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Addendum to Site-Wide Remedial Investigation Report Lawrence Livermore National Laboratory Site 300: Building 850/Pit 7 Complex Operable Unit

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Table of Contents

List of Figures

List of Tables

Appendices

Executive Summary

This report is an addendum to the East and West Firing Areas (EFA/WFA) portion (Chapter 11) of the Final Site-Wide Remedial Investigation (SWRI) report for Lawrence Livermore National Laboratory (LLNL) Site 300 (Webster-Scholten, 1994). The Building 850/Pit 7 Complex operable unit (OU) is a part of the EFA/WFA. The OU includes the Building 850 firing table, the landfills of the Pit 7 Complex (pits 3, 4, 5, and 7), and the plumes of tritium, trichloroethylene (TCE), and uranium in ground water that emanate from them. This report summarizes the additional characterization, modeling, and risk assessment necessary to assess potential removal actions and define the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) pathway for the Building 850/Pit 7 Complex OU. These tasks were performed between January 1, 1992, and December 31, 1995. The post-SWRI data cutoff date for this evaluation is June 30, 1995. The additional work was required to calculate potential risks posed by uranium and thorium in ground water; uranium, thorium, polychlorinated biphenyl compounds (PCBs), dioxins, furans, and metals in surface soil; and tritium in Building 850 indoor air.

As a result of our 1992–95 investigations, we:

- Defined three plumes of depleted uranium in ground water emanating from pit 5, pit 7, and Building 850, respectively. Many samples of surface soil from Building 850 and the Pit 7 Complex also showed signatures of depleted uranium. Depleted uranium was the only form of uranium used in explosives tests at Site 300.
- Evaluated the concentrations of two metals (barium and vanadium) that during the post-SWRI evaluation period exceeded concentration limits (CLs) for post-closure ground water monitoring of pit 7. We also evaluated the concentration of lead in ground water. We determined that although some of the barium and lead in ground water may result from landfill release, the concentrations are comparable to natural concentrations and are significantly below MCLs.
- Detected low concentrations of thorium in surface soil, subsurface soil and rock, and ground water.
- Identified low concentrations of beryllium, cadmium, and lead in Building 850 surface soil.
- Identified PCBs, dioxins, and furans in samples of surface soil at Building 850. No PCBs were detected in surface and subsurface soil from the Pit 7 Complex.
- Conducted a passive soil vapor survey (SVS) at pit 5, and drilled and sampled 10 boreholes in the Pit 7 Complex for volatile organic compounds (VOCs) to identify a source for TCE in ground water downgradient of pit 5 . No TCE source was identified.
- Detected low activities of tritium in indoor air in Building 850.
- Identified a generally decreasing trend in post-SWRI tritium activities in lysimeter subsurface moisture and ground water.

- Identified a general decrease in post-SWRI TCE concentrations and extent in ground water downgradient of pit 5.
- Solved the advective-dispersive equation and estimated ground water uranium activities that could reach potential exposure points from the plumes originating at pits 5 and 7 and Building 850.
- Determined chemical-specific cancer risk and hazard indices (HIs) for areas in and near Building 850 and for the entire OU (Table EX-1).
- Determined risks and HIs associated with potential exposure to uranium-bearing ground water to be $<10^{-6}$ and <1, respectively.
- Determined that the potential exposure to surface soil containing, uranium, thorium, and metals presents a risk of 7×10^{-6} and a HI of <1. The risk is driven primarily by a beryllium concentration in a single soil sample.
- Determined that tritium activities in Building 850 indoor air do not pose an unacceptable risk to Building workers.
- Compared preliminary remediation goals (PRGs) for PCBs, chlorinated dibenzo-p-dioxins (CDDs), and chlorinated dibenzofurans (CDFs) to concentrations detected in soil at the Building 850 firing table. Some locations exceed the U.S. Environmental Protection Agency (U.S. EPA) Region IX PRG and/or remedial action goals for PCBs at superfund sites. Several locations also have a total tetrachloro-di-benzodioxin (TCDD) equivalent concentration greater than the U.S. EPA Region IX PRG.

We have also compared SWRI contaminant hydrogeologic data to post-SWRI data. The distributions of water elevations and recharge are consistent with SWRI observations. It appears that preferential recharge in the Pit 7 Complex continues to periodically inundate portions of the landfills during and after periods of unseasonably high rainfall.

As reported in this document, we have completed the post-SWRI assessment for the Building 850/Pit 7 Complex OU. Our next steps are to 1) examine potential response actions to address environmental contaminants present in the OU that pose excessive risk to human health and the environment, and 2) work with the Department of Energy (DOE) and the regulatory agencies to determine the appropriate regulatory pathway for this OU.

Table EX-1. Summary of cancer risk and HIs in and near Building 850 and for the entire operable unit.

Risk	Risk evaluation	HI	Exposure pathway
Maximum incremental excess cancer	6×10^{-7}	0.0492	Residential use of ground water containing uranium
Cumulative incremental lifetime cancer	7×10^{-6}	0.029	Ingestion and dermal contact with surface soil containing radionuclides and metals in or near Building 850
Cumulative incremental lifetime cancer	3×10^{-7}	1.9×10^{-4}	Inhalation of resuspended particulates containing radionuclides and metals in or near Building 850
Cumulative incremental lifetime cancer	3×10^{-8}	1.3×10^{-3}	Ingestion and dermal contact with radionuclides for entire OU
	3×10^{-8}	8.8×10^{-6}	Inhalation of dust containing radionuclides for entire OU
Additive risk	6×10^{-8}	1.3×10^{-3}	Inhalation of resuspended particulates and ingestion and dermal contact of contaminants (radionuclides) by adults on site throughout entire OU

1. Introduction

This report is an addendum to the SWRI report (Webster-Scholten, 1994) that was prepared by LLNL. This SWRI report was submitted to the U.S. Environmental Protection Agency (U.S. EPA), California Department of Toxic Substances Control (DTSC), and California Regional Water Quality Control Board (RWQCB)–Central Valley Region. Specifically, this report supplements the remedial investigation for the Building 850/Pit 7 Complex OU within the EFA/WFA study area of the LLNL Site 300 experimental test facility near Tracy, California. We describe the additional characterization and the ecological and risk assessment work performed to complete the investigation of this OU. Data presented and evaluated were collected between January 1, 1992, and June 30, 1995. We collected and analyzed these data to complete our assessment of metals; PCBs; dioxins/furans; VOCs; and thorium and uranium in surface soil, subsurface soil, and ground water.

All hydrogeologic and chemical data collected prior to December 31, 1991, are presented in Chapter 11 of the SWRI report. We have compared the SWRI and post-SWRI data to document and evaluate any changes in the contaminant hydrogeologic system.

1.1. Description of the Building 850/Pit 7 Complex Operable Unit

The Building 850/Pit 7 Complex OU, as shown on Figure 1-1, includes:

- Landfill pits 3, 4, 5, and 7 (Pit 7 Complex);
- Building 850 firing table, sand pile, and upper and lower corporation yards;
- Three plumes of tritium in ground water originating at pits 3 and 5 and Building 850;
- Three plumes of depleted uranium in ground water originating at pits 5 and 7 and Building 850; and
- A small plume of trichloroethylene (TCE) in ground water originating at pit 5.

1.2. Scope of Additional Work Performed

During preparation of the SWRI report, we identified additional work needed to evaluate several chemicals and environmental media at several previously identified release sites in the Building 850/Pit 7 Complex OU. These chemicals, environmental media, and release sites are listed in Table 1-1.

On the basis of the results of our additional characterization and ground water modeling, we calculated potential additional lifetime cancer risks and non-cancer HIs associated with:

- Metals, uranium, and thorium in surface soil (ingestion, dermal contact, and inhalation of re-suspended dust);
- Uranium in ground water (ingestion); and
- Tritium in Building 850 indoor air (inhalation).

In addition, for the Building 850 area, we compared surface soil concentrations of PCBs, CDDs, and CDFs with PRGs) developed by Region IX of the U.S. EPA.

1.3. Report Format

This report is comprised of 5 chapters and 11 appendices.

Chapter 1	Presents the purpose of the report, a description of the OU, the scope of additional work performed, and the report format.
Chapter 2	Contains our evaluation of chemical data collected and comparisons with the SWRI assessment of the nature and extent of contamination.
Chapter 3	Documents the fate and transport modeling of uranium in ground water and contains the exposure-point activity results.
Chapter 4	Contains the post-SWRI risk assessment.
Chapter 5	Summarizes our conclusions.
Appendices A and B	Provide the post-SWRI tables of chemical analyses for soil, rock, and water.
Appendix C	Presents time-series plots of tritium and uranium activities in ground water.
Appendix D	Includes post-SWRI ground water elevation and precipitation data, a hydrogeologic update of the OU, comparison between SWRI and post-SWRI water elevation data, plots of water elevation change, and hydrographs.
Appendix E	Contains chemical-specific log-probability plots for surface soil. These plots often show differences between background concentrations and concentrations indicative of contamination.
Appendix F	Contains calculations of dioxin toxicity equivalence factors (TEFs). These TEFs are used to assign an equivalent toxicity or each dioxin compound to one proxy compound.
Appendix G	Contains recalculation of chemical-specific, 95% upper confidence limits (UCLs) for VOCs in ground water.
Appendix H	Presents the graphic logs for the 10 boreholes and wells completed in the Pit 7 Complex during this post-SWRI period.

Appendix I	Evaluates metals (barium and vanadium) in ground water that exceeded the CLs for post-closure monitoring of pit 7 during the post-SWRI evaluation period. This appendix also contains an evaluation of lead in ground water at pit 7.
Appendix J	Contains the results of aquatic bioassays that evaluate the potential toxicity of waters from spring 6 and well 8 spring.
Appendix K	Evaluates whether ^{232}Thorium (^{232}Th) has contaminated ground water in the OU.

2. Nature and Extent of Contamination in the Building 850/Pit 7 Complex Operable Unit

2.1. Introduction

During preparation of the SWRI report, we determined that additional characterization of uranium, thorium, metals, VOCs, and PCBs was required in the Building 850/Pit 7 Complex OU. In this chapter, we describe the post-SWRI efforts to fully characterize the nature and extent of contamination in this OU. These efforts include the collection and analysis of samples for contaminants of concern identified in the SWRI (Webster-Scholten, 1994). These samples were collected from surface and subsurface soil, rock, and moisture, surface water, ground water, indoor air, outdoor air, and biota. To complete our characterization, we describe 1) the analytical results of samples collected January 1, 1992, through June 30, 1995, and 2) our interpretation of these data.

2.2. Sources of Contamination

As presented in the SWRI report, tritium, depleted uranium, VOCs, PCBs, and several metals were released to the environment from the Building 850 firing table, sand pile, corporation yard, and the Pit 7 Complex landfills. Tritium, depleted uranium, and metals were used in explosives experiments at the firing table. Depleted uranium is the by-product (^{238}Uranium-rich) remaining after the more highly radioactive ^{235}U isotope is removed from natural uranium. At least several times, PCB-bearing capacitors were exploded on the firing table.

2.3. Nature and Extent of Contamination in Soil Vapor

2.3.1. VOCs

During September 1994, to locate potential ground water TCE sources, we collected and analyzed 30 passive soil vapor samples for VOCs. The samplers, installed approximately 18 in. below the surface, were left in place approximately 3 weeks. This semi-quantitative sampling method was used to screen locations for surface and subsurface soil sampling conducted later the same year (boreholes Pit7-01 through Pit7-10). In the soil vapor samples, the maximum ion counts detected for TCE and tetrachloroethylene (PCE) were 22,751 and 25,293, from locations SVX-Pit5-012-19D and SVX-Pit3-001-19D, respectively. Figure 2-1 shows the distribution of TCE and PCE in soil vapor in the Pit 7 Complex area, and Table A-20 lists the analytical results. The ion counts for TCE and PCE in soil vapor are relatively low, a condition confirmed by a lack of TCE and PCE detections in subsurface soil and rock as determined from subsequent drilling in the same area. Section 2.7.5. describes these subsequent analyses. The passive SVS failed to identify a TCE source for the TCE ground water at pit 5 plume. In fact, PCE was found to be far more prevalent in soil vapor than TCE.

2.4. Nature and Extent of Contamination in Surface Soil Moisture

2.4.1. Tritium

Pit 7 Complex Area. We collected and analyzed 12 soil moisture samples for tritium from surface soil collected while drilling in the Pit 7 Complex area. We collected these samples between October 13 and November 9, 1994, and analyzed them using a scintillation counting method. Where detected, tritium activities ranged from 225 pCi/L_{sm} (location Pit7-08) to 1.81×10^4 pCi/L_{sm} (location Pit7-04) [Fig. 2-2]. Table A-13 lists the analytical results for tritium activities in soil moisture from borehole samples collected. If we account for radioactive decay and dilution by recharge water, these data are consistent with data collected during the SWRI assessment period.

2.5. Nature and Extent of Contamination in Subsurface Soil Moisture

2.5.1. Tritium

Building 850/Pit 7 Complex Areas. We collected and analyzed 58 samples from dedicated lysimeters for tritium activity in soil moisture. We analyzed these samples with scintillation counting. Where detected, tritium activities ranged from 3.27 pCi/L_{sm} to 3.02×10^6 pCi/L_{sm} in samples collected from lysimeters K1-05A and NC7-32A, respectively. Figure 2-3 shows lysimeter locations, and Table A-4 lists the analytical results for tritium activities in soil moisture from lysimeters. If we account for radioactive decay and recharge water dilution, the data are consistent with data collected during the SWRI assessment period. Lysimeters NC7-02, -05A, -07, -08, -09, -13, -32B, -39A, -39B, -42A, and -42B either no longer maintain a sufficient vacuum to collect a sample, or they monitor a currently dry zone.

Pit 7 Complex Area. We also analyzed 24 soil moisture samples for tritium from subsurface soil collected while drilling in the Pit 7 Complex area. We collected these samples between October 13 and November 14, 1994, and analyzed them with scintillation counting. Where detected, tritium activities ranged from 229 pCi/L_{sm} to 2.56×10^6 pCi/L_{sm} from borehole locations W-Pit7-10 and Pit7-07 (Fig. 2-2) at depths of 42.5 and 10.3 ft, respectively. Table A-3 lists the analytical results for tritium activities in subsurface soil moisture. These data are also consistent with SWRI data.

2.6. Nature and Extent of Contamination in Surface Soil and Rock

2.6.1. Gross Alpha and Beta Radioactivity

Pit 7 Complex Area. To analyze for gross alpha and beta radioactivity, we collected 10 surface soil and rock samples from the Pit 7 Complex area. We collected these samples between October 13 and November 14, 1994, and analyzed them using EPA Method 9310. Where detected, gross alpha and beta activities ranged from 4.39 pCi/g to 23.3 pCi/g and 10.1 pCi/g to 42.4 pCi/g, respectively. Table A-16 lists the analytical results for gross alpha and beta radioactivity in surface soil and rock, and Fig. 2-2 shows the sample locations. These data are consistent with SWRI data.

2.6.2. Uranium

Pit 7 Complex Area. To analyze for uranium isotopes, we collected 12 surface soil samples from the Pit 7 Complex area. We collected these samples between October 13 and November 9, 1994, and analyzed them using LLNL's State-certified analytical laboratory and the inductively coupled plasma/mass spectrometry (ICP/MS) method. An HNO_3/HCl-derived leaching procedure was used to extract soluble uranium in surface and subsurface materials. We collected the surface samples at the locations of boreholes Pit7-01 through W-Pit7-10 prior to drilling. The ^{238}U activities ranged from 0.26 pCi/g to 24 pCi/g from borehole locations W-Pit7-10 and Pit7-07, respectively. The ^{235}U activities ranged from 0.01 to 0.225 pCi/g from locations W-Pit7-10 and Pit7-03, respectively. The maximum and minimum detected $^{235}U/^{238}U$ activity ratios were 0.00705 and 0.00195 from boreholes Pit7-06 and Pit7-03, respectively. A mass ratio of $^{235}U/^{238}U$ equivalent to 0.0072 indicate that the uranium detected is natural; ratios significantly above 0.0072 indicate enriched uranium contamination, and ratios significantly below 0.0072 indicate depleted uranium contamination. In this context, a significant variance is defined as 0.0004, which results from analytical uncertainty. All locations, except Pit7-06, contain some depleted uranium .

Tables A-14 and A-15 list uranium isotope activities and $^{235}U/^{238}U$ mass ratios, respectively, in surface soil and rock in the Pit 7 Complex area.

Building 850 Area. To analyze for uranium isotopes, we collected 37 surface soil samples from the Building 850 area. We collected these samples on July 26, 1994, and analyzed them using LLNL's ICP/MS method. The ^{238}U activities ranged from 0.29 pCi/g to 24.75 pCi/g from sampling locations 3SS-850-128 and 3SS-850-107, respectively. The ^{235}U activities ranged from 0.01 pCi/g to 0.045 pCi/g from locations 3SS-850-118, 3SS-850-119, and 3SS-850-100, respectively. The maximum and minimum detected $^{235}U/^{238}U$ activity ratios were 0.00729 and 0.00189 from locations 3SS-850-128 and 3SS-850-107, respectively. Figures 2-4 and 2-5 show the distribution of ^{238}U and $^{235}U/^{238}U$ mass ratios, and ^{235}U, respectively, in surface soil and rock. All surface sampling locations at Building 850, except 3SS-850-128, contain some depleted uranium. Depleted uranium content generally decreases with radial distance from the firing table. Tables A-14 and A-15 list the analytical results.

2.6.3. Thorium

Pit 7 Complex Area. Prior to drilling at the location of boreholes Pit7-01 through Pit7-10, we collected and analyzed for thorium (^{232}Th) 12 surface soil samples from the Pit 7 Complex area. We collected these samples between October 13 and November 9, 1994, and analyzed them using LLNL's ICP/MS method. The ^{232}Th activities ranged from 0.48 pCi/g to 0.93 pCi/g from boreholes Pit7-01 and Pit7-06, respectively. Table A-18 lists the analytical results, and Figure 2-2 shows the sample locations.

Building 850 Area. We collected 37 surface soil samples from the Building 850 area and analyzed them for ^{232}Th. We collected these samples on July 26, 1994, and analyzed them using LLNL's ICP/MS method. The ^{232}Th activities ranged from 0.3 pCi/g to 0.55 pCi/g from sampling locations 3SS-850-103 and 3SS-850-125, respectively. Table A-17 lists the analytical results. Sample locations are shown on Figure 2-6.

2.6.4. PCBs, Dioxins, and Furans

Pit 7 Complex Area. Prior to drilling at the location of boreholes Pit7-01 through Pit7-10, we collected and analyzed 10 surface soil samples for PCBs. We collected these samples between October 13 and November 9, 1994, and analyzed them using EPA Method 8080. No PCB compounds were detected in these samples. Table A-19 lists the analytical results.

Building 850 Area. We collected and analyzed 32 surface soil samples from the Building 850 area for PCBs. We collected these samples between July 26 and December 5, 1994, and analyzed them using EPA Method 8080. Although we tested for seven Aroclor compounds (PCBs), only Aroclor 1254 was detected. We also collected and analyzed 46 samples for total PCBs using immunoassay field test kits. The combined data were used to define the areal extent of PCB contamination. Where detected, PCB concentrations ranged from 0.09 mg/kg (at 3SS-850-131a) to 180 mg/kg (at 3SS-850-142). Although the PCBs are generally bounded on the slopes above the firing table, we identified PCBs at the maximum sampling distance of 1,000 ft from the Building 850 firing table in western Doall Ravine (sample location 3SS-850-131a; 0.090 mg/kg). Figure 2-7 shows the surface soil sample locations, and Table A-18 lists the analytical results.

We also collected and analyzed 9 surface soil samples for 11 dioxin compounds and 14 furan compounds. We collected these samples on December 16, 1994, and analyzed them using EPA Method 8290. Where detected, concentrations of tetrachloro-di-benzodioxin (TCDD) (total) ranged from 0.7 pg/g to 4.3 pg/g (ppt) at locations 3SS-850-142 and 3SS-850-140, respectively. Tetrachloro-di-benzofuran (TCDF) (total) concentrations ranged from 29 pg/g to 15,000 pg/g (ppt) at locations 3SS-850-126, 3SS-850-154, and 3SS-850-142, respectively. Figure 2-8 shows the distribution of TCDD (total) and TCDF (total) concentrations in surface soil and rock, and Table A-19 lists the analytical results.

The distributions of PCB, dioxin, and furan concentrations in surface soil and rock generally show a decrease with distance from the Building 850 firing table. This pattern is consistent with the mode of release. Prior to regulation of PCB oils, capacitors containing PCB oils were occasionally exploded on the Building 850 firing table as part of the test assemblies.

2.6.5. Metals

Pit 7 Complex Area. Prior to drilling at the locations of boreholes Pit7-01 through Pit7-10, we collected and analyzed for metals 10 surface soil samples from the Pit 7 Complex area. We collected these samples between October 13 and November 9, 1994, and had them leached and analyzed for total threshold limit concentrations (TTLC). The maximum metals TTLC concentrations detected are listed by location in Table 2-1; the analytical results for metals concentrations in surface soil and rock are presented in Table A-12. We did not detect antimony, molybdenum, selenium, silver, or thallium. Sample locations are shown in Figure 2-2.

Building 850 Area. We collected and analyzed 36 surface soil and rock samples from the Building 850 area for metals. We collected these samples on July 26, 1994, and analyzed them for TTLC and soluble threshold limit concentration (STLC) metals. The maximum concentrations of TTLC and STLC metals detected are listed by location in Tables 2-2 and 2-3, respectively. Metals not detected are presented in Table 2-4. The entire suite of metals analyses is provided in Tables A-11 and A-12. Sample locations and beryllium STLC concentrations are shown in Figure 2-9.

2.6.6. HE Compounds

Building 850 Area. We collected and analyzed 32 surface soil and rock samples from the Building 850 area for HE compounds. We collected these samples on July 26, 1994, and analyzed them for HMX, RDX, and TNT using EPA Method 8330. We detected HMX (2.4 mg/kg) at only one location, 3SS-850-107; neither RDX nor TNT were detected in any sample. Figure 2-6 shows the sample locations, and Table A-10 lists the analytical results for the samples collected.

2.7. Nature and Extent of Contamination in Subsurface Soil and Rock

2.7.1. Gross Alpha and Beta Radioactivity

Pit 7 Complex Area. We analyzed 24 subsurface soil and rock samples from the Pit 7 Complex area for gross alpha and beta radioactivity. We collected these samples between October 13 and November 14, 1994, and analyzed them using EPA Method 9310. Where detected, gross alpha activities ranged from 5.45 ± 0.92 pCi/g to 39.9 ± 1.4 pCi/g in samples from boreholes Pit7-06 (14.0 ft) and W-Pit7-02 (18.0 ft), respectively. Gross beta activities ranged from 11.7 ± 1.1 pCi/g to 37.4 ± 1.2 pCi/g in samples from boreholes Pit7-09 (10.8A) and W-Pit7-02 (18.0A), respectively. Table A-7 lists the analytical results. Sample locations are shown on Figure 2-2.

2.7.2. Uranium

Pit 7 Complex Area. During the drilling of boreholes Pit7-01 through Pit7-10, we collected and analyzed 30 subsurface soil and rock samples for uranium isotopes. We collected these samples between October 13 and November 14, 1994, and analyzed them using LLNL's ICP/MS method. The ^{238}U activities ranged from 0.31 pCi/g in borehole Pit7-05, at a depth of 12.5 ft, to 1.84 pCi/g in borehole Pit7-07, at a depth of 20.0 ft. ^{235}U activities ranged from 0.013 pCi/g in borehole Pit7-04 at a depth of 12.5 ft, to 0.085 pCi/g in borehole Pit7-07 at a depth of 20.0 ft. ^{235}U/^{238}U mass ratios ranged from 0.00737 and 0.00294 and were detected in boreholes Pit7-09 and Pit7-04, at depths of 10.0 and 21.0 ft, respectively. Soil and rock samples from moderate depths (10–15 ft) in boreholes Pit7-01, -04, and -07 contain depleted uranium; this depleted uranium was presumably leached from the landfills. The presence of the higher activities of depleted uranium in this shallow depth range well above the post 1982 water table, indicate that the uranium release was coincident with the original release of tritium in 1981–1982. Tables A-5 and A-6 list the analytical results for ^{235}U and ^{238}U activities and ^{235}U/^{238}U mass ratios.

Building 850 Area. We also collected and analyzed for uranium isotopes, subsurface soil and rock samples from previously drilled boreholes NC7-44 (one sample from 35.5 ft depth) and NC7-74 (11 samples, Fig. 2-3). Both borehole locations are outside of expected uranium contamination. We collected these samples from our core storage area on July 6, 1994, and analyzed them using LLNL's ICP/MS method. Detected ^{238}U activity in HNO_3/HCl-derived leachate for the single sample from NC7-44 was 0.98 pCi/g. The $^{235}U/^{238}U$ mass ratio in this leachate was 0.00743. The ^{238}U activities in the leachate from NC7-74 core samples ranged from 0.15 pCi/g to 1.57 pCi/g from depths of 101.5 and 87.0 ft, respectively. The ^{235}U activities in the NC7-74 leachate ranged from 0.008 pCi/g to 0.059 pCi/g from depths of 35.5 and 496.5 ft, respectively. The $^{235}U/^{238}U$ activity ratios detected in leachate for NC7-74 ranged from 0.00741 and 0.00713 from depths of 457.3 and 513.5 ft, respectively. As anticipated, all subsurface rock core samples from the Building 850 area yielded natural uranium isotopic ratios. Tables A-5 and A-6 list the analytical results for ^{235}U and ^{238}U activities and $^{235}U/^{238}U$ mass ratios.

2.7.3. Thorium

Pit 7 Complex Area. During the drilling of boreholes Pit7-01 through Pit7-10, we collected and analyzed 30 subsurface soil and rock samples for ^{232}Th. We collected these samples between October 13 and November 14, 1994, and analyzed them using LLNL's ICP/MS method. The ^{232}Th activities ranged from 0.5 ± 0.01 pCi/g from borehole Pit7-01, at a depth of 10.0 ft, to 2.98 ± 0.12 pCi/g from borehole W-Pit7-10, at a depth of 31.0 ft. Table A-8 lists the analytical results.

Building 850 Area. We also analyzed for ^{232}Th the 12 subsurface soil and rock samples from previously drilled boreholes NC7-44 and NC7-74; these samples had also been analyzed for uranium isotopes. On July 6, 1994, we collected one sample (from a depth of 35.5 ft) from borehole NC7-44 and 11 samples from NC7-74 for analyses using LLNL's ICP/MS method. We detected a ^{232}Th activity of 1.30 pCi/g in HNO_3/HCl-derived leachate from the single NC7-44 sample. The ^{232}Th activities detected in leachate from the 11 NC7-74 samples ranged from 0.23 pCi/g, from a depth of 184.5 ft, to 3.20 pCi/g from a depth of 87.0 ft. Figure 2-3 shows sample locations, and Table A-8 lists the analytical results.

2.7.4. PCBs, Dioxins, and Furans

Pit 7 Complex Area. While drilling at borehole locations Pit7-01 through Pit7-10, we collected and analyzed 23 subsurface soil and rock samples for PCBs. We collected these samples between October 17 and November 14, 1994, and analyzed them using EPA Method 8080. No PCBs were detected in these samples. Table A-9 lists the analytical results.

Building 850 Area. We collected and analyzed for Aroclor compounds (PCBs) one subsurface soil and rock sample from the Building 850 area. We collected this sample on December 2, 1994, and analyzed it using EPA Method 8080. Although we tested for seven compounds, we only detected Aroclor 1254 at 96 mg/kg. We also collected and analyzed 14 samples for total PCBs using immunoassay field test kits. We used these data to define the vertical extent of PCB contamination. Where detected, total PCB concentrations ranged from 0.95 mg/kg, from sample location 3SS-850-139, at a depth of 1.3 ft, to 32.5 mg/kg from locations 3SS-850-142 at a depth of 2 ft. PCBs were identified at a maximum depth of 2.7 ft at sample location 3SS-850-142 (14.45 mg/kg). Figure 2-6 shows locations of subsurface soil and rock samples, and Table A-9 lists the analytical results.

The distribution of PCBs generally shows a decrease with depth and radial distance from the firing table. This pattern is consistent with the low solubility and high viscosity of PCB oils.

2.7.5. Volatile Organic Compounds (VOCs)

Pit 7 Complex Area. To discern potential VOC (TCE) sources to ground water, we collected 88 subsurface soil and rock samples from the Pit 7 Complex area while drilling boreholes Pit7-01 through Pit7-10 (Fig. 2-2). We collected these samples between October 13 and November 14, 1994, and analyzed them using EPA Method 8010. No VOCs were detected in these samples and, thus, no VOC sources to ground water were identified. Table A-1 lists the analytical results.

2.7.6. Aromatics and Fuel Hydrocarbons (FHCs)

Pit 7 Complex Area. While drilling boreholes Pit7-01 through Pit7-10 (Fig. 2-2), we collected and analyzed 184 subsurface soil and rock samples for FHCs. We collected these samples between October 13 and November 14, 1994, and analyzed them using EPA Method 8020. No FHCs were detected in these samples. Table A-2 lists the analytical results.

2.8. Nature and Extent of Contamination in Surface Water

In May 1994, we conducted two bioassays on samples collected from spring 6 (812 CRK) and well 8 spring: the *Ceriodaphnia dubia* (water flea) chronic 7-day toxicity test (EPA Method 1002) and the *Selenastrum capricornutum* (algae) 4-day growth test (EPA Method 1003). The species used in these tests are most representative of the types of species expected in these springs. Appendix J presents a detailed discussion of the sampling and test procedures, as well as the results. We did not detect statistically significant toxicity resulting from exposing the two test species to water samples from either spring.

2.9. Nature and Extent of Contamination in Ground Water

2.9.1. VOCs

We collected and analyzed 653 ground water samples for VOCs. VOC samples were analyzed by EPA Method 601, 624, or 542.5. Maximum concentrations detected are listed by location in Table 2-5. No carbondisulfide, chloroform, cis-1,2 DCE, trans-1,2 dichloroethylene (DCE), 1,2-DCA, PCE, 1,1-dichloroethane (DCA), or methylene chloride were detected in any of the samples. Table B-1 provides the analytical results and individual sample collection dates for these maxima and other samples.

The maximum TCE concentration detected at the Pit 7 Complex during the SWRI period was 15.6 µg/L in a sample collected from well K7-05 in February 1985. Since then, this well has been destroyed and replaced by wells K7-09 and K7-10. For the post-SWRI period, the maximum TCE concentration detected was 15 µg/L in a ground water sample collected from well NC7-51 on March 21, 1995. Figure 2-10 shows the distribution of TCE concentrations in ground water at the Pit 7 Complex during the second quarter of 1995. Comparing this figure with Figure 11-58 of Webster-Scholten, 1994 (page 11-4-52) shows that the TCE plume has decreased in area by one-third since April 1988. The source continues to appear to be the northern portion of pit 5. Appendix G is a comparative statistical analysis of SWRI and post-SWRI VOC and water data for pit 5.

2.9.2. Aromatic and Fuel Hydrocarbons (FHCs)

We collected and analyzed 732 ground water samples for aromatic and fuel hydrocarbon compounds. The samples were analyzed using EPA Method 602 or 625. Maximum concentrations detected are listed in Table 2-6. The analytical results are presented in Table B-2. Benzene, 1,2-dichlorobenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, chlorobenzene, and total xylenes and total fuel hydrocarbons were not detected in any of the samples.

2.9.3. HE Compounds

We collected and analyzed 172 ground water samples for HE compounds. Ground water samples were analyzed for HMX, RDX, and TNT using EPA Method 8330. As is true for the SWRI data, no HE compounds were detected in any ground water samples. Table B-3 provides the analytical results.

2.9.4. Metals

We collected and analyzed 1,288 ground water samples for metals. From January 1993 through June 1995, following Pit 7 Resource Conservation and Recovery Act (RCRA) closure, three metals have exceeded their CLs: barium and vanadium (Christofferson et al., 1993a,b; 1994). These CLs were established for post-closure ground water monitoring of closed pit 7 by RCRA and State waste discharge requirements. Exceedance of a ground water CL signals that additional investigation should be conducted to determine whether a release has occurred. LLNL/ERD has assumed the responsibility for achieving closure on these CL issues under CERCLA (with oversight provided by the remedial project managers [RPMs] from the regulatory agencies). The concentration distribution of these metals in ground water is discussed in greater detail in Appendix I. One ground water sample from a pit 7 monitor well exceeded the lead CL; however, upon confirmatory resampling, lead concentration was below the CL. An evaluation of lead is presented in Appendix I for completeness.

Our evaluation indicates that some of the barium and lead may have been released from the Pit 7 Complex landfill. The vanadium observed in ground water is likely natural (Appendix I). In Table 2-7, we provide the maximum concentrations of barium, lead, and vanadium detected in ground water samples from wells downgradient of the Pit 7 Complex landfills; CLs; and the State maximum concentration limits (MCLs) for these metals in ground water. These metal concentrations did not exceed their respective MCLs during the post-SWRI period, and are all well within ranges encountered in natural waters (Hem, 1985) and in the Coast Range and Great Valley Physiographic provinces, in particular (Davis and Coplen, 1990; Dubrovsky et al., 1991; U.S. Geological Survey, 1992). Table B-4 contains ground water analytical results for metals in the Building 850/Pit 7 Complex OU.

2.9.5. Tritium

We collected 1,775 ground water samples for tritium activity and analyzed them using EPA Method 906 (scintillation counting). The maximum validated tritium activity detected was 323,000 ± 16,000 pCi/L in a sample collected from well NC7-25 on April 10, 1992. The non-validated maximum tritium activity detected was 623,540 ± 2190 pCi/L in a sample from well NC7-51 collected on April 7, 1993, but appears anomalous in being twice as high as the average recent tritium maximum. Figure 2-11 is a contour map of tritium activity distribution in ground water for the second quarter 1995; Table B-5 contains the analytical results. Comparing these data with a 1991 map of ground water tritium activity in the EFA/WFA study area (Webster-Scholten, 1994, Chapter 11, Fig. 11-59) indicates 1) ground water tritium activities have declined at the vast majority of wells, and 2) the areal extent of the ground water plumes has generally not increased. These two characteristics have prevailed over the past 4 years in spite of two unseasonably wet winters.

There continues to be three overlapping plumes from three separate sources: pit 3, pit 5, and Building 850. These three plumes contain approximately 0.53, 1.66, and 8.1 Ci of tritium, respectively. In 1987, the plumes contained 2.8, 1.2, and 3.2 Ci of tritium, respectively. The net increase in the total activity of the Building 850 plume reflects the nature of a continuous and decaying source. However, maximum activities in the plume continue to decline.

Tritium activities in ground water have generally declined from a historical 1984 maximum activity of 1,118,000 pCi/L (well NC7-23). We have constructed tritium time-series plots (Appendix C) for wells downgradient of the three sites of tritium release to ground water: pit 3, pit 5, and Building 850. These wells are located along three rough transects proximal to the release sites and the plume centers of mass (Fig. 2-3): Transect 1 (pit 3) wells (NC7-75, NC7-64, NC7-25, and NC7-65); Transect 2 (pit 5) wells (NC7-51, K7-03, NC7-40, K7-01, and NC7-26); and Transect 3 (Building 850) wells (NC7-70, NC7-28, NC7-61, and well 8 spring). As indicated by the tritium time-series plots (Appendix C), small tritium releases occurring at pits 3 and 5 and Building 850 after winter storm seasons in 1992–93 and 1994–95 caused minor tritium activity rises (spikes), which are generally superimposed on long-term downward trends. During both of these rainfall periods, nearly 15 in. of rain fell in the Site 300 area over several months (Appendix D, Table D-2). Appendix C contains representative well hydrographs. During the 1981–82 winter season, when initial slug releases of tritium occurred from pit 3, a total of 14.39 in. of rain fell. Normal rainfall at Site 300 is 10.03 in./year.

Tritium activities increased in wells immediately downgradient of the landfills. Wells K7-03, NC7-26, NC7-34, NC7-51, and NC7-64 exhibited increases in tritium activities within a few months of the highest 1993 water levels, whereas activities were declining in these wells earlier. Some monitor wells (NC7-20, NC7-21, and NC7-40) located close to the ephemeral stream channel east of the pits exhibited declining activities, probably as a result of preferential recharge and natural dilution of ground water.

For the winter of 1994–95, only ground water samples from one monitor well, NC7-34, contained tritium of distinctly higher activity than prior to the rain onset. Examination of activity trends during the remainder of 1995 should aid in determining whether an additional mobilization occurred as a result of 1994–95 rainfall. At the Pit 7 Complex, declining ground water tritium activities are a continuing general trend. The observed general decline is occurring at a rate faster than could be attributed solely to radioactive decay. Presumably, it is the result of natural dilution by recharge and dispersive mixing with water of low tritium activity.

Three wells in the vicinity of Building 850 (NC7-43, NC7-70, and NC7-71) yielded water samples indicating moderate increases in tritium activity following the wet winters of 1992–93 and 1994–95. Ground water from all other monitoring points, particularly near the western head of Doall Ravine (NC7-11, well 8 spring), exhibited tritium activity declines, presumably from natural dilution by infiltration of surface runoff. As at the Pit 7 Complex, the general trend indicates declining ground water tritium activities in the area.

As the Building 850 ground water tritium plume migrates farther into the EFA, tritium activity in ground water is progressively increasing in samples from wells K1-02B, NC2-06, NC2-11D, NC2-11I, NC2-12D, and NC2-12I. These wells define the leading edge of the tritium plume. Although tritium activities are in the 10^3 pCi/L range (Appendix B, Table B-5), they may increase as tritium from the continuous source at Building 850 moves down Doall Ravine into the EFA. Tritium in ground water in the EFA is migrating both northeast (south of pit 1) and southeast (along Elk Ravine).

2.9.6. Uranium

We collected and analyzed 863 ground water samples for uranium isotopic analysis. Initially, we used the alpha spectrometry method for uranium isotopic analysis. However, we changed to the more sensitive ICP/MS method because: 1) the error in the ^{235}U activity obtained from alpha spectrometry could be as great as 15–20%, resulting in inaccurate mass and activity ratios; and 2) the detection limit for ^{235}U was high. This ICP/MS method provided more accurate data to help determine which ground water samples contained natural or depleted uranium $^{235}U/^{238}U$ mass ratios. No mass ratios indicating enriched uranium were detected. In addition, because only depleted uranium was used in experiments in the OU (Roberts, 1982), we can conclude that all uranium at Site 300 found to contain natural $^{235}U/^{238}U$ signatures is considered natural in origin.

The maximum total uranium activity detected was 119.7 pCi/L in a ground water sample collected from well NC7-40 on November 30, 1994. This sample had a $^{235}U/^{238}U$ mass ratio of 0.0036 and, thus, contained depleted uranium. The State MCL for uranium in drinking water is 20 pCi/L. The ground water sample, measured by ICP/MS and containing the highest natural total uranium activity (21.32 pCi/L), was collected from well NC7-25 on April 26, 1995. The sample analyses indicated a $^{235}U/^{238}U$ mass ratio of 0.0073. The map on Figure 2-12 shows total uranium activity and $^{235}U/^{238}U$ mass ratios in ground water for the second quarter 1994. As shown, three plumes of depleted uranium are present in ground water; separate plumes emanate from each of pit 5, pit 7, and Building 850. Table B-6 lists the analytical results, and Table B-7 contains $^{235}U/^{238}U$ mass ratios.

Alpha spectrometry data collected during the SWRI assessment suggest that depleted uranium was originally released from pit 5 prior to 1985 and from pit 7, prior to 1991. The activity ratio of ^{234}U to ^{238}U ($a_{^{234}U} / a_{^{238}U}$) is ≥ 1 for natural uranium. Depleted uranium yields an $a_{^{234}U} / a_{^{238}U}$ of <1.

Three samples of ground water were collected from Well K7-07 (downgradient of pit 5) on February 27, May 20, and July 15, 1985). All samples were analyzed by alpha spectrometry which indicated $a_{^{234}U} / a_{^{238}U}$ of 0.77 ± 0.57, 0.77 ± 0.54, and 0.83 ± 0.49, respectively (Appendix H, Webster Scholten, 1994). Although the errors allow the ratios to enter the natural range, the fact that all three samples fall in the depleted range, strongly suggests depleted uranium contamination. The high errors associated with alpha spectrometry led us to use the more precise mass spectrometry method.

Two samples of ground water were collected from well NC7-34 (downgradient of pit 7) on January 11, and April 15, 1991, and indicated $a_{^{234}U} / a_{^{238}U}$ ratios of 0.53 ± 0.35 and 0.47 ± 0.31. There is no question that these samples contain depleted uranium. Likewise, the nine ground water samples collected from well NC7-28, downgradient of Building 850, all yield $a_{^{234}U} / a_{^{238}U}$ ratios indicative of depleted uranium. The samples were collected between February 22, 1990, and October 17, 1991, and analyzed by alpha spectrometry.

Appendix C contains selected time-series plots of total uranium activity in ground water for wells in the OU. The time-series plot for well NC7-48 indicates the likely occurrence of slug releases following the 1992–93 and 1994–95 rainfall seasons. This well is located directly downgradient (east) of pit 7. Uranium activities in samples from this well decreased after post-rainfall highs in ground water elevation were reached.

The time-series plot for well NC7-36, located between pits 3 and 5, indicates the occurrence of a slug release, presumably from pit 7, in early 1994 with generally declining activities since then.

The plot for well NC7-34, located between pits 3 and 5, suggests that slug releases from pit 7 occurred in early 1994 and 1995.

The time-series plot for well NC7-75 does not show evidence for any release from pit 3 at the low activities observed (<4 pCi/L).

The plot for well NC7-25, downgradient of pit 3, shows consistently high uranium activities; the source of these activities, as determined by isotopic ratios, is natural. This well and well NC7-51 define a region of high, natural uranium activities in ground water (Fig. 2-12).

2.9.7. Gross Alpha and Beta Radioactivity

We collected 483 ground water samples for gross alpha and beta radioactivity and analyzed them using EPA Method 900. The maximum activities detected were 152 and 148 pCi/L, respectively, both collected from monitor well NC7-48 on March 4, 1993. Table B-8 lists the analytical results, which are consistent with SWRI data.

2.9.8. Thorium

We collected 287 ground water samples for thorium isotopes and analyzed them with an alpha or mass spectrometer. The maximum activities detected are listed in Table 2-8. Table B-9 contains the complete analytical results. Appendix K contains an evaluation of ^{232}Th in ground water.

2.9.9. Radium

We collected 466 samples for radium isotopes and analyzed them using EPA Method 904. The maximum activities detected are listed in Table 2-8. Table B-10 contains the complete analytical results, which are consistent with SWRI data.

2.9.10. Other Radionuclides

We collected 40 ground water samples for miscellaneous radionuclides and analyzed them using EPA Method 901.1 (gamma spectroscopy). The maximum activities detected are listed in

3. Chemical Fate and Transport

In this chapter, we present the results of our fate and transport modeling of uranium migration in ground water from sources within the Building 850/Pit 7 Complex OU. No other contaminant release scenarios in the OU required modeling to generate data for the post-SWRI risk assessment. All previous documentation and results of such modeling are located in Chapter 11, Section 5, of the SWRI report (Webster-Scholten, 1994).

3.1. Post-SWRI Update of Contaminant Releases

In the final SWRI report, published in 1994, we noted the need to conduct an in-depth characterization of the nature and extent of uranium in environmental media in the OU. We have completed this investigation and identified three plumes of depleted uranium in ground water. All three plumes occur in a laterally extensive, perched water-bearing zone; the respective sources for the three plumes are pit 5, pit 7, and Building 850. The maximum total uranium activities detected in ground water downgradient of each of these sources are shown in Table 3-1.

3.2. Modeling of Uranium Fate and Transport in Ground Water

3.2.1. Model Description

To model the fate and transport of uranium in ground water, we used the 2-D, semi-analytical model PLUME (version 2.1, In-Situ, December 1986). As part of the baseline public health risk assessments, this model was previously applied to the LLNL Main Site (Layton et al., 1990) and Site 300 (Webster-Scholten, 1994). PLUME can simulate contaminant migration from multiple, areally distributed sources. The 2-D advective-dispersive transport equation can simulate advection, longitudinal and lateral dispersion, linear sorption partitioning, and first-order contaminant decay:

$$R\frac{\partial c}{\partial t} = D_x \frac{\partial^2 C}{\partial x^2} + D_y \frac{\partial^2 C}{\partial y^2} - v\frac{\partial c}{\partial x} - \lambda RC, \qquad (3\text{-}1)$$

where

R = retardation factor [dimensionless],

C = ground water total uranium activity [$\text{pCi} \bullet L^{-1}$] or [$M \bullet L^{-3}$],

D_x = longitudinal dispersion coefficient [$L^2 \bullet T^{-1}$],

D_y = transverse dispersion coefficient [$L^2 \bullet T^{-1}$],

v = average linear pore water velocity in the x-direction [$L \bullet T^{-1}$], and

λ = decay constant [T^{-1}].

The dispersion coefficient is the product of the dispersivity ($\propto$) and the pore water velocity:

$$D_i = \propto_i v. \tag{3-2}$$

The retardation factor is calculated as:

$$R = 1 + \frac{K_d \bullet \rho (1 - n)}{n} \tag{3-3}$$

where

ρ = particle density $[M \bullet L^{-3}]$,

n = porosity [dimensionless], and

K_d = soil-water partition coefficient for a particular chemical $[L^3 \bullet M^{-1}]$.

For this model we assumed that uranium-source activities are distributed uniformly over squares with sides parallel and perpendicular to the dominant flow direction (by definition along the x-axis). The rate of contaminant release at the source may be continuous, instantaneous, or may decline exponentially at a specified rate. We assume that aquifer properties are homogeneous and constant in time. We applied the model to simulate instantaneous vertical mixing of the contaminant within a constant thickness of uniform flow field, creating a 2-D problem. Use of a three-dimensional model would have produced longer flowpaths and longer travel times. Because PLUME simulates the shortest possible flow path, the calculated exposure-point activities are higher and, therefore, more health conservative.

3.2.2. Model Assumptions and General Input Parameters

The following assumptions are inherent in the PLUME model:

- Aquifer is thin and vertical mixing is rapid, thus enabling the plume to be treated in two dimensions,
- Aquifer materials are homogeneous and isotropic,
- Aquifer thickness is constant, and
- Ground water flow velocity is constant.

Also, we conservatively assume that no retardation occurs due to sorption, because uranium species tend to be mobile in the oxidizing, bicarbonate-rich ground waters of Site 300. We evaluate the effects of sorption as part of the sensitivity analysis (discussed in Section 3.2.3.4.). Additionally, we treat uranium as a non-decaying species, because the very long half-lives of uranium isotopes (millions–billions of years) relative to time-frames of concern, make any reduction in activity insignificant due to radioactive decay.

The model does not distinguish between depleted and natural uranium as both would be transported at the same rate. Because the calibration-point uranium activity was high, any uranium activity predicted by the model along the flow path will exceed the observed natural uranium activity. Thus, any potential effects of natural uranium migration are included in the model results.

For this application, we model dispersivity as increasing with distance from the source. The dispersivity relationships we used (linear increase with distance from the source) are well established in the scientific literature (Pickens and Grisak, 1981; Gelhar et al., 1985). The increase in dispersivity with distance from source is conceptually based on the fact that, at large spatial scales in the natural geologic environment, more variations in the hydraulic characteristics of the geologic materials are encountered. These variations enhance the macroscopic scale dispersive spreading of the plume. This approach is also consistent with the majority of the other simulations performed as part of the SWRI. Previous tritium modeling of this OU utilized dispersivity values based on the tritium distribution two years after the release, when the distances traveled by the plumes were much smaller than the distances of concern to the exposure points. Using the dispersivity values calibrated for short travel distances is unrealistically conservative when large distances are involved. The longitudinal dispersivity value utilized is 10% of the distance from the source to the exposure point for which activities are being calculated, and the transverse dispersivity is 10% of the longitudinal dispersivity.

The remaining parameters used in the modeling are consistent with those used for the ground water tritium modeling in the SWRI report (Webster-Scholten, 1994). The modeled flow paths (shown on Fig. 3-1) are based on OU hydrogeology and are consistent with those selected for the SWRI ground water tritium modeling.

3.2.3. Modeling of Uranium in Ground Water Downgradient of Pit 7

3.2.3.1. Specific Input Parameters

Input parameters for modeling the fate and transport of uranium in ground water downgradient of pit 7 are shown in Table 3-2.

3.2.3.2. Source

We assumed the source release to be instantaneous and sufficiently large to produce a modeled uranium activity of 150 pCi/L, 60 m downgradient of pit 7, 10 years after release. This location 60 m downgradient of pit 7 represents the center of mass of the ground water uranium plume at that time. Use of the 150 pCi/L source, which is over two times the highest observed ground water activity, assures a conservative simulation. The source area is simulated as a 10 m × 10 m square. A slug release activity of 9.1×10^{-5} Ci of uranium was required to achieve a uranium activity of 150 pCi/L at the calibration point 60 m downgradient from the source 10 years after release.

3.2.3.3. Results

The predicted maximum ground water uranium activity at the northern Site 300 boundary was 0.36 pCi/L, arriving in the year 2164 (Table 3-3). This value is representative of the entire exposure period because it varies by only a few percentage points over the 30-year period of concern used in the risk assessment (Chapter 4).

3.2.3.4. Sensitivity Analyses

Dispersivity. For the model calibration point at 60 m, the longitudinal and transverse dispersivity values are 6 m and 0.6 m, respectively. For the exposure point at the site boundary, 1,320 m downgradient in the direction of flow (north-northeast), the respective dispersivity values are 132 m and 13.2 m. These values are different from those used in the SWRI tritium modeling (15 m and 4 m), which were based on an initial calibration 2 years after tritium was released. We apply dispersivities that increase with distance, rather than those that remain constant because, in the field, dispersion increases along the flow path as mixing increases. The sensitivity analysis evaluates the differences in results arising from application of different dispersivity values. The results are given in Table 3-4. To calibrate the model at the calibration point with the latter dispersivities, a slug release of 3.6×10^{-4} Ci of uranium is necessary. Compared to the base case, this activity is greater because the dispersivities (15 m, 4 m) are larger than those used to calibrate with the base case (6 m, 0.6 m). The greater dispersive mixing requires a larger initial release to produce the 150 pCi/L at the calibration point. At the potential exposure point, however, the situation is reversed. The smaller dispersivity values used for this scenario (15 m, 4 m, versus 132 m, 13.2 m in the base case) yielded a higher potential exposure-point activity (Table 3-4).

Source Release Mechanism. Despite the fact that data indicate that uranium was released from pit 7 as a slug (Chapter 2), we compared the effects of continuous release and instantaneous slug release. The results are also shown in Table 3-4. For both sets of dispersivities tested, the exposure-point activities stabilized to significantly higher activities, because of the continuous addition of uranium to the aquifer.

Exceedence of Drinking Water Standard. As part of the sensitivity analysis, we determined what activities would have to be present currently in the near-source areas in order to exceed 20 pCi/L (the State of California drinking water standard for uranium) at the Site boundary. Table 3-5 summarizes the uranium activities in ground water at the near source calibration point (60 m downgradient of pit 7 at a time 10 years after the initial release) that would yield a uranium activity of 20 pCi/L when modeled to a hypothetical well at the northern Site 300 boundary exposure point. To achieve that 20 pCi/L activity for the sensitivity analysis, a continuous source leaching from pit 7 would produce a near-source, present-day uranium activity approximating that observed in the field. An instantaneous release, which field uranium data indicate (Chapter 2), requires near-source uranium activities much greater than those observed.

Retardation. We also evaluated the effects of possible uranium sorption onto the geologic materials, also using a K_d value of 35 L/Kg (Thibault et al., 1990). This K_d represents the geometric mean of 24 values (0.03–2,200 L/Kg) determined for sandy soil. This K_d value made calibration problematic because it produced a retardation factor of 372, which is unreasonably high for Site 300. If the model is calibrated to 150 pCi/L at a point 60 m from the landfill and a retardation factor of 372 is used, that activity is reached after 3,720 years. Furthermore, it results in the same potential exposure-point uranium activity of 0.36 pCi/L approximately 65,000 years after release. If we calibrate the model at a point 0.16 m from the edge of the source area (the approximate distance the uranium would travel at that rate of retardation) for 10 years after release, a exposure-point activity of 0.024 pCi/L is predicted at the Site 300 boundary. Thus, depending on the model calibration, the potential exposure-point uranium activity is the same as or less than that predicted by the base case (non-retarded) analysis.

3.2.4. Modeling of Uranium in Ground Water Downgradient of Pit 5

3.2.4.1. Specific Input Parameters

Input parameters for the pit 5 simulation are shown in Table 3-6 for modeling the fate and transport of uranium in ground water downgradient of pit 5.

3.2.4.2. Source

The pit 5 source is assumed to be instantaneous and sufficiently large to produce a uranium activity of 300 pCi/L (approximately three times the highest observed activity), 100 m downgradient of pit 5, 10 years after release. This location represents the center of mass of the ground water uranium plume at that time. The source area is simulated as a 10 m × 10 m square. If the source area dimensions increased to produce a line source (10 m × 150 m), the total released activity shows a slight increase; however, a decrease occurs in the potential exposure-point activities. We discarded the line-source approach in favor of the more conservative 10 m^2 square point-source approach. A slug release activity of 5.0×10^{-4} Ci of uranium was required to achieve a uranium activity of 300 pCi/L at a modeled calibration point 100 m downgradient from the source 10 years after release.

3.2.4.3. Results

The predicted maximum ground water uranium activity at the northern Site 300 boundary was 1.77 pCi/L, arriving in the year 2098 (Table 3-3). This activity is representative of the entire exposure period because it varies by only a few percentage points over the 30-year period of concern.

3.2.4.4. Sensitivity Analyses

Dispersivity. For the calibration point at 100 m, the dispersivities are 10 m and 1.0 m, respectively. For the exposure point at the Site 300 boundary, 1,400 m downgradient in the direction of flow (north-northwest), the respective dispersivities are 140 m and 14 m. The results are given in Table 3-7. To calibrate the model at the calibration point, a slug release of 1.3×10^{-3} Ci of uranium is necessary. Compared to the base case, this activity is greater because the dispersivities (15 m, 4 m) are larger than those used to calibrate with the base case (10 m, 1.0 m). The greater dispersive mixing requires a larger initial release to produce the 300 pCi/L at the modeled calibration point. At the potential exposure point, however, the situation is reversed. The smaller dispersivity values used for this scenario (15 m, 4 m, versus 140 m, 14 m in the base case) yielded a higher potential exposure-point activity.

Source Release Mechanism. Despite that fact that data indicate that the uranium was released from pit 5 as a slug, we also compared the effects of a continuous release to the instantaneous release. The results are also given in Table 3-7. For both sets of dispersivities tested, the exposure-point activities stabilize to significantly higher activities because of the continuous addition of uranium to the aquifer.

Exceedence of Drinking Water Standard. As part of the sensitivity analysis we determined what activities would have to be present currently in the near-source areas in order to exceed 20 pCi/L (the State of California drinking water standard for uranium) at the Site boundary. Table 3-5 summarizes the uranium activities in ground water at the near source calibration point

(100 m downgradient of pit 5 at a time 10 years after the initial release) that would yield a uranium activity of 20 pCi/L when modeled to a hypothetical well at the northern Site 300 boundary exposure point. To achieve that 20 pCi/L activity for the sensitivity analysis, a continuous source leaching from pit 5 would produce a near-source, present-day uranium activity approximating that observed in the field. An instantaneous release, which field uranium data indicate (Chapter 2), requires near-source uranium activities much greater than those observed. We note that this is only a sensitivity analysis.

Retardation. As for pit 7, above, we also evaluated the effects of possible uranium sorption onto the geologic materials, using the same K_d value of 35 L/Kg (Thibault et al., 1990). This K_d value produces a retardation factor of 372. If the model is calibrated to 300 pCi/L at a point 100 m from the landfill, the plume reaches the site boundary exposure point after 43,000 years at a predicted activity of 1.77 pCi/L, the same activity as for the unretarded plume. Retardation slows down the movement of the plume but does not change (neglecting radioactive decay) the maximum activity at a specific point. If the model is calibrated at a point 0.3 m from the edge of the source (the approximate distance the uranium would travel at that rate of retardation) 10 years after release, a potential exposure-point activity of 0.059 pCi/L is predicted at the Site 300 boundary. Thus, depending on the model calibration, the potential exposure-point activity is the same as or less than that predicted by the base case scenario.

3.2.5. Modeling of Uranium in Ground Water Downgradient of Building 850

3.2.5.1. Specific Input Parameters

Input parameters for the Building 850 simulation are shown in Table 3-9 for modeling the fate and transport of uranium in ground water downgradient of Building 850.

3.2.5.2. Source

The source is assumed to be continuous and sufficiently large to produce a uranium activity of 15 pCi/L (approximately three times the highest observed uranium activity [5.42 pCi/L in a sample collected from well 8 spring on September 27, 1993] at the 300-m distance from the source area), 300 m downgradient of Building 850, 30 years after release began in 1963 (assumed). Calibration to this more distant point is necessary because PLUME is unstable (activities oscillate) at short distances from the source. The source area is simulated as a 10 m × 10 m square. A continuous uranium release rate of 7.2×10^{-6} Ci/year was required to achieve a uranium activity of 15 pCi/L at the calibration point 300 m downgradient from the source, 30 years after release began in 1963.

3.2.5.3. Results

The predicted maximum uranium activity at the eastern Site 300 boundary was 1.26 pCi/L, arriving in the year 2199 (Table 3-3). We also simulated the effects of mixing the southeastern component of the pit 5 uranium plume with the Building 850 plume. In this case, the parameters used to simulate the migration of the pit 5 plume are 1) same activity released as modeled for pit 5 alone, 2) pore-water velocity of 45 mo/year, and 3) aquifer thickness of 2 m. The predicted maximum uranium activity at the eastern Site 300 boundary was 1.04 pCi/L, arriving in the year 2055 (Table 3-3). This arrival time is for the maximum contribution from pit 5. The predicted activity for the combined sources is less than that for Building 850 alone because the Building 850 plume reaches its maximum activity at the potential exposure point significantly later. The predicted activities are stable and representative of the entire 30-year exposure period utilized in the risk assessment.

3.2.5.4. Sensitivity Analyses

Dispersivity. For the modeled calibration point at 300 m, the dispersivities are 30 m and 3.0 m, respectively. For the potential exposure point at the Site 300 boundary, 3,500 m downgradient in the direction of flow, the respective dispersivities are 350 m and 35 m. The results are given in Table 3-10. The smaller dispersivity values used for this scenario (15 m, 4 m) yield a higher exposure-point activity than those values used in the base case (350 m, 35 m for the Site 300 boundary, and 290 m, 29 m for spring 6).

For the larger dispersivities, the contribution from pit 5 is small (approximately 0.3 pCi/L) and arrives at the exposure points earlier than the maximum activity from Building 850. Therefore, at the time of the maximum pit 5 contribution to the potential exposure point at the eastern Site 300 boundary, the maximum total activity is less than that produced by the Building 850 source along at a later time point. For the lower dispersivities, the pit 5 plume dominates, and the total activity has significant contributions from both sources.

Exceedence of Drinking Water Standard. As part of the sensitivity analysis we determined what activities would have to be present currently in the near-source areas in order to exceed 20 pCi/L (the State of California drinking water standard for uranium) at the Site boundary. Table 3-11 summarizes the uranium activities in ground water at the near source calibration point (300 m downgradient of Building 850 at a time 30 years after the initial release) that would yield a uranium activity of 20 pCi/L when modeled to a hypothetical well at the southern Site 300 boundary exposure point. To achieve that 20 pCi/L activity for the sensitivity analysis, a continuous source leaching from Building 850 would produce a near- source, present-day uranium activity one to two orders of magnitude greater than what is observed in the field. In this analysis, the contribution of uranium from the pit 5 plume is minor.

Retardation. Because of PLUME code limitations, we did not evaluate the effects of retardation for this scenario. In the code, the maximum time period for release from a continuous source is 999 years. This time period is much less than is required for a retarded uranium plume to reach either exposure point. In the retardation models for pit 5 and pit 7, the results indicate that the potential exposure-point activities would be equal to or less than the predicted base case activities.

3.3. Summary

Our modeling predicts that maximum potential uranium exposure-point activities in ground water reaching the Site 300 boundary are likely to be significantly less than the State MCL of 20 pCi/L. The maximum calculated uranium potential exposure-point activity in ground water at the Site 300 boundary, arising from OU sources, is 1.77 pCi/L. Our results are based on health conservative assumptions.

4. Post-SWRI Risk Assessment for the Building 850/Pit 7 Complex Operable Unit

The post-SWRI risk assessment for the Building 850/Pit 7 Complex operable unit is divided into two principle categories: 1) an assessment of human exposure and risk [Section 4.1.] and 2) an assessment of ecological exposure and risk [Section 4.2.].

From our review and evaluation of environmental monitoring data presented in Chapter 2, we identified contaminants of potential concern in ground water, surface soil, and indoor air, that were collected and analyzed after the cutoff date for the SWRI (December 31, 1991). In Chapter 2, we provide the results of direct measurements of tritium in air inside Building 850. Chapter 3 presents discussion and results of environmental fate and transport modeling used to estimate exposure-point concentrations of uranium in ground water originating within the OU. The assessments presented here evaluate potential present and future public health and ecological risks associated with that contamination based on the assumption that no cleanup or remediation activities will take place at the Site. However, as noted in the SWRI report (Webster-Scholten, 1994), both DOE and LLNL are committed to ensuring that appropriate actions are taken to reduce risks to acceptable levels and mitigate any adverse impacts to the environment associated with past activities in this OU.

4.1. Human Health Exposure and Risk Assessment

In this section, we provide data and analyses of issues related to human health risks and hazards associated with the Building 850/Pit 7 Complex OU. We first present the results of calculations of potential exposure, risk, and hazard arising from several metals, uranium, and thorium in surface soil. These calculations pertain to adults on site who may work outdoors in the immediate vicinity of the Building 850 firing table, or outdoors throughout the OU. In addition, we compare surface soil concentrations of PCBs, CDDs, and CDFs with PRGs developed by Region IX of the U.S. EPA (U. S. EPA, 1995b). We also describe the results of calculations of potential exposure and risk from tritium in indoor air to individuals who work inside Building 850. Following a discussion of these data, we evaluate the potential exposure, risk, and non-cancer hazard to hypothetical residents at three locations near the Site 300 boundary based on predicted use of ground water contaminated with depleted uranium ^{238}U-rich. The methodology used to calculate exposure, and the associated incremental cancer risk and noncancer hazard, are presented in Chapter 6 of the SWRI report (Webster-Scholten, 1994).

4.1.1. Calculation of Potential Exposure, Risk, and Noncancer Hazard Attributable to Surface Soil Contamination

Data available at the time of the SWRI report (Webster-Scholten, 1994), in combination with data collected after the SWRI data cut-off date of December 31, 1991, indicate that surface soil in the Building 850/Pit 7 Complex OU is contaminated with several metals and two isotopes of uranium (from depleted uranium). The ^{232}Th may also be present as a surface soil contaminant in localized areas (Chapter 2, Appendix E). To evaluate potential adult on-site exposures to these materials, we separated the OU into two regions based on employee activity patterns. One activity area encompasses the immediate vicinity of the Building 850 firing table, and was selected based on interviews with LLNL-Site 300 personnel regarding the area used in daily activities (Hall, 1995). The second activity area encompasses the remainder of the OU, and reflects the fact that outdoor activity in the OU outside of the immediate area of the firing table is not focused in a specific region. Table 4-1 lists the location identifiers for surface soil samples contained within each of the activity areas.

Surface soil at the Building 850 firing table activity area is contaminated with beryllium, cadmium, copper, ^{238}U, and ^{235}U (Table 4-2). We evaluated potential exposure of adults on site to these surface soil contaminants via inhalation of contaminated, resuspended particulates, dermal absorption through direct contact, and incidental ingestion. Tables 4-3 and 4-4 provide the variables used to calculate potential incremental cancer risk and noncancer hazard associated with inhalation exposure in this area. Tables 4-5 and 4-6 give analogous data for dermal absorption and incidental ingestion. The results of these calculations are summarized in Tables 4-7 and 4-8. Table 4-9 presents the potential additive risk and HI attributable to all three exposure pathways for adults who may work in this area. These tables indicate that the additive risk of 7×10^{-6} is due entirely to incidental ingestion and dermal absorption of surface soil contaminated with beryllium. The total HI of 2.9×10^{-2} is also due to dermal and ingestion exposures, but is the result of exposure to surface soil contaminated with copper, cadmium, and ^{238}U.

Surface soil throughout the OU is contaminated with ^{235}U and ^{238}U (from depleted uranium). Limited data indicate that localized areas of surface soil may also be contaminated with ^{232}Th (Table 4-10, Appendix E, Figure E-25). We evaluated potential exposure, risk, and noncancer hazard from these substances based on inhalation of resuspended contaminated particulates, dermal absorption, and incidental ingestion. Tables 4-11 and 4-12 present variables used to calculate incremental cancer risk and noncancer hazard associated with inhalation exposure in this area. Tables 4-13 and 4-14 give the corresponding variables used in calculations of dermal absorption and incidental ingestion. Our calculations yielded estimates of risk of 3×10^{-8} from dermal and ingestion exposures and inhalation of resuspended contaminated particulates. These values, along with the HIs, are given in Tables 4-15 and 4-16. The additive risk and HI from all three exposure pathways are presented in Table 4-17.

4.1.2. PCBs, CDDs, and CDFs in Surface Soil: Comparison with Preliminary Remediation Goals

Prior to regulation of PCBs, PCB-containing capacitors were used in certain test activities conducted at the Building 850 firing table. PCBs were subsequently detected in 18 of 32 surface soil samples (analyzed by EPA method 8080) collected near the firing table (Appendix I, Table I-19; Fig. 2-7). As noted in Chapter 2, the concentration of these substances in surface soil generally decreases with increasing distance from the firing table. Based on discussions with Dr. Dan Stralka, Toxicologist, U.S. EPA Region IX (Carlsen, 1994), we compared each PCB concentration with the U.S. EPA Region IX PRGs for an industrial site (0.34 mg/kg) and a residential site (0.066 mg/kg) (U.S. EPA, 1995b). Each PRG represents the concentration of PCBs in surface soil associated with an incremental cancer risk of 1×10^{-6}; the exposure parameters and assumptions used to derive the PRGs are available in U.S. EPA (1995b). Fifteen of the 18 surface soil sample locations with measured PCB concentrations (Appendix Table I-19) exceed the industrial PRG; all 18 of these locations have concentrations of PCBs that exceed the residential PRG. We also compared PCB concentrations to remedial action goals for Superfund Sites (U.S. EPA, 1990b). These remedial action goals range from 0.1 to 10.0 mg/kg, and correspond to an incremental cancer risk of 2×10^{-6} to 2×10^{-4}, respectively. These risk estimates were developed by the U.S. EPA based on exposure assumptions associated with residential land use (U.S. EPA, 1990a). PCB concentrations exceed the remedial action goal of 0.1 mg/kg at 17 of 18 locations; only 6 of 18 locations have PCB concentrations in excess of 10.0 mg/kg. Four of these locations are within the immediate vicinity of the Building 850 firing table.

Combustion of chlorine-containing material such as PCBs is believed to form CDDs and CDFs (U.S. EPA, 1989). Surface soil sampling conducted in December 1994 in the vicinity of the Building 850 firing table (Appendix I and Figure 2-8) yielded detections of CDDs and/or CDFs in each of 10 samples (collected from 8 locations). We used the TEF approach to evaluate the potential risks associated with exposure to CDDs and CDFs in the vicinity of the Building 850 firing table (U.S. EPA, 1989). This approach relates the toxicity of the 209 CDD and CDF congeners or homologues to that of the CDD 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD). The data and TEF evaluation are presented in Appendix F. That evaluation identified four discrete surface soil sample locations (3SS-850-107, 3SS-850-142, 3SS-850-139, and 3SS-850-140) where the total TCDD equivalent concentration exceeds the TCDD PRG of 2.4×10^{-5} (mg/kg) (U.S. EPA, 1995b). All of these locations are within the Building 850 firing table activity area.

4.1.3. Calculation of Exposure and Risk Attributable to Tritium Vapor in Building 850

As noted in the SWRI report (Webster-Scholten, 1994), the Building 850 firing table has been one of the principal detonation sites for experimental test assemblies at Site 300. Most of the tritium shipped to Site 300 was used at this table (Buddemeier, 1985), and infiltration of water through the firing table has contaminated the soil and ground water below.

Samples of tritium in air inside Building 850 were collected over a 5-1/2-month period to determine whether tritium vapor is migrating from soil to indoor air, and if so, whether it is present at levels that could pose a potential risk to human health. Table 2-10 provides the tritium activity concentrations measured in indoor air at Building 850 during each sampling period. The mean of these values, 2.1×10^{-12} µCi/mL, was used to estimate the magnitude of exposure for individuals who regularly work inside Building 850. We assumed that this activity-concentration 1) would remain constant over the theoretical 25-year exposure period, and 2) would not decline due to dilution, dispersion, or radioactive decay.

For individuals inside Building 850, we considered potential exposure to tritium vapor from two pathways, inhalation and dermal absorption. Osborne (1966) demonstrated that tritium vapor can be absorbed dermally, and that the magnitude of exposure by this route is approximately half the intake that results from inhalation. The variables used to calculate incremental excess cancer risk from tritium inside Building 850 are given in Table 4-18. Our calculations indicate that the risk associated with exposure to tritium vapor in Building 850 is 1×10^{-8}.

4.1.4. Calculation of Exposure, Risk, and Noncancer Hazard Attributable to Uranium in Ground Water

Data presented in Chapter 2 indicate that releases of depleted uranium from pit 5, pit 7, and the Building 850 firing table have contaminated ground water in each of these regions. Each release was modeled to a point at the nearest site boundary in the direction of ground water flow, where each point represents a theoretical residential exposure location (water-supply well). Additional modeling accounted for a small mass of uranium-contaminated ground water from pit 5 intermingling with the Building 850 plume as it moves toward the site boundary. As stated in Chapter 3, maximum activities of uranium are predicted to occur in the year 2164 (pit 7 source), 2098 (pit 5 source), 2199 (Building 850 source), and the year 2055 (combined sources from Building 850 and pit 5). These activities were used to estimate the 30-year cumulative dose and incremental cancer risk associated with residential use of uranium-contaminated ground water. A hazard quotient was also calculated to evaluate the potential for noncancer health effects attributable to uranium exposure.

The pathway exposure factors we developed to estimate the annual dose of uranium incorporated a series of age-specific physiological parameters (U.S. EPA, 1990a; U.S. Nuclear Regulatory Commission (U.S. NRC), 1977). These parameters are the same as those used in our SWRI calculations of age-specific exposure and risk from tritium-contaminated ground water (Webster-Scholten, 1994). We calculated potential exposure to uranium-contaminated ground water from direct ingestion of water, and from ingestion of home-grown beef, milk, and produce raised with uranium-contaminated ground water. The transfer factors used to estimate uptake of uranium by dairy cattle were obtained from the National Council on Radiation Protection and Measurements (NCRP) (1984). No transfer factor has been developed that directly relates ingestion of uranium-contaminated water to the quantity of uranium in beef tissue. However, a transfer factor is available (NCRP) (1984), which translates the uptake of uranium by plants to a quantity in beef cattle that ingest those plants. We assumed that the transfer of uranium directly from water to beef would occur by the same processes. Table 4-19 summarizes the predicted activity of uranium in ground water at the site boundary for each receptor location, and the corresponding estimates of potential incremental cancer risk and hazard. The predicted risks range from 1×10^{-7} (pit 7 source) to 6×10^{-7} (pit 5 source); the HIs range from 9.9×10^{-3} (pit 7 source) to 4.9×10^{-2} (pit 5 source).

4.1.5. Conclusions

From the evaluation of potential human health risks presented in this section, we determined that:

- The potential exposure of adults on site to surface soil contamination in the Building 850 firing table activity area is associated with a risk of 7×10^{-6}. The noncancer HI for this location is <1, and indicates that it is unlikely an individual would experience adverse noncancer health effects from exposure. The risk and noncancer hazard attributable to surface soil contaminants throughout the OU are within generally acceptable levels (U.S. EPA, 1990b).

- Surface soil in the vicinity of the Building 850 firing table is contaminated with PCBs; sample results indicate that some locations exceed the U.S. EPA Region IX PRG for PCBs (U.S. EPA, 1995b) and/or remedial action goals for PCBs for Superfund Sites (U.S. EPA, 1990b).

Four of the locations with PCB contamination also have a total TCDD equivalent concentration greater than the U.S. EPA Region IX PRG for TCDD (U.S. EPA, 1995b).

- Tritium vapor in air inside Building 850 does not pose an unacceptable health risk to individuals who may work in this building on a regular basis. Similarly, the potential risks and noncancer hazards associated with residential use of ground water contaminated with uranium are also within generally acceptable levels (U.S. EPA, 1990a).

4.2. Ecological Assessment

As part of the baseline risk assessment presented in the SWRI report, we evaluated potential hazards to ecological receptors as a result of surface water, surface soil, and subsurface soil contamination (Webster-Scholten, 1994). In that assessment, we evaluated the potential hazard to perennial grasses, aquatic invertebrates, and three vertebrate species (California ground squirrel, black-tailed deer, and the San Joaquin kit fox) from exposure to both radionuclides and non-radiologic parameters. As a result of this evaluation, we concluded that a potential hazard exists to aquatic organisms as a result of copper in spring 6, and to the three vertebrate species as a result of cadmium in surface soil. In this section, we update our ecological assessment by evaluating the characterization data more recently collected and presented in Chapter 2.

4.2.1. Aquatic Bioassays

In the spring of 1994, we conducted two bioassays on samples collected from spring 6 to further evaluate the potential ecological hazard to aquatic organisms from water in this spring. The two bioassays conducted were chronic toxicity tests using the *Ceriodaphnia dubia* (water flea) 7-day renewal test (EPA Method 1002) and the *Selenastrum capricornutum* (algae) 4-day static test (EPA Method 1003). These tests were selected because they use organisms most representative of the types likely found in this spring. Sampling details, test methods, and bioassay results are presented in Appendix J.

We also conducted the bioassays on samples collected from well 8 spring. Although no potential ecological hazard was indicated to aquatic organisms from water in well 8 spring in our original baseline assessment, we wanted to verify that the relatively high tritium activities detected were not of ecological concern.

No statistically significant effects were observed on *Ceriodaphnia* survival or reproduction or on *Selenastrum* growth in any of the samples tested. Our original baseline assessment indicated copper concentrations in spring 6 may be of ecological concern as they slightly exceeded national ambient water quality criteria. However, the results of these bioassays provide a more realistic picture of the true ecological hazard associated with the spring water. Therefore, we conclude that exposure to water from springs 6 and well 8 spring does not represent an ecological hazard to aquatic organisms.

4.2.2. Cadmium in Surface Soil

We collected additional surface soil samples throughout the OU and analyzed them for cadmium. Cadmium concentrations in these samples confirmed that high concentrations of cadmium (> 0.5 mg/kg) are confined primarily to areas around the firing tables, buildings, and roads in the more developed portions of the OU. Cadmium contamination is not observed in the undeveloped areas of the OU.

We also tracked all reported deer sightings throughout Site 300. These sightings have occurred almost exclusively in the southwestern corner of the Site, near most of the flowing springs. No sightings have occurred in areas of high cadmium contamination. Therefore, it appears that only resident species in the immediate vicinity of the cadmium surface soil contamination may be at some risk. Adequate controls are in place through the existing biological survey program to ensure that sensitive species do not move into those areas.

4.2.3. PCBs and CDDs in Surface Soil

As a result of the additional characterization work conducted in the OU, we detected low levels of a PCB and CDDs in the immediate vicinity of the Building 850 firing table. The compounds detected are the PCB Aroclor 1254; various CDDs, particularly the CDD isomer 2,3,7,8-tetrachlorodibenzo-*para*-dioxin (2,3,7,8-TCDD); and various CDFs. The distribution of these substances is discussed in Chapter 2, and analytical results are presented in Appendix A, Table A-18. Due to the high levels of chlorination, these compounds are highly persistent and generally environmentally stable, although volatilization and photolysis are major removal processes for CDDs (National Research Council of Canada, 1981).

The toxicity of these compounds is enhanced by their ability to bioaccumulate and biomagnify within the food chain as a result of their extremely high liposolubility (Eisler, 1986a,b). Ecological receptors that may be potentially impacted by the PCBs/CDDs detected at the Building 850 firing table are soil invertebrates, resident rodent populations (both fossorial and non-fossorial), birds feeding on the soil fauna and rodent population, and canids (foxes and coyotes) feeding on the rodent population. Therefore, we briefly review some of the relevant literature available on the ecological impacts of PCBs and CDDs, and qualitatively evaluate the potential for adverse impact to those receptors identified at the Building 850 firing table.

4.2.3.1. PCBs

Within upper trophic-level vertebrates, birds are more resistant than mammals to PCBs, with LC_{50}s varying from 604 to more than 6,000 mg Aroclor/kg diet (Eisler 1986a) (an LC_{50} is the concentration in the diet that is lethal to 50% of the test organisms). Within sensitive avian species, PCBs disrupt normal patterns of growth, reproduction, metabolism, and behavior. For most avian species, a reduction in eggshell thickness of 15 to 20% is a critical value beyond which population numbers will decline. Although this mechanism is well known for other organochlorines, particularly pesticides, the evidence implicating PCBs as a major source of eggshell thinning is inconclusive (Eisler, 1986a). Avian species that are comparatively resistant to the reproductive effects of PCBs include Japanese quail, northern bobwhites, mallards, and screech owls. Delayed reproductive impairment was documented in ringed turtle-doves that were given 10 mg Aroclor 1254/kg of diet for 3 mo. American kestrels that were given 33 mg Aroclor 1254 /kg of diet for 62–69 days showed a significant decline in sperm concentration (Bird et al., 1983).

Within the higher trophic-level mammals, mink is one of the most sensitive wildlife species to PCB; diets containing 6.7–8.6 PCB/kg fresh weight of diet kill 50% of the mink in 9 mo (Eisler 1986a). Diets with as little as 2 mg/kg of Aroclor 1254 for 8 mo resulted in near reproductive failure, but dietary levels of 1 mg/kg did not affect reproduction. The European ferret is significantly more resistant than mink to PCBs, demonstrating wide variance in interspecies sensitivity to PCBs, even among closely related species. Dogs that were fed various Aroclor PCBs for 2 years showed no measurable effects at daily dietary levels equivalent to a dose of 0.255 mg/kg body weight (Eisler, 1986a).

In rats, a total intake of Aroclor 1254 at about 500–2,000 mg/kg body weight is the lethal level for dietary exposure 1–7 weeks (Eisler 1986a). Rats fed various Aroclor PCBs daily for 2 years showed no measurable effects at a PCB dietary level equivalent to 0.5 mg/kg of body weight. Aroclor 1254 administered at dietary levels of 25–100 mg/kg for up to 3 weeks can significantly reduce sleeping times in animals that normally aestivate or hibernate, such as white-footed mice (*Peromyscus leucopus*) and raccoons (*Procyon lotor*). The implications of this observation is not clear (Eisler 1986a). No significant increases in chromosome damage were identified in three species of rodents (*Peromyscus leucopus*, *Sigmodon hispidus*, and *Reithrodontomys fulvescens*) collected from a site contaminated with Aroclor 1254 at 0.3–863 mg/kg of soil (Shaw-Allen and McBee 1993). This lack of increased chromosome damage is supported by findings of previously published laboratory studies.

In a 14-day laboratory soil bioassay, the LC_{50} for the house cricket was 1,200 mg Aroclor 1254 per kg of soil (Paine et al, 1993), with significant PCB body accumulations after 3 days of exposure. These same authors found no adverse effect on abundance in field crickets at a landfill site containing 29–9,320 mg/kg of PCBs, predominantly Aroclor 1254. They concluded, therefore, that the likelihood of sufficient body burdens to cause acute mortality is low even though PCBs in soil can rapidly move into epigeal fauna (Paine et al., 1993).

4.2.3.2. CDDs

Information on the biological properties of CDD isomers is generally lacking or scarce, and the information available is generally restricted to 2,3,7,8-TCDD. The following information is summarized from Eisler (1986b).

For birds, a single oral dose of 2,3,7,8-TCDD produced LD_{50} values from 15 µg/kg body weight for the northern bobwhite to > 810 µg/kg body weight for the ringed turtle dove. The 2,3,7,8-TCDD exposure in birds is accompanied by edema.

In mammals, significant inter- and intraspecies differences in sensitivity to 2,3,7,8-TCDD are documented. A difference in sensitivity of 8,400 × was observed between the single oral LD_{50} dose for the guinea pig and the hamster, 0.5 µg/kg vs. 1,1557 µg/kg. The 0.6 µg/kg LD_{50} dose for the guinea pig suggests that 2,3,7,8-TCDD may be the most toxic compound ever tested on small laboratory animals. An intraspecific difference up to 14 × may also occur in 2,3,7.8-TCDD sensitivity. Effects of 2,3,7,8-TCDD exposure in mammals include loss of body weight and delayed lethality, with severe liver damage in rats, mice, and rabbits. A three-generation study with rats detected a decreased litter size at birth, increased number of stillborns, and reduced survival and growth of young in the F_1 and F_2 generations at dietary concentrations of 120–290 ng/kg 2,3,7,8-TCDD. Reproduction was not affected at dietary concentrations of 12–30 ng/kg.

In soil invertebrates, two species of earthworms (*Allolobophophor caliginosa*, *Lumbricus rebellus*) showed no adverse effects when held for 85 days in soils containing extremely high concentrations of 2,3,7,8-TCDD at 5 mg/kg, but both species died at 10 mg/kg. In soil with lower concentrations of 50 µg/kg, the earthworms accumulated five times the soil concentration in 7 days. No soil avoidance by the earth worms was observed.

4.2.4. Impacts of PCBs/CDDs on Ecological Receptors at the Building 850 Firing Table

The evidence provided above suggests that soil invertebrates identified at the Building 850 firing table will not be adversely impacted by the presence of PCBs or CDDs, given the generally low concentrations. Although less clear, this conclusion appears to apply to resident rodents as well. Even if some localized impact to rodents results from the presence of PCBs or CDDs, given the extremely limited extent of contamination, it is unlikely that significant population impacts will occur. The ecological receptors most likely at risk appear to be those higher trophic-level predators that feed or den exclusively in the area. However, given the extremely limited areal extent and relatively low concentrations of these compounds detected near the Building 850 firing table, it is unlikely that upper trophic-level receptors (mammalian or avian) will be adversely impacted by the presence of these compounds. The nature of the activities at the active firing table help to preclude any higher trophic-level vertebrates from denning or feeding exclusively in the area. Future biological surveys will be used to monitor the area for the presence of any sensitive species.

