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Final Report for

HYDROLOGICAL FLOW ANALYSIS AT YUCCA MOUNTAIN, NEVADA

Submitted to
Los Alamos National Laboratory
Los Alamos, New Mexico
Subcontract 520HH0015-3G

Submitted by
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INTRODUCTION

This final report, prepared by Hydro Geo Chem staff for Los Alamos National Laboratory, summarizes work conducted by the company under Subcontract 520HH0015-3G, which was terminated by LANL effective 7 February 1995 for practical reasons, in that responsibilities for all tasks in the Statement of Work had been transitioned to LANL employees. The ultimate objective of this work is to characterize the movement of subsurface water in the vicinity of Yucca Mountain, Nevada. Data produced under this contract is to be used by the U.S. Department of Energy in its Yucca Mountain Site Characterization Project (YMP) to help determine hydrologic flows that may affect the performance of a potential nuclear waste repository. The data may be used in the licensing proceedings, and certain quality assurance procedures have thus been required. The work has focussed on measuring the distribution of environmental tracers—chlorine-36, chlorine, and bromine—and on evaluating the depth to which these conservative solutes have percolated in the unsaturated zone at Yucca Mountain.

The period of performance for the original Subcontract was 1 October 1994 to 31 December 1996. Obviously, we have not completed, nor are we expected to complete, all of the scope of work in the Subcontract. The following discussion summarizes progress made on the tasks outlined in the Statement of Work for this Subcontract. Details of this work and all data acquired by Hydro Geo Chem for this Subcontract have been systematically organized in logbooks and laboratory notebooks (Appendices A and B). These documents have been structured to make it easy to trace the analytical history of a sample, from time of receipt to the final analytical results. The current status of this work and its relevance for the Yucca Mountain Project are described in a LANL report co-authored by Hydro Geo Chem staff (in preparation):

- Fabryka-Martin, J.T., S.J. Wightman, B.A. Robinson, and E.W. Vestal (in review). Infiltration processes at Yucca Mountain inferred from chloride and chlorine-36 distributions, Milestone Report 3417. Draft dated 21 December 1994.

STATUS OF TASKS IN THE SCOPE OF WORK

TASK 1: CHLORINE-36 AND HALIDE ANALYSES OF SOILS AND ROCKS

1.0 Analyze soil samples, drillhole cuttings, and samples from the Exploratory Studies Facility for chloride, bromide and chlorine-36, as well as for other constituents useful for interpreting the chlorine-36 data in terms of separating the meteoric component of chloride from the rock component.

- 1.1 Document technical procedures used to process and analyze samples for chlorine-36 and other constituents as necessary to achieve the objective of task 1.0.
- 1.2 Process and analyze on the order of 1000 samples for chloride and bromide.
- 1.3 Process and analyze samples on the order of 200 samples for chlorine-36, as well as for chloride, bromide and other constituents.

As of the end of the contract period, 7 February 1995, the following routine technical procedures had been written or revised by Hydro Geo Chem employees and had been issued by LANL/YMP as controlled documents (i.e., these have been incorporated into the LANL/YMP Quality Assurance Program):

LANL-INC-DP-103, R0	Identification, storage and handling of samples for the Water Movement Test
LANL-INC-DP-94, R2	Using ion chromatography to determine chloride and bromide concentrations

In conjunction with the other technical procedures co-authored by Hydro Geo Chem staff under the preceding Subcontract, 9-XG1-N3993-1, these documents have governed nearly all of the work conducted by Hydro Geo Chem in the processing and analysis of YMP samples. Data generated following these procedures have been systematically recorded in several logbooks (see Appendices A and B), as noted throughout this report.

From 1 October 1994 to 7 February 1995, Hydro Geo Chem staff had processed and analyzed samples as follows:

- 29 soil, rock and groundwater samples (including replicates) for chlorine-36 analysis, documented in the logbook for chlorine isotope results, TWS-INC-7-04-92-04
- 160 soil, rock and groundwater samples for chloride and bromide (including replicates), documented in ion chromatography logbooks TWS-CST-01-94-10 and LA-CST-NBK-95-006.

In addition, Hydro Geo Chem has routinely evaluated the reliability and reproducibility of ^{36}Cl ,

chloride and bromide results by analysis of blanks, standards, and replicate samples. The results of these quality-check analyses are documented in the chlorine isotope logbook (TWS-INC-7-04-92-04) and in the ion chromatography logbooks (TWS-CST-03-94-03, LA-CST-NBK-95-006). During the contract period, Hydro Geo Chem processed and analyzed 8 samples to monitor background contributions of ^{36}Cl . The main purpose of these background samples has been to serve as quality checks, prepared concurrently with each suite of environmental samples in order to verify the lack of any significant contamination. All of these blanks have had $^{36}\text{Cl}/\text{Cl}$ ratios less than or equal to 2×10^{-14} ; and most ratios have been less than 0.5×10^{-14} , always well below the ratios of the samples they accompanied, thus indicating no significant contamination was present.

