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General Investigation of Radionuclide Retention in Migration Pathways at the West Valley, New York Low-Level Burial Site

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ABSTRACT

This report is the final one in a series of reports presenting the results of a study to evaluate the containment capability of a low-level, solid radioactive waste burial ground at West Valley, New York. The present investigation includes several basic parts: a surface water study, a trench water study, geotechnical and radiochemical studies of soils, a geotechnical study of a research trench and an analysis of sub-trench core data.

Tritium, as tritiated water, is the most abundant radionuclide detected in both surface water and trench water samples. Strontium-90 is the predominant beta emitter detected in surface water samples. It is estimated that strontium-90 contributes approximately one-half of the total beta activity in whole water samples. Strontium-90 ranks as the second most abundant trench water radionuclide in six of the eleven trenches studied.

In general, the results of standard engineering tests on soils from the West Valley site confirm the results predicted by testing performed in 1977. The strength of the walls of Research Trench III was estimated. The minimum developed cohesion was estimated as 18.9 kN/m^2. In shallow, softened soils of the trench walls the developed cohesion at failure under submerged conditions was estimated to be 2.54 kN/m^2, and failure under sudden drawdown conditions was estimated to be 4.79 kN/m^2. Analyses of soil samples from the north burial area trench caps for tritium showed approximate background levels at the surface and above-background levels at depths of 20 to 50 centimeters.

The maximum observed vertical migration of tritium was beneath trench 8. Detection limits were reached at a depth slightly greater than 3.2 m below the estimated trench floor with a possible trench floor location error of ±0.3 meters. Carbon-14 was found to migrate at a much slower rate than tritium. There may be evidence for the migration of strontium-90 beneath the trenches, but it is inconclusive. Plutonium-238 was detected beneath all three trenches studied and in four of the five sub-trench cores; whether or not in all cases these values reflect actual migration in the soil is difficult to ascertain. All other radionuclides studied showed either essentially no detectable activity or activity attributable to the element as it occurs naturally.

SUMMARY

The New York State Geological Survey is the lead agency in an interdisciplinary research program to investigate the potential pathways of migration of low-level radioactive waste from a commercial shallow land-burial ground at West Valley, New York. This final report covers all work undertaken to date with the exception of an in-progress geomorphic study that will be completed the summer of 1981. This report is divided into several parts: a study of potential migration pathways, including sub-trench soils, the trench cap soil and the surface water pathways; a study of the radiochemical characteristics of water in the trenches, to be used in conjunction with migration studies; and a study of engineering properties of the trenches, trench caps and burial medium.

The surface water program is an interagency study that includes monitoring of precipitation and streamflow at the site, and the systematic collection of stream water and sediment samples for radiochemical analysis. The trench cap and sub-trench studies include endeavors to detail radionuclide migration in the disturbed and undisturbed tills that encapsulate the radioactive wastes. The trench water study involves periodic collection and detailed radiochemical analyses of trench water samples to define spatial and temporal variations in radionuclide concentrations, and to identify the radionuclides available for migration. Geotechnical analysis of samples of the trench cap and burial till soils is directed toward evaluating the physical properties that could influence overall trench stability and, consequently, radioisotope migration.

Tritium, as tritiated water, is the most abundant radionuclide detected in surface water samples. The highest tritium concentrations occurred in samples collected during periods of low precipitation, probably the result of the lack of diluting precipitation that contains ambient levels of tritium. Higher than expected tritium concentrations were found in all surface water samples collected during May, 1979. This may reflect, in part, the normal increase in tritium concentrations in precipitation accompanying vernal tropospheric inversions that occur at these latitudes.

Surface water samples collected at Stations No. 3 and 4 during late July and August of 1978 exhibited increased alpha and beta activity that may be associated with well excavation and trench recapping operations that were carried out at that time. Eleven pre-existing wells were excavated by backhoe and capped below grade, prior to trench recapping, near the north burial trenches on July 24-26. The excavations, up to 1 m deep, remained open until July 27, exposing trench cap sediments for transport to nearby streams. During trench recapping operations, August 7-30, total alpha activity at one station increased from <4pCi/l to 1900

pCi/l in response to added sediment load. Radioactivity subsequently decreased to 20 pCi/l during the week in which recapping operations were completed.

Strontium-90 is the predominant beta emitter detected in surface water samples for which analyses for specific radionuclides were performed. It is estimated that strontium-90 contributes approximately one-half of the total beta activity in whole water samples.

Tritium as ^{3}HHO is by far the most abundant trench water radionuclide in all the trenches studied, without exception. Strontium-90 ranks as the second most abundant trench water radionuclide in six of the eleven trenches studied. Cesium-134 values observed in trench water samples from 9 of the 10 trenches studied, when plotted against the time interval between burial of waste and trench water analysis, fall on a line of steadily decreasing activity as the time for decay increases. Carbon-14 (total) in trench water ranks second or third among radionuclides in all the south trenches studied. In the north trenches in general, carbon-14 values are much smaller than in the south trenches, though isolated higher values have been found. This relationship is in good agreement with the quantities of carbon-14 known to be buried in the trenches, though burial records are somewhat ambiguous. Iodine-129 in trench water is observed in very low concentrations in the trenches studied to date.

In general, the results of standard engineering tests in soils from the West Valley site confirm the results predicted by testing performed in 1977. Samples from the walls of Research Trench III showed some increase in moisture content after submersion for almost two years, accompanied by a decrease in strength and unit weight. This indicates a slight swelling of the soil, as would be expected. We do not know what the maximum strength is for the slope as a whole. But a minimum strength for the Research Trench III wall slope can be estimated, since the slope remained stable under sudden drawdown conditions. The minimum developed cohesion is approximately 18.9kN/m^2. Portions of the lowermost trench that were greater than approximately 1.2 m above the floor failed. It is believed that failures occurred both before and after drawdown. In these shallow, softened soils a value was estimated for the developed cohesion at failure under submerged conditions (2.54 kN/m^2), and a slightly higher value was estimated for failure under sudden drawdown conditions (4.79 kN/m^2).

Analyses of samples of soil from the north burial area trench caps for total alpha and total beta showed no values above the estimated natural background activity of the burial till.

Analyses of samples of soil from the north burial area trench caps for tritium showed approximate background levels at the surface and above-background levels at depths of 20 to 50 cm. Samples from the south burial area were analyzed at depth only; these values were also above background levels for tritium.

The maximum observed vertical migration of tritium in sub-trench core holes was beneath trench 8. Detection limits (3×10^{-6} μCi/ml) were reached at a depth slightly greater than 3.2 m below the estimated trench floor with a possible trench floor location error of ±0.3 m. The minimum observed vertical migration of tritium was beneath trench 4. Activity dropped below detectable limits at a maximum depth of 2.25 m below the trench floor. Migration beneath trench 8 represents just under seven years of migration; the shorter distance beneath trench 4 represents ten years of migration.

Because of different trench water concentrations and different limits of detection it is not possible to compare directly the migration distances of tritium and carbon-14. However, in comparing measurements of the two radionuclides beneath trench 5 to a depth of approximately 9 m below land surface a clear general relationship does emerge. Over this range the carbon-14 concentration dropped by a factor of approximately 20, whereas tritium decreased by a factor of 2 to 3 over the same depth interval. This indicates that the carbon-14 migrates at a much slower rate than the tritium.

Detectable concentrations of strontium-90 below the trenches were found beneath trenches 4 and 5. Beneath trench 4 values above detection limits were found and may have been up to 70 cm below the trench floor; the uncertain location of the trench floor precludes a more accurate estimate. Beneath trench 5 values above detection limits were found 5 cm below the estimated trench floor with a possible trench floor location error of ±15 cm. In short, evidence for the migration of strontium-90 beneath the trenches is inconclusive, at best.

Plutonium-238 was detected beneath all three trenches studied and in four of the five sub-trench cores. Most of the data show values above computed background levels for West Vally soil. Whether in all cases these values reflect actual migration in the soil is difficult to ascertain. The large potential laboratory counting errors for most of these analyses make any interpretation somewhat speculative.

Radionuclides showing essentially no detectable activity beneath the trench floor include iron-55, nickel-63, iodine-129, americium-241, cobalt-60, and ruthenium-106. Radionuclides showing activity attributable to the naturally occurring element

include plutonium-239, potassium-40, thorium-232, uranium-234, -235, and -238.

In the course of this investigation a number of possible future paths of investigation were identified. These recommendations are presented in brief below.

Because trench recapping activities conducted in 1978 significantly altered the drainage pattern at the burial site, any continued surface water study must include remapping of the drainage basins.

Any further studies must address the problem of identifying on-site sources of radionuclides other than the low-level radioactive waste burial site. For example, a new surface water monitoring station that would monitor all runoff from the NRC-licensed burial area would be essential for addressing the problem of radionuclide source, a persistent problem throughput these investigations.

Another problem encountered in these investigations is in the analysis of americium-241 in trench water. High concentrations of plutonium-238 appear to constructively interfere with the analysis of americium-241. This problem has been encountered in trench 10 and may be affecting values of americium-241 in other trenches as well. The effects of plutonium-238 on americium-241 analyses should be investigated.

Because it has been surmised that the trench caps may serve as a medium for migration of tritiated gases and for exchange with stable fluids, continued analysis of trench cap samples should be undertaken to further define the magnitude, mechanism and extent of migration of tritium at shallow depths within the trench cap. In conjunction with this, parallel studies of soil and trench gases would identify some of the nuclides available for diffusion through, or retention in, the trench caps. Earlier studies suggest that ^{3}HH may exchange with water contained in the trench caps, and that $^{3}HCH_3$, $^{14}CH_4$, and $^{14}CO_2$ undergo "substantial aerobic decomposition in the trench caps". Continued studies of the efficiency of the trench caps in retaining radionuclides should include an evaluation of these equilibration processes and rates. In addition, quantitiative effects of trench cap fractures upon gas flux remain to be defined.

Future studies of sub-trench migration of radionuclides should include additional analyses of cores using longer core sections to obtain higher sensitivity in the regions showing values near detection limits. This would provide greater accuracy in defining the migration rate of tritium, as well as help clear up problems associated with the interpretation of data on carbon-14, strontium-90 and plutonium-238 migration rates.

Now that a substantial body of information has been obtained from field experiments on migration rates and from computer modeling of this migration, laboratory experiments should be done to study the adsorption and desorption properties of the West Valley soil. Adsorption and desorption should be reversible procedures; if not, this is evidence for the creation of neutral substances or the formation of radiocolloids. In order to test the various components of the West Valley soil for its adsorption properties, a sample of uncontaminated soil from the West Valley site could be broken down into its various components for testing with a sample of water from the burial trenches. Desorption could then be carried out on these same samples to test the reversibility of adsorption experiments.

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All radiochemical analyses were performed by the Radiological Sciences Laboratory of the New York State Department of Health.

LIST OF ABBREVIATIONS

General Items

cm/s	centimeters per second
Σ	total
ft	feet
g/l	grams per liter
ISCO	trade name for Instrumentation Specialties Company
kg	kilogram
kN/m^2	Kilonewtons per square meter
LLRWB	Low-Level Radioactive Waste Burial
m	meters
meq	milligram-equivalents
MeV	milli-electron volts
NFS	Nuclear Fuel Services, Incorporated
nm	nanometers
NYSGS	New York State Geological Survey
pcf	pounds per cubic foot
pCi/l	picocuries (10^{-12} curies) per liter
RSL	Radiological Sciences Laboratory of the New York State Department of Health
t.u.	tritium unit = $\frac{\text{Total No. } {}^3H \text{ Atoms}}{10^{18} \times \text{Total No. Hydrogen Atoms}}$
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
USNRC	United States Nuclear Regulatory Commission
μCi/l	microcuries (10^{-6} curies) per liter
μ	microns
σ	Standard deviation

Radionuclides *

Alpha Emitters

Th-232	Thorium-232
Pu-238	Plutonium-238
Pu-239, 240	Plutonium-239, 240
U-234	Uranium-234
U-235	Uranium-235
U-238	Uranium-238
Am-241	Americium-241
Cm-244	Curium-244

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*Radionuclides discussed in this report are listed according to their characteristic emission.

Beta Emitters*

H-3	Tritium
C-14	Carbon-14
Na-22	Sodium-22
K-40	Potassium-40
Co-60	Cobalt-60
Ni-63	Nickel-63
Sr-90	Strontium-90
Zr-95	Zirconium-95
I-129	Iodine-129
Cs-134	Cesium-134
Cs-137	Cesium-137

Gamma Emitters

Mn-54	Manganese-54
Ru-106	Ruthenium-106
Ba-133	Barium-133

Electron Capture

Fe-55	Iron-55

*Radionuclides discussed in this report are listed according to their characteristic emission.

1.0 INTRODUCTION

The Western New York Nuclear Service Center is located in West Valley, Cattaraugus County, 48 km southeast of Buffalo, N.Y. The major installation on the site is a nuclear fuel reprocessing plant which is not currently in operation. North and south of the plant respectively are the high-level waste tanks and the NRC-licensed burial area. The present study concerns a commercial low-level radioactive waste burial (LLRWB) area located southeast of the reprocessing facility (Figure 1).

The LLRWB area consists of 12 trenches, each approximately 180 m long, 11 m wide, and 6 m deep. The trenches were excavated in a thick clay-silt till of low permeability ($\sim 5 \times 10^{-8}$ cm/s) and relatively high ion-exchange capacity (10.3±42%meq/100g). A variety of solid large-volume, low specific-activity wastes were emplaced in the trenches, which were then each covered with a 1- to 5-m thick cap of weathered and unweathered till. Burial operations were voluntarily suspended by Nuclear Fuel Services, Inc. (NFS), the site operator, in 1975 after leachate seepage was observed at three north trenches.

The New York State Geological Survey (NYSGS) is the lead agency in an interdisciplinary research program to investigate pathways of potential radionuclide migration from the LLRWB site. The project involves several elements of investigation, including trench water, surface water, and sub-trench soil core studies, geotechnical analyses of the burial till and trench caps, and radiochemical analyses of trench cap samples. This final report covers all work undertaken under Contract No. NRC-04-77-169 with the exception of an in-progress geomorphic study that will be completed the summer of 1981. A topical report will be completed at that time.

Studies of the West Valley LLRWB site were first sponsored by the United States Environmental Protection Agency (USEPA), then jointly by the USEPA and the United States Nuclear Regulatory Commission (USNRC), and now fully by the USNRC. They involve cooperative programs with the United States Geological Survey (USGS) and a number of New York State agencies, including the Radiological Sciences Laboratory of the New York State Department of Health (RSL), the Department of Environmental Conservation, and the Energy Office.

Previous reports published by the USNRC under Contract No. NRC-04-77-169 include: "Geotechnical Analysis of Soil Samples" (NUREG/CR-0644); "Annual Report, Oct. 1, 1977 - Oct. 31, 1978" (NUREG/CR-0794); "Geomorphic and Erosion Studies" (NUREG/CR-0795. "Geotechnical Analysis of Soil Samples and Study of a Research Trench" (NUREG/CR-1566) is completed and soon to be published.

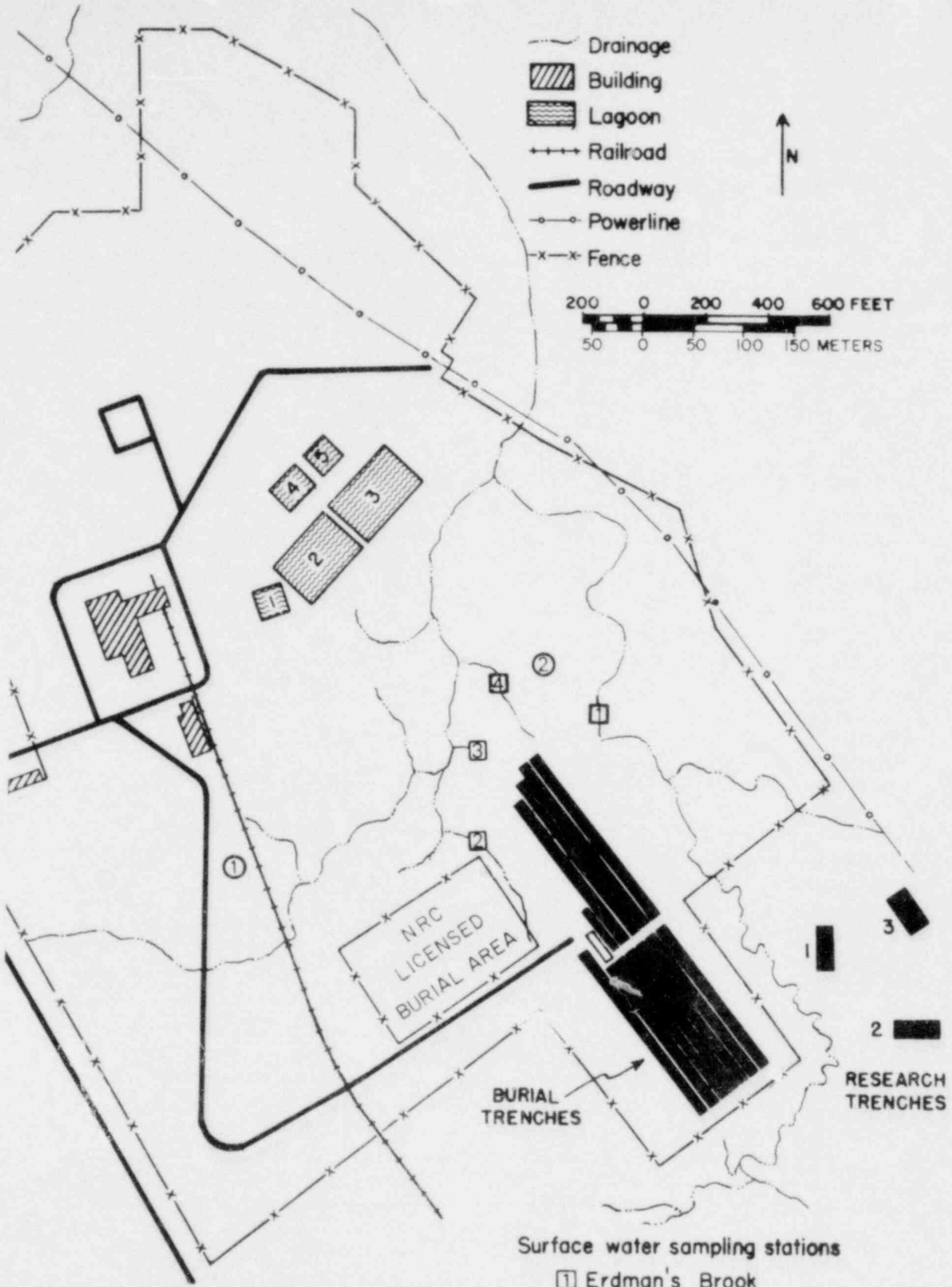

Figure 1. Map of a portion of the Western New York Nuclear Service Center showing low-level radioactive waste burial trenches and research trenches. Special burial area 7 is the unshaded rectangle.

2.0 PURPOSE OF STUDY

Short- and long-lived radionuclides, varying from trace to significant amounts, are buried at the LLRWB site. If containment of these wastes is to be insured, perhaps for as long as several thousand years, then the geologic environment and engineering properties of the burial site must be carefully assessed.

This study originally was undertaken in 1975 in order to identify and assess both potential subsurface pathways by which radionuclides could migrate from the trench to the surface environment and also to assess the surface pathways (surface water, atmospheric, biologic) by which radionuclides could be transported off site. Because degradation of the site itself was considered to be a potential problem in the long-term integrity of the burial site, a study of the engineering properties of the trenches, trench caps, and burial medium was undertaken as well.

The specific elements of the present phase of the investigation are described below in section 3.

3.0 SCOPE OF STUDY

This final phase of the investigation involves several general elements: a study of several migration pathways, including the sub-trench soils, the trench cap soil, and the surface water pathways; a study of the radiochemical characteristics of water in the trenches to be used in conjunction with migration studies; and a study of the engineering properties of the trenches, trench caps and burial medium.

The surface water program is an interagency study that includes monitoring of precipitation and streamflow at the site, and the systematic collection of stream water and sediment samples for analyses for tritium, total alpha, and total beta activities. The total tritium transported annually in one ephemeral, on-site stream has been estimated.

The trench cap and sub-trench studies include endeavors to detail radionuclide migration in the disturbed and undisturbed tills that encapsulate the radioactive wastes. Trench cap samples are analyzed for tritium, total alpha, and total beta; sub-trench soils are analyzed for several radionuclides, including tritium, strontium-90, carbon-14, and others. The study of sub-trench soils required the design and implementation of a technique for satisfactory extraction of uncontaminated cores from directly beneath the waste burial trenches. Appropriate drilling techniques were devised and undertaken by the USGS in 1977. The project was initiated in order to assess directions, extent, and relative rates of specific nuclide migration, and the radiochemical and geologic parameters that affect radionuclide distribution in the soil.

The trenchwater study involves periodic collection and detailed radiochemical analyses of trenchwater samples to define spatial and temporal variations in source term radionuclide concentrations, and to identify radionuclides available for migration. The radionuclides under investigation include dissolved and suspended tritium, strontium-90, cesium, plutonium, carbon-14, uranium, and several others.

Geotechnical analysis of samples of the trench cap and burial till soils is directed toward evaluating the physical properties that could influence overall trench stability and, consequently, radioisotope migration. The present investigation is a continuation of studies begun in 1976 when the first of three research trenches was excavated near the LLRWB trenches. Recently-collected soil samples were subjected to various geotechnical tests, and the results of those tests were compared to results obtained in previous investigations.

4.0 CONCLUSIONS

The more significant conclusions reached during the course of these investigations are listed below. These conclusions are discussed in more detail in sections 6.0 through 10.0 of this report.

4.1 Tritium, as tritiated water, is the most abundant radionuclide detected in surface water samples. The highest tritium concentrations occurred in samples collected during periods of low precipitation, probably the result of the lack of diluting precipitation that contains ambient levels of tritium.

4.2 Higher than normal tritium concentrations were found in all on-site surface water samples collected during May, 1979. This may reflect, in part, the normal increase in tritium concentrations in precipitation accompanying vernal tropospheric inversions that occur at these latitudes.

4.3 Total alpha activity was found to be below detection limits for most samples, including those collected at Station No. 2, which exhibits the highest tritium and total beta levels at the site.

4.4 Samples collected at Stations No.2,3,and 4 during late July and August of 1978 exhibited increased alpha and beta activity that may be associated with well excavation and trench recapping operations that were carried out at that time. Eleven pre-existing wells were excavated by backhoe and capped below grade, prior to trench recapping, near the north burial trenches on July 24-26. The excavations, up to 1 m deep, remained open until July 27, exposing trench cap sediments for transport to nearby streams. During the trench recapping operations, August 7-30, total alpha activity increased from <4pCi/ to 1900 pCi/ in response to added sediment load. Radioactivity subsequently decreased to 20 pCi/l during the week in which recapping operations were completed.

4.5 Strontium-90 is the predominant beta emitter detected in surface water samples for which analyses for specific radionuclides were performed. It is estimated that strontium-90 contributes approximately one-half of the total beta activity in whole water samples.

4.6 Tritium as ^{3}HHO is by far the most abundant trench water radionuclide in all the trenches studied, without exception. In most cases, tritium is more than two orders of magnitude greater than the second most abundant radionuclide.

4.7 Strontium-90 ranks as the second most abundant trench water radionuclide in six of the eleven trenches studied. Strontium-90 ranks among the top four in all trenches studied. Values in trench 4 are the highest of any trench studied;

this is consistent with burial records showing burial of a large number of curies of strontium-90 in trench 4.

4.8 Because of the turbulence created by the water sampling technique and because of adsorption and other complicating factors, measured concentrations of plutonium in trench water probably do not reflect the amount of plutonium released into the water in any given trench. Though comparisons of relative concentrations between trenches may be valid, the data should not be used as a measure of the amount of plutonium in each trench.

4.9 Cesium-134 values observed in trench water samples from 9 of the 10 trenches studied, when plotted against the time interval between burial of waste and trench water analysis, fall on a line of steadily decreasing activity as the time for decay increases. Because of the relatively short half life of cesium-134, this relationship between activity and age is expected.

4.10 Carbon-14 (total) in trench water ranks second or third among radionuclides in all the south trenches studied. In the north trenches in general, carbon-14 values are much smaller than in the south trenches, though isolated higher values have been found. This relationship is in good agreement with the quantities of carbon-14 known to be buried in the trenches, though burial records are somewhat ambiguous.

4.11 Iodine-129 in trench water is observed in very low concentrations in the trenches studied to date. However, the concentration of stable iodine in trench 10 was found to be extremely high (17.2 mg/l). The most probable source for this stable iodine is from activated charcoal filtering systems, which are quite wide-spread in use in the nuclear industry.

4.12 In general, the results of standard engineering tests in soils from the West Valley site confirm the results predicted by testing performed in 1977.

4.13 Samples from the walls of Research Trench III showed some increase in moisture content after submersion for almost two years, accompanied by a decrease in strength and unit weight. This indicates a slight swelling of the soil, as would be expected. The small amount of swelling confirms results of swell testing in the 1977 investigation.

4.14 A minimum strength for the Research Trench III wall slope can be estimated, since the slope remained stable under sudden draw down conditions. The minimum developed

cohesion is approximately 18.9kN/m^2.

4.15 The maximum strength of soils of the lowermost bench in Research Trench III - in the shallow, softened soils of the trench wall - can be estimated from failure data. Portions of the lowermost bench that were greater than approximately 1.2 m above the floor failed. It is believed that failures occurred both before and after drawdown. A value was estimated for the developed cohesion at failure under submerged conditions (2.54 kN/m^2), and a slightly higher value was estimated for failure under sudden drawdown conditions (4.79 kN/m^2).

4.16 Analyses of samples of soil from the north burial area trench caps for total alpha and total beta showed no values above the estimated natural background activity of the burial till.

4.17 Analyses of samples of soil from the north burial area trench caps for tritium showed approximate background levels at the surface and levels of tritium up to two orders of magnitude above background levels at depths of 20 to 50 cm. Samples from the south burial area were analyzed at depth only; these values were also nearly two orders of magnitude above background levels for tritium.

4.18 The maximum observed vertical migration of tritium was beneath trench 8. Detection limits ($3x10^{-6}$ μCi/ml) were reached at a depth slightly greater than 3.2 m below the estimated trench floor with a possible trench floor location error of ±0.3 m. The minimum observed vertical migration of tritium was beneath trench 4. Activity dropped below detectable limits at a maximum depth of 2.25 m below the trench floor. Migration beneath trench 8 represents just under seven years of migration; the shorter distance beneath trench 4 represents ten years of migration.

4.19 In comparing measurements of tritium and carbon-14 beneath trench 5 to a depth of approximately 9 m below land surface a clear general relationship does emerge. Over this range the carbon-14 concentration dropped by a factor of approximately 20, whereas tritium decreased by a factor of 2 to 3 over the same depth interval. This indicates that the carbon-14 migrates at a much slower rate than the tritium. However, because of different trench water concentrations and different limits of detection it is not possible to compare directly the migration distances of tritium and carbon-14.

4.20 Detectable concentrations of strontium-90 below the trenches were found beneath trenches 4 and 5. Beneath trench 4 values above detection limits were found and may have been

up to 70 cm below the trench floor; the uncertain location of the trench floor precludes a more accurate estimate. Beneath trench 5 values above detection limits were found 5 cm below the estimated trench floor with a possible trench floor location error of ±15 cm. In short, evidence for the migration of strontium-90 beneath the trenches is suggestive, but inconclusive.

4.21 Plutonium-238 may have been detected beneath all three trenches studied and in four of the five sub-trench cores. Most of the dat show values above computed background levels for West Valley soil. Whether in all cases these values reflect actual migration in the soil is difficult to ascertain. The large potential laboratory counting errors for most of these analyses make any interpretation somewhat speculative.

4.22 Radionuclides showing essentially no detectable activity beneath the trench floor include iron-55, nickel-63, iodine-129, americium-241, cobalt-60, and ruthenium-106. Radionuclides showing activity attributable to the naturally occurring element include plutonium-239, potassium-40, thorium-232, uranium-234, -235, and -238.

5.0 RECOMMENDATIONS

In the course of this investigation a number of possible future paths of investigation were identified. These recommendations are discussed in more detail in sections 6.0 through 10.0 of this report.

5.1 Because trench recapping activities conducted in 1978 significantly altered the drainage pattern at the burial site, any continued surface water study must include remapping of the drainage basins.

5.2 Any further studies must address the problem of identifying on-site sources of radionuclides other than the low-level radioactive waste burial site. For example, a new surface water monitoring station that would monitor all runoff from the NRC-licensed burial area would be essential in addressing the problem of radionuclide source.

5.3 In order to better understand the mechanisms for transport of certain radionuclides, a study of grain size versus total beta in sediment from surface water samples should be undertaken. If this shows any clear relationships, a further study involving specific radionuclides could be undertaken.

5.4 High concentrations of plutonium-238 in trench water appear to constructively interfere with the analysis of americium-241. This problem has been encountered in trench 10 and may be affecting values of americium-241 in other trenches as well. The effects of plutonium-238 on americium-241 analyses should be investigated.

5.5 Because of the very high value of stable iodine observed in trench 11, further analyses should be done to determine the values in other trenches.

5.6 Because it has been surmised that the trench caps may serve as a medium for migration of tritiated gases and for exchange with stable fluids, continued analysis of trench cap samples should be undertaken to further define the magnitude, mechanism and extent of migration of tritium at shallow depths within the trench cap.

5.7 In conjunction with the above recommendation, parallel studies of soil and trench gases would identify some of the nuclides available for diffusion through, or retention in, the trench caps. Earlier studies suggest that ^{3}HH may exchange with water contained in the trench caps, and that $^{3}HCH_3$, $^{14}CH_4$, and $^{14}CO_2$ undergo "substantial aerobic decomposition in the trench caps". Continued studies of the efficiency of the

trench caps in retaining radionuclides should include an evaluation of these equilibration processes and rates. In addition, quantitiative effects of trench cap fractures upon gas flux remain to be defined.

5.8 Future studies of sub-trench migration of radionuclides should include additional analyses of cores using longer core sections to obtain higher sensitivity in the regions showing values near detection limits. This would provide greater accuracy in defining the migration rate of tritium, as well as help clear up problems associated with the interpretation of data on carbon-14, strontium-90 and plutonium-238 migration rates.

5.9 Now that a substantial body of information has been obtained from field experiments on migration rates and from computer modeling of this migration, laboratory experiments should be done to study the adsorption and desorption properties of the West Valley soil. Adsorption and desorption should be reversible procedures; if not, this is evidence for the creation of neutral substances or the formation of radiocolloids. In order to test the various components of the West Valley soil for its adsorption properties, a sample of uncontaminated soil from the West Valley site could be broken down into its various components for testing with a sample of water from the burial trenches. Desorption could then be carried out on these same samples to test the reversibility of adsorption experiments.

6.0 SURFACE WATER STUDY

6.1 Introduction

NRC-funded studies at West Valley include a program to examine potential radionuclide migration from the LLRWB site by means of the surface water pathway. Some elements of this study are a continuation of research efforts that were begun in December, 1975, as reported by Ragan and others (39).

Collection and analysis of surface water and sediment samples were undertaken in order to evaluate the hydrologic and radiochemical factors that influence radionuclide concentrations in surface waters, and to estimate the total tritium activity passing through the monitoring stations. Water samples were collected from three small streams that drain the burial site, and from two larger off-site streams. Samples were analyzed for total alpha, total beta, and tritium activity; in addition, selected surface water samples were analyzed for specific radionuclides.

The surface water study was designed, and is conducted jointly by the NYSGS, the USGS - Water Resources Division, and the RSL, NY State Health Department. The NYSGS has principal responsibility for sample collection and interpretation of surface water data. The USGS, through a cooperative agreement, purchases, installs, and maintains surface water equipment and interprets hydrologic records. The RSL analyzes surface water and sediment samples and interprets radiochemical data.

6.2 Method of Study

Equipment to record stream stage and automatically collect flow-proportioned water samples was installed in December, 1975, as part of USEPA-funded Part I research. Locations of the sampling stations are shown in Figure 1.

Stations No. 2 and 4 are located on two small streams* that drain approximately one-half of the LLRWB site; in addition, part of the adjacent NRC-licensed burial area is included in the drainage sampled at Station No. 2. Station No. 1 collects

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* In August of 1978 an earthen berm was installed approximately 10 m upstream of the flume at Station No. 3 (shown on Figure 1), redirecting runoff from that station to the area drained by the State No. 4 stream. Surface water sample collection at Station No. 3 was terminated in August, 1978.

samples of drainage from the remainder of the burial site, and from a large area outside the confines of the LLRWB site. Approximate drainage basin boundaries are shown in Figure 2.

Stations No. 2 and 4 are equipped with Instrumentation Specialties Co. (ISCO) flow-proportioned composite samplers and Stevens graphical stage recorders. Station No. 1 is equipped with a Fisher-Porter digital stage recorder and an ISCO sequential sampler. Equipment layout is illustrated in Figure 3 and summarized in Table 1. The use of both flow meters and stage recorders at Stations No. 2 and 4 results in two sets of streamflow data. Streamflows calculated from digital flow meter totalizer recordings are nearly the same as those calculated by summing the mean daily discharge values obtained from stage recorder data. Discrepancies generally occur when there are known monitoring device malfunctions or when the limits of the equipment are reached. Unless otherwise indicated in report, weekly streamflows at Stations No. 2 and 4 have been computed on the basis of flow meter (which measures streamflow directly and continuously) rather than stage recorder data. Streamflow values derived from flow meter and stage records are given in Appendix A.

Several types of samples are collected at the LLRWB site. These include flow-proportioned weekly composites, and grab samples collected during high and low stages. Table 2 lists and describes sample types, and Figures 4 through 8 depict sample processing.

Ice in the flumes and stilling wells frequently clogged the automatic sampling equipment during the winter. A revised surface water sampling program (shown in Table 3) was put into effect in November, 1979, in order to insure the continued sampling of surface water during the winter months.

Subsurface flow at Station No. 4 was monitored at a portable weir installed at that station in November, 1979. In order to compare the low levels of site-associated radioactivity with those occurring in nearby off-site streams, samples are collected monthly at Buttermilk Creek at Fox Valley Road in Riceville Station, and at Connoisarauley Creek at Connoisarauley Road in East Otto. Background samples are analyzed for total alpha, total beta, and tritium activity. Results of analyses are included in Appendix B.

Precipitation at West Valley is measured at two rain gages that were adapted for snow between November 14th and April 9th, 1980. Precipitation for July, 1978* through December, 1979 is given in Appendix A.

* Some surface water samples collected in 1978 were analyzed in 1979. For that reason, precipitation and streamflow for portions of 1978 are included in this annual report.

