or dissolution of radionuclides from puddle glass and the rubble chimney is important. These radionuclides become mobile in dissolved form and occur in both cationic and anionic forms. Third, cationic species tend to be less mobile in groundwater than anionic forms because of their greater tendency to sorb onto mineral surfaces. Generally, the most significant sorption process is some form of ion exchange (Borg *et al.*, 1976). Fourth, radionuclides also sorb onto colloidal particles which can increase their mobility as the suspended particles move with groundwater. Fifth, electrostatically neutral species such as the radioactive gas ^{85}Krypton or water molecules with a tritium atom (HTO) are unaffected by the previously mentioned processes and will move with groundwater. Finally, concentrations of groundwater transported radionuclides are probably affected by dispersion which decreases concentrations with time. Table 5 lists long-lived radionuclides produced from nuclear testing that may be observable in groundwater at the NTS as described by Borg *et al.* (1976).

Present groundwater monitoring programs at the NTS as outlined above are best described as detection monitoring programs. Their primary function is to identify the presence of weapons-related radionuclides in groundwater. In almost every case, sampling locations are existing wells drilled for geologic or hydrologic exploration, nuclear device emplacement, post-shot evaluation, or water supply. None were specially designed, sited, and drilled to track weapons-related radionuclides in groundwater (Russell, 1991). Thus, groundwater monitoring locations at the NTS can best be described as points of opportunity. The present groundwater monitoring programs can only assure that weapons-related radionuclides are not found in groundwater at those points sampled. Because of the great depth to water, the large surface area, and the great expense of drilling, the possibility of drilling new wells to add to the present groundwater monitoring programs is limited. However, the UGTA/RIFS is presently drilling wells for site groundwater characterization. In the future, that program will drill wells to identify underground nuclear testing source terms, quantifying those source terms, and will also drill wells specifically designed to track radionuclides in groundwater at the NTS.

TABLE 5. UNDERGROUND NUCLEAR WEAPONS TESTING RELATED RADIONUCLIDES WITH LONG HALF-LIVES THAT MAY BE PRESENT IN GROUNDWATER AT THE NEVADA TEST SITE (after Borg et al., 1976).

Nuclide	Half-Life (years)	Source
^{235}Uranium	7.1×10^8	Device Material
^{99}Technetium	2.1×10^5	Nuclear Reaction
^{239}Plutonium	2.4×10^4	Device Material
^{14}Carbon	5730	Neutron Activation
^{39}Argon	270	Neutron Activation
^{151}Samarium	87	Nuclear Reaction
^{137}Cesium	30	Nuclear Reaction
^{90}Strontium	28	Nuclear Reaction
^{3}Hydrogen	12.3	Neutron Activation
^{152}Europium	12	Neutron Activation
^{85}Krypton	10.8	Nuclear Reaction
^{60}Cobalt	5.3	Neutron Activation
^{125}Antimony	2.7	Nuclear Reaction
^{147}Promethium	2.6	Nuclear Reaction
^{55}Iron	2.6	Neutron Activation
^{134}Cesium	2	Neutron Activation
^{155}Europium	1.8	Nuclear Reaction
^{106}Ruthenium	1	Nuclear Reaction

Regulatory Requirements

Compliance groundwater monitoring at the NTS is conducted to satisfy both State of Nevada and federal regulatory requirements. State and federal regulations include the Safe Drinking Water Act (SDWA), CERCLA, and RCRA. A brief description of pertinent portions of these regulations are listed below.

Safe Drinking Water Act

The SDWA is a federal and State of Nevada regulation that is administered by the Health Division of Nevada's Department of Human Resources. The regulation sets water-quality standards for public water-supply systems. Descriptions of the regulation pertaining to the groundwater monitoring programs at the NTS are listed below. Copies of SDWA regulations sited below are included in Appendix B.

Nevada Revised Statute (NRS). Chapter 445.361 to 445.399 outlines the basic legal requirements of public water systems. It is the policy of the state to provide water that is safe for drinking and other domestic purposes (NRS 445.361). A public water system is defined as any system that provides the public with piped water for human consumption and serves 25 or more people for 60 days or more per year (NRS 445.376). The state board of health is required to adopt by regulation the primary and secondary drinking-water standards established by the Federal SDWA (NRS 445.379).

Nevada Administrative Code (NAC). Chapter 445.244 to 445.262 describes the water-quality requirements of public water systems. All public water systems must meet the primary standards of the National Primary Drinking Water regulations listed in 40 Code of Federal Regulations (CFR) chapters 141.1, 141.4, 141.5, 141.11 to 141.16 inclusive, 141.61, 141.62, 141.63, 141.100, 141.101, 141.110, and 141.111 (NAC 445.247). Monitoring and analytical requirements for primary standards must be performed as required in 40 CFR chapter 141.21 to 141.30 inclusive, and 141.40 to 141.42 inclusive (NAC 445.2475). Secondary standards must also be met and are listed in NAC 445.248. Monitoring requirements for secondary standards are listed in NAC 445.249. Analysis methods for secondary standards are listed in NAC 445.250.

Sampling Frequency Requirements, National Primary Drinking Water Regulations. 40 CFR 141.2 defines the monitoring compliance cycle as the nine-year calendar-year cycle where public water systems must monitor. The first calendar-year cycle begins January 1, 1993 and ends December 31, 2001. A compliance cycle is divided into three compliance periods of three years each. Constituents required to be analyzed during the compliance periods are listed below.

- Coliform (40 CFR 141.21): monitoring frequency for total coliform for community water systems is based on population served.
- Turbidity (40 CFR 141.22): required for systems using surface-water sources in whole or in part (40 CFR 141.13).
- Inorganic chemicals (40 CFR 141.23): community water systems utilizing only groundwater sources will have analyses completed within two years of effective date of 40 CFR 141.23. Analyses must be repeated at three-year intervals.
- Organic chemicals other than total trihalomethanes (40 CFR 141.24): community water systems utilizing only groundwater sources will have analyses completed as specified by the state.
- Radioactivity (40 CFR 141.26 (a)): initial sampling for gross alpha particle activity, ^{226}Radium and ^{228}Radium to determine compliance will begin within two years of the effective date of 40 CFR 141.26. Compliance will be based on the analysis of an annual composite of four consecutive quarterly samples or the average of the analyses of four samples obtained at quarterly intervals. Continued monitoring will be conducted at least once every four years following the initial analysis. A gross alpha particle activity measurement may be substituted for the required ^{226}Radium and ^{228}Radium analyses provided the gross alpha activity does not exceed five picocurries per liter (pCi/L). When gross alpha activity exceeds five pCi/L, a sample will be analyzed for ^{226}Radium. If the ^{226}Radium concentration exceeds three pCi/L, a sample will be analyzed for ^{228}Radium.
- Radioactivity (40 CFR 141.26 (b)): sampling for man-made radioactivity in community water systems using surface-water sources and serving more than 100,000 persons, or

systems designated by the state, is required within two years of the effective date of 40 CFR 141.26. Compliance will be based on the analysis of a composite of four consecutive quarterly samples or analysis of four quarterly samples. At the discretion of the state, suppliers of water utilizing only groundwaters may be required to monitor for manmade radioactivity. After initial analysis, suppliers will monitor at least every four years. Any community water system designated by the state as utilizing waters contaminated by effluents from nuclear facilities will initiate quarterly monitoring for gross beta particle and ^{131}Iodine radioactivity, and annual monitoring for ^{90}Strontium and tritium. Quarterly monitoring for gross beta particle activity will be based on the analysis of monthly samples or the analysis of a composite of three monthly samples. If the gross beta activity in a sample exceeds 15 pCi/L, a sample will be analyzed for ^{89}Strontium and ^{134}Cesium. If the gross beta activity exceeds 50 pCi/L, an analysis will be performed to identify the major radioactive constituents present and the appropriate organ and total body doses will be calculated to determine compliance. For ^{131}Iodine, a composite of five consecutive daily samples will be analyzed once each quarter. Annual analysis of ^{90}Strontium and tritium will be conducted on a composite of four consecutive quarterly samples or on four quarterly samples.

- Total trihalomethanes (40 CFR 141.30): community water systems that serve a population of 10,000 or more individuals and that add a disinfectant to the water will analyze for total trihalomethanes.

Sampling Frequency Requirements, Nevada Secondary Standards. Secondary standards (NAC 445.249): analysis of all public water systems must be completed by June 24, 1979, and repeated at three-year intervals or less as required by the health authority.

Comprehensive Environmental Response, Compensation and Liability Act

CERCLA was enacted by Congress to clean up hazardous waste sites for which responsible parties might not be readily known, or if known, be unwilling to participate in the cleanup. EPA is the lead agency and main regulatory body implementing CERCLA. The procedures and protocols for conducting investigations and remediation under CERCLA are found in the National Contingency Plan (NCP) which is a guidance document that prescribes a general methodology for conducting the investigations and selection of mitigation alternatives. Once a hazardous waste site is identified, a preliminary site assessment is made in which general information and the risks of the site are evaluated. Then the site is ranked for inclusion on the National Priority List (NPL), and, if the site receives a high enough score, it will be placed on the NPL and in the CERCLA "Superfund" program. Once a site has been ranked and placed on the NPL, a priority is assigned, and a time frame for site investigation is developed. Given the restricted staff and financial resources of EPA, only a limited number of sites are investigated at any one point in time (Executive Enterprises, Inc., 1991).

The procedures put forth in the NCP are called the remedial investigation and feasibility study (RI/FS). The RI/FS process calls for scoping and site-planning activities which include; the development of a site-specific work plan that details the procedures, scope of work, schedule, and analytical plan to conduct the investigation; a quality assurance project plan; a health and safety plan; and a data management plan. Upon completion of the planning, the actual remedial investigation is conducted to define the nature, extent, and magnitude of the problem. Following the remedial investigation, a risk assessment is conducted to evaluate and assess the potential public health and environmental impacts that the site may pose. The results of the remedial investigation and risk assessment are then combined to develop remedial action objectives. Remedial action objectives are generally health-based clean-up criteria and are developed for each affected environmental medium. Next, the feasibility study process begins and a series of alternatives to solving the problem are developed and evaluated. Evaluation considers economic, technical, timing, regulatory, and permitting requirements. From there the EPA selects a response action for implementation to remediate the site.

At the time of this report, the NTS has not been listed on the NPL. However, activities are being conducted in compliance with CERCLA requirements as required by DOE Order 5400.4 (U.S. DOE, 1993b). These activities are described in the DOE Order Requirements section below.

Resource Conservation and Recovery Act

RCRA requires hazardous waste treatment, storage, and disposal (TSD) facilities to obtain federal permission to operate. Interim TSD status is required under 40 CFR 265. Facilities may operate and accept waste under interim status until a 40 CFR 264 Part B permit, to operate a hazardous waste TSD facility and accept waste, is approved (Executive Enterprises, Inc., 1991). To obtain a Part B permit, TSD facilities must conduct site characterization activities to understand the local hydrologic system and to evaluate the potential for the release and migration of waste from the TSD facility. These site characterization activities generally include drilling and sampling of monitoring wells. Approved RCRA Part B permits usually require land disposal facilities to have groundwater monitoring wells and a groundwater monitoring program. RCRA requirements are administered by the Division of Environmental Protection of Nevada's Department of Conservation and Natural Resources.

The Area 5 RWMS is presently operating under RCRA interim status. Three groundwater characterization wells have been drilled in Area 5 to supply information for the RCRA Part B permit (U.S. DOE, 1993a). Initial groundwater samples have been collected for groundwater characterization. Presently, no routine groundwater monitoring is conducted at these wells; however, more groundwater monitoring wells and routine groundwater monitoring may be required as part of an approved RCRA Part B permit.

DOE Order Requirements

DOE Orders pertaining to groundwater monitoring are included in the 5400 series. Brief descriptions of the pertinent portions of the 5400 series are presented below.

DOE Order 5400.1. General Environmental Protection Program.

This Order establishes environmental protection program requirements to ensure that DOE operations are in compliance with applicable federal, state, and local environmental protection laws and regulations, executive orders, and DOE internal policies.

DOE Order 5400.1 Chapter III. Environmental Protection Program Plans.

Section 4.a. A Groundwater Management Protection Program for each DOE facility is required. The program should include design and implementation of a groundwater monitoring program to support resource management and comply with applicable environmental laws and regulations; a management program for groundwater protection and remediation including specific SDWA, RCRA, and CERCLA actions; and a remedial action program that is part of the site CERCLA program.

DOE Order 5400.1 Chapter IV. Environmental Monitoring Requirements.

This order contains requirements and guidance for environmental programs concerned with surveillance through measurement, monitoring, and calculation of the effects of operations on the environment and public health.

Section 5.b. Environmental surveillance shall be conducted to monitor the effects of DOE activities on both on-site and off-site environments and their resources. Surveillance shall be designed to verify compliance with applicable environmental laws and regulations, and other environmental commitments; characterize and define trends in physical, chemical and biological condition of environmental media; establish baselines of environmental quality; and identify new or existing environmental quality problems.

Section 9. Groundwater Monitoring Program. Groundwater that is or could be affected by DOE activities shall be monitored to determine and document the effects of operations on groundwater quality and quantity and to demonstrate compliance with DOE requirements and applicable federal, state, and local laws and regulations.

Section 9.a. Groundwater Monitoring Plans. A groundwater monitoring plan shall be developed and shall identify all DOE requirements and regulations applicable to groundwater protection and include monitoring strategy.

Section 9.b. General Requirements.

- Obtain data for the purpose of determining baseline conditions of groundwater quality and quantity.
- Demonstrate compliance with and implementation of all applicable regulations and DOE Orders.
- Provide data to permit the early detection of groundwater pollution or contamination.

- Provide a reporting mechanism for detected groundwater pollution or contamination.
- Identify existing and potential groundwater contamination sources and to maintain surveillance of these sources.
- Provide data upon which decisions can be made concerning land disposal practices and the management and protection of groundwater resources.

Section 9.c. Site-specific characteristics shall determine monitoring needs. Where appropriate, groundwater monitoring programs shall be designed and implemented in accordance with 40 CFR part 264, sub-part f, or 40 CFR part 265 sub-part f. For multiple groundwater pollutant sources, extensive pollution or unique site problems, programs may require more extensive information. Monitoring for radionuclides shall be in accordance with DOE Orders in the 5400 series dealing with radiation protection of the public and the environment.

DOE Order 5400.4. CERCLA Requirements.

Describes DOE CERCLA policies and procedures. DOE will characterize and remediate contaminated sites to reduce the adverse impacts on public health and the environment regardless of listing on the NPL.

DOE Order 5400.5. Radiation Protection of the Public and the Environment.

DOE will operate its facilities and conduct its activities so that radiation exposures to members of the public are maintained within the limits established, and will protect the environment from radioactive contamination to the extent practical.

DOE Order 5400.5 Chapter II. Requirements for Radiation Protection of the Public and the Environment.

Section 1.d. Public dose limits for drinking-water pathways will be provided at a level of protection for persons consuming water from a public drinking-water supply operated by the DOE that is equivalent to that provided by the public community drinking-water standards of 40 CFR Part 141. Combined ^{226}Radium and ^{228}Radium shall not exceed 5 pCi/L and gross alpha activity (including ^{226}Radium but excluding radon and uranium) shall not exceed 15 pCi/L. Also, the liquid effluents from DOE activities shall not cause private or public drinking-water systems downstream of the facility discharge to exceed the drinking-water radiological limits in 40 CFR Part 141.

Section 6.a. Compliance with the dose limits listed in this order will be demonstrated by documentation of an appropriate combination of measurements and calculations.

DOE Order 5480.1b. Environment, Safety, and Health Program for Department of Energy Operations.

This program encompasses DOE requirements, activities, and functions that are concerned with controlling air, water, and soil pollution and limiting the risks to the well being of both operating personnel and the general public to acceptably low levels.

REVIEW OF NTS ANALYTICAL METHODS FOR TRITIUM ACTIVITY

The presence of measurable tritium in deep groundwater at the NTS is generally considered to be the by-product of nuclear testing. A nuclear detonation produces large amounts of tritium as some water molecules are converted from H_2O to HTO by neutron activation. Because tritium is incorporated in the water molecule, tritium will move with groundwater and be unaffected by most processes that normally inhibit the movement of radionuclides in groundwater. Also, the half-life of tritium is sufficiently long so that once tritium is formed, it will be present in measurable concentrations in groundwater for many years. Thus, all groundwater monitoring programs at the NTS analyze samples for the presence of tritium. Since both REECo's and EMSL-LV's groundwater monitoring programs monitor regularly for tritium activity in many of the same wells, a review of their analytical methods for tritium is presented below. A qualitative comparison of REECo's and EMSL-LV's 1992 tritium analyses using the enrichment method is also presented. Copies of REECo's and EMSL-LV's analytical procedures for tritium activity are listed in Appendix C.

Conventional Analytical Method for Tritium Activity

Both REECo and EMSL-LV conduct the conventional analytical method for tritium activity. The conventional method requires a sample to be distilled to remove dissolved solids and minimize interfering quenching. After distillation, an aliquot is mixed with liquid scintillation solution and counted in a liquid scintillation spectrometer. A background sample and a standard solution of known tritium activity are also counted. The tritium concentration of the sample is calculated by:

$$Tritium\ (pCi/L) = \frac{S - B}{2.22\ EV}$$

where
S = gross counts per minute of the sample
B = gross counts per minute of the background sample
E = fractional efficiency determined from a standard solution of known tritium activity
V = sample size in liters.

REECo reports a maximum detectable concentration (MDC) for the conventional method of approximately 300 pCi/L (U.S. DOE, 1993a). EMSL-LV reports an MDC ranging from approximately 400 to 700 pCi/L (U.S. DOE, 1993a). REECo uses distilled water delivered to the NTS from Las Vegas for their background sample. EMSL-LV uses NTS groundwater from Water Well 4 for their background sample. All conventional method results determined by REECo on NTS groundwater samples are reported in DOE/NV's Annual Site Environmental Report (ASER). EMSL-LV reports only conventional method results above the MDC in the ASER.

Enrichment Analytical Method for Tritium Activity

Both REECo and EMSL-LV conduct the enrichment analytical method for tritium activity. The enrichment method requires a sample to first be distilled and then the distillate's volume decreased by electrolysis to enrich the hydrogen concentration of the sample. After enrichment, the sample is vacuum distilled, an aliquot is mixed with liquid scintillation solution, and then counted in a liquid scintillation spectrometer. The tritium concentration of the sample is calculated by:

$$Tritium\ (pCi/L)\ =\ \frac{S - B}{2.22\ EVDF}$$

where
S = gross counts per minute of the sample
B = gross counts per minute of the background sample
E = fractional efficiency determined from a standard solution of known tritium activity
V = sample size in liters
D = dilution factor
F = enrichment factor.

REECo reports an MDC for the enrichment method of approximately 10 pCi/L (U.S. DOE, 1993a). EMSL-LV reports an MDC ranging from approximately five to seven pCi/L (U.S. DOE, 1993a). REECo enriches each sample to 10-milliliters volume, uses distilled water delivered to the NTS from Las Vegas for their background sample, and counts each sample for two 100-minute intervals. EMSL-LV enriches each sample to five-milliliters volume, uses NTS groundwater from Water Well 4 for their background sample, and counts each sample for three 100-minute intervals. All enrichment method results determined by REECo and EMSL-LV on NTS groundwater samples are reported in DOE/NV's ASER.

Qualitative Comparison of 1992 Enriched Tritium Results

Because of the large difference in detection limits between the conventional and enrichment methods, results from the two methods cannot be compared. However, qualitative comparisons can be made between REECo's and EMSL-LV's enriched tritium results. REECo started using the enrichment method in 1991. No results from REECo were submitted for inclusion in the 1991 ASER, so the only data set available for comparison is from 1992. Table 6 lists selected enriched tritium results of groundwater samples collected by REECo and EMSL-LV in 1992 from water-supply wells common to each monitoring program at the NTS. A complete listing of 1992 enriched tritium results from wells common to each program is in Appendix D. When examining the selected 1992 results of the two programs, several observations can be made.

Most of REECo's and EMSL-LV's enriched tritium results are below the MDC for the method and are centered around zero with standard deviations ranging from less than one to about seven pCi/L. Eight REECo results, all from samples collected on October 5, 1992, are substantially below zero (-17 to -30). The reasons for these negative results as compared with other results are not explained in the ASER. These results may be caused by in-house analytical errors such as shorter than normal counting times, machine efficiency problems, improper sample enrichment, incomplete distillation after enrichment, bad scintillation solution, background samples with larger than normal tritium content, and/or miscalculations. The nature of such problems should be noted with the reported analytical results.

Historically, Well C has exhibited measurable tritium activity with a significant decrease in that activity over time (Russell, 1991; U.S. DOE, 1993a). This is the only well at the NTS that has tritium activity above the enrichment MDC and that is sampled by both REECo's and EMSL-LV's monitoring programs. EMSL-LV's 1992 enriched tritium results for groundwater from Well C for 11 samples range from a maximum of 24 pCi/L to a minimum of 11 pCi/L with a mean of 16 pCi/L. REECo's enriched tritium results for groundwater from Well C for four samples range from a maximum of 23 pCi/L to a minimum of -9.1 pCi/L. Although REECo's sample population consists of only four data points, it exhibits a much larger range of values than that of EMSL-LV's sample population. The range is extended at the lower end with two of the results below REECo's MDC. The variability in Well C results reported by REECo and EMSL-LV could occur by variation in several parameters including the activity of the background sample used (B), sample enrichment factor (F), and the machine efficiency (E).

TABLE 6. SELECTED 1992 ENRICHED TRITIUM RESULTS OF GROUNDWATER SAMPLES COLLECTED BY REECo AND EMSL-LV FROM WATER-SUPPLY WELLS COMMON TO EACH MONITORING PROGRAM.

