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Hydrology and Radionuclide Migration Program 1987 Progress Report

Compiled by
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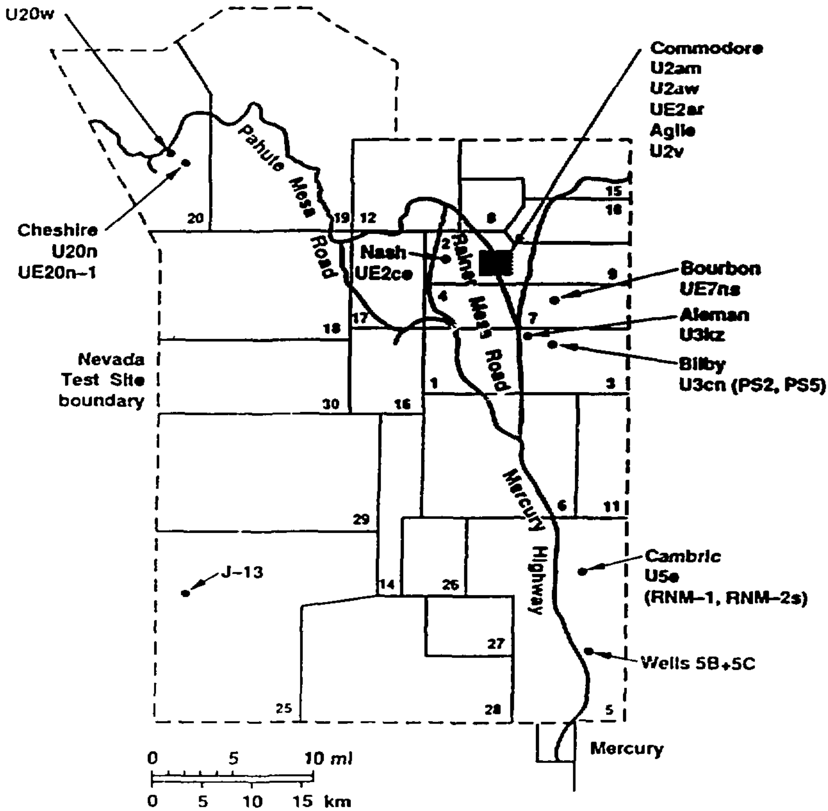

Frontispiece Locations of wells and Events relevant to the Hydrology and Radionuclide Migration Program. Small numbers indicate NTS areas.

Acknowledgments

In the sections of this report that present data or interpretational results, the individuals who made significant scientific or technical contributions to the specific effort are listed as contributors. Many others, however, have provided general support, assistance, and advice important to the overall report. We gratefully acknowledge the contributions of the following organizations and individuals:

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Hydrology and Radionuclide Migration Program 1987 Progress Report

Abstract

This report presents results from the Lawrence Livermore National Laboratory's participation in the Hydrology and Radionuclide Migration Program at the Nevada Test Site (NTS) during the fiscal year 1987. The report discusses initial data from a new well (UE20n-1) drilled at the Cheshire site; presents a description of a proposed laboratory study of migration of colloids in fractured media; lists data collected during the drilling and initial sampling of UE20n-1; and describes a tentative proposal for work to be performed in FY88 by Lamont-Doherty Geological Observatory.

Groundwater sampled from the new well at the Cheshire site contains tritium concentrations comparable to those measured in previous years from locations above and within the Cheshire cavity. This presence of tritium, as well as several other radionuclides, in a well 100 m away from the cavity region indicates transport of radionuclides, validates a proposed model of the flow path, and provides data on rates of groundwater flow.

Previous work at the Cheshire site has shown that radionuclides are transported by colloids through fractured media. However, we have no data that can be used for predictive modeling, and existing theories are not applicable. While physical transport mechanisms of sub-micrometer colloids to defined mineral surfaces are well known, predictions based on well-defined conditions differ from experimental observations by orders of magnitude. The U.C. Berkeley group has designed a laboratory experiment to quantify colloid retention and permeability alteration by the retained colloids.

Two appendices include a summary log of activities at UE20n-1 from the start of drilling through the initial sampling, describe the samples collected, and present results of early field and laboratory measurements. A third appendix consists of a listing of all Tests at the Nevada Test Site between July, 1957, and October, 1987 that were fired near or below the water table. Appendix D is a tentative proposal from Lamont-Doherty Geological Observatory for work in the HRMP in FY88.

Section 1. Introduction

This report presents the results of technical studies conducted by the Lawrence Livermore National Laboratory (LLNL) as part of the Hydrology and Radionuclide Migration Program (HRMP) at the Nevada Test Site (NTS). The program is intended to assess the potential for radionuclide migration away from the underground nuclear test cavities at the NTS, with particular emphasis on issues relating to groundwater contamination and transport. The Frontispiece shows the locations of the sites and wells studied at the NTS.

The project, which was initiated in 1974, continues as a multi-agency research project [LLNL, Los Alamos National Laboratory (LANL), the Desert Research Institute (DRI) of the University of Nevada, and the U.S. Geological Survey (USGS)] coordinated and funded by the Nevada Operations Office of the U.S. Department of Energy (DoE-NVO).

The agencies involved in the project issue a variety of letter reports, technical reports, and scientific publications on aspects of HRMP studies. The most recent LLNL report generally available is the 1985–1986 Progress Report.[1] The present report is a comprehensive account of LLNL activities and results, both direct and subcontracted, for the HRM Program for FY87.

The report is organized on a topical basis. Section 2 summarizes our current investigations into transport of radionuclides at the Cheshire site. We describe initial results of investigations in a new well drilled to study transport of radionuclides from the detonation cavity down the hydrologic gradient. Section 3 describes the initiation of a laboratory experiment to study colloid migration in fractured media. The report concludes with appendices documenting work at the new Cheshire well, a list of detonations below or near the water table, and a tentative proposal for work to be done by personnel from the Lamont-Doherty Geological Observatory.

Section 2. Radionuclide Migration at the Cheshire Event Site

R. W. Buddemeier, J. H. Rego, R. A. Failor, and K. V. Marsh

Introduction

The Cheshire detonation site (U20n, see Frontispiece) at the NTS has been under investigation by the HRMP for several years and has been most recently described by Buddemeier.[1] The Event was fired in 1976 with an announced yield in the range 200–500 kt. The detonation occurred beneath the water table in the fractured rhyolitic lavas of Pahute Mesa. Because of the event's size, its location in a relatively permeable formation, and the proximity of the NTS boundary hydrologically down-gradient from the Event site, it was considered an excellent candidate for studies of radionuclide migration in groundwater.

Site Studies

In 1976, our efforts to sample water from the bottom of the postshot drillback hole below the cavity were only marginally successful. However, the hole was reconditioned in 1983 and substantial quantities of water were pumped from the cavity region. The radionuclide analyses showed activity levels well below those expected if the total yield had remained in the vicinity of the cavity, leading to the suggestion that considerable migration might have occurred. United States Geological Survey (USGS) investigations of U20a No. 2, a nearby well, indicated the existence of a vertical head gradient from below the shot point upwards to the permeable zones located at depths of 2400 to 2700 ft and 2900 to 3100 ft. Groundwater could be expected to flow upward through natural or shot-induced fractures, then horizontally away from the shot area through permeable zones.[2]

A preliminary test of flow and migration hypotheses was possible because the slant-drilled reentry hole used for the study intercepted the water table and permeable zone above and down-gradient from the cavity and outside the probable chimney region. In 1985, the well casing was plugged above the cavity and reperforated in the upper permeable zone. When sampling resumed at that level, it became apparent that concentrations were only slightly lower than those observed in the cavity, and that radionuclides in both dissolved and particulate (colloidal) form had moved from the cavity to the upper sampling location. Detailed interpretations were not possible, however, because of concerns over the likelihood of migration along the well casing annulus and the possibility that the second sampling point was within the range of blast-induced fracturing or radionuclide injection.

Because of strong evidence that radionuclide migration was occurring, a second test well was drilled in May and June, 1987. Located approximately 100 m farther down-gradient from the upper permeable zone sampling point in the reentry well, the new well (UE20n-1) was offset laterally to minimize the possibility of interaction with transport pathways associated with the older well. Drilling was planned and supervised by the four agencies involved in the HRMP (LLNL, LANL, DRI, and the USGS). LLNL was responsible for field analysis of formation water and drilling fluids for tritium and gamma-emitting nuclides.

Records for well UE20n-1 are included as Appendix A (initial summary log) and Appendix B (sample log and results of measurements during drilling, preliminary bailing, and initial pumping).

Results

Table 2-1 presents a summary of decay-corrected tritium activities observed at the various sampling depths in the reentry hole and during the drilling of the new well. The tritium values observed during drilling are necessarily lower limits on the activity of the formation water because of dilution with the non-tritium-containing water used to make up the drilling foam.