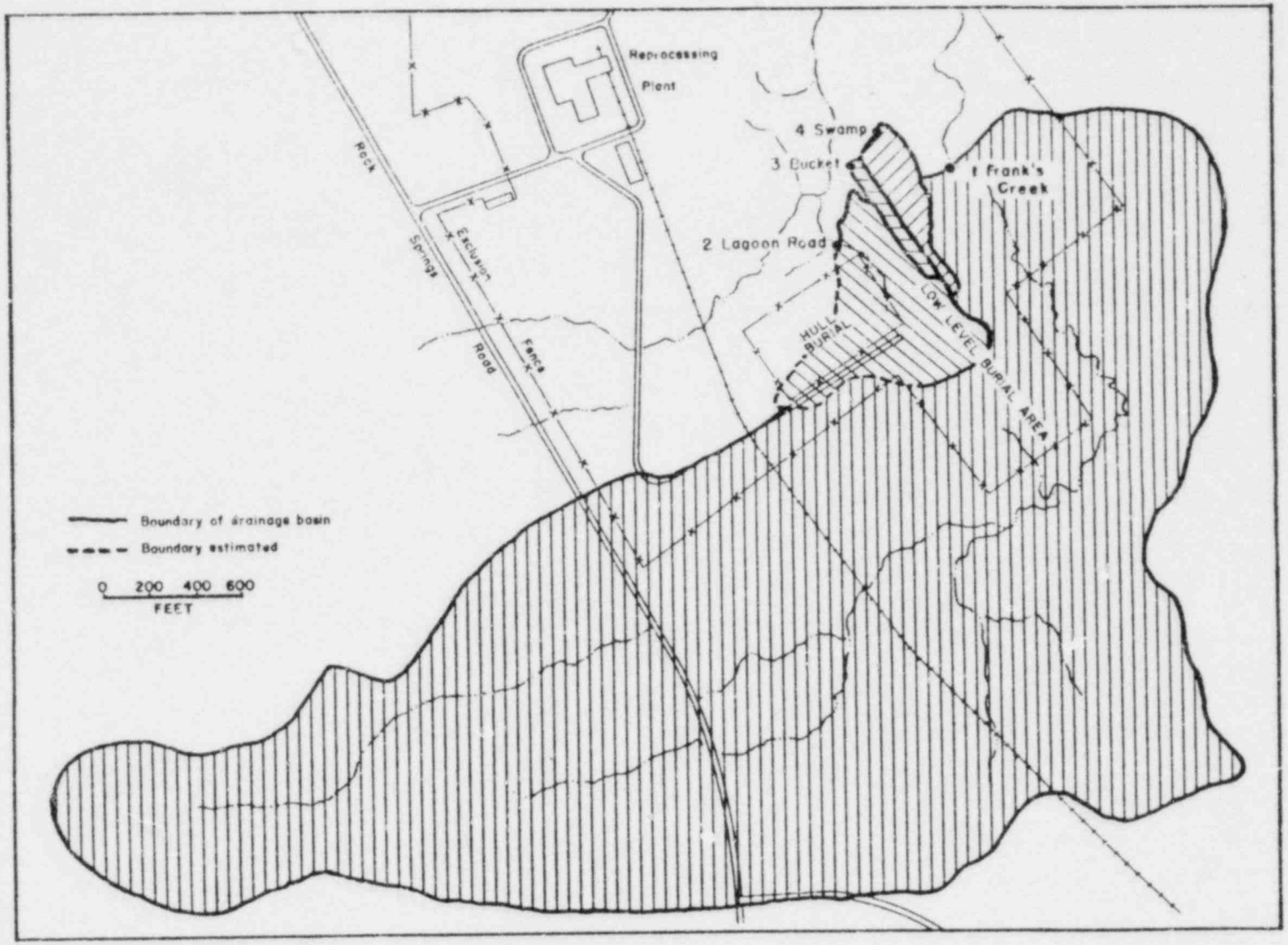

Figure 2. Drainage basins of surface water sampling stations 1 through 4 prior to recapping of north trenches in August, 1978.

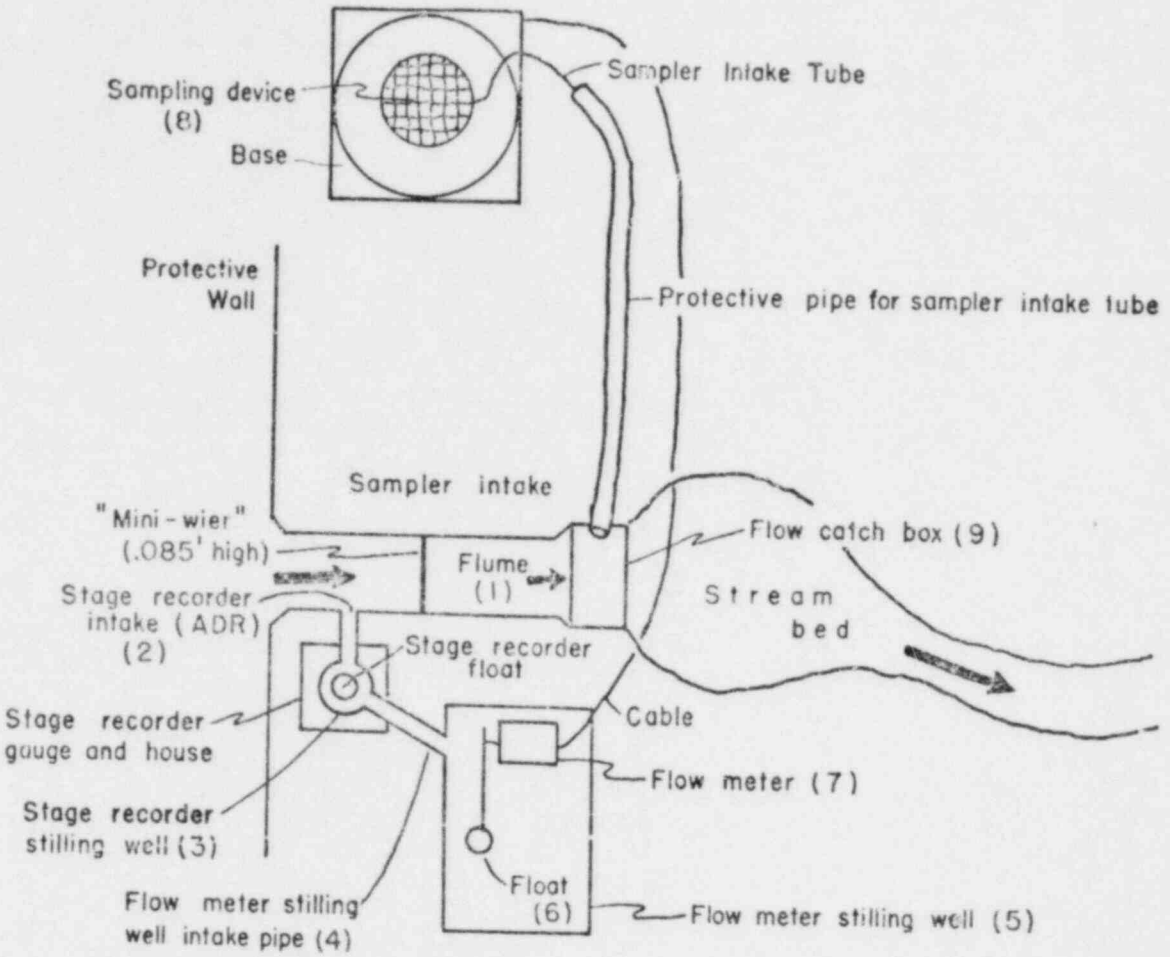

Figure 3. Plan view of surface water monitoring and sampling equipment. A portion of water passing through flume (1) enters stage recorder stilling well intake pipe (2) to stage recorder stilling well (3) to flow meter stilling well intake pipe (4) and to flow meter stilling well (5). Float (6) is raised and flow meter (7) sends signals to sampler at frequency proportional to preset flow in accordance with preset multiplier setting. Sampler (8) is activated and sample drawn from catch box (9).

TABLE 1. Stream monitoring and sampling equipment installed at the West Valley burial site.

Item	Purpose	Stations where installed
6" Parshall Flume	Directs stream flow through an artificial channel that has pre-calibrated stage-discharge relationship.	2, 4
Stevens A-35 Stage Recorder	Provides continuous graphical record of stream stage for calculation of streamflow.	2, 4
Instrument Specialties Co. (ISCO) Model 1470 Flow Meter	1. Provides digital record of flow volume for any given time period. 2. Sends activator signal to sampler at preset flow-volume intervals.	2, 4
ISCO Model 1580 Composite Sampler	Collects composite of individual samples upon receipt of signals from flow meter.	2, 4
ISCO Model 1392 Sequential Sampler	Collects one 250-ml surface water grab sample at pre-determined time intervals.	1
Fisher Porter Digital Punch Recorder	Provides record of stream stage at 15-minute intervals and produces punched tape which becomes standard input for USGS hydrologic analysis computer programs.	1

TABLE 2. Surface water samples collected near low-level radioactive waste burial site.

Sample Type	Description
Surface Water Grab	An incidental, two-liter grab sample collected during the absence of automated surface water sampling.
Monthly Sediment Grabs	"Fine" sediment deposits collected manually from areas upstream of Station No. 2 and adjacent to Station No. 1.
Weekly Low Flow Grabs	Two-liter, whole water grab samples collected at Stations No. 2 and 4 when outside staff gage is <4.3 cm. Collected at Station No. 1 based upon visual observation of turbidity.
Automatically-Collected Weekly Composites	Variable-volume samples collected with ISCO automatic surface water sampling equipment.
Storm Grabs	Two-liter surface water grab samples collected manually during and after storms.
Monthly Background Grabs	Two-liter, whole water samples collected from nearby Connoisarauley and Buttermilk Creeks.
Automatically-collected Daily Surface Water Grab	A fixed-volume (250 ml) automatically-collected daily grab sample collected at Station No. 1.
Ion-exchange Column Composites	Two-year composites of filtered (50μ, gravity filtration) surface water samples. Column resins analyzed for specific nuclides.

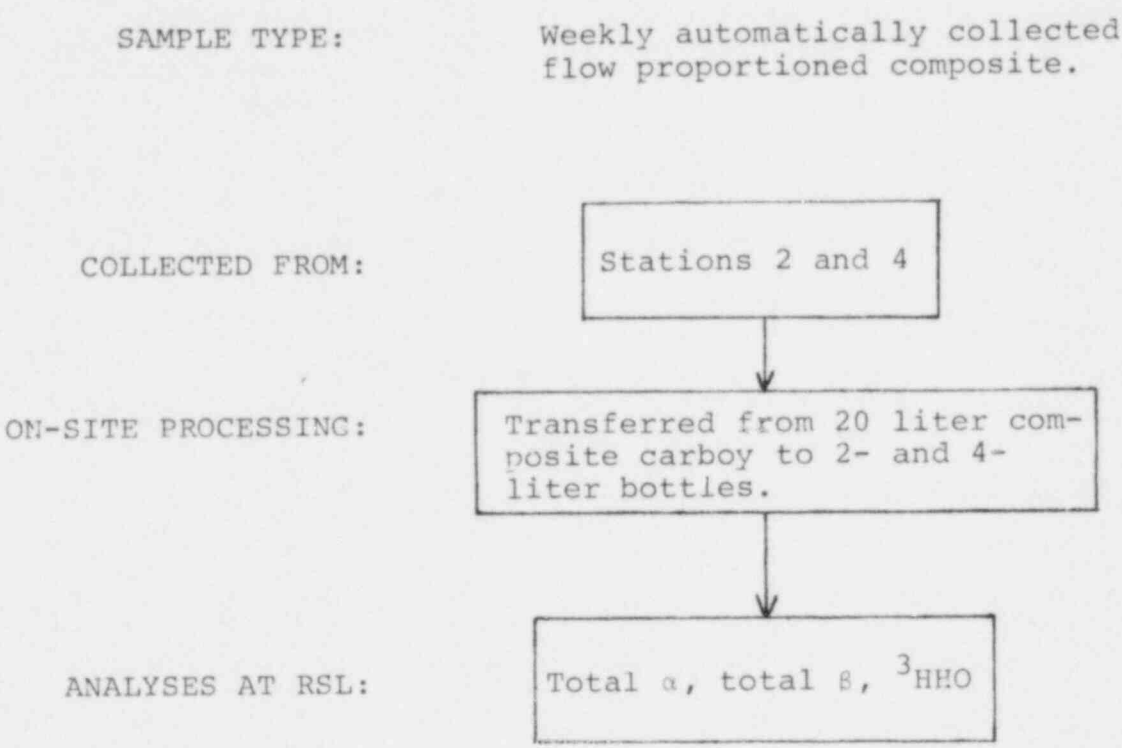

Figure 4. Weekly composite Sample Processing.

SAMPLE TYPE: 2 weekly low flow whole water grabs, ∿ 2 liters each.

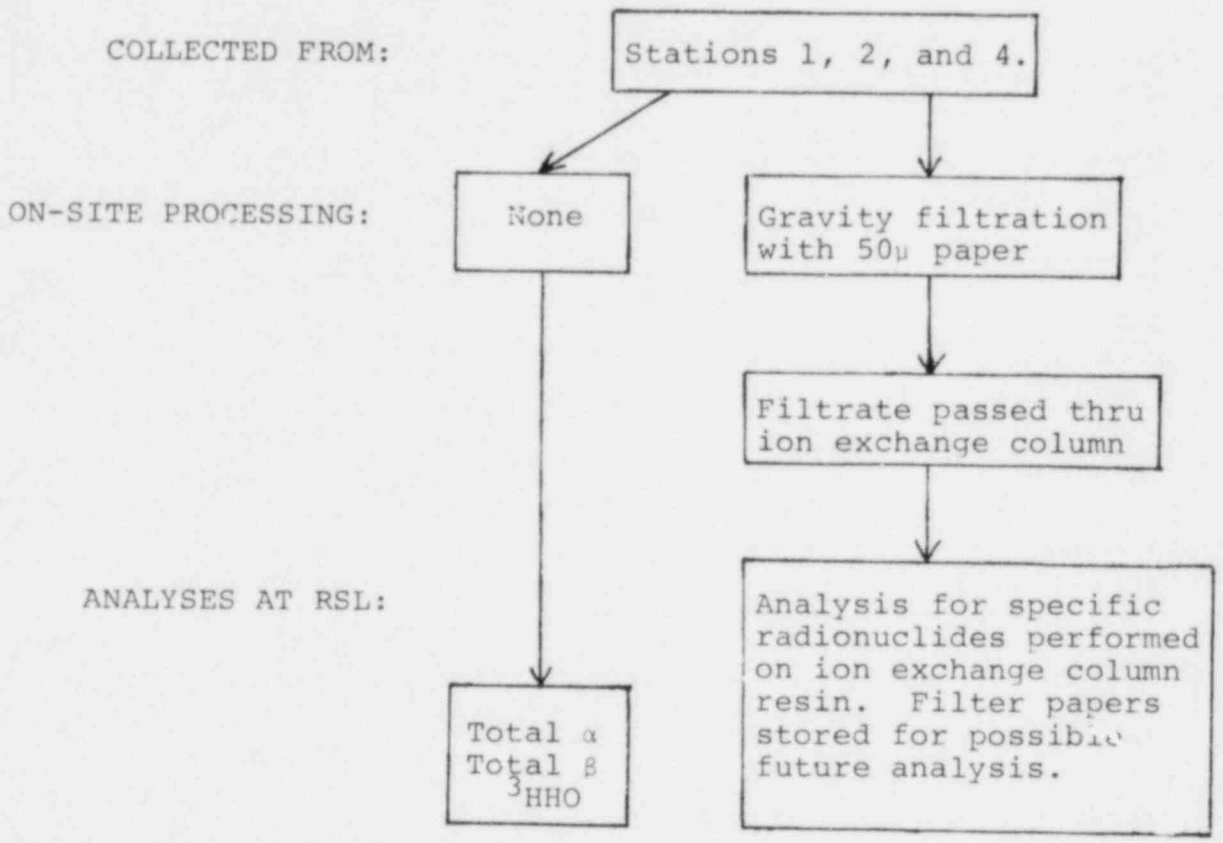

Figure 5. Weekly Low Flow Grab Sample Processing.

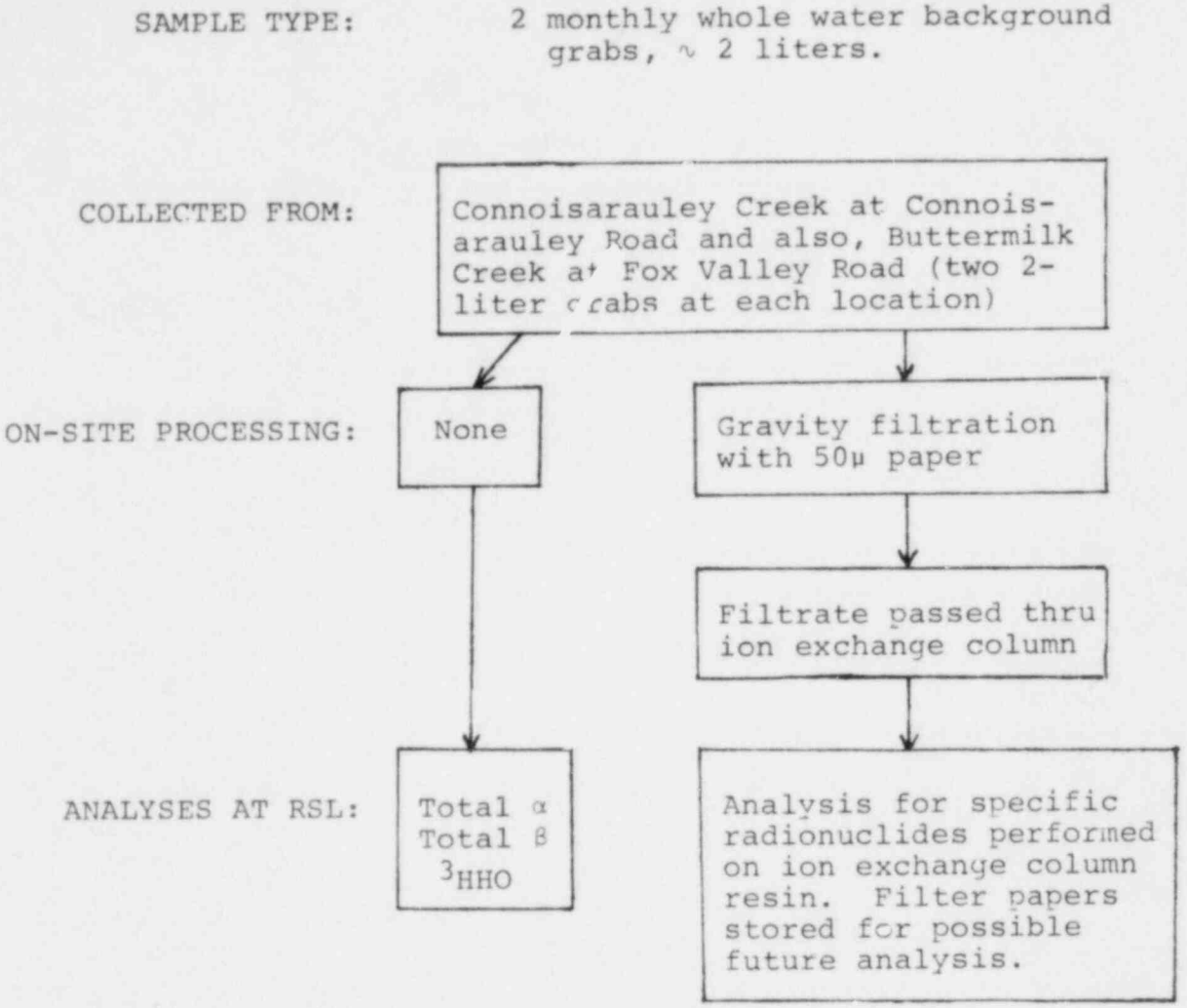

Figure 6. Monthly Background Grab Sample Processing.

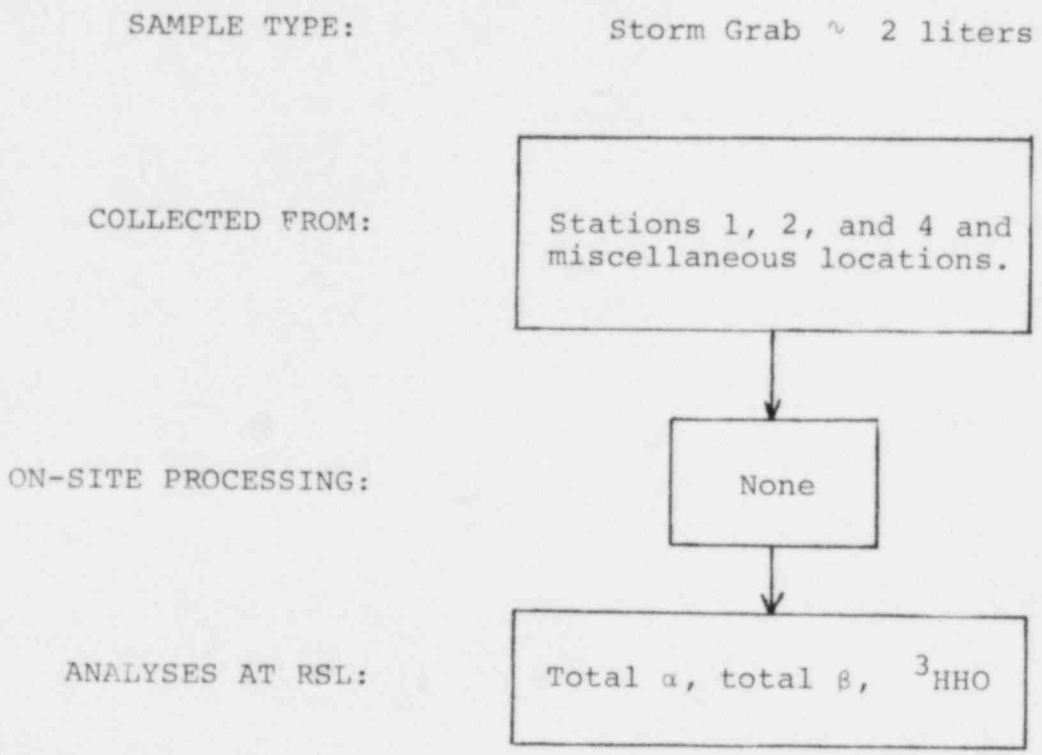

Figure 7. Storm Grab Sample Processing.

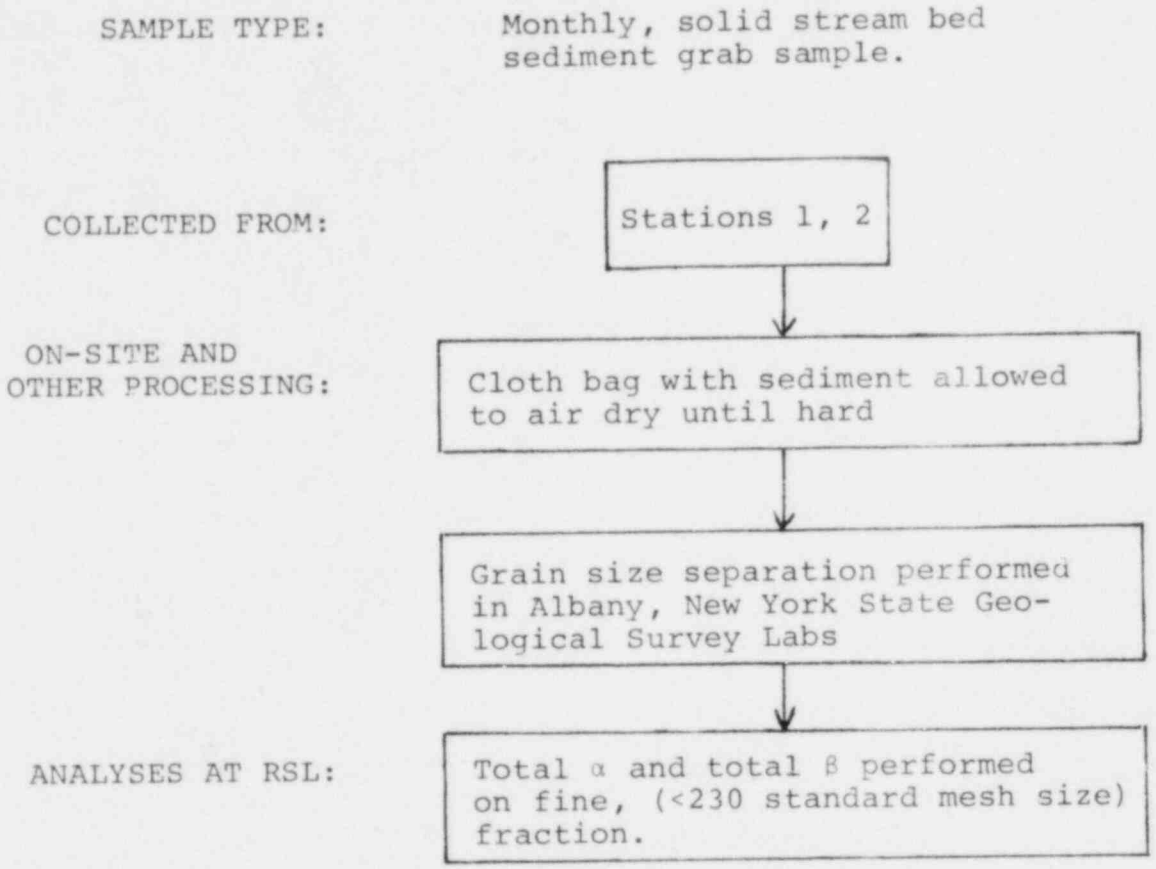

Figure 2. Monthly Stream Bed Sediment Grab Sample Processing.

TABLE 3. Winter Surface Water Sampling Program

Stations	Sample Type	Explanation
1,2 & 4	Grab, Low Flow	At Stations 2 & 4 these samples are collected when the outside staff gauge exhibits <a 4.3 cm stage. Analysis of graphical records of stage at these stations indicates that "base" or low flows are at stages of 4.3 cm or less. At station #1 a visual determination is used to assess turbidity for the purpose of determining if a low flow condition exists.
1,2 & 4	Grab, snowmelt and/or storm runoff	These grab samples were collected to examine those flows caused by melting snow, ice and/or winter rainstorms, generally when the channel was not choked with ice.
1,2 & 4	Grab, Supra and Sub Ice Flow	These grab samples were collected to examine flows over, between and under ice accumulations in the channel.
4	-Grab, surface water flow -Grab, subsurface flow -Grab, mixed surface and subsurface flow	In September of 1979, record flows occurred in response to residual precipitation from Hurricane Frederick High flows at the #4 Swamp station created an apparent piping system below it. Measured discharge through this piping network ranges from 5ml/s to 300ml/s when no surface flow is evident.
1,2 & 4	Grabs, incidental	These samples are collected to examine unusual flow conditions created by natural extremes in climate or the activities of humans.

6.3 Results and Discussion

6.3.1 Tritium

Tritium, as tritiated water, is the most abundant radionuclide detected in surface water samples. It is estimated that roughly 1.8×10^{-1} Ci* of tritium were transmitted through Station No. 2 during the period 7/24/78 - 12/17/79.**

Tritium concentrations in composite samples collected at Station No. 2 during the study period varied from 1820 pCi/l±10% to 88,000 pCi/l±4%. As indicated in Figure 9, highest tritium concentrations occurred in samples collected during periods of low precipitation. This increased activity in stream samples probably reflects the loss to the drainage basin of diluting precipitation, which contains lower, ambient levels of tritium.***

Total tritium activity for Stations No. 1 and 4 was not calculated for 1979 because submitted analytical values were frequently below detection limits, or contained large deviations. Tritium activity in samples collected at these two stations during 1979 remained within the range of variation for ambient tritium.

Higher than expected tritium concentrations were found in all samples collected during May, 1979. This may reflect, in part, the normal increase in tritium concentrations in precipitation accompanying vernal tropospheric inversions that occur at these latitudes (25).

6.3.2 Total Alpha and Total Beta Activities in Water Samples

Total alpha and total beta measurements are performed for each water sample in order to screen for the presence of radionuclides and to provide a basis for selection of samples to be analyzed furtner for specific radioisotopes.

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*Total tritium activity is determined by summing the products of tritium activities (pCi/l) in composite samples and the streamflows (l) for the corresponding time periods.

**No data available for 10/10/78 - 4/29/79, or 9/30/79 - 11/15/79.

***General ambient levels of tritium in precipitation due to cosmic rays and nuclear weapons testing are approximately 200-1000 pCi/liter (14). On-site values of tritium measured in 1979 by NFS range from 600-1200 pCi/liter. Maximum permissible concentration of tritium in drinking water is 20,000 pCi/l(44).

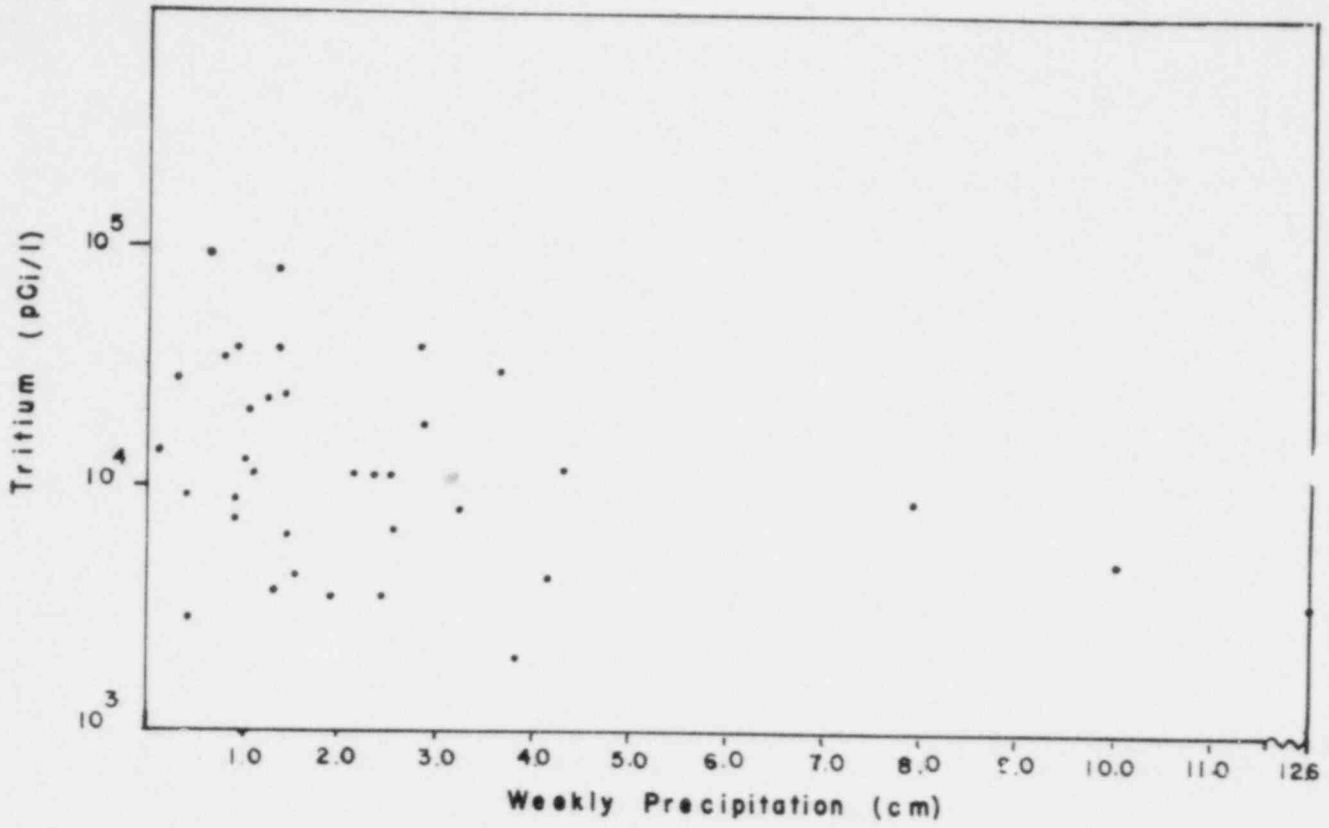

Figure 9. Graph of tritium activity in composite surface water samples collected at Station No. 2 versus weekly precipitation (cm).

Laboratory limitations inherent in this analysis are the loss of volatile fractions (especially radioiodine, tritium and carbon-14), difficulty in establishing radiometric standardization for a mixture of unknown alpha and beta emitters (31), and absorption of beta particles by sediments that overlie other beta emitters in the sample.

Total alpha and total beta activities of surface water samples are included in Appendix B. Alpha activity is below detection limits for most samples, including those collected at Station No. 2, which exhibits the highest tritium and total beta levels at the site.

Samples collected at Stations No. 2, 3 and 4 during late July and August of 1978 exhibited increased alpha and beta activity that may be associated with well excavation and trench recapping activities carried out at that time. Eleven pre-existing wells were excavated by backhoe and capped below grade, prior to trench recapping, near the north burial trenches on July 24-26. The excavations, which were up to 1 m deep, remained open until July 27, exposing trench cap sediments for transport to nearby streams. (Radioactivity of the new trench caps is discussed in section 9.0 of this report). Recapping of the north burial trenches (which required removing several cm of topsoil) began on August 7th and was completed on August 30th. A more detailed description of recapping procedures is given in our 1978 Annual Report (10).

Total alpha and total beta activities in composite water samples collected at Stations No. 2, 3, and 4 are shown in Figure 10. Activity levels clearly increased at all stations during the weeks of trench recapping operations, and subsequently decreased to ambient levels after operations ceased. (Note that ambient levels of total beta activity for Station No. 2, plotted on Figure 10, are above values for the other two stations). The major cause of the elevated activity is probably the ten- to twenty-fold increased in sediment loads that occurred at all stations while the trenches were being recapped. This correlation between sediment load and radionuclide concentrations also explains why tritium (not shown in Figure 10), a radionuclide not associated with the sediment fraction, showed no increase during that time.

6.3.3 Detailed Radiochemical Analyses of Water Samples

Strontium-90 is the predominant beta emitter detected in surface water samples for which analyses for specific radionuclides were performed. It is estimated that Sr-90 contributes approximately one-half of the total beta activity in whole water samples (Table 4).

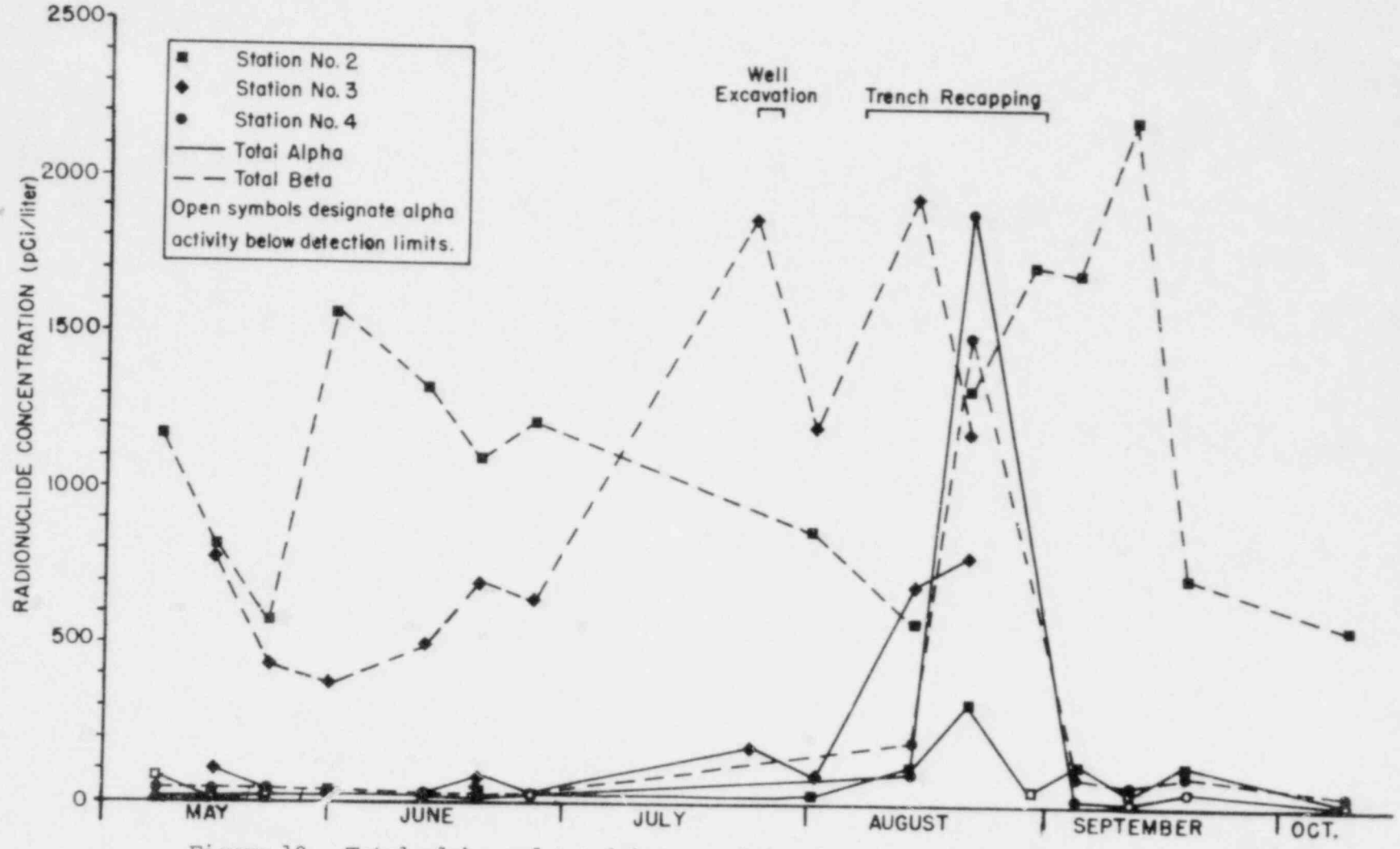

Figure 10. Total alpha and total beta activity in composite samples collected at Stations No. 2, 3, and 4, May 1 through October 9, 1978. Points designate last day of week of composite sample collection.