4.2.5. Conclusions

With the evidence presented in this section, we conclude the following with respect to the potential for adverse ecological impact as a result of contaminants found in surface water and surface soil in the Building 850/Pit 7 Complex OU.

- Results from two bioassays indicate that aquatic receptors will not be adversely impacted by substances found in water from spring 6 and well 8 spring.
- Cadmium is found in surface soil in the OU at concentrations that may adversely impact burrowing and grazing vertebrates. However, this contamination is limited to the more developed portions of the OU, greatly reducing the likelihood that sensitive ecological receptors will come into contact with the contaminated surface soil.
- Surface soil in the immediate vicinity of the Building 850 firing table contains low concentrations of PCBs and CDDs. Although these two types of compounds are well known for their potential to cause adverse ecological impact, the low concentrations and extremely limited areal extent of contamination makes it unlikely that significant hazard to ecological receptors exists as a result of the presence of these compounds.

5. Summary and Conclusions

We have completed the additional characterization, modeling, and risk assessment to assess potential removal actions and define the appropriate future regulatory pathway for the Building 850/Pit 7 Complex OU. This additional work was required to calculate potential risks posed by uranium and thorium in ground water; uranium, thorium, PCBs, dioxins, furans, and metals in surface soil; and tritium in Building 850 indoor air. As a result of our recent environmental investigations (1992–95), we have confirmed the inadvertent release of depleted uranium to soil and ground water as a result of firing table experiments at Building 850, and disposal of the resulting debris in the Pit 7 Complex landfills. We have also defined the nature and extent of thorium, metals, PCBs, dioxins, and furans in surface soil in the OU. In this process, we also collected and analyzed additional surface soil samples for other substances. The results of these analyses are consistent with findings presented in the SWRI report (Webster-Scholten, 1994). Maximum chemical concentrations detected in environmental media in the OU are listed in Table 5-1.

As a result of this investigation, we:

- Defined three plumes of depleted uranium in ground water emanating from pit 5, pit 7, and Building 850, respectively. The samples of surface soil from Building 850 and the Pit 7 Complex, and ground water containing the maximum activities of uranium, showed signatures of depleted uranium; the samples of subsurface soil and rock did not. Depleted uranium was the only form of uranium used in explosives tests at Site 300.
- Evaluated the concentrations of metals (barium, lead, and vanadium) that exceeded CLs for post-closure ground water monitoring of pit 7. We determined that although some of the barium and lead in ground water may be due to landfill release, the concentrations are comparable to natural concentrations and are significantly below MCLs.
- Detected thorium in surface soil, subsurface soil and rock, and ground water at Building 850 and the Pit 7 Complex.
- Identified beryllium, cadmium, and copper in surface soil at Building 850.
- Identified PCBs, dioxins, and furans in samples of surface soil at Building 850. No PCBs were detected in surface and subsurface soil from the Pit 7 Complex.
- Conducted comprehensive field investigation, which included conducting a passive SVS at pit 5, and drilling and sampling 10 boreholes in the Pit 7 Complex for EPA 8010 (VOC) compounds to identify a source for TCE in ground water downgradient of pit 5. No TCE sources were identified.
- Detected low activities of tritium in indoor air in Building 850.
- Identified a decreasing trend in maximum post-SWRI tritium activities in lysimeter subsurface moisture and ground water.
- Identified a general decrease in post-SWRI TCE concentrations in ground water downgradient of pit 5.

- Utilized a solution to the advective-dispersive equation to estimate ground water uranium activities that could reach potential exposure points from the plumes originating at pits 5 and 7 and Building 850 (Table 5-2).
- Determined chemical-specific cancer risk and HIs for areas in and near Building 850 and for the entire OU (Table 5-3).
- Determined that risks and HIs associated with potential exposure to uranium-bearing ground water are $<10^{-6}$ and $<10^{-1}$, respectively. Potential exposure to surface soil containing uranium, thorium, and metals presents a risk of 7×10^{-6} and an HI <1.
- Determined that tritium in vapor inside Building 850 does not pose an unacceptable health risk to building workers.
- Compared PRGs for PCBs, CDDs, and CDFs to concentrations detected in soil at the Building 850 firing table. Some locations exceed the U.S. EPA Region IX PRG and/or remedial action goals for PCBs at Superfund sites. Several locations also have a total TCDD equivalent concentrations greater than the U.S. EPA Region IX PRG.

We have also compared SWRI data on contaminant hydrogeology to post-SWRI data. The distributions of water elevations and recharge are consistent with SWRI observations. It appears that preferential recharge in the Pit 7 Complex continues to periodically inundate portions of the landfills during and after unseasonably high rainfall periods.

As reported in this document, we have completed the post-SWRI assessment for the Building 850/Pit 7 OU. Our next steps are to 1) examine potential response actions to remediate any environmental contaminants present in the OU that pose excessive risk to human health and the environment, and 2) work with DOE and the regulatory agencies to determine the appropriate future regulatory pathway for this OU.

References

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Figures

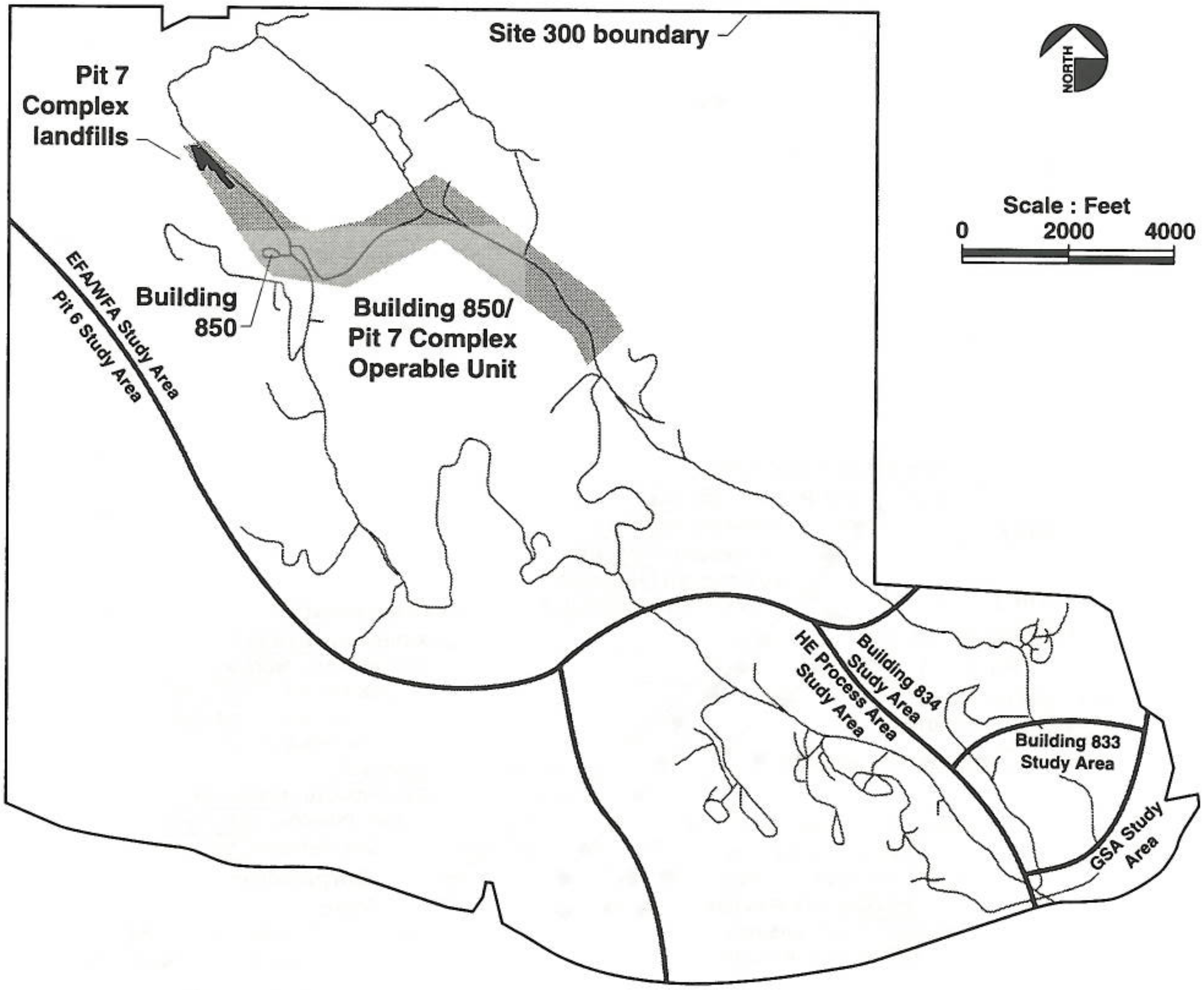
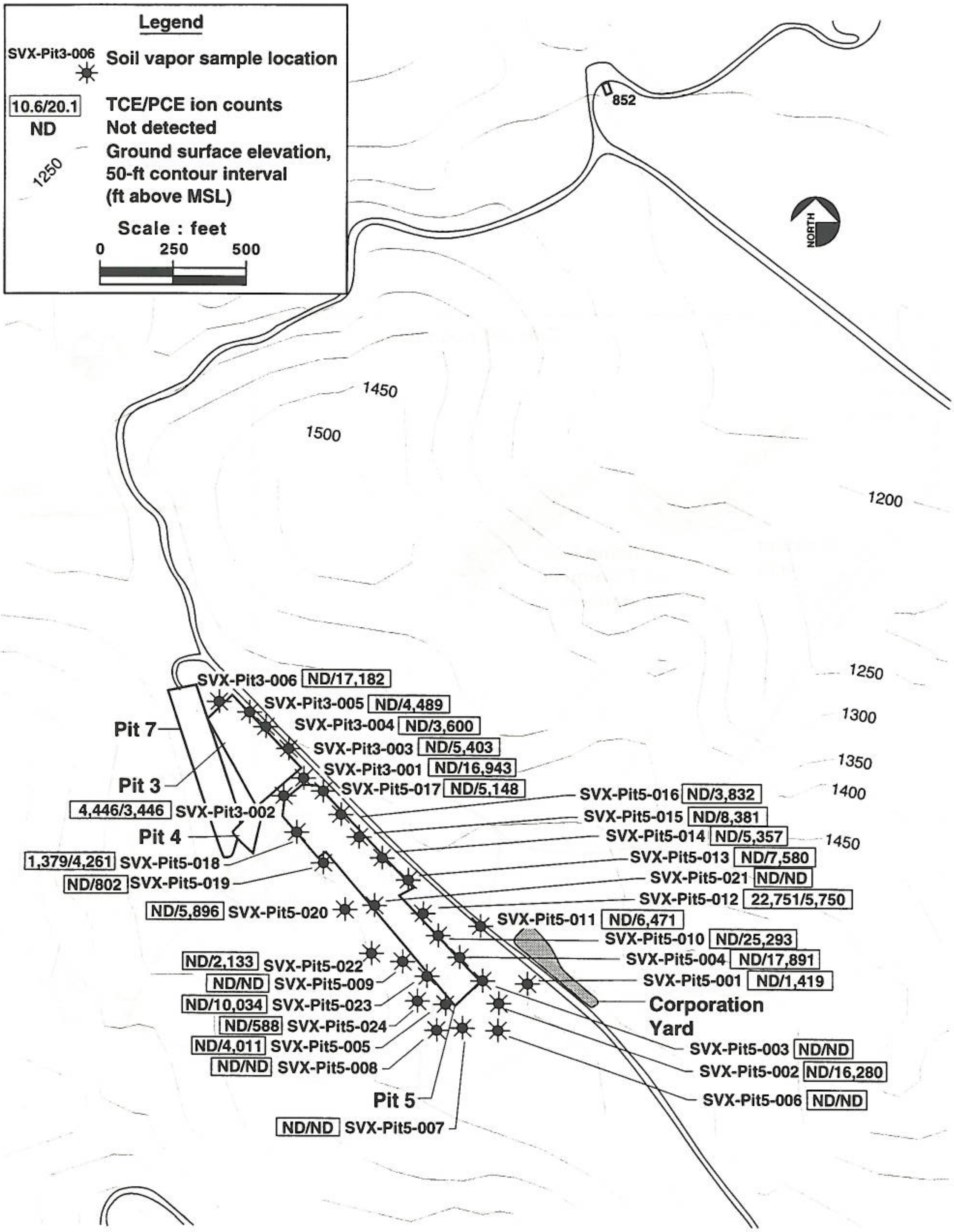


Figure 1-1. Location of the Building 850/Pit 7 Complex operable unit and SWRI study areas at LLNL Site 300. Operable unit boundaries are approximate.



ERD-S3R-95-0025

Figure 2-1. Passive soil vapor survey location points and analytical results for TCE and PCE at the Pit 7 Complex, 1994.

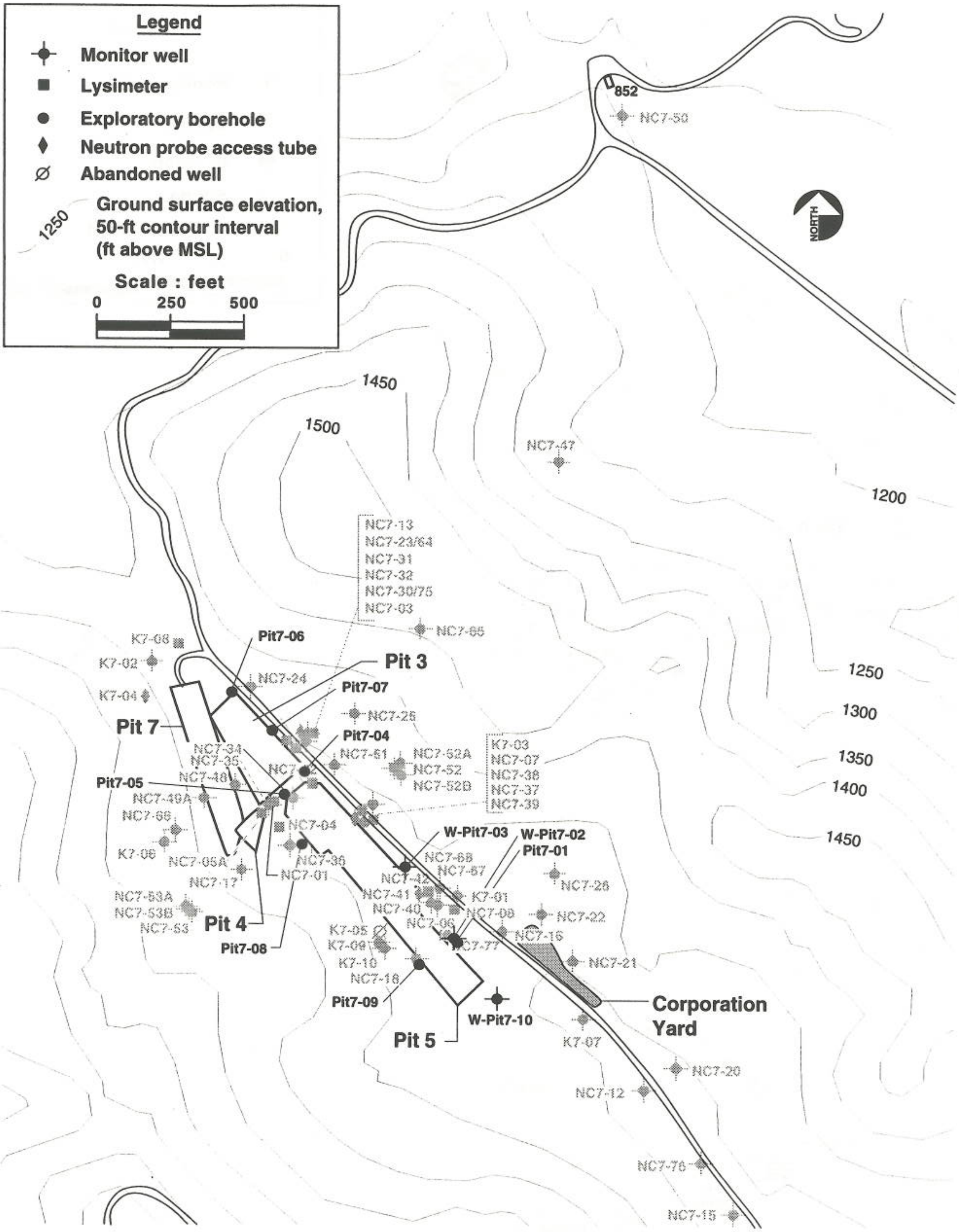


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Figure 2-2. Map of the Pit 7 Complex showing the locations of monitor wells and boreholes completed during 1994.

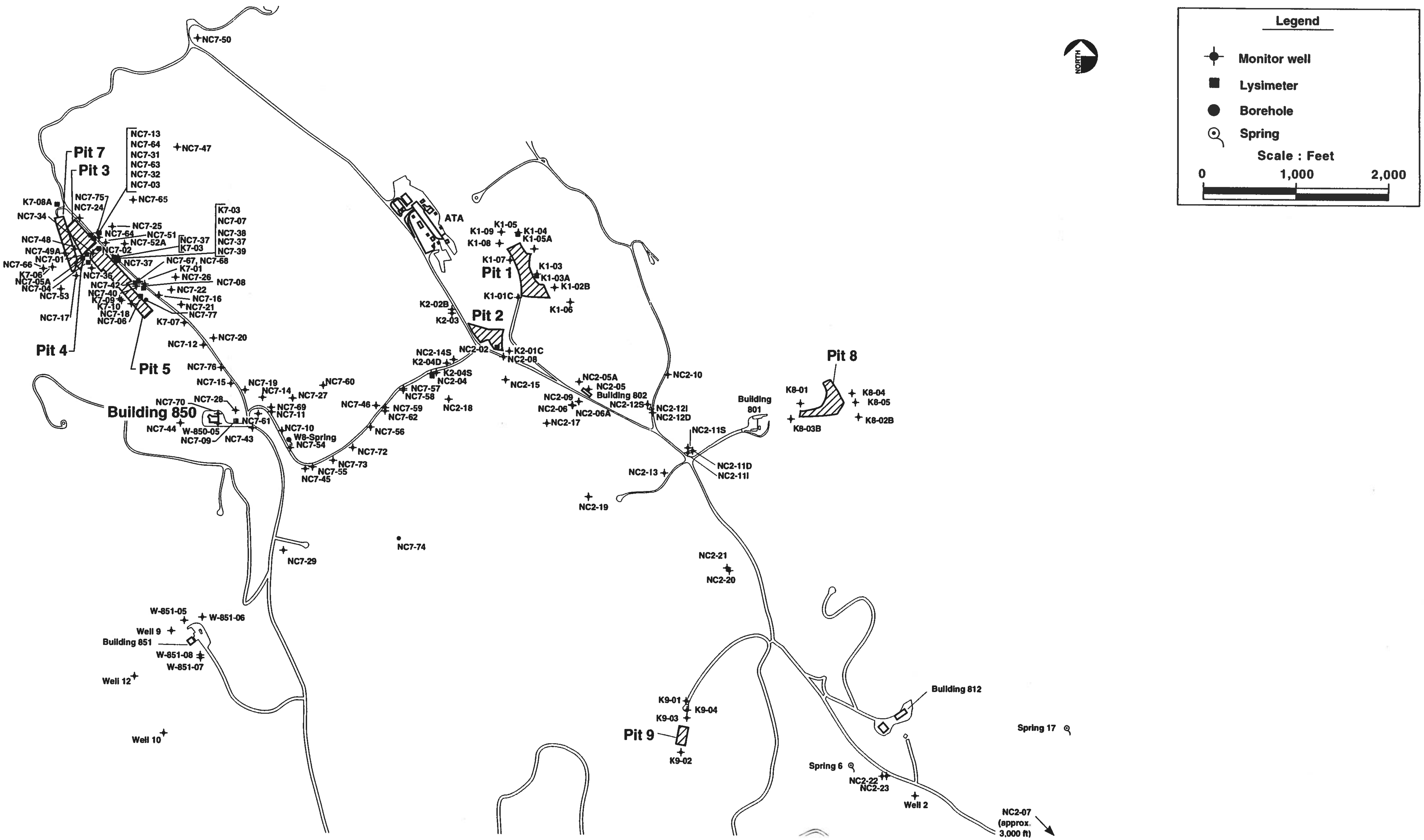

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Figure 2-3. Map of the Building 850/Pit 7 Complex OU showing the locations of monitor wells, lysimeters, and selected boreholes.

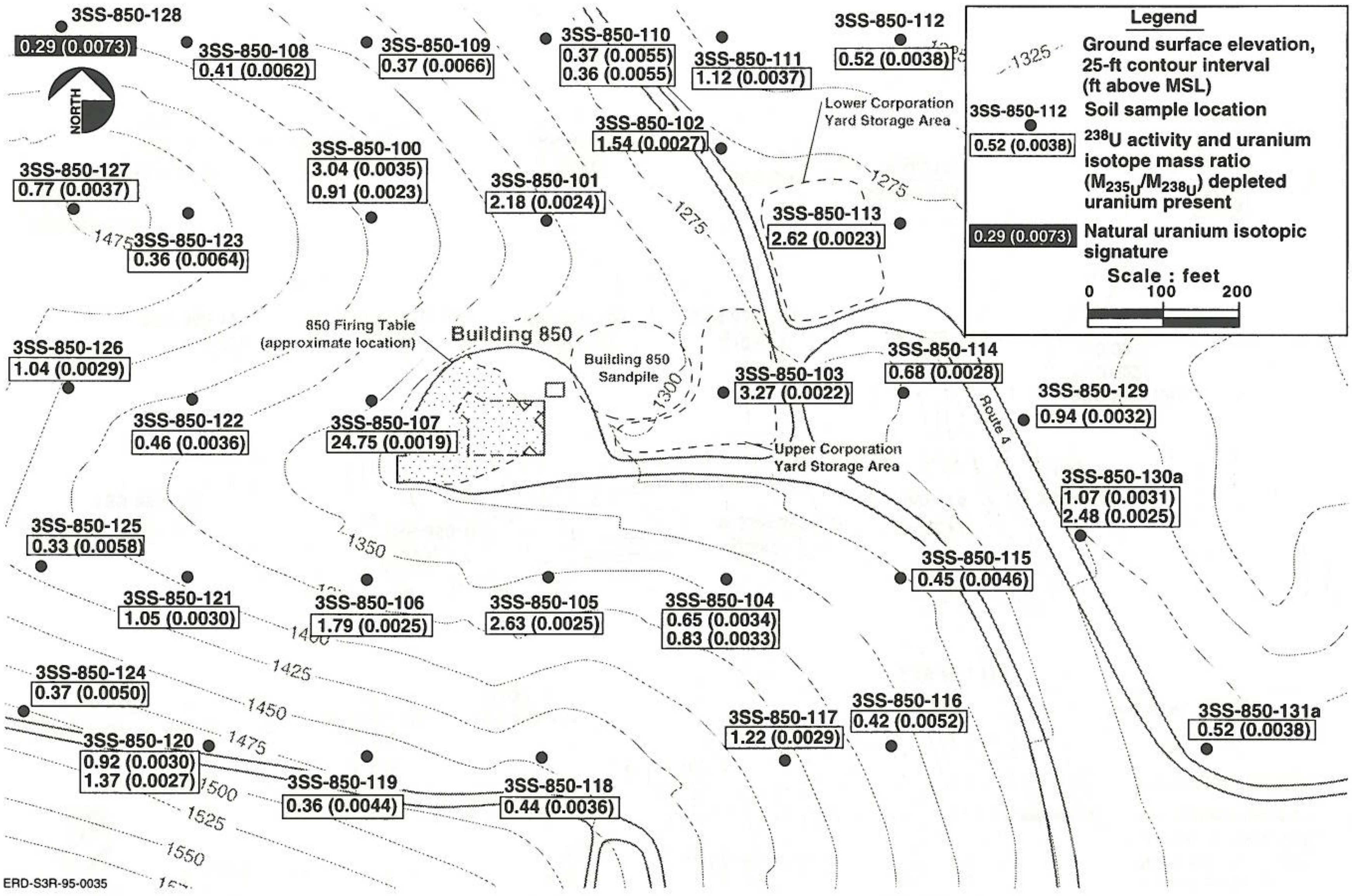

Figure 2-4. ^{238}Uranium activity (pCi/g) and mass ratio (^{235}U/^{238}U) in surface soils at the Building 850 firing table.

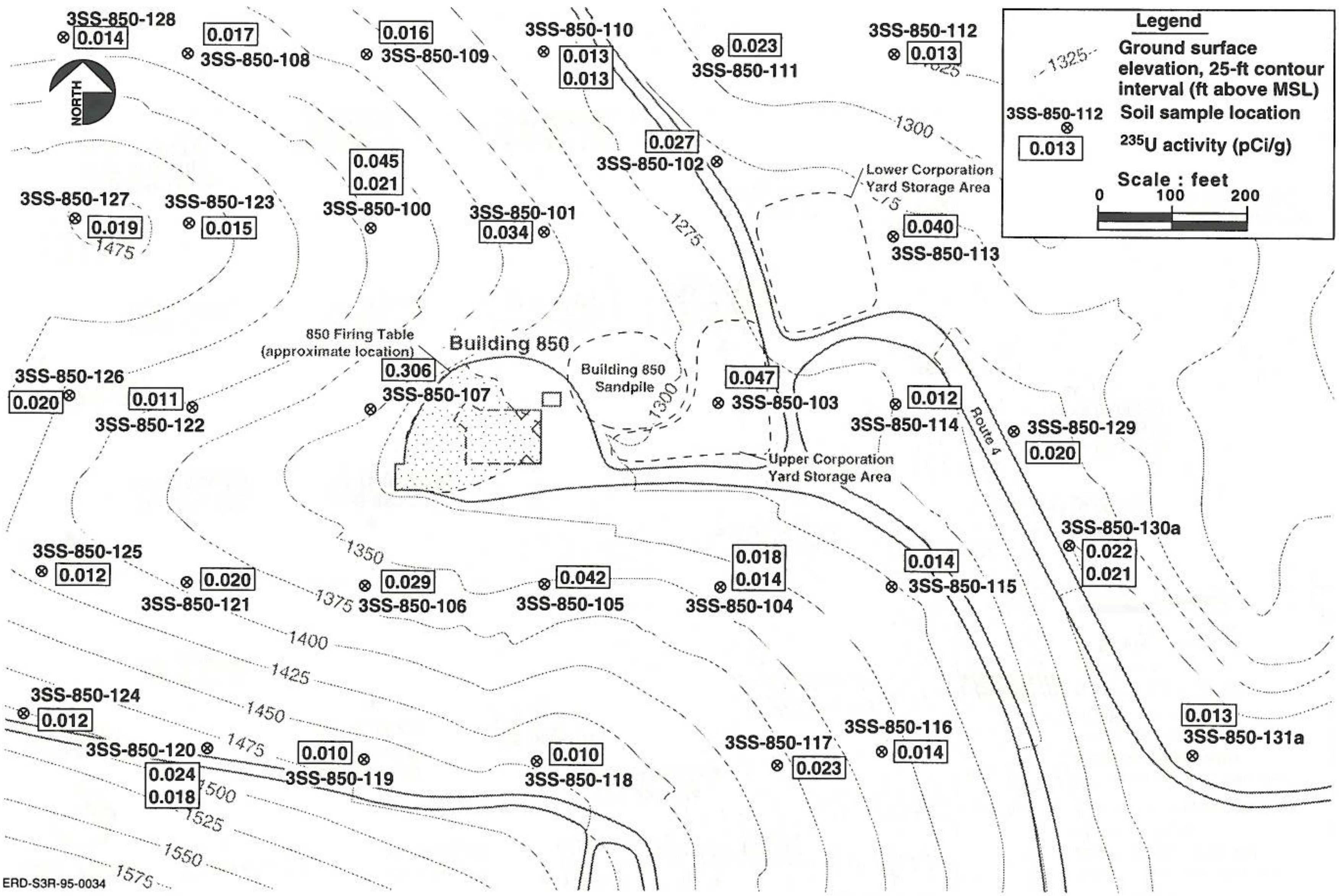

Figure 2-5. ^{235}Uranium activity (pCi/g) in surface soil in the Building 850 area.

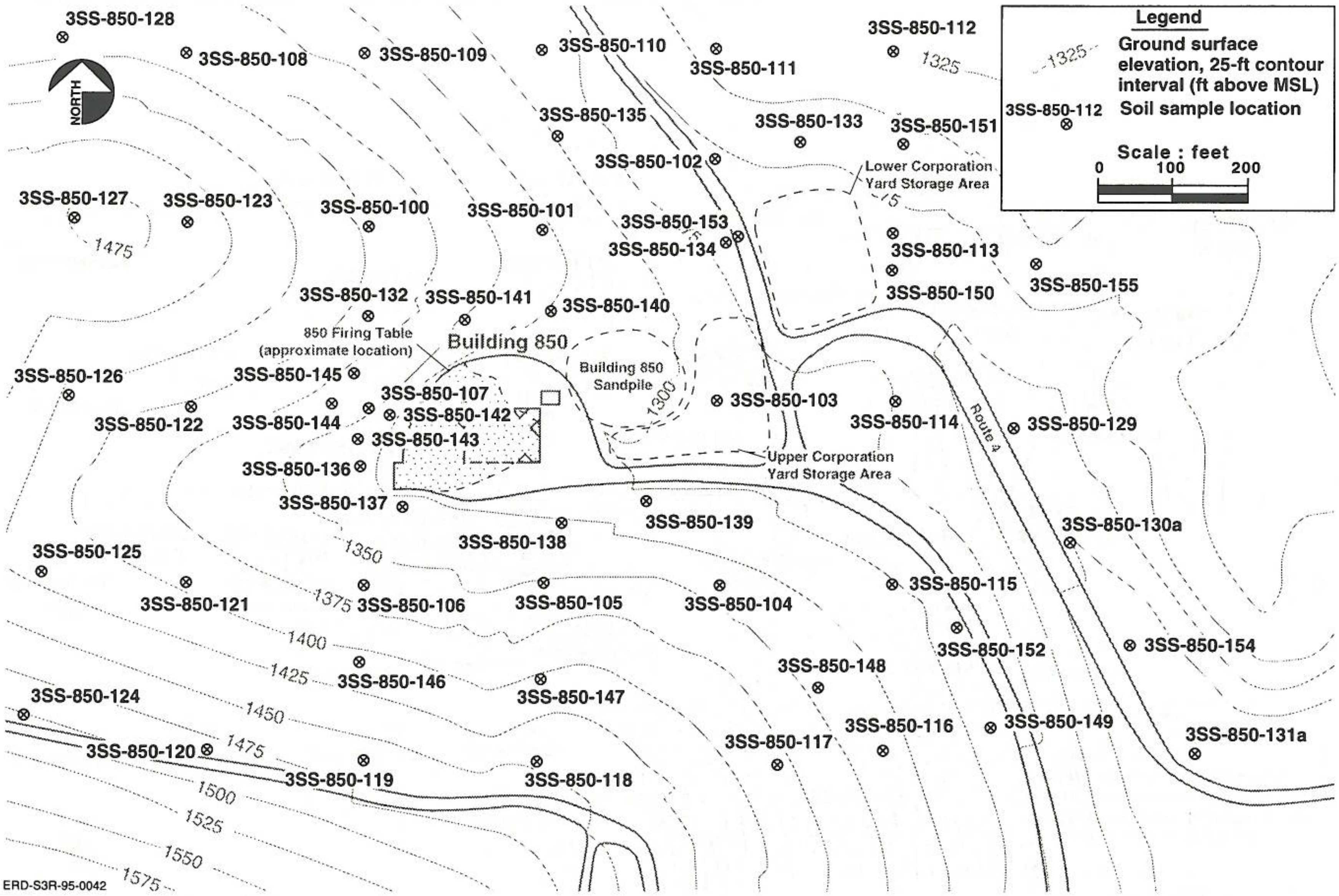

Figure 2-6. Surface soil sampling locations in the Building 850 area.

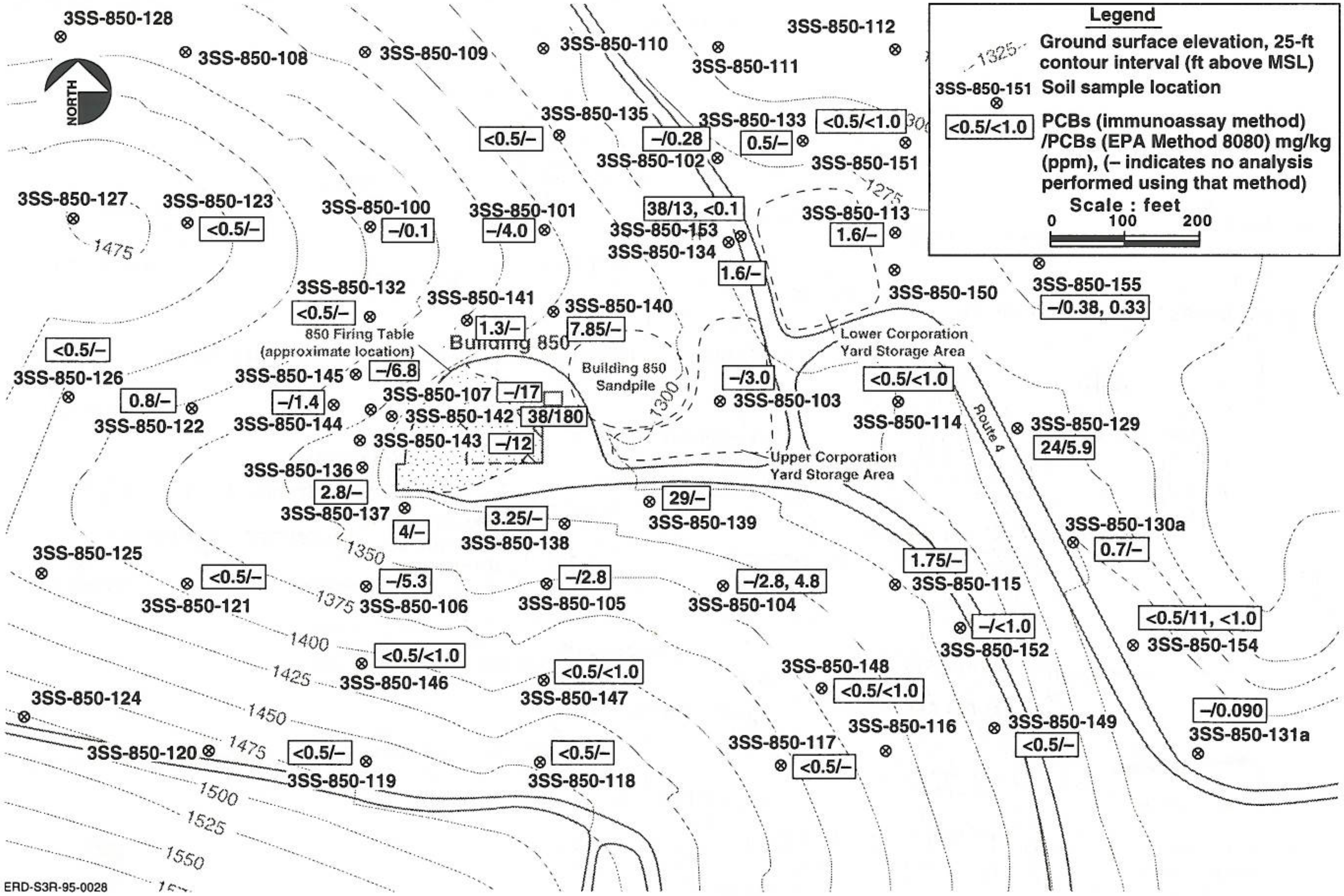

Figure 2-7. PCB concentrations (mg/kg) in surface soil in the Building 850 area.

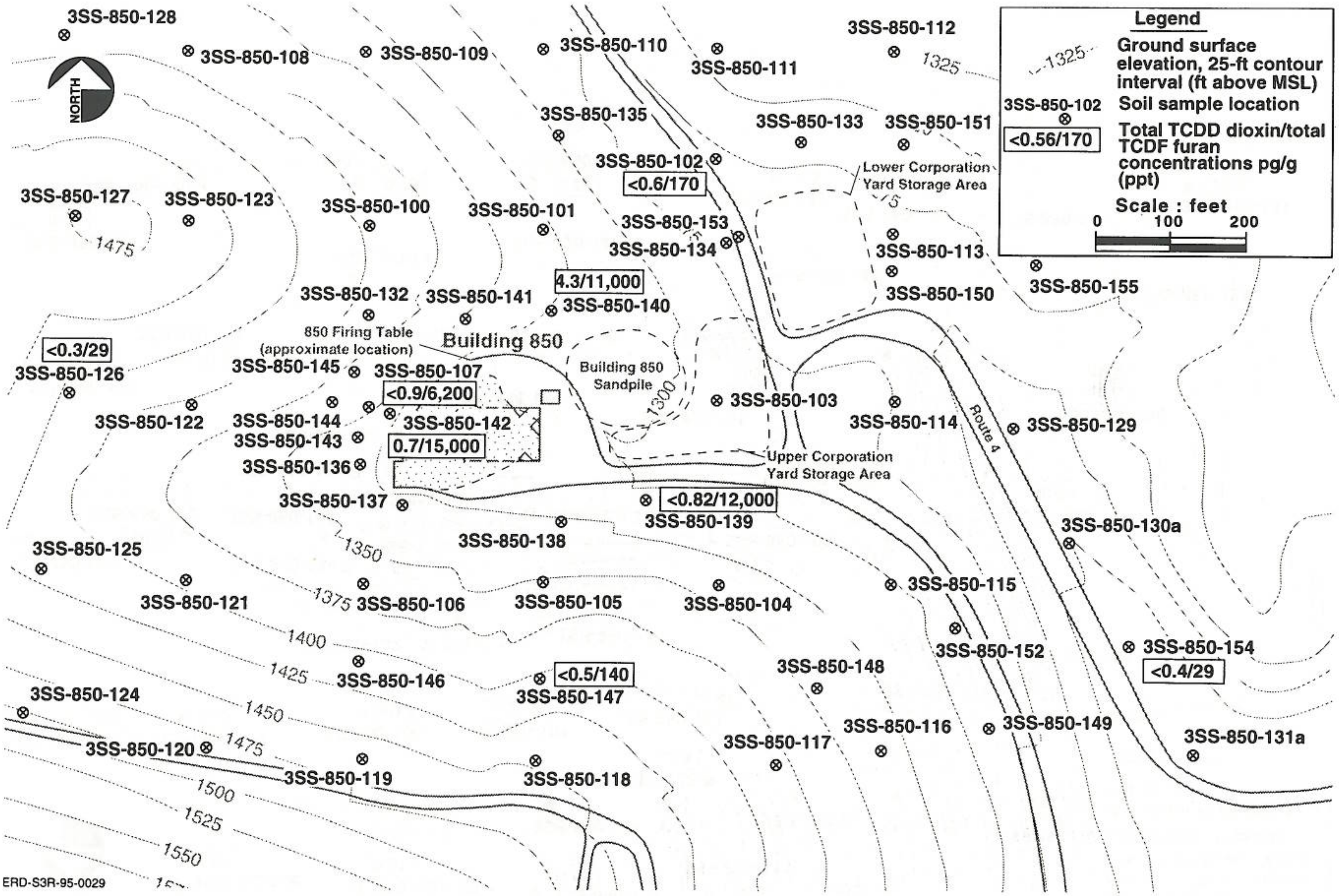

Figure 2-8. Total TCDD dioxin and total TCDF furan concentrations (pg/g [ppt]) in surface soil (0.0 ft) in the Building 850 area.

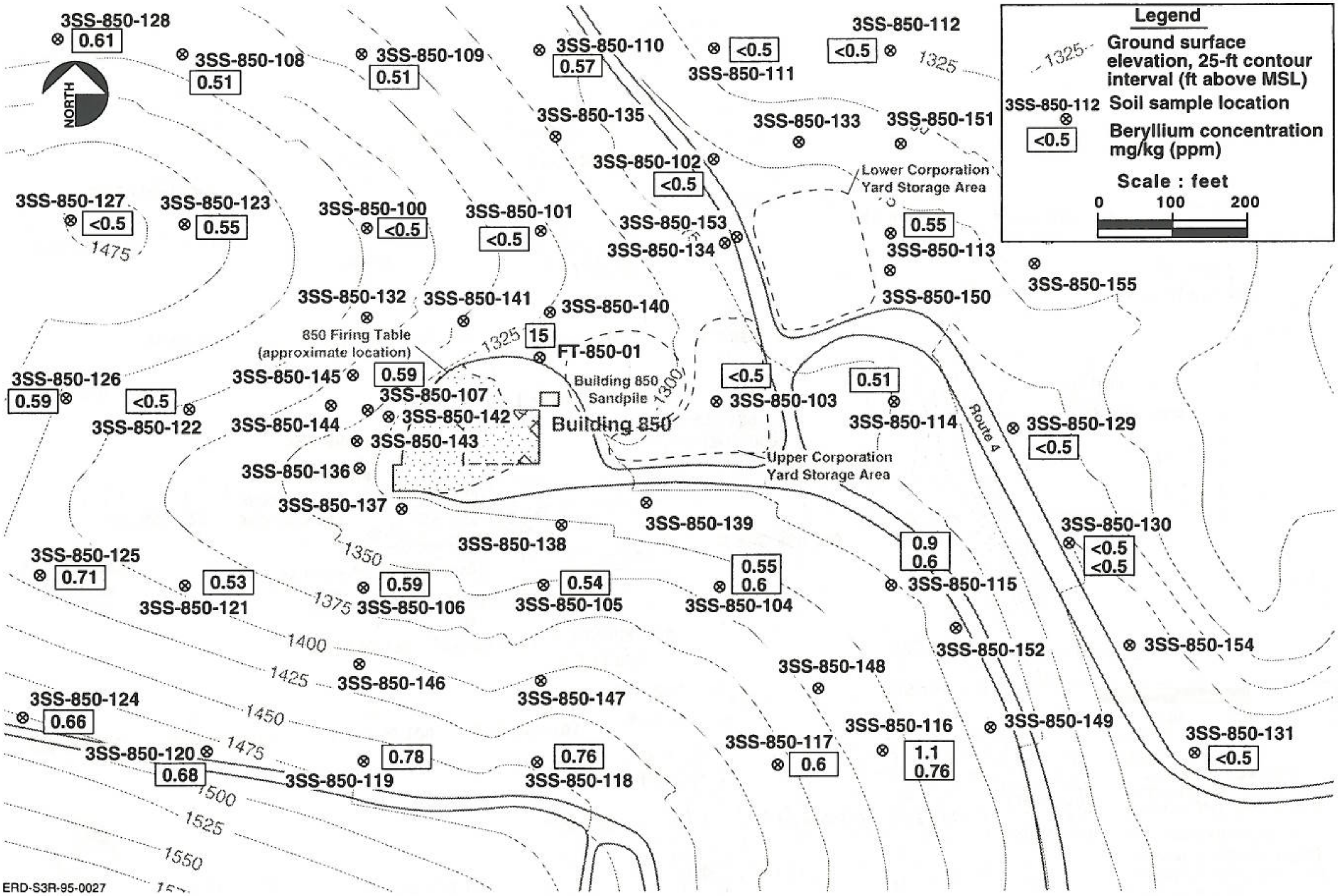

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Figure 2-9. Beryllium concentration (mg/kg) in surface soil in the Building 850 area.

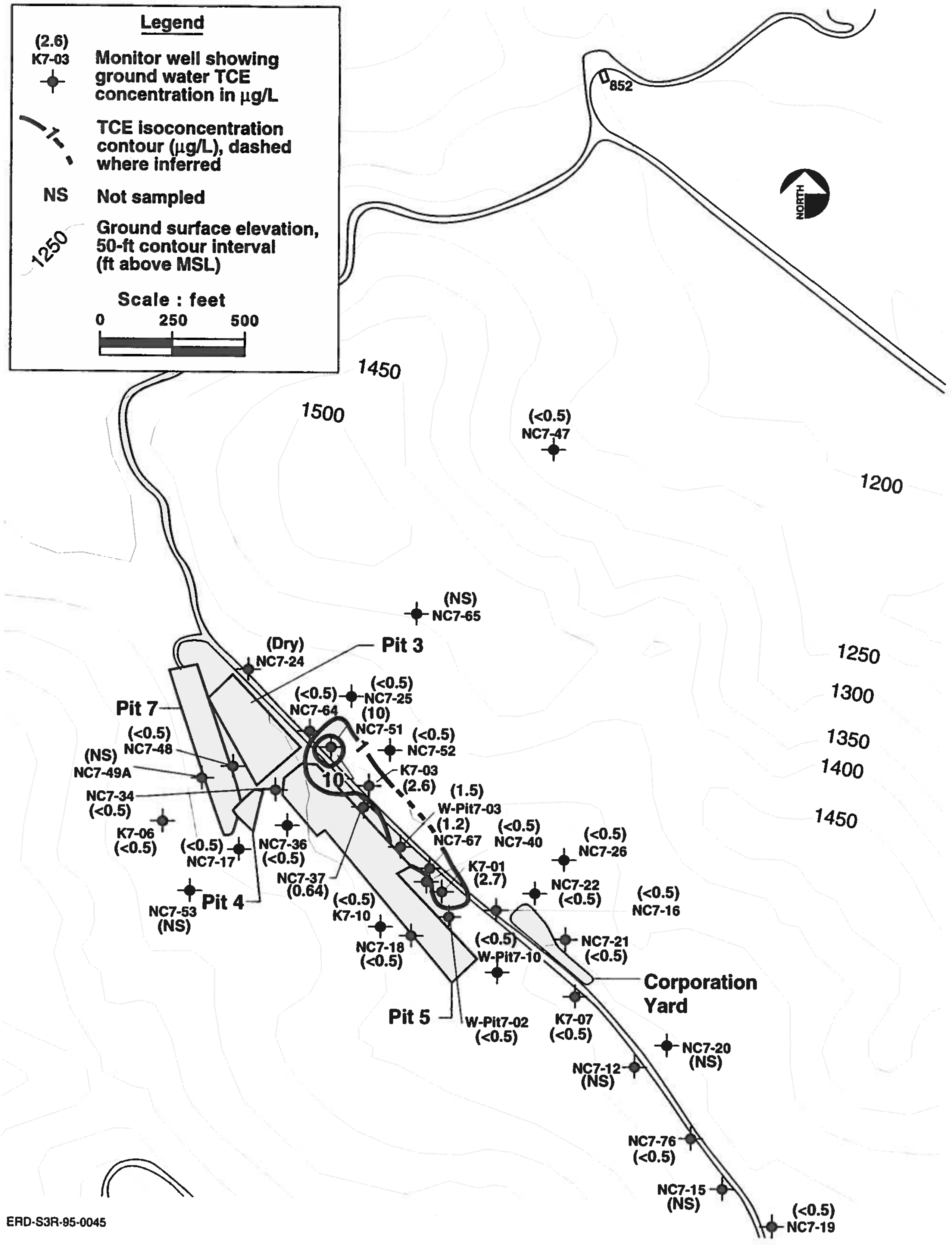

Figure 2-10. TCE concentrations (µg/L) in ground water at the Pit 7 Complex, April-May 1995.

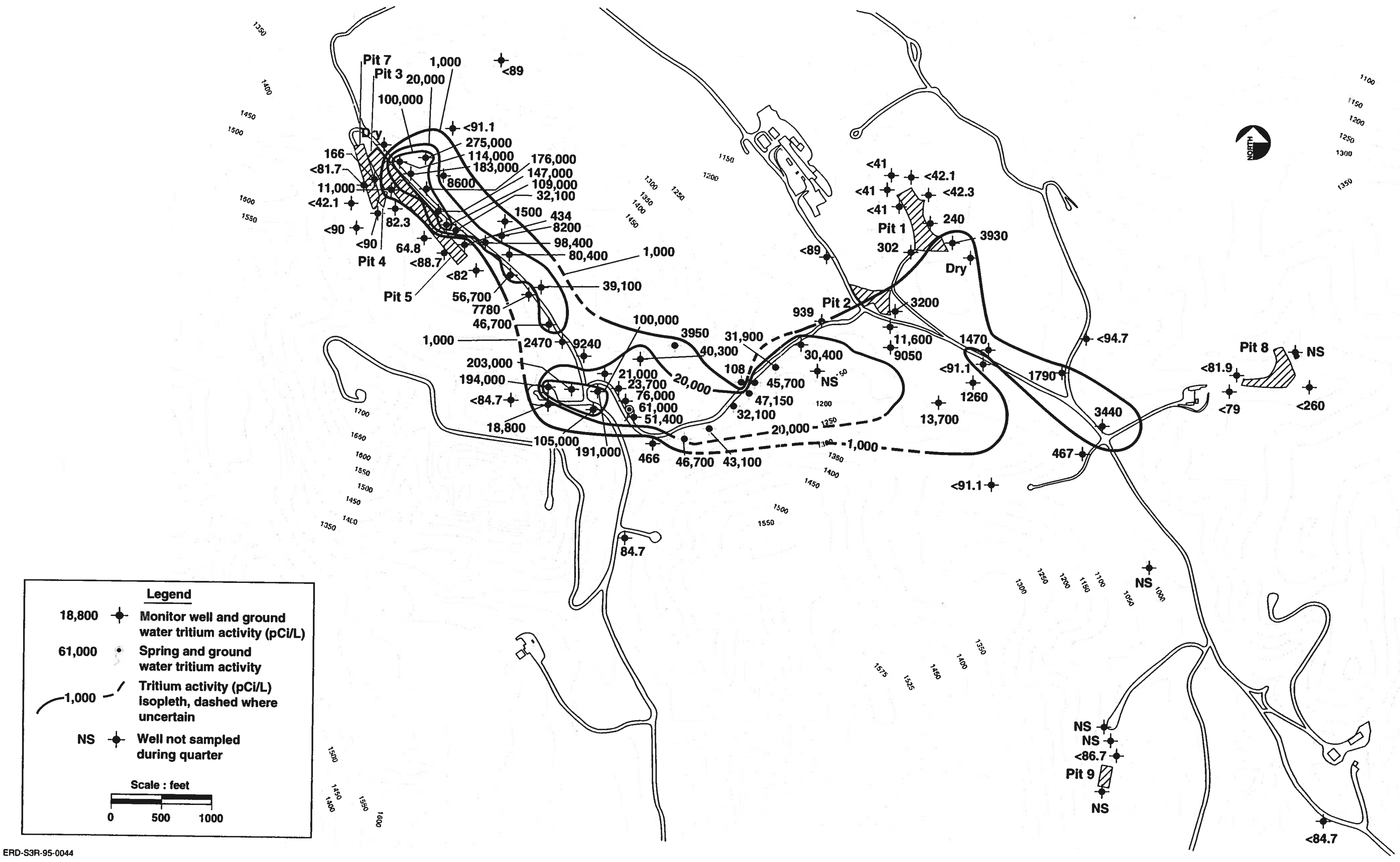

Figure 2-11. Isopleth map of ground water tritium activity (pCi/L) for the first water-bearing zone, East and West Firing Areas, April 1995.

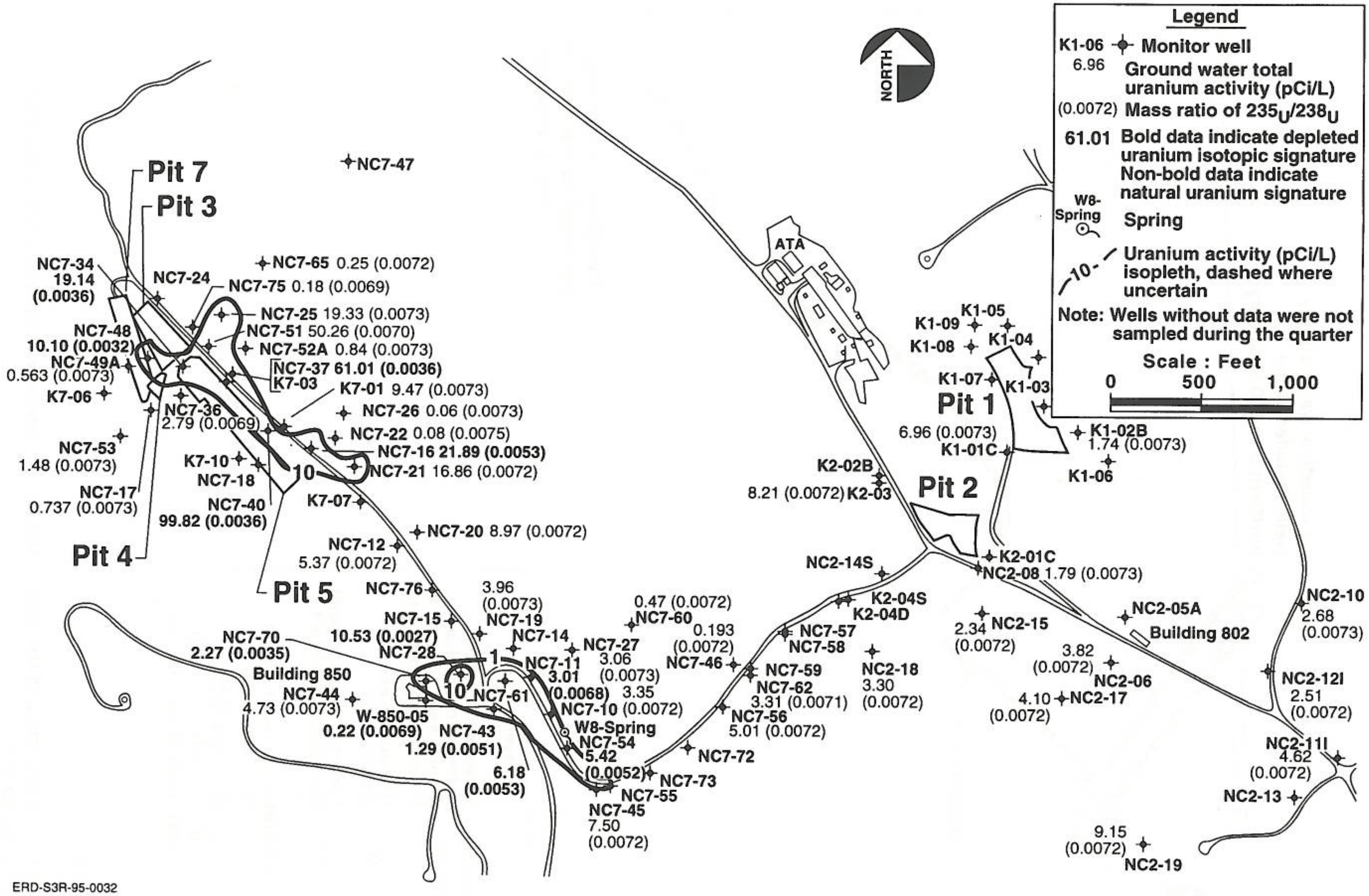

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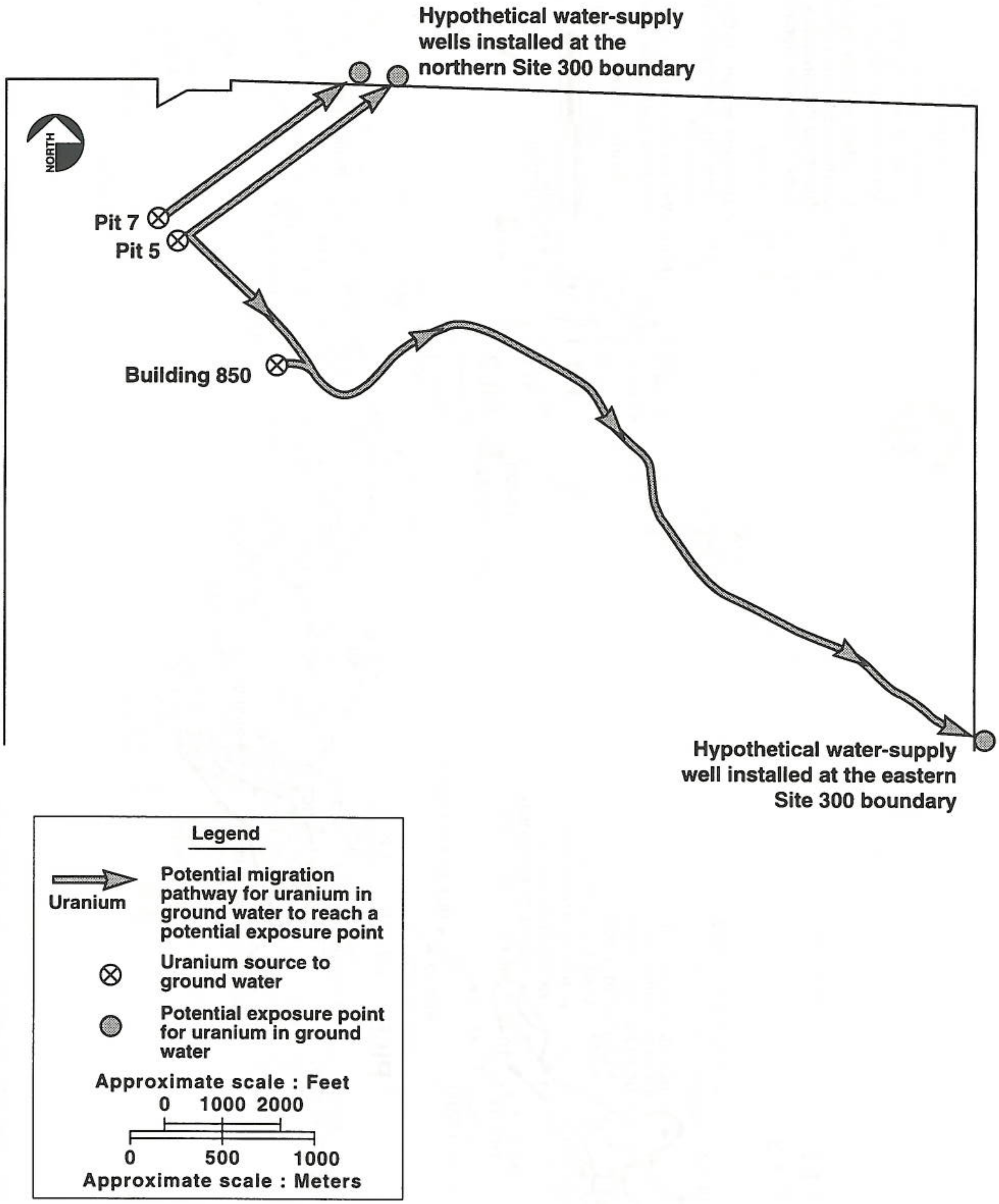
Figure 2-12. Total uranium activities (pCi/L) in ground water in the Building 850/Pit 7 Complex OU, second quarter 1994.



ERD-S3R-95-0037

Figure. 3-1. Potential fate and transport pathways for uranium in ground water in the Building 850/Pit 7 Complex OU.

Tables

Table 1-1. Scope of post-SWRI activities in/for the Building 850/Pit 7 Complex operable unit.

Location	Purposes	Activity	Constituents analyzed for or modeled
Pit 7 Complex	Define source of TCE in downgradient ground water	Installed and analyzed 30 passive soil vapor samplers	PCE, TCE
		Drilled 10 boreholes; completed 3 of these as monitor wells. Collected and analyzed surface and subsurface soil and rock samples	VOCs
	Evaluate metals that exceed ground water CLs for pit 7 post-closure monitoring	Collected and analyzed ground water samples	Barium Lead Vanadium
	Refine knowledge of other chemicals in the area	Collected and analyzed samples of surface and subsurface soil and rock	Gross alpha and beta radioactivitiy Metals PCBs, dioxins, and furans Thorium Tritium Uranium isotopes
Building 850 firing table and vicinity	Delineate the nature and extent of contaminants	Collected surface soil samples	Dioxins/furans Metals PCBs Thorium Uranium isotopes
Building 850	Determine the tritium activity in Building 850 indoor air	Sampled the air moisture for three consecutive 2-week intervals	Tritium

Table 1-1. (Continued)

Location	Purposes	Activity	Constituents analyzed for or modeled
OU-Wide	Characterize the nature and extent of specific contaminants	Collected and analyzed ground water samples	Metals Uranium isotopes Thorium isotopes
	Calculate risk and HIs posed from chemicals in the OU. Compare PRGs to concentrations of PCB, dioxins, and furans in surface soil.	Post-SWRI risk assessment	Metals (soil) PCBs, dioxins, and furans (soil) Thorium (soil) Tritium (indoor air) Uranium (soil and ground water)
Site 300 boundary	Predict potential uranium exposure-point activities in ground water	Applied 2-dimensional (2-D) semi-analytical solution to the advective-dispersive equation	Uranium

Table 2-1. Maximum metals concentrations detected in surface soil and rock at the Pit 7 Complex, October 13 through November 9, 1994.

Metal detected	Concentration (mg/kg)	Surface location
Arsenic	3.6	Pit 7-05
Barium	220	Pit 7-10
Beryllium	0.68	Pit 7-06
Cadmium	0.14	Pit 7-05
Chromium	22	Pit 7-10
Cobalt	11	Pit 7-02
Copper	42	Pit 7-05
Lead	13	Pit 7-04
Mercury	0.066	Pit 7-06
Nickel	19	Pit 7-10
Vanadium	69	Pit 7-05
Zinc	48	Pit 7-05

Table 2-2. Maximum TTLC metals concentrations detected in surface soil and rock at the Building 850 area, July 26, 1994.

Metal detected	Concentration (mg/kg)	Surface location
Antimony	1	3SS-850-107
Arsenic	4.3	3SS-850-123
Barium	220	3SS-850-116/125
Beryllium	1.1	3SS-850-116
Cadmium	0.54	3SS-850-100
Chromium	28	3SS-850-125
Cobalt	14	3SS-850-111/116/118
Copper	180	3SS-850-107
Lead	51	3SS-850-131A
Molybdenum	9	3SS-850-121
Nickel	36	3SS-850-103
Selenium	0.57	3SS-850-106
Vanadium	110	3SS-850-112/129/130A
Zinc	65	3SS-850-104

Table 2-3. Maximum STLC metals concentrations detected in surface soil and rock at the Building 850 area, July 26, 1994.

Metal detected	Concentration (mg/kg)	Surface location
Barium	16	3SS-850-116
Cadmium	0.017	3SS-850-100
Cobalt	0.8	3SS-850-107
Copper	34	3SS-850-131A
Lead	4	3SS-850-103
Nickel	0.96	3SS-850-119
Vanadium	0.89	3SS-850-107
Zinc	5.7	3SS-850-36

Table 2-4. TTLC and STLC metals not detected at the Building 850 area, July 26, 1994.

TTLC metal	STLC metal
Mercury	Antimony
Silver	Arsenic
Thallium	Beryllium
	Chromium
	Mercury
	Molybdenum
	Selenium
	Silver
	Thallium

Table 2-5. Maximum VOC concentrations detected in ground water in the Pit 7 Complex and Building 850 areas (analyses by EPA Methods 601, 624, or 542.5).

VOC detected	Maximum concentration (µg/L)	Sample date	Monitor well
1,1-DCE	6.2	03-21-95	NC7-51
1,1-DCE (total)	1	08-16-93	K7-01
TCE	15	03-21-95	NC7-51
1,2-DCA	0.7	11-14-94	NC7-71
1,1,1-TCA	1.2	03-07-92	NC7-26
Chloroform	1	07-21-92	NC7-28
Freon 11	2	08-17-93	NC7-48
Freon 113	120	11-18-94	K1-09

Table 2-6. Maximum concentrations of aromatic and fuel hydrocarbons detected in ground water in the Pit 7 Complex and Building 850 areas (analyses by EPA Method 602 or 625).

Compound detected	Maximum concentration (µg/L)	Sample date	Monitor well
Toluene	5.1	05-19-93	NC7-48
Ethylbenzene	0.8	03-29-95	NC7-71
Total xylene	2	02-14-94	NC7-71

Table 2-7. Maximum concentrations of metals that exceeded RCRA Post-Closure Monitoring Concentration Limits (CLs) in ground water samples from wells downgradient of pit 7.

Metal detected	Concentration (mg/L)	CL (mg/L)	State MCL (mg/L)	Sample date	Monitor well
Barium	0.378	0.09	1.0	06-01-94	NC7-37
Lead	0.006[a]	0.002	0.050	05-25-94	NC7-36
Vanadium	0.012	0.05	–[b]	12-02-94	NC7-48

[a] This concentration was not confirmed on resampling. A second sample analysis yielded lead below the CL.

[b] No MCL or action level exists.

Table 2-8. Maximum activities of radionuclide isotopes detected in ground water samples from the Building 850/Pit 7 Complex operable unit (post-SWRI period).

Radionuclide	Isotopes detected	Activities (pCi/L)	Sample date	Monitor well
Thorium	^{228}Th	2.35 ± 1	08-05-95	K1-09
	^{230}Th	39.5 ± 19.4	04-12-94	NC7-47
	^{232}Th	4.26 ± 0.45	03-01-94	K1-09
	$^{\text{total}}$Th	39.5 ± 19.4	04-12-94	NC7-47
Radium	^{226}Ra	91.8	06-02-94	NC7-44
	^{228}Ra	0.7	12-20-94	NC7-28
Bismuth	^{214}Bi	19.1	06-02-94	NC7-44
Cesium	^{127}Cs	8.09	05-19-94	K7-01
Iodine	^{129}I	34.3	12-02-94	NC7-61
Lead	^{210}Pb	54	12-01-94	K7-06
	^{214}Pb	20.4	03-17-95	K7-01
Potassium	^{40}K	185	11-30-94	K7-01

Table 2-9. Maximum activities of TOC and TOX detected in ground water samples from the Building 850/Pit 7 Complex operable unit (post-SWRI period).

Compound or analyte	Concentration (mg/L)	Sample date	Monitor well
TOC	27	01-18-95	NC7-25
TOX	0.063	05-04-94	K1-01C

Table 2-10. Tritium concentration in indoor air of Building 850.[a]

Tritium concentration (µCi/mL)	Sample date
2.10×10^{-12}	09-08-94
1.99×10^{-12}	09-22-94
2.34×10^{-12}	11-17-94
1.98×10^{-12}	12-01-94
2.31×10^{-12}	12-15-94
2.35×10^{-12}	12-28-94
1.64×10^{-12}	01-12-95
2.09×10^{-12}	01-26-95

[a] Each concentration represents the average value obtained during a sampling period of approximately two weeks.

Table 3-1. The maximum total uranium activities detected in ground water downgradient of identified sources.

Source	Concentration (pCi/L)	Well	Sample date
Pit 5	119.7	NC7-40	10/30/93
Pit 7	55	NC7-48	05/19/93
Building 850	14	NC7-28	04/16/93

Table 3-2. Input parameters for modeling the fate and transport of uranium in ground water downgradient of pit 7.

Parameter	Data used
Aquifer thickness	2 m[a]
Pore water velocity	6 m/year[a]
Porosity	20%[a]
Release year	1983[a]
Release point	Center of the landfill
Exposure point	Site 300, northern boundary 1,320 m downgradient in direction of flow (north-northeast)[a]
Particle density	2.65 g/cm^3[b]

[a] Data used for tritium modeling of the adjacent pit 3 plume in SWRI report (Webster-Scholten, 1994).

[b] Value typical for sand.

Table 3-3. Potential ground water uranium exposure-point activity (pCi/L) at Site 300 boundary.

Scenario	Potential exposure-point activity[a]	Year of arrival
Pit 7, instantaneous release	0.36	2164
Pit 5, instantaneous release	1.77	2098
Building 850, continuous release	1.26	2199
Building 850, continuous release plus pit 5 instantaneous release	1.04	2055

[a] Potential exposure-point activity results were calculated using dispersivities of 0.1X, 0.01X, where X = distance from release point to potential exposure point.

Table 3-4. Summary of sensitivity analysis for two different modes of release from pit 7.

	Potential exposure-point activities of uranium (pCi/L) for two dispersivities	
Release from pit 7	0.1x[a], 0.01x[a]	15 m, 4 m
Instantaneous	0.36	6.9
Continuous	11	71

[a] x = Distance from release point to potential exposure point.

Table 3-5. Near source (pit 7) calibration-point uranium activities (pCi/L) required to produce 20 pCi/L at the northern Site 300 boundary.

	Calibration-point activities of uranium (pCi/L) for two dispersivities	
Release from pit 7	0.1x[a], 0.01x[a]	15 m, 4 m
Instantaneous	8,200	430
Continuous	270	43

[a] x = Distance from release point to calibration point.

Table 3-6. Input parameters for modeling the fate and transport of uranium in ground water downgradient of pit 5.

Parameter	Data used
Aquifer thickness	2 m[a]
Pore water velocity	10 m/year[a]
Porosity	20%[a]
Release year	1983[a]
Release point	Center of pit 5
Exposure point	Site 300 boundary, 1,400 m downgradient in direction of flow (north-northeast)[a]
Particle density	2.65 g/cm^3[b]

[a] Data used for tritium modeling in SWRI report (Webster-Scholten, 1994).

[b] Value typical for sand.

Table 3-7. Summary of sensitivity analysis for two different modes of release from pit 5.

	Potential exposure-point activities of uranium (pCi/L) for two dispersivities	
Release from pit 5	0.1x[a], 0.01x[a]	15 m, 4 m
Instantaneous	1.77	22.2
Continuous	52	179

[a] x = Distance from release point to potential exposure point.

Table 3-8. Near source (pit 5) calibration-point uranium activities (pCi/L) required to produce 20 pCi/L at the northern Site 300 boundary.

	Calibration-point activities of uranium (pCi/L) for two dispersivities	
Release from pit 5	0.1x[a], 0.01x[a]	15 m, 4 m
Instantaneous	3,440	281
Continuous	113	34.6

[a] x = Distance from release point to calibration point.

Table 3-9. Input parameters for modeling the fate and transport of uranium in ground water downgradient of Building 850.

Parameter	Data used
Aquifer thickness	5 m[a]
Pore water velocity	45 m/year[a]
Porosity	20%[a]
Release year	1963[a]
Release point	Center of firing table
Exposure point	Southern boundary of Site 300, 3,500 m downgradient in direction of flow (northeast to Elk Ravine and then south-southeast); and spring 6, which is 2,900 m downgradient of the direction of flow.[a]
Particle density	2.65 g/cm^3[b]

[a] Data used for tritium modeling in SWRI report (Webster-Scholten, 1994).

[b] Value typical for sand.

Table 3-10. Summary of sensitivity analysis for release from Building 850.

	Dispersivities = 0.1x[a], 0.01x[a]		Dispersivities = 15 m, 4 m	
	Spring 6	Site boundary	Spring 6	Site boundary
Continuous release (Building 850 alone)	1.52	1.26	4.88	4.45
Continuous release (Building 850 and maximum pit 5 contribution)	1.37	1.04	14.11	12.28

[a] x = Distance from release point to calibration point.

Table 3-11. Near source (Building 850) calibration-point uranium activities (pCi/L) required to produce 20 pCi/L at the southern Site 300 boundary.

Calibration-point activities of uranium (pCi/L) for two dispersivities	
0.1x[a], 0.01x[a]	15 m, 4 m
241	67

[a] x = Distance from release point to calibration point.

Table 4-1. Location identifiers of surface soil samples in the vicinity of the Building 850 firing table and throughout the operable unit.

Location identifiers			
Vicinity of Building 850 firing table			
3SS-04-02	FT-850-1-01	FT-850-1-16	FT-850-7-04
3SS-850-103	FT-850-1-02	FT-850-1-32	FT-850-7-08
3SS-850-107	FT-850-1-04	FT-850-7-01	FT-850-7-16
850-18	FT-850-1-08	FT-850-7-02	FT-850-7-32
Throughout operable unit			
3SS-02-02	3SS-B850-104	3SS-B850-119	Pit 7-02
3SS-03-01	3SS-B850-105	3SS-B850-120	Pit 7-03
3SS-03-02	3SS-B850-106	3SS-B850-121	Pit 7-04
3SS-04-01	3SS-B850-108	3SS-B850-122	Pit 7-05
3SS-04-03	3SS-B850-109	3SS-B850-123	Pit 7-06
3SS-04-04	3SS-B850-110	3SS-B850-124	Pit 7-07
3SS-05-02	3SS-B850-111	3SS-B850-125	Pit 7-08
3SS-06-01	3SS-B850-112	3SS-B850-126	Pit 7-09
3SS-06-02	3SS-B850-113	3SS-B850-127	Pit 7-10
3SS-06-03	3SS-B850-114	3SS-B850-128	W-Pit7-02
3SS-07-01	3SS-B850-115	3SS-B850-129	W-Pit7-03
3SS-B850-100	3SS-B850-116	3SS-B850-130a	W-Pit7-10
3SS-B850-101	3SS-B850-117	3SS-B850-131a	
3SS-B850-102	3SS-B850-118	Pit 7-01	

Table 4-2. Summary statistics for contaminants in surface soil in the Building 850 activity area.

Chemical	Maximum concentration[a]	Mean concentration[a,b]	95% UCL[a]
Beryllium	15	0.872	4.34
Cadmium	8.6	4.49	5.72
Copper	1000	186	759
^{235}Uranium	0.0637	0.0121	0.0205
^{238}Uranium	24.8	2.2	10.3

[a] Units are mg/kg except for uranium-235 and uranium-238 (pCi/g).

[b] Estimate of the arithmetic mean of the underlying log-normal distribution.

Table 4-3. Variables used to calculate potential incremental lifetime cancer risk associated with inhalation exposure to resuspended particulates in the Building 850 activity area.

Chemical	Cp (ss)[a]	PEF[b]	Dose	Cancer slope factor[c]
Beryllium	9.9×10^{-8} (mg/m^3)	6.99×10^{-2} (m^3/kg•d)	6.98×10^{-9} (mg/kg•d)	8.4×10^{0} [risk/(mg/kg•d)]
Cadmium	1.3×10^{-7} (mg/m^3)	6.99×10^{-2} (m^3/kg•d)	9.20×10^{-9} (mg/kg•d)	1.5×10^{1} [risk/(mg/kg•d)]
Copper	1.7×10^{-5} (mg/m^3)	1.96×10^{-1} (m^3/kg•d)	3.42×10^{-6} (mg/kg•d)	Not carcinogenic
^{238}Uranium	2.4×10^{-4} (pCi/m^3)	1.25×10^{5} (m^3)	2.96×10^{1} (pCi)	1.24×10^{-8} (risk/pCi)
^{235}Uranium	4.7×10^{-7} (pCi/m^3)	1.25×10^{5} (m^3)	5.9×10^{-2} (pCi)	1.30×10^{-8} (risk/pCi)

[a] Cp(ss) = Concentration (C) of contaminant on resuspended particulates in air (p, the exposure medium), which results directly from the presence of contaminant in surface soil (ss).

[b] PEF is the pathway exposure factor and is derived in Chapter 6 of the SWRI report (Webster-Scholten, 1994).

[c] California Environmental Protection Agency (Cal EPA, 1994); U.S. EPA (1995a).

Table 4-4. Variables used to calculate potential noncancer hazard associated with inhalation exposure to resuspended particulates in the Building 850 activity area.

Chemical	Cp(ss)[a]	PEF[b]	Dose	Reference dose (mg/kg•d)[c]
Beryllium	9.9×10^{-8} (mg/m^3)	1.96×10^{-1} (m^3/kg•d)	1.96×10^{-8} (mg/kg•d)	5.00×10^{-3}
Cadmium	1.3×10^{-7} (mg/m^3)	1.96×10^{-1} (m^3/kg•d)	2.58×10^{-8} (mg/kg•d)	5.00×10^{-4}
Copper	1.7×10^{-5} (mg/m^3)	1.96×10^{-1} (m^3/kg•d)	3.42×10^{-6} (mg/kg•d)	3.70×10^{-2}
^{238}Uranium	7.01×10^{-7} (mg/m^3)	1.96×10^{-1} (m^3/kg•d)	1.37×10^{-7} (mg/kg•d)	3.00×10^{-3}
^{235}Uranium	2.16×10^{-10} (mg/m^3)	1.96×10^{-1} (m^3/kg•d)	4.22×10^{-11} (mg/kg•d)	3.00×10^{-3}

[a] Cp(ss) = Concentration (C) of contaminant on resuspended particulates in air (p, the exposure medium), which results directly from the presence of contaminant in surface soil (ss).

[b] PEF is the pathway exposure factor and is derived in Chapter 6 of the SWRI report (Webster-Scholten, 1994).

[c] U.S. EPA (1995b).

Table 4-5. Variables used to calculate potential incremental lifetime cancer risk associated with dermal absorption and incidental ingestion of contaminated surface soil in the Building 850 activity area.

Chemical	Cs[a] (ss)	Dermal PEF[b]	Ingestion PEF[b]	Dose	Cancer slope factor[c]
Beryllium	4.34×10^{0} (mg/kg)	7.06×10^{-8} (kg/kg • d)	1.74×10^{-7} (kg/kg • d)	1.06×10^{-6} (mg/kg • d)	7.0×10^{0} [risk/(mg/kg • d)]
Cadmium	5.72×10^{0} (mg/kg)	7.06×10^{-8} (kg/kg • d)	1.74×10^{-7} (kg/kg • d)	1.40×10^{-6} (mg/kg • d)	Not available
Copper	7.59×10^{2} (mg/kg)	1.98×10^{-7} (kg/kg • d)	4.89×10^{-7} (kg/kg • d)	5.21×10^{-4} (mg/kg • d)	Not carcinogenic
^{238}Uranium	1.03×10^{4} (pCi/kg)	1.26×10^{-1} (kg)	3.13×10^{-1} (kg)	4.52×10^{3} (pCi)	6.20×10^{-11} (risk/pCi)
^{235}Uranium	2.05×10^{1} (pCi/kg)	1.26×10^{-1} (kg)	3.13×10^{-1} (kg)	8.99×10^{0} (pCi)	4.70×10^{-11} (risk/pCi)

[a] Cs = Concentration (C) of contaminant in surface soil (s, the exposure medium), which results directly from the presence of contaminant in surface soil (ss).

[b] PEF is the pathway exposure factor and is derived in Chapter 6 of the SWRI report (Webster-Scholten, 1994).

[c] California Environmental Protection Agency (Cal EPA, 1994): U.S. EPA (1995a).

Table 4-6. Variables used to calculate potential noncancer hazard associated with dermal absorption and incidental ingestion of contaminated surface soil in the Building 850 activity area.

Chemical	Cs[a] (ss) (mg/kg)	Dermal PEF[b] (kg/kg • d)	Ingestion PEF[b] (kg/kg • d)	Dose (mg/kg • d)	Reference dose (mg/kg • d)[c]
Beryllium	4.34×10^{0}	1.98×10^{-7}	4.89×10^{-7}	2.98×10^{-6}	5.00×10^{-3}
Cadmium	5.72×10^{0}	1.98×10^{-7}	4.89×10^{-7}	3.93×10^{-6}	5.00×10^{-4}
Copper	7.59×10^{2}	1.98×10^{-7}	4.89×10^{-7}	5.21×10^{-4}	3.70×10^{-2}
^{238}Uranium	3.05×10^{1}	1.98×10^{-7}	4.89×10^{-7}	2.09×10^{-5}	3.00×10^{-3}
^{235}Uranium	9.38×10^{-3}	1.98×10^{-7}	4.89×10^{-7}	2.04×10^{-7}	3.00×10^{-3}

[a] Cs = Concentration (C) of contaminant in surface soil (s, the exposure medium), which results directly from the presence of contaminant in surface soil (ss).

[b] PEF is the pathway exposure factor and is derived in Chapter 6 of the SWRI report (Webster-Scholten, 1994).

[c] California Environmental Protection Agency (Cal EPA, 1994): U.S. EPA (1995b).

Table 4-7. Predicted incremental lifetime cancer risk and hazard index (HI) attributable to incidental ingestion and direct dermal contact with contaminated surface soil at and near the Building 850 firing table (adult on-site exposure).

Chemical	$C_{s(ss)}$[a]	Individual lifetime cancer risk	Hazard quotient (dose/RfD)[b]
Beryllium	4.34 mg/kg	7×10^{-6}	6.0×10^{-4}
Cadmium	5.72 mg/kg	Not available[c]	7.9×10^{-3}
Copper	759 mg/kg	Not carcinogenic	1.4×10^{-2}
^{238}Uranium	1.03×10^{4} pCi/kg	1×10^{-7}	6.9×10^{-3}
^{235}Uranium	2.05×10^{1} pCi/kg	1×10^{-10}	1.5×10^{-10}
		$\Sigma Risk = 7 \times 10^{-6}$	$HI = 2.9 \times 10^{-2}$

[a] $C_{s(ss)}$ = Concentration (C) of contaminant in surface soil (s, the exposure medium), which results directly from the presence of contaminant in surface soil (ss).

[b] RfD = Reference dose.

[c] A slope factor for ingestion or dermal absorption of cadmium is not available.

Table 4-8. Predicted incremental lifetime cancer risk and hazard index (HI) attributable to inhalation of resuspended particulates at and near the Building 850 firing table (adult on-site exposure).

Chemical	$C_{p(ss)}$[a]	Individual lifetime cancer risk	Hazard quotient (dose/RfD)[b]
Beryllium	9.9×10^{-8} mg/m^3	6×10^{-8}	3.9×10^{-6}
Cadmium	1.3×10^{-7} mg/m^3	1×10^{-7}	5.2×10^{-5}
Copper	1.7×10^{-5} mg/m^3	Not carcinogenic	9.3×10^{-5}
^{238}Uranium	2.4×10^{-4} pCi/m^3	1×10^{-7}	4.6×10^{-5}
^{235}Uranium	4.7×10^{-7} pCi/m^3	3×10^{-10}	1.4×10^{-8}
		$\Sigma Risk = 3 \times 10^{-7}$	$HI = 1.9 \times 10^{-4}$

[a] $C_{p(ss)}$ = Concentration (C) of contaminant on resuspended particulates in air (p, the exposure medium), which results directly from the presence of contaminant in surface soil (ss).

[b] RfD = Reference dose.

Table 4-9. Additive risk and hazard index (HI) for adults on site at and near the Building 850 firing table.

Route of exposure	Calculated risk	Calculated HI associated with region or source of exposure
Inhalation of resuspended particulates	3×10^{-7}	1.9×10^{-4}
Ingestion and dermal contact, contaminants in surface soil	7×10^{-6}	2.9×10^{-2}
	$\Sigma Risk = 7 \times 10^{-6}$	$\Sigma HI = 2.9 \times 10^{-2}$

Table 4-10. Summary statistics for contaminants in surface soil throughout the operable unit.

Contaminant	Maximum concentration[a]	Mean concentration[a,b]	95% UCL[a]
^{232}Thorium	0.93	0.497	0.528
^{235}Uranium	0.53	0.0361	0.0495
^{238}Uranium	24.0	1.36	1.93

[a] Units are pCi/g.

[b] Estimate of the arithmetic mean of the underlying log-normal distribution.

Table 4-11. Variables used to calculate potential incremental lifetime cancer risk associated with inhalation exposure to resuspended particulates throughout the Building 850/Pit 7 Complex operable unit.

