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

Annual Report
September 1, 1977 - September 30, 1978

Prepared by R. H. Dana, Jr. S. A. Molello, R. H. Fickies, R. H. Fakundiny

New York State Geological Survey/State Museum
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Prepared for
Division of Safeguards, Fuel Cycle and Environmental Research
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ABSTRACT

The scope of this research program includes several basic parts: a surface water program, a geomorphic and erosion study, a trench water study, and a soil analysis study. The study involved the collection of surface water data, a geomorphic study and mapping of a 4.1 km reach of Buttermilk Creek and adjacent areas within the drainage basin, the analysis of water samples collected from waste burial trenches, and the analysis of soil samples collected from a research trench near the burial site. Buttermilk Creek Valley is being actively subjected to erosion by a combination of fluvial transport, lateral channel scour processes, transport on alluvial fans, and landsliding. Local ponding may contribute to landsliding and slumping by bringing moisture contents close to the liquid limit of the soil. Tests indicate that the soil in which the waste is buried has been subjected to a load greater than the present day overburden loading. The theoretical depth limit to which cracks can penetrate in the soil is approximately 50 feet.

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Alison Chandler for illustration layout and drafting.

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Radiochemical analyses were performed by the Radiological Sciences Laboratory of the N.Y. State Health Department.

LIST OF ABBREVIATIONS

LLRWB	Low-level, radioactive waste burial
NFS	Nuclear Fuel Services, Inc.
NYSDEC	New York State Department of Environmental Conservation
NYSERDA	New York State Energy Research and Development Authority
NYSGS	New York State Geological Survey
RSL	New York State Health Department - Radiological Sciences Laboratory
URI	University of Rhode Island
USGS	United States Geological Survey - Water Resources Division

Standard abbreviations have been used for units of weight, area and length. Metric units have been used whenever possible. However, in the case of certain engineering tests and standards and where equipment was originally designed for use in the English System, the original units have been retained.

1.0 INTRODUCTION

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, N.Y. The study is funded by the U.S. Environmental Protection Agency, and the U.S. Nuclear Regulatory Commission, and involves cooperative programs with the U.S. Geological Survey, the N.Y. Department of Conservation, N.Y. Health Department, and the N.Y. Energy Office.

The West Valley commercial burial area is located 48 km south of Buffalo, N.Y., in northern Cattaraugus County, at the Western New York Nuclear Service Center (Figure 6-1). The major installation on the site is a nuclear fuel reprocessing plant not currently in operation. Just north of the area are the high-level waste tanks. South of the plant area is the NRC-licensed high-level burial area. And, to the east of that is the commercial low-level radioactive waste burial (LLRWB) area with which this study is concerned. The 6 acre LLRWB area consists of a series of 12 burial trenches approximately 180 meters long, 11 meters wide, and 6 meters deep. Between 1963 and 1975, these trenches were dug in a thick clay-silt till of low permeability and relatively high ion exchange capacity. As the trenches were filled, the uncompacted waste was covered with a 1 to 5 meter thick cap of soil, consisting of weathered and unweathered till.* The project involves several elements of study, including a Landform Modification Process Study, a Trench Water Study, and a Surface Water Study.

* A more detailed description is available in references (1) and (2).

2.0 CONCLUSIONS

1) Surface water samples collected at No. 2 Lagoon Road Station (see Figure 6-1) on the west branch of Erdman's Brook continue to show higher values of gross α and gross β activities than samples collected at the other three stations.

2) Surface water samples collected at No. 3 Bucket Station continue to show values of gross α and gross β higher than those at #1 Erdman's Brook Station and No. 4 Swamp Station.

3) Surface water samples collected at No. 1 Erdman's Brook Station on the east branch of Erdman's Brook continue to show the lowest values of gross α and gross β of any of the 4 surface water station locations.

4) The Buttermilk-Bond reach of Buttermilk Creek is a coarse gravel, high gradient, degrading stream with a gradient-clast size relationship similar to many gravel braided streams.

5) Buttermilk exhibits a highly variable stream hydrograph. Discharge rises from base-flow conditions to flood-stage in a few hours, and subsides just as quickly due to the impermeable nature of the till mantling the drainage basin. This high effective runoff enhances sediment transport in the creek, probably in part because high stages allow more of the bar surface area to be covered and thus more bedload is available to be moved.

6) The agents responsible for lowering and widening of Buttermilk Creek are: 1) fluvial transport of material down and out of the Creek causing lowering of the active bar and channel surface; 2) lateral erosion of the active flood channel to remove previously deposited terrace material and valley-wall till; 3) landslides that remove material from the valley wall and deliver it to the valley bottom; 4) sediment transport on alluvial fans that delivers valley-wall material to the Creek channel system.

7) Channel sweep, leading to lateral erosion of older terraces and the valley wall till, is an extremely active process in the Buttermilk-Bond reach. Landslides occur in areas where the active channel system shows a history of valley-wall erosion. These landslides are not a major sediment provider to Buttermilk Creek except in the vicinity of the waste burial site. Future landsliding is to be expected in this area.

8) Initial soils tests indicate that the moisture content of the silty till is generally near the plastic limit of the soil.

Local ponding and puddling of water on steep slopes may contribute to landsliding and slumping by bringing moisture contents close to the liquid limit of the soil.

Laboratory tests on undisturbed samples collected from a research trench indicate that:

-the soil is classifiable as CLAY and SILT, little coarse to fine sand, traces of fine gravel according to the Burmister system.

-clay is of low to medium plasticity.

-the soils have an average shrinkage limit of 12, an average plastic limit of 19 and an average liquid limit of 31.

-near surface weathered soil (0-12 feet depth) are in a solid state - closer to the shrinkage limit than the plastic limit. Deeper samples (depth of 37 feet) are borderline between solid and plastic states. This indicates that the upper soil has lost moisture by dessication.

-the soil has been subjected to a load greater than the present overburden loading, and has been considerably disturbed.

-the average vertical permeability is 2×10^{-8}cm/sec and the average horizontal permeability is 56×10^{-8}cm/sec.

-the soil is not highly expansive, though at low stress levels, such as adjacent to open shrinkage cracks, it will swell sufficiently in contact with water to close the cracks.

-pin hole dispersion tests performed to evaluate the potential for erosion in the soil indicate that the soil is non-dispersive.

-the theoretical depth limit to which cracks can penetrate is approximately 50 feet, though observations in the field have indicated only a depth from 10-15 feet below the original land surface.

3.0 RECOMMENDATIONS

1) Because of recent trench cap alterations, a major portion of any continued surface water study should examine the effects of new drainage patterns on the amount and direction of flow of radionuclides leaving the site through the surface water pathway. (See Section 7.5)

2) The source of higher values of gross α and gross β in water samples collected at #2 Lagoon Road Station should be investigated. Specific sources to the south and to the west of the station will have to be monitored. This will also allow the investigation of the extent to which the LLRWB site contributes to these high values.

3) Detailed mapping of landslide, slump, and creep features on Frank's Creek are necessary for a clear understanding of future erosion around the LLRWB site. Also necessary is another field season of monitoring of Buttermilk Creek bedload, suspended and dissolved sediments, landslide movements stream stage, velocity and discharge measurements, and the remeasuring of cross sections of the creek bottom. Detailed mapping of older bar and channel complexes preserved on higher fluvial terraces should be combined with an extensive terrace dating study in order to establish erosion rates for the recent past on Buttermilk Creek.

4) Further sampling of trench water would be beneficial towards evaluating changes over time in trench water composition and activities. Trenches 10, 11, and 13 have never been sampled. Trench 14, because it is filling at a greater-than-average rate, should be monitored for changes in concentrations and activities. Various north-end trenches are slowly filling and should also be re-sampled periodically.

5) One critical question still unanswered is whether the majority of radionuclides originally isolated in containers are in contact with the trench water. Also, the effects of a 50 ton proof roller, used in trench recapping operations, on the integrity of these containers should also be evaluated.

4.0 PURPOSE OF STUDY

In November, 1963, Nuclear Fuel Services, Inc., (NFS) was granted an exemption by the New York State Health Department to bury low-level radioactive wastes at the Nuclear Fuels Service Center, a State-owned site located at West Valley, New York. The approval of the exemption was based on hydrologic and geologic studies that had been made of a 13.3 km^2 site on which a nuclear fuels reprocessing plant was to be located. The studies made as of November, 1963, for the overall site were considered to be rather extensive at that time. Some extrapolations were made from a regional perspective to the site to be used for burial of low-level radionuclide waste. These early studies recognized the major factors concerning possible migration of radioactivity from the burial site as shown by actual operating experience. Both erosion control and the maintenance of adequate covers over the trenches to exclude water were considered to be a necessary part of the long-term perpetual care and maintenance of the site.

In March of 1975, one of the waste trenches filled with water and overflowed onto the surface. Following that incident, waste burial voluntarily was suspended for an indefinite period of time by the site operator.

In 1975, the NYSGS was designated by NYSERDA the lead agency in an interdisciplinary and interagency research program to develop the ability to predict long-term effects of migration of radionuclides from the site and for effects of erosion at and around the site.

The principal goal of this study is to determine the containment effectiveness of the West Valley LLRWB site. Two general approaches are being employed, first; by analyzing the distribution of radionuclides in various potential migration pathways, rates of migration away from the site can be established for various radionuclides; and second, by studying the landform modification processes on and around the site, the rate of erosion towards the site may be estimated.

5.0 SCOPE OF WORK

5.1 The scope of the NRC-funded study in Part II of the research program includes three basic parts: a Surface Water Program a Trench Water Study, and a Landform Modification Processes Study. In addition, a report is presented on recently completed maintenance work performed by NFS on the northern trench caps. This work is considered significant to ongoing research because it:

a) necessitated removal of several monitoring wells,
b) resulted in an alteration of surface drainage in that area, and
c) may have altered the deterioration rate of containers within the trenches.

The Surface Water Program is part of an agency study originally funded by the U.S. Environmental Protection Agency. This includes the monitoring around the site of rainfall at 2 rain gauges, and runoff at 4 surface water stations, and the collection of flow proportional stream samples for analysis of HTO, gross α and gross β activities. The purpose is to assess the significance of the surface water pathway as a route for radionuclide migration off site, and to determine the direction, extent, and character of any migration.

The trench water study involves an evaluation of the trench water for a number of radionuclides including: ^{3}HHO, ^{90}Sr, ^{238}Pu, $^{239,240}Pu$, ^{134}Cs, ^{137}Cs, ^{55}Fe, ^{60}Co, ^{63}Ni, ^{234}U, ^{235}U, ^{238}U, ^{232}Th, ^{22}Na, ^{133}Ba, ^{106}Ru, gross α and gross β .

The intent is to develop a picture of which radionuclides are available for migration, which of them can be best used as tracers of migration, and what temporal and spatial variations there are in the trench water composition and activity.

This first phase of the Landform Modification Processes Study involves a detailed examination of the reach of Buttermilk Creek between Buttermilk Road and Bond Road. This is primarily for the purpose of establishing a data base, from which erosion rates may then be calculated. Secondarily, two environmental geologic maps - one of the site and one of the drainage basin as a whole - and a slope map of the drainage basin are to be prepared.

5.2 Maintenance Work On North Burial Area (Trench Recapping)

5.2.1 In a letter to the president of Nuclear Fuel Services, Inc., dated April 28, 1978, James L. Larocca, Chairman of the N.Y. State Energy Research and Development Authority (owners of the low-level burial area) mandated that the north trenches (trenches 1 through 5) receive additional cover to prevent vertical infiltration of rain water.

Work plans were developed during May, June, and July, 1978. The NYSGS attended several meetings involving the various interested parties. At the request of NYSERDA, NYSGS reviewed the plans and specifications prepared by Edwards and Moncreiff, dated July 8, 1978.

Both the NYSGS and the USGS participated in discussions and made recommendations as to which test wells should be retained and which should be plugged. The ultimate decision, however, rested with the NYSERDA and with the NYSDEC.

5.2.2 Recapping Procedures

Prior to the actual recapping, all USGS and NYSGS wells and holes on the north-end trenches had to be plugged, capped, or extended. This was done by the USGS Water Resources Division.

All 1¼" holes driven in 1976 were plugged using a procedure developed by the USGS to minimize their future impact on trench integrity. All 1¼ inch water and gas sampling wells in trenches 2 through 5 were cut off 2 feet below land surface and filled with a bentonite-cement grout. The uppermost 2 feet of each hole was backfilled with till. Hole 5-2E was filled in the same manner, Hole C and I4 were plugged with an injection epoxy while holes A, A2, B, C2, D, D2, F, I3, and 4-4A were cut off and capped 2 to 3 feet below land surface. The location of capped holes was determined in relation to a set of reference points so that they can be recovered after completion of trench capping work. To date these holes have not been recovered.

Plugging, capping and extending was completed July 29, 1978. A map showing the remaining holes in the north-end trenches is shown in Figure 5-1.

Trench recapping work began on August 7, 1978. The topsoil was removed and stockpiled and approximately 4.5' of additional cover were applied to trenches 1-5 in compacted lifts averaging 8" initial thickness. The additional soil was dug from a borrow pit to the east of Frank's Creek (see Figure 5-2 and transported across the west branch of Frank's Creek (Tributary 2) to the LLWRB area. Figure 5-2 shows the borrow pit area, and the extent of the area of regrading and reseeding.

5.2.3 Effects of the Recapping

An earthen berm was installed approximately 10 m up drainage of the flume at the #3 Bucket Station on August 17. This berm has altered the drainage pattern at the north ends of trenches 2, 3, 4, and 5, and redirected runoff so that the No. 4 Swamp Station now receives runoff from the area previously drained by No. 3 Bucket Station. No. 2 Lagoon Road Station and No. 1 Frank's Creek Station were also affected by this operation.

Future monitoring of surface water will require a re-evaluation of the drainage basins of all surface water monitoring stations, assessing the effects of the berm, the pipe and crossing over the west branch of Frank's Creek, the changes in drainage basin area, and the changes in topography.

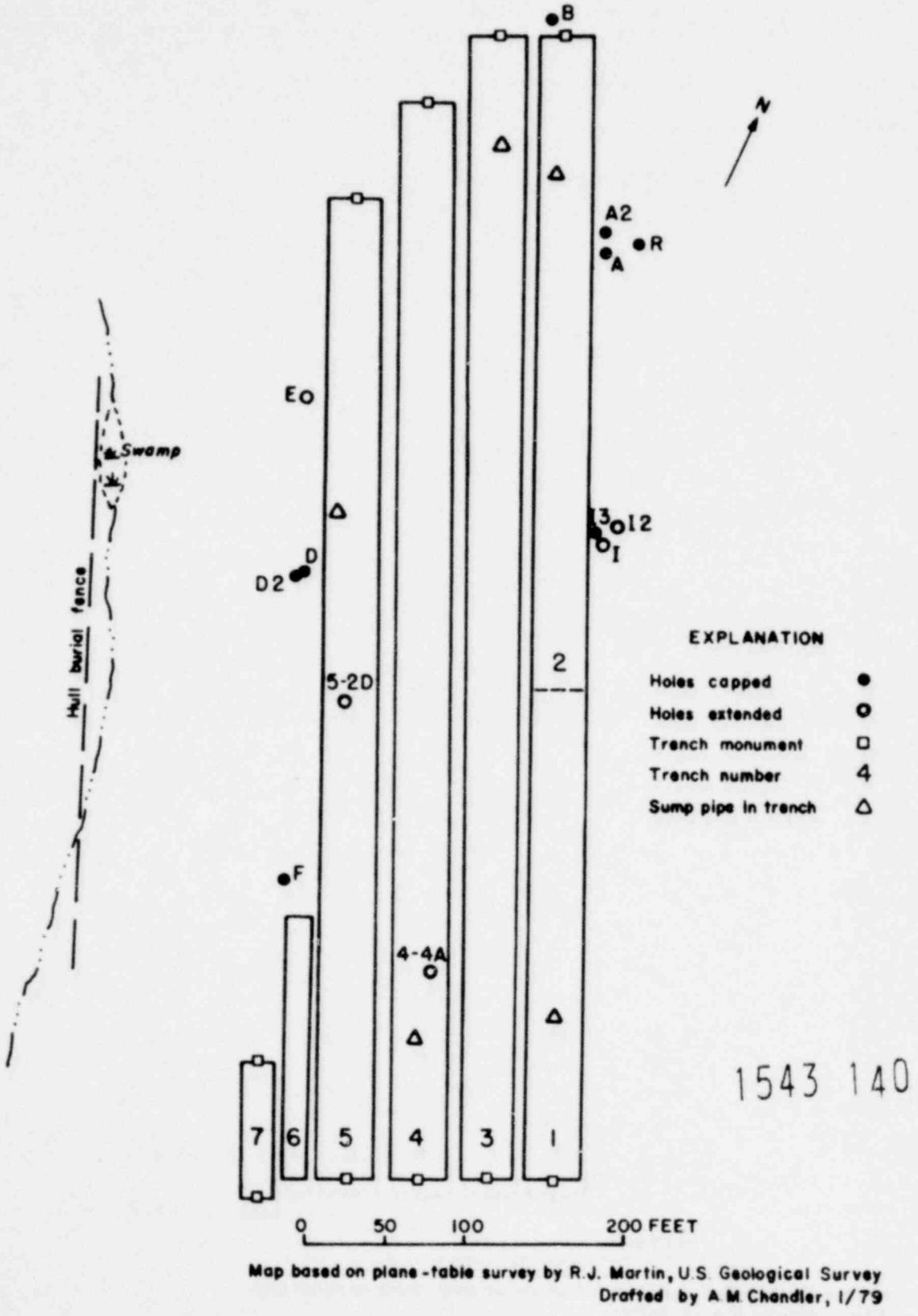

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Figure 5-1. Wells in the North Burial Area as of August, 1978.

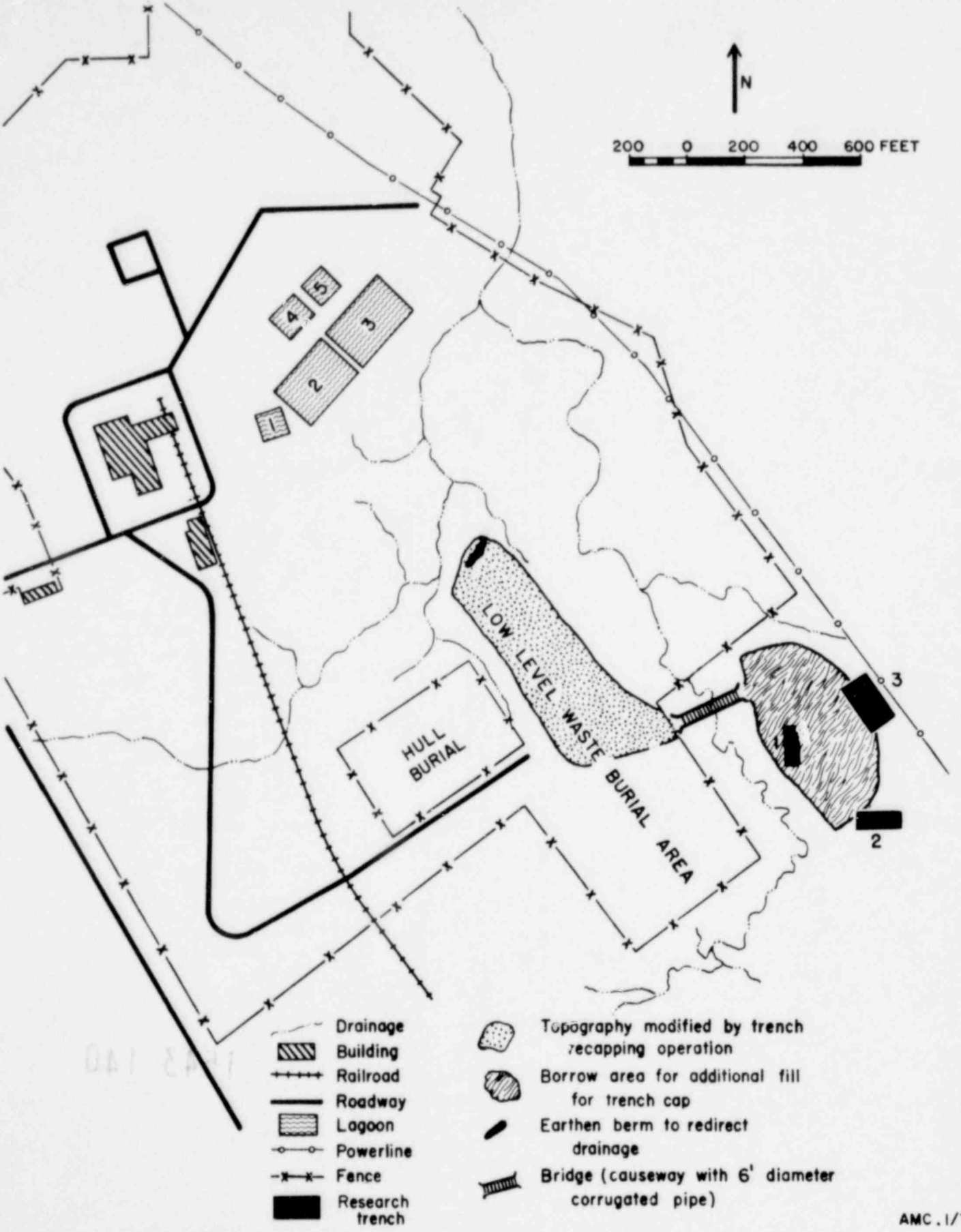


Figure 5-2. Map of the Western New York Nuclear Service Center showing regraded areas on the north burial trenches and the borrow pit across the west branch of Erdman's Brook (August, 1978).

6.0 SURFACE WATER STUDY

6.1 Introduction

NRC-funded work under the Part II investigation at West Valley includes an effort to detail potential radionuclide migration away from the low-level burial site through an analysis of the surface water pathway. Some elements of this study are a continuation of monitoring efforts that were begun in December, 1975, as reported in the Part I final report to the EPA (NYSGS Open File #78-2401). The purpose of this portion of the study is to obtain data necessary for an understanding of radionuclide migration through the surface water pathway and to determine the total radioactivity leaving the burial site by this pathway. Small streams which drain the burial site were monitored for volume of flow and systematically sampled at four locations. Water and sediment samples are being analyzed for gross α , gross β , and tritium activity.

The surface water study was designed by the West Valley Task Force under the leadership of the State Geological Survey. The United States Geological Survey was subcontracted to purchase, install, and maintain the surface water equipment. Water sampling was conducted by the State Geological Survey. The State Department of Health is analyzing the samples.

6.2 Methods of Study

Surface water monitoring and sampling stations were installed in December, 1975, by the United States Geological Survey as part of EPA Part I research. Locations of the sampling stations are shown in Figure 6-1; Stations 2, 3, and 4 contain equipment as displayed in Figure 6-2. Station 1 is not flume-dependant and does not take flow-proportioned samples. A variety of equipment is in use at the stations as shown in Table 6-1. Table 6-2 contains descriptions of the various types of samples that were collected during this study. Surface water sampling was carried out from the start-up date of September 1, 1977, until December, at which time all automated surface water sampling equipment was removed from the various stations and stored in the equipment shed on site. Severe winter weather prevented reinstallation through early April.