Well	Sample Date	REECo Result (pCi/L)	REECo Standard Deviation (pCi/L)	EMSL-LV Result (pCi/L)	EMSL-LV Standard Deviation (pCi/L)
Army Well #1	10/05/92	-25	6.5	3.2	1.7
Well 4	10/05/92	-23	6.6	1.6	1.6
Well 5C	10/05/92	-24	6.6	-0.5	1.6
Well 8	10/05/92	-30	6.6	1.9	1.5
Well C	01/07/92			11	1.8
	02/03/92			24	2.0
	02/24/92	5.3	4.5		
	04/01/92			21	2.3
	04/06/92	23	4.5		
	05/12/92			12	1.7
	06/02/92			19	1.8
	07/07/92			15	1.9
	07/13/92	15	4.4		
	08/04/92			20	1.8
	09/01/92			12	1.9
	10/05/92	-9.1	6.8	13	1.9
	11/09/92			18	1.7
	12/01/92			17	2.1
Well C-1	10/05/92	-17	6.7	4.7	1.6
Well J-12	10/05/92	-30	6.6	0	1.4
Well J-13	10/05/92	-26	6.5	3.1	1.5
UE-16d	10/05/92	-26	6.5		
	11/09/92			2.3	1.4

EMSL-LV uses water from Water Well 4 with a reported tritium activity (enrichment method) of -4.8 to 2.9 pCi/L which is below their MDC (U.S. DOE, 1993a) for their background sample. REECo uses distilled water delivered to Area 6 from Las Vegas with a reported tritium activity (conventional method) of -300 to 310 pCi/L (U.S. DOE, 1993a). Concerning REECo's reported results, the 1992 ASER states "commercially available distilled water was used for the background matrix for both the conventional and the enrichment analysis method. Clearly the tritium concentration in the commercial product was frequently higher than in the samples themselves resulting in negative values. This was particularly pronounced in the results obtained from the enrichment method. Thus, except for possible statistical fluctuations, the negative values indicate that the water from the potable supply wells contained less tritium than the commercially available distilled water." Normally, a background sample (also called a laboratory blank) of known very low tritium activity is analyzed periodically (usually at least once daily) to account for normal laboratory bias (for example, systematic errors or background laboratory contamination). As shown in the equation, the activity of the background sample (in counts per minute) is subtracted from the activity of the sample to remove the laboratory bias from the reported value. When using the conventional method with an MDC of 300 pCi/L, the difference in counts per minutes of Water Well 4 water and the distilled water from Las Vegas does not affect the reported value significantly. However, when using the enrichment method and measuring sample activities close to the MDC, the counts per minute of the background sample will have a significant affect on the reported value (assuming all other variables are held constant).

Surface waters are influenced by atmospheric tritium. Most of Las Vegas' water is supplied from the Colorado River and Lake Mead. Therefore, it is possible that the distilled water delivered to the NTS from Las Vegas and used by REECo for its background samples, has measurable tritium activity because it is produced from surface water. From a hydrologic viewpoint, deep groundwater at the NTS is very old and is not influenced by tritiated atmospheric water. Therefore, no measurable tritium activity should be present in NTS groundwater unless influenced by underground nuclear testing. Also, large quantities of tritium are produced during an underground test, and because tritium can become part of the water molecule, it is an ideal groundwater tracer for monitoring the movement of weapons-related radionuclides. The enrichment method for analyzing tritium activity is an excellent tool for the hydrogeologist to detect small quantities of tritium as it moves with groundwater toward a well. Therefore, for the early detection of radionuclide migration, it is critical that reported tritium activity values from the enrichment method are as accurate as possible. Correcting sample tritium activity by using background samples with measurable tritium resulting in negative or artificially low values will only mask the possible early detection of radionuclide contamination in groundwater.

Reported values can also be influenced by the sample enrichment factor. The enrichment process drives off the lighter H_2O molecules, reducing the sample volume and concentrating the heavier HTO molecules. As noted above, REECo enriches to a volume of 10 milliliters and EMSL-LV enriches to a volume of five milliliters. These are target reduction volumes and each batch of samples enriched will vary in their final volume. Therefore the sample enrichment factor will vary for each laboratory and each batch of samples and thus potentially creating small variations in reported values.

Machine efficiency can also affect reported values. Machine efficiency can vary according to the standards used to calibrate the liquid scintillation spectrometer. Depending on the expected activity of a batch of samples, appropriate standards are selected to calibrate the spectrometer. Different standards will be used when calibrating for high concentration post-shot samples as opposed to standards used to calibrate for drinking-water supply samples. The standards used in conjunction with the samples will vary the machine efficiency and thus create variations in reported values.

On May 13, 1993, a meeting was held at EMSL-LV to address these concerns. Representatives from EMSL-LV, REECo, the Desert Research Institute (DRI), and Lawrence Livermore National Laboratory (LLNL) were present to discuss current laboratory methodology, quality assurance, and quality control. The group recommended the implementation of an interlaboratory comparison study between the attending institutions for their enriched tritium analyses. A copy of this letter with the group's recommendations is in Appendix E. Implementation of this program as recommended by the group would greatly increase the confidence in reported analytical results and would identify problems that might be occurring within individual DOE/NV contractor laboratories.

GROUNDWATER MONITORING NETWORK DESIGN CRITERIA

Groundwater monitoring network design is defined as the selection of sampling points and sampling frequency to determine physical, chemical, and biological characteristics of groundwater (Loaiciga *et al.*, 1992). In developing a groundwater monitoring network design, consideration should be given to the objectives of the monitoring program; the complex nature of geologic, hydrologic, and source-term factors; the uncertainty of parameters (geologic, hydrologic, and source term) needed in the design process; and the methodology used for network design.

The primary objective of a groundwater monitoring program should be to collect, manage, and analyze geologic, hydrologic, and economic data on groundwater quality and the sources and causes of groundwater contamination. A groundwater monitoring program will also provide other information necessary to enable the federal and state agencies involved to fulfill their statutory responsibilities in regards to protection of groundwater quality, as required by law (Everett, 1984; Todd *et al.*, 1976).

Federal Regulations

Three major federal laws deal specifically with groundwater contamination related to underground nuclear testing at the NTS: SDWA, RCRA, and CERCLA. Of these, only RCRA has specific groundwater monitoring design requirements. DOE has determined that all expended underground nuclear tests fall under the jurisdiction of CERCLA legislation (Bruce Green, DOE memorandum, June 6, 1987). Although CERCLA does not specify groundwater monitoring design requirements, it is likely that standards and procedures similar to those given in RCRA will be applied to CERCLA regulated contamination (Barcelona *et al.*, 1983). DOE Order 5400.1 Chapter IV, Section 9.c also states what groundwater monitoring programs are to be designed and implemented in accordance with RCRA regulations where appropriate.

The basic concept of RCRA groundwater monitoring is to statistically compare wells located hydrologically upgradient and downgradient from a contamination site. Upgradient wells are designed to give an estimate of ambient groundwater quality. Downgradient wells are positioned to determine if contaminant transport is occurring beyond the boundaries of a predetermined Hazardous Waste Management Area (HWMA). An HWMA is defined as an area within a facility's property which encompasses one or more hazardous waste management units or cells. However, if several distinct areas of activity are present which are widely separated within the boundaries of one facility, then separate HWMAs may be established.

By regulation, downgradient wells must be located as close as possible to the edge of hazardous waste management units, and a minimum of one upgradient well must be installed. Generally the spatial placement (both horizontal and vertical) and sampling frequency of downgradient wells are determined by such factors as: likely stratigraphic horizons for contaminant transport, vertical potentiometric gradient, groundwater velocity, dispersion and sorption, and contaminant characteristics. Upgradient monitoring wells must be located in the same hydrostratigraphic section of the aquifer as the downgradient monitoring wells to permit a comparison of groundwater quality. Although only one upgradient well is required by regulation, an adequate number of background monitoring wells must be installed to fully characterize the site, and allow for depth-discrete comparisons of groundwater quality.

Methodology for Groundwater Monitoring Network Design

The basic purpose of a methodology for monitoring groundwater is to provide a framework for the planning and development of a monitoring program. The following is a outline of a methodology for developing a groundwater monitoring program based on ideas presented by Everett (1984), and include selected concepts from Todd *et al.* (1976), Loaiciga *et al.* (1992), Hood *et al.* (1988), Brown *et al.* (1989), Luo and Hobbs (1991), and Desmarais (1990). The following steps describe procedures for implementing a groundwater monitoring program. The steps are arranged in chronological order of investigation and implementation.

Define Objectives of the Program

The objective of a groundwater monitoring program is the primary factor which determines the cost, effort level, and appropriate methodology to be incorporated into a monitoring network (Loaiciga, *et al.*, 1992). The objectives of a monitoring program may include ambient, research monitoring; detection monitoring; and/or compliance monitoring. Detection and compliance monitoring are driven by regulatory considerations, with resultant program objectives defined by applicable state and federal regulations. The main function of detection monitoring is to identify the presence of targeted contaminants at pre-established concentration thresholds as defined by regulators. A typical detection monitoring network would include the placement of upgradient and downgradient monitoring wells in the vicinity of a point or nonpoint pollution source.

By contrast, a compliance-driven program is generally required by the regulator to monitor the progress and/or success of groundwater remediation activities. In this case, groundwater contamination has already occurred, and the resultant monitoring program is defined by applicable regulations and site-specific factors which evolved out of earlier characterization efforts. While contaminant tracking is the primary function of a compliance program, there is also usually a detection function which is driven by public health considerations.

Generally speaking, most monitoring programs share the broad objectives of collecting, managing, and analyzing groundwater quality, contaminant source, geologic, hydrologic, and economic data. These data are then used by the investigator to address the specific objectives of their monitoring program (e.g., developing remediation strategies; delineating extent of contamination; demonstrating regulatory compliance). These data may also be used by regulators in fulfilling their statutory responsibilities to protect groundwater resources. The data obtained may be used for many purposes including:

- provision of background information and quality,
- detection of quality trends,
- identification and assessment of the sources and causes of contamination,
- planning,
- establishment of water-quality standards and effluent limitations,
- formulation of regulatory control and management actions necessary to protect quality,
- risk assessment
- compliance,
- enforcement, and
- reporting.

An effective monitoring program must recognize the dynamic nature of groundwater systems since both are affected by natural phenomena and man-induced changes. The program must, therefore, be ongoing as the scope and emphasis changes over time, and the objectives must be both flexible and modifiable. The data obtained must continue to be adequate enough to predict quality problems and to formulate plans to prevent contamination.

Identify Source Terms

The design of a monitoring program requires that the potential sources and causes of groundwater contamination and the methods of waste disposal within an area be identified. The identification of the type of source term such as a point, line, or diffuse source is also important. The potential contaminants for each source must also be identified.

Identify Receptor Sites

To evaluate the impact of contamination or potential contamination of groundwater, the usage of the resource becomes a key item. Thus, it is important to define both the quantities of groundwater being extracted and the location of the pumping centers within the monitoring areas. A receptor site can be considered a location where potentially contaminated groundwater becomes available for potential consumption. Receptor site identification also includes determining the type of risk to individual receptors to help define the scope of monitoring which will be required.

Define Hydrogeology

To understand where and how groundwater occurs and moves within a monitoring area, the hydrogeologic framework must be understood. This information will aid in the design of an effective and efficient groundwater quality monitoring system. Specific information needed for groundwater monitoring programs include:

- aquifer locations, depths, and areal extent,
- transmissivities, storage coefficients, permeabilities, and porosities of aquifers,
- maps of groundwater levels,
- areas and magnitudes of natural groundwater recharge,
- areas and magnitudes of natural groundwater discharge, and
- directions and velocities of groundwater flows.

This information serves as tools for monitoring. All hydrogeologic data are incomplete in a relative sense, what is important is an overall picture of the hydrogeologic setting in the monitoring area. With time and increasing amounts of groundwater data, knowledge of the hydrogeologic setting improves.

Define Existing Groundwater Quality

Defining existing groundwater quality is extremely important for two reasons: determination of natural (background) water quality as a reference for future sample analysis, and development and confirmation of conceptual groundwater flow models. Water-quality data must be utilized in conjunction with the inventory of source terms and hydrogeologic data to identify the areal extent, direction, and rate of movement of contaminants. Initially, significant portions of a monitoring area may entirely lack groundwater-quality data. However, existing water-quality data, along with hydrogeologic and source-term data, may suggest locations for future sampling and monitoring efforts.

Evaluate Distribution/Attenuation of Contamination

Percolating water passes vertically through the vadose zone to the water table. In some semiarid or arid climates, contaminants may be retained above the water table, for practical purposes, almost permanently. Percolating waters may become perched above layers of low permeability resulting in lateral movement for substantial distances above the water table. Factors controlling the attenuation of contaminants include dilution, filtration, sorption, chemical precipitation, and radioactive decay. Man-made influences on contaminant distribution must also be considered, such as "short-circuiting" of groundwater flow from poorly constructed wells and well pumping. Information on the mobility and attenuation of contaminants is extremely important in considering the possible extent of contaminant distribution from source-term areas.

Prioritize Source Terms

Initial prioritization of source terms is generally not possible because of incomplete data and knowledge regarding the fate and transport of contaminants in site-specific situations. However, groundwater monitoring programs should be dynamic, and with time, should allow the accurate prioritization of source terms as more information is gained. Of the possible uses of groundwater, usage as potable water supplies is the most important. Therefore, sources that pose a health threat to potable water supplies should have priority over non-health-related uses.

Evaluate Existing Monitoring Programs

Every effort should be made to incorporate past and ongoing monitoring efforts into a new monitoring program. Information sharing agreements with other characterization and monitoring programs are essential if a monitoring program is to be both comprehensive and cost effective. Data from past and ongoing investigations should be compiled and examined in an effort to minimize the number of sampling sites required. The results of this process will be a priority listing of areas having monitoring deficiencies.

Select and Implement Monitoring Program

The eight steps as outlined above should result in a good appreciation of the source-term areas with the highest priority and in the identification of data and information deficiencies. Based on this information, with consideration given to budgetary constraints, it is possible to initiate a new monitoring program. The new monitoring program will most likely require the addition of new sampling locations and possibly the deletion of redundant or unneeded sampling locations. In addition to groundwater quality samples, determination of hydrogeologic parameters such as hydraulic gradients (horizontal and vertical), aquifer transmissivity, storage coefficient, and aquifer geometry will be required to begin characterization of the monitoring area.

Review and Interpret Monitoring Results

Following implementation of a monitoring program, a key function is to collect and review all current monitoring data. New data should be analyzed and compared with existing data to define water-quality trends, refine groundwater flow models, assess the quality of the monitoring program, and define monitoring deficiencies.

Effective data analysis requires that relevant information be available in a concise, comprehensive, timely, economical, and reliable manner. Information contained in a groundwater database management system should include, sample location descriptions, quality control/quality assurance criteria, geologic information, hydrologic information, results of measurements, information qualification data to determine "goodness" of data, and temporal or time-series information for detection of trends.

Review and Revise Monitoring Program Based on Monitoring Results

As new data are collected and analyzed, the quality of the monitoring program can be assessed and monitoring deficiencies defined. To eliminate monitoring and/or characterization information deficiencies, new sampling locations may be added to the monitoring network. Two methods exist for determining the placement of the sampling locations: hydrogeological, and statistical.

The hydrogeological approach is the most commonly used method and is based on qualitative and quantitative hydrogeologic information. The number and location of sampling sites are strictly determined by the hydrogeologic conditions. The hydrogeologic approach generally provides the fundamental data and rationale needed to initiate any groundwater monitoring network.

Once a sufficient amount of hydrogeologic data has been acquired, the statistical approach can be employed to determine areas of monitoring and informational deficiencies, and to approximate hydrogeologic conditions. The hydrogeological approach seeks to define hydrogeological parameters which are extremely complicated and, in general, defy exact description. The statistical approach, most commonly employing geostatistics, utilizes the concept of spatially distributed random variables to: calculate the most accurate predictions (according to well-defined criteria) based on measurements and other relevant information, quantify the accuracy of these predictions, and develop hydrogeologic models which are statistically consistent with available information.

Summary of Methodology for Groundwater Monitoring Network Design

Successful groundwater monitoring network design must be based on well-defined monitoring objectives. These objectives are generally influenced by federal and state regulations. Source terms and receptor sites must be identified, at least on a regional scale. The hydrogeologic setting in the monitoring area must also be understood, at least on a regional scale. Existing groundwater quality data should be evaluated to determine the natural (background) water quality as a reference for future sample analysis, and to aid in the development and confirmation of conceptual groundwater flow models. The distribution and attenuation of contamination from source terms should be investigated and source terms prioritized to the extent possible with available data. Past and ongoing monitoring efforts should be evaluated, and a new monitoring program implemented based on available information. Following implementation of the monitoring program, data should be collected and reviewed periodically. Existing and new data should be entered into a comprehensive, easily accessible data management system to facilitate data analysis. As new data are acquired, the network design should be revised and updated in response to changes in information needs and the gathered data. It is important to remember that monitoring network design is an iterative process, whereby the monitoring program is reviewed and updated, and conceptual models of groundwater flow and contaminate transport evolve, as data become available.

Specific Nevada Test Site Design Considerations

Define Objectives

Routine groundwater monitoring is conducted at the NTS by REECo's Environmental Monitoring Program and EPA's EMSL-LV's LTHMP. REECo's groundwater monitoring program objectives are as stated in Section 9.b of DOE Order 5400.1 (Ferate, 1993):

- Obtain data for the purpose of determining baseline conditions of groundwater quality and quantity.
- Demonstrate compliance with and implementation of all applicable regulations and DOE Orders.
- Provide data to permit the early detection of groundwater pollution or contamination.
- Provide a reporting mechanism for detected groundwater pollution or contamination.
- Identify existing and potential groundwater contamination sources and to maintain surveillance of these sources.
- Provide data upon which decisions can be made concerning land disposal practices and the management and protection of groundwater resources.

As specified in various LTHMP publications (i.e., R.E. Miller to M.W. Carter, 3 February 1972; U.S. EPA, 1988) the objectives of the LTHMP are:

- Assure public safety,
- Document compliance with standards and regulations,
- Detect migration of radioactivity, and
- Disseminate information.

Under the monitoring program criteria outlined by Logaiciga, *et al.* (1992), both of the above programs would contain elements of detection and compliance monitoring. The objectives listed above are appropriate objectives for an NTS groundwater monitoring program and would be fulfilled utilizing the methodology presented in this report. As stated previously, the primary objective of a groundwater monitoring program is to collect, manage, and analyze groundwater data and to facilitate compliance with environmental regulations. The REECo and LTHMP objectives are encompassed in this broad objective.

Identify Source Terms

Identification of source terms for groundwater at the NTS, in a regional sense, is relatively straightforward. LLNL, Los Alamos National Laboratory (LANL), and DOE/NV have extensive records for nuclear testing events conducted at the NTS. These records include the depth of emplacement and cavity diameter, and in many cases, extensive pre-test and post-test geologic and hydrologic investigations. Additionally, investigations have been conducted by LLNL, LANL, DRI, and the USGS in the mechanisms of radionuclide transport and attenuation near test cavities. However, on a local level, the mechanics controlling the contamination of groundwater from underground nuclear testing is still poorly understood.

Identify Receptor Sites

Receptor sites related to underground tests at the NTS can be divided into two categories. The first category includes wells used for potable and non-potable water supply at the NTS. The second category includes the wells and springs located in discharge areas west and south of the NTS as described for the three hydrologic subbasins. Both categories should be considered in the design of a groundwater monitoring network. However, as noted by Daniels *et al.*, (1993), evaluating the risk at individual receptor sites, especially those outside NTS boundaries, is a difficult task. A paucity of appropriate source term data, coupled with inadequate local-scale hydrogeologic information, make risk-based analysis a speculative endeavor at the NTS. Thus, incorporating this important consideration into monitoring programs may be a slow, incremental process as our understanding of site-specific risk improves.

Define Hydrogeology

As discussed at the beginning of this report, the hydrogeological framework of the NTS is fairly well understood in a regional sense. However, much more information is needed to begin characterization of groundwater flow at the NTS on a local scale. Information is needed to delineate aquifer locations, depths, transmissivities, and areal extents. Distribution of composite hydraulic gradients have been examined on the regional scale, however, the distribution of local hydraulic gradients, both horizontal and vertical, is poorly understood. This information is essential in the design of an effective and efficient groundwater monitoring system.

Groundwater flow to receptor sites west and south of the NTS occurs through valley-fill, volcanic, and carbonate aquifers. Although generally understood on a regional scale, this flow system is extremely complex and poorly understood on the local scale. Groundwater movement within the system consists of combined intergranular, fracture, and possibly cavernous modes of fluid flow. Local cross-aquifer flow caused by structural, depositional, and erosional juxtaposition of aquifers may produce localized deviations in groundwater flow. The structure of the underlying lower clastic aquitard probably produces localized compartmentalization of groundwater flow. Additionally, lateral and vertical gradients, with the potential to greatly influence local groundwater flow, are poorly understood. A great deal of hydrogeologic information is needed to characterize and design a monitoring program for these southern receptor sites.

Define Existing Groundwater Quality

NTS groundwater quality is discussed in the Hydrogeology of the NTS section of this report. Inorganic water-quality constituents have been used to classify NTS groundwater into three broad geochemical categories or facies. These water-quality data have been used to develop regional scale models of groundwater movement at the NTS. However, more work needs to be done to address the conceptual models of local groundwater flow for each source term. Radionuclide occurrence in groundwater has not been thoroughly investigated at the NTS. Radionuclide analyses of groundwater are listed annually in the ASER.

Evaluate Distribution/Attenuation of Contamination

As discussed earlier in the Identification and Tracking of Radioactive Constituents section of this report, long half-life radionuclides associated with underground nuclear testing are the principal source of groundwater contamination of interest at the NTS. Very limited knowledge on radionuclide distribution and attenuation in groundwater is available, however, radionuclides have been found in groundwater at the NTS as described in Thompson (1991), Russell (1991), and Lyles (1990). The attenuation of radionuclides in groundwater at the NTS is not well understood, but limited research suggests that several processes are important as described earlier. For more detailed discussion of these processes, consult Borg *et al.* (1976).

Prioritize Source Terms

Source terms related to underground nuclear testing at the NTS are extremely variable in terms of concentration and volume of contaminants, proximity to receptor sites, and hydrogeologic setting. Present groundwater monitoring programs only address source terms generally, that is, the principal source terms are from underground nuclear testing in Pahute Mesa, Rainier Mesa, and Yucca Flat. Present monitoring programs are only concerned with monitoring receptor sites that may be affected by underground testing, those receptor sites are NTS water-supply wells and any radionuclides that may be leaving the boundaries of the NTS. A risk-based screening analysis of NTS groundwater radionuclide contamination assumed that potential groundwater contamination would first leave Area 20 in the northwestern corner of the NTS. Oasis Valley (19 km southwest of Area 20) was selected as the closet accessible offsite environment (Daniels *et al.*, 1993).

Evaluation of Existing Groundwater Monitoring Programs at NTS

REECo's and EMSL-LV's groundwater monitoring programs at the NTS are conducted on a routine basis and have been the main focus of this report. Wells utilized by REECo and EMSL-LV for groundwater monitoring at the NTS consist almost exclusively of wells drilled for either water supply or geologic and hydrologic exploration related to nuclear testing. For this reason, the majority of wells currently sampled are located within testing areas of the NTS and do not meet the RCRA definition of either upgradient or downgradient monitoring wells. However, REECo's and EMSL-LV's monitoring of potable and non-potable water-supply wells at the NTS does qualify as monitoring for contamination at NTS receptor sites and as monitoring required by state and federal SDWA.

REECo samples a total of 13 water-supply wells at the NTS, of these wells, three produce water from the valley-fill (alluvium) aquifer, six produce water from various Tertiary volcanic aquifers, and four produce water from carbonate aquifers (one from the upper carbonate aquifer and three from the lower carbonate aquifer). Ten of the wells sampled by REECo are located within or between testing areas. Of the remaining three wells, Water Well Army #1 (lower carbonate aquifer) is located at the extreme southern end of the NTS, in the Ash Meadows subbasin. The other two wells, Water Well J-13 and Water Well J-12 (Tertiary volcanic aquifers), are located in the southwestern corner of the NTS, within the Alkali Flats-Furnace Creek subbasin. These three wells are too distant from underground testing to meet RCRA downgradient water-quality monitoring location criteria.