TASK 2: INTERPRETATION OF CHLORINE-36 DATA

- 2.0 Develop and evaluate the procedure used to interpret the chlorine-36 data in terms of separating the meteoric component of chloride from the rock component.

Apparent water residence times based upon the measured chlorine-36 signal in a rock sample may be older than the true ages due to the effect of dilution of the meteoric signal by older chloride released from the rock during the drilling process. Thus, a procedure is needed to estimate and correct for dilution by rock chloride. Hydro Geo Chem has investigated the use of chloride/bromide (Cl/Br) ratios as an indicator of the extent of mixing of these two sources. Employees analyzed 94 surface-soil samples to assess variability in the meteoric Cl/Br ratio; results are included in the ion chromatography logbooks, TWS-CST-01-94-10 and LA-CST-NBK-95-006, as well as in the draft Milestone Report 3417 (Fabryka-Martin et al., in review). Hydro Geo Chem staff also conducted a preliminary experiment to assess the use of acid-dissolution in diffusion cells to extract chloride and bromide from rock matrices, followed by analysis of the extractant on the ion chromatography system. Results are recorded in the laboratory notebook, LA-CST-03-94-03; refinement of this technique is needed to manage for the effects of species that interfere in the analysis.

TASK 3: CHLORINE-36 ANALYSES OF GROUNDWATERS

- 3.0 Analyze water samples from the saturated zone and from perched water zones from the YMP region for chlorine-36, chloride and bromide, to be used for determining the age of the water.

During the contract period, Hydro Geo Chem received 4 groundwater samples from the USGS for chlorine-36, Cl and Br analysis; 2 porewater samples (about 2-mL each) from the USGS for Cl/Br analysis only; and 6 rainwater samples from the University of Nevada at Las Vegas for

Cl/Br analysis. Documentation of the receipt and subsequent history of these samples is contained in the water sample logbook TWS-INC-7-02-92-03. During the contract period, Hydro Geo Chem staff processed and/or analyzed 15 water samples for chlorine-36 (including several which had been received and archived during the previous contract period). Documentation of ^{36}Cl analyses for these samples is contained in the chlorine isotope logbook (TWS-INC-7-04-92-04). Documentation of chloride and bromide analyses for the USGS-collected samples is found in the ion chromatography logbooks (TWS-CST-01-94-10 and LA-CST-NBK-95-006).

TASK 4: SAMPLE COLLECTION

4.0 Participate in collecting samples for analysis.

There was no request from the LANL technical representative to conduct work on this task during the contract period.

TASK 5: HYDROGEOLOGIC INTERPRETATION OF DATA

5.0 Provide a hydrogeologic interpretation of the data in terms of flow and solute transport in the unsaturated zone at Yucca Mountain. Evaluate preliminary hypotheses and working conceptual models and revise work conducted under tasks 1 through 4 accordingly.

Work on this task was halted following a change to the Subcontract's Statement of Work, pursuant to a letter received by Hydro Geo Chem from the Senior Contract Administrator (Ron Tokay, dated 21 March 1994) in which it was stated that all modeling tasks would be performed by LANL.

TASK 6: CONFERENCE ABSTRACTS AND MANUSCRIPTS

6.0 Prepare conference abstracts and manuscripts for publication as appropriate.

Hydro Geo Chem staff participated in the preparation of Milestone Report 3417. In addition, data produced by Hydro Geo Chem staff contributed materially to a conference paper prepared by Liu et al.:

- Liu, B., J. Fabryka-Martin, A. Wolfsberg, B. Robinson, and P. Sharma (in press), Significance of apparent discrepancies in water ages derived from atmospheric radionuclides at Yucca Mountain, Nevada, to be published in Proceedings of the 1995

American Institute of Hydrology Annual Meeting, to be held 14-18 May 1995, Denver, CO. LANL Report LA-UR-95-572.

TASK 7: SAMPLE STORAGE

- 7.0 Arrange for storage of samples in a facility protected from weather as long as necessary.

All samples have been received and stored at Los Alamos where they are being stored in sheds and a boxcar (LANL Technical Area TA-48, Buildings RC-36, RC-40 and RC-89). Hydro Geo Chem staff have been responsible for documenting and maintaining proper storage conditions. Documentation has been maintained in the various sample logbooks (see Appendix B).

TASK 8: PROGRESS REPORTS

- 8.0 Submit quarterly and annual progress reports to Los Alamos National Laboratory outlining the progress of work.