Chemical	Cp(ss)[a] (pCi/m^3)	PEF[b] (m^3)	Dose (pCi)	Cancer slope factor[c] (risk/pCi)
^{232}Thorium	1.21×10^{-5}	1.25×10^{5}	1.51×10^{0}	1.93×10^{-8}
^{238}Uranium	4.45×10^{-5}	1.25×10^{5}	5.56×10^{0}	1.24×10^{-8}
^{235}Uranium	1.14×10^{-6}	1.25×10^{5}	1.43×10^{-1}	1.30×10^{-8}

[a] Cp(ss) = Concentration (C) of contaminant on resuspended particulates in air (p, the exposure medium), which results directly from the presence of contaminant in surface soil (ss).

[b] PEF is the pathway exposure factor and is derived in Chapter 6 of the SWRI report (Webster-Scholten, 1994).

[c] California Environmental Protection Agency (Cal EPA, 1994); U.S. EPA (1995a).

Table 4-12. Variables used to calculate potential noncancer hazard associated with inhalation exposure to resuspended particulates throughout the Building 850/Pit 7 Complex operable unit.

Chemical	Cp(ss)[a] (mg/m^3)	PEF[b] (m^3/kg•d)	Dose (mg/kg•d)	Reference dose (mg/kg•d)[c]
^{232}Thorium	1.11×10^{-7}	1.96×10^{-1}	2.18×10^{-8}	Not available
^{238}Uranium	1.31×10^{-7}	1.96×10^{-1}	2.57×10^{-8}	3.00×10^{-3}
^{235}Uranium	5.20×10^{-10}	1.96×10^{-1}	1.02×10^{-10}	3.00×10^{-3}

[a] Cp(ss) = Concentration (C) of contaminant on resuspended particulates in air (p, the exposure medium), which results directly from the presence of contaminant in surface soil (ss).

[b] PEF is the pathway exposure factor and is derived in Chapter 6 of the SWRI report (Webster-Scholten, 1994).

[c] U.S. EPA (1995b).

Table 4-13. Variables used to calculate potential incremental lifetime cancer risk associated with dermal absorption and incidental ingestion of contaminated surface soil throughout the Building 850/Pit 7 Complex operable unit.

Chemical	Cs[a] (ss) (pCi/kg)	Dermal PEF[b] (kg)	Ingestion PEF[b] (kg)	Dose (pCi)	Cancer slope factor[c] (risk/pCi)
^{232}Thorium	5.28×10^{2}	1.26×10^{-1}	3.13×10^{-1}	2.32×10^{2}	3.28×10^{-11}
^{238}Uranium	1.93×10^{3}	1.26×10^{-1}	3.13×10^{-1}	8.47×10^{2}	6.20×10^{-11}
^{235}Uranium	4.95×10^{1}	1.26×10^{-1}	3.13×10^{-1}	2.17×10^{1}	4.70×10^{-11}

[a] Cs = Concentration (C) of contaminant on in surface soil (s, the exposure medium), which results directly from the presence of contaminant in surface soil (ss).

[b] PEF is the pathway exposure factor and is derived in Chapter 6 of the SWRI report (Webster-Scholten, 1994).

[c] California Environmental Protection Agency (Cal EPA, 1994): U.S. EPA (1995a).

Table 4-14. Variables used to calculate potential noncancer hazard associated with dermal absorption and incidental ingestion of contaminated surface soil throughout the Building 850 /Pit 7 Complex operable unit.

Chemical	Cs[a] (ss) (mg/kg)	Dermal PEF[b] (kg)	Ingestion PEF[b] (kg)	Dose (mg/kg•d)	Reference dose (mg/kg•d)[c]
^{232}Thorium	4.83×10^{0}	1.98×10^{-7}	4.89×10^{-7}	3.32×10^{-6}	Not available
^{238}Uranium	5.71×10^{0}	1.98×10^{-7}	4.89×10^{-7}	3.92×10^{-6}	3.00×10^{-3}
^{235}Uranium	2.26×10^{-2}	1.98×10^{-7}	4.89×10^{-7}	1.55×10^{-8}	3.00×10^{-3}

[a] Cs = Concentration (C) of contaminant on in surface soil (s, the exposure medium), which results directly from the presence of contaminant in surface soil (ss).

[b] PEF is the pathway exposure factor and is derived in Chapter 6 of the SWRI report (Webster-Scholten, 1994).

[c] California Environmental Protection Agency (Cal EPA, 1994); U.S. EPA (1995b).

Table 4-15. Predicted incremental lifetime cancer risk and hazard index (HI) attributable to incidental ingestion and direct dermal contact with contaminated surface soil throughout the Building 850/Pit 7 Complex operable unit (adult on-site exposure).

Chemical	$C_{s(ss)}$[a] (pCi/kg)	Individual lifetime cancer risk	Hazard quotient (dose/RfD)[b]
^{232}Thorium	5.28×10^{2}	3×10^{-9}	Not available[c]
^{238}Uranium	1.93×10^{3}	2×10^{-8}	1.3×10^{-3}
^{235}Uranium	3.57×10^{2}	4×10^{-10}	5.2×10^{-6}
		$\Sigma Risk = 3 \times 10^{-8}$	$HI = 1.3 \times 10^{-3}$

[a] $C_{s(ss)}$ = Concentration (C) of contaminant in surface soil (s, the exposure medium), which results directly from the presence of contaminant in surface soil (ss).

[b] RfD = Reference dose.

[c] An RfD for ^{232}Thorium is not available.

Table 4-16. Predicted incremental lifetime cancer risk and hazard index (HI) attributable to inhalation of resuspended particulates throughout the Building 850 /Pit 7 Complex operable unit (adult on-site exposure).

Chemical	$C_{p(ss)}$[a] (pCi/m^3)	Individual lifetime cancer risk	Hazard quotient (dose/RfD)[b]
Thorium-232	1.21×10^{-5}	1×10^{-8}	Not available[c]
Uranium-238	4.45×10^{-5}	2×10^{-8}	8.6×10^{-6}
Uranium-235	1.14×10^{-6}	7×10^{-10}	3.4×10^{-8}
		$\Sigma Risk = 3 \times 10^{-8}$	$HI = 8.8 \times 10^{-6}$

[a] $C_{p(ss)}$ = Concentration (C) of contaminant on resuspended particulates in air (p) (the exposure medium), which results directly from the presence of contaminant in surface soil (ss).

[b] RfD = Reference dose.

[c] An RfD for ^{232}Thorium is not available.

Table 4-17. Additive risk and hazard index (HI) for adults on site throughout the Building 850/Pit 7 Complex operable unit.

Route of exposure	Calculated risk	Calculated HI associated with region or source of exposure
Inhalation of resuspended particulates	3×10^{-8}	8.8×10^{-6}
Ingestion and dermal contact, contaminants in surface soil	3×10^{-8}	1.3×10^{-3}
	$\Sigma Risk = 6 \times 10^{-8}$	$\Sigma HI = 1.3 \times 10^{-3}$

Table 4-18. Variables used to calculate incremental lifetime cancer risk associated with exposure to tritium vapor inside of Building 850.

Tritium concentration (pCi/m^3)	Inhalation PEF[a] (m^3/y)	Slope factor[b] (risk/pCi)	Dermal PEF[a] (m^3/y)	Slope factor[b] (risk/pCi)
2.12	5×10^3	3.4×10^{-14}	2.5×10^3	2.5×10^{-14}

[a] PEF is the pathway exposure factor. The inhalation PEF is derived in Chapter 6 of the SWRI; the dermal PEF is one-half of the inhalation PEF. That value is based on experimental data of Osborne (1966).

[b] Slope factors are from U.S. EPA (1995a), and are adjusted by 25/70 to account for the 25-year exposure period.

Table 4-19. Predicted incremental lifetime cancer risk and hazard index (HI) attributable to residential use of ground water contaminated with ^{238}Uranium (^{238}U) at the boundary of Site 300.

Source location	Predicted ^{238}U activity at the Site boundary (pCi/L)	Incremental excess cancer risk	Hazard quotient (dose/RfD)[a]
Pit 7	0.36	1×10^{-7}	9.9×10^{-3}
Pit 5	1.77	6×10^{-7}	4.9×10^{-2}
Building 850	1.26	4×10^{-7}	3.5×10^{-2}
Building 850 and pit 5	1.04	4×10^{-7}	2.9×10^{-2}

[a] RfD = Reference dose.

Table 5-1. Maximum concentrations/activities of selected chemicals detected in the Building 850/Pit 7 Complex operable unit.

Constituents identified	Media	Maximum concentration (unless noted otherwise)
Depleted uranium	Surface soil	49.5 pCi/g
	Subsurface soil and rock	1.84 pCi/g
	Ground water	119.7 pCi/L
Natural uranium	Ground water	21.32 pCi/L[a]
Thorium	Surface soil	0.93 pCi/g (^{232}Th)
	Subsurface soil and rock	2.98 pCi/g (^{232}Th)
	Ground water	39.5 ± 19.4 pCi/L (^{230}Th)
Tritium	Subsurface moisture	7.8×10^6 pCi/L_{sm}[b]
		3.02×10^6 pCi/L_{sm}[c]
	Ground water	1.2×10^6 pCi/L[b]
		623,000 pCi/L[b]
	Indoor air	2.1×10^{-12} µCi/mL (avg.)
PCBs	Surface soil (Bldg. 850)	180 mg/kg
CDD dioxins	Surface soil (Bldg. 850)	4.3 pg/g
CDF furans	Surface soil (Bldg. 850)	15,000 pg/g
TCE	Soil vapor	22,751 tics[d]
	Ground water (downgradient of pit 5)	15.6 µg/L[b] 15 µg/L[c]

[a] Highest activity measured by ICP/MS. The highest post-SWRI uranium activity measured by alpha spectrometry waS 28.62 pCi/L.

[b] SWRI data.

[c] Post-SWRI data.

[d] Tics = total ion counts.

Table 5-2. Estimated ground water uranium activities that could reach potential exposure points from plumes originating at pits 5 and 7 and Building 850.

Plume source location	Predicted potential exposure point	Calculated activities at exposure point (pCi/L)
Pit 7	Northern boundary of Site 300	0.36
Pit 5	Northern boundary of Site 300	1.77
Building 850	Spring 6	1.52
	Eastern boundary of Site 300	1.26
Pit 5, Building 850	Spring 6	1.37
(simultaneous and additive)	Eastern boundary of Site 300	1.04

Table 5-3. Summary of cancer risk and HIs in and near Building 850 and for the entire operable unit.

Risk	Risk evaluation	HI	Exposure pathway
Maximum incremental excess cancer	6×10^{-7}	0.0492	Residential use of ground water containing uranium
Cumulative incremental lifetime cancer	7×10^{-6}	0.029	Ingestion and dermal contact with surface soil containing radionuclides and metals in or near Building 850
Cumulative incremental lifetime cancer	3×10^{-7}	1.9×10^{-4}	Inhalation of resuspended particulates containing radionuclides and metals in or near Building 850
Cumulative incremental lifetime cancer	3×10^{-8}	1.3×10^{-3}	Ingestion and dermal contact with radionuclides for entire OU
	3×10^{-8}	8.8×10^{-6}	Inhalation of dust containing radionuclides for entire OU
Additive risk	6×10^{-8}	1.3×10^{-3}	Inhalation of resuspended particulates and ingestion and dermal contact of contaminants (radionuclides) by adults on site throughout entire OU

Appendix A

Chemical Analytical Data for Soil and Rock

NOTE: DATA TABLES ARE NOT INCLUDED WITH THIS COPY

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Appendix B

Chemical Analytical Data for Ground and Surface Water

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Appendix C

Ground Water Chemical Time-Series Plots

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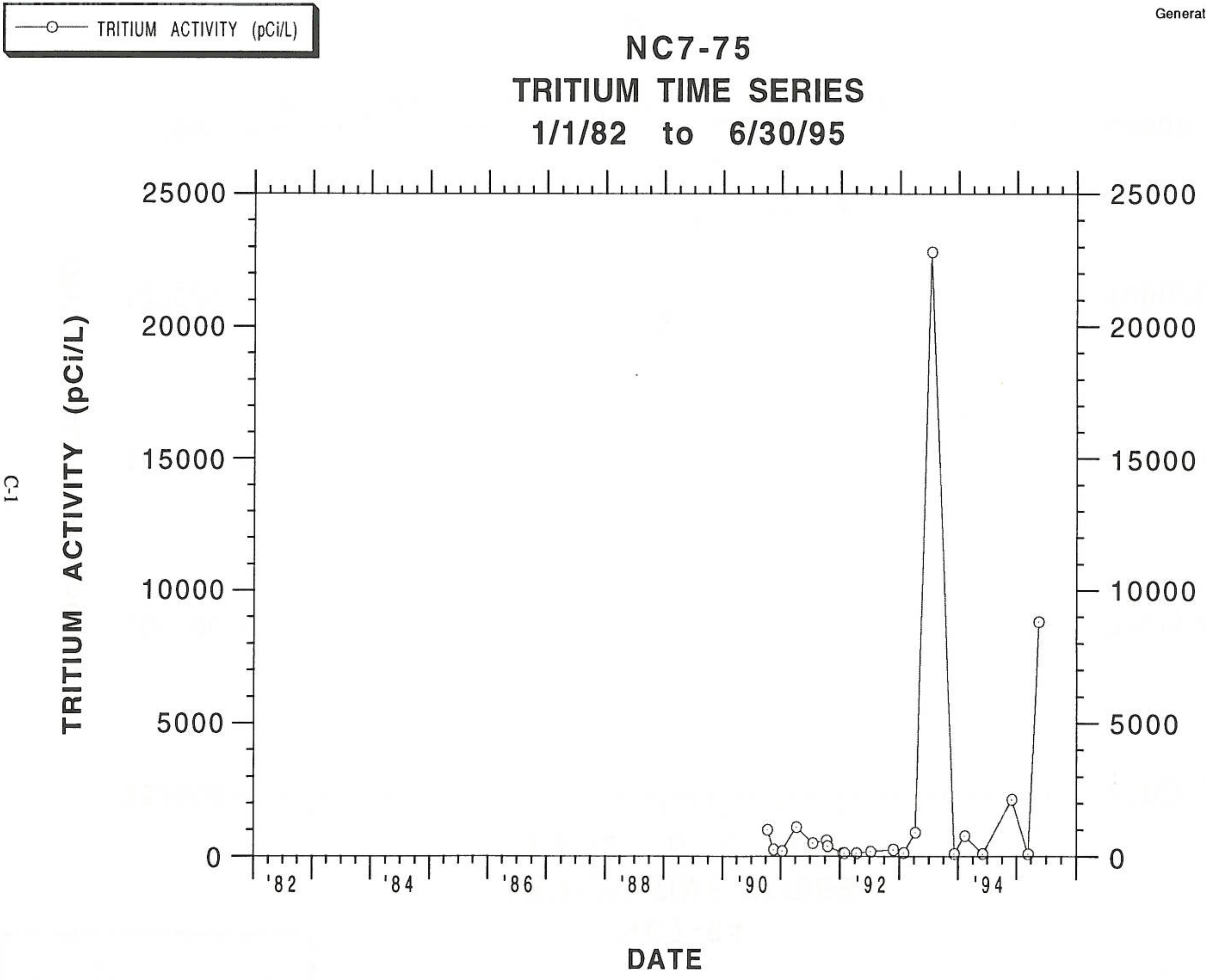

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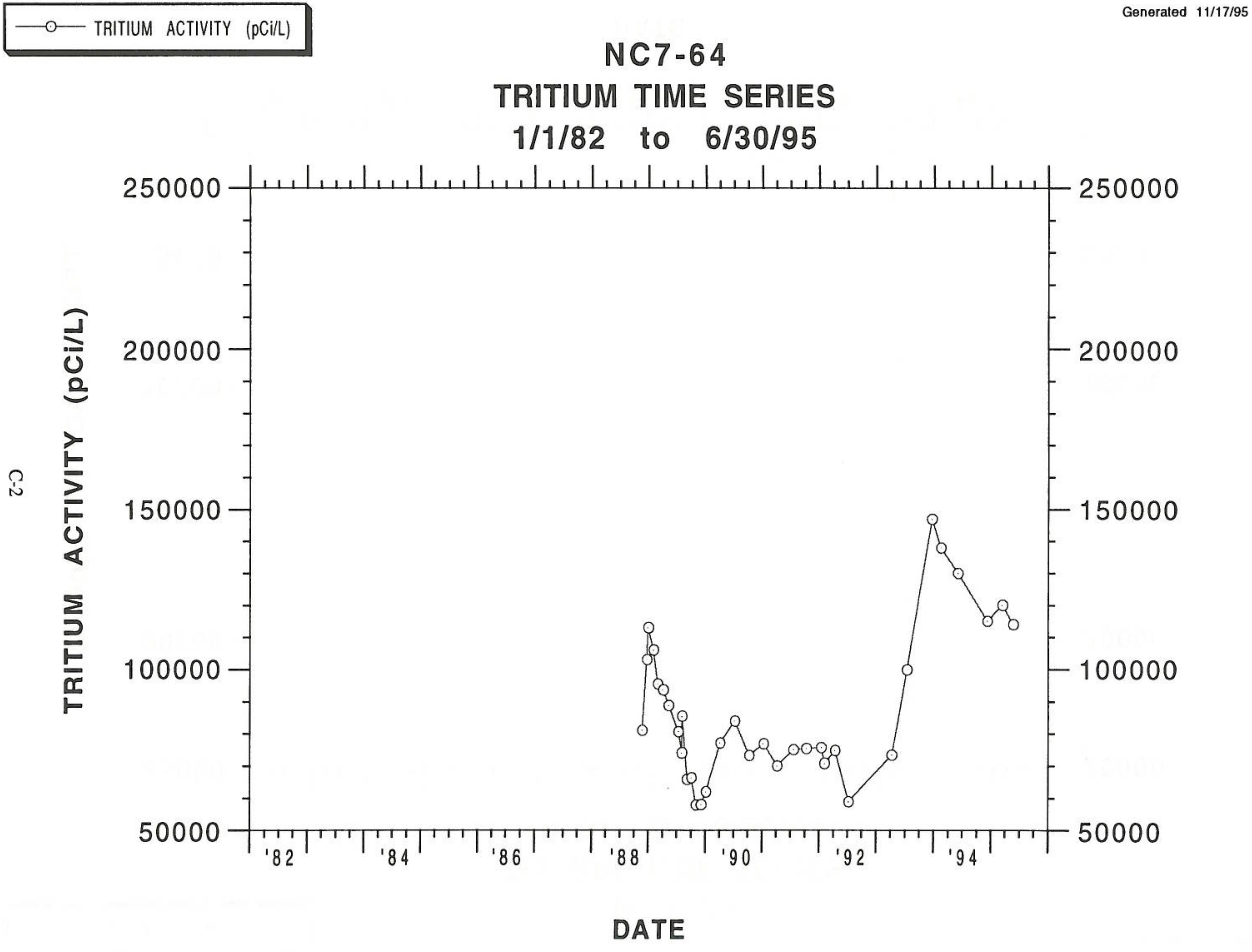

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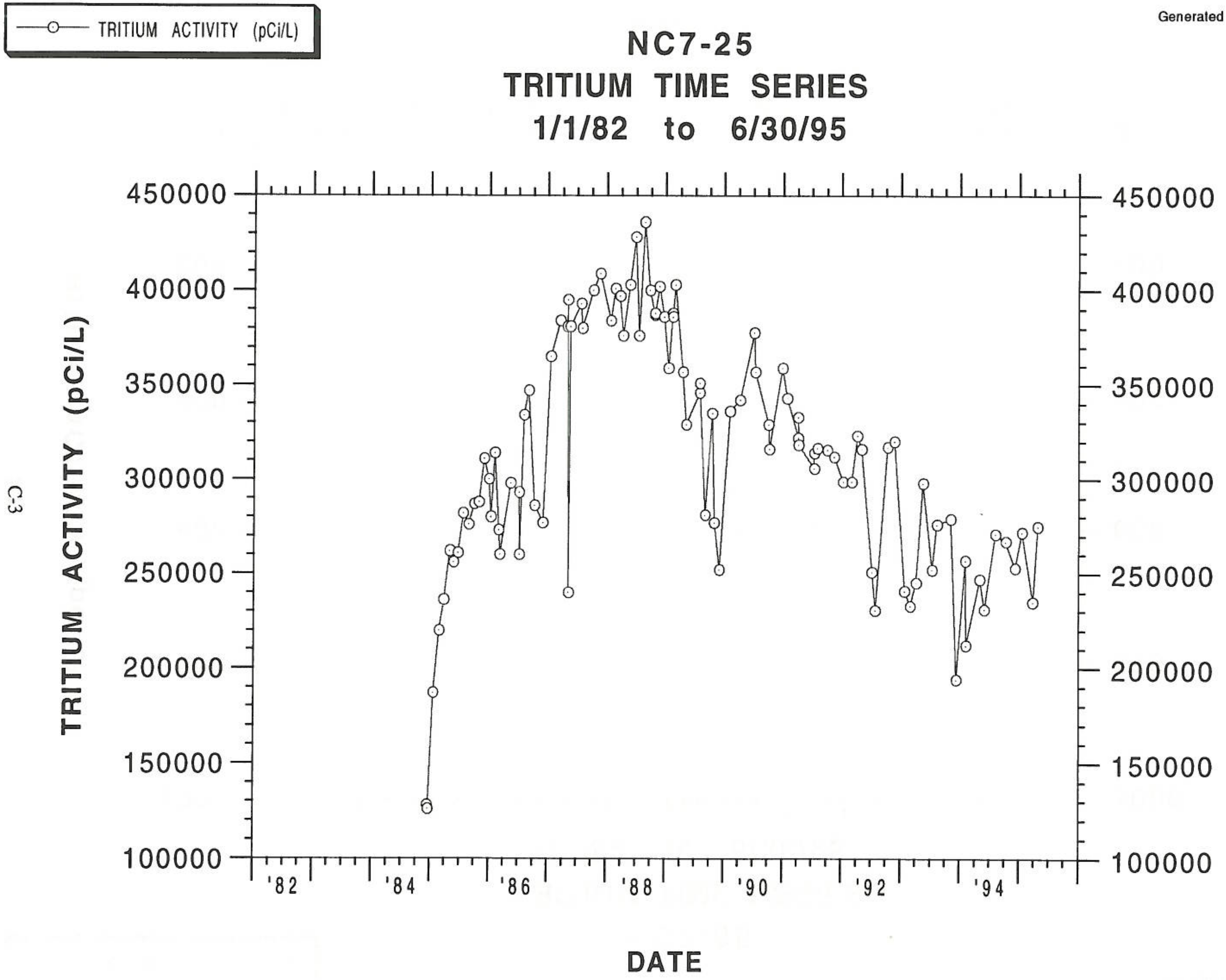

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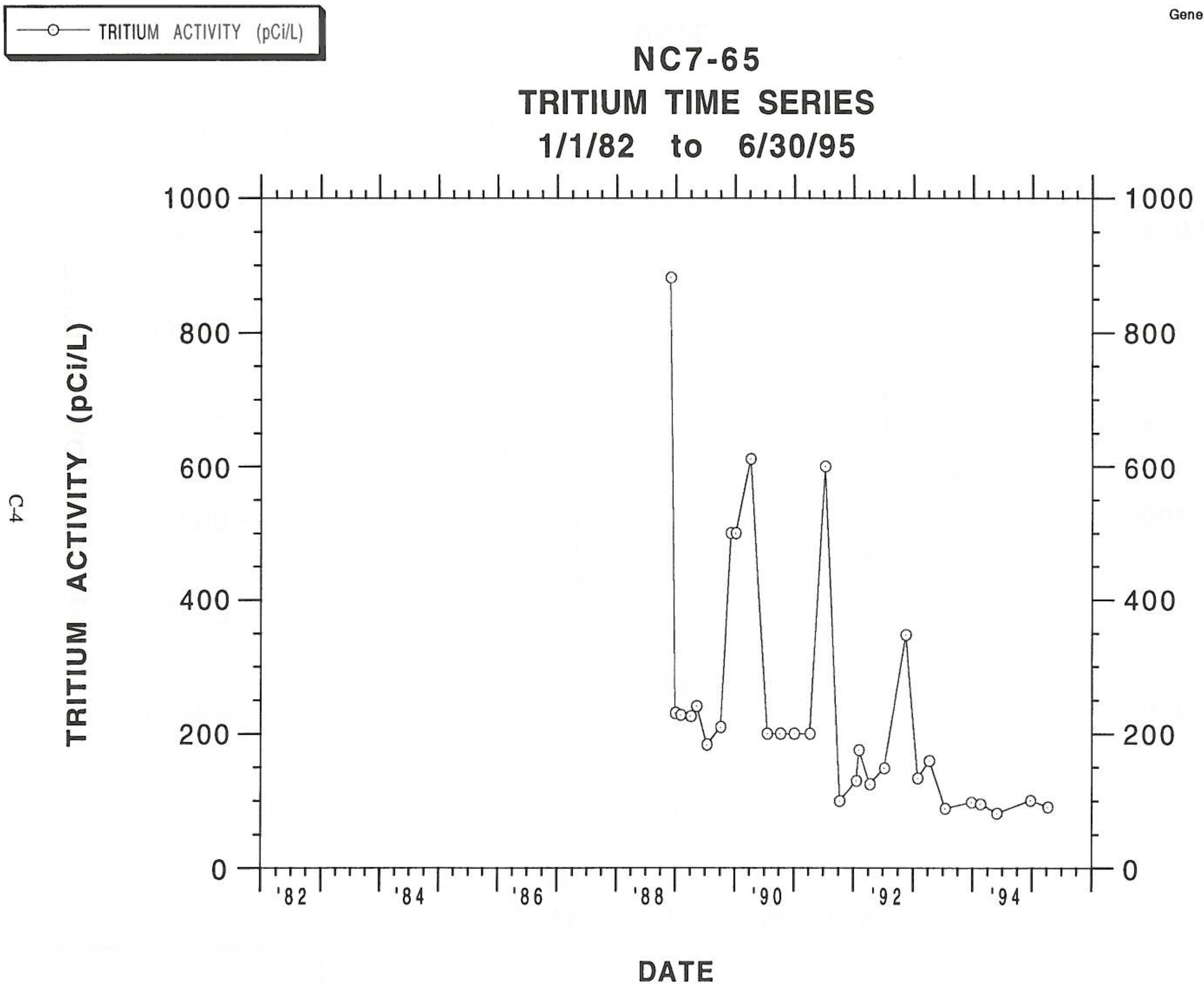

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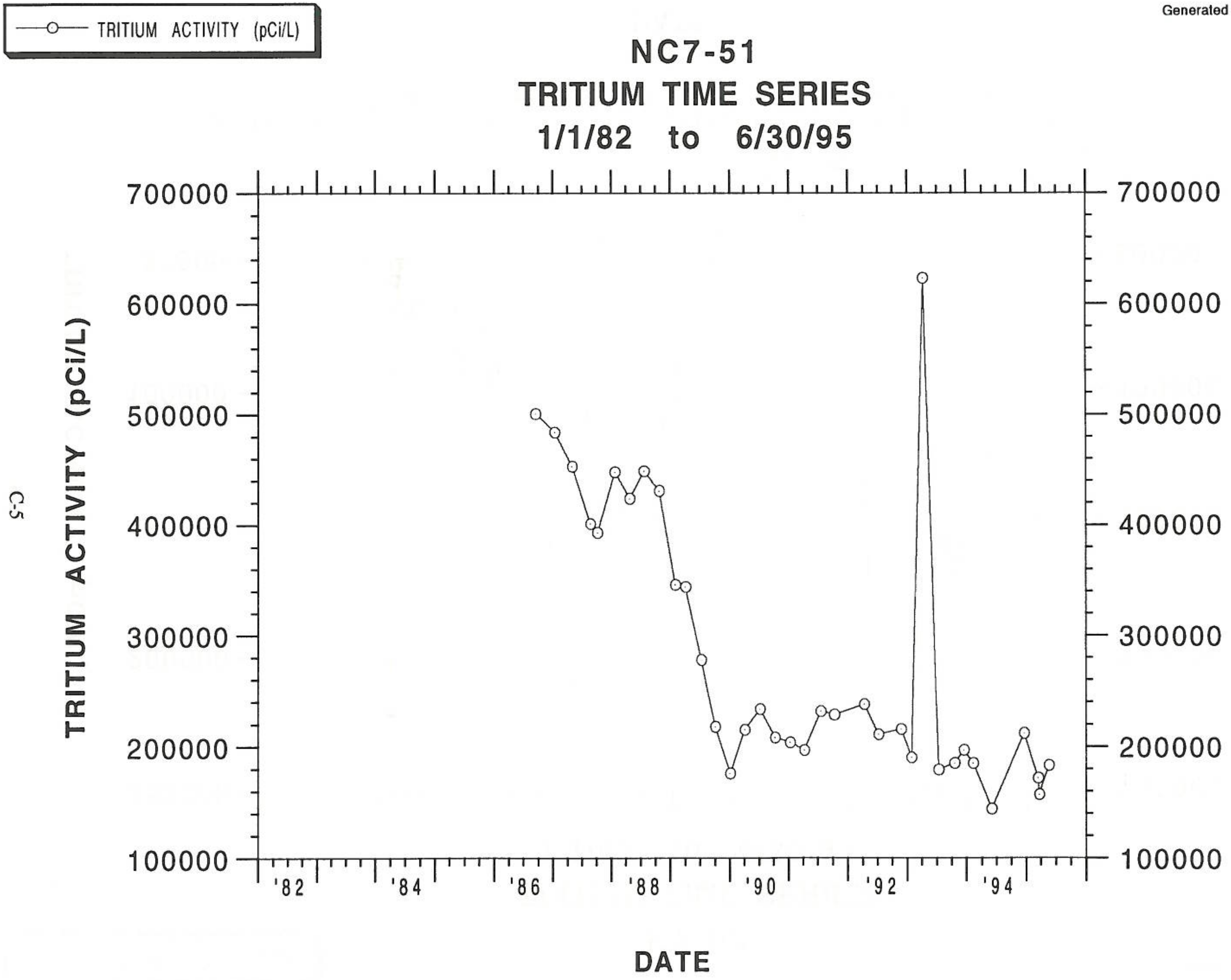

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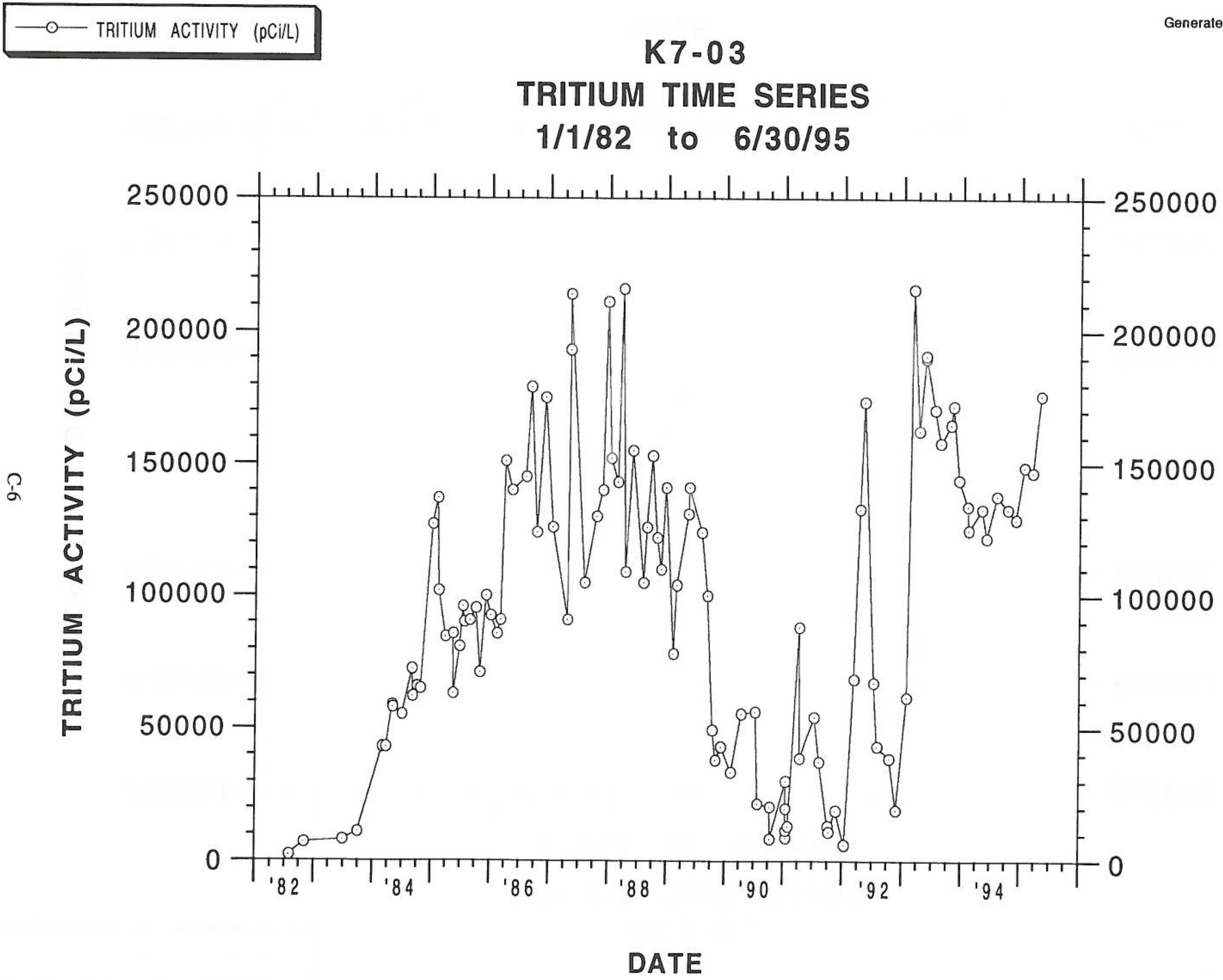

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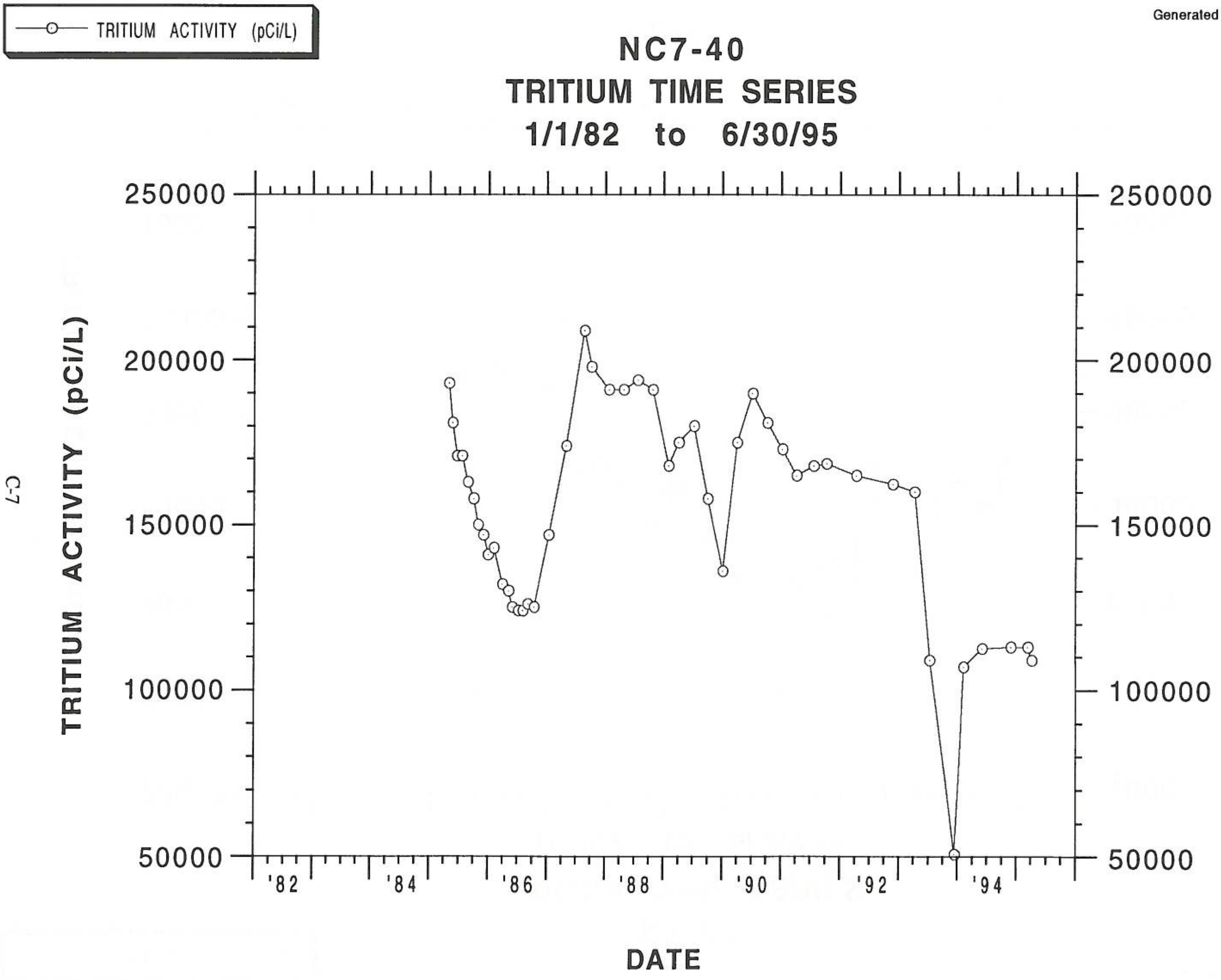

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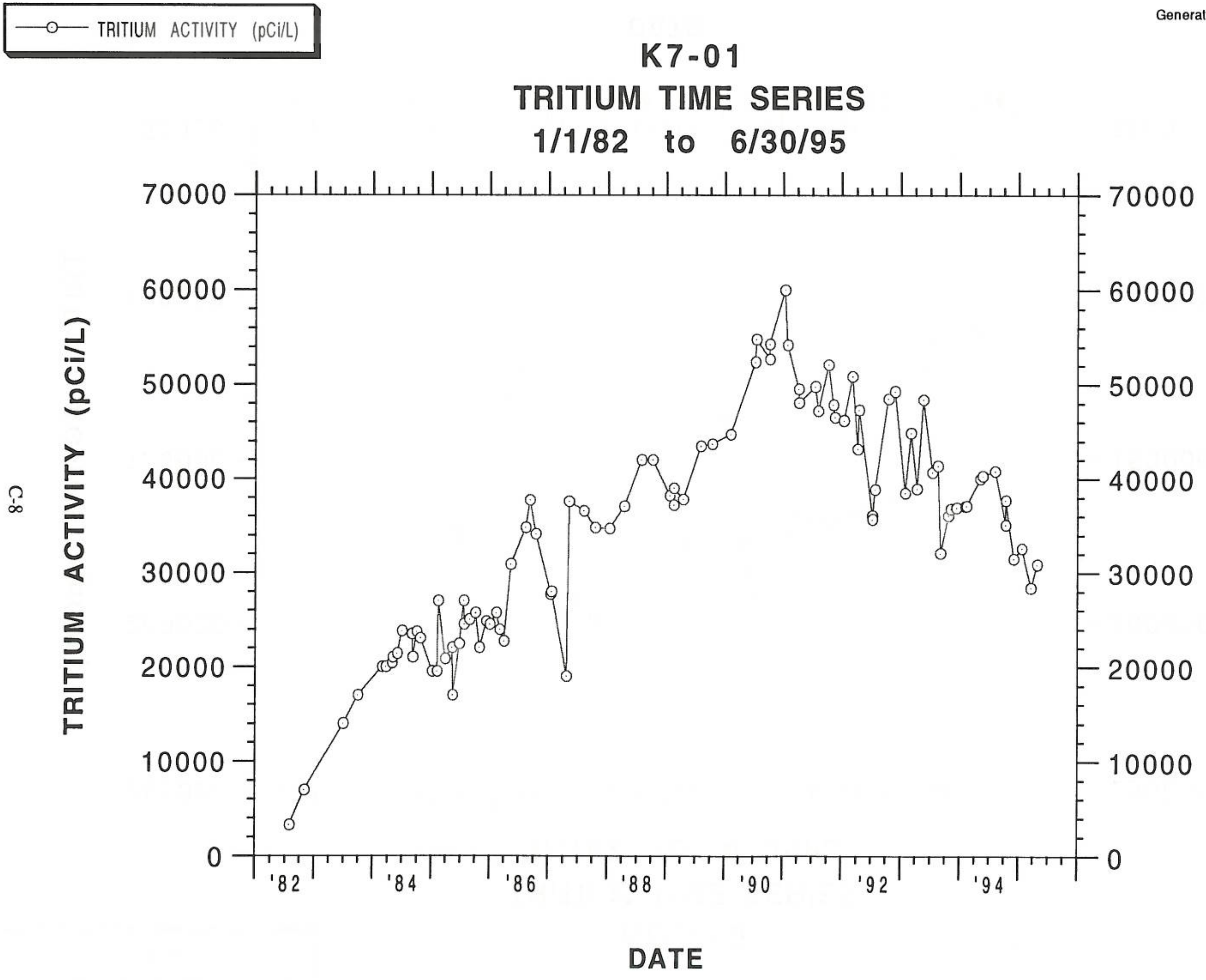

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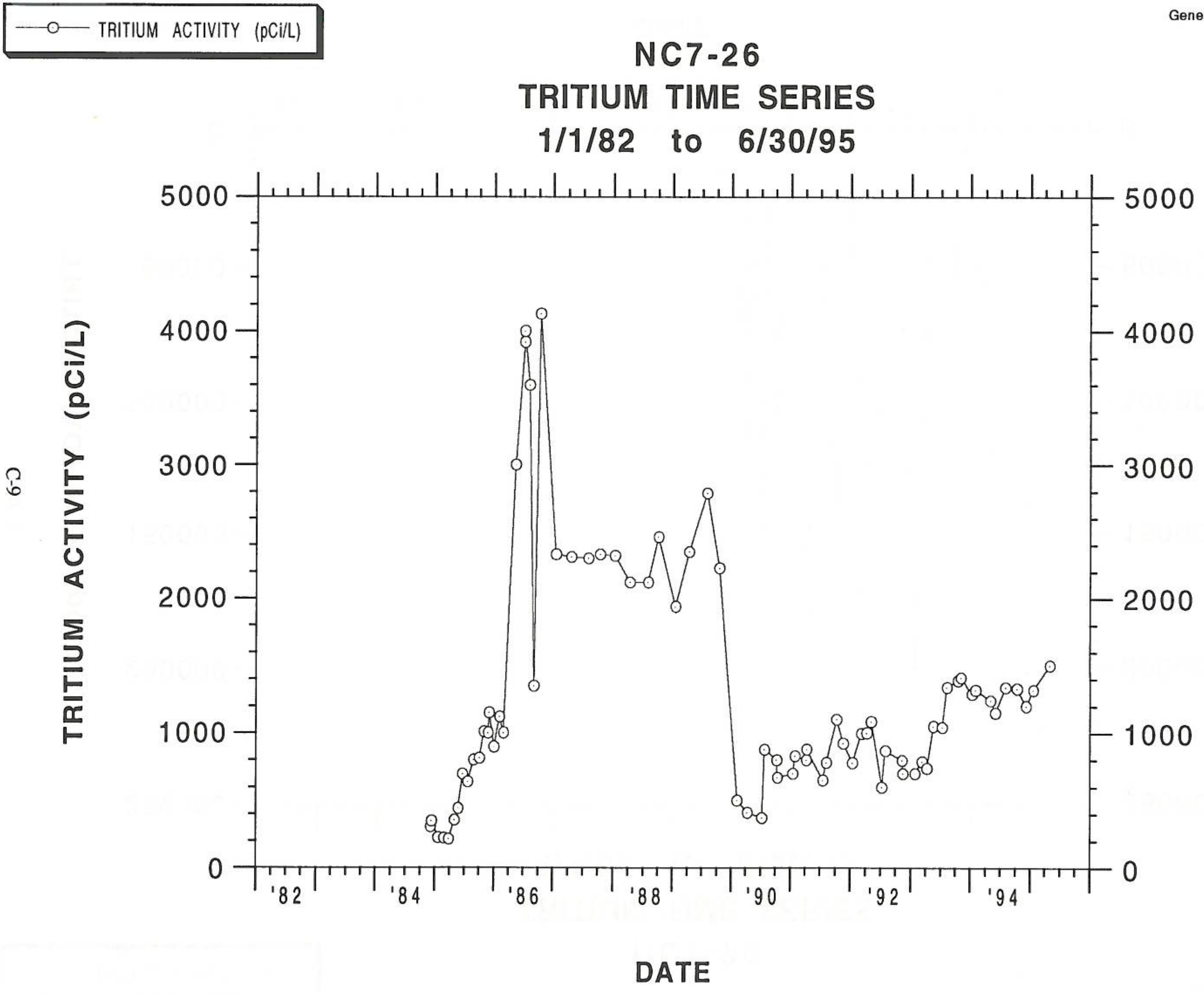

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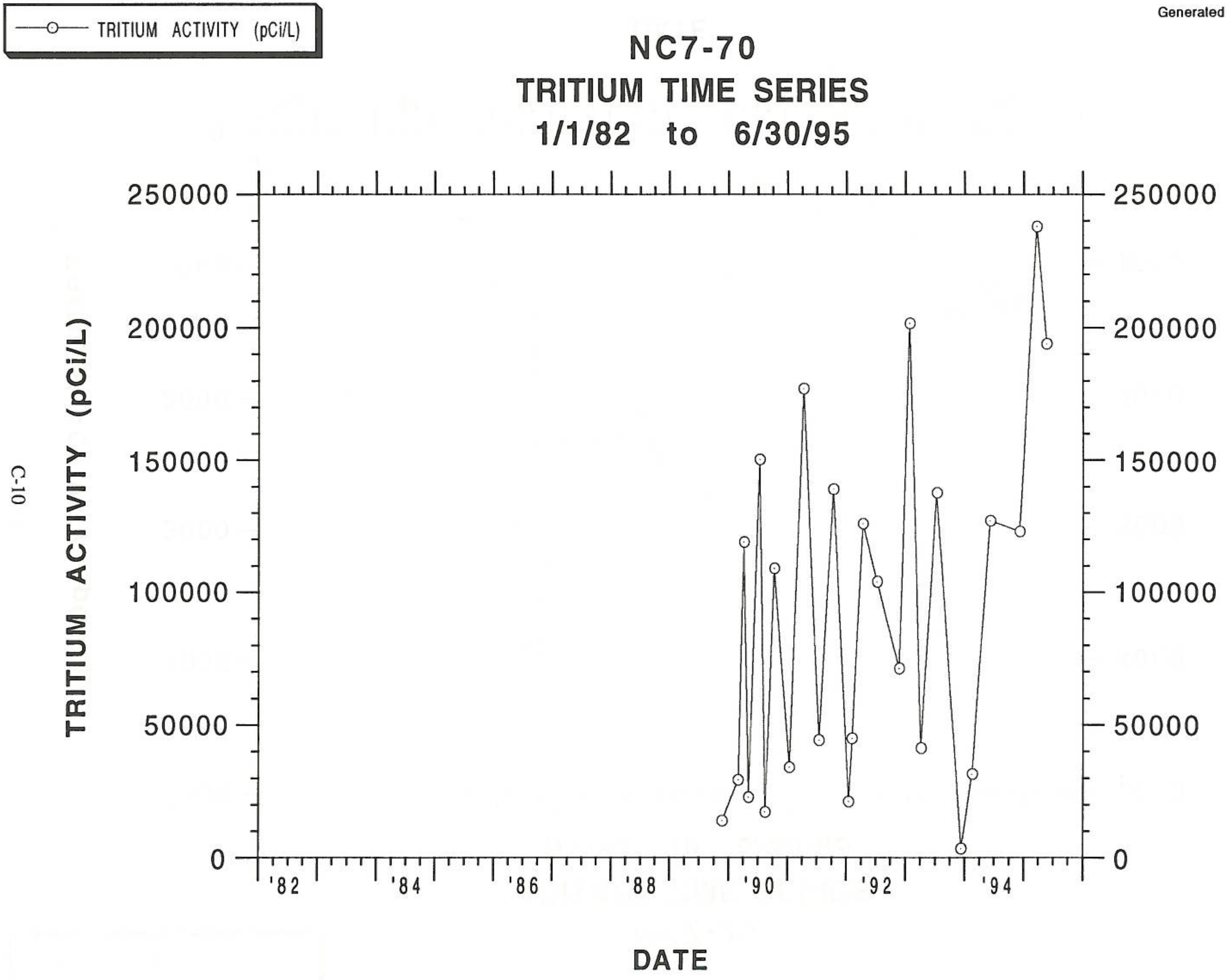

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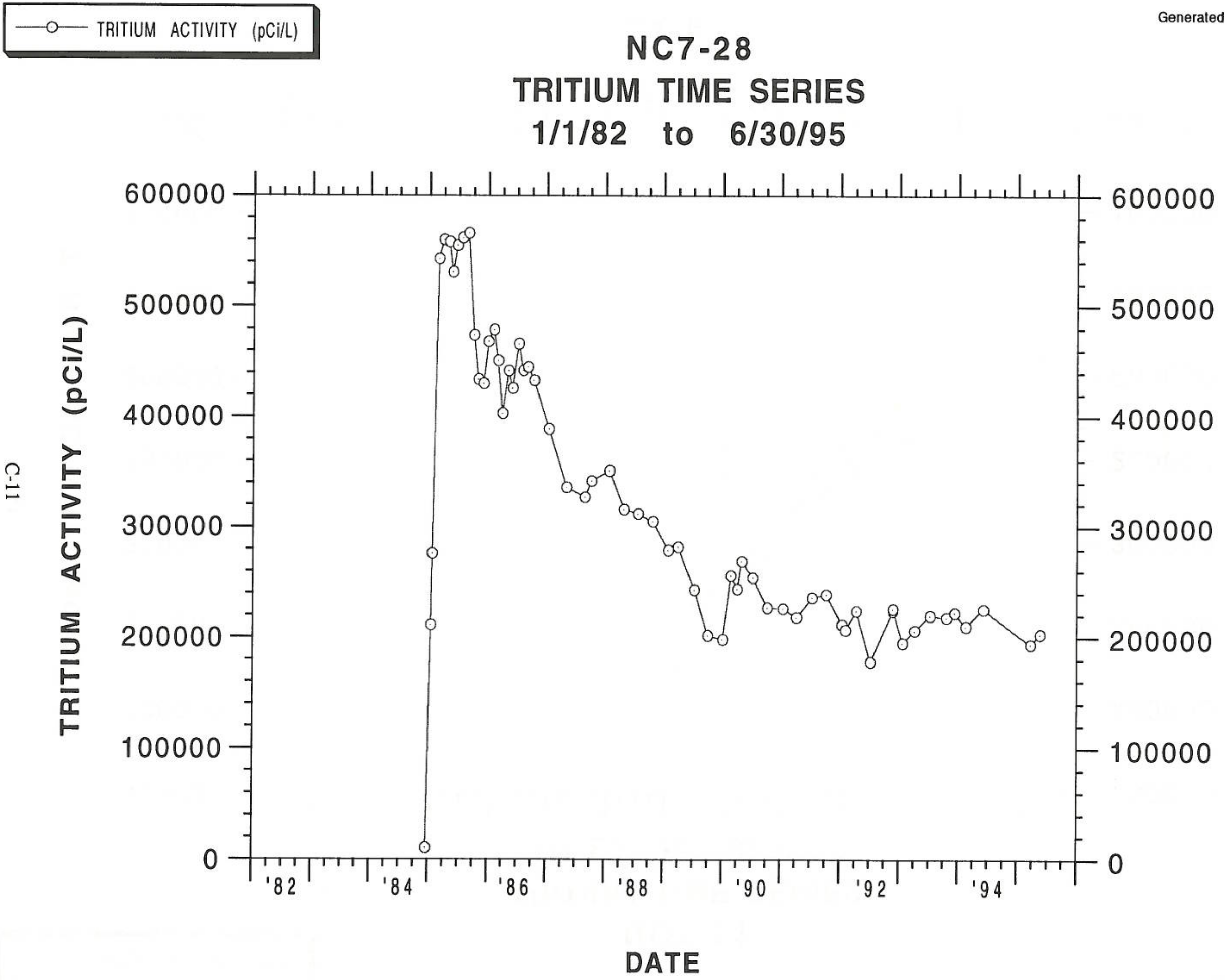

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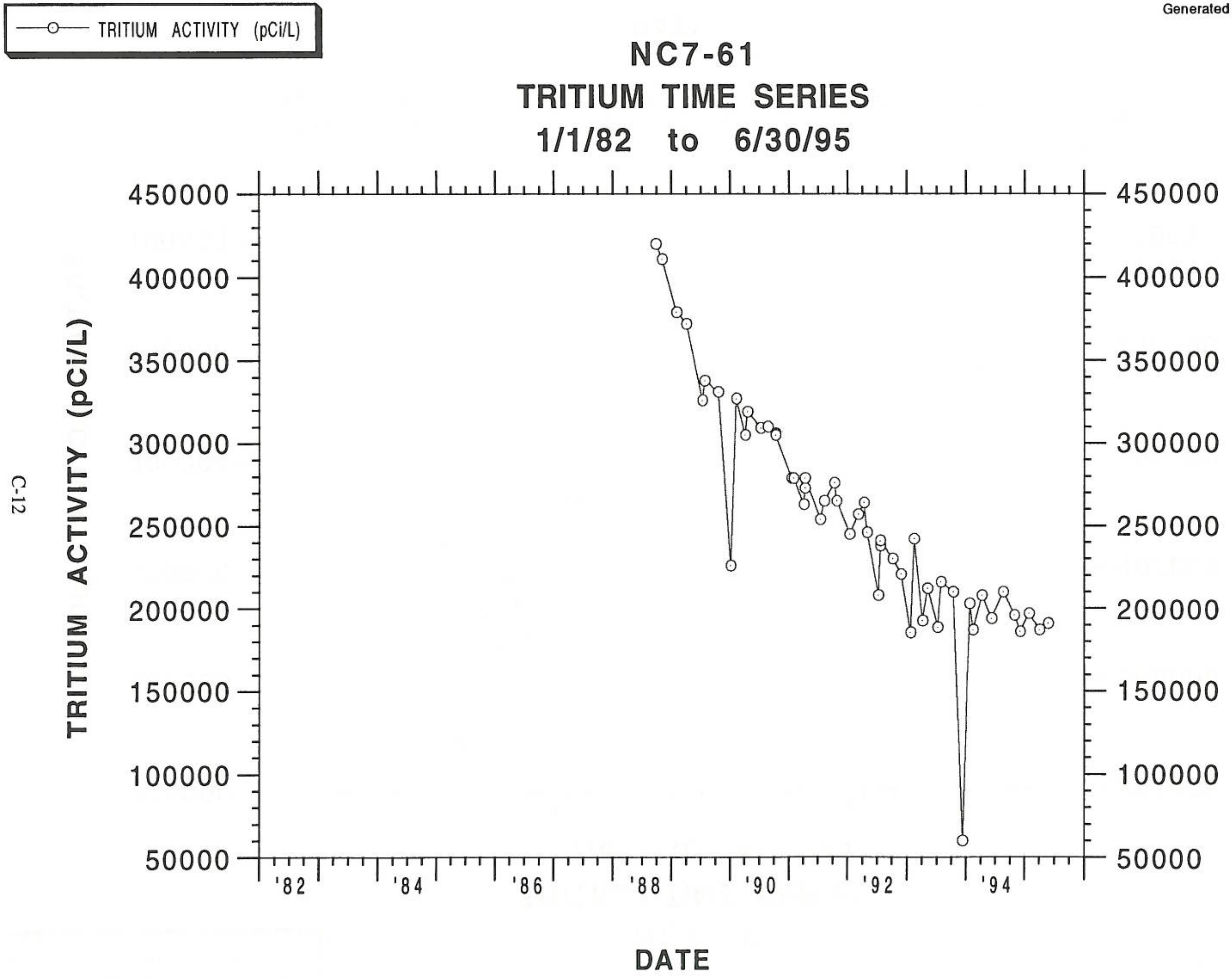

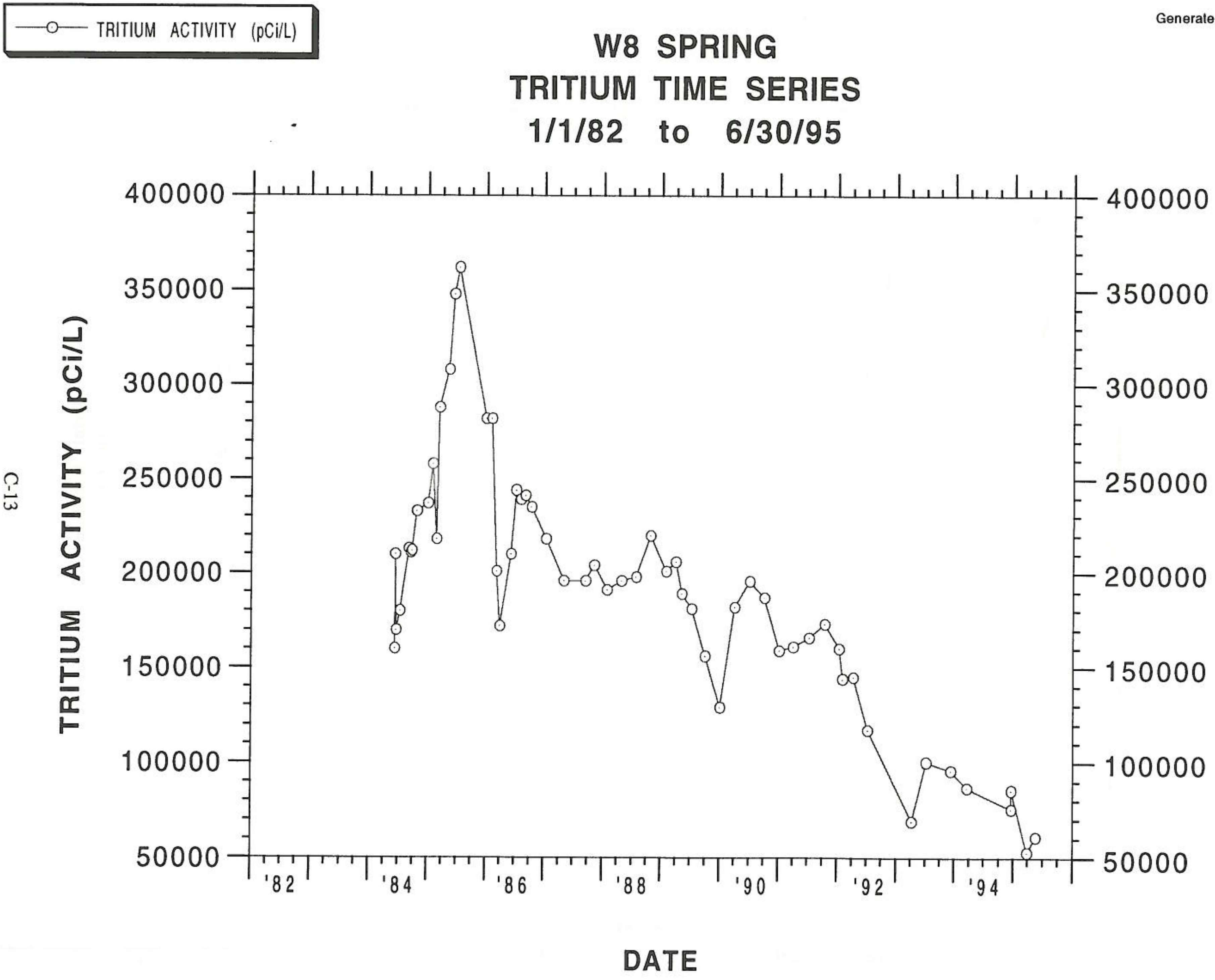

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W8 SPRING
TRITIUM TIME SERIES
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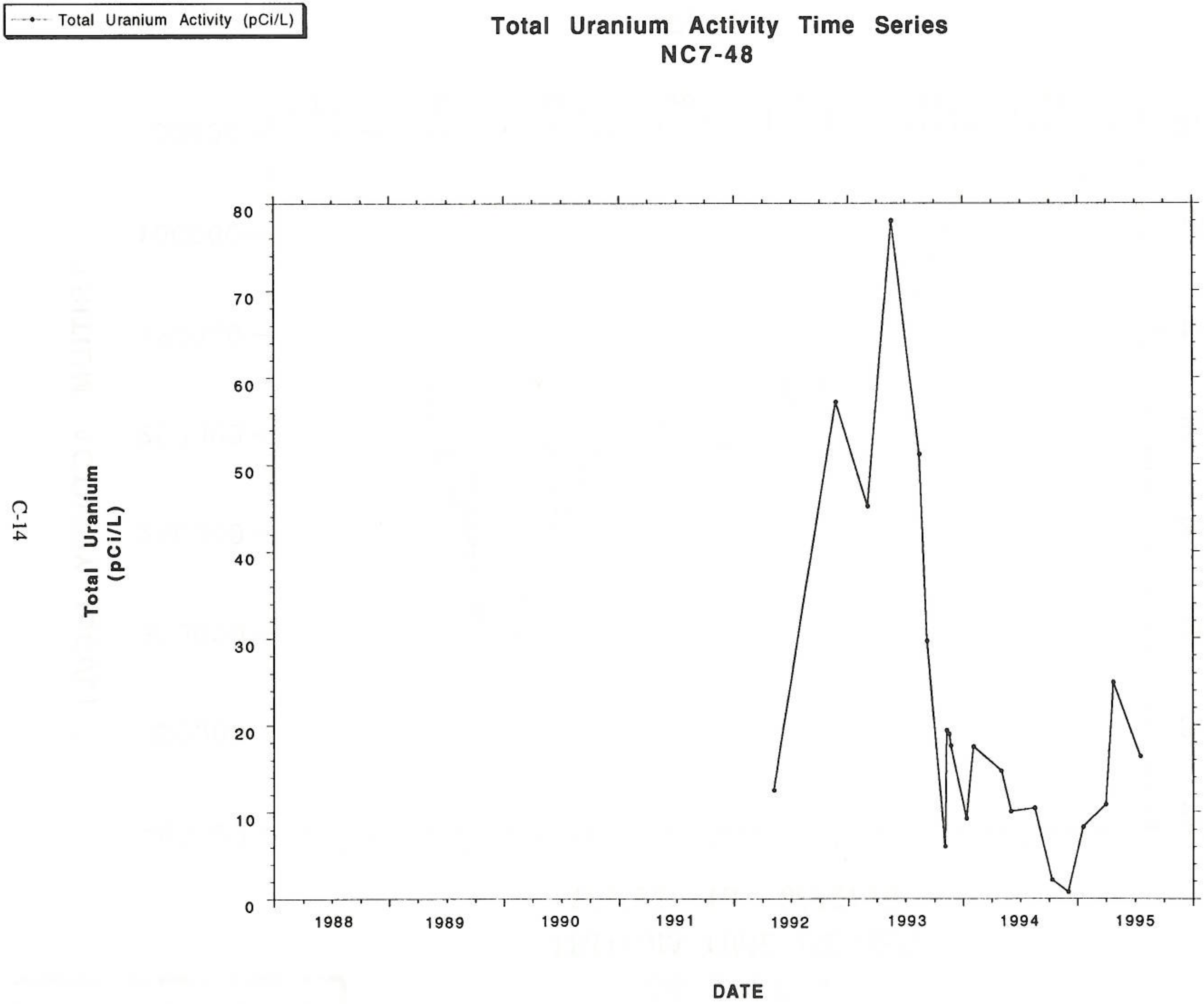
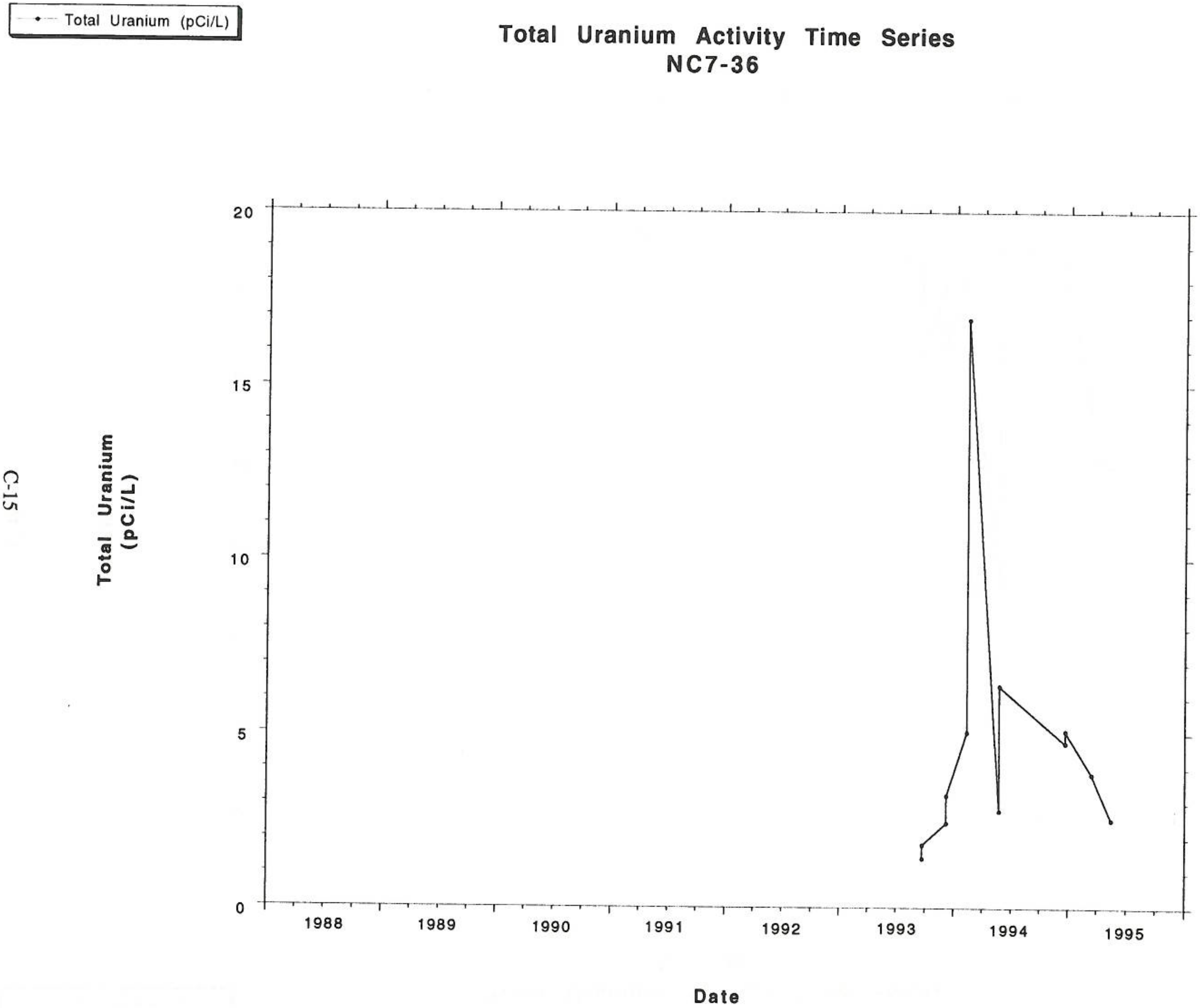
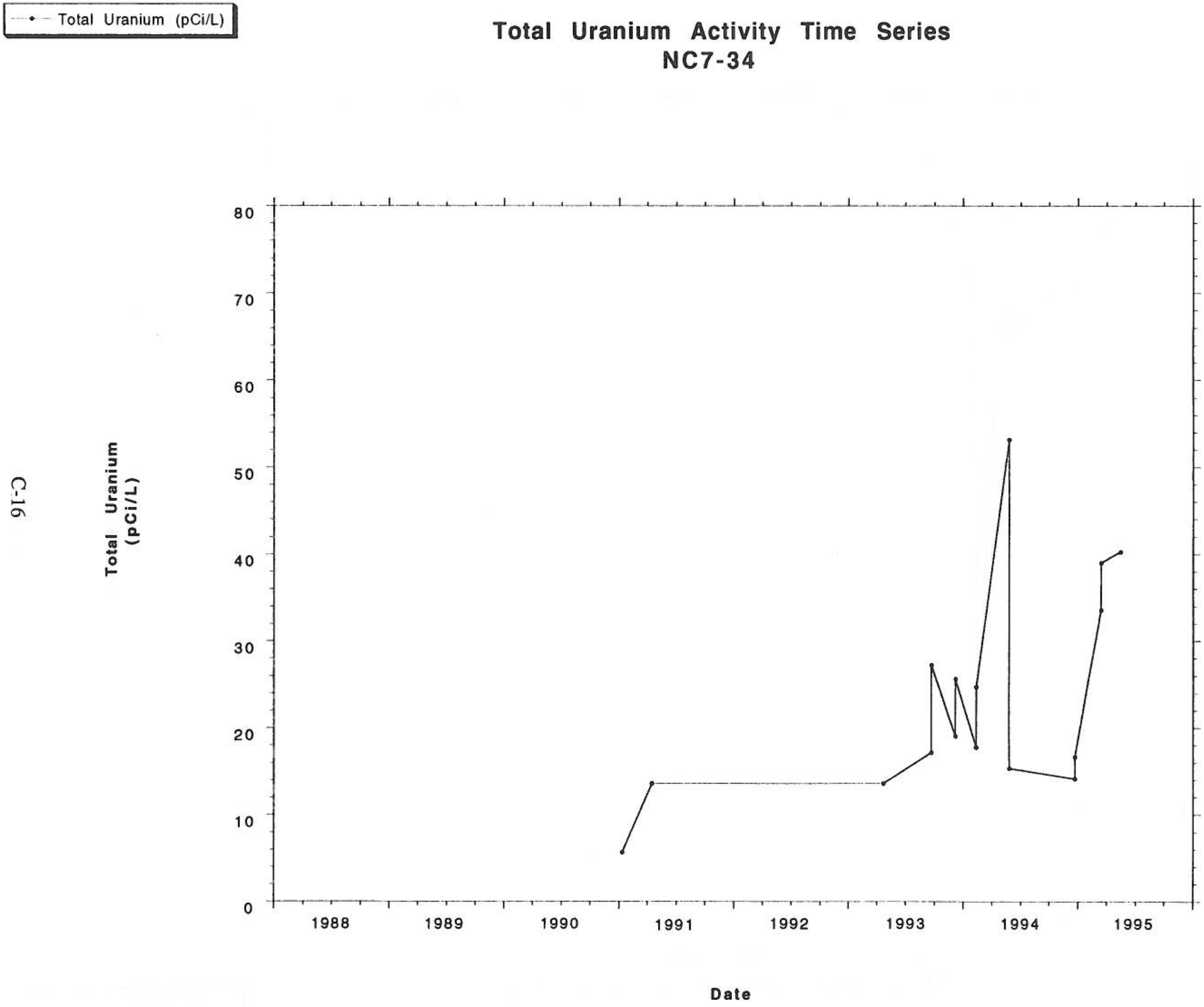
Total Uranium Activity Time Series
NC7-48

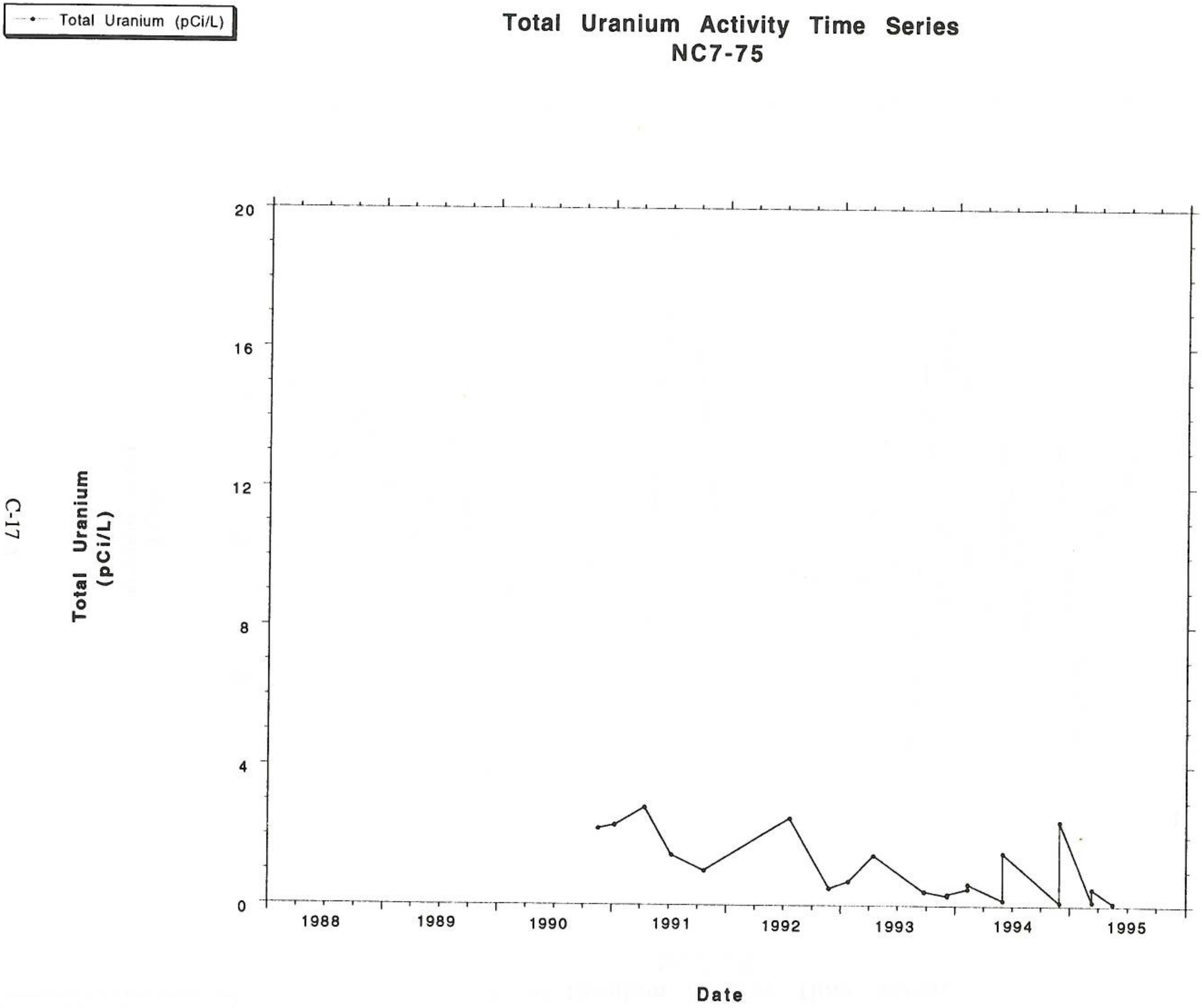




Total Uranium Activity Time Series
NC7-36

Total Uranium Activity Time Series
NC7-34

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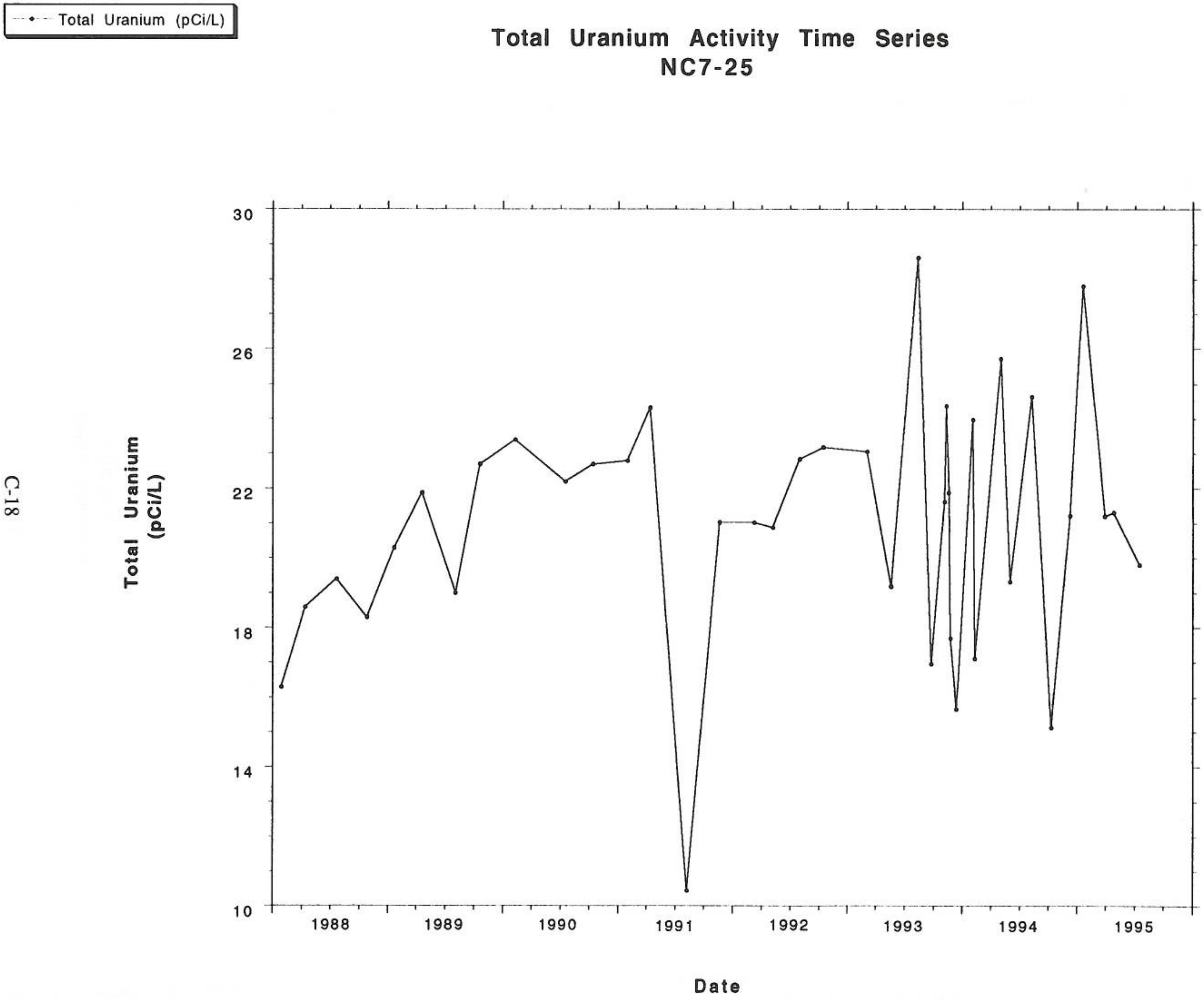
Total Uranium Activity Time Series
NC7-75
20
16
12
8
4
0
Total Uranium (pCi/L)
1988
1989
1990
1991
1992
1993
1994
1995
Date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NC7-25
Total Uranium (pCi/L)
30
26
22
18
14
10
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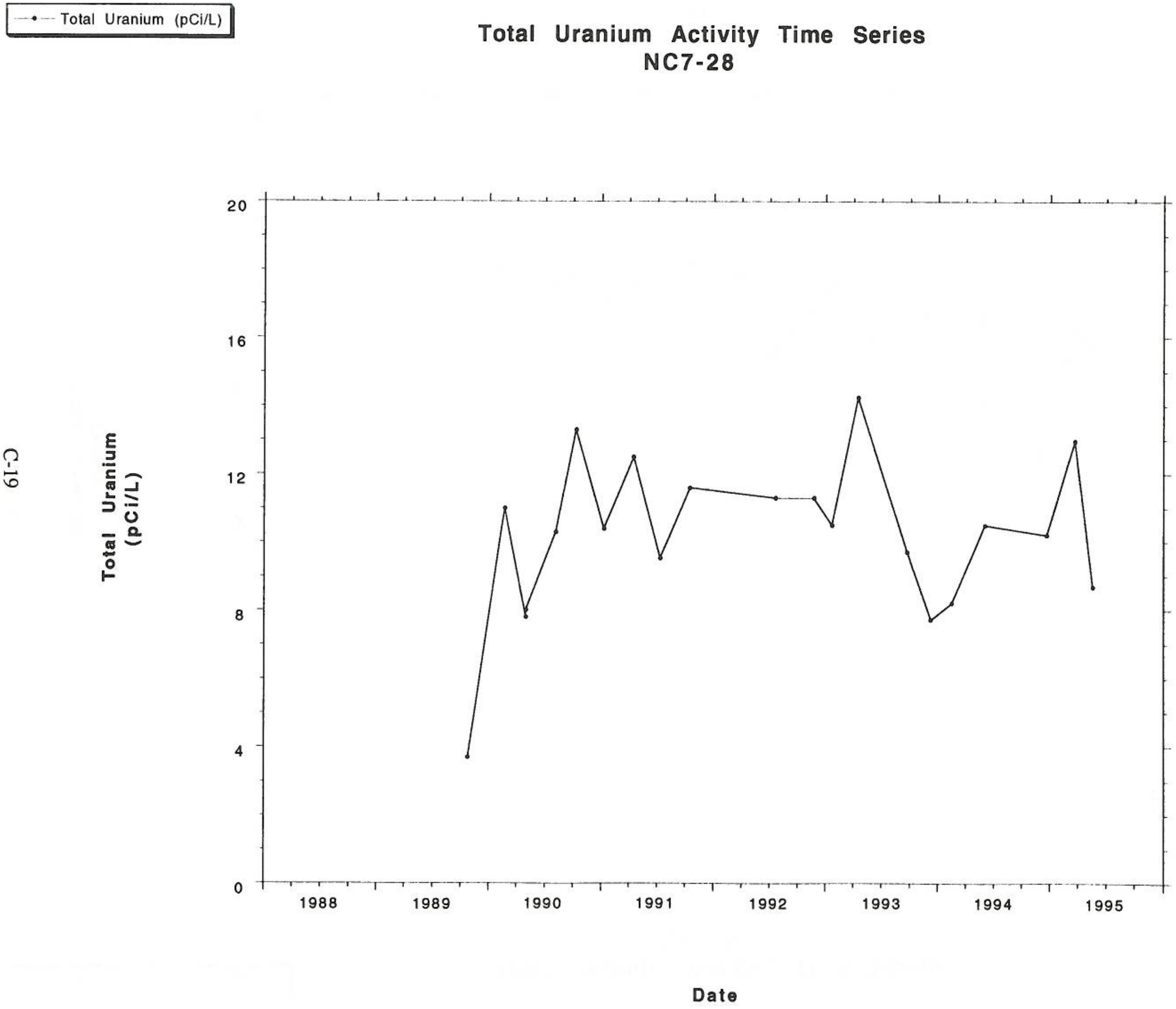
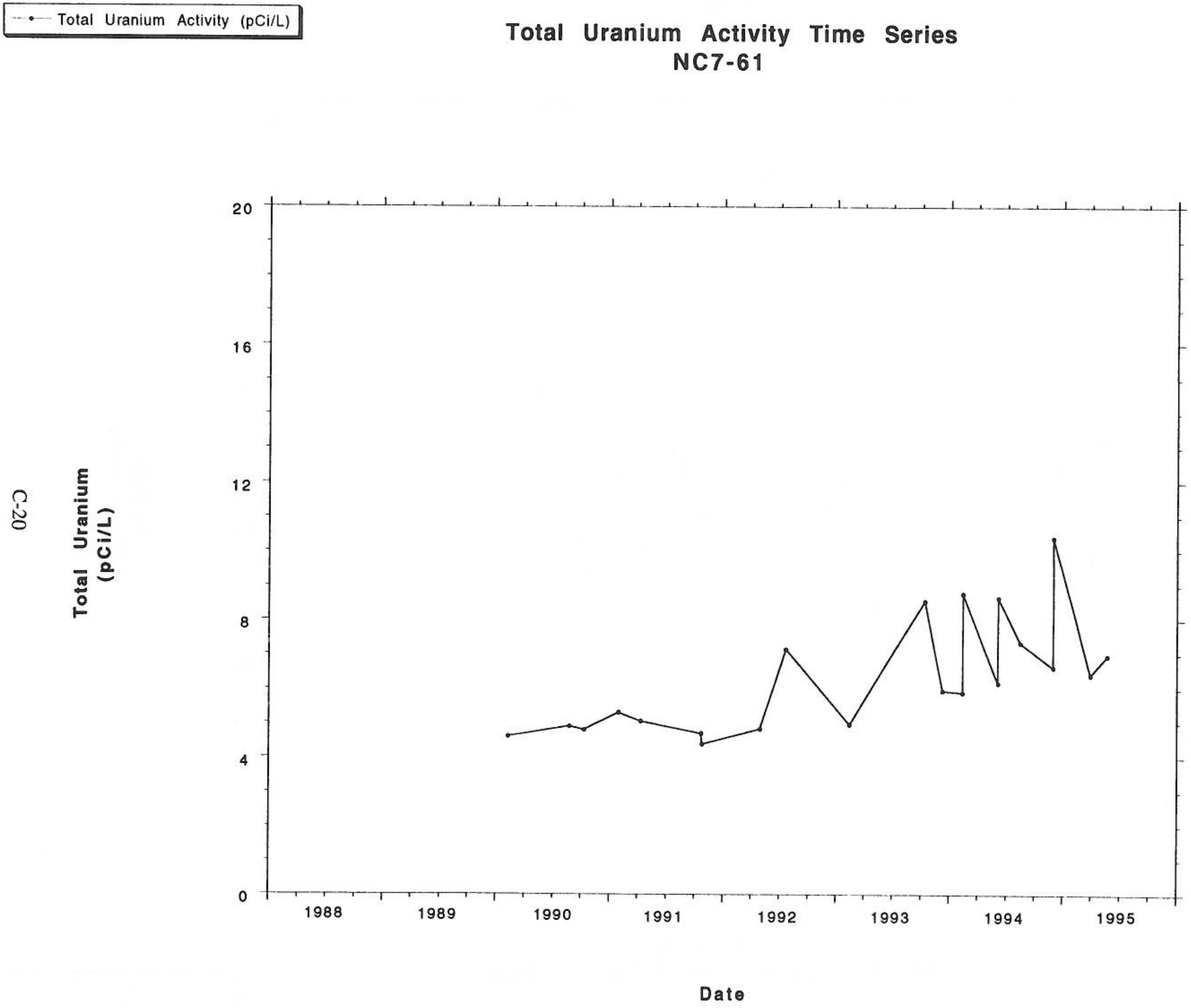
1991
1992
1993
1994
1995
Date



Total Uranium Activity Time Series
NC7-28


Total Uranium Activity (pCi/L)
Total Uranium Activity Time Series
NC7-61
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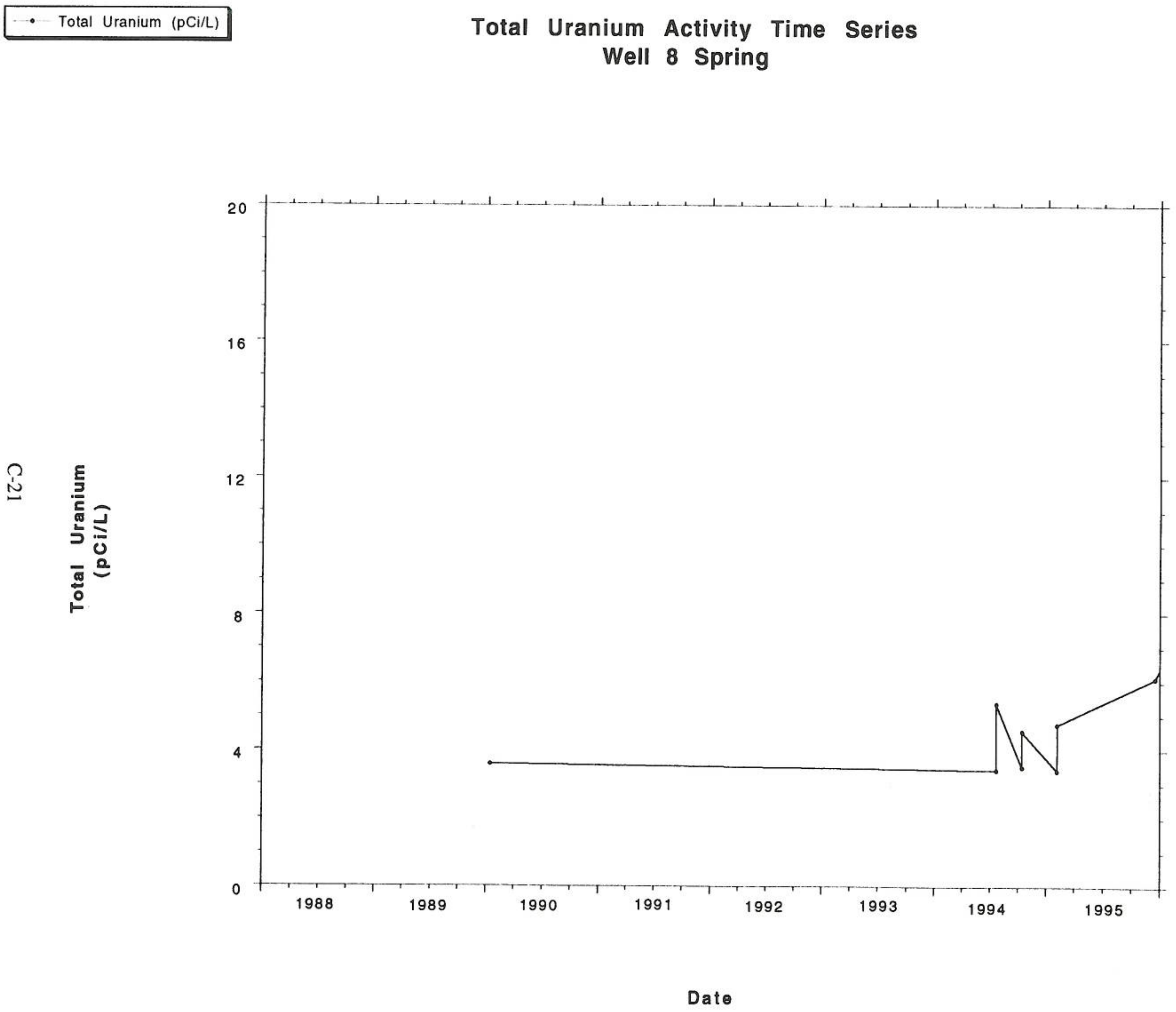
16
12
8
4
0
Total Uranium (pCi/L)
1988
1989
1990
1991
1992
1993
1994
1995
Date



Total Uranium (pCi/L)
Total Uranium Activity Time Series
Well 8 Spring
Total Uranium (pCi/L)
20
16
12
8
4
0
1988
1989
1990
1991
1992
1993
1994
1995
Date

Appendix D

Assessment of Post-SWRI Hydrogeology

Appendix D

Assessment of Post-SWRI Hydrogeology

Our post-SWRI assessment of hydrogeology at the Building 850/Pit 7 Complex OUs is generally consistent with observations made during the SWRI assessment period (1982–91). Figure D-1 is a water-elevation contour map for the first continuous water-bearing zone beneath the area for April 1995. Comparing this map with the SWRI water-elevation contour map for December 1991 (Fig. 11-14 in Chapter 11 of Webster-Scholten, 1994), shows the same general contour distribution with slightly higher water elevations proximal to recharge areas in the western portion of the OU. These higher water elevations result from high precipitation and recharge in early 1995. Table D-1 contains post-SWRI ground water elevation data for the OU.