Table 2-2 presents the maximum observed levels of ^{99}Tc, ^{125}Sb, and ^{137}Cs, the major non-tritium radionuclides. Figure 2-1 shows the combined geology, hydrology, and geometry of the sampling points relative to the estimated cavity-chimney region. Also depicted in Fig. 2-1 are the temperature profile measured in one of the post-drilling logging operations and a profile of

Table 2-1. Groundwater tritium concentrations, corrected to detonation time, at various depths at the Cheshire site, μCi/ml.

	Hole region and sampling dates			
Depth, m	UE20n-1 down-gradient 5/87, 7/87	U20nPS above cavity 11/85, 5/85	U20nPS cavity 10/84, 9/83	U20nPS below cavity 9/76
600	0.007			
	0.003			
700	0.290			
	0.620, 0.580[a]			
	0.670			
	0.530			
800	0.460	0.4, 0.430		
	0.4			
900	0.030			
1000	0.030			
1100				
1200			0.5, 0.620	
1300				2.20

a. After pumping 9.70×10^5 gallons.

Table 2-2. Maximum ^{99}Tc, ^{125}Sb, and ^{137}Cs concentrations, corrected to detonation time, for various groundwater sampling locations at the Cheshire site, μCi/ml.

	Hole region, depths, and sampling dates			
Radionuclide	UE20n-1 down-gradient 701-734 m 5/87, 7/87	U20nPS above cavity 763-858 m 5/85	U20nPS in cavity 1206-1220 m 9/83	U20nPS below cavity 1239-1272 m 9/76
^{99}Tc	–	3.7×10^{-8}	4.8×10^{-8}	–
	5.6×10^{-8} (7/87)			
^{125}Sb	2.2×10^{-6} (5/87)	4.0×10^{-6}	7.2×10^{-6}	1.8×10^{-6}
	2.3×10^{-6} (7/87)			
^{137}Cs	$<3.3 \times 10^{-8}$ (5/87)	7.4×10^{-7}	4.6×10^{-6}	5.1×10^{-9}
	$<5.0 \times 10^{-10}$ (7/87)			

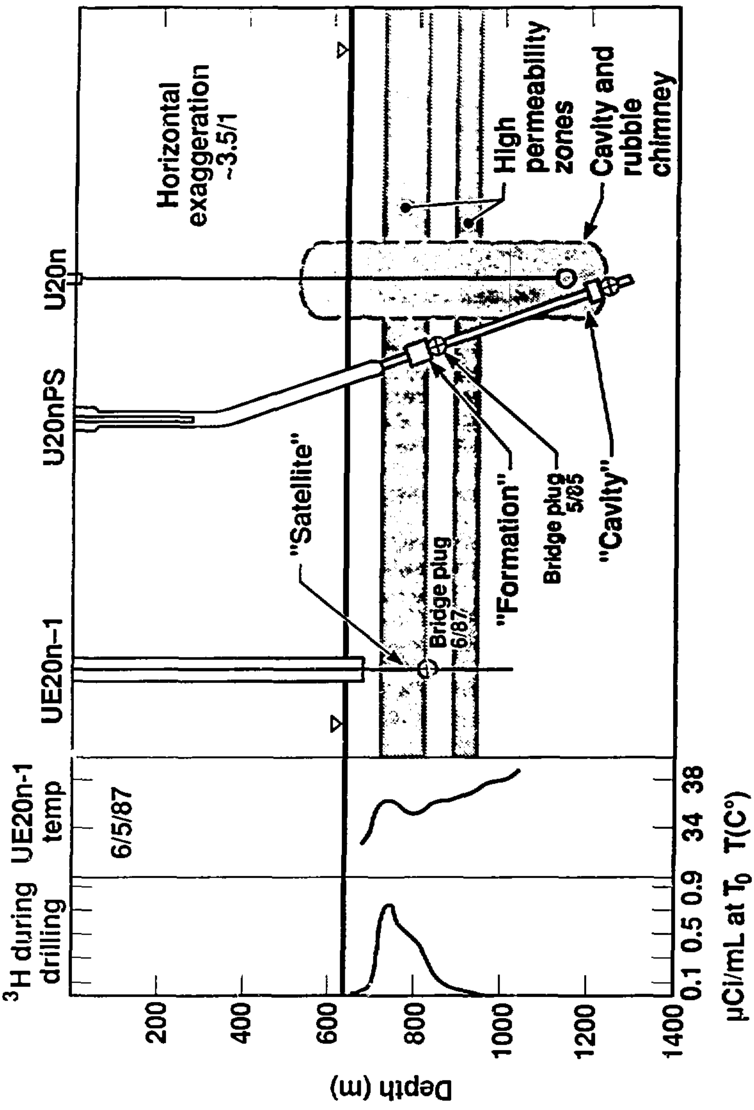

Figure 2-1. Vertical section showing Cheshire study locations, hydrogeology, and initial tritium and temperature observations in hole UE20n-1.

the tritium concentrations observed during the drilling.

Although these results are preliminary and further work is planned, important information has already been obtained. First, we note that the tritium concentration maximum and the shallow-temperature maximum observed in the new well are coincident and occur at approximately the upper boundary of the upper permeable zone. This provides strong evidence in support of the model that convectively-driven warmer water from deeper zones is flowing upward through the cavity and chimney, then horizontally through the permeable layers. The temperatures observed are consistent with other measurements by the USGS in the area and do not appear to be directly attributable to residual heat from the detonation.

Second, it is significant that at the new well location we have observed the highest tritium activity seen since the first postshot samples taken outside and above the cavity. Both inside and above the cavity, tritium concentrations decreased over the course of the observations; this suggests that we were looking at the tail of a contaminant pulse, the peak of which had already passed both locations. The higher activity observed downgradient (note that only decay corrections have b... made, and no dispersion corrections have been applied) shows that the peak of the tritium activity pulse has moved well out of the cavity; observations over time will tell us whether the new location is on the leading or trailing edge of that pulse. In either case, the volume of formation material now shown to contain significant levels of radionuclides is large enough to explain why the observed cavity concentrations in 1983 were lower than predicted.

The data of Table 2-2 indicate that the general pattern observed in comparing the radionuclide concentrations between the cavity and first external sampling location is qualitatively consistent with the new observations: antimony and technetium are mobile contaminants, while cesium is much more strongly retarded in its movement through the formation. If we estimate rates of water movement by assuming that tritium is a conservative tracer and that vertical equilibration of the cavity and chimney took place promptly after the Event, then horizontal flow velocity (and conservative radionuclide migration velocity) in the formation must be significantly in excess of 10 m/yr. The actual value cannot be determined without identifying the leading edge of the contaminant plume and the direction of the most rapid flow.

All four agencies agreed that we should not vigorously pump or surge the new well, but rather, in an attempt to observe as nearly as possible natural migration rates, we should install a low-volume pump and collect samples with as little stress on the aquifer as possible. A 14-gpm pump was installed as the best solution to collecting representative samples with minimum disturbance. We intend to collect samples over the next few years with minimum pumping to try to determine whether we are observing the front, middle, or tail of the plume

Conclusions

These initial results are important for the following reasons.

- We conclude that we are dealing with transport of device-originated radionuclides by the natural hydrologic regime.
- We have obtained important new data on the rates of groundwater flow and the behavior of the plume of mixed radionuclides.
- We can use these data to validate a proposed model of the flow path.

Additional work is planned and in progress to characterize the geochemistry, hydrology, and ... nuclide concentrations and speciation at the new well site. Addition of this third sampling point, particularly because of its validation of the results obtained at the earlier sites, will permit more detailed interpretation of the interactions between the aquifer and the contaminated water. We anticipate that the combination of the water studies with characterization of the cores and cutting samples obtained during drilling will permit us to extract important data from what is essentially the first documented study of large-scale radionuclide transport in a deep hard-rock environment. The results will be significant to broad areas of geochemistry and waste disposal as well as to the HRMP.

Section 3. Laboratory Studies of Colloid Migration in Fractured Media

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Introduction

The experimental results of the colloid investigation at the Cheshire site were discussed in detail in last year's HRMP report,[1] and a brief summary of that work will be useful as an introduction to our planned laboratory studies.

Large-volume water samples collected from the "cavity" and "formation" locations in the directional-drilled reentry hole were processed at LLNL by serial-filtration and ultrafiltration techniques. The results showed that some radionuclides produced during detonation were present both in solution and associated with colloidal materials at the two locations. The data also showed that cesium adsorption to colloids at the Cheshire site followed previously-determined isotherms. Geochemical modeling, X-ray diffraction studies, and X-ray fluorescence analyses were all consistent in supporting the existence and transport of colloids from the cavity to the external formation. This is the first field demonstration that radionuclides are transported by colloids through fractured media.

The Cheshire data from the reentry hole indicated that for the strongly-sorbed radionuclides, their total activity at the formation location was only 2.5% of the cavity activity. This indicates removal of colloids from suspension onto fracture surfaces and may be a mechanism that limits colloid migration in the region. Still, mobility of strongly-sorbing species hundreds of meters is entirely unexpected using conventional models that are based on the assumption that sorbed species are immobile.