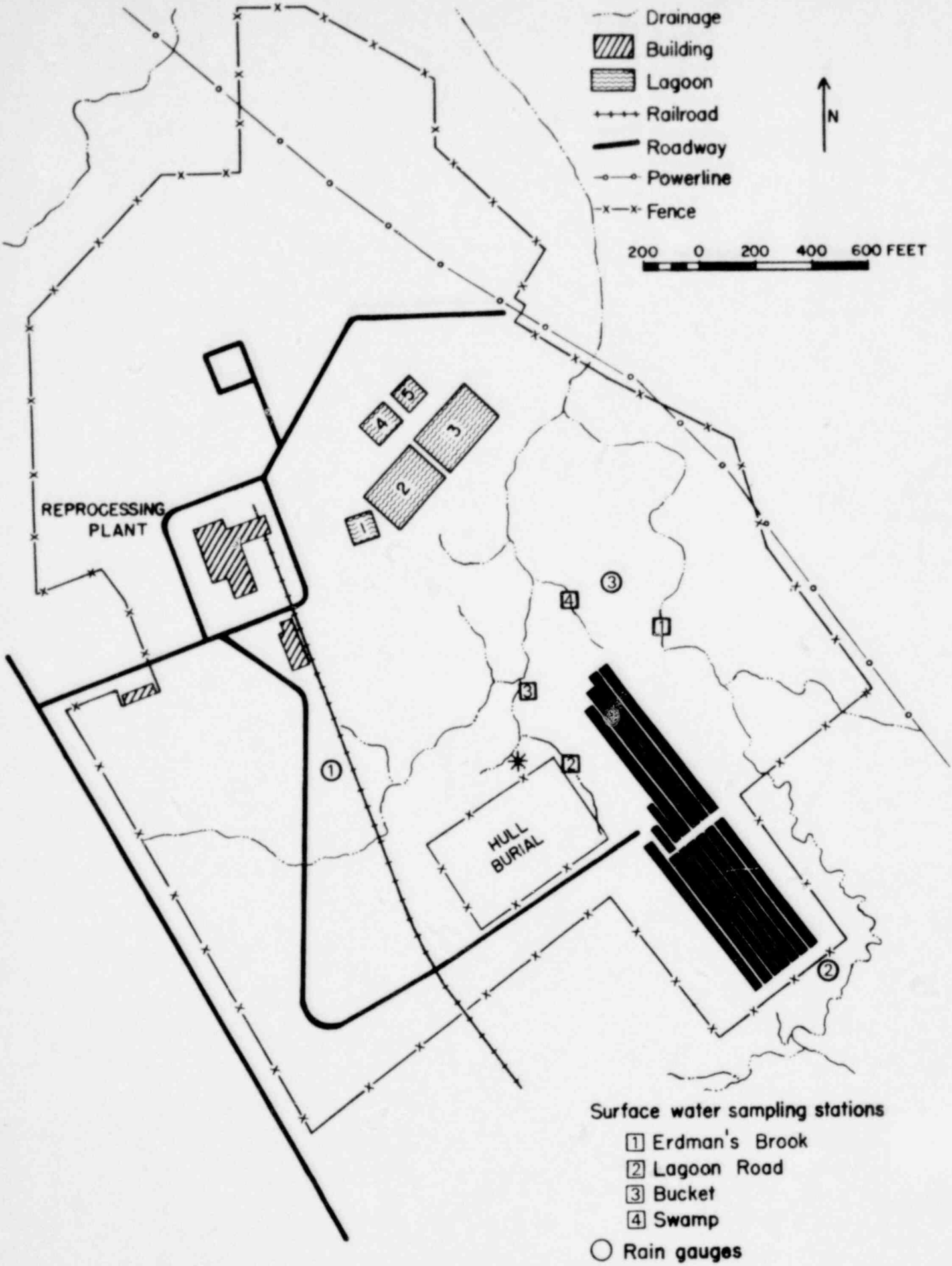


Figure 6-1. Western New York Nuclear Service Center, showing low-level radioactive waste burial trenches in solid black.

SURFACE WATER MONITORING AND SAMPLING EQUIPMENT

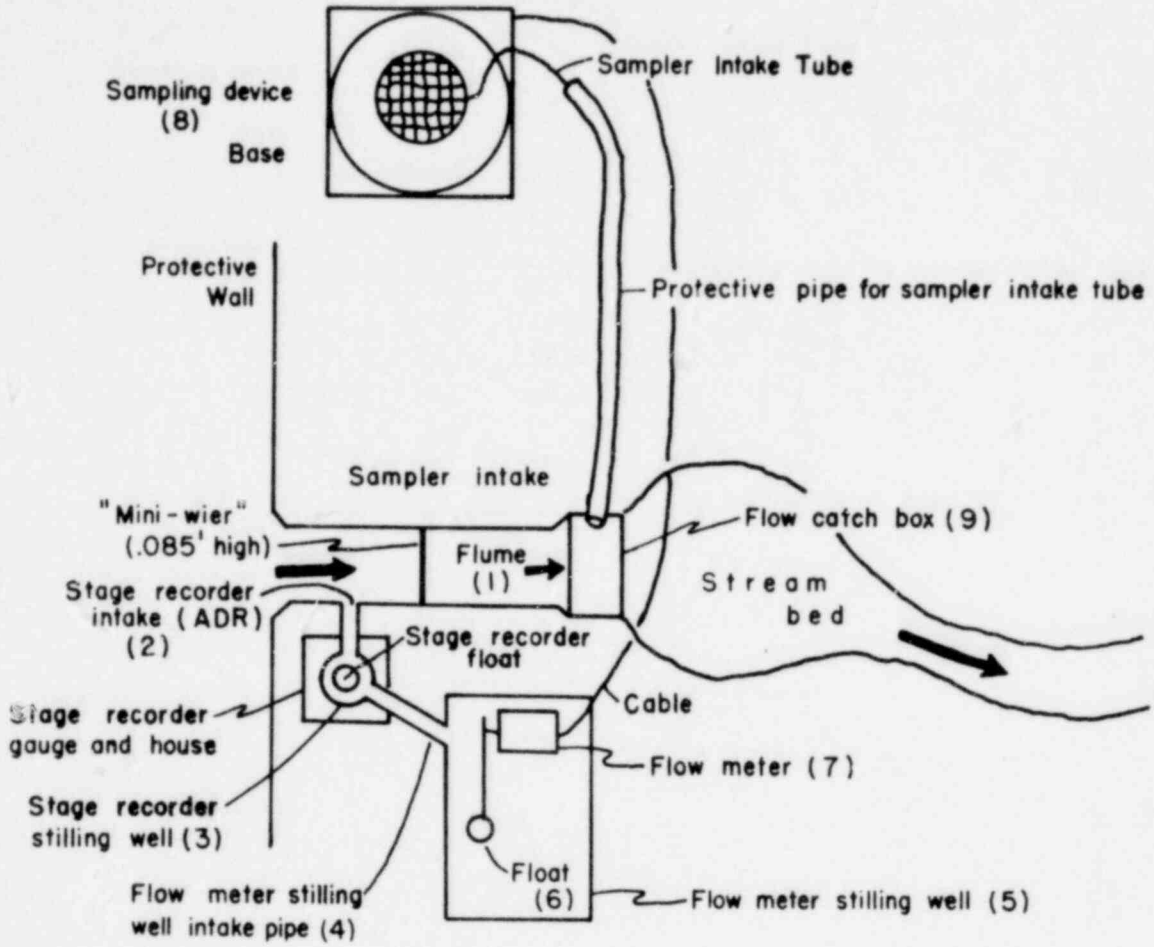


Figure 6-2. Schematic map showing surface water monitoring station. A portion of water passing through flume (1) enters Stage Recorder stilling well intake pipe (2) to Stage Recorder stilling well (3) then flow meter stilling well intake pipe (4) to flow meter stilling well (5). Float (6) is raised and flow meter (7) sends signals to sampler at frequency proportional to preset flow in accordance with present multiplier setting. Sampler (8) is activated and sample drawn from catch box (9).

TABLE 6-1

EQUIPMENT USED FOR SURFACE WATER

MONITORING AND SAMPLING

Item	Purpose	Stations
6" Parshall Flume	Direct channel flow through an artificial channel with a pre-calibrated stage discharge relationship.	2,3,4
Stevens A-35 Stage Recorder	Provide a continuous graphical record of stream stage (and by inference, discharge in flume).	2,3,4
Instrument Specialties Co. Model 1470 Flow Meter	1. Provides a digital record of flow volume for any given time period. 2. Sends activator signal to sampler at preset flow volume intervals.	2,3,4
ISCO Model 1580 Composite Sampler	Collects composite of individual samples based upon signal from flow meter.	2,3,4
ISCO Model 1392 Sequential Sampler	Collects daily surface water grab samples at preset time intervals.	1
Fisher Porter Digital Punch Recorder	Provides a record of the stage at 15 minute intervals, punched tape is standard input for USGS hydrologic analysis computer programs.	1

TABLE 6-2

SURFACE WATER SAMPLING PROGRAM

SUMMARY TABLE

Sample Type	Collection Frequency	Processing	Notes
Flow proportioned surface water composite	Weekly	Transferred to 2 and 4 liter bottles for shipment to HRI for analysis.	Sample is automatically collected. Dilute HNO_3 added when decomposing organic matter is evident.
Low flow grab, whole water	Weekly	None	Manual grab sample using 2 liter bottle.
Filter pads from filtered low flow grab	Weekly	Filtrate is passed through ion exchange column	Sample is collected at the same time as the weekly low flow whole water grab.
Background grab, whole water	Weekly	None	Manual grab sample using 2 liter bottle.
Filter pads from filtered background grabs	Weekly	Filtrate is passed through ion exchange column	Sample is collected at the same time as the weekly background grab.
Stream bed sediment grab	Monthly	Allowed to air dry until hard, grain size separation	Collected manually using cloth bag.
Storm grabs	During flow events	None	Collected manually using 2 liter bottle.
Miscellaneous grabs	.....		Collected to sample unusual or extreme environments.
Ion exchange column composites	Added to on a weekly basis	Sample is filtered before passing through I.E.C.	These composites will be analyzed when sufficient sample volume has been passed through them.

While in storage, the sampling equipment was water-proofed, lubricated, and tested to prepare it for spring installation.

Field activities carried on throughout the winter included routine maintenance of 3 rain gauges (Figure 6-1), which were adapted for snow gauging early in 1978. Surface water sampling stations were inspected regularly and grab samples taken when appropriate. Winter damages to the surface water sampling stations were assessed, and repairs undertaken in mid-April. Interference with flow-proportioned sampling occurred at stations 2,3, and 4 by creation at each station of a bypass channel. At stations 2 and 4 these channels were created by ice plucking of small soil blocks and subsequent through-flow and scour. At station 3, Bucket, an underflow was created beneath the flume.

At all 3 stations, repair required removal of the monitoring equipment, landfill, installation of a new concrete pad, and reinstallation of the monitoring equipment.

Winter damage to station 1, Erdman's Brook, was caused by upstream migration of a knickpoint, which deposited a sand bar over the recorder intake and sampler intake pipes. Repair was effected by moving the intake pipes to new locations.

On April 24, all surface water sampling equipment was reinstalled, tested, and activated. All equipment has functioned continuously since that date.

Precipitation recorded at West Valley during the study period is shown in Table 6-3. Surface water sampling has been carried out continuously during the study period.

Techniques for surface water analysis are similar to those used for trench water and subtrench core samples. Refer to Appendix A for details of the procedure.

6.3 Data

6.3.1 In all, four-hundred-ninety-three (493) surface water samples were collected during the study period, and eighty (80) additions to the ion exchange columns were made. A flow chart of the handling of specimens, from collection to final radiochemical analysis is shown in Figures 6-3 through 6-7.

6.3.2 To date, one-hundred-ninety-five (195) surface water samples have been forwarded to RSL to be analyzed for gross α and gross β and HTO, and one-hundred-thirty-four (134)

TABLE 6-3

Precipitation, 1 September 1977 to 30 September 1978
at West Valley*, New York

Time Period	Inches of Precip.	Time Period	Inches of Precip.
1-5 Sept. 1977	1.15†	21-28 March	0.35
6-12 Sept.	0.00	28-31 March	0.10/.85
13-19 Sept.	5.10	1-3 April	0.00‡
20-26 Sept.	2.40	3-10 April	1.15
27-30 Sept.	1.20/8.75**	10-17 April	0.35
1-3 Oct.	0.00	17-24 April	0.70
4-10 Oct.	0.55	24 April - 1 May	0.00/2.20
11-17 Oct.	0.10	1-8 May	0.60
18-24 Oct.	0.05	8-15 May	1.15
25-31 Oct.	0.00/.70	15-22 May	1.20
1-7 Nov.	0.80	22-30 May	0.10/3.05
8-14 Nov.	1.30	30 May - 5 June	0.10
15-22 Nov.	2.00	5-12 June	0.45
23-28 Nov.	0.35	12-19 June	1.00
29-30 Nov.	0.25/4.70	19-26 June	0.25
1-8 Dec.	0.35	26-30 June	0.05/1.85
9-12 Dec.	0.35	1-3 July	0.00†
13-19 Dec.	0.90	3-10 July	0.15
20-26 Dec.	0.10/1.70	10-17 July	0.10
27-31 Dec. 1977	0.00	17-24 July	0.40
1-3 Jan. 1978	0.35	24 July - 1 Aug.	0.75/1.40
3-12 Jan.	1.20	1-7 August	0.25
12-16 Jan.	0.75	7-14 August	1.40
16-23 Jan.	0.85	14-21 August	1.10
23-20 Jan.	0.40/3.55	21-29 August	0.25/3.00
30 Jan. - 7 Feb.	0.40	29 Aug. - 4 Sept.	0.50
7-13 Feb.	0.00	4-11 Sept.	0.50
13-20 Feb.	0.00	11-18 Sept.	3.10
20-28 Feb.	0.30/.70	18-25 Sept.	0.40
28 Feb. - 8 March	0.10	25-30 Sept. 1978	0.15/4.65
8-14 March	0.10		
14-21 March	0.20	TOTAL	37.75

*Based on record of rain gauge(s) at Nuclear Fuel Services, Inc., operated by New York State Geological Survey.

†Data for 1 September '77 through 31 March '78 and 1 July '78 through 30 September '78 based on record of rain gauge No. 1 at NFS.

‡Data for 1 April '78 through 30 June '78 based on record of rain gauges Nos. 1 and 2 at NFS. Differences in recorded precipitation between these two gauges are less than 0.1 inches, which is less than the measurement accuracy of either gauge.

**Number after slash is monthly total.

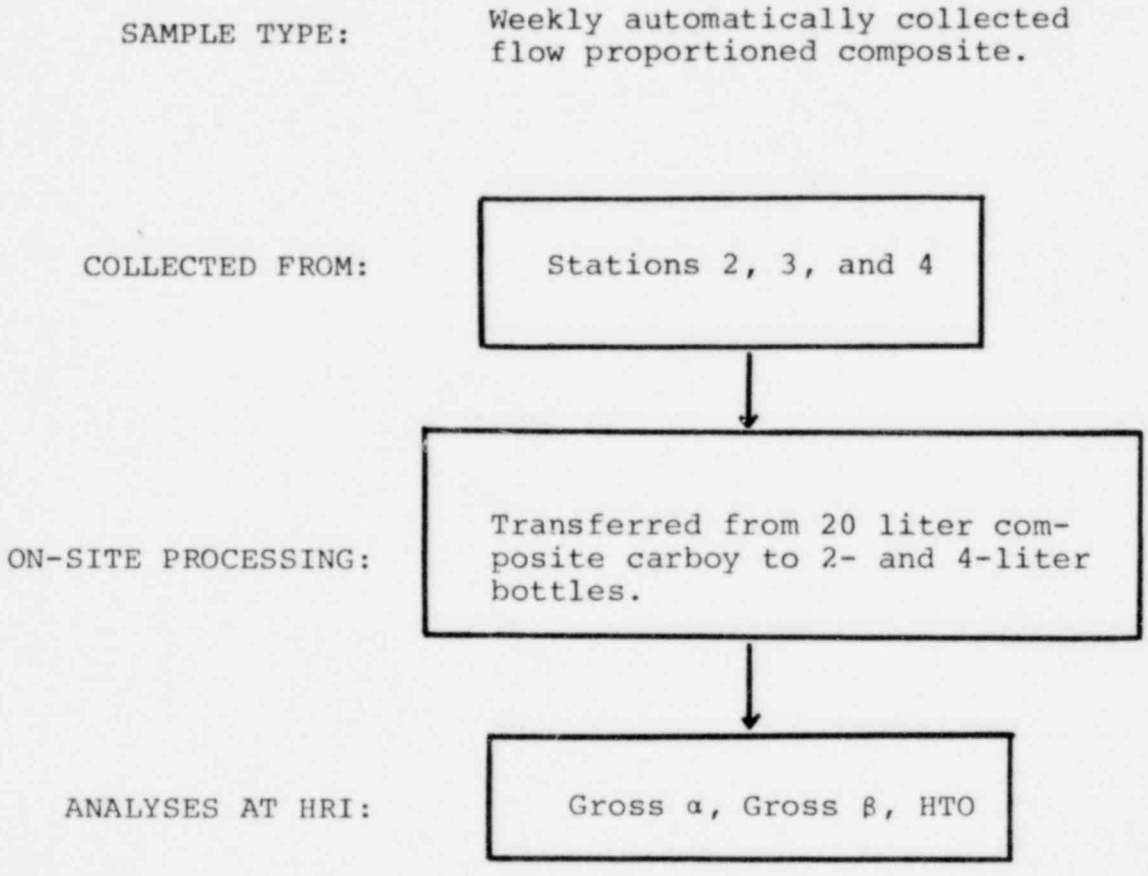


Figure 6-3. Flow Diagram of Weekly Composite Sample Processing.

1543 149

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

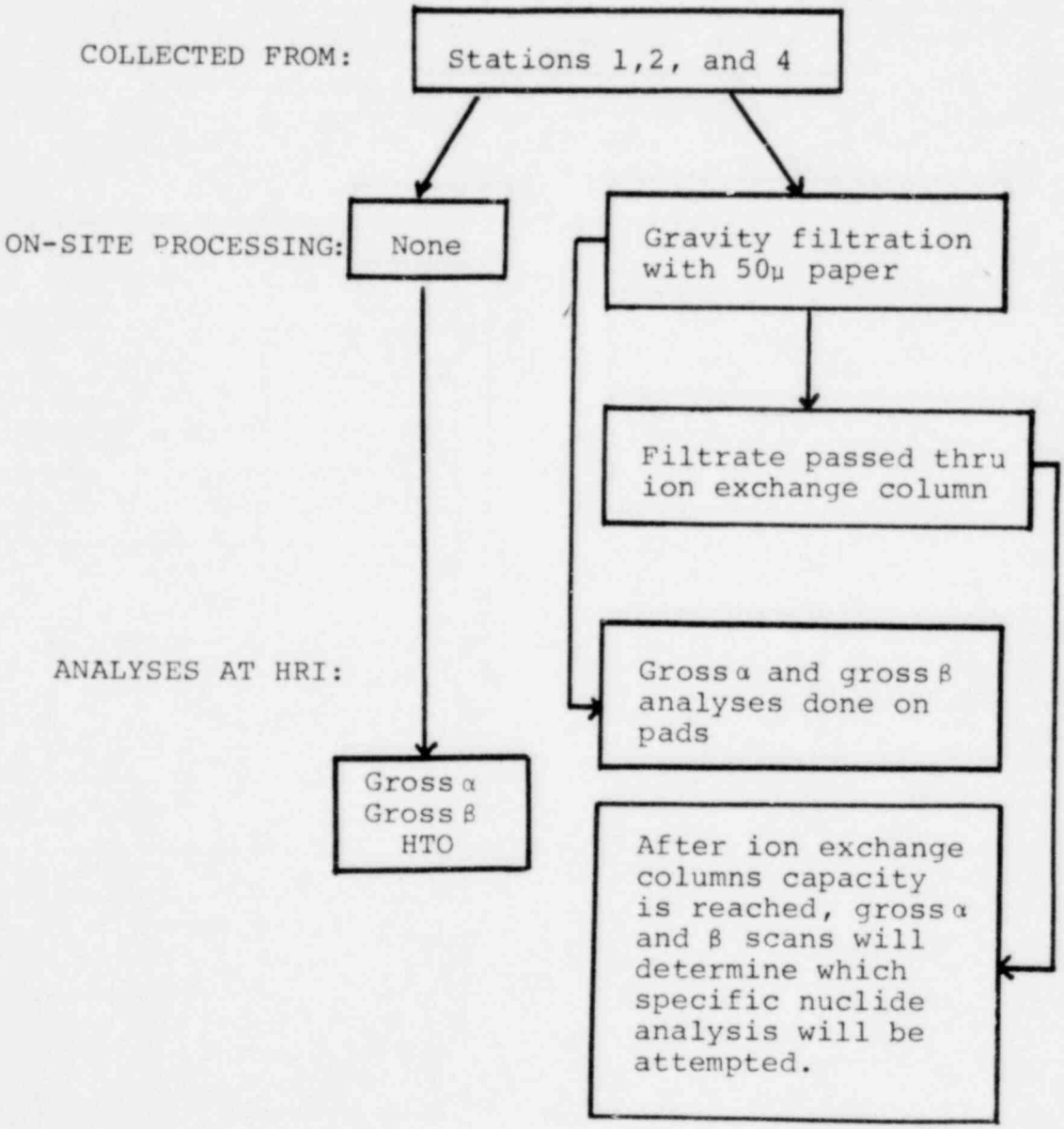


Figure 6-4. Flow Diagrams of Weekly Low Flow Grab Sample Processing.