Since the SWRI evaluation period ended on December 31, 1991, we have assessed recharge by evaluating water-level responses to precipitation. Following the two wetter-than-average winters of 1992–93 and 1994–95, large water-level responses were observed in the western portion of the OU. In January and March 1995, we recorded the two highest monthly rainfall totals (almost 6 in. per mo) since monitoring began in 1981. In 1992, the February rainfall was also unusually high, in excess of 4 in. Monthly rainfall data collected since 1982 are plotted on Figure D-2. Monthly rainfall data for the post-SWRI period are tabulated in Table D-2.

D-1. Pit 7 Complex

The water table response to recharge from the post-SWRI, heavy winter rains was similar to that observed following the winter of 1986-87 (Webster-Scholten, 1994, Section 11-3.6.5.1.1). Since 1992, the locus of recharge has shifted several hundred ft southeast, from southern pit 7 to the southeast side of pit 5. We believe this shift is the result of the RCRA cap and interceptor trench installed in late 1992, diverting surface water flow along the west side of pit 7.

Following the heavy rains, the water level rose rapidly in the vicinity of the Pit 7 Complex landfills, with maximum water elevations generally occurring in April 1993 and 1995. For wells located farther downgradient (wells NC7-25 and NC7-26), the water-level maxima occurred later; in 1993, it occurred in October. Water elevations were still rising in these wells at the end of June 1995 (post-SWRI data cutoff date). It appears to take approximately 6 mo for the hydraulic response from elevated water levels to migrate downgradient to these more distal monitoring points. Hydrographs for selected Pit 7 Complex wells are presented in Figures D-3 through D-16.

In the vicinity of the Pit 7 Complex landfills, water levels rose approximately 5–7 ft, except in wells near the southern end of pit 3 and the northern and southern ends of pit 5. Changes in ground water elevations are illustrated in Figures D-17a and b for late 1992 to early 1993 and late 1994 to early 1995, respectively. Water elevation increases in excess of 10 ft can be observed in some parts of the Pit 7 Complex.

Because ground water elevations remained generally high following the 1992–93 winter, the ground water elevation increases in 1995 added to these levels. As a consequence, maximum water levels for the post-SWRI period were measured during the spring of 1995. Based on elevation estimates of pit bottoms relative to ground water elevations in adjacent wells (McConachie and Liddle, 1993), portions of pit 3 and pit 5 may have been inundated by 3–6 ft of water following the winter rains of 1992–93 and 1994–95. However, water levels in two older wells (K7-01 and K7-03) remained approximately 7 ft lower than the maximum water levels reached in 1983 when the major release of tritium occurred from the landfills.

Following the high water levels in 1993, it appears that residual tritium may have been mobilized from the soil or the disposed debris, with tritium activities increasing in samples from ground water monitor wells adjacent to the landfills (Appendix C provides tritium time-series plots). Ground water samples from five wells (K7-03, NC7-26, NC7-34, NC7-51, and NC7-64) exhibited increases in sample tritium activities within a few months of the highest water levels, whereas ground water tritium activities were declining in these wells earlier (Appendix B, Table B-5). Ground water samples collected from some monitor wells (NC7-20, NC7-21, and NC7-40), located close to the ephemeral stream channel east of the pits, exhibited declining tritium activities; the decline probably resulted from high seepage of surface water near the channel and subsequent dilution of ground water. It is difficult to assess the effects of high water levels in April 1995 because only a single ground water sample (April 1995) was collected and analyzed subsequent to most of the precipitation. Only ground water samples collected from one monitor well, NC7-34, located between pits 3 and 5, contained tritium of distinctly higher activity than prior to the heavy rain. Future analysis of post-June 1995 trends should help identify any additional mobilization caused by inundation of portions of the pits or leaching of residual soil moisture tritium.

The 1991–92 construction of the RCRA cap and interceptor trench at pit 7 was designed to minimize recharge in the vicinity of the pits by: 1) diverting surface and shallow subsurface flow, and 2) minimizing direct infiltration through the landfill. Analysis of water-level response to rainfall indicates that method 1 had limited success because the observed water-table rises are similar to or greater than those observed prior to pit 7 capping.

D-2. Building 850 Area

Following the 1992–93 and 1994–95 winter rains, ground water levels rose 3–6 ft in the vicinity of Building 850 and Doall Ravine. The highest increases were observed in the western head of Doall Ravine near well 8 spring and in the eastern portion of Doall Ravine at well NC7-58. Figures D-18a and b are maps showing changes in ground water elevation for the late 1992 to early 1993 and late 1994 to early 1995, respectively. During both rainfall periods, the ground water-level maxima occurred primarily in April. As with the Pit 7 Complex, the rise in water levels was somewhat greater in this area in 1995 than in 1993; the maximum post-SWRI water levels occurred in April 1995. Figures D-19 and D-20 are hydrographs for wells NC7-28 and NC7-44, located downgradient (east) and upgradient (west) of Building 850, respectively. The alluvium, which is usually unsaturated in the center of Doall Ravine, contained 2–3 ft of water as observed in two wells that are normally dry, NC7-55 and NC7-57.

Following the wet winters of 1992–93 and 1994–95, water samples from several wells in the vicinity of Building 850 (NC7-43, NC7-70, and NC7-71) showed moderate increases in tritium activity (Appendix B, Table B-5). Samples collected at other monitoring points, particularly near the western head of Doall Ravine (NC7-11, well 8 spring) exhibited decreases in ground water tritium activity, presumably caused by dilution via infiltration of surface runoff. The general trend indicates a decline in ground water tritium activities in the area. Furthermore, the decline is occurring at a faster rate than can be accounted for solely by radioactive decay. The most likely causes for decrease in tritium activities are undergoing natural dispersive mixing and dilution by recharged water.

D-3. East Firing Area (EFA)

We observed much smaller ground water-level changes in the EFA than elsewhere, except at the intersection of Doall and Elk Ravines and near wells NC2-21 and NC2-22. Figures D-21a and b are maps of ground water-elevation changes in the EFA for the wet winters of 1992–93 and 1994–95, respectively. The large increase in ground water elevations in the eastern end of Doall Ravine may be caused by: 1) enhanced recharge of stream channel water in this area, and 2) aquifer water accumulating behind the southwestern splay of the Elk Ravine Fault, which is a low-permeability, leaky barrier to ground water flow (Webster-Scholten, 1994). The wells surrounding pit 1 showed very small increases (approximately 1 ft) in water-level elevation.

As documented in the SWRI report, the ground water-level maxima in the EFA continue to occur much later after the rainy periods than elsewhere in the OU. For the winter of 1992–93, the highest water elevations were measured July–October, whereas for the winter of 1994–95, water elevations were still rising in many of the wells when the last measurements were made in June 1995. Ground water-level maxima in wells in the vicinity of pit 1 were not observed until almost a year after the 1992–93 rainfall ceased.

Our analysis of post-SWRI data from the Building 850/Pit 7 Complex OU indicates similar hydrogeologic character and response to rainfall as has been observed since ground water monitoring began in 1981–82.

D-4. References

McConachie, W. A. and R. D. Liddle (1993), *Evaluation of Water Table Rises at Lawrence Livermore National Laboratory Site 300 Pit 7 Complex*, Letter report to Lida Tan, Susan Timm, and Robert Feather (May 17, 1993), Lawrence Livermore National Laboratory, Livermore, Calif.

Webster-Scholten, C. P., Ed. (1994), *Final Site-Wide Remedial Investigation Report, Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-21010).

Appendix D

Figures

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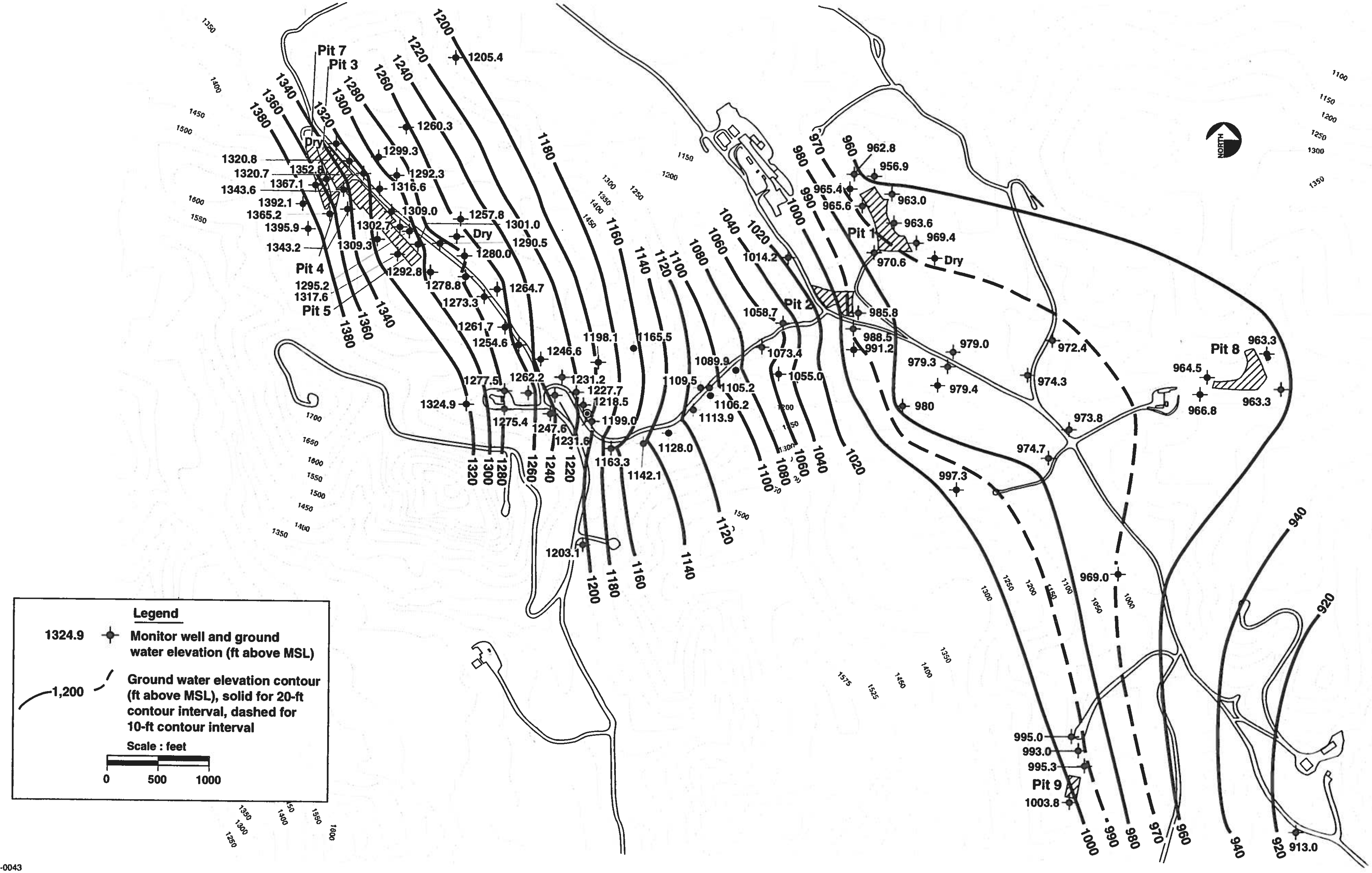
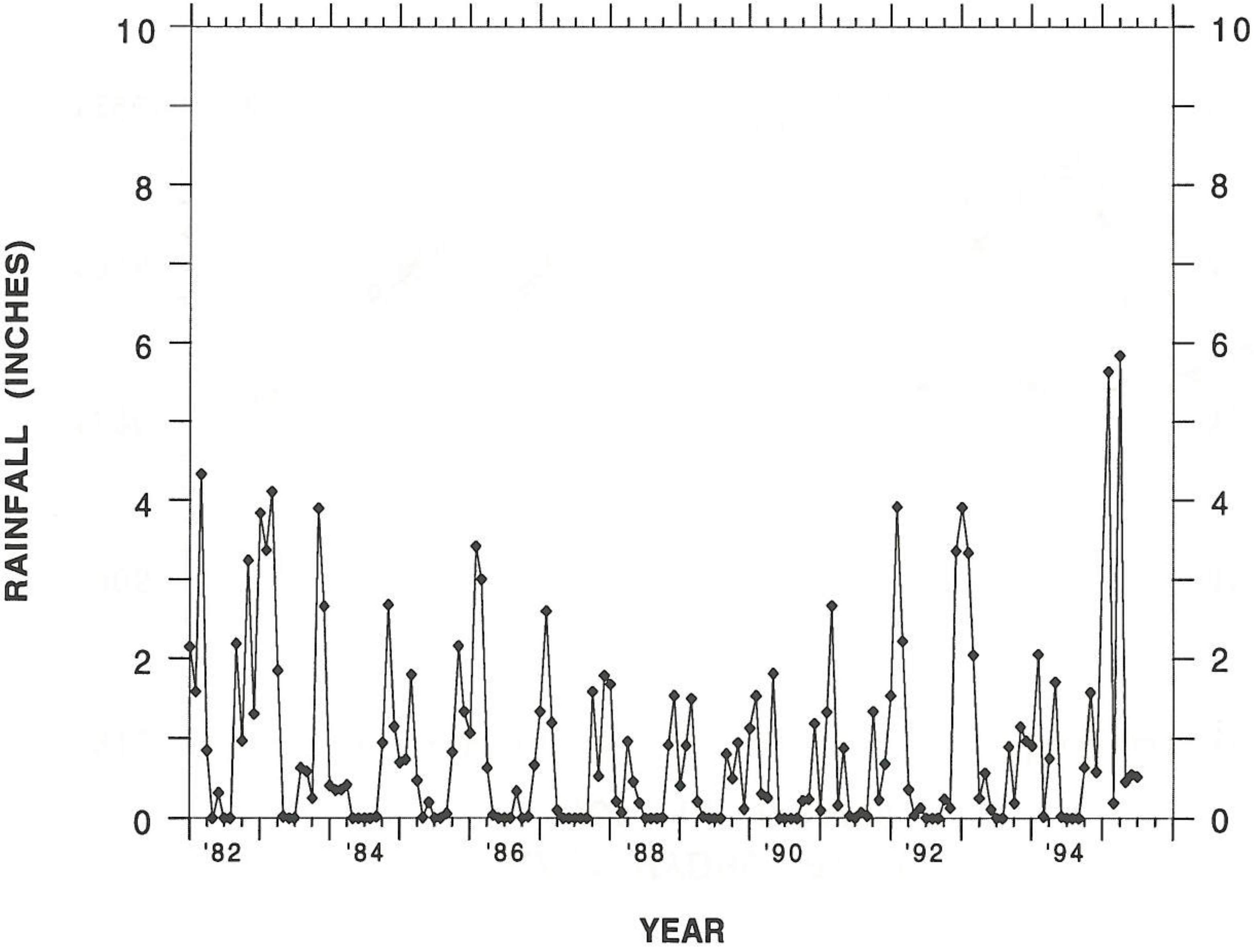


ERD-S3R-95-0043

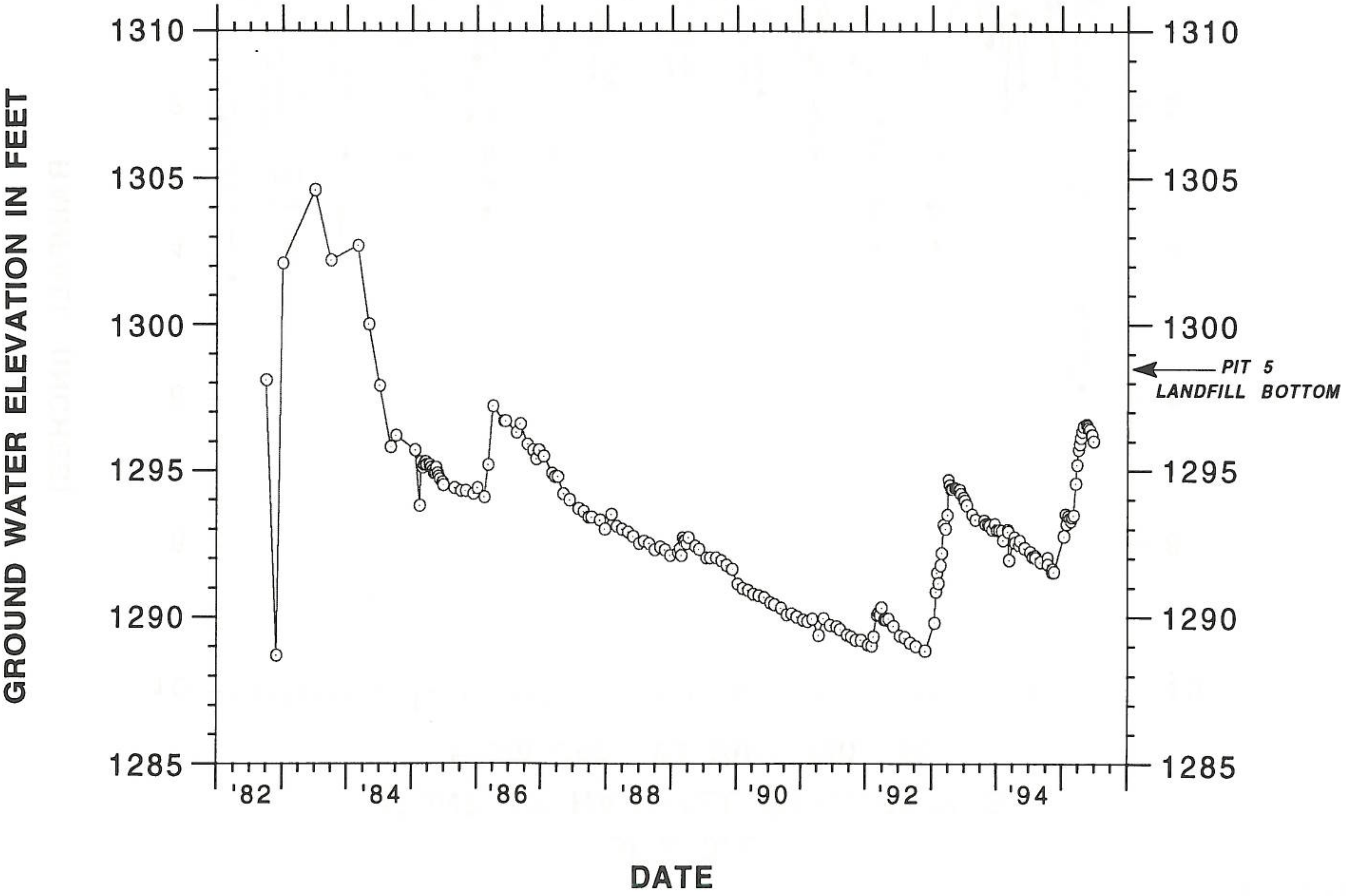
Figure D-1. Ground water elevation contour map for the first continuous water-bearing zone beneath the Building 850/Pit 7 Complex OU, April 1995.

Updated 12/18/95

SITE 300
MONTHLY RAINFALL DATA POINTS
From Jan. '82 thru Jun. '95



K7-01 HYDROGRAPH
1/1/82 to 6/30/95



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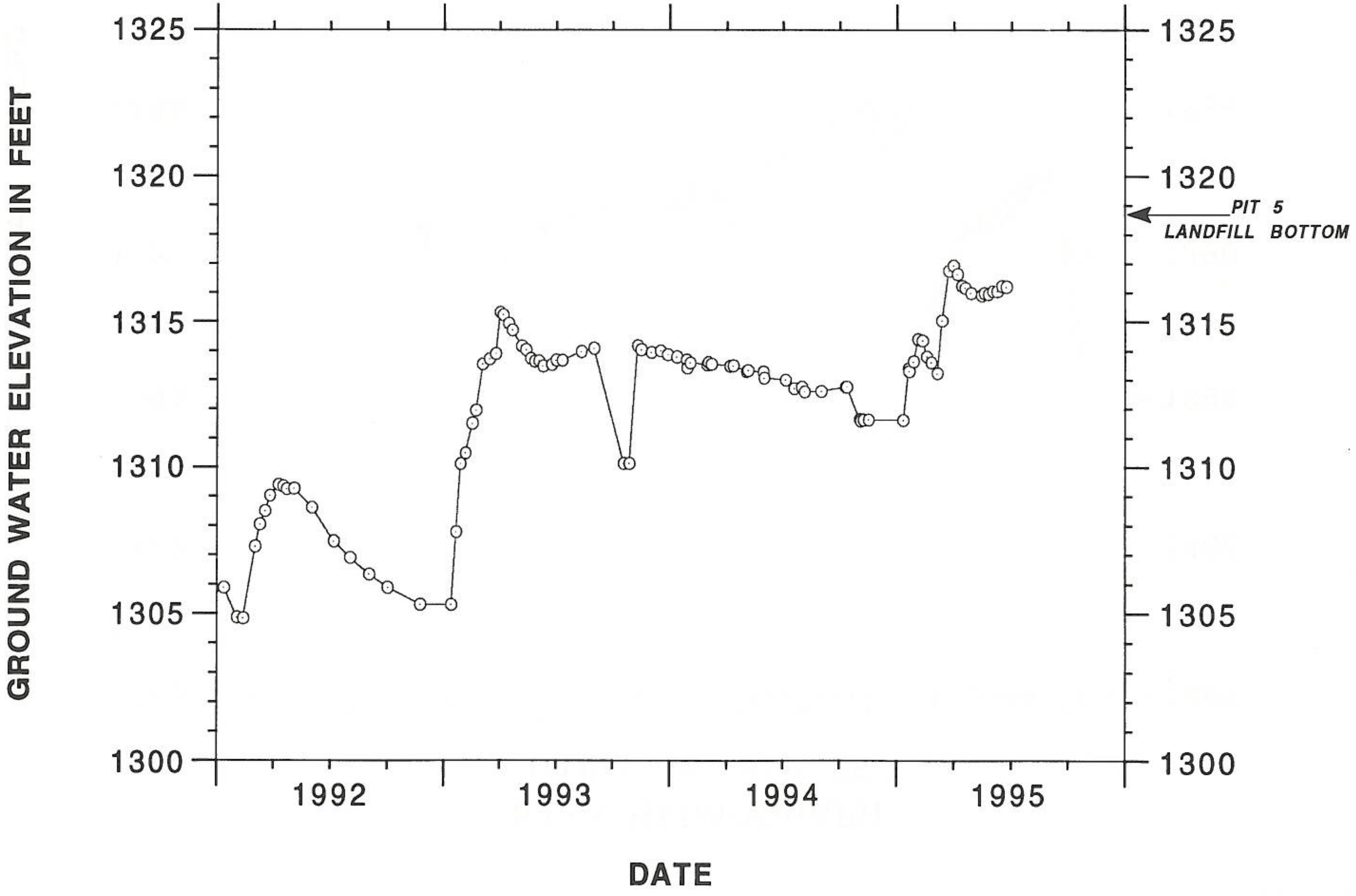
K7-03 HYDROGRAPH
1/1/92 to 6/30/95



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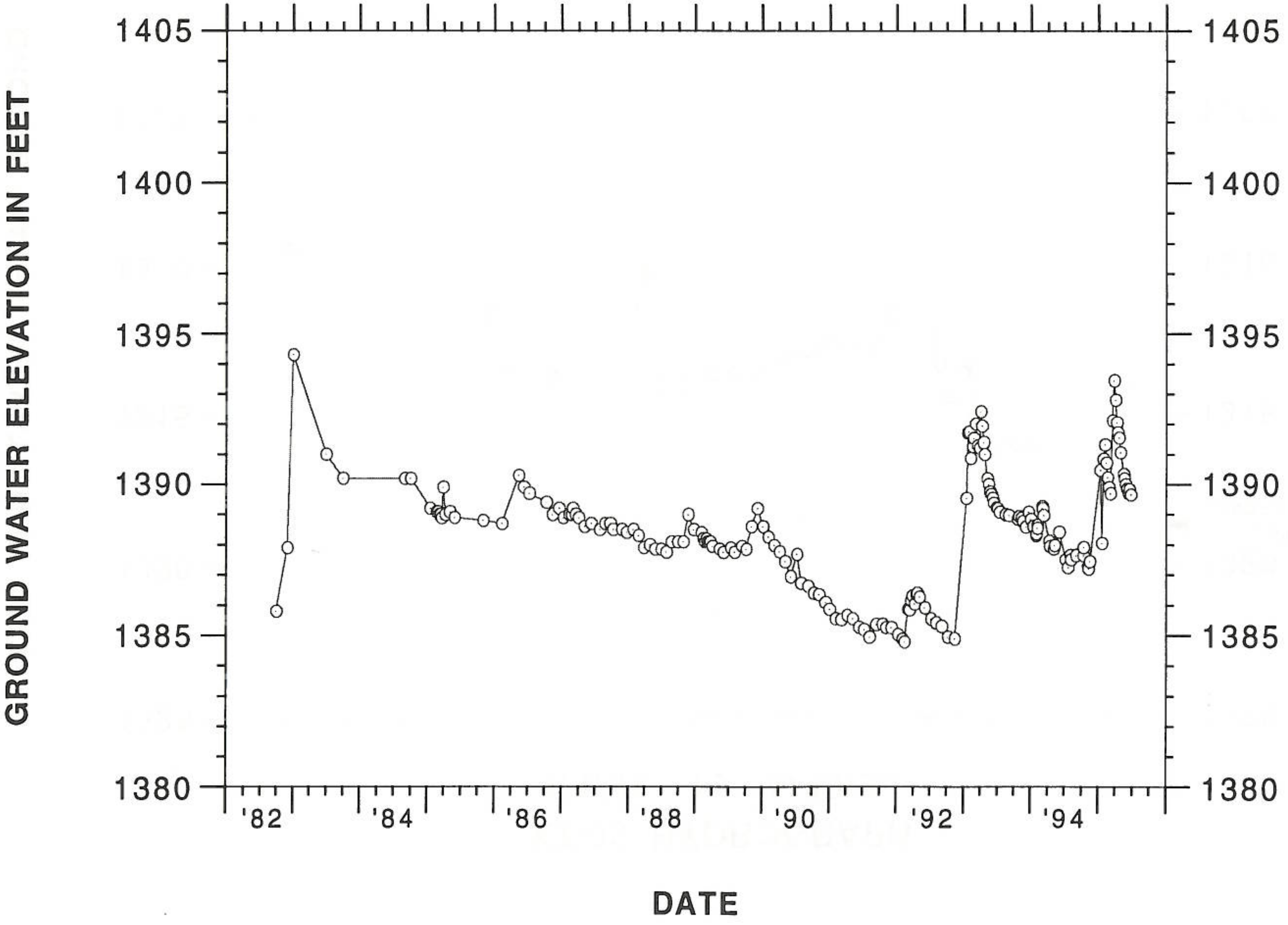
K7-06 HYDROGRAPH
1/1/82 to 6/30/95



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NC7-17 HYDROGRAPH
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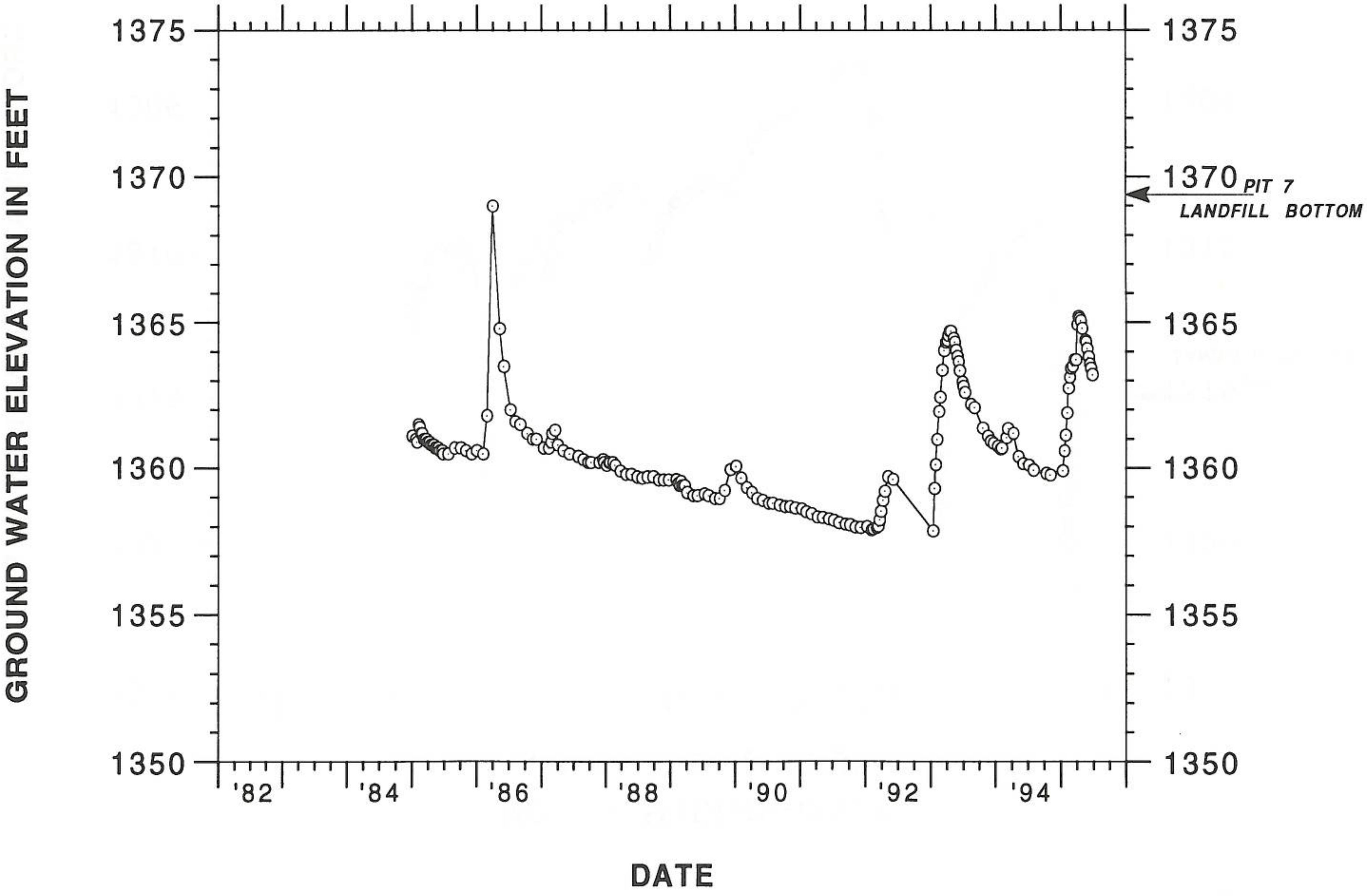

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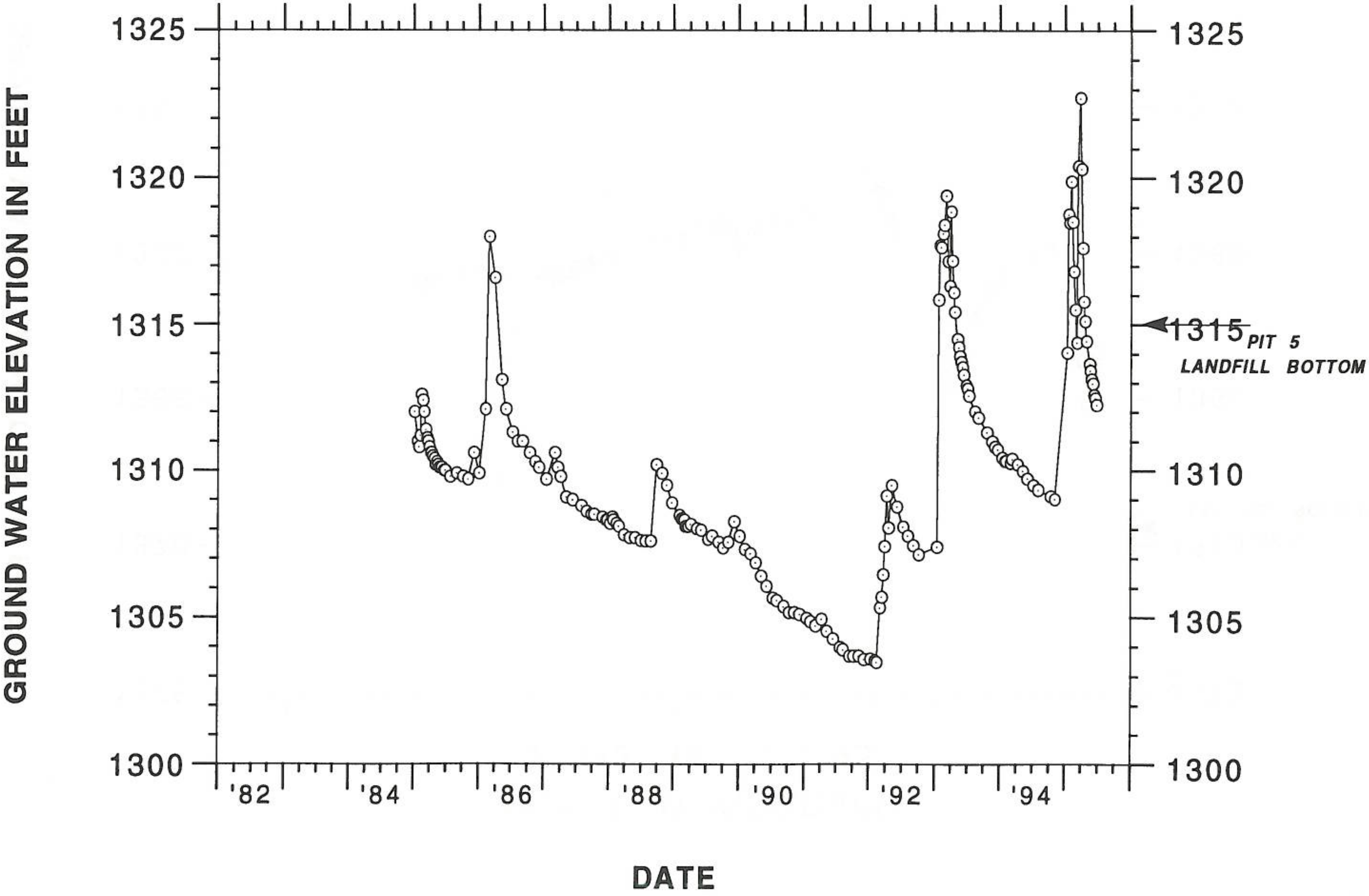
NC7-18 HYDROGRAPH
1/1/82 to 6/30/95



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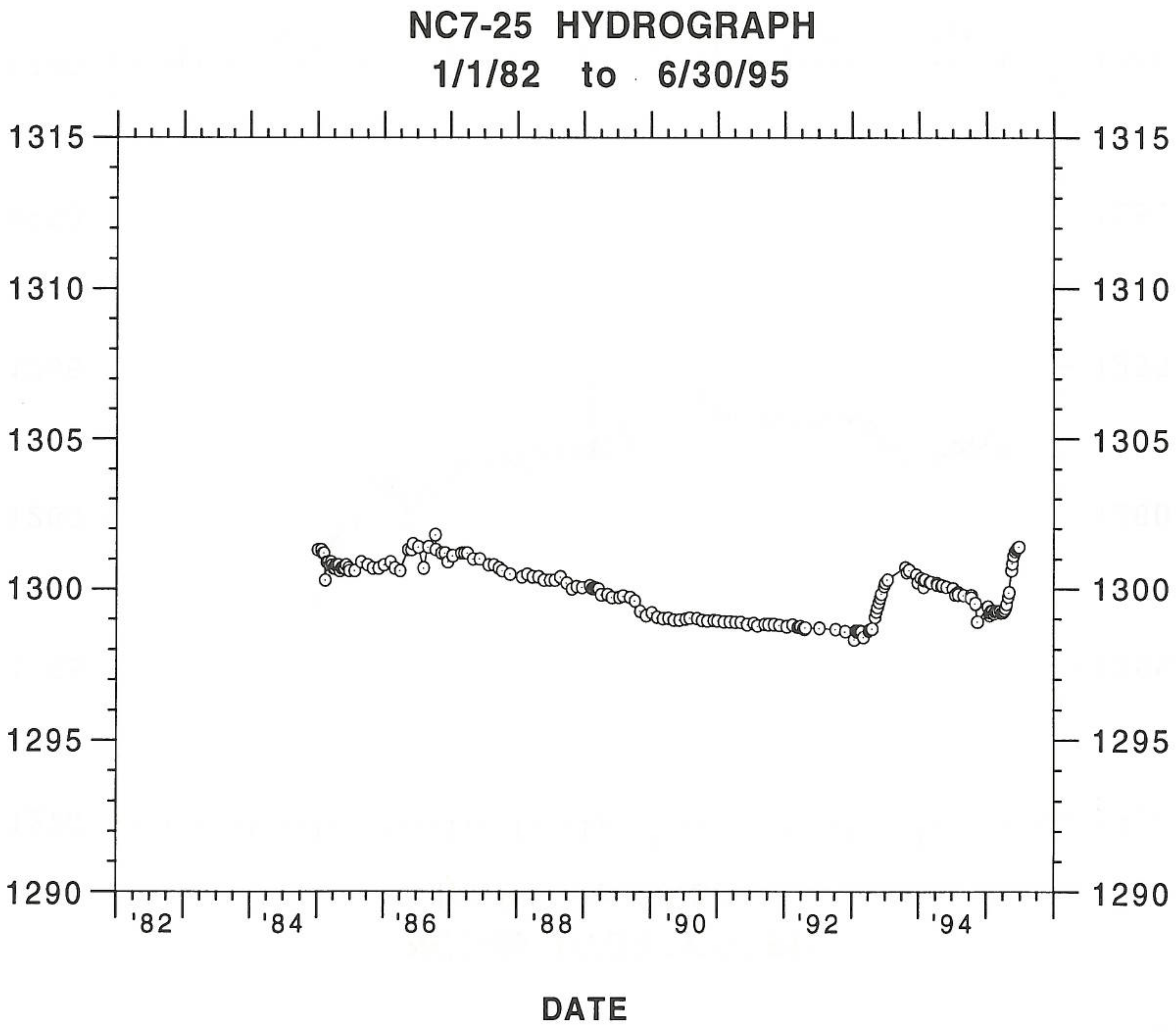

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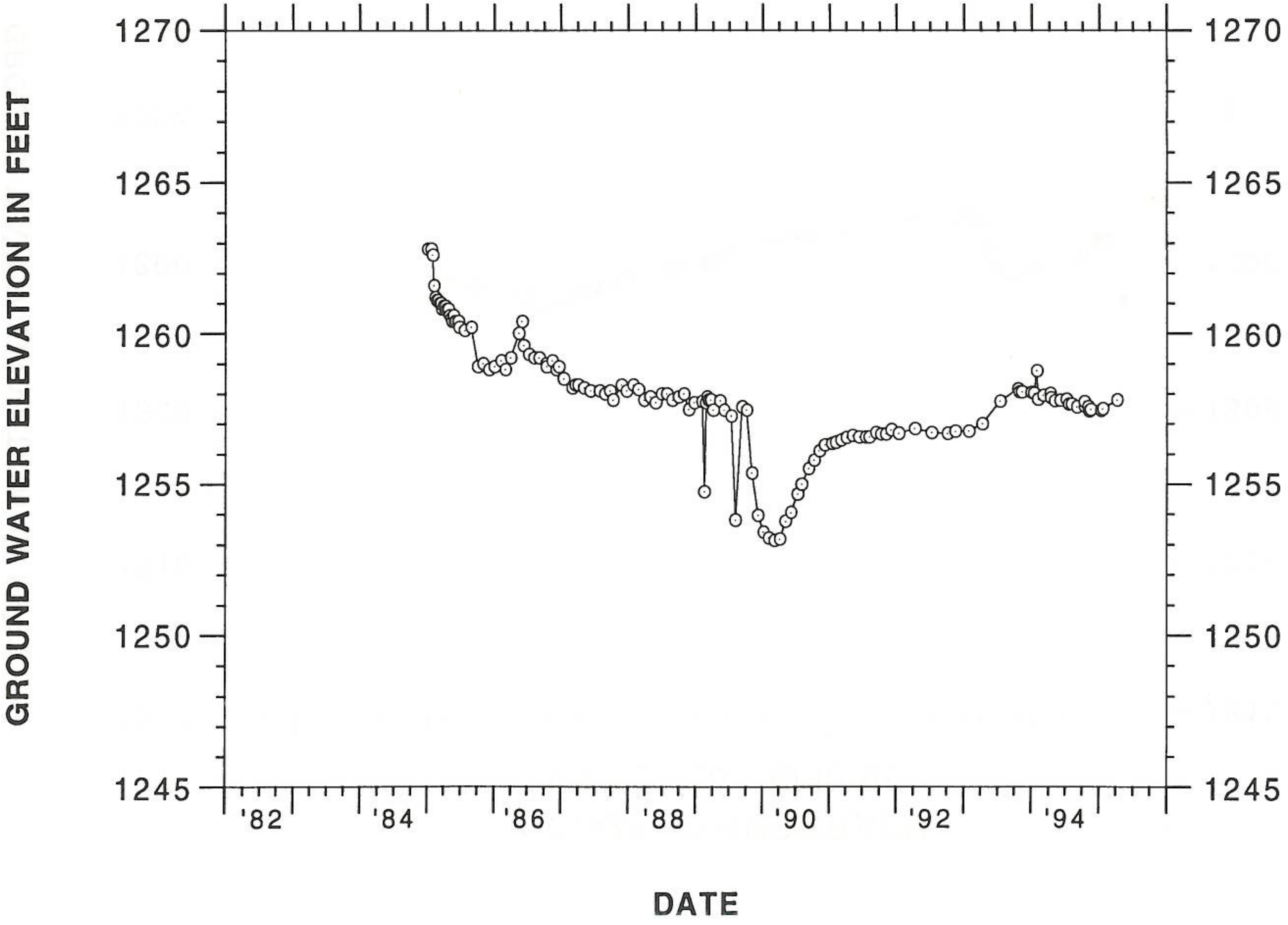
NC7-26 HYDROGRAPH
1/1/82 to 6/30/95



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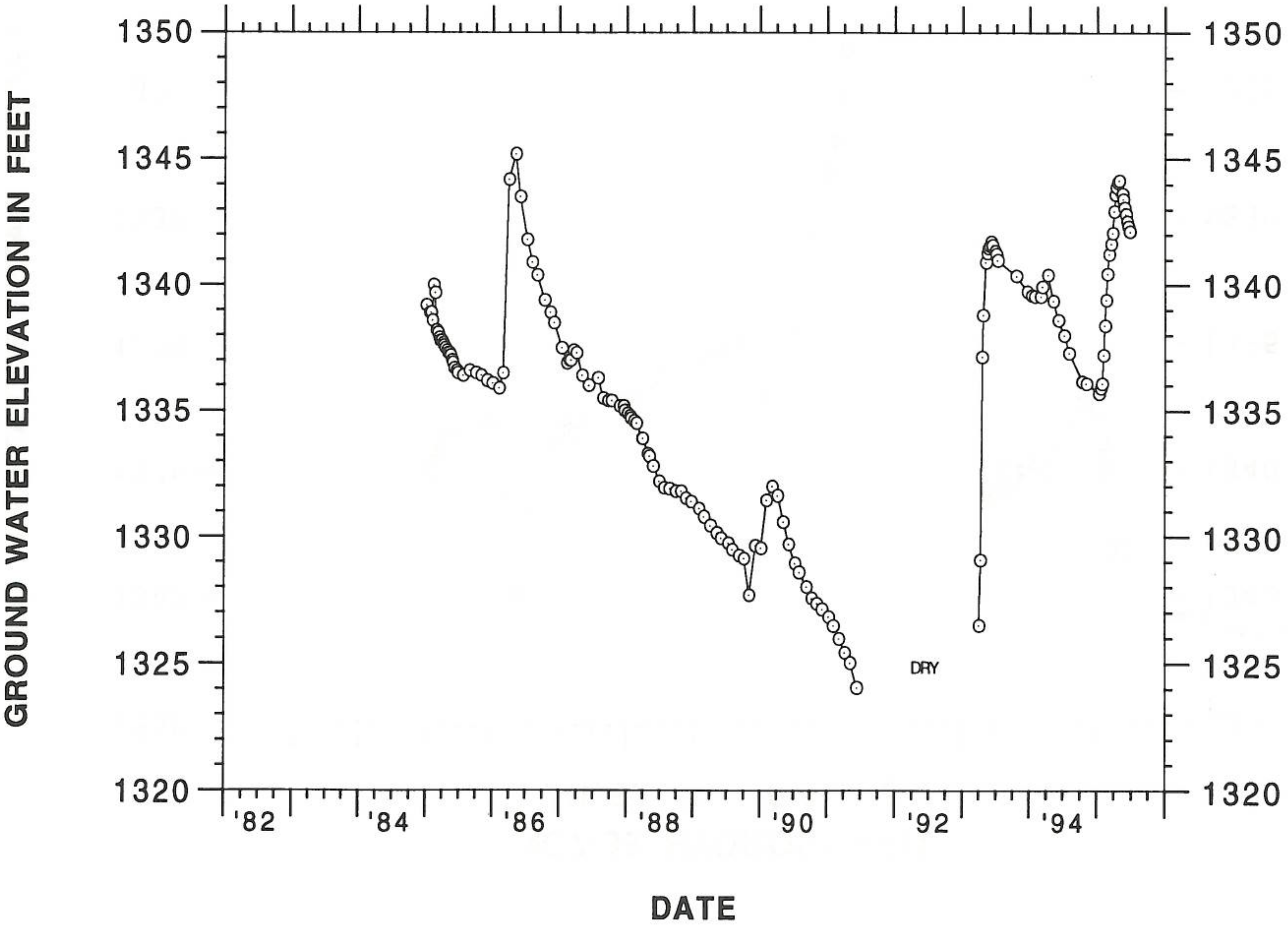
NC7-34 HYDROGRAPH
1/1/82 to 6/30/95



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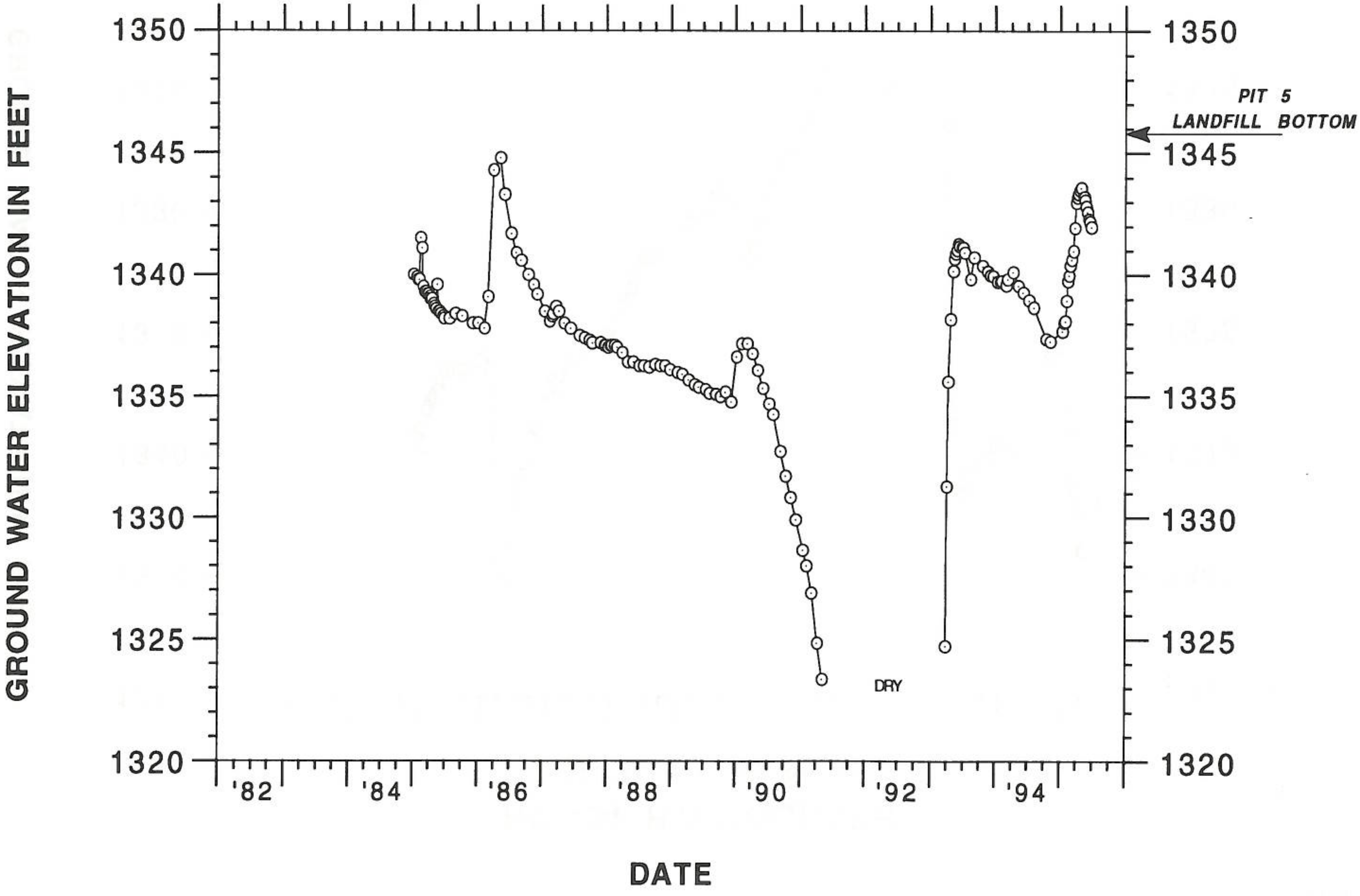
NC7-36 HYDROGRAPH
1/1/82 to 6/30/95



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NC7-40 HYDROGRAPH
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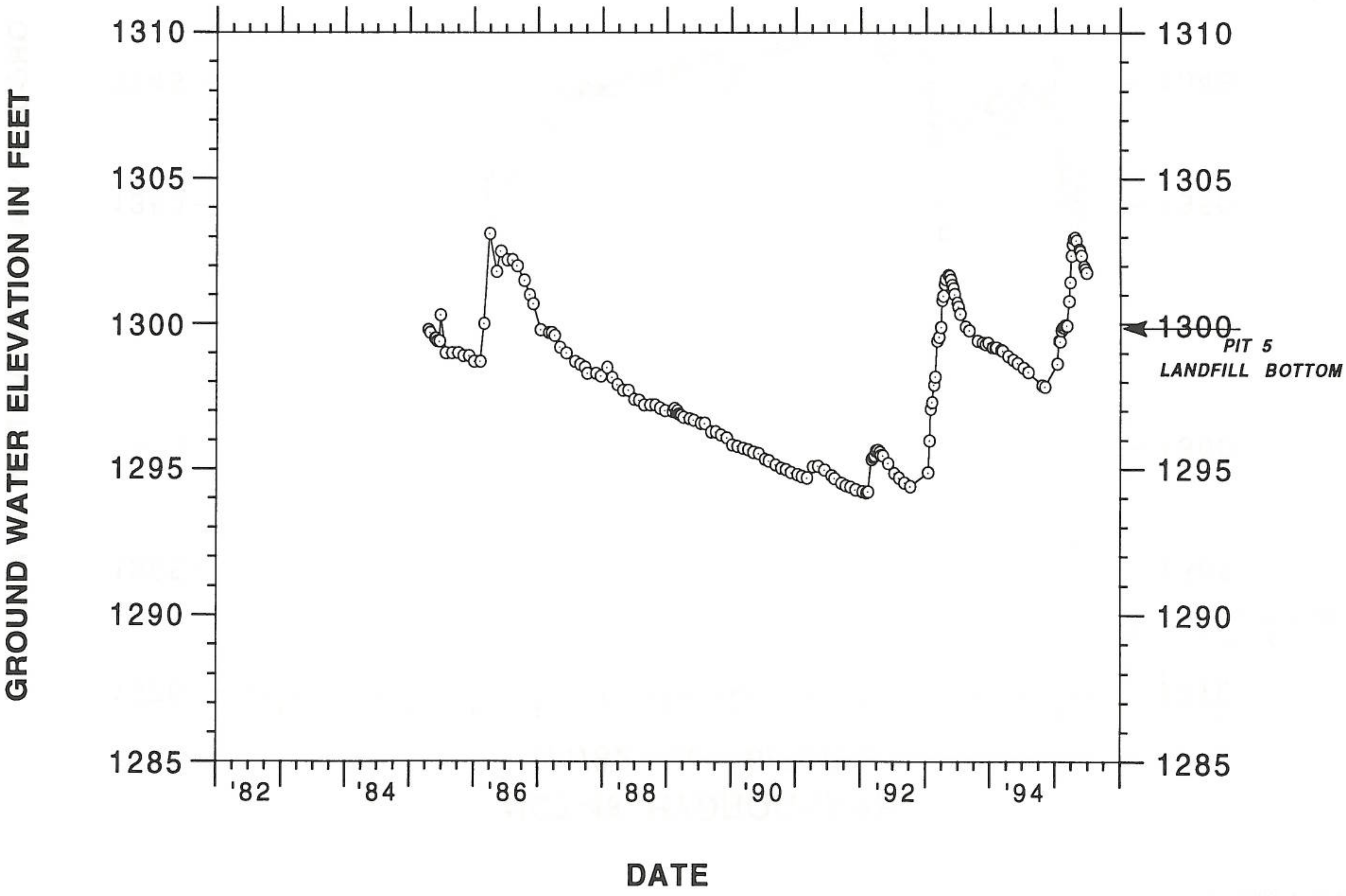

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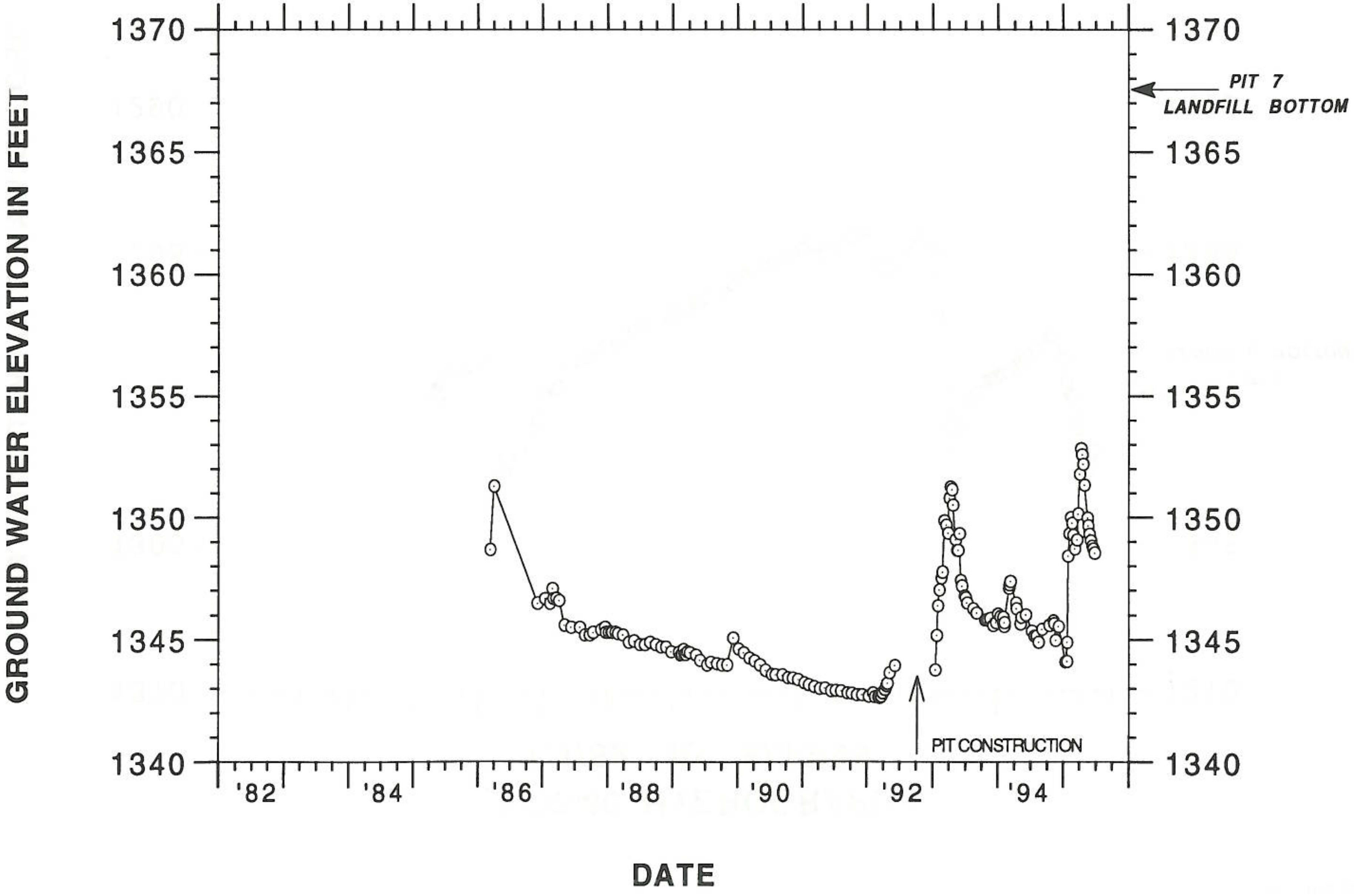
NC7-48 HYDROGRAPH
1/1/82 to 6/30/95



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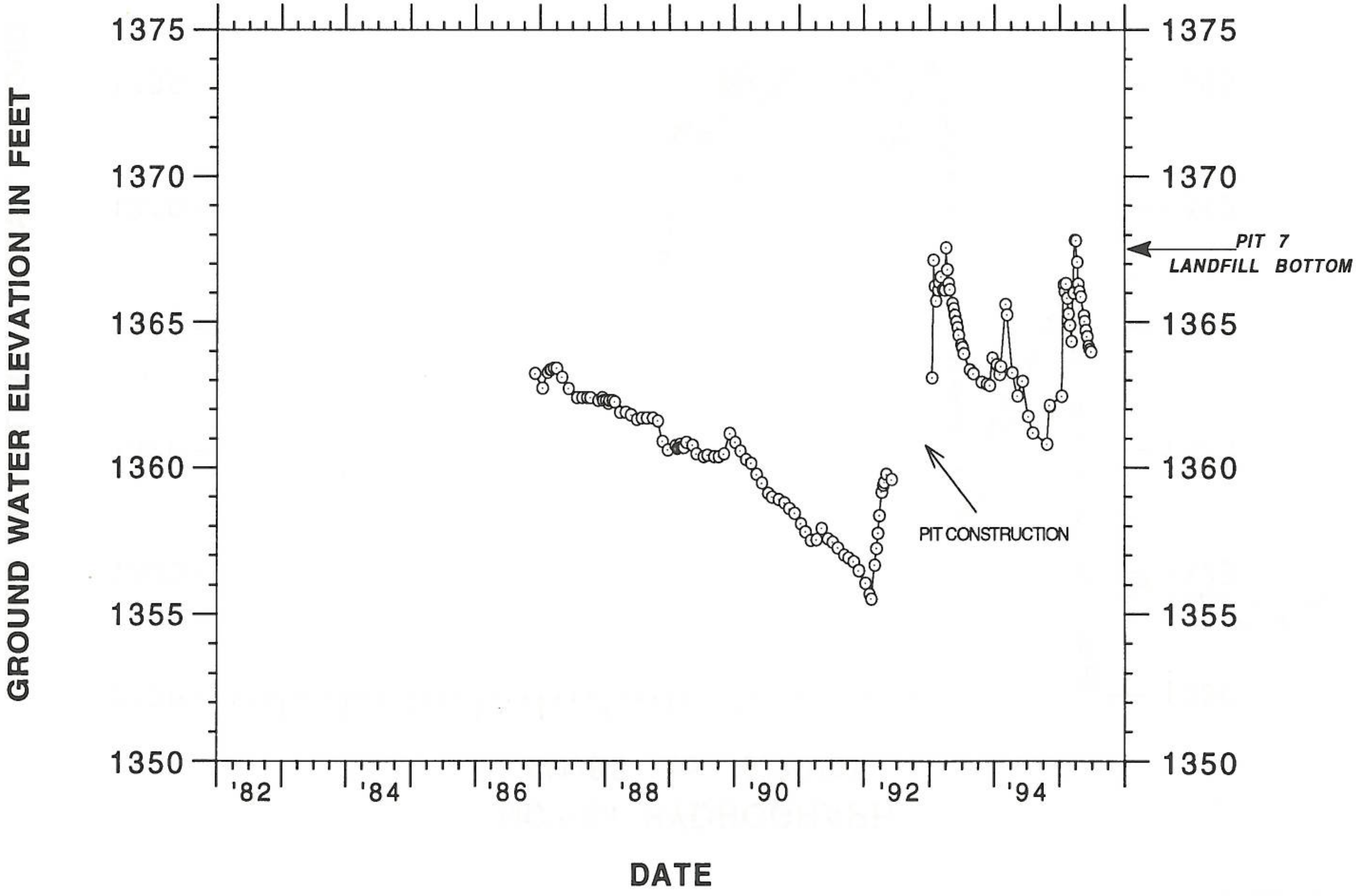
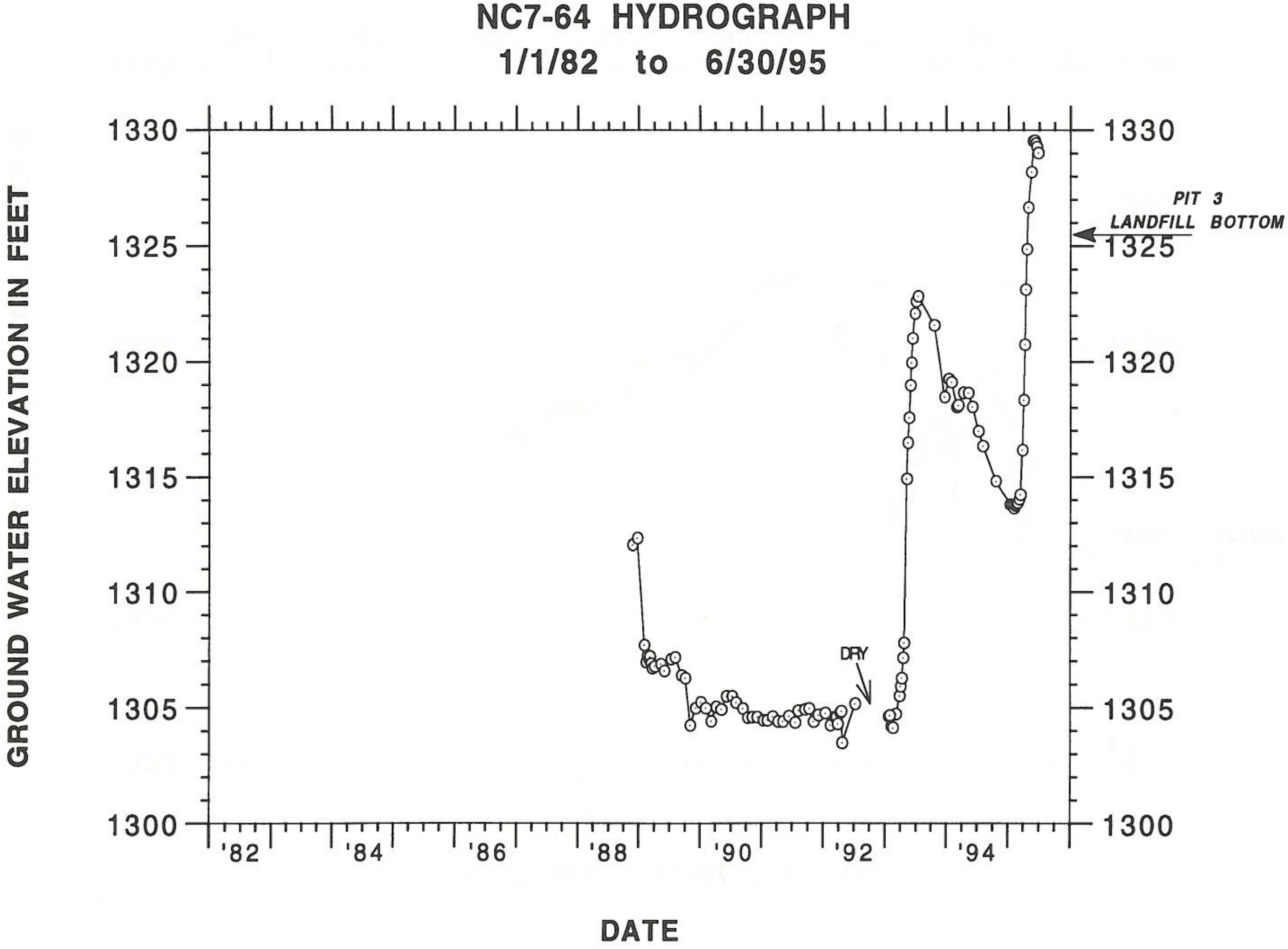
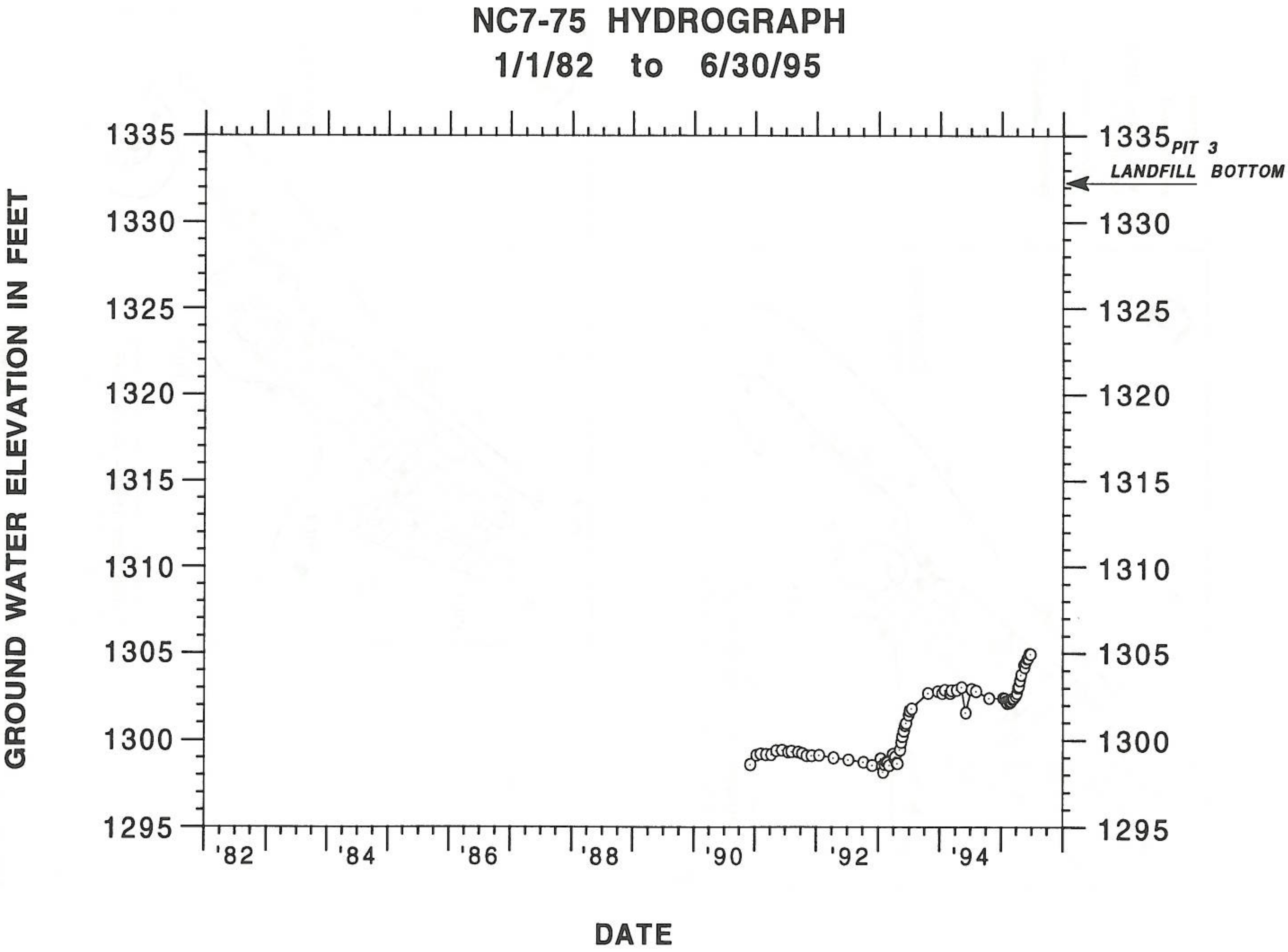
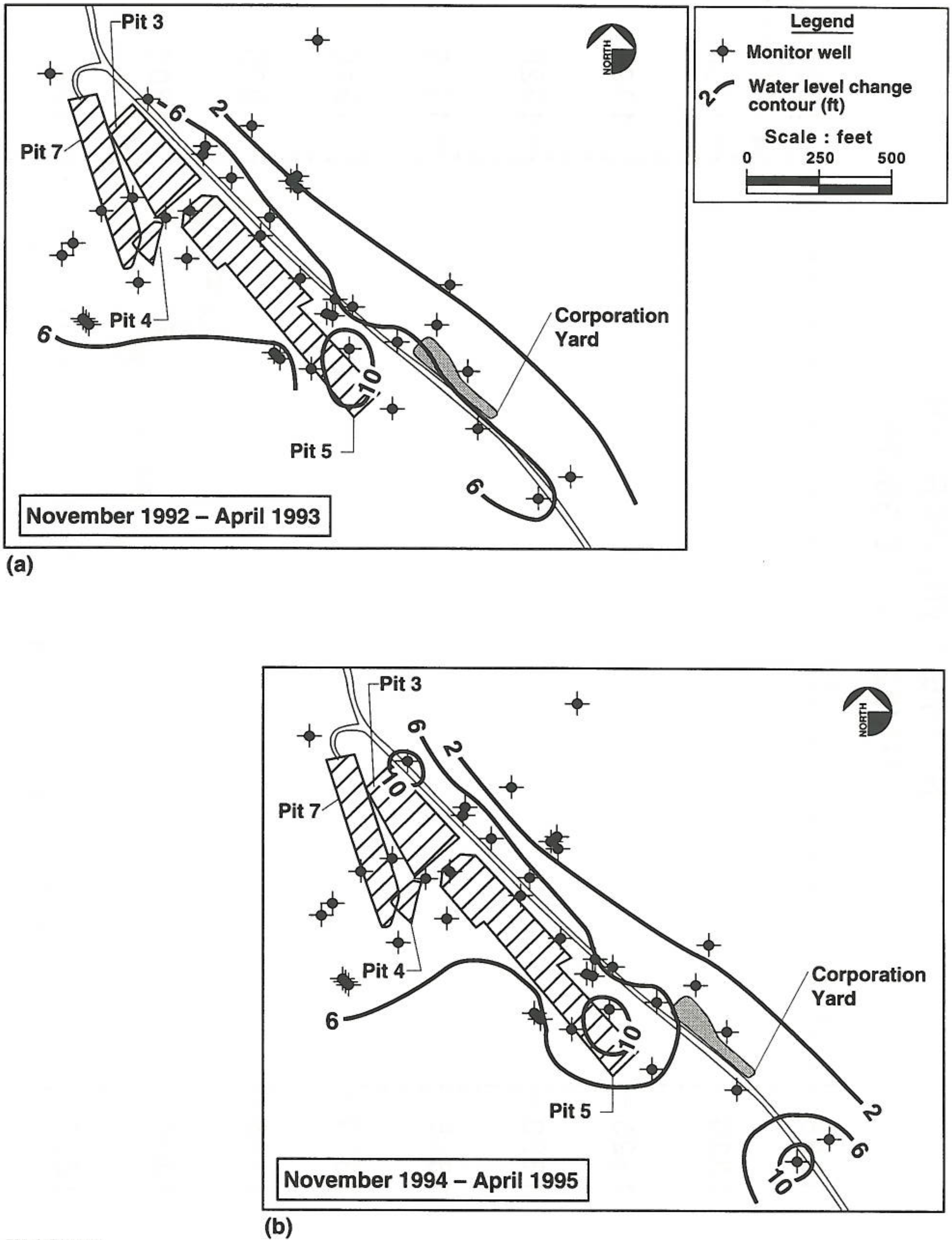
NC7-49A HYDROGRAPH
1/1/82 to 6/30/95




NC7-64 HYDROGRAPH
1/1/82 to 6/30/95
GROUND WATER ELEVATION IN FEET
1330
1325
1320
1315
1310
1305
1300
PIT 3
LANDFILL BOTTOM
DRY
'82
'84
'86
'88
'90
'92
'94
DATE

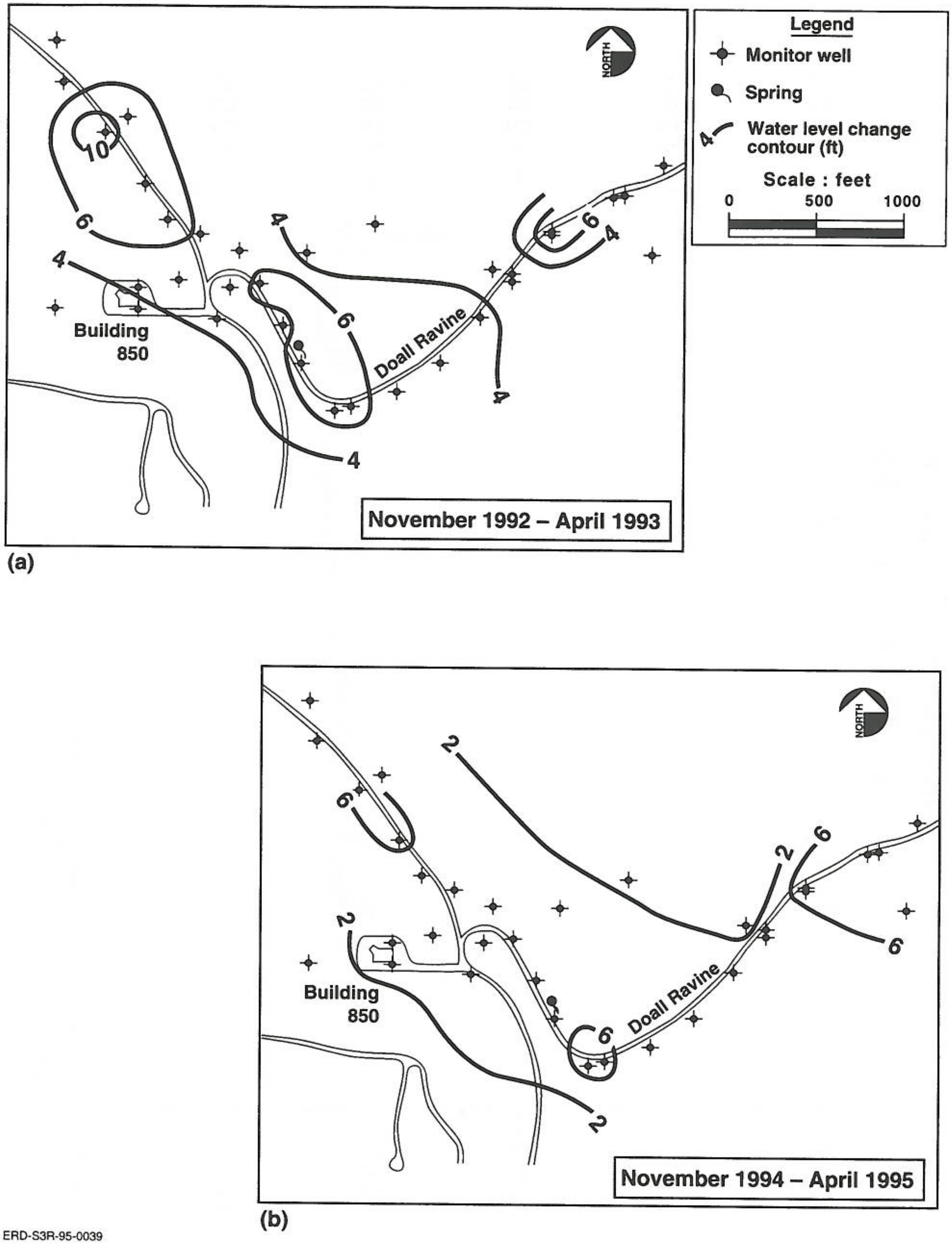
Generated 11/27/95





ERD-S3R-95-0038

Figures D-17 a and b. Water level changes in the Pit 7 Complex.