The existing data on radionuclide migration at the Cheshire site cannot be used for predictive modeling, nor are existing theories applicable. The two major problems are to identify the mobile colloids at Cheshire and then to develop predictive models for their mobility in fractured media. Identification of colloids collected from various locations within the NTS is being undertaken by Dr. Roger Jacobson (DRI), while the U.C. Berkeley group has identified critical experimental measurements needed to quantify colloid migration in fractured media.

Laboratory Experiments

Experimental data collected in the laboratory are essential because available theories for colloid removal are inadequate. The physical transport mechanisms of sub-micrometer colloids to defined mineral surfaces are well known and experimentally verified. However, under natural water conditions, colloid collision with mineral surfaces only occasionally results in attachment because of electrostatic repulsion between particle and mineral surfaces. Theoretical predictions for electrostatic effects under well-defined conditions differ from experimental observations by orders-of-magnitude. Furthermore, fracture surfaces are covered with secondary minerals produced by weathering reactions, and thus do not represent ideal, flat mineral surfaces. Colloid deposition on surfaces containing previously deposited colloids on secondary mineral growths is the important issue on long-term transport in natural environments, but no applicable theory or experimental data are available.

Considering the above, the U.C. Berkeley group has designed a laboratory experiment to quantify colloid retention and permeability alteration by the retained colloids. The experiments initially will be conducted by flowing a dilute suspension of known clay colloids in a narrow (≤1 mm) channel between two parallel glass plates. With time, a deposit of clay colloids will begin to plug the channel until an equilibrium is reached when particles are no longer retained because hydrodynamic shear forces exceed colloid-deposit attachment forces. Colloid retention over time and at different locations will be monitored by passing a light beam through the glass plates. The independent parameters of interest are imposed flow rate, aqueous solution composition, and channel width. The measurements will determine colloid mass retention, and permeability alteration. It is expected that predictive, although empirical, relationships will result between these measures of clogging and the structural characterization of colloid aggregates through rheological measurements.

The above experimental design will be tested with a well-characterized clay mineral, probably kaolinite, during the coming year. At the completion of these experiments, a sufficient supply of NTS colloids may be available to permit using them in the experimental apparatus. On completion of the experiment, we will understand the mechanism of colloid retention and permeability alteration in fractured media. We can then address the important issues of colloid release from fracture surfaces following detonations and issues of regional colloid migration through fracture networks.

References

1. R. W. Buddemeier, *Hydrology and Radionuclide Migration Program 1985–1986 Progress Report*, Lawrence Livermore National Laboratory, Livermore, California, UCRL 53779 (1988).
2. R. K. Blankennagel and J. E. Weir, Jr., *Geohydrology of the Eastern Part of Pahute Mesa, Nevada Test Site, Nye County, Nevada*, United States Geological Survey Professional Paper 712-B, United States Government Printing Office, Washington, D.C. (1973).
3. R. Gunnink and J. B. Niday, *Computerized Quantitative Analysis by Gamma-Ray Spectrometry*, Lawrence Livermore National Laboratory, Livermore, California, UCRL-51061 (1972).

Appendix A

Initial Summary Log of UE20n-1

This summary log covers the period from the start of drilling for the surface casing on 5/15/87 through initial pumping on 9/17/87. Corrections and additions to this log have been solicited from the other HRMP organizations, and a final revision will be published by the USGS. The data, compiled by USGS, are included here as a convenient one-source working reference of the status of the well when various samples were collected.

Note that the flow meter was not installed until 7/22/87, so the flow volumes are estimates that include the volume before 7/22/87.

Table A-1. Initial summary log of UE20n-1.

Date	Time	Activity	Meter reading, gal	Incremental volume,[a] gal	Total volume,[a] gal
05/15/87		Drill 17-1/2" hole and set 13-3/8" casing	-	-	-
05/18/87		Set up to drill	-	-	-
05/19/87		Begin drilling through surface casing cement	-	-	-
05/20/87	0000	591 feet	-	-	-
05/21/87		Setting up bottom hole assembly to bring hole back into line	-	-	-
05/22/87	0000	1392 feet	-	-	-
05/23/87	0000	1952 feet	-	-	-
	0905	2325 feet	-	-	-
	0928	Blow hole and collect samples	-	-	-
	1300	Out of hole	-	-	-
	1400	Start logging (fluid density, caliper, induction, gamma)	-	-	-
05/24/87		No spikes in gamma log — OK to case to 2300 ft	-	-	-
	1000	Start running 9-5/8" casing into hole, casing run to 2283 feet, cement hole	-	-	-
05/25/87		Holiday	-	-	-
05/26/87		Cement job resulted in cement not being pumped into annulus as expected; because of poor tacking strength, drilling of the cement proceeded slowly.	-	-	-
05/27/87	0000	2103 feet still drilling out cement	-	-	-
	1140	2407 feet — trip out for coring	-	-	-
	1600	Trip in with core barrel	-	-	-
	1800	Blow hole	-	-	-
	1845	Start coring	-	-	-
	2010	Blow hole and collect sample	-	-	-
05/28/87	0330	2422 feet — trip out with core barrel	-	-	-
	0600	Core on table	-	-	-
	1430	Trip into hole	-	-	-
	1615	Blow hole and collect sample	-	-	-
05/29/87	0213	Trip in with core barrel	-	-	-
	0400	Blow hole	-	-	-
	0518	Start coring	-	-	-
	0745	2654 feet — trip out with core barrel	-	-	-

Table A-1 (continued).

Date	Time	Activity	Meter reading, gal	Incremental volume, gal	Total volume, gal
05/29/87	1000	Core on table	–	–	–
	1330	Trip into hole	–	–	–
	1355	Blow hole	–	–	–
05/30/87	0026	2877 feet	–	–	–
	0634	3003 feet — trip out for coring	–	–	–
	1000	Trip in with core barrel	–	–	–
	1130	Blow hole	–	–	–
	1245	Start coring	–	–	–
	1600	3017 feet — trip out with core barrel	–	–	–
	1745	Core on table	–	–	–
	1830	Trip into hole	–	–	–
	2121	Blow hole	–	–	–
05/31/87	0200	3066 feet	–	–	–
	1604	3300 feet	–	–	–
	1830	Start gyro survey	–	–	–
	2310	Blow hole	–	–	–
06/01/87	0200	Finish pulling pipe from hole	–	–	–
	0500	Start logging	–	–	–
06/02/87		Still running logs	–	–	–
06/04/87		USGS barrel samples	–	–	–
06/05/87		DRI logging and barrel samples	–	–	–
06/08/87		DRI logging and barrel samples	–	–	–
06/09/87		Special gravity log	–	–	–
06/10/87		Set drillable bridge plug at 2842 feet; sand plug on top of bridge plug	–	–	–
06/10/87	2315	Cement on top of sand	–	–	–
06/11/87		Bigin running dual casing string, set Moyno pump and sucker rods	–	–	–
06/12/87	1015	D/W [b]2033.65	–	–	–
06/22/87	1020	D/W 2032.35	–	–	–
	1307	Pump on	–	–	–
06/23/87	0925	Pump off	–	–	17,000
	1125	D/W 2032.40	–	–	–
06/26/87	1000	D/W 2032.6	–	–	–
07/02/87	1130	D/W 2032.45	–	–	–
07/07/87	1000	D/W 2032.65	–	–	–
	1055	Pump on	–	–	–
07/09/87	1225	D/W 2036.25	–	–	–
	1225	Pump off	–	21,000	38,000
	1227	D/W 2032.5	–	–	–
07/13/87		DRI logging	–	–	–
07/14/87		DRI logging and barrel samples	–	–	–
07/20/87		DRI logging and barrel samples	–	–	–
		Pump on	–	–	–
07/21/87		Pump off (sometime during graveyard)	–	15,000	53,000
		LANL samples	–	–	–

Table A-1 (continued).

Date	Time	Activity	Meter reading, gal	Incremental volume, gal	Total volume, gal
07/22/87		Pump on, flow meter installed	-	-	-
07/23/87	0950	Pump off, DRI logging	-	50,718	103,718
07/27/87	1022	Pump on	125,470	-	-
	1024		125,498	-	-
	1025		125,509	-	-
	1045	(125,790 G–125,470 G)/23 min = 14 GPM	125,790	-	-
	1045	Pump off, needs repacking. Repack pump, install flowmeter, pump on	-	-	-
07/28/87		Moyno pump breaks down, noticed during early morning check	-	-	-
08/03/87		Moyno pump repairs, sucker rod failed	-	-	-
	1403	Pump on	-	-	-
	1441	Water at wellhead	-	-	-
08/04/87	1800	Pump off	176,773	51,303	155,021
08/06/87	1145	D/W 2033.15	-	-	-
08/24/87	1120	D/W 2033.15	179,756	-	-
09/01/87	1130	D/W 2032.9	-	-	-
09/08/87	1020	D/W 2033.3	-	-	-
	1055	Pump on	179,756	-	-
	1300	Pump off	180,900	1,144	156,165
09/11/87	1000	Pump on	180,963	-	-
	1230	Pump off	182,551	1,588	157,753
09/17/87	1020	D/W 2032.5	-	-	-
	1022	Pump on	182,532	-	-
	1205	Pump off	183,452	920	158,673

a. Incremental volume estimated before 8/4/87

b. D/W = depth to standing water, feet

Appendix B

Summary of Initial Measurements on Water Samples from UE20n-1

B-1: UE20n-1 sample log — A description of all samples collected from start of drilling on 5/20/87 through the final pumping on 8/6/87.