Of the 10 wells sampled by REECo that are located between testing areas, four could possibly be considered downgradient wells for individual testing areas. Water Well 8, located southwest of Rainier Mesa, is completed in Tertiary volcanic rocks within the Alkali Flats-Furnace Creek subbasin and could be considered a potential downgradient monitoring well for source term areas within Rainier Mesa. USGS Water Well C and Water Well C-1, located at the southern edge of Yucca Flat, are completed in the lower carbonate aquifer. However, the degree of connectivity between these carbonate rocks and those underlying the rest of Yucca Flat is uncertain. These wells may be appropriate downgradient monitoring locations for source-term areas within Yucca Flat provided a large degree of connectivity can be proven. Water Well 5c is located downgradient from testing in Frenchman Flat and is completed in alluvium. Groundwater is though to exit Frenchman Flat (Ash Meadows subbasin) through the lower carbonate aquifer. This well could be considered a satisfactory downgradient monitoring well for the alluvial aquifer but not for the carbonate aquifers. None of the wells sampled by REECo at the NTS could be considered satisfactory upgradient water quality monitoring wells.

In addition to the 13 water-supply wells sampled by REECo, EMSL-LV samples 16 other wells at the NTS. None of these 16 wells produce water from the valley-fill (alluvium) aquifer. Nine wells produce water from Tertiary volcanic aquifers. Three wells are completed entirely within Paleozoic rocks; two within the lower carbonate aquifer and one within the lower clastic aquitard. Three wells are completed within both Tertiary volcanic and Paleozoic rocks; two wells penetrate lower carbonate rocks and volcanic rocks, and one well encounters volcanic rocks and lower clastic rocks. The lithology of the water producing interval for one well, UE-6d, is uncertain, but is most likely Tertiary volcanic rocks.

All but one of the 16 non-water-supply wells sampled by EMSL-LV are located within or between testing areas on the NTS. Army 6A is completed within the lower carbonate aquifer and is located immediately south of the NTS within the Ash Meadows subbasin. Army 6A is too distant from underground testing to be an appropriate downgradient monitoring location. Of the wells located between testing areas, one could be considered a downgradient monitoring well. Well USGS HTH-1 is located south of Rainier Mesa near the divide between the Ash Meadows and Alkali Flat-Furnace Creek subbasins. Because of the uncertainty of the location of this divide, USGS HTH-1 could serve as a downgradient monitoring location pending future study and a better definition of localized groundwater flow patterns south of Rainier Mesa. Wells UE-18r and UE-18t, located south of testing areas in the northern portion of Pahute Mesa, are completed in Tertiary volcanic rocks. These wells are too distant from underground testing to be appropriate downgradient monitoring locations for source-term areas in northern Pahute Mesa. None of the wells sampled by EMSL-LV could be considered satisfactory upgradient water-quality monitoring wells.

The majority of wells sampled by the groundwater monitoring programs lie within underground test areas. Although unsuitable for use as either upgradient or downgradient water quality monitoring locations, these wells and the data obtained from them are extremely valuable. Water-level measurement, sampling, and special investigation efforts by LLNL, LANL, USGS, and DRI are essential in producing and refining groundwater flow and contaminate transport models for the NTS, which are required for proper groundwater monitoring network design. Other existing NTS wells should be evaluated for their potential inclusion in the groundwater monitoring network to try to satisfy the RCRA upgradient and downgradient criteria.

Select and Implement Monitoring Program

Since groundwater monitoring programs already exist, this step is unnecessary.

Review and Interpret Monitoring Results

New monitoring data are reported and preliminary data analyses are described in the ASER.

Review and Revise Monitoring Program

The main emphasis of this report is to review REECo's and EMSL-LV's groundwater monitoring programs in an effort to eliminate redundancy. An effort was also made to examine groundwater monitoring literature to develop a sound groundwater monitoring network program design. As described above, monitoring network design requires detailed evaluations of many different problems. Because of the limited scope of this report and because of the wide range of topics that need to be reviewed in the design criteria listed above, this subsection emphasizes identifying other potential groundwater monitoring locations at the NTS that may help achieve the groundwater monitoring objectives and design requirements.

Potential Groundwater Monitoring Locations. Appendix F contains a listing of wells located at the NTS that was compiled utilizing data from Raytheon Services of Nevada's (RSN) Red Book; RSN hole histories; and USGS, LLNL, LANL, and DRI special investigation reports. The listing contains information on well name, location, ground-surface elevation, total depth, year completed, casing and hole size and depth, completion type and depth, static water level, lithology and sampling status. The wells in the listing are organized by NTS operational area. The wells included in Appendix F consist of wells currently sampled by REECo's Environmental Monitoring Program, EMSL-LV's LTHMP, and those wells which could possibly be available for sampling, that is, those wells which could not be shown to be plugged or otherwise inaccessible in the information sources indicated above.

From the list in Appendix F, approximately 30 wells were selected based on how recently water levels or samples had been obtained, and were then examined for inclusion in the groundwater monitoring network (Table 7). As with the wells sampled currently, most wells were drilled in support of the nuclear testing program and are located in or between underground testing sites. Of the 30 wells examined, six are recommended for immediate inclusion in the groundwater monitoring network based on their locations relative to testing sites, lithology encountered, and regional groundwater flow patterns. Five of these six wells are recently completed UGTA/RIFS wells. These are the first wells drilled at the NTS for the sole purpose of groundwater characterization and water-quality monitoring. The other recommended well is a NTS water-supply well with an inoperable pump that needs replacement or repair.

At the outset, it should be strongly emphasized that the designation of these wells as either downgradient or upgradient (see *Network Criteria*, Table 7) is highly qualitative, and is not intended to adhere to the criteria for upgradient/downgradient monitoring wells as defined in RCRA legislation. Rather, these wells have been determined to be either downgradient or upgradient based on their locations in the framework of regional-scale flow and/or water table maps. Thus, the local-scale hydrogeologic information one would require in siting monitoring wells under RCRA guidelines was not available for this analysis and suggested network design.

TABLE 7. LIST OF POTENTIAL SAMPLING LOCATIONS THAT COULD BE ADDED TO EXISTING GROUNDWATER SAMPLING NETWORK AT THE NEVADA TEST SITE.

Sampling Location	NTS Operational Area	Testing Area	Network Criteria	Geology
Pahute Mesa #3 string #1	offsite	Pahute Mesa	Downgradient	Tr Volcanics
Pahute Mesa #3 string #2	offsite	Pahute Mesa	Downgradient	Tr Volcanics
UE-1q	1	Yucca Flat	Downgradient	
UE-1a	1	Yucca Flat	Downgradient	Tr Volcanics and Eleana
UE-1b	1	Yucca Flat	Downgradient	Eleana
UE-1	1	Yucca Flat	Downgradient	
UE-2ce Water Well	2	Yucca Flat and Rainier Mesa	Downgradient	Pz Carbonates
UE-3e #4 string #1	3	Yucca Flat	Downgradient	
UE-3e #4 string #2	3	Yucca Flat	Downgradient	
UE-3e #4 string #3	3	Yucca Flat	Downgradient	
UE-4t string #1	4	Yucca Flat	Downgradient	Tr Volcanics
UE-4t string #2	4	Yucca Flat	Downgradient	Tr Volcanics
USGS HTH #3	5	Frenchman Flat	Upgradient or Downgradient	Pz Carbonates
UE-5n	5	Frenchman Flat	Downgradient	Alluvium
Water Well 5A	5	Frenchman Flat	Downgradient	Alluvium
ER-6-1	6	Yucca Flat	Downgradient	Pz Carbonates
ER-6-1 #1	6	Yucca Flat	Downgradient	Tr Volcanics
ER-6-2	6	Yucca Flat	Downgradient	Pz Carbonates
Well 3	6	Yucca Flat	Downgradient	Alluvium

TABLE 7. Continued.

Sampling Location	NTS Operational Area	Testing Area	Network Criteria	Geology
U-7cd #1	7	Yucca Flat	Downgradient	Tr Volcanics
UE-10j	8	Rainier Mesa Yucca Flat	Downgradient Upgradient	Pz Carbonates
ER-12-1	12	Rainier Mesa Yucca Flat	Downgradient Upgradient	Pz Carbonates and Eleana
UE-15d Water Well	15	Yucca Flat	Upgradient	Tr Volcanics
ER-19-1	19	Pahute Mesa	Downgradient	Tr Volcanics and Pz Carbonates
UE-19h	19	Pahute Mesa	Upgradient or Downgradient	Tr Volcanics
ER-20-1	20	Pahute Mesa	Downgradient	Tr Volcanics
Pahute Mesa Ex. Hole #2	20	Pahute Mesa	Upgradient or Downgradient	Tr Volcanics
U-20n PS #1DD-H	20	Pahute Mesa	Downgradient	
UE-20n #1	20	Pahute Mesa	Downgradient	Tr Volcanics

UGTA/RIFS well ER-12-1 is located southeast of Rainier Mesa (Ash Meadows subbasin) and is completed in the lower carbonate aquifer and lower clastic aquitard. This well would serve as a downgradient well for source terms from Rainier Mesa. UGTA/RIFS well ER-19-1 is located southwest of Rainier Mesa (Alkali Flat-Furnace Creek subbasin) and is currently completed in Tertiary volcanic rocks. This well would serve as a downgradient well for source terms from Rainier Mesa. UGTA/RIFS wells ER-6-1 and ER-6-2 are located at the southeast and southwest portions of Yucca Flat (Ash Meadows subbasin) downgradient from underground testing. Both wells are completed in the Paleozoic lower carbonate aquifer. UE-10j is located in north Yucca Flat (Ash Meadows subbasin), northwest of Yucca Flat testing. This well is completed in the Paleozoic lower carbonate aquifer and would serve as a much needed upgradient water-quality monitoring location. UE-15d, previously part of the groundwater monitoring network, is presently inaccessible for sampling because of the presence of a nonfunctional pump. If this pump could be repaired, replaced, or at least removed to permit sampling by bailer, the well would be useful additions to the groundwater monitoring network. UE-15d, located in northeast Yucca Flat, is completed in Tertiary volcanic and Paleozoic lower clastic rocks, and would serve as another upgradient monitoring location.

Because of the limited number of monitoring locations available at the NTS, it is not recommended that any wells be deleted from the groundwater monitoring network at this time. Currently, any information obtained on the hydrogeology or hydrogeochemistry of the NTS is valuable in determining both regional and local hydrogeologic settings.

RECOMMENDATIONS

Listed below are recommended changes to the NTS groundwater monitoring programs to eliminate redundant and unnecessary sampling and analysis of groundwater, improve the comparability of enriched tritium data from different DOE/NV contractor laboratories, and improve the overall groundwater monitoring network.

Sampling Frequency and Constituents to be Analyzed

Safe Drinking Water Act Requirements

Under the present groundwater monitoring programs, a large number of samples are collected and analyzed that are not required by the SDWA. Based on the above referenced state and federal SDWA regulations, the following sampling frequency and specific constituent analyses are recommended:

Potable Water-Supply Wells

- Coliform bacteria- continue present sampling and analysis at consumption points.
- Turbidity - not required.
- Inorganics - continue present sampling and analysis.
- Organics - continue present sampling and analysis.
- Naturally occurring radioactivity - quarterly sampling and analysis for gross alpha activity, ^{226}Radium, and ^{228}Radium.
- Man-made radioactivity - sample monthly and analyze for gross beta activity, sample quarterly and analyze for tritium (enrichment method) and ^{90}Strontium, and a composite of five consecutive days each quarter for ^{131}Iodine.
- Total Trihalomethanes - not required.
- Secondary standards - continue present sampling and analysis.

Non-Potable Water-Supply Wells

- State of Nevada does not require monitoring, see recommendations under DOE Orders.

Drinking-Water Consumption Points

- Continue present sampling and analysis for coliform bacteria, pH, residual chlorine, and inorganic constituents.
- State of Nevada does not require radioactivity monitoring at consumption points, see recommendations under DOE Orders.
- No sampling required, see recommendations under DOE Orders.

Non-Water Supply Wells

- No sampling required, see recommendations under DOE Orders.

DOE Order Requirements

DOE Orders in the 5400 series do not list specific groundwater monitoring sampling frequency or constituent analysis requirements. DOE Order 5400.5, Radiation Protection of the Public and the Environment, lists radiation protection dose limits, but does not recommend specific groundwater sampling frequency or constituent analysis requirements. DOE Order 5400.1 lists general environmental protection and groundwater monitoring program requirements, but does not make specific monitoring recommendations. Therefore, because DOE Orders are not specific, the following recommendations are subjective:

Potable Water-Supply Wells

- Tritium - sample quarterly, analyze with enrichment method for early detection of movement of radionuclide contaminated groundwater.
- Gamma activity - sample annually until enriched tritium activity above the MDC is observed.
- ^{238}Plutonium and $^{239+240}$Plutonium - sample annually until enriched tritium activity above the MDC is observed.
- Other radionuclide analysis covered under SDWA requirements.

Non-Potable Water-Supply Wells

- Tritium - sample quarterly, analyze with enrichment method for early detection of movement of radionuclide contaminated groundwater.
- Gamma activity - sample annually until enriched tritium activity above the MDC is observed.
- ^{238}Plutonium and $^{239+240}$Plutonium - sample annually until enriched tritium activity above the MDC is observed.
- Other radionuclide analysis not recommended until enriched tritium activity is consistently above the MDC.

Drinking-Water Consumption Points

- Tritium - sample weekly, analyze with conventional method only. Reduce conventional analysis of distilled water from Las Vegas to monthly.
- Other radionuclides - continue present sampling and analysis.
- Tritium - sample quarterly, analyze with enrichment method for early detection of movement of radionuclide contaminated groundwater.

- Gamma activity - sample annually until enriched tritium activity above the MDC is observed.

- ^{238}Plutonium and $^{239+240}$Plutonium - sample annually until enriched tritium activity above the MDC is observed.

- Other radionuclide analysis not recommended unless enriched tritium activity is consistently above the MDC.

Non-Water Supply Wells

- Continue LTHMP frequency and constituent analysis except for water-supply wells. Monitor water-supply wells for constituents and on frequency described above.

Analytical Methods for Tritium Analysis

Based on the review of analytical methodology for tritium analysis used by REECo and EMSL-LV, the following recommendations are:

- Note with published results analytical problems resulting in very negative values.

- Use water with very low tritium activity for REECo's background sample in their enrichment method for analysis of tritium activity. Recommend using water from Water Well 4, same as EMSL-LV.

- Institute interlaboratory comparison program for enriched tritium analysis as recommended by tritium subcommittee letter (Appendix E). Quarterly analysis of tritium activity in water-supply wells by both REECo and EMSL-LV using the enrichment method should continue in FY94 until results from interlaboratory comparison program can be reviewed. FY94 quarterly water-supply well samples should be collected by one contractor and splits supplied to both REECo's and EMSL-LV's laboratory.

Groundwater Monitoring Network Design

The inclusion of other wells, presently not sampled, in the existing groundwater monitoring programs is recommended to improve the overall monitoring network. As discussed above, more upgradient and downgradient sampling locations are needed to achieve groundwater monitoring network objectives. The following steps are recommended:

- Begin negotiations with DOE/NV's Environmental Restoration Division to gain access to UGTA/RIFS wells for inclusion in the groundwater monitoring network.

- Add wells ER-6-1, ER-6-2, ER-12-1, ER-19-1, and UE-10j to the network and sample at non-water-supply well frequency.

- Repair or remove pump at well UE-15d and sample at non-water-supply well frequency.

- Begin the evaluation of 30 other selected wells to determine their potential for inclusion in the network.

- Give consideration to the establishment of a comprehensive and easily accessible data base for past and current data as discussed in the groundwater monitoring program network design methodology section.
- Utilize trained hydrogeologists familiar with the hydrogeology of the NTS and the objective's of the monitoring programs to annually evaluate the groundwater monitoring program.
- Continue to fund local and regional groundwater studies, and source-term evaluations, to refine conceptual models of NTS radionuclide transport to facilitate refinement of monitoring network.

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APPENDIX A

ANNOUNCED UNDERGROUND NUCLEAR WEAPONS TESTS AT THE NEVADA TEST SITE CONDUCTED BELOW OR NEAR THE GROUNDWATER TABLE (FROM MARSH, 1992)

Event name	Hole Name	Sponsor	Date	Depth of Burial (meters)	Water Level (meters)	Water Level Measurement
Bilby	U3CN	LANL	09/13/63	714.300	503	est.
Wagtail	U3AN	LANL	03/03/65	749.600	509	est.
Cup	U9CB	LLNL	03/26/65	538.890	562	est.
Buteo	U20A	LANL	05/12/65	695.550	658	meas.
Cambric	U5E	LLNL	05/14/65	294.740	213	est.
Diluted Waters	U5B	LLNL/DoD	06/16/65	192.630	213	est.
Bronze	U7F	LANL	07/23/65	530.810	553	est.
Corduroy	U10K	LLNL	12/03/65	678.790	568	meas.
Buff	U3DH	LANL	12/16/65	500.410	520	est.
Lampblack	U7I	LANL	01/18/66	561.480	549	est.
Rex	U20HE	LLNL	02/24/66	671.170	642	meas.
Chartreuse	U19D	LANL	05/06/66	666.750	662	meas.
Piranha	U7E	LANL	05/13/66	548.720	533	est.
Dumont	U2T	LLNL	05/19/66	670.870	549	est.
Piledriver	U15A.01	LANL/DoD	06/02/66	462.690	457	est.
Tan	U7K	LANL	06/03/66	560.680	511	est.
Puce	U3BS	LANL	06/10/66	485.550	504	est.
Halfbeak	U19B	LANL	06/30/66	819.300	645	meas.
Daiquiri	U7O	LANL	09/23/66	561.150	561	est.
Greeley	U20G	LLNL	12/20/66	1216.460	615	meas.
Agile	U2V	LLNL	02/23/67	733.350	564	est.
Commodore	U2AM	LLNL	05/20/67	745.240	567	est.
Scotch	U19AS	LANL	05/23/67	977.390	672	meas.
Knickerbocker	U20D	LLNL	05/26/67	630.630	632	meas.
Zaza	U4C	LANL	09/27/67	667.000	535	est.
Lanpher	U2X	LLNL	10/18/67	715.060	552	est.
Cobbler	U7U	LANL	11/08/67	667.120	556	est.
Knox	U2AT	LLNL	02/21/68	644.800	549	est.
Stinger	U19L	LANL	03/22/68	667.760	640	meas.
Boxcar	U20I	LLNL	04/26/68	1165.860	580	meas.
Rickey	U19C	LANL	06/15/68	683.280	707	meas.
Chateaugay	U20T	LLNL	06/28/68	607.230	632	est.
Sled	U19I	LANL	08/29/68	728.880	667	meas.
Noggin	U9BX	LLNL	09/06/68	582.170	558	est.
Benham	U20C	LLNL	12/19/68	1402.080	641	meas.
Blenton	U7P	LANL	04/30/69	557.730	553	est.
Thistle	U7T	LANL	04/30/69	560.470	578	est.
Purse	U20V	LLNL	05/07/69	598.780	601	meas.
Jorum	U20E	LLNL	09/16/69	1160.890	556	meas.
Pipkin	U20B	LLNL	10/08/69	623.620	640	est.
Calabash	U2AV	LLNL	10/29/69	624.840	578	est.
Grape A	U7S	LANL	12/17/69	550.670	568	est.

Event name	Hole Name	Sponsor	Date	Depth of Burial (meters)	Water Level (meters)	Water Level Measurement
Grape B	U7V	LANL	02/04/70	554.030	565	est.
Shaper	U7R	LANL	03/23/70	560.440	549	est.
Handley	U20M	LLNL	03/26/70	1209.000	387	meas.
Tijeras	U7Y	LANL	10/14/70	560.620	543	meas.
Carpetbag	U2DG	LLNL	12/17/70	661.700	576	est.
Miniata	U2BU	LLNL	07/08/71	528.830	491	meas.
Algodones	U3JN	LANL	08/18/71	527.610	501	est.
Monero	U3JQ	LANL	05/19/72	537.350	526	meas.
Oscuro	U7Z	LANL	09/21/72	560.220	521	est.
Miera	U7AD	LANL	03/08/73	568.760	553	est.
Angus	U3JG	LANL	04/25/73	452.930	472	meas.
Starwort	U2BS	LLNL	04/26/73	563.880	526	meas.
Almendro	U19V	LANL	06/06/73	1063.750	686	meas.
Latir	U4D	LANL	02/27/74	640.990	503	est.
Escabosa	U7AC	LANL	07/10/74	639.990	545	est.
Portmanteau	U2AX	LLNL	08/30/74	655.290	585	meas.
Stanyan	U2AW	LLNL	09/26/74	572.990	553	meas.
Topgallant	U4E	LANL	02/28/75	713.200	515	meas.
Cabrillo	U2DR	LLNL	03/07/75	600.500	567	meas.
Obar	U7AG	LANL	04/30/75	569.000	521	meas.
Tybo	U20Y	LLNL	05/14/75	765.000	630	meas.
Mizzen	U7AH	LANL	06/03/75	637.000	515	meas.
Stilton	U20P	LLNL/DoD	06/03/75	731.500	280	meas.
Mast	U19U	LANL	06/19/75	911.300	666	meas.
Camembert	U19Q	LLNL	06/26/75	1310.600	668	meas.
Kasseri	U20Z	LLNL	10/28/75	1265.000	628	meas.
Inlet	U19F	LANL	11/20/75	819.000	703	meas.
Chiberta	U2EK	LLNL	12/20/75	716.000	536	meas.
Muenster	U19E	LLNL	01/03/76	1452.400	676	meas.
Esrom	U7AK	LLNL	02/04/76	655.300	523	meas.
Keelson	U7AI	LANL	02/04/76	640.000	498	meas.
Fontina	U20F	LLNL	02/12/76	1219.000	595	meas.
Cheshire	U20N	LLNL	02/14/76	1167.000	625	meas.
Estuary	U19G	LANL	03/09/76	868.100	627	meas.
Colby	U20AA	LLNL	03/14/76	1273.400	571	meas.
Pool	U19P	LANL	03/17/76	879.300	690	meas.
Strait	U4A	LANL	03/17/76	780.300	506	meas.
Billet	U7AN	LANL	07/27/76	635.500	503	meas.
Banon	U2DZ	AWRE/LLNL	08/26/76	536.400	548	meas.
Rudder	U7AJS	LANL	12/28/76	640.000	520	meas.
Marsilly	U2EL	LLNL	04/05/77	690.000	541	meas.
Bulkhead	U7AM	LANL	04/27/77	594.300	532	meas.