ERD-S3R-95-0039

Figures D-18 a and b. Changes in water level in the Building 850 area.

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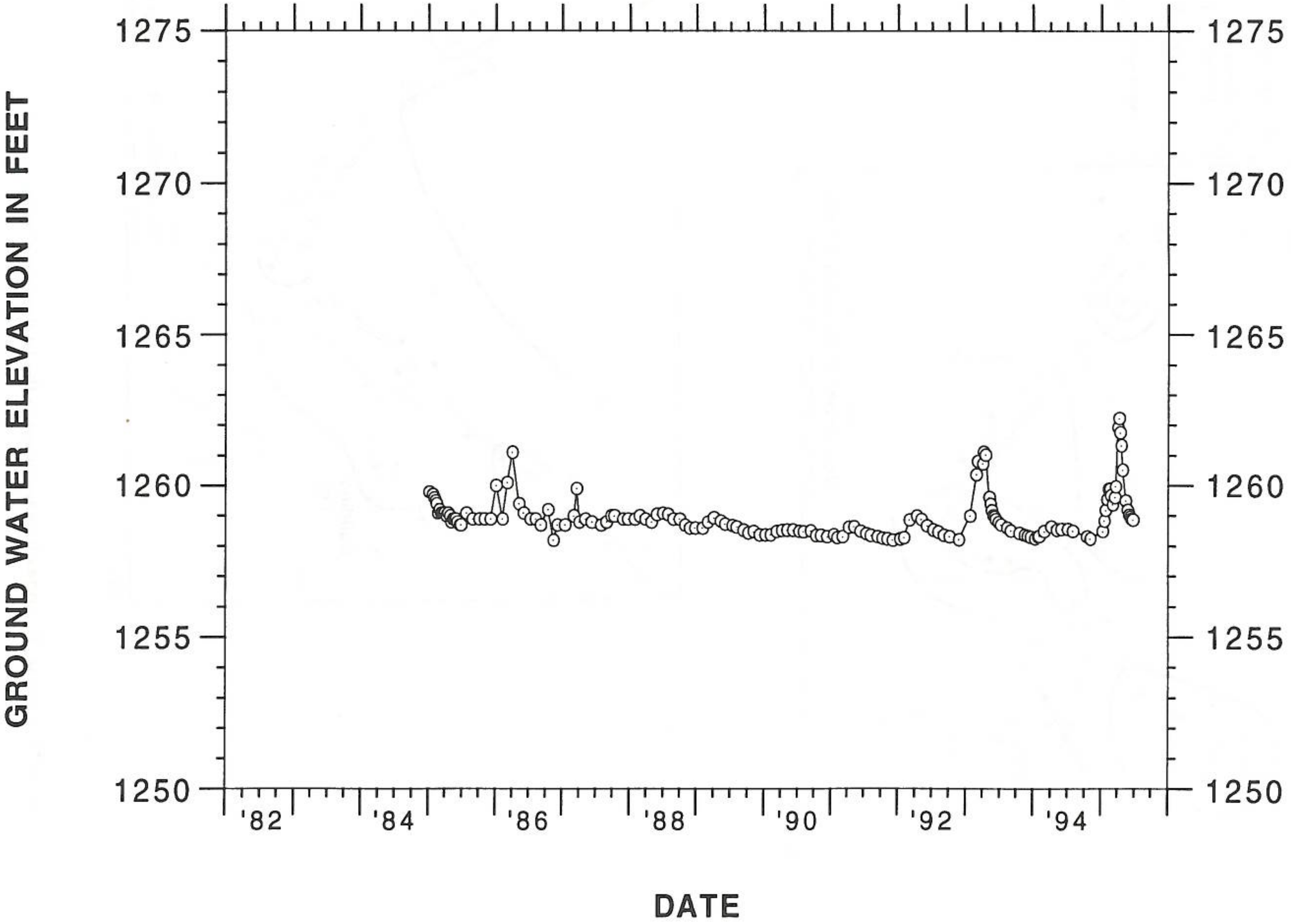
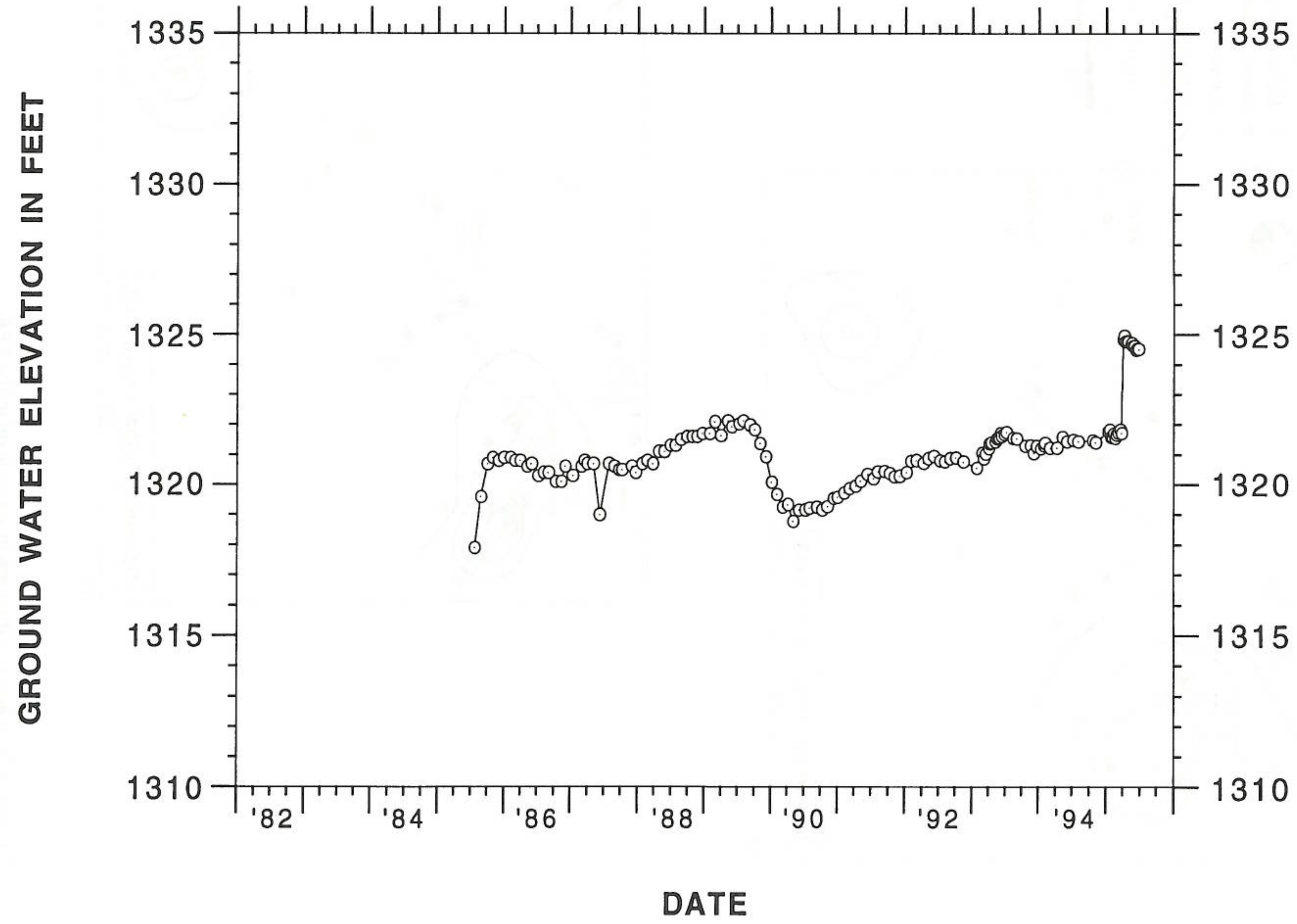
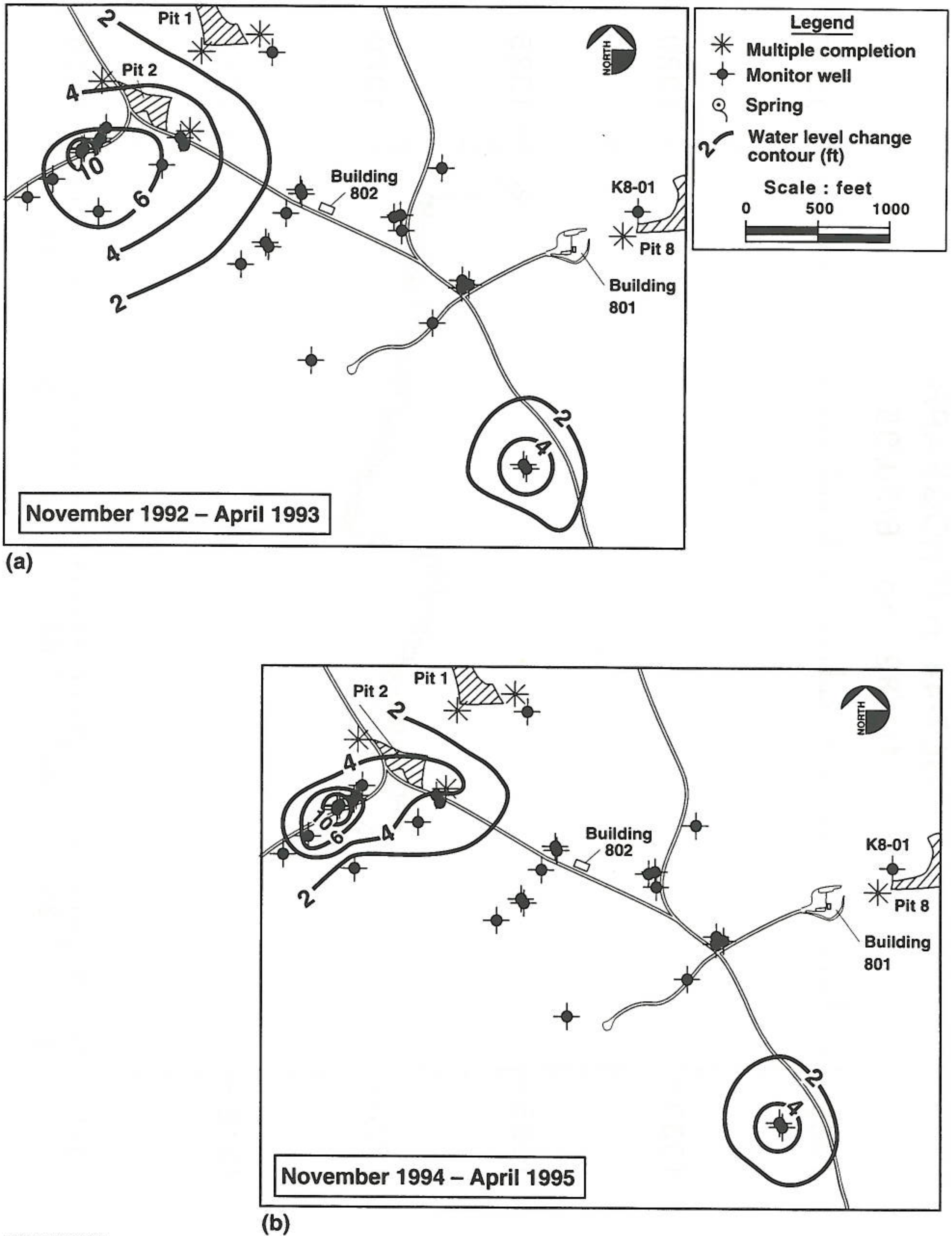
NC7-28 HYDROGRAPH
1/1/82 to 6/30/95



Generated 11/22/95

NC7-44 HYDROGRAPH
1/1/82 to 6/30/95





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Figures D-21 a and b. Changes in water level in the EFA.

Appendix D

Tables

NOTE: DATA TABLES ARE NOT INCLUDED WITH THIS COPY

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Appendix E

Re-evaluation of Metals and Radionuclides in Surface Soil at Site 300

Appendix E

Re-evaluation of Metals and Radionuclides in Surface Soil at Site 300

In the SWRI report (Webster-Scholten, 1994), we evaluated the concentrations of metals and radionuclides in surface soil to identify areas with evidence of surface soil contamination. To do this, we constructed a series of log-probability plots using surface soil analytical data available through the end of 1991. In this appendix, we update these plots using data available through November 1994.

This appendix contains 29 log-probability plots (Figs. E-1 through E-29) of metals concentrations and radionuclide activities detected in surface soil at Site 300. As in Webster-Scholten (1994), these plots are constructed using data from the entire site. Surface soil data from the active firing tables 801, 850, and 851 are also included. Since these plots were originally constructed, we have obtained surface soil data collected by the Operations and Regulatory Affairs Division (ORAD) as part of their pre-construction soil survey program. These data are also included in this analysis.

The log-probability plots presented in this appendix display the concentration or activity of a substance measured on the y-axis (log-scale) against cumulative percent on the x-axis. These plots are constructed based on the method of Michels (1971). This method allows us to distinguish between background levels of metals and radionuclides and those indicative of contamination, by revealing whether a set of data is described by single or multiple distributions. When more than one distribution is observed in these plots, the data are assumed to be heterogeneous (i.e., a separate source is associated with each distribution). In the current analysis, we also evaluated data from the upper end of the distribution of each plot to determine if high concentration samples were collocated.

In the SWRI report, the surface soil data for antimony, molybdenum, and silver were limited to fewer than five detections of each metal, which did not allow the evaluation of the presence or absence of contamination. In addition, we did not evaluate ^{232}Th data. There continues to be inadequate data available to evaluate silver (fewer than five detections). Although the data set for both antimony and molybdenum increased, fewer than 10 detections of each metal are available. A rudimentary evaluation of these plots suggest a maximum background concentration of 4 mg/kg for antimony, and 15 mg/kg for molybdenum. No evidence of collocation of high concentration samples was found for antimony. Five of the six highest concentration samples for molybdenum were located within the vicinity of the Building 850 firing table, with concentrations in the range 6.4–9 mg/kg. However, with fewer than 10 data points, we cannot conclude that this is evidence of contamination.

Also, we have no clear evidence of ^{232}Th contamination in surface soil, with a maximum apparent background activity of 8.5 pCi/g. However, the highest three data points suggest a second distribution, and these data points are all collocated in the vicinity of pit 7. Therefore, we estimated the risk from inhalation of suspended soil particles containing ^{232}Th (Chapter 4). In addition, we evaluated ground water for evidence of ^{232}Th contamination (Appendix K).

From our current evaluation of the remaining log-probability plots, we agree with the conclusion presented in the SWRI report: at Site 300, we have no evidence of surface soil contamination with barium, cobalt, lead, mercury, nickel, selenium, vanadium, gross alpha, gross beta, or ^{234}U. Maximum apparent background concentrations observed for lead, mercury, and vanadium did not change as a result of this evaluation. Maximum apparent background concentrations or activities did increase for the following:

Barium (330–450 mg/kg)
Cobalt (19–25 mg/kg)
Nickel (80–110 mg/kg)
Selenium (<1.0–1.2 mg/kg)
Gross alpha (18–23.3 pCi/g)
Gross beta (20–42.2 pCi/g)
^{234}U (1.6–3.4 pCi/g).

We did not re-evaluate tritium, because we cannot resolve separate distributions due to the large variability in the data set. However, based on high activities detected in surface soils, we conclude that tritium contamination is evident.

We also evaluated these plots for evidence of collocation of high-concentration samples. The only evidence was detected for selenium; four of the six samples with the highest concentrations were collected along Corral Hollow creek, in the General Services Area (GSA) study area (range 1–1.2 mg/kg). This finding is not particularly surprising, as Corral Hollow creek is an ephemeral creek with a large amount of evaporative loss. It is well known that selenium will concentrate as a result of surface water evaporation (Besser et al., 1993). Because three of these samples were collected upgradient of the existing treatment facility discharge, it is likely these levels of selenium in the surface soil samples result from selenium concentrating naturally in the seasonal creek water.

Evidence of surface soil contamination was apparent for arsenic, beryllium, cadmium, chromium, copper, zinc, ^{234}U, and ^{238}U. The concentrations and areas of contamination for beryllium and copper were consistent with those presented in the SWRI report, although the maximum apparent background concentration for copper increased from 37 to 95 mg/kg. The evidence of surface soil contamination by arsenic and chromium, which was not found in the SWRI report evaluation, resulted from an inadvertent waste sludge release at Building 865. Samples from this area were collected by ORAD. This sludge has subsequently been removed, although residual high concentrations may remain. The maximum apparent background concentration for arsenic increased from 11 to 16 mg/kg. Two very high concentrations were also observed in the zinc data. One sample containing zinc at 6,200 mg/kg was also the result of the Building 865 sludge release. However, the sample with the highest zinc concentration (14,000 mg/kg) was collected near Building 801 by ORAD. As this Building contains an active firing table, it is possible this soil sample contained components from one of the experimental test apparatuses. In addition to these two high concentrations, our increased data set allowed us to resolve three distinct distributions within the zinc data, indicating multiple zinc sources at the site. However, the concentrations within these distributions are not significantly different from those presented in the SWRI report. The data in the upper two distributions were primarily obtained from samples collected within or near developed portions of the site actively used by the programs (i.e., firing tables, shops, buildings, etc.). The maximum apparent background concentration for zinc increased from 63 to 72 mg/kg. No other collocation of high concentration samples was apparent for any of these metals.

In our updated effort, we again found evidence of cadmium surface soil contamination. We again detected the impact of the Building 865 sludge release, which contained the highest concentration of cadmium (530 mg/kg). In addition, our increased data set allowed us to resolve three distinct distributions, indicating the presence of multiple sources of cadmium at the Site. As observed in the zinc data, the cadmium data in the upper distributions were detected primarily in samples collected within or near the developed portions of the site. In addition, cadmium data from the upper end of the third distribution were obtained from samples collected in a compact grouping east of the sewage treatment lagoon in the GSA study area. The maximum apparent background concentration for cadmium increased from 0.1 to 0.2 mg/kg.

In the current analysis, we again found evidence of ^{238}U surface soil contamination. The maximum activity observed was again 134.5 pCi/g, and the contamination was limited to areas within the EFA/WFA, primarily within the vicinity of the firing tables and the Pit 7 complex. In addition to the sample with the singularly high activity, our increased data set allowed us to resolve three distinct distributions, suggesting the presence of multiple sources of ^{238}U at the Site. However, because the ^{238}U contamination likely occurred as a result of open-air high-explosive test shots, these separate distributions may represent distinct experiments that contained test components with different ^{238}U activities, or resulted in particulate ejecta of different sizes and/or activities. The apparent background activity of ^{238}U increased from 1 to 1.3 pCi/g. Unlike the analysis presented in the SWRI report, the current evaluation detected evidence of ^{235}U surface soil contamination. This contamination was again restricted to the vicinity of the firing tables and the Pit 7 complex. The maximum apparent background activity for ^{235}U remained 0.07 pCi/g.

Reference

Besser, J. M., T. J. Canfield, and T. W. La Point (1993), "Bioaccumulation of Organic and Inorganic Selenium in a Laboratory Food Chain," *Environ. Toxicol. and Chem.* **12**, 57-72.

Michels, D. E. (1971), "Log-Normal Analysis of Data for Plutonium in the Outdoors," in *Proceedings of Environmental Plutonium Symposium*, August 4–5, 1971, Los Alamos National Laboratory, Los Alamos, N. Mex. (LA-756), pp. 105-111.

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Appendix E

Figures

Figure E-1. Total threshold limit concentrations for antimony from surface soil sampling data (above the limit of detection) for LLNL Site 300 using data collected through October 1994.

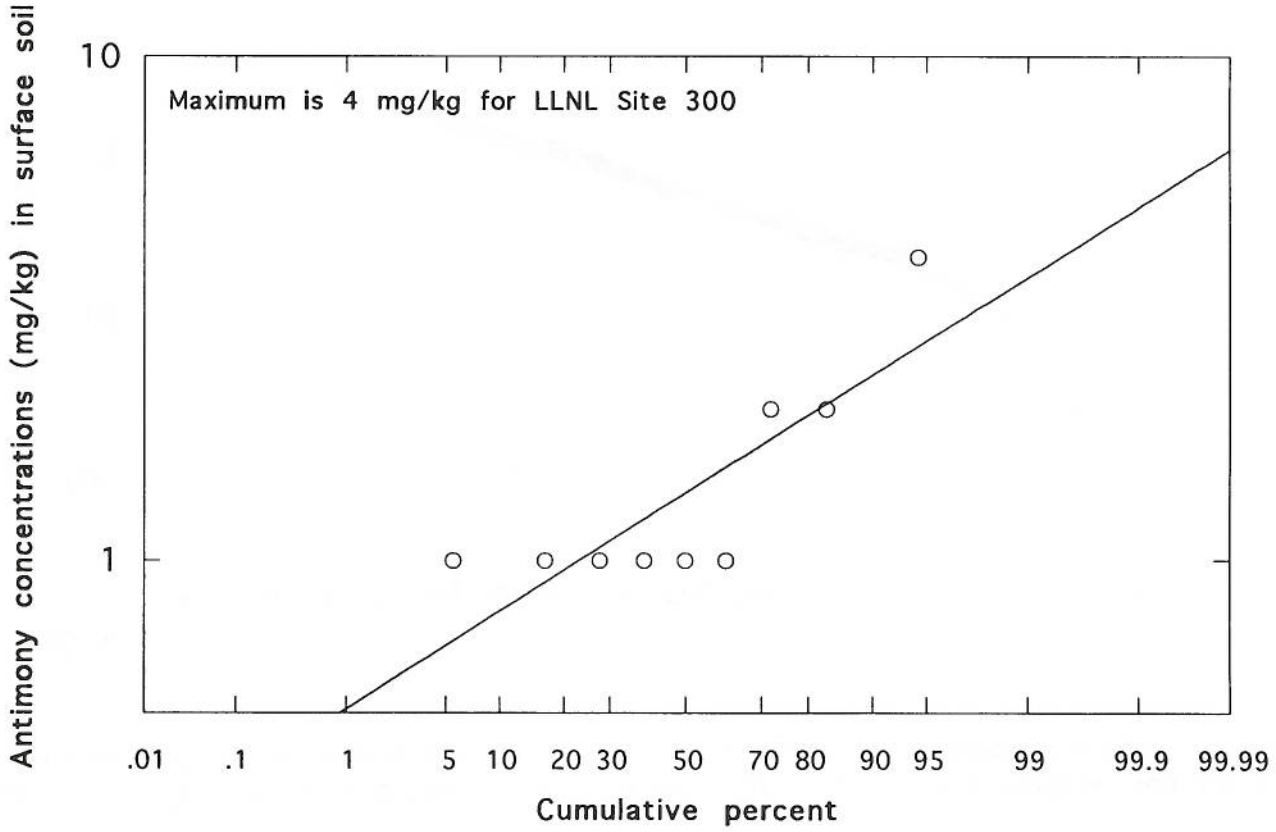


Figure E-2. Total threshold limit concentrations for arsenic from surface soil sampling data (above the limit of detection) for LLNL Site 300 using data collected through October 1994.

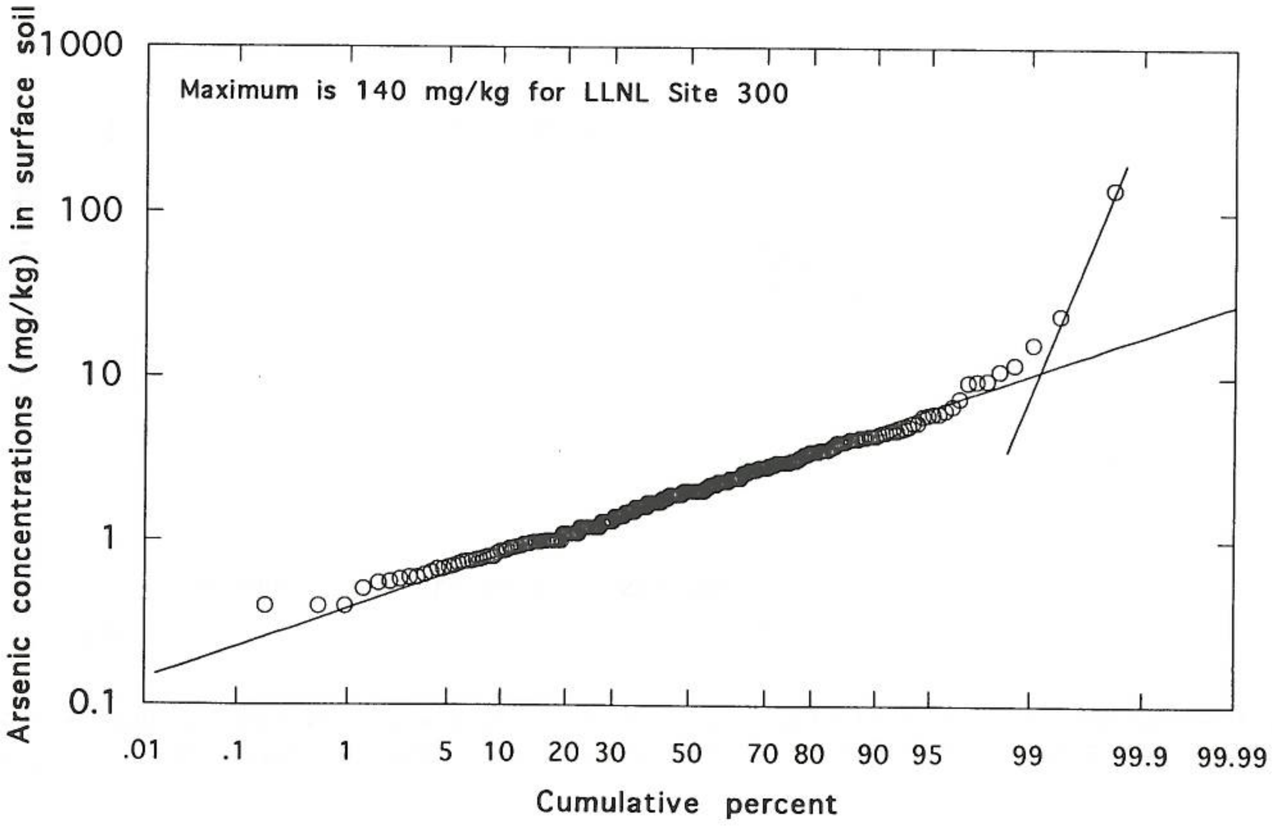


Figure E-3. Arsenic concentrations in surface soil (above the limit of detection) for LLNL Site 300. Data are replotted from Figure E-2.

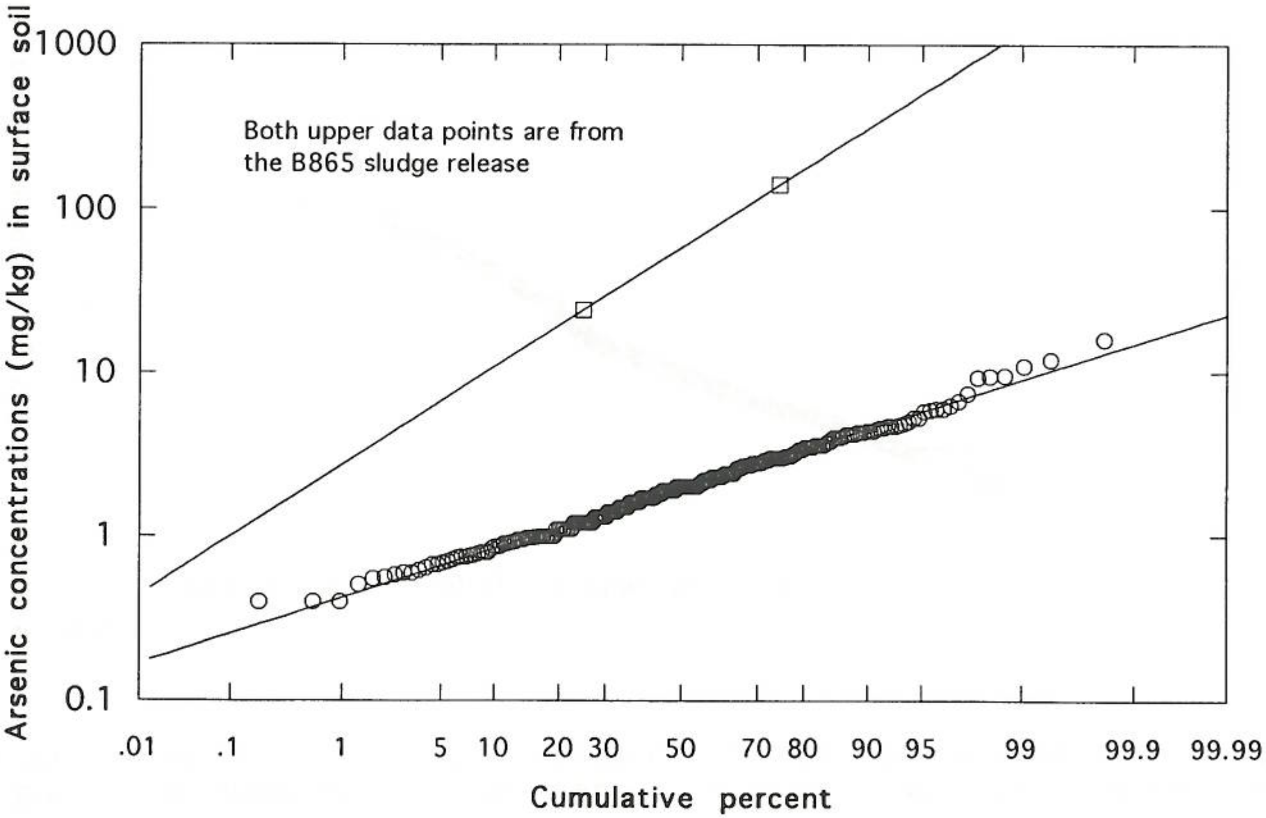


Figure E-4. Total threshold limit concentrations for barium from surface soil sampling data (above the limit of detection) for LLNL Site 300 using data collected through October 1994.

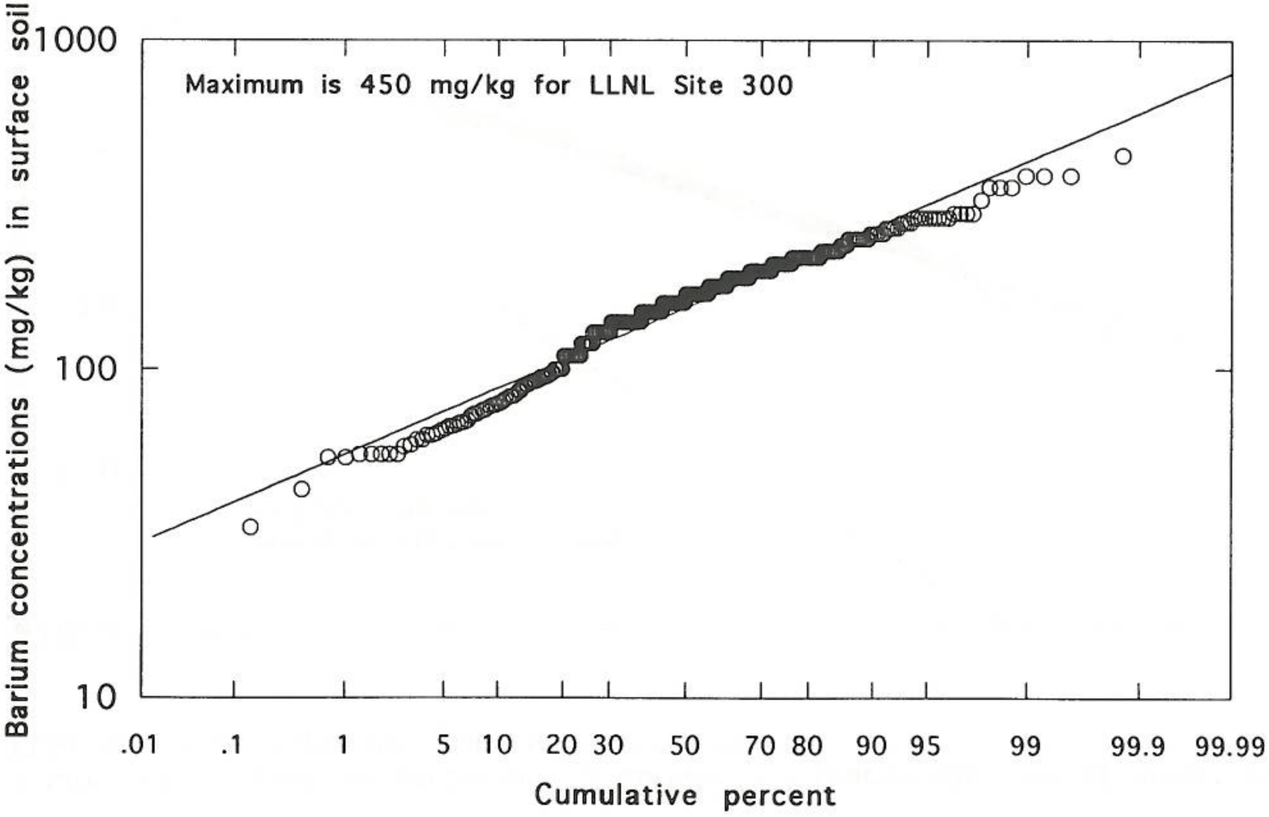


Figure E-5. Total threshold limit concentrations for beryllium from surface soil sampling data (above the limit of detection) for LLNL Site 300 using data collected through October 1994.

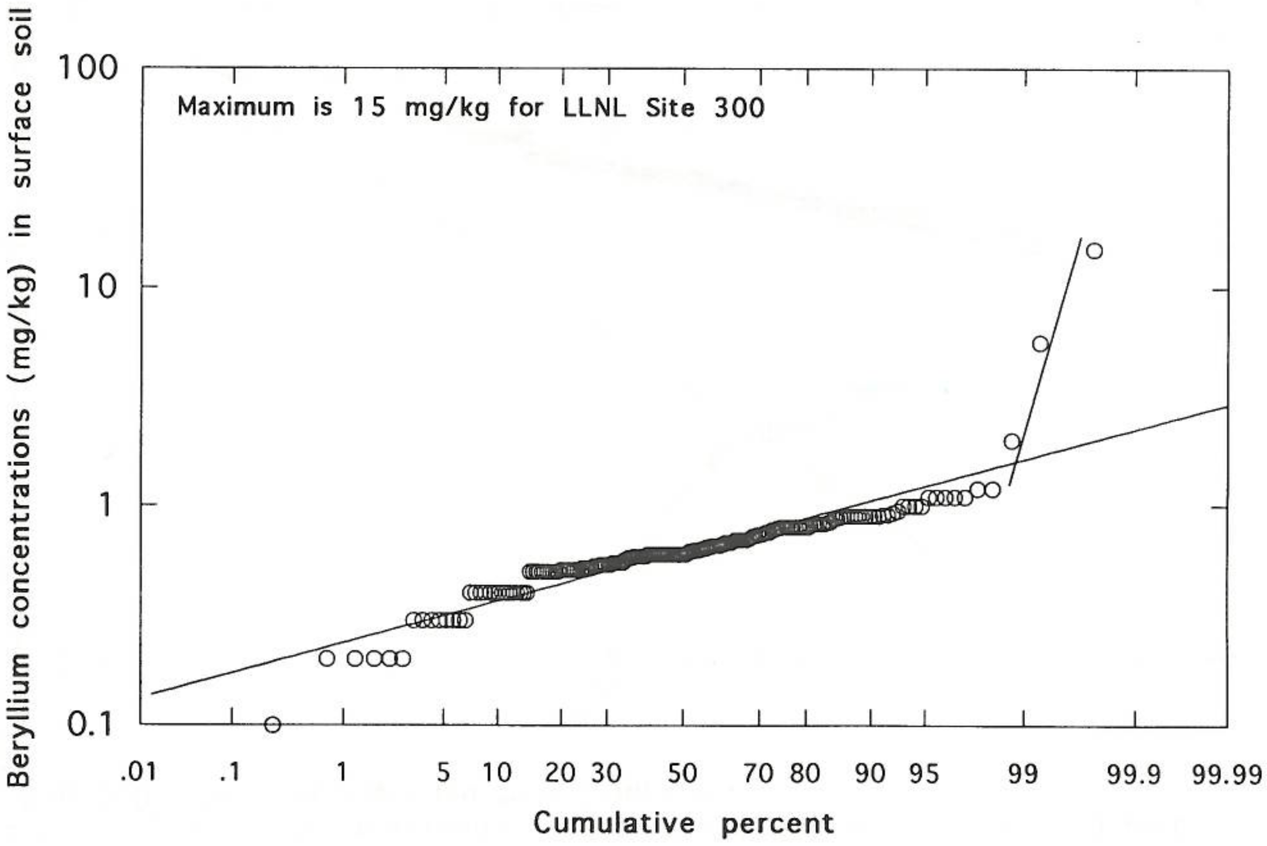


Figure E-6. Beryllium concentrations in surface soil (above the limit of detection) for LLNL Site 300. Data are replotted from Figure E-5.

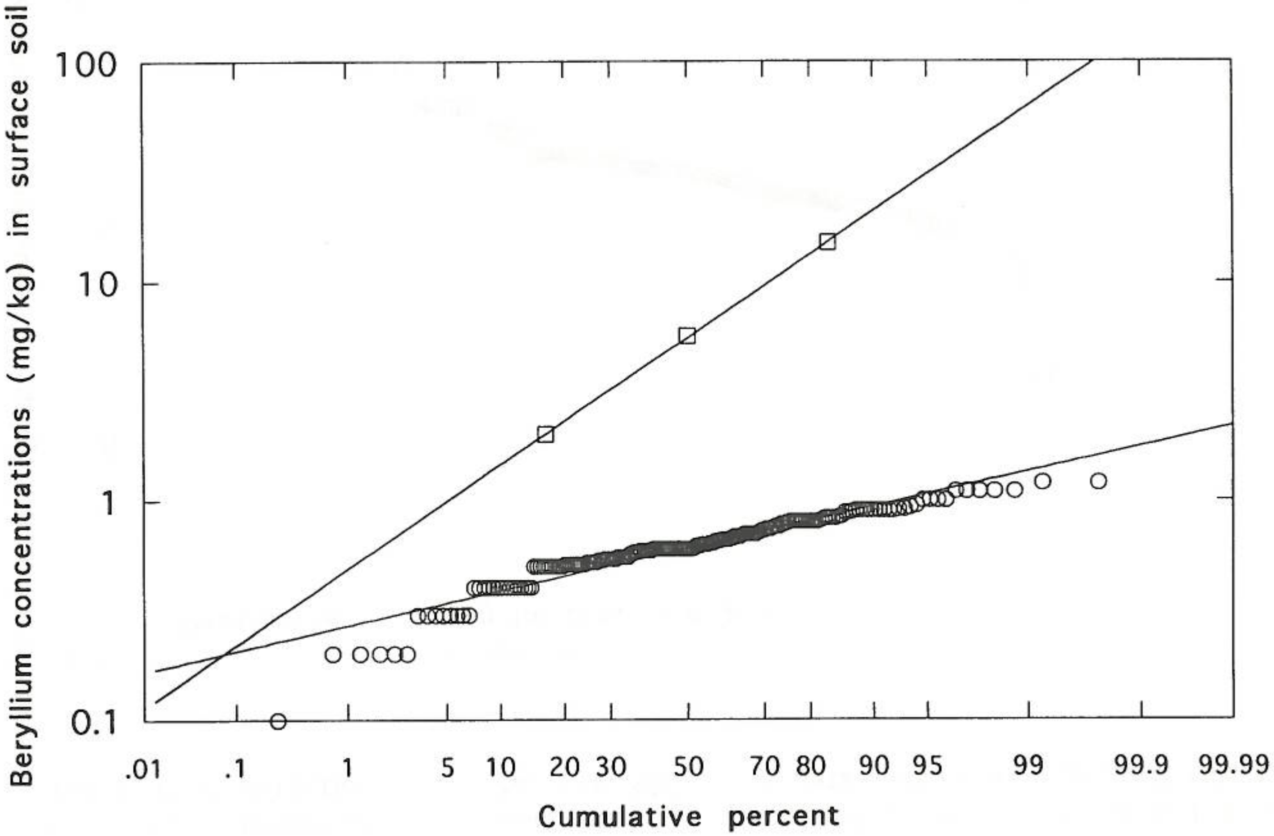


Figure E-7. Total threshold limit concentrations for cadmium from surface soil sampling data (above the limit of detection) for LLNL Site 300 using data collected through October 1994.

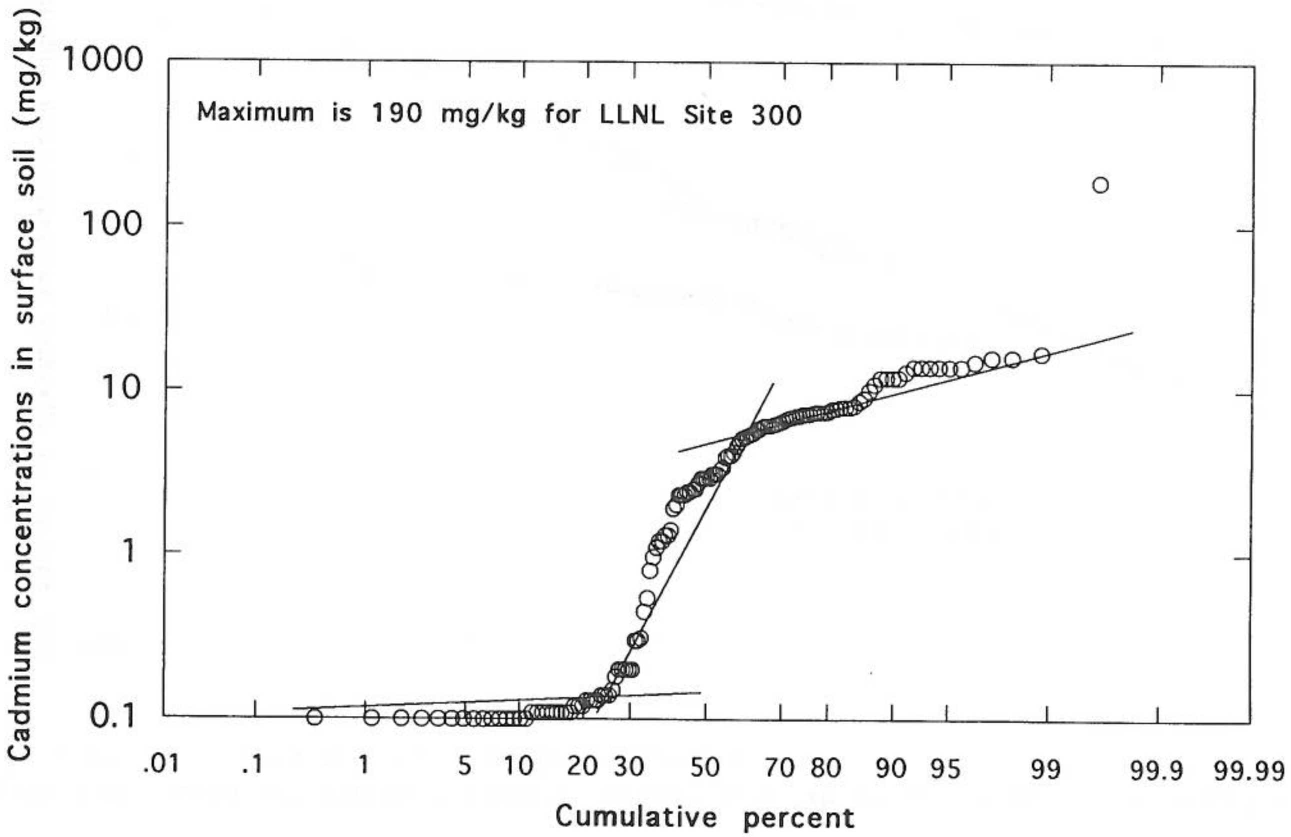


Figure E-8. Cadmium concentrations in surface soil (above the limit of detection) for LLNL Site 300. Data are replotted from Figure E-7.

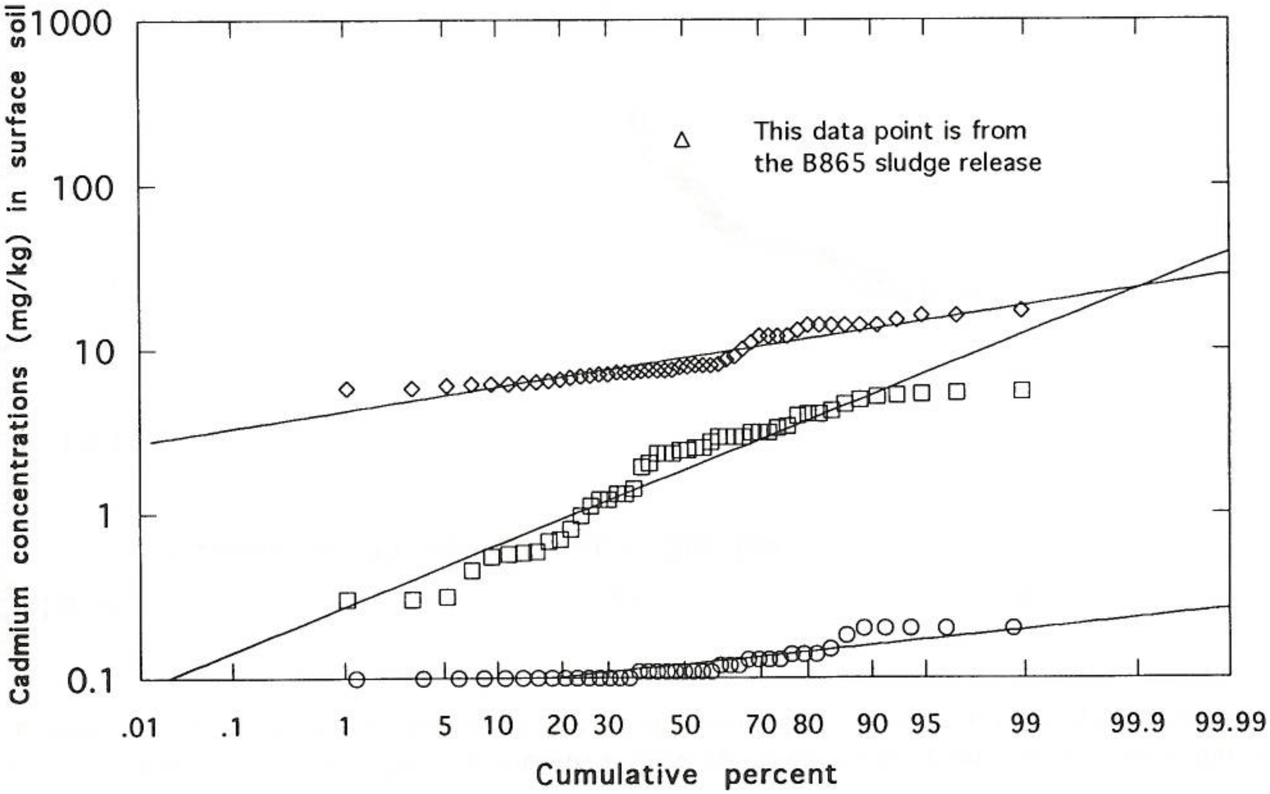


Figure E-9. Total threshold limit concentrations for chromium from surface soil sampling data (above the limit of detection) for LLNL Site 300 using data collected through October 1994.

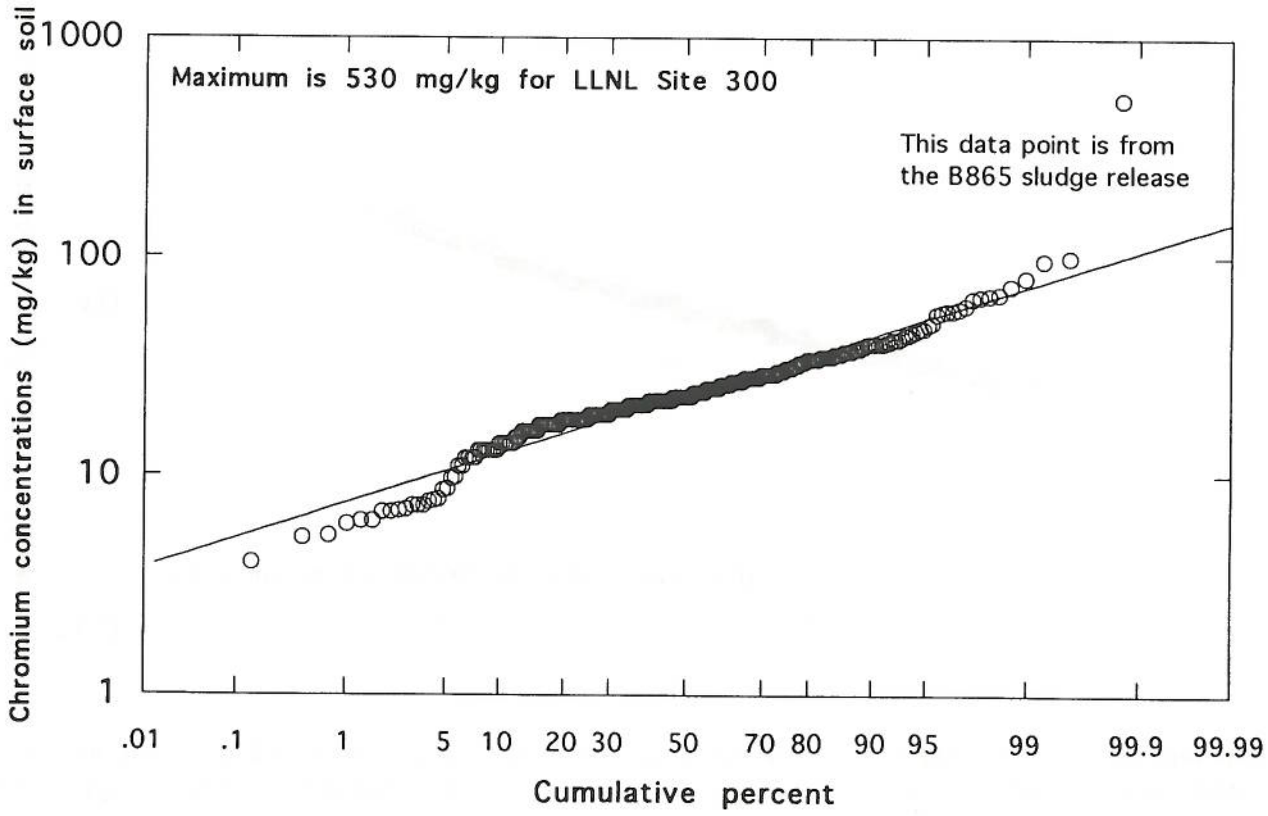


Figure E-10. Total threshold limit concentrations for cobalt from surface soil sampling data (above the limit of detection) for LLNL Site 300 using data collected through October 1994.

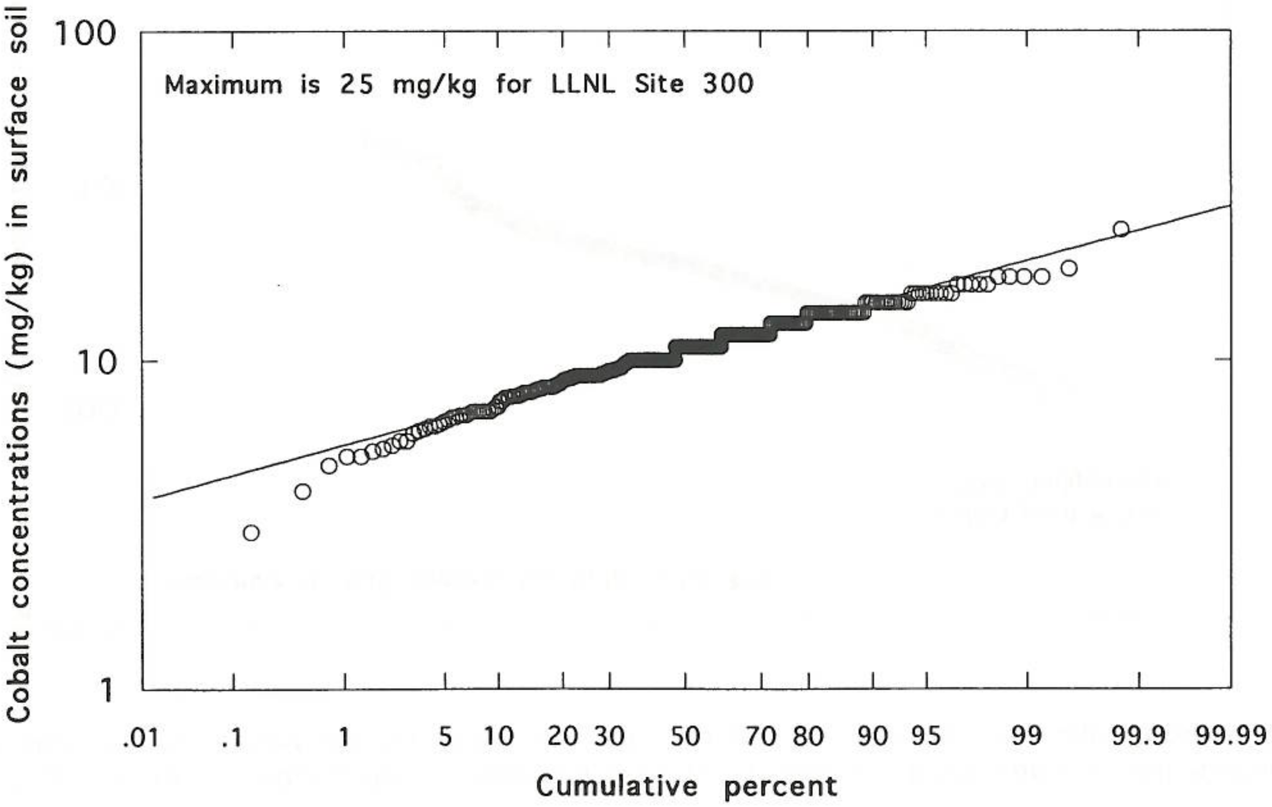


Figure E-11. Total threshold limit concentrations for copper from surface soil sampling data (above the limit of detection) for LLNL Site 300 using data collected through October 1994.

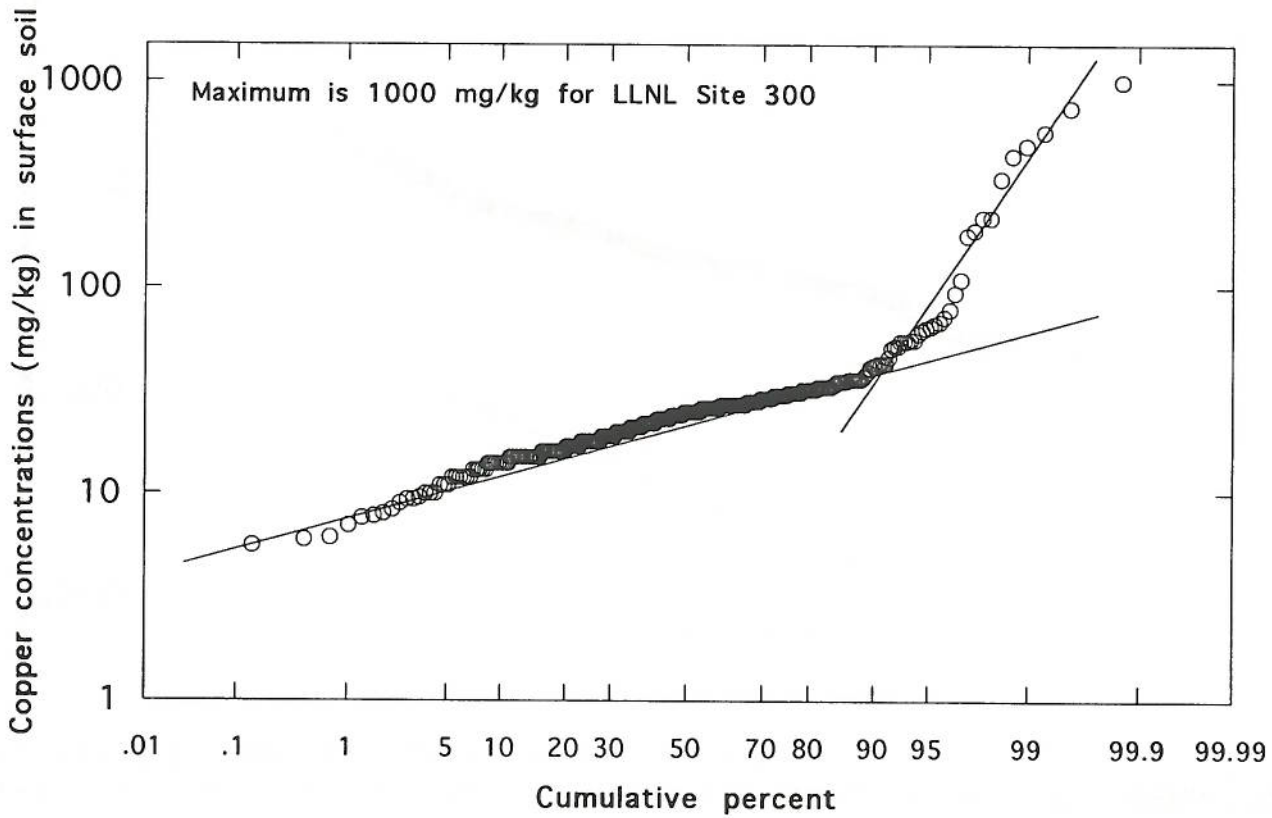


Figure E-12. Copper concentrations in surface soil (above the limit of detection) for LLNL Site 300. Data are replotted from Figure E-11.

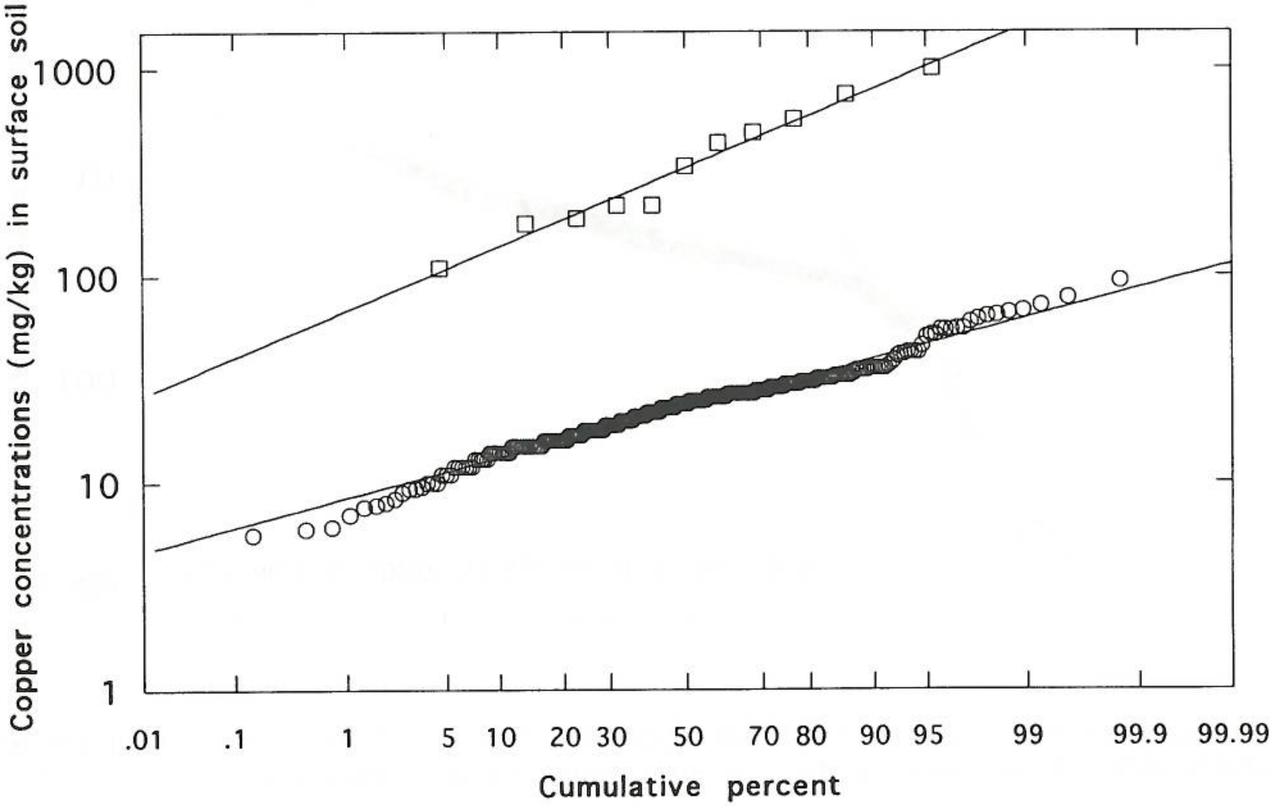


Figure E-13. Total threshold limit concentrations for lead from surface soil sampling data (above the limit of detection) for LLNL Site 300 using data collected through October 1994.

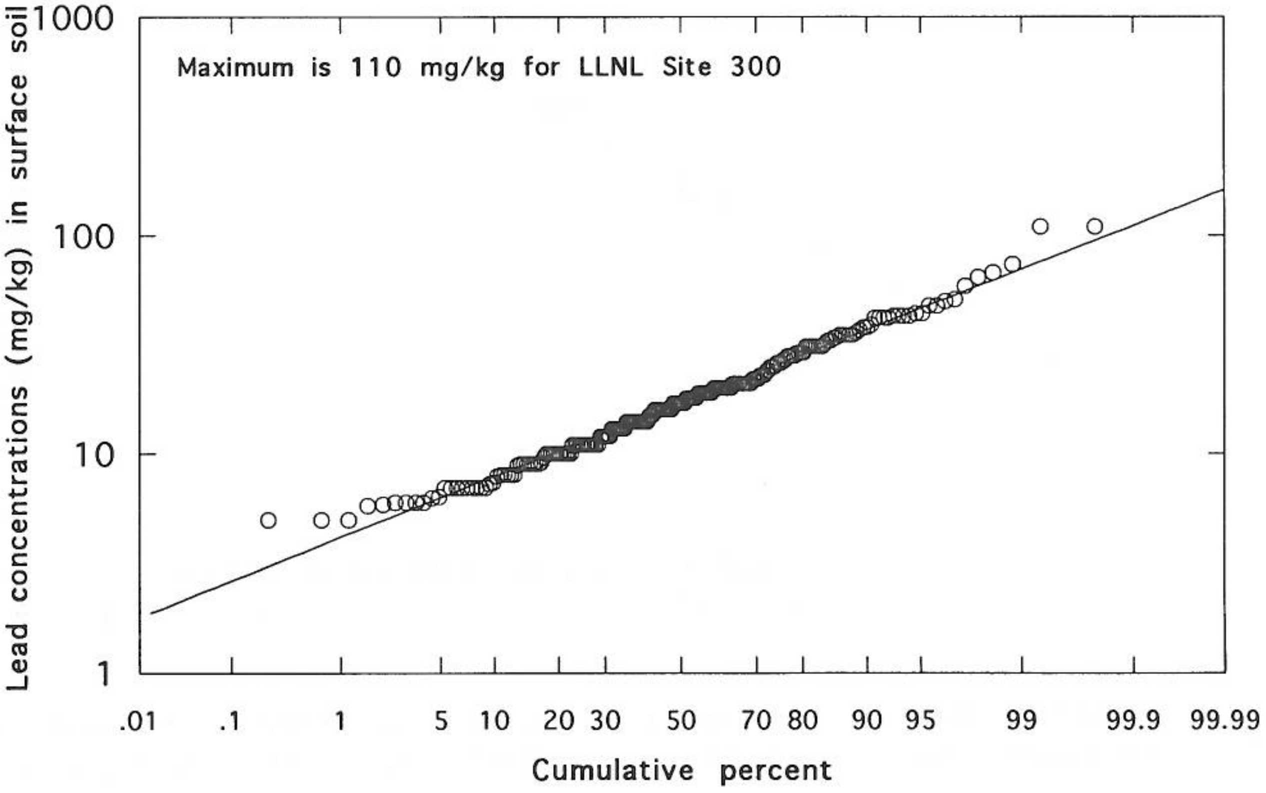


Figure E-14. Total threshold limit concentrations for mercury from surface soil sampling data (above the limit of detection) for LLNL Site 300 using data collected through October 1994.

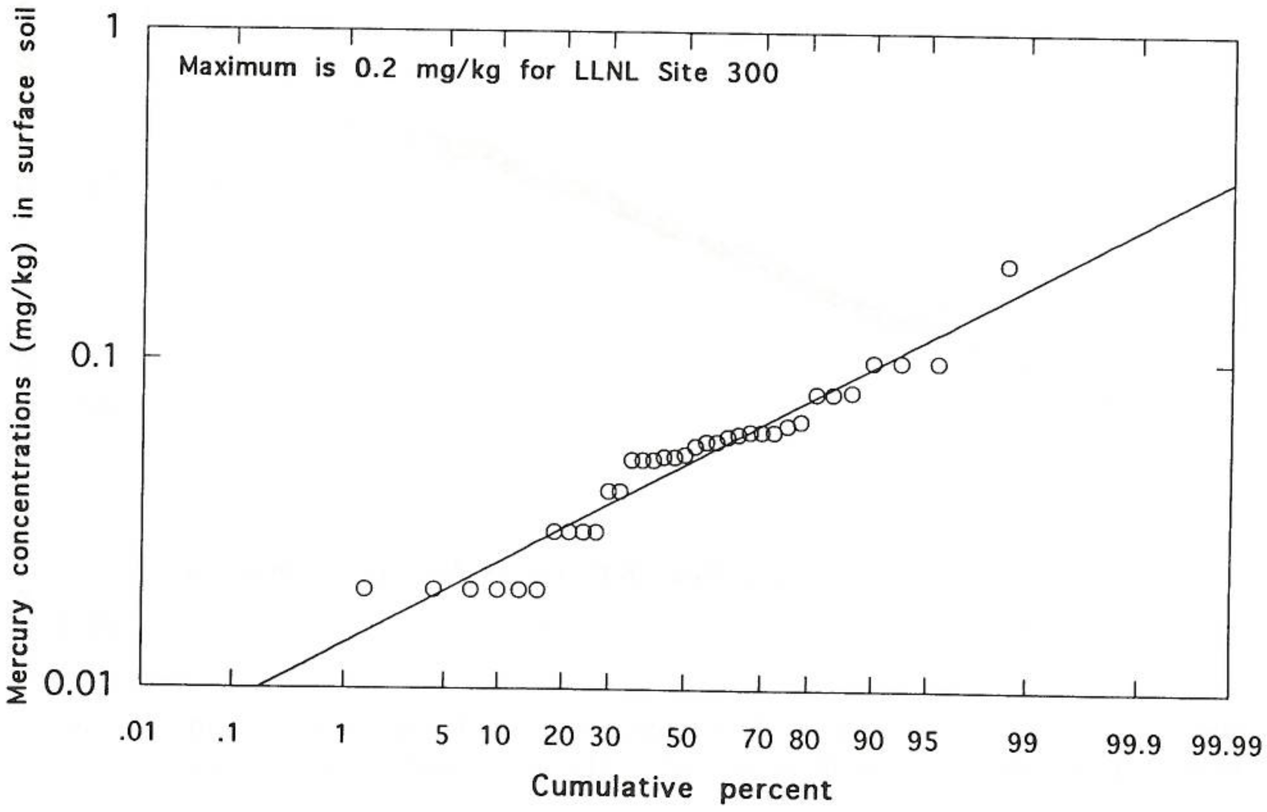


Figure E-15. Total threshold limit concentrations for molybdenum from surface soil sampling data (above the limit of detection) for LLNL Site 300 using data collected through October 1994.

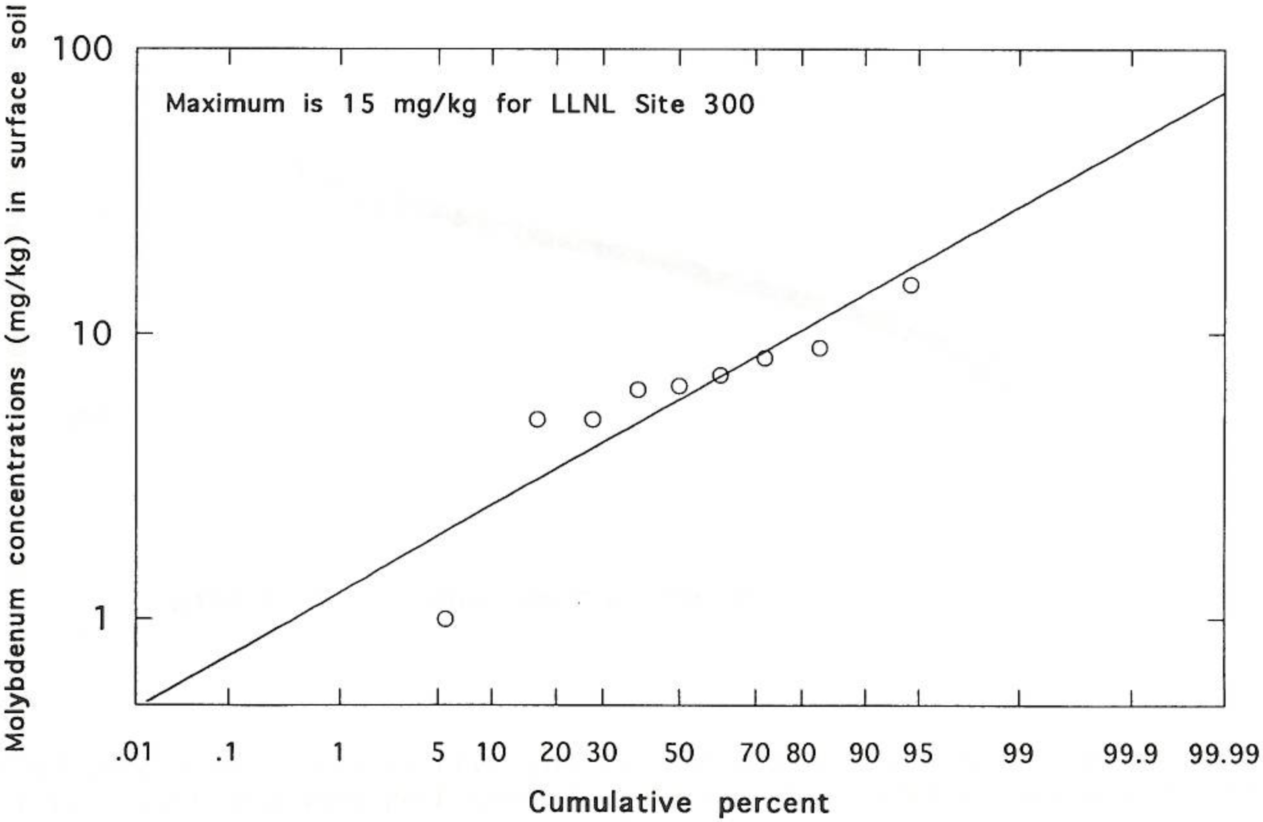


Figure E-16. Total threshold limit concentrations for nickel from surface soil sampling data (above the limit of detection) for LLNL Site 300 using data collected through October 1994.

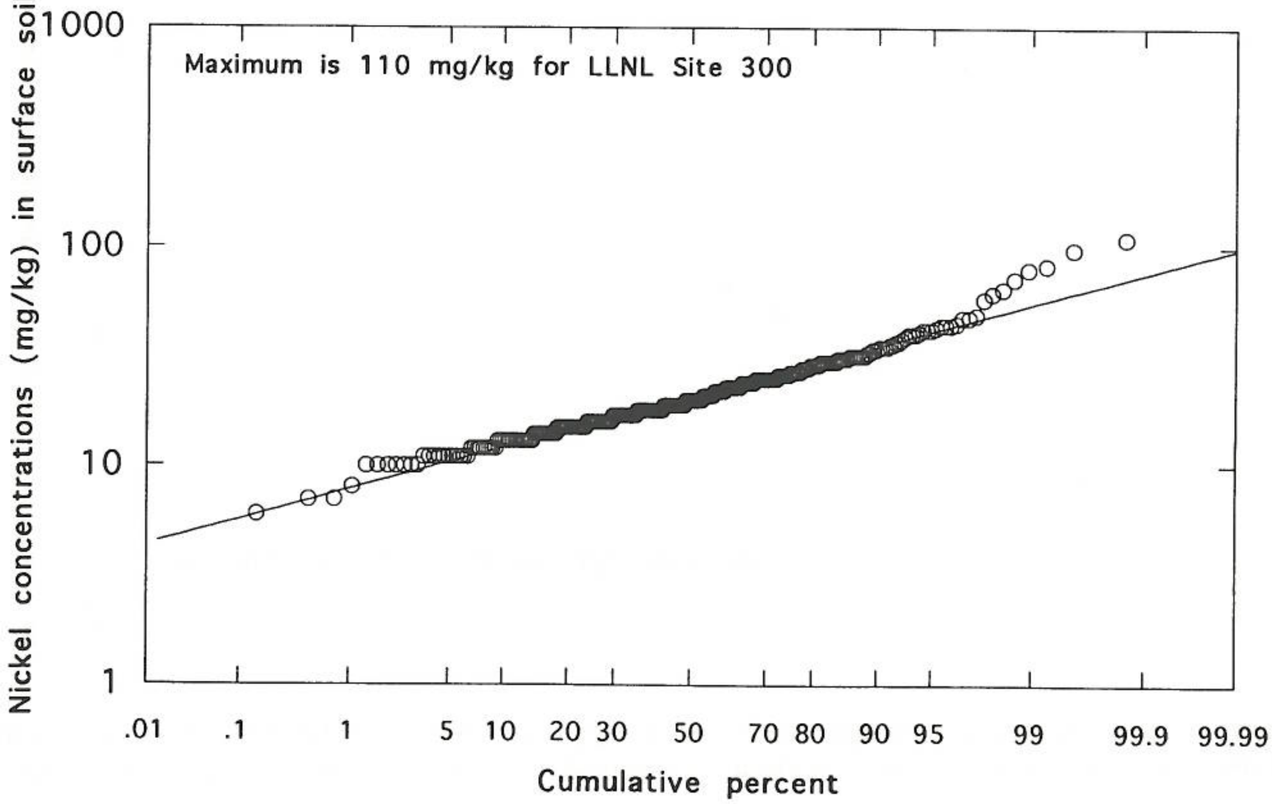


Figure E-17. Total threshold limit concentrations for selenium from surface soil sampling data (above the limit of detection) for LLNL Site 300 using data collected through October 1994.

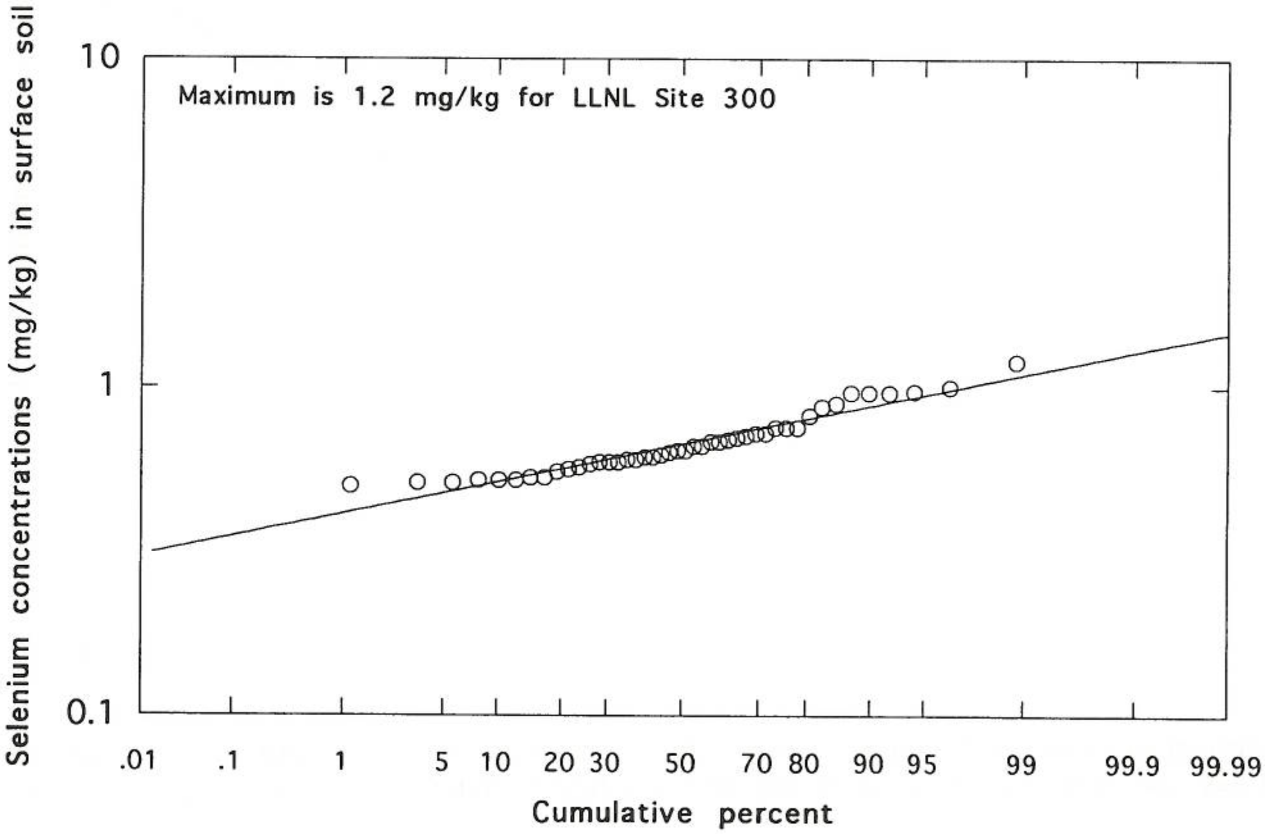


Figure E-18. Total threshold limit concentrations for silver from surface soil sampling data (above the limit of detection) for LLNL Site 300 using data collected through October 1994.

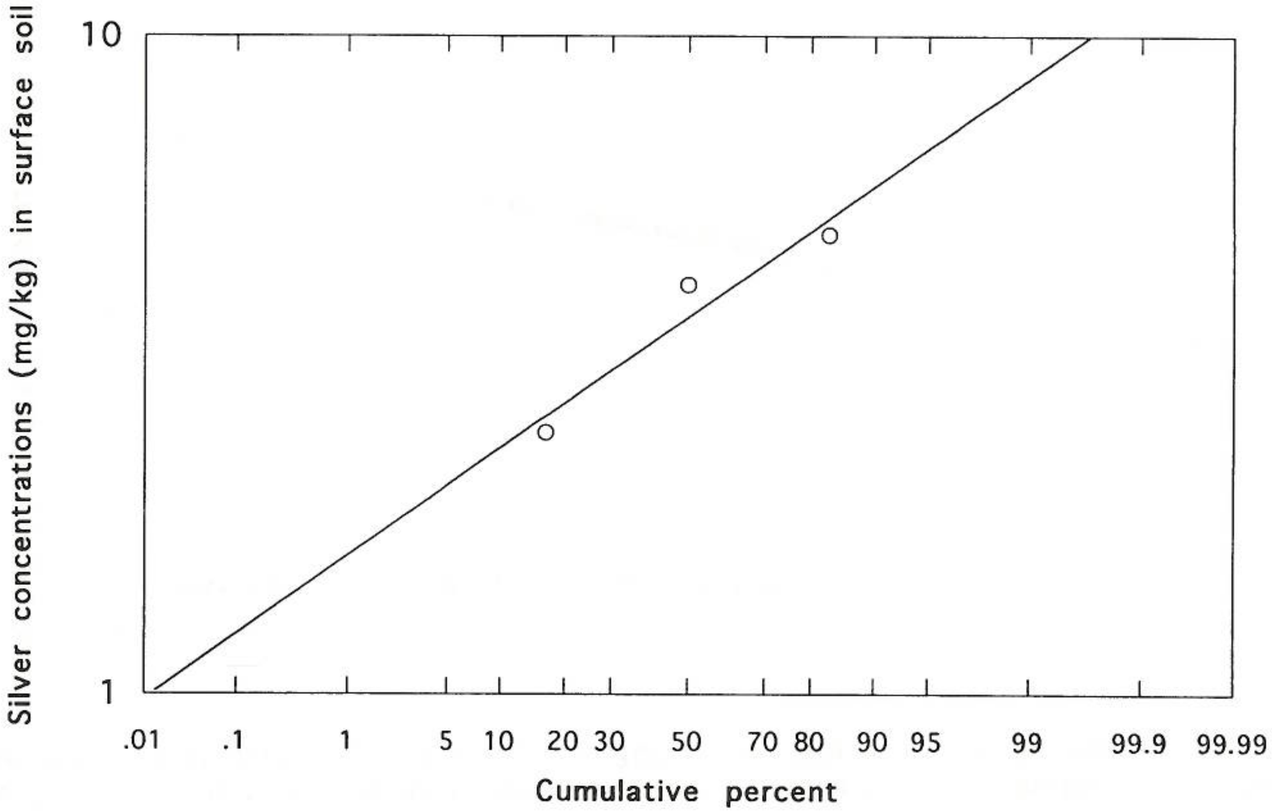


Figure E-19. Total threshold limit concentrations for vanadium from surface soil sampling data (above the limit of detection) for LLNL Site 300 using data collected through October 1994.