TABLE 4. Sr-90 Activity (as minimum percent of total beta activity) in surface water samples from Station No. 2.

Collection Date	Total beta (pCi/l)	Sr-90 (pCi/l)	Sr-90 (as % of T.Beta)	Suspended Sediment (g/l)
5/1/78 +	1210 ± 4%	780 ± 5%	58.9%	0.8
5/8/78 +	1210 ± 4%	610 ± 6%	45.6%	0.8
5/1/79 +	1550 ± 9%	1040 ± 3%	59.7%	2.5
5/7/79 +	1290 ± 8%	1080 ± 3%	54.2%	3.4
4/30-5/7/79*	1410 ± 9%	1060 ± 3%	66.9%	2.7
5/15-5/21/79*	1620 ± 9%	850 ± 3%	46.7%	2.5
6/4/79 +	1740 ± 8%	910 ± 3%	47.0%	0.7
6/18/79 +	1470 ± 9%	850 ± 3%	51.5%	1.4
9/17/79 +	1290 ± 9%	650 ± 3%	44.8%	1.3
9/17-9/24/79*	1320 ± 9%	630 ± 3%	42.5%	3.1

\+ Low Flow Grab

* Composite

Although earlier studies (39) indicate that total beta activity (and presumably, Sr-90) is contained primarily in the fine sediment fractions, there is not a well-defined correspondence of Sr-90 activity in the samples analyzed to the amount of suspended sediment in the samples. This may reflect degraded counting efficiency due to sample self-absorption in samples that contain relatively large amounts of sediment. It also suggests that samples with large sediment concentrations (which are generally those collected during high flow events) contain greater fractions of sand and coarser sediments, thus, the activity is not proportionate to the weight of sediment in the sample, as the surface area (per gram of sediment) available for adsorption of strontium is reduced.

Other specific radionuclides for which analyses were performed are presented in Appendix B. Many nuclides (Na-22, Fe-55, Ba-133, and Cs-134) are consistently below detection limits. Others (C-14, Ni-63, Sr-90, Pu-238, Pu-239, -240) fluctuate sporadically; however, the small number of samples analyzed precludes any valid conclusions being drawn from relating activity variations to other factors (discharge, precipitation, sediment load).

6.3.4 Analysis of Sediment Samples

Stream sediments collected from Stations No. 1 and 2 were analyzed for total alpha and total beta activity. Sediment samples were crushed, sieved, and the <0.0625 mm fractions submitted for analysis. All samples collected at Station No. 1 exhibited total alpha and total beta activity that was not above the estimated natural radioactivity of the burial till (9). Sediment samples collected at Station No. 2 exhibited near-ambient alpha activity; beta activity of these stream sediments, however, was nearly one order of magnitude greater than the burial till's estimated background beta activity. A soil sample* collected during the study from the north burial area within the Station No. 2 drainage basin exhibited ambient levels of beta activity. This may suggest that there is a source other than the trench caps for the high beta values. Potential sources within the Station No. 2 drainage basin include: the continuing burial operations and the surface of the NRC-licensed burial area, the two buried lagoons shown on figure 14, and various other possible sources such as the buried line for pumping trench water to the low-level waste treatment plant near the main process buildings.

*Sections 8.0 and 9.0 discuss in detail the trench cap soil analyses.

6.3.5 Sorption Experiment

Surface water samples were collected at Stations No. 1, 2, and 4, and at Buttermilk Creek and Connoisarauley Creek to evaluate which radioions, if any, are present in solution. Two-liter samples were collected weekly at each station from August, 1977 to September, 1979. The samples were filtered, composited, and passed through Barnstead mixed-bed cation-anion exchange columns (Figures 5 & 6). The column resins were analyzed for Cs-137, Ru-106, and Zr-95. In addition, the column resin for samples collected at Station No. 2 was analyzed for Cs-134, Co-60, Ba-133, and Na-22. All radionuclides for which analyses were performed (given in Appendix B) were below detection limits. This may indicate that the radionuclides, if present, are sorbed to the sediments and transported in that medium, or, perhaps that insufficient sample volume was passed through the columns to allow detection of dissolved nuclides. It may indicate, also, that there has been insufficient time for equilibration with the column resins, or that neutral complexes (eg. humic and fulmic acids) containing radionuclides are present in the natural aquatic system.

6.4 Further Studies

Trench recapping activities conducted in 1978 significantly altered the drainage patterns of the LLRWB site. Any continued surface water study must include remapping of the drainage basins to establish runoff and channelled flow drainage patterns and radionuclide transport in surface water.

The revised surface water program currently being planned for the waste burial site will incorporate a new, or revamped surface water station (or stations), near the present site of Station No. 2. This new station (or stations) will use a new design that should address the site-specific monitoring problems encountered in earlier studies. The study will assess the sediment load and radiochemistry of the drainage, and will include an effort to identify the radionuclides derived from the NRC-licensed burial area, the LLRWB area, and other possible source areas within the drainage basin.

Analyses on samples passed through ion exchange columns showed values below detection limits. The filter pads containing sediment, filtered from these samples prior to being processed through the ion exchange columns, should be analyzed for specific radionuclides, including strontium-90 and carbon-14. These analyses would determine which, if any, radionuclides are adsorbed onto these sediments.

7.0 TRENCH WATER STUDY

7.1 Introduction

Both infiltrated water in contact with the wastes in the burial trenches and gases liberated from the wastes and generated by the decomposition of the wastes are potential sources of environmental contaminants. In order to define the chemical and radiochemical characteristics of these materials for use in modeling and direct measurement of migration rates, a program of sampling and analysis of trench water and trench gas was undertaken in 1976 during the first phase of this project. Wells for sampling were installed by the USGS in a cooperative program with the NYSGS with the assistance of RSL personnel. All chemical and radiochemical analyses were carried out by the RSL. The phase of the study described in this report represents a continuation of the on-going study of trench water.

In 1976 trench water samples were collected from the five north-end trenches (1 through 5) and analyzed chemically and radiochemically. In September, 1977, nine additional samples were collected from four north trenches (1, 2, 4, and 5) and four south trenches (8, 9, 12, and 14). The purpose was to resample some of the north-end trenches to gain a time perspective on radiochemical contents of the trench water and to sample some of the south trenches for study for the first time.

The original plan for the present phase of study was to drive two to four wells for collection of anoxic water samples from the south burial trenches. Trenches 8 and 13 were chosen for sampling, the former because it had yielded the highest recorded values for several radionuclides, and the latter because it had only one well (13-1A) from which to collect water samples. Because of a four-month delay in gaining permission to drive the planned wells, in August the decision was made by the NYSGS and the RSL to collect samples from existing wells rather than from two planned wells in order to allow timely completion of detailed radiochemical analyses. Samples were collected in mid-August from wells 8-1B, 10-sump, 11-sump and 14-1A.

7.2 Water Sample Collection

Collection of trench water samples was carried out by personnel of the Radiological Sciences Laboratory of the N.Y. State Health Department on August 14-15, 1979.

In order to insure that no oxidation of the trench water samples takes place during the sampling process, a technique was developed so that water samples are in contact with an inert gas atmosphere (argon) and not with ambient air. This technique is modeled on a procedure originally developed by Columbo, Weiss and Francis (2) at Brookhaven Laboratory. The field sampling apparatus is assembled as shown in the schematic diagram in Figure 11, using Tygon laboratory grade (R3606) tubing. The system is evacuated and filled with argon. Three evacuation/argon fill cycles are performed to insure that the system is air-free and the samples are as anoxic as possible. A small, positive argon pressure is maintained during the collection. To obtain anoxic water, the first twenty liters or more is pumped out and disposed of. The presence of anoxic water in the sampling system is evidenced by a stabilization of Eh. At that time the pH, Eh and temperature are measured and the filter reservoir is filled with trench water. After the peristaltic pump is shut off and the pump stopcock closed, the trench water is pressure filtered through a 9 cm glass-fiber filter*. The filtered sample is preserved in an anoxic state in the collection bottle. The filter is removed from the reservoir and stored with the collection bottle in a styrofoam-lined, wooden box at ambient air temperature prior to shipment to the laboratory.

Four well points were initially chosen for sample collection; the decision of which two samples to analyze was to be made in the laboratory. The well points chosen were: 8-1B on Trench 8, the north 6-inch sump well on Trench 10, the 6-inch sump well on Trench 11, and well 13-1A on Trench 13. Because of sampling problems (see below) well 14-1A was substituted for well 13-1A.

Attempts to collect trench water from well 13-1A on August 14 were not successful. During pumping prior to actual sampling (in order to ensure as anoxic a sample as possible) the well ran dry. Well 14-1A was chosen as an alternate sampling point. During sampling at well 14-1A the filtering equipment developed leaks, however, a sample was obtained. On August 15, samples were collected from trenches 8, 10, and 11: wells 8-1B, the trench 10 new 6-inch sump(north) and the trench 11 6-inch sump. All attempts at collection were successful and only minor problems with the peristaltic pump were encountered.

It should be noted that immediately after collection,samples from trenches 14 and 11 showed signs of oxidation. This was evidenced by brown "$Fe(OH)_3$" adhering to the walls of the glass container. This process continued progressively for several days before apparently stabilizing.

*Because of problems with filtering using millipore filters, as described in Section 8.3 of last year's Annual Report (10) a new system was devised.

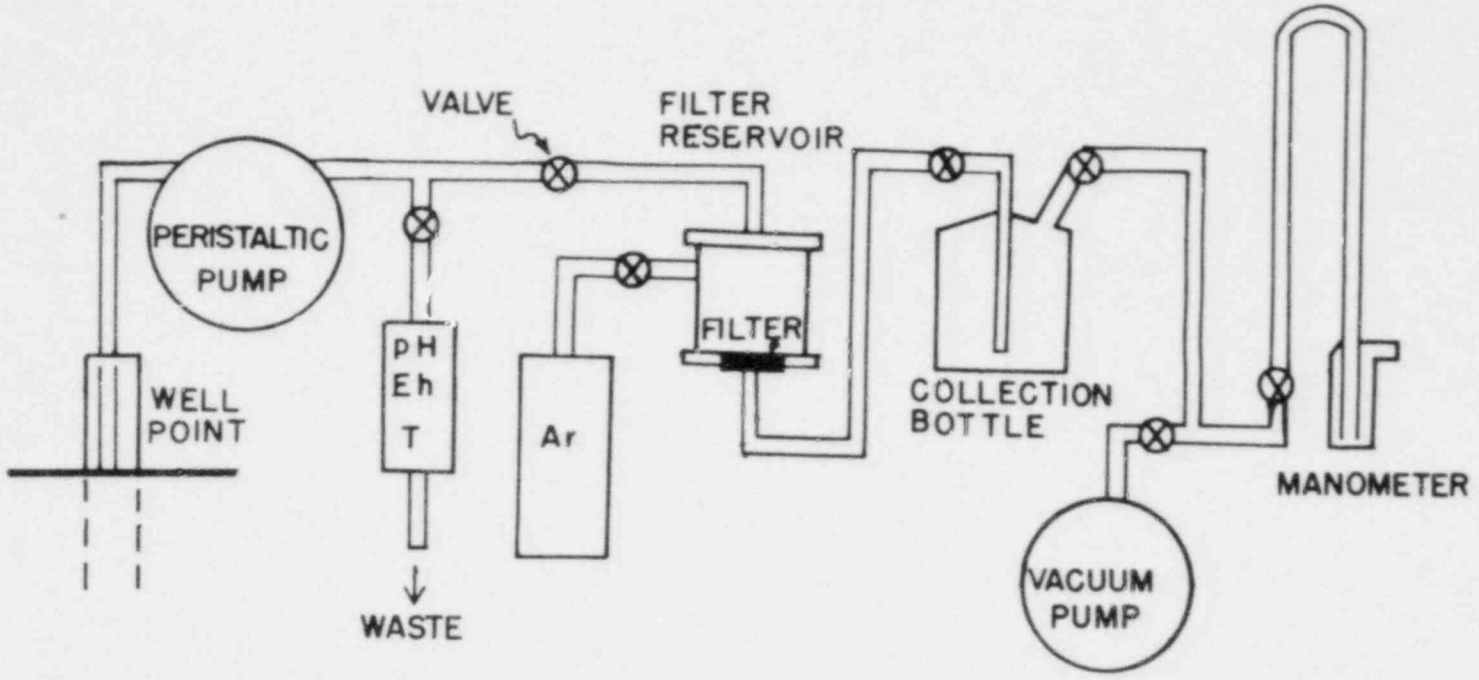

Figure 11. Schematic diagram of trench water collection apparatus.

7.3 Water Wells

On November 27 and 28, 1979, two 1¼-inch diameter 60-mesh, 24-inch, button or washer screen well points were driven into trenches 13 and 8. Using a portable aluminum tripod equipped with motor-driven cathead and 140-pound hammer, 1¼-inch diameter galvanized pipe sections were driven to depths below the trench water level. The procedure was as follows: 1) hand-auger to a depth of three feet, 2) drive well point and initial length of pipe, 3) test for methane with a portable, battery operated methanometer (accurate to 0.1% methane), 4) add bentonite and water around the pipe as a sealant, 5) drive additional lengths of pipe using same procedure until depth to trench water is reached, 6) add a length of pipe to extend well two to three feet above ground surface, and 7) add bentonite and water around the pipe and tamp.

Several factors were considered in the location of wells. First, the depth to water level in the trenches was ascertained. Because the trench floors slope southward, the depth of water in the trenches controls the length of trench bottom covered by water. Second, the location of subtrench core holes was determined, since proximity to core holes increases the value of the data collected. Third, burial records were scanned for location of any impenetrable objects, such as concrete casks, to be avoided.

Well 8-2C was driven to a depth of 29 feet below land surface so that the top of the two-foot screen section of the well point is at water level (26.5 ft.). This driven depth is one-half foot above the estimated trench bottom (29.5 ft.) Well 13-2A was driven to a depth of 25.5 feet below the surface so that the top of the well screen is more than two feet below water level (20.8 ft.). This driven depth is 4.5 feet above the estimated trench bottom (30 ft.). Hard objects - those that essentially stop driving of the pipe for several blows - were encountered at 16.5 feet and 21.5 feet depth in both wells. This coincidence may be the result of a similar method of stacking waste in these two trenches, though an analysis of blow counts during previous drilling programs at the site revealed no pattern of hard object distribution.

7.4 Radiochemical Analyses of Trench Water

Two of the four samples collected in August were selected for analysis: one from the six-inch diameter sump in the northern half of trench 10 and the other from the six-inch diameter sump in trench 11. These were chosen because no detailed analyses

had yet been done on water samples from trenches 10 and 11.* The oxidation in the sample from trench 11 was effectively reversed by the addition to an aliquot of a small amount of concentrated HNO_3, re-adsorbing the precipitate and allowing analyses to proceed as normal.

All radiochemical analyses were carried out by staff of the Radiological Sciences Laboratory of the New York State Health Department (RSL). Samples were analyzed radiochemically for dissolved ^{3}HHO, ^{90}Sr, ^{238}Pu, ^{239}, ^{240}Pu, ^{134}Cs, ^{137}Cs, ^{55}Fe, ^{60}Co, ^{63}Ni, ^{14}C (Inorganic), ^{14}C (Organic), ^{129}I, ^{234}U, ^{235}U, ^{238}U, ^{241}Am, ^{232}Th, ^{22}Na, ^{54}Mn, ^{106}Ru, ^{40}K, total α, and total β. For certain radionuclides the suspended fraction was analyzed as well. Samples also were analyzed for stable iodine. Eh, pH and temperature were determined in the field. The data are listed in Table 5. A detailed description of the trench water laboratory analysis techniques is included as Appendix C.

7.5 Discussion of Trench Water Data

Review of records of the contents of the trenches (shipping documents, NFS log books, and miscellaneous notes) reveals a variety of waste material and containers, including 55-gallon drums, wood and cardboard crates, steel and concrete casks, and dozens of miscellaneous waste forms distributed in the trenches without systematic variation from north to south (29,30).

Detailed investigation of trench 5, one of the north trenches, demonstrated that, despite the heterogeneity of the trench contents, variations between different parts of trench 5 are apparently small, and variations over time are also relatively small (12). As for the mode of burial, we know that in the south trenches, in general, metal drums were stacked on their sides, one on top of the other. These stacks were placed at intervals of about 20 feet (according to recollections by NFS personnel). Between these stacks cardboard and wooden boxes and other packages were buried. Large steel or concrete casks were usually placed at the bottom of the trench, between stacks of drums (37). In view of this apparent heterogeneity of the south trenches and the fact that certain nuclide species in the trench water are not in chemical equilibrium (see below), it is prudent to draw conclusions relating only to data from specific holes and not to generalize over the length of a trench. In any case, the limited scope of the available data - only 1

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*Columbo, Weiss and Francis (4) of Brookhaven Laboratory collected samples from all 12 trenches during June and July of 1977. These samples were analyzed for total α, total β, tritium, and various gamma emitters. Their results are similar to the results reported here.

TABLE 5. Radiochemical and Chemical Analyses of Water Samples From Trenches 10 and 11, collected 8/14/79 (Data in μ Ci/ml unless otherwise stated). Error term gives 2 σ counting uncertainty in percent.

Radionuclide	TRENCH 10 - NORTH SUMP Dissolved	Suspended	TRENCH 11 - SUMP Dissolved	Suspended
^{3}HHO	4.27 ±3%		2.77 ±3%	
^{3}H-organic	3.25 E-02 ± 3%	2.42 E-05 ± 3%	2.5 E-02 ± 3%	4.27 E-05 ± 3%
^{90}Sr	6.8 E-04 ± 5%	3.59 E-07 ± 3%	1.61 E-04 ± 3%	1.67 E-07 ± 3%
^{238}Pu	2.8 E-04 ±15%	6.0 E-05 ±11%	3.1 E-08 ±19%	9.6 E-09 ±10%
$^{239,240}Pu$	6.0 E-07 ±35%	1.2 E-07 ±31%	5.0 E-09 ±37%	6.1 E-09 ±11%
^{134}Cs	2.1 E-06 ±14%	3.5 E-10 ±67%	3.3 E-06 ± 9%	3.1 E-09 ±23%
^{137}Cs	5.46 E-05 ± 4%	1.59 E-08 ± 6%	4.23 E-04 ± 3%	3.56 E-07 ± 3%
^{55}Fe	<1.6 E-07	<1.1 E-08	1.8 E-06 ±15%	<1.0 E-08
^{60}Co	3.1 E.07 ±45%	4.2 E-10 ±71%	6.7 E-07 ±19%	3.20 E-08 ± 6%
^{63}Ni	1.96 E-04 ± 3%	<3.0 E-09	1.52 E-04 ± 3%	<3.0 E-09
^{14}C-inorganic	3.32 E-05 ± 5%	3.4 E-08 ± 6%	2.44 E-04 ± 5%	4.9 E-08 ± 5%
^{14}C-organic	3.59 E-04 ± 3%	3.05 E-07 ± 5%	1.88 E-03 ± 5%	3.62 E-06 ± 5%
^{129}I	5.8 E-08 ±25%	<4 E-09	1.25 E-07 ±14%	<2 E-09
^{234}U	2.9 E-07 ± 9%	2.6 E-08 ± 9%	1.4 E-08 ±37%	3.2 E-09 ±16%
^{235}U	<6 E-10	<1.2 E-11	<8 E-10	2.6 E-10 ±45%
^{238}U	8.0 E-09 ±20%	1.8 E-09 ±17%	6.8 E-08 ±22%	1.59 E-08 ±12%
^{241}Am	<1.1 E-06	<7.0 E-08	2.1 E-08 ±31%	3.8 E-09 ±33%
^{232}Th	<6 E-07	1.1 E-09 ±43%	<5 E-07	<9 E-10
^{22}Na	2.13 E-05 ± 5%	2.2 E-09 ±23%	1.47 E-06 ±12%	1.4 E-09 ±34%
^{54}Mn	<1.8 E-07	<3 E-10	--	<6 E-09
^{106}Ru	<2 E-06	<3 E-09	--	<1.2 E-09
Total α	1.33 E-03 ± 3%	<1.4 E-06	8.5 E-04 ± 3%	1.17 E-06 ±15%
Total α (μCi/g)	1.35 E-01 ± 3%	--	8.2 E-02 ± 3%	--
Total β	1.42 E-04 ± 4%	5.2 E-05 ±11%	<8 E-08	<3 E-07
Total β (μCi/g)	1.44 E-02 ± 4%	--	<7 E-06	--
^{40}K	<1.4 E-06	<5 E-09	<1.9 E-06	<5 E-09
Eh(mv)	-160		-270	
pH	6.5		6.4	
Temp (C)	13		11	
I stable	17.2 mg/l		1.0 mg/l	
ΣFe	220 mg/l		88 mg/l	
Ni	2.4 mg/l		55/mg/l	

well each in 5 of the 11 trenches studied - allows little room for general conclusions. Therefore, this discussion will concentrate on inter-hole variations, comparing the data collected in sumps 10N and 11 with data collected earlier from other holes.

By comparing the data listed in Table 5 with data from the other 9 trenches studied to date, a table of the major radionuclide species listed in order of abundance for each trench studied has been prepared (Table 6).

Tritium

As shown in Table 6, tritium as ^{3}HHO* is by far the most abundant radioactive element in all the trenches studied, without exception; in most samples, ^{3}H as ^{3}HHO is more than two orders of magnitude greater than the second most abundant radionuclide. Furthermore, the present study shows that tritium activities in both trenches 10 and 11 are the highest values yet measured in the trenches at West Valley (4.27±3% and 2.77±3% μCi/ml, respectively).**

The tritium concentration per ml of trench water has been analyzed for total tritium, dissolved organic tritium, and suspended organic tritium. The tritium associated with dissolved organic material is approximately 1 percent of the tritium concentration and the suspended organic tritium is approximately 0.001 percent of the tritium concentration.

It was not possible to weigh the amount of suspended organic material on the glass fiber filters, thus the tritium units (t.u.)*** could not be directly estimated****. The dissolved organic carbon has been measured, however, and assuming that there are two hydrogen atoms associated with each organic carbon atom,***** the t.u. for the dissolved organic material can be

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*Unless stated otherwise, "tritium" refers to tritium as ^{3}HHO.

**A comparable value (5.6 μCi/ml with <2σ% counting uncertainty) was reported in a sample from sump 10N by Columbo and others (4 , p. 29).

***Tritium unit (t.u.) = $\frac{\text{\# tritium atoms}}{10^{18} \text{ hydrogen atoms}}$

****For this reason activity values for suspended material, shown in Table 5 are given only in μCi/ml and not in relation to weight (μCi/g).

*****This is an approximation only, but probably a reasonably accurate one.

TABLE 6. List of Radionuclides Dissolved in Trench Water in Order of Abundance in Trenches 1 through 5, 8 through 12, and 14.

NORTH TRENCHES

Order of Abundance	1	2	3	4	5
1	^{3}HHO	^{3}HHO	^{3}HHO	^{3}HHO	^{3}HHO
2	$^{90}Sr/^{63}Ni$ (1)	^{90}Sr	^{90}Sr	^{90}Sr	^{90}Sr
3	$^{90}Sr/^{63}Ni$	$^{63}Ni/^{137}Cs$	^{137}Cs	^{137}Cs	^{63}Ni
4	-- (2)	$^{63}Ni/^{137}Cs$	^{63}Ni	^{63}Ni	^{137}Cs
5	--	--	^{55}Fe	^{55}Fe	^{55}Fe
6	--	--	^{60}Co	--	^{134}Cs
7	--	--	--	--	--
8	--	--	--	--	--

SOUTH TRENCHES

	8 (3)	9	10 (3)	11 (3)	12 (4)	14 (3)
1	^{3}HHO	^{3}HHO	^{3}HHO	^{3}HHO	^{3}HHO	^{3}HHO
2	^{63}Ni	^{14}C (total)	^{90}Sr	^{14}C (total)	^{137}Cs	^{90}Sr
3	^{14}C (total)	^{90}Sr	^{14}C (total)	^{137}Cs	^{14}C (total)	^{14}C (total)
4	^{137}Cs	$^{137}Cs/^{63}Ni$	^{238}Pu	^{90}Sr	^{90}Sr	^{137}Cs
5	^{238}Pu	$^{137}Cs/^{63}Ni$	^{63}Ni	^{63}Ni	^{63}Ni	^{63}Ni
6	^{90}Sr	--	^{137}Cs	^{134}Cs	^{60}Co	^{134}Cs
7	^{134}Cs	--	^{22}Na	^{55}Fe	^{232}Th	^{55}Fe
8	--	--	--	^{22}Na	--	^{60}Co

(1) If two radionuclides are equally ranked they are listed side by side.
(2) A dash indicates that values are close to or below detection limits; not enough information is available for ranking purposes.
(3) Order of abundance based on analysis of only one sample.
(4) Order of abundance based on analysis of one unfiltered total sample.

estimated. Trenches 10 and 11 contain 1,765 mg carbon/liter and 1,228 mg carbon/liter respectively. Calculation shows that the t.u. in the dissolved organic material is greater by approximately a factor of 3 than the t.u. in the water for both trenches. The t.u. in the methane in trenches 10 and 11 were found to be greater by factors of 25 and 16 than in the trench water for the respective trenches (26). Some of the dissolved organic material is lost in the lyophilization process which may account for the difference in tritium concentration (t.u.) in the methane and the dissolved organic material.

The higher tritium concentration in the dissolved organic material and the methane relative to the t.u. for the trench water indicates that the organic tritium is not in equilibrium with the trench water. In comparing the methane and trench water it was observed that in the older north trenches (1 through 5) the t.u. were in good agreement. However, in the newer south trenches (8 through 14) the t.u. for the methane was one to three orders of magnitude higher than the t.u. for the trench water (26). It appears that in these newer trenches there has not been sufficient time for the organic material to have exchanged tritium with the trench water to reach equilibrium. This may be the result either of high initial concentrations of tritium in the trench water, the result of rapid breaching of burial containers, or of an on-going process of breaching of containers and the slow release of relatively high concentrations of tritium into the trench water.

Strontium-90

Strontium-90 ranks as the second most abundant radionuclide in all north trenches and one of the south trenches (trench 10). In the other trenches studied ^{90}Sr ranks among the top four radionuclides. Values of ^{90}Sr found in trenches 10 and 11 were average for the other trenches studied, leaving strontium-90 values in trench 4 still the highest of any trench studied. This is consistent with the burial of 15,763 Ci of strontium-90 in trench 4 (22). The actual quantities of strontium-90 buried in other trenches are not accurately known.

Plutonium

The present study indicates that a sample collected from the trench 10 sump has the highest value of plutonium-238 yet measured in the trench water, surpassing by a small percentage the activity value measured in trench 8. This high concentration in water collected from trench 10 is in basic agreement with the high number of curies buried there (15,000 Ci according to Kelleher and Michael (22)). The dissolved plutonium-239, -240 activity for trench 10 is among the highest observed in

the trenches to date, along with water samples collected from well 8-1B and the sump in trench 5. Plutonium is not among the more abundant radioactive elements in the trenches studied, though in trenches 8 and 10 plutonium-238 values rank fifth and fourth in abundance, respectively.

Both plutonium-238 and plutonium-239,-240 are known to be easily adsorbed onto suspended particles (32), and evidence for this was observed at West Valley. Of the eight samples that were analyzed for both suspended and dissolved fractions over the course of this study (1-sump, 2-1A, 4-sump, 5-3A, 8-1B, 9-new sump (2 samples), and 14-1A), one (14-1A) shows higher values for suspended than for dissolved plutonium-238 and four (1-sump, 8-1B, 9-new sump, and 14-1A) show higher values for suspended plutonium-239, -240 than for dissolved plutonium-239,-240. Adsorption ultimately leads to depletion of plutonium dissolved in the water by adsorption onto objects and walls in the trenches and by the settling out of suspended material.

Possible evidence for this method of depletion was found over a period of eleven days, during pumping of trench 5. During this time, when turbulence could cause the stirring up of particulates, the concentration of plutonium-238 in water being pumped from the sump tripled, and the concentration of plutonium-239, -240 increased more than four times. Unfortunately, no data are available as to how much of this increase was related to increased suspended material, since the sample was analyzed as a whole water sample. This leaves open the possibility of several alternative explanations for the variations in plutonium described above. First, a concentration gradient may exist that was destroyed by the turbulence of pumping; second, waste containers over time may have been breached, causing the release of more plutonium and an increase in trench water values; and third, the earlier sample may have suffered rapid oxidative precipitation prior to containment in the sampling bottle, since the sample collection procedure was not anoxic. As for the first explanation, no evidence has yet been found for concentration gradients in the trenches; samples at different levels have revealed no significant difference. The second explanation, breaching of containers, is a definite possibility, though no direct evidence to support this has been found. The third explanation, rapid oxidative precipitation, is supported by two lines of evidence: 1) in addition to plutonium, eleven other radionuclides of the eighteen analyzed showed an increase in activity from the earlier to the later sample; and 2) of those eleven showing an increase, uranium-238, known for its capacity to be readily adsorbed, showed one of the greatest increases. But because of the turbulence created by pumping, it is very probable that a significant portion of the increase in

activity was the result of increased suspended material.

Because of the turbulence created by the water sampling technique and because of adsorption and other complicating factors,measured concentrations of plutonium in trench water probably do not reflect the amount of plutonium released into the water in any given trench. Though comparisons of relative concentrations between trenches may be valid, the data should not be used as a measure of the amount of plutonium in each trench.

Cesium

Cesium-134 values observed in water samples from 9 of the 10 trenches, when plotted against the time interval between burial of waste and trench water analysis, fall on a line of steadily decreasing activity as the time for decay increases (Figure 12). Because of the relatively short half-life of cesium-134 (2.062 years for the ground isomeric state*), this relationship between activity and age is expected. The conclusions that can be drawn from this relationship, however, are severely limited by the large numbers of unknown factors that must be considered. The fact that the data point for trench 14 lies well off the curve may be the result of a number of factors: 1) since trench 14 is the newest trench, this may reflect the integrity of the burial containers and the small amount of leaking of cesium-134 into the trench 14 water; 2) there may have been fewer curies of cesium-134 buried in 14 than in other trenches; 3) there may have been more dilution of trench water by rain water** in trench 14 than in the other trenches studied; and 4) exchange and precipitation of cesium-134 may have been more extensive in trench 14 than in the other trenches studied. Any or all of these factors may have played a role in producing low cesium-134 activity in trench 14.

^{137}Cs, with its longer half-life (30.17 years), does not show a consistent trend with time. Concentrations observed in samples from sumps in trenches 10 and 11 are similar to values found in other trenches.

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*All radionuclide half-life values are taken from Chart of the Nuclides, Twelfth Edition, Revised to April 1977 (45).

**For more information on infiltration of rain water see "Studies of Trench Gas at a Low-Level Radioactive Waste Burial Site, West Valley, New York," (20).

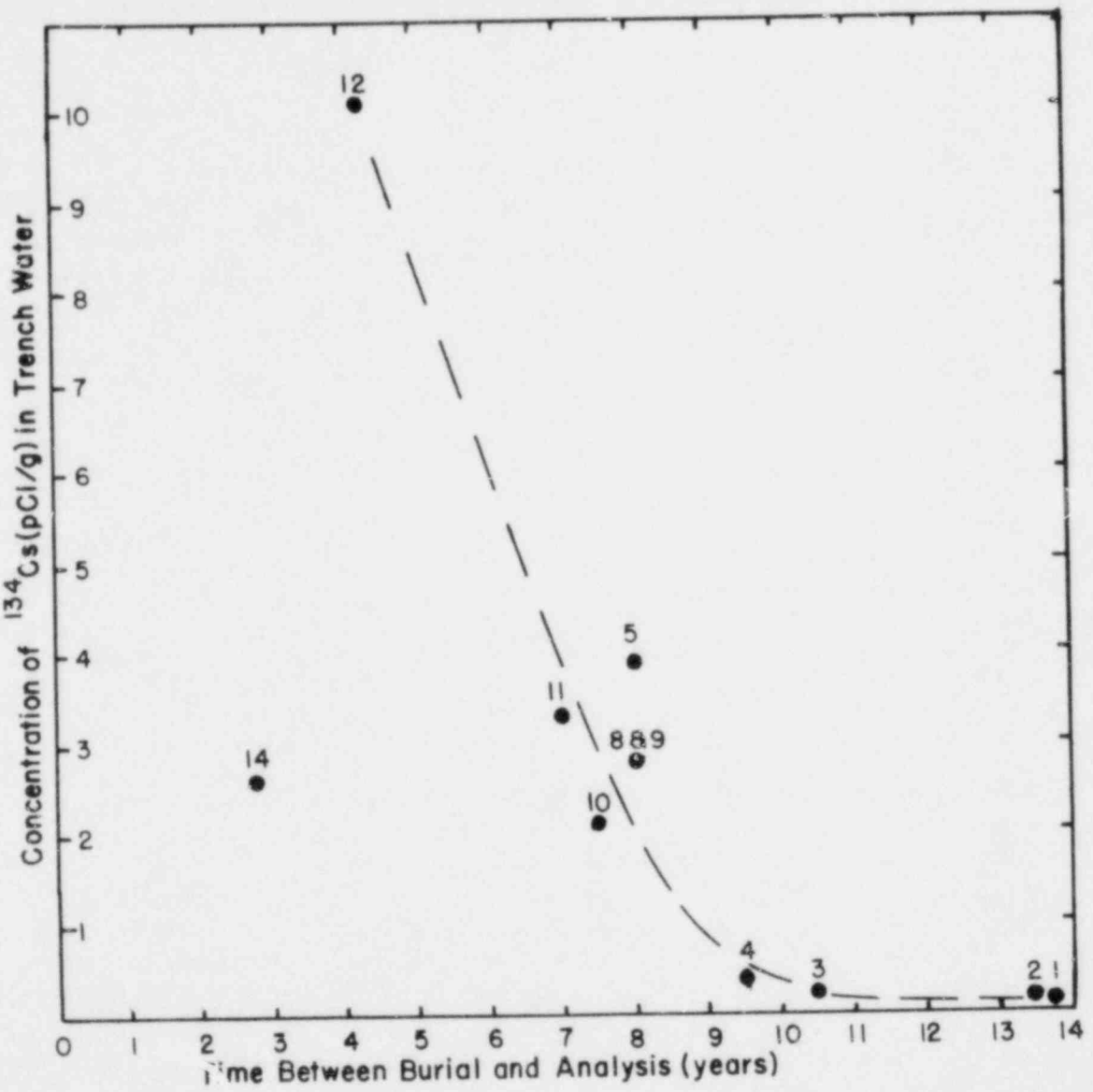

Figure 12. Concentration of cesium-134 in the West Valley trenches versus the time interval between burial of waste and analysis of trench water. Numbers above data points are trench numbers.

In general, radio-cesium shows higher concentrations in water samples than most radionuclides in the trenches. Cesium-134 is the sixth most abundant radionuclide in trenches 5, 11, and 14, seventh in trench 8 and eighth in trench 10. Cesium-137 is the third or fourth most abundant radionuclide in the north trenches (no data for trench 1), and between the second (trench 12) and sixth (trench 10) most abundant radionuclide in the south trenches (no data for trench 13).

Iron

Iron-55 activities observed in trenches 10 and 11 are approximately average for the trenches as a whole. Because of the 2.7 year half-life, average activity in these two later (south) burial trenches indicates either that smaller amounts were initially buried in these trenches than in earlier trenches, or that the release of iron-55 from containers has been most rapid in trenches 10 and 11. A review of the burial records does not support the first explanation, therefore, the second appears most likely.