B-2: Laboratory measurements of γ-ray-emitting radionuclides.

B-3: Field measurements conducted during the drilling, bailing, and pumping sequences.

B-4: Laboratory measurements of trace cations and anions.

Appendix B-1. UE20n-1 Sample Log from 5/20/87 through 8/6/87

Background

We felt that it would be useful to make measurements of tritium, γ-ray-emitting radionuclides, bromide, and detergent concentrations in the field as aids in making decisions during drilling and initial sampling of UE20n-1. We equipped a trailer with a simple, single-sample, 2-channel liquid scintillation counter and two intrinsic germanium γ-detectors, one in "up-looker" configuration, the other as a "side-looker." Output signals from each detector were processed by an ND-66 analyzer, and stored on disk for spectral analysis, in the field, on an LSI-11 processor using GRPANAL, a small scale version of GAMANAL.[3] The side-looker was used for counting core samples and rock chips, mostly in a survey mode. Although counting efficiencies for core and chip samples were not well known due to their irregular size and shape, this had no effect on isotope identification, and quantitative determinations of radionuclide concentrations in such samples was of limited utility at best. Furthermore, from a practical standpoint, no artificial radionuclides were detected in any core or chip sample; however, counting times were necessarily short, a few hours to a day at most, due to the number of samples we had to process. The up-looker was used mostly for counting water samples in Marinelli beakers, but could also be used to survey cores and chips. (See ref. 1 for a discussion of our use of Marinelli beakers.) Counting times in the field for liquid samples were also necessarily short, and no radioactivity above background was detected, although several samples counted later for one week under laboratory conditions did show very low concentrations of several radionuclides. These results are reported in Appendix B-2.

Before valid samples could be collected from the well, we needed to know that they were representative of the water at depth, uncontaminated by drilling water. Bromide ion was maintained at a concentration of 30–60 ppm in the drilling fluid to indicate its presence, but the detergent added as a drilling aid at a concentration of about 5500 ppm proved to be a more sensitive indicator. Bromide and detergent concentrations were measured in the field both by LANL and LLNL personnel using a LANL-supplied ion chromatograph. Detergent concentrations measured during the bailing and pumping sequences are listed in Appendix B-3.

Introduction to the Log

The sample collection log was designed to keep track of the many samples collected during the drilling, bailing, and initial pumping activities conducted at UE20n-1.

The first four characters of the sample number were derived by combining the first two letters of the site name (Cheshire) and two characters from the well name (UE20n-1) to indicate samples collected from the first satellite well at the Cheshire site. The remainder of the number is merely a sequential number; sub-sample aliquots are identified alphabetically.

Tritium was measured on most of the samples and results are not listed separately in this log. A summary of the tritium data is included in Section 2, and results of individual determinations are included in Appendix B-3. The analysis key indicates other analyses performed on each sample or aliquot. A list of the abbreviations and corresponding analyses is given below:

C.A.	LLNL 1-l Marinelli beaker gamma count
IC	Anion concentrations measured by ion chromatography
ICP	Cation concentrations measured by inductively-coupled-plasma emission spectroscopy
I-129	To be analyzed for I-129 by accelerator mass spectrometry
REECo	Submitted for tritium and gamma spectrometric analyses by REECo Environmental Monitoring Laboratory, Mercury
Tc	Analyzed for ^{99}Tc

The **Volume** column indicates the sample volume used for analysis, not necessarily the total volume collected. The **Agency** column lists the original sample-collection laboratory. For example, DRI collected samples for field measurements of pH, temperature, and conductivity. Most of these samples were later released to LLNL for further analysis. All the samples listed here were analyzed in the field or laboratory, or placed in archives. Field and laboratory analytical results are presented in the accompanying tables. The sample description gives information concerning activities occurring during, or immediately preceding the sample collection period. It is necessarily short, and often contains drilling terminology. Further information regarding activities affecting sampling during the drilling operation can be obtained by referring to the drilling log (Appendix A).

All samples listed here are water with the exception of CH-E1-13E, which is chips. This sample was requested from the USGS core library for background studies. All chips and core samples were logged and saved by the USGS using their labeling conventions.

Table B-1. Cheshire satellite sample log (UE20n-1).

Log No.	Date	Time (hrs)	Depth (ft)	Analysis key	Volume (l)	Agency	Description
CH-E1-000	05/20/87	0900	840–850		0.1	LLNL	Wash of the Blooie line
CH-E1-001	05/20/87	1700	985		0.1	LLNL	Wash of the Blooie line
CH-E1-001A	05/20/87	1700	985	IC,ICP	2.0	LLNL	Wash of the Blooie line
CH-E1-002	05/21/87	1200	1232		0.1	LLNL	End of the Blooie line
CH-E1-003	05/21/87	2140	1360	C.A.	1.0	LLNL	End of the Blooie line
CH-E1-004	05/22/87	0950	?		0.1	LLNL	End of the Blooie line
No Log #	05/23/87	0304	2080		0.1	LLNL	End of the Blooie line
CH-E1-005	05/23/87	0530	2080		0.1	LLNL	End of the Blooie line
CH-E1-006	05/23/87	0700	2201		0.1	LLNL	End of the Blooie line
CH-E1-007	05/23/87	0900	2320		0.1	LLNL	Bailed during logging
CH-E1-008	05/23/87	0930	2323	C.A.	1.0	LLNL	First of first stage blowdown
CH-E1-009	05/23/87	0930	2323		3.0	LLNL	Second of first stage blowdown
CH-E1-009A	05/23/87	0930	2323		1.0	LLNL	Second of first stage blowdown
CH-E1-009B	05/23/87	0930	2323	REECo	1.0	LLNL	Second of first stage blowdown
CH-E1-010	05/23/87	0930	2323		4.0	LLNL	Third (last) of first stage blowdown
CH-E1-011	05/23/87	0930	2323		200	LLNL	Mud pit after first water zone
CH-E1-012	05/24/87	0500	2323		0.1	LLNL	Bailed during logging
CH-E1-013	05/24/87	1820	2407		200	LLNL	Blowdown—precoring
CH-E1-013A	05/24/87	1820	2407	IC	0.5	DRI	Blowdown—precoring
CH-E1-013B	05/24/87	1820	2407	ICP	0.5	DRI	Blowdown—precoring
CH-E1-013C	05/24/87	1820	2407	REECo	0.25	LLNL	Blowdown—precoring
CH-E1-013D	05/24/87	1820	2407	REECo	1.0	LLNL	Blowdown—precoring
CH-E1-013E	05/24/87	1820	2407		0.5	LLNL	Blowdown—precoring
CH-E1-014	05/27/87	1100	2408	C.A./Tc	1.0	LLNL	Last drillstring—precoring
CH-E1-015	05/27/87	1150	2410	Tc	0.1	LLNL	Last drillstring—precoring
CH-E1-015A	05/27/87	1150	2410		2.0	LLNL	Last drillstring—precoring
CH-E1-015B	05/27/87	1150	2410		0.25	LLNL	Last drillstring—precoring
CH-E1-015C	05/27/87	1150	2410		1.0	LLNL	Last drillstring—precoring
CH-E1-016	05/27/87	1800	2408	C.A.	4.0	LLNL	Second blowdown before coring
CH-E1-017	05/28/87	1600	2423		200.	LLNL	Blowdown after coring
CH-E1-018	05/28/87	1640	2423	C.A.	8.0	LLNL	Last fraction after coring
CH-E1-019	05/29/87	0415	2629		1.0	LLNL	Pre-coring blowdown
CH-E1-020	05/29/87	0430	2629		200.	LLNL	Blowdown before second coring
CH-E1-020A	05/29/87	0430	2629		4.0	LLNL	Blowdown before second coring
CH-E1-021	05/29/87	0550	2629		1.0	LLNL	Unlabeled sample
CH-E1-022	05/29/87	0600	2629		1.0	LLNL	Unlabeled sample

Table B-1 (continued).