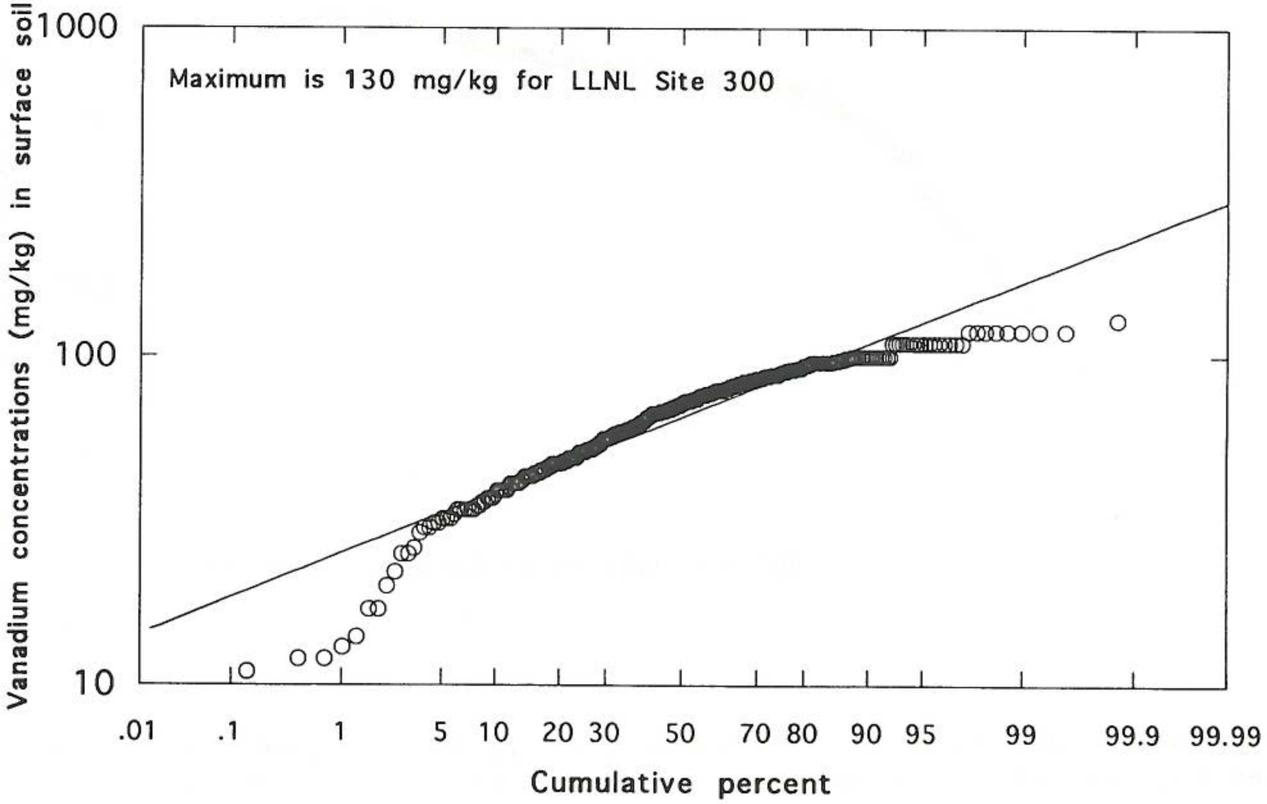


Figure E-20. Total threshold limit concentrations for zinc from surface soil sampling data (above the limit of detection) for LLNL Site 300 using data collected through October 1994.

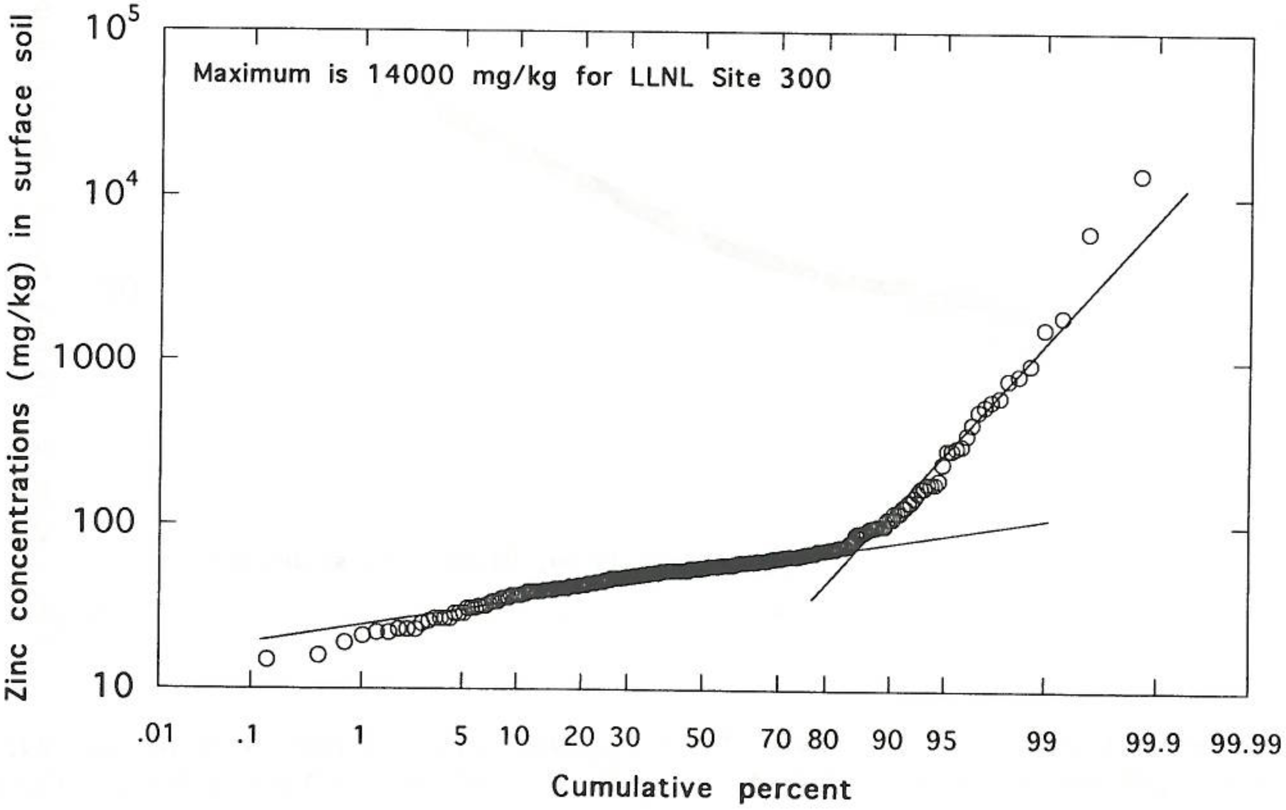


Figure E-21. Zinc concentrations in surface soil (above the limit of detection) for LLNL Site 300. Data are replotted from Figure E-19.

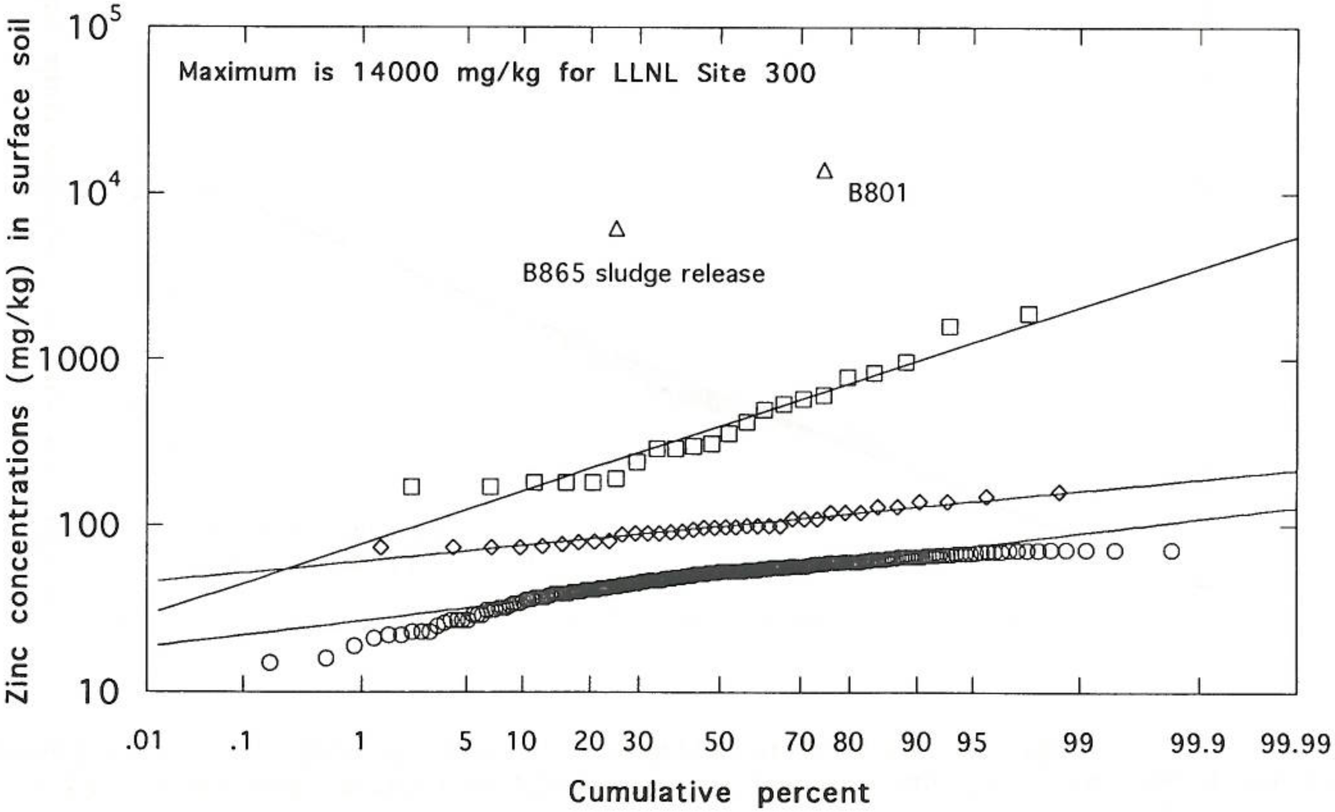


Figure E-22. Gross alpha activity in pCi/g from surface soil sampling data (above the limit of detection) for LLNL Site 300 using data collected through October 1994.

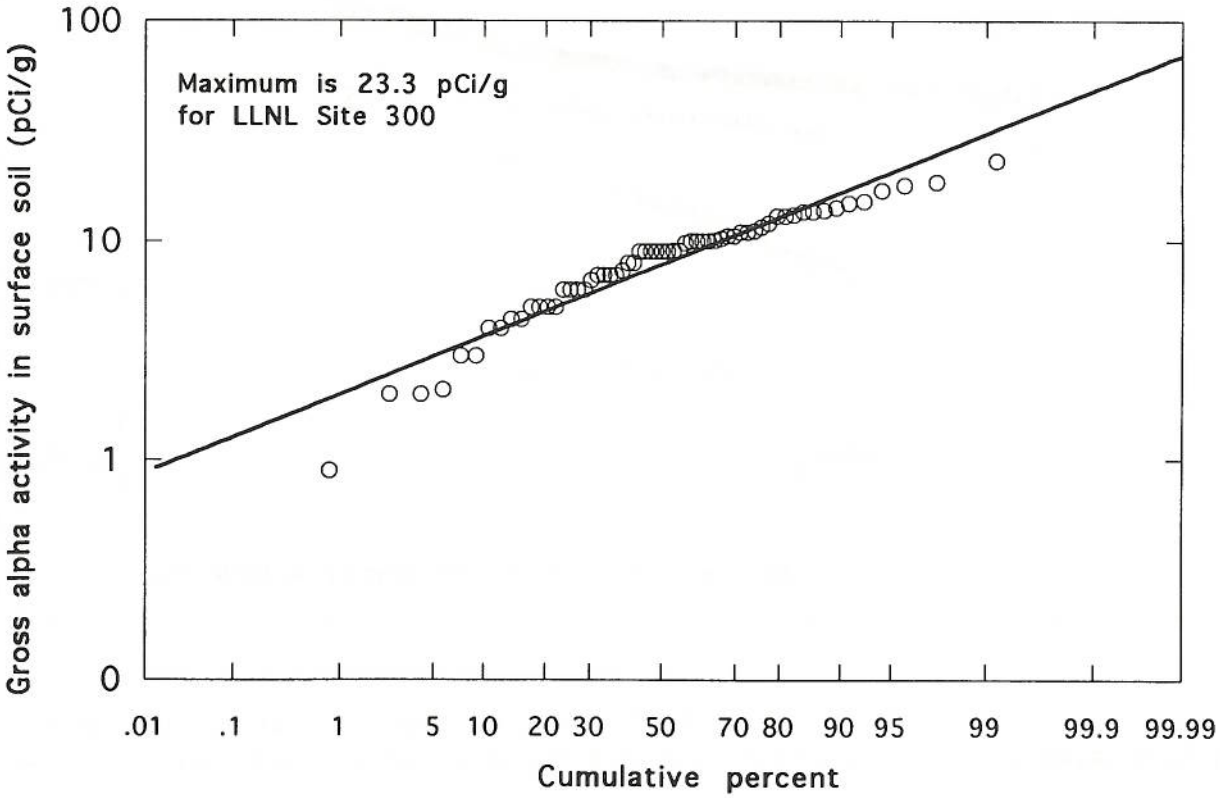


Figure E-23. Gross beta activity in pCi/g from surface soil sampling data (above the limit of detection) for LLNL Site 300 using data collected through October 1994.

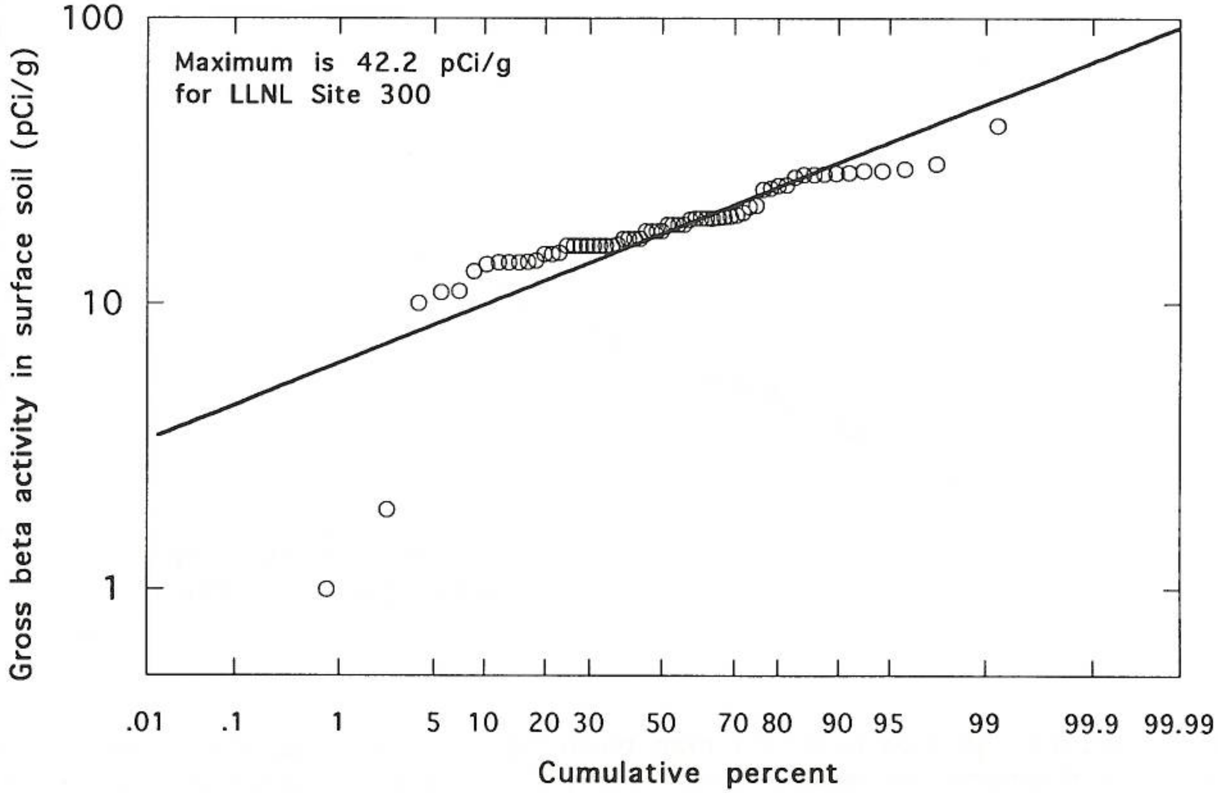


Figure E-24. Thorium-232 activity in pCi/g from surface soil sampling data (above the detection limit) for LLNL Site 300 using data collected through October 1994.

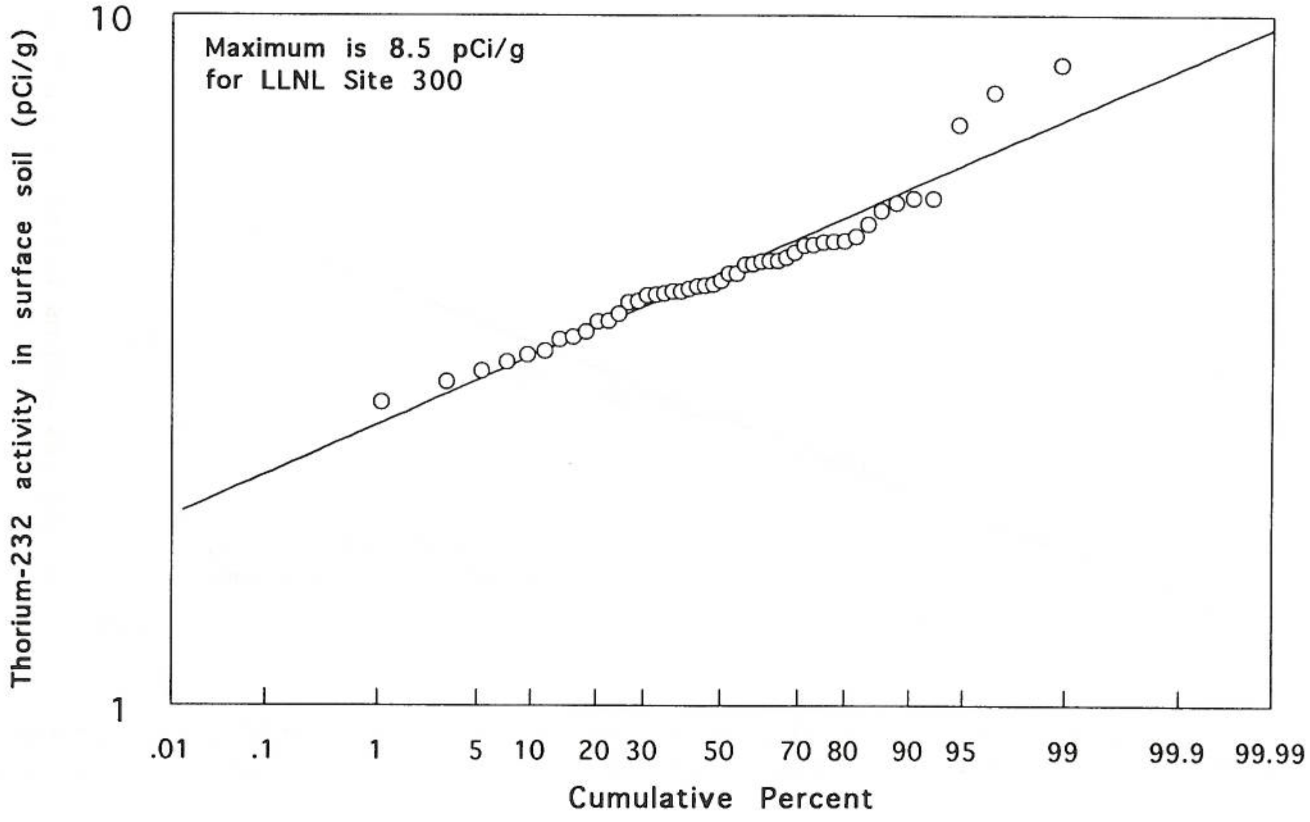


Figure E-25. Uranium-234 activity in pCi/g from surface soil sampling data (above the limit of detection) for LLNL Site 300 using data collected through November 1994.

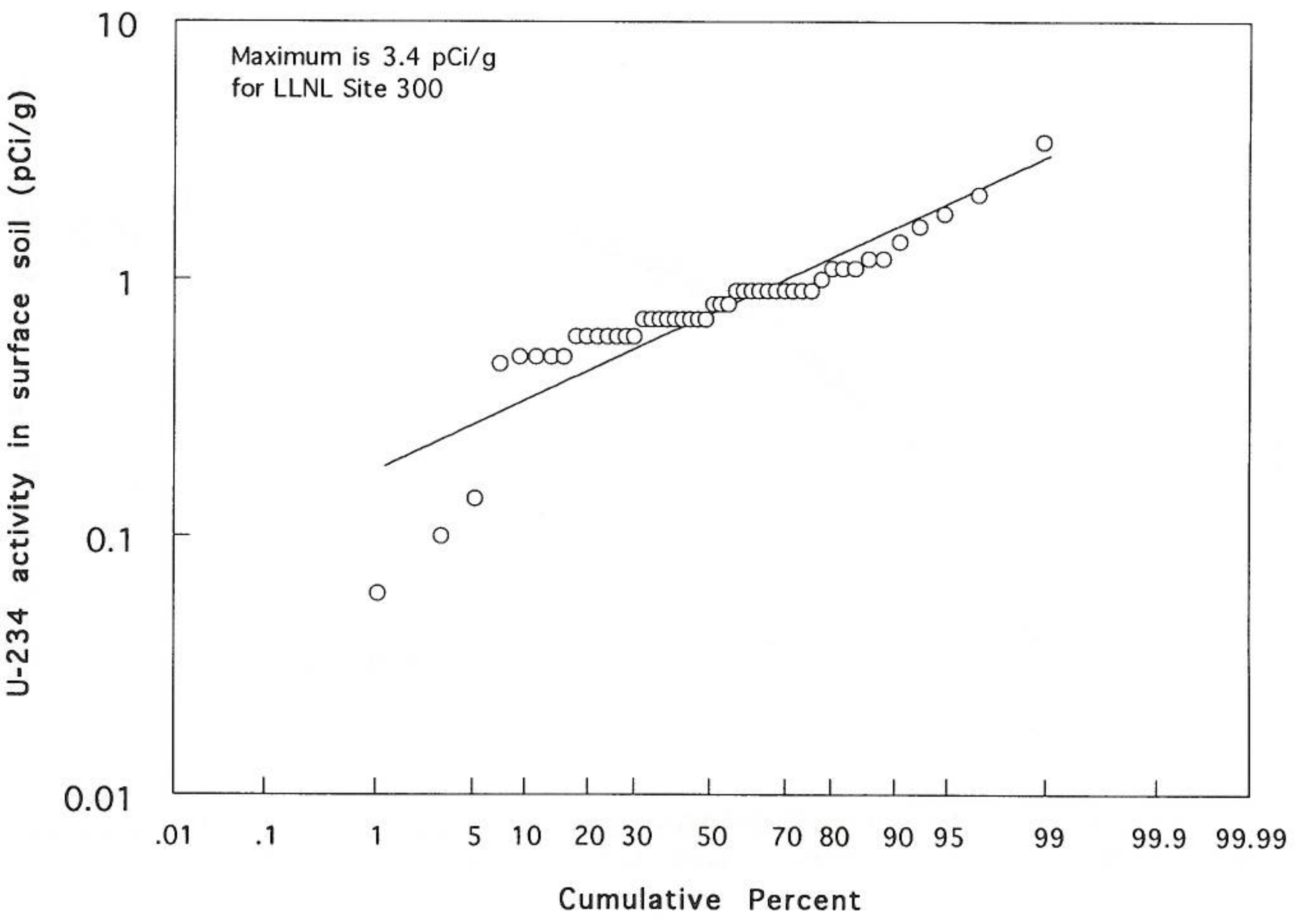


Figure E-26. Uranium-235 activity in pCi/g from surface soil sampling data (above the limit of detection) for LLNL Site 300 using data collected through November 1994.

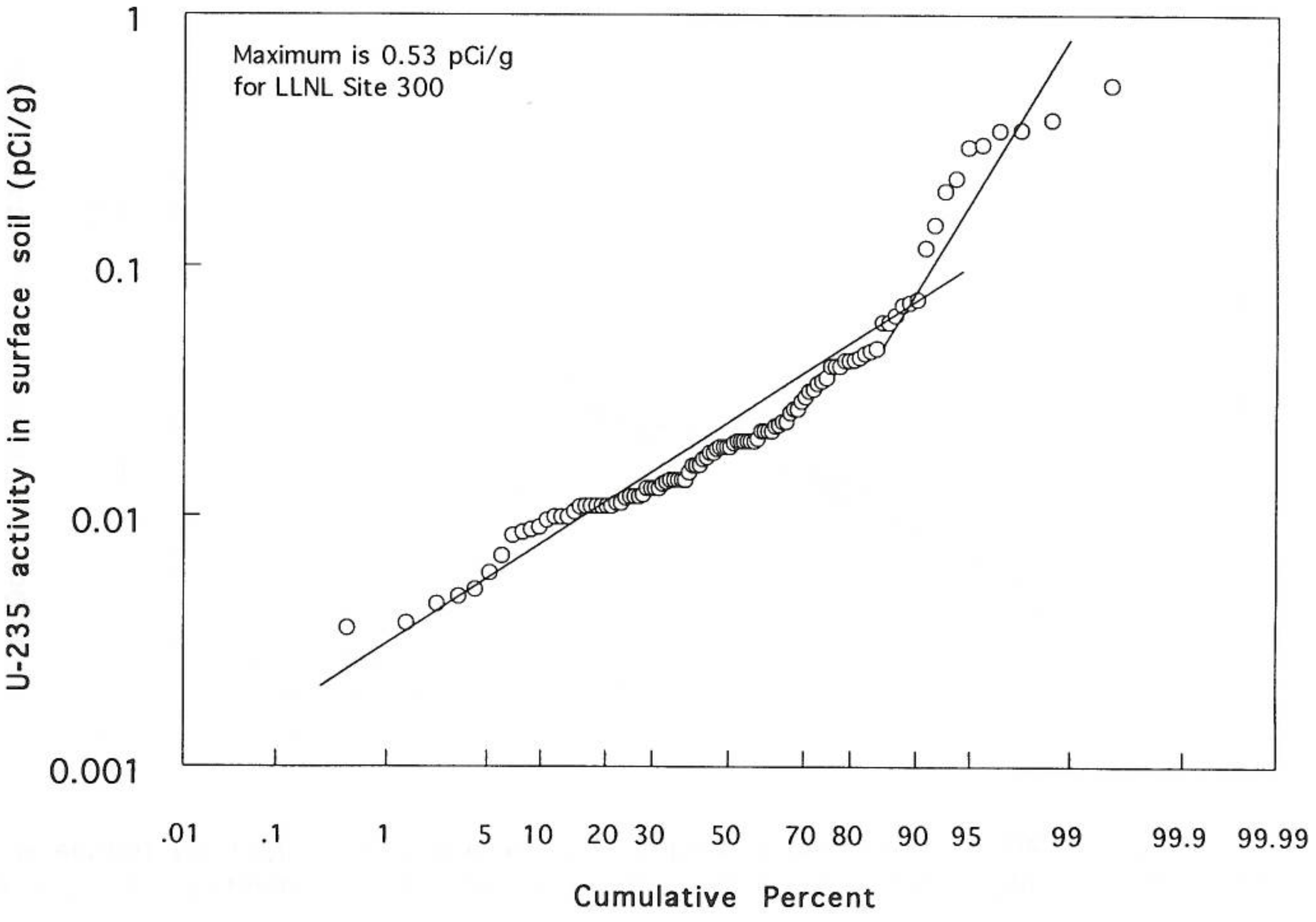


Figure E-27. Uranium-235 activity in pCi/g from surface soil sampling data (above the limit of detection) for LLNL Site 300. Data are reploted from Figure E-26.

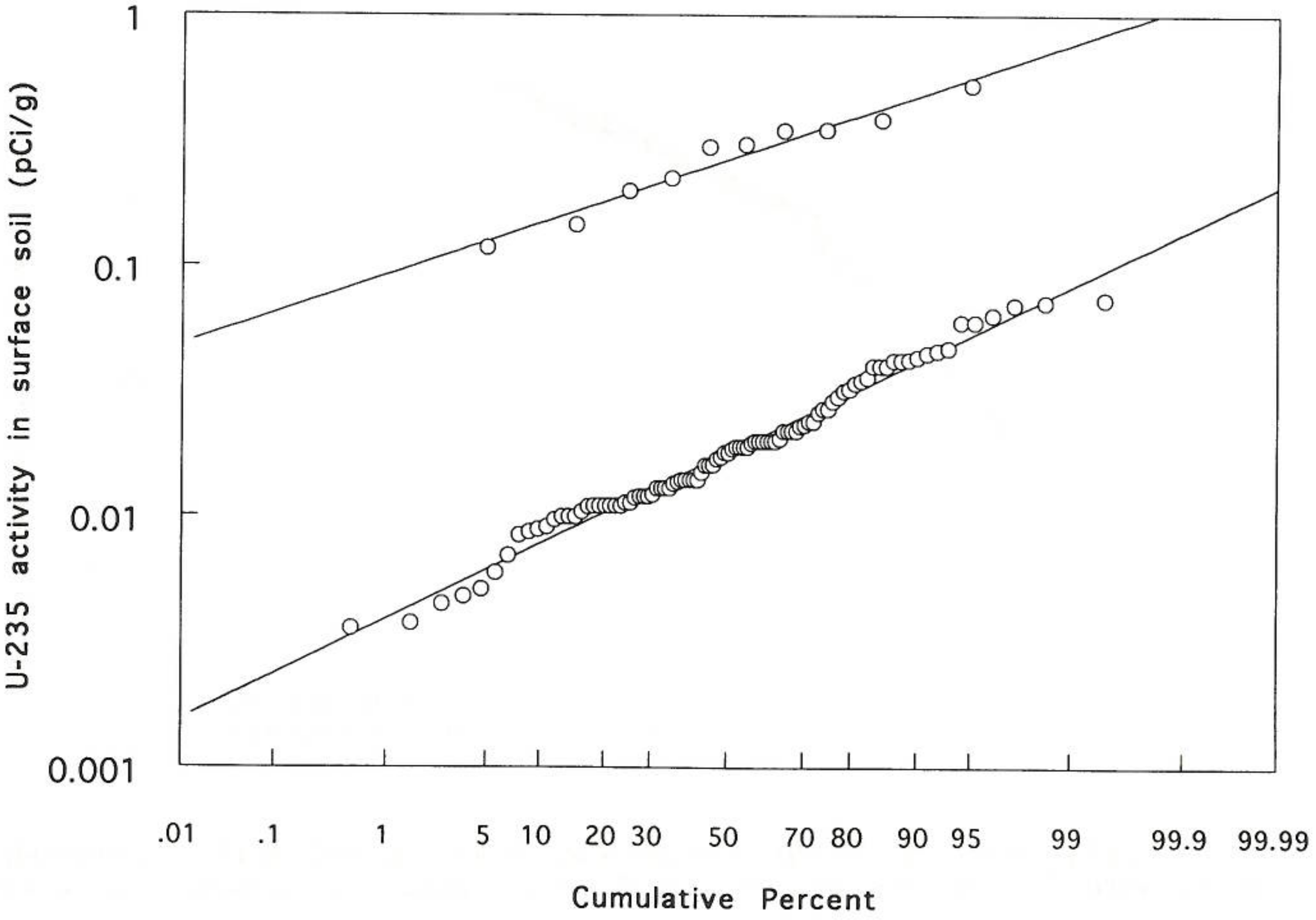


Figure E-28. Uranium-238 activity in pCi/g from surface soil sampling data (above the limit of detection) for LLNL Site 300 using data collected through November 1994.

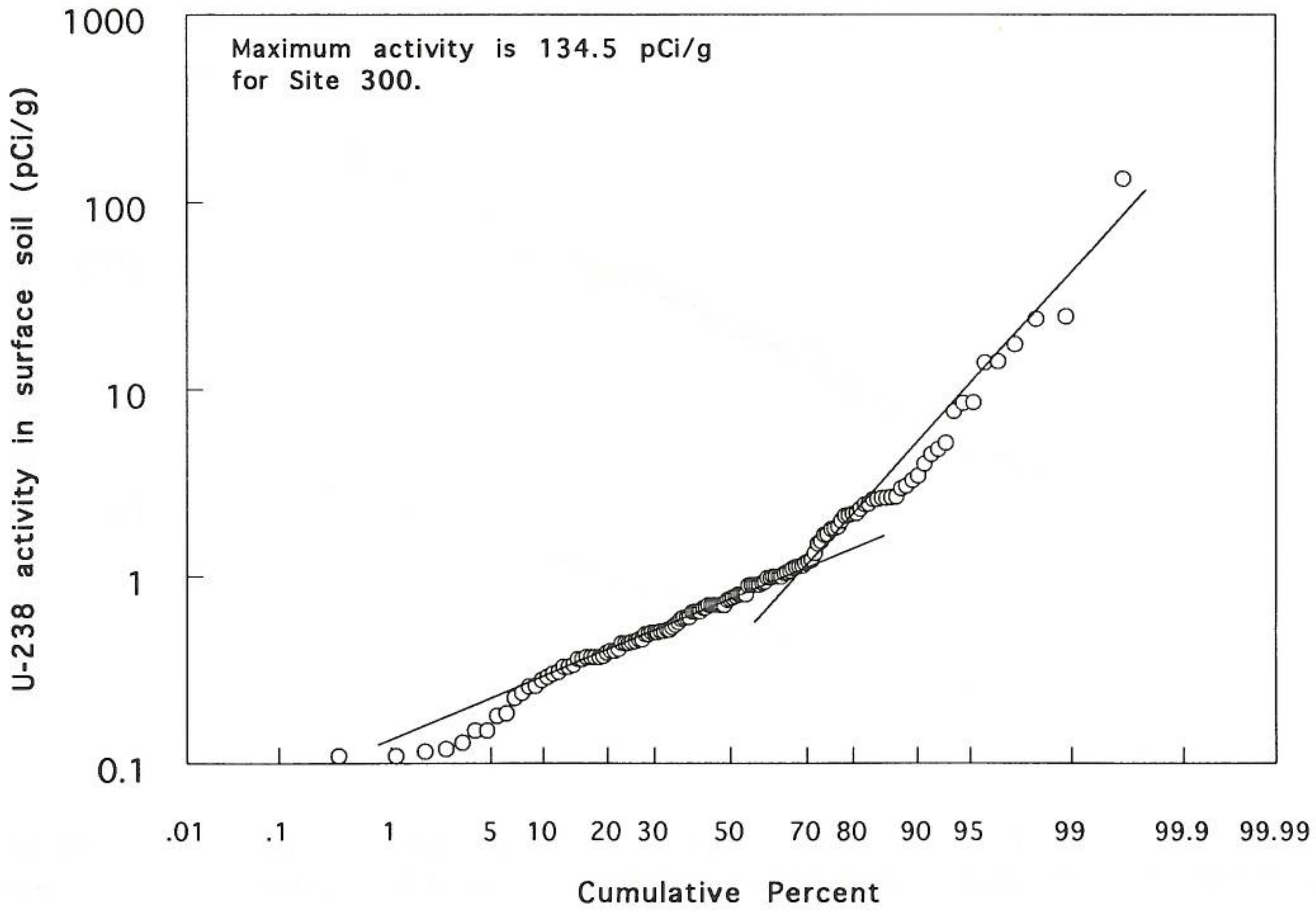
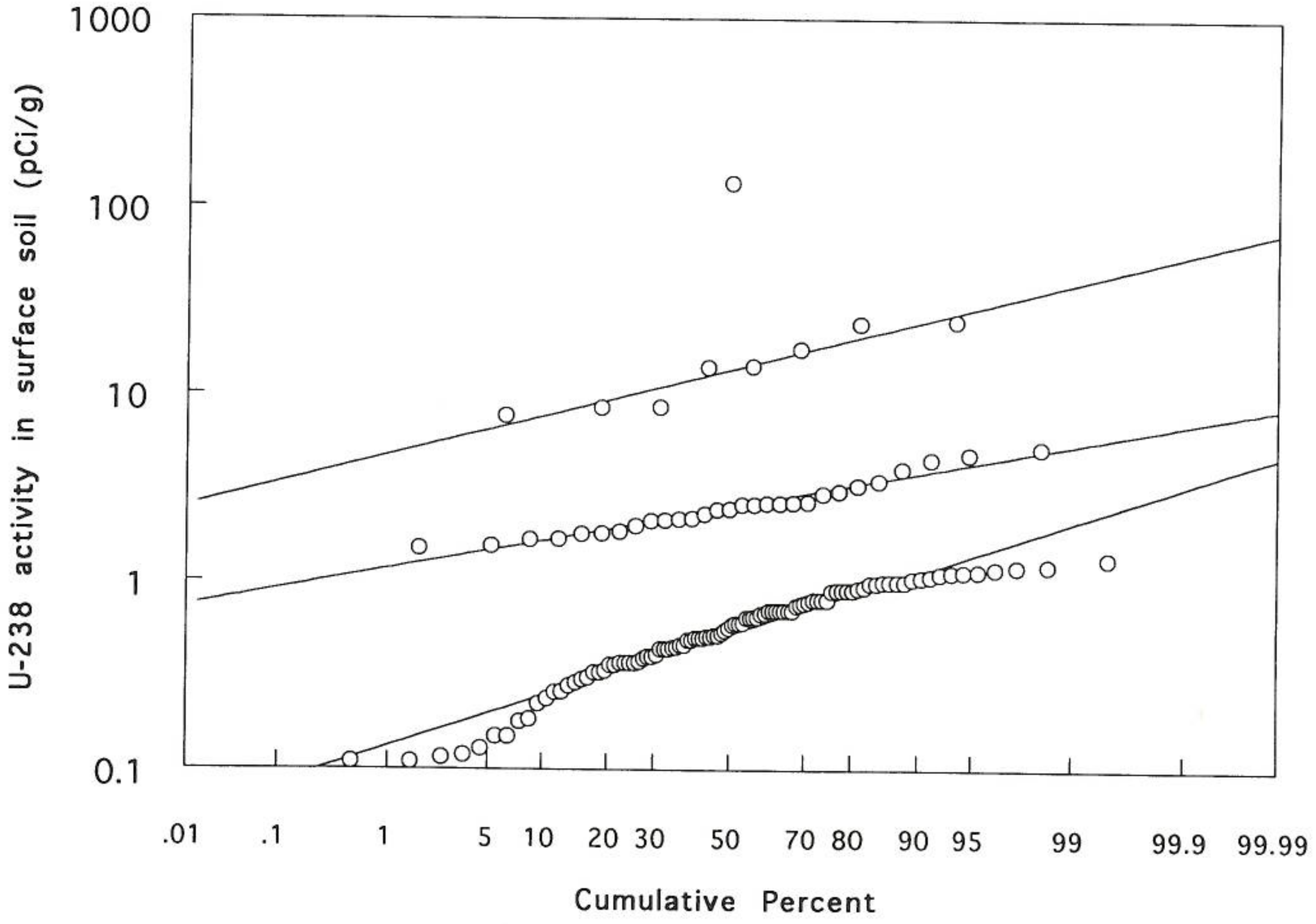


Figure E-29. Uranium-238 activity in pCi/g from surface soil sampling data (above the limit of detection) for LLNL Site 300. Data are replotted from Figure E-28.



Appendix F

Dioxin Toxicity Equivalence Factors

Appendix F

Dioxin Toxicity Equivalence Factors

Interviews with LLNL-Site 300 personnel conducted in 1995 (Hall, 1995) indicated that capacitors containing polychlorinated biphenyls (PCBs) were used in certain past test activities conducted at the Building 850 firing table. PCBs were subsequently detected in 18 of 32 surface soil samples (analyzed by EPA method 8080) collected near the firing table (Chapter 2, Fig. 2-7).

Combustion of chlorine-containing material such as PCBs is believed to form chlorinated dibenzo-p-dioxins (CDDs) and chlorinated dibenzofurans (CDFs) (U.S. EPA, 1989). In December 1994, surface soil sampling conducted in the vicinity of the Building 850 firing table (Chapter 2, Fig. 2-8) yielded detections of CDDs and/or CDFs in each of 10 samples (collected from 8 locations).

Based upon recommendations from Dr. D. Stralka, Toxicologist, U.S. EPA Region IX (Carlsen, 1995), we used the Toxicity Equivalence Factor (TEF) approach to evaluate the potential risks associated with exposure to CDDs and CDFs in the vicinity of the Building 850 firing table (U.S. EPA, 1989). This approach relates the toxicity of the 209 CDD and CDF cogeners or homologues to that of the CDD 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD). It is based on the fact that these substances exert their toxicological effects through the same biochemical mechanism as 2,3,7,8-TCDD, although with varying potency (U.S. EPA, 1989).

Applying the TEF approach for each surface soil sample location, we multiplied the TEF of each CDD or CDF cogener or homologue by the measured concentration for that substance; we then added the results from all CDD or CFD cogeners or homologues detected at a given location to yield a total 2,3,7,8-TCDD equivalent concentration (the total concentration based on TEFs). For each of the 10 surface soil samples in the Building 850 OU, Tables F-1 through F-10 provide the measured concentration of each CDD or CDF cogener or homologue, the corresponding TEF, the surface soil concentration for each analyte based on the TEF, and the total concentration based on TEF.

Each location-specific total TEF concentration was compared to the U.S. EPA Region IX Preliminary Remediation Goal (PRG) of 2.4×10^{-5} mg/kg for 2,3,7,8-TCDD in industrial soil. That value corresponds to an incremental excess cancer risk of 1×10^{-6}, and is based on exposure assumptions and parameters described in PRG documentation (U.S. EPA, 1995). The total TEF concentration exceeded the PRG at six sample locations. These data are summarized in Table F-11.

References

Carlsen, T. (1995), personal communication with Dr. D. Stralka, Toxicologist, U.S. EPA Region IX, February 28, 1995.

Hall, L. (1995), personal communication with F. Sator regarding past and present uses and employee activity patterns at the Building 850 firing table, March 1995.

U.S. EPA (1989), *Interim Procedures for Estimating Risks Associated with Exposures to Mixtures of Chlorinated Dibenzo-p-Dioxins and-Dibenzofurans (CDDs and CDFs) and 1989 Update*, Risk Assessment Forum, Office of Research and Development, U. S. Environmental Protection Agency, Washington, D.C., PB90-145756.

U.S. EPA (1995), memorandum from Stanford J. Smucker, Ph.D., Technical Support Section (H-9-3), U. S. Environmental Protection Agency, Region IX.

Appendix F

Tables

Table F-1. Soil concentration and Toxicity Equivalence Factors (TEFs) of chlorinated dibenzodioxins (CDD) and chlorinated dibenzofurans (CDF) at location 3SS-850-102 (0.0 feet).

CDD/CDF analyte	Measured concentration (ppt)	Measured concentration (ppm)	Toxicity equivalence factor (TEF)	Concentration based on TEF (ppm)
2,3,7,8-TCDD	ND	ND	1.00E+00 ✓	
Total TCDD	ND	ND	0.00E+00 ✓	
Other TCDD	ND	ND	1.00E-02 ?	
1,2,3,7,8-PeCDD	ND	ND	5.00E-01 1	
Total PeCDD	ND	ND	0.00E+00 ✓	.04
Other PeCDD	ND	ND	5.00E-03 ?	
1,2,3,4,7,8-HxCDD	ND	ND	4.00E-02 .1	
1,2,3,6,7,8-HxCDD	1.70E+00	1.70E-06	4.00E-02 .1	6.80E-08
1,2,3,7,8,9-HxCDD	2.40E+00	2.40E-06	4.00E-02 .1	9.60E-08
Total HxCDD	7.30E+00	7.30E-06	0.00E+00 ✓	0.00E+00
Other HxCDD	7.30E+00	7.30E+06	4.00E-04 ?	0.00E+00
1,2,3,4,6,7,8-HpCDD	1.80E+01	1.80E-05	1.00E-03 .01	1.80E-08
Total HpCDD	3.10E+01	3.10E-05	0.00E+00 ✓	0.00E+00
Other HpCDD	1.30E+01	1.30E-05	1.00E-05 ?	1.30E-10
OCDD	1.60E+02	1.60E-04	0.00E+00 .0001	0.00E+00
2,3,7,8-TCDF	2.20E+01	2.20E-05	1.00E-01 .1 ✓	2.20E-06
Total TCDF	1.70E+02	1.70E-04	0.00E+00 ✓	0.00E+00
Other TCDF	1.48E+02	1.48E-04	1.00E-03 ?	1.48E-07
1,2,3,7,8-PeCDF	6.30E+00	6.30E-06	1.00E-01 .05	6.30E-07
2,3,4,7,8-PeCDF	1.40E+01	1.40E-05	1.00E-01 .5	1.40E-06
Total PeCDF	8.40E+01	8.40E-05	0.00E+00 ✓	0.00E+00
Other PeCDF	6.37E+01	6.37E-05	1.00E-03 ?	6.37E-08
1,2,3,4,7,8-HxCDF	4.20E+00	4.20E-06	1.00E-02 .1	4.20E-08
1,2,3,6,7,8-HxCDF	2.40E+00	2.40E-06	1.00E-02 .1	2.40E-08
2,3,4,6,7,8-HxCDF	2.00E+00	2.00E-06	1.00E-02 .1	2.00E-08
1,2,3,7,8,9-HxCDF	2.60E+00	2.60E-06	1.00E-02 .1	2.60E-08
Total HxCDF	2.20E+01	2.20E-05	0.00E+00 ✓	0.00E+00
Other HxCDF	1.08E+01	1.08E-05	1.00E-04 ?	1.08E-09
1,2,3,4,6,7,8-HpCDF	4.60E+00	4.60E-06	1.00E-03 .01	4.60E-09
1,2,3,4,7,8,9-HpCDF	5.90E-01	5.90E-07	1.00E-03 .01	5.90E-10
Total HpCDF	1.30E+01	1.30E-05	0.00E+00 ✓	0.00E+00
Other HpCDF	7.81E+00	7.81E-06	1.00E-05 ?	7.81E-11
OCDF	1.10E+01	1.10E-05	0.00E+00 .0001	0.00E+00
		Total concentration based on TEF	=	*4.74E-6*

Note: Footnotes to appear on the following page.

Table F-1. (Continued)

Footnotes:

CDD = Chlorinated dibenzo-p-dioxin.

CDF = Chlorinated dibenzofuran.

HpCDD = Heptachlorinated dibenzo-p-dioxin.

HpCDF = Heptachlorinated dibenzofuran.

HxCDD = Hexachlorinated dibenzo-p-dioxin.

HxCDF = Hexachlorinated dibenzofuran.

ND = Not detected.

OCDD = Octachlorodibenzo-p-dioxin.

OCDF = Octachlorodibenzofuran.

PeCDD = Pentachlorinated dibenzo-p-dioxin.

PeCDF = Pentachlorinated dibenzofuran.

ppm = Parts per million.

ppt = Parts per trillion.

TCDD = Tetrachlorodibenzo-p-dioxin.

TCDF = Tetrachlorinated dibenzofuran.

TEF = Toxicity Equivalence Factor

Table F-2. Soil concentration and Toxicity Equivalence Factors (TEFs) of chlorinated dibenzodioxins (CDD) and chlorinated dibenzofurans (CDF) at location 3SS-850-107 (0.0 feet).

CDD/CDF analyte	Measured concentration (ppt)	Measured concentration (ppm)	Toxicity equivalence factor (TEF)	Concentration based on TEF (ppm)
2,3,7,8-TCDD	ND	ND	1.00E+00	
Total TCDD	ND	ND	0.00E+00	
Other TCDD	ND	ND	1.00E-02	
1,2,3,7,8-PeCDD	ND	ND	5.00E-01	
Total PeCDD	ND	ND	0.00E+00	
Other PeCDD	ND	ND	5.00E-03	
1,2,3,4,7,8-HxCDD	8.60E-01	8.60E-07	4.00E-02	3.44E-08
1,2,3,6,7,8-HxCDD	2.50E+00	2.50E-06	4.00E-02	1.00E-07
1,2,3,7,8,9-HxCDD	1.60E+00	1.60E-06	4.00E-02	6.40E-08
Total HxCDD	1.50E+01	1.50E-05	0.00E+00	0.00E+00
Other HxCDD	1.00E+01	1.00E-05	4.00E-04	4.02E-09
1,2,3,4,6,7,8-HpCDD	4.80E+01	4.80E-05	1.00E-03	4.80E-08
Total HpCDD	8.50E+01	8.50E-05	0.00E+00	0.00E+00
Other HpCDD	3.70E+01	3.70E-05	1.00E-05	3.70E-10
OCDD	4.10E+02	4.10E-04	0.00E+00	0.00E+00
2,3,7,8-TCDF	1.00E+03	1.00E-03	1.00E-01	1.00E-04
Total TCDF	6.20E+03	6.20E-03	0.00E+00	0.00E+00
Other TCDF	5.20E+03	5.20E-03	1.00E-03	5.20E-06
1,2,3,7,8-PeCDF	3.30E+02	3.30E-04	1.00E-01	3.30E-05
2,3,4,7,8-PeCDF	7.80E+02	7.80E-04	1.00E-01	7.80E-05
Total PeCDF	4.30E+03	4.30E-03	0.00E+00	0.00E+00
Other PeCDF	3.19E+03	3.19E-03	1.00E-03	3.19E-06
1,2,3,4,7,8-HxCDF	2.40E+02	2.40E-04	1.00E-02	2.40E-06
1,2,3,6,7,8-HxCDF	2.00E+02	2.00E-04	1.00E-02	2.00E-06
2,3,4,6,7,8-HxCDF	6.60E+01	6.60E-05	1.00E-02	6.60E-07
1,2,3,7,8,9-HxCDF	2.80E+01	2.80E-05	1.00E-02	2.80E-07
Total HxCDF	1.20E+03	1.20E-03	0.00E+00	0.00E+00
Other HxCDF	6.66E+02	6.66E-04	1.00E-04	6.66E-08
1,2,3,4,6,7,8-HpCDF	7.90E+01	7.90E-05	1.00E-03	7.90E-08
1,2,3,4,7,8,9-HpCDF	1.60E+01	1.60E-05	1.00E-03	1.60E-08
Total HpCDF	1.40E+02	1.40E-04	0.00E+00	0.00E+00
Other HpCDF	4.50E+01	4.50E-05	1.00E-05	4.50E-10
OCDF	2.00E+01	2.00E-05	0.00E+00	0.00E+00
		Total concentration based on TEF	=	*2.25E-04*

Note: Footnotes to appear on the following page.

Table F-2. (Continued)

Footnotes:

CDD = Chlorinated dibenzo-p-dioxin.
CDF = Chlorinated dibenzofuran.
HpCDD = Heptachlorinated dibenzo-p-dioxin.
HpCDF = Heptachlorinated dibenzofuran.
HxCDD = Hexachlorinated dibenzo-p-dioxin.
HxCDF = Hexachlorinated dibenzofuran.
ND = Not detected.
OCDD = Octachlorodibenzo-p-dioxin.
OCDF = Octachlorodibenzofuran.
PeCDD = Pentachlorinated dibenzo-p-dioxin.
PeCDF = Pentachlorinated dibenzofuran.
ppm = Parts per million.
ppt = Parts per trillion.
TCDD = Tetrachlorodibenzo-p-dioxin.
TCDF = Tetrachlorinated dibenzofuran.
TEF = Toxicity Equivalence Factor

Table F-3. Soil concentration and Toxicity Equivalence Factors (TEFs) of chlorinated dibenzodioxins (CDD) and chlorinated dibenzofurans (CDF) at location 3SS-850-107 (0.5 feet).

CDD/CDF analyte	Measured concentration (ppt)	Measured concentration (ppm)	Toxicity equivalence factor (TEF)	Concentration based on TEF (ppm)
2,3,7,8-TCDD	7.20E-01	7.20E-07	1.00E+00	7.20E-07
Total TCDD	2.00E+00	2.00E-06	0.00E+00	0.00E+00
Other TCDD	1.28E+00	1.28E-06	1.00E-02	1.28E-08
1,2,3,7,8-PeCDD	ND	ND	5.00E-01	
Total PeCDD	ND	ND	0.00E+00	
Other PeCDD	ND	ND	5.00E-03	
1,2,3,4,7,8-HxCDD	ND	ND	4.00E-02	
1,2,3,6,7,8-HxCDD	1.50E+00	1.50E-06	4.00E-02	6.00E-08
1,2,3,7,8,9-HxCDD	1.30E+00	1.30E-06	4.00E-02	5.20E-08
Total HxCDD	6.60E+00	6.60E-06	0.00E+00	0.00E+00
Other HxCDD	3.80E+00	3.80E-06	4.00E-04	1.52E-09
1,2,3,4,6,7,8-HpCDD	1.90E+01	1.90E-05	1.00E-03	1.90E-08
Total HpCDD	3.40E+01	3.40E-05	0.00E+00	0.00E+00
Other HpCDD	1.50E+01	1.50E-05	1.00E-05	1.50E-10
OCDD	1.70E+02	1.70E-04	0.00E+00	0.00E+00
2,3,7,8-TCDF	5.90E+02	5.90E-04	1.00E-01	5.90E-05
Total TCDF	3.60E+03	3.60E-03	0.00E+00	0.00E+00
Other TCDF	3.01E+03	3.01E-03	1.00E-03	3.01E-06
1,2,3,7,8-PeCDF	2.10E+02	2.10E-04	1.00E-01	2.10E-05
2,3,4,7,8-PeCDF	4.50E+02	4.50E-04	1.00E-01	4.50E-05
Total PeCDF	2.70E+03	2.70E-03	0.00E+00	0.00E+00
Other PeCDF	2.04E+03	2.04E-03	1.00E-03	2.04E-06
1,2,3,4,7,8-HxCDF	1.40E+02	1.40E-04	1.00E-02	1.40E-06
1,2,3,6,7,8-HxCDF	1.20E+02	1.20E-04	1.00E-02	1.20E-06
2,3,4,6,7,8-HxCDF	4.30E+01	4.30E-05	1.00E-02	4.30E-07
1,2,3,7,8,9-HxCDF	1.80E+01	1.80E-05	1.00E-02	1.80E-07
Total HxCDF	7.40E+02	7.40E-04	0.00E+00	0.00E+00
Other HxCDF	4.19E+02	4.19E-04	1.00E-04	4.19E-08
1,2,3,4,6,7,8-HpCDF	4.50E+01	4.50E-05	1.00E-03	4.50E-08
1,2,3,4,7,8,9-HpCDF	1.20E+01	1.20E-05	1.00E-03	1.20E-08
Total HpCDF	8.30E+01	8.30E-05	0.00E+00	0.00E+00
Other HpCDF	2.60E+01	2.60E-05	1.00E-05	2.60E-10
OCDF	8.10E+00	8.10E-06	0.00E+00	0.00E+00
		Total concentration based on TEF	=	*1.34E-04*

Note: Footnotes to appear on the following page.

Table F-3. (Continued)

Footnotes:

CDD = Chlorinated dibenzo-p-dioxin.
CDF = Chlorinated dibenzofuran.
HpCDD = Heptachlorinated dibenzo-p-dioxin.
HpCDF = Heptachlorinated dibenzofuran.
HxCDD = Hexachlorinated dibenzo-p-dioxin.
HxCDF = Hexachlorinated dibenzofuran.
ND = Not detected.
OCDD = Octachlorodibenzo-p-dioxin.
OCDF = Octachlorodibenzofuran.
PeCDD = Pentachlorinated dibenzo-p-dioxin.
PeCDF = Pentachlorinated dibenzofuran.
ppm = Parts per million.
ppt = Parts per trillion.
TCDD = Tetrachlorodibenzo-p-dioxin.
TCDF = Tetrachlorinated dibenzofuran.
TEF = Toxicity Equivalence Factor

Table F-4. Soil concentration and Toxicity Equivalence Factors (TEFs) of chlorinated dibenzodioxins (CDD) and chlorinated dibenzofurans (CDF) at location 3SS-850-126 (0.0 feet).

CDD/CDF analyte	Measured concentration (ppt)	Measured concentration (ppm)	Toxicity equivalence factor (TEF)	Concentration based on TEF (ppm)
2,3,7,8-TCDD	ND	ND	1.00E+00	
Total TCDD	ND	ND	0.00E+00	
Other TCDD	ND	ND	1.00E-02	
1,2,3,7,8-PeCDD	ND	ND	5.00E-01	
Total PeCDD	ND	ND	0.00E+00	
Other PeCDD	ND	ND	5.00E-03	
1,2,3,4,7,8-HxCDD	ND	ND	4.00E-02	
1,2,3,6,7,8-HxCDD	ND	ND	4.00E-02	
1,2,3,7,8,9-HxCDD	ND	ND	4.00E-02	
Total HxCDD	ND	ND	0.00E+00	
Other HxCDD	ND	ND	4.00E-04	
1,2,3,4,6,7,8-HpCDD	1.10E+01	1.10E-05	1.00E-03	1.10E-08
Total HpCDD	1.80E+01	1.80E-05	0.00E+00	0.00E+00
Other HpCDD	7.00E+00	7.00E-06	1.00E-05	7.00E-11
OCDD	8.80E+01	8.80E-05	0.00E+00	0.00E+00
2,3,7,8-TCDF	4.10E+00	4.10E-06	1.00E-01	4.10E-07
Total TCDF	2.90E+01	2.90E-05	0.00E+00	0.00E+00
Other TCDF	2.49E+01	2.49E-05	1.00E-03	2.49E-08
1,2,3,7,8-PeCDF	1.50E+00	1.50E-06	1.00E-01	1.50E-07
2,3,4,7,8-PeCDF	2.70E+00	2.70E-06	1.00E-01	2.70E-07
Total PeCDF	1.50E+01	1.50E-05	0.00E+00	0.00E+00
Other PeCDF	1.08E+01	1.08E-05	1.00E-03	1.08E-08
1,2,3,4,7,8-HxCDF	1.00E+00	1.00E-06	1.00E-02	1.00E-08
1,2,3,6,7,8-HxCDF	6.90E-01	6.90E-07	1.00E-02	6.90E-09
2,3,4,6,7,8-HxCDF	6.80E-01	6.80E-07	1.00E-02	6.80E-09
1,2,3,7,8,9-HxCDF	2.40E+00	2.40E-06	1.00E-02	2.40E-08
Total HxCDF	9.30E+00	9.30E-06	0.00E+00	0.00E+00
Other HxCDF	4.53E+00	4.53E-06	1.00E-04	4.53E-10
1,2,3,4,6,7,8-HpCDF	3.90E+00	3.90E-06	1.00E-03	3.90E-09
1,2,3,4,7,8,9-HpCDF	ND	ND	1.00E-03	
Total HpCDF	1.60E+01	1.60E-05	0.00E+00	0.00E+00
Other HpCDF	1.21E+01	1.21E-05	1.00E-05	1.21E-10
OCDF	1.90E+01	1.90E-05	0.00E+00	0.00E+00
		Total concentration based on TEF	=	*9.29E-07*

Note: Footnotes to appear on the following page.

Table F-4. (Continued)

Footnotes:

CDD = Chlorinated dibenzo-p-dioxin.
CDF = Chlorinated dibenzofuran.
HpCDD = Heptachlorinated dibenzo-p-dioxin.
HpCDF = Heptachlorinated dibenzofuran.
HxCDD = Hexachlorinated dibenzo-p-dioxin.
HxCDF = Hexachlorinated dibenzofuran.
ND = Not detected.
OCDD = Octachlorodibenzo-p-dioxin.
OCDF = Octachlorodibenzofuran.
PeCDD = Pentachlorinated dibenzo-p-dioxin.
PeCDF = Pentachlorinated dibenzofuran.
ppm = Parts per million.
ppt = Parts per trillion.
TCDD = Tetrachlorodibenzo-p-dioxin.
TCDF = Tetrachlorinated dibenzofuran.
TEF = Toxicity Equivalence Factor

Table F-5. Soil concentration and Toxicity Equivalence Factors (TEFs) of chlorinated dibenzodioxins (CDD) and chlorinated dibenzofurans (CDF) at location 3SS-850-139 (0.0 feet).

CDD/CDF analyte	Measured concentration (ppt)	Measured concentration (ppm)	Toxicity equivalence factor (TEF)	Concentration based on TEF (ppm)
2,3,7,8-TCDD	ND	ND	1.00E+00	
Total TCDD	ND	ND	0.00E+00	
Other TCDD	ND	ND	1.00E-02	
1,2,3,7,8-PeCDD	ND	ND	5.00E-01	
Total PeCDD	ND	ND	0.00E+00	
Other PeCDD	ND	ND	5.00E-03	
1,2,3,4,7,8-HxCDD	ND	ND	4.00E-02	
1,2,3,6,7,8-HxCDD	3.70E+00	3.70E-06	4.00E-02	1.48E-07
1,2,3,7,8,9-HxCDD	2.20E+00	2.20E-06	4.00E-02	8.80E-08
Total HxCDD	1.60E+01	1.60E-05	0.00E+00	0.00E+00
Other HxCDD	1.01E+01	1.01E-05	4.00E-04	4.04E-09
1,2,3,4,6,7,8-HpCDD	5.70E+01	5.70E-05	1.00E-03	5.70E-08
Total HpCDD	9.70E+01	9.70E-05	0.00E+00	0.00E+00
Other HpCDD	4.00E+01	4.00E-05	1.00E-05	4.00E-10
OCDD	4.80E+02	4.80E-04	0.00E+00	0.00E+00
2,3,7,8-TCDF	1.80E+03	1.80E-03	1.00E-01	1.80E-04
Total TCDF	1.20E+04	1.20E-02	0.00E+00	0.00E+00
Other TCDF	1.02E+04	1.02E-02	1.00E-03	1.02E-05
1,2,3,7,8-PeCDF	3.60E+02	3.60E-04	1.00E-01	3.60E-05
2,3,4,7,8-PeCDF	1.20E+03	1.20E-03	1.00E-01	1.20E-04
Total PeCDF	6.60E+03	6.60E-03	0.00E+00	0.00E+00
Other PeCDF	5.04E+03	5.04E-03	1.00E-03	5.04E-06
1,2,3,4,7,8-HxCDF	3.10E+02	3.10E-04	1.00E-02	3.10E-06
1,2,3,6,7,8-HxCDF	1.70E+02	1.70E-04	1.00E-02	1.70E-06
2,3,4,6,7,8-HxCDF	9.70E+01	9.70E-05	1.00E-02	9.70E-07
1,2,3,7,8,9-HxCDF	4.10E+01	4.10E-05	1.00E-02	4.10E-07
Total HxCDF	1.20E+03	1.20E-03	0.00E+00	0.00E+00
Other HxCDF	5.82E+02	5.82E-04	1.00E-04	5.82E-08
1,2,3,4,6,7,8-HpCDF	7.70E+01	7.70E-05	1.00E-03	7.70E-08
1,2,3,4,7,8,9-HpCDF	2.80E+01	2.80E-05	1.00E-03	2.80E-08
Total HpCDF	1.70E+02	1.70E-04	0.00E+00	0.00E+00
Other HpCDF	6.50E+01	6.50E-05	1.00E-05	6.50E-10
OCDF	1.70E+01	1.70E-05	0.00E+00	0.00E+00
		Total concentration based on TEF	=	*3.58E-04*

Note: Footnotes to appear on the following page.

Table F-5. (Continued)

Footnotes:

CDD = Chlorinated dibenzo-p-dioxin.
CDF = Chlorinated dibenzofuran.
HpCDD = Heptachlorinated dibenzo-p-dioxin.
HpCDF = Heptachlorinated dibenzofuran.
HxCDD = Hexachlorinated dibenzo-p-dioxin.
HxCDF = Hexachlorinated dibenzofuran.
ND = Not detected.
OCDD = Octachlorodibenzo-p-dioxin.
OCDF = Octachlorodibenzofuran.
PeCDD = Pentachlorinated dibenzo-p-dioxin.
PeCDF = Pentachlorinated dibenzofuran.
ppm = Parts per million.
ppt = Parts per trillion.
TCDD = Tetrachlorodibenzo-p-dioxin.
TCDF = Tetrachlorinated dibenzofuran.
TEF = Toxicity Equivalence Factor

Table F-6. Soil concentration and Toxicity Equivalence Factors (TEFs) of chlorinated dibenzodioxins (CDD) and chlorinated dibenzofurans (CDF) at location 3SS-850-140 (0.0 feet).

CDD/CDF analyte	Measured concentration (ppt)	Measured concentration (ppm)	Toxicity equivalence factor (TEF)	Concentration based on TEF (ppm)
2,3,7,8-TCDD	1.40E+00	1.40E-06	1.00E+00	1.40E-06
Total TCDD	4.30E+00	4.30E-06	0.00E+00	0.00E+00
Other TCDD	2.90E+00	2.90E-06	1.00E-02	2.90E-08
1,2,3,7,8-PeCDD	ND	ND	5.00E-01	
Total PeCDD	ND	ND	0.00E+00	
Other PeCDD	ND	ND	5.00E-03	
1,2,3,4,7,8-HxCDD	ND	ND	4.00E-02	
1,2,3,6,7,8-HxCDD	1.10E+00	1.10E-06	4.00E-02	4.40E-08
1,2,3,7,8,9-HxCDD	ND	ND	4.00E-02	
Total HxCDD	5.90E+00	5.90E-06	0.00E+00	0.00E+00
Other HxCDD	4.80E+00	4.80E-06	4.00E-04	1.92E-09
1,2,3,4,6,7,8-HpCDD	2.30E+01	2.30E-05	1.00E-03	2.30E-08
Total HpCDD	3.70E+01	3.70E-05	0.00E+00	0.00E+00
Other HpCDD	1.40E+01	1.40E-05	1.00E-05	1.40E-10
OCDD	1.60E+02	1.60E-04	0.00E+00	0.00E+00
2,3,7,8-TCDF	1.90E+03	1.90E-03	1.00E-01	1.90E-04
Total TCDF	1.10E+04	1.10E-02	0.00E+00	0.00E+00
Other TCDF	9.10E+03	9.10E-03	1.00E-03	9.10E-06
1,2,3,7,8-PeCDF	6.10E+02	6.10E-04	1.00E-01	6.10E-05
2,3,4,7,8-PeCDF	1.70E+03	1.70E-03	1.00E-01	1.70E-04
Total PeCDF	8.60E+03	8.60E-03	0.00E+00	0.00E+00
Other PeCDF	6.29E+03	6.29E-03	1.00E-03	6.29E-06
1,2,3,4,7,8-HxCDF	5.40E+02	5.40E-04	1.00E-02	5.40E-06
1,2,3,6,7,8-HxCDF	4.30E+02	4.30E-04	1.00E-02	4.30E-06
2,3,4,6,7,8-HxCDF	1.50E+02	1.50E-04	1.00E-02	1.50E-06
1,2,3,7,8,9-HxCDF	9.70E+01	9.70E-05	1.00E-02	9.70E-07
Total HxCDF	2.70E+03	2.70E-03	0.00E+00	0.00E+00
Other HxCDF	1.48E+03	1.48E-03	1.00E-04	1.48E-07
1,2,3,4,6,7,8-HpCDF	1.50E+02	1.50E-04	1.00E-03	1.50E-07
1,2,3,4,7,8,9-HpCDF	5.60E+01	5.60E-05	1.00E-03	5.60E-08
Total HpCDF	3.00E+02	3.00E-04	0.00E+00	0.00E+00
Other HpCDF	9.40E+01	9.40E-05	1.00E-05	9.40E-10
OCDF	2.50E+01	2.50E-05	0.00E+00	0.00E+00
		Total concentration based on TEF	=	*4.50E-04*

Note: Footnotes to appear on the following page.

Table F-6. (Continued)

Footnotes:

CDD = Chlorinated dibenzo-p-dioxin.
CDF = Chlorinated dibenzofuran.
HpCDD = Heptachlorinated dibenzo-p-dioxin.
HpCDF = Heptachlorinated dibenzofuran.
HxCDD = Hexachlorinated dibenzo-p-dioxin.
HxCDF = Hexachlorinated dibenzofuran.
ND = Not detected.
OCDD = Octachlorodibenzo-p-dioxin.
OCDF = Octachlorodibenzofuran.
PeCDD = Pentachlorinated dibenzo-p-dioxin.
PeCDF = Pentachlorinated dibenzofuran.
ppm = Parts per million.
ppt = Parts per trillion.
TCDD = Tetrachlorodibenzo-p-dioxin.
TCDF = Tetrachlorinated dibenzofuran.
TEF = Toxicity Equivalence Factor

Table F-7. Soil concentration and Toxicity Equivalence Factors (TEFs) of chlorinated dibenzodioxins (CDD) and chlorinated dibenzofurans (CDF) at location 3SS-850-142 (0.0 feet).

CDD/CDF analyte	Measured concentration (ppt)	Measured concentration (ppm)	Toxicity equivalence factor (TEF)	Concentration based on TEF (ppm)
2,3,7,8-TCDD	8.10E-01	8.10E-07	1.00E+00	8.10E-07
Total TCDD	3.80E+00	3.80E-06	0.00E+00	0.00E+00
Other TCDD	2.99E+00	2.99E-06	1.00E-02	2.99E-08
1,2,3,7,8-PeCDD	ND	ND	5.00E-01	
Total PeCDD	ND	ND	0.00E+00	
Other PeCDD	ND	ND	5.00E-03	
1,2,3,4,7,8-HxCDD	ND	ND	4.00E-02	
1,2,3,6,7,8-HxCDD	ND	ND	4.00E-02	
1,2,3,7,8,9-HxCDD	ND	ND	4.00E-02	
Total HxCDD	ND	ND	0.00E+00	
Other HxCDD	ND	ND	4.00E-04	
1,2,3,4,6,7,8-HpCDD	3.10E+01	3.10E-05	1.00E-03	3.10E-08
Total HpCDD	5.70E+01	5.70E-05	0.00E+00	0.00E+00
Other HpCDD	2.60E+01	2.60E-05	1.00E-05	2.60E-10
OCDD	2.40E+02	2.40E-04	0.00E+00	0.00E+00
2,3,7,8-TCDF	9.60E+03	9.60E-03	1.00E-01	9.60E-04
Total TCDF	4.80E+04	4.80E-02	0.00E+00	0.00E+00
Other TCDF	3.84E+04	3.84E-02	1.00E-03	3.84E-05
1,2,3,7,8-PeCDF	2.60E+03	2.60E-03	1.00E-01	2.60E-04
2,3,4,7,8-PeCDF	9.10E+03	9.10E-03	1.00E-01	9.10E-04
Total PeCDF	5.70E+04	5.70E-02	0.00E+00	0.00E+00
Other PeCDF	4.53E+04	4.53E-02	1.00E-03	4.53E-05
1,2,3,4,7,8-HxCDF	2.30E+03	2.30E-03	1.00E-02	2.30E-05
1,2,3,6,7,8-HxCDF	2.10E+03	2.10E-03	1.00E-02	2.10E-05
2,3,4,6,7,8-HxCDF	7.50E+02	7.50E-04	1.00E-02	7.50E-06
1,2,3,7,8,9-HxCDF	2.50E+02	2.50E-04	1.00E-02	2.50E-06
Total HxCDF	1.10E+04	1.10E-02	0.00E+00	0.00E+00
Other HxCDF	5.60E+03	5.60E-03	1.00E-04	5.60E-07
1,2,3,4,6,7,8-HpCDF	6.40E+02	6.40E-04	1.00E-03	6.40E-07
1,2,3,4,7,8,9-HpCDF	2.00E+02	2.00E-04	1.00E-03	2.00E-07
Total HpCDF	1.30E+03	1.30E-03	0.00E+00	0.00E+00
Other HpCDF	4.60E+02	4.60E-04	1.00E-05	4.60E-09
OCDF	1.10E+02	1.10E-04	0.00E+00	0.00E+00
		Total concentration based on TEF	=	*2.27E-03*

Note: Footnotes to appear on the following page.

Table F-7. (Continued)

Footnotes:

CDD = Chlorinated dibenzo-p-dioxin.
CDF = Chlorinated dibenzofuran.
HpCDD = Heptachlorinated dibenzo-p-dioxin.
HpCDF = Heptachlorinated dibenzofuran.
HxCDD = Hexachlorinated dibenzo-p-dioxin.
HxCDF = Hexachlorinated dibenzofuran.
ND = Not detected.
OCDD = Octachlorodibenzo-p-dioxin.
OCDF = Octachlorodibenzofuran.
PeCDD = Pentachlorinated dibenzo-p-dioxin.
PeCDF = Pentachlorinated dibenzofuran.
ppm = Parts per million.
ppt = Parts per trillion.
TCDD = Tetrachlorodibenzo-p-dioxin.
TCDF = Tetrachlorinated dibenzofuran.
TEF = Toxicity Equivalence Factor

Table F-8. Soil concentration and Toxicity Equivalence Factors (TEFs) of chlorinated dibenzodioxins (CDD) and chlorinated dibenzofurans (CDF) at location 3SS-850-~~102~~ 142 (0.5 feet).

CDD/CDF analyte	Measured concentration (ppt)	Measured concentration (ppm)	Toxicity equivalence factor (TEF)	Concentration based on TEF (ppm)
2,3,7,8-TCDD	ND	ND	1.00E+00	
Total TCDD	7.40E-01	7.40E-07	0.00E+00	0.00E+00
Other TCDD	7.40E-01	7.40E-07	1.00E-02	7.40E-09
1,2,3,7,8-PeCDD	ND	ND	5.00E-01	
Total PeCDD	ND	ND	0.00E+00	
Other PeCDD	ND	ND	5.00E-03	
1,2,3,4,7,8-HxCDD	ND	ND	4.00E-02	
1,2,3,6,7,8-HxCDD	3.30E+00	3.30E-06	4.00E-02	1.32E-07
1,2,3,7,8,9-HxCDD	ND	ND	4.00E-02	
Total HxCDD	3.30E+00	3.30E-06	0.00E+00	0.00E+00
Other HxCDD	ND	ND	4.00E-04	
1,2,3,4,6,7,8-HpCDD	5.20E+01	5.20E-05	1.00E-03	5.20E-08
Total HpCDD	9.30E+01	9.30E-05	0.00E+00	0.00E+00
Other HpCDD	4.10E+01	4.10E-05	1.00E-05	4.10E-10
OCDD	5.50E+02	5.50E-04	0.00E+00	0.00E+00
2,3,7,8-TCDF	2.60E+03	2.60E-03	1.00E-01	2.60E-04
Total TCDF	1.50E+04	1.50E-02	0.00E+00	0.00E+00
Other TCDF	1.24E+04	1.24E-02	1.00E-03	1.24E-05
1,2,3,7,8-PeCDF	6.70E+02	6.70E-04	1.00E-01	6.70E-05
2,3,4,7,8-PeCDF	2.20E+03	2.20E-03	1.00E-01	2.20E-04
Total PeCDF	1.00E+04	1.00E-02	0.00E+00	0.00E+00
Other PeCDF	7.13E+03	7.13E-03	1.00E-03	7.13E-06
1,2,3,4,7,8-HxCDF	5.50E+02	5.50E-04	1.00E-02	5.50E-06
1,2,3,6,7,8-HxCDF	5.10E+02	5.10E-04	1.00E-02	5.10E-06
2,3,4,6,7,8-HxCDF	1.80E+02	1.80E-04	1.00E-02	1.80E-06
1,2,3,7,8,9-HxCDF	6.30E+01	6.30E-05	1.00E-02	6.30E-07
Total HxCDF	3.10E+03	3.10E-03	0.00E+00	0.00E+00
Other HxCDF	1.80E+03	1.80E-03	1.00E-04	1.80E-07
1,2,3,4,6,7,8-HpCDF	1.70E+02	1.70E-04	1.00E-03	1.70E-07
1,2,3,4,7,8,9-HpCDF	4.60E+01	4.60E-05	1.00E-03	4.60E-08
Total HpCDF	3.40E+02	3.40E-04	0.00E+00	0.00E+00
Other HpCDF	1.24E+02	1.24E-04	1.00E-05	1.24E-09
OCDF	2.60E+01	2.60E-05	0.00E+00	0.00E+00
		Total concentration based on TEF	=	*5.80E-04*

Note: Footnotes to appear on the following page.

Table F-8. (Continued)

Footnotes:

CDD = Chlorinated dibenzo-p-dioxin.
CDF = Chlorinated dibenzofuran.
HpCDD = Heptachlorinated dibenzo-p-dioxin.
HpCDF = Heptachlorinated dibenzofuran.
HxCDD = Hexachlorinated dibenzo-p-dioxin.
HxCDF = Hexachlorinated dibenzofuran.
ND = Not detected.
OCDD = Octachlorodibenzo-p-dioxin.
OCDF = Octachlorodibenzofuran.
PeCDD = Pentachlorinated dibenzo-p-dioxin.
PeCDF = Pentachlorinated dibenzofuran.
ppm = Parts per million.
ppt = Parts per trillion.
TCDD = Tetrachlorodibenzo-p-dioxin.
TCDF = Tetrachlorinated dibenzofuran.
TEF = Toxicity Equivalence Factor

Table F-9. Soil concentration and Toxicity Equivalence Factors (TEFs) of chlorinated dibenzodioxins (CDD) and chlorinated dibenzofurans (CDF) at location 3SS-850-147 (0.0 feet).

CDD/CDF analyte	Measured concentration (ppt)	Measured concentration (ppm)	Toxicity equivalence factor (TEF)	Concentration based on TEF (ppm)
2,3,7,8-TCDD	ND	ND	1.00E+00	
Total TCDD	ND	ND	0.00E+00	
Other TCDD	ND	ND	1.00E-02	
1,2,3,7,8-PeCDD	ND	ND	5.00E-01	
Total PeCDD	ND	ND	0.00E+00	
Other PeCDD	ND	ND	5.00E-03	
1,2,3,4,7,8-HxCDD	ND	ND	4.00E-02	
1,2,3,6,7,8-HxCDD	9.30E-01	9.30E-07	4.00E-02	3.72E-08
1,2,3,7,8,9-HxCDD	1.10E+00	1.10E-06	4.00E-02	4.40E-08
Total HxCDD	3.60E+00	3.60E-06	0.00E+00	0.00E+00
Other HxCDD	1.57E+00	1.57E-06	4.00E-04	6.28E-10
1,2,3,4,6,7,8-HpCDD	3.70E+00	3.70E-06	1.00E-03	3.70E-09
Total HpCDD	6.40E+00	6.40E-06	0.00E+00	0.00E+00
Other HpCDD	2.70E+00	2.70E-06	1.00E-05	2.70E-11
OCDD	2.20E+01	2.20E-05	0.00E+00	0.00E+00
2,3,7,8-TCDF	1.90E+01	1.90E-05	1.00E-01	1.90E-06
Total TCDF	1.40E+02	1.40E-04	0.00E+00	0.00E+00
Other TCDF	1.21E+02	1.21E-04	1.00E-03	1.21E-07
1,2,3,7,8-PeCDF	4.60E+00	4.60E-06	1.00E-01	4.60E-07
2,3,4,7,8-PeCDF	9.70E+00	9.70E-06	1.00E-01	9.70E-07
Total PeCDF	6.10E+01	6.10E-05	0.00E+00	0.00E+00
Other PeCDF	4.67E+01	4.67E-05	1.00E-03	4.67E-08
1,2,3,4,7,8-HxCDF	2.10E+00	2.10E-06	1.00E-02	2.10E-08
1,2,3,6,7,8-HxCDF	1.40E+00	1.40E-06	1.00E-02	1.40E-08
2,3,4,6,7,8-HxCDF	1.00E+00	1.00E-06	1.00E-02	1.00E-08
1,2,3,7,8,9-HxCDF	7.40E-01	7.40E-07	1.00E-02	7.40E-09
Total HxCDF	1.10E+01	1.10E-05	0.00E+00	0.00E+00
Other HxCDF	5.76E+00	5.76E-06	1.00E-04	5.76E-10
1,2,3,4,6,7,8-HpCDF	1.70E+00	1.70E-06	1.00E-03	1.70E-09
1,2,3,4,7,8,9-HpCDF	ND	ND	1.00E-03	
Total HpCDF	3.20E+00	3.20E-06	0.00E+00	0.00E+00
Other HpCDF	1.50E+00	1.50E-06	1.00E-05	1.50E-11
OCDF	1.50E+00	1.50E-06	0.00E+00	0.00E+00
		Total concentration based on TEF	=	*3.64E-06*

Note: Footnotes to appear on the following page.

Table F-9. (Continued)

Footnotes:

CDD = Chlorinated dibenzo-p-dioxin.
CDF = Chlorinated dibenzofuran.
HpCDD = Heptachlorinated dibenzo-p-dioxin.
HpCDF = Heptachlorinated dibenzofuran.
HxCDD = Hexachlorinated dibenzo-p-dioxin.
HxCDF = Hexachlorinated dibenzofuran.
ND = Not detected.
OCDD = Octachlorodibenzo-p-dioxin.
OCDF = Octachlorodibenzofuran.
PeCDD = Pentachlorinated dibenzo-p-dioxin.
PeCDF = Pentachlorinated dibenzofuran.
ppm = Parts per million.
ppt = Parts per trillion.
TCDD = Tetrachlorodibenzo-p-dioxin.
TCDF = Tetrachlorinated dibenzofuran.
TEF = Toxicity Equivalence Factor

Table F-10. Soil concentration and Toxicity Equivalence Factors (TEFs) of chlorinated dibenzodioxins (CDD) and chlorinated dibenzofurans (CDF) at location 3SS-850-154 (0.0 feet).