Cobalt

Cobalt-60 values observed in trenches 10 and 11 are approximately average for the trenches as a whole. In fact, cobalt-60 values range over only approximately two orders of magnitude in the 11 trenches studied. This is unexpected because of the very large range in quantities of cobalt-60 buried in the various trenches (from 34 Ci in trench 1 to 46,469 Ci in trench 5 according to Kelleher and Michael (22)). We would expect a correspondingly large range of activities,but not only is this large range not reflected in the concentrations observed, but the concentrations in general are lower than expected. One possible explanation is that cobalt-60 was buried in containers that, for the most part, are still intact, such as stainless steel or concrete casks. A second possible explanation is that manganese oxides present in the waste or surrounding soil have adsorbed much of the cobalt-60 in some trenches. Manganese oxides are known to play an important role in the adsorption of radionuclides, especially cobalt-60 (28).

Nickel-63

Nickel-63 activity values in trenches 10 and 11 are approximately average for the trenches as a whole. This is approximately two orders of magnitude less than the highest value yet observed, in trench 8 (well 8-1B). Nickel-63 ranks consistently between 2 and 5 among radionuclides in all the trenches studied.

Carbon-14

Carbon-14 (total) activity observed in samples from trench 10 is slightly above average for the trenches as a whole. Carbon-14 activity in trench 11, however, is the highest yet observed in the trenches, by a factor of 4. Carbon-14 (total) ranks second or third among radionuclides in all south trenches studied. In the north trenches, in general carbon-14 values are much smaller than in the south trenches though isolated higher values have been found. This relationship is in good agreement with the quantities of carbon-14 known to be buried in the trenches, though burial records are somewhat ambiguous (22). The ambiguity results form a burial record category consisting of a mixture of ^{3}H and carbon-14 in an unknown ratio.

In the south trenches, where values for both organic and inorganic carbon-14 have been obtained (trenches 8, 9, 10, 11, 12, and 14), organic carbon shows consistently higher activity than inorganic carbon. The relationship between organic and inorganic carbon activity values is certainly much dependent on the action of microorganisms that are known to be active in these trenches (3). The action of microorganisms may act to break down existing organo-radionuclide materials, or it may form new ones by the reaction of microbial metabolites with radionuclides. In either case, such action may have significant effect on the long-term storage, solubility, mobility, and migration of radionuclides from the site (28).

Iodine

Iodine-129 is observed in very low concentrations in the trenches studied to date (1,2, 3, 4, 5, 9, 10, and 11). In fact, the concentration of 1.25 E-07 ±14% μCi/ml observed in trench 11 is the highest value yet observed. However, the concentration of stable iodine in samples from trench 10 is extremely high, 17.2 mg/l, or more than an order of magnitude higher than the concentration in trench 11. Because stable iodine is a very difficult element to accurately assay, especially in samples from anoxic environments, two types of analysis were employed: a spectrophotometric method and a specific ion electrode method. The spectrophotometric method was repeated once. These methods are briefly described in Appendix C.

There are several potential sources of the stable iodine in trench 10. The most probable source is from activated charcoal filtering systems, which are quite wide-spread in use in the nuclear industry. Charcoal impregnated with potassium iodide (KI) is used for extraction of radio-iodine from spent

fuel rods (18). Similar methods are used for laboratory extractions in hospitals, chemical companies and various research institutions. An attempt was made to identify specific sources of stable iodine in trench 10 by reviewing the burial inventory records. Because trench 10 is divided into two sections by a barrier of unknown height or size,* from the standpoint of liquid waste, it is actually two separate trenches. For this reason only the burial records for the north end of the trench were reviewed. They reveal several potential sources of stable iodine. A pharmaceutical company, a manufacturer of various nuclear reactor-related equipment, and a large university were all major sources of iodine-131/-135 in trench 10. Their burial shipments may also have contained the large quantities of stable iodine necessary to result in a concentration of 17.2 mg/l.

Uranium

Uranium is observed in the trenches in very low concentrations. Activity values for uranium-234, uranium-235, and uranium-238 in trenches 10 and 11 are consistent with the low values for the trenches in general. As with plutonium, however, these low values may be caused by adsorption of uranium by suspended material. For further discussion see the section on plutonium above.

Americium-241

The americium-241 values in all of the trenches studied (1, 2, 4, 5, 9, 10, 11, 14) are near or below detection limits. To date, attempts to lower detection limits for dissolved water from trench 10 have been unsuccessful. The high concentration of plutonium-238 in the trench 10 sample appears to be constructively interfering with the americium-241 analysis (23). Further work is being done by the RSL to circumvent this problem.

Thorium-232

Thorium-232 activity values in all the trenches studied (1, 2, 4, 8, 9, 10, 11, 12, and 14) are below detection limits with the exception of one of two values in trench 9, new sump (4.5 E-07 ±40% μCi/ml). Values in trenches 10 and 11 illustrate these low values (Table 5).

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*Persistent differences in water levels between the north sump and the south sump confirm this.

Sodium-22

Both trenches 10 and 11 show the highest sodium-22 activity yet measured in the south trenches. Because of the short half-life of sodium-22 (2.601 years) and because the youngest north trench was completed early in 1968, no north trenches have been analyzed for sodium-22.

Manganese-54

All trenches analyzed for manganese-54 (1, 2, 3, 4, 5, and 10) show results below detection limits with one exception. The exception is one value for suspended material in the trench 5 sump, collected during pumpout in 1975 (12 E-08 ± 42% μ Ci/ml). These results are consistent with the relatively short half-life of manganese-54 (313 days).

Ruthenium-106

All trenches analyzed for dissolved ruthenium-106 (1, 2, 3, 4, 5, and 10) show values below detection limits, with the exception of one well in trench 5 (5-3A) that shows a value of 6 E-06 ± 87% μ Ci/ml. These results are consistent with the relatively short half-life of ruthenium-106 (368 days).

Potassium-40

All trenches analyzed for potassium-40 (2, 5, 8, 9, 10, 11, 12 and 14) show values below detection limits.

Total Beta/Total Alpha

The methods used for Total β and α analyses are adequate only for screening purposes. Samples are screened so that expensive specific analyses are performed only on samples that may produce results above detection limits. The effect of uneven distribution of the sample on a planchet may lead to inaccuracies in the results, and loss of volatile radionuclides such as radioiodine, tritium, carbon-14, and the difficulty in radiometric standardization for a mixture of unknown emitters causes problems with interpretation of results. One such problem is found in trench 10. Concentrations of plutonium-238, an alpha emitter, appear to be twice the total alpha concentration. A similar phenomenon was observed in trench 8 in our studies and in studies by Columbo and Weiss (1). One possible explanation offered by Columbo and Weiss is that the chemical composition of the water prevents the preparation by evaporation of a uniform, reproducible counting specimen. For example, in the presence of >500 mg/l barium, plutonium is preferentially scavenged with the first precipitate that forms upon drying a sample in a planchet and

This could result in a non-uniform plutonium-238 distribution resulting in significant self-adsorption of some beta emissions and especially the alpha emissions in the counting sample. Concentrations of barium in the north trenches reach 300 mg/l (12) so that values of 500 mg/l would not be unreasonable. Difficulties in interpretation of results from earlier studies are also evident with total β values in relation to strontium-90 and carbon-14 (total). And in the present study carbon-14 in trench 11 appears to be 2.5 times the total β activity. Such a high value is not unexpected and is considered a limitation of the method of analysis (Appendix C). Therefore, when available only the specific analyses should be used, and the total α and β values should be viewed as approximations only.

7.6 Future Studies

A problem encountered in the analysis of trench water involved plutonium-238. High concentrations of plutonium-238 in trench water appear to constructively interfere with the analysis of americium-241 (23). This problem has been encountered in trench 10 and may be affecting values of americium-241 in other trenches as well. The effects of plutonium-238 on americium-241 analyses should be investigated thoroughly before any conclusions are based on the americium-241 data obtained to date.

Because of the very high value of stable iodine observed in trench 11, further analyses should be done to determine the values in other trenches. Such high values may have a strong effect on the adsorption of radioiodine by trench walls and waste containers.

8.0 GEOTECHNICAL ANALYSIS OF RESEARCH TRENCH III TRENCH CAP SOILS

8.1 Introduction

Geotechnical evaluation of the soils at the low-level radioactive waste burial (LLRWB) site was undertaken by Vernon Hoffman, P.E., as part of a comprehensive, continuing geologic and hydrologic study of the West Valley site that is being conducted by the New York State Geological Survey (NYSGS).

Samples of the trench cap material at the LLRWB site and the soils at Research Trench III were collected and analyzed in August, 1979. Previous sub-surface investigations (5,6,7) for the Western New York Nuclear Service Center discuss the design of the facility and the physical characteristics of the soil. Results of soil tests performed in 1977 (17) are compared to the most-recently obtained test results.

The recently studied research trench was the last of three research trenches excavated in the vicinity of the LLRWB trenches (See Site Plan, Figure 1). Descriptions of Research Trenches I and II may be found in a previous report to the USEPA (9).

8.2 Purpose of Study

The data presented here represent a geotechnical analysis of soil conditions encountered in a research trench excavated in undisturbed till, approximately 152 m (500 ft.) east of the LLRWB trenches. The trench had filled with surface water since completion of the earlier soil investigation there in 1977 (17). The current investigation was an attempt to recreate as nearly as possible the moisture conditions of flooded burial trenches, specifically trenches 4 and 5 that filled to overflowing in March, 1975(11). The research trench was left open after the 1977 studies and was allowed to fill with rain water.

The current investigation involved dewatering the research trench to gain access for sampling and making measurements. This study was conducted to determine what changes had occurred in the soil conditions at Research Trench III since the excavation and since the initial soil investigations were conducted. The basic soil engineering properties were determined in the previous investigations; the present study focused on any changes in the soils, and changes in the shape of the trench that might have occurred during the interval of flooding.

Trench cap soils, that consisted of disturbed, compacted till, both weathered and unweathered, were collected in August, 1979, and in November, 1979. These samples were tested for geotechnical properties as well as the presence of radionuclides. The significance of the radionuclide data is reported in section 9.0 of this report.

8.3 Method of Study

The research trench studied was excavated in July, 1977, in a manner similar to that of the trenches at the actual waste burial grounds. Research Trench III was originally approximately 39m (130 ft.) long, 7.9m (26 ft.) deep, and 6.1m (20 ft.) wide at the bottom (Figure 13). A backhoe pit was extended into a portion of the bottom for a total depth below land surface of about 12.5m (41 ft.). The trench was allowed to collect surface water. It filled to land surface until August 6, 1979. At that time, under the direction of personnel of the NYSGS, Benz Construction Co., Inc., of West Valley, N.Y., began pumping water from the trench. The pumping was completed on August 10, 1979. The final drawdown level was approximately 6.3m (20.6 ft.) below land surface.

On August 14, 1979, personnel of the NYSGS and Vernon C. Hoffman, P.E., entered the dewatered trench to take soil samples from the sides and bottom, to make measurements of the shape of the trench, and to observe the conditions of the trench. Seven soil samples were recovered from the trench using a hand-driven, two-inch diameter, thin-wall, tube sampler. Descriptions of the sampling locations and the orientation of the samples (horizontal or vertical) are given in Appendix D of this report.

On the same day five similar tube samples were taken from the trench cap materials in the LLRWB area. Five additional tube samples were collected in November, 1979 by personnel of the NYSGS. The locations of the trench cap sampling points are indicated in Figure 14.

The thin-wall tubes were sealed with rubber caps in the field to prevent moisture loss and shipped to the laboratory of Soil and Material Testing, Inc. The following tests were conducted on the samples:

Unit Weight
Unconfined Compressive Strength
Calibrated Penetrometer (to estimate the Unconfined Strength)
Atterberg Limits
Shrinkage Limits
Grain-size Distribution
Moisture Content

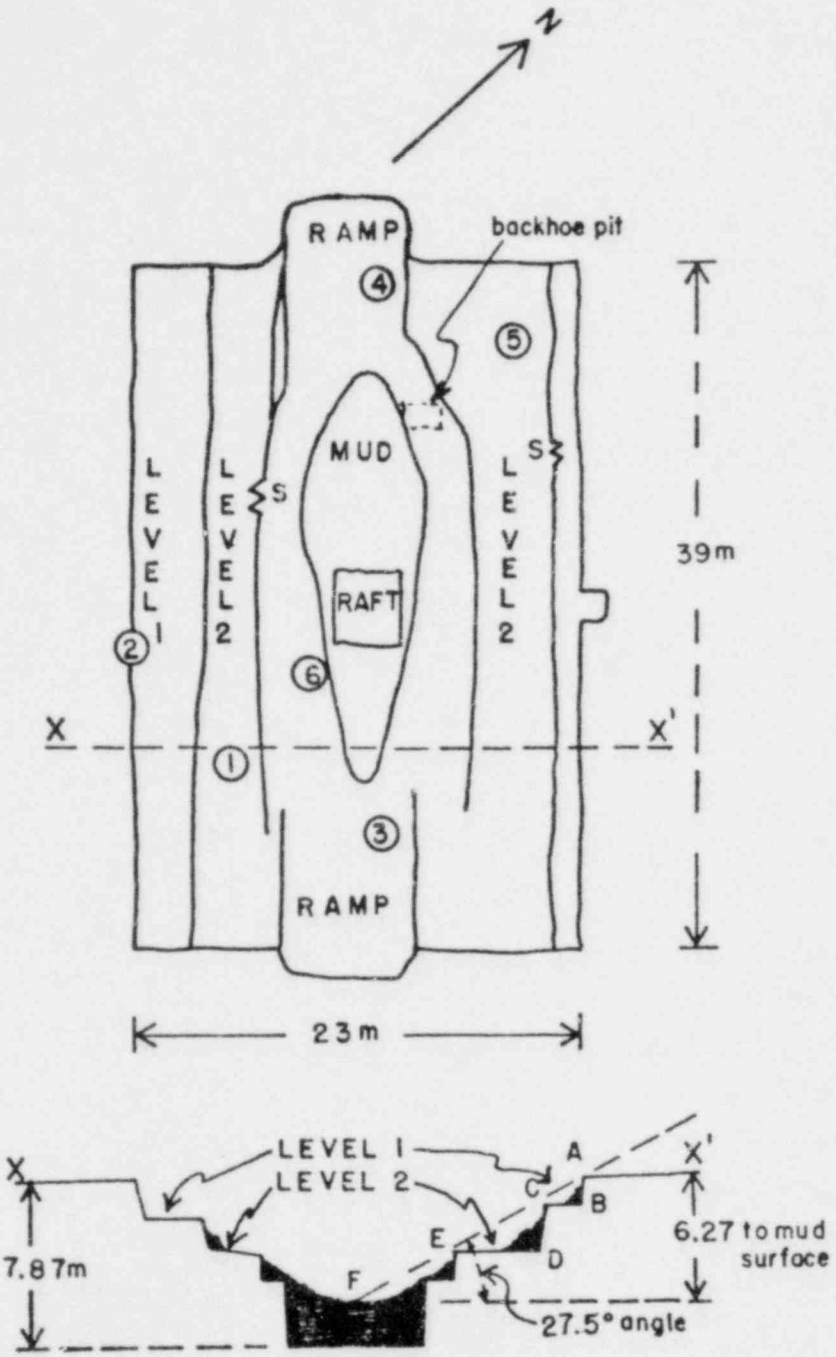

Figure 13. Sketch map and cross section approximately to scale of Research Trench III after pumping in August 1979. Area of mud is where soil above its liquid limit has ponded. Mud surface is depth to which pumping was done. Dark areas in cross section are areas of disturbed soil. "S" designates areas of slumping prior to filling with rain water. Circled numbers are sampling locations.

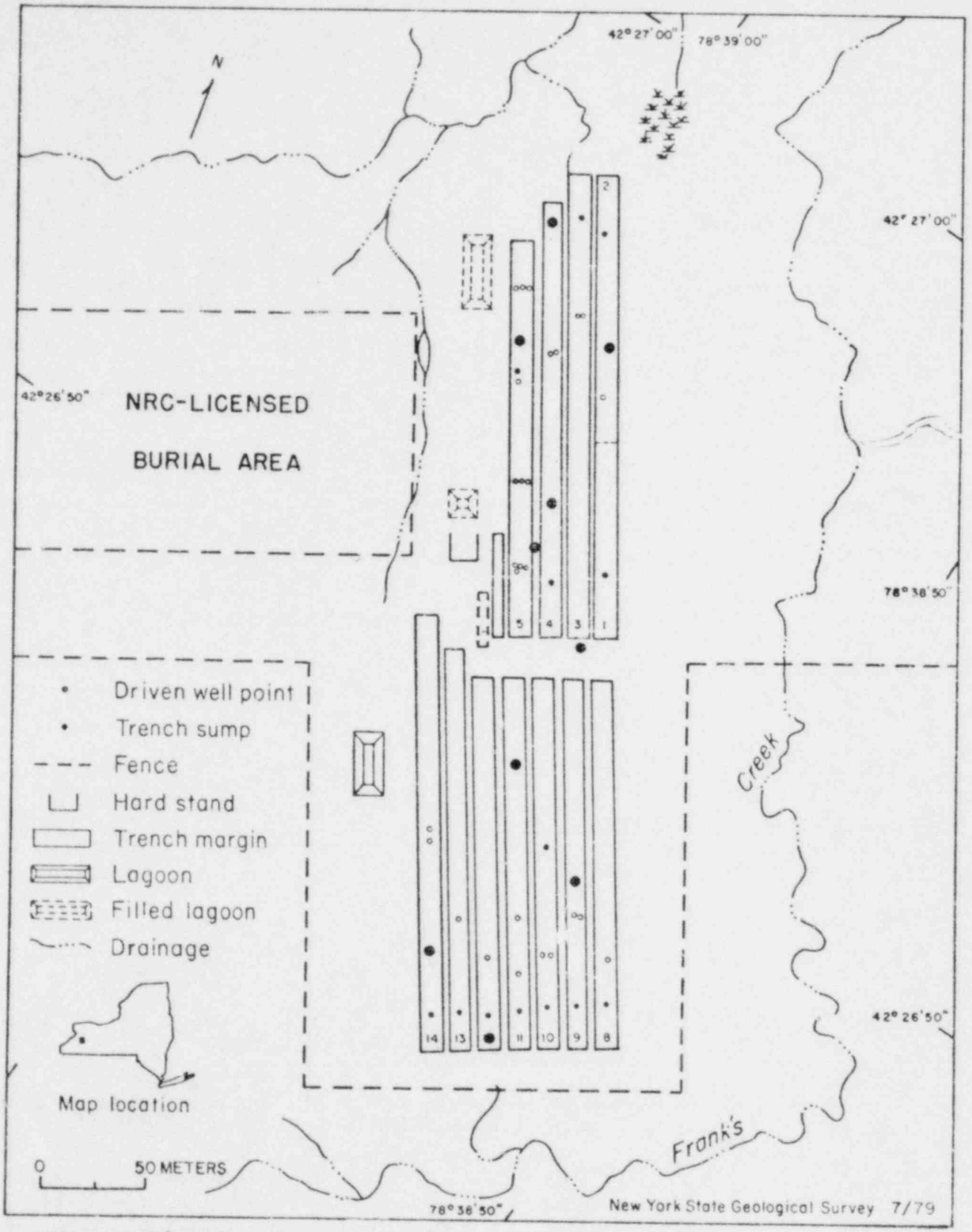

Figure 14. Location map of trench cap samples collected in 1979. Large dots indicate sampling locations.

A summary of the results of tests made on each sample is shown in Table 7, "Summary of Laboratory Test Results".*

8.4 Discussion

8.4.1 Soil Description

Soil sample identification has been determined by means of visual classification by the soil engineer, and by soil index or classification tests that include Atterberg limits and grain-size distribution.

All of the soil samples removed from the trench have similar descriptions, based upon texture and plasticity. The soils are classified as CL and ML, or borderline cases of these categories, under the Unified Soil Classification System (described in Appendix E). Within the Burmeister System, they would generally be classified as silt and clay or clay and silt with trace sand and a trace of gravel. The compacted trench cap soils are similar except that they have higher percentages of sand and gravel. Commonly, the trench cap samples have "a little or trace sand and gravel".

The clay soils are generally very stiff in weathered zones and are fractured to depths of up to 4.6m (15 ft.). The presence of fractures, that sometimes are filled with silt or fine sand particles, may result in the shear strength of the soil being substantially less than that of unfractured portions of the soil.

8.4.2 Research Trench Test Results

The test results from the current investigation in undisturbed till have been compared to the test results obtained during the 1977 investigation. A summary of the average values at various depths, and overall averages for both sets of results have been tabulated in Table 8. The depth ranges indicated correspond to the weathered and desiccated soils (shallow), the partially weathered soils (medium), and the relatively unweathered soils at greater depths (deep).

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*Individual test data sheets, stress-strain plots, and graphs of grain-size distribution will be included in a future, more detailed report of this work (NUREG/CR-1566).

TABLE 7. Summary of Laboratory Test Results on Samples Collected at the Western New York Nuclear Service Center. Trench cap soils are from the Low-Level Waste Burial Trenches.

Sample Number	Approx. Depth (ft.) of top of core *	Sampling Interval Below Core Top (Inches)	Moisture Content (%)	Liquid Limit (%)	Plastic Limit (%)	Shrinkage Limit (%)	Unit Weight (pcf)	Unconfined Strength (tsf)	Calibrated Penetrometer (tsf)
Soils From Research Trench III (August, 1979):									
1	11	13-17	17.4	30	24	16.1	115.2	2.7	3.8
2	4H**	0-4	15.5	30	30	16.3	117.5	5.2	4.5-5.0
3A	16	0-4	20.6	30	20	18.9	106.0	2.1	2.0
3B	16	16-20	20.7	32	21	18.6	107.0	2.0	
4	14	0-4	18.5	32	22	12.2	112.7	2.3	3.5-1.8
5	12	0-4	17.6	29	21	19.4	115.1	3.4	2.5
6A	18H	½-4½	22.1	41	28	19.9	105.6	1.9	2.0
6B	18H	11½-15½	23.4	34	4	16.9	104.4	1.7	1.8
Trench Cap Soils (August, 1979):									
7	0	14-18	12.7	30	21	16.3			
8	0	9-13	12.5	32	23	18.9			
9	0	6-9	12.5	29	19	17.0			
10	0	11-15	10.8	31	23	16.4			
11	0	18-21	14.1	32	23	17.4			
Trench Cap Soils (November, 1979):									
12A	0	6-10	22.8	29	23	17.6	107.7	0.8	1.0
12B	0	12-16	30.3	31	20	15.4	118.3	4.4	2.5-4.5
13A	0	3-7½	30.3	30	26	20.8	80.6	0.4	0.5-0.8
13B	0	13½-17½	29.8	30	23	23.1	108.9	5.3	1.5-3.2
14A	0	4-8	28.9	29	19	17.9	106.6	0.6	0.4-1.0
14B	0	11-15	29.4	30	18	17.4	107.0	1.5	1.8-3.8
15A	0	3-7½	30.0	30	25	20.1	107.2	0.7	1.0-1.8
15B	0	11-15	16.9			16.8	116.6	2.3	2.2-3.8
16A	0	3-7	36.7	37	28	22.9	86.1	0.3	0.8
16B	0	8½-12½	30.3	31	20	17.6	110.0	1.4	1.5-2.8

* Depth below original ground. All samples taken 0 - 2 ft. from existing grade.

** Samples are vertical unless indicated as horizontal (H).

TABLE 8. Comparison of Test Results,* 1977 and 1979 Investigations.

	Depth Range	Depth (ft.)	Moisture Content (%)	Liquid Limit (%)	Plastic Limit (%)	Shrinkage Limit (%)	Unit Wt. (pcf)	Unconfined Strength (tsf)
1979	Shallow	4	15.5**	30**	21**	16**	117.5**	5.2**
	Medium	11,12 14,16	19.0	31	22	17	111.2	2.5
	Deep	18	22.8	38	16	18	105.0	1.8
	Average	--	19.5	32	20	17	110.4	2.6
1977	Shallow	4,8	15.2	30**	19**	13**	115.7	--
	Medium	12,16	17.4	30	18	13	112.8	5.4
	Deep	20	20.0	31**	19**	11**	109.5	--
	Greater than 20'		20.1	32	20	11	110.6	2.8
	Average	--	18.5	31	19	12	111.9	3.9

*Results given are average values at each depth range.
**One Sample.

The test results obtained during the two investigations are very close to each other, particularly considering the relatively small number of measurements or test results that were involved in the averages.

The results suggest some increase in moisture content and a decrease in strength and unit weight during the two-year interval. This indicates a slight swelling of the soil. Given the reduction in confining pressure, and water available to maintain a saturated condition, this is expected. Based on the relatively small changes in moisture content, unit weight, and strength, it appears that the amount of swell was small. This was also indicated by the swell testing in the 1977 investigation.

The Atterberg limit results indicate that the changes in plasticity, if any, are not significant within the precision of the sampling and testing methods. The shrinkage limits indicate a significant change in test results. This change appears to be systematic and occurring at all depths. Although it is possible that the soils have undergone some changes, it is more likely that there was a difference in testing procedure. The shrinkage limit test is sensitive to operator differences. There is also some flexibility in the initial moisture content for testing allowed under the ASTM specification, which could have some effects on the results.

It is important to realize that the soils sampled during the recent investigation were removed from within 0.6 m (2 ft.) of the existing sides and bottom of the research trench. In this surface zone the confining pressure has been reduced to low values and there has been an ample supply of water to keep the surface soils saturated. However, soils further from the faces of the slopes (which were not sampled in the current investigation) would probably tend to exhibit moisture contents, unit weights, and strengths closer to those measured in 1977. The confining pressures deeper in the slope have not decreased as much as at the surface, and the swell that has occurred is probably small compared to the swell experienced by the surface soils.

3.4.3 Trench Cap Soil Test Results

No detailed description or analysis of the trench cap soils is included here beyond the soil descriptions given in Table 7. In general, the significant properties are the low permeabilities and the volume changes sufficient to allow the soils to crack upon drying.

The average liquidity index of trench cap soils that were col-

lected during August was -1.05*; the average liquidity index of trench cap samples collected in November was 0.87. This difference reflects a large increase in the average water content from 12.5 to 31.7 percent. No change in average liquid limit and only minor increase in average plastic limit were observed. In one sample (13 A in Table 7) the actual water content exceeded the liquid limit by 0.3 percent, however, this may be accounted for by sampling and testing inaccuracies.

The maximum compressive strength of trench cap samples collected in November (following a period of precipitation) increased significantly with depth.

8.4.4 Soil Strengths

The condition of the sides and bottom of the trench after dewatering indicated that, although the overall side slopes remained stable, considerable surface sloughing of the soils occurred. Some of it may have occurred during or immediately after the dewatering. Runoff, wave action, and frost action caused some surface erosion near the top of the trench. The trench partially filled with eroded and sloughed soil, that was covered by a low-viscosity soil slurry for a total combined height of 1.5 m (5 ft.) above the original trench bottom. The backhoe trench below the trench bottom was entirely filled. The sides of the trench above this soft soil fill remained stable, for the most part, except for portions of the level-2 benches, whose slopes sloughed to the bottom. It appears that this probably happened at the time of dewatering. Portions of the level-2 benches that were greater than approximately 1.2 m (4 ft.) above the ramp failed. Elevations of the slopes described are shown in Figure 13.

Some estimates of the strength of the soils in the slopes can be made from observations of the conditions of the trench after dewatering. Slope stability charts (43) were used. This type of chart solution is adequate for the rough estimates of strength required for this study.

A minimum strength for the greater slope (A to F in Figure 13) can be estimated, since the slope remained stable under sudden drawdown conditions. This is done using standard tables by Taylor (43). The minimum developed cohesion is approximately 18.9 kN/m^2 (394 psf), assuming a slope angle of 27.5 degrees, a slope height of 6.0 m (20.6 ft.) and a total (moist) unit weight of 2115 kg/m^3 (132 pcf). For the greater slope

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*Liquidity Index, or water plasticity ratio, relates the water content of a soil to the liquid and plastic limits.

$$\text{Liquidity Index} = \frac{\text{Water Content} - \text{Plastic Limit}}{\text{Liquid Limit} - \text{Plastic Limit}}$$

(A to F) the cohesion at failure is most probably significantly greater than this minimum strength, but probably does not approach the values obtained by unconfined compression tests. This is because of the formation of tension cracks at the top of the slopes and some reduction in strength at the toe due to swelling.

The maximum strength of these soils can be estimated from failure data. Portions of the bench at level-2 (E to F), whose heights above the trench bottom exceeded 1.2 m (4 ft.) failed. It is believed that failures occurred both before and after drawdown. One value can be estimated for failure under submerged conditions, and a slightly higher value can be estimated for failure under sudden drawdown conditions, which cause higher stress levels in the soil. The developed cohesion at failure for sudden drawdown would be approximately 4.79 kN/m^2, assuming a slope angle of 60° and a unit wieght of 2115 kg/m^3 (132 pcf). The same slope data and a bouyant unit wieght of about 1122 kg/m^3 (70 pcf) for the submerged condition yield an approximate developed cohesion of 2.54 kN/m^2 (53 psf). These values correspond to soil strengths reduced by soil cracking, with swelling and reduction of confining pressure to very low values. Given enough time, more sloughing of the sides of the trench would occur. Each failure mass would reduce the confining pressure on the remaining soil and probably expose it to a greater water supply, promoting swelling and softening of the soil. The rate of such progressive failure would tend to decrease as the height and angle of the slope lessened.

The estimated developed cohesion values suggested above for the shallow failures indicate the substantial difference between the unconfined compressive strength test results and those calculated from stability conditions. The unconfined compressive strength tests and calibrated penetrometer tests tend to indicate the strengths of the uncracked (higher strength) portions of the clays. In the field, the strengths of the clays are limited by the presence of fractures and, at some places, softened soils.

8.4.5 Stability of Waste-filled Trench

The stability conditions for a burial trench, were it filled with waste material, would vary widely depending on the strength and compressibility of the waste material. If the waste material were of very low strength, the stability conditions would approach those of the water-filled trench or of an empty trench.

If the trench fill were of high strength and low compressibility, the sides of the trench would be stable and no sloughing of the sides would occur. The actual conditions in

the burial trenches probably fall between these extremes. A useful analysis of the likely service conditions would not be possible without knowing at least the approximate mechanical properties of the fill material. It can be seen that non-compacted wastes could consolidate enough to remove support from the side slopes of the trench, thus allowing shear failure to occur. It is safe to assume in the long term that all but the most resistant trench fill containers - for example, the few concrete casks that are buried - will eventually degrade, allowing sloughing to occur.

9.0 RADIOCHEMICAL ANALYSES OF TRENCH CAP SOILS

9.1 Introduction

The LLRWB area consists of 12 burial trenches, each roughly 180 m long, 11 m wide, and 6 m deep. The trenches were excavated in a thick, clay-silt till of low permeability (hydraulic gradient is approximately 10^{-8} cm/s) and relatively high ion-exchange capacity. As the trenches were filled, the waste was covered with a [illegible] to 5 m cap of compacted, weathered and unweathered till.

In 1978 trenches 1 through 5 were recapped in order to retard infiltration of precipitation into the trenches. The topsoil was removed, stockpiled, and approximately 1 to 3 m additional cover (excavated from a borrow pit in the vicinity of the Research Trenches) was replaced over the trenches.

9.2 Purpose of Study

Five trench cap samples were collected from the south trenches of the LLRWB site in August, 1979, and five samples were collected from the north trenches in November, 1979 (Figure 14). Trench cap samples were collected and analyzed for total alpha, total beta, and tritium in order to determine the presence and magnitude of surface concentrations of radionuclides, and to evaluate the geologic and meteorologic parameters that affect activity distribution. In addition, geotechnical aspects of the trench cap soils (discussed in Section 8.4 of this report) were evaluated in conjunction with geotechnical studies of in situ till samples collected from a nearby research trench.

9.3 Method of Study

Hand-driven 2-inch diameter, thin-wall Shelby tubes were used for sample collection. The sample tubes were driven to a depth of approximately 50 to 60 cm, extracted, and the tubes sealed at both ends with rubber caps. The sealed samples were shipped to Soil and Material Testing, Inc., to be analyzed for various geotechnical properties.* Portions of the soil cores were removed for analyses for tritium, total alpha, and total beta activity.

.4 Discussion

Total Alpha and Total Beta

Total alpha and total beta activity of the trench cap soils

*A detailed description of the tests performed is included in Section 8.0 of this report.

(Table 9) did not exceed the estimated natural background activity of the burial till. Beta activity did not vary systematically with depth or with sample collection location (i.e., north vs. south burial trenches).

Tritium

Concentrations of tritium in trench cap samples were found to be at approximate background levels at the surface and above background at depth (20 to 50 cm)* . Most samples exhibited at least one order of magnitude increase of tritium activity at depth relative to surface activity (Figure 15). This distribution of tritium may be partially attributed to surface contaminants (stack effluent deposition, burial operation spills) transported downward through the trench caps by percolating precipitation. Earlier studies found a similar increase in values of tritium from the surface down in holes not directly on the trench cap (38).

There may, however, be additional sources of tritium. The north trenches were recapped in 1978 in order to retard infiltration of precipitation into the trenches. Prior to actual recapping, approximately 20 cm of topsoil was removed from the north trench caps, stockpiled, and later compacted over the new trench caps. While any tritium from prior contamination remaining in the topsoil could percolate into the new trench cap, it is also reasonable to expect that tritium at such shallow depths in the soil would be rapidly diluted by precipitation and dissipated by transpiration. Its continued presence near the surface may indicate upward migration of tritium (probably as ^{3}HH and $^{3}HCH_{3}$)** by diffusion through trench cap fractures, and interstices. It has been shown that many soils, when "undersaturated," develop a network of large soil pores or channels which form a "subterranean arterial system for rapidly distributing free surface water to locations within the soil mass," and, presumably, fluids and gases migrating laterally and vertically through the trench caps. These large pores are produced by clay shrinkage, ice lenses, animal activity, and other causes (15). Subsequent exchange of tritium with stable hydrogen and, to a lesser extent, hydroxyls, in the trench cap clays and organic matter (26) could serve to "trap" tritium within the trench cap.

Formation of fractures also may account for some of the activity in samples collected from the south trenches. This explanation is especially plausible for trench 12, where tritium concentrations are an order of magnitude higher than

*On-site values of tritium measured in 1979 by NFS vary from 600-1200 pCi/liter.

**For more detailed information on studies of trench gas see Matuszek, and others (26).

TABLE 9. Radiochemical Analysis of Trench Cap Soils

Trench *	Approximate Depth Below Land Surface (cm)	Tritium (pCi/l)	Total α ** (pCi/g)	Total β *** (pCi/g)
		NORTH TRENCHES		
5 m S of 3	0-6.4	3,000±7%	14±87%	25±36%
5 m S of 3	38.1-45.7	6,600±5%	< 7	24±36%
4 - 5 septum	0-7.6	750±19%	---	34±23%
4 - 5 septum	40.0-41.9	13,800±4%	---	29±25%
5	0-7.6	4,700±6%	---	31±26%
5	45.1-48.3	98,000±3%	---	30±28%
4N	0-7.6	620±24%	---	20±35%
4N	37.5-43.5	32,300±3%	---	29±28%
4S	0-7.6	3,800±6%	---	16±44%
4S	38.1-41.9	170,000±3%	---	16±47%
2 - 3 septum	0-7.6	1,410±12%	---	24±33%
2 - 3 septum	30.8-35.9	46,600±3%	---	29±29%
		SOUTH TRENCHES		
14	26.7-35.6	6,700±5%	14±87%	27±36%
12	33.0-40.6	149,000±3%	24±60%	22±37%
9	30.5-38.1	28,800±3%	22±63%	25±35%
11	20.3-27.9	46,000±3%	14±87%	30±37%

* Refer to Figure 12 for sample collection locations.
** Calculated natural alpha activity of burial till is ∿18 pCi/g.
*** Calculated natural beta activity of burial till is ∿32 pCi/g.