1543 150

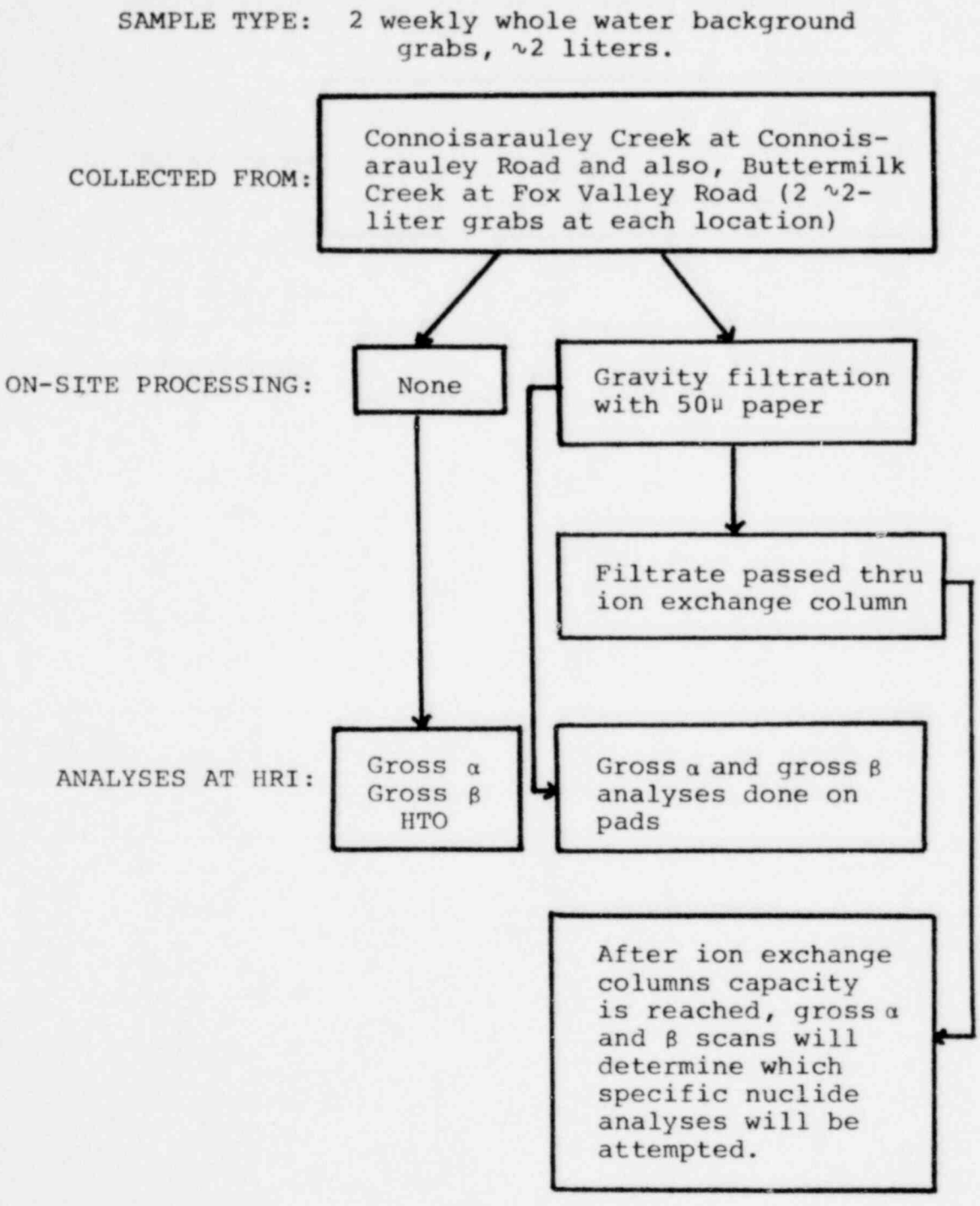


Figure 6-5. Flow Diagram of Weekly Background Grab Sample Processing.

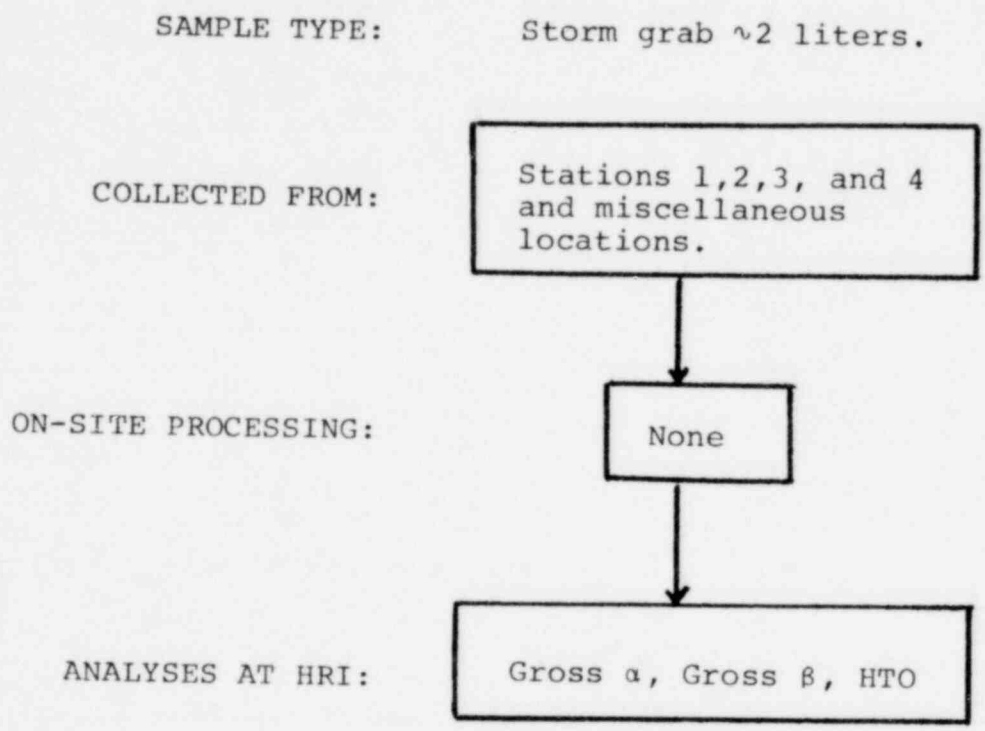


Figure 6-6. Flow Diagram of Storm Grab Sample Processing.

1543 152

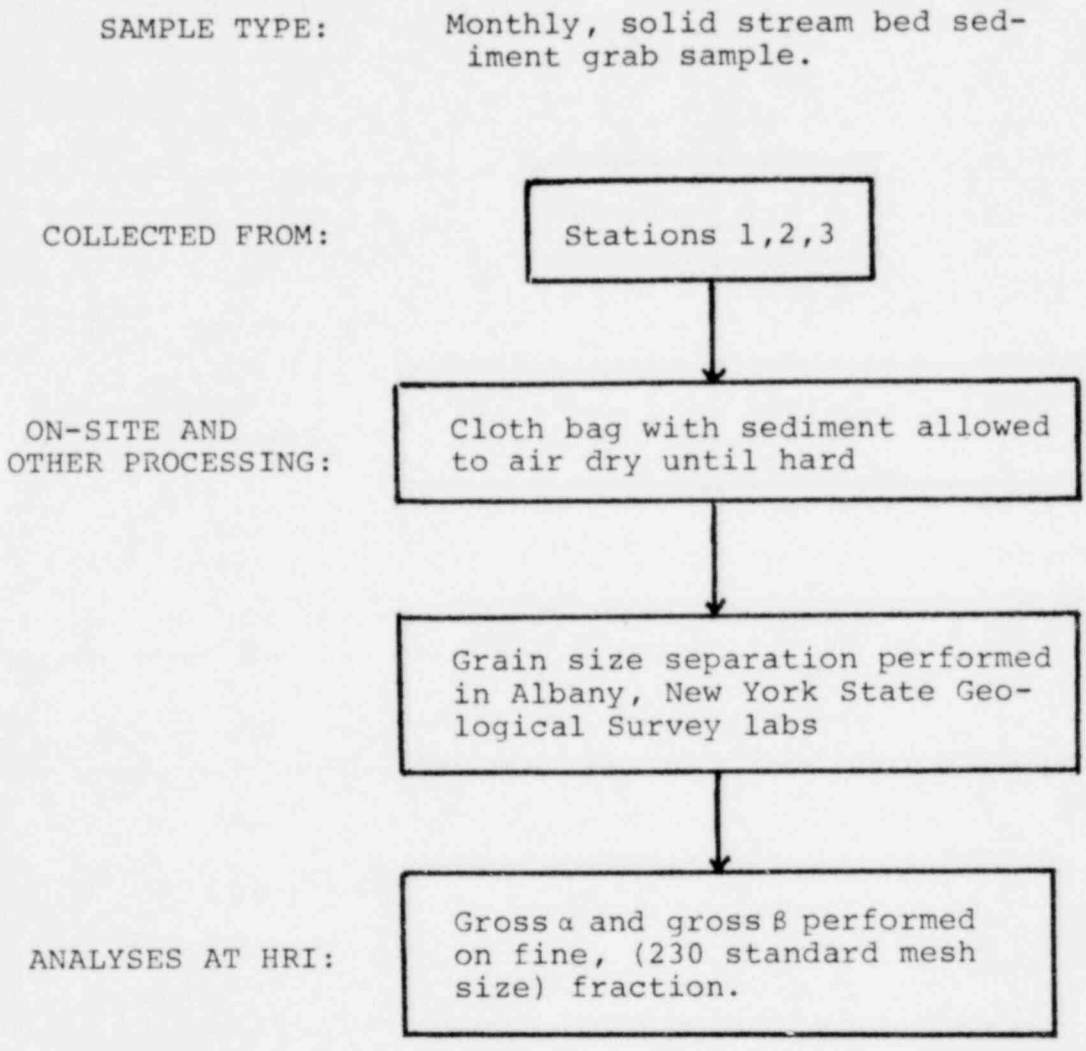


Figure 6-7. Flow Diagram of Monthly, Stream Bed Sediment Grab Sample Processing.

1543 153

analyses have been returned to the Geological Survey.

Results of analyses received thus far are found in Appendix B, Tables B-1 to B-12.

6.3.3 Twelve (12) samples have been selected by the RSL for detailed analysis for γ-emitters (isotopic γ), ^{14}C, ^{63}Ni, ^{55}Fe, and $^{238,239,240}Pu$. In addition, two (2) samples which exhibited high values for the gross α measurement will be analyzed for $^{238,239,240}Pu$.

6.4 Discussion and Conclusions

Figure 6-8 shows the drainage basins represented at the four stations during the major portion of this study. Surface water samples collected at Station No. 2, Lagoon Road on the west branch of Erdman's Brook continue to show higher values of gross α and gross β activity than samples collected at the other stations. Samples from No. 3 Bucket Station, downstream from Lagoon Road Station, exhibit values intermediate between those at Lagoon Rd. and those from stations 1 and 4. While station No. 1, Erdman's Brook, drains the largest area of any of the monitoring stations, it shows the lowest values for gross α and gross β of any of the stations.

There are several possible explanations of the high gross α and gross β measurements exhibited at Lagoon Road. These include the fact that Lagoon Road is the only station that drains portions of the hull burial area. Also, Lagoon Road (station 2) drains an area much larger, and a significantly greater portion of the low-level burial site than either station 3 or 4. In addition, Station 2 collects surface run-off from two lagoons backfilled with till that at one time had trench water pumped into them. It also receives drainage from a portion of the road to the low-level burial area.

It is also known that the old north lagoon spilled trench water into the channel now occupied by station 2 during September 1975. A section of the channel including the location of the station was removed by a backhoe and the dirt placed into the north lagoon before it was backfilled with till. However, it is conceivable some of the radio-nuclides were absorbed by surface materials not scraped and are being released gradually to surface runoff. In addition and probably a major consideration, station 2 (Lagoon Road) includes within it's drainage area the largest area where seeps were identified from trench water overflow in March 1975. Tritium results from cores collected near land surface at holes D & E were 100 to 1000 times higher than near-surface tritium results from other holes (3).

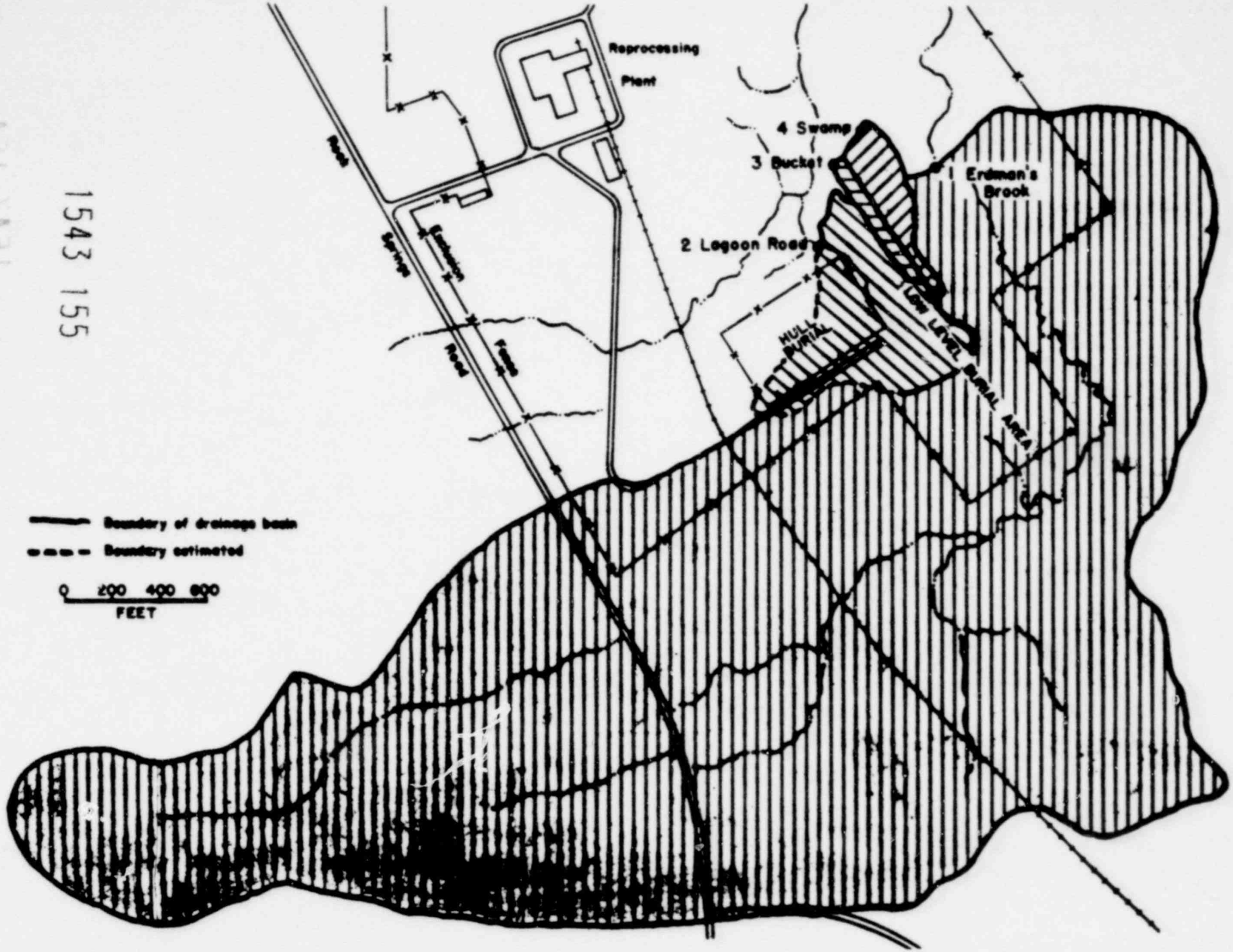


Figure 6-8. Drainage basins of surface water sampling stations 1 through 4 prior to August, 1978.

Station 2 may be detecting releases of radionuclides from the soil at landsurface during periods of runoff.

Any combination of these factors may be causing the observed differences in radioactivity passing the four monitoring stations.

6.5 Suggestions for Further Study

In August of 1978, trench recapping was carried out at the low-level burial area. One very important effect of this work was to significantly alter the drainage patterns in the area. A major portion of any continued surface water study should examine the effects of new drainage patterns on the amount and direction of an radionuclides leaving the site through the surface water pathway. A preliminary step in this effort will be to completely remap the surface water station drainage basins. In addition, continued surface water monitoring should be carried out to establish new patterns of radionuclide migration.

Trench cap modification is intended to prevent infiltration of precipitation into the trenches. This evaluation of the trench cap repairs has significance to future management of the burial site and to management practices at other waste burial sites as well.

As mentioned above, very high values of gross α and gross β have been observed in the past at station No. 2, Lagoon Road. A number of possible explanations for this have been proposed A part of the continued study will be to positively identify the cause of observed elevated readings at that station.

7.0 GEOMORPHIC AND EROSION STUDY OF BUTTERMILK CREEK

7.1 Introduction

This aspect of the study is being carried out by Dr. Jon C. Boothroyd, a fluvial geomorphologist at the University of Rhode Island under the direction of the NYSGS.

Dr. Boothroyd is conducting a detailed system and erosion study of the reach of Buttermilk Creek adjacent to the low-level radioactive waste burial (LLRWB) site. The primary goal of the study is to investigate sediment yield and mechanisms of erosion and mass-wasting in order to establish a rate of denudation for the drainage basin. Much of the data from this first period of study will gain significance only after another season of monitoring and measurement is complete. The techique for measuring future erosion has been developed, but in many areas, we have yet to measure the actual erosion.

Three general approaches to the problem of estimating denudation rates are being employed. First, sediment yield data from rivers in western N.Y. that generally fit characteristics of Buttermilk Creek are being analyzed to establish a reasonable range of erosion rates for Buttermilk Creek.

The second general approach is the collection of various discharge data from the stretch of Buttermilk Creek adjacent to the burial site (between Buttermilk Road Bridge and Bond Road Bridge). Buttermilk Creek stage height is being constantly monitored by a stage monitoring station and is tied in with periodic velocity measurements done with a Price pygmy current meter at measured cross sections in order to compute discharge. Bars and channels are being surveyed and clasts are being tagged to monitor movement.

The third general approach to this study involves the mapping and dating of river terraces to establish a rate of downcutting for Buttermilk Creek.

7.1.1 Objectives of Study

The major objectives of Period I of the landform modification study are to determine in general terms the seasonal and annual modification of the Buttermilk Creek drainage adjacent to the low-level radioactive waste disposal site by: 1) mass wasting of slopes and delivery of sediment to Buttermilk Creek and its distributaries; and 2) transport of sediment

down and out of Buttermilk Creek by bedload and suspended load processes.

7.1.1.1 Information Products

The following information products were proposed at the initiation of the study. Some were later modified as detailed in 7.1.1.2.

1. An environmental geological map at a scale to be determined by consensus between investigators from NYSGS and the URI work group. The regional extent of the area to be mapped is shown on the attached map (Figure 7-1).

2. Map(s) showing sequential mass wasting and stream drainage patterns derived from the existing aerial photo coverage (1939 to present).

3. Graphic and tabular presentation of Buttermilk discharge data which has been collected in past years by the USGS, including:

a) stage-discharge rating curve
b) hydrographs, both yearly and for specific flow events
c) flow-duration curve
d) flood-frequency curve.

4. A feasibility study and preliminary work on suspended load and bedload data to include:

a) suspended load and discharge versus time
b) sediment rating curve (suspended load versus discharge)
c) movement of clasts with time
d) changes in bar morphology with time.

5. Point-bar maps with topographic, sediment size, bedform, and vegetation information, and sequential maps of changes in these quantities.

6. Data on clast movement within the fluvial system characterizing the relationship between clast size, distance, and flow.

7. A photographic file of:

a) geomorphic-sedimentologic units
b) stratigraphic units
c) bedforms
d) clast movement
e) stream stages
f) slumps.

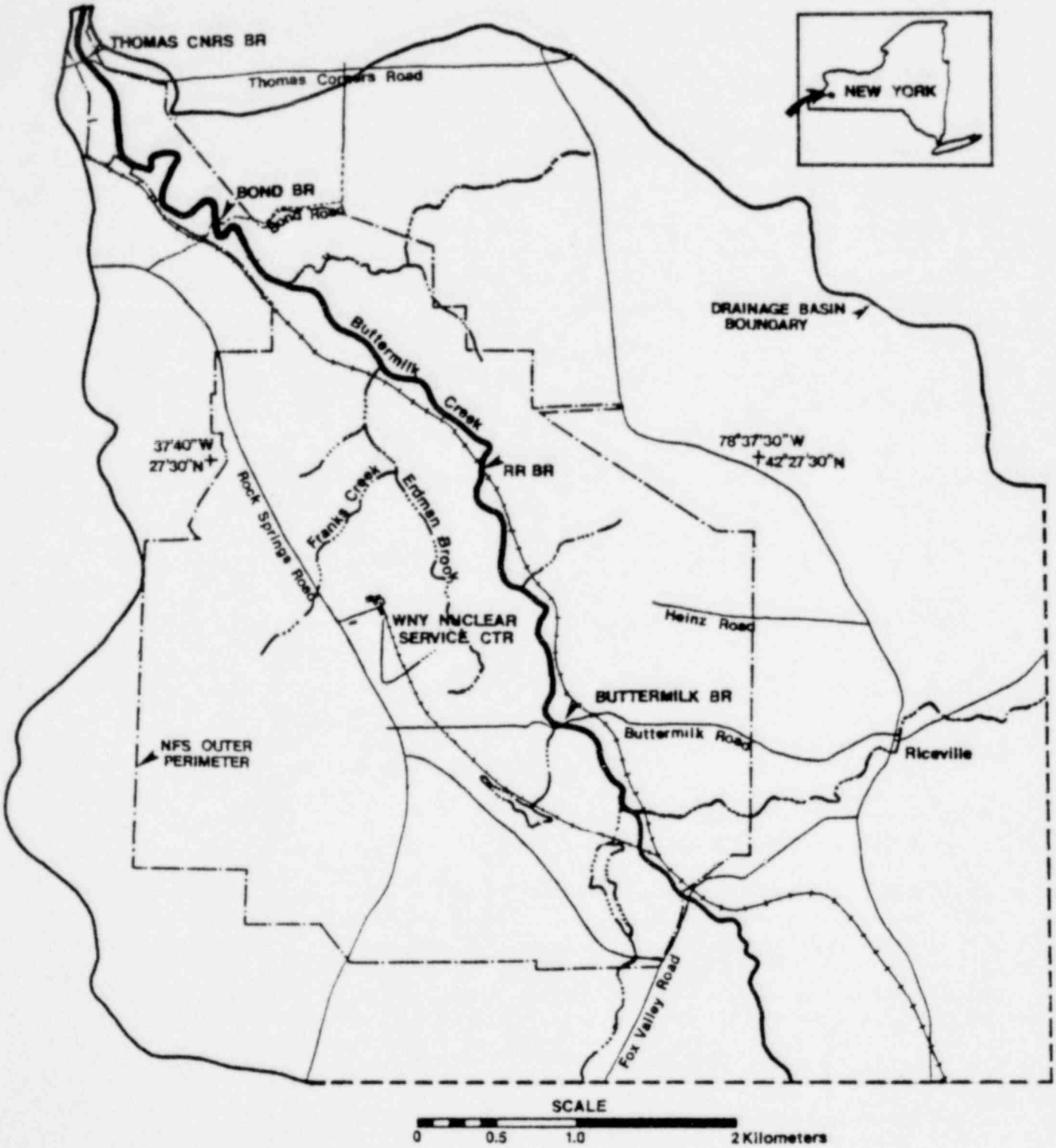


Figure 7-1. Location map of part of Buttermilk Creek drainage basin.

8. Preliminary work on computation of:

a) total suspended load removed from the reach for specific flow events and a yearly average of suspended load;
b) total bedload transport for specific flow events and a yearly average.

7.1.1.2 Changes to Information Products

Environmental Geologic Map - It was originally envisioned that the map would be produced at a scale of 1:24,000 or 1:12,000. Subsequent discussions resulted in a decision to map at a scale of 1:4,800, on already existing maps, of the 3,300 acre area owned by Nuclear Fuel Services, Inc. Thus, a more detailed map was produced of a smaller area than originally envisioned. In addition, the detail on the surficial geologic maps of the Ashford Hollow and West Valley 7½" Quadrangles (4) make additional mapping unnecessary.