CDD/CDF analyte	Measured concentration (ppt)	Measured concentration (ppm)	Toxicity equivalence factor (TEF)	Concentration based on TEF (ppm)
2,3,7,8-TCDD	ND	ND	1.00E+00	
Total TCDD	ND	ND	0.00E+00	
Other TCDD	ND	ND	1.00E-02	
1,2,3,7,8-PeCDD	ND	ND	5.00E-01	
Total PeCDD	ND	ND	0.00E+00	
Other PeCDD	ND	ND	5.00E-03	
1,2,3,4,7,8-HxCDD	ND	ND	4.00E-02	
1,2,3,6,7,8-HxCDD	2.00E+00	2.00E-06	4.00E-02	8.00E-08
1,2,3,7,8,9-HxCDD	1.30E+00	1.30E-06	4.00E-02	5.20E-08
Total HxCDD	9.00E+00	9.00E-06	0.00E+00	0.00E+00
Other HxCDD	5.70E+00	5.70E-06	4.00E-04	2.28E-09
1,2,3,4,6,7,8-HpCDD	2.10E+01	2.10E-05	1.00E-03	2.10E-08
Total HpCDD	3.40E+01	3.40E-05	0.00E+00	0.00E+00
Other HpCDD	1.30E+01	1.30E-05	1.00E-05	1.30E-10
OCDD	1.40E+02	1.40E-04	0.00E+00	0.00E+00
2,3,7,8-TCDF	4.30E+00	4.30E-06	1.00E-01	4.30E-07
Total TCDF	2.90E+01	2.90E-05	0.00E+00	0.00E+00
Other TCDF	2.47E+01	2.47E-05	1.00E-03	2.47E-08
1,2,3,7,8-PeCDF	1.20E+00	1.20E-06	1.00E-01	1.20E-07
2,3,4,7,8-PeCDF	3.10E+00	3.10E-06	1.00E-01	3.10E-07
Total PeCDF	1.80E+01	1.80E-05	0.00E+00	0.00E+00
Other PeCDF	1.37E+01	1.37E-05	1.00E-03	1.37E-08
1,2,3,4,7,8-HxCDF	1.80E+00	1.80E-06	1.00E-02	1.80E-08
1,2,3,6,7,8-HxCDF	ND	ND	1.00E-02	
2,3,4,6,7,8-HxCDF	9.30E-01	9.30E-07	1.00E-02	9.30E-09
1,2,3,7,8,9-HxCDF	ND	ND	1.00E-02	
Total HxCDF	9.10E+00	9.10E-06	0.00E+00	0.00E+00
Other HxCDF	6.37E+00	6.37E-06	1.00E-04	6.37E-10
1,2,3,4,6,7,8-HpCDF	4.00E+00	4.00E-06	1.00E-03	4.00E-09
1,2,3,4,7,8,9-HpCDF	0.00E+00	0.00E+00	1.00E-03	0.00E+00
Total HpCDF	1.00E+01	1.00E-05	0.00E+00	0.00E+00
Other HpCDF	6.00E+00	6.00E-06	1.00E-05	6.00E-11
OCDF	7.00E+00	7.00E-06	0.00E+00	0.00E+00
		Total concentration based on TEF	=	*1.09E-06*

Note: Footnotes to appear on the following page.

Table F-10. (Continued)

Footnotes:

CDD = Chlorinated dibenzo-p-dioxin.
CDF = Chlorinated dibenzofuran.
HpCDD = Heptachlorinated dibenzo-p-dioxin.
HpCDF = Heptachlorinated dibenzofuran.
HxCDD = Hexachlorinated dibenzo-p-dioxin.
HxCDF = Hexachlorinated dibenzofuran.
ND = Not detected.
OCDD = Octachlorodibenzo-p-dioxin.
OCDF = Octachlorodibenzofuran.
PeCDD = Pentachlorinated dibenzo-p-dioxin.
PeCDF = Pentachlorinated dibenzofuran.
ppm = Parts per million.
ppt = Parts per trillion.
TCDD = Tetrachlorodibenzo-p-dioxin.
TCDF = Tetrachlorinated dibenzofuran.
TEF = Toxicity Equivalence Factor

Table F-11. Total Toxicity Equivalence Factors (TEFs) for surface soil sample locations in the Building 850 Operable Unit.

Sample location	Total TEF concentration (mg/kg)
3SS-850-102	4.74×10^{-6}
3SS-850-107-0.0F	2.25×10^{-4}[a]
3SS-850-107-0.5F	1.34×10^{-4}[a]
3SS-850-126	9.27×10^{-7}
3SS-850-139	3.58×10^{-4}[a]
3SS-850-140	4.50×10^{-4}[a]
3SS-850-142-0.0F	2.27×10^{-3}[a]
3SS-850-142-0.5F	5.80×10^{-4}[a]
3SS-850-147	3.64×10^{-6}
3SS-850-154	1.09×10^{-6}

[a] Value exceeds the Preliminary Remediation Goal (PRG) (U.S. EPA, 1995).

Appendix G

Comparative Statistical Analysis of Baseline (SWRI) and Post-SWRI Data for Volatile Organic Compounds in Ground Water from Pit 5

Appendix G

Comparative Statistical Analysis of Baseline (SWRI) and Post-SWRI Data for Volatile Organic Compounds in Ground Water from Pit 5

This appendix presents an evaluation of the data on ground water contaminants originating at pit 5. We evaluate the data obtained between the data cutoff date for the SWRI report (Webster-Scholten, 1994) of December 31, 1991, and August 1, 1995. The primary purpose of this evaluation is to determine whether our current understanding of VOC contamination in ground water from the pit 5 area differs substantially from our understanding of that contamination at the time the SWRI was prepared.

We examined the new ground water data to determine if any organic chemicals have been reported, other than those identified in the SWRI report as contaminants of potential concern. This examination included the monitor wells that were considered to characterize the region of contamination at the time of the SWRI (Table G-1). Data from the recently-constructed well W-Pit7-03 were also evaluated.

Our examination of post-SWRI data indicates that one VOC, 1,2-DCE, which had not been detected at the time of the SWRI, has been reported in samples collected from ground water monitor wells at pit 5 wells since the SWRI data cut-off date. However, 1,2-DCE has been reported only once, at a concentration of 1.0 µg/L. This reported detection was from a sample obtained from well K7-01 on August 16, 1993. Quarterly samples collected after that date have not revealed any additional evidence that 1,2-DCE is present as a ground water contaminant in the pit 5 region.

Our evaluation of ground water data collected from the pit 5 area after December 31, 1991, indicates the continued presence of several VOCs that were identified in the SWRI report (Webster-Scholten, 1994) as ground water contaminants in this area. These VOCs are TCE, 1,1-DCE, toluene, and acetone.

For the SWRI report, we calculated the 95% upper confidence limit of the mean concentration (95% UCL) of VOC contaminants in ground water from pit 5. Table G-2 presents summary statistics for these contaminants; these data were originally presented in Chapters 4 and 11 of the SWRI report (Webster-Scholten, 1994).

To determine whether the mean concentration of VOCs has changed over time, we re-calculated the 95% UCLs using data collected between December 31, 1991, and August 1, 1995. Table G-3 presents the summary statistics that resulted from these calculations. The most notable difference between the two tables is the substantially fewer number of compounds listed in Table G-3 than in G-2. This difference is a consequence of the fact that 1,2-DCA, carbon disulfide, chloroform, phenolics, PCB, and xylenes (total isomers) have not been detected in ground water in this region since the SWRI data cut-off date.

As indicated by the data provided in Table G-3, both the maximum concentration and the 95% UCL for acetone have increased since preparation of the SWRI. However, acetone has only been reported a single time (14 total analyses), and the increased 95% UCL apparently reflects the variability in data for this analyte (see Appendix P-8 in Webster-Scholten, 1994). The maximum concentration of 1,1-DCE and toluene have declined, and the 95% UCLs for both compounds have increased slightly since the SWRI report. The maximum concentration of TCE has not changed, although the 95% UCL has approximately doubled since the SWRI. However, none of these differences reflect substantial changes in VOC concentrations in ground water in this region and, consequently, suggest that no additional VOC releases have occurred from pit 5.

Reference

Webster-Scholten, C.P., Ed. (1994), *Final Site-Wide Remedial Investigation Report, Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-108131).

Table G-1. Monitor wells that defined VOC contamination of ground water originating at pit 5 as of December 31, 1991.

Wells that define VOC contamination near pit 5
K7-01
K7-03
K7-05
K7-09
NC7-16
NC7-21
NC7-37
NC7-40
NC7-47
NC7-51
NC7-76

Table G-2. Summary statistics (SWRI data set[a])for VOC contaminants in ground water from pit 5.

Contaminant	Maximum concentration (μg/L)	Mean concentration[b] (μg/L)	95% UCL (μg/L)
1,1-DCE	1.1×10^{1}	5.56×10^{-1}	7.05×10^{-1}
1,2-DCA	2.4×10^{1}	1.10×10^{-1}	1.73×10^{-1}
Acetone	1.4×10^{1}	1.51×10^{0}	2.31×10^{0}
Carbon disulfide	9.0×10^{0}	9.81×10^{-1}	2.17×10^{0}
Chloroform	1.6×10^{2}	7.00×10^{-1}	3.87×10^{1}
Phenolics	6.0×10^{0}	4.44×10^{0}	5.25×10^{0}
PCE	3.1×10^{0}	1.66×10^{0}	2.34×10^{-1}
Toluene	2.0×10^{0}	2.83×10^{-1}	4.62×10^{-1}
TCE	1.5×10^{1}	3.45×10^{0}	4.54×10^{0}
Trichlorotrifluoroethane (Freon-113)[c]	5.9×10^{0}	2.47×10^{-1}	5.34×10^{0}
Xylenes (total isomers)	1.0×10^{1}	1.02×10^{0}	2.02×10^{0}

[a] Values include data collected through December 31, 1991.

[b] Estimate of the arithmetic mean of the log-normal distribution.

[c] The summary statistics presented for trichlorotrifluoroethane in the SWRI were in error. The correct values are those given here.

Table G-3. Summary statistics (post-SWRI data set[a]) for VOC contaminants in ground water from pit 5.

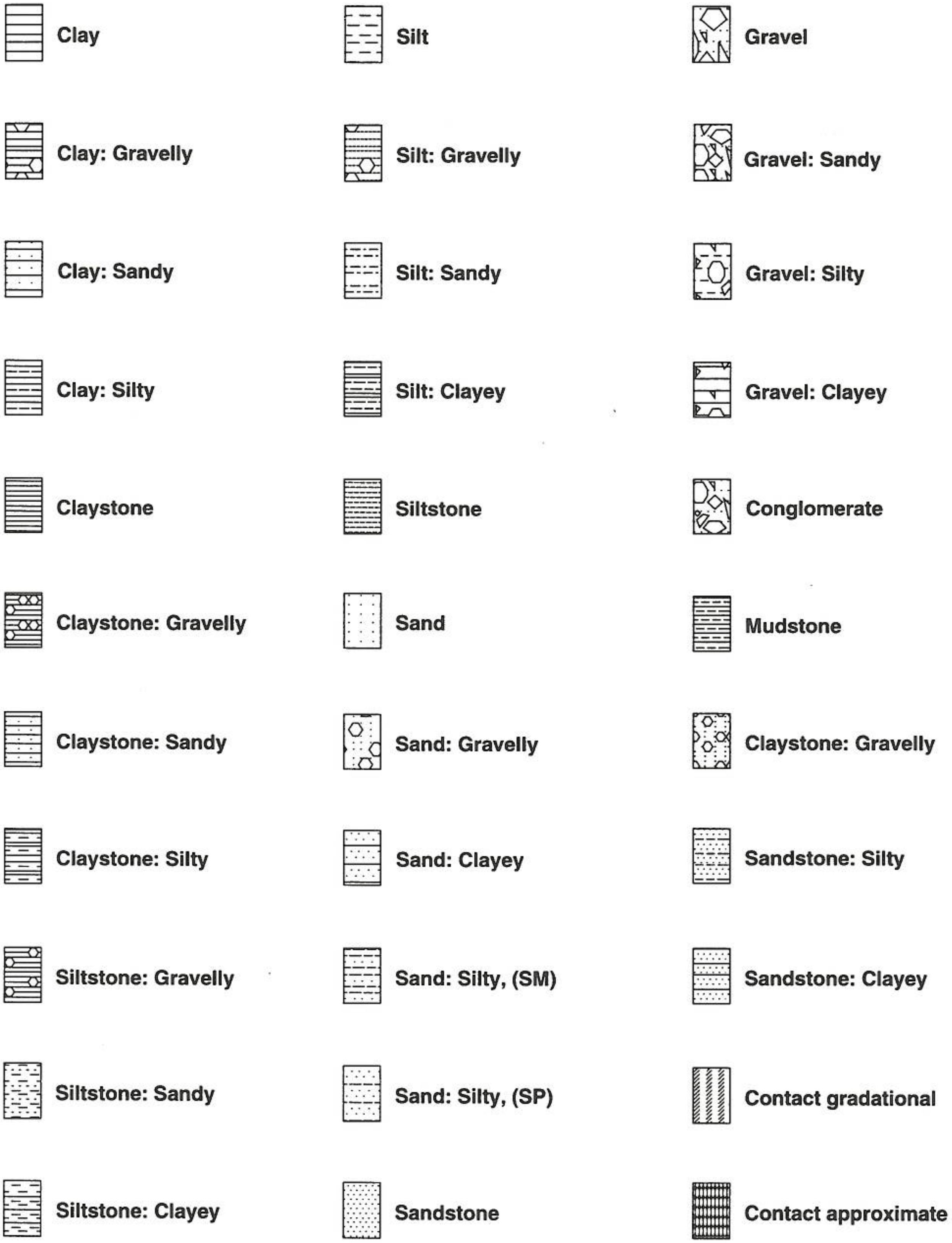
Contaminant	Maximum concentration (µg/L)	Mean concentration[b] (µg/L)	95% UCL (µg/L)
1,1-DCE	6.2×10^{0}	5.73×10^{-1}	7.40×10^{-1}
Acetone	2.3×10^{1}	5.75×10^{0}	8.96×10^{0}
Toluene	6.0×10^{-1}	3.49×10^{-1}	5.55×10^{-1}
TCE	1.5×10^{1}	4.96×10^{0}	9.14×10^{1}

[a] Values include data collected from December 31, 1991 to August 1, 1995.

[b] Estimate of the arithmetic mean of the log-normal distribution.

Appendix H

Logs of Wells and Boreholes Drilled During the Post-SWRI Assessment Period



ERD-S3R-96-0001

Figure H-1. Symbols used for the lithologies shown on the computer generated logs in this appendix.

LOG: BOREHOLE PIT7-01

Log: Borehole PIT7-01
Geologic Logging: Jen Martin, Weiss Associates, Emeryville, CA
Location: Approximately 250 feet west of north east corner of Pit 7 complex corporation yard, adjacent to monitor well NC7-77.
Coordinates: N427740.23 E1694980.35 and Elev: 1314.62
Driller/Helper: Sonne Fleming/Chris Northhart, P.C. Exploration, Inc. Roseville, CA
Dates Drilled: 10/13/94 - 10/17/94

Recovery histograms show percent recovery and inferred recovery locations.
Estimates of gravels, sands, and fines are field visual estimates.
Notation of fractures and bedding: [Depth(s)/dip.(s)/comment(s)]

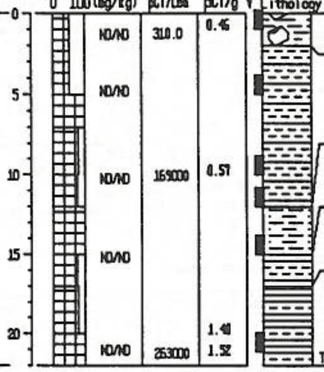
Drilling Method: 9-inch hollow stem auger.
Geophysical logging: none performed

Sampling method: 1.5-inch split-spoon sampler advanced by a 140-pound weight falling 30 inches.

1K = estimated primary permeability
2K = estimated fracture permeability
VH = very high
H = high
M = moderate
L = low
VL = very low

INDEX TO SYMBOLS

- ▯ BLADDER PUMP
- ▮ SUBMERSIBLE PUMP
- ▽ FIRST WATER
- ▼ STATIC WATER LEVEL
- ↓ DRIVE OR CORE SAMPLING
- ■ ANALYTICAL SOIL SAMPLE
- ? APPROXIMATE CONTACT
- ◪ GRADATIONAL CONTACT
- ⬚ *0 SAND
- ☐ *3 SAND PACK
- ■ BENTONITE
- ▤ SLOTTED CASING
- ▨ NEAT CEMENT GROUT
- ☒ CEMENT-BENTONITE GROUT
- ▩ CEMENT-CAL SEAL GROUT
- ◯ SLOUGH MATERIAL
- ▧ CLOSED FRACTURES
- ☐ OPEN FRACTURES
- ☐ FRACTURE ZONE



232 Th pCi/g	235 U pCi/g	Depth (ft)	PCB/TCE (mg/kg)	Tritium pCi/Lea	238 U pCi/g
0.48	0.0185	0	ND/ND	310.0	0.45
		5	ND/ND		
0.50	0.0212	10	ND/ND	169000	0.57
		15	ND/ND		
2.11	0.0661	20			1.40
2.03	0.0689		ND/ND	253000	1.52

Lithologic descriptions and/or remarks

QUATERNARY ALLUVIAL DEPOSITS
(0.0 - 2.0) GRAVELLY SILT, [ML], fill gravels to 1"

(2.0 - 12.0) CLAYEY SILT, [ML], dark grey brown 10YR 4/2, damp, stiff to very stiff, 15% very fine to medium sand, 20% clay, 10% light gray pebbles to 0.3", 1K=L-M, drys very hard

(12.0 - 15.0) SANDY SILT, [ML], dark yellow brown 10YR 3/4, damp, medium stiff, 30-40% very fine to medium sand, 10% clay, 5% decomposed pebbles to 1", FeO staining common, 1K=L-M

(15.0 - 17.0) CLAYEY SILT, [ML], light yellowish brown 2.5Y 6/4, moist to damp, stiff, 10% very fine to medium sand, 20% clay, 1K=L-M, orange (FeO) specks common, decomposed pebbles to 0.3" common

(17.0 - 22.0) SILTY CLAY, light yellow brown 2.5Y 6/3, damp, soft to stiff, 20% silt, 5-10% sand, FeO staining along 90 degree natural fractures, semi consolidated, 1K=L, 2K=M 90 degree natural fractures, black staining at 22 feet

TD = 22'

LOG: MONITOR WELL W-PIT7-02

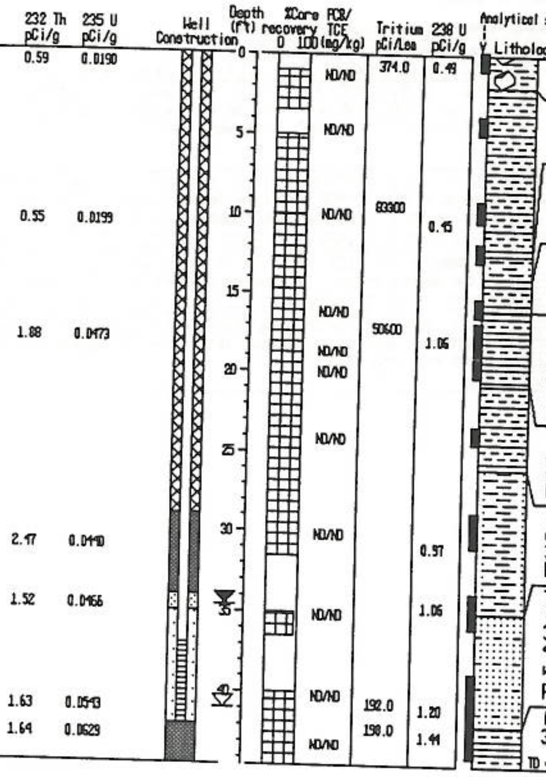
Log: Monitor Well W-PIT7-02
Geologic Logging: Jen Martin, Weiss Associates, Emeryville, CA
Location: Approximately 250 feet west of north east corner of Pit 7 complex corporation yard, adjacent to monitor well NC7-77.
Coordinates: N427745.49 E1659473.40 and Elev: 1315.67 (shiner)
Driller/Helper: Sonne Fleming/Chris Northhart, P.C. Exploration, Inc. Roseville, CA
Dates Drilled: 10/17/94 - 10/19/94
Ground Water: First Water @ 41' Static @ 34.6'
Recovery histograms show percent recovery and inferred recovery locations.
Estimates of gravels, sands, and fines are field visual estimates.
Notation of fractures and bedding: [Depth(s)/dip. (s)/comment(s)]

Drilling Method: 9-inch hollow stem auger, 4.5 inch ID, Sch. 40 PVC casing to 40 feet. High Flow 0.020 slotted casing from 37-42 ft.
Geophysical logging: none performed
Sampling method: 1.5-inch split-spoon sampler advanced by a 140-pound weight falling 30 inches.

1K = estimated primary permeability
2K = estimated fracture permeability
VH = very high
H = high
M = moderate
L = low
VL = very

INDEX TO SYMBOLS

BLADDER PUMP
SUBMERSIBLE PUMP
▽ FIRST WATER
▼ STATIC WATER LEVEL
↓ DRIVE OR CORE SAMPLING
■ ANALYTICAL SOIL SAMPLE
? APPROXIMATE CONTACT
◪ GRADATIONAL CONTACT
⛆ #0 SAND
□ #3 SAND PACK
▩ BENTONITE
☰ SLOTTED CASING
▨ NEAT CEMENT GROUT
⊠ CEMENT-BENTONITE GROUT
▦ CEMENT-CAL SEAL GROUT
SLOUGH MATERIAL
CLOSED FRACTURES
OPEN FRACTURES
FRACTURE ZONE



Lithologic descriptions and/or remarks

QUATERARY ALLUVIAL DEPOSITS
(0.0 - 2.0) GRAVELLY SILT, fill

(2.0 - 12.5) CLAYEY SILT, [ML], dark grayish brown 10YR 4/2, damp, stiff to very stiff, 15% very fine to medium sand, 20% clay, 10% light gray pebbles to 0.3", 1K=L-M, lower contact approximate

(12.5 - 14.0) SANDY SILT [ML], dark yellow brown, 10YR 3/4, damp, medium stiff to stiff, 20-30% very fine to medium sand, 10% clay, < 5% decomposed pebbles to 1", FeO staining common, 1K=L-M, 16.0' bedrock (driller), lower contact approximate

(14.0 - 16.0) CLAYEY SILT, [ML], light yellowish brown 2.5Y 6/4, moist to damp, stiff, 10% very fine to medium sand, 20% clay, 1K=L-M, FeO grains common

(16.0 - 20.5) SILTY CLAY / silty claystone, mottled grayish brown 2.5Y 5/2, olive yellow 2.5Y 6/6 and dark reddish brown 2.5YR 3/3, moist to wet, very soft to stiff to very stiff, 30% silt, 5% very fine to medium sand, moderate plasticity, 1K=L, black mottles also common, 20' becomes moist, silty clay increase in dark reddish brown mottles, 16.0' hard chunks

(20.5 -26.0) CLAYEY SILT, [ML], Mottled light yellowish brown 2.5Y 6/4 and yellowish brown 10YR 5/6, moist, 20% clay, 10% very fine to medium sand, low plasticity, 1K=M-L, black (MnO?) flakes common, black mica flakes common, quartz sand grains

(26.0 -35.0) SANDY SILT (ML), mottled olive 5Y 5/4, black Y 2.5/1, dry, and yellowish brown 10YR 5/6, damp to moist, stiff to very stiff, 30% very fine to medium sand, 5-10% clay, 1K=M, (for mainly sand is black and red), 31.5 - 35.0 cuttings have high clay content

TERTIARY SEDIMENTS
(35.0 -42.0) SILTY SANDSTONE, greenish gray 5GY 5/1, damp, very soft, 30% silt, 5-10% clay, white and black ang to subang pebbles to 0.1" at 40', cuttings hot and giving off water vapor, dust meter reads 3.6 when held over cuttings, at 41.5', becomes very fine to fine sand, no pebbles, micas continue

(42.0 -44.5) SILTY CLAYSTONE, greenish gray 5G 5/1, very soft, damp, 30% silt, < 5% very fine to coarse sand, 1K=L-VL

TD = 44.5'

LOG: MONITOR WELL W-PIT7-03

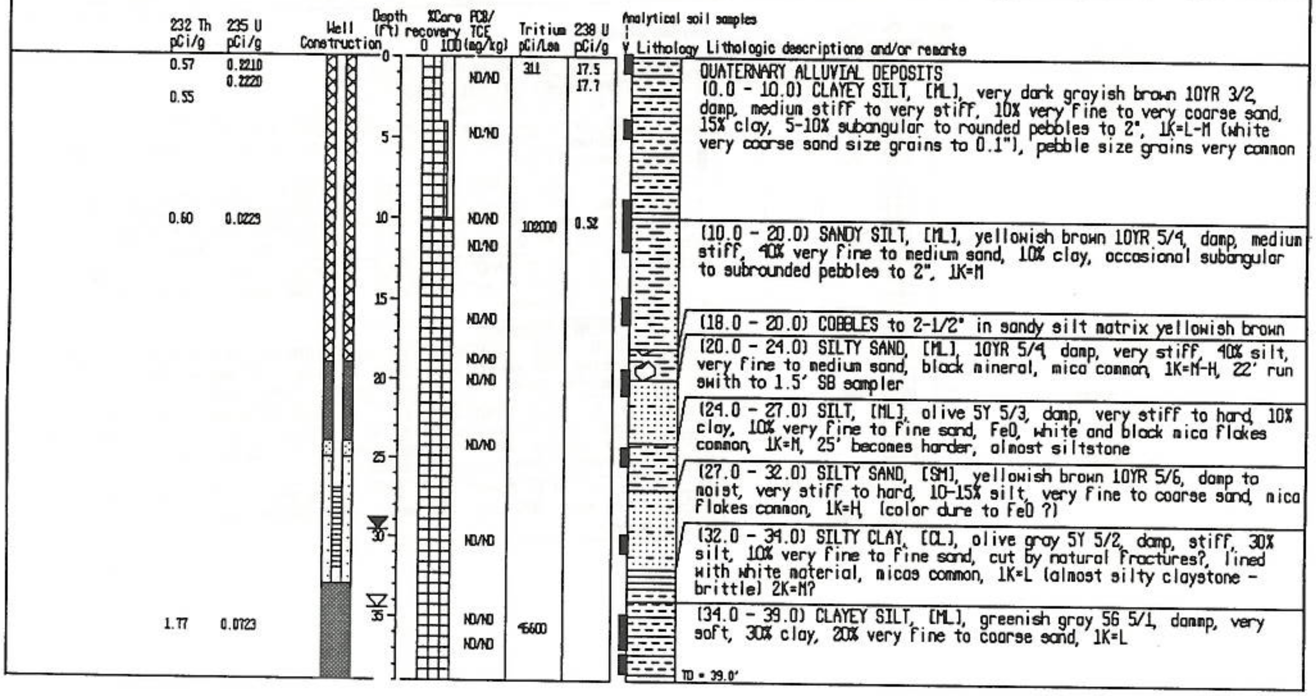
Log: Monitor Well W-PIT7-03
Geologic Logging: Jen Martin, Weiss Associates, Emeryville, CA
Location: Approximately 500 feet north west of Pit 7 Complex corporation yard.
Coordinates: N427995.54 E1694797.96 and Elev: 1327.22 (shiner)
Driller/Helper: Sonne Fleming/Chris Northhart, P.C. Exploration, Inc. Roseville, CA
Dates Drilled: 10/20/94 - 10/25/94
Ground Water: First Water @ 34.5' Static @ 29.6'
Recovery histograms show percent recovery and inferred recovery locations.
Estimates of gravels, sands, and fines are field visual estimates.
Notation of fractures and bedding: [Depth(s)/dip. (s)/comment(s)]

Drilling Method: 9-inch hollow stem auger, 4.5 inch ID, Sch. 40 PVC casing to 27 feet. High flow 0.020 slotted casing from 27-32 ft.
Geophysical logging: none performed
Sampling method: 1.5-inch split-spoon sampler advanced by a 140-pound weight falling 30 inches.

1K = estimated primary permeability
2K = estimated fracture permeability
VH = very high
H = high
M = moderate
L = low
VL = very

INDEX TO SYMBOLS

BLADDER PUMP	↓ DRIVE OR CORE SAMPLING	⁚ •0 SAND	☰ SLOTTED CASING	SLOUGH MATERIAL
SUBMERSIBLE PUMP	▮ ANALYTICAL SOIL SAMPLE	•3 SAND PACK	▨ NEAT CEMENT GROUT	CLOSED FRACTURES
▽ FIRST WATER	? APPROXIMATE CONTACT	▩ BENTONITE	☒ CEMENT-BENTONITE GROUT	OPEN FRACTURES
▼ STATIC WATER LEVEL	◪ GRADATIONAL CONTACT		☒ CEMENT-CAL SEAL GROUT	FRACTURE ZONE



232 Th pCi/g	235 U pCi/g	PCB/TCE (mg/kg)	Tritium pCi/Lm	238 U pCi/g
0.57	0.2210	ND/ND	311	17.5
	0.2220			17.7
0.55				
		ND/ND		
0.60	0.0229	ND/ND	102000	0.52
		ND/ND		
		ND/ND		
		ND/ND		
		ND/ND		
		ND/ND		
		ND/ND		
1.77	0.0723	ND/ND	45600	
		ND/ND		

Lithology Lithologic descriptions and/or remarks

QUATERNARY ALLUVIAL DEPOSITS

(0.0 - 10.0) CLAYEY SILT, [ML], very dark grayish brown 10YR 3/2, damp, medium stiff to very stiff, 10% very fine to very coarse sand, 15% clay, 5-10% subangular to rounded pebbles to 2", 1K=L-M (white very coarse sand size grains to 0.1"), pebble size grains very common

(10.0 - 20.0) SANDY SILT, [ML], yellowish brown 10YR 5/4, damp, medium stiff, 40% very fine to medium sand, 10% clay, occasional subangular to subrounded pebbles to 2", 1K=M

(18.0 - 20.0) COBBLES to 2-1/2" in sandy silt matrix yellowish brown

(20.0 - 24.0) SILTY SAND, [ML], 10YR 5/4, damp, very stiff, 40% silt, very fine to medium sand, black mineral, mica common, 1K=M-H, 22' run swith to 1.5' SB sampler

(24.0 - 27.0) SILT, [ML], olive 5Y 5/3, damp, very stiff to hard, 10% clay, 10% very fine to fine sand, FeO, white and black mica flakes common, 1K=M, 25' becomes harder, almost siltstone

(27.0 - 32.0) SILTY SAND, [SM], yellowish brown 10YR 5/6, damp to moist, very stiff to hard, 10-15% silt, very fine to coarse sand, mica flakes common, 1K=H, (color dure to FeO ?)

(32.0 - 34.0) SILTY CLAY, [CL], olive gray 5Y 5/2, damp, stiff, 30% silt, 10% very fine to fine sand, cut by natural fractures?, lined with white material, micas common, 1K=L (almost silty claystone - brittle) 2K=M?

(34.0 - 39.0) CLAYEY SILT, [ML], greenish gray 5G 5/1, dammp, very soft, 30% clay, 20% very fine to coarse sand, 1K=L

LOG: BOREHOLE PIT7-04

Log: Borehole PIT7-04
Geologic Logging: Jen Martin, Weiss Associates, Emeryville, CA
Location: Approximately 1100 feet north west of Pit 7 Complex corporation yard near south east corner of Pit 3.
Coordinates: N428318.88 E1694463.31 and Elev: 1348.83
Driller/Helper: Sonne Fleming/Chris Northhart, P.C. Exploration, Inc. Roseville, CA
Dates Drilled: 10/26/94 - 10/27/94

Recovery histograms show percent recovery and inferred recovery locations.
Estimates of gravels, sands, and fines are field visual estimates.
Notation of fractures and bedding: [Depth(s)/dip. (s)/comment(s)]

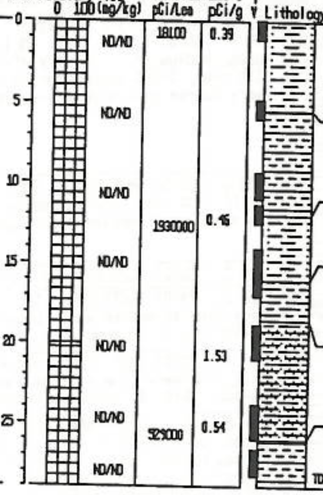
Drilling Method: 9-inch hollow stem auger.
Geophysical logging: none performed

Sampling method: 1.5-inch split-spoon sampler advanced by a 140-pound weight falling 30 inches.

1K = estimated primary permeability
2K = estimated fracture permeability
VH = very high
H = high
M = moderate
L = low
VL = very low

INDEX TO SYMBOLS

- BLADDER PUMP
- SUBMERSIBLE PUMP
- FIRST WATER
- STATIC WATER LEVEL
- ↓ DRIVE OR CORE SAMPLING
- ▮ ANALYTICAL SOIL SAMPLE
- ? APPROXIMATE CONTACT
- ◪ GRADATIONAL CONTACT
- °0 SAND
- °3 SAND PACK
- ▩ BENTONITE
- ☰ SLOTTED CASING
- ▨ NEAT CEMENT GROUT
- ☒ CEMENT-BENTONITE GROUT
- ▦ CEMENT-CAL SEAL GROUT
- SLOUGH MATERIAL
- CLOSED FRACTURES
- OPEN FRACTURES
- FRACTURE ZONE



232 Th pCi/g	235 U pCi/g	Depth (ft)	PCB/TCE (mg/kg)	Tritium pCi/Lea	238 U pCi/g
0.51	0.0142	0	ND/ND	18100	0.39
		5	ND/ND		
		10	ND/ND		
0.70	0.0135			1930000	0.46
		15	ND/ND		
1.12	0.0289	20	ND/ND		1.53
1.60	0.0247	25	ND/ND	529000	0.54
			ND/ND		

Lithologic descriptions and/or remarks

QUARTERNARY ALLUVIAL DEPOSITS
(0.0 - 5.5) SANDY SILT, [ML], gray brown 2.5Y 5/2, dry to damp, stiff, 20% very fine to very coarse sand, 10% subangular to subrounded pebbles to 2", 5% clay, low plasticity, white very coarse sand grains common, 1K=M-H

(5.5 - 12.0) CLAYEY SILT, [ML], very dark grayish brown 10YR 3/2, damp, stiff to very stiff, 10% sand, 15% clay, 5-10% subangular to subrounded pebbles to 2", 1K=L-M, white very coarse sand to 0.1" pebble size grains common, 7.5'- color change to brown, 10YR, 5/3

(12.0 - 16.0) SANDY SILT, [ML], light olive brown 2.5Y 5/4, damp to moist, stiff to very stiff, 5% clay, 20% very fine to medium sand, 1K=M, FeO common

TERTIARY SEDIMENTS
(16.0 - 18.5) SILTSTONE, light gray 10YR 7/1, dry to damp (?), hard, 5% clay, 10% sand?, 1K=L, 2K=M, brittle, 0-90 degree natural fractures lined with FeO very common, lower contact from driller

(18.5 - 26.0) SANDY SILT, [ML], to SANDY SILTSTONE pale olive 5Y 6/3, damp, stiff to very stiff to soft, 30% very fine to medium sand, 20% clay, 1K=M-H, 2K=M 0-90 degree natural fractures lined with white and or reddish brown mineral, micas common

(26.0 - 29.0) CLAYEY SILT, [ML], olive gray 5Y 5/2, damp to moist, very soft, 30% clay, 20% very fine to coarse sand, 1K=L

TD = 29.0'

LOG: BOREHOLE PIT7-05

Log: Borehole PIT7-05
Geologic Logging: Jen Martin, Weiss Associates, Emeryville, CA
Location: Approximately 1100 feet north west of Pit 7 Complex corporation yard, near the north west corner of Pit 5.
Coordinates: N428248.69 E1694396.15 and Elev: 1354.90
Driller/Helper: Sonne Fleming/Chris Northhart, P.C. Exploration, Inc. Roseville, CA
Dates Drilled: 11/1/94 - 11/1/94

Recovery histograms show percent recovery and inferred recovery locations.
Estimates of gravels, sands, and fines are field visual estimates.
Notation of fractures and bedding: [Depth(s)/dip. (s)/comment(s)]

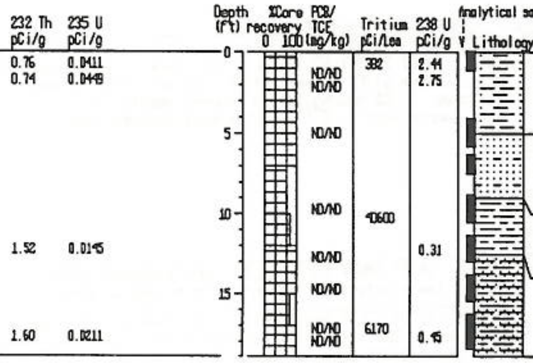
Drilling Method: 9-inch hollow stem auger.
Geophysical logging: none performed

Sampling method: 1.5-inch split-spoon sampler advanced by a 140-pound weight falling 30 inches.

1K = estimated primary permeability
2K = estimated fracture permeability
VH = very high
H = high
M = moderate
L = low
VL = very low

INDEX TO SYMBOLS

BLADDER PUMP
SUBMERSIBLE PUMP
▽ FIRST WATER
▼ STATIC WATER LEVEL
↓ DRIVE OR CORE SAMPLING
▮ ANALYTICAL SOIL SAMPLE
? APPROXIMATE CONTACT
◪ GRADATIONAL CONTACT
⁙ #0 SAND
· #3 SAND PACK
▩ BENTONITE
☰ SLOTTED CASING
▨ NEAT CEMENT GROUT
☒ CEMENT-BENTONITE GROUT
▦ CEMENT-CAL SEAL GROUT
SLOUGH MATERIAL
CLOSED FRACTURES
OPEN FRACTURES
FRACTURE ZONE



Lithologic descriptions and/or remarks

QUARTERNARY ALLUVIAL DEPOSITS
(0.0 - 5.5) SANDY SILT, [ML], grayish brown 2.5Y 5/2, dry, stiff, 20% very fine to very coarse sand, 10% subangular to subrounded pebbles to 2", 5% clay low plasticity, 1K=M-H

TERTIARY SEDIMENTS
(5.5 - 9.0) SILTY SANDSTONE, mottled olive yellow 2.5Y 6/6, and light olive brown 2.5Y 5/3, dry, soft, fine to coarse grained, 20% silt, 1K=H, at 7.5' becomes reddish brown 5YR 4/4

(9.0 - 12.5) SILTSTONE, white 5 8/1, to, gray 5Y 6/1, dry, medium hard, 5% clay, 10% fine to medium sand, 1K=L, FeO and white mineral common, black mineral common

(12.5 - 19.0) SANDY SILT/SANDY SILTSTONE, light olive brown 2.5Y 5/4, moist, very soft, 20-30% very fine to medium sand, 10% clay, 1K=M, FeO staining common along 0 degree planes, individual grains

TD = 19.0'

LOG: BOREHOLE PIT7-06

Log: Borehole PIT7-06
Geologic Logging: Jen Martin, Weiss Associates, Emeryville, CA
Location: Approximately 1500 feet north west of Pit 7 Complex corporation yard, near north east corner of Pit 3.
Coordinates: N428594.92 E1694207.64 and Elev: 1362.92
Driller/Helper: Sonne Fleming/Chris Northhart, P.C. Exploration, Inc. Roseville, CA
Dates Drilled: 11/2/94 - 11/2/94

Recovery histograms show percent recovery and inferred recovery locations.
Estimates of gravels, sands, and fines are field visual estimates.
Notation of fractures and bedding: [Depth(s)/dip. (s)/comment(s)]

Drilling Method: 9-inch hollow stem auger.
Geophysical logging: none performed

Sampling method: 1.5-inch split-spoon sampler advanced by a 140-pound weight falling 30 inches.

1K = estimated primary permeability
2K = estimated fracture permeability
VH = very high
H = high
M = moderate
L = low
VL = very low

INDEX TO SYMBOLS

- BLADDER PUMP
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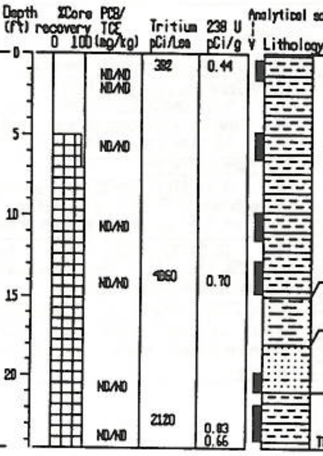
- ▽ FIRST WATER
- ▼ STATIC WATER LEVEL
- ↓ DRIVE OR CORE SAMPLING
- ▮ ANALYTICAL SOIL SAMPLE
- ? APPROXIMATE CONTACT
- ◩ GRADATIONAL CONTACT
- ⛆ *0 SAND
- ☐ *3 SAND PACK
- ▩ BENTONITE
- ☰ SLOTTED CASING
- ▨ NEAT CEMENT GROUT
- ☒ CEMENT-BENTONITE GROUT
- ▩ CEMENT-CAL SEAL GROUT
- SLOUGH MATERIAL
- CLOSED FRACTURES
- OPEN FRACTURES
- FRACTURE ZONE

232 Th pCi/g	235 U pCi/g	PCB/ TCE (mg/kg)	Tritium pCi/Lea	238 U pCi/g
0.93	0.0198	ND/ND ND/ND	382	0.44
		ND/ND		
		ND/ND		
0.92	0.0325	ND/ND	4060	0.70
		ND/ND		
1.98 1.83	0.0380 0.0298	ND/ND	2120	0.83 0.66



Lithologic descriptions and/or remarks

QUARTERNARY ALLUVIAL DEPOSITS
(0.0 - 15.0) CLAYEY SILT, [ML], very dark grayish brown 10Y/R 3/2, damp, medium stiff to very stiff, 10% very fine to very coarse sand, 15% clay, 5-10% subangular to rounded pebbles to 2", 1K=L-M, white very coarse sand to 0.1", pebble-size grains common

(15.0 - 18.0) SANDY SILT, [ML], light yellowish brown 2.5Y 6/4, damp, stiff, low plasticity, 40% very fine to medium sand, 5% clay, 1K=M-H

(18.0 - 21.0) SILTY SAND, [SM], pale olive 5Y 6/3, damp, stiff, low plasticity, 20% silt, 1K=H, reddish brown clay blebs common at 20', FeO? stained 10% clay, 1K=M-L

(21.0 - 24.5) CLAYEY SILT, olive gray 5Y 5/2, damp to moist, very soft, 30% clay, 20% fine to coarse sand, 1K=L

LOG: BOREHOLE PIT7-07

Log: Borehole PIT7-07
Geologic Logging: Jen Martin, Weiss Associates, Emeryville, CA
Location: Approximately 1250 feet north west of Pit 7
Complex corporation yard.
Coordinates: N428462.02 E1694352.72 and Elev:1350.80
Driller/Helper: Sonne Fleming/Chris Northhart, P.C. Exploration, Inc.
Roseville, CA
Dates Drilled: 11/3/94 - 11/3/94

Recovery histograms show percent recovery and inferred recovery locations.
Estimates of gravels, sands, and fines are field visual estimates.
Notation of fractures and bedding: [Depth(s)/dip (s)/comment(s)]

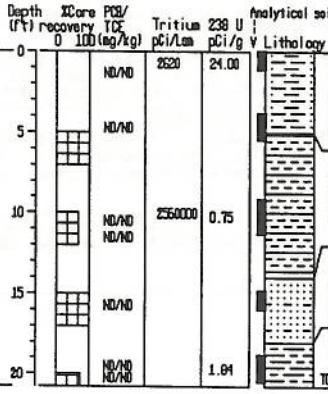
Drilling Method: 9-inch hollow stem auger.
Geophysical logging: none performed

Sampling method: 1.5-inch split-spoon sampler advanced by a 140-pound
weight falling 30 inches.

1K = estimated primary permeability
2K = estimated fracture permeability
VH = very high
H = high
M = moderate
L = low
VL = very low

INDEX TO SYMBOLS

BLADDER PUMP	↓ DRIVE OR CORE SAMPLING	⁚ *0 SAND	☰ SLOTTED CASING	SLOUGH MATERIAL
SUBMERSIBLE PUMP	▮ ANALYTICAL SOIL SAMPLE	☐ *3 SAND PACK	▨ NEAT CEMENT GROUT	CLOSED FRACTURES
▽ FIRST WATER	? APPROXIMATE CONTACT	▩ BENTONITE	☒ CEMENT-BENTONITE GROUT	OPEN FRACTURES
▼ STATIC WATER LEVEL	◩ GRADATIONAL CONTACT		☒ CEMENT-CAL SEAL GROUT	FRACTURE ZONE



Depth (ft)	232 Th pCi/g	235 U pCi/g	PCB/TCE (mg/kg)	Tritium pCi/Lm	238 U pCi/g
0	0.60	0.3463	ND/ND	2620	24.00
5			ND/ND		
10	0.61	0.0182	ND/ND ND/ND	2560000	0.75
15			ND/ND		
20	0.49	0.0938	ND/ND ND/ND		1.84

Lithologic descriptions and/or remarks

QUARTERNARY ALLUVIAL DEPOSITS
(0.0 - 5.0) SANDY SILT, [ML], gray brown 2.5Y 5/2, dry to damp, stiff, 20% very fine to very coarse sand, 5% clay, 10 % SA to SR pebbles to 2", low plasticity 1K=M-H; white (quartz?), very coarse sand grains common

(5.0 - 14.0) CLAYEY SILT, [ML], very dark grayish brown 10YR 3/2, damp, stiff to very stiff, 10% sand, 15% clay, 10% subangular to subrounded pebbles to 2", 1K=L-M at 12 ft and 15 ft, 0-38 on ground surface during drilling

TERTIARY SEDIMENTS
(14.0 - 18.0) SILTY SANDSTONE, light olive brown 2.5Y 5/4, damp to moist, very soft to soft, 5% clay, 40% silt, very fine to medium sand, 1K=M

(18.0 - 20.8) SILTSTONE, light gray 10 7/1, damp, hard, 5% clay(?), less than 10% sand(?), 1K=L

TD = 20.8'

LOG: BOREHOLE PIT7-08

Log: Borehole PIT7-08
Geologic Logging: Jen Martin, Weiss Associates, Emeryville, CA
Location: Approximately 1100 feet north west of Pit 7 Complex corporation yard, adjacent to monitor well NC7-36.
Coordinates: N428074.24 E1694460.19 and Elev: 1353.05
Driller/Helper: Sonne Fleming/Chris Northhart, P.C. Exploration, Inc. Roseville, CA
Dates Drilled: 11/7/94 - 11/7/94

Recovery histograms show percent recovery and inferred recovery locations.
Estimates of gravels, sands, and fines are field visual estimates.
Notation of fractures and bedding: [Depth(s)/dip. (s)/comment(s)]

Drilling Method: 9-inch hollow stem auger.
Geophysical logging: none performed

Sampling method: 1.5-inch split-spoon sampler advanced by a 140-pound weight falling 30 inches.

1K = estimated primary permeability
2K = estimated fracture permeability
VH = very high
H = high
M = moderate
L = low
VL = very low

INDEX TO SYMBOLS

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- SUBMERSIBLE PUMP
- ▽ FIRST WATER
- ▼ STATIC WATER LEVEL
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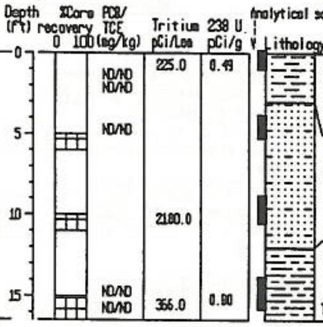
- ▮ ANALYTICAL SOIL SAMPLE
- ? APPROXIMATE CONTACT
- ◪ GRADATIONAL CONTACT
- ⁘ *0 SAND
- ⁘ *3 SAND PACK
- ▩ BENTONITE
- ☰ SLOTTED CASING
- ▨ NEAT CEMENT GROUT
- ☒ CEMENT-BENTONITE GROUT
- ▩ CEMENT-CAL SEAL GROUT
- SLOUGH MATERIAL
- CLOSED FRACTURES
- OPEN FRACTURES
- FRACTURE ZONE

232 Th pCi/g	235 U pCi/g	Depth (ft)	PCB/TCE (mg/kg)	Tritium pCi/Lea	238 U pCi/g
0.85	0.0199	0	ND/ND ND/ND	225.0	0.49
		5	ND/ND		
		10		2100.0	
1.78	0.0370	15	ND/ND ND/ND	366.0	0.90



Lithologic descriptions and/or remarks

QUARTERNARY ALLUVIAL DEPOSITS
(0.0 - 3.0) SANDY SILT, [ML], grayish brown 2.5Y, 5/2, dry, stiff, 20% very fine to very coarse sand, 10% subangular to subrounded pebbles to 2.5", 5% clay, low plasticity, 1K=M-H

TERTIARY SEDIMENTS
(3.0 - 12.0) SILTY SANDSTONE, brown 10YR, 5/3, dry, soft to very soft, 20% silt, fine to coarse grained, 1K=H, white mineral lined natural fractures at 0-90 degrees common, bery oxidized-reddish brown at 12'

(12.0 - 16.5) SILTSTONE, light olive brown 2.5Y 5/4, moist, very soft, 10-20% very fine to medium sand, 10% clay, 1K=M-L, black micas FeO common
TD = 16.5'

LOG: BOREHOLE PIT7-09

Log: Borehole PIT7-09
Geologic Logging: Jen Martin, Weiss Associates, Emeryville, CA
Location: Approximately 400 feet west of Pit 7 Complex corporation yard, adjacent to monitor well NC7-18.
Coordinates: N427660.00 E1694856.15 and Elev: 1330.00
Driller/Helper: Sonne Fleming/Chris Northhart, P.C. Exploration, Inc.
Roseville, CA
Dates Drilled: 11/08/94 - 11/08/94

Recovery histograms show percent recovery and inferred recovery locations.
Estimates of gravels, sands, and fines are field visual estimates.
Notation of fractures and bedding: [Depth(s)/dip. (s)/comment(s)]

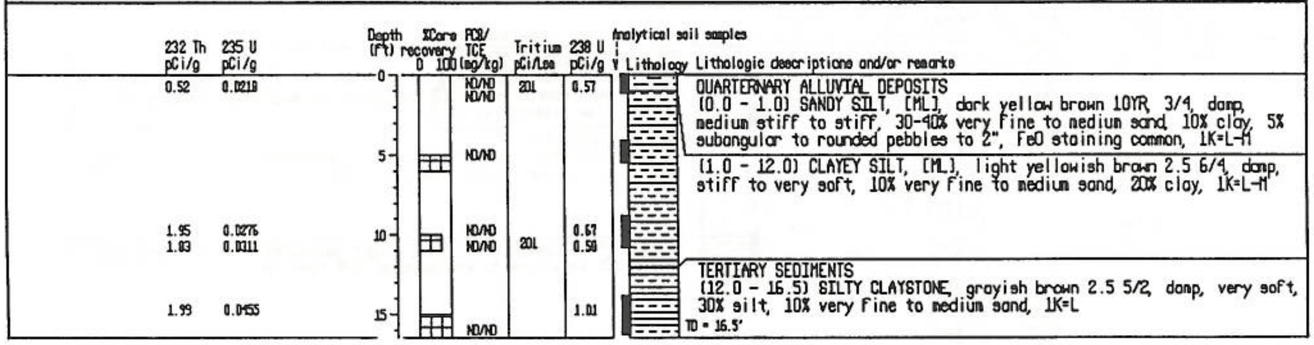
Drilling Method: 9-inch hollow stem auger.
Geophysical logging: none performed

Sampling method: 1.5-inch split-spoon sampler advanced by a 140-pound weight falling 30 inches.

1K = estimated primary permeability
2K = estimated fracture permeability
VH = very high
H = high
M = moderate
L = low
VL = very low

INDEX TO SYMBOLS

BLADDER PUMP	↓ DRIVE OR CORE SAMPLING		▤ SLOTTED CASING	SLOUGH MATERIAL
SUBMERSIBLE PUMP	▮ ANALYTICAL SOIL SAMPLE	*0 SAND	▨ NEAT CEMENT GROUT	CLOSED FRACTURES
▽ FIRST WATER	? APPROXIMATE CONTACT	*3 SAND PACK	☒ CEMENT-BENTONITE GROUT	OPEN FRACTURES
▼ STATIC WATER LEVEL	◪ GRADATIONAL CONTACT	▩ BENTONITE	CEMENT-CAL SEAL GROUT	FRACTURE ZONE



Analytical soil samples

232 Th pCi/g	235 U pCi/g	Depth (ft)	%Core recovery 0 100	PCB/TCE (mg/kg)	Tritium pCi/Lea	238 U pCi/g
0.52	0.0218	0		ND/ND ND/ND	20L	0.57
		5		ND/ND		
1.95 1.03	0.0276 0.0311	10		ND/ND ND/ND	20L	0.67 0.50
1.99	0.0455	15		ND/ND		1.01

Lithology Lithologic descriptions and/or remarks

QUARTERNARY ALLUVIAL DEPOSITS
(0.0 - 1.0) SANDY SILT, [ML], dark yellow brown 10YR 3/4, damp, medium stiff to stiff, 30-40% very fine to medium sand, 10% clay, 5% subangular to rounded pebbles to 2", FeO staining common, 1K=L-M

(1.0 - 12.0) CLAYEY SILT, [ML], light yellowish brown 2.5 6/4, damp, stiff to very soft, 10% very fine to medium sand, 20% clay, 1K=L-M

TERTIARY SEDIMENTS
(12.0 - 16.5) SILTY CLAYSTONE, grayish brown 2.5 5/2, damp, very soft, 30% silt, 10% very fine to medium sand, 1K=L
TD = 16.5'

LOG: MONITOR WELL W-PIT7-10

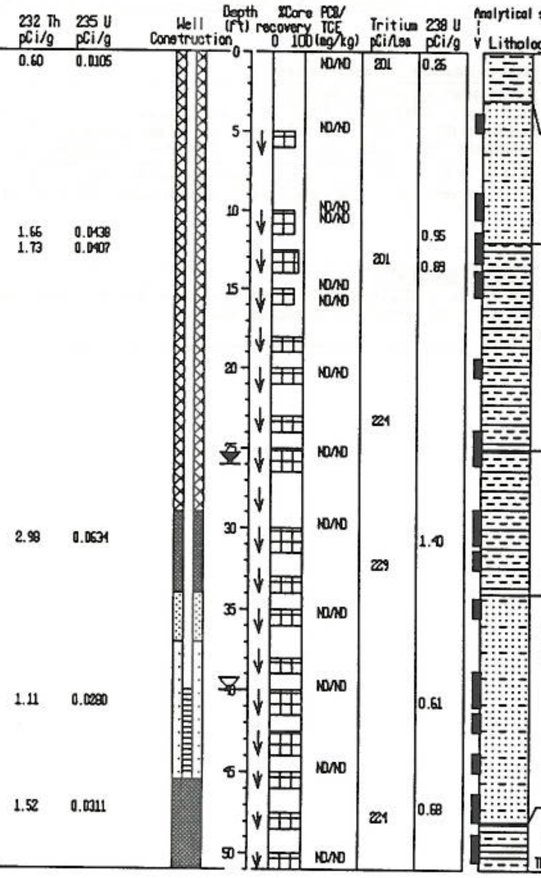
Log Monitor Well W-PIT7-010
Geologic Logging: Jen Martin, Weiss Associates, Emeryville, CA
Location: Approximately 250 feet west of
Pit 7 Complex corporation yard.
Coordinates: N427543.26 E1695118.13 and Elev: 1316.11 (shiner)
Driller/Helper: Sonne Fleming/Chris Northhart, P.C. Exploration, Inc.
Roseville, CA
Dates Drilled: 11/9/94 - 11/14/94
Ground Water: First Water @ 40' Static @ 26'
Recovery histograms show percent recovery and inferred recovery locations.
Estimates of gravels, sands, and fines are field visual estimates.
Notation of fractures and bedding: (Depth(s)/dip. (s)/comment(s))

Drilling Method: 9-inch hollow stem auger, 4.5 inch ID, Sch. 40 PVC casing to 40 feet. High flow 0.020 slotted casing from 40-45 ft.
Geophysical logging: none performed
Sampling method: 1.5-inch split-spoon sampler advanced by a 140-pound weight falling 30 inches.

1K = estimated primary permeability
2K = estimated fracture permeability
VH = very high
H = high
M = moderate
L = low
VL = very

INDEX TO SYMBOLS

- BLADDER PUMP
- SUBMERSIBLE PUMP
- ▽ FIRST WATER
- ▼ STATIC WATER LEVEL
- ↓ DRIVE OR CORE SAMPLING
- ▮ ANALYTICAL SOIL SAMPLE
- ? APPROXIMATE CONTACT
- ◪ GRADATIONAL CONTACT
- ⁘ #0 SAND
- ⁘ #3 SAND PACK
- ▓ BENTONITE
- ☰ SLOTTED CASING
- ▨ NEAT CEMENT GROUT
- ☒ CEMENT-BENTONITE GROUT
- ▩ CEMENT-CAL SEAL GROUT
- SLOUGH MATERIAL
- CLOSED FRACTURES
- OPEN FRACTURES
- FRACTURE ZONE



Lithologic descriptions and/or remarks

QUATERNARY ALLUVIAL DEPOSITS
(0.0 - 3.0) SANDY SILT, [ML], gray brown 2.5Y 5/2, dry-stiff, 20% very fine to very coarse sand, 10% subangular to subrounded pebbles to 2", 5% clay, low plasticity, 1K=M

TERTIARY SEDIMENTS
(3.0 - 12.0) SILTY SANDSTONE, light olive brown 2.5Y 5/3, dry to damp, soft, fine to coarse sand, 20% silt, 1K=M-H

(12.0 - 25.0) CLAYEY SILT, [ML], light yellowish brown 2.5 6/4, damp, stiff, 10% very fine to medium sand, 20% clay, 1K=L-M

(25.0 - 34.0) CLAYEY SILT, [ML], light yellowish brown 2.5 6/4, damp, stiff, 15% clay, 15% very fine to medium sand, 1K=M, becomes damp to moist at 33.0 ft.

(34.0 - 48.0) SILTY SANDSTONE, light olive brown 2.5 5/3, moist to wet, very soft, 25%-30% silt, 5% clay, very fine to coarse sand, 1K=M-H, micas and FeO common, moist, fine to coarse at 37.5-39.0, hit first water at 40.0 ft., sand becomes very fine to medium at 46.0 ft.

(48.0 - 51.0) SILTY CLAYSTONE, greenish gray 56, 5/1 damp, very soft, 30% silt, 5% very fine to medium sand, 1K=L

TD = 51.0'

Appendix I

Evaluation of Metals in Ground Water Samples that Exceeded Concentration Limits (CLs) for RCRA Post-Closure Monitoring of Pit 7

Appendix I

Evaluation of Metals in Ground Water Samples that Exceeded Concentration Limits (CLs) for RCRA Post-Closure Monitoring of Pit 7

Post-closure monitoring of ground water downgradient of pit 7 began during the second quarter of 1992. In 1993, LLNL/ORAD (Operations and Regulatory Affairs Division) applied CLs to the analytical data for metals in ground water. These CLs were calculated by LLNL/ORAD using State guidance (Central Valley Regional Water Quality Control Board [CVRWQCB], 1993) to ensure that the slightest increases in concentrations of constituents of concern between upgradient and downgradient well water samples would be identified. Exceedence of these CLs is considered statistically significant evidence of a release and requires further investigation and, if deemed necessary, construction of an engineered structure to curtail contaminant migration. Because LLNL Site 300 is a CERCLA site, resolution of all CL exceedances will be achieved in discussions between the CERCLA RPMs and LLNL/ERD (Christofferson et al., 1993a,b; 1994).

We have observed that metals may occur both in the firing table wastes and naturally in the rocks (Davis and Coplen, 1991; Buddemeier et al., 1987). The Neroly and Cierbo Formations are composed of volcaniclastic materials deposited in brackish water at a continental margin. It is well known that such rocks would be expected to yield high levels of salts to ground water. Pit 7 is located just below a ground water recharge area, where very dilute recent recharge water (rain water) enters the water-bearing zone and is sampled by upgradient well K7-06. It is expected that this dilute rainwater would dissolve concentrations of naturally occurring metals (salts) as it proceeds progressively downgradient. Thus, increases in ground water metals concentrations downgradient of pit 7 could be attributable to either source (firing table wastes or natural rocks).

During the post-SWRI assessment period, two metals (barium and vanadium) exceeded their respective CLs (Table I-1) in ground water samples collected from wells downgradient of pit 7. Laboratory analysis of one ground water sample from a monitor well (Table I-1) reported lead at a concentration that exceeded the CL. Upon resampling, the CL for lead was not exceeded in the second sample. However, we have included an evaluation of lead in pit 7 ground water here for completeness. RCRA post-closure monitoring at pit 7 involves the sampling of 9 wells. To improve our knowledge of the distribution of these metals in ground water, we sampled ground water from additional wells in the area. We evaluated trends in metals concentrations over time and compared the concentrations of these three metals to concentrations observed in Central Valley waters.

I-1. Barium

Table I-1 contains the maximum post-SWRI barium concentration detected in a Pit 7 Complex ground water sample, and the pit 7 CL and State MCL for barium. Table A-4 contains all ground water metals data for the post-SWRI assessment period. Barium concentrations in pit 7 ground water have not exceeded the MCL. Volcaniclastic rocks (*such as those at Site 300*) may contain appreciable concentrations of barium (Hem, 1989).

Figures I-1 through I-6 are time-series plots of barium in ground water. In general, wells closest to the downgradient edges of the landfills (K7-01, NC7-34, NC7-36, NC7-37, and NC7-40) yielded ground water samples containing the greatest concentrations of barium. These wells also sample ground water containing some of the highest activities of depleted uranium at Site 300. For these reasons, we believe that at least some of the barium observed in ground water near the Pit 7 Complex landfills may arise from leaching of buried wastes.

I-2. Lead

Table I-1 contains the maximum post-SWRI lead concentration detected in a Pit 7 Complex ground water sample, and the pit 7 CL and State MCL for lead. Lead concentrations in pit 7 ground water have not exceeded the MCL. Figures I-7 through I-14 are time-series plots of lead in ground water. Prior to 1987, lead concentrations fluctuated greatly in ground water samples collected, and have gradually become less variable and of lower magnitude. Since the maximum ground water lead concentration was detected in the sample from well NC7-36 (Table I-1), four subsequent samples collected from the well have not contained detectable lead. However, the presence of lead in ground water samples from several wells on the downgradient edge of the landfills (wells NC7-37 and NC7-48) indicates that some lead may be leaching from the pits to ground water. Studies by Hem (1989) indicate that alkaline, bicarbonate-dominant water such as that present at the Pit 7 Complex, will precipitate lead as bicarbonate complexes and, thus, maintain a lead concentration appreciably below the State MCL.

Dubrovsky et al. (1991) found that the median lead concentration in semi-confined ground waters in the western San Joaquin Valley was about 0.001 mg/L; the maximum concentration was 0.005 mg/L. Comparing frequency histograms for lead in Central Valley ground water (U.S. Geological Survey, 1991) to EFA/WFA study area ground water (Webster-Scholten, 1994) indicates that the latter waters contain appreciably less lead than do Central Valley waters (page P-4-16 of Appendix P in Webster-Scholten, 1994).

I-3. Vanadium

Table I-1 contains the maximum post-SWRI vanadium concentration detected in a Pit 7 Complex ground water sample, and the pit 7 CL. No state or federal MCL exists for vanadium. Figures I-15 through I-20 are time-series plots of vanadium in ground water. Dubrovsky et al. (1991) found that the median vanadium concentration in semi-confined ground waters in the western San Joaquin Valley was about 0.010 mg/L; the maximum concentration was 0.025 mg/L. Vanadium is a typical trace component of Central Valley rocks (Dubrovsky et al., 1991). Vanadium is ubiquitous in ground water within the OU at concentrations in the range of 0.01–0.1 mg/L. Its distribution in ground water strongly suggests that the vanadium concentrations observed in Pit 7 Complex ground water are natural.

Comparing frequency histograms for vanadium in Central Valley ground water (U.S. Geological Survey, 1992) to EFA/WFA study area ground water (Webster-Scholten, 1994) indicates that the latter waters contain vanadium at concentrations equivalent to the upper limits of those observed in Central Valley waters (page P-4-23 of Appendix P in Webster-Scholten, 1994).

I-4. References

Buddemeier, R. W., D. H. Armstrong, and M. G. Brown (1987), *Appendix E: Metals in Ground Water—The Geochemistry of Occurrence and Variability in LLNL Site 300 Ground Water Monitoring Program Quarterly Report, April–June 1987*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCAR-10191-87-2).

Christofferson, E., D. H. MacQueen, N. L. Hankla, and W. G. Hoppes (1993a), *LLNL Site 300 Ground Water Monitoring Program Quarterly Report, July–September 1993,* Lawrence Livermore National Laboratory, Livermore, Calif. (UCAR-10191-93-3).

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Central Valley Regional Water Quality Control Board (1993): "Order No. 93-100: Waste Discharge Requirements for University of California Lawrence Livermore National Laboratory Site 300 and U.S. Department of Energy Landfill Pits 1 and 7, San Joaquin County, California," June 25, 1993.

Davis, G., and T. Coplen (1990), *Late Cenozoic Paleohydrogeology of The Western San Joaquin Valley*, Geological Society of America Special Paper 248.

Dubrovsky, N. M., J. M. Neil, M. C. Welker, and K. D. Evenson (1991), *Geochemical Relations and Distribution of Selected Trace Elements in Ground Water of the Northern Part of the Western San Joaquin Valley, California*, U.S. Geological Survey Open-file report 90-108, Sacramento, Calif.

Hem, J. D. (3rd edition, 1989), *Study and Interpretation of the Chemical Characteristics of Natural Water*, U.S. Geological Survey Water-Supply Paper 2254, Alexandria, Va.

U.S. Geological Survey (1992), "WATSTORE; Database of Ground Water Quality."

Webster-Scholten, C. P., Ed. (1994), *Final Site-Wide Remedial Investigation Report, Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-21010).

Appendix I

Table

Table I-1. Maximum concentrations of metals that exceeded concentration limits (CLs) in ground water samples from wells downgradient of pit 7.

Compound detected	Maximum concentration (mg/L)	CL (mg/L)	State MCL (mg/L)	Sample date	Monitor well
Barium	0.378	0.09	1.0	06-01-94	NC7-37
Lead	0.006[a]	0.002	0.050	05-25-94	NC7-36
Vanadium	0.012	0.05	–[b]	12-02-94	NC7-48

[a] This concentration was not confirmed on resampling. A second sample analysis yielded lead at a concentration below the CL.

[b] No MCL or action level exists.

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Appendix I

Figures

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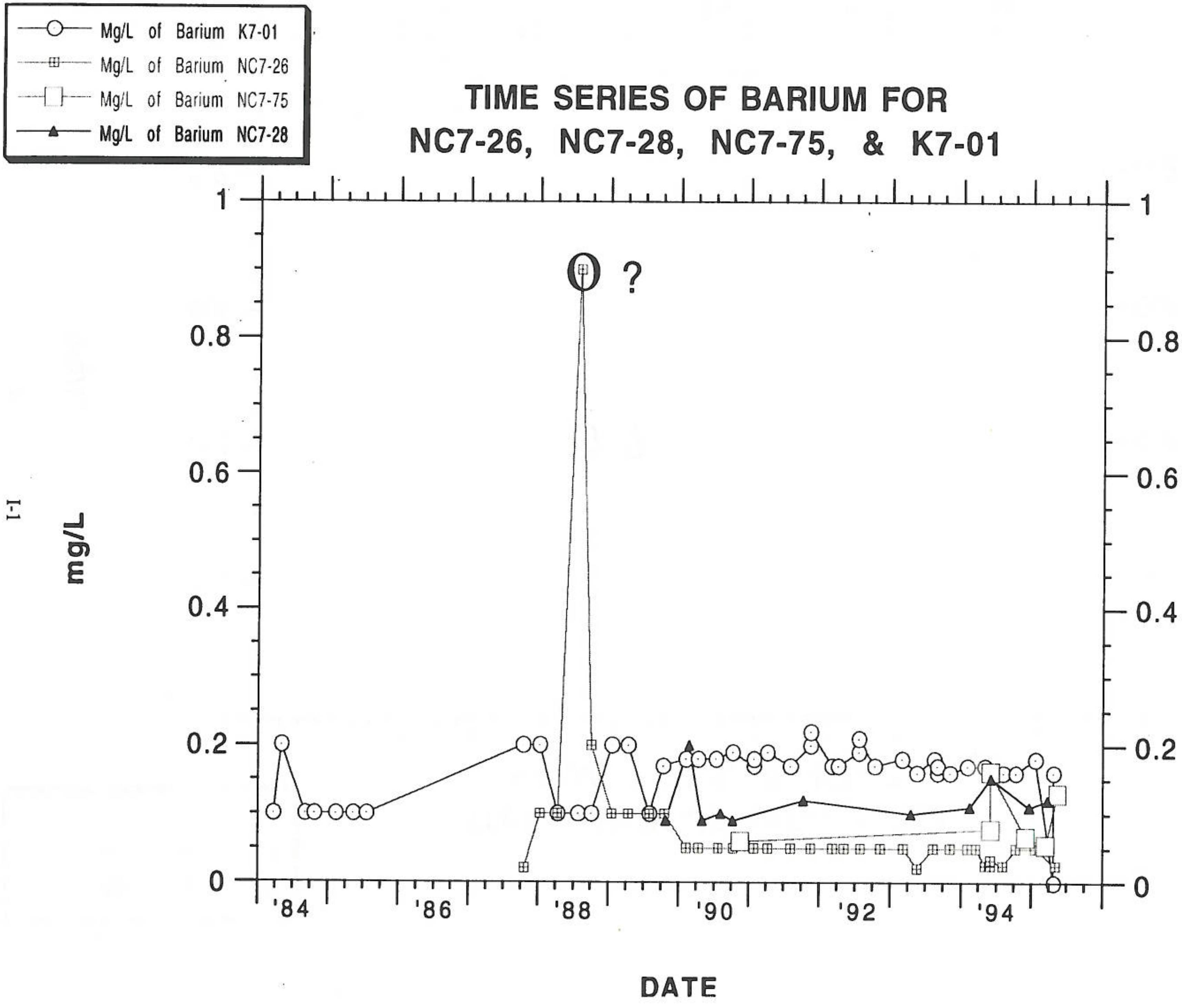
TIME SERIES OF BARIUM FOR NC7-26, NC7-28, NC7-75, & K7-01



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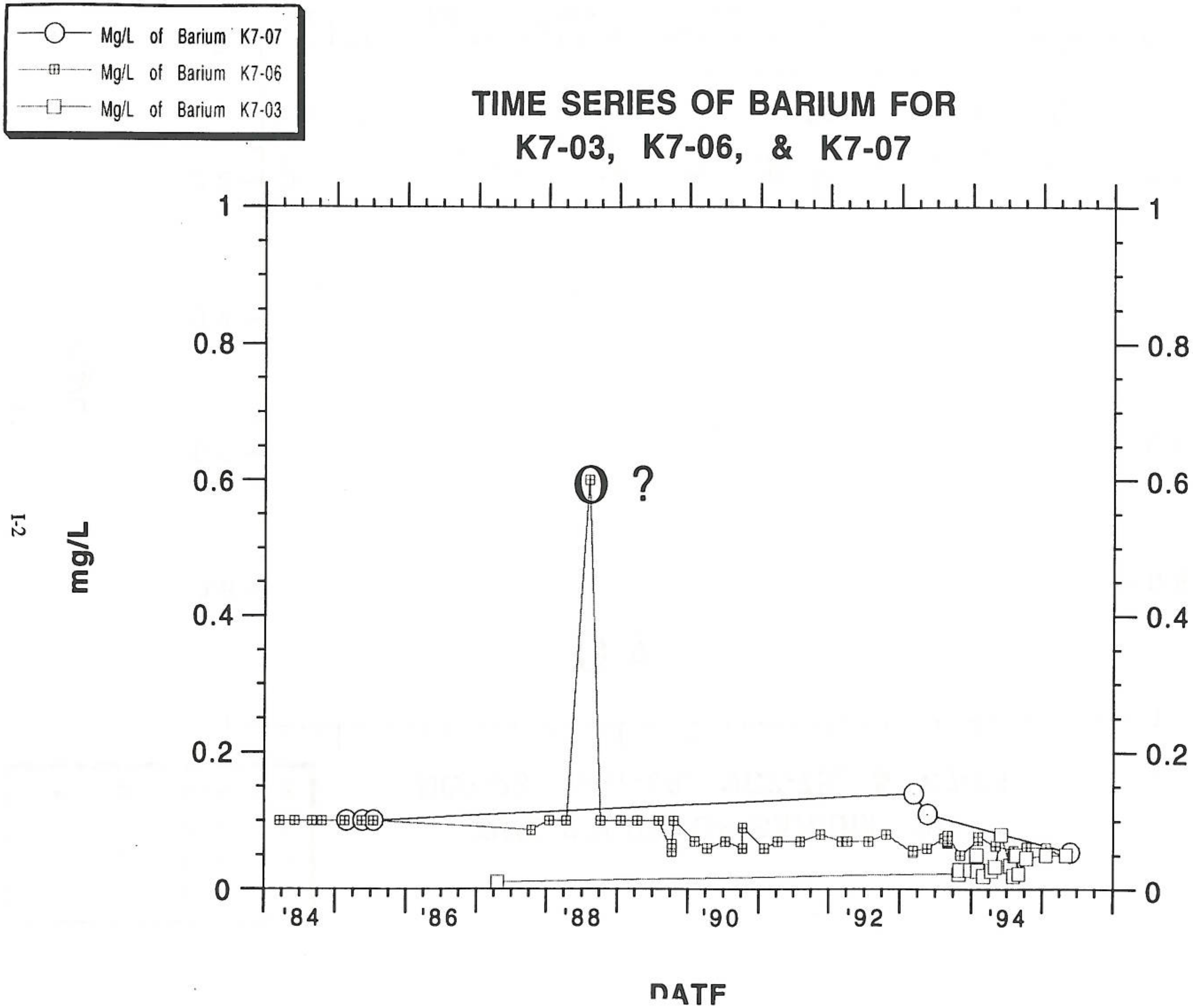

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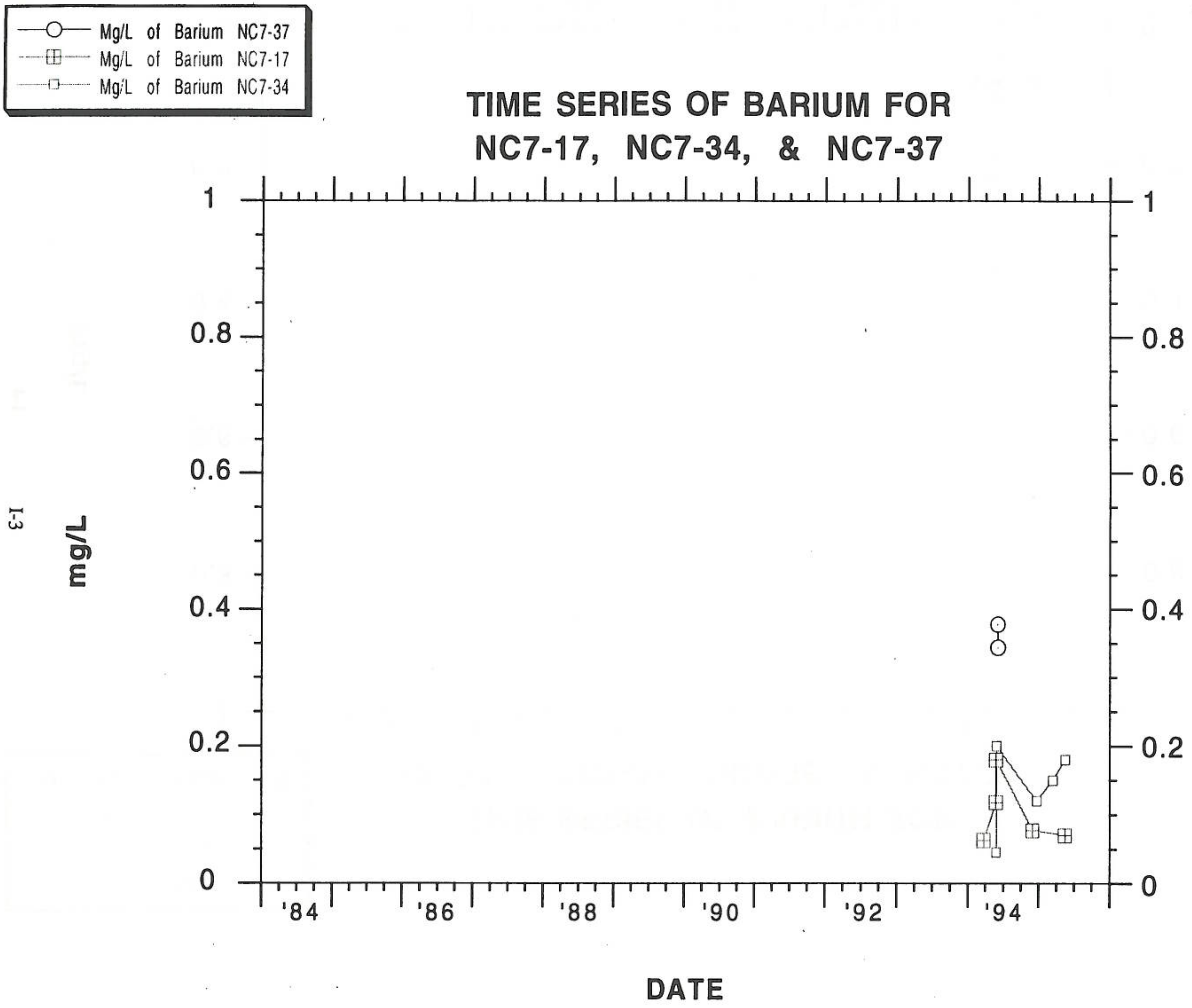

TIME SERIES OF BARIUM FOR NC7-17, NC7-34, & NC7-37

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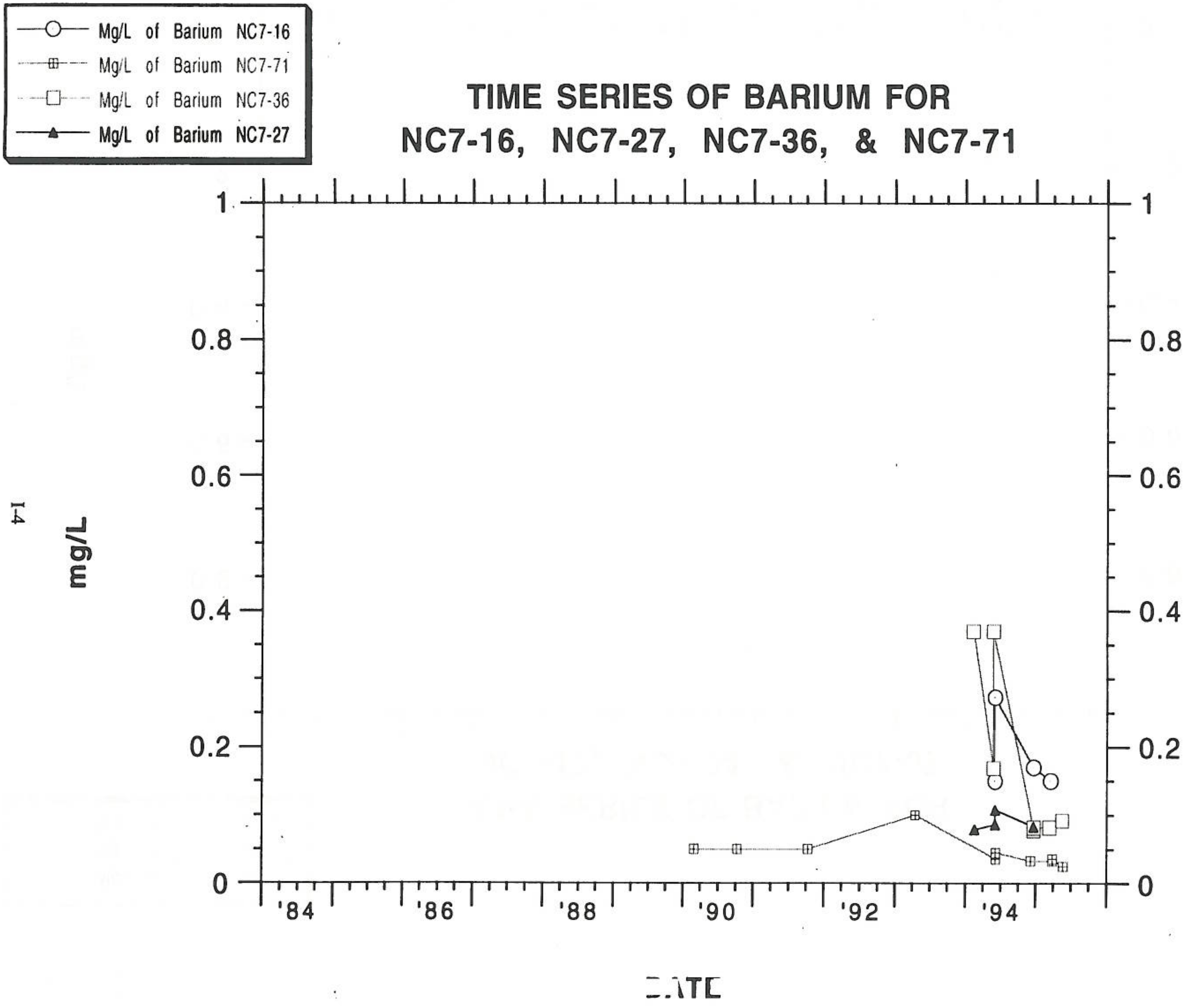