Event name	Hole Name	Sponsor	Date	Depth of Burial (meters)	Water Level (meters)	Water Level Measurement
Crewline	U7AP	LANL	05/25/77	563.900	503	meas.
Strake	U7AE	LANL	08/04/77	518.200	541	meas.
Scantling	U4H	LANL	08/19/77	701.000	511	meas.
Sandreef	U7AQ	LANL	11/09/77	701.000	503	meas.
Farallones	U2FA	LLNL	12/14/77	668.000	554	meas.
Reblochon	U2EN	LLNL	02/23/78	658.400	540	est.
Iceberg	U4G	LANL	03/23/78	640.000	507	meas.
Transom	U4F	LANL	05/10/78	640.000	507	meas.
Lowball	U7AV	LANL	07/12/78	563.900	501	meas.
Panir	U19YS	LLNL	08/31/78	681.000	645	est.
Rummy	U7AU	LANL	09/27/78	640.000	504	est.
Quargel	U2FB	AWRE/LLNL	11/18/78	542.000	539	meas.
Farm	U20AB	LLNL	12/16/78	689.000	649	est.
Quinella	U4L	LANL	02/08/79	579.100	512	est.
Pepato	U20AD	LLNL	06/11/79	681.000	579	meas.
Hearts	U4N	LANL	09/06/79	640.000	507	meas.
Pyramid	U7BE	LANL	04/16/80	579.100	540	meas.
Colwick	U20AC	LLNL	04/26/80	633.000	630	est.
Kash	U20AF	LLNL	06/12/80	645.000	602	est.
Tafi	U20AE	LLNL	07/25/80	680.000	607	meas.
Baseball	U7BA	LANL	01/15/81	563.900	512	meas.
Rousanne	U4P	LANL	11/12/81	518.200	495	est.
Jornada	U4J	LANL	01/28/82	640.000	507	est.
Molbo	U20AG	LLNL	02/12/82	638.000	614	meas.
Bouschet	U3LA	LANL	05/07/82	563.900	500	est.
Atrisco	U7BP	LANL	08/05/82	640.100	538	meas.
Borrego	U7BR	LANL	09/29/82	563.900	501	meas.
Turquoise	U7BU	LANL	04/14/83	533.000	500	est.
Chancellor	U19AD	LANL	09/01/83	625.000	647	meas.
Techado	U4O	LANL	09/22/83	533.400	500	est.
Tortugas	U3GG	LANL	03/01/84	640.100	497	meas.
Mundo	U7BO	LANL	05/01/84	567.000	558	est.
Caprock	U4Q	LANL	05/31/84	600.000	500	est.
Kappeli	U20AM	LLNL	07/25/84	640.000	652	meas.
Breton	U4AR	LLNL	09/13/84	483.000	505	est.
Hermosa	U7BS	LANL	04/02/85	640.100	506	meas.
Towanda	U19AB	LANL	05/02/85	664.500	614	meas.
Salut	U20AK	LLNL	06/12/85	608.000	622	meas.
Serena	U20AN	LLNL	07/25/85	597.000	606	meas.
Kinibito	U3ME	LANL	12/05/85	579.100	488	est.
Glencoe	U4I	LANL	03/22/86	609.600	522	est.
Jefferson	U20AI	LLNL	04/22/86	609.000	625	meas.

Event name	Hole Name	Sponsor	Date	Depth of Burial (meters)	Water Level (meters)	Water Level Measurement
Darwin	U20AQ	LLNL	06/25/86	549.000	574	meas.
Cybar	U19AR	LANL	07/17/86	627.900	645	meas.
Aleman	U3KZ	LANL	09/11/86	502.900	500	est.
Labquark	U19AN	LLNL	09/30/86	616.000	641	meas.
Belmont	U20AS	LLNL	10/16/86	605.000	613	meas.
Gascon	U4T	LANL	11/14/86	593.140	505	est.
Bodie	U20AP	LLNL	12/13/86	635.000	652	meas.
Hardin	U20AV	LLNL	04/30/87	625.000	632	meas.
Tahoka	U3MF	LANL	08/13/87	640.100	493	est.
Borate	U2GE	LLNL	10/23/87	542.500	567	meas.
Kernville	U20AR	LLNL	02/15/88	541.600	561	est.
Comstock	U20AY	LLNL	06/02/88	620.300	626	meas.
Alamo	U19AU	LANL	07/07/88	621.800	624	meas.
Bullfrog	U4AU	LLNL	08/30/88	489.200	500	meas.

APPENDIX B

SAFE DRINKING WATER ACT REGULATIONS

NEVADA REVISED STATUTES

of the state and no municipal corporation, county or other political subdivision having jurisdiction over water pollution prevention, abatement and control may permit, under authority of such jurisdiction, the discharge of wastes into the waters of the state which would result in the pollution of any of such waters in excess of any water quality standard promulgated by the commission. (1973, p. 1718.)

445.351. Provisions of Title 48 of NRS unaffected.

Nothing in NRS 445.131 to 445.354, inclusive, shall be construed to amend, modify or supersede the provisions of Title 48 of NRS or any rule, regulation or order promulgated or issued thereunder by the state engineer. (1973, p. 1719.)

445.354. Effective date of regulations and standards.

All rules, regulations and standards promulgated by the state commission of environmental protection and the state board of health pertaining to water pollution control in force on July 1, 1973, shall remain in effect until such time as revised by the state environmental commission pursuant to NRS 445.131 to 445.354, inclusive. (1973, p. 1719.)

Public Water Systems

445.361. Declaration of state policy.

It is the policy of this state to provide for water which is safe for drinking and other domestic purposes and thereby promote the public health and welfare. (1977, p. 442.)

445.363. Definitions.

As used in NRS 445.361 to 445.399, inclusive, unless the context otherwise requires, the terms defined in NRS 445.366 to 445.377, inclusive, have the meanings ascribed to them in those sections. (1977, p. 443.)

445.366. "Contaminant" defined.

"Contaminant" means any physical, chemical, biological, radiological or other substance which can cause or transmit infectious disease, chemical poisoning, chronic disease or other impairment to man. (1977, p. 443.)

445.367. "Federal Act" defined.

"Federal Act" means the Safe Drinking Water Act (42 U.S.C. §§ 300f et seq.). (1977, p. 443.)

445.369. "Health authority" defined.

"Health authority" means the officers and agents of the health division or the officers and agents of the local boards of health. (1977, p. 443.)

445.371. "Health division" defined.

"Health division" means the health division of the department of human resources. (1977, p. 443.)

445.373. "Person" defined.

"Person" includes the State of Nevada, any political subdivision of this or another state, and any agency of the United States. (1977, p. 443.)

445.376. "Public water system" defined.

"Public water system" means any system which provides the public with piped water for human consumption if the system has 15 or more service connections or regularly serves 25 or more persons for 60 or more days a year. A public water system includes:

1. Any collection, treatment, storage and distribution facility under control of the operator of the system and used primarily in connection with the system; and
2. Any collection or pretreatment storage facility not under such control but used primarily in connection with the system. (1977, p. 443.)

LEGAL PERIODICALS

Review of Selected Nevada Legislation, Environmental Protection, 1985 Pac. L.J. Rev. Nev. Legis. 139.

445.377. "Supplier of water" defined.

"Supplier of water" means a person who owns, controls or operates a public water system. (1977, p. 443.)

445.379. State board of health: Adoption of primary and secondary standards of drinking water.

The state board of health shall adopt by regulation:

1. Primary drinking water standards which prescribe the maximum permissible levels for contaminants in any public water system and provide for the monitoring and reporting of water quality. In establishing the standards the board shall consider, among other things, the standards established pursuant to the Federal Act.

2. Secondary drinking water standards which reasonably insure that drinking water is aesthetically adequate. (1977, p. 443; 1981, p. 1900.)

445.381. State board of health: Regulations governing construction, operation and maintenance of public water systems; establishment of system for issuance of operating permits.

The state board of health may:

1. Adopt such regulations as may be necessary to govern the construction, operation and maintenance of public water systems if those activities affect the quality of water, but the regulations do not supersede any regulation of the public service commission of Nevada.

2. Establish by regulation a system for the issuance of operating permits for suppliers of water and set a reasonable date after which a person shall not operate a public water system without possessing a permit issued by a health authority. (1977, p. 443; 1985, p. 336.)

Effective date. — The 1985 amendment became effective April 10, 1985.

445.383. State board of health: Contracts; assistance; hearings; subpenas.

To carry out the provisions and purposes of NRS 445.361 to 445.399, inclusive, the state board of health may:

1. Through the state health officer and the administrator of the health division:

(a) Enter into agreements, contracts or cooperative arrangements with other state agencies, federal or interstate agencies, municipalities, local health departments, educational institutions or other organizations or persons.

(b) Accept financial and technical assistance from the Federal Government, other public agencies or private contributors.

2. Hold hearings and issue subpenas requiring the attendance of witnesses and the production of evidence. (1977, p. 443; 1981, p. 82; 1983, p. 837.)

445.386. Review and approval of plans and specifications by health authority.

1. Except as provided in subsection 2, plans and specifications for any substantial addition to or alteration of a public water system subject to a regulation of the state board of health shall be submitted to the health authority for review and approval.

2. A public water system is not required to submit any plans and specifications if the addition or alteration complies with standards previously approved by a health authority.

NEVADA ADMINISTRATION CODE

4. "Health division" means the health division of the department of human resources.

5. "Laboratory certification officer" means the person approved by the Environmental Protection Agency to act as the laboratory certification officer for this state.

6. "Primary standard" means a standard which specifies a maximum contaminant level for any constituent found in a public water supply which, if exceeded, may adversely affect the health of persons.

7. "Secondary standard" means a standard which specifies a maximum level for constituents found in a public water supply which, if exceeded, may adversely affect the public welfare. These standards apply to constituents which adversely affect the taste, odor, appearance and other esthetic qualities of water.

8. "Surface water" means water which is exposed to the atmosphere and subject to surface runoff.

9. The words and terms defined in 40 C.F.R. § 141.2 have the meanings ascribed to them in that section.

[Bd. of Health, Water Quality Standards Art. 1, eff. 12-14-77]--(NAC A 5-23-90; 9-19-90; 12-3-90; 8-1-91)

445.245 Applicability. NAC 445.244 to 445.262, inclusive, apply to all public water systems unless a public water system:

1. Consists only of distribution and storage facilities and does not have any collection or treatment facilities;

2. Obtains all of its water from, but is not owned or operated by, a public water system to which NAC 445.244 to 445.262, inclusive, apply;

3. Does not sell water to any person; and

4. Is not a carrier which conveys passengers in interstate commerce.

[Bd. of Health, Water Quality Standards Art. 2 §§ 2.3-2.3.1.4, eff. 12-14-77]

445.246 Construction.

1. Nothing contained in NAC 445.244 to 445.262, inclusive, may be interpreted to circumvent any of those sections to make them less effective.

2. If more than one interpretation exists for a section, the more restrictive interpretation applies.

[Bd. of Health, Water Quality Standards Art. 2 §§ 2.2-2.2.2, eff. 12-14-77]

445.247 Primary standards.

1. Except as otherwise provided in subsection 2, all public water systems must meet the requirements of NAC 445.244 to 445.262, inclusive, and of the National Primary Drinking Water Regulations, as set forth in the July 1, 1991, edition of 40 C.F.R. §§ 141.1, 141.4, 141.5, 141.11 to 141.16, inclusive, 141.61, 141.62, 141.63, 141.100, 141.101, 141.110 and 141.111.

2. The effective date of the regulations contained in § 141.61(c)(2), (3) and (4) is postponed pursuant to National Primary Drinking Water Regulations: Aldicarb, Aldicarb Sulfoxide, and Aldicarb Sulfone, 57 Fed. Reg. 22178 (1992), until notice that the postponement has been cancelled is published in the Federal Register.

3. The National Primary Drinking Water Regulations, as set forth in the July 1, 1991, edition of 40 C.F.R. §§ 141.1, 141.4, 141.5, 141.11 to 141.16,

inclusive. 141.61. 141.62. 141.63. 141.100. 141.101. 141.110 and 141.111 are adopted by reference. Copies of those regulations are available for purchase from the office of the Health Division. 505 E. King Street. Room 103. Carson City. Nevada 89710. at a price of $7 each.

4. Wherever the current National Primary Drinking Water Regulations. as adopted in subsection 2. provide state discretion in establishing monitoring frequencies. check sampling requirements. determination of compliance with maximum contaminant levels. recordkeeping or notification requirements. that discretion must be exercised by the health authority.

[Bd. of Health. Water Quality Standards Art. 3. eff. 12-14-77: A 5-3-81]--(NAC A 3-22-89: 12-3-90: 7-16-92)

445.2475 Monitoring and analytical requirements for primary standards.

1. Except as otherwise provided in subsection 2. the activities of monitoring and analytical requirements for the primary standards contained in NAC 445.247 must be performed as required by the July 1. 1991. edition of 40 C.F.R. §§ 141.21 to 141.30. inclusive. and 141.40 to 141.42. inclusive. of the "National Primary Drinking Water Regulations."

2. Monitoring for the contaminants aldicarb. aldicarb sulfoxide and aldicarb sulfone must be conducted in accordance with the July 1. 1991. edition of 40 C.F.R. § 141.40 until the effective date of the regulations referred to in subsection 2 of NAC 445.247 is no longer postponed.

3. If the MMO-MUG Test for total coliform detection is used. all total coliform-positive cultures must be tested for fluorescence. To test for fluorescence. an ultraviolet light (366 nanometers) must be used in the dark after incubating the tube or container at 35 ± 0.5 degrees Centigrade for 24 to 28 hours. If fluorescence is observed. the sample is Escherichia coli-positive. If fluorescence is not observed. a 0.1 milliliter 28-hour culture must be transferred to Escherichia coli medium + MUG with a pipet. The results must be observed and the Escherichia coli medium + MUG must be formulated and incubated in the manner described in paragraph (f)(6)(i) of the July 1. 1991. edition of 40 C.F.R. § 141.21.

4. For the purposes of this section. "MMO-MUG Test" means a Minimal Medium ONPG-MUG Test approved by the United States Environmental Protection Agency for testing for the presence or absence of fecal coliform and Escherichia coli.

(Added to NAC by Bd. of Health. eff. 7-16-92)

445.248 Secondary standards: General requirements: public notice.

1. Whenever any of the following chemical substances. as measured at representative points in the distribution system. is present in a public water supply in excess of the listed levels. and the health authority determines that there is another more suitable supply of water which is economically feasible. available in a sufficient quantity. and of a significantly higher quality. the supplier of water shall give notice to the public:

Substance	Level. Milligrams Per Liter
Chloride	250.0
Color	15.0 color units
Copper	1.0
Foaming Agents	0.5
Iron	0.3
Magnesium	125.0
Manganese	0.05
Odor	3.0 threshold odor number
pH	6.5-8.5
Sulfate	250.0
TDS (total residue dried at 103°-105°C)	500.0
Zinc	5.0

2. The following chemical substances, as measured at representative points in the distribution system, must not be present in a public water supply in excess of the listed levels:

Substance	Level. Milligrams Per Liter
Chloride	400.0
Iron	0.6
Magnesium	150.0
Manganese	0.1
Sulfate	500.0
TDS (total residue dried at 103°-105°C)	1000.0

3. The standard for fluoride in community and nontransient, noncommunity water systems is 2.0 milligrams per liter.

4. If a public water system exceeds one of the standards set by subsection 2 or 3 or the state board of health grants a variance from the requirement concerning that contaminant level, the supplier of water shall give notice to the public.

5. The notices required by subsections 1 and 4 must be:

(a) Published in a newspaper of general circulation in the area served by the system as soon as possible, but not more than 30 days after the standard is exceeded;

(b) Delivered personally or by mail to each person served by the system not more than 45 days after the standard is exceeded; and

(c) Published and delivered annually thereafter as provided in this section if the standard continues to be exceeded.

[Bd. of Health, Water Quality Standards Art. 4 §§ 4.1-4.2, eff. 12-14-77]--(NAC A 3-22-89; 12-3-90)

445.249 Secondary standards: Monitoring.

1. Analysis for all public water systems must be completed by June 24, 1979. Analysis must be repeated at 3-year intervals or at lesser intervals if required by the health authority.

2. If the result of an analysis made pursuant to subsection 1 indicates that the level of any contaminant listed in NAC 445.248 exceeds the maximum level, the supplier of water must report to the health authority within 30 days and initiate 3 additional analyses at the same sampling point within 90 days. When the average of four analyses made pursuant to this subsection exceeds the maximum level, the supplier of water must notify the health authority and give notice to the public. Notice to the public must be in such form and manner as prescribed by the health authority and must ensure that the public using the system is adequately informed.

3. Monitoring after public notification must be at a frequency designated by the health authority and must continue until the level has not been exceeded in two successive samples or until a monitoring schedule as a condition to a variance or enforcement action becomes effective.

4. A supplier of water is not required to report results to the health authority where a state laboratory performs the analysis and reports the results to the health authority.

[Bd. of Health, Water Quality Standards Art. 4 §§ 4.3-4.3.3.3, eff. 12-14-77]

445.250 Secondary standards: Analysis. Any analysis conducted to determine compliance with NAC 445.248 must be made in accordance with one of the following methods:

1. Any method listed in 40 C.F.R. Part 143. A copy of Part 143 may be purchased from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, at a cost of $3.50.

2. Any method published in any of the following standard reference sources:

(a) United States Environmental Protection Agency, EMSL-Cincinnati, "Methods for Chemical Analysis of Water and Waste," EPA-600/4-79-020, March 1979, and its revisions, available free of charge from ORD Publications, CERI, EPA, Cincinnati, Ohio 45268.

(b) "Standard Methods for the Examination of Water and Wastewater," available from the American Public Health Association, 1015 Eighteenth Street N.W., Washington, D.C. 20036, at a cost of $93.

(c) "Annual Book of ASTM Standards," volumes 11.01 and 11.02, available from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103, at a cost of $58 and $82, respectively.

(d) United States Geological Survey, "Methods for Determination of Inorganic Substances in Water and Fluvial Sediments," Book 5, stock number 024-001-03177-9, 1979 and its revisions, available for the cost of reproduction from the consumer health protection section of the bureau of regulatory health services of the health division, 505 East King Street, Room 103, Carson City, Nevada 89710.

3. Any method approved by the United States Environmental Protection Agency as an accepted alternative test procedure for drinking water.

[Bd. of Health, Water Quality Standards Art. 4 §§ 4.4-4.4.10, eff. 12-14-77]--(NAC A 3-22-89)

445.251 Conduct of analysis.

1. Except as provided in this section, each analysis required by NAC 445.247 to 445.250, inclusive, must be performed by a properly certified laboratory.

2. For the purposes of this section, "properly certified laboratory" means a laboratory that is certified as acceptable by the laboratory certification officer in accordance with a certification plan approved by the Environmental Protection Agency and regulations and procedures adopted by the state board of health.

3. Turbidity measurements may be made by a certified laboratory or by water supply personnel utilizing an instrument capable of meeting the requirements of § 141.22(a) of the "National Drinking Water Regulations," page 12.

4. Chlorine residual measurements when authorized as a substitute for coliform bacteria monitoring may be made by the water supplier utilizing an instrument and methods capable of meeting the requirements of § 141.21(h) of the "National Drinking Water Regulations," page 11.

[Bd. of Health, Water Quality Standards Art. 5, eff. 12-14-77]--(NAC A 3-22-89; 5-23-90)

445.252 Methods of obtaining samples of water.

1. Samples of water taken for the purpose of a complete chemical analysis must be taken as provided in this section.

2. A sample taken for the purpose of analyzing levels of components not requiring preservation must be collected in a clean glass or plastic half-gallon or gallon container. A thoroughly rinsed plastic distilled water bottle or unused plastic milk bottle, obtainable at a dairy or a food or drug store, is recommended for this purpose.

3. A sample taken for the purpose of analyzing levels of nitrates and metals must be collected in a container provided by the laboratory performing the analysis, using the appropriate materials for preservation provided by the laboratory. These materials may be added to the containers by the laboratory before the sample is taken. Care must be exercised in using such materials because of their hazardous nature.

4. A sample taken for the purpose of analyzing levels of trace organic materials must be taken in a glass container provided by the laboratory performing the analysis. The laboratory shall also provide any preservatives required for preventing deterioration of the organic materials.

5. If any representative sample is taken from a well for the purpose of chemical analysis:

(a) Except as provided in paragraph (b), an amount of water equivalent to four to ten times the bore volume of the well must be pumped from the well before the sample is taken.

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tion 1412 of the Public Health Service Act, as amended by the Safe Drinking Water Act (Pub. L. 93-523); and related regulations applicable to public water systems.

§ 141.2 Definitions.

As used in this part, the term:

Act means the Public Health Service Act, as amended by the Safe Drinking Water Act, Pub. L. 93-523.

Action level, is the concentration of lead or copper in water specified in § 141.80(c) which determines, in some cases, the treatment requirements contained in subpart I of this part that a water system is required to complete.

Best available technology or *BAT* means the best technology, treatment techniques, or other means which the Administrator finds, after examination for efficacy under field conditions and not solely under laboratory conditions, are available (taking cost into consideration). For the purposes of setting MCLs for synthetic organic chemicals, any BAT must be at least as effective as granular activated carbon.

Coagulation means a process using coagulant chemicals and mixing by which colloidal and suspended materials are destabilized and agglomerated into flocs.

Community water system means a public water system which serves at least 15 service connections used by year-round residents or regularly serves at least 25 year-round residents.

Compliance cycle means the nine-year calendar year cycle during which public water systems must monitor. Each compliance cycle consists of three three-year compliance periods. The first calendar year cycle begins January 1, 1993 and ends December 31, 2001; the second begins January 1, 2002 and ends December 31, 2010; the third begins January 1, 2011 and ends December 31, 2019.

Compliance period means a three-year calendar year period within a compliance cycle. Each compliance cycle has three three-year compliance periods. Within the first compliance cycle, the first compliance period runs from January 1, 1993 to December 31, 1995; the second from January 1, 1996 to December 31, 1998; the third from January 1, 1999 to December 31, 2001.

Confluent growth means a continuous bacterial growth covering the entire filtration area of a membrane filter, or a portion thereof, in which bacterial colonies are not discrete.

Contaminant means any physical, chemical, biological, or radiological substance or matter in water.

Conventional filtration treatment means a series of processes including coagulation, flocculation, sedimentation, and filtration resulting in substantial particulate removal.

Corrosion inhibitor means a substance capable of reducing the corrosivity of water toward metal plumbing materials, especially lead and copper, by forming a protective film on the interior surface of those materials.