Terrace Mapping - The importance of older, elevated stream terraces to the understanding of erosion rates was recognized after field work began and mapping at a scale of 1:4,800 was completed and added as a special component of the environmental geologic map.

Landslide Monitoring - A transit survey of one of the largest landslides was conducted for later resurvey and monitoring.

7.1.2 Scope and Conditions of Study

Study Area - The field area was confined to the reach of Buttermilk Creek between Buttermilk Road Bridge downstream to Bond Road Bridge, including the valley walls, the high surface adjacent to the incised Buttermilk reach, and the mouth of tributary drainages. A brief inspection was made of the Frank's Creek/Erdmans' Brook area. Limited field checking of environmental geologic map units was also carried out inside and outside the NFS outer perimeter. Field work was specifically excluded inside the high security perimeter, although we were allowed access to observe other geologic/ hydrologic work in progress.

Working conditions were excellent for bar mapping and other field mapping during the summer of 1978 because of extremely low discharge in Buttermilk Creek.

No flood-stage discharge measurements were made for suspended and bedload transport computation because no flood-stage discharges occurred during the field season. The original plan was to measure events during the 1978 spring ice breakup and

melt water flooding, but the field program did not begin in time.

7.1.3 Pevious Work

The glacial history of western New York that includes the Buttermilk Creek drainage has been summarized by Muller (5) and Coates (6).

Buttermilk Creek drainage basin - Detailed 1:24,000 scale quadrangle mapping was carried out by LaFleur (4). A gauging station was maintained on Buttermilk Creek at the Bond Road Bridge from 1962-1968 (References 7 through 14). A special investigation was made of the large-scale flood event of September, 1967 (14).

7.2 Procedures

7.2.1 Field Methods

General Location - Field inspection of the Buttermilk Road to Bond Road reach of Buttermilk Creek revealed that the stream was divided into a series of emergent gravel-bar complexes separated by the low-stage thalweg of the stream. These bar complexes were numbered consecutively downstream (1 through 25) and marked by placing wooden stakes on the high points of the bar surfaces. The location and elevation of the tops of these stakes was determined during the survey of the longitudinal profile. Clast size and clast movement stations, bar maps, landslide maps, and location of features on the valley walls are referenced by bar complex or stake location.

Gradient - The gradient or longitudinal profile of the 4.8 kilometer reach from Buttermilk Road Bridge to Bond Road Bridge was measured by standard transit and rod leveling techniques to .01 feet vertically and 1.0 feet horizontally. Backsight and foresight distances ranged from 150 to 400 feet. Because of the type of equipment available distances were measured in English units and converted to metric system. Stations were chosen at the water's edge of the low-stage thalweg. Stage height did not appear to vary during the 2 days the profile was obtained. The profile was tied to a USGS benchmark on the B & O railroad bridge located approximately halfway down the reach.

Clast size - Clasts were measured at one station on each bar complex. The technique is as follows: 1) the bar complex was inspected for concentrations of large clasts and a likely location was chosen; 2) a 3 meter distance was marked in the direction of sediment transport; 3) the ten largest clasts

falling on or within one clast length of the line were marked; and 4) the 3 axes (L, I, S) were measured to 0.5 cm. This technique is similar to that followed in Boothroyd and Ashley (15) and Smith (16). Further rationale is included in the Results section.

Bar mapping - Topographic surveys of 2 bar complexes were accomplished using two different techniques. Pertinent geologic information was recorded for each station.

Bar complex 11 - Standard transit and rod techniques were used to determine distance and elevation along 18 transects, for a total of 387 stations. The stations are tied to the bar complex 11 location stake and hence to an absolute elevation.

Bar complex 4,5,6 - The double rod and hand-level method was used to level along 21 transects for a total of 526 stations. The standard transit and rod method was used to obtain an additional 119 stations in geologically interesting areas between transects, for a grand total of 645 stations. Three stations on each transect were tied to either the bar complex 4 or 5 location stake, and thus to an absolute elevation.

Landslide mapping - An active landslide on the West Valley wall opposite bar complex 6 was surveyed by the transit and rod technique. Eight transects with a total of 35 stations were marked. The instrument station was marked and tied to the bar complex 6 stake of known elevation and location.

Clast movement stations - Nine stations along 5 transects on 5 separate bar complexes were selected for variation in geographic area, bar-complex type, and topography. The technique is similar to that developed by Helley (17), to record gravel movement in Blue Creek, California.

The procedure was as follows: 1) four 10-meter transects were marked perpendicular to the sediment transport direction; 2) approximately 10 clasts of average largest size (long axes of 21 to 30.5 cm), and 10 of smaller size (medium) were numbered and painted at each station (red = large, green = medium); 3) clasts selected were within several lengths upstream or downstream of the transect; 4) locations along, upstream and downstream of the transect line were measured to 1.0 cm; and 5) the transect line was marked with yellow paint to identify smaller clasts. A total of 146 clasts (red and green) were marked.

The transect lines were tied by survey to stakes placed on terraces on both sides of the active bar and channel system. Clast stations were located along transects from the topo-

graphic survey on bar complex 4 (transect 5) and bar complex 11 (transect 10).

Discharge measurements - Five sets of measurements were made on Buttermilk Creek at Thomas Corners Road Bridge. Four low-flow data sets were obtained at a section measured perpendicular to the low-stage channel beneath the bridge, and another at a slightly higher flow stage about 100 meters upstream of the bridge. Standard USGS techniques were used (18). Both Price type AA and Price pygmy current meters were used with a topset wading rod. Measurements were obtained at 0.6 unit depth every 0.5 meter across the section. Cross-sections ranged from 5 to 10 meters wide. The midsection method was used to compute cross-sectioned area. Water-surface (stage) height was marked on the west abutment of the Thomas Corners Road Bridge for later comparsion with values from the stage-height recorder installed at the bridge.

Suspended-sediment samples - A single suspended-sediment sample was obtained from the midpoint of the channel during the measurement of each discharge data set by a depth-integrating, hand-type (DH 59) sampler (19).

Terrace mapping - Fluvial terraces were mapped between Buttermilk Road Bridge and Bond Road Bridge on both sides of Buttermilk Creek valley and on the burial-site surface between Erdman's Brook/Frank's Creek and Buttermilk Creek. This was accomplished by walking the area and recording information directly onto 1:4,800 scale base maps. Terraces were recorded only if fluvial gravel was present in natural cuts or in 1 meter deep test pits. Thus, other terrace remnants may have gone undetected. Additional terraces were identified upstream of Buttermilk Road Bridge by aerial-photo interpretation and were not field checked.

Environmental geologic mapping - The environmental geologic map was field checked during the terrace mapping. In addition, the burial site surface outside of the high security fence, Erdman's Brook, and Frank's Creek valleys were inspected in detail. Other spot checks were made both inside and outside the NFS perimeter. (See section 7.2.2 for more details.)

Photographic documentation - Approximately 600 color slide photos were taken during the field season of bar-surface features, landslide surface features, clast orientation, bed forms, bar and channel geometry, and terrace internal structure. Clast-movement stations were documented in detail.

7.2.2 Office Work

Environmental geologic mapping - The environmental geologic

map was prepared on a 1:4,800 scale topographic base. The major sources of information were: 1) 1:24,000 surficial geologic mapping by LaFleur (6) of the Ashford Hollow and West Valley quadrangles: 2) 1966 (1:4,800 scale) and 1977 (1:4,800 scale) vertical aerial photographs; and 3) detailed mapping by Dr. Boothroyd in the Buttermilk-Bond reach and on the burial site surface. Twenty-three units were delineated and transferred by hand to the base map. The time-stratigraphic interpretation of LaFleur (4) was followed particularly in regard to Wisconsinan till units. The effort was concentrated on a detailed interpretation of Holocene fluvial and mass-wasting processes and products. This map is somewhat similar to those produced in the Texas coastal mapping program (20) and to that developed by Boothroyd and others (21) for the Alaskan Outer Continental Shelf Energy Program (OCSEP).

Slope map - The Buttermilk Creek drainage basin was delineated on the 1:24,000 scale topographic quadrangles (Ashford Hollow and West Valley) by inspection of topographic divides. Five slope domains were chosen and boundaries were mapped by measurement of contour density within the drainage basin area.

Channel sweep - The active bar and channel pattern was determined on 5 series of vertical aerial photographs:

1) 1939 (1:14,000 scale)
2) 1961 (1:9,600 scale)
3) 1966 (1:4,800 scale)
4) 1968 (1:9,600 scale)
5) 1977 (1:4,800 scale).

The bar and channel boundaries were photogrametrically transferred to a 1:4,800 scale base with a Bausch and Lomb Zoon Transfer Scope. This base was later reduced in scale with a Map-O-Graph. A map for each year and a composite change map were produced, with bar and channel boundaries illustrated with respect to base of valley wall, top of valley wall, and the low-level burial site.

7.3 Results

The following discussion is a general description of the results and does not make use of the maps produced by this study. A more detailed account of the results and a more in-depth discussion including maps and figures, are being published by the NYSGS and the USNRC under the title, "Geomorphic and Erosion Studies at the Western N.Y. Nuclear Service Center, West Valley, New York (NUREG/CR-0795).

7.3.1 Environmental Geologic Map

The boundaries or contacts of Wisconsinan units, particularly till, follow those mapped by LaFleur (4). We have added additional units subdivided on the basis of slope gradient. The latest Wisconsinan(?) fluvial surface has been remapped and somewhat changed from LaFleur (4). The Holocene fluvial and mass-wasting environments have been subdivided in detail and boundaries and interpretations may differ from those of LaFleur. The mapped area is divided into 23 units in 5 categories as noted below. Descriptions of various environments are outlined in following sections.

Moraine Systems - Eight till units have been identified on the basis of LaFleur's boundaries (4), his stratigraphy, and slopes identified on the 1:4,800 scale map.

Fluvial/Alluvial Fan Systems - Ten units were identified ranging from presently-active bar and channel systems to late Woodfordian proglacial channels.

Bedrock - Devonian sandstone and shale crop out in limited areas, mostly in deeply-incised channel bottoms and valley walls.

Lakes and ponds - Most are quite small, either natural or man-made. The largest lakes are 2 NFS reservoirs.

Man-made fill or excavation - These range from road grades and railroad grades to excavations inside the NFS high-security fence. Particularly important is the Baltimore and Ohio railroad grade in the Buttermilk-Bond reach of Buttermilk Creek.

7.3.2 Gradient

The mean gradient is 6.76 m/km, as measured along the low stage thalweg. The profile may be divided into a number of segments of varying downstream spacing or wavelengths. The shortest segments, measuring 50 to 100 m, are pool-and-riffle alterations. Some bar complexes, 100 to 200 m long, are also remarkably flat. Longer-spaced segments are on the order of 500 m to 1 km in length. The gradient is steeper than the mean value for that portion of Buttermilk Creek closest to the waste-burial site.

7.3.3 Bar and channel geometry

The basic channel pattern of Buttermilk Creek is an entrenched meander system when the active, unvegetated bars and the low-stage thalweg are considered together. The channel has several

abrupt, 90° bends, for example, some gentle meanders, some relatively straight reaches, and a reach with very sinuous meanders. The overall sinuosity, however, is low (22), measured as 1.14 along the low-stage thalweg.

Topographic Mapping - Two areas were selected to construct topographic maps of bar complexes and adjacent channels in some detail. These two locations are at thalweg bends, but represent a contrast in overall channel pattern, bar morphology, and detail on bar tops as described below.

Detailed bar and channel pattern - The bars (100 to 200 m in length) exist as complex, elongate, erosional, and depositional features flanked by and often cut by the present low-stage channel. Riffles are present where the channel crosses over a large bar and in the vicinity of the downstream edges of the bars. Pools are present as deeper areas in the narrow thalweg and also as very deep scour holes between advancing bars and eroding banks. Dry chutes exist along the margins of many bars. The overall bar and channel pattern is similar to that of small, gravelly, braided streams (15 and 16).

In contrast, some bar and channel patterns are relatively simple. The low-stage thalweg bends around the 2 large bar complexes. Riffles occur at the crossover points between bar complexes and also in a regular spaced (50-100 m) pool-and-riffle sequence in the low-stage thalweg. The overall bar and channel pattern is similar to that described as a coarse-grained meander pattern by McGowan and Garner (23), although the grain size is much larger in Buttermilk Creek. The presently-active, mostly unvegetated, bars and channels are separated from adjacent, vegetated low terraces by a 1-2 meter erosional scarp. The active bars are in places up to 1 meter lower than the surrounding terrace, but may be at the same elevation or slightly higher than the terrace. Bar complex 4 is an example of an elevated bar surface.

Bar surface features - The surfaces of the large bar complexes, up to several hundred meters long, exhibit complicated microtopography and clast-size groupings. These forms are similar in size, shape, and clast concentrations to gravel, longitudinal and unit bars of braided-stream, depositional environments (15 and 16). Surfaces of most bars have abundant features that record high-stage upper-flow regime transport. Transverse ribs are one such feature. The ribs, preserved antidune beforms (15 and 24), show similar clast size-spacing correlations as those described in other high-energy gravel streams. Some bar complexes have well-developed slip faces or depositional edges on their downstream margins. Depositional edges may be gravel or sand and record the downstream growth of bars.

7.3.4 Clast size and shape

Clast size - Average largest clast size (long axes) ranges from 21 to over 30.5 cm, but shows no systematic variation in a downstream direction. The mean size of the average largest clast is 25.0 cm. The clasts are well imbricated and occur in groups or concentrations on the surfaces of bar complexes and in chutes. Clasts of all sizes form an armor on the bar, channel, and chute surfaces; about 2 percent of these clasts are much larger than the average maximum size; about 5 to 10 percent are of average maximum size; and the remainder are smaller. However, grain-size measurements of bulk samples were not carried out.

Clast shape - A study of clast shape was carried out by C. Sherwood, University of Rhode Island, Department of Geology. Plotted on a Folk form diagram for clast shapes, clasts are shown to be very bladed to very platy in shape. They consist mostly of Devonian sandstones, the most resistant bedrock of the area (5).

Other bed material - The bar surfaces have very little sand and few types of other material are exposed to cuts in the bars or terraces, because the valley-wall stratigraphy consists primarily of a clay-rich basal till.

7.3.5 Stream discharge

USGS gauging data - The USGS operated a gauging station on Buttermilk Creek near the Bond Road Bridge during water years 1973-1968 (references 8 through 14). Stage discharge rating tables and curves and indirect-measurement calculations for a large flood event are included in these publications and in a special report (14).

A hydrograph of daily discharge for water year 1962 is very "spikey" with high discharge flow events lasting only a day or two. Base-flow occurs from early summer to mid-fall and is approximately $0.3m^3$/sec or less. The fall and winter peaks represent discrete rainstorm or thaw events. Spring runoff from snow melt is punctuated by rainfall events. The mean monthly discharge is much less (maximum = $2.5m^3$/sec in May) than the summation of daily discharge that includes a rainfall peak ($14.5m^3$/sec, max).

A stage-discharge rating curve for Buttermilk Creek, adapted from those compiled by the USGS (14), includes the highest discharge events for each year the stage-height recorder was in place. These readings (max = $110.65m^3$/sec) of instantaneous discharge indicate that peak flow events are much higher than those that appear as the daily summation. This means

that the large discharge events are of extrememly short duration, probably several hours in length.

Because instantaneous discharge data were not available, a flow duration curve was not constructed. The daily discharge information does not yield sufficient detail for a meaningful duration curve. Also, because there are only 8 years of record, construction of a flood-frequency curve was not justified.

Stage-height records (new) - A stage-height recorder was installed at Thomas Corners Road Bridge on August 28, 1978 by the NYSGS (recorder on loan from USGS). The Bond Road site was not reoccupied, because the road is no longer passable to vehicles, thus there is no easy access. A section of the record from October 15-29 recorded 2 rainstorms and numerous small "spikes". The numerous small spikes are the result of automatic dumping of excess accumulation in NFS reservoirs. No stage-discharge relations have been measured except for October 28, 1978. The stage recorder is operational at present.

Discharge measurement (new) - Five discharges were measured during the summer and fall. They are as follows:

1)	June 26	$0.31 m^3/sec$
2)	July 17	$0.16 m^3/sec$
3)	July 21	$0.72 m^3/sec$
4)	July 27	$0.23 m^3/sec$
5)	October 28	$1.4 m^3/sec$.

The October 28th measurement was taken about 200m upstream of the Thomas Corners Road Bridge; the others were obtained at a cross-section beneath the bridge. A stream discharge of $1.4 m^3/sec$ corresponds to a stage height of 30cm. The new measurements were obtained at low-flow stages (non-flood events), except for three that were made during base-flow conditions.

7.3.6 Clast movement

Recorded movement - Movement of clasts occurred at transects on 4 different bar complexes between August 26 and October 29, 1978. Inspection of the stage-height records from the Thomas Corners Road station indicates that the most probable time of movement was during the October 23, 1978 event that had a stage increase of about 100cm above base flow. The maximum distance moved for a medium-size clast was 19.1cm; and maximum distance moved for any clast (of those located) was 1491 cm (2.0 cm L-axis). The clasts tended to move at an angle to the direct downstream direction, across

the bar surface toward the low-stage channel. The depth of flow over the station is not known.

7.3.7 Channel sweep

The active bar and channel system is that area of Buttermilk reach that is flooded at least once yearly, as determined by debris lines and amount of vegetation cover. The location of channel in relation to the bars also changes annually. Some of the lowermost terraces are also flooded during large flood events, perhaps yearly.

A series of 6 maps of channel positions consisting of 5 maps of particular years and one composite map have been compiled from aerial photos. An inspection of the maps indicates that since 1938, 30-40 percent of the valley-flood area has been swept by the active bar and channel system. The swept area increases to over 50 percent if the inactive terraces are removed from consideration.

The lateral movement of the active channel places the stream in a position to erode the valley-wall till. Thus, younger terraces are either quickly removed or again eroded, and thus provide little resistance to lateral erosion. Active landslides initiate where channel sweep has resulted in prolonged erosion into valley-wall till.

7.3.8 Active landslides

Active landslides occur in areas where the active channel has continuously impinged on the valley wall over a time at least as long as the time of photo documentation. These slides may be, but are not always, on the outside of low-stage thalweg meander bends.

The landslides are actually slumps with slide scars up to 100 meters wide. Coherent slump blocks measure 20 to 50 meters wide. Most slides have a debris-flow base, where the coherent blocks have broken into a hummocky, tension-cracked topography.

The landslide zones have shown repeated activity, resulting in the formation of new scars and slide masses over the 1938-1977 timespan. One landslide was marked with a series of stakes in October, 1978, but has not been resurveyed as yet. Observations of older stake fields by Prudic and Molello (personal communication) indicate meters of downslope movement over three years.

7.3.9 Stream Terraces

Physical description - Fluvial terraces of the Buttermilk-

Bond reach are surfaces with grass and shrubs, or heavy vegetation, that retain much of their original bar, channel, and chute topography. Most terrace surfaces are covered with bar-top gravel, although small areas of flood-plain marsh and swamp do occur. Cuts in the lower, inactive terraces also reveal a gravel fabric similar to that of active bars.

Location and elevation - Detailed mapping revealed the existence of 14 terrace levels ranging from 1 meter above presently-active bars to a fluvial gravel on the burial-site surface 35 meters above the bar surfaces. These terrace levels are grouped in 3 categories according to general elevation: 1) low, up to 3 meters above bar surfaces; 2) middle, 3 to 8 meters above bar surfaces; and 3) high, all higher terraces.

Correlation and Age - An attempt has not been made to correlate terraces either along the reach or across the valley at a given cross-section. Many separate terrace levels occur within the middle group, particularly on the east side of the valley. Most of the highest terraces exist on the west side of the valley.

Wood fragments buried 50 cm below the surface in fluvial gravel were collected from the highest terrace group. One of the fragments was determined to have an age of 9920± 240 BP (uncorrected ^{14}C years) (dated by Richard Pardi, Queens College). This appears to mark the initial stages of downcutting of Buttermilk Creek after the recession of the Woodfordian glacier.

7.3.10 Alluvial Fans

Physical description - Alluvial fans along Buttermilk Creek can be classified into 3 groups: 1) short, steep active fans, measuring 100-200 m long; 2) larger fans with both inactive and active segments; and 3) large fans at the junction of tributary streams with Buttermilk Creek. All are heavily vegetated. The short fans begin part-way up the valley wall, with an entrenched stream extending to the top of the wall. The fanhead may or may not contain an incised stream with the fan commonly having a single active lobe. The larger fans also head in the valley walls, but the entrenched streams above the fanheads are incised into the upland surface. These fans contain both inactive and active segments with inactive lobes existing as terraces above incised, active streams that feed distal, active lobes. The fans may have mutiple, active lobes. The largest fans occur at the confluence of small tributary streams with Buttermilk Creek. They are similar to the medium-sized fans in appearance, except for larger size and deeper incision of the active stream.

Fan activity - The small fans are active only during rainfall events and have dry channels the rest of the time. The larger fans remain active during lower-flow stages, even though runoff is very low. The largest tributary fans have an active low-flow channel even during base-flow conditions. During flood stage, overbank flow can reactivate fan lobes.

7.4 Conclusions

7.4.1 The Buttermilk-Bond reach of Buttermilk Creek is a coarse gravel, high gradient, degrading stream with a gradient-clast size relationship similar to many gravel, braided streams.

7.4.2 The bar and channel geometry consists of large bar complexes with a complicated microtopography superimposed on the complexes. The low-stage thalweg is bent around the bar complexes and its location is determined by bar complex migration. Bar complex is determined in turn by the rate of braid bar movement on the surfaces of the complexes.

7.4.3 A few bar complexes are relatively simple gravel sheets, ending in depositional edges, suggesting that the complexes migrate as a unit during catastrophic flood events. The temporary storage of gravel could affect the gradient downstream of the bar complex, resulting in enhanced sediment transport. Such a condition exists adjacent to the waste-burial site on Buttermilk Creek.

7.4.4 Buttermilk exhibits a highly variable stream hydrograph. Discharge rises from base-flow conditions to flood-stage in a few hours, and subsides just as quickly due to the impermeable nature of the till mantling the drainage basin. This high, effective runoff aids sediment transport in the creek. Effectiveness is promoted when the high stages allow more of the bar surface area to be covered and thus more bedload is available to be moved.

7.4.5 Holocene landscape evolution began soon after deglaciation when large alluvial fans debouched on the surface at the burial-site elevation and drainage from the fans flowed northward. The fan systems formed the loci for later development of the Buttermilk tributary systems.

7.4.6 Thus the agents responsible for lowering and widening of Buttermilk Creek are: 1) fluvial transport of material down and out of the Creek causing lowering of the active bar and channel surface; 2) lateral erosion of the active flood channel to remove previously deposited terrace material and valley-wall till; 3) landslides that remove material from the valley wall and deliver it to the valley bottom; 4) sediment transport on alluvial fans that delivers valley-wall

material to the creek channel system.

7.4.7 Channel sweep, leading to lateral erosion of older terraces and the valley wall till, is an extremely active process in the Buttermilk-Bond reach. Landslides occur in areas where the active channel system shows a history of valley-wall erosion. These landslides are not a major sediment provider to Buttermilk Creek except in the vicinity of the waste-burial site. Future landsliding is to be expected in this area.