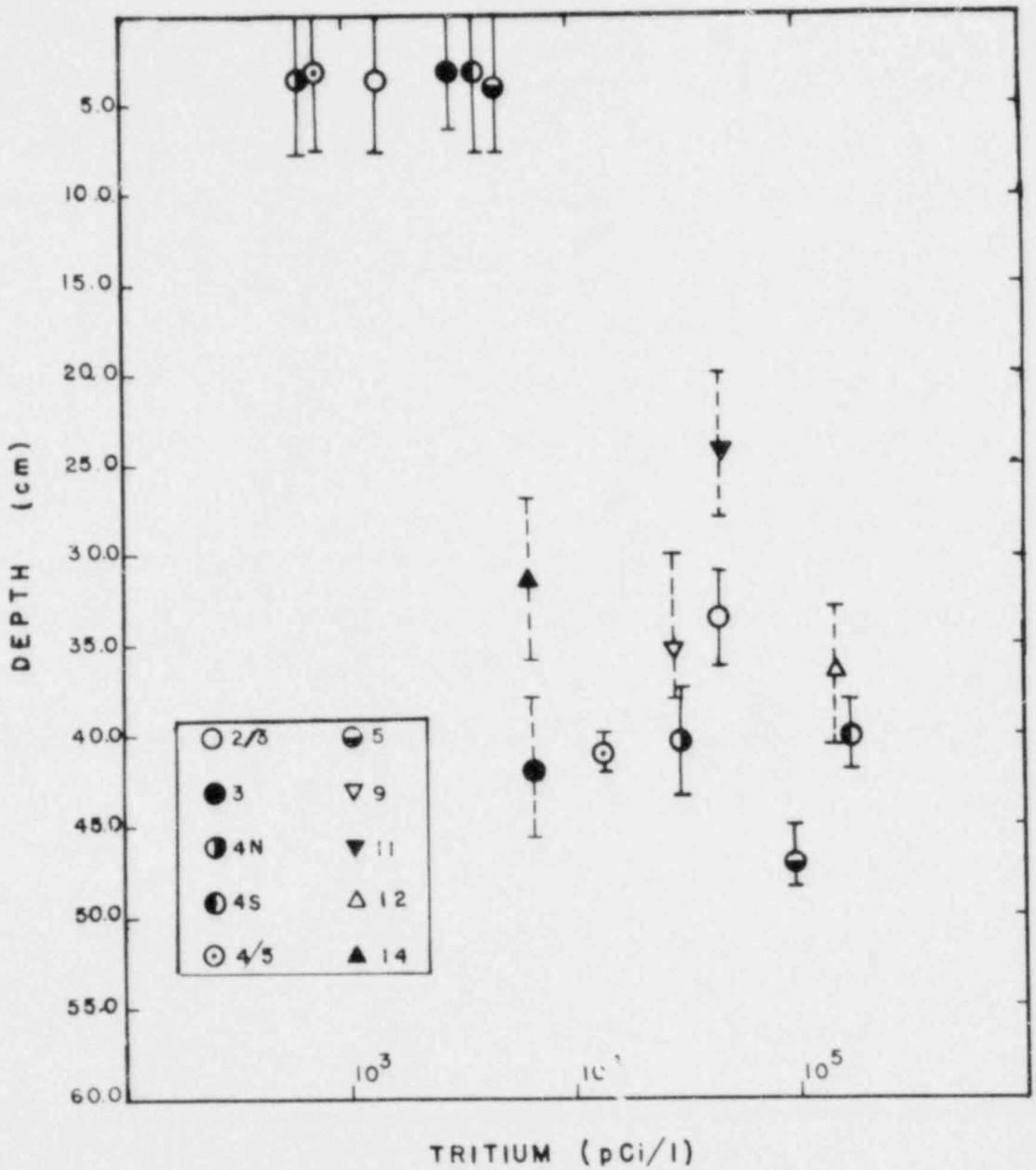

Figure 15. Tritium concentrations in trench cap soil samples collected from above trenches 3,4, 5, 9, 11, 12, and 14, and from septa between trenches 2 and 3, and between 4 and 5.

tritium concentrations in other south trench cap samples. Prudic (35) reports that upward-extending fractures may form at the base of the trench cover, as a result of decomposition and settling of buried wastes. One settlement feature observed on trench 12 during April, 1979, approximately 1 m square and 1 m deep after settlement, may have formed in this manner, allowing tritiated gases to migrate through the fracture network and exchange with stable hydrogen in the trench cap.

9.5 Recommendations

The trench caps may serve as a medium for migration of tritiated gases and their exchange with stable fluids. Continued analysis of trench cap samples should be undertaken to further define the magnitude, mechanism, and extent of migration of tritium at shallow depths within the trench caps. In addition, if as speculated, upward migration of tritiated gases and water is occurring, maximum tritium concentrations would be expected at the bases of the trench covers. Trench cap samples collected in the future must encompass the entire thickness of the caps (1 to 5 m) to verify existence of a concentration gradient.

In conjunction with the above recommendation, parallel studies of soil and trench gases would identify some of the nuclides available for diffusion through, or retention in, the trench caps. Earlier studies suggest that ^{3}HH may exchange with water contained in the trench caps, and that $^{3}HCH_3$, $^{14}CH_4$, and $^{14}CO_2$ undergo "substantial aerobic decomposition in the trench caps" (26). Continued studies of the efficiency of the trench caps in retaining radionuclides should include an evaluation of these equilibration processes and rates. In addition, quantitative effects of trench cap fractures upon gas flux remain to be defined.

10.0 ANALYSIS OF SUB-TRENCH CORE DATA

Vertical infiltration of precipitation through the trench caps and into the trenches* places water in direct contact with the solid low-level radioactive waste. Various radionuclides are mobilized, either by being adsorbed on suspended matter or dissolved in the water. The purpose of this study was to develop and implement a technique to extract cores from beneath the waste burial trenches, and, through radiochemical analyses of these cores, measure the migration of radionuclides away from the burial area. On-site groundwater studies** had shown that the primary component of groundwater movement is vertically downward. It was decided to attempt to extract cores from beneath the trenches in order to attempt to measure the migration of radionuclides in the trench water through the sub-trench earth materials.

This study was begun under Contract No. 68-01-3543 with the USEPA (United States Environmental Protection Agency) and is being continued under the present contract with the USNRC. Some of the data shown in graphs in this section are from the earlier USEPA study (1977-78) as well as the present USNRC study (1979-80). The USEPA data were analyzed in 1977-78 and are listed in the report "Sampling, Analysis, and Study of Migration of Trench Water from a Low-Level Solid Radioactive Waste Burial Ground at West Valley, New York" (12). The USNRC data were analyzed under the present study in 1979-80, and are listed in Appendix F.

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*For more detailed information, see "Geologic Study of the Burial Medium at a Low-Level Radioactive Waste Burial Site at West Valley, New York," a report by the NYSGS to the USEPA to be published in 1980 by the USEPA (12).

**For more detailed information on groundwater conditions see the USGS report by D.E. Prudic and A.D. Randall, "Groundwater Hydrology and Subsurface Migration of Radioisotopes at a Low-Level Solid Radioactive Waste Burial Disposal Site" (38). See also, "Study of Groundwater Flow at a Low-Level Radioactive Waste Burial Site, West Valley, New York," a report by the NYSGS to the USEPA to be published in 1980 by the USEPA (13).

10.1 Radiochemical Analysis of Cores

A preliminary analysis of some of the cores for tritium and strontium-90 was made in the field. The cores were then transported to the N.Y. State Health Department's Radiological Sciences Laboratory in Albany for detailed analysis. These detailed analyses are listed in Appendix F. Table 10 relates these depths to estimated depth below the trench bottom. Concentrations of selected radionuclides in relation to depth below land surface are shown in the graphs in Figures 16-24. The error terms ("plus or minus values") give the 2σ counting uncertainty in percent. The error varies considerably because of 1) variations in analytical techniques from radionuclide to radionuclide, 2) variations in the size of the sample analyzed, and 3) variations in the concentration of the analyzed radionuclide within a sample. "Less-than" values are given where the error term exceeded 100 percent of the measured value. These limits vary with the radionuclide and also with the size of the sample. Techniques of radiochemical analysis for ^{3}HHO and various other radionuclides are described in Appendix C.

10.2 Evaluation of Coring Technique*

The drilling technique used at West Valley to produce cores for evaluation of radionuclide migration posed two problems: 1) how to avoid impenetrable objects within the refuse, and 2) how to determine when the bottom of the trench had been reached. Both are discussed below. Otherwise, the technique worked smoothly. The drive points unscrewed easily and showed little distortion after penetrating resistant objects that required as many as 370 blows/0.3 meter. Core recovery was very good (75 to 90 percent). Commonly 2 to 9 centimeters of cuttings remained in the hole after cleanout, but were not difficult to detect and remove from the top of the subsequent core. (Small amounts of cuttings result from the cleanout spoon not always retaining materials below the basket; larger amounts, recovered below the depth reached by the previous core, suggest that the cleanout spoon sometimes pushed cuttings ahead into the plastic till; errors in measuring hole depth or drillrod length are also possible.) No significant contamination of cores due to drilling was detected, as explained in a later section of this report.

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*Much of the information in sections 10.2 and 10.3 is from Prudic, "Core Sampling Beneath Low-Level Radioactive-Waste Trenches, West Valley, New York," (36).

A total of 10 pipes was driven into the burial trenches at West Valley. Of these, 3 pipes met refusal on hard objects within the trenches, 2 penetrated to the trench floor but were deflected by hard objects and bent sufficiently to prevent extraction of the point; and 5 were used as planned to collect cores. All 5 successful holes were driven in areas where the approximate locations of buried material and container types had been recorded by the burial-ground operator; hole sites were selected to avoid the recorded position of concrete casks and large metal objects.

Inquiry has thus far failed to disclose any geophysical technique capable of detecting concrete objects a meter or so in diameter beneath 4 to 8 meters of till and refuse.

10.3 Locating Trench Floor

An estimate of trench-floor depth accurate to within about 0.3 meter is required to avoid removing the point above the trench floor (in which case contaminated trench water would probably enter the pipe) or a meter or more below the trench floor (in which case no cores would be obtained from the depth interval expected to encompass migration of isotopes other than tritium). The same or better accuracy is needed for interpretation of radiochemical analyses; if most isotopes have migrated a meter or less in 10 years through the till beneath the trenches, as anticipated, exact knowledge of the starting point is critical to rate calculations.

The field supervisor's decision to stop driving pipe and begin coring was based on three lines of evidence indicative of trench-floor depth:

1) Historical: reported design of trench depth and slope, altitude of pre-trench land surface in nearby test holes, records of a few well points driven to sample trench water. Use of these criteria is discussed by Prudic (34).

2) Blows required to drive casing: unusually resistant layers (upwards of 25 blows with essentially no progress) or very soft material (less than 50 blows per 0.3 m) were generally inferred to reflect refuse. Steady progress with gradually increasing blow counts was expected to characterize undisturbed materi below the trench floor. However, this circumstance did not occur at some locations; at these locations the trench floor could not confidently be identified after only 0.3 meter penetration; neither did the magnitude of blow counts nor the "feel" of the driving process in undisturbed material prove to be distinctive.

3) Geophysical: gamma logs in each hole demonstrated that gamma radiation from the subtrench till was comparable to that from the trench cover (50-100 counts per second) and much less than generally recorded from the refuse. However, because the detector "sees" and averages radiation somewhat above and below its actual position, and could not be lowered within 0.4 meter of the end of the pipe before the point was extracted, the transition from relatively high to background radiation could not be completely defined until the pipe had already penetrated more than 0.4 meter into undisturbed material. Therefore, while gamma logs run before removing the point were helpful in showing whether the pipe had penetrated beyond relatively radioactive waste, often they did not distinguish whether material opposite the bottom of the pipe was at background or merely close to it.

10.4 Radionuclide Migration

Table 10 relates depths below trench bottom to depths below land surface. The error factors in these figures require explanation prior to a discussion of radionuclide migration based on core analysis so that the reader may understand the problems associated with estimating the trench floor depth. The depth of the trench floor in hole 4-4A is the least well-defined, estimated to be at least 9.0 m below land surface. The uncertainty is the result of having encountered material much more dense than the waste approximately 2 m above the trench floor depth interpreted from a gamma log survey. The most probable interpretation is that the pipe was driven through the sloping side of the trench before reaching trench bottom. Other interpretations are possible: the pipe may have been driven through collapsed till from the trench wall, or through virtually uncontaminated, compacted waste. These interpretations are discussed in a report by David Prudic (36, p.20).

The interpretation of trench bottom in hole 5-2D is complicated by 0.7 m of collapsed or slumped till above the trench floor. It was for this reason that 5.2E was drilled with the aim of coring through the trench/soil interface (36).

The trench bottom in hole 8-1C is defined only to within ±0.3 m. This is because no core was taken which penetrated the trench/soil interface. However, the trench bottom is extremely well-defined for hole 8-2A. This is because a third set of cores was extracted from beneath trench 8 (hole 8-2B) encountering a clear-cut boundary between trench waste material and soil.

Figures 16 through 24 show radionuclide concentrations versus depth below trenches. Data from the present study are listed

Table 10. Correlations between depths below land surface and depths below trench bottom for core samples listed in Appendix F (Tables 16-18) and shown in Figures 16-24.

Trench-Hole	Depth (m) below land surface	Depth (m) below trench bottom
4-4A	> 9.0*	0.00 (max.)
"	9.63-9.66	0.66 (max.)
"	9.66-9.70	0.70 (max.)
"	9.70-9.74	0.74 (max.)
"	9.74-9.79	0.79 (max.)
"	9.79-9.83	0.83 (max.)
"	9.83-9.88	0.88 (max.)
"	9.88-9.92	0.92 (max.)
"	9.92-9.98	0.98 (max.)
"	9.98-10.03	1.05 (max.)
"	10.00-10.03	1.03 (max.)
"	10.06-10.21	1.21 (max.)
"	10.21-10.33	1.33 (max.)
"	10.33-10.45	1.45 (max.)
"	10.71-10.83	1.83 (max.)
"	11.26-11.38	2.38 (max.)
8-1C	9.3±0.3*	0.00 ±0.3
"	10.09-10.11	0.80 ±0.3
"	10.11-10.14	0.825±0.3
"	10.19- 0.29	0.96 ±0.3
"	10.29-10.40	1.045±0.3
"	10.38-10.40	1.09 ±0.3
"	10.53-10.66	1.30 ±0.3
"	11.58-11.66	1.32 ±0.3
8-2A	9.21±0.07*	0.00 ±0.07
"	9.99-10.02	0.795±0.07
"	10.02-10.06	0.83 ±0.07
"	10.9-10.18	0.925±0.07
"	10.27-10.30	1.075±0.07
"	10.30-10.43	1.155±0.07

*Estimate of trench floor from Prudic, "Core Sampling Beneath Low-Level Radioactive Waste Trenches, West Valley, New York" (36).

Table 10. (continued)

Trench-Hole	Depth (m) below land surface	Depth (m) below trench bottom
5-2D	8.6 ±0.15*	0.00 ±0.15
"	8.60-8.63	0.015±0.15
"	8.63-8.66	0.045±0.15
"	8.88-8.92	0.29 ±0.15
"	9.16-9.28	0.62 ±0.15
"	9.77-9.89	1.23 ±0.15
"	10.35-10.47	1.81 ±0.15
"	10.88-10.94	2.34 ±0.15
5-2E	8.60±0.15*	0.00 ±0.15
"	8.21-8.29	-0.35 ±0.15
"	8.29-8.33	-0.29 ±0.15
"	8.33-8.37	-0.25 ±0.15
"	8.37-8.42	-0.205±0.15
"	8.42-8.45	-0.195±0.15
"	8.56-8.59	-0.025±0.15
"	8.59-8.63	0.01 ±0.15
"	8.63-8.65±0.12	0.04 ±0.27
"	8.65-8.71±0.12	0.085±0.27
"	8.71-8.73±0.12	0.12 ±0.27
"	8.73-8.78±0.12	0.155±0.27
"	8.91-8.95	0.33 ±0.15
"	9.03-9.02	0.45 ±0.15
"	9.15-9.19	0.57 ±0.15

in Appendix F. Data obtained from earlier studies are listed in an earlier report to the USEPA (12).

Tritium

Because of its capacity to exchange with non-tritiated water, tritiated water (^3HHO) will migrate the farthest of all radionuclide species studied. For this reason, it is necessary to analyze core samples for tritium* at greater depth than for the other radionuclide species. This was first done in the field laboratory for the purpose of estimating roughly the extent of tritium migration, so that cores would be collected to the depths necessary for a full analysis of migration rates. Further, more accurate and detailed analyses were done later at the RSL in Albany. The results are plotted in Figures 16 through 18.

Because detection limits for tritium in this study were approximately 2 to 3x 10^{-6} µCi/ml**, while expected background levels in the soil from pre-1950 cosmogenic production rates of tritium are estimated to be approximately two orders of magnitude less than that***, we did not establish the precise maximum distance of migration. One possible method of estimating this maximum distance would be to project the curves shown in Figures 16-19 down to the depth where background values theoretically should be reached. We know no justification for the accuracy of such a technique; so instead, we choose to identify the maximum detectable migration distance, or the depth of migration measured at the detection limits. Because analyses were not performed for every depth interval, the exact depth of migration measured at detectable limits cannot be identified. The depth of migration falls within a range, the maximum and minimum of which are given below.

In hole 4-4A beneath trench 4, tritium activity dropped below detectable limits (3 x 10^{-6} µCi/ml) at a maximum depth of 2.25 m below the trench floor (Figure 16). In hole 5-2D beneath trench 5, tritium activity dropped below detectable limits at a maximum depth of 2.9 m below the estimated trench

*In this report the term "tritium" is assumed to refer to tritium in the form of tritiated water.

**Since most soil cores were divided into small segments for analysis, there was not enough sample to allow detection to a lower level. For further discussion of the limits of detection of tritium, see Appendix C.

***This assumes the soil has not been exposed to tritium in the atmosphere. For more information on cosmogenic production rates of tritium, see Jacobs (19).

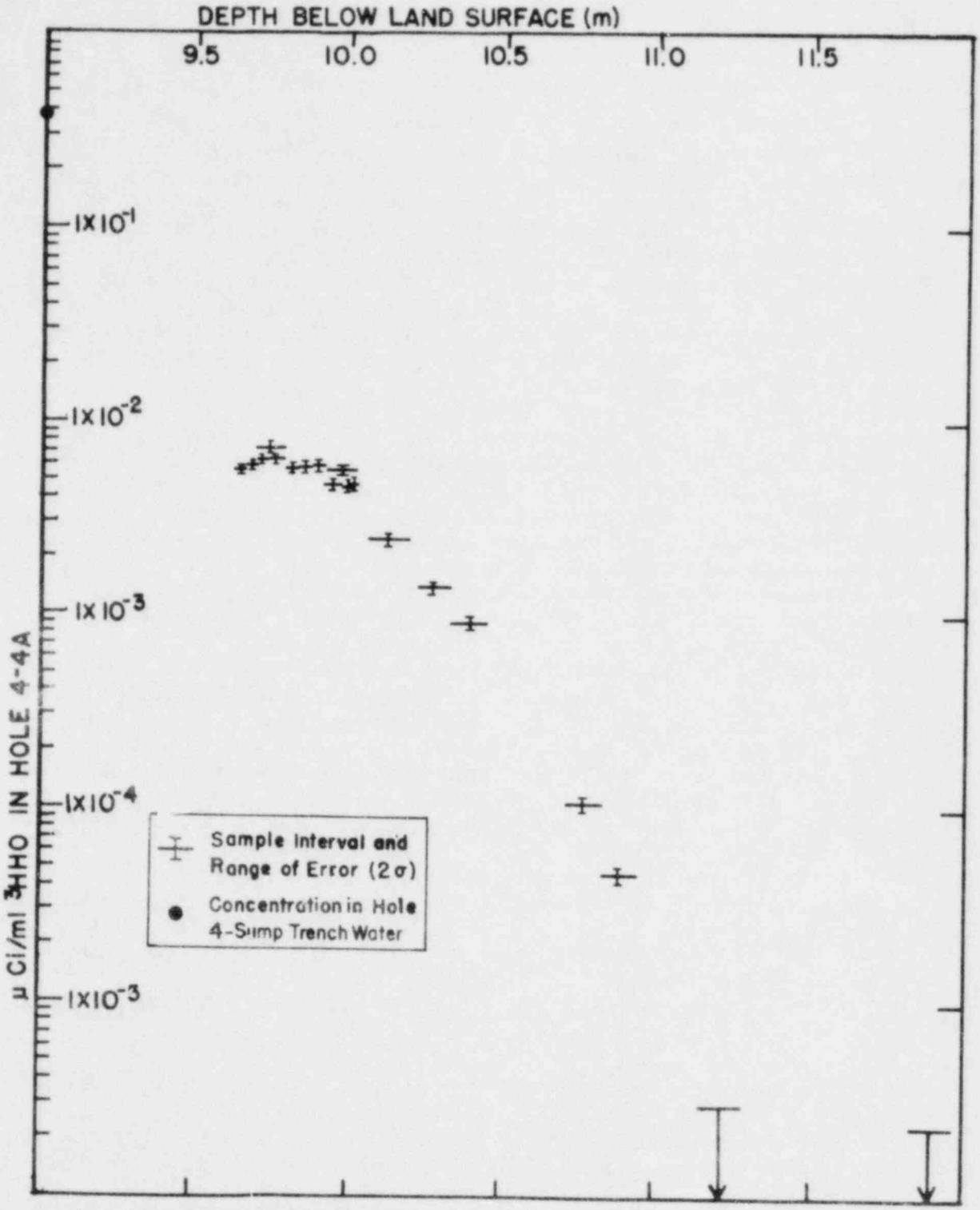

Figure 16. Concentration of tritiated water versus depth below land surface in hole 4-4A. Minimum trench floor depth is 9.0 m below land surface. Data are from both a 1977-78 study (12) and the present study (Appendix F).

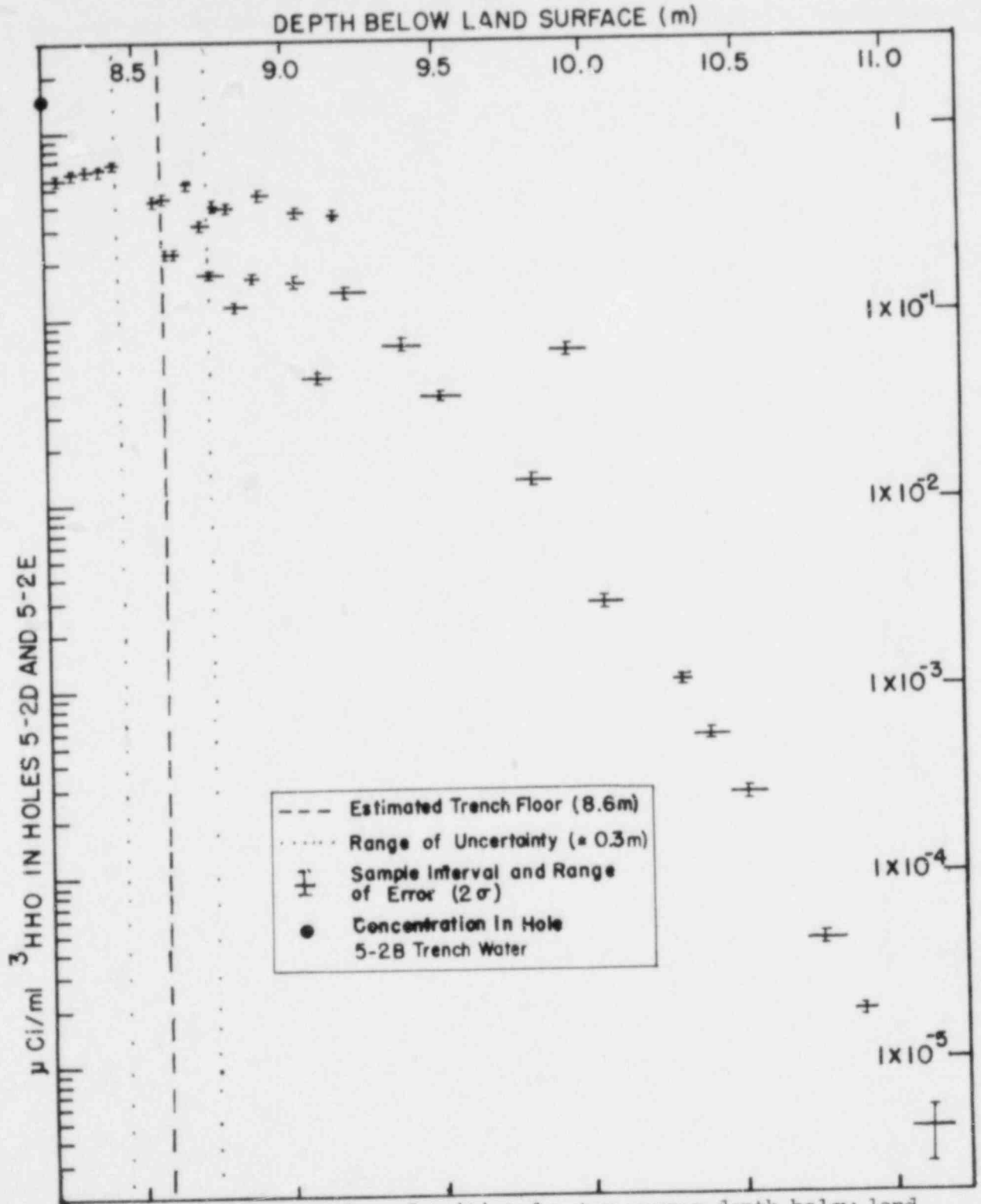

Figure 17. Concentration of tritiated water versus depth below land surface in holes 5-2D and 5-2E. All data above 3×10^{-1} μCi/ml are from hole 5-2E, all below are from 5-2D. Detection limits for tritiated water (2×10^{-6} μCi/ml) were reached in a core section from 11.48 to 11.58 in depth below land surface. Data are from both a 1977-78 study (12) and the present study (Appendix F).

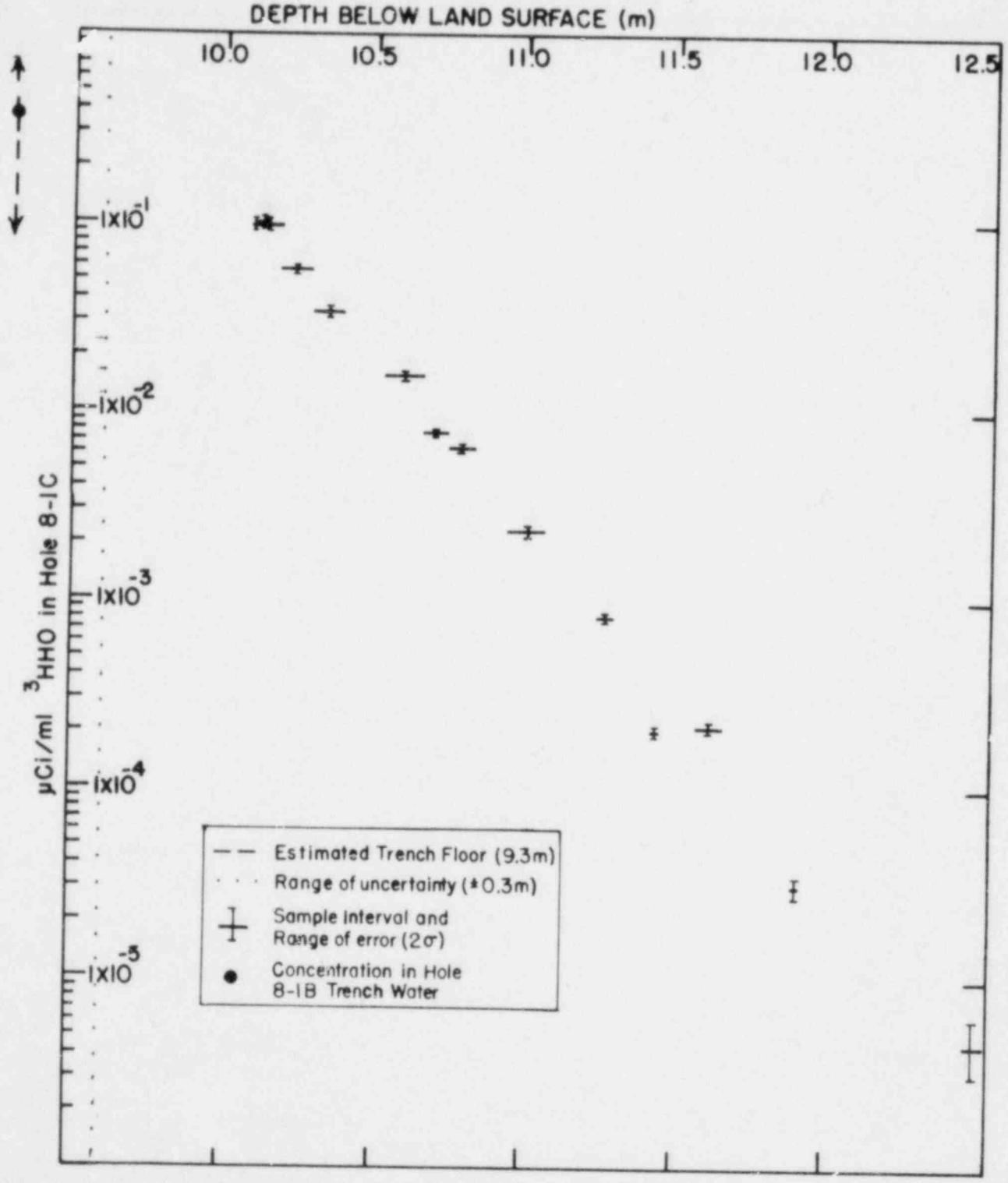

Figure 18. Concentration of tritiated water versus depth below land surface in hole 8-1C. Data are from both a 1977-78 study (12) and the present study (Appendix F).

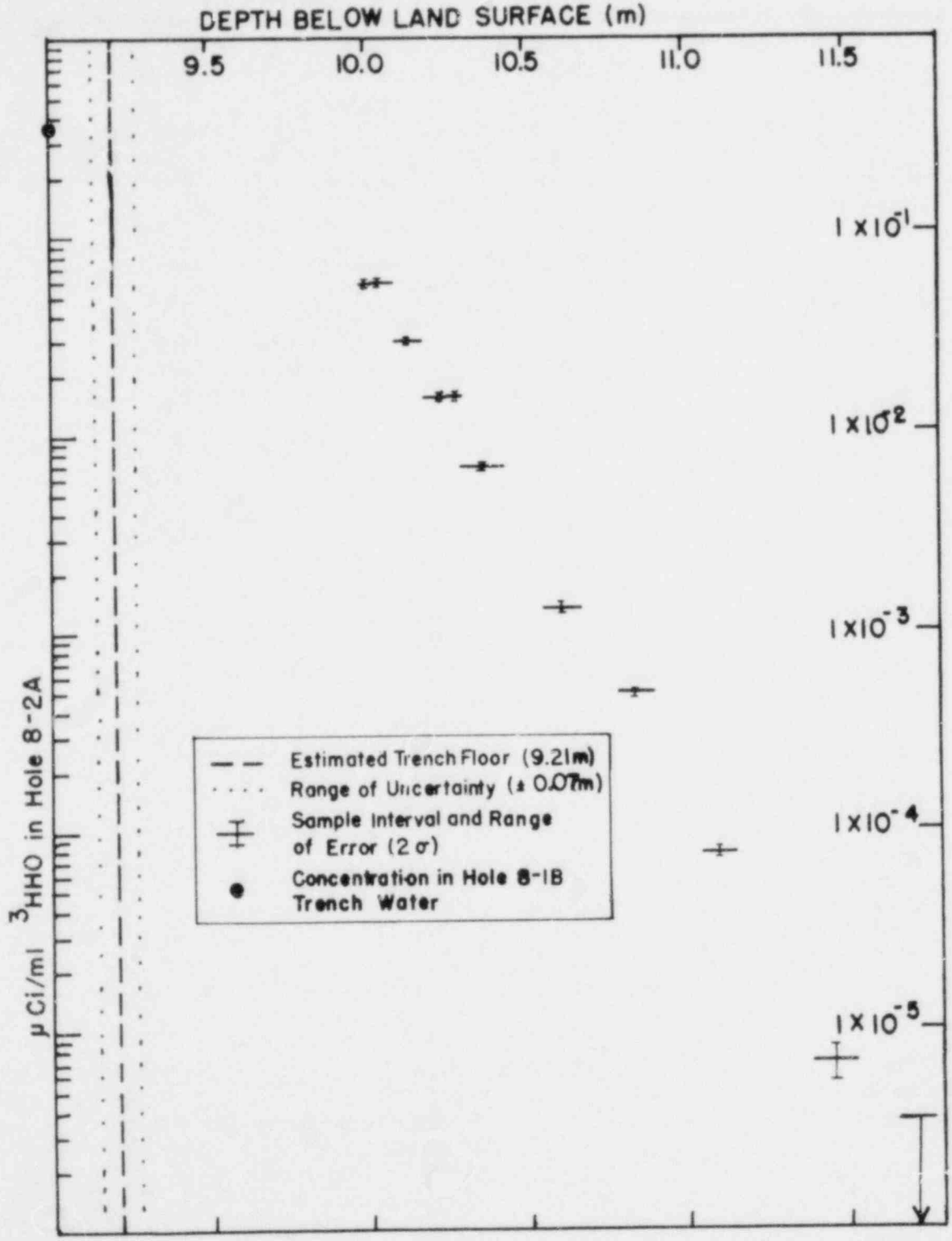

Figure 19. Concentration of tritiated water versus depth below land surface in hole 8-2A. Data are from both a 1977-78 study (12) and the present study (Appendix F).

floor, with a possible trench floor location error of ±0.15m (Figure 15). In hole 8-1C beneath trench 8, tritium activity dropped below detectable limits at a depth slightly greater than 3.2 m below the estimated trench floor, with a possible trench floor location error of ±0.07 m (Figure 17).

The values given above are maximum depth of detectable migration. Minimum values range from zero meters of migration in hole 4-4A to 2.25 m (±0.07 m) in hole 8-2A, to 2.55 m (±0.15 m) in hole 5-2E, to 3.2 m (±0.3 m) in hole 8-1C.

Hole 4-4A was driven through the oldest trench studied. Trench 4 was closed in June 1967 while trench 5 was closed in February 1969 and trench 8 in September 1970. The times for migration are 10, 8 and 7 years, respectively. It is logical to expect that migration in trench 4 would have exceeded that in trenches 5 and 8. Conversely, however, migration of tritium in trench 4 was the least of all holes studied over the ten-year period. One explanation is that if the pipe was driven through the side of the trench as described earlier in this section, then the true distance of migration would be greater than the vertical distance from trench floor to sample depth (see Prudic (36), p. 32).

This is in contrast to hole 8-1C where tritium shows the deepest detectable migration. Hole 8-1C was driven chiefly through massive silts and distorted layers of lake beds. The proportion of coarse to fine sediments in hole 8-1C was much higher than in the other holes (see Appendix G). In fact, the ratio of coarse silt and sand layers to clay and fine silt layers was, in general, higher than anticipated in all core holes. Further evidence to support this second explanation is observed by comparing the tritium fronts shown in Figures 14-17. The tritium front slope will reflect the soil profile permeability other than the adsorbtive capacities of the various layers. The steeper the diffusion front, the more impermeable the soil. In the case of tritium, the tritium diffusion front for hole 8-1C is clearly less steep than the tritium front for the other three holes, indicating more permeable soils. The deeper half of the tritium front curve for hole 4-4A is steeper than the tritium front curve for the other three holes. This may indicate more permeable soils at depth, an hypothesis not supported by the existing data (Appendix G, Table 19). A more likely explanation, however, is that the dense material above the trench floor altered the direction of the flow path, and, consequently, the shape of the tritium front curve.

One exception to the generally smooth trends observed beneath the trenches is in hole 5-2D (Figure 15). At a depth of 9.89-10.01 m below the trench floor a value more than an order of magnitude above the smooth trend stands out from the curve. The depth of collection of this sample is the depth at which two intersecting, steeply-dipping fractures were identified (see Appendix G, Table 20). The fractures were not open nor was any chemical alteration visible. However, the possibility remains that one or both of these fractures served as an avenue of preferential migration.