CT or *CTcalc* is the product of "residual disinfectant concentration" (C) in mg/l determined before or at the first customer, and the corresponding "disinfectant contact time" (T) in minutes, i.e., "C" x "T". If a public water system applies disinfectants at more than one point prior to the first customer, it must determine the CT of each disinfectant sequence before or at the first customer to determine the total percent inactivation or "total inactivation ratio." In determining the total inactivation ratio, the public water system must determine the residual disinfectant concentration of each disinfection sequence and corresponding contact time before any subsequent disinfection application point(s). "$CT_{99.9}$" is the CT value required for 99.9 percent (3-log) inactivation of *Giardia lamblia* cysts. $CT_{99.9}$ for a variety of disinfectants and conditions appear in Tables 1.1-1.6, 2.1, and 3.1 of § 141.74(b)(3).

$$\frac{CTcalc}{CT_{99.9}}$$

is the inactivation ratio. The sum of the inactivation ratios, or total inactivation ratio shown as

$$\sum \frac{(CTcalc)}{(CT_{99.9})}$$

is calculated by adding together the inactivation ratio for each disinfection

1963, U.S. Department of Commerce. If two or more radionuclides are present, the sum of their annual dose equivalent to the total body or to any organ shall not exceed 4 millirem/year.

TABLE A—AVERAGE ANNUAL CONCENTRATIONS ASSUMED TO PRODUCE A TOTAL BODY OR ORGAN DOSE OF 4 MREM/YR

Radionuclide	Critical organ	pCi per liter
Tritium	Total body	20,000
Strontium-90	Bone marrow	8

[41 FR 28404, July 9, 1976]

Subpart C—Monitoring and Analytical Requirements

§ 141.21 Coliform sampling.

(a) *Routine monitoring.* (1) Public water systems must collect total coliform samples at sites which are representative of water throughout the distribution system according to a written sample siting plan. These plans are subject to State review and revision.

(2) The monitoring frequency for total coliforms for community water systems is based on the population served by the system, as follows:

TOTAL COLIFORM MONITORING FREQUENCY FOR COMMUNITY WATER SYSTEMS

Population served	Minimum number of samples per month
25 to 1.000 [1]	1
1.001 to 2.500	2
2.501 to 3.300	3
3.301 to 4.100	4
4.101 to 4.900	5
4.901 to 5.800	6
5.801 to 6.700	7
6.701 to 7.600	8
7.601 to 8.500	9
8.501 to 12.900	10
12.901 to 17.200	15
17.201 to 21.500	20
21.501 to 25.000	25
25.001 to 33.000	30
33.001 to 41.000	40
41.001 to 50.000	50
50.001 to 59.000	60
59.001 to 70.000	70
70.001 to 83.000	80
83.001 to 96.000	90
96.001 to 130.000	100
130.001 to 220.000	120
220.001 to 320.000	150
320.001 to 450.000	180
450.001 to 600.000	210
600.001 to 780.000	240
780.001 to 970.000	270
970.001 to 1 230.000	300
1 230.001 to 1 520.000	330
1 520.001 to 1 850.000	360
1 850.001 to 2.270.000	390
2.270.001 to 3.020.000	420
3.020.001 to 3.960.000	450
3.960.001 or more	480

[1] Includes public water systems which have at least 15 service connections, but serve fewer than 25 persons.

If a community water system serving 25 to 1,000 persons has no history of total coliform contamination in its current configuration and a sanitary survey conducted in the past five years shows that the system is supplied solely by a protected groundwater source and is free of sanitary defects, the State may reduce the monitoring frequency specified above, except that in no case may the State reduce the monitoring frequency to less than one sample per quarter. The State must approve the reduced monitoring frequency in writing.

(3) The monitoring frequency for total coliforms for non-community water systems is as follows:

(i) A non-community water system using only ground water (except ground water under the direct influence of surface water, as defined in § 141.2) and serving 1,000 persons or fewer must monitor each calendar quarter that the system provides water to the public, except that the State may reduce this monitoring frequency, in writing, if a sanitary survey shows that the system is free of sanitary defects. Beginning June 29, 1994, the State cannot reduce the monitoring frequency for a non-community water system using only ground water (except ground water under the direct influence of surface water, as defined

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§ 141.74(b)(2).

in § 141.2) and serving 1,000 persons or fewer to less than once/year.

(ii) A non-community water system using only ground water (except ground water under the direct influence of surface water, as defined in § 141.2) and serving more than 1,000 persons during any month must monitor at the same frequency as a like-sized community water system, as specified in paragraph (a)(2) of this section, except the State may reduce this monitoring frequency, in writing, for any month the system serves 1,000 persons or fewer. The State cannot reduce the monitoring frequency to less than once/year. For systems using ground water under the direct influence of surface water, paragraph (a)(3)(iv) of this section applies.

(iii) A non-community water system using surface water, in total or in part, must monitor at the same frequency as a like-sized community water system, as specified in paragraph (a)(2) of this section, regardless of the number of persons it serves.

(iv) A non-community water system using ground water under the direct influence of surface water, as defined in § 141.2, must monitor at the same frequency as a like-sized community water system, as specified in paragraph (a)(2) of this section. The system must begin monitoring at this frequency beginning six months after the State determines that the ground water is under the direct influence of surface water.

(4) The public water system must collect samples at regular time intervals throughout the month, except that a system which uses only ground water (except ground water under the direct influence of surface water, as defined in § 141.2), and serves 4,900 persons or fewer, may collect all required samples on a single day if they are taken from different sites.

(5) A public water system that uses surface water or ground water under the direct influence of surface water, as defined in § 141.2, and does not practice filtration in compliance with Subpart H must collect at least one sample near the first service connection each day the turbidity level of the source water, measured as specified in § 141.74(b)(2), exceeds 1 NTU. This sample must be analyzed for the presence of total coliforms. When one or more turbidity measurements in any day exceed 1 NTU, the system must collect this coliform sample within 24 hours of the first exceedance, unless the State determines that the system, for logistical reasons outside the system's control, cannot have the sample analyzed within 30 hours of collection. Sample results from this coliform monitoring must be included in determining compliance with the MCL for total coliforms in § 141.63.

(6) Special purpose samples, such as those taken to determine whether disinfection practices are sufficient following pipe placement, replacement, or repair, shall not be used to determine compliance with the MCL for total coliforms in § 141.63. Repeat samples taken pursuant to paragraph (b) of this section are not considered special purpose samples, and must be used to determine compliance with the MCL for total coliforms in § 141.63.

(b) *Repeat monitoring.* (1) If a routine sample is total coliform-positive, the public water system must collect a set of repeat samples within 24 hours of being notified of the positive result. A system which collects more than one routine sample/month must collect no fewer than three repeat samples for each total coliform-positive sample found. A system which collects one routine sample/month or fewer must collect no fewer than four repeat samples for each total coliform-positive sample found. The State may extend the 24-hour limit on a case-by-case basis if the system has a logistical problem in collecting the repeat samples within 24 hours that is beyond its control. In the case of an extension, the State must specify how much time the system has to collect the repeat samples.

(2) The system must collect at least one repeat sample from the sampling tap where the original total coliform-positive sample was taken, and at least one repeat sample at a tap within five service connections upstream and at least one repeat sample at a tap within five service connections downstream of the original sampling site. If a total coliform-positive sample is at the end of the distribution system, or one

amination of Water and Wastewater may be obtained from the American Public Health Association *et al.*; 1015 Fifteenth Street, NW.; Washington, DC 20005. Copies of the methods set forth in *Microbiological Methods for Monitoring the Environment, Water and Wastes* may be obtained from ORD Publications, U.S. EPA, 26 W. Martin Luther King Drive, Cincinnati, Ohio 45268. Copies of the MMO-MUG Test as set forth in the article "National Field Evaluation of a Defined Substrate Method for the Simultaneous Enumeration of Total Coliforms and *Escherichia coli* from Drinking Water: Comparison with the Standard Multiple Tube Fermentation Method" (Edberg *et al.*) may be obtained from the American Water Works Association Research Foundation, 6666 West Quincy Avenue, Denver, CO 80235. Copies may be inspected at EPA's Drinking Water Docket; 401 M Street, SW.; Washington, DC 20460, or at the Office of the Federal Register; 1100 L Street, NW.; Room 8401; Washington, DC 20408.

(g) *Response to violation.* (1) A public water system which has exceeded the MCL for total coliforms in § 141.63 must report the violation to the State no later than the end of the next business day after it learns of the violation, and notify the public in accordance with § 141.32.

(2) A public water system which has failed to comply with a coliform monitoring requirement, including the sanitary survey requirement, must report the monitoring violation to the State within ten days after the system discovers the violation, and notify the public in accordance with § 141.32.

[54 FR 27562, June 29, 1989, as amended at 54 FR 30001, July 17, 1989; 55 FR 25064, June 19, 1990; 56 FR 642, Jan. 8, 1991]

§ 141.22 Turbidity sampling and analytical requirements.

The requirements in this section apply to unfiltered systems until December 30, 1991, unless the State has determined prior to that date, in writing pursuant to section 1412(b)(7)(iii), that filtration is required. The requirements in this section apply to filtered systems until June 29, 1993. The requirements in this section apply to unfiltered systems that the State has determined, in writing pursuant to section 1412(b)(7)(C)(iii), must install filtration, until June 29, 1993, or until filtration is installed, whichever is later.

(a) Samples shall be taken by suppliers of water for both community and non-community water systems at a representative entry point(s) to the water distribution system at least once per day, for the purposes of making turbidity measurements to determine compliance with § 141.13. If the State determines that a reduced sampling frequency in a non-community will not pose a risk to public health, it can reduce the required sampling frequency. The option of reducing the turbidity frequency shall be permitted only in those public water systems that practice disinfection and which maintain an active residual disinfectant in the distribution system, and in those cases where the State has indicated in writing that no unreasonable risk to health existed under the circumstances of this option. The turbidity measurements shall be made by the Nephelometric Method in accordance with the recommendations set forth in "Standard Methods for Examination of Water and Wastewater," American Public Health Association, 14th Edition, pp. 132-134; or "Methods of Chemical Analysis of Water and Wastes," EPA Environmental Monitoring and Support Laboratory, March 1979, Method 180.1—Nephelometric Method. Calibration of the turbidimeter shall be made either by the use of a formazin standard as specified in the cited references or a styrene divinylbenzene polymer standard (Amco-AEPA-1 Polymer) commercially available from Amco Standards International, Inc., 230 Polaris Avenue, No. C, Mountain View, California 94043.

(b) If the result of a turbidity analysis indicates that the maximum allowable limit has been exceeded, the sampling and measurement shall be confirmed by resampling as soon as practicable and preferably within one hour. If the repeat sample confirms that the maximum allowable limit has been exceeded, the supplier of water shall report to the State within 48 hours. The repeat sample shall be the

sample used for the pu
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monthly average of the
exceeds the maximum a
or if the average of two
on consecutive days exc
supplier of water shall
State and notify the pu
in §§ 141.31 and 141.32.

(c) Sampling for
water systems shall be
years after the effectiv
part.

(d) The requirements
shall apply only to pu
tems which use wate
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(e) The State has th
determine compliance
forcement action based
cal results or other in
piled by their sanction
tives and agencies.

[40 FR 59570, Dec. 24, 197
45 FR 57344, Aug. 27, 19
Mar. 3, 1982; 47 FR 10998,
FR 27527, June 29, 1989]

§ 141.23 Inorganic chemi
analytical requirement

(a) Analyses for the
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required as follows:

(1) Analyses for all co
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shall be completed with
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These analyses shall
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(2) Analyses for all co
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sources shall be comple
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(3) For non-commun
tems, whether supplie
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shall be completed by
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(b) If the result of a
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sample used for the purpose of calculating the monthly average. If the monthly average of the daily samples exceeds the maximum allowable limit, or if the average of two samples taken on consecutive days exceeds 5 TU, the supplier of water shall report to the State and notify the public as directed in §§ 141.31 and 141.32.

(c) Sampling for non-community water systems shall begin within two years after the effective date of this part.

(d) The requirements of this § 141.22 shall apply only to public water systems which use water obtained in whole or in part from surface sources.

(e) The State has the authority to determine compliance or initiate enforcement action based upon analytical results or other information compiled by their sanctioned representatives and agencies.

[40 FR 59570, Dec. 24, 1975, as amended at 45 FR 57344, Aug. 27, 1980; 47 FR 8998, Mar. 3, 1982; 47 FR 10998, Mar. 12, 1982; 54 FR 27527, June 29, 1989]

§ 141.23 Inorganic chemical sampling and analytical requirements.

(a) Analyses for the purpose of determining compliance with § 141.11 are required as follows:

(1) Analyses for all community water systems utilizing surface water sources shall be completed within one year following the effective date of this part. These analyses shall be repeated at yearly intervals.

(2) Analyses for all community water systems utilizing only ground water sources shall be completed within two years following the effective date of this part. These analyses shall be repeated at three-year intervals.

(3) For non-community water systems, whether supplied by surface or ground sources, analyses for nitrate shall be completed by December 24, 1980. These analyses shall be repeated at intervals determined by the State.

(4) The State has the authority to determine compliance or initiate enforcement action based upon analytical results and other information compiled by their sanctioned representatives and agencies.

(b) If the result of an analysis made under paragraph (a) of (g) of this section indicates that the level of any contaminant listed in § 141.11 or § 141.62 exceeds the maximum contaminant level, the supplier of the water shall report to the State within 7 days and initiate three additional analyses at the same sampling point within one month.

(c) When the average of four analyses made pursuant to paragraph (b) of this section, rounded to the same number of significant figures as the maximum contaminant level for the substance in question, exceeds the maximum contaminant level, the supplier of water shall notify the State pursuant to § 141.31 and give notice to the public pursuant to § 141.32. Monitoring after public notification shall be at a frequency designated by the State and shall continue until the maximum contaminant level has not been exceeded in two successive samples or until a monitoring schedule as a condition to a variance, exemption or enforcement action shall become effective.

(d) The provisions of paragraphs (b) and (c) of this section notwithstanding, compliance with the maximum contaminant level for nitrate shall be determined on the basis of the mean of two analyses. When a level exceeding the maximum contaminant level for nitrate is found, a second analysis shall be initiated within 24 hours, and if the mean of the two analyses exceeds the maximum contaminant level, the supplier of water shall report his findings to the State pursuant to § 141.31 and shall notify the public pursuant to § 141.32.

(e) For the initial analyses required by paragraph (a)(1), (2) or (3) of this section, data for surface waters acquired within one year prior to the effective date and data for ground waters acquired within 3 years prior to the effective date of this part may be substituted at the discretion of the State.

(f) Analyses conducted to determine compliance with § 141.11 shall be made in accordance with the following methods, or their equivalent as determined by the Administrator.

148-152. Atomic Absorption-
piration: or Method [1] 239.2.
bsorption Furnace Tech-
Method [8] 200.7, Inductively
lasma Technique.
rcury—Method [1] 245.1. or
D-3223-79. or Method [2] 301-
156-159. Manual Cold Vapor
: or Method [1] 245.2. Auto-
d Vapor Technique.
rate—Method [1] 352.1. or
D-992-71. or Method [2] 419-D.
9, Colorimetric Brucine; or
353.3. or Method [4] D-3867-
ethod [2] 419-C. pp. 423-427.
tric. Cadmium Reduction:
53.1. Automated Hydrazine
or Method [1] 353.2. or
D-3867-79A. or Method [2] 605.
4. Automated Cadmium Re-

elenium—Method [1] 270.2.
bsorption Furnace Tech-
Method [1] 270.3: or Method [2]
pp. 237-239. or Method [4] D-
r Method [2] 301-A VII. pp.
Hydride Generation—Atomic
Spectrophotometry.
lver-Method [1] 272.1. or
01-A II. pp. 148-152. Atomic
-Direct Aspiration: or
272.2. Atomic Absorption
echnique: or Method [8] 200.7.
Coupled Plasma Tech-

ride:

Sediments." Book 5. 1979. Stock
177-9. Available from Superin-
Documents. U.S. Government
ce. Washington. DC 20402.
Book of ASTM Standards. part
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976 Race Street. Philadelphia.
19103.
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ely Coupled Plasma-Atomic
ectrometic Method for Trace
alysis of Water and Wastes—
7" with Appendix to Method
. "Inductively Coupled Plasma-
ssion Analysis of Drinking
ch 1987. Available from EPA's
al Monitoring and Support
Cincinnati. Ohio 45268.

Methodology	Reference (method number)			
	EPA [1]	ASTM [4]	SM [5]	Other
Colorimetric SPADNS; with distillation	340.1	D1179-72A	43 A and C	
Potentiometric ion selective electrode	340.2	D1179-72B	413 B	
Automated Alizarin fluoride blue: with distillation (complexone)	340.3		413 E	129-71W [6]
Automated ion selective electrode				380-75WE [7]

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[1] "Methods of Chemical Analysis of Water and Wastes," EPA Environmental Monitoring and Support Laboratory, Cincinnati, Ohio 45268 (EPA-600/4-79-020), March 1979. Available from ORD Publications, CERI, EPA, Cincinnati, Ohio 45268. For approved analytical procedures for metals, the technique applicable to total metals must be used.

[2] [Reserved]

[3] [Reserved]

[4] Annual Book of ASTM Standards, part 31 Water, American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.

[5] "Standard Methods for the Examination of Water and Wastewater," 16th Edition, American Public Health Association, American Water Works Association, Water Pollution Control Federation, 1985.

[6] "Fluoride in Water and Wastewater, Industrial Method #129-71W," Technicon Industrial Systems, Tarrytown, New York, 10591, December 1972.

[7] "Fluoride in Water and Wastewater," Technicon Industrial Systems, Tarrytown, New York 10591, February 1976.

(g) *Fluoride.* In addition to complying with paragraphs (a) through (f) of this section, systems monitoring for fluoride must comply with the requirements of this paragraphs.

(1)(i) Where the system draws water from one source, the system shall take one sample at the entry point to the distribution system.

(ii) Where the system draws water from more than one source, the system must sample each source at the entry points to the distribution system.

(iii) If the system draws water from more than one source and sources are combined before distribution, the system must sample at an entry point to the distribution system during periods representative of the maximum fluoride levels occurring under normal operating conditions.

(2) The state may alter the frequencies for fluoride monitoring as set out in paragraph (a) of this section to increase or decrease such frequency considering the following factors:

(i) Reported concentrations from previously required monitoring,

(ii) The degree of variation in reported concentrations and,

(iii) Other factors which may affect fluoride concentrations such as changes in pumping rates in ground water supplies or significant changes in the system's configuration, operating procedures, source of water, and changes in stream flows.

(3) Monitoring may be decreased from the frequencies specified in paragraph (a) of this section upon application in writing by water systems if the state determines that the system is unlikely to exceed the MCL, considering the factors listed in paragraph (g)(2) of this section. Such determination shall be made in writing and set forth the basis for the determination. A copy of the determination shall be provided to the Administrator. In no case shall monitoring be reduced to less than one sample every 10 years. For systems monitoring once every 10 years, the state shall review the monitoring results every ten years to determine whether more frequent monitoring is necessary.

(4) Analyses for fluoride under this section shall only be used for determining compliance if conducted by laboratories that have analyzed Performance Evaluation samples to within ±10% of the reference value at fluoride concentrations from 1.0 mg/l to 10.0 mg/l, within the last 12 months.

(5) Compliance with the MCL shall be determined based on each sampling point. If any sampling point is determined to be out of compliance, the system is deemed to be out of compliance.

[40 FR 59570, Dec. 24, 1975, as amended at 45 FR 57344, Aug. 27, 1980; 47 FR 10998, Mar. 12, 1982; 51 FR 11410, Apr. 2, 1986; 51 FR 24329, July 3, 1986; 53 FR 5146, Feb. 19, 1988]

EFFECTIVE DATE NOTE 1: At 56 FR 3579, Jan. 30, 1991, § 141.23 was revised, effective July 30, 1992.

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[1] 206.2. Atomic Ab-
chnique: or Method [1]
2972-88B or Method [4]

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"Methods for Deter-
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307A. or Method [3] I-1062-85. Atomic Absorption—Gaseous Hydride: or Method [1] **206.4.** or Method [4] D-2972-88A. or Method [2] **307B.** Spectrophotometric. Silver Diethyldithiocarbamate: or Method [6] 200.7. Inductively Coupled Plasma Technique.

(2) **Barium**-Method [1] 208.1 or Method [2] **308.** Atomic Absorption—Direct Aspiration: or **Method** [1] 208.2. Atomic Absorption Furnace Technique: or Method [6] 200.7. Inductively Coupled Plasma Technique.

(3) **Camium**-Method [1] 213.1 or Method [4] D 3557-78A or B. or Method [2] 310A. Atomic Absorption—Direct Aspiration: or Method [1] **213.2** Atomic Absorption Furnace Technique: or Method [6] 200.7. Inductively Coupledd Plasma Technique.

(4) **Chromium**-Method [1] 218.1 or Method [4] D 1687-77D. or Method [4] 312A. Atomic Absorption—Direct Aspiration: or Chromium-**Method** [1] 218.2 Atomic Absorption Furnace Technique: or Method [6] 200.7. Inductively Couple Plasma Technique.

(5) **Mercury**-Method [1] 245.1. or Method [4] D-3223-69. or Method [2] 320A. Manual Cold Vapor Technique: or Method [1] 245.2. Automated Cold Vapor Technique.

(6) **Nitrate**-Method [1] 352.1. or Method [4] D-992-71. or Method [1] 353.3. or Method [4] D-3867-79B. or Method [2] 418-C. Spectrometric. Cadmium Reduction: Method [1] 353.1. Automated Hydrazine Reduction: or Method [1] 353.2. or Method [4] D-3867-79A. or Method [4] 418F. Automated Cadmium Reduction.

(7) **Selenium**-Method [1] 270.2. Atomic Absorption Furnace Technique: or Method [1] 270.3: or Method [3] I-1667-85. or Method [4] D-3859-79. or Method [4] 303F. Hydride Generation—Atomic Absorption Spectrophotometry.

(8) **Lead**-Method [1] 239.1 or Method [4] D3559-78A or B. or Method [2] 301-A II or III. pp. 148-152. Atomic Absorption—Direct Aspiration: or Method [1] 239.2. Atomic Absorption Furnace Technique: or Method [6] 200.7. Inductively Coupled Plasma Technique.

[56 FR 3579. Jan. 30. 1991. as amended at 56 FR 30274. July 1. 1991]

§ 141.24 Organic chemicals other than total trihalomethanes. sampling and analytical requirements.

(a) An analysis of substances for the purpose of determining compliance with § 141.12(a) and § 141.12(b) shall be made as follows:

(1) For all community water systems utilizing surface water sources. analyses shall be completed within one year following the effective date of this part. Samples analyzed shall be collected during the period of the year designated by the State as the period when contamination by pesticides is most likely to occur. These analyses shall be repeated at intervals specified by the State but in no event less frequently than at three year intervals.

(2) For community water systems utilizing only ground water sources. analyses shall be completed by those systems specified by the State.

(3) The State has the authority to determine compliance or initiate enforcement action based upon analytical results and other information compiled by their sanctioned representatives and agencies.

(b) If the result of an analysis made pursuant to paragraph (a) of this section indicates that the level of any contaminant listed in § 141.24 (a) and (b) exceeds the maximum contaminant level. the supplier of water shall report to the State within 7 days and initiate three additional analyses within one month.