7.4.8 Alluvial fans are an important denudation agent in the widening of the valley wall but the rate of fan processes is unknown at this time.

7.4.9 Migration of gravel at clast movement stations established on Buttermilk Creek has indicated that movement occurs at discharge peaks lower than the maximum recorded. This suggests that significant clast and bar movement occurs at peak flooding, particularly during spring runoff. In fact, catastrophic flood events may be the prime movers of bedload and suspended load.

7.4.10 Initial Buttermilk Creek incision began before 9920± 240 BP, the oldest dated terrace. Future evolution is expected to proceed by Buttermilk valley lowering, tributary widening, and stream capture until the burial-site surface is destroyed. No rate has yet been established.

7.5 Recommendations

7.5.1 To continue study by direct measurement of sediment discharge, the following should be carried out:

- -Remap bar complexes 4 through 6 and 11 to gain information on the rate of mass gravel movement down Buttermilk Creek.

- -Continue measurements at clast movement stations to determine rate of bedload transport for a small area, and how often bedload moves.

- -Continue measuring velocity and cross-sectional areas in order to conduct a new stage-discharge curve. Tie this curve to stage heights at the clast movement sites in order to compute sediment transport rates.

- -Initiate suspended-sediment sampling with a pumping station at Thomas Corners Road Bridge.

- -Install a stage recorder on Frank's Creek and a suspended-sediment pump station.

-Obtain bulk sediment samples of valley-wall till to determine ratio of potential bedload to suspended load. Sample bars to determine size distribution of bedload.

-Measure sediment volume impounded in NFS reservoirs and compute volume/year.

-Monitor spring freshet discharge and events.

-Attempt to sample bedload during a flood event to determine sediment transport rate.

-Place a screen across the channel at Bond Road Bridge to sample total bedload above a given size over a given time.

-Resurvey landslide (BC6) to determine magnitude of slumping.

-Devise a system to monitor sediment transport on, and changes of, selected alluvial fans.

-An additional site representative would be needed at least part-time to: a) make velocity area measurements; b) tend the stage recorders and pumping stations; c) monitor clast movement and, d) process suspended-sediment samples.

7.5.2 To continue study of the Holocene evolution of Buttermilk Valley, the following are suggested:

-Correlate the mapped terraces downstream and across valley to gain information on the early dimensions of the valley.

-Collect age dateable material, if possible, from the terraces.

-Assess tributary development in relation to topography, processes, and gradient.

-Measure longitudinal profiles of tributaries for base line information on sediment transport.

-Construct cross-sectional profiles at selected locations of tributaries to assess nature of valley development.

-Compute sediment volume removed from Buttermilk as a function of the ages of the terraces, to obtain a volume/year.

8.0 Trench Water Study

8.1 Introduction

The materials in the low-level waste burial area that are potential sources of environmental contaminants are the waters that have infiltrated into the burial trenches and have been in contact with the buried waste and the gases generated during decomposition of the waste. 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 was undertaken during 1975 and 1976 under Phase I of the project. Wells for sampling were installed by the USGS, under subcontract to the NYSGS. 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 1975 and 1976, trench water samples were collected from the 5 north-end trenches and analyzed (Figure 8-1). The purpose of the present phase of the study was 1) to resample some of the north-end trenches in order to gain a time perspective on the activities and compositions of these trenches, and 2) to sample some of the south trenches for the first time (Figure 8-2). A thorough understanding of the radiochemical composition of the trench water is needed to define the transport of radionuclides from the trenches. This includes the sampling of trench water at different depths and locations along the trench axes to evaluate spatial variations in trench water composition.

8.2 Method of Study

8.2.1 Field Drilling*

At the time well installation in the south trenches was being planned, water levels were so low that the north ends of some of the trenches, which slope southward, were probably dry. Well sites intended for water sampling were placed as far north of each sump as possible where the saturated thickness would be at least 2 feet. Longitudinal sections along the center of each trench were drawn from information on sump

*Partially excerpted from Prudic, 1978, USGS Open File Report 78-718 (reference 25).

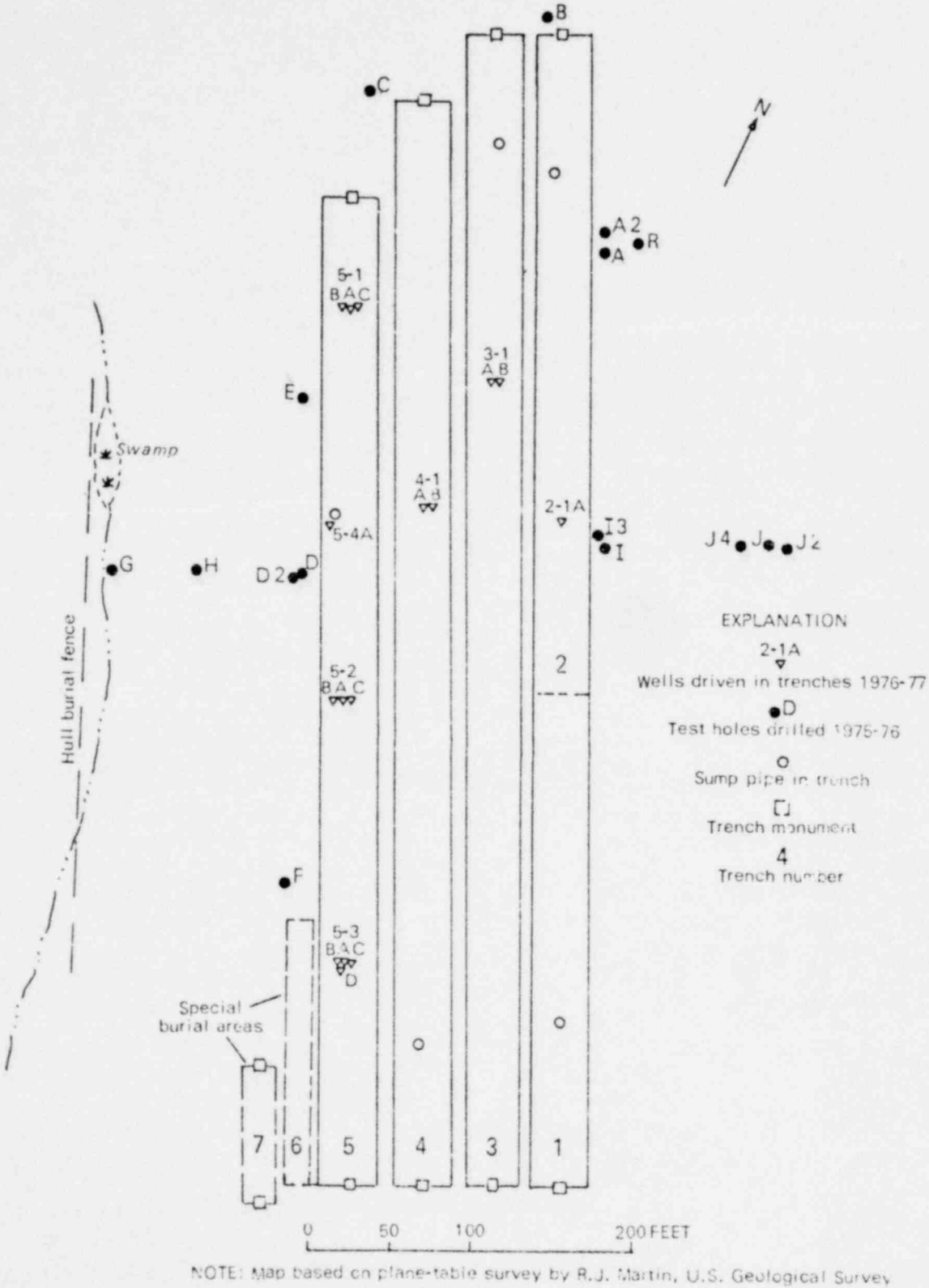
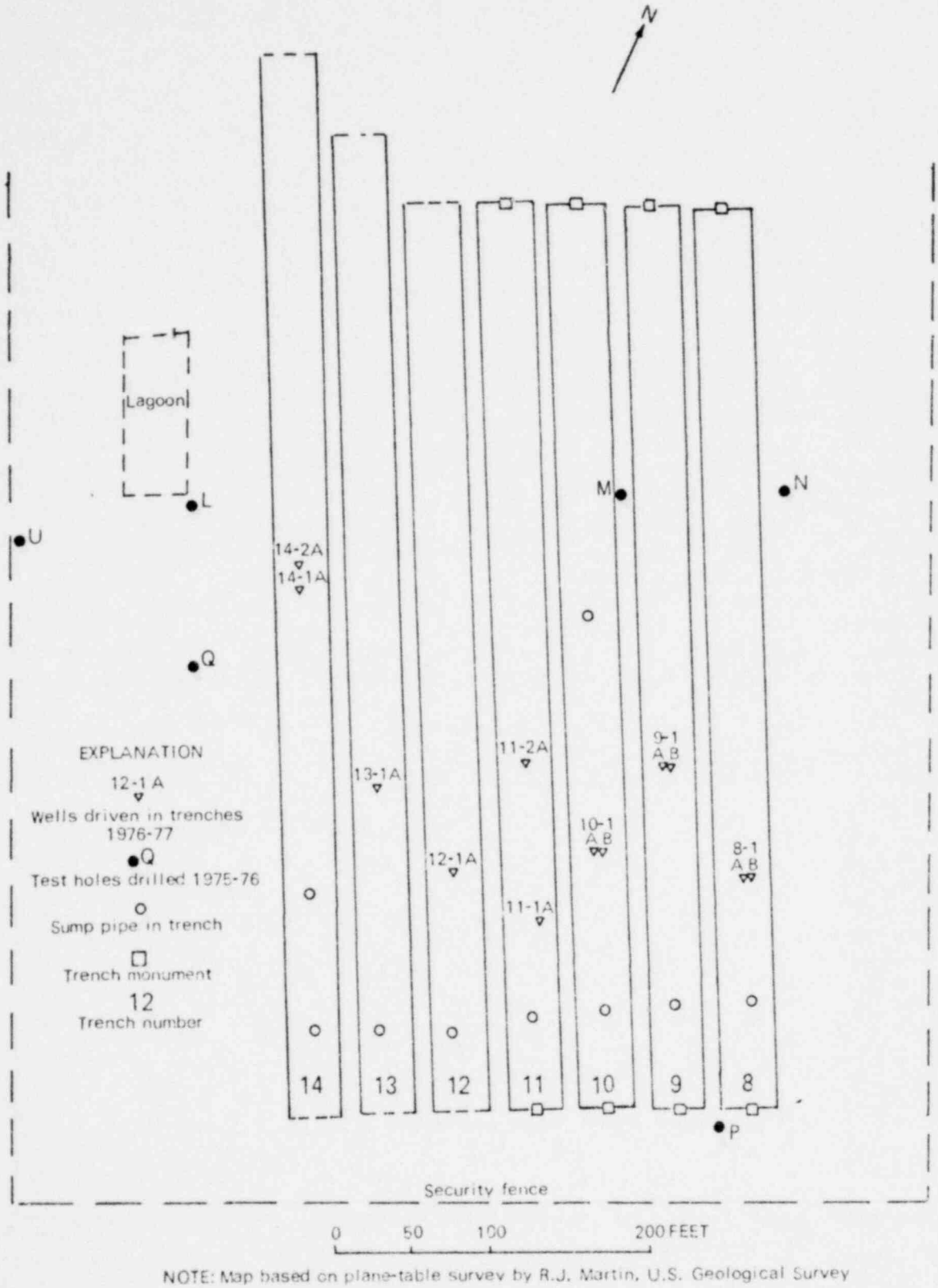


Figure 8-1.--Locations of driven wells, test holes, sump pipes, and trench monuments in north burial trenches.
(from Prudic, 1978: USGS Open File Report 78-718)



NOTE: Map based on plane-table survey by R.J. Martin, U.S. Geological Survey

Figure 8-2.--Locations of driven wells, test holes, sump pipes, and trench monuments in south burial trenches. (from Prudic, 1978: USGS Open File Report 78-718)

design and trench depth supplied by the site operators (see Reference 25, Figures 4 through 6). According to the site operators (A.G. Bockelman, oral commun; 1977), land surface in the south burial area had been graded to a 2-percent southward slope by removal of the upper soil zone before construction of the trenches; and because the trench depth had been maintained constant, the trench floors would have approximately the same slope as land surface. However, geologic logs from test holes drilled nearby and the bare sloping surface west of trench 14 suggest a shallower land-surface slope. The longitudinal trench sections were revised to correspond to the drilling and topographic data and were then used to determine the maximum distance from each sump where 2 or more feet of water could be expected in each trench. In trench 12 this point was less than 50 feet from the sump; therefore, no attempt was made to drive a pipe to water level. Site selection also considered the need to avoid the recorded locations of "special nuclear materials".

One-hundred-pound and 140-pound weights were used to drive the pipe and well points, which were sealed from surface water contamination by filling the augered hole around the pipe with bentonite. Samples were collected from the sumps on trenches 1,4,9, and 12, well 2-1A on trench 2, well 5-3A on trench 5, well 8-1B on trench 8, and well 14-1A on trench 14 (see figures 8-1 and 8-2).

8.2.2 Field Sampling Procedures for Anoxic Trench Water

Equipment:
- peristaltic pump
- vacuum pump
- Wildco Model #2210 water filtering apparatus
- portable mercury manometer
- tygon tubing
- power cable
- power source
- small tank of high purity argon
- water sample container (glass)
- miscellaneous adapters
- Millipore filter (0.24-µm pore size; 90-mm diameter)

Trench water samples collected prior to September, 1977, were not collected in anoxic conditions. Therefore, 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 come in contact only with an inert gas atmosphere (argon). Care was taken so that no standing water in sumps or wells that has been in contact with atmospheric oxygen would be included

in the samples. In order to prevent or minimize reactions that would affect the organic or inorganic species present, care was taken to maintain uniform temperatures during transportation. Storage time before analysis was kept to a minimum.

A pre-weighed Millipore filter is placed in the water filtering apparatus and the apparatus is then sealed shut. A peristaltic pump, the inlet of which is in communication with the trench water through a length of tygon tubing inserted in a well-point or sump pipe, is used to pump water through a reducing nipple and tygon tubing into the filtering apparatus. Tee joints, a vacuum pump, mercury manometer, and a tank of argon complete the closed sampling system. Prior to actual collection of a sample, the system is alternately pumped to near vacuum and then flushed with argon in order to ensure that any air is eliminated from the system. The system is checked for air leaks with a mercury manometer and then filled with argon.

Before actual sampling, five to ten gallons of trench water (until a definite gray water is observed) are pumped from the well-point or sump to ensure that the water is as anoxic as possible. Approximately 2 liters of anoxic (gray) water is then pumped by the peristaltic pump into the water filtering apparatus, displacing argon through the mercury manometer. The filtering apparatus is then closed from the well and manometer and more argon is introduced to force the trench water through the filter (where any particulate matter is deposited). The water passing through the filter is collected in the water sample container, where again anoxic conditions are maintained by displacing argon through the mercury manometer. After all of the water has been filtered and collected in the sampler, the sampler is sealed off with the teflon valves. The result is a filtered anoxic trench water sample maintained under a pressure of high purity argon.

8.3 Data Collection and Analyses

8.3.1 Field Collection of Trench Water Samples

The initial attempt at anoxic water sampling in September 1977 required the construction of a portable water sampling system which could be used under the unique field conditions at the LLRWB site. Ten anoxic-water sample collection bottles, similar in design to bottles developed by Brookhaven National Laboratory, were manufactured by a local glassblower to suit our specific needs. Two portable mercury manometers were also prepared. Special containers

for the bottles were designed and constructed; unfortunately, the containers were not manufactured until after the initial sample collections had been completed. Two commercially available Wildco water filtering devices were purchased, as were various miscellaneous supplies such as Millipore filters, tygon tubing, clamps, extension cords, etc. A peristaltic pump and vacuum pump were made available from state-owned equipment. Prior to the field trip, the system was tested using an old surface water sample which appeared to be of turbidity representative of trench water.

The weather at West Valley during the field-sampling effort was cold with record rainfall. All excess trench water from each sampling was pumped into a large bucket, then poured back into the trenches through the sump holes. The field sampling system was set up at each sump- or well-point to be sampled. Sump water level recorders provided the height of the trench water at each location. A length of tygon tubing, weighted at the end to ensure that it would sink below the water surface, was dropped into each sump and then connected to the peristaltic pump which in turn was connected to the water sampling system. The water pumped to the surface entered the Wildco water filtering apparatus.

Problems arose with several samples during force-filtering of the water from the Wildco into the water sampling bottle. Several water samples could not be filtered unless forced through by pressures as high as 80 psi. Consequently, the Wildco filtering apparatus eventually began to leak, causing concern that oxygen might contaminate the samples and that radioactive water might spill on the surface of the trench or contaminate personnel handling the sampling system. For trenches 8 and 9 a valid sample could be obtained only after the Wildco filtering apparatus had been repaired several times or a failed filter replaced. On two occasions, sampling was discontinued until the following day to allow epoxy glue to set up properly after leaks were discovered in the filtering apparatus. After each valid sample was collected, the pre-weighed Millipore filter and loaded sediment were placed in an envelope for shipment to the RSL. Nine samples from eight different locations were eventually collected. Two of these were accidentally exposed to air while in transport to the RSL, because the glass adapter valves were broken.

An additional trench water sample was obtained in July, 1978. The Wildco sampler was repaired and tested to be leak-tight before the field trip was undertaken. The sampling operation was successful and the anoxic sample was transferred to the RSL.

8.3.2 Laboratory Analysis of Trench Water Samples

Nine samples from trenches 1,2,4,5,8,9 (two samples),12, and 14 were analyzed for ^{3}HHO, ^{90}Sr, ^{238}Pu, $^{239,240}Pu$, ^{134}Cs, ^{137}Cs, ^{55}Fe, ^{60}Co, ^{63}Ni, ^{234}U, ^{235}U, ^{238}U, ^{232}Th, ^{22}Na, ^{133}Ba, ^{106}Ru, Gross α, and Gross β. Analysis of the 9 trench water samples was completed in October, 1978, by the RSL. Results are tabulated in Appendix C. For 8 of the 9 samples the dissolved and suspended fractions were analyzed separately. The third column of data represents the suspended fraction converted from $\mu Ci/g$ to $\mu Ci/ml$. The sample from trench #12 was not filtered. Therefore, only figures for total $\mu Ci/ml$ are shown. Gross α and Gross β values are shown in $\mu Ci/g$ as well as $\mu Ci/ml$ because the analysis procedure involves evaporating the sample onto a planchet. Procedures for these analyses are described in Appendix A.

8.4 Discussions and Conclusions

The trench water samples were collected for several purposes: 1) to observe the concentrations of the various radionuclides in the south trenches for the first time; 2) to compare these observations with analyses done previously on the north trenches (1), 3) to observe changes in concentrations over time in the north trenches; and 4) to compare results of 2 samples taken from the same location within 25 hours of each other.

8.4.1 Variations between trenches

General similarities between the various trenches include the following: ^{3}H as ^{3}HHO is by far the most abundant radioactive element in all the trenches studied; in most cases, ^{3}HHO activity is more than 2 orders of magnitude greater than the second most abundant radionuclide. In the majority of trenches studied ^{90}Sr is the second most abundant radionuclide (exceptions: trenches 1,8, and 12). In all cases, it is more than 1 order of magnitude greater than the next most abundant radionuclide.

Other radionuclides which are commonly among the top 4 most abundant radionuclides are ^{14}C (total) and ^{137}Cs; ^{14}C (total) is ranked number four or higher in all but trench 2; ^{137}Cs is ranked number four or higher in all but trenches 1 and 4. ^{63}Ni ranked in the top 5 in all the trenches studied.

The highest ^{3}HHO values found to date are in trench 5, well 5-4A. Relatively low values are found in trenches 1 and 2 of the north burial area and trench 14 of the south burial area. The highest ^{90}Sr activities were found in trench 4, Sump.

This value (2.02 E-02 5%) is 1 to 2 orders of magnitude greater than those found in any other trench. In trench 8, well 8-1B ^{90}Sr is the highest found in the south trenches (1.48 E-04 6%). Even so ^{90}Sr is only the sixth most abundant radionuclide in trench 8. This is because the activities of ^{63}Ni, ^{14}C (total), ^{238}Pu and $^{239,240}Pu$ are all highest in Trench 8. ^{134}Cs is commonly below detectable limits in trenches 1 through 4, while ^{137}Cs in trenches 5,8,9,12, and 14 is generally an order of magnitude above detectable limits. For the other radionuclides analyzed no strong trend between trenches is in evidence.

8.4.2 Variations within trenches between sampling points

Considering the heterogeneity of the buried waste in the trenches, the variation in the concentration of any given radionuclide within a given trench is small. Concentrations rarely vary more than an order of magnitude, and in these cases the variation can usually be ascribed to the stirring action of trench pumping over a long period of time. This stirring action may be bringing radionuclides into suspension in the immediate vicinity of the sump hole.

8.4.3 Variations over time at the same location

To date only 4 holes have been analyzed for changes over time: Trench 1, Sump well; Trench 2, well 2-1A; trench 4, Sump well; Trench 5, well 5-3A. In general, the majority of radionuclides have remained the same or decreased over time. However, several radionuclides, including ^{238}Pu, $^{239,240}Pu$ and ^{137}Cs show a marked increase in concentration over time in certain trenches. ^{238}Pu increased over time in trenches 1,2, and 5; $^{239,240}Pu$ increased over time in trenches 4 and 5; and ^{137}Cs increased over time in trenches 2,4, and 5. This is most probably the result of the disintegration of containers and the leaking of specific radionuclides into the trench water over a period of time, thereby increasing the concentrations of these radionuclides.

8.4.4 Short term changes with time

Two samples were collected from the same location - the new sump in trench #9 - within one day of each other. The purpose was to observe any short term changes in the composition of radionuclides in the trench water. Detectable changes in concentration - taking laboratory error terms into account - were observed for ^{3}HHO, ^{238}Pu, ^{134}Cs (Cs_2PtCl_6), ^{137}Cs (Cs_2PtCl_6), ^{60}Co, and ^{63}Ni. All but one showed a decrease in concentration; and only one, ^{63}Ni, showed a decrease greater than 25% (^{63}Ni showed a decrease of 67%).

The exception is ^{238}Pu, which showed an increase of 26%.

Previous studies during pump-outs have shown ^{238}Pu concentrations to be variable over short periods of time. Over a period of several days (between September 25 and October 5, 1975), the concentration of ^{238}Pu from trench #5 water being pumped from the sump well tripled. This variation however, may readily be attributed to turbulence created within the trench by the action of pumping especially if a large portion of the radionculides are adsorbed onto suspended particles in the sample. Empirical evidence for relatively high adsorption properties of ^{238}Pu can be seen by comparing the relative concentrations of a radionuclide in dissolved vs. suspended material (Appendix C). Clear evidence exists that ^{238}Pu is being more readily adsorbed by suspended particles than by most other radionuclides. Other readily adsorbed radionuclides observed include $^{239,240}Pu$ and ^{238}U.