Log No.	Date	Time (hrs)	Depth (ft)	Analysis key	Volume (l)	Agency	Description
CH-E1-023	05/29/87	0600	2630	IC	0.5	DRI	Pre-coring blowdown
CH-E1-023A	05/29/87	0600	2630	ICP	0.5	DRI	Pre-coring blowdown
CH-E1-024	05/29/87	1410	2659	IC	0.5	DRI	First sample after drill resume
CH-E1-024A	05/29/87	1410	2659	ICP	0.5	DRI	First sample after drill resume
CH-E1-025	05/30/87	1200	3003	C.A.	1.0	LLNL	Last fraction before coring
CH-E1-026	05/30/87	1230	3003	IC	0.5	DRI	Last fraction before coring
CH-E1-026A	05/30/87	1230	3003	ICP	0.5	DRI	Last fraction before coring
CH-E1-026B	05/30/87	1230	3003		200.	LLNL	Last fraction before coring
CH-E1-027	05/31/87	0930	3003		1.0	LLNL	Blowdown post core
CH-E1-027A	05/31/87	0930	3003		4.0	LLNL	Blowdown post core
CH-E1-028	05/31/87	1700	3016		200.	LLNL	Blowout after coring
CH-E1-029	05/31/87	2300	3294	IC	0.5	DRI	Drilling resumed
CH-E1-029A	05/31/87	2300	3294	ICP	0.5	DRI	Drilling resumed
CH-E1-030	05/31/87	2315	3300		200.	LLNL	Blowout after drilling to T.D.
CH-E1-031	05/31/87	2335	3300		1.0	LLNL	After Gyro log
CH-E1-032	06/02/87	1300	2400		1.0	USGS	Bailed by USGS
CH-E1-033	06/02/87	1410	2650		1.0	USGS	Bailed by USGS
CH-E1-034	06/02/87	1515	3000		1.0	USGS	Bailed by USGS
CH-E1-035	06/02/87	1630	3250	IC,ICP	1.0	USGS	Bailed by USGS
CH-E1-036	06/05/87	?	2400		1.0	DRI	Bailed by DRI
CH-E1-037	06/05/87	1600	2650		1.0	DRI	Bailed by DRI
CH-E1-038	06/05/87	1700	3000		1.0	DRI	Bailed by DRI
CH-E1-038A	06/05/87	1700	3000		1.0	DRI	Bailed by DRI
CH-E1-039	06/05/87	2040	3286		1.0	DRI	Bailed by DRI
CH-E1-039A	06/05/87	2040	3286		1.0	DRI	Bailed by DRI
CH-E1-040	06/08/87	1430	2400	IC,ICP	1.0	DRI	Bailed by DRI
CH-E1-040A	06/08/87	1430	2400		1.0	DRI	Bailed by DRI
CH-E1-041	06/08/87	1530	2650	IC,ICP,C.A.	1.0	DRI	Bailed by DRI
CH-E1-041A	06/08/87	1530	2650		1.0	DRI	Bailed by DRI
CH-E1-042	06/08/87	1659	3000	IC,ICP	1.0	DRI	Bailed by DRI
CH-E1-042A	06/08/87	1659	3000		1.0	DRI	Bailed by DRI
CH-E1-043	06/08/87	?	3250	IC,ICP	1.0	DRI	Bailed by DRI
CH-E1-043A	06/08/87	?	3250		1.0	DRI	Bailed by DRI
CH-E1-044	06/22/87	1315	2850		1.0	DRI	Pumped by DRI
CH-E1-045	06/22/87	1345	2850		1.0	DRI	Pumped by DRI
CH-E1-046	06/22/87	1400	2850		1.0	DRI	Pumped by DRI
CH-E1-047	06/22/87	1500	2850		1.0	DRI	Pumped by DRI
CH-E1-048	06/22/87	1600	2850		1.0	DRI	Pumped by DRI
CH-E1-049	06/22/87	1700	2850		1.0	DRI	Pumped by DRI
CH-E1-050	06/22/87	1800	2850		1.0	DRI	Pumped by DRI
CH-E1-051	06/22/87	1900	2850		1.0	DRI	Pumped by DRI
CH-E1-052	06/22/87	2100	2850		1.0	DRI	Pumped by DRI
CH-E1-053	06/22/87	2200	2850		1.0	DRI	Pumped by DRI
CH-E1-054	06/23/87	0000	2850		1.0	DRI	Pumped by DRI
CH-E1-055	06/23/87	0200	2850		1.0	DRI	Pumped by DRI
CH-E1-056	06/23/87	0400	2850		1.0	DRI	Pumped by DRI
CH-E1-057	06/23/87	0600	2850		1.0	DRI	Pumped by DRI
CH-E1-058	06/23/87	0900	2850	IC,ICP	1.0	LLNL	Collected at the end of 20 hrs
CH-E1-059	07/07/87	1200	2850		1.0	LLNL	Started pump at 1055 water level 2033 ft

Table B-1 (continued).

Log No.	Date	Time (hrs)	Depth (ft)	Analysis key	Volume (l)	Agency	Description
CH-E1-059A	07/07/87	1200	2850		0.250	DRI	Started pump at 1055 water level 2033 ft
CH-E1-060	07/07/87	1300	2850		1.0	LLNL	LLNL sampling/monitoring
CH-E1-060A	07/07/87	1300	2850	IC,ICP	.250	DRI	LLNL sampling/monitoring
CH-E1-061	07/07/87	1400	2850		1.0	LLNL	LLNL sampling/monitoring
CH-E1-061A	07/07/87	1400	2850	IC	.250	DRI	LLNL sampling/monitoring
CH-E1-062	07/07/87	1500	2850		1.0	LLNL	LLNL sampling/monitoring
CH-E1-062A	07/07/87	1500	2850		.250	DRI	LLNL sampling/monitoring
CH-E1-063	07/07/87	1600	2850		1.0	LLNL	Pumped sample
CH-E1-063A	07/07/87	1600	2850		.250	DRI	Pumped sample
CH-E1-064	07/07/87	1700	2850	Tc	1.0	LLNL	Pumped sample
CH-E1-064A	07/07/87	1700	2850		.250	DRI	Pumped sample
CH-E1-065	07/07/87	1800	2850	Tc	1.0	LLNL	Pumped sample
CH-E1-065A	07/07/87	1800	2850		.250	DRI	Pumped sample
CH-E1-066	07/07/87	2100	2850		1.0	LLNL	Pumped sample
CH-E1-066A	07/07/87	2100	2850	IC,ICP	.250	DRI	Pumped sample
CH-E1-067	07/08/87	0645	2850		1.0	LLNL	Pumped sample
CH-E1-068	07/08/87	0800	2850		1.0	LLNL	Pumped sample
CH-E1-068A	07/08/87	0800	2850		.250	DRI	Pumped sample
CH-E1-069	07/08/87	0900	2850		1.0	LLNL	Pumped sample
CH-E1-070	07/08/87	1000	2850		1.0	LLNL	Pumped sample
CH-E1-071	07/08/87	1100	2850		1.0	LLNL	Pumped sample
CH-E1-072	07/08/87	1300	2850		1.0	LLNL	Pumped sample
CH-E1-073	07/08/87	1400	2850		1.0	LLNL	Pumped sample
CH-E1-074	07/08/87	1500	2850		1.0	LLNL	Pumped sample
CH-E1-075	07/08/87	1600	2850		1.0	LLNL	Pumped sample
CH-E1-076	07/08/87	1700	2850		1.0	LLNL	Pumped sample
CH-E1-077	07/08/87	1900	2850	IC,ICP	1.0	LLNL	Pumped sample
CH-E1-077A	07/08/87	1900	2850	IC,ICP	.250	LLNL	Pumped sample
CH-E1-078	07/09/87	0645	2850		1.0	LLNL	Pumped sample
CH-E1-079	07/09/87	0800	2850		1.0	LLNL	Pumped sample
CH-E1-079A	07/09/87	0900	2850		1.0	LLNL	Pump off at 1225
CH-E1-079B	07/09/87	1000	2850	IC,ICP	1.0	LLNL	Pumped sample
CH-E1-079C	07/09/87	1100	2850		1.0	LLNL	Pumped sample
CH-E1-079D	07/09/87	1100	2850	Tc	200.	LLNL	Pumped sample
CH-E1-079E	07/09/87	1100	2850	Tc	200.	LLNL	Pumped sample
CH-E1-080	07/20/87	—	2400		1.0	LLNL	DRI bailed samples
CH-E1-080A	07/20/87	—	2400	ICP	.250	LLNL	DRI bailed samples
CH-E1-081	07/20/87	—	2600	C.A.	1.0	LLNL	DRI bailed samples
CH-E1-081A	07/20/87	—	2600	ICP	.250	LLNL	DRI bailed samples
CH-E1-082	07/20/87	—	2750	Tc	1.0	LLNL	DRI bailed samples
CH-E1-082A	07/20/87	—	2750		.250	LLNL	DRI bailed samples
CH-E1-083	07/20/87	1300	2750	C.A.	1.0	LLNL	LLNL sampling/monitoring
CH-E1-084	07/20/87	1400	2750		1.0	LLNL	LLNL sampling/monitoring
CH-E1-085	07/20/87	1500	2750		1.0	LLNL	LLNL sampling/monitoring
CH-E1-086	07/20/87	1600	2750	Tc	1.0	LLNL	LLNL sampling/monitoring
CH-E1-087	07/20/87	1700	2750		1.0	LLNL	LLNL sampling/monitoring
CH-E1-088	07/20/87	1800	2750		1.0	LLNL	LLNL sampling/monitoring
CH-E1-089	07/22/87	1000	2750	IC,ICP	1.0	LLNL	LLNL sampling/monitoring
CH-E1-090	07/22/87	1100	2750		1.0	LLNL	LLNL sampling/monitoring

Table B-1 (continued).