(c) When the average of four analyses made pursuant to paragraph (b) of this section. rounded to the same number of significant figures as the maximum contaminant level for the substance in question. exceeds the maximum contaminant level. the supplier of water shall report to the State pursuant to § 141.31 and give notice to the public pursuant to § 141.32. Monitoring after public notification shall be at a frequency designated by the State and shall continue until the maximum contaminant level has not been exceeded in two successive samples or until a monitoring schedule as a condition to a variance. exemption or enforcement action shall become effective.

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[4] Annual Book of ASTM Standards. part 31 Water. American Society for Testing and Materials. 1976 Race Street. Philadelphia. Pennsylvania 19103.

[5] [7][Reserved].

[6] "Inductively Coupled Plasma-Atomic Emission Spectrometric Method for Trace Element Analysis of Water and Wastes—Method 200.7" with Appendix to Method 200.7 entitled. "Inductively Coupled Plasma-Atomic Emission Analysis of Drinking Water." March 1987. Available from EPA's Environmental Monitoring and Support Laboratory. Cincinnati. Ohio 45268.

Contaminant	Detection limit (mg/l)
Chlordane	0002
Dibromochloropropane (DBCP)	00002
2,4-D	0001
Ethylene dibromide (EDB)	00001
Heptachlor	00004
Hetpachlor epoxide	00002
Lindane	00002
Methoxychlor	0001
Polychlorinated biphenyls (PCBs) (as decachlorobiphenyl)	0001
Pentachlorophenol	00004
Toxaphene	001
2,4,5-TP (Silvex)	0002

(19) Analysis under this section shall only be conducted by laboratories that have received certification by EPA or the State and have met the following conditions:

(i) To receive certification to conduct analyses for the contaminants in § 141.61(c) the laboratory must:

(A) Analyze Performance Evaluation samples which include those substances provided by EPA Environmental Monitoring and Support Laboratory or equivalent samples provided by the State.

(B) Achieve quantitative results on the analyses that are within the following acceptance limits:

Contaminant	Acceptance limits (percent)
DBCP	± 40.
EDB	± 40.
Alachlor	± 45.
Atrazine	± 45.
Carbofuran	± 45.
Chlordane	± 45.
Heptachlor	± 45.
Heptachlor Epoxide	± 45.
Lindane	± 45.
Methoxychlor	± 45.
PCBs (as Decachlorobiphenyl).	0 – 200.
Toxaphene	± 45.
Aldicarb	2 standard deviations.
Aldicarb sulfoxide	2 standard deviations.
Aldicarb sulfone	2 standard deviations.
Pentachlorophenol	± 50.
2,4-D	± 50.
2,4-TP	± 50.

(ii) [Reserved]

§ 141.25 Analytical methods for radioactivity.

(a) The methods specified in *Interim Radiochemical Methodology for Drinking Water*, Environmental Monitoring and Support Laboratory, EPA-600/4-75-008, USEPA, Cincinnati, Ohio 45268, or those listed below, are to be used to determine compliance with §§ 141.15 and 141.16 (radioactivity) except in cases where alternative methods have been approved in accordance with § 141.27.

(1) Gross Alpha and Beta—Method 302 "Gross Alpha and Beta Radioactivity in Water" *Standard Methods for the Examination of Water and Wastewater*, 13th Edition, American Public Health Association, New York, NY, 1971.

(2) Total Radium—Method 304 "Radium in Water by Precipitation" Ibid.

(3) Radium-226—Method 305 "Radium-226 by Radon in Water" Ibid.

(4) Strontium-89,90 — Method 303 "Total Strontium and Strontium-90 in Water" Ibid.

(5) Tritium—Method 306 "Tritium in Water" Ibid.

(6) Cesium-134 — ASTM D-2459 "Gamma Spectrometry in Water," *1975 Annual Book of ASTM Standards, Water and Atmospheric Analysis*, Part 31, American Society for Testing and Materials, Philadelphia, PA (1975).

(7) Uranium—ASTM D-2907 "Microquantities of Uranium in Water by Fluorometry," Ibid.

(b) When the identification and measurement of radionuclides other than those listed in paragraph (a) of this section is required, the following references are to be used, except in cases where alternative methods have been approved in accordance with § 141.27.

(1) *Procedures for Radiochemical Analysis of Nuclear Reactor Aqueous Solutions*, H. L. Krieger and S. Gold, EPA-R4-73-014, USEPA, Cincinnati, Ohio, May 1973.

(2) *HASL Procedure Manual*, Edited by John H. Harley, HASL 300, ERDA Health and Safety Laboratory, New York, NY, 1973.

(c) For the purpose of monitoring radioactivity concentrations in drinking water, the required sensitivity of the radioanalysis is defined in terms of a detection limit. The detection limit shall be that concentration which can be counted with a precision of plus or minus 100 percent at the 95 percent confidence level (1.96σ where σ is the standard deviation of the net counting rate of the sample).

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exceed the co
Table B.

TABLE B—DETEC
BETA PARTICLE

Radionuclide
Tritium
Strontium-89
Strontium-90
Iodine-131
Cesium-134
Gross beta
Other radionuclides

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ium—Method 304 by Precipitation"

26—Method 305 Radon in Water"

.90 — Method 303 nd Strontium-90 in

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identification and adionuclides other n paragraph (a) of ired. the following be used. except in ative methods have accordance with

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ose of monitoring ra- trations in drinking d sensitivity of the fined in terms of a The detection limit entration which can precision of plus or at the 95 percent .96σ where σ is the of the net counting .

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(1) To determine compliance with § 141.15(a) the detection limit shall not exceed 1 pCi/1. To determine compliance with § 141.15(b) the detection limit shall not exceed 3 pCi/1.

(2) To determine compliance with § 141.16 the detection limits shall not exceed the concentrations listed in Table B.

TABLE B—DETECTION LIMITS FOR MAN-MADE BETA PARTICLE AND PHOTON EMITTERS

Radionuclide	Detection limit
Tritium	1,000 pCi/1
Strontium-89	10 pCi/1
Strontium-90	2 pCi/1
Iodine-131	1 pCi/1
Cesium-134	10 pCi/1
Gross beta	4 pCi/1
Other radionuclides	1/10 of the applicable limit

(d) To judge compliance with the maximum contaminant levels listed in §§ 141.15 and 141.16, averages of data shall be used and shall be rounded to the same number of significant figures as the maximum contaminant level for the substance in question.

(e) The State has the authority to determine compliance or initiate enforcement action based upon analytical results or other information compiled by their sanctioned representatives and agencies.

[41 FR 28404, July 9, 1976, as amended at 45 FR 57345, Aug. 27, 1980]

§ 141.26 Monitoring frequency for radioactivity in community water systems.

(a) Monitoring requirements for gross alpha particle activity, radium-226 and radium-228.

(1) Initial sampling to determine compliance with § 141.15 shall begin within two years of the effective date of these regulations and the analysis shall be completed within three years of the effective date of these regulations. Compliance shall be based on the analysis of an annual composite of four consecutive quarterly samples or the average of the analyses of four samples obtained at quarterly intervals.

(i) A gross alpha particle activity measurement may be substituted for the required radium-226 and radium-228 analysis *Provided*, That the measured gross alpha particle activity does not exceed 5 pCi/1 at a confidence level of 95 percent (1.65σ where σ is the standard deviation of the net counting rate of the sample). In localities where radium-228 may be present in drinking water, it is recommended that the State require radium-226 and/or radium-228 analyses when the gross alpha particle activity exceeds 2 pCi/1.

(ii) When the gross alpha particle activity exceeds 5 pCi/1, the same or an equivalent sample shall be analyzed for radium-226. If the concentration of radium-226 exceeds 3 pCi/1 the same or an equivalent sample shall be analyzed for radium-228.

(2) For the initial analysis required by paragraph (a)(1) of this section, data acquired within one year prior to the effective date of this part may be substituted at the discretion of the State.

(3) Suppliers of water shall monitor at least once every four years following the procedure required by paragraph (a)(1) of this section. At the discretion of the State, when an annual record taken in conformance with paragraph (a)(1) of this section has established that the average annual concentration is less than half the maximum contaminant levels established by § 141.15, analysis of a single sample may be substituted for the quarterly sampling procedure required by paragraph (a)(1) of this section.

(i) More frequent monitoring shall be conducted when ordered by the State in the vicinity of mining or other operations which may contribute alpha particle radioactivity to either surface or ground water sources of drinking water.

(ii) A supplier of water shall monitor in conformance with paragraph (a)(1) of this section within one year of the introduction of a new water source for a community water system. More frequent monitoring shall be conducted when ordered by the State in the event of possible contamination or when changes in the distribution system or treatment processing occur which may increase the concentration of radioactivity in finished water.

(iii) A community water system using two or more sources having dif-

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iodine-131 is identified in the finished water.

(iii) Annual monitoring for strontium-90 and tritium shall be conducted by means of the analysis of a composite of four consecutive quarterly samples or analysis of four quarterly samples. The latter procedure is recommended.

(iv) The State may allow the substitution of environmental surveillance data taken in conjunction with a nuclear facility for direct monitoring of manmade radioactivity by the supplier of water where the State determines such data is applicable to a particular community water system.

(5) If the average annual maximum contaminant level for man-made radioactivity set forth in § 141.16 is exceeded, the operator of a community water system shall give notice to the State pursuant to § 141.31 and to the public as required by § 141.32. Monitoring at monthly intervals shall be continued until the concentration no longer exceeds the maximum contaminant level or until a monitoring schedule as a condition to a variance, exemption or enforcement action shall become effective.

[41 FR 28404, July 9, 1976]

§ 141.27 Alternate analytical techniques.

(a) With the written permission of the State, concurred in by the Administrator of the U.S. EPA, an alternate analytical technique may be employed. An alternate technique shall be accepted only if it is substantially equivalent to the prescribed test in both precision and accuracy as it relates to the determination of compliance with any MCL. The use of the alternate analytical technique shall not decrease the frequency of monitoring required by this part.

[45 FR 57345, Aug. 27, 1980]

§ 141.28 Approved laboratories.

(a) For the purpose of determining compliance with §§ 141.21 through 141.27, 141.41 and 141.42, samples may be considered only if they have been analyzed by a laboratory approved by the State except that measurements for turbidity, free chlorine residual, temperature and pH may be performed by any person acceptable to the State.

(b) Nothing in this part shall be construed to preclude the State or any duly designated representative of the State from taking samples or from using the results from such samples to determine compliance by a supplier of water with the applicable requirements of this part.

[45 FR 57345, Aug. 27, 1980; 47 FR 10999, Mar. 12, 1982]

§ 141.29 Monitoring of consecutive public water systems.

When a public water system supplies water to one or more other public water systems, the State may modify the monitoring requirements imposed by this part to the extent that the interconnection of the systems jusifies treating them as a single system for monitoring purposes. Any modified monitoring shall be conducted pursuant to a schedule specified by the State and concurred in by the Administrator of the U.S. Environmental Protection Agency.

§ 141.30 Total trihalomethanes sampling, analytical and other requirements.

(a) Community water system which serve a population of 10,000 or more individuals and which add a disinfectant (oxidant) to the water in any part of the drinking water treatment process shall analyze for total trihalomethanes in accordance with this section. For systems serving 75,000 or more individuals, sampling and analyses shall begin not later than 1 year after the date of promulgation of this regulation. For systems serving 10,000 to 74,999 individuals, sampling and analyses shall begin not later than 3 years after the date of promulgation of this regulation. For the purpose of this section, the minimum number of samples required to be taken by the system shall be based on the number of treatment plants used by the system, except that multiple wells drawing raw water from a single aquifer may, with the State approval, be considered one treatment plant for determining the minimum number of samples. All samples taken within an established

APPENDIX C

TRITIUM ANALYTICAL METHODS

Reynolds Electrical & Engineering Co., Inc. ENVIRONMENT, SAFETY, & HEALTH DIVISION HEALTH PHYSICS DEPARTMENT LABORATORY OPERATIONS SECTION LABORATORY ANALYSIS BRANCH STANDARD OPERATING PROCEDURE	TITLE DETERMINATION OF TRITIUM IN AIR, WATER, TISSUE AND SOIL	NO. AABAB.D.04.45 PAGE 1 of 7
	APPROVED for L.S. Sygitowicz Department Manager	REV. 1 DATE 9-11-91 DIST. HP04

Procedure Approval

The subject procedure has been prepared, approved, and quality reviewed in compliance with applicable quality requirements.

Approved by L.S. Sygitowicz Date 9-11-91
L. S. Sygitowicz, Laboratory Operations Section Chief

Approved by F.L. Mabry Date 9-11-91
F. L. Mabry, Health Physics Dept. Quality Coordinator

Approved by Steven g. Bakhtiar for HAH Date 9-11-91
H. A. Hawthorne, Env. Laboratory Superintendent

UNCONTROLLED COPY

I. FILING INSTRUCTIONS

This procedure should be filed under Analytical Chemistry Methods in the "Laboratory Analysis Branch Standard Operating Procedures" binder. It supersedes Revision 0 dated May 29, 1990. Underlining marks the major changes in this procedure.

II. PURPOSE

This procedure describes the preparation of air, water, tissue and soil samples for tritium counting.

III. RESPONSIBILITY

The certified Radiochemistry Laboratory Technicians are responsible for preparing air, water, tissue and soil samples for tritium counting.

IV. REFERENCES

A. AABAB.D.04.10, "Determination of Plutonium in Water, Urine, Soil, and Biological Tissue."

B. "REECo ESD Laboratory Operations Radioanalytical Laboratory Procedures," September 1985.

V. PRINCIPLE

A portion of the sample is distilled to remove contaminants and minimize interfering quenching. Several different techniques are used to recover a pure distilled fraction. These techniques include azeotropic distillation, vacuum distillation, and ambient pressure distillation. Details of these techniques will be discussed under procedure sections. After distillation, an aliquot is mixed with liquid scintillation solution and counted in a liquid scintillation spectrometer. Standards and background samples are prepared and counted with each group of samples.

VI. APPLICABILITY

This is applicable for the determination of tritium in air, water, animal tissue, blood, and urine.

VII. INTERFERENCES

A. Volatile radionuclides are the most common interferences. Alcohols, acids, ketones, and most OH-radicals and hydrocarbons are common chemical interferences, but all may be eliminated by proper and careful sample preparation.

INTERFERENCES (Continued)

B. Light and chemical phosphorescence must be considered. This can be eliminated by allowing the sample to dark-adapt for at least two hours. Electrostatic charges built up on the outside of the plastic sample vials may produce seriously erratic counting results. Electrostatic charges can be eliminated by using the built-in static eliminator and/or wiping the vials with an anti-static cloth or fabric softener.

VIII. PRECISION AND ACCURACY

Internal samples have indicated a precision of better than 5%. Reference materials have been analyzed on a routine basis and results have been obtained that were better than 5%.

IX. SHIPMENT AND STORAGE OF SAMPLES

Water samples should be collected and stored in glass bottles with no preservatives. Biological samples should be kept refrigerated until ready for analysis.

X. REAGENTS

A. Cyclohexane: reagent grade.

B. Liquid scintillation solution: Beckman Ready-Safe^{TM*}.

C. Silver nitrate, crystals: reagent grade.

XI. APPARATUS AND MATERIALS

A. Flask, boiling, 1 neck: 500-mL

B. Distilling receivers, Modified Dean-Stark: 10-mL and 25-mL

C. Glas-Col heating mantle and insulating ponchos.

D. Desiccator, vacuum

E. Trap, Johns

F. Tube, connecting: 105-degrees, and 75-degrees

G. Vacuum pump

H. Liquid nitrogen

XII. PRECAUTIONS

Technicians should wear gloves and work under the ventilated hood.

XIII. METHODS

A. Water and Urine

1. About 30 mL of sample are poured into a 500-mL round bottom flask. Load the flask into the Glas-Col heating mantle in the exhaust hood with the exhaust fan on. All urine samples should be handled only with gloves and under the ventilated hood.
2. Mount the insulating metal poncho on top of the flask and turn the heating switch to a setting of 3. Vent the first steam (approximately for 2 minutes) and collect the distillate in a distilling receiver. If radioiodine is present, add 0.1 g silver nitrate before distilling.
3. When 5.0 mL of distillate are collected, turn off the heat and wait for the distillate to cool down to room temperature. The total amount of distillate collected should be more than 5.0 mL.
4. Pipet a 5-mL portion of the distillate into a polyethylene counting vial. Add 14 mL of the liquid scintillation solution and shake well to mix the sample with the liquid scintillation solution. Label the cap of the vial with the sample number, sample type and event code.
5. Prepare a background sample by pipetting 5.0 mL of distilled low-tritium background water into a polyethylene counting vial and mixing well with 14 mL of liquid scintillation solution. Prepare a standard in the same way using 5.0 mL of a National Institute of Standards and Technology traceable tritium standard solution.
6. Load the samples in the sample changer of the Beckman LS 5801 Liquid Scintillation Spectrometer. Allow to dark-adapt for at least two hours. Count for two 35-minute intervals or until successive counts are within 2 sigma of 0.10%

B. Air

The Laboratory usually uses silica gel and/or Drierite columns to collect tritiated water vapor in air.

1. Check the weight of the water collected. A minimum of 7 to 8 grams of water is needed for distillation. If a lesser amount is collected, add distilled low-tritium background water to make up a total water weight of 8 g. Record the weight of the added water for use in calculating the activity of the air sample later.

METHODS (Continued)

2. Make sure the hood exhaust fan is on. Use a funnel to transfer the Drierite or silica gel into a 500-mL round bottom flask. Heat to 300°C (heating setting at 5 to 6).

3. Collect the water in a modified Dean-Stark distilling receiver.

4. Proceed as in XIII.A.3-6.

C. Soil

1. Weigh out a 1 g sample on a glass watch-glass. Dry in an oven at 105°C overnight. Reweigh and determine the fractional water content of the soil.

2. Weigh out an appropriate amount of soil sample in a 500-mL round bottom flask. Record the weight and add 10 mL of distilled low-tritium background water to soak up the soil (more water may be needed if larger amount of soil is used). Seal the flask with a rubber stopper and let stand for about an hour.

3. Make sure the hood ventilation is on. Proceed as in XIII.A.2-6.

D. Milk and Blood

1. Turn on the ventilation fan of the exhaust hood. Add 50 mL of sample and 50 mL cyclohexane to a 500-mL round bottom flask. Load the flask on the heating mantle. Mount the insulating poncho on top of the flask. Put on the 25-mL distilling receiver. Distill at low heat until 6 to 7 mL of water are collected. Allow the distillate to cool and the phases to separate.

2. Carefully withdraw 5.0 mL of the water phase with a 5-mL disposable pipet. Wipe off any cyclohexane on the outside wall of the pipet before dispensing the water into the scintillation vial. Proceed as in XIII.A.4-6.

E. Vegetation or Animal Tissue

1. Weigh 100 to 200 g of vegetable material or 25 to 50 g of animal tissue, place in a vacuum desiccator, and record the weight. Cool the trap with liquid nitrogen and apply a vacuum.

2. Allow vacuum distillation to continue for several hours until all of the water content is extracted. Weigh the amount of water collected and determine the fractional water composition.

3. Proceed as in XIII.A.4-6, above.

XIV. QUALITY CONTROL

A background and a NIST-traceable standard are counted along with each group of not more than ten field samples. The background counts and efficiency of the instrument are recorded on a daily basis in the Instrument Logbook to provide an indication of the instrument performance.

Tritium spike samples are prepared from a NIST-traceable tritiated water standard and stored by the QA Unit. The H-3 activity of the spiked samples is in the range of several hundred picocuries per milliliter. A set of two spiked samples is issued twice a week along with routine field samples for tritium analysis. Every tenth urine sample and every contaminated waste pond water sample are split as duplicates. QC samples are issued by the Sample Preparation Technician following the procedure outlined in Reference A, XV.B. QC charts are prepared and QC data are reviewed as described in Reference A, XV.C.

XV. CALCULATIONS

A. Water, Urine, Milk, and Blood

$$\text{Tritium } (\mu\text{Ci/mL}) = \frac{\text{CPM(S)} - \text{CPM(BKG)}}{2.22 \times 10^{6} \cdot E \cdot V}$$

where,

CPM(S) = Gross counts per minute of the sample

CPM(BKG) = Gross counts per minute of the background

E = Fractional efficiency determined with the standard counted with the sample group

V = Sample size in mL (e.g. 5 mL)

B. Air

$$\text{Tritium } (\mu\text{Ci/m}^{3}) = \text{Tritium } (\mu\text{Ci/mL}) \times \frac{\text{g of water}}{\text{m}^{3}\text{ of air}}$$

where,

Tritium (μCi/mL) = H-3 activity of the sample counted

g of water = Amount of water collected + any amount of water added before distillation

m^3 of air = Total volume of air passing through the column in m^3

CALCULATIONS (Continued)

C. Soil

$$\text{Tritium } (\mu\text{Ci/g}) = \text{Tritium } (\mu\text{Ci/mL}) \times \frac{W + (F \cdot S)}{S}$$

where,

Tritium (μCi/mL) = H-3 activity of the sample counted

S = Weight of soil samples in g used for distillation

W = Amount of water in g added before distillation

F = Fractional water composition of the soil

D. Vegetation and Animal Tissue

$$\text{Tritium } (\mu\text{Ci/g}) = F \times \text{Tritium } (\mu\text{Ci/mL})$$

where,

F = Fractional water composition (mL/g)

XVI. GLASSWARE CLEAN-UP

A. Wash and rinse all glassware thoroughly with hot water. If dirt or residue is found inside a flask, wash with a 50/50 (by volume) HCl solution or shake with small pieces of wet sand gravel inside the flask until the dirts and/or residue are removed.

B. After thoroughly rinsing with warm water, wash the glassware two or three times with distilled water squirted from a wash bottle. Rinse the inside of glassware with an approximately 1:10 acetone/ethanol mixture.

C. Place the glassware in a metal pan and dry in a drying oven at 200°F until completely dry.

Reynolds Electrical & Engineering Co., Inc.

ENVIRONMENT & HEALTH DIVISION

LABORATORY OPERATIONS SECTION
STANDARD OPERATING PROCEDURE

TITLE
DETERMINATION OF LOW-LEVEL TRITIUM IN WATER (ALKALINE ELECTROLYTIC ENRICHMENT)

APPROVED

Department Manager

NO. AABAB.D.04.70
PAGE 1 of 7
REV. 0
DATE 4/11/91
DIST:

Procedure Approval

The subject procedure has been prepared, approved, and quality reviewed in compliance with applicable quality requirements.

Approved by __________ Date 4-10-91
L. S. Sygitowicz, Section Chief

Approved by F. L. Mabry Date 4/10/91
F. L. Mabry, Department Quality Coordinator

Reviewed by H. A. Hawthorne Date 4/09/91
H. A. Hawthorne, Env. Laboratory Superintendent

Reviewed by K. D. Lee Date 4-3-91
K. D. Lee, Chemical Analysis Supervisor

Reviewed by William Colucci Date 4-3-91
W. Colucci, Laboratory Technician

UNCONTROLLED COPY

Procedure was first routinely used in Jan 1991.

I. FILING INSTRUCTIONS

This new procedure should be filed under Analytical Chemistry Methods in the "Laboratory Analysis Branch Standard Operating Procedures" binder.