8.5 Suggestions for Future Work

Further sampling, using existing wells in the north-end and south-end burial trenches, would be beneficial for evaluating changes in trench water composition and activities over time. Trenches 10, 11, and 13, have never been sampled. Trench 14, because it is the only south-end trench without a thick cap of soil, should be monitored for changes in concentrations and activities related to water level changes. Also, north-end trenches, until the recent maintenance operations, have been slowly filling, and should be re-sampled.

An important question, yet still unanswered, is whether some radionuclides remain isolated in containers or whether relative concentrations of the various radionuclides have been distributed evenly throughout a given trench. Future radiochemical data in conjunction with presently available data may be used to predict future changes in trench water activity and composition.

Closely associated with the above question is the question of whether the trench cap maintenance operations, including the use of a 50 ton proof roller, opened up any previously sound containers, thereby changing the composition of the trench water. Other effects of the trench recapping operations and the effectiveness of these responses in isolating the water should also be studied.

9.0 GEOTECHNICAL ANALYSIS OF SOIL SAMPLES FROM TEST TRENCH

9.1 Introduction

In July 1977, a research trench was excavated in glacial till at the Western New York Nuclear Service Center located at West Valley, Cattaraugus County, New York. This was the last of three research trenches to be excavated in the vicinity of several low-level radioactive waste burial (LLRWB) trenches (See Site Plan, Figure 9-1).

9.2 Methods of Study

At the test site a trench similar to the ones at the actual waste burial grounds was excavated by Benz Construction Co., Inc. of Springville, N.Y., using a large dozer. The research trench was approximately 100 feet long, 25 feet deep and varied in width from 10 to 20 feet at the bottom. NYSGS geologists observed and logged all soil profiles as the excavation proceeeded. After observations had been completed pits in the trench's ramp and bottom were dug with a backhoe to a maximum depth of 41 feet so that samples could be taken at desired elevations for laboratory tests. The laboratory testing program was conducted by Ernest T. Mosely, P.E., of Raamot Assoc. P.G., Fayetteville, N.Y. Ten samples were obtained at depths below grade as shown:

Depth	Sample Orientation
4 ft.	Vertical
8 ft.	Vertical
12 ft.	Vertical
16 ft.	Vertical
20 ft.	Vertical
20 ft.	Horizontal
24 ft.	Vertical
24 ft.	Horizontal
28.8 ft.	Vertical
37.1 ft.	Vertical

The samples were cut from the surrounding soil by hand such that they fit a 6-inch diameter aluminum casing. The two ends of the casing were then sealed with paraffin. These samples were all opened at Raamot's soils laboratory where visual identification was made of each. The following tests were conducted on certain samples:

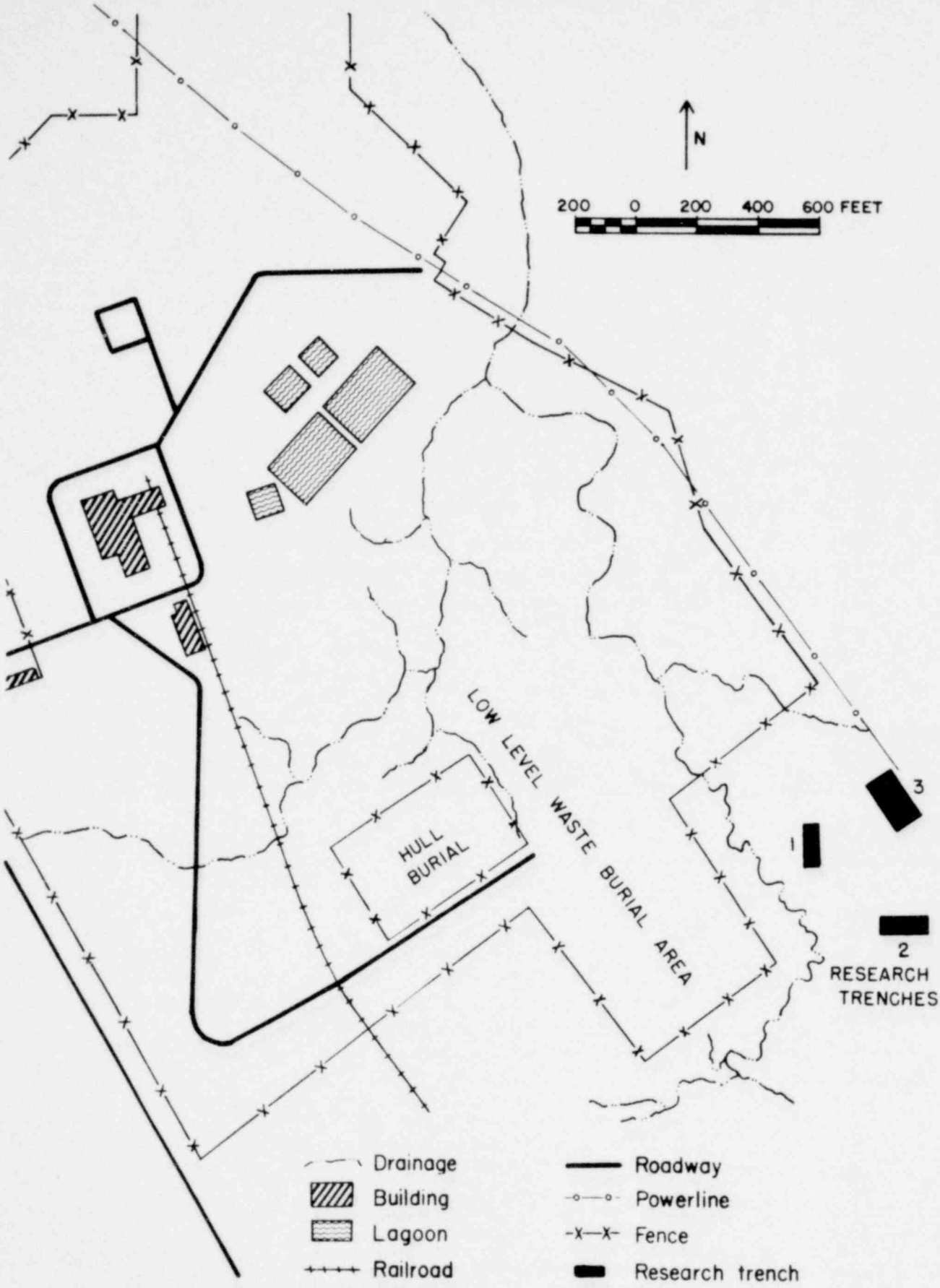


Figure 9-1. Western New York Nuclear Service Center showing location of research trenches 1, 2, and 3.

Moisture content
Unit weight
Liquid limit
Plastic limit
Shrinkage limit
Unconfined compression test
Dispersion test
Swell test
Permeability test
Consolidation test

9.3 Soil Description

Soil sample identification has been determined by means of visual classification by the soil engineer and by Atterberg Limit tests (liquid limit, plastic limit, shrinkage limit).

All ten soil samples have a similar description. They generally have been classified as CLAY and SILT, little coarse medium to fine sand, trace fine gravel according to the Burmister system. The clay, silt, sand, and gravel is generally a mixture. The only exception found in the samples was in the sample taken from a sand pod at the 37.1-foot depth, which had thin (1/8" to 1/4") fine sand seams dipping approximately 20° from the horizontal. The color of the samples was generally a uniform grey except for the samples at the 8 and 12-foot depths, which had thin (1/16" to 1/8") brown discolored seams.

9.3.1 Plasticity and Moisture Contents

The Atterberg limits indicate the soil is a clay of low to medium plasticity. The soil samples have an average shrinkage limit of 12, an average plastic limit of 19 and an average liquid limit of 31. Atterberg limits are useful as a basis for comparison for the soil's natural water content. At moisture contents greater than the liquid limit, the soil is in a liquid state. At a moisture content between the plastic limit and liquid limit, the soil is in a plastic state. At the moisture content between the shrinkage limit and the plastic limit, the soil is in a solid state. The shrinkage limit defines the mositure content at which a further reduction in moisture does not cause further shrinkage. The first three soil samples at depths of 4, 8, and 12 feet have a natural moisture content of little over 15 percent. This indicates they are borderline between the solid and plastic states. These comparsions indicate the upper soil, represented by the first three samples, has lost moisture due to dessication. This is confirmed by the appearance of the upper 15 feet of soil in the test trench. It contained

shrinkage cracks which diminished in frequency with depth, and had a typical brownish weathered color.

These comparisons also indicate that the lower seven soil samples at some time in their past history have been subjected to loads greater than the overburden loads present today. Had the soil never been subjected to a load greater than that existing today, the natural moisture content would have been closer to the liquid limit. This is a fairly common phenomenon in the northeast where till deposits have borne the weight of great thicknesses of glacial ice.

9.3.2 Permeability and Seepage Characteristics

The seepage characteristics of the soil have been investigated by making permeability tests, consolidation tests, swelling tests, and dispersion tests.

Permeability tests in a vertical direction were made on the samples at depths of 20, 24, 28.8, and 37.1 feet. Permeability tests were also made in a horizontal direction on samples at depths of 20 and 24 feet. The average of the four vertical permeability tests is 2×10^{-8}cm/sec and the average of the two horizontal permeability tests is 56×10^{-8}cm/sec.

The permeability in a vertical direction has also been calculated based on the consolidation tests made on the samples at the 24 and 37.1-foot depths. The average for the two tests for soil loads of 1 to 2 tons per square foot, approximately the present overburden pressure, is 7×10^{-8} cm/sec.

The swelling test results indicate that the clay and silt soil is not highly expansive. At present in situ stress levels the clay will not swell when it has access to water. However, at low stress levels, such as adjacent to open shrinkage cracks, it will swell sufficiently when in contact with water to close the cracks. Although the cracks will close on wetting it is quite probable that the overall permeability of the fractured clay will be greater than unfractured clay because silt, fine sand, and organic matter that has been washed into open cracks after rainfalls keeps these cracks partially propped open. This filling action would probably be more significant near the ground surface than at greater depths. A field test would be required to measure the overall permeability, and it can be expected to vary considerably from place to place on the site.

9.3.3 Dispersion

Dispersion tests were made to evaluate the soil's potential for soil erosion due to water flowing through fine cracks in the soil mass. The primary cause for erosion in certain clay soils has been attributed to a low total dissolved salt content in the seepage water and a high concentration of sodium cations in the double layer of the clay structure.

Six pin hole dispersion tests were performed using procedures outlined by Sherard and others (26). The testing procedure consists of compacting a small sample in a Harvard Miniature Permeameter, puncturing the sample with a 1 mm probe, sealing the unit, and running a series of constant head permeability tests at each of four pressure heads. All samples tested are non-dispersive and classified as ND-2 or ND-3 with ND-2 classifications showing a greater resistance to erosion than ND-3.

9.3.4 Unit Weight and Unconfined Compression

The unit weight and unconfined compression test results are necessary data for the study of landform modification. Landslides are common along the steep slopes from the uplands to the stream valleys in the vicinity of the site. The occurrence of shrinkage cracks which fill with water after rainfalls must be considered in the slope stability analyses as well as the shearing strength of the uncracked clay and silt. The soil's average unit weight (moist) is approximately 133 pounds per cubic foot. The unconfined compression tests show the cohesion of the soil to be approximately 2 to 3 tons per square foot in the lower part of the weathered zone (12 and 16-foot samples) and approximately 1.5 tons per square foot in the unweathered soil below.

Based on the soil's cohesion as measured by the unconfined compression tests and the soil's unit weight, the theoretical limit to which cracks can penetrate is approximately 50 feet. Apparently the weather conditions at the site are such that this limit has not been reached because cracks could not be seen penetrating further than approximately 15 feet at the test trench. Similar maximum depths were observed earlier in the waste trenches themselves.

9.3.5 Consolidation

The two consolidation tests show that the soil has been considerably disturbed. This is evident by the absence of a well-defined break in the strain vs. log of pressure curves

(consolidation curves). The consolidation tests made during previous investigations for the nuclear fuel reprocessing plant show the same feature. The disturbance may have been partly the result of the sampling procedure which is necessary in very stiff clay. However, the disturbance is probably largely the result of being reworked by glaciation. The absence of a well-defined break in the consolidation curves makes it impossible to estimate the preconsolidation load with any degree of accuracy.

9.4 Significance of Test Results

Permeability tests yielded information on horizontal and vertical permeabilities which will prove valuable in computing migration rates of various radionuclides through the clay-rich silt underlying the burial trenches. Oxidized shrinkage cracks were observed to a depth of 15' in research trench no.3. Swell tests indicate that the presence of water will cause the cracks to close (a phenomenon observed directly on the LLRWB trench caps after a significant amount of rain has fallen in a short period of time). However, rainfall will cause the washing of silt, fine sand, and organic matter into open cracks, preventing full closure of the cracks and causing the overall permeability of the fractured clay to increase. On the burial trench caps cracks wider than 5 cm have been observed. The longest of these was 10 meters.

It should be noted that cracks on the trench caps may be caused by several different processes:

1) shrinking - as a result of dessication
2) tension caused by settling of the trench cap itself
3) compaction of material within the trench
4) cyclic extension and contraction by frost action and freezing.

Based on unconfined compression tests and the soils' unit weight, the theoretical limit to which cracks of any origin can penetrate is approximately 50 ft. Apparently weather conditions of the recent past preclude such a depth. But it is also probable that a prolonged series of drought years would increase the 15 ft. depth to which dessication cracks presently penetrate.

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APPENDIX A

RADIOCHEMICAL ANALYSES FOR WATER AND SEDIMENT SAMPLES

Because of the small size of the soil samples analyzed, many of these soil samples were done in sequence on the same aliquot. For example, Isotopic Uranium, Isotopic Plutonium and ^{55}Fe were all done from the same aliquot.

.--Gross 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 samples 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 gross alpha/beta.

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

The method is only adequate for screening purposes. Loss of volatile radionuclides such as radioiodine and tritium 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 gross beta - $^{90}Sr^{90}Y$
for gross alpha- natural uranium.

.--Analysis of Tritium as ^{3}HHO. Samples were vacuum distilled and the distillate collected to separate tritium from other interfering radionculides 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 500pCi/l.

.--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 N HNO_3. Soil samples were fused. Silicates were removed and the sample was dissolved in 7.2 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 N HCl - 0.01 N HF solution. Plutonium was electrodeposited 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 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 $^{239,240}Pu$ 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 the 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 separated from the solution by adsorption on a cation exchange column. The column was sashed with 0.5 N HCl. The 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 were 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, was 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 efficienty factor for the photo-peak 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, ^{133}Ba, 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. 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 antion-exchange column. Iron was removed from the column with a solution of 9 N HCl - 0.25 M NH_4I. 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, purfied 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 2-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 and tissue 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.

APPENDIX B

RESULTS OF ANALYSES ON SURFACE WATER AND SOIL SAMPLES

TABLE B-1. SURFACE WATER SAMPLES COLLECTED DURING ICE CONDITIONS

Sample Type and Location		Collection Date/Time
"Sub-Ice" Flow	#1 Erdman's Brook	24 Jan. 78 1547
" "	#3 Bucket	25 Jan. 78 1445-1455
" "	#1 Erdman's Brook	13 Feb. 78 1412
" "	#1 Erdman's Brook	20 Feb. 78 1224
" "	#1 Erdman's Brook	28 Feb. 78 1535
" "	#1 Erdman's Brook	9 Mar. 78 1300
" "	#1 Erdman's Brook	13 Mar. 78 1420
" "	#3 Bucket	13 Mar. 78 1450
"Sub- + Supra-Ice" Flow	#2 Lagoon Rd.	14 Mar. 78 1435
" " "	#3 Bucket	14 Mar. 78 1440
" " "	#4 Swamp	14 Mar. 78 1500
" " "	#1 Erdman's Brook	14 Mar. 78 1512

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Table B-2. WEEKLY COMPOSITES OF GRAB SAMPLES (1977)

#1 ERDMAN's BROOK

Date	* Gross α	* Gross β	^{3}HHO(μCi/ml)
8/27-9/2, 9/7	<1.2 E-05μCi/g <3 E-09μCi/ml	<1.6 E-05μCi/g <4 E-09μCi/ml	<5 E-07
9/8-9/11	<1.1 E-05μCi/g <4 E-09μCi/ml	2.5 E-05μCi/g±54% 9 E-09μCi/ml±54%	7 E-07±56%
9/12-9/15, 9/19	<1.0 E-05μCi/g <2 E-09μCi/ml	4.1 E-05μCi/g±37% 1.0 E-08μCi/ml±37%	<5 E-07
9/20-9/26	<1.0 E-05μCi/g <3 E-09μCi/ml	2.1 E-05μCi/g±61% 5 E-09μCi/ml±61%	<4 E-07
9/27-10/3	<1.2 E-05μCi/g <2 E-09μCi/ml	5.6 E-05μCi/g±35% 1.0 E-08μCi/ml±35%	<5 E-07
10/4-10/10	<1.1 E-05μCi/g <2 E-09μCi/ml	4.2 E-05μCi/g±39% 8 E-09μCi/ml±39%	<5 E-07
10/11-10/17	<9 E-06μCi/g <2 E-09μCi/ml	3.6 E-05μCi/g±32% 9 E-09μCi/ml±32%	<4 E-07
10/18-10/24	<8 E-06μCi/g <2 E-09μCi/ml	<8 E-06μCi/g <2 E-09μCi/ml	7 E-07±58%
10/25-10/31	<8 E-06μCi/g <3 E-09μCi/ml	<8 E-06μCi/g <3 E-09μCi/ml	9 E-07±45%
11/1-11/7	<8 E-06μCi/g <3 E-09μCi/ml	<1.0 E-05μCi/g <3 E-09μCi/ml	1.6 E-06±27%
11/8, 11/9, 11/10 11/11, 11/13, 11/14	<1.7 E-05μCi/g <4 E-09μCi/ml	5 E-05μCi/g±64% 1.2 E-08μCi/ml±64%	3.4 E-06±14%

Table B-2 (Cont.)

#1 ERDMAN'S BROOK

Date	* Gross α	* Gross β	^{3}HHO (μCi/ml)
11/15-11/21	<1.5 E-09μCi/ml <9 E-06μCi/g	1.1 E-08μCi/ml±30% 7 E-05μCi/g±30%	2.3 E-06±14%
11/22-11/25, 11/28	<1.8 E-09μCi/ml <1.0 E-05μCi/g	7 E-09μCi/ml±53% 4 E-05μCi/g±19%	1.7 E-06±19%
11/30, 12/1-12/3	<1.7 E-09μCi/ml <1.2 E-05μCi/g	8 E-09μCi/ml±48% 6 E-05μCi/g±48%	1.4 E-06±22%

*Gross α and Gross β presented both in activity vs. weight and activity vs. volume modes.

Table B-3. FLOW-PROPORTIONED WEEKLY COMPOSITES (AUTOMATICALLY COLLECTED)

#2 LAGOON ROAD

Collection Period (Date/Time)	Gross α*	Gross β*	^{3}HHO(μCi/ml)
26 Aug.77/0950-7 Sept.77/0848	3.2 E-05μCi/g±52% 1.6 E-07μCi/ml±52%	2.90E-04μCi/g±7% 1.41E-06μCi/ml±7%	9.1 E-06±6%
12 Sept.- 19 Sept. 77/0808	1.6 E-05μCi/g±81% 3.6 E-08μCi/ml±81%	3.6 E-04μCi/g±8% 5.8 E-07μCi/ml±8%	3.2 E-06±14%
19 Sept.77/0808 - 26 Sept.77/1015	4.2 E-05μCi/g±44% 1.1 E-07μCi/ml±44%	2.9 E-04μCi/g±8% 7.6 E-07μCi/ml±8%	3.9 E-06±11%
26 Sept.77/1015 - 3 Oct.77/1010	<6 E-06μCi/g <1.2 E-08μCi/ml	3.8 E-04μCi/g±7% 7.5 E-07μCi/ml±7%	6.1 E-06±8%
3 Oct.77/1010 - 10 Oct.77/0947	<7 E-06μCi/g <8 E-09μCi/ml	5.9 E-04μCi/g±7% 6.8 E-07μCi/ml±7%	1.41E-05±5%
10 Oct.77/0947 - 17 Oct.77/0910	<6 E-06μCi/g <6 E-09μCi/ml	1.28E-03μCi/g±4% 1.16E-06μCi/ml±4%	4.7 E-05±4%
17 Oct.77/0910 - 24 Oct.77/1125	1.9 E-05μCi/g±70% 1.4 E-08μCi/ml±70%	1.69E-03μCi/g±4% 1.19E-06μCi/ml±4%	5.8 E-05±3%
24 Oct.77/1125 - 31 Oct.77/0940	<7 E-06μCi/g <4 E-09μCi/ml	1.96E-03μCi/g±4% 1.25E-06μCi/ml±4%	7.2 E-05±3%
31 Oct.77/0940 - 7 Nov.77/1518	<7 E-06μCi/g <6 E-09μCi/ml	1.14E-03μCi/g±5% 1.09E-06μCi/ml±5%	8.4 E-05±3%
7 Nov.77/1518 - 14 Nov.77/1535	1.4 E-05μCi/g±88% 1.9 E-08μCi/ml±88%	5.4 E-04μCi/g±5% 7.5 E-07μCi/ml±5%	4.7 E-05±4%
14 Nov.77/1535 22 Nov.77/1400	2.2 E-05μCi/g±76% 3 E-08μCi/ml±76%	4.2 E-04μCi/g±9% 5.8 E-07μCi/ml±9%	4.9 E-05±4%

Table B-3. (Cont.) FLOW-PROPORTIONED WEEKLY COMPOSITES (AUTOMATICALLY COLLECTED)

#2 LAGOON ROAD

Collection Period (Date/Time)	Gross α*	Gross β*	^{3}HHO(μCi/ml)
22 Nov.77/1400 - 28 Nov.77/1515	<8 E-06μCi/g <5 E-09μCi/ml	1.23E-03μCi/g±5% 8.5 E-07μCi/ml±5%	1.44E-04±3%
28 Nov.77/1515 - 12 Dec.77/1035	<9 E-06μCi/g <4 E-09μCi/ml	1.06E-03μCi/g±6% 4.5 E-07μCi/ml±6%	6.2 E-05±3%
25 April 78/1345 - 1 May 78/1345	<5 E-08μCi/ml <8 E-05μCi/g	1.12E-06μCi/ml±4% 1.69E-03μCi/g±4%	8.6 E-05±3%
1 May 78/1345 - 8 May 78/1031	<7 E-08μCi/ml <8 E-05μCi/g	1.16E-06μCi/ml±4% 1.42E-03μCi/g±4%	4.2 E-05±4%
8 May 78/1031 - 15 May 78/1120	<1.2E-08μCi/ml <6 E-06μCi/g	7.7 E-07μCi/ml±8% 4.0 E-04μCi/g±8%	1.97E-05±4%
15 May 78/1120 - 22 May 78/1055	<1.0E-08μCi/ml <7 E-06μCi/g	5.8 E-07μCi/ml±9% 3.8 E-04μCi/g±9%	1.77E-05±4%
22 May 78/1055 - 30 May 78/1135	<4 E-08μCi/ml <1.3E-05μCi/g	1.56E-06μCi/ml±6% 5.2 E-04μCi/g±6%	6.9 E-05±3%
5 June 78/1025 - 12 June 78/1024	<4 E-09μCi/ml <6 E-06μCi/g	1.32E-06μCi/ml±4% 1.74E-03μCi/g±4%	1.43E-05±5%
12 June 78/1024 - 19 June 78/1105	4 E-08μCi/ml±87% 1.5E-05μCi/g±87%	1.10E-06μCi/ml±7% 4.2 E-04μCi/g±7%	6.8 E-06±7%
19 June 78/1105 - 26 June 78/0940	<1.0E-08μCi/ml <7 E-06μCi/g	1.21E-06μCi/ml±7% 7.6 E-04μCi/g±7%	4.4 E-06±9%