At the request of the Principal Investigator and to be consistent with the monthly reporting requirement of the YMP program, Hydro Geo Chem staff have filed informal monthly letter reports summarizing the work accomplished during each month. These reports have generally been very short, with details provided in the laboratory notebooks and logbooks:

Date of letter	Reporting period	# pages
11/11/94	October 1994	1
12/08/94	November 1994	1
01/30/94	December 1994	1
02/06/95	January 1995	1

TASK 9: QUALITY ASSURANCE REQUIREMENTS

- 9.0 Perform all work under a Quality Assurance (QA) Program designed by the contractor to demonstrate the quality of the data generated under this contract and approved by the Los Alamos Yucca Mountain Project (YMP) office. Work cannot start until such approval has been obtained. Alternatively, perform all work under the QA Program established by the Los Alamos YMP office.
- 9.1 Cooperate with the YMP office in its annual auditing of the contractor's facilities and documents to verify compliance with the adopted QA program.
- 9.2 LANL YMP personnel, their authorized subcontractors, and U.S. DOE personnel shall

have the right of access to facilities and documents relating to work performed under this contract, for the purpose of performing under this contract, for the purpose of performing audits on the implementation of the adopted QA program, with reasonable notice to the contractor.

9.3 The work shall not be subcontracted without LANL and LANL/YMP review and written approval. Any subcontract must include flow-down of any appropriate QA requirements.

9.4 Any non-conformance shall be reported in compliance with the appropriate provisions of the adopted QA program.

Hydro Geo Chem staff have performed all work for this Subcontract under the Los Alamos YMP QA program. The effectiveness with which the company has implemented these requirements during the contract period has been documented in Los Alamos Audit Report LA-AR-CST/HGC-94-13 (dated December 19, 1994). Eight minor deficiencies were noted in this report, but all were easily corrected during the audit. The report's conclusions stated that 'Implementation of Los Alamos YMP Quality Assurance (QA) requirements...was adequate and effective.... The audit team appreciated the cooperation and very proactive attitude of the Hydro Geo Chem and CST staff...'

APPENDIX A

ORGANIZATION OF DATA ACQUIRED BY HYDRO GEO CHEM FOR SUBCONTRACT 520HH0015-3G

All data acquired by Hydro Geo Chem for this subcontract have been systematically organized in logbooks and laboratory notebooks. These documents have been structured to make it easy to trace the analytical history of a sample, from time of receipt to the final analytical results.

1. *Sample logbooks* are used to track the receipt of the original sample, the withdrawal of individual aliquots for analysis, and the final disposition of the original sample. There are separate logbooks depending upon the nature of the sample: rock cuttings, soils, waters, or drillcore. These logbooks provide traceability for each sample to a unique SMF barcode ID, and assign a unique laboratory ID and aliquot ID following LANL-INC-DP-87 or its successor, LANL-CST-DP-103.
2. *Ion chromatography logbooks* are used to document sample leaching following LANL-INC-DP-92, and analysis of leachates and water samples following LANL-INC-DP-94. Any sample sieving that may be required following LANL-INC-DP-89 is also documented in these logbooks.
3. The *chlorine-36 logbook* is used to document activities associated with the analysis of samples for chlorine-36, beginning with the preparation of silver chloride following LANL-INC-DP-95, submission of the silver chloride to an outside laboratory for chlorine-36 analysis, and receipt of the analytical results. Sample submission and receipt of results for stable chlorine isotopic analyses are also included in this logbook.
4. *Laboratory notebooks* are used primarily to document troubleshooting activities, and scoping, prototype or research and development activities. These notebooks may also be used to provide details as appropriate on deviations and possible sources of uncertainty associated with activities governed by detailed technical procedures (DPs). Very few data associated with activities governed by DPs are reported in these notebooks, once the first ion chromatography logbook was initiated.

APPENDIX B

NOTEBOOKS AND LOGBOOKS MAINTAINED BY HYDRO GEO CHEM
FOR SUBCONTRACT 520HH0015-3G

NOTEBOOK TYPE AND ID	NOTEBOOK TITLE	DATE STARTED
SAMPLE LOGBOOKS		
TWS-INC-7-10-91-04	Logbook #1 for rock samples	02-12-92
TWS-INC-02-93-05	Logbook #2 for rock samples	02-10-93
TWS-INC-7-03-92-05	Logbook #1 for soil samples	03-16-92
LA-CST-NBK-94-004	Logbook #2 for soil samples	12-01-94
TWS-INC-7-02-92-03	Logbook for water and carrier salt samples	02-14-92
TWS-INC-09-93-02	Logbook for drillcore samples	09-10-93
TWS-INC-7-02-92-04	Logbook binder (correspondence related to sample acquisition and transfer)	03-03-92
LABORATORY NOTEBOOKS		
TWS-INC-7-02-92-02	Hydro Geo Chem laboratory notebook #1	02-14-92
TWS-INC-01-93-03	Hydro Geo Chem laboratory notebook #2	12-01-92
LA-CST-03-94-03	Hydro Geo Chem laboratory notebook #3	03-01-94
ION CHROMATOGRAPHY LOGBOOKS		
TWS-INC-7-05-92-01	Ion chromatography logbook #1	06-01-92
TWS-INC-11-92-03	Ion chromatography logbook #2	11-11-92
TWS-CST-01-94-10	Ion chromatography logbook #3	01-28-94
LA-CST-NBK-95-006	Ion chromatography logbook #4	01-23-95
CHLORINE-36 LOGBOOK		
TWS-INC-7-04-92-04	Chlorine-36 logbook #1	05-01-92