Variations in concentration values between holes at a given depth below the trench floor may be the result of one or more different factors. The

adsorptive capacities of the till encountered below the trenches will affect the actual height of the curve, or concentration values, in relation to depth below the trench floor; but adsorption is probably less variable in the till than other factors. Other factors that affect the relationship between concentration values and depth are: water content, known to vary widely in sandy materials; flow rate, a function of the type of material and of the hydraulic gradient in the till, factors both known to vary; and the length of the flow path, probably also variable, as discussed above.

Concentration values in hole 4-4A stand apart from values in the other four holes studied. At any given depth below the trench floor, concentrations of tritium in trench 8 (holes 8-1C and 8-2A) are a smaller fraction of the trench water concentration than in hole 4-4A, smaller by at least one order of magnitude. The relationship between values in trench 5 (holes 5-2D and 5-2E) and hole 4-4A is much closer; however, the same general trend as between 4-4A and trench 8 holds true. At any given depth below the trench floor, the concentration of tritium beneath trench 5 is a smaller fraction of the trench water concentration than in hole 4-4A.

Data from holes 5-2D and 5-2E pose a special problem. Even though the holes were intended as comparison holes to be used as the upper and lower portions of the same data curve as illustrated in Figure 17, they show a pattern that does not support an assumption of similar initial concentrations of tritium. In fact, a horizontal line may be drawn on Figure 17 to separate hole 5-2E values above from hole 5-2D values below. If trench water tritium values have changed over time* (and we know from sampling records that they have) then differential sedimentation could explain the discrepancy between holes 5-2D and 5-2E. Another possibility is that an isolated pocket of higher or lower tritium concentration is located in the trench directly above one or the other of these holes, causing initial concentrations to differ. There are two other explanations suggested by Prudic (36, p. 44). There may be a greater permeability of earth materials near hole 5-2E, or a shorter distance from hole 5-2E to the lateral edge of the loose collapsed till atop the trench floor and(or) to the outcrop on the trench floor of the dipping lacustrine deposits beneath the trench (Appendix G, Tables 20-21).

Carbon-14

At the trench-water/soil interface a number of processes involving carbon-14 may be taking place: 1) carbon-14 may be sorbed, or filtered if in suspension, into soil immediately below the trench floor and go no farther; 2) inorganic carbon-14, possible as bicarbonate or carbonate ions, may

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*This would be not only the result of decay of tritium, but also the result of the random release of new sources of tritium to the trench water by breaching of containers.

complex with soil cations allowing it to migrate rapidly through the soil (21); 3) inorganic and organic carbon compounds may decompose* to release carbon-14 to the soil solution (33); or 4) inorganic and organic carbon compounds may decompose to produce gaseous forms of carbon-14 (26).

As for process number one listed above, there is no evidence supporting sorption or rapid filtering into soil at West Valley. Analyses for carbon-14 at or near the estimated trench floor show no unusually high concentrations at that interface (Figures 20 and 21)**.

As for complexing with soil ions, process number 2, there is no evidence for preferrential complexing of organic or inorganic forms of carbon-14. A study by the RSL shows very similar behavior patterns for these two chemical forms (24). However, there are certain patterns that may be the result of certain forms of carbon moving more rapidly through the soil than others. In trench 5 (Figure 21) 40-60 cm below the estimated trench floor carbon-14 concentrations rise to what appears to be a secondary peak before falling off to values below detection limits. This secondary peak may be the result of certain forms of carbon migrating at a higher rate than others (41). Because of the large counting errors for most of the data beneath trench 5, the peak in values may be primarily an artifact of this large error. More data would help to confirm or deny this.

This possible secondary peak occurs at a depth where core logging located a dipping wedge of silty coarse sand 6 cm thick in hole 5-2D and two coarse silt layers, each 2 cm thick, in hole 5-2E (see Appendix G). Also at this depth in hole 5-2E is a dipping fault contact that is saturated. These features may have resulted in preferrential migration to this depth causing the secondary peak in holes 5-2D and 5-2E.

A third explanation for such a secondary peak would be that at some time in the past the concentration of carbon-14 in trench 5 was much higher than in 1977, resulting in a "slug" of high-concentration trench water migrating downward. Possibly the breaching in trench 5 of containers with high concentrations of carbon-14 caused this high concentration. Subsequent drop off in concentration could be the result of

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*An intermediate step may involve retention on sediment before hydrolytic decomposition (24).

**In these and subsequent figures, trench water activity values have been converted from μCi/ml to μCi/g soil, assuming a 15 percent moisture content of the soil (17). This was done so as to be able to compare trench water values directly with subtrench soil values.

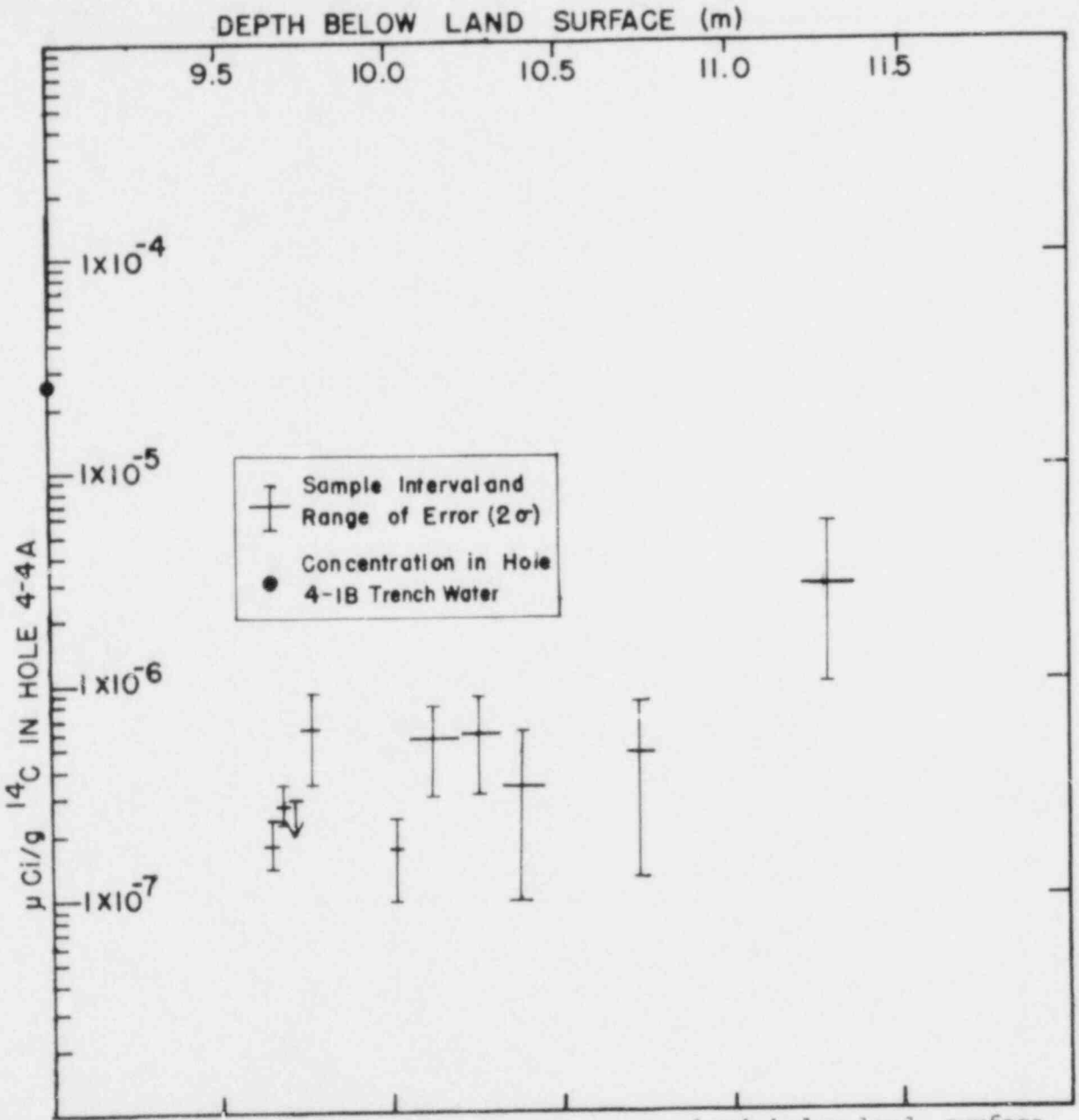

Figure 20. Concentration of carbon-14 versus depth below land surface in hole 4-4A. Minimum trench floor depth is 9.0 m below land surface. Activity in 4-1B trench water is converted from μCi/ml to μCi/g soil for direct comparison with soil for analyses. Background levels in soils are less than 1.1×10^{-7} μCi/g. Data are from both a 1977-78 study (12) and the present study (Appendix F).

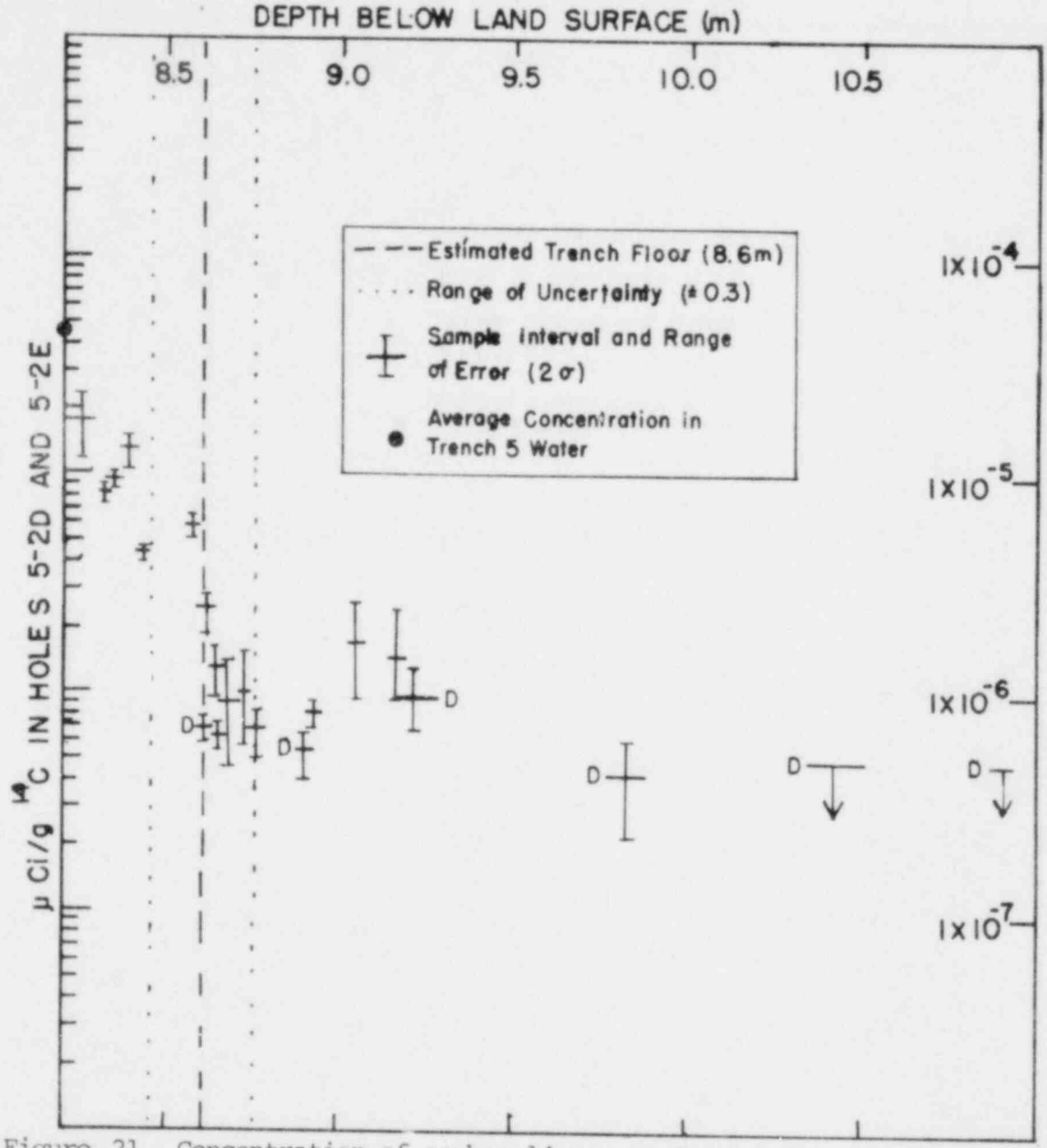

Figure 21. Concentration of carbon-14 versus depth below land surface in holes 5-2D and 5-2E. Data from hole 5-2D are labelled with a "D". Soil/trench-sediment interface is at 8.21 m depth. Trench water activity is an average of 8 measurements at 4 different locations in 1975 and 1976. The value was decreased by a factor of 3 in order to account for dilution by rainwater (see footnote, p. 79) and converted from μCi/ml to μCi/g soil for direct comparison with soil analyses. Data are from both a 1977-78 study (12) and the present study (Appendix F).

dilution by infiltrating water* or the result of rapid sedimentation or slumping on the floor of the trench, temporarily preventing further radionuclide migration from the trench water into the subtrench soil.

Beneath Trench 4 (Figure 20) carbon-14 concentrations show what appears to be an increase with depth below the trench floor. Because of the large error terms on many of those values and because of the small number of data points it is not possible to determine if this trend is real or not. Regardless, the migration of carbon-14 beneath trench 4, if real, may be the result of several different factors as described above for trench 5.

Evidence for process number 3, the decomposition of carbon compounds and release to solutions, does not exist, although such a process is probably a necessary precursor to process number 4. However, evidence does show the existence of process number 4, decomposition to produce gaseous releases. Gases such as $^{14}CH_4$, ^{14}C as hydrocarbons above methane (C_2H_6, C_3H_8, C_4H_{10}, etc.) and $^{14}CO_2$ have been detected in the trench gases of all the trenches at West Valley (26).

Because of different concentrations and different limits of detection it is not possible to compare directly the migration distances of tritium and carbon-14. With the additional carbon-14 analyses during 1979-80 at greater depths than in 1977, detection limits are still not reached at a depth of 11.3 m below land surface, so maximum migration is not known. However, in comparing carbon-14 measurements with tritium measurements in trench 5 to a depth of approximately 9 m a clear general relationship does emerge. Over this range the carbon-14 concentration drops by a factor of approximately 20, whereas tritium decreases by a factor of 2 to 3 over the same depth interval. This indicates that the carbon-14 migrates at a much slower rate than the tritium, as would be expected.

The carbon-14 measurements below 9 m depth in trench 5 and most of the measurements in trench 4 are near the limit of detection and have high potential errors associated with them. Therefore, the interpretations proffered above are open to question. For example, as described above, the peak in values detected in soils beneath trench 5 may not be real but an artifact of the large potential counting error. It is also significant that carbon-14 values show no consistent migration front, as do the tritium values (Figures 16-19). The rapid decrease in carbon-14 concentration directly beneath the trench

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*Clear evidence exists for the dilution of tritium in trench 5 by a factor of 3 over 15 months. Similar dilutions of carbon-14 should have occurred also.

floor indicates that there should be no measureable carbon-14 in deeper cores; however, deeper cores beneath trenches 4 and 5 do show positive measurements. This may be a result of migration rates of different carbon-14 ionic forms or be the result of sample analyses near detection limits, where positive values are the result of very slight contamination. Gas-proportional counting of CO_2 is sensitive to minute concentrations of impurities and occasional positive values from samples below detection limits are an artifact of the system. Future studies should include additional analyses of cores using larger core sections to obtain higher sensitivity in the regions showing values near detection limits.

Concentrations of carbon-14 beneath trench 8 (holes 8-1C and 8-2A) were all below detection limits. These values were not plotted on a graph, but are listed in Table 16 of Appendix F.

Strontium-90

Detectable concentrations of strontium-90 below the trenches were found beneath trenches 4 and 5 (Figure 22). Beneath trench 4 (hole 4-4A) values above detection limits were found and may have been up to 70 cm below the trench floor; the uncertain location of the trench floor precludes a more accurate estimate. Beneath trench 5 (holes 5-2D and 5-2E) values above detection limits were found 5 cm below the estimated trench floor with a possible trench floor location error of ±15 cm. Evidence for the migration of strontium-90 beneath the trenches is inconclusive.

The concentrations of strontium-90 measured beneath trench 4 are 40 to 50 times the concentrations found beneath trench 5. This result is reasonable because: 1) water collected from trench 4 has the highest concentration of strontium-90 of all the trenches studied to date (more than 100 times the concentration found in the water collected from trench 5); and 2) because the permeability of the soil beneath trench 4 is much higher than that beneath trench 5, the sorbtive properties are probably lower as well.

Detectable concentrations of strontium-90 were found deeper below trench 4 than below trench 5. This may be the result of one or both of the following: 1) the generally more permeable nature of the soil beneath trench 4 may have allowed migration to proceed to greater depths than beneath trench 5; and 2) because detectable concentrations of strontium-90 below the trench floor in hole 4-4A are found at the same depth as

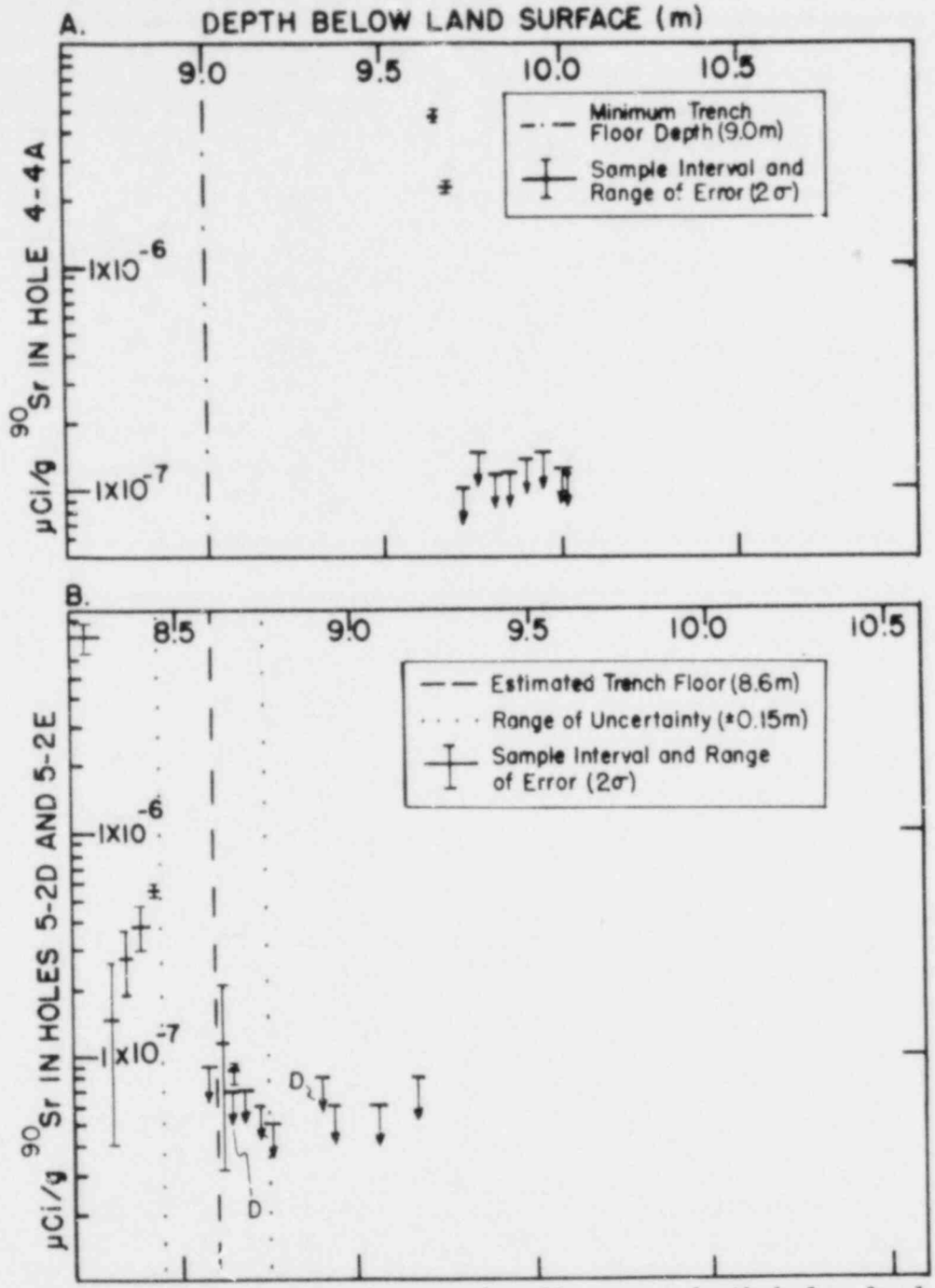

Figure 22. Concentration of strontium-90 versus depth below land surface in holes 4-4A, and 5-2D and 5-2E. In graph A, the minimum trench floor depth is shown. In graph B the estimated trench floor depth and the range of error are shown. Data are from both a 1977-78 study (12) and the present study (Appendix F). Concentration of strontium-90 in the trench water above holes 5-2D and 5-2E is 1.1E-04±6%. Concentrations in trench 4 trench water range from 4.0E-03±5% to 2.02E-02±5%.

a 3 cm thick layer of very fine to medium sand underlain by a 4 cm layer of silt dipping at 45 degrees, these layers might be providing a more rapid pathway from the trench allowing strontium-90 at this depth to exceed the expected levels. No analyses were done between this depth and the trench floor and thus it is not known whether these high values constitute a separate peak or are merely part of the sloping front.

Values above detection limits were also found beneath trench 5 between the trench/sediment interface and the estimated trench floor, among the sediment laid down during or since trench excavation. Except for the topmost value in hole 5-2E, the concentrations steadily increase from top to bottom of this section above the trench floor. (This clear trend, also observed for tritium in trench 5 (Figure 17), appears to be the result of decreasing concentrations in the trench water during the time sedimentation was taking place. This decrease may be the result of precipitation of strontium-90 over time depleting the concentration in trench water, or dilution of the trench water by the infiltration of rain water. One or both of these factors may have contributed to this decrease in concentration).

No migration of strontium-90 beneath trench 8 (holes 8-1C and 8-2A) was detected.

Cesium-134, -137

Cesium-134 and -137 are anthropogenic (man-made) nuclides not naturally present in the soil at West Valley (36) but found in the trenches (see Section 7.0). Furthermore, being cationic, they will tend to be readily absorbed by the anionic, clay-rich till underlying the trenches (20,42), making the possibility of migration more than a few millimeters extremely unlikely. Therefore, any detectable radio-cesium below a few millimeters depth would almost certainly be the result of contamination during the collection process. For this reason, any radio-cesium detected in this study may be thought to be evidence for down-hole contamination.

Both cesium-134 and -137 show evidence for possible contamination 15 cm below the estimated trench floor in hole 5-2E (Figure 23). Radio-cesium was detected using both the germanium-lithium detector system and the cesium chloroplatinate method of analysis (see Appendix C). This depth, however, is within the range of error possible for the location of the trench floor; the radio-cesium in these samples may be the result of direct contact with the trench waste before silt accumulation began on the trench floor. In conclusion, the absence of good evidence for detectable radio-cesium below the trench floor strongly suggests we collected uncontaminated cores.

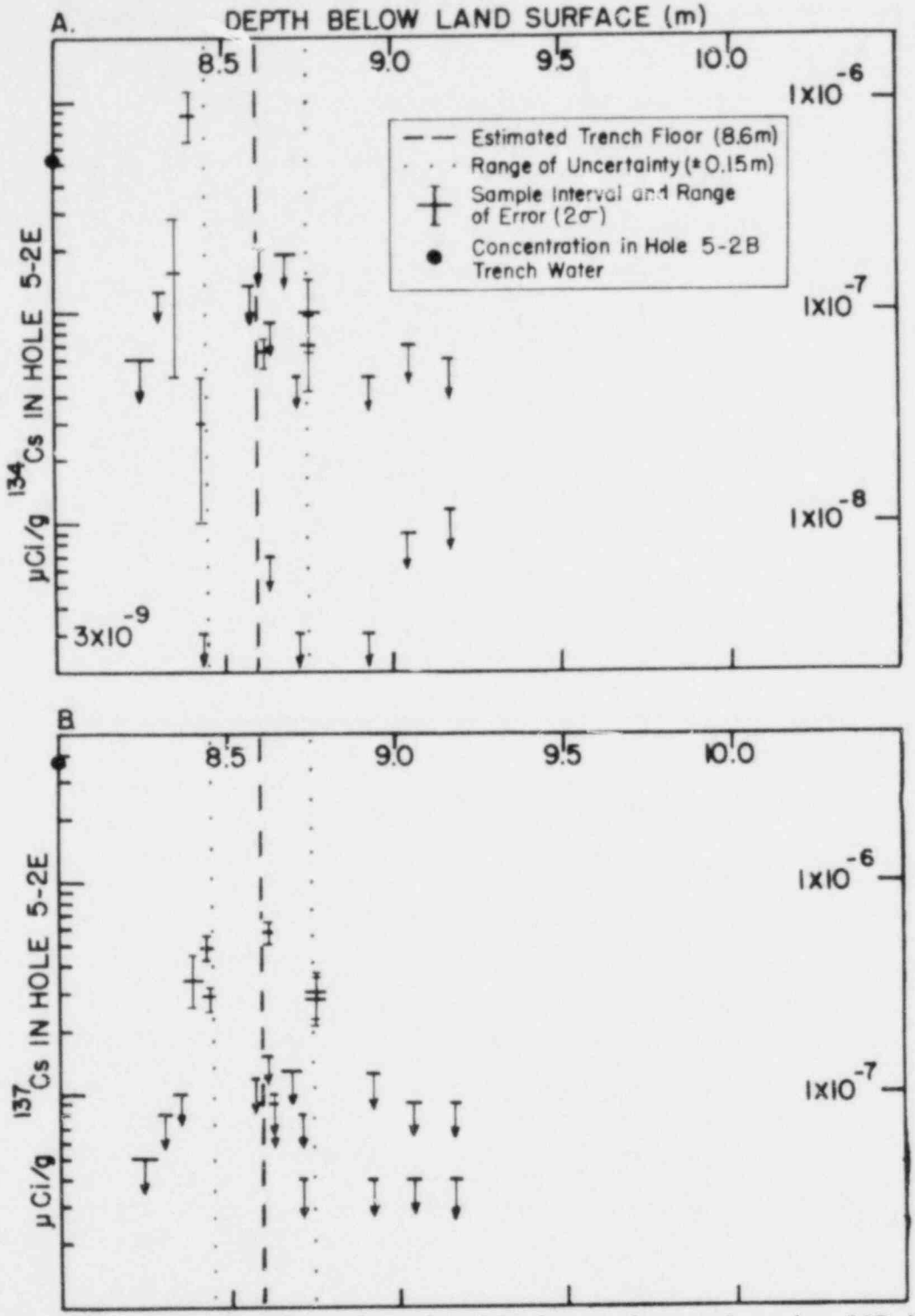

Figure 23. Concentration of cesium-134 in graph A and cesium-137 in graph B versus depth below land surface in hole 5-2E. Activity in hole 5-2B trench water sample has been converted from µCi/ml to µCi/g soil for ready comparison with soil analyses. Data are from both a 1977-78 study (12) and the present study (Appendix F).

Plutonium-238

Plutonium-238 was detected beneath all three trenches studied and in four of the five sub-trench cores. Most of the data show values above computed background levels for West Valley soil (23). Whether in all samples the values reflect actual migration in the soil is difficult to ascertain. The large potential laboratory counting errors for most of these analyses make any interpretations somewhat speculative. It should be noted, however, that because of the extreme insolubility of plutonium (32,34) and the strong sorption of plutonium on geologic material, and especially on anionic material such as the till at West Valley (32, 40), migration of more than a few centimeters or millimeters is extremely unlikely.

Beneath trench 8, at two different depths concentrations of plutonium-238 were detected an order of magnitude above any other trenches measured (Figure 24). Error terms for these two values are ±13 percent and ±16 percent. Also, trench water concentration of plutonium-238 in trench 8 is more than three orders of magnitude above either trench 4 or 5 trench water values. For these reasons migration cannot be ruled out as a possibility. The values detected well below the floor of trench 8 may possibly be the result of migration (80 cm in hole 8-1C (±0.3 m) and 108 cm in hole 8-2A (±0.12 m)), but are probably the result of high background values. The values suspected of being background are within one order of magnitude of the only background analysis to date (23).

Other Radionuclides

All other radionuclide species measured show either no detectable activity below the trench floor, or a range of activity attributable to activity of the naturally occurring element. This range of activity is characterized by a reasonably steady level of activity throughout the soil profile, showing no systematic decrease in activity with depth, and in some cases, by the existence of lower values of activity in the trench water than in the underlying soil. Radionuclides showing no detectable activity beneath the trench floor include iron-55, nickel-63*, iodine-129, americium-241**, cobalt-60*, and ruthenium-106. Radionuclides showing activity attributable to the naturally occurring element include plutonium-239, potassium-40, thorium-232, uranium-234, -235, and -238.

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*Beneath trench 8 nickel-63 shows one value and cobalt-60 shows two values that were approximately equal to concentrations found to occur naturally in West Valley soils (23).

**In hole 8-2A a value of 7×10^{-11} μCi/g (±75%) was detected for americium-241. The large potential laboratory counting error leaves this extremely low value suspect.

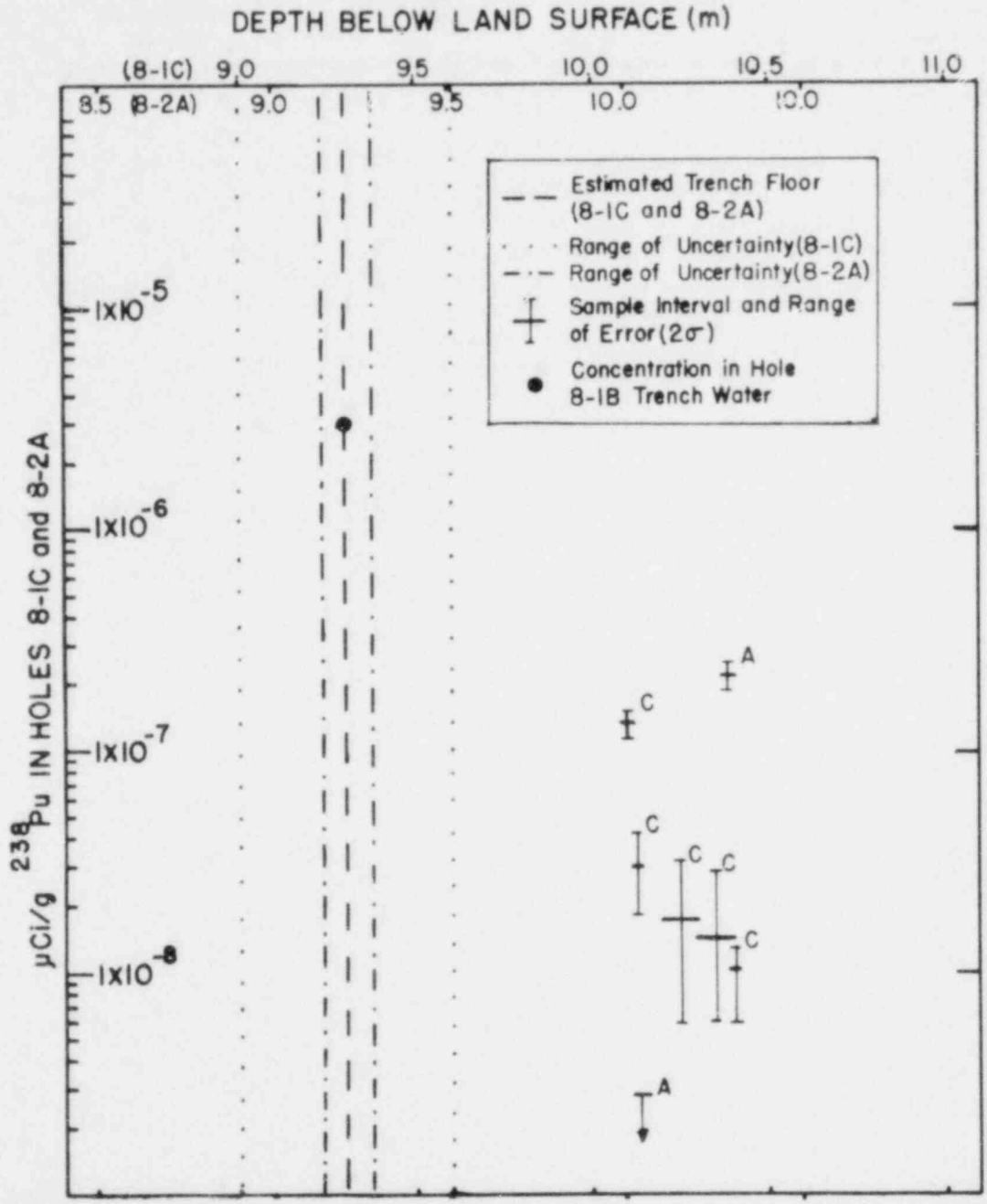

Figure 24. Concentration of plutonium-238 versus depth below land surface in holes 8-1C and 8-2A. Trench floors coincide on this graph for direct comparison of migration depths. Activity in hole 8-1B trench water sample has been converted from µCi/ml to µCi/g soil for ready comparison with soil analyses. "A" designates samples from hole 8-2A and "C" from hole 8-1C. Data are from both a 1977-78 study (12) and the present study (Appendix F).

10.5 Future Studies

Future studies of sub-trench migration of radionuclides should include additional analyses of cores using longer core sections to obtain higher sensitivity in the regions showing values near detection limits. This would provide greater accuracy in defining the migration rate of tritium, as well as help clear up problems associated with the interpretation of data on carbon-14, strontium-90 and plutonium-238 migration rates.

Now that a substantial body of information has been obtained from field experiments on migration rates and from computer modeling of this migration, laboratory experiments should be done to study the adsorption and desorption properties of the West Valley soil. Adsorption and desorption should be reversible procedures; if not, this is evidence for the creation of neutral substances or the formation of radiocolloids. In order to test the various components of the West Valley soil for its adsorption properties, a sample of uncontaminated soil from the West Valley site could be broken down into its various components for testing with a sample of water from the burial trenches. Desorption could then be carried out on these same samples to test the reversibility of adsorption experiments.

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APPENDIX A

PRECIPITATION AND STREAMFLOW DATA FOR THE WESTERN NEW YORK NUCLEAR SERVICE CENTER (July, 1978 through December, 1979)

TABLE 11. Precipitation at Nuclear Fuel Services, Inc., West Valley, New York from 7/24/78 through 12/31/79.

(All precipitation measured at Raingage #2, except where indicated.)

Date	cm
7/24/78-8/1/78	1.91
8/1 -8/7	0.64
8/7 -8/14	3.56
8/14 -8/21	2.79
8/21 -8/29	0.64
8/29 -9/4	1.27
9/4 -9/11	1.27
9/11 -9/18	7.87
9/18 -9/25	1.02
9/25 -10/2	0.64
10/2 -10/9	5.08
10/9 -10/16	3.68
10/16 -10/23	1.02
10/23 -10/31	2.03
10/31 -11/6	0.25
11/6 -11/13	0.38
11/13 -11/20	1.14
11/20 -11/27	0.84
11/27 -12/8	1.17
12/8 -12/31/78	No record
Total 7/24/78 to 12/8 /78	37.20
1/1/79 -1/8/79	No record
1/9 -1/15	1.27
1/15 -1/23	2.79
1/23 -1/30	6.73
1/30 -3/5	8.76
3/5 -3/22	1.40
3/22 -3/29	2.67
3/29 -4/4	2.29
4/4 -4/17	5.21
4/17 -4/23	0.13
4/23 -4/30	1.27
4/30 -5/7	0.89
5/7 -5/14	4.32
5/14 -5/21	0.76
5/21 -5/28	2.29
5/28 -6/4	1.40
6/4 -6/11	2.79

TABLE 11 (Continued).