TABLE B-4 FLOW-PROPORTIONED WEEKLY COMPOSITES
(AUTOMATICALLY COLLECTED)

#3 BUCKET

Collection Period (Date/Time)	* Gross α	* Gross β	^{3}HHO(μCi/ml)
26 Aug 77/1005 -	3.1 E-05μCi/g±54%	1.15 E-04μCi/g±14%	1.3 E-06±32%
7 Sept 77/0920	2.7 E-07μCi/ml±54%	1.01 E-06μCi/ml±14%	
12 Sept 77-19 Sept 77/0825	1.5 E-05μCi/g±81%	1.2 E-04μCi/g±13%	1.3 E-06±32%
	6 E-08μCi/ml±81%	5.2 E-07μCi/ml±13%	
19 Sept 77/0825 -	2.1 E-05μCi/g±67%	1.2 E-04μCi/g±12%	1.3 E-06±33%
26 Sept 77/1030	8 E-08μCi/ml±67%	4.5 E-07μCi/ml±12%	
26 Sept 77/1030 -	2.0 E-05μCi/g±67%	1.47 E-04μCi/g±10%	1.7 E-06±25%
3 Oct 77/1035	7.0 E-08μCi/ml±67%	5.0 E-07μCi/ml±10%	
26 Sept 77/1251	2.0 E-05μCi/g±71%	9.7 E-05μCi/g±15%	1.0 E-06±45%
	5.0 E-08μCi/ml±71%	2.4 E-07μCi/ml±15%	
3 Oct 77/1035 -	<1.3 E-05μCi/g	3.5 E-04μCi/g±7%	3.2 E-06±14%
10 Oct 77/1011	<1.3 E-08μCi/ml	3.7 E-07μCi/ml±7%	
10 Oct 77/1011 -	<7 E-06μCi/g	7.3 E-04μCi/g±5%	2.4 E-06±18%
17 Oct 77/0930	<4 E-09μCi/ml	4.2 E-07μCi/ml±5%	
17 Oct 77/0930 -	<6 E-06μCi/g	7.3 E-04μCi/g±5%	2.4 E-06±18%
24 Oct 77/1140	<6 E-09μCi/ml	6.6 E-07μCi/ml±5%	
31 Oct 77/1000 -	1.3 E-05μCi/g±88%	5.6 E-04μCi/g±5%	1.19 E-05±5%
7 Nov 77/1540	1.8 E-08μCi/ml±88%	7.4 E-07μCi/ml±5%	
7 Nov 77/1540 -	<6 E-06μCi/g	1.91 E-04μCi/g±9%	6.9 E-06±8%
14 Nov 77/1600	<1.4 E-08μCi/ml	4.4 E-07μCi/ml±9%	
14 Nov 77/1600 -	<8 E-06μCi/g	1.58 E-04μCi/g±12%	2.02 E-05±5%
22 Nov 77/1415	<1.7 E-08μCi/ml	3.4 E-07μCi/ml±12%	
22 Nov 77/1415 -	<8 E-06μCi/g	4.9 E-04μCi/g±7%	2.86 E-05±4%
28 Nov 77/1535	<6 E-09μCi/ml	4.2 E-07μCi/ml±7%	
28 Nov 77/1535 -	2.2 E-05μCi/g±81%	6 E-05μCi/g±32%	1.36 E-05±6%
12 Dec 77/1110	1.8 E-08μCi/ml±81%	5.0 E-08μCi/ml±32%	

TABLE B-4 con't. FLOW-PROPORTIONED WEEKLY COMPOSITES
(AUTOMATICALLY COLLECTED)

#3 Bucket

Collection Period (Date/Time)	* Gross α	* Gross β	^{3}HHO(μCi/ml)
25 April 78/1437 -	<1.5 E-08μCi/ml	8.2 E-07μCi/ml±6%	1.02 E-05±5%
1 May 78/1410	<8 E-06μCi/g	4.6 E-04μCi/g±6%	
8 May 78/1047 -	1.0 E-07μCi/ml±63%	7.9 E-07μCi/ml±8%	8.6 E-06±6%
15 May 78/1141	2.4 E-05μCi/g±63%	2.0 E-04μCi/g±8%	
15 May 78/1141 -	<1.7 E-08μCi/ml	4.3 E-07μCi/ml±11%	5.3 E-06±8%
22 May 78/1115	<6 E-06μCi/g	1.4 E-04μCi/g±11%	
22 May 78/1115 -	<3 E-09μCi/ml	3.9 E-07μCi/ml±6%	6.6 E-06±7%
30 May 78/1145	<1.3 E-05μCi/g	5.4 E-04μCi/g±6%	
5 June 78/1040 -	<4 E-09μCi/ml	5.0 E-07μCi/ml±5%	7.0 E-06±7%
12 June 78/1040	<6 E-06μCi/g	6.3 F-04μCi/g±5%	
12 June 78/1040 -	6 E-08μCi/ml±87%	7.0 E-07μCi/ml±9%	2.25 E-05±4%
19 June 78/1117	1.5 E-05μCi/g±87%	1.8 E-04μCi/g±9%	
19 June 78/0956 -	<6 E-09μCi/ml	6.5 E-07μCi/ml±5%	1.47 E-05±5%
26 June 78/1117	<6 E-06μCi/g	6.5 E-04μCi/g±5%	

* Gross α and Gross β presented as both activity vs. weight and activity vs. volume.

TABLE B-5 FLOW-PROPORTIONED WEEKLY COMPOSITE SAMPLES
(AUTOMATICALLY COLLECTED)

#4 Swamp

Collection Period (Date/Time)	*Gross α	*Gross β	^{3}HHO (μCi/ml)
26 Aug 77/1015 -	1.7 E-05μCi/g±75%	6.6 E-05μCi/g±17%	7 E-07±61%
7 Sept 77/0945	1.8 E-08μCi/ml±75%	7.2 E-08μCi/ml±17%	
12 Sept 77 - 19 Sept 77/0900	2.3 E-05μCi/g±67%	7.6 E-05μCi/g±22%	7 E-07±59%
	2.0 E-08μCi/ml±67%	6.5 E-08μCi/ml±22%	
19 Sept 77/0900 -	2.2 E-05μCi/g±67%	6.4 E-05μCi/g±15%	6 E-07±63%
26 Sept 77/1048	2.0 E-08μCi/ml±67%	6.0 E-08μCi/ml±15%	
26 Sept 77/1048 -	<1.3 E-05μCi/g	9.4 E-05μCi/g±16%	8 E-07±53%
3 Oct 77/1050	<9 E-09μCi/ml	6.5 E-08μCi/ml±16%	
3 Oct 77/1050 -	1.2 E-05μCi/g±97%	8.8 E-05μCi/g±13%	9 E-7±45%
10 Oct 77/1030	8 E-09μCi/ml±97%	5.8 E-08μCi/ml±13%	
10 Oct 77/1030 -	1.1 E-04μCi/g±27%	7.1 E-05μCi/g±20%	9 E-07±45%
17 Oct 77/0952	5.3 E-08μCi/ml±27%	3.5 E-08μCi/ml±20%	
31 Oct 77/1010 -	<6 E-06μCi/g	1.1 E-04μCi/g±13%	4.5 E-06±15%
7 Nov 77/1550	<4 E-09μCi/ml	7.6 E-08μCi/ml±13%	
7 Nov 77/1550 -	<8 E-06μCi/g	<7 E-06μCi/g	5.0 E-06±13%
14 Nov 77/1612	<5 E-09μCi/ml	<4 E-09μCi/ml	
14 Nov 77/1612 -	<8 E-06μCi/g	2.0 E-04μCi/g±10%	6.8 E-06±10%
22 Nov 77/1430	<7 E-09μCi/ml	2.0 E-07μCi/ml±10%	
22 Nov 77/1430 -	<9 E-06μCi/g	7.6 E-05μCi/g±21%	8.3 E-06±8%
28 Nov 77/1550	<4 E-09μCi/ml	3.4 E-08μCi/ml±21%	
28 Nov 77/1550 -	<8 E-06μCi/g	9.0 E-05μCi/g±19%	7.1 E-06±9%
12 Dec 77/1235	<2 E-09μCi/ml	2.7 E-08μCi/ml±19%	
25 April 78/1455 -	<3 E-09μCi/ml	3.3 E-08μCi/ml±17%	2.6 E-06±15%
1 May 78/1430	<8 E-06μCi/g	8.0 E-05μCi/g±17%	
1 May 78/1430 -	<4 E-09μCi/ml	4.2 E-08μCi/ml±15%	1.7 E-06±21%
8 May 78/1100	<8 E-06μCi/g	9.0 E-05μCi/g±15%	

TABLE B-6 WEEKLY LOW-FLOW WHOLE WATER GRAB SAMPLES

#1 Erdman's Brook

Date/Time	*Gross α	*Gross β	^{3}HHO(μCi/ml)
12 Sept 77/1100	<7 E-06μCi/g <1.9 E-09μCi/ml	3.0 E-05μCi/g±47% 8 E-09μCi/ml±47%	<5 E-07
10 Oct 77/1055	<1.5 E-05μCi/g <3 E-09μCi/ml	5 E-05μCi/g±54% 1.1 E-08μCi/ml±54%	8 E-07±58%
17 Oct 77/1020	<1.1 E-05μCi/g <2 E-09μCi/ml	3.0 E-05μCi/g±61% 7 E-09μCi/ml±61%	1.0 E-06±45%
24 Oct 77/1207	<8 E-06μCi/g <3 E-09μCi/ml	1.3 E-05μCi/g±75% 4 E-09μCi/ml±75%	1.1 E-06±39%
31 Oct 77/1015	<1.0 E-05μCi/g <3 E-09μCi/ml	<1.5 E-05μCi/g <4 E-09μCi/ml	2.2 E-06±22%
1 May 78/1450	<1.0 E-05μCi/g <1.9 E-09μCi/ml	3.2 E-05μCi/g±45% 6 E-0 μCi/ml±45%	6 E-07±59%
8 May 78/1125	<1.0 E-05μCi/g <1.9 E-09μCi/ml	4.8 E-05μCi/g±32% 9 E-09μCi/ml±32%	4 E-07±81%

#2 Lagoon Road

12 Sept 77/1030	<6 E-06μCi/g <5 E-09μCi/ml	1.59 E-03μCi/g±4% 1.19 E-06μCi/ml±4%	3.6 E-06±13%
19 Sept 77/0815	<6 E-06μCi/g <3 E-09μCi/ml	1.19 E-03μCi/g±4% 6.3 E-07μCi/ml±4%	2.09 E-05±4%
10 Oct 77/0958	<8 E-06μCi/g <5 E-09μCi/ml	9.7 E-04μCi/g±6% 5.3 E-07μCi/ml±6%	1.57 E-05±6%
17 Oct 77/0919	<7 E-06μCi/g <7 E-09μCi/ml	1.10 E-03μCi/g±4% 9.6 E-07μCi/ml±4%	4.9 E-05±4%
24 Oct 77/1132	<8 E-06μCi/g <7 E-09μCi/ml	1.37 E-03μCi/g±4% 1.31 E-06μCi/ml±4%	6.9 E-05±3%

TABLE B-6 con't. WEEKLY LOW-FLOW WHOLE WATER GRAB SAMPLES

Date/Time	*Gross α	*Gross β	^{3}HHO (μCi/ml)
31 Oct 77/0950	<8 E-06μCi/g <7 E-09μCi/ml	1.54 E-03μCi/g±4% 1.42 E-06μCi/ml±4%	8.5 E-05±3%
#4 Swamp			
19 Sept 77/0910	<6 E-06μCi/g <2 E-09μCi/ml	1.1 E-04μCi/g±15% 3.6 E-08μCi/ml±15%	9 E-07±47%
10 Oct 77/1030	<1 E-05μCi/g <4 E-09μCi/ml	6.1 E-05μCi/g±31% 2.4 E-08μCi/ml±31%	1.4 E-06±31%
17 Oct 77/0945	<8 E-06μCi/g <4 E/09μCi/ml	8.7 E-05μCi/g±17% 4.5 E-08μCi/ml±17%	1.7 E-06±26%

*Gross α and Gross β presented both in activity vs. weight, and activity vs. volume modes.

TABLE B-7. WEEKLY BACKGROUND GRAB SAMPLES

CONN. CREEK AT CONN. ROAD

Date/Time	*Gross α	*Gross β	^{3}HHO(μCi/ml)
21 Sept.77/1330	1.3×10^{-5}μCi/g±88% 1.0×10^{-8}μCi/ml±88%	2.6×10^{-5}μCi/g±33% 1.9×10^{-8}μCi/ml±33%	$<5 \times 10^{-7}$
28 Sept.77/1040	$<8 \times 10^{-6}$μCi/g $<4 \times 10^{-9}$μCi/ml	1.8×10^{-5}μCi/g±60% 8×10^{-9}μCi/ml±60%	$<5 \times 10^{-7}$
12 Oct. 77/1345	$<9 \times 10^{-6}$μCi/g $<3 \times 10^{-9}$μCi/ml	$<1.2 \times 10^{-5}$μCi/g $<4 \times 10^{-9}$μCi/ml	$<5 \times 10^{-7}$
3 Nov. 77/0910	$<7 \times 10^{-6}$μCi/g $<3 \times 10^{-9}$μCi/ml	$<6 \times 10^{-6}$μCi/g $<2 \times 10^{-9}$μCi/ml	7×10^{-7}±63%

BUTTERMILK CREEK AT FOX VALLEY ROAD

Date/Time	Gross α	Gross β	^{3}HHO(μCi/ml)
21 Sept.77/1345	$<7 \times 10^{-6}$μCi/g $<6 \times 10^{-9}$μCi/ml	2.2×10^{-5}μCi/g 34% 2.0×10^{-8}μCi/ml 34%	$<5 \times 10^{-7}$
28 Sept.77/1055	$<6 \times 10^{-6}$μCi/g $<4 \times 10^{-9}$μCi/ml	2.8×10^{-5}μCi/g 31% 1.6×10^{-8}μCi/ml 31%	$<5 \times 10^{-7}$
12 Oct. 77/1400	$<1.1 \times 10^{-5}$μCi/g $<3 \times 10^{-9}$μCi/ml	$<1.6 \times 10^{-5}$μCi/g $<4 \times 10^{-9}$μCi/ml	$<5 \times 10^{-7}$
3 Nov. 77/0935	$<1.0 \times 10^{-5}$μCi/g $<3 \times 10^{-9}$μCi/ml	$<1.4 \times 10^{-5}$μCi/g $<4 \times 10^{-9}$μCi/ml	$<5 \times 10^{-7}$

*Gross α and Gross β presented both in activity vs. weight and activity vs. volume.

TABLE B-8 SURFACE WATER GRAB SAMPLES

Date/Time	Gross α	Gross β	^{3}HHO (μCi/ml)
#1 Erdman's Brook			
3 April 78/1610	<1.6 E-09μCi/ml <1.2 E-05μCi/g	6 E-09μCi/ml ±44% 5 E-05μCi/g±44%	2.8 E-07±89%
#2 Lagoon Road			
3 April 78/1540	<5 E-09μCi/ml <9 E-06μCi/g	7.3 E-07μCi/ml±5% 1.34 E-03μCi/g±5%	6.1 E-05±3%
#4 Swamp			
3 April 78/1555	<3 E-09μCi/ml <8 E-06μCi/g	2.2 E-08μCi/ml±19% 7.2 E-05μCi/g±19%	1.3 E-06±21%
Culvert Entrance, South End			
18 Sept 77/1835	3 E-08μCi/ml±70% 1.9 E-05μCi/g±70%	8.0 E-08μCi/ml±19% 5.0 E-05μCi/g±19%	8 E-07±48%
Location "X" of "Missed Flow" Adjacent to #2 Lagoon Road (During V-Notch Wier Discharge Measurements)			
26 Sept 77/1330	<4 E-09μCi/ml <7 E-06μCi/g	5.9 E-07μCi/ml±5% 1.10E-03μCi/g±5%	1.43 E-05±5%

TABLE B-9. RAIN AND SNOW MELT RUNOFF GRAB SAMPLES (STATIONS 1-4)

#1 ERDMAN'S BROOK

Date/Time	Gross α	Gross β	^{3}HHO (μCi/ml)
14 Dec. 77/1055	<3 x 10^{-5} μCi/g <3 x 10^{-9} μCi/ml	1.2 x 10^{-4} μCi/g±44% 1.5 x 10^{-8} μCi/ml±44%	1.6 x 10^{-6}±25%

#2 LAGOON ROAD

Date/Time	Gross α	Gross β	^{3}HHO (μCi/ml)
14 Dec. 77/1030	<1.3 x 10^{-5} μCi/g <3 x 10^{-9} μCi/ml	6.9 x 10^{-4} μCi/g±9% 1.58 x 10^{-7} μCi/ml±9%	8.6 x 10^{-6}±8%

#3 BUCKET

Date/Time	Gross α	Gross β	^{3}HHO (μCi/ml)
14 Dec. 77/1040	1.7 x 10^{-5} μCi/g±78% 3 x 10^{-8} μCi/ml±78%	1.06 x 10^{-4} μCi/g±12% 1.8 x 10^{-7} μCi/ml±12%	2.9 x 10^{-6}±15%

#4 SWAMP

Date/Time	Gross α	Gross β	^{3}HHO (μCi/ml)
14 Dec. 77/1045	<2 x 10^{-5} μCi/g <3 x 10-9 μCi/ml	1.2 x 10^{-4} μCi/g±37% 1.5 x 10^{-8} μCi/ml±37%	2.5 x 10^{-6}±17%

TABLE B-10. MISC. GRAB SUB-ICE FLOW GRAB SAMPLES

#1 ERDMAN'S BROOK

Date/Time	†Gross α	†Gross β	^{3}HHO(μCi/ml)
24 Jan. 78/1547	$<1.1 \times 10^{-5}$μCi/g $<1.9 \times 10^{-9}$μCi/ml	2.9×10^{-5}μCi/g±59% 5×10^{-9}μCi/ml±59%	7×10^{-7}±49%
13 Feb. 78/1412	$<1.0 \times 10^{-5}$μCi/g $<1.8 \times 10^{-9}$μCi/ml	4.4×10^{-5}μCi/g±36% 8×10^{-9}μCi/ml±36%	$<4 \times 10^{-7}$
20 Feb. 78/1224	$<9 \times 10^{-6}$μCi/g $<1.9 \times 10^{-9}$μCi/ml	2.7×10^{-5}μCi/g±52% 5×10^{-9}μCi/ml±52%	4×10^{-7}±82%
28 Feb. 78/1535	$<9 \times 10^{-6}$μCi/g $<1.9 \times 10^{-9}$μCi/ml	2.7×10^{-5}μCi/g±51% 6×10^{-9}μCi/ml±51%	5×10^{-7}±61%
9 March 78/1300	$<9 \times 10^{-6}$μCi/g $<1.9 \times 10^{-9}$μCi/ml	3.0×10^{-5}μCi/g±46% 6×10^{-9}μCi/ml±46%	$<4 \times 10^{-7}$
13 March78/1520	$<1.8 \times 10^{-9}$μCi/g $<8 \times 10^{-6}$μCi/ml	7×10^{-9}μCi/g±44% 3×10^{-5}μCi/ml±44%	7×10^{-7}±47%
*14 March78/1512	$<1.4 \times 10^{-5}$μCi/g $<1.9 \times 10^{-9}$μCi/ml	6×10^{-5}μCi/g±46% 8×10^{-9}μCi/ml±46%	4×10^{-7}±84%

#2 LAGOON ROAD

Date/Time	Gross α	Gross β	^{3}HHO(μCi/ml)
*14 March78/1435	$<2 \times 10^{-9}$μCi/ml $<1.2 \times 10^{-5}$μCi/g	1.3×10^{-7}μCi/ml±8% 7.1×10^{-4}μCi/g±8%	8.1×10^{-6}±6%

#3 BUCKET

Date/Time	Gross α	Gross β	^{3}HHO(μCi/ml)
25 Jan. 78/1445-1455	$<4 \times 10^{-9}$μCi/ml $<8 \times 10^{-6}$μCi/g	1.07×10^{-7}μCi/ml±9% 2.0×10^{-4}μCi/g±9%	3.7×10^{-6}±11%

#3 BUCKET TABLE B-10. cont.

Date/Time	Gross α	Gross β	^{3}HHO (μCi/ml)
13 March78/1420	5 x 10^{-8} μCi/ml 78% 1.8 x 10^{-5} μCi/g 78%	2.2 x 10^{-6} μCi/ml±5% 7.9 x 10^{-4} μCi/g±5%	4.0 x 10^{-6}±10%
*14 March78/1440	<2 x 10^{-8} μCi/ml <8 x 10^{-6} μCi/g	2.0 x 10^{-7} μCi/ml±17% 8.1 x 10^{-5} μCi/g±17%	3.7 x 10^{-6}±11%

#4 SWAMP

Date/Time	Gross α	Gross β	^{3}HHO (μCi/ml)
*14 March78/1500	<3 x 10^{-9} μCi/ml <1.0 x 10^{-6} μCi/g	2.6 x 10^{-8} μCi/ml±19% 9.8 x 10^{-5} μCi/g±19%	1.6 x 10^{-6}±22%

*These samples are sub and supra ice flow grabs
†Gross α and Gross β presented both in activity vs. weight and activity vs. volume modes.