Log No.	Date	Time (hrs)	Depth (ft)	Analysis key	Volume (l)	Agency	Description
CH-E1-091	07/22/87	1200	2750		1.0	LLNL	LLNL sampling/monitoring
CH-E1-092	07/22/87	1300	2750		1.0	LLNL	LLNL sampling/monitoring
CH-E1-093	07/22/87	1400	2750		1.0	LLNL	LLNL sampling/monitoring
CH-E1-094	07/22/87	1500	2750	Tc	1.0	LLNL	LLNL sampling/monitoring
CH-E1-095	07/22/87	1600	2750	IC,ICP	1.0	LLNL	LLNL sampling/monitoring
CH-E1-095A	07/22/87	1600	2750	IC,ICP	.250	LLNL	LLNL sampling/monitoring
CH-E1-096	07/23/87	0950	2750	C.A./Tc	1.0	LLNL	Planned continuous pumping
CH-E1-096A	07/23/87	0950	2750		200	LLNL	Planned continuous pumping
CH-E1-097	07/23/87	1015	2750		200	LLNL	Planned continuous pumping
CH-E1-098	07/23/87	?	2400	I-129	1.0	DRI	Bailed by DRI
CH-E1-098A	07/23/87	?	2400		0.25	DRI	Bailed by DRI
CH-E1-099	07/23/87	?	2600	Tc	1.00	DRI	Bailed by DRI
CH-E1-099A	07/23/87	?	2600	IC,ICP	0.25	DRI	Bailed by DRI
CH-E1-100	08/06/87	1600	2750	Tc	0.25	DRI	Pump failed and was rebuilt
CH-E1-101	08/06/87	1700	2750		1.00	DRI	Collected by DRI Huckens
CH-E1-102	08/06/87	1800	2750	IC,ICP	1.00	DRI	Collected by DRI Huckens
CH-E1-103	08/06/87	1830	2750		1.00	DRI	Collected by DRI Huckens
CH-E1-104	08/06/87	1930	2750	IC,ICP,C.A.	1.00	DRI	Collected by DRI Huckens

Analysis key: C.A. — Counting aliquot
REECo — LLNL results confirmed by REECo Environmental Monitoring Laboratory
Tc — Aliquot for ^{99}Tc
IC — Anions measured by ion chromatograph
ICP — Cations measured by inductively-coupled-plasma emission spectroscopy
I-129 — Measurement by accelerator mass spectrometry

Appendix B-2. γ-Ray-Emitting Radionuclides in 1987 Samples of Water from UE20n1 (Detonation Time, 2/14/76).

Table B-2. Concentrations of gamma-emitting radionuclides in unfiltered water from UE20n-1, as determined by counting in Marinelli beakers, corrected to detonation time, µCi/ml

Date	5/21/87	5/23/87	5/27/87	5/28/87	5/30/87	6/8/87	7/20/87	7/20/87	7/23/87	8/6/87
Depth (ft)	1360	2323	2408	2423	3003	2650[a]	2600[a]	2750[b]	2750[b]	2750[b]
Volume (l)	0.8621	0.9838	0.9464	0.9542	0.9725	0.9473	0.9709	0.9801	0.9797	0.9583
Log No.	CH-E1-3	CH-E1-8	CH-E1-14	CH-E1-18	CH-E1-25	CH-E1-41	CH-E1-81	CH-E1-83	CH-E1-96	CH-E1-104
Nuclide										
^{22}Na	<1E-08	<1E-08	<1E-08	2.31E-08	<1E-08	4.08E-08	<1E-08	<1E-08	<1E-08	1.18E-08
^{40}K	1.63E-07	1.33E-07	<5E-08	9.00E-08	1.10E-07	1.27E-07	1.43E-07	<5.2E-08	1.05E-07	1.21E-07
^{125}Sb	<1E-08	1.33E-07	2.27E-06	1.79E-06	2.46E-08	8.41E-07	1.54E-06	1.07E-06	1.03E-06	9.07E-07
^{137}Cs	<1E-09	<1E-09	<1E-09	<1E-09	<1E-09	<1E-09	3.17E-09	<1E-09	<1E-09	<1E-09

a. Bailed
b. Pumped

Several other long-lived radionuclides might be present in the water from UE20n-1.
Upper limits for their detection in a 1-liter sample are given below (µCi/ml):

^{54}Mn	1E-09	^{144}Ce	2E-09
^{60}Co	1E-09	^{152}Eu	3E-09
^{85}Kr-	1E-09	^{154}Eu:	2E-09
^{106}Ru	2E-09	^{155}Eu:	3E-09

Table A-1 (continued).

Event name	Hole name	Sponsor	Date	DOB, m	SWL, m	SWLql
Dalhart	U4U	LANL	10/13/88	640.100	508	est.
Texarkana	U7CA	LANL	02/10/89	502.900	519	meas.
Amarillo	U19AY	LANL	06/27/89	640.100	649	meas.
Hornitos	U2QBC	LLNL	10/31/89	563.900	569	meas.

* Erratum. The 1987 report incorrectly gives the units as feet, instead of meters.

Table B-3. Part 3: Pumping sequence.

Sample Log No.	Date	Time	Total volume pumped (gal)	DRI[a] temp (deg C)	DRI[a] pH	DRI[a] E.C.	LLNL detergent (ppm)	LLNL[c] ^3H at T_0 (µCi/ml)	LLNL[c] ^3H S.D. (% error)
—	06/22/87	1307	—						
CH-E1-046	06/22/87	1400	742	—	—	—	—	4.19E-01	(1)
CH-E1-047	06/22/87	1500	1582	—	—	—	—	4.54E-01	(1)
CH-E1-048	06/22/87	1600	2422	—	—	—	—	4.39E-01	(1)
CH-E1-049	06/22/87	1700	3262	—	—	—	—	4.77E-01	(1)
CH-E1-050	06/22/87	1800	4102	—	—	—	—	4.76E-01	(1)
CH-E1-051	06/22/87	1900	4942	—	—	—	—	4.86E-01	0.61
CH-E1-052	06/22/87	2100	6622	—	—	—	—	4.13E-01	(1)
CH-E1-053	06/22/87	2200	7462	—	—	—	—	4.48E-01	(1)
CH-E1-054	06/23/87	0000	9142	—	—	—	—	5.07E-01	2.52
CH-E1-055	06/23/87	0200	10822	—	—	—	—	5.00E-01	2.82
CH-E1-056	06/23/87	0400	12502	—	—	—	—	5.14E-01	(1)
CH-E1-057	06/23/87	0600	14182	—	—	—	—	4.99E-01	1.48
CH-E1-058	06/23/87	0900	16702	—	—	—	—	5.00E-01	2.30
—	07/07/87	1055	17052						
CH-E1-059	07/07/87	1200	17962	28	8.08	445	—	4.83E-01	0.98
CH-E1-060	07/07/87	1300	18802	30	7.96	429	—	5.84E-01	3.17
CH-E1-061	07/07/87	1400	19642	31	7.72	387	16	5.94E-01	2.70
CH-E1-062	07/07/87	1500	20482	33	7.74	390	—	5.88E-01	1.14
CH-E1-063	07/07/87	1600	21322	33	7.74	404	—	6.36E-01	0.78
CH-E1-064	07/07/87	1700	22162	33	—	—	—	6.35E-01	1.00
CH-E1-065	07/07/87	1800	23002	31	—	—	15	6.01E-01	5.13
CH-E1-066	07/07/87	2100	25522	33	—	—	—	6.10E-01	1.69
CH-E1-067	07/08/87	0645	33712	33	7.78	345	15	5.13E-01	2.95
CH-E1-068	07/08/87	0800	34762	34	7.74	368	—	5.16E-01	4.67
CH-E1-069	07/08/87	0900	35602	33	7.90	370	—	5.64E-01	4.65
CH-E1-070	07/08/87	1000	36442	33	7.80	346	—	5.77E-01	4.26
CH-E1-071	07/08/87	1100	37282	33	7.86	377	—	5.20E-01	5.14
CH-E1-072	07/08/87	1300	38962	32	7.96	356	—	5.79E-01	4.93
CH-E1-073	07/08/87	1400	39802	32	7.91	376	—	6.18E-01	5.01
CH-E1-074	07/08/87	1500	40642	32	7.74	360	—	6.12E-01	3.16
CH-E1-075	07/08/87	1600	41482	33	7.76	352	—	5.32E-01	5.00
CH-E1-076	07/08/87	1700	42322	34	7.72	348	16	5.57E-01	5.08
CH-E1-077	07/08/87	1900	44002	32	—	340	—	6.48E-01	4.52
CH-E1-078	07/09/87	0645	53872	34	7.40	344	14	6.27E-01	1.81
CH-E1-079	07/09/87	0800	54922	—	7.65	353	—	5.76E-01	1.64
CH-E1-079A	07/09/87	0900	55762	32	7.75	363	—	4.91E-01	1.26
CH-E1-079B	07/09/87	1000	56602	33	7.90	368	—	5.41E-01	3.66
CH-E1-079C	07/09/87	1100	57442	33	7.82	350	—	6.17E-01	4.40
—	07/09/87	1225	58632	Pump off					

Table B-3. Part 3 (continued).