Date	cm
6/11/79-6/19/79	0.25
6/19 -6/25	1.02
6/25 -7/2	3.18
7/2 -7/9	0.38
7/9 -7/16	4.06
7/16 -7/23	0.25
7/23 -7/30	2.54
7/30 -8/6	2.41
8/6 -8/13	1.52
8/13 -8/20	1.27
8/20 -8/27	3.81
8/27 -9/3	4.57
9/3 -9/6	5.46
9/6 -9/10	0.89
9/12 -9/17	12.57
9/17 -9/24	1.02
9/24 -10/9	7.49
10/9 -10/15	2.03
10/15 -11/6	4.06
11/6 -11/13	2.79
11/13 -11/19	1.14
11/19 -11/26	2.54
11/26 -12/3	2.03
12/3 -12/10	1.4
12/10 -12/17	0.89
12/17 -12/26	0.76*
12/26 -12/31	0.0
1979 Total	115.30

* Rain Gage #1

TABLE 12. Streamflow at NFS site, West Valley, N.Y.

Station	Date	Streamflow (liters)
No. 1 Frank's Creek(all values calculated from mean daily discharge)	1978 10/1 - 10/8	6.9×10^6
	10/9 - 10/16	1.2×10^2
	10/17 - 10/31	1.8×10^7
	11/1 - 11/6	2.7×10^6
	11/7 - 11/3	2.1×10^6
	11/14 - 11/20	2.1×10^6
	11/21 - 11/27	5.8×10^6
	11/28 - 12/8	2.2×10^7
	12/9 - 12/15	1.4×10^7
	12/16 - 12/22	1.7×10^7
	12/23 - 12/31	1.7×10^7
	1979 1/1 - 1/14	8.2×10^7
	1/15 - 1/28	3.2×10^7
	1/29 - 2/11	1.6×10^7
	2/12 - 2/25	1.5×10^7
	2/26 - 3/11	7.9×10^7
	3/12 - 3/31	7.9×10^7
	4/1 - 4/7	2.4×10^7
	4/8 - 4/14	4.2×10^7
	4/15 - 4/25	1.5×10^7
	4/26 - 4/30	4.0×10^6
	5/1 - 5/7	3.1×10^6
	5/8 - 5/14	7.9×10^6
	5/15 - 5/21	1.6×10^6
	5/22 - 5/28	3.3×10^6
	5/29 - 6/4	3.1×10^6
	6/5 - 6/11	9.6×10^5
	6/12 - 6/18	1.7×10^5
	6/19 - 6/25	0
	6/26 - 7/2	9.7×10^4
	7/3 - 7/9	4.9×10^4
	7/10 - 7/16	1.4×10^6
	7/17 - 7/24	2.4×10^4
	7/25 - 7/31	1.7×10^5
	8/1 - 8/6	1.9×10^5
	8/7 - 8/13	2.4×10^4
	8/14 - 8/20	7.3×10^4
	8/21 - 8/27	8.1×10^5
	8/28 - 9/6	7.9×10^6
	9/7 - 9/10	1.7×10^6
	9/11 - 9/17	8.3×10^7
	9/18 - 9/24	1.3×10^6
	9/25 - 9/30	3.4×10^5

TABLE 12 (continued).

Station	Date			Streamflow (liters)
No. 2 Lagoon Road	1978	7/24	- 8/1	3.79×10^4
		8/7	- 8/14	2.73×10^5
		8/14	- 8/21	3.10×10^5
		8/21	- 8/29	6.06×10^4
		8/29	- 9/4	9.84×10^4
		9/4	- 9/11	9.08×10^4
		9/11	- 9/18	9.54×10^5
		9/18	- 10/9	1.03×10^6
		10/9	- 10/16	6.06×10^4
		10/16	- 10/23*	6.9×10^5
		10/23	- 10/31*	5.3×10^5
		10/31	- 11/6*	2.9×10^4
		11/6	- 11/13*	1.2×10^4
		11/13	- 11/20*	3.0×10^4
		11/20	- 11/27*	2.6×10^5
		11/27	- 12/8*	7.3×10^5
	1979	4/1	- 4/7*	5.5×10^5
		4/8	- 4/14*	1.1×10^6
		4/15	- 4/25*	8.5×10^4
		4/26	- 4/30*	1.7×10^4
		4/30	- 5/7	2.27×10^5
		5/7	- 5/15	1.12×10^6
		5/15	- 5/21	1.29×10^5
		5/21	- 5/28	2.80×10^5
		5/28	- 6/4	3.18×10^5
		6/4	- 6/11	2.57×10^5
		6/11	- 6/19	6.81×10^4
		6/19	- 6/25	8.32×10^4
		6/25	- 7/2	1.97×10^5
		7/2	- 7/9	9.08×10^4
		7/9	- 7/16	2.80×10^5
		7/16	- 7/24	6.06×10^4
		7/24	- 7/30	2.73×10^5
		7/30	- 8/6	2.57×10^5
		8/6	- 8/13	1.51×10^5
		8/13	- 8/20	1.59×10^5
		8/20	- 8/27	3.63×10^5
		8/27	- 9/6	9.69×10^5
		9/6	- 9/10	1.97×10^5
		9/10	- 9/17*	4.2×10^6
		9/17	- 9/24	1.97×10^5
		9/24	- 9/30*	5.2×10^4
		9/30	- 11/15	No data
		11/15	- 11/16	7.57×10^3
		11/16	- 11/19	1.14×10^5
		11/19	- 11/26	7.49×10^5

*Calculated from mean daily discharge. All others calculated from digital flow totalizer.

TABLE 12 (continued).

Station		Date			Streamflow (liters)
No. 2 Lagoon Road	1979	11/26	-	12/3	6.43×10^5
		12/3	-	12/10	9.54×10^5
		12/10	-	12/17	3.56×10^5
No. 4 Swamp	1978	9/18	-	10/9	1.14×10^5
		10/9	-	10/16	2.04×10^5
		10/16	-	10/23*	4.6×10^4
		10/23	-	10/31*	1.6×10^5
		10/31	-	11/6*	C
		11/6	-	11/13*	0
		11/13	-	11/20*	5.0×10^3
		11/20	-	11/27*	4.9×10^4
		11/27	-	12/8*	2.0×10^5
	1979	4/1	-	4/7*	1.1×10^5
		4/8	-	4/14*	4.2×10^5
		4/15	-	4/25*	3.4×10^4
		4/26	-	4/30	0
		4/30	-	5/7	0
		5/7	-	5/15	2.5×10^5
		5/15	-	5/21	0
		5/21	-	5/28	3.03×10^4
		5/28	-	6/4	6.06×10^4
		6/4	-	6/11	4.0×10^3
		6/11	-	6/19	2.0×10^3
		6/19	-	6/25*	7.2×10^3
		6/25	-	7/2*	2.4×10^3
		7/2	-	7/9	0
		7/9	-	7/16	7.5×10^3
		7/16	-	7/24	0
		7/24	-	7/30	0
		7/30	-	8/6	3.79×10^3
		8/6	-	8/13	0
		8/13	-	8/20	0
		8/20	-	8/27	1.14×10^4
		8/27	-	9/6	1.29×10^5
		9/6	-	9/10	3.79×10^3
		9/10	-	9/17	4.92×10^5
		9/17	-	9/24	0
		9/24	-	11/15	No data
		11/16	-	11/19	0
		11/19	-	11/26	1.14×10^5
		11/26	-	12/3	1.14×10^4
		12/3	-	12/10	4.16×10^4
		12/10	-	12/17	0

*Calculated from mean daily discharge. All others calculated from digital flow totalizer.

APPENDIX B

RADIOCHEMICAL ANALYSES OF SURFACE WATER AND SEDIMENT SAMPLES COLLECTED AT WEST VALLEY, NEW YORK

TABLE 13. Radiochemical analyses of Surface Water and Sediment Samples Collected 1/24/78 - 9/24/79.

I. Flow-proportioned Weekly Composite Samples:

Station	Collection Date	Total α (p Ci/l)	Total β (p Ci/l)	$^{3}H_{HO}$ (p Ci/l)
#2 Lagoon Road	7/24/78-8/1/78	<40	870 ± 12%	3500 ±29%
	8/7 -8/14	110 ± 74%	570 ± 15%	29400 ± 6%
	8/14 -8/21	320 ± 53%	1320 ± 10%	38000 ± 5%
	8/21 -8/29	<50	1730 ± 8%	88000 ± 4%
	8/29 -9/4	140 ± 64%	1700 ± 8%	37000 ± 7%
	9/4 -9/11	<40	2200 ± 7%	78000 ± 5%
	9/11 -9/18	110 ± 61%	730 ± 13%	9000 ±22%
	9/18 -10/9	<30	560 ± 14%	13000 ±16%
	4/30/79-5/7/79	<40	1410 ± 9%	37200 ± 5%
	5/7 -5/15	<50	1180 ± 10%	13400 ± 7%
	5/15 -5/21	<40	1620 ± 9%	34000 ± 5%
	5/21 -5/28	<40	800 ± 13%	11100 ± 8%
	5/28 -6/4	<30	1210 ± 10%	25000 ± 8%
	6/4 -6/11	<40	1260 ± 10%	18600 ± 9%
	6/11 -6/18	<30	1300 ± 9%	27000 ± 7%
	6/18 -6/25	<30	1250 ± 10%	13800 ±12%
	6/25 -7/2	<20	1140 ± 10%	8000 ±12%
	7/2 -7/9	<17	1060 ± 11%	9600 ±11%
	7/9 -7/16	60 ± 83%	960 ± 12%	4200 ±22%
	7/16 -7/24	<20	1170 ± 10%	15400 ± 8%
	7/24 -7/30	<30	1030 ± 11%	6700 ±12%
	7/30 -8/6	<30	1120 ± 10%	3500 ±20%
	8/6 -8/13	<40	1320 ± 9%	4300 ±17%
	8/13 -8/20	<20	660 ± 13%	3800 ±19%
	8/20 -8/27	60 ± 93%	760 ± 12%	1820 ±10%
	8/27 -9/6	<50	830 ± 12%	4600 ± 6%
	9/6 -9/10	<40	950 ± 11%	7200 ±14%
	9/10 -9/17	<40	300 ± 21%	3700 ± 7%
	9/17 -9/24	<40	1320 ± 9%	19500 ± 7%
	11/16 -11/19	<40	1980 ± 8%	23800 ± 6%
	11/19 -11/26	<14	910 ± 11%	10600 ±10%
	11/26 -12/3	<13	700 ± 13%	10300 ±10%
	12/3 -12/10	<12	520 ± 15%	6400 ± 5%
	12/10 -12/17	<20	800 ± 12%	9900 ±11%
#3 Bucket	7/17/78-7/24/78	190 ± 53%	1880 ± 8%	880 ±15%
	7/24 -8/1	90 ± 70%	1220 ± 10%	17800 ± 4%
	8/7 -8/14	700 ± 56%	1900 ± 17%	1980 ± 8%
	8/14 -8/21	800 ± 46%	1200 ± 16%	500 ±24%
#4 Swamp	5/8/78 -5/15/78	<4	47 ± 12%	1700 ±20%
	5/15 -5/22 .	8 ± 82%	47 ± 12%	1600 ±22%
	5/22 -5/30	<3	47 ± 14%	2100 ±17%
	6/5 -6/12	<6	38 ± 40%	2300 ±15%
	6/12 -6/19	<3	30 ± 29%	1100 ±31%

TABLE 13 (continued).

Station	Collection Date	Total α (p Ci/l)	Total β (p Ci/l)	^{3}HHO (p Ci/l)
#4 Swamp (continued)	6/19/78-6/26/78	<4	42 ± 30%	1200 ± 28%
	8/7 -8/14	100 ± 64%	200 ± 34%	460 ± 28%
	8/14 -8/21	1900 ± 52%	1500 ± 26%	<130
	8/29 -9/4	20 ± 76%	97 ± 18%	380 ± 37%
	9/4 -9/11	<4	71 ± 16%	570 ± 25%
	9/11 -9/18	<30	100 ± 35%	220 ± 62%
	9/18 -10/9	<5	44 ± 32%	340 ± 40%
	5/7/79-5/15/79	<9	4 ± 78%	370 ± 41%
	5/21 -5/28	<4	28 ± 19%	380 ± 40%
	5/28 -6/4	<3	27 ± 19%	<300
	6/4 -6/11	<4	24 ± 28%	<300
	7/9 -7/16	<2	23 ± 29%	500 ± 69%
	7/30 -8/6	<4	25 ± 37%	300 ± 51%
	8/20 -8/27	<1.8	23 ± 19%	300 ± 51%
	8/27 -9/6	<1.6	25 ± 15%	330 ± 39%
	9/6 -9/10	<5	26 ± 46%	<500
	9/10 -9/17	<1	9 ± 30%	186 ± 69%
	11/19 -11/26	<1.7	16 ± 32%	480 ± 27%

II. Frank's Creek Daily Grab Samples, Composited:

Collection Dates	Total α (p Ci/l)	Total β (p Ci/l)	^{3}HHO (p Ci/l)
4/25/78-4/30/78	<1.6	7 ± 44%	<400
5/1 - 5/7	<2	6 ± 48%	<400
5/8 - 5/14	<2	7 ± 46%	400 ± 79%
5/15 - 5/21	<1.8	7 ± 55%	<400
5/24 - 5/29	<2	9 ± 37%	400 ± 77%
5/30 - 6/4	<3	5 ± 60%	400 ± 76%
6/5 - 6/11	<3	11 ± 30%	400 ± 94%
6/12 - 6/18	<2	13 ± 27%	400 ± 82%
4/26/79-4/30/79	<1.5	10 ± 30%	210 ± 71%
5/1 - 5/7	<3	6.0± 48%	<180
5/8 - 5/14	<1.5	8.0± 35%	<180
5/15 - 5/22	<1.6	8.0± 35%	<180
5/23 - 5/27	<1.9	6.0± 38%	<300
5/28 - 6/3	<1.7	6.0± 39%	<300
6/4 - 6/10	<2	8.0± 32%	<300
6/11 - 6/17	<3	13 ± 23%	<300
6/18 - 6/24	<2	16 ± 20%	800 ± 50%
6/25 - 7/1	<2	19 ± 25%	700 ± 53%
7/2 - 7/8	<2	11 ± 39%	500 ± 75%
7/9 - 7/15	<2	17 ± 27%	500 ± 72%
7/16 - 7/22	<1.9	16 ± 18%	190 ± 72%

TABLE 13 (continued).

II. Daily Grab Samples, Composited-Continued:

Collection Dates	Total α (p Ci/l)	Total β (p Ci/l)	^{3}HHO (p Ci/l)
7/23 - 7/29/79	<2	21 ± 16%	180 ± 80%
7/30 - 8/5	<2	20 ± 21%	150 ± 86%
8/6 - 8/12	<2	21 ± 16%	220 ± 58%
8/13 - 8/19	<2	17 ± 18%	220 ± 59%
8/20 - 8/26	7.0 ± 84%	24 ± 18%	380 ± 35%
8/27 - 9/2	<1.7	20 ± 17%	190 ± 65%
9/3 - 9/9	<1.5	13 ± 24%	310 ± 42%
9/10 - 9/13	<1.2	6.0 ± 41%	190 ± 66%
9/16 - 9/23	<1.2	9.0 ± 31%	200 ± 65%
9/24 - 9/26	<1.2	9.0 ± 29%	260 ± 52%

III. Weekly Low Flow Grab Samples:

Station	Collection Date	Total α (p Ci/l)	Total β (p Ci/l)	^{3}HHO (p Ci/l)
#1 Frank's Creek	5/15/78	<1.3	14 ± 21%	800 ± 41%
	5/22	<1.4	7 ± 34%	700 ± 47%
	5/30	<1.9	8 ± 32%	600 ± 57%
	6/5	<3	13 ± 26%	800 ± 42%
	6/12	<5	22 ± 23%	900 ± 38%
	6/20	<3	12 ± 28%	500 ± 58%
	6/26	14 ± 80%	24 ± 29%	900 ± 36%
	5/1/79	<1.5	5.0 ± 46%	480 ± 32%
	5/7	<1.6	5.0 ± 47%	400 ± 38%
	5/15	<1.5	8.0 ± 32%	320 ± 48%
	5/21	<1.7	4.0 ± 57%	410 ± 37%
	5/28	<1.7	7.0 ± 38%	210 ± 72%
	6/4	<2	8.0 ± 33%	500 ± 60%
	6/11	<2	1.0 ± 26%	<300
	7/2	<1.6	12 ± 28%	900 ± 45%
	8/6	<3.0	19 ± 18%	<200
	9/7	<1.5	12 ± 25%	<120
	9/17	<1	6.0 ± 43%	140 ± 90%
	9/24	<1.1	900 ± 31%	220 ± 58%

TABLE 13 (continued).

III. Weekly Low Flow Grab Samples: (continued)

Station	Collection Date	Total α (p Ci/l)	Total β (p Ci/l)	$^{3}H_{HO}$ (p Ci/l)
#2 Lagoon Road	5/1/78	<6	1210 ± 4%	78000 ± 3%
	5/8	<7	1210 ± 4%	59000 ± 3%
	5/15	<4	820 ± 4%	43700 ± 4%
	5/22	<6	1280 ± 4%	51700 ± 3%
	5/30	<4	870 ± 4%	77000 ± 3%
	6/5	<3	790 ± 4%	68000 ± 3%
	6/12	<4	1230 ± 4%	19000 ± 4%
	6/20	<4	1050 ± 4%	11700 ± 5%
	6/26	<4	1690 ± 4%	15400 ± 5%
	5/1/79	<40	1550 ± 9%	34300 ± 5%
	5/9	<40	1790 ± 8%	46000 ± 4%
	5/15	<11	88 ±22%	32400 ± 5%
	5/21	<40	890 ±12%	6500 ±12%
	5/28	<30	1230 ±10%	23400 ± 6%
	6/4	<30	1740 ± 8%	47000 ± 6%
	6/11	<30	1170 ±10%	16100 ±11%
	6/18	<30	1470 ± 9%	38000 ± 6%
	6/25	<30	970 ±11%	12400 ±13%
	7/3	<18	1140 ±10%	11500 ± 9%
	7/9	<16	930 ±11%	14700 ± 8%
	7/16	<16	1170 ±10%	16300 ± 7%
	7/24	<16	910 ±12%	14400 ± 8%
	8/6	<20	740 ±12%	9400 ± 9%
	8/20	<20	650 ±13%	6900 ±12%
	9/7	<30	1300 ± 9%	12600 ± 9%
	9/17	<30	1290 ± 9%	27100 ± 6%
	9/24	<20	1220 ±10%	32300 ± 5%
#4 Swamp	5/15/78	<3	27 ±16%	1900 ±21%
	5/22	<3	34 ±14%	1600 ±23%

TABLE 13 (continued).

IV. Storm and Miscellaneous Grab Samples:

Station	Collection Date	Total α (p Ci/l)	Total β (p Ci/l)	$^{3}H_{HO}$ (p Ci/l)
#1 Frank's Creek	1/24/78*	<1.9	5 ± 59%	700 ± 49%
	2/13 *	<1.8	8 ± 36%	<400
	2/20 *	<1.9	5 ± 52%	<400
	2/28 *	<1.9	6 ± 51%	500 ± 61%
	3/9 *	<1.9	6 ± 46%	<400
	3/13 *	<1.8	7 ± 44%	700 ± 47%
	3/14 *	<1.9	8 ± 46%	400 ± 84%
	4/3 *	<1.6	6 ± 44%	280 ± 89%
	5/5 +	<2	9 ± 39%	600 ± 60%
	5/9 +	<3	13 ± 33%	500 ± 70%
	9/14/79 0910 hr.+	<3	16 ± 31%	560 ± 24%
	1215 hr.	<2	13 ± 20%	140 ± 90%
	1405 hr.	<1.4	80 ± 26%	<120
	1530 hr.	<1.2	7.0 ± 29%	<120
	9/15 +	<1.3	7.0 ± 29%	150 ± 83%
#2 Lagoon Road	1/24/78*	<1.9	5.0 ± 59%	700 ± 49%
	3/3 +	<5	730 ± 5%	61000 ± 3%
	3/14 *	<2	130 ± 8%	8100 ± 6%
	5/5 +	18 ± 83%	590 ± 6%	6400 ± 7%
	6/21 +	<40	1070 ± 11%	1300 ± 25%
	9/14/79+ 0900 hrs.	80 ± 70%	300 ± 24%	1800 ± 11%
	1200 hrs.	70 ± 75%	280 ± 26%	1290 ± 15%
	1355 hrs.	<20	180 ± 35%	2500 ± 9%
	1700 hrs.	<20	260 ± 27%	5800 ± 14%
	9/15+	<19	730 ± 13%	10200 ± 9%
	11/28/79 +	<13	470 ± 16%	
	12/17/79 *	<20	1770 ± 8%	
#3 Bucket	1/25/78 *	<4	107 ± 9%	3700 ± 11%
	3/13 *	50 ± 78%	2200 ± 5%	4000 ± 10%
	3/14 *	<20	200 ± 17%	3700 ± 11%
	5/9 +	<18	600 ± 9%	10300 ± 5%
#4 Swamp	3/14/78 +	<3	26 ± 19%	1600 ± 22%
	4/3 +	<3	22 ± 19%	1300 ± 21%
	5/9 +	<4	41 ± 16%	1400 ± 21%
	9/14/79+ 0903 hrs.	<1.3	6.3 ± 31%	280 ± 47%
	1205 hrs.	<1.3	6.3 ± 31%	190 ± 67%
	1400 hrs.	<1.2	6.3 ± 31%	320 ± 41%
	1655 hrs.	<1.3	9.0 ± 24%	210 ± 58%
	11/20/79 T	<1.9	27 ± 23%	620 ± 22%
	12/14/79 T	<2	19 ± 17%	

* Sub-ice flow grab
\+ Storm runoff grab
T Subsurface flow grab

TABLE 13 (continued).

V. Background Grab Samples:

Station	Collection Date	Total α (p Ci/l)	Total β (p Ci/l)	^{3}HHO (p Ci/l)
Buttermilk Creek	5/18/78	<2	<3	500 ± 69%
	5/25	<1.8	<2	400 ± 94%
	5/31	<1.9	<2	<400
	6/7	<2	<2	500 ± 69%
	6/15	<2	<2	<400
	6/22	<2	9 ± 84%	<400
	6/27	<2	<2	<400
	5/4/79	<1.7	<2	<150
	6/1	<2	3 ± 79%	<300
	6/7	<2	3 ± 75%	<300
	8/10	<1.4	2.4± 67%	<160
	9/19	9 ± 68%	14 ± 22%	210 ± 59%
Connoisarauley Creek	5/18/78	<2	6 ± 47%	<200
	5/25	<2	<2	<400
	5/31	<3	<2	<400
	6/7	<3	<2	<400
	6/15	<2	<2	500 ± 75%
	6/22	<2	<2	500 ± 69%
	6/27	<2	3 ± 93%	<400
	5/4/79	<2	<2	240 ± 61%
	6/1	<2	<2	<300
	6/7	<2	3 ± 70%	<300
	8/10	<1.6	2.5± 66%	250 ± 58%
	9/19	<2	7	180 ± 68%

VI. Sediment Grab Samples:

Station	Collection Date	Total α (p Ci/g)	Total β (p Ci/g)
#1 Frank's Creek	5/4/79	19.0 ± 64%	29.0 ± 24%
	6/7/79	33.0 ± 50%	37.0 ± 19%
	8/7/79	33.0 ± 46%	32.0 ± 23%
#2 Lagoon Road	5/4/79	19.0 ± 66%	102.0 ± 11%
	6/7/79	26.0 ± 55%	120.0 ± 11%
	8/7/79	30.0 ± 51%	109.0 ± 11%

TABLE 14 Radionuclide Concentrations(p Ci/l) in Surface Water.
(all samples collected at Lagoon Road)

Collection Date	Total Alpha	Total Beta	^{3}HHO	C-14 Inorganic	C-14 Organic	Na-22	Fe-55	Co-60	Ni-63	Sr-90	I-129
5/1/78 *	<50	1120 ± 4%	86000 ±3%	3.6 ±32%	2.8 ±16%	<19	--	<19	<8	--	--
5/1/78 +	< 6	1210 ± 4%	78000 ±3%	8.8 ±23%	<0.5	<50	<4	<60	6.0 ± 56%	780 ±5%	--
5/8/78 *	<70	1160 ± 4%	42000 ±4%	<1	3.6 ± 8%	<17	<2	<19	<3	--	--
5/8/78 +	< 7	1210 ± 4%	59000 ±3%	103.0± 7%	4.9 ±18%	<50	<4	<60	10.0 ± 34%	610 ±6%	--
5/30/78 *	<40	1560 ± 6%	69000 ±3%	<7	15.0 ±22%	<50	<6	<50	<10	--	--
5/1/79 +	<40	1550 ± 9%	34300 ±5%	<3	<1.7	<4	<20	<3	7.0 ± 66%	1040 ±3%	<3
5/7/79 *	<40	1410 ± 9%	37200 ±5%	<0.9	6.3 ±24%	<8	<20	8.0 ±60%	7.0 ± 70%	1060 ±3%	<3
5/7/79 +	<40	1790 ± 8%	46000 ±4%	2.2±44%	4.0 ±12%	<4	<16	<3	7.0 ± 69%	1080 ±3%	<3
5/21/79 *	<40	1620 ± 9%	34000 ±5%	10.0±33%	1.6 ±76%	<3	<40	<2	<5	850 ±3%	<5
6/4/79 +	<30	1740 ± 8%	47000 ±6%	2.0±33%	3.0 ±14%	<4	<19	<3	<5	910 ±3%	<2
6/18/79 +	<30	1470 ± 9%	38000 ±6%	1.0±82%	2.2 ±60%	<4	<13	<3	6.0 ± 67%	850 ±3%	<2
9/17/79 +	<30	1290 ± 9%	27100 ±6%	1.6±80%	7.0 ± 9%	<3	<17	<2	‡	650 ±3%	<2
9/24/79 *	<40	1320 ± 9%	19500 ±7%	<1.5	3.0 ±33%	<3	<40	<4	6.0 ± 85%	630 ±3%	<1.6

* Composite
\+ Low Flow Grab
‡ Not yet reported

TABLE 14 Radionuclide Concentrations (p Ci/l) in Surface Water. (Continued)
(all samples collected at Lagoon Road)

Collection Date	Ba-133	Cs-134	Cs-137	U-234	U-235	U-238	Pu-238	Pu-239, 240	Am-241	Cm-244
5/1/78 *	<30	<20	<19	--	--	--	<0.14	<0.2	--	--
5/1/78 +	<70	<50	<50	--	--	--	<2	<0.07	--	--
5/8/78 *	<20	<19	<19	--	--	--	<0.17	<0.04	--	--
5/8/78 +	<80	<60	<50	--	--	--	11.2 ± 9%	0.03 ±88%	--	--
5/30/78 *	<60	<50	<40	--	--	--	<6	<1.2	--	--
5/1/79 +	<4	<3	<3	--	--	2.9 ±20%	<5	<5	<0.2	<0.06
5/7/79 *	<8	<7	1.3 ±62%	2.7±22%	0.11±92%	2.1 ±23%	<0.015	<0.015	0.34 ±57%	<0.04
5/7/79 +	<4	<3	2.0 ±67%	3.0±27%	<0.04	2.7 ±28%	<0.2	<0.3	<0.2	<0.06
5/21/79 *	<3	<3	4.0 ±50%	3.4±19%	0.12±81%	2.7 ±20%	0.3 ±82%	<0.03	‡	‡
6/4/79	<4	<3	<3	2.4±30%	0.26±82%	1.7 ±39%	<0.4	<0.5	<0.1	<0.04
6/18/79 +	<4	<3	<3	2.5±21%	<0.014	2.1 ±23%	<0.07	<0.07	‡	‡
9/17/79 +	<3	<2	<3	2.4±29%	<0.02	2.2 ±30%	<0.9	<0.9	‡	‡
9/24/79 *	<4	<3	13.0 ±38%	‡	‡	‡	2.1 ±77%	<0.03	1.2 ±40%	<0.04

* Composite
+ Low Flow Grab
‡ Not yet reported

TABLE 15. Radiochemical Analyses of Barnstead Cation-Anion Mixed Bed Ion Exchange Column Resins

Station/Sample Description	Collection Date	Filtrate Volume (l)	Cs-134 (μCi/kg)	Cs-137 (μCi/kg)	Ru-106 (μCi/kg)	Zr-95 (μCi/kg)	Co-60 (μCi/kg)	Ba-133 (μCi/kg)	Na-22 (μCi/kg)
No. 1 Low flow grabs	8/15/77-9/24/79	61.69	--	<6	<20	<12	--	--	--
No. 2 Low flow grabs	8/15/77-9/24/79	85.26	$<3\times10^{-6}$	$<1.3\times10^{-5}$	$<1.4\times10^{-4}$	$<6\times10^{-5}$	$<3\times10^{-6}$	$<3\times10^{-6}$	$<3\times10^{-6}$
No. 4 Low flow grabs	8/15/77-9/18/78	13.31	--	<7	<30	<13	--	--	--
Buttermilk Creek at Fox Valley Rd. Background grab	8/15/77-9/19/79	59.61	--	<7	<20	<10	--	--	--
Connoisarauley Creek at Connoisarauley Rd. Back	8/14/77-9/19/79	59.09	--	<7	<30	<11	--	--	--

APPENDIX C

RADIOCHEMICAL ANALYSES FOR WATER AND SOIL SAMPLES

Because of the small size of the samples analyzed, many of the water and soil samples were done in sequence on the same aliquot. For example, isotopic uranium, isotopic plutonium, and iron-55 were all done from the same aliquot. All analyses were done by the Radiological Sciences Laboratory, N.Y. State Department of Health, Albany, New York.

Total Alpha/Beta Analysis--An aliquot of a water sample was evaporated to dryness and the residue was quantitatively transferred to a planchet . An aliquot of soil or sediment sample was mixed with distilled water and a portion of the mixture was evaporated to dryness in a planchet . Sediment samples collected on filters were placed directly onto the planchet Not more than 100 mg. of sample residue can be measured for total alpha/beta.

The sample planchets were counted on a gas flow proportional counter. The sample planchets were counted first on the alpha/beta plateau then on the alpha plateau.

The method is only adequate for screening purposes. Loss of volatile radionuclides such as radioiodine, tritium, and carbon-14 is one problem. Another drawback is the difficulty in radiometric standardization for a mixture of unknown alpha and beta emitters.

The radionuclides used as standards in the laboratory are:

for total beta - $^{90}Sr^{90}Y$
for total alpha - natural uranium.

Analysis of Tritium as ^{3}HHO--Samples were vacuum distilled and the distillate collected to separate tritium from other interfering radionuclides and to remove chemical and/or physical quenching agents. An aliquot of the distillate was mixed with an organic scintillator and counted in a liquid scintillation spectrometer. Water known to be of low tritium content was used as a background sample.

The degree of quenching in a sample was determined by external standardization. The quench factor obtained was used to determine the counting efficiency for calculation of the tritium activity in the sample. Analysis of a 10 ml aliquot of the distillate resulted in a sensitivity of approximately 500 p Ci/l.

The Radiological Sciences Laboratory has three levels of tritium detection: 2×10^{-6} µCi/ml is the standard analysis limit of detection; a 2×10^{-7} µCi/ml limit of detection can be obtained only if ten times more sample is available; a 2×10^{-8} µCi/ml limit of detection is a much more expensive process involving enrichment of the sample. In these studies the enriched tritium technique was considered too expensive for the additional benefit derived.

Analysis of Dissolved Organic Tritium--In this procedure it is necessary to separate the inorganic tritium (^3HHO and metal hydroxides) from the organic material. Fifty ml of filtered, anoxic trench water was aerated and filtered to remove metal hydroxides such as $Fe(OH)_3$. The filtered water was then acidified to pH 1 with HCl. The acidified trench water was lyophylized, redissolved in low-tritium, double-distilled water and lyophylized a second time. The residue was dissolved in 50 ml of low-tritium, double-distilled water and 10 ml were taken for liquid scintillation measurement of the dissolved organic tritium. The interference from carbon-14 in the dissolved organic material was relatively small and could be corrected for.

Analysis of Suspended Organic Tritium--Approximately 3.5 liters of trench water was anoxically filtered using a glass fiber filter. The filter was dried. The weight of material reclaimed by the filter, however, could not be determined. A portion of the filter was combusted using a wet combustion procedure to oxidize the carbon to CO_2 and the hydrogen to H_2O. The CO_2 was purged from the combustion mixture and 10 ml of water was removed by distillation. The tritium in the distilled water was then measured using liquid scintillation counting.

Isotopic-Plutonium Analysis--^{242}Pu was added to an aliquot of the samples to determine the chemical and electrodeposition recovery. The samples were evaporated to dryness and the residue was dissolved in 7.2 $\underline{N}$ HNO_3. Soil samples were fused. Silicates were removed and the sample was dissolved in 7.2 $\underline{N}$ HNO_3.

Plutonium was oxidized to the (IV) valence state with sodium nitrite and the plutonium nitrate complex formed in the strong nitric acid solution was adsorbed on an anion exchange column. The column was washed with HNO_3 and HCl solutions, then the plutonium was eluted with a 0.36 $\underline{N}$ HCl 0.01 $\underline{N}$ HF solution. Plutonium was electrodeposited from an ammonium sulphate solution onto a stainless steel disc.

The electroplated disc samples were counted on an alphaspectrometry system using a 450 mm^2 silicon surface barrier detector. The systems amplifier was biased to cover an energy range of about 4 MeV to 6 MeV.

The net cpm in each region were calculated and the values corrected for interference from higher energy alpha peaks, if necessary. The ^{238}Pu and the $^{239,240}Pu$ activity levels were then calculated by applying the appropriate chemical recovery and counting efficiency factors.

Isotopic-Uranium Analysis--^{232}U was added as a tracer to determine the chemical and electrodeposition recovery. Water samples were evaporated to dryness and the residue was dissolved in 7.2 N HNO_3. Soil samples were fused. Silicates were removed and the sample was dissolved in 7.2 N HNO_3.

Uranium and plutonium were oxidized to the (IV) valence state with sodium nitrite. The plutonium nitrate complex formed in the strong nitric acid solution was removed on an anion exchange column. The effluent was evaporated to dryness, taken up in 9 N HCl and the uranium chloride complex adsorbed on an anion-exchange column. Iron was removed from the column with a solution of 9 N HCl - 0.25 M NH_4I. The uranium was then eluted with 1.2 N HCl and electroplated onto a stainless steel disc from an ammonium sulphate solution.

The electroplated disc samples were counted on an alpha spectrometry system using a 450 mm^2 silicon surface barrier detector. The system's amplifier was biased to cover an energy range of about 4 MeV to 6 MeV.

The net cpm in each region were calculated and the values corrected for interference from higher energy alpha peaks, if necessary. The ^{235}U and ^{238}U activity levels were then calculated by applying the appropriate chemical recovery and counting efficiency factors.

^{241}Am Analysis--^{243}Am was added to an aliquot of the sample to determine the chemical and electrodeposition recovery. Water samples were evaporated to dryness and the residue was dissolved in 7.2 N HNO_3. Soil samples were fused. Silicates were removed and the sample was dissolved in 7.2 N HNO_3.

Uranium and plutonium were oxidized to the (IV) valence state with sodium nitrite. The plutonium nitrate complex formed in the strong nitric acid solution was removed on an anion-exchange column. The effluent was evaporated to dryness, taken up in 9 N HCl and the uranium chloride complex adsorbed on an anion exchange column. The effluent was collected for separation of americium. Iron was removed from the column with a solution of 9 N HCl - 0.25 M NH_4I, and the solution was combined with the effluent just previous to being used for the americium separation. The combined solution was evaporated to dryness and iodine was oxidized with HNO_3. The residue was dissolved in 0.5 N HCl. Americium is then separated from the alkaline earths and iron by successive AG50W-X4 cation exchange columns in 0.5 N HCL. The americium is further purified by an AG1-X2, 1 M HNO_3 - 90% CH_3OH ion exchange system.

The final eluent was taken to dryness and the americium was electroplated from an ammonium sulphate solution onto a stainless steel disc.

The electroplated disc samples were counted on an alpha-spectrometry system using a 450 mm^2 silicon surface-barrier detector. The system's amplifier was biased to cover an energy range of about 4 MeV to 6 MeV.

The net cpm in each region was calculated. The ^{241}Am activity was then calculated applying the appropriate chemical recovery and counting efficiency factors.