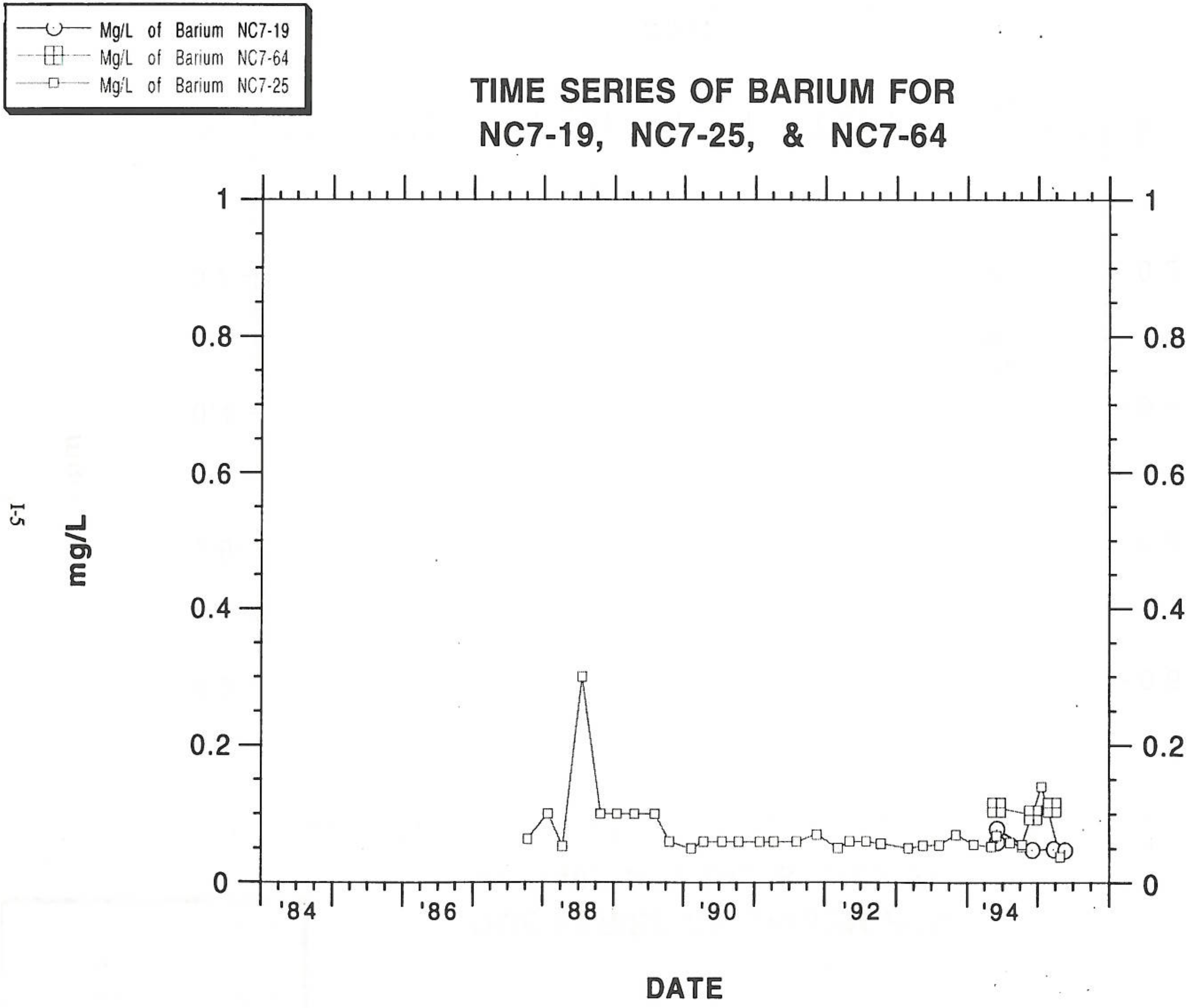

TIME SERIES OF BARIUM FOR NC7-19, NC7-25, & NC7-64

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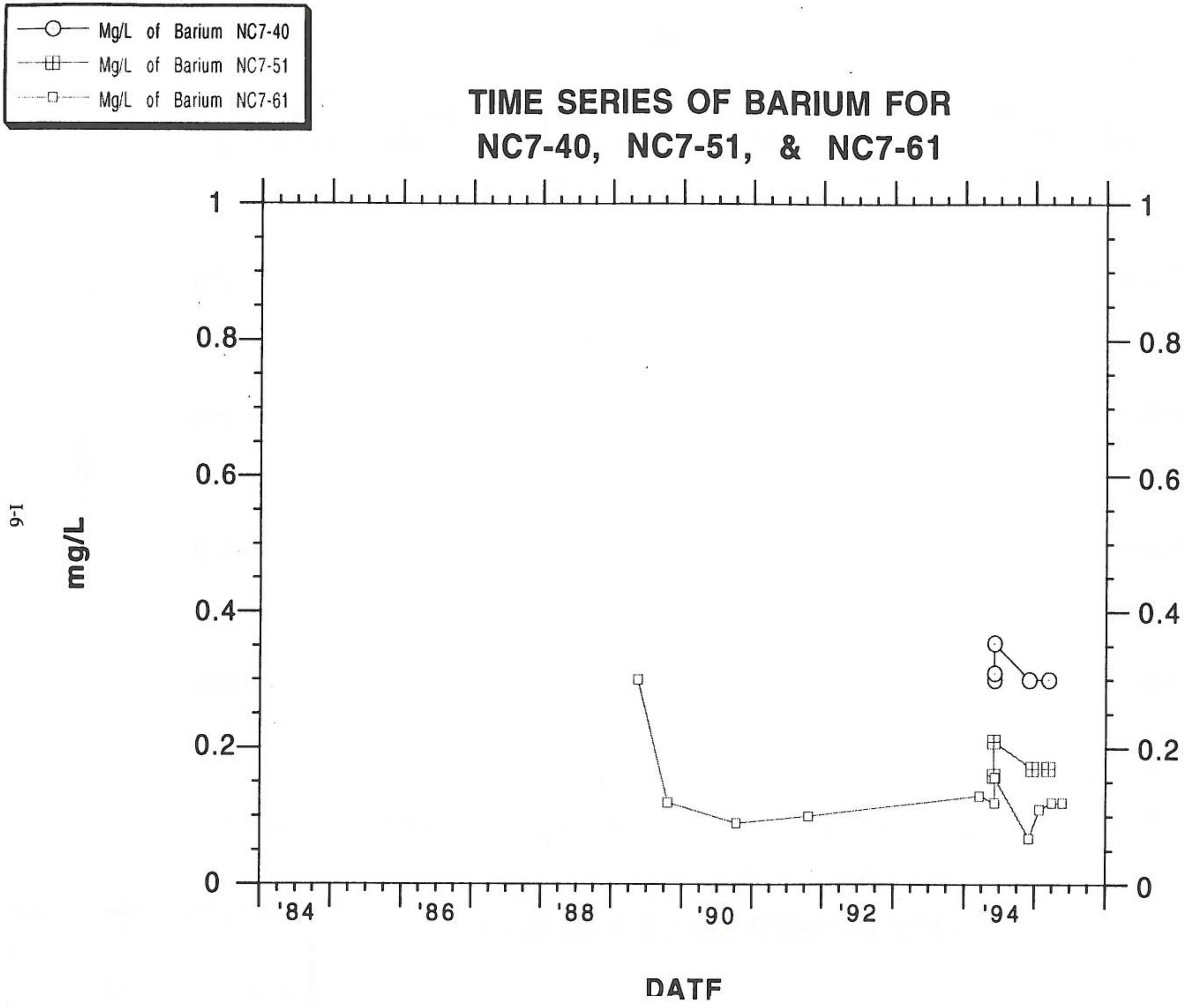

TIME SERIES OF BARIUM FOR NC7-40, NC7-51, & NC7-61

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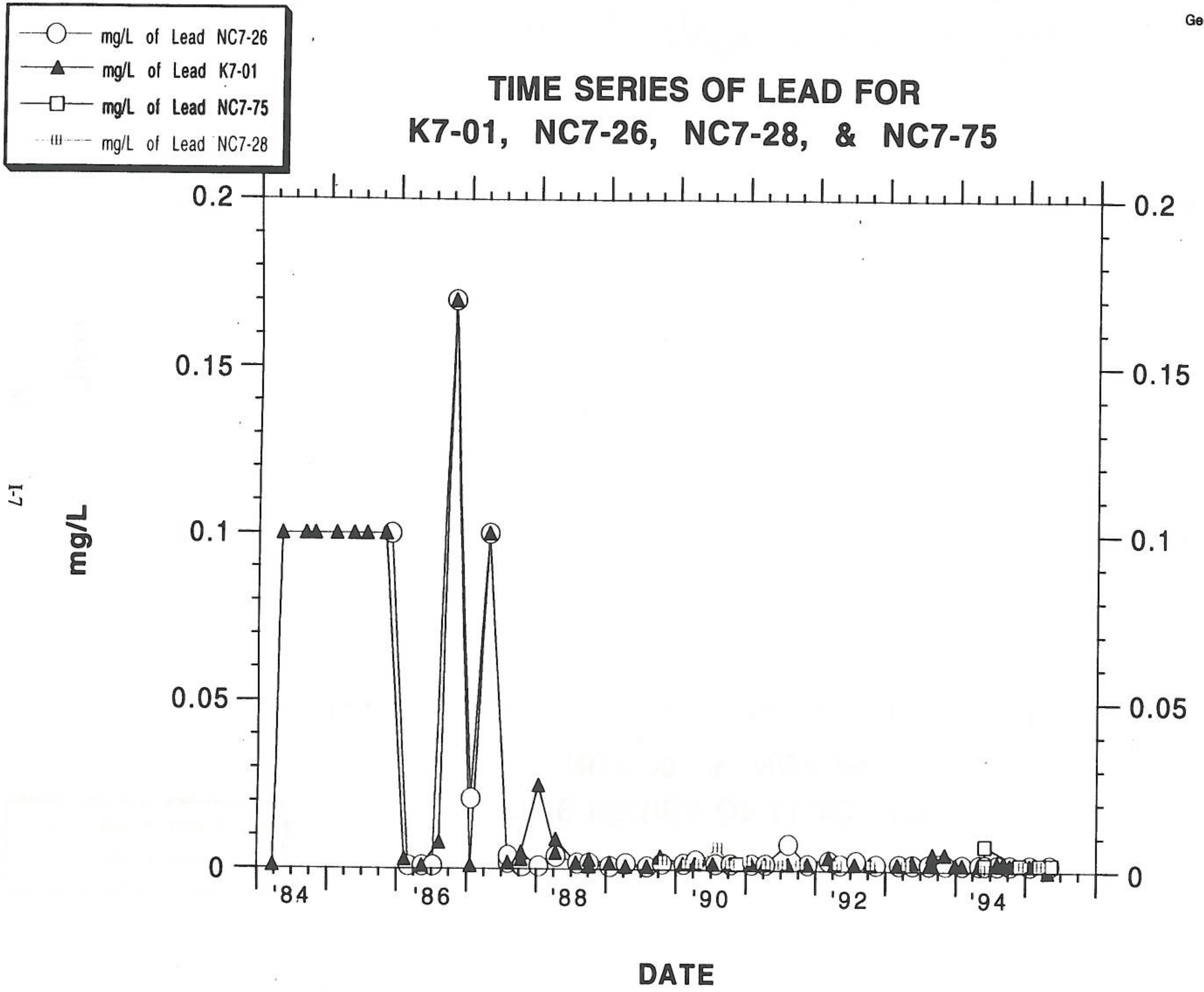

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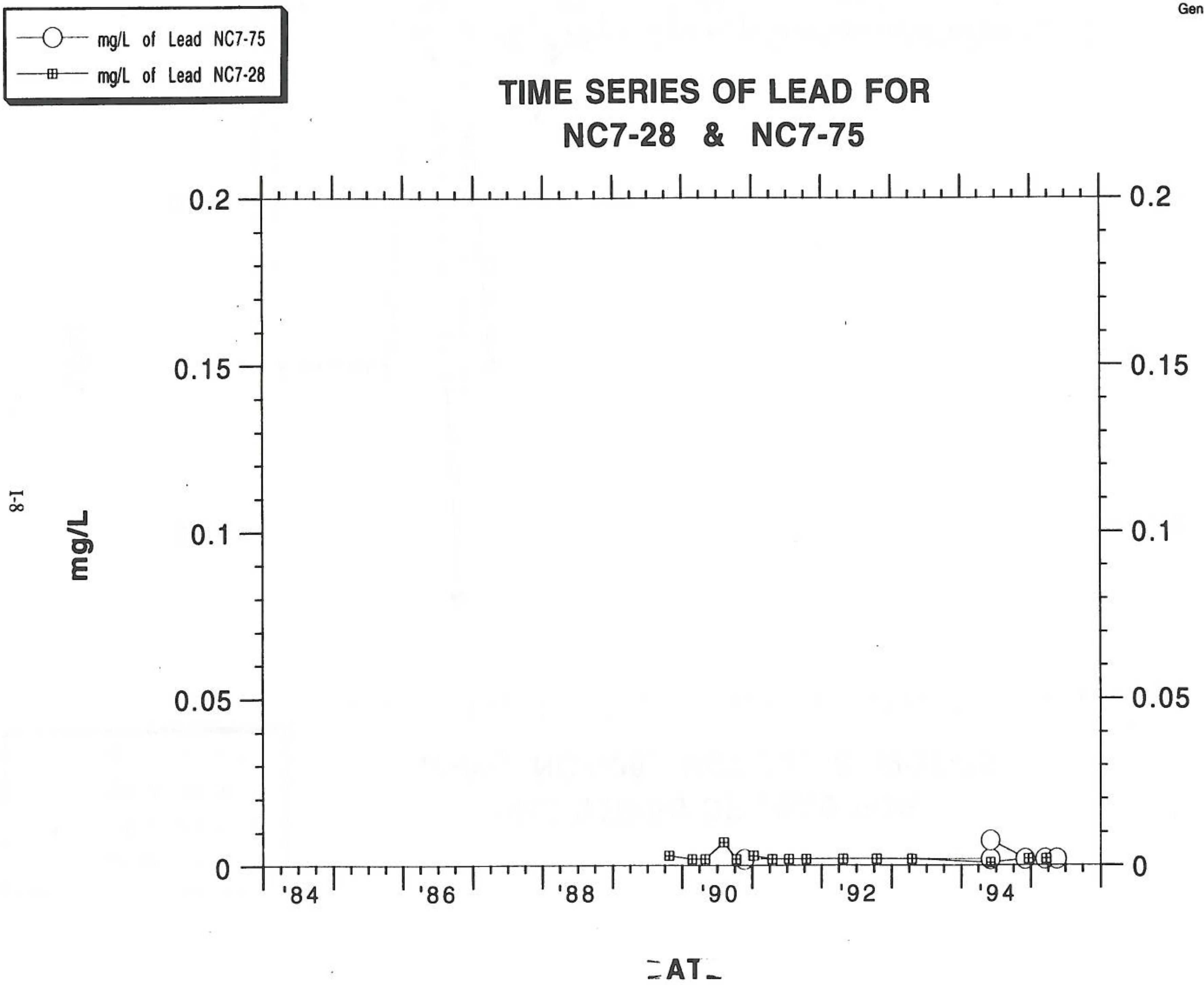
TIME SERIES OF LEAD FOR NC7-28 & NC7-75



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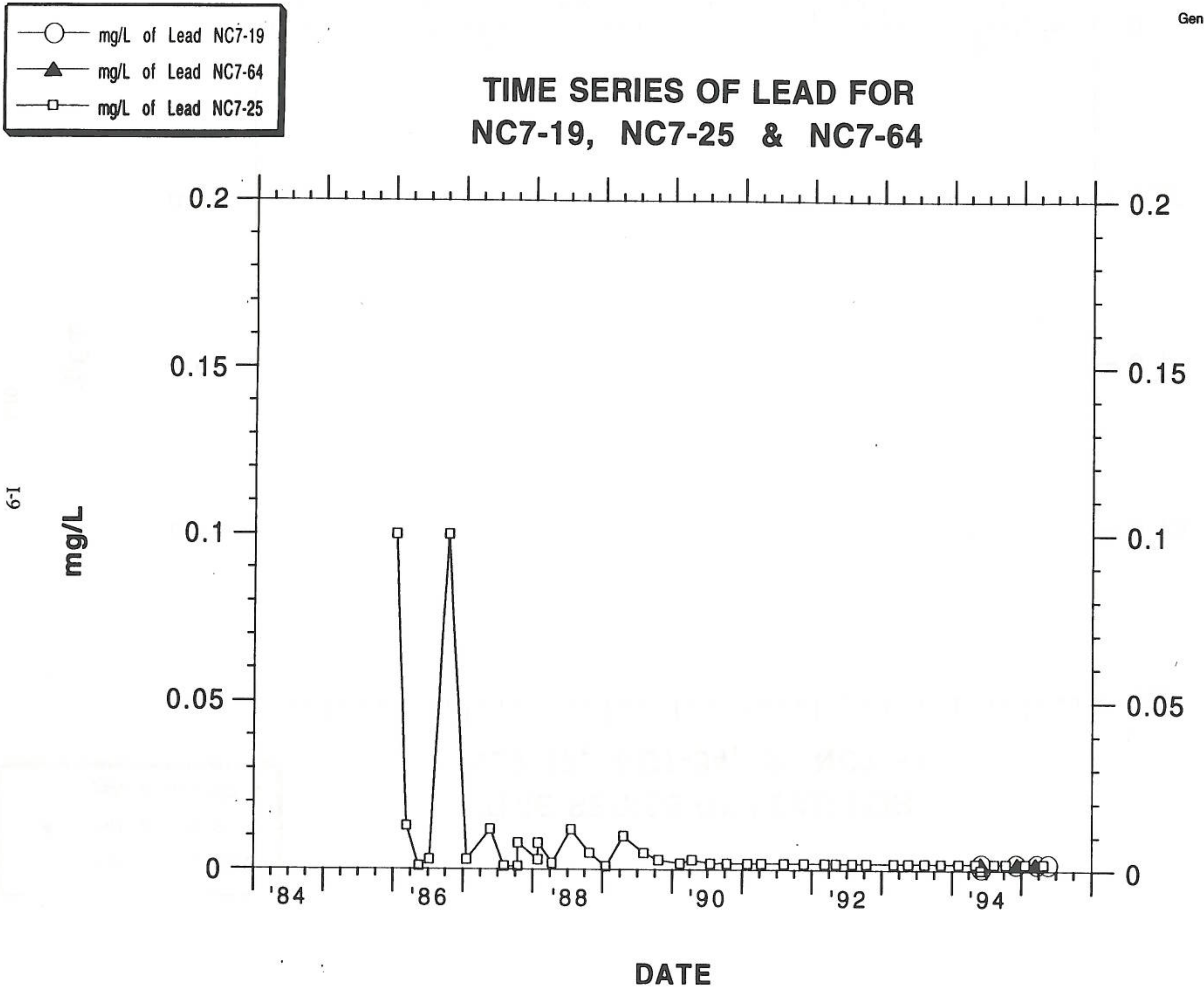

TIME SERIES OF LEAD FOR NC7-19, NC7-25 & NC7-64

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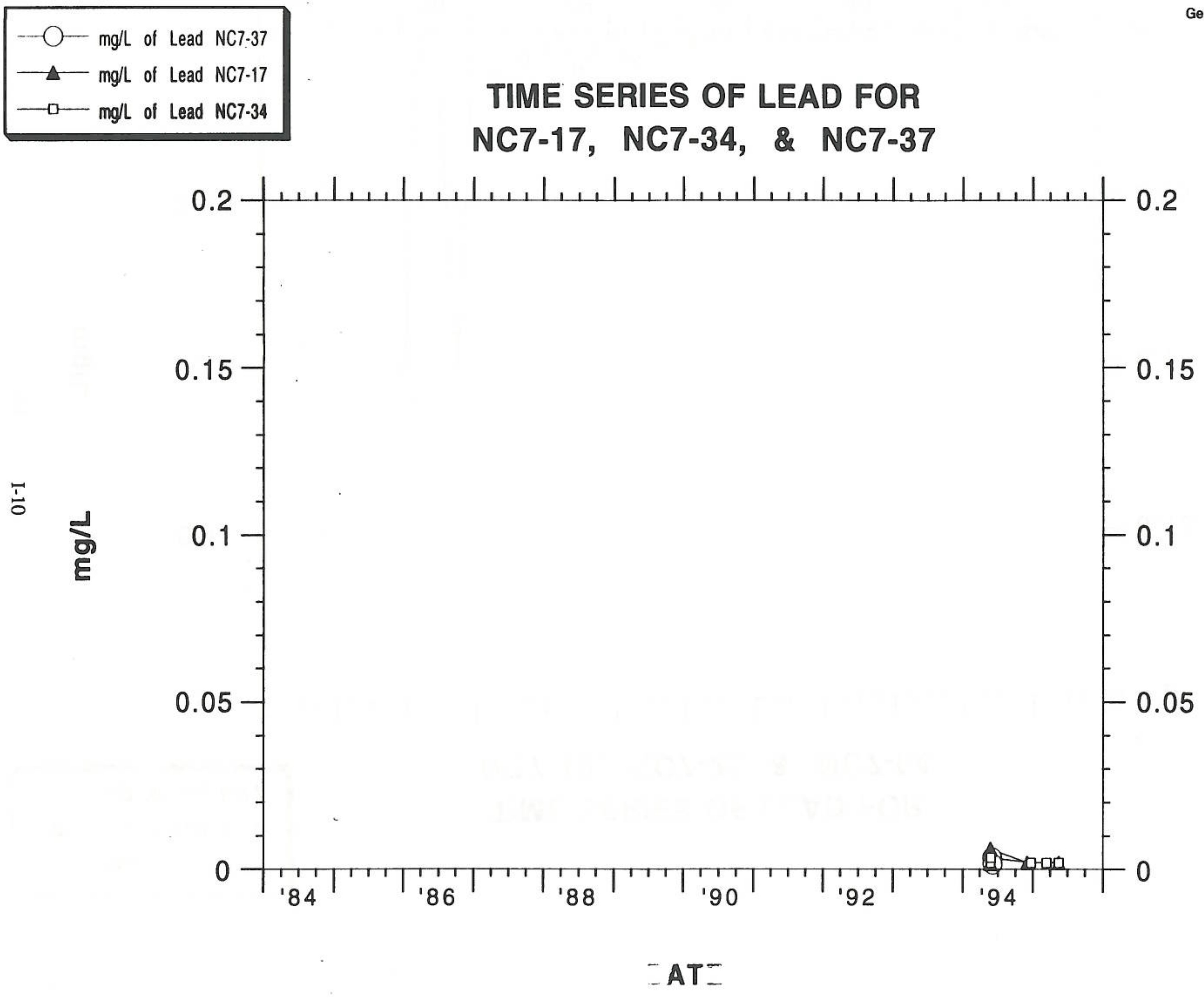

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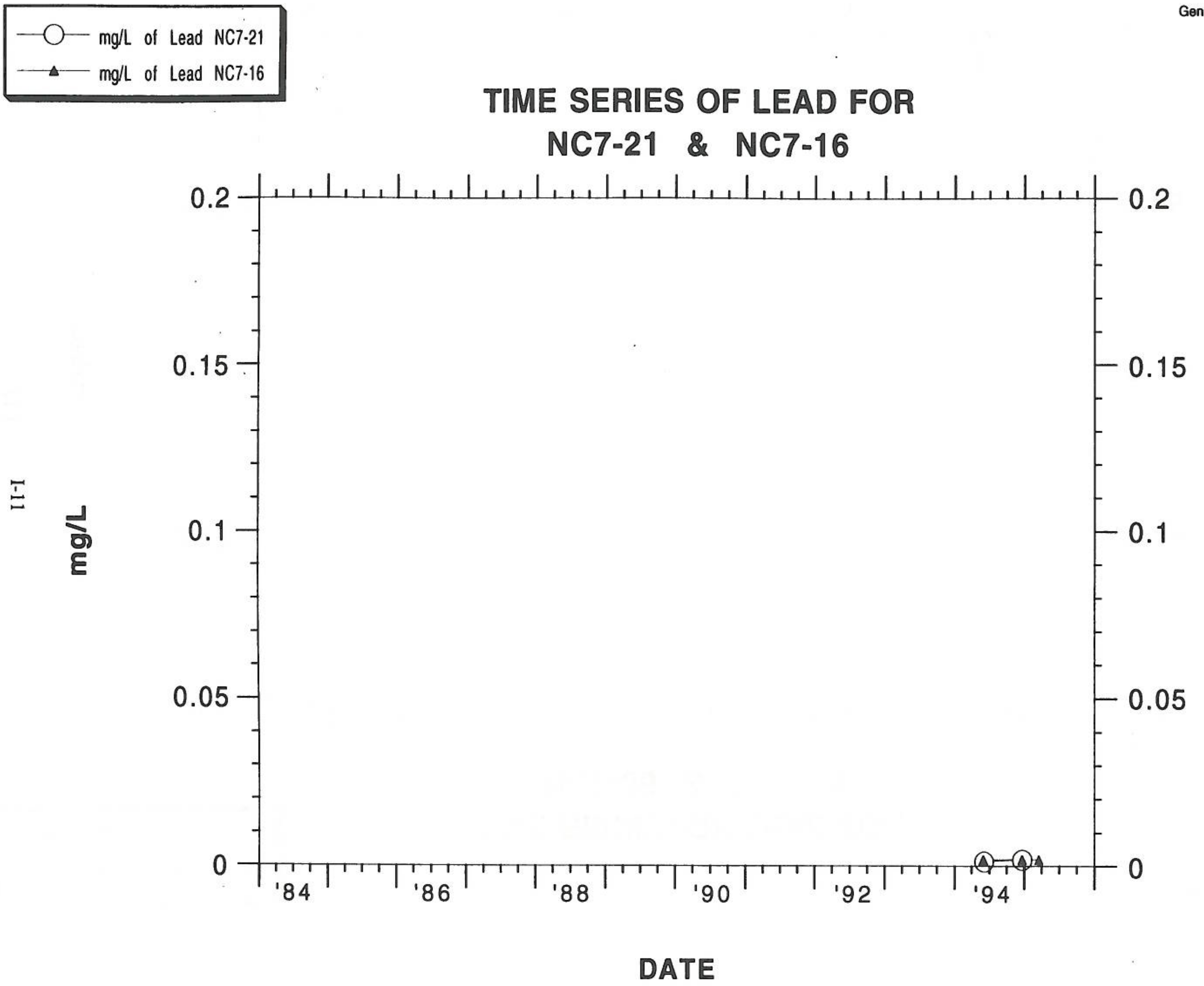

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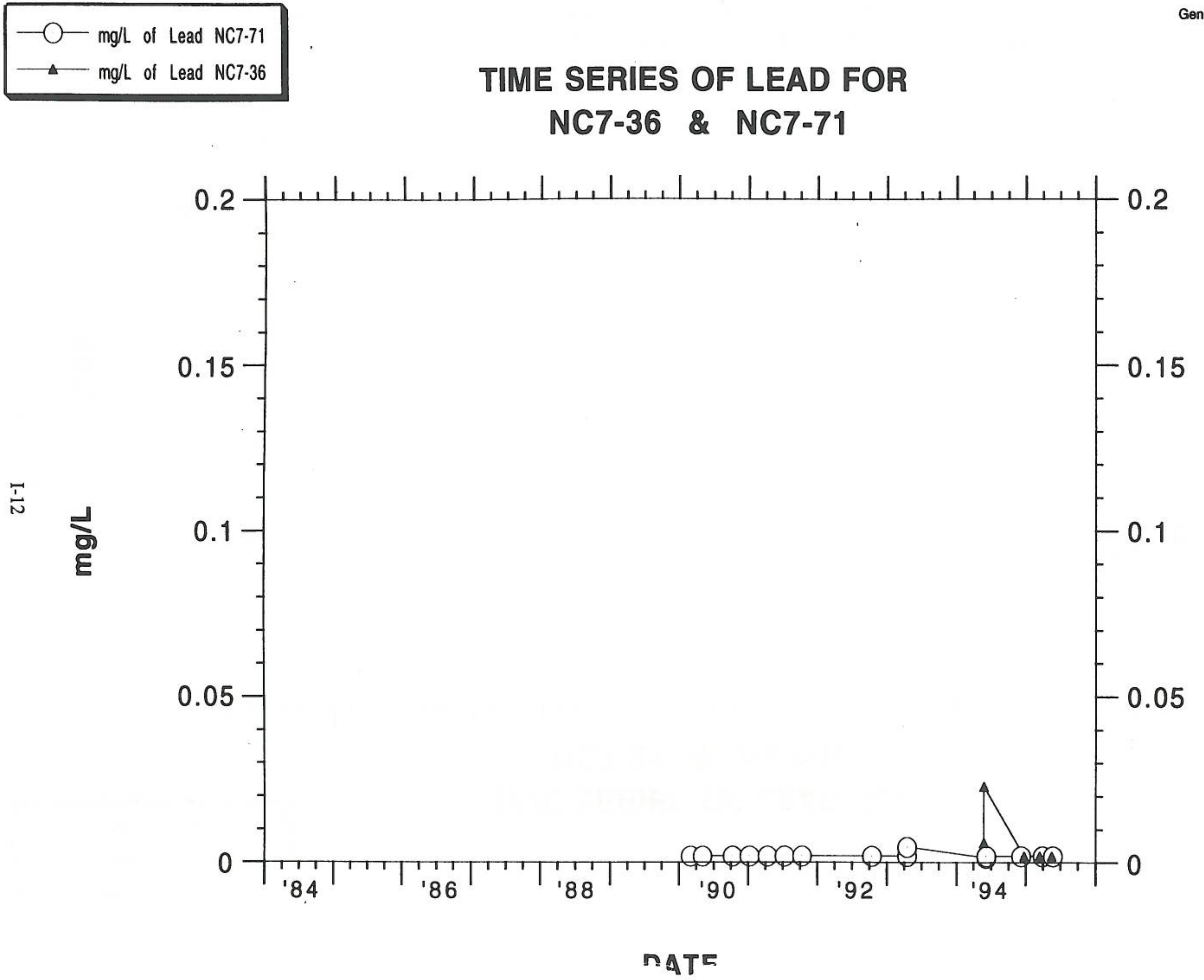
TIME SERIES OF LEAD FOR
NC7-36 & NC7-71



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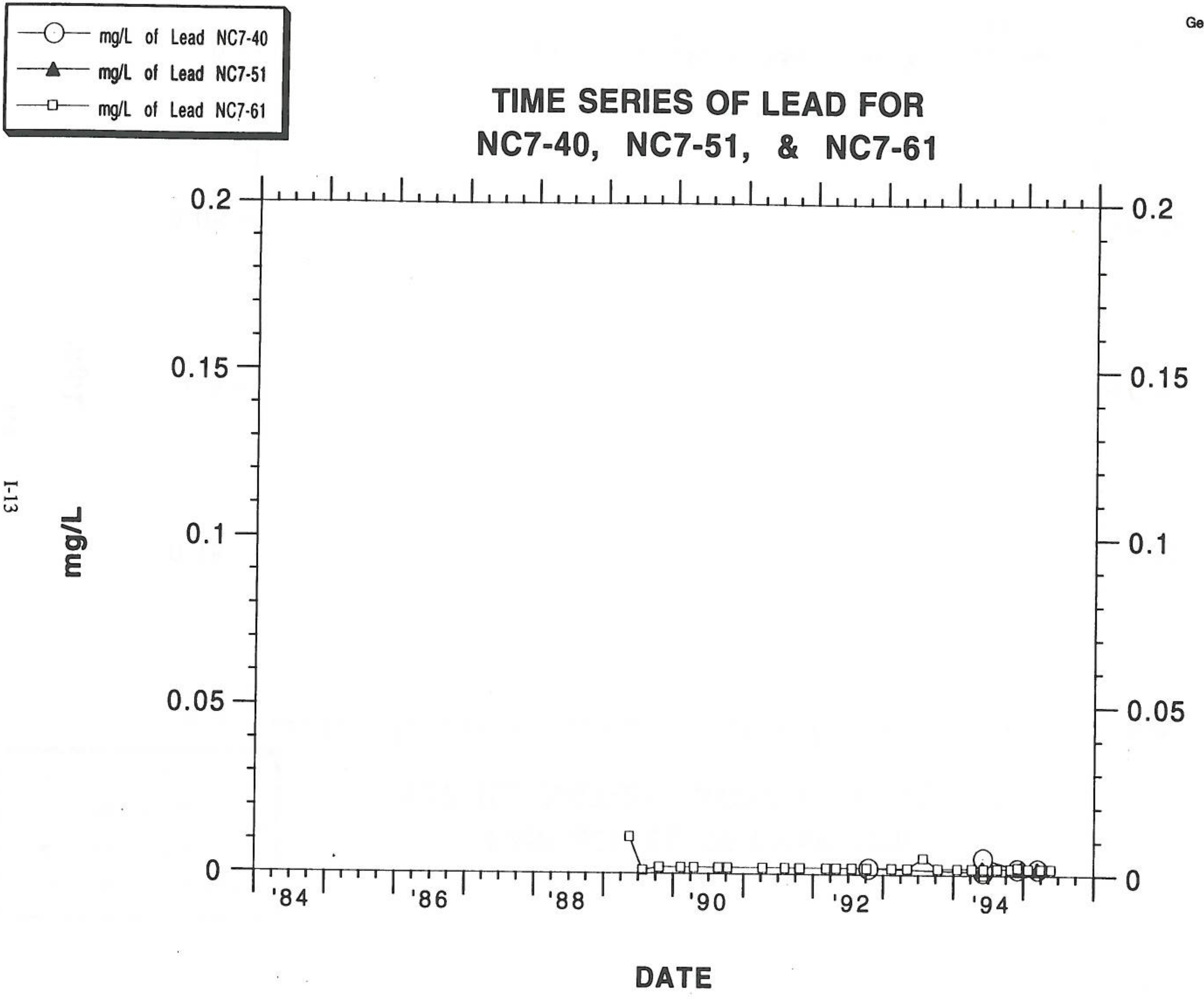
TIME SERIES OF LEAD FOR NC7-40, NC7-51, & NC7-61



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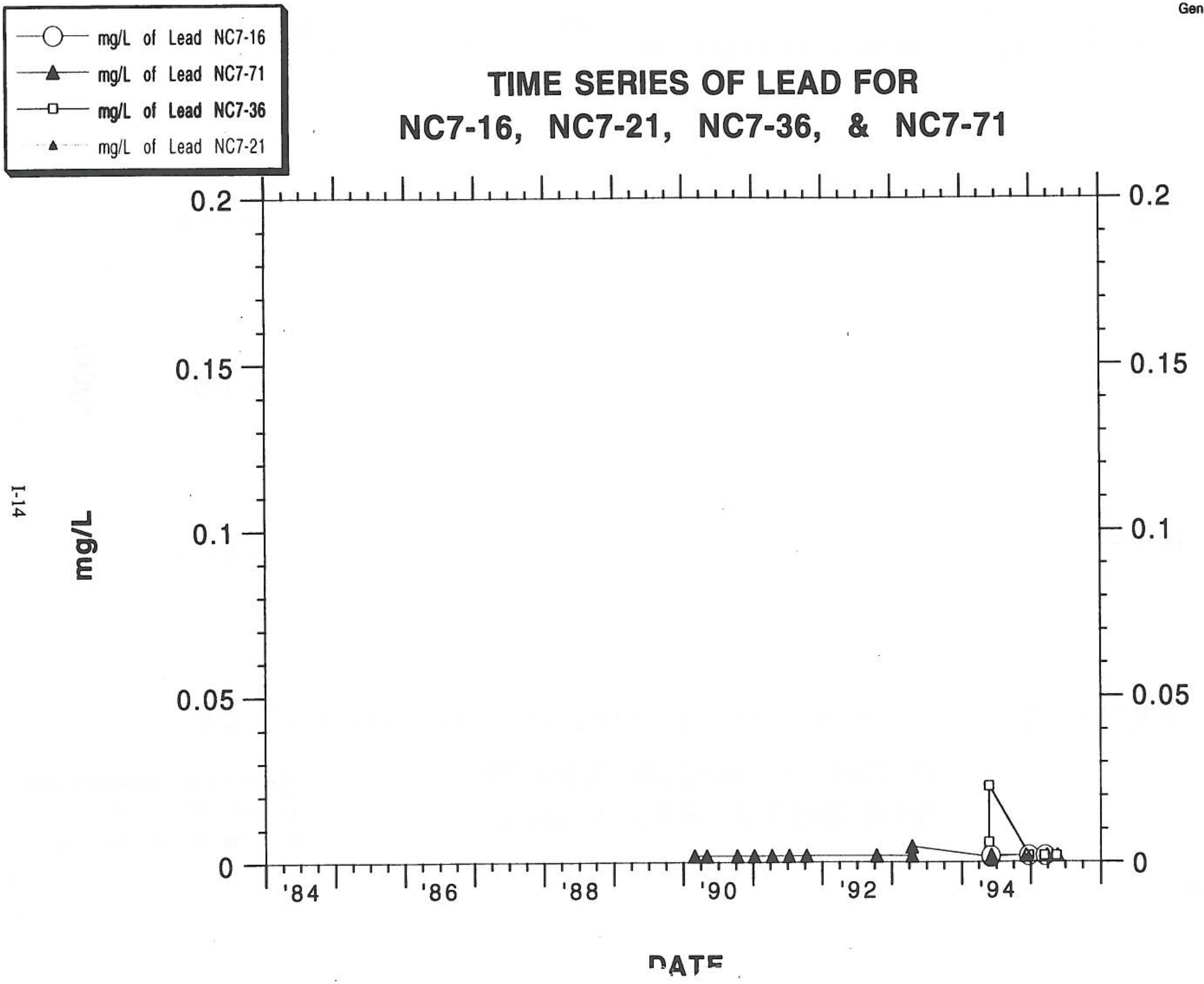

TIME SERIES OF LEAD FOR
NC7-16, NC7-21, NC7-36, & NC7-71

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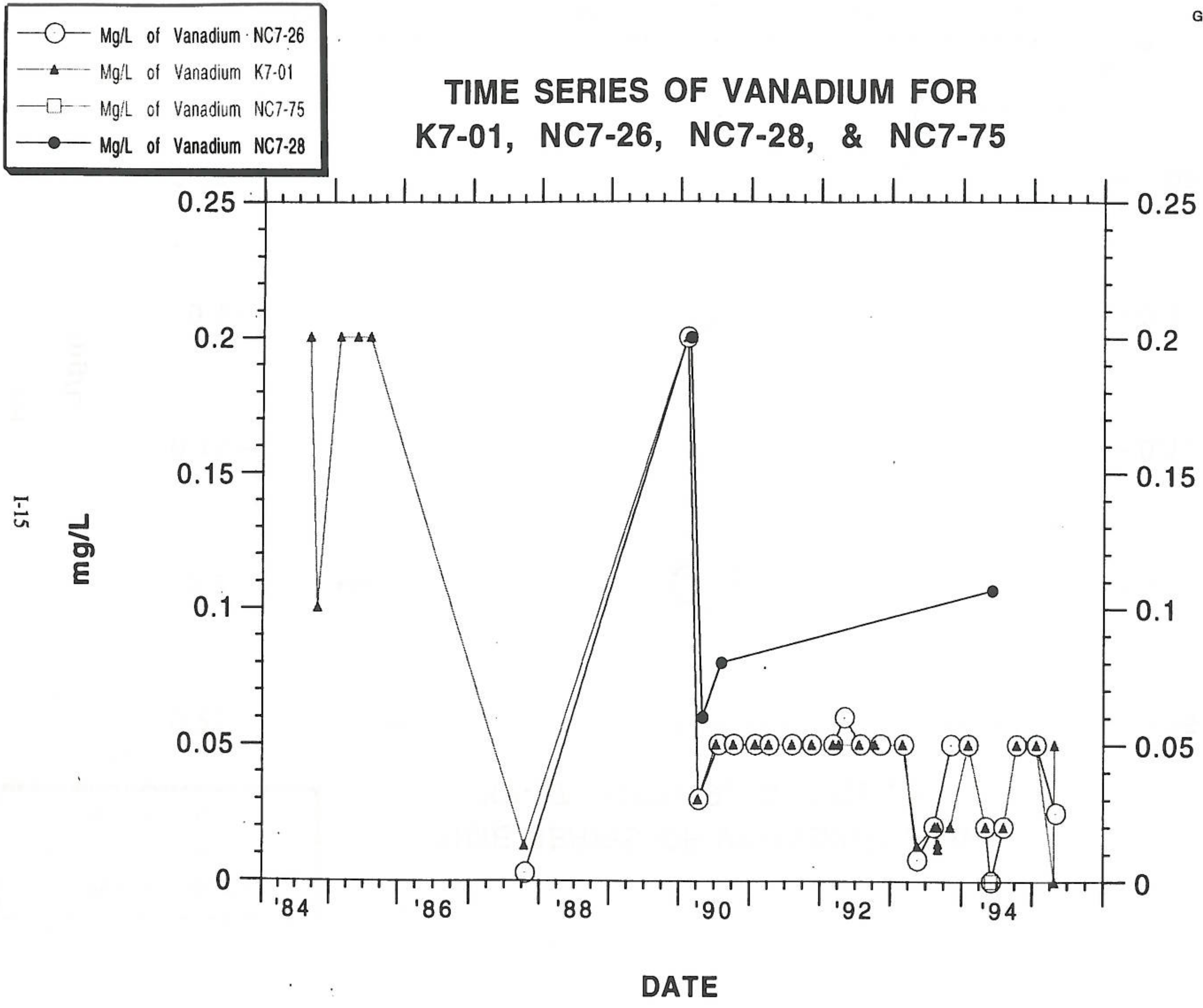
TIME SERIES OF VANADIUM FOR K7-01, NC7-26, NC7-28, & NC7-75



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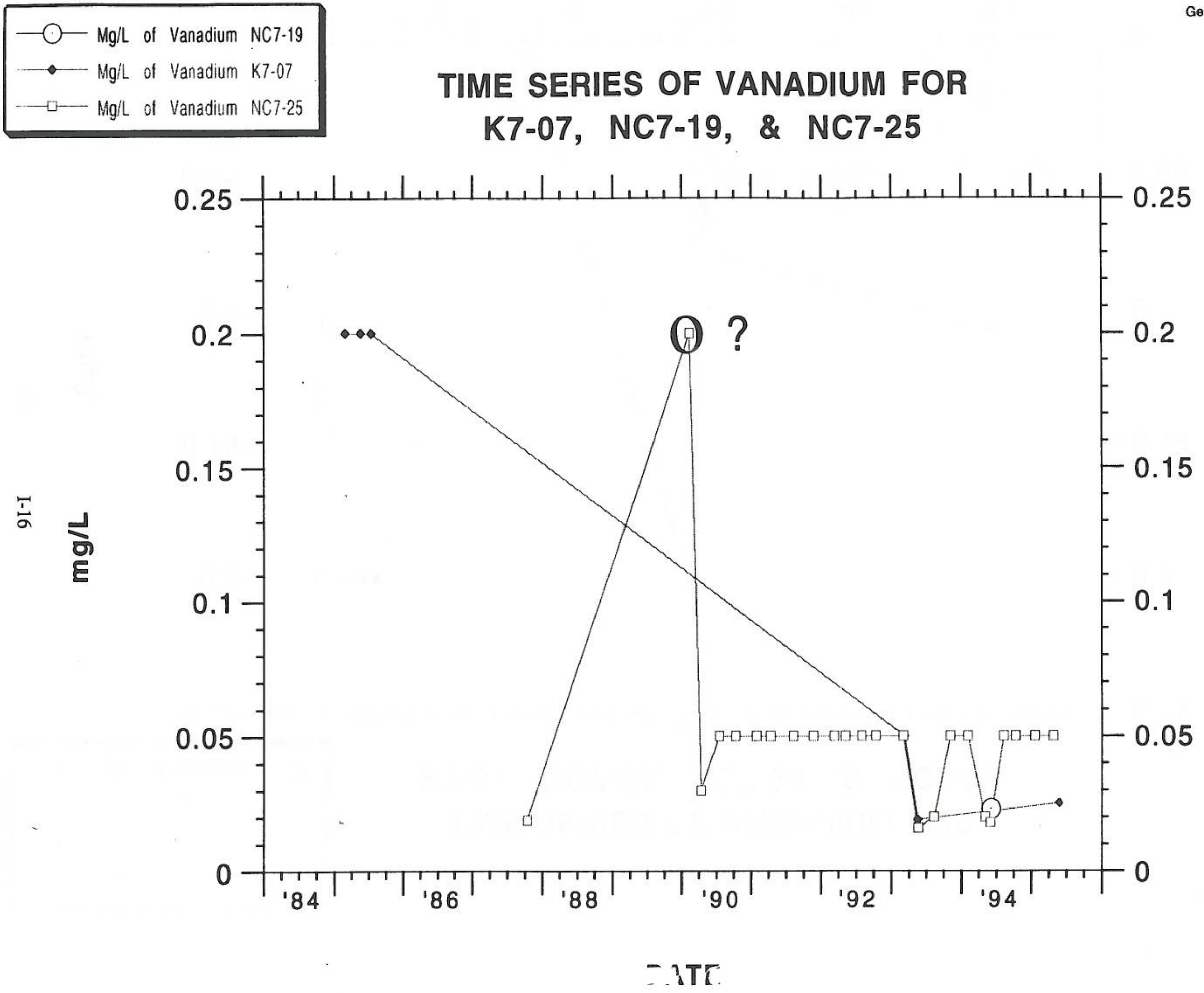
TIME SERIES OF VANADIUM FOR K7-07, NC7-19, & NC7-25



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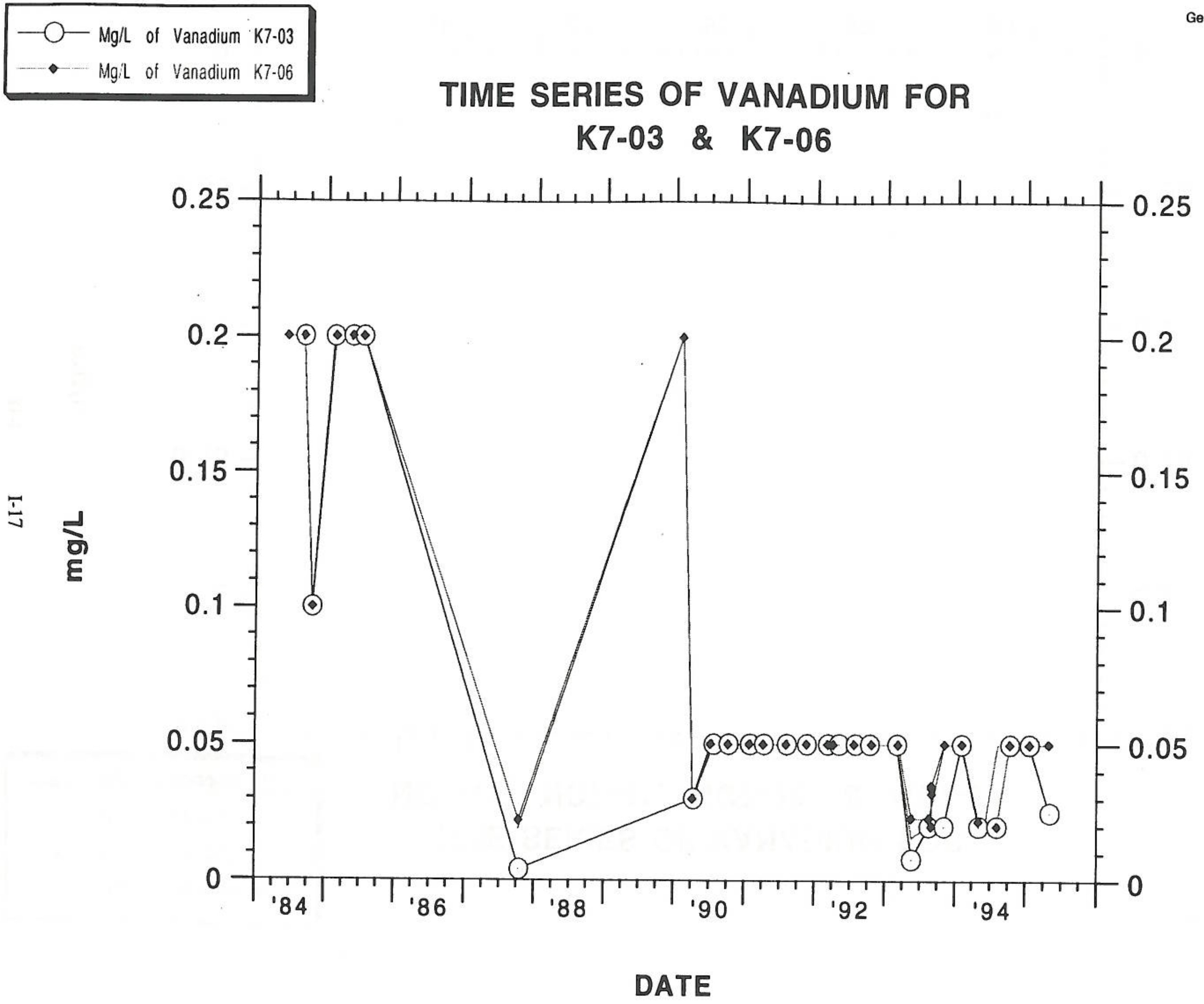

TIME SERIES OF VANADIUM FOR K7-03 & K7-06

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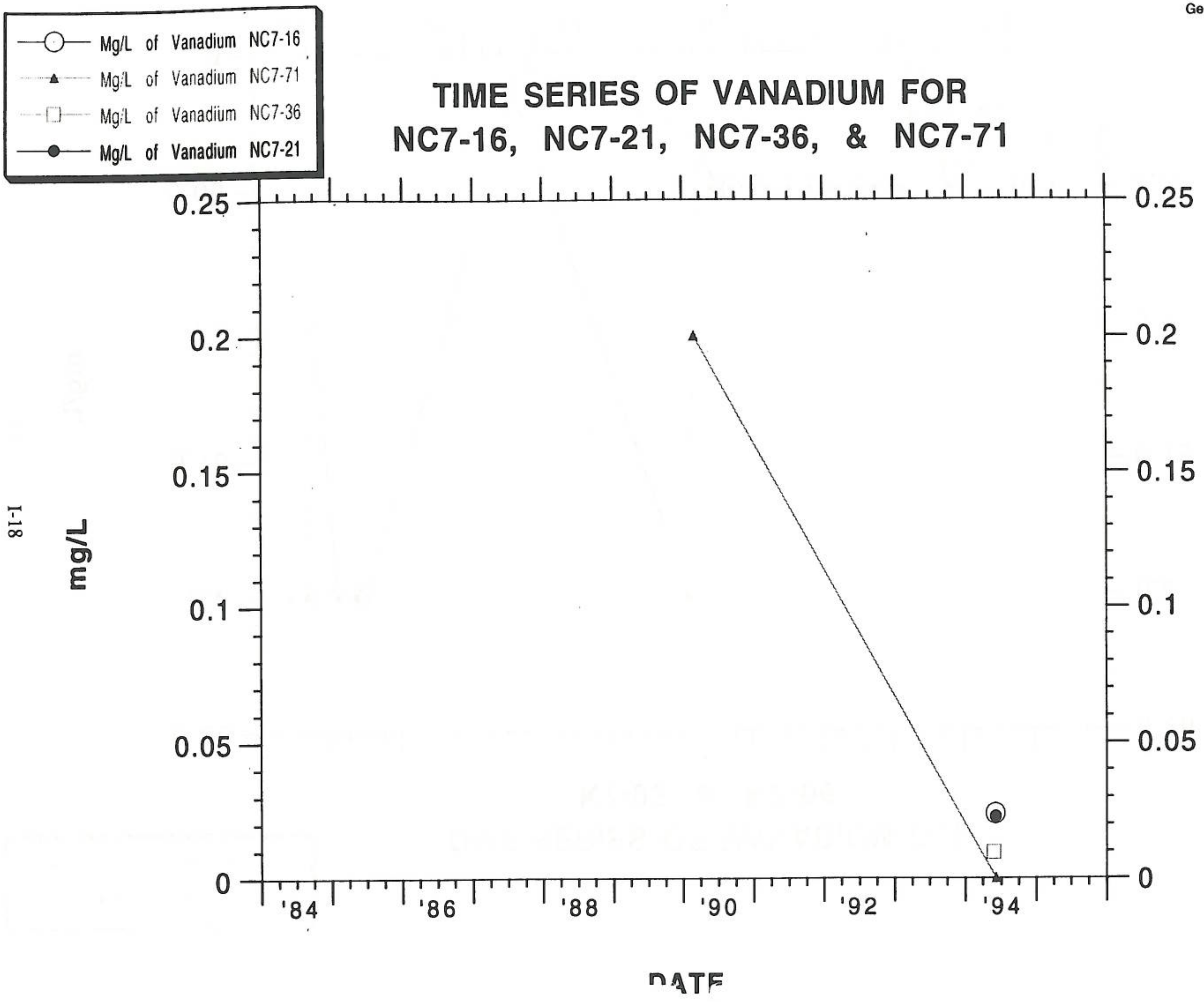
TIME SERIES OF VANADIUM FOR NC7-16, NC7-21, NC7-36, & NC7-71



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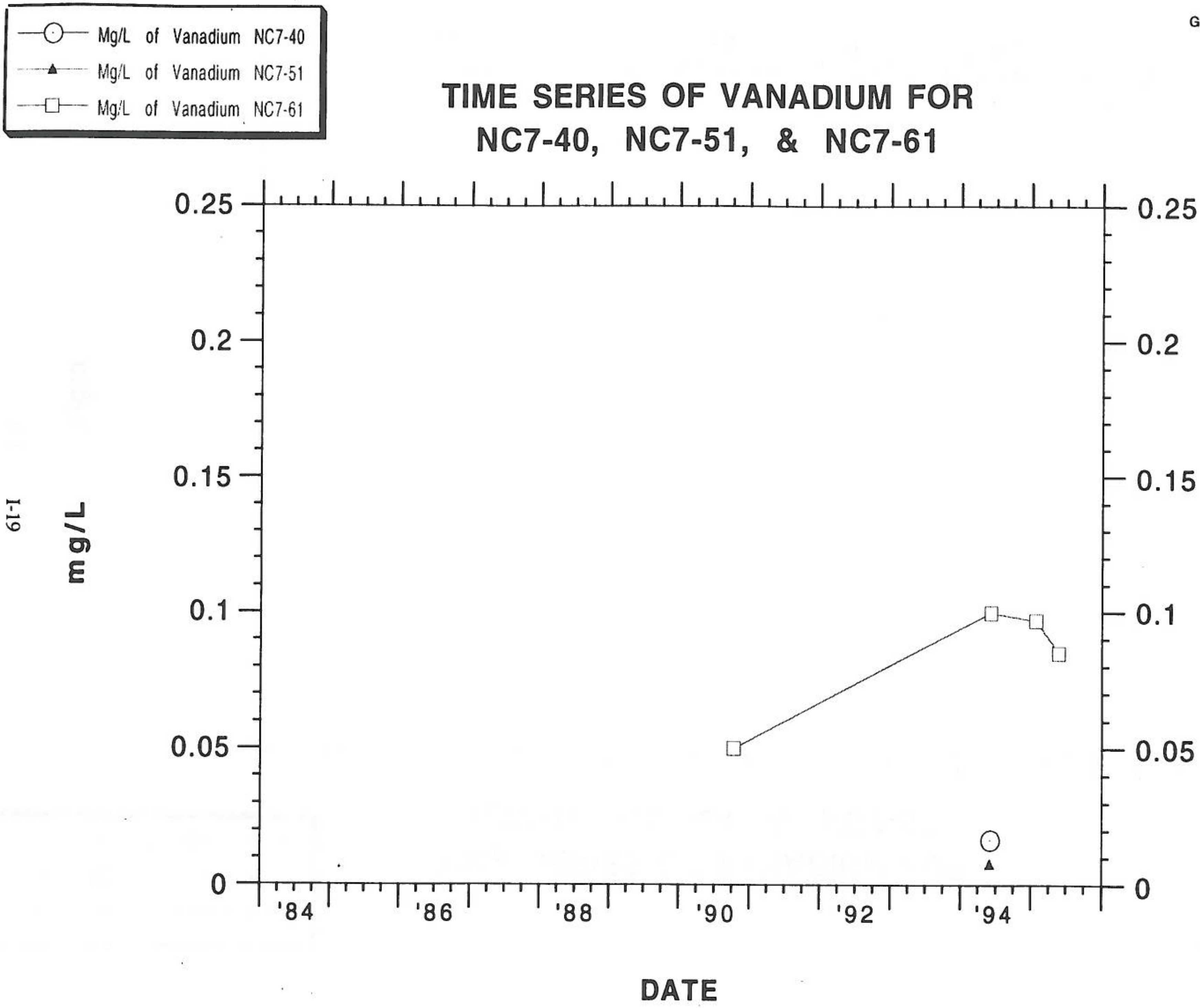

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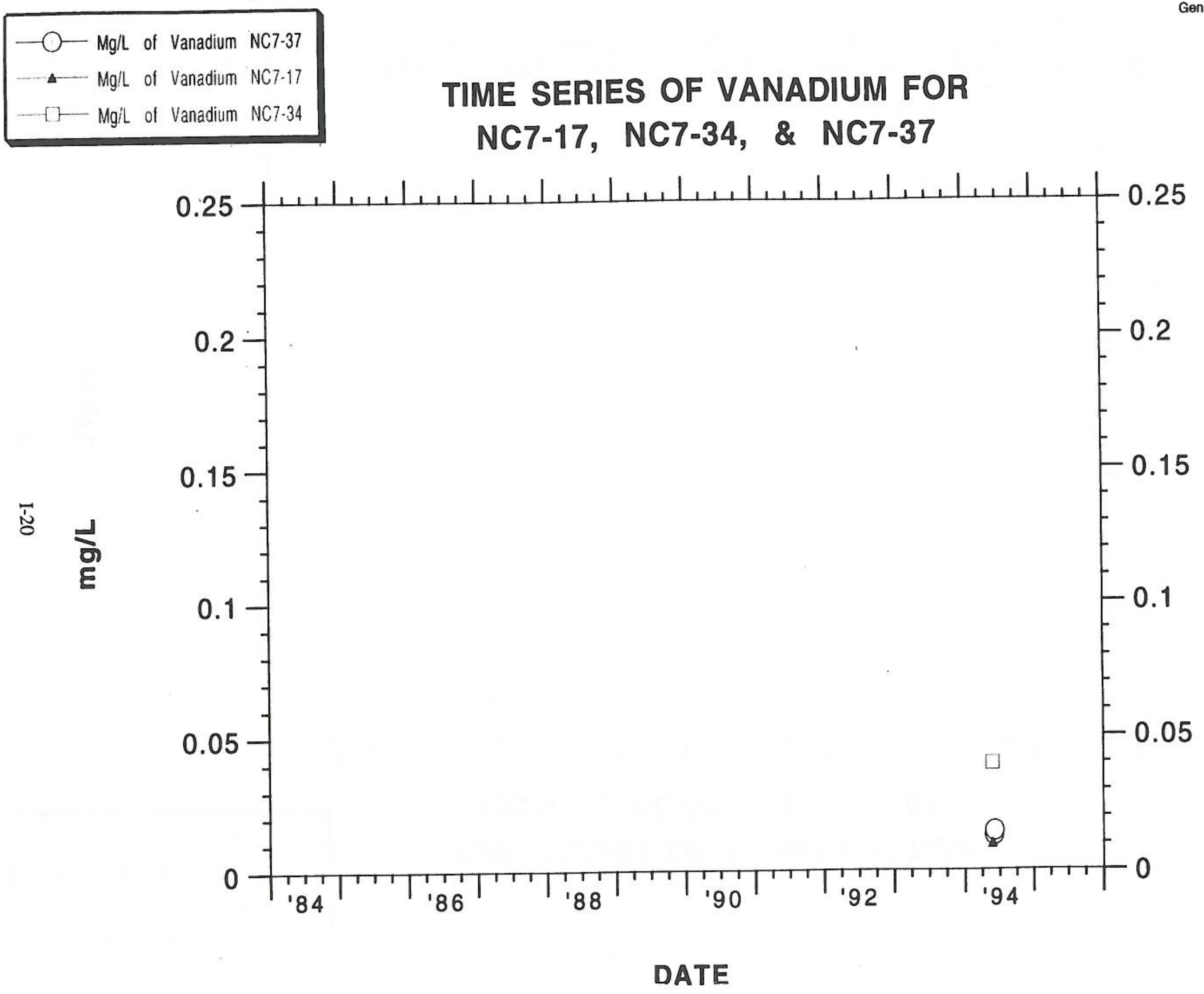

TIME SERIES OF VANADIUM FOR
NC7-17, NC7-34, & NC7-37

Appendix J

Aquatic Bioassays on Spring 6 and Well 8 Spring

Appendix J

Aquatic Bioassays on Spring 6 and Well 8 Spring

The Bioassay Division of MEC Analytical Systems, Inc., performed a series of aquatic bioassays on surface water samples from two springs (spring 6 and well 8 spring) in the Building 850 operable unit. The tests conducted were chronic toxicity with *Ceriodaphnia dubia* (EPA Method 1002) and the 4-day *Selenastrum capricornutum* growth (EPA Method 1003, U.S. EPA, 1989). The study was conducted at the MEC Analytical Systems Bioassay Laboratory in Tiburon, California, under the management of Diane Griffin.

J-1. Sampling Protocol

We sampled spring 6 and well 8 spring May 2–6, 1994. The spring water was collected directly into precleaned, 1-gal cubitainers supplied by the analytical laboratory. For the *Ceriodaphnia* test (EPA Method 1002), a 7-day test requiring daily renewal of the test water, we collected 1-gal water samples from each spring or well for four successive days. On the fifth day, we collected 3 gal of water from each spring to provide enough sample water for the daily renewal of the test water over the weekend. The spring water collected on the first day of sampling was also used for the *Selenastrum* test (EPA 1003), a 4-day static test that does not require daily renewal of the test water.

J-2. Analytical Methods

Maintenance of *Ceriodaphnia* and *Selenastrum* and their testing procedures are described by U.S. EPA (1989). The *Ceriodaphnia* test was a static 7-day test with daily renewal of the test solutions. The *Selenastrum* test was run as a static, 96-hour test.

J-2.1. Test Solution Preparation

The spring water samples were chilled in coolers and delivered to MEC Analytical Systems by California Laboratory Services personnel. The samples were stored in the dark at 4°C until tested.

The spring water sample concentrations for all tests were 6.25, 12.5, 25, 50, and 100%. Control and dilution water for the *Ceriodaphnia* test was Nanopure-filtered water adjusted to a moderate hardness (80–100 mg/L $CaCO_3$) with Evian™ water.

Control and dilution water for the *Selenastrum* test was Evian™ water with added nutrients for freshwater medium (U.S. EPA, 1989). Freshwater medium nutrients were also added to the spring water samples. All water for the *Selenastrum* test was filtered at 0.45 µm.

J-2.2. *Ceriodaphnia dubia* Test

For the test, neonates less than 24 hours old were obtained from the third to eighth brood of female batchstock selected from in-house laboratory cultures. A single neonate was placed in each of 10 replicate 25-mL test chambers containing 20 mL of test solution. The test was run at 25 ± 1°C under a 16-hour light/8-hour dark photoperiod. Test solutions were renewed daily. Water quality measurements, including temperature, pH, conductivity, and dissolved oxygen, were taken on initial and renewal solutions. Mortality and number of neonates were recorded daily. Animals were fed daily a 0.15 mL mix of a Yeast-Cerophyll-Tetramin-Trout Chow (Y-C-T-T) and 350,000 cells/mL *Selenastrum capricornutum*. The test was terminated when at least 60% of the controls had produced three broods of neonates.

J-2.3. *Selenastrum capricornutum* Test

Triplicate 250-mL flasks containing 100 mL of test solution were inoculated using a log-phase, in-house culture to a density of approximately 10,000 cells/mL of phytoplankton. The test was run at 25 ± 1°C under continuous light for 96 hours. Test containers were randomized and shaken twice daily. Upon initiation, conductivity and pH were recorded in each concentration. Alkalinity and hardness were measured in the control and 100% concentrations. At the conclusion of the 96-hour exposure period, duplicate readings for turbidity were made on each replicate using a Hach DR 2000 spectrophotometer. A calibration curve was constructed to establish the relationship between turbidity and cell density.

J-2.4. Criteria for Test Acceptability

The criteria used to determine test acceptability were the following:

Ceriodaphnia dubia

1. Animal survival in control or 100% effluent treatments must equal or exceed 80%.
2. Sixty percent of the surviving control females must produce at least three broods to an average of 15 neonates per female.

Selenastrum capricornutum

1. Control culture must contain at least an average of 200,000 cells/mL.
2. Percent coefficient of variation (c.v.) between control replicates must be 20% or less.

J-2.5. Statistical Analysis

Statistical effects can be measured by the IC_p, the estimated concentration that causes sublethal or inhibitory (IC) effects on p% of the test population. The IC_{50} or IC_{25} is the point estimate of the concentration at which an inhibitory effect in a sublethal parameter (e.g., growth, reproduction) is observed in 50% or 25% of the organisms. The IC_p values include 95% confidence limits when available.

The No Observable Effect Concentration (NOEC) is the highest tested concentration at which mortality and other sublethal measured effects are not significantly different from the same parameters in the control. The TUc is defined as 100%/NOEC.

Acute survival data are obtained for *Ceriodaphnia* by calculating percent survival in 100% concentration at 48 hours.

Data were evaluated statistically using ToxCalc™ to determine IC_p, NOEC, and TUc values where appropriate. ToxCalc™ is a comprehensive statistical application that follows standard guidelines for data analysis of acute and chronic toxicity. An alpha level of 0.05 was used for tests for statistical significance.

J-3. Results

All tests met or exceeded passing criteria. Tables J-1 and J-2 summarize the results of the bioassays. Tables J-3 and J-4 present the reference toxicant test results, and Tables J-5 and J-6 summarize the test conditions. Laboratory bench sheets are archived at LLNL and are available for review.

J-3.1. *Ceriodaphnia dubia* Test

For the *Ceriodaphnia dubia* test, water quality parameters were within acceptable limits. Control survival of *Ceriodaphnia* was 100%. The mean of neonates per initial female was 17.8. Acute survival was 100% for both spring waters. All IC_{25} and IC_{50} values were >100%. No statistically significant effects were observed on *Ceriodaphnia* survival or reproduction in any of the samples tested. The NOECs were 100%, and the TUcs were 1.0.

J-3.2. *Selenastrum capricornutum* Test

For the *Selenastrum capricornutum*, water quality parameters were within acceptable limits. The controls averaged 925,500 cells/mL. Algal growth in samples from spring 6 exceeded growth in the control at all concentrations tested. The IC_{25} and IC_{50} values for spring 6 were >100%, NOECs were 100%, and TUcs were 1.0. The results of the *Selenastrum* test conducted with the well 8 spring sample show a 25% reduction in algal cell density in the 100% sample as compared to the control; however, this difference is not statistically significant. One replicate in this treatment had a cell density much lower than the other two (431,700 cells/mL as compared to 865,300 and 756,900 cells/mL). Although this datapoint is not an outlier using Dixon's Test, the large variance suggests that the calculated reduction may result from test variability rather than sample toxicity. The IC_{25} and IC_{50} values for this sample were 68.3% and 95.2%, respectively; the NOEC was 100%, and the TUc was 1.0.

J-4. Quality Assurance

Reference toxicant tests were conducted concurrently with both bioassays to determine the sensitivity of the test organisms. Reference toxicant IC_{50} values within two standard deviations of the laboratory mean indicate that the test organisms used were of normal sensitivity.

The reference toxicant test conducted with the *Ceriodaphnia* bioassay used sodium chloride (NaCl) as the toxicant. The resulting IC_{50} was 1.3 g/L, which was within one standard deviation of the lab mean of 0.9 g/L.

Zinc (added as zinc chloride) was used as the reference toxicant for the *Selenastrum* growth test. The IC_{50} was 50.9 µg/L (standard deviation = 14.4). The laboratory database mean value is 83.5 µg/L. When reference toxicant text results are greater than two standard deviations from the laboratory mean, the test animals are considered abnormally sensitive, either more or less sensitive than normal. These results indicate that the algae was more sensitive than normal

(IC50<<lab mean). This information must be applied to interpretations of the spring water testing results.

J-5. Reference

U.S. EPA (1989), *Methods for Measuring the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms*, second edition, C. I. Weber et al., Eds., U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory, Cincinnati, Ohio (EPA/600/4-89/001), as reported by MEC Analytical Systems, Inc.

Table J-1. Summary of results of *Ceriodaphnia dubia* tests on surface water samples from spring 6 and well 8 spring.[a]

Spring (test dates)	Concentration (%)	Survival (%)	Mean neonates /initial females	IC_p[b] (%)	NOEC[c] (%)	TUc[d]	Acute survival (%)
Spring 6 (5/3–9/94)	Control	100.0	17.8	IC_{50} >100	100	1.0	100
	6.25	100.0	19.7	IC_{40} >100			
	12.5	90.0	20.0	IC_{25} >100			
	25	100.0	18.9	IC_{15} >100			
	50	100.0	19.0	IC_{10} 87.8			
	100	90.0	16.7				
Well 8 spring (5/3–9/94)	Control	100.0	17.8	IC_{50} >100	100	1.0	100
	6.25	100.0	14.0	IC_{40} >100			
	12.5	100.0	13.5	IC_{25} >100			
	25	90.0	19.2	IC_{15} >100			
	50	100.0	16.8	IC_{10} >100			
	100	90.0	17.5				

[a] No results were statistically significant at $p < 0.05$.

[b] IC_p = Lethal/Inhibition Concentration for p% of the organisms.

[c] NOEC = No Observable Effect Concentration.

[d] TUc = 100%/NOEC.

Table J-2. Summary of results of *Selenastrum capricornutum* tests on surface water samples from spring 6 and well 8 spring.[a]

Spring (test dates)	Cells/mL /1,000	Inhibition (%)	IC_p[b] (%)	NOEC[c] (%)	TUc[d]
Spring 6 (5/3–7/94)	926	NA[e]	IC_{50} >100	100	1.0
	1263	0.0	IC_{40} >100		
	1335	0.0	IC_{25} >100		
	2154	0.0	IC_{15} >100		
	1311	0.0	IC_{10} >100		
	1456	0.0			
Well 8 spring (5/3–/94)	926	NA[e]	IC_{50} 95.2	100	1.0
	1889	0.0	IC_{40} 84.4 (72.4-96.2)		
	1636	0.0	IC_{25} 68.3 (46.4-78.8)		
	1564	0.0	IC_{15} 57.5 (37.9-66.8)		
	1383	0.0	IC_{10} 52.1 (33.5-61.2)		
	685	26.0			

[a] No results were statistically significant at $p < 0.05$.

[b] IC_p = Lethal/Inhibition Concentration for p% of the organisms. Values in parentheses are 95% confidence limits.

[c] NOEC = No Observable Effect Concentration.

[d] TUc = 100%/NOEC.

[e] NA = Not applicable.

Table J-3. Summary of results of *Ceriodaphnia dubia* reference toxicant test.[a]

Toxicant (test dates)	Concentration (g/L)	Survival (%)	Mean neonates /initial females	IC_p[b] (g/L)	NOEC[c] (g/L)
NaCl (5/3–9/94)	Control	100.0	17.8	IC_{50} 1.3 (0.9–1.5)	0.32
	0.056	100.0	17.4	IC_{40} 1.1 (0.7–1.4)	
	0.32	100.0	18.9	IC_{25} 0.8	
	1.0	80.0	11.9*	IC_{15} 0.6	
	2.0	60.0	1.3*	IC_{10} 0.5	
	4.0	0.0*	0.0*		

[a] * = Statistically significant results at alpha = 0.05.

[b] ICp = Lethal/Inhibition Concentration for p% of the organisms. Values in parentheses are 95% confidence limits.

[c] NOEC = No Observable Effect Concentration.

Table J-4. Summary of results of *Selenastrum capricornutum* reference toxicant test.[a]

Toxicant (test dates)	Concentration (µg/L)	Cells/mL /1,000[a]	Inhibition (%)	IC_p[b] (µg/L)	NOEC[c] (µg/L)
Zinc (5/3–7/94)	Control	2575.6	NA[d]	IC_{50} 50.9 (42.2-63.8)	25
	10	2864.6	0.0	IC_{40} 44.6 (37.7-56.2)	
	25	2539.4	1.4	IC_{25} 35.8 (30.0-43.5)	
	50	1383.2*	46.3	IC_{15} 29.9 (22.2-35.7)	
	100	94.5*	96.3	IC_{10} 27.0 (18.1-32.2)	
	150	<34.3*	>98.7		

[a] * = Statistically significant results at alpha = 0.05.

[b] ICp = Lethal/Inhibition Concentration for p% of the organisms. Values in parentheses are 95% confidence limits.

[c] NOEC = No Observable Effect Concentration.

[d] NA = Not applicable.

Table J-5. Summary of bioassay procedure and organism data for the three-brood bioassay using *Ceriodaphnia dubia* (EPA Method 1002).

Data type	Data recorded
Sample identification	
Dates sampled	5/2–6/94
Dates received at MEC	5/3–6/94
Volume received	1 gal/day (3 gal for last sample)
Sample storage conditions	4°C in the dark
Species	
Test species	Water flea, *Ceriodaphnia dubia*
Supplier	MEC in-house culture
Acclimation water	Deionized and Evian™ waters mixed to moderate hardness
Acclimation temperature	25 ± 2°C
Age group	Neonates <24 hours old
Procedure	
Test type	EPA Method 1002; Chronic/renewal
Duration	6 days (144 hours)
Test dates	5/3–9/94
Control water	Deionized and Evian™ waters mixed to moderate hardness
Test temperature	25 ± 1°C
Test photo period	16 hours light/8 hours dark
Salinity	Fresh water
Test chamber	25 mL vial
Animals/replicate	1
Exposure volume	20 mL
Replicates/treatment	10
Feeding	7.5 mL/L Y-C-T-T[a] and 350,000 cells/mL *Selenastrum capricornutum*
Deviations from procedures	None

[a] Y-C-T-T = Yeast-Cerophyll-Tetramin-Trout chow.

Table J-6. Summary of bioassay procedure and organism data for the 4-day *Selenastrum capricornutum* growth bioassay (EPA Method 1003).

Data type	Data recorded
Sample identification	
Dates sampled	5/2/94
Dates received at MEC	5/3/94
Volume received	1 gal
Sample storage conditions	4°C in the dark
Species	
Test species	Green alga, *Selenastrum capricornutum*
Supplier	MEC in-house culture
Age of culture	4 days
Acclimation water	Evian^{TM} water mixed with fresh water medium
Acclimation temperature	24 ± 2°C
Acclimation photoperiod	Continuous light
Procedure	
Test type	EPA Method 1003; Chronic/static
Duration	4 days (96 hours)
Start date	5/3/94
Completion date	5/7/94
Test photoperiod	Continuous light
Control water	Evian^{TM} water mixed with fresh water medium
Test temperature	25 ± 1°C
Organisms/chamber	1,000,000 cells
Test chamber/exposure volume	250 mL flask/100 mL
Replicates/treatment	3
Deviations from procedures	None

Appendix K

Evaluation of ^{232}Thorium in Ground Water

Appendix K

Evaluation of ^{232}Thorium in Ground Water

In this appendix, we evaluate analytical data on ^{232}Thorium (^{232}Th) in ground water for evidence of contamination. For this evaluation, we used analytical data obtained from samples collected from the nine monitor wells in the Pit 7 complex monitoring network (wells K7-01, K7-03, K7-06, K7-09, K7-10, NC7-25, NC7-26, NC7-47, and NC7-48). These wells monitor the ground water underlying the Pit 7 complex to comply with the post-closure permit issued by the Central Valley Regional Water Quality Control Board (CVRWQCB, 1993). Under the post-closure monitoring, the LLNL Operations and Regulatory Affairs Division (ORAD) was required to collect monthly samples for 1 year on constituents with no historical data. From October 1993 through October 1994, each of the nine wells was sampled monthly for ^{232}Th, for a total of 13 monthly samples. At the end of the 13-mo sampling, ^{232}Th monitoring was placed on a quarterly sampling frequency. For our evaluation, we use the data from samples collected from October 1993 through July 1995, which includes the 13 monthly samples plus three rounds of quarterly samples.

Appendix B contains the ground water analytical results for ^{232}Th, presenting activities as either limit of sensitivity or greater. Activities are obtained by considering the observed activity in the sample, then subtracting the background activity of the analytical instruments. If, after this subtraction, the calculated activity for the sample is zero or negative, the result is reported as less than the limit of sensitivity. However, the analytical laboratory provides us with the "calculated value," even if it is zero or negative, which is more appropriate than censored data for use in statistical analyses. For the analysis in this appendix, we use the calculated value. In addition, we only use routine samples; no duplicate data are included.

Figure K-1 shows ^{232}Th activities in ground water samples collected from Pit 7 Complex wells between October 1993 through July 1995. One value, excluded from the graph, is from a sample collected from NC7-47 on April 12, 1994; the result was reported as < 57.6 pCi/L. In this case, the counting error of 23.1 pCi/L was greater than the calculated value of 16.6 pCi/L, resulting in the large limit of sensitivity. This large counting error suggests some question in the analytical result. We excluded this value from the graph to allow greater resolution in the activities between wells. As shown in Figure K-1, ^{232}Th activities are equally distributed among the samples from each well. Samples from the upgradient well, K7-06, do not appear to contain activities of ^{232}Th significantly lower than those of the downgradient wells.

To further evaluate these data, we performed two statistical tests, analysis of variance and the Wilcoxon Score. All data, including the apparent outlier (April 12, 1994) from NC7-47, were included in the tests. The first test, the analysis of variance, compares the mean of the activity of each well to determine if a statistically significant difference exists between wells. The null hypothesis under the analysis of variance is that no difference exists between means. Because this is a parametric test, it assumes a normally distributed data set. However, the inclusion of apparent outliers may make this assumption invalid. Therefore, we also conducted a non-parametric

Wilcoxon Scores test. In this test, the data are ordered and ranked, and these ranks are compared to the expected ranks under the null hypothesis that no difference exists in ranks between wells.

Tables K-1 and K-2 present the results of the statistical analysis. In the analysis of variance test (Table K-1), the test statistic is the F value. In the Wilcoxon Scores test (Table K-2), the test statistic is the χ^2 value. For both tests, the null hypothesis (H_o) is that there is no difference in ^{232}Thorium activity between wells. To reject H_o, the probability (P_r) that the test statistic has the observed magnitude (or a greater magnitude) by chance must be 0.05 or less (i.e., $Pr > F$ or $Pr > \chi^2$ must be 0.05 or less). As inferred by these tables, the null hypothesis cannot be rejected using either test. If we exclude the apparent outliers from the analysis of variance, that test has a significance level comparable to the Wilcoxon Scores test.

As a result of these analyses, we have no convincing evidence of ground water contamination by ^{232}Th in the Pit 7 complex.

Reference

CVRWQCB (1993), Order No. 93-100, *Waste Discharge Requirements for University of California Lawrence Livermore National Laboratory Site 300 and U.S. Department of Energy, Landfill Pits 1 and 7, San Joaquin County,* June 25, 1993.

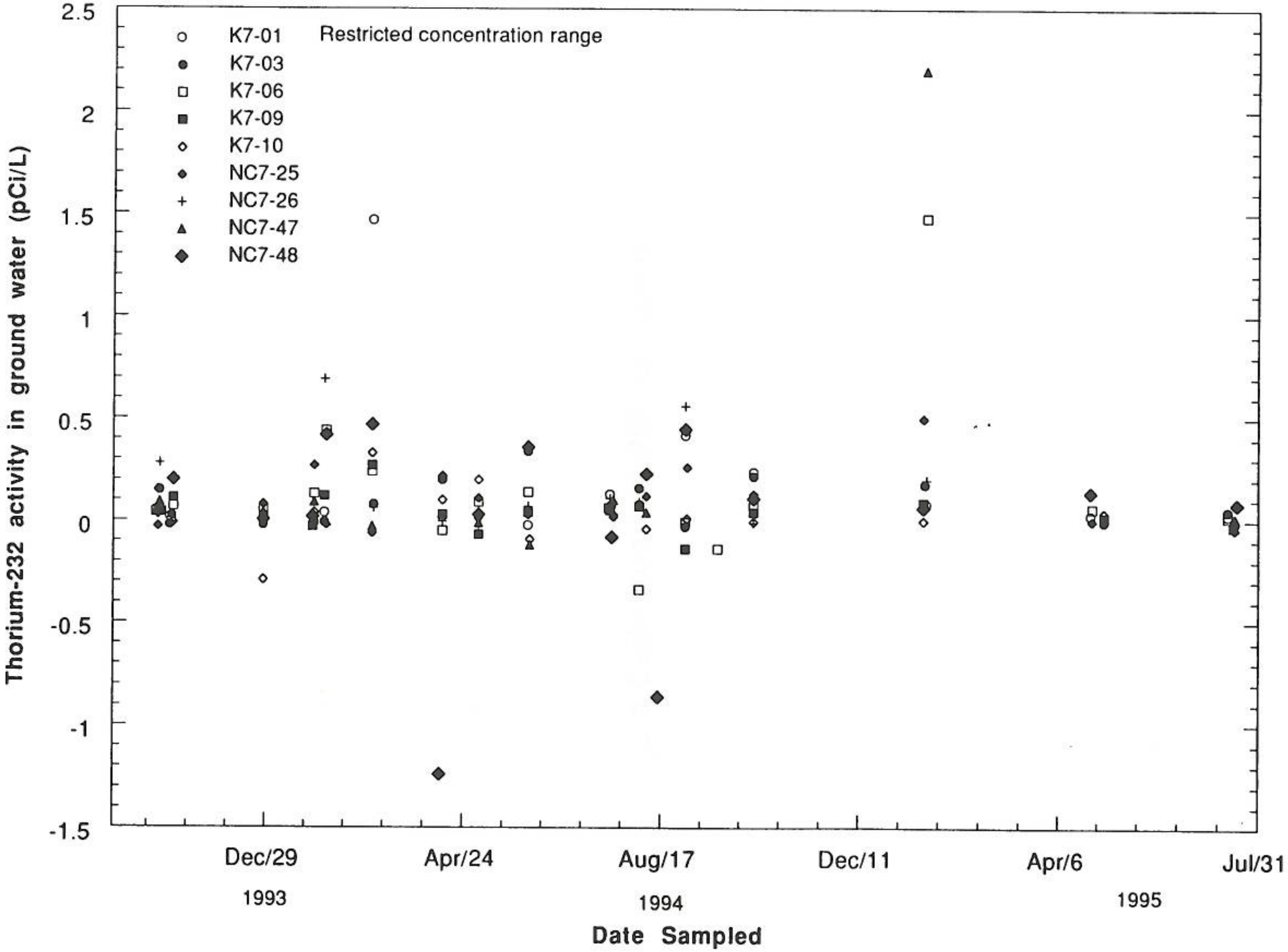

Figure K-1. Thorium-232 activity in ground water at the Pit 7 complex from October 1993 through July 1995. Well K7-06 is upgradient of the complex.

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Table K-1. Analysis of variance on the calculated activity detected in samples obtained from the Pit 7 complex monitor wells between October 1993 and July 1995.

Source	DF[a]	Sum of squares (SS)	Mean square (MS)	F value[b]	Probability Pr > F[c]
Model	8	27.2809	3.4101	1.71	0.1019
Error	137	273.6639	1.9975		
Corrected total	*145*	*300.9449*			

[a] Degrees of freedom.

[b] F = The Fisher value, the test statistic.

[c] Pr = probability.

Table K-2. Nonparametric Wilcoxon Scores (rank sum) test on the calculated activity detected in samples obtained from the Pit 7 complex monitor wells between October 1993 and July 1995.

Well	Number of observations	Sum of scores[a]	Expected value under H_0[b]
K7-01	16	1226.0	1176.0
K7-03	16	1205.5	1176.0
K7-06	17	1307.0	1249.5
K7-09	16	1021.0	1176.0
K7-10	16	1001.5	1176.0
NC7-25	16	1202.0	1176.0
NC7-26	16	1124.5	1176.0
NC7-47	16	1231.0	1176.0
NC7-48	17	1412.0	1249.5

Kruskal-Wallis Test (χ^2[c] approximation)

χ^2 value	DF[d]	Pr > χ^2[e]
3.2297	8	0.9191

[a] Average scores were used for ties.

[b] Null hypothesis.

[c] χ^2 = chi-squared, the test statistic.

[d] Degrees of freedom.

[e] Pr = probability.

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