Sample Log No.	Date	Time	Total volume pumped (gal)	DRI[a] temp (deg C)	DRI[a] pH	DRI[a] E.C.	LLNL detergent (ppm)	LLNL[c] ^3H at T_0 (μCi/mL)	LLNL[e] ^3H S.D. (% error)
—	07/19/87	1950	58632	Pump on					
CH-E1-083	07/20/87	1300	72142	—	—	—	2.5	6.02E-01	1.48
CH-E1-084	07/20/87	1400	72982	—	—	—	—	6.12E-01	1.01
CH-E1-085	07/20/87	1500	73822	—	—	—	—	5.93E-01	(1)
CH-E1-086	07/20/87	1600	74662	—	—	—	—	5.78E-01	1.70
CH-E1-087	07/20/87	1700	75502	—	—	—	—	5.80E-01	0.33
CH-E1-088	07/20/87	1800	76342	—	—	—	—	5.72E-01	1.22
—				—	—	—	—		
CH-E1-089	07/22/87	1000	85582	—	—	—	5.0	5.66E-01	2.76
CH-E1-090	07/22/87	1100	86422	—	—	—	—	5.71E-01	0.16
CH-E1-091	07/22/87	1200	87262	—	—	—	—	5.64E-01	3.17
CH-E1-092	07/22/87	1300	88102	—	—	—	—	5.99E-01	0.90
CH-E1-093	07/22/87	1400	88942	—	—	—	—	5.84E-01	1.80
CH-E1-094	07/22/87	1500	89782	—	—	—	—	5.78E-01	1.92
CH-E1-095	07/22/87	1600	90622	—	—	—	—	5.73E-01	1.17
—	07/22/87	2200	95662	—	—	—	—		
CH-E1-096	07/23/87	0950	103784	—	—	—	3.0	5.91E-01	0.78
—	07/23/87	1545	103784	—	—	—	—		
—	07/27/87	1045	178856	—	—	—	—		
—	07/28/87	2257	208820	—	—	—	—		
—	08/03/87	1441	208820	—	—	—	—		
—	08/04/87	1800	259802	—	—	—	—		
CH-E1-100	08/06/87	1600	260223	—	—	—	—	5.48E-01	(1)
CH-E1-101	08/06/87	1700	261063	—	—	—	—	5.56E-01	(1)
CH-E1-102	08/06/87	1800	261903	—	—	—	—	5.63E-01	(1)
CH-E1-103	08/06/87	1830	262323	—	—	—	1.0	5.97E-01	0.63
CH-E1-104	08/06/87	1930	263163	—	—	—	—	5.69E-01	(1)

a. Temperature, pH, and electrical conductivity (μmhos/cm) were measured by DRI.

b. Field measurements are only approximate due to counting conditions. Results of more accurate measurements made under laboratory conditions are given in Appendix B-2.

c. Samples for tritium analysis were filtered through 0.45 micron filter prior to mixing with liquid scintillation counting cocktail.

d. These two samples were also analyzed by REECo Environmental Monitoring Laboratory, who confirmed the LLNL results.

e. Numbers in parentheses are one standard deviation based on a single count. Others are calculated from two or more replicates.

Table B-4. Laboratory-measured concentrations in UE20n-1 water of trace cations and anions,[a] mg/l (ppm).

Sample log no.	Date	Time	Depth (ft)	Al	K	Fe	B	Li	Na	Si	Mg	Ca	F	Cl	NO_3	SO_4	HCO_3	Br	Detergent
Drilling Series																			
CH-E1-1A	05/20/87	1700	985	0.637	1.5	0.133	0.092	0.09	52.68	17.12	0.230	3.59	2.8	5.4	2.9	14.3	-	0.49	—
CH-E1-8	05/23/87	0930	2323	—	—	—	—	—	—	—	—	—	N.A.[b]	N.A.	N.A.	N.A.	—	2.36	—
CH-E1-9	05/23/87	0930	2323	—	—	—	—	—	—	—	—	—	N.A.	N.A.	N.A.	N.A.	—	2.74	—
CH-E1-12	05/24/87	0500	2323	—	—	—	—	—	—	—	—	—	N.A.	N.A.	N.A.	N.A.	—	2.17	—
CH-E1-13	05/24/87	1820	2407	<0.005	—	0.294	0.279	0.190	85.8	36.81	0.880	39.0	5.2	16.7	<1	47.2	170.6	N.A.	—
CH-E1-23	05/29/87	0600	2630	<0.005	—	1.590	0.248	0.099	75.9	30.07	0.258	8.38	4.5	13.9	<1	37.5	113.6	N.A.	—
CH-E1-24	05/29/87	1410	2659	<0.005	—	0.812	0.200	0.483	118.4	25.64	0.246	10.1	4.1	20.9	<1	41.0	167.3	N.A.	15
CH-E1-26	05/30/87	1230	3003	<0.005	—	1.260	0.138	0.080	70.5	29.23	0.081	7.12	2.8	11.4	~2	27.7	58.2	0.20	—
CH-E1-29	05/31/87	2300	3294	<0.005	—	0.456	0.091	0.044	65.2	26.62	0.034	7.30	2.8	10.7	~2	25.5	80.2	0.23	6
Bailing Series																			
CH-E1-35	06/05/87	1630	3250	—	—	—	—	—	—	—	—	—	N.A.	N.A.	N.A.	N.A.	—	N.A.	2.5
CH-E1-40	06/08/87	1430	2400	0.107	—	1.540	0.212	0.175	74.0	19.02	0.147	7.13	3.7	12.6	<1	33.8	69.9	1.16	—
CH-E1-41	06/08/87	1530	2650	0.198	—	0.608	0.213	0.163	77.0	26.48	0.101	6.17	3.4	12.0	<1	32.9	78.7	0.91	—
CH-E1-42	06/08/87	1659	3000	0.083	—	0.610	0.208	0.106	71.8	24.74	0.044	4.80	3.7	12.2	<1	32.4	89.4	0.86	—
CH-E1-43	06/08/87	?	3250	0.291	—	0.553	0.169	0.134	66.0	25.28	0.003	5.32	2.8	20.4	<1	30.3	76.1	0.72	—
CH-E1-80A	07/20/87	?	2400	<0.05	10.9	0.303	0.276	0.162	68.9	20.58	0.918	14.0	—	—	—	—	—	—	—
CH-E1-81A	07/20/87	?	2600	<0.05	3.99	0.247	0.321	0.133	73.2	29.59	0.461	11.7	—	—	—	—	—	—	—
CH-E1-98	07/23/87	?	2400	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.11	0.22
CH-E1-99A	07/23/87	?	2600	0.103	2.36	0.046	0.208	0.115	87.6	28.70	0.171	9.59	3.5	12.4	11.7	37.2	—	—	—
Pumping Series																			
CH-E1-46	06/22/87	1200	2850	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.32	—
CH-E1-58	06/23/87	0900	2850	0.005	—	1.17	0.255	0.086	75.3	26.4	0.154	7.77	4.4	12.7	<1	30.9	92.6	0.55	—
CH-E1-58	06/23/87	0900	2850	<0.005	—	1.12	0.251	0.079	74.9	26.2	0.195	7.87	4.4	12.2	~1.5	30.5	100.7	—	—
CH-E1-60A	07/07/87	1300	2850	<0.005	3.81	2.15	0.298	0.177	76.3	18.2	0.301	11.9	4.5	12.7	3.0	34.0	—	—	—
CH-E1-61A	07/07/87	1400	2850	—	—	—	—	—	—	—	—	—	4.7	13.5	13.7	34.1	—	—	16
CH-E1-66A	07/07/87	2100	2850	0.043	2.92	5.64	0.309	0.126	95.73	38.2	0.206	10.8	4.5	12.8	6.1	33.4	—	—	15
CH-E1-76	07/08/87	1700	2850	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.46	16
CH-E1-77	07/08/87	1900	2850	0.054	2.80	7.64	0.288	0.102	95.31	26.5	0.184	9.58	4.5	12.8	5.8	35.2	—	—	—
CH-E1-77A	07/08/87	1900	2850	0.028	2.79	7.64	0.295	0.112	94.57	26.7	0.167	10.2	4.5	12.5	2.6	35.0	—	—	—
CH-E1-78	07/09/87	0645	2850	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.34	14
CH-E1-79B	07/09/87	1000	2850	0.093	3.75	5.14	0.281	0.099	80.02	25.0	0.211	8.79	4.5	12.4	2.6	35.7	—	0.34	—
CH-E1-83	07/21/87	1300	2850	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.48	2.5
CH-E1-87	07/21/87	1700	2850	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.17	—
CH-E1-89	07/22/87	1000	2850	0.026	2.77	8.76	0.312	0.111	94.50	23.5	0.179	8.72	4.6	16.0	14.1	36.9	—	—	5.0
CH-E1-95	07/22/87	1600	2850	0.002	3.04	9.51	0.037	0.110	95.19	24.8	0.186	8.71	4.1	13.5	4.6	~37	—	0.06	—
CH-E1-95A	07/22/87	1600	2850	0.041	3.09	13.8	0.313	0.109	97.02	25.7	0.161	6.88	4.3	12.7	22.7	34.9	—	0.04	3.0
CH-E1-100	08/06/87	1600	2850	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.21	—
CH-E1-102	08/06/87	1800	2850	<0.05	2.70	2.16	0.317	0.11	96.77	16.4	0.191	9.71	4.3	13.0	9.4	34.1	—	0.16	—
CH-E1-103	08/06/87	1830	2850	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.0
CH-E1-104	08/06/87	1930	2850	0.014	2.96	4.77	0.313	0.099	88.5	16.5	0.194	7.83	4.3	13.2	7.3	33.8	—	0.19	—