II. PURPOSE

To describe the method used to determine tritium in water samples using Tritium Enrichment Analysis.

III. PRINCIPLE

The water samples are first distilled using a total and a closed distillation method. The distillate is charged into an electrolysis enrichment cell where the volume is decreased and the sample is enriched. The enriched samples are then vacuum distilled. The sample is placed in a liquid scintillation vial, scintillation cocktail is added and the sample is counted in a liquid scintillation counter.

IV. REFERENCES

A. H. G. Ostlund and E. Werner, "The Electrolytic Enrichment of Tritium and Deuterium for Natural Tritium Measurements," Discussion VII, Tritium in the Physical and Biological Sciences, Vol. I, Proceedings, Symposium on the Detection and Use of Tritium in the Physical and Biological Sciences, International Atomic Energy Agency, Vienna, Austria, May 3-10, 1961.

B. "Radiochemical Procedures for Analysis of Environmental Samples" EMSL-LV-0539-17, U.S. Environmental Protection Agency, Las Vegas, Nevada, 1979.

C. "American National Standard for Performance Criteria for Radiobioassay," ANSI N13.30 (Draft), American National Standards Institute, Inc., 1430 Broadway, New York, New York, 1989.

V. APPLICABILITY

This method is applicable for the determination of tritium at low levels for all distilled waters.

VI. INTERFERENCES

Other radionuclides and stable elements present in water do not interfere.

VII. PRECISION AND ACCURACY

No data is available at this time.

VIII. SHIPMENT AND STORAGE OF SAMPLES

Water samples should be collected and stored in glass bottles with no preservatives.

IX. REAGENTS

A. Sodium hydroxide, pellets, reagent grade

B. Potassium permanganate crystals, reagent grade

C. Carbon dioxide, gas, commercial grade

D. Liquid nitrogen, commercial grade

E. Hydrochloric acid, 6N

F. Scintillation cocktail solution, Packard, "Pico-Fluor LLT"

G. Ethyl alcohol, reagent grade

H. Ethylene glycol, commercial grade

I. Oil, vacuum pump

X. APPARATUS AND MATERIALS

A. Balance, analytical

B. Bottle, 500 mL screw cap

C. Chips, boiling: Teflon

D. Condenser, Liebig 300 mm

E. Constant current supply 3 amp and 0.3 amp are required.

F. Constant temperature bath

G. Distillation column, Snyder

H. Electrolytic cell, 160 mL

I. Flask, round bottom: 1000 mL

J. Flask, volumetric: 250 mL

K. Glass, fiber: 8 micron

L. Mantle, heating: 1000 mL

M. Oven, drying

N. Oven, heating

X. APPARATUS AND MATERIALS (Continued)

O. Pipettors, adjustable: 10-100 mL, 0-1000 mL

P. Racks, electrolytic cells

Q. Racks, liquid scintillation vials: 20 mL

R. Rack, traps: 50 mL

S. Stopper, glass 34/28

T. Trap, receiving: 50 mL

U. Tube, adapter: 105°

V. Tube, connecting: 75°

W. Tube, connecting, bridge: 34/28 to 18/9

X. Vacuum pump

XI. PROCEDURE

A. Before starting on this procedure, check all equipment, fluid levels, reagents, and apparatus to confirm they are operational or in sufficient supply.

B. Transfer up to 800 mL of sample to a 1000-mL, round-bottom boiling flask.

C. Add approximately 0.5 gram of potassium permanganate ($KMnO_2$) to form a permanent pink-colored solution.

D. Add 7-10 PTFE boiling stones.

E. Distill to dryness and discard the first few drops, collecting the sample in a 500-mL glass screw-top bottle or a 250-mL volumetric flask.

F. Transfer 250 mL of sample to a 250-mL volumetric flask if a 500-mL glass screw-top bottle has been used; be sure to keep it tightly capped. At this step, prepare one background and one standard for every ten samples.

G. With the electrode assembly removed, weigh and record the tared weight of each cell.

H. Transfer 50 mL of the sample into the electrolytic cell; cap with a glass stopper.

I. Add about one gram of sodium hydroxide (NaOH) pellets; cap and shake until the pellets are completely dissolved. Allow to settle for about 30 minutes.

XI. PROCEDURE (Continued)

J. Add another 100 mL of sample and insert the iron-nickel electrode assembly into the electrolytic cell. Place the cell in a cooling bath maintained between 2°C and 4°C.

K. Connect the electrolytic cells to a constant power supply, observing proper polarity.

NOTE: **Before turning the power on, be sure the liquid nitrogen dewars are full and the LN_2 flow rate is approximately 1.5 SCFH. Also, the lid on the protective box covering the cells must be closed any time the power is on to reduce the possibility of explosion.**

L. With all the amp and volt dials set on zero, turn the power supply on. Turn the current dials to maximum. Adjust the current using the coarse voltage dial until the amp meter reads 3 amperes. The volt meter should indicate approximately 2.7 volts times the number of cells being used. A lower voltage reading indicates a short circuit and a higher reading may indicate an open circuit. Take corrective action.

M. When the sample volume has decreased to between 25 and 50 mL, add the remaining 100 mL of sample from the 250-mL volumetric flask .

N. Permit the volume to decrease to approximately 10 mL but not less than 8 mL.

NOTE: **When running the samples overnight and weekends, give careful attention to the sample volume, considering the reduction rate of 1 mL/hr.**

O. Remove the cells from the cooling bath, wiping all the ethylene glycol off the outside walls of the cell; place in a cell rack.

P. Remove the electrode assembly and replace with a glass stopper.

Q. Weigh the cells with the stopper removed and record the gross weight.

R. Using a disposable pipette attached to tubing, bubble carbon dioxide (CO_2 gas) through the sample for 2 to 3 minutes. When completed, place a plug of glass fiber in the cell and replace the glass stopper.

S. Place the cells in the openings of the final distillation ovens.

T. Label the traps to correspond to the cells and place in the dewar adjacent to the appropriate cell.

U. Place the bridge into the cell and connect to the trap with a ball-and-socket clamp to the center socket. Connect the outer socket to the ball from the vacuum pump.

XI. PROCEDURE (Continued)

V. Turn on the vacuum pump, and check all the connections; then fill each trap dewar 1/3 full with liquid nitrogen.

W. Turn on the heating ovens to 150°C, applying heat to the electrolytic cells. Cover the outside cell wall with aluminum foil from the top of the oven to the bridge. Continue heating until the entire sample has been distilled. The temperature may be increased to 200°C if necessary. When completed, turn off the heat and let the vacuum run for approximately 15 more minutes.

X. Remove the traps, place in a rack, cover the socket openings with para-film, and allow to defrost.

Y. Transfer the sample from the trap to a labeled scintillation vial. Pipet 5 mL of sample into a labeled scintillation vial containing 10 mL of Pico-Fluor scintillation cocktail.

Z. Place the scintillation vials containing the samples into a varisette cassette and allow to dark adapt one to two hours.

AA. Count each sample twice for 100 minutes or whatever time is deemed appropriate for the samples.

BB. Check the printer for paper and to begin counting, press the green start key on the keyboard.

XII. CALIBRATION

Prepare an enrichment curve by enriching a set of standard tritium samples using the same procedure as for the unknowns. Allow the final volume of enriched solution to vary so that different points are obtained for the construction of the curve.

XIII. QUALITY CONTROL

As the activity of many of the samples is below the minimum detectable concentration, samples with higher activities are recycled as blind duplicates.

A. Calculations

$$\text{Tritium } (\mu\text{Ci/ml}) = \frac{A - B}{2.22 \times 10^6 \times \text{Eff} \times D \times E \times V}$$

where A = counts per minute of the sample
B = counts per minute of the background sample
2.22×10^6 = dpm/μCi
Eff = fractional counting efficiency
D = sample dilution factor (volume of sample divided by volume counted, if dilution to 5 mL is necessary)

XIII. QUALITY CONTROL (Continued)

E = enrichment factor (from the calibration graph)
V = volume of sample (μL)

B. Lower Limit of Detection

The lower limit of detection (LLD) is defined as the smallest concentration of radioactive material sampled that has a 95% probability of being validly detected.

$$\text{LLD} = \frac{4.66 \times S + 3 \; *}{2.22 \times 10^{6} \times E \times V}$$

where 4.66 = 2.83 x k, where k is the value for the upper percentile of the standardized normal variate corresponding to the preselected risk for concluding falsely that activity is present (α) = .05
S = standard deviation of the background
2.22×10^{6} = dpm/μCi
E = counting efficiency
V = volume of the sample (μL)
*(ANSI N13.30, page 34)

EPA EMSL-LV NUCLEAR RADIATION ASSESSMENT DIV. RADIOANALYSIS BRANCH	Number NRA 1.07	Page Page 1 of 5
	Revision 1.0	Eff. date May 31, 1991
Subject Tritium Enrichment Analysis	Approved	

1.0 PURPOSE:

This procedure provides instructions for enriching water samples by electrolysis and measuring tritium in the enriched samples.

2.0 APPLICABILITY:

This procedure only applies to water samples for which the most sensitive analytical procedure is required. Water samples containing high levels of tritium should not be analyzed by this method. Water containing more than 800 pCi/l of tritium should not be enriched.

3.0 DEFINITIONS:

3.1 Cocktail - A preparation containing an organic solvent base that is mixed with water samples for counting tritium in a liquid scintillation counter.

3.2 Electrolysis - The decomposition of the water molecule into hydrogen and oxygen by an electric current.

3.3 Conventional Tritium Analysis - No enrichment, distillation only.

4.0 REFERENCES:

4.1 F.B. Johns and P.B. Hahn, Radiochemical Analytical Procedures for Analysis of Environmental Samples, U.S. Environmental Protection Agency Report EMSL-LV-0539-17 (1979).

5.0 DISCUSSION:

The tritium enrichment method is designed for activity levels less than 800 pCi/l. Above that level, the conventional method (distillation only) gives acceptable results. Samples arriving at the laboratory will be marked for conventional analysis or analysis by enrichment. If a sample is designated for enrichment, a conventional analysis will be performed first to insure that the activity is below 800 pCi/l. If it is below 800, then the sample can be analyzed by enrichment. If it is above 800, then enrichment is not necessary. Every effort should be made to avoid the enrichment of samples above 800 pCi/l because of the possibility of contaminating other samples being enriched at the same time.

8.7 The electrolysis procedure produces hydrogen gas which may explode if a spark or other source of ignition is present. Cover the cells with the protective cover when in use to contain any glass that may be released by the small explosions that have sometimes occurred. TO AVOID SPARKS, THE CURRENT MUST BE TURNED OFF BEFORE REMOVING THE PROTECTIVE COVER. Failure to do this could result in serious injury.

8.8 Add additional water to the cells when ever the original volume is decreased by 50 percent. Repeat these additions until a total of 250 ml of water has been reduced to approximately 5 ml.

8.9 Remove the electrodes from the cells and bubble carbon dioxide through the remaining liquid for a few minutes. The sample is now ready for vacuum distillation.

8.10 Connect the elctrolysis cell to the glass cold trap with a ground joint adapter. Connect the assembly to a vacuum pump. Immerse trap in liquid nitrotgen and apply vacuum. When trap is cold, apply heat to electrolytic cell. Continue heating to dryness. Discontinue heat but continue vacuum for 10 to 15 minutes.

8.11 Disconnect the apparatus and allow the ice to thaw. Keep evaporation to a minimum and seal sample container if there is any delay in processing.

8.12 Transfer the water to a tared scintillation vial and weigh.

8.13 Obtain the weight of the water by subtracting the empty vial weight. If needed, add background water to the vial until it contains 5 ml. Record the volume of water added (1 ml = 1 gram).

8.14 Add 15 ml of scintillation cocktail to each vial and prepare standards and backgrounds in the same proportion.

8.15 Place samples in counter for at least one day before counting. Count each sample three times for 100 minutes each time.

8.16 After the samples are counted, average the counts and use the chemistry programs on the DOE/VAX to calculate the results. Final results will be checked by the laboratory supervisor before the data is entered into the data base. (See NRA 1.10).

12.0 MODIFICATIONS:

When field modifications to this procedure become necessary, the supervisor shall fully document the changes, submit the documentation for the same review and distribution processes as for the original procedure, and indicate whether the change should result in a subsequent revision to the technical procedure.

13.0 ATTACHMENTS:

N/A

14.0 APPROVAL:

This TSOP shall become effective upon completion of all required signatures and dates on this TSOP and the TSOP QA and Technical Review.

APPENDIX D

ENRICHED TRITIUM RESULTS OF GROUNDWATER SAMPLES COLLECTED BY REECo AND EMSL–LV IN 1992 FROM WATER-SUPPLY WELLS AT THE NEVADA TEST SITE

Enriched tritium results of groundwater samples collected by REECo in 1992
from water-supply wells at the Nevada Test Site.

Water Well	Sample Date	Concentration (pCi/L)	Standard Deviation (pCi/L)
Army #1	02/24/93	3.9	4.4
	04/06/92	1.5	4.6
	07/13/92	-2.1	4.2
	10/05/92	-25	6.5
4	02/24/93	-1.2	4.3
	04/06/92	0.4	4.2
	07/13/92	-1.9	4.2
	10/05/92	-23	6.6
5B	10/05/92	3.9	6.6
5C	02/24/93	-4.1	4.2
	04/06/92	-0.3	4.2
	07/13/92	-1.8	4.1
	10/05/92	-24	6.6
8	02/24/93	-3.3	4.5
	04/06/92	0.7	4.2
	07/13/92	-2.3	4.0
	10/05/92	-30	6.6
U-20	04/06/92	0.5	4.4
	07/13/92	0.4	4.2
	10/05/92	-1.1	7.0
C	02/24/93	5.3	4.5
	04/06/92	23	4.5
	07/13/92	15	4.4
	10/05/92	-9.1	6.8
C-1	02/24/93	1.2	4.5
	04/06/92	4.3	4.2
	07/13/92	5.2	4.2
	10/05/92	-17	6.7
J-12	05/12/92	-2.4	3.9
	07/13/92	-2.4	4.2
	10/05/92	-30	6.6
J-13	02/24/93	0.2	4.3
	04/06/92	2.3	4.2
	07/13/92	-2.6	4.2
	10/05/92	-26	6.5
UE-5C	02/24/92	-1.0	4.3
UE-19c	02/24/92	0.6	4.4
UE-16d	02/24/93	-3.5	4.2
	04/06/92	-0.7	4.2
	07/13/92	-2.1	4.1
	10/05/92	-26	6.5

Enriched tritium results of groundwater samples collected by EMSL–LV in 1992 from water-supply wells at the Nevada Test Site.

Water Well	Sample Date	Concentration (pCi/L)	Standard Deviation (pCi/L)
Army #1	01/07/92	1.0	1.8
	02/03/92	-1.1	1.8
	03/03/92	1.0	1.7
	04/02/92	-1.5	2.2
	05/12/92	0	1.4
	06/03/92	-2.1	1.7
	07/08/92	0.9	1.9
	08/04/92	-0.5	1.7
	09/01/92	1.6	1.4
	10/05/92	3.2	1.7
	11/09/92		1.5
	12/01/92		1.5
4	01/07/92	-1.1	1.8
	02/03/92	1.2	2.0
	03/03/92	-0.8	1.5
	04/02/92	-2.1	1.9
	05/12/92	0	1.4
	06/02/92	-2.1	1.7
	07/07/92	2.9	1.8
	08/04/92	-2.2	1.4
	09/02/92	-0.5	1.9
	10/05/92	1.6	1.6
	11/09/92	-4.8	1.5
	12/01/92	0.5	1.5
5B	08/04/92	3.1	1.4
5C	01/07/92	1.7	1.5
	02/03/92	3.7	2.1
	03/03/92	-1.6	1.4
	04/02/92	-1.3	1.2
	05/12/92	1.6	1.5
	06/02/92	-2.7	1.4
	07/08/92	1.4	1.6
	08/04/92	0.5	1.3
	09/01/92	1.8	1.3
	10/05/92	-0.5	1.6
	11/10/92	-2.5	1.4
	12/01/92	-0.6	2.0

Enriched tritium results of groundwater samples collected by EMSL–LV in 1992 from water-supply wells at the Nevada Test Site (continued).

Water Well	Sample Date	Concentration (pCi/L)	Standard Deviation (pCi/L)
8	01/07/92	0	1.7
	02/03/92	0	2.0
	03/03/92	10	1.9
	04/01/92	-1.7	1.5
	05/12/92	-0.6	1.6
	06/02/92	-5.1	1.5
	07/07/92	0	1.6
	08/04/92	-1.3	1.5
	09/01/92	2.1	1.4
	10/05/92	1.9	1.5
	11/09/92	-1.5	1.3
	12/01/92	-0.4	1.5
U-20	04/02/92	-1.9	1.7
	05/12/92	-3.0	1.7
	06/02/92	-0.7	1.5
	07/07/92	4.0	1.7
	08/04/92	1.9	1.6
	09/01/92	1.6	1.6
	10/05/92	4.9	1.7
	12/02/92	1.0	1.4
C	01/07/92	11	1.8
	02/03/92	24	2.0
	04/01/92	21	2.3
	05/12/92	12	1.7
	06/02/92	19	1.8
	07/07/92	15	1.9
	08/04/92	20	1.8
	09/01/92	12	1.5
	10/05/92	13	1.9
	11/09/92	18	1.7
	12/01/92	17	2.1
C-1	04/01/92	17	2.1
	10/05/92	4.7	1.6
J-12	05/12/92	1.0	1.7
	06/02/92	-3.2	1.8
	07/08/92	1.1	1.9
	08/04/92	-0.2	1.6
	09/01/92	2.2	1.4
	10/05/92	0	1.4
	11/10/92	-3.9	1.4
	12/02/92	1.3	1.5

Enriched tritium results of groundwater samples collected by EMSL–LV in 1992 from water-supply wells at the Nevada Test Site (continued).

Water Well	Sample Date	Concentration (pCi/L)	Standard Deviation (pCi/L)
J-13	01/07/92	0	1.6
	02/03/92	-2.0	1.7
	03/03/92	-2.6	2.2
	04/02/92	0	1.5
	05/12/92	0	1.4
	06/12/92	-0.7	1.6
	07/08/92	0.2	1.2
	08/04/92	3.7	1.9
	09/01/92	1.6	1.7
	10/05/92	3.1	1.5
	11/09/92	-1.5	1.6
	12/01/92	2.6	1.4
UE-5C	05/12/92	-2.9	1.6
	09/01/92	-1.1	1.5
UE-19c	01/07/92	-1.1	1.8
	02/03/92	-1.1	1.8
	03/02/92	0	1.5
	04/02/92	-2.1	1.9
	05/12/92	-2.1	1.5
	06/02/92	0.5	1.8
	07/07/92	0.9	1.5
	08/04/92	5.3	1.5
	09/01/92	-0.7	1.4
	10/05/92	0.8	1.5
	12/02/92	5.0	1.7
UE-16d	05/12/92	-4.6	1.8
	11/09/92	2.3	1.4

APPENDIX E

U.S. ENVIRONMENTAL PROTECTION AGENCY LETTER RECOMMENDING ENRICHED TRITIUM INTERLABORATORY COMPARISON PROGRAM

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF RESEARCH AND DEVELOPMENT
ENVIRONMENTAL MONITORING SYSTEMS LABORATORY-LAS VEGAS
P.O. BOX 93478
LAS VEGAS, NEVADA 89193-3478
(702/798-2100 - FTS 545-2100)

MAY 14 1993

Mr. Richard H. Pearl, Physical Scientist
Environmental Protection Division (M/S 505)
U.S. Department of Energy
P.O. Box 98518
Las Vegas, Nevada 89193-8518

SUBJECT: Summary of Enriched Tritium Subcommittee Meeting, May 13, 1993

Dear Mr. Pearl:

The Enriched Tritium Subcommittee met at the Environmental Protection Agency Environmental Monitoring Systems Laboratory-Las Vegas on May 13, 1993. Attendees are listed in Enclosure 1. Topics of discussion included design of an intercomparison study for enriched tritium, methodology, and quality assurance/quality control. A copy of the agenda is included as Enclosure 2.

The attendees unanimously and vigorously support the implementation of an intercomparison study. Participation in a long-term, ongoing intercomparison study is critical for all laboratories using the enriched tritium analysis method. The following summarizes the group's recommended specifications:

- The intercomparison study samples should be prepared by an independent laboratory, such as Environmental Measurements Laboratory.
- For the first year, one round per quarter should be conducted. After completion of the first year, the frequency should be evaluated and, possibly, modified.
- Each round should consist of three intercomparison study samples of the same activity and one matrix blank.
- Each intercomparison study sample should be approximately 1 liter. Samples need to be in glass containers, with a minimum of headspace (10%), and sealed. Fossil water is required for the sample matrix.
- Intercomparison study samples should be in the range of 100 to 200 pCi/L.
- Data analysis is the responsibility of the preparation laboratory.

Enclosure 1

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Enclosure 2

AGENDA
ENRICHED TRITIUM SUBCOMMITTEE
WORKSHOP

Meeting Date: Thursday, May 13, 1993, 8:00am-2:00pm

Place: Quality Assurance Division Conference Room
U.S. Environmental Protection Agency
944 E. Harmon Ave.
Las Vegas, Nevada
(see enclosed map)

I. Introductory Remarks (8:00am - 8:15am)
  Introductions
  Purpose of Committee

II. Intercomparison Study (All) (8:15am - 9:45am)
  Spiked or natural samples?
  Desired activity range?
  Frequency/total no. of samples?
  Single or double-blind?
  Logistic issues (shipping, storage, etc.)
  Source/supplier?
  Data submission/compilation?
  Results/reports?
  Costs?
  Other issues?

Break (9:45am - 10:00am)

IIIa. Analytical Methods (Chemists) (10:00am - 11:30am)
  Is a standard method available?
    If so, who is using, who is not, why?
  Is a standard method appropriate?
    Why/why not?
    If yes, who to develop, who to test, where to document (publish)?
  Should methodology be performance-based?
    If so, specify criteria
    If not, how can comparability of analytical methods be assured/measured?
  Costs?
  Other issues?