Isotopic Gamma Analysis--The liquid or solid samples, in a standardized geometry, were analyzed with a Ge(Li) detector system. The system utilized a 4096-channel analyzer with an energy calibration of 0.5 keV/channel.

The activity of each gamma-emitting radionuclide in the sample was determined by using the efficiency factor for the photopeak of the isotope. The efficiency was obtained from a gamma ray efficiency curve, prepared by measuring selected standards, in the standardized geometry, and using their known gamma ray intensities to determine photon efficiencies. Gamma emitters analyzed include ^{232}Th, ^{106}Ru, ^{60}Co, ^{54}Mn, ^{40}K, and ^{22}Na.

^{63}Ni Analysis--Nickel was isolated from water samples by forming nickel dimethylglyoximate which was extracted into chloroform. Nickel carrier, measured spectrophotometrically, was used to determine the chemical recovery. The nickel dimethylglyoximate was decolorized with hydrochloric acid and the 67-keV beta of ^{63}Ni counted on a liquid scintillation spectrometer.

^{55}Fe Analysis--If the iron content of the sample was low, then stable iron was added as a carrier to determine chemical recovery. If the iron concentration in the sample was sufficient, the iron originally present was used to determine the chemical recovery. Water samples were evaporated to dryness and the residue dissolved in a 50% acetone-water solution.

The sample was then passed through a chromatographic column containing AG50W-X8 cation-exchange resin which has been equilibrated with 50% acetone-water solution. The Fe (III) was eluted with 80% acetone - 0.5 M HCl solution. The iron was electrodeposited from a $NH_4H_2PO_4$-$(NH_4)_2CO_3$ solution onto

a polished copper disc, and the 5.9 keV x-ray was then measured with an intrinsic-germanium detector.

^{90}Sr Analysis--^{85}Sr tracer and stable strontium were added to the sample. The ^{85}Sr tracer was used to radiometrically determine the chemical recovery of strontium, while the stable strontium provided a carrier. Water samples were acid digested and the strontium precipitated as the carbonate. Soil samples were fused, silicates and iron were removed, and the strontium was precipitated as the oxalate then converted to the oxide.

The carbonate or the oxide from the sample pretreatment was dissolved in nitric acid. The rare earths, ruthenium and any remaining calcium were removed by precipitation of strontium nitrate from concentrated HNO_3. Yttrium carrier was added. The chemical recovery of strontium was determined by gamma counting the ^{85}Sr tracer using a NaI detector. The sample was set aside 10-14 days for ^{90}Y ingrowth.

At the end of the ingrowth period, yttrium was precipitated as the hydroxide, purified by repeated extractions into TBP and back-extractions into water. Yttrium was collected as the hydroxide, reprecipitated as the oxalate, converted to the oxide, and mounted on a filter-paper disc. The yttrium recovery was determined gravimetrically. The yttrium oxide was mounted on a nylon planchet and counted in an end-window, gas-flow proportional counter.

Three or more measurements, beginning immediately after the chemical separation of yttrium from strontium and continuing at approximately two-day intervals, were made on the ^{90}Y fraction in order to follow its decay. A computer program, using the half-life of ^{90}Y as a known, performed a least-squares-fit to the counting data to calculate the ^{90}Sr activity.

^{134}Cs and ^{137}Cs Analysis by Counting Cesium Chloroplatinate--Cesium carrier is added to the sample to determine gravimetrically the chemical recovery. Soil samples are fused and the melt dissolved in water.

Water samples or the solution from fused samples are adjusted to pH 1 using hydrochloric acid. AMP is added to adsorb cesium and remove it from solution. The cesium loaded AMP is dissolved in NH_4OH and reprecipitated using HNO_3. The cesium, collected from the sample on the AMP, is purified by cation exchange. The cesium is precipitated as cesium chloroplatinate, Cs_2PtCl_6.

^{134}Cs is determined by β/γ coincidence counting of the precipitate. ^{137}Cs is determined by β counting the precipitate and subtracting the ^{134}Cs contribution.

.--^{14}C Analysis. Water and soil samples were analyzed for inorganic and total (inorganic + organic) ^{14}C activity.

To measure the inorganic ^{14}C activity in water, the sample is placed in a flask and sodium carbonate carrier is added. The flask is then attached to a gas flow system and helium is bubbled through the sample. Hydrochloric or phosphoric acid is added to the sample and the carbon in the form of carbonate is evolved as CO_2. The CO_2 is carried with the helium through a liquid nitrogen cold trap which retains the CO_2. The CO_2 is then passed through a chromatograph for purification and the ^{14}C activity is measured using internal gas proportional counting tubes.

To measure the total ^{14}C activity in a water sample potassium hydrogen phthalate carrier is added and potassium persulfate is added as an oxidizing agent. The sample with carrier and oxidizer is attached to the gas flow system, helium is bubbled through the sample and phosphoric acid is added. The sample is then heated to boiling and the evolved CO_2 is trapped, purified, and the ^{14}C activity measured as described above.

Carrier, either inorganic or organic, is not added to samples containing carbon sufficient to produce more than about 5 cc of CO_2.

Soil samples are treated in a similar manner. Several grams of finely ground soil are placed in a flask containing about 100 ml of distilled water. To measure the inorganic ^{14}C activity the soil-water mixture is placed in the gas flow system, helium is bubbled through the mixture and hydrochloric acid is added. The evolved CO_2 is trapped, purified and the ^{14}C activity measured as described for the water analysis.

To measure the total ^{14}C activity in a soil sample potassium dichromate is added to the soil-water mixture and the flask is attached to the gas flow system. Helium is bubbled through the sample and a digestion mixture of concentrated sulfuric acid and phosphoric acid is added. The sample mixture is then heated to boiling and the evolved CO_2 is trapped, purified and the ^{14}C activity measured as described previously.

.--^{129}I Analysis. Stable iodine carrier was added to the sample to determine the chemical recovery. Samples were treated to convert all iodine in the sample to a common oxidation state prior to chemical separation and purification.

Water samples were taken through an oxidation-reduction step using hydroxylamine hydrochloride and sodium bisulfite to convert all iodine to iodide form suitable for processing through an anion exchange column.

Iodine, as the iodide, was concentrated by adsorption on an anion exchange column. Following a NaCl wash, the iodine was eluted with sodium hypochlorite. Iodine, as iodate, was reduced to elemental iodine for extraction into CCl_4. The iodine was reduced to iodide for back-extraction into water and finally precipitation as palladium iodide.

Chemical recovery of the added carrier was determined gravimetrically.

The PdI_2 precipitate was counted on an intrinsic-germanium detector and the intensities of the Kα X-rays from the ^{129}Xe measured. The detector is standardized for ^{129}I as a function of the weight of the PdI_2 precipitate. The Kα X-rays at 29.7 and 29.4 keV for ^{129}Xe are used.

The counts in the ^{129}I region were summed. The net counting rate was computed. The appropriate decay, volume, counting efficiency and chemical recovery corrections were then applied to compute the ^{129}I activity.

.--Analysis of Stable Iodine.

Spectrophotometric Method- To determine the chemical recovery, ^{131}I tracer is added to the sample. After pH adjustment and filtering, all of the iodine present is converted to a common oxidation state. The iodine is separated from the sample by anion exchange, and is purified by solvent extraction into carbon tetrachloride. The iodine is back extracted, reduced to I_2 and then extracted into toluene. An aliquot of the final toluene extract is gamma counted to measure the ^{131}I tracer which yields the chemical recovery. Using a Beckman Spectrophotometer and the remainder of the final toluene extract, the absorbance at 500 nm is measured. The stable iodine concentration is calculated and corrected for chemical losses, and reported as mg per unit volume.

Specific Ion Electrode Method- Iodide ion was measured by the standard addition, using an Orion 94-53A iodide electrode, an Orion 90-01 single junction reference electrode and a Beckman pHasar I (pH) meter. Samples were made in 0.1M $NaNO_3$. Because the sample was collected from a reducing environment and readings were unstable, the sample from Research Trench II was made in

0.01 M $NaHSO_3$. Results were obtained by solving the equation:

$$\{I\} = \frac{V_{std} \quad \{I_{std}\}}{(V_{sample} + V_{std}) \ (\text{Inv. log } \frac{\Delta E}{10}) - V_{sample}}$$

where V_{std} = Volume of Standard
V_{sample} = Volume of Sample
ΔE = Change in the potential charge.

By using the specific iodide ion electrode mentioned above, the iodine concentration of the sample was determined.

APPENDIX D

RESEARCH TRENCH AND TRENCH CAP SAMPLING DATA

SAMPLES COLLECTED AUGUST 15, 1979
FROM RESEARCH TRENCH III

Research trench III is approximately 23 meters x 39 meters, major axis oriented NW - SE. Original excavation depth 13+ meters, depth to surface of water covering trench floor is approximately 6.3 meters.

Sample #1

Vertical sample removed from floor of level 2, west face, south end of trench.

17" driven
15" recovered
Penetrometer (TSF):
3.25
3.50

Sample #2

Horizontal sample removed from level 1 wall (west face) 15.5 meters from south end of trench, 1.3 meter below land surface. Brown weathered t. .l.

16" driven
12" recovered
Penetrometer (TSF):
4.50
4.50

Sample #3

Vertical sample removed from south ramp, approximately 1.5 meter above water covering trench floor.

20" driven
15" recovered
Penetrometer (TSF):
2.50
2.50

Sample #4

Vertical sample removed from no. .1 ramp, approximately 2.1 meters above water covering trench floor.

20" driven
17" recovered
Penetrometer (TSF):
2.25
2.50

Sample #5

Vertical sample removed from level 2 floor (east face) northern end of trench.

16.5" driven
12" recovered
Penetrometer (TSF):
3.50
3.50
3.50

Sample #6

Horizontal sample removed from west face, near south end of trench, approximately 1 meter above water covering trench floor.

16" driven
14" recovered
Penetrometer (TSF):
2.25
2.25
2.25

ADDITIONAL DATA

Slump material

In Situ penetrometer (TSF):
1.50
1.20
0.25
0.75

Tor vein (TSF):
0.2
0.1
0.2

CORE SAMPLES COLLECTED AUGUST 15, 1979
FROM TRENCH CAPS

Sample #7

Vertical sample removed 15 feet north of sump 14N on center line.

18" driven
18" recovered

Sample #8

Vertical sample removed 12 feet south of south monument on trench 12 on center line.

16" driven
16" recovered
Penetrometer (TSF):
4.50

Sample #9

Vertical sample removed from trench 9, 25 feet south of perpendicular to sump 10N.

15" driven
15" recovered

Sample #10

Vertical sample removed 125 feet south of north monument, on center line, trench 11.

15" driven
14" recovered

Sample #11

Vertical sample removed 15 feet south of south monument, on center line, trench 3.

21" driven
20" recovered

APPENDIX E

SOIL CLASSIFICATION TERMINOLOGY

I. Burmeister Classification

II. Unified Soil Classification

BURMEISTER SOIL CLASSIFICATION TERMINOLOGY*

Soil Components based on Sieve Size

Gravel	- coarse	(3" to 1")
	- medium	(1" to 3/8")
	- fine	(3/8" to #10)
Sand	- coarse	(#10 to #30)
	- medium	(#30 to #60)
	- fine	(#60 to #200)
Silt or Clay-Silt	-	(< #200)

Identification of <#200 Soil based on Plasticity Index (PI)

Silt	- PI = 0
Clayey Silt	- PI = 1 to 5
Silt & Clay	- PI = 5 to 10
Clay & Silt	- PI = 10 to 20
Silty Clay	- PI = 20 to 40
Clay	- PI = > 40

Component Proportions

,and·	- 35 to 50% by weight
,some·	- 20 to 35% by weight
,**little**·	- 10 to 20% by weight
,trace·	- 1 to 10% by weight
·and,	- 50 to 65% by weight**
·some,	- 65 to 80% by weight**
·little,	- 80 to 90% by weight**
·trace,	- 90 to 99% by weight**

Notes:

1. + or - superscripts indicate the upper or lower limits of a proportion.
2. Predominant component (> 50% of sample) is written in capital letters.

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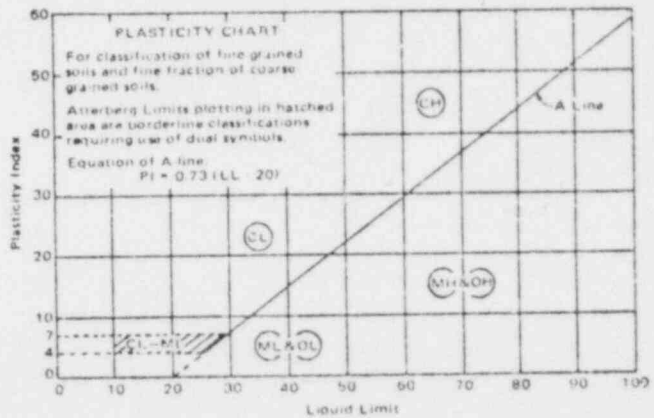
* Based upon procedures outlined by D.M. Burmeister "Special Procedures for Testing Soil and Rock for Engineering Purposes", (Fifth Edition), Special Technical Publication 479, ASTM, 1970, pp. 311-323.

** Used only in 3 component soils when sand does not predominate.

ASTM Soil Classification System (Unified)

Major Divisions			Group Symbols	Typical Names	Classification Criteria	
Coarse-Grained Soils: More than 50% retained on No. 200 sieve*	Gravels: 50% or more of coarse fraction retained on No. 4 sieve	Clean Gravels	GW	Well-graded gravels and gravel-sand mixtures, little or no fines	Classification on basis of percentage of fines: Less than 5% pass No. 200 sieve: GW, GP, SW, SP; More than 12% pass No. 200 sieve: GM, GC, SM, SC; 5% to 12% pass No. 200 sieve: Borderline classification requiring use of dual symbols	$C_u = D_{60}/D_{10}$ Greater than 4; $C_z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3
			GP	Poorly graded gravels and gravel-sand mixtures, little or no fines		Not meeting both criteria for GW
		Gravels with Fines	GM	Silty gravels, gravel-sand-silt mixtures		Atterberg limits plot below "A" line or plasticity index less than 4
			GC	Clayey gravels, gravel-sand-clay mixtures		Atterberg limits plot above "A" line and plasticity index greater than 7
	Sands: More than 50% of coarse fraction passes No. 4 sieve	Clean Sands	SW	Well-graded sands and gravelly sands, little or no fines		$C_u = D_{30}/D_{10}$ Greater than 6; $C_z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3
			SP	Poorly graded sands and gravelly sands, little or no fines		Not meeting both criteria for SW
		Sands with Fines	SM	Silty sands, sand-silt mixtures		Atterberg limits plot below "A" line or plasticity index less than 4
			SC	Clayey sands, sand-clay mixtures		Atterberg limits plot above "A" line and plasticity index greater than 7
Fine Grained Soils: 50% or more passes No. 200 sieve*	Silts and Clays: Liquid limit 50% or less		ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands		Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays		
			OL	Organic silts and organic silty clays of low plasticity		
	Silts and Clays: Liquid limit greater than 50%		MH	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts		
			CH	Inorganic clays of high plasticity, fat clays		
			OH	Organic clays of medium to high plasticity		
Highly Organic Soils			PT	Peat, muck, and other highly organic soils	Visual-Manual Identification, see ASTM Designation D2488.	



*Based on the material passing the 3 in. (75-mm.) sieve.

APPENDIX F

RADIOCHEMICAL ANALYSES OF SUB-TRENCH CORES

(Collected 12/77, Analyzed 1979-80)

Table 16. Radiochemical analyses of tritiated water, total carbon-14, and strontium-90.

Trench	Hole	Core	Depth (m)	^{3}HHO (μCi/ml)	Total C-14 (μCi/g soil)	Sr-90 (μCi/g soil)
4	4A	1	9.70- 9.74	6.26E-03 ±3%	<2.9 E-07	<1 E-07
4	4A	1	9.74- 9.79	6.24E-03 ±3%	6.1 E-07 ± 74%	<1.4E-07
4	4A	1	9.79- 9.83	5.68E-03 ±3%	-	<1.1E-07
4	4A	1	9.83- 9.88	5.74E-03 ±3%	-	<1.1E-07
4	4A	1	9.88- 9.92	5.79E-03 ±3%	-	<1.3E-07
4	4A	1	9.92- 9.98	4.62E-03 ±3%	-	<1.4E-07
4	4A	1	9.98-10.03	4.58E-03 ±3%	-	<1.2E-07
4	4A	2	10.06-10.21	2.40E-03 ±3%	5.4 E-07 ± 59%	-
4	4A	2	10.21-10.33	1.28E-03 ±3%	5.6 E-07 ± 64%	-
4	4A	2	10.33-10.45	9.0 E-04 ±3%	3.2 E-07 ± 75%	-
4	4A	3	10.71-10.83	1.09E-04 ±4%	4.9 E-07 ± 69%	-
4	4A	4	11.26-11.38	<3 E-06	12.9 E-07 ± 28%	-
5	2D	2	9.16- 9.28	1.43E-01 ±3%	9.4 E-07 ± 27%	-
5	2D	4	9.77- 9.89	1.37E-02 ±3%	4.2 E-07 ± 46%	-
5	2D	5	10.35-10.47	5.68E-04 ±3%	<5 E-07	-
5	2D	7	10.88-10.94	1.95E-05 ±6%	<5 E-07	-
5	2E	1	8.21- 8.29	5.7 E-01 ±3%	1.62E-05 ± 6%	7.7 E-06 ± 17%
5	2E	1	8.29- 8.33	6.06E-01 ±3%	8.3 E-06 ± 8%	1.4 E-07 ± 73%
5	2E	1	8.33- 8.37	6.13E-01 ±3%	9.8 E-06 ± 9%	2.7 E-07 ± 31%
5	2E	1	8.37- 8.42	6.16E-01 ±3%	11.3 E-06 ± 8%	3.8 E-07 ± 24%
5	2E	1	8.56- 8.59	4.19E-01 ±3%	5.9 E-06 ± 11%	<9 E-08
5	2E	1	8.59- 8.63	4.28E-01 ±3%	2.31E-06 ± 19%	1.1 E-07 ± 80%
5	2E	1	8.65- 8.71*	3.15E-01 ±3%	9.0 E-07 ± 49%	<7 E-08
8	1C	1	10.19-10.29	5.58E-02 ±3%	< 4.5 E-07	<1.1E-07
8	1C	1	10.29-10.40	3.34E-02 ±3%	-	-
8	1C	1	10.53-10.66	1.42E-02 ±3%	< 5 E-07	-
8	1C	5	11.58-11.66	2.16E-04 ±3%	< 5 E-07	-
8	2A	1	10.09-10.18	3.0 E-02 ±3%	7.0 E-07 ± 88%	< 5 E-08
8	2A	2	10.31-10.43	6.9 E-03 ±3%	< 5 E-07	< 3 E-08

* Possible error of ± 0.12 because of compressed core. For details see Prudic, 1979 (36).

Table 17. Radiochemical analyses of iodine-129, plutonium-238, plutonium-239, 240 and americium-241.

Trench	Hole	Core	Depth (m)	I-129 (μCi/g)	Pu-238 (μCi/g)*	Pu-239, 240 (μCi/g)*	Am-241 (μCi/g)*
4	4A	1	9.70- 9.74	< 7 E-08	1.4 E-08 ± 61%	<4 E-09	-
4	4A	1	9.74- 9.79	<1.2E-07	< 2 E-10	<2 E-10	-
4	4A	1	9.79- 9.83	-	-	-	-
4	4A	1	9.83- 9.88	-	-	-	-
4	4A	1	9.88- 9.92	-	-	-	-
4	4A	1	9.92- 9.98	-	-	-	-
4	4A	1	9.98-10.03	-	-	-	-
4	4A	2	10.06-10.21	-	-	-	-
4	4A	2	10.21-10.33	-	-	-	-
4	4A	2	10.33-10.45	-	-	-	-
4	4A	3	10.71-10.83	-	-	-	-
4	4A	4	11.26-11.38	-	-	-	-
5	2D	2	9.16- 9.28	< 3 E-08	-	-	-
5	2D	4	9.77- 9.89	< 3 E-08	-	-	-
5	2D	5	10.35-10.47	< 4 E-08	-	-	-
5	2D	7	10.88-10.94	< 2 E-08	-	-	-
5	2E	1	8.21- 8.29	<1.9E-08	<1.9E-08	<6 E-10	<2 E-06
5	2E	1	8.29- 8.33	< 6 E-08	-	-	-
5	2E	1	8.33- 8.37	<1.2E-07	-	-	-
5	2E	1	8.37- 8.42	<1.7E-07	-	-	-
5	2E	1	8.56- 8.59	<1.0E-07	-	-	-
5	2E	1	8.59- 8.63	< 9 E-08	-	-	-
5	2E	1	8.65- 8.71**	< 7 E-08	-	-	-
8	1C	1	10.19-10.29	<1.3E-07	1.7E-08 ±88%	<5 E-09	-
8	1C	1	10.29-10.40	-	1.5E-08 ±91%	<5 E-09	7.0E-11±75%
8	1C	1	10.53-10.66	-	-	-	-
8	1C	5	11.58-11.66	-	-	-	-
8	2A	1	10.09-10.18	-	-	-	-
8	2A	2	10.31-10.43	-	-	-	-

*g is per gram soil
**Possible error of ± 0.12 because of compressed air. For details see Prudic, 1979 (36).

Table 18. Radiochemical analyses of uranium-234, -235, and -238.

Trench/Hole/Core			Depth	U-234 (μCi/g)**	U-235 (μCi/g)	U-238 (μCi/g)
4	4A	1	9.70- 9.74	5.0 E-07 ±62%	<3 E-09	4.0 E-07 ± 64%
4	4A	1	9.74- 9.79	1.1 E-06 ±23%	3 E-08 ±70%	1.4 E-06 ± 22%
4	4A	1	9.79- 9.83	-	-	< 3 E-06
4	4A	1	9.83- 9.88	-	-	-
4	4A	1	9.88- 9.92	-	-	
4	4A	1	9.92- 9.98	-	-	-
4	4A	1	9.98-10.03	-	-	< 4 E-06
4	4A	2	10.06-10.21	-	-	-
4	4A	2	10.21-10.33	-	-	-
4	4A	2	10.33-10.45	-	-	-
4	4A	3	10.71-10.83	-	-	-
4	4A	4	11.26-11.38	-	-	-
5	2D	2	8.60- 8.63	9.0 E-07 ±37%	<1 E-08	1.0 E-06 ± 36%
5	2D	2	9.16- 9.28	-	-	-
5	2D	4	9.77- 9.89	-	-	-
5	2D	5	10.35-10.47	-	-	-
5	2D	7	10.88-10.94	-	-	-
5	2E	1	8.21- 8.29	9.0 E-07 ±37%	<1 E-08	1.0E-06 ± 36%
5	2E	1	8.29- 8.33	-	-	1.9E-06 ± 83%
5	2E	1	8.33- 8.37	-	-	2.4E-06 ± 81%
5	2E	1	8.37- 8.42	-	-	5.7E-06 ± 31%
5	2E	1	8.56- 8.59	-	-	1.9E-06 ± 81%
5	2E	1	8.59- 8.63	-	-	3.6E-06 ± 50%
5	2E	1	8.65- 8.71	-	-	5.1E-06 ± 32%
5	2E	1	8.71- 8.73*	-	-	<1.1E-06
5	2E	1	8.73- 8.78*	-	-	<5 E-07
8	1C	1	10.19-10.29	8.0 E-07 ±31%	<1.3E-09	8.0E-07 ± 31%
8	1C	1	10.29-10.40	9.5 E-07 ±15%	2.7E-08 ±49%	1.1E-06 ± 14%
8	1C	1	10.53-10.66	-	-	-
8	1C	5	10.58-11.66	-	-	-
8	2A	1	10.09-10.18	-	-	-
8	2A	2	10.31-10.43	-	-	-

* Possible error of ± 0.12 because of compressed core. For details see Prudic, 1979 (36).

** "g" is "per gram soil"

APPENDIX G

GEOLOGIC DESCRIPTION OF SUB-TRENCH CORES

(4-4A, 5-2D, 5-2E, 8-1C and 8-2A)

From field notes of David E. Prudic

Table 19
Geologic Log
Core Hole 4-4A
December 5-6, 1977
Land Surface Altitude . . . 423.1 meters

Depth below land surface (meters)	Core No.	Core depth interval (meters)	
9.62-9.65	(1)	0.0-0.03	Sand, chiefly very fine but ranging to medium sand at base and probably to coarse silt; wet, incoherent, dipping.
9.65-9.69	(1)	0.03-0.08	Silt, cut by one bed of fine sand 4mm thick, dipping 45°.
9.69-9.88	(1)	0.08-0.26	Clay or silty clay, plastic, firm, olive gray; includes 3 zones each 5 mm thick, all roughly parallel and dipping at 35°, in which numerous parallel but discontinuous layers of coarse white silt each <1 mm thick make up half of core volume.
9.88-9.91	(1)	0.26-0.29	Sand, fine to coarse, pebbly, incoherent, damp but not obviously saturated.
9.91-10.00	(1)	0.29-0.38	Silt, fine to coarse; one layer of silty pebbly very fine to coarse sand, dip parallel to those above and below at about 45°, 15 mm thick.
10.00-10.04	(1)	0.38-0.41	Coarse silt, incoherent, dipping.
10.04-10.24	(2)	0.0-0.18	Clayey silt, dark olive-gray, nearly pebble-free; interbedded with light-colored coarse silt generally arranged in discontinuous subhorizontal irregular layers 1-2 mm thick, but one layer nearly 15 mm thick.

Table 19 (cont'd.)

Depth below land surface (meters)	Core No.	Core depth interval (meters)	
10.24-10.45	(2)	0.18-0.40	Clayey silt, dark olive gray, nearly pebble free, very firm, interbedded with coarse silt; like unit above, except that the discontinuous coarse silt interbeds are even more abundant, totally irregular in attitude, and variable laterally in thickness. One wedge of sandy pebbly brownish-gray silt, dipping at 20°, 3 mm thick.
10.45-10.49	(2)	0.40-0.43	Coarse silt, in bulbous structures; core is nearly incoherent.
10.49-10.53	(3)	0.0-0.03	Coarse to fine silt, massive.
10.53-10.71	(3)	0.03-0.21	Silty clay, dark, very rare pebbles, numerous very thin discontinuous streaks of coarse silt; one non-bedded layer of mostly coarse silt 4mm thick; one dipping layer of numerous pebbles in silty clay 15 mm thick.
10.71-11.60	(3) (4) (5)	0.21-0.46 0.0-0.43 0.03-0.17	Till, rich in silt and clay, firm, plastic low to normal in pebble content (5-10%); two zones 11.19-11.28 m, each maximum thickness 2 cm, in which till is distinctly sandier and slightly more brown in color. Possibly some discontinuous fine silt streaks and/or partings near base, difficult to recognize.
11.60-11.96	(5)	0.17-0.53	Till, rich in silt and clay like that above but abnormally pebbly (15% estimated); firm and plastic; rare 2 mm blebs of dark clay at top.
11.96-12.12	(6)	0.08-0.19	Till, as above but normally pebbly.

Table 20
Geologic Log
Core Hole 5-2D
November 30-31, 1977
Land Surface Altitude . . . 422.22 Meters

Depth below land surface (meters)	Core No.	Core depth interval (meters)	
8.60-8.81	(1)	0.0-0.21	Till, silt and clay-rich, more pebbly than normal near base, very firm and only moderately plastic, olive-gray, unoxidized. Top 3 cm carries imprint of point, also some oxidized till close to top surface. From 8.61 to 8.65 m, noted strong microlaminations at 20° angle to core, subparallel to sand lens (did not look for these below). A lens of very fine sand to coarse silt about 3 mm thick at about 8.65 m, dips at <30° angle to core, also some deformed wisps of coarse silt.
8.81-8.84	(1)	0.21-0.24	Coarse silt, top and bottom surfaces irregular but dip at 20° angle to core.
8.84-8.87	(1)	0.24-0.27	Wedge-shaped mass of clayey silt, a few pebbles and coarse sand (might be till, did not carefully check). Minimum thickness, 2 cm, maximum 6 cm. Lower surface dips in opposite direction from upper surface.
8.87-8.90	(1)	0.27-0.30	Sand, very fine to very coarse, and granules, slightly silty, friable.
8.90-8.92	(1)	0.30-0.32	Coarse silt interlayered with clayey silt, layers irregular in thickness and attitude; mess-bedded.
8.92-9.02			Not cored, cuttings are lacustrine clay, silt, sand.

Table 20 (cont'd.)

Depth below land surface (meters)	Core No.	Core depth interval (meters)	
9.02-9.07	(2)	0.08-0.12	Pebble 1 cm diam, enveloped in a dipping wedge of silty coarse sand; bordered by silty clay with a few pebbles and traces of bedding toward base. This material could be disturbed by previous drilling.
9.07-9.20	(2)	0.12-0.26	Interlayered coarse silt and fine silt; fine silt may range to clay and coarse silt may range to very fine sand locally; a few pebbles; firm and seemingly dry. Layers parallel and fairly uniform in thickness but discontinuous near base. Fault, dipping at 60°, cuts core 9.07-9.14 m; not presently a plane of weakness. Layers dip at about 20°.
9.20-9.31	(2)	0.26-0.34	Silty clay to fine silt, very firm, beds dip at 20° to core, very rare pebbles or sand grains, near base, a bleb of deformed coarse white silt 20 x 5 x 10 mm (approx).
9.31-9.51	(3)	0.06-0.23	Till, silt and clay rich, very sparsely pebbly at top but increasing pebble content with depth, deformed wisps of silt evident throughout; core break, along irregular surface partly coated with coarse silt at 45° angle to core, at 0.23 m.
9.51-10.21	(3) (4)	0.23-0.30 0.06-0.43	Till, silt and clay rich, normally pebbly (5-10%) estimated); one bleb of brownish sandy sediment 3 x 5 mm at 9.60 m; a trace of white coarse silt at 10.06 m; strong subhorizontal micro-laminations. At 9.91 m, broken surface of core reveals two intersecting, steeply dipping fractures, not visibly open and showing

Table 20 (cont'd.)

Depth below land surface (meters)	Core No.	Core depth interval (meters)	
			no chemical alteration, but still planes of weakness along which the core could be pulled apart.
10.21-11.96	(5)	0.14-0.43	Till, like that above but more pebbly, probably 10-15 percent; firm, plastic. One pebble 6 cm long at 10.88 m. Subhorizontal microlaminations present generally.
	(6)	0.15-0.35	
	(7)	0.19-0.40	
	(8)	0.11-0.41	
	(9)	0.12-0.40	

Table 21
Geologic Log
Core Hole 5-2E
December 9, 1977
Land Surface Altitude . . . 422.25 Meters

Depth below land surface (meters)	Core No.	Core depth interval (meters)	
7.77-8.20	-	-	Soft material, probably same as that below (interpreted from blow counts).
8.20-8.50	(1)	0.0-0.24	Disturbed till, soft and very plastic; numerous streaks of moderate-yellowish-brown oxidized or weakly oxidized till; no sand or silt recognized; caves readily.
8.50-8.58	(1)	0.24-0.32	Till, predominantly silt and clay with more than 10 percent small pebbles and coarse sand, plastic, olive-gray, unoxidized; with abundant thin deformed layers of coarse silt and one pod of medium to fine sand 5 mm diameter. This material is in place.
8.58-8.70	(1)	0.32-0.44	Lake beds: layers of light-gray coarse silt to possibly very fine sand up to 2 cm thick, alternating with dark clayey silt with coarse silt partings or thin layers; beds dipping (or possibly faulted) at substantial angle to core.
8.70-8.90			Probably lake beds, not cored. (Note: it is possible that the till and lake beds described above are actually from the interval 8.70-8.90 m and the top of undisturbed material is at 8.70 m, but this seems less likely).
8.90-9.05	(2)	0.02-0.17	Lake beds: chiefly fine clayey silt, pebble free; two beds of coarser silt each 2 cm thick; upper silt bed is uniform coarse silt, has

Table 21 (cont'd.)

Depth below land surface (meters)	Core No.	Core depth interval (meters)	
			basal fault contact at angle to core and is saturated; lower bed consists of severely distorted fine layers of coarse and fine silt, apparently dry.
9.05-9.14	(2)	0.17-0.26	Coarse silt to very fine sand, apparently dry, with minor fine clayey silt layers; layers terminate against fault dipping at 45°.
9.14-9.19	(2)	0.26-0.30	Fine clayey silt, with thin subhorizontal layers of coarse silt and one thin layer of silt and granules.

Table 22
Geologic Log
Core Hole 8-1C
November 17-18, 1977
Land Surface Altitude . . . 423.18 Meters

Depth below land surface (meters)	Core No.	Core depth interval (meters)	
10.09- 10.63	(1) (2)	0.0-0.32 0.0-0.10	Till, silt and clay rich, olive gray, normally pebbly (5-10%). Wisps of light gray coarse silt and a smaller pebble content (<3%) below 10.52 m.
10.63- 11.02	(2) (3)	0.10-0.29 0.0-0.18	Predominantly coarse gray silt interbedded with thin layers of very fine gray sand, fine gray to buff sand, and olive gray clay. The sandy units are clearly water-saturated. Below 10.97 m layering is lost; blobs of silt and clay give core a mottled texture. At base of interval is a thin (<.63 cm) fine brownish gray sand dipping 25° from vertical.*
11.02- 11.81	(3) (4) (5)	0.18-0.23 0.02-0.29 0.01-0.38	Massive coarse gray silt; when broken has a sugary texture. Saturated; deforms readily and flows when shaken.
11.81- 12.54	(5) (6)	0.38-0.46 0.04-0.25	Clay, olive gray with wisps of coarse silt; pebbles absent. One large (about 2.54 cm in diameter) blob of very fine brownish sand or coarse silt incorporated in the clay at 12.50 m to 12.54 m.

*More detailed description of individual layers in this interval available in field notes.

Table 23
Geologic Log
Core Hole 8-2A
November 22, 1977
Land Surface Altitude . . . 423.18 Meters

Depth below land surface (meters)	Core No.	Core depth interval (meters)	
9.96-10.24	(1)	0.03-0.28	Till, olive-gray pebbly silty clay with pebbles and coarse sand >10 percent. Pebbles generally <0.6 cm diameter; no bedding or fractures. One bleb of light-gray coarse silt 0.6 cm diameter near top.
10.24-10.34	(1) (2)	0.28-0.34 0.02-0.06	Lake beds (7), sand, fine to very fine, brownish gray, dipping slightly, 1 cm thick, at top; overlying sandy clay with rare pebbles, abundant deformed beds of coarse silt, and a few fine sand blebs.
10.34-11.67	(2) (3) (4) (5) (6)	0.06-0.40 0.02-0.21 0.02-0.24 0.08-0.46 0.02-0.09	Till; olive-gray pebbly silty clay, pebbles and coarse sand 10-15 percent; top 0.30 m is firm, with rare tiny blebs of light-gray silt; more plastic and moldable next 0.3-0.9 m, firm again below. Most cores appear moist and saturated. No bedding or fractures.
11.67-11.89	(6)	0.09-0.30	Till, as above but few pebbles (5%+), also light-gray deformed silt wisps and blebs increasing from traces at top to perhaps 2 percent at base.

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ABSTRACT (200 words or less)

This is a final report evaluating the containment capabilities of the low-level, solid radioactive waste burial ground at West Valley, New York. The investigation included a surface water study, a trench water study, geotechnical and radiochemical studies of woils, a geotechnical analysis of a research trench and analysis of subtrench core data.

Tritium is the most abundant beta emitter in trench water while strontium-90 is the predominant beta emitter in surface water. Strontium-90 ranks as the second most abundant trench water radionuclide in 6 of the 11 trenches studies.

Four radionuclides were found to have either definite or possible migration. Carbon-14 was found to migrate at a much slower rate than tritium, which migrated to a depth slightly greater than 3.2m below the trench flow. There is also inconclusive evidence for strontium-90 migration beneath the trenches. Plutonium-238 was detected immediately beneath all 3 trenches studied and in 4 of the 5 trench cores. Results predicted by testing performed in 1977 were confirmed by standard engineering tests on soils from the site. Soil samples taken from the north burial area trench caps and analyzed for tritium showed approximate background levels at the surface and above background levels at depths of 20 to 50 centimeters.

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