a. Cation concentrations measured by inductively coupled plasma-emission spectroscopy (ICP-ES), anion concentrations measured by ion chromatography (IC)
b. Not analyzed

Appendix C

Tests Fired Near or Below the Water Table

This table lists all announced Events from July, 1957, through October, 1987, that were fired below the water table or just above it (within 25 m). This information is from the Containment Data Base, formerly called the LLNL Containment Program Nuclear Test Effects and Geologic Data Base. The entries are listed chronologically and give the Event name, hole name, Event sponsor, date of detonation, depth of burial (DOB), standing water level (SWL), and SWL qualifier (measured or estimated).

DOB—This is the depth below the ground reference elevation where the center of the device was located. The description of the center of the device varies somewhat from different sources. The description is consistent for all LLNL data after 1970. Before that date, the nominal center might vary from the bottom of the device can to the top of the device can energy center. The values in the table also reflect a mix of planned and as-built numbers. Accuracy for older Events may be on the order of ±2 m. Accuracy and definitions of LANL data are not known.

SWL—This is the depth to the hydraulic head potential surface. Ideally this is the depth to the static water level table or the regional water table. The water table level is defined as the top of the saturated zone. However, due to the layered nature of the rock and the structure of this area, there are many locations at which the rock may be saturated. Also, careful measurements are needed over time to determine that the observed level actually is static.

About 100 measurements made at the NTS can be accurately described as indicating the depth to the static water level. About 50 boreholes actually penetrated into the static saturated zone, and careful measurements were made over time in these holes to accurately determine the SWL. About 20 cased boreholes had careful measurements made in them with packers in place, and these measurements represent separate saturated zones. There are a few holes that penetrated static saturated zones, but the measurements represent composite values, i.e., a resultant water level due to all the formations that are open to the borehole.

In many cases, data include measurements of levels that may not actually be static. The water level may be considered standing because of fluid invasion due to drilling, to rain or runoff water, or mounding of the static water level as a result of nearby tests. Frequently, for operational reasons, there is not sufficient time to make a series of careful measurements. Thus the level measured may be "standing," but not necessarily static. Unfortunately there has been no attempt to differentiate these measurements. Also, generally speaking, these are composite measurements, representing a value for all formations open to the borehole. We strongly recommend that for greatest accuracy in determining the SWL in a particular location, all data available regarding the measurement be obtained from the data base.

Much more information is available on each Event than is given here–for example lithologic and geologic data from each borehole, as well as more detail on the events themselves. For more information contact Gayle Pawloski, Nuclear Test Containment Program, Earth Sciences Department, LLNL.

Table C-1. Data for all Tests fired below or near the water table, for the period 6/1957–10/1987.

Event name	Hole name	Sponsor	Date	DOB, ft	SWL, ft	SWLql
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.
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.

Table C-1 (continued).

Event name	Hole name	Sponsor	Date	DOB	SWL, ft	SWLql
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.
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.

Table C-1 (continued).

Event name	Hole name	Sponsor	Date	DOB	SWL, ft	SWLql
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	619	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.
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.

Appendix D

Tentative Proposal from Lamont-Doherty Geological Observatory of Columbia University for Work in the HRMP

After preliminary discussions with Dr. H. J. Simpson Jr. at Lamont-Doherty, it seems that some of their work and experience in the study of natural radionuclides in ground and surface water would be applicable to the HRMP program at the NTS. We asked him to write an informal proposal of his ideas for our consideration. The following is the result and for the moment should only be considered as suggestions for the types of work that could be done. We would like Dr. Simpson to participate in the program as we feel his knowledge and experience would be valuable, and it would also help us include academic researchers in the program, a policy encouraged by the DoE. We will probably develop some type of co-operative research project for FY88, when we have more definite information on our budget.

Title of Proposal: Natural Radionuclide Activity Transport Processes and Rates in NTS Groundwaters Compared with Those for Detonation Nuclides

Migration of radionuclides from waste packages placed in underground repositories can be projected by a variety of approaches. Tracer experiments, especially on a large scale, offer one of the most powerful verification tools available for model calculations. However, for many environments in which large-scale tracer experiments are not practical, information can be gained from the transport behavior of natural radionuclides.

The ongoing Radionuclide Migration Project at the NTS offers an ideal opportunity to link understanding of transport processes for natural and detonation radionuclides with the goal of improving verification of model calculations for waste package radionuclides. We propose to add a new component of measurements to current activities at the NTS to help provide this linkage.

Our initial effort would be made in cooperation with planned sampling during early fall 1987 at UE20n-1. We would analyze samples of water shipped to LDGO for isotopes of uranium, thorium, radium, and other daughter products of the U-238, U-235, Th-232 parent nuclides. If feasible, we would also analyze for natural radionuclides in splits of samples passed through the filtration cascade (ultra-filter) by the LLNL group to provide direct comparison with the colloid speciation distributions derived for detonation nuclides.

During previous research at the WIPP site and nearby oil and gas production wells, we observed uranium and thorium series radionuclide distributions that clearly demonstrated extremely large effects of redox conditions on radionuclide transport, even for elements that are present in only a single oxidation state, as well as strong indications of colloidal associations for both uranium and thorium. Although the redox and other chemical characteristics of these New Mexico groundwaters contrast greatly with those at the NTS, the conclusions derived from the natural radionuclide distributions there are sufficiently similar to those derived from filtration studies on detonation nuclides at the NTS to suggest the need for more intensive investigation.

We would use a combination of laboratory and counting techniques developed over several decades of research on marine systems as well as other natural water radionuclide studies to make the measurements proposed here. Our intention would be to use equipment at LDGO for alpha, beta, and gamma counting for our initial measurements. As the work progressed, we would plan to initiate measurements of other nuclides that require either separations and/or counting at the sampling site, using counting equipment at the NTS or transported temporarily from LDGO.

The sampling at the NTS and shipping of water required for this research effort would be a relatively small perturbation of activities already planned for the Radionuclide Migration Program. Several other directions of research also would be pursued if they were deemed promising and not already planned by other groups. These would include:

1. Collection of a long time series of measurements of detonation products, such as tritium and a few gamma-emitting nuclides, at UE20n-1 to provide detailed data on the variability of radionuclide activities pumped from the groundwater system. For tritium, and other easily measured nuclides, these could be sampled and analyzed on a daily basis.
2. Collection of samples for natural radionuclide measurements from the "formation" location in the reentry hole. These data would be useful for comparison with the detonation nuclide data already obtained.
3. Collection of data on rare gas radionuclides in NTS groundwaters near the Cheshire site. We have an active research group at LDGO currently analyzing Kr-85 in sea water for ocean mixing studies, and a history of more than two decades of research involving Rn-222 in natural waters.
4. Analysis of drill core cuttings from post detonation holes near the Cheshire site for uranium and thorium series nuclides for comparison with the groundwater data. Both absolute concentrations and nuclide ratios in these rhyolites would provide critical complementary information concerning radionuclide transport processes. Disequilibria observed through these measurements on rock samples could yield insights about transport processes over much longer periods than those accessible from the groundwater samples alone.
5. Characterization of some nuclide binding and other properties of colloidal materials separated from unfiltered water samples at the NTS. Although the organic carbon components of NTS groundwaters are relatively low, the observations we have made in New Mexico suggest that even small amounts of organic compounds may be important in radionuclide transport.