Enclosure 3

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APPENDIX F

LIST OF POTENTIAL GROUNDWATER MONITORING WELLS

AREA :

Well Name		Elevation	TD	Completed	Case	From	To	Hole	From	To	Interval	From	To
Army 6A	N 665641	3445	1253	1956	12.000	0	1200	18.000	0	50	Perfs	1050	1150
Paleozoic Carbonates	E 690214				10.000	1157	1228	16.000	50	1200	Perfs	1157	1228
								10.000	1200	1253			
SWL : 1030 WLM : N/A	Sampled by : EPA												
PM-3 #1	N 906022	5823	3019	1992	10.750	0	1473	9.875	1647	3019	Slots	1917	2142
Tertiary Volcanics	E 530998				2.875	0	2142						
SWL : 1460 WLM : USGS	Sampled by : N/A												
PM-3 #2	N 906022	5823	3019	1992	10.750	0	1473	9.875	1647	3019	Slots	1442	1667
Tertiary Volcanics	E 530998				2.875	0	1667						
SWL : 1458 WLM : USGS	Sampled by : N/A												

AREA :1

Well Name		Elevation	TD	Completed	Case	From	To	Hole	From	To	Interval	From	To
UE-1Q	N 841500	4082	2600	1992	7.625	0	2459	12.250	80	2600	Open	2459	2600
Paleozoic Carbonates	E 677500												
SWL : 1655 WLM : USGS	Sampled by : N/A												
UE-1c	N 837000	4206	1880	1964	10.750	0	74	26.000	0	80	Open	74	1880
Tertiary/Paleozoic Carbonates	E 666000							9.000	80	1280			
SWL : 1298 WLM : USGS	Sampled by : EPA												
Tertiary/Pz Carb at 1875'.													
UE1A	N 837000	4303	957	1964	10.750	0	64	15.000	0	78	Open	64	957
Tertiary Volcanics/Eleana	E 660000							9.000	78	947			
								8.500	947	953			
SWL : 545 WLM : USGS	Sampled by : N/A												
UE1B	N 837000	4273	1254	1964	10.750	0	76	9.000	0	1254	Open	76	1254
Eleana (Upper Clastic Aquitard)	E 662000												
SWL : 645 WLM : USGS	Sampled by : N/A												
UE1H	N 819998	3995	3358	1968	9.500	0	2134	12.250	111	2349	Open	2135	3358
	E 674999							8.750	2349	3358			
SWL : 1556 WLM : USGS	Sampled by : N/A												
UE1L	N 837000	4454	5339	1972	13.375	0	716	17.500	76	726	Open	716	5339
	E 654001							12.250	726	5339			
SWL : 519 WLM : USGS	Sampled by : N/A												

AREA .2

Well Name		Elevation	TD	Completed	Case	From	To	Hole	From	To	Interval	From	To
UE-2ce Water Well	N 871100	4764	1650	1977	13.375	0	81	12.250	0	1650			
Paleozoic Carbonates	E 654900				8.625	0	1624						

SWL : 1446 WLM : USGS Sampled by : N/A

WATER WELL 2 (USGS HTH #2)	N 880000	4470	3422	1962	8.500	0	2550	15.000	0	1594	Slots	3412	3164
Paleozoic Carbonates	E 668720				6.500	2500	3422	11.000	1594	2550	Perfs	2950	2700
								7.875	2550	3422			

SWL : 2055 WLM : USGS Sampled by : EPA

Non-drinking water supply well. Pump set in hole. Does not work.Monitor line present in well.

AREA :3

Well Name		Elevation	TD	Completed	Case	From	To	Hole	From	To	Interval	From	To
TW-7	N 843192	4066	2272	1954	12.000	0	2014	10.625	0	2272	Open	2014	2272
Tertiary	E 684654												
SWL : 1633 WLM : USGS	Sampled by : EPA												
U-3cn 5	N 841255	4012	3030	1966	9.625	0	2385	5.750	2835	3028	Open	2832	3030
Tuff/Lower Carbonate/Lower Clastic	E 687998				6.625	2321	2832	5.125	3028	3030			
SWL : 1625 WLM : USGS	Sampled by : EPA												
Tertiary/Pz Carbonates at 2821', Pz/Clastic at 2924'.													
UE-3E #4-1	N 844888	4082	2300	1990	20.000	0	117	36.000	0	120			
	E 680001				13.375	0	1436	17.500	120	1442			
					2.875	0	2181	12.250	1442	2300			
SWL : 1084 WLM : USGS	Sampled by : N/A												
Plugged to 2182' with cement. Completed with 3 piezometer tubes.													
UE-3E #4-2	N 844888	4082	2300	1990	20.000	0	117	36.000	0	120			
	E 680001				13.375	0	1436	17.500	120	1442			
					2.875	0	1919	12.250	1442	2300			
SWL : 1309 WLM : USGS	Sampled by : N/A												
Plugged to 2182' with cement. Completed with 3 piezometer tubes.													
UE-3E #4-3	N 844888	4082	2300	1990	20.000	0	117	36.000	0	120			
	E 680001				13.375	0	1436	17.500	120	1442			
					2.875	0	1661	12.250	1442	2300			
SWL : 1551 WLM : USGS	Sampled by : N/A												
Plugged to 2182' with cement. Completed with 3 piezometer tubes.													
USGS Water Well A	N 833000	4006	1870	1960	12.625	0	1555	16.000	0	601	Slots	1608	1870
Alluvium	E 684000				10.625	1555	1870	15.000	601	1600			
								12.250	1600	1870			
SWL : 1605 WLM : N/A	Sampled by : EPA												

AREA :4

Well Name		Elevation	TD	Completed	Case	From	To	Hole	From	To	Interval	From	To
TEST WELL D	N 846600	4152	1950	1961	11.500	0	1700	15.000	0	1700	Slots	1772	1882
Dolomite/Tertiary Volcanics	E 672600				10.500	1650	1900	12.000	1700	1900			
								9.000	1900	1950			
SWL : 1723 WLM : USGS	Sampled by : EPA												
U4u PS#2A	N 851215	4117	2280	1990	10.750	0	120	9.875	0	2280	Open	1770	2280
	E 680078				2.875	0	1770						
SWL : 1681 WLM : USGS	Sampled by : N/A												
UE-4t 1	N 855565	4144	2413	1990	88.000	0	8	104.000	0	8	Slots	1963	1992
Tertiary Volcanics	E 680350				13.375	0	119	26.000	0	121			
					2.875	0	1993	9.875	0	2413			
SWL : 289 WLM : USGS	Sampled by : N/A												
UE-4t 2	N 855565	4144	2413	1990	88.000	0	8	104.000	0	8	Slots	1664	1724
Tertiary Volcanics	E 680350				26.000	0	119	26.000	0	119			
					2.875	0	1724	9.875	0	1724			
SWL : 1144 WLM : USGS	Sampled by : N/A												

AREA :5

Well Name		Elevation	TD	Completed	Case	From	To	Hole	From	To	Interval	From	To
TW-3 (HTH -3)	N 750189	3477	1860	1962	12.750	0	163	9.000	165	1850	Slots	1193	1517
Paleozoic Carbonates	E 736937				6.500	0	1517	7.500	1850	1860			
SWL : 1105 WLM : USGS	Sampled by : N/A												
Cement Shoe at 1516'													
UE-5C	N 760133	3216	2682	1964	13.375	0	1682	12.250	1682	2385	Perfs	1100	1300
Alluvium	E 700997							9.875	2385	2682			
SWL : WLM : N/A	Sampled by : REECO/EPA												
UE-5n	N 754460	3112	1687	1976	10.750	0	1523	15.000	0	1687	Perfs	720	730
Alluvium	E 706415												
SWL : 705 WLM : USGS	Sampled by : N/A												
WATER WELL 5A	N 738361	3093	910	1951	12.000	0	608		0	910	Slots	642	877
Alluvium	E 707263				10.000	0	877						
SWL : 711 WLM : USGS	Sampled by : N/A												
WATER WELL 5B	N 747359	3092	900	1951	12.000	0	460		0	1951	Perfs	700	900
Alluvium	E 704263				10.000	440	900						
SWL : 683 WLM : N/A	Sampled by : REECO/EPA												
Water Well 5c	N 741644	3081	1200		10.750	0	1187		0	1200	Perfs	887	1187
Alluvium	E 706305												
SWL : 692 WLM : N/A	Sampled by : REECO/EPA												

AREA :6

Well Name		Elevation	TD	Completed	Case	From	To	Hole	From	To	Interval	From	To
ER-6-1	N 814000	3940	2129	1992	13.375	0	1795	22.500	0	1819	Open	1819	2192
Paleozoic Carbonates	E 696799							12.500	1819	2097			
								8.750	2097	2192			
SWL : 1546 WLM : N/A	Sampled by : N/A												
ER-6-1 Piezometer Tube	N 814000	3940	2129	1992	2.875	0	1295				Slots	450	1508
Tertiary	E 696799												
SWL : 1474 WLM : N/A	Sampled by : N/A												
Tube tack welded to side of 13.375" casing in ER-6-1													
ER-6-2	N 805311		2006	1993	13.375	0	1740	20.500	0	1896	Open	1740	2006
Paleozoic Carbonates	E 672494							10.625	1896	2006			
SWL : 1787 WLM : N/A	Sampled by : N/A												
TW-B	N 812500	3929	1675	1961	12.750	0	1539	15.000	573	1539	Perfs	1432	1452
Tertiary	E 690713				10.750	1375	1675	12.000	1539	1670	Perfs	1512	1656
								10.000	1670	1675			
SWL : 1503 WLM : N/A	Sampled by : EPA												
UE6D	N 813998	3947	3896	1968	7.375	0	2125	9.875	110	2617	Open	2125	3869
	E 677499							6.750	2617	3886			
								6.125	3886	3896			
SWL : 1516 WLM : USGS	Sampled by : EPA												
Junk at 3865'.													
UE6E	N 814000	3936	4209	1992	9.750	0	2090	12.250	120	2886	Open	2090	
Tertiary	E 688200							8.750	2886	4209			
SWL : 1509 WLM : USGS	Sampled by : EPA												
Fish at 2336'.													

AREA :6

Well Name		Elevation	TD	Completed	Case	From	To	Hole	From	To	Interval	From	To
USGS Water Well C	N 790803	3921	1701	1967	12.750	0	1373	15.000	0	1622	Perfs	1580	1620
Paleozoic Carbonates	E 692061				10.750	1326	1624	12.000	0	1701			
SWL : 1541 WLM : N/A	Sampled by : REECO/EPA												
Pump hung at 1594' on 5.5" casing, 1/31/90, WL monitor not present. Drinking water supply well.													
WATER WELL 4	N 784999	3603	1479	1981	13.375	0	1438	20.000	0	1479	Open	1438	1479
Volcanic Tuffs	E 687900												
SWL : 836 WLM : USGS	Sampled by : REECO/EPA												
Drinking water supply well.													
WATER WELL 4A	N 784348	3606	1516	1990	24.000	0	535	48.000	0	31	Slots	1066	1457
Volcanic Tuffs	E 686898				13.375	0	1501	30.000	31	536			
								20.500	536	1516			
SWL : 835 WLM : USGS	Sampled by : N/A												
WATER WELL C-1	N 790011	3921	1707	1962	24.000	0	910	22.625	914	1539	Perfs	1536	1650
Paleozoic Carbonates	E 692132				16.625	910	1650	19.000	1539	1596			
								18.625	1596	1707			
SWL : 1547 WLM : N/A	Sampled by : REECO/EPA												
Pump hung at 1631' on 5.5" casing, 1989, WL monitor not present, Drinking water supply well.													
WELL 3	N 817795	3969	1799	1952	8.625	0	1209		0	256	Slots	1535	1765
Alluvium	E 677762				6.625	0	1765	10.000	256	1575			
								8.000	1575	1800			
SWL : 1533 WLM : USGS	Sampled by : N/A												

AREA :7

Well Name		Elevation	TD	Completed	Case	From	To	Hole	From	To	Interval	From	To
U-7cd-1	N 849002	4116	1700	1992	20.000	0	114	12.250	0	1700	Open	114	1700
Tertiary	E 681431												
SWL : 1419 WLM : USGS	Sampled by : N/A												
UE7N S	N 855600	4367	2199	1976	7.625	0	2199	17.500	0	1789			
Paleozoic Carbonates	E 693700							10.625	0	2205			
SWL : 1970 WLM : USGS	Sampled by : EPA												

AREA :8

Well Name		Elevation	TD	Completed	Case	From	To	Hole	From	To	Interval	From	To
UE8F	N882387	4560	2248	1971	9.625	0	1129	8.750	0	2235	Open	1129	2248
	E 666019							6.250	0	2248			

SWL :

WLM : N/A

Sampled by : N/A

AREA :9

Well Name			Elevation	TD	Completed	Case	From	To	Hole	From	To	Interval	From	To
U-9 ITS UE-U-29 #1		N871618	4248	1248	1971	13.375	0	77	12.250	0	1248	Open	77	1248
Tertiary		E 683624												
SWL :	WLM : N/A	Sampled by : N/A												
U-9 ITS UE-U-29 #2		N871505	4242	1572	1971	10.750	0	79	9.875	0	1572	Open	79	1572
Tertiary		E 683105												
SWL :	WLM : N/A	Sampled by : N/A												

AREA :10

Well Name		Elevation	TD	Completed	Case	From	To	Hole	From	To	Interval	From	To
UE-10 ITS #3	N 887201	4353	2160	1969	10.750	0	84	9.875	85	2160	Open	84	2160
Alluvium/Tertiary/Paleozoic Carbonates	E 680700												
SWL : 1890 WLM : N/A	Sampled by : N/A												
Alluvium/Tertiary contact at 840', Tertiary/Paleozoic contact at 2050', Plugged with cement to 1926'.													
UE-10J	N 887033	4574	2514	1993	20.000 13.375	0 0	55 2198	9.635	61 2198	2380 2515	Open	2198	2514
Paleozoic Carbonates	E 670453												
SWL : 2162 WLM : N/A	Sampled by : N/A												

AREA :11

Well Name		Elevation	TD	Completed	Case	From	To	Hole	From	To	Interval	From	To
UE11A	N777128	3547	1400	1982	20.000	0	29	15.000	0	610	Open	599	1400
Tertiary	E 708279				10.750	0	599	9.875	610	1400			

SWL : 1128 WLM : USGS Sampled by : N/A

AREA :12

Well Name		Elevation	TD	Completed	Case	From	To	Hole	From	To	Interval	From	To
ER-12-1	N 886639	5830	3588	1991	13.375	0	1474	17.500	0	1700	Slots	1693	1821
Lower Carbonate/Lower Clastic	E 640540				7.625	0	3520	12.250	1700	3520	Slots	1920	1960
					5.500	0	3435				Slots	2509	2594
											Slots	2990	3162
											Slots	3358	3442

SWL : 1547　WLM : N/A　Sampled by : N/A

5-1/2" pipe with sliding side door sleves and external packers have been run to 3434 feet. Sleeves are all closed except top one at 1760 feet. DRI completed pump and sample test on 01/06/93. Pump to be removed soon

Well Name		Elevation	TD	Completed	Case	From	To	Hole	From	To	Interval	From	To
U-12t6	N 901402	6907	1461	1988	7.000	0	23	6.250	23	674	Cut	416	
	E 638431				4.500	75	674	4.000	674	1460	Cut	466	
											Cut	490	
											Cut	540	
											Cut	570	
											Cut	620	

SWL : 784　WLM : N/A　Sampled by : N/A

AREA :14

Well Name		Elevation	TD	Completed	Case	From	To	Hole	From	To	Interval	From	To
UE14B	N794100	4353	2060	1984	20.000	0	79	13.500	0	2290	Open	79	2060
	E 650111							12.250	0	3300			

SWL : 1666 WLM : N/A Sampled by : N/A

AREA :15

Well Name		Elevation	TD	Completed	Case	From	To	Hole	From	To	Interval	From	To
UE-15d	N 895709	4586	6001	1962	7.000	0	1735	9.500	765	1833	Hole in Ca	734	751
Volcanic Tuffs	E 682084				4.500	1667	5400	6.250	1833	6001	Open	5400	6001

SWL : 667

WLM : N/A

Sampled by : EPA

AREA :16

Well Name		Elevation	TD	Completed	Case	From	To	Hole	From	To	Interval	From	To
UE-16d Eleana Water Well	N 844878	4684	3000	1981	10.750	0	80	6.250	0	2321	Perfs	1145	1310
Sidetrack	E 646567				7.000	0	2117						
Upper Carbonate Aquifer													
SWL : 750 WLM : USGS	Sampled by : REECO/EPA												
Plug at 1680'. Drinking water supply well.													
UE16F	N 832355	4652	1479	1977	13.375	0	213	36.000	0	28	Open	1293	1479
Clastics	E 648843				9.625	0	1243	17.500	28	215			
								12.250	215	1293			
SWL : 367 WLM : USGS	Sampled by : EPA							8.750	1293	1479			
Bridge at 1409'.													

AREA :17

Well Name		Elevation	TD	Completed	Case	From	To	Hole	From	To	Interval	From	To
UE17A	N 846138	4697	1214	1976	7.625	0	36	26.000	4	38	Perfs	745	825
	E 645991				4.500	0	1210	6.250	38	1214	Perfs	1005	1015
											Perfs	1065	1190

SWL : 636 WLM : USGS Sampled by : EPA

Junk at 1207'.

USGS HTH #1	N 876855	6156	4206	1962	11.750	0	1615	7.625	0	4206	Perfs	1910	1950
Bedded Tuff/Lower Carbonate	E 629310				8.625	1560	3711				Perfs	2030	2050
											Perfs	2100	2160
											Perfs	2230	2270
											Perfs	2370	2430

SWL : 1465 WLM : USGS Sampled by : EPA

Tertiary/Carbonate contact at 3702', Bridge at 3700'.

AREA :18

Well Name		Elevation	TD	Completed	Case	From	To	Hole	From	To	Interval	From	To
UE18R	N 868100	5538	5004	1968	10.750	0	1629	9.875	0	4988	Open	1629	5004
Volcanic Tuffs	E 564700							6.125	0	5004			
SWL : 1365 WLM : USGS	Sampled by : EPA												
Bridge at 4941'.													
UE18T	N 865800	5201	2600	1978	4.500	0	812	26.000	0	120	Open	812	2600
Volcanic Tuffs	E 598400				2.375	0	1896	6.250	0	810			
								3.875	0	1875			
SWL : 915 WLM : USGS	Sampled by : EPA							3.000	0	2600			
Junk at 1556'.													
Water Well 8 (USGS HTH-8)	N 879468	5695	5499	1963	11.750	0	2031	7.625	2940	5483	Perfs	1250	1300
Volcanic Tuffs	E 609999				7.625	1942	2936	6.125	5483	5490	Perfs	1450	1500
											Perfs	1630	1780
SWL : 1080 WLM : N/A	Sampled by : REECO/EPA										Slots	2038	2070
Plugged with Cement to 1862'. Drinking water supply well. Monitoring line not present in well.											Slots	2139	2170

AREA :19

Well Name		Elevation	TD	Completed	Case	From	To	Hole	From	To	Interval	From	To
ER-19-1	N 884237		3572	1993	36.000	0	82	20.000	82	3572	Open	82	3572
Tertiary/Paleozoic Carbonates	E 624535												
SWL : 1009 WLM : N/A	Sampled by : N/A												
Tertiary/Pz contact at approximately 2840'.													
UE-19c Water Well	N 917000	7033	8489	1964	13.375	0	2422	12.250	2422	3209	Open	2422	3035
Volcanic Tuffs	E 601027							9.875	3209	8489			
SWL : 2314 WLM : USGS	Sampled by : REECO/EPA												
Bridge at 3035'. Non-drinking water supply well.													
UE-19h	N 943901	6780	3705	1992	13.375	0	2321	17.500	65	2370	Slots	2161	2287
Tertiary	E 585204				2.875	0	2287	9.875	2370	3705			
SWL : 2109 WLM : USGS	Sampled by : N/A												
Plugged with cement to 2288'.													

AREA :20

Well Name		Elevation	TD	Completed	Case	From	To	Hole	From	To	Interval	From	To
ER-20-1	N 899650		2056	1992	24.000	0	1937	30.000	0	1940	Open	1937	2056
Tertiary	E 550996							20.000	1940	2056			
SWL : 1986 WLM : N/A	Sampled by : N/A												
PM-1	N 921104	6558	7858	1962	10.750	0	7534	9.625	0	7858	Open	7534	7858
Volcanic Tuffs	E 575868												
SWL : 2085 WLM : USGS	Sampled by : EPA												
PM-2	N 944581	5586	8782	1964	13.375	0	2472	8.625	0	8775	Open	5499	8782
Tertiary	E 528656				9.625	0	5499	6.125	0	8782			
SWL : 852 WLM : N/A	Sampled by : N/A												
U-20 Water Well	N 910582	6468	3268	1982	13.375	0	3199	17.500	2684	3268	Slots	3055	2271
Volcanic Tuffs	E 569090												
SWL : 2035 WLM : N/A	Sampled by : REECO/EPA												
Non-drinking water supply well.													
U-20n PS #1DD-H	N 906531	6468	4250	1985				17.500	0	2430			
	E 570834							9.875	3110	4520			
SWL : 2097 WLM : USGS	Sampled by : N/A												
Bridge Plug set at 3025', 5-15-85.													
UE-20e	N 934564	6297	6395	1968	13.375	0	694	17.500	50	701	Open	694	6395
Tertiary	E 560957							12.250	701	1450			
								9.625	1450	2440			
SWL : WLM : N/A	Sampled by : N/A												
Cemented back to 2440', Bridge at 1228'.													

AREA :20

Well Name		Elevation	TD	Completed	Case	From	To	Hole	From	To	Interval	From	To
UE20N1	N 906545	6461	3300	1987	13.375	0	192	17.500	0	197	Open	2282	3300
Tertiary	E 571239				9.625	0	2282	12.250	0	2323			
								8.750	0	2407			
								8.500	0	3300			

SWL : 2040 WLM : USGS Sampled by : N/A

Bridge Plug at 2842', 6/10/87.

AREA :22

Well Name		Elevation	ID	Completed	Case	From	To	Hole	From	To	Interval	From	To
Army #1 Water Well	N670902	3154	1953	1962	13.375	0	610	9.000	1370	1684	Perfs	792	1042
Paleozoic Carbonates	E 684772				10.750	0	1263	6.750	1684	1771			
					7.625	1197	1360	6.125	1771	1953			

SWL : 800 WLM : N/A Sampled by : REECO/EPA

Drinking water supply well.

AREA :25

Well Name		Elevation	TD	Completed	Case	From	To	Hole	From	To	Interval	From	To
J-12 Water Well	N 733508	3130	887	1957	12.750	0	887	11.750	0	1139	Perfs	793	868
Volcanic Tuffs	E 581012												
SWL : 745 WLM : N/A	Sampled by : REECO/EPA												
Drinking water supply well.													
Water Well J-13 USGS HTH #6	N 749209	3318	3488	1963	13.375	0	1301	26.000	0	445	Perfs	996	1301
Volcanic Tuffs	E 579651				11.750	1301	1546	17.250	0	1008	Perfs	1301	1386
					5.500	1484	3385	17.000	0	1331	Perfs	2690	3312
SWL : 925 WLM : N/A	Sampled by : REECO/EPA							15.000	0	1556			
								9.875	0	1561			
Drinking water supply well.								9.000	0	2020			
								7.625	0	3488			

AREA :27

Well Name		Elevation	ID	Completed	Case	From	To	Hole	From	To	Interval	From	To
HTH F (TW-F)	N 731853	4143	3400	1962	8.625	0	3150	7.500	0	3400	Open	3150	3400
Paleozoic Carbonates	E 661153												

SWL : 1734 WLM : USGS Sampled by : EPA

Dead Pump in hole.

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