TABLE B-11 STORM GRAB SAMPLES - STATIONS #1, 2, 3 AND 4

Date/Time	*Gross α	*Gross β	^{3}HHO(μCi/ml)
#1 Erdman's Pool			
26 Sept 77/0733	1.9 E-05μCi/g±71% 9 E-09μCi/ml±71%	6.4 E-05μCi/g±17% 3.2 E-08μCi/ml±17%	<6 E-07
26 Sept 77/1258	2.0 E-05μCi/g±78% 1.0 E-08μCi/ml±78%	3.5 E-05μCi/g±42% 1.7 E-08μCi/ml±42%	9 E-07μ48%
14 Dec 77/1055	<3 E-05μCi/g <3 E-09μCi/ml	1.2 E-05μCi/g±44% 1.5 E-08μCi/ml±44%	1.6 E-06±25%
5 May 78/1056	<2 E-09μCi/ml <1.0 E-05μCi/g	9 E-09μCi/ml±39% 3.7 E-05μCi/g±39%	6 E-07±60%
9 May 78/0940	<3 E-09μCi/ml <1.0 E-05μCi/g	1.3 E-08μCi/ml±33% 4.5 E-05μCi/g±33%	5 E-07±70%
#2 Lagoon Road			
26 Sept 77/0730	5 E-05μCi/g±39% 1.9 E-07μCi/ml±39%	2.20 E-04μCi/g±8% 7.9 E-07μCi/ml±8%	1.3 E-06±33%
26 Sept 77/1246	<7 E-06μCi/g <2 E-08μCi/ml	2.09 E-04μCi/g±9% 7.0 E-07μCi/ml±9%	2.1 E-06±23%
14 Dec 77/1030	<1.3 E-05μCi/g <3 E-09μCi/ml	6.9 E-04μCi/g±9% 1.58 E-07μCi/ml±9%	8.6 E-06±15%
5 May 78/1025	1.8 E-08μCi/ml±83% 1.5 E-05μCi/g±83%	5.9 E-07μCi/ml±6% 4.6 E-04μCi/g±6%	6.4 E-06±7%
#3 Bucket			
26 Sept 77/0731	<1.2 E-05μCi/g <1.3 E-08μCi/ml	1.69 E-03μCi/g±9% 1.98 E-07μCi/ml±9%	6 E-07±71%
26 Sept 77/1251	2.0 E-05μCi/g±71% 5 E-08μCi/ml±71%	9.7 E-05μCi/g±15% 2.4 E-07μCi/ml±15%	1.0 E-06±45%

TABLE B-11 con't. STORM GRAB SAMPLES - STATIONS #1, 2, 3, AND 4

Date/Time	*Gross	*Gross	^{3}HHO (Ci/ml)
14 Dec 77/1040	1.7 E-05μCi/g±78% 3 E-08μCi/ml±78%	1.06 E-04μCi/g±12% 1.8 E-07μCi/ml±12%	2.9 E-06±15%
9 May 78/0925	<1.8 E-08μCi/ml <9 E-06μCi/g	6.0 E-07μCi/ml±9% 2.8 E-04μCi/g±9%	1.03 E-05±5%
#4 Swamp			
14 Dec 77/1045	<2 E-05μCi/g <3 E-09μCi ml	1.2 E-04μCi/g±37% 1.3 E-08μCi/ml±37%	2.5 E-06±17%
5 May 78/1047	<2 E-09μCi/ml <1.2 E-05μCi/g	2.7 E-08μCi/ml±21% 1.3 E-04μCi/g±21%	2.0 E-06±18%
9 May 78/0959	<4 E-09μCi/ml <8 E-06μCi/g	4.1 E-08μCi/ml±16% 9.3 E-05μCi/g±16%	1.4 E-06±20%

*Gross α and Gross β are presented both in "Activity vs. Weight" and "Activity vs. Volume" modes.

TABLE B-12 MONTHLY SEDIMENT GRAB SAMPLES (1977)

Date	Gross α	Gross β
#1 Erdman's Brook (pooltail)		
7 Sept 77/1000	<8 E-06μCi/g	2.4 E-05μCi/g±30%
#2 Lagoon Road		
7 Sept 77/0845	3.0 E-05μCi/g±55%	7.9 E-05μCi/g±13%
1 Dec 77/0800	2.0 E-05μCi/g±69%	8.7 E-05μCi/g±14%
#3 Bucket		
7 Sept 77/0936	<8 E-06μCi/g	8.6 E-05μCi/g ±12%
1 Dec 77/0805	2.9 E-05μCi/g±55%	6.2 E-05μCi/g±17%

APPENDIX C

RESULTS OF ANALYSES ON TRENCH WATER SAMPLES

TRENCH #1 SUMP
(Collected 9-14-77)

	Dissolved (μCi/ml)	Suspended (μCi/g)	Suspended (μCi/ml)
^{3}HHO	$9.75 \times 10^{-3} \pm 3\%$		
^{90}Sr	$1.50 \times 10^{-5} \pm 6\%$	$2.4 \times 10^{-4} \pm 25\%$	
^{238}Pu	$5.70 \times 10^{-8} \pm 17\%$	$5 \times 10^{-7} \pm 57\%$	$8 \times 10^{-10} \pm 57\%$
$^{239,240}Pu$	$< 3 \times 10^{-10}$	$2.3 \times 10^{-7} \pm 83\%$	$4 \times 10^{-10} \pm 83\%$
^{134}Cs	$< 1.9 \times 10^{-7}$	$< 7 \times 10^{-6}$	$< 1.1 \times 10^{-8}$
^{137}Cs	$6 \times 10^{-7} \pm 57\%$	$2.3 \times 10^{-4} \pm 6\%$	$3.6 \times 10^{-7} \pm 6\%$
$^{134}Cs(Cs_2PtCl_6)$	$3.0 \times 10^{-7} \pm 33\%$		$2.2 \times 10^{-8} \pm 67\%$
$^{137}Cs(Cs_2PtCl_6)$	$4.3 \times 10^{-7} \pm 39\%$		$< 2 \times 10^{-8}$
^{55}Fe	$< 1.9 \times 10^{-7}$	$2.9 \times 10^{-5} \pm 53\%$	$5 \times 10^{-8} \pm 53\%$
^{60}Co	$1.0 \times 10^{-7} \pm 80\%$	$3.6 \times 10^{-4} \pm 6\%$	$5.6 \times 10^{-7} \pm 6\%$
^{63}Ni	$3.8 \times 10^{-6} \pm 23\%$	$1.3 \times 10^{-5} \pm 34\%$	$2.0 \times 10^{-8} \pm 34\%$
^{14}C(total)	$2.1 \times 10^{-6} \pm 17\%$	$< 7 \times 10^{-6}$	
^{129}I			
^{234}U	$1.8 \times 10^{-8} \pm 13\%$	$4.2 \times 10^{-6} \pm 17\%$	$6.6 \times 10^{-9} \pm 17\%$
^{235}U	$< 3 \times 10^{-10}$	$< 3 \times 10^{-8}$	$< 5 \times 10^{-11}$
^{238}U	$1.8 \times 10^{-9} \pm 48\%$	$1.5 \times 10^{-6} \pm 30\%$	$2.3 \times 10^{-9} \pm 30\%$
^{241}Am		$< 4 \times 10^{-6}$	$< 6 \times 10^{-9}$
$^{232}Th(^{212}Pb)$	$< 3 \times 10^{-7}$	$< 5 \times 10^{-5}$	$< 8 \times 10^{-8}$
^{22}Na	1.8×10^{-7}		
^{133}Ba	1.8×10^{-7}	$< 5 \times 10^{-5}$	$< 8 \times 10^{-8}$
^{54}Mn			
^{106}Ru	$< 3 \times 10^{-6}$	$< 6 \times 10^{-5}$	
^{125}Sb			
6 Beta	$2.11 \times 10^{-5} \pm 6\%$	$< 3 \times 10^{-4}$	$< 6 \times 10^{-7}$
6 Alpha	$< 2 \times 10^{-7}$	$< 4 \times 10^{-4}$	$< 5 \times 10^{-7}$

TRENCH #2 Well 2-1A
(Collected 9-14-77/1800)

	Dissolved (μCi/ml)	Suspended (μCi/g)	Suspended (μCi/ml)
^{3}HHO	$1.02 \times 10^{-4} \pm 37\%$		
^{90}Sr	$3.6 \times 10^{-5} \pm 6\%$	$< 9 \times 10^{-2}$	$< 1.1 \times 10^{-6}$
^{238}Pu	$1.0 \times 10^{-8} \pm 30\%$	$2.8 \times 10^{-5} \pm 35\%$	$3.4 \times 10^{-10} \pm 35\%$
$^{239,240}Pu$	$5.0 \times 10^{-8} \pm 13\%$	$2.2 \times 10^{-4} \pm 12\%$	$2.7 \times 10^{-9} \pm 12\%$
^{134}Cs	$< 3 \times 10^{-7}$	$1.6 \times 10^{-4} \pm 63\%$	$2.0 \times 10^{-9} \pm 63\%$
^{137}Cs	$4.66 \times 10^{-5} \pm 4\%$	$4.4 \times 10^{-3} \pm 7\%$	$5.7 \times 10^{-9} \pm 7\%$
$^{134}Cs(Cs_2PtCl_6)$	$1.3 \times 10^{-7} \pm 18\%$	$1.3 \times 10^{-4} \pm 48\%$	$1.6 \times 10^{-9} \pm 48\%$
$^{137}Cs(Cs_2PtCl_6)$	$2.83 \times 10^{-5} \pm 3\%$	$4.5 \times 10^{-3} \pm 7\%$	$5.5 \times 10^{-8} \pm 7\%$
^{55}Fe	$< 2 \times 10^{-7}$	$< 1.4 \times 10^{-3}$	1.7×10^{-8}
^{60}Co	$8 \times 10^{-8} \pm 33\%$	$5.9 \times 10^{-4} \pm 31\%$	$7 \times 10^{-9} \pm 31\%$
^{63}Ni	$5.07 \times 10^{-6} \pm 3\%$	$5 \times 10^{-4} \pm 50\%$	$6 \times 10^{-9} \pm 50\%$
^{14}C (total)	$2.4 \times 10^{-5} \pm 5\%$		
^{129}I			
^{234}U	$< 6 \times 10^{-10}$	$< 2 \times 10^{-6}$	$< 2 \times 10^{-11}$
^{235}U	$< 6 \times 10^{-10}$	$< 1.2 \times 10^{-6}$	$< 1.5 \times 10^{-11}$
^{238}U	$< 9 \times 10^{-10}$	$7 \times 10^{-6} \pm 70\%$	$9 \times 10^{-11} \pm 70\%$
^{241}Am	$< 4 \times 10^{-8}$	$5 \times 10^{-4} \pm 50\%$	$6 \times 10^{-11} \pm 50\%$
$^{232}Th(^{212}Pb)$	$6 \times 10^{-7} \pm 83\%$	$< 1.9 \times 10^{-3}$	
^{22}Na	$3 \times 10^{-7} \pm 67\%$		
^{133}Ba	$< 4 \times 10^{-7}$	$< 1.6 \times 10^{-3}$	$< 2 \times 10^{-8}$
^{54}Mn			
^{106}Ru		$< 1.5 \times 10^{-3}$	
^{125}Sb			
6 Beta	$6.8 \times 10^{-5} \pm 4\%$	$< 3 \times 10^{-2}$	$< 4 \times 10^{-7}$
6 Alpha	$< 2 \times 10^{-7}$	$< 5 \times 10^{-2}$	$< 6 \times 10^{-7}$
^{40}K	$< 9 \times 10^{-6}$		

TRENCH #4 SUMP
(Collected 9-14-77/1200)

	Dissolved (μCi/ml)	Suspended (μCi/g)	Suspended (μCi/ml)
^{3}HHO	$3.82 \times 10^{-1} \pm 3\%$		$2.7 \times 10^{-6} \pm 6\%$
^{90}Sr	$2.02 \times 10^{-2} \pm 5\%$	$6.40 \times 10^{-1} \pm 61\%$	
^{238}Pu	$2.5 \times 10^{-8} \pm 16\%$	$2.0 \times 10^{-4} \pm 18\%$	$8.4 \times 10^{-10} \pm 18\%$
$^{239,240}Pu$	$6.5 \times 10^{-8} \pm 10\%$	$3.9 \times 10^{-4} \pm 13\%$	$1.6 \times 10^{-9} \pm 13\%$
^{134}Cs	$< 3 \times 10^{-7}$	$< 3 \times 10^{-4}$	$< 1.3 \times 10^{-9}$
^{137}Cs	$1.02 \times 10^{-5} \pm 5\%$	$8 \times 10^{-4} \pm 27\%$	$3.4 \times 10^{-9} \pm 27\%$
$^{134}Cs(Cs_2PtCl_6)$	$2.2 \times 10^{-7} \pm 39\%$	$1.0 \times 10^{-4} \pm 75\%$	$4 \times 10^{-10} \pm 75\%$
$^{137}Cs(Cs_2PtCl_6)$	$9.5 \times 10^{-6} \pm 6\%$	$< 8 \times 10^{-4} \pm 25\%$	$3.4 \times 10^{-9} \pm 25\%$
^{55}Fe	$1.1 \times 10^{-5} \pm 25\%$	$6 \times 10^{-3} \pm 44\%$	$2.5 \times 10^{-8} \pm 44\%$
^{60}Co	$1.9 \times 10^{-6} \pm 16\%$	$4.6 \times 10^{-3} \pm 9\%$	$1.93 \times 10^{-8} \pm 9\%$
^{63}Ni	$1.32 \times 10^{-5} \pm 5\%$	$< 8 \times 10^{-4}$	$< 2 \times 10^{-9}$
^{14}C(total)	$3.4 \times 10^{-5} \pm 5\%$		
^{129}I			
^{234}U	$2.8 \times 10^{-9} \pm 34\%$	$8 \times 10^{-5} \pm 30\%$	$3.4 \times 10^{-10} \pm 30\%$
^{235}U	$< 1.3 \times 10^{-10}$	$< 3 \times 10^{-6}$	$< 1.3 \times 10^{-11}$
^{238}U	$1.7 \times 10^{-9} \pm 42\%$	$3.6 \times 10^{-5} \pm 48\%$	$1.5 \times 10^{-10} \pm 48\%$
^{241}Am			
$^{232}Th(^{212}Pb)$	$< 6 \times 10^{-7}$	$< 4 \times 10^{-3}$	$< 1.7 \times 10^{-8} \pm$
^{22}Na	$< 2 \times 10^{-7}$	$< 1.7 \times 10^{-3}$	$< 7 \times 10^{-9}$
^{133}Ba	$< 4 \times 10^{-7}$	$< 2 \times 10^{-3}$	$< 8 \times 10^{-9}$
^{54}Mn			
^{106}Ru	$< 4 \times 10^{-6}$	$< 3 \times 10^{-3}$	$< 1.3 \times 10^{-8}$
^{125}Sb			
6 Beta	$1.67 \times 10^{-2} \pm 3\%$	$1.08 \times 10^{-0} \pm 10\%$	$4.5 \times 10^{-6} \pm 10\%$
6 Alpha	$< 3 \times 10^{-7}$	$< 8 \times 10^{-2}$	$< 3 \times 10^{-7}$

TRENCH #5 Well 5-3 A
(Collected 9-14-77)

	Dissolved (μCi/ml)	Suspended (μCi/g)	Suspended (μCi/ml)
^{3}HHO	3.19 E-01 3%		
^{90}Sr	2.9 E-05±6%	3.3 E-01±39%	1.2 E-07 ±39%
^{238}Pu	2.7 E-08±16%	5.3 E-04±9%	1.9 E-09±9%
$^{239,240}Pu$	5.3 E-08±11%	2.7 E-04±12%	9.7 E-10±12%
^{134}Cs		2.4 E-04±71%	9 E-10±71%
^{137}Cs		2.5 E-04±56%	9 E-10±56%
$^{134}Cs(Cs_2PtCl_6)$	8 E-07±24%	1.5 E-04±70%	5 E-10±70%
$^{137}Cs(Cs_2PtCl_6)$	2.3 E-06±13%	6 E-04±40%	2.2 E-09±40%
^{55}Fe	8.1 E-05±8%	4 E-03±60%	1.4 E-08±60%
^{60}Co	< 4 E-07	< 1.9 E-04	
^{63}Ni	6.9 E-06±7%	1.0 E-03±56%	3.6 E-09±56%
^{14}C(total)	7.4 E-05±5%		
^{129}I			
^{234}U	7.4 E-08±9%	1.8 E-04±28%	6.5 E-10±28%
^{235}U	2.3 E-09±35%	< 7 E-06	<3 E-11
^{238}U	7.3 E-08±9%	1.5 E-04±30%	5.4 E-10±30%
^{241}Am			
$^{232}Th(^{212}Pb)$	< 5 E-07	< 3 E-03	<1.1 E-08
^{22}Na	< 5 E-07	< 1.8 E-03	< 6 E-08
^{133}Ba	1.4 E-06±27%	< 1.9 E-03	< 7 E-09
^{54}Mn			
^{106}Ru	6 E-06±87%	< 2 E-03	< 7 E-09
^{126}Sb			
6 Beta	4.8×10^{-5}±4%	< 3 E-02	< 3 E-07
6 Alpha	9×10^{-7}±42%	< 9 E-02	<1.1E-07
^{40}K	<1.3 E-05	< 6 E-03	< 2 E-08
^{110m}Ag			< 7 E-10

TRENCH #8 Well 8-1B
(Collected 9-16-77/1500)

	Dissolved (μCi/ml)	Suspended (μCi/g)	Suspended (μCi/ml)
^{3}HHO	3.84 E-01 ±3%		
^{90}Sr	1.48 E-04±6%	7.6 E-03±10%	5.8 E-08±10%
^{238}Pu	2.09 E-04±3%	1.16E-10±10%	8.9 E-06±10%
$^{239,240}Pu$	5.5 E-07±27%	3.2 E-03±21%	2.5 E-06±21%
^{134}Cs	2.8 E-06±14%	< 2 E-04	< 1.5 E-09
^{137}Cs	2.21 E-04±3%	4.5 E-03±7%	3.5 E-08±7%
$^{134}Cs(Cs_2PtCl_6)$	2.09 E-06±5%	1.0 E-04±60%	8 E-10±60%
$^{137}Cs(Cs_2PtCl_6)$	1.46 E-04±3%	4.0 E-03±8%	3.1 E-08±8%
^{55}Fe	< 1.3 E-07	1.5 E-02±18%	< 1.2 E-07
^{60}Co	3.3 E-07±48%	9 E-04±24%	6.9 E-09±24%
^{63}Ni	2.37 E-02±3%	< 1.5 E-06	< 1.2 E-11
^{14}C(total)	5.2 E-04±5%		
$^{14}CO_3^2$(INORG)	1.8 E-05±5%		
^{129}I			
^{234}U	1.08 E-07±7%		
^{235}U	1. E-08±17%		
^{238}U	1.10 E-06±3%		
$^{238}U(^{234}Th)$			
^{241}Am			
$^{232}Th(^{212}Pb)$	< 5 E-07	< 3 E-03	< 2 E-08
^{22}Na	5 E-07±60%	< 1.4 E-03	< 1.1 E-08
^{133}Ba	< 5 E-07	< 1.5 E-08	< 1.2 E-08
^{54}Mn			
^{106}Ru		< 2 E-03	< 1.5 E-08
^{125}Sb			
G. Beta	3.16 E-04±3%	7 E-02±56%	5 E-07±56%
G. Alpha	1.98 E-05±9%	7.4 E-01±20%	5.7 E-07±20%
^{40}K	< 9 E-06	< 5 E-03	< 4 E-08

TRENCH #9 - New Sump
(Collected 9-15-77)

	Dissolved (μCi/ml)	Suspended (μCi/g)	Suspended (μCi/ml)
^{3}HHO	4.1 E-01±3%		
^{90}Sr	4.2 E-05±6%	4.9 E-03±7%	3.6 E-07±7%
^{238}Pu	2.8 E-07±16%	9.2 E-04±8%	6.8 E-08±8%
$^{239,240}Pu$	2.1 E-09±76%	1.5 E-04±19%	1.1 E-08±19%
^{134}Cs	3.1 E-06±10%	7 E-04±43%	5 E-08±43%
^{137}Cs	3.7 E-05±4%	7.3 E-03±8%	5.4 E-07±8%
$^{134}Cs(Cs_2PtCl_6)$	2.90 E-06±4%	3.9 E-04±29%	2.9 E-08±29%
$^{137}Cs(Cs_2PtCl_6)$	3.88 E-05±3%	1.5 E-03±14%	1.11E-07±14%
^{55}Fe	<1.1 E-07	<1.1 E-03	<8 E-08
^{60}Co	1.2 E-06±17%	3.5 E-03±17%	2.6 E-07±17%
^{63}Ni	4.1 E-05±3%	<9 E-04	<7 E-08
^{14}C (total)			
^{129}I			
^{234}U		1.9 E-04±15%	1.4 E-08±15%
^{235}U		1.6 E-05±55%	1.2 E-09±55%
^{238}U		6.2 E-04±9%	4.6 E-08±9%
^{241}Am			
$^{232}Th(^{212}Pb)$	5 E-07±60%	<3 E-03	
$^{232}Th(^{210}Pb)$			2 E-07
^{22}Na	4.5 E-07±40%	<2 E-03	<1.5 E-07
^{133}Ba	<2 E-07	<2 E-03	<1.5 E-07
^{54}Mn			
^{106}Ru			
^{125}Sb			
$^{6}Beta$	9.0 E-05±4%	<4 E-02	<3 E-06
$^{6}Alpha$	<2 E-07	<6 E-02	<4 E-06
^{40}K	<6 E-06	<8 E-03	<6 E-07

TRENCH #9 - New Sump
(Collected 9-16-77)

	Dissolved μCi/ml	Suspended μCi/g	Suspended μCi/ml
^{3}HHO	3.77 E-01±3%		
^{90}Sr	3.8 E-05±6%	4.8 E-02±32%	2.0 E-07±32%
^{238}Pu	4.6 E-07±4%	6.5 E-03±4%	2.73 E-08±4%
$^{239,240}Pu$	2.9 E-09±48%	5.7 E-05±33%	2.4 E-10±33%
^{134}Cs	2.5 E-06±17%	6 E-04±50%	3 E-09±50%
^{137}Cs	3.7 E-05±4%	4.9 E-03±6%	2.06 E-08±6%
$^{134}Cs(Cs_2PtCl_6)$	2.55 E-06±4%	4.3 E-04±35%	1.8 E-09±35%
$^{137}Cs(Cs_2PtCl_6)$	3.41 E-05±3%	3.8 E-03±11%	1.6 E-08±11%
^{55}Fe		9.6 E-02±8%	4.0 E-07±8%
^{60}Co	5 E-07±40%	3.3 E-03±15%	1.3 E-08±15%
^{63}Ni	1.26 E-05±3%	<4 E-03	<1.7 E-08
^{14}C(total)	8.4 E-05±5%		
$^{14}Co_3^{2-}$(Inorg.)	2.2 E-05±5%		
^{129}I			
^{234}U	3.8 E-09±39%	3.3 E-04±20%	1.4 E-09±20%
^{235}U	<3 E-10	4 E-05±58%	1.7 E-10±58%
^{238}U	4.2 E-09±36%	2.9 E-03±7%	1.22 E-08±7%
^{241}Am	3.6 E-08±18%		
$^{232}Th(^{212}Pb)$	<5 E-07	<4 E-03	<1.7 E-08
^{22}Na	<3 E-07	<3 E-03	<1.3 E-08
^{133}Ba	<4 E-07	<3 E-03	<1.3 E-08
^{54}Mn			
^{106}Ru			
^{125}Sb			
6 Beta	8.3 E-05±4%	8 E-02±52%	3.4 E-07±52%
6 Alpha	6 E-07±63%	<8 E-02	<3 E-07
^{40}K	<9 E-06	<8 E-03	<3 E-08

TRENCH #12 Sump
(Collected 9-21-77)

	Unfiltered Total Sample (*µCi/ml)
^{3}HHO	3.17 E-01±3%
^{90}Sr	1.08 E-04±6%
^{238}Pu	2.6 E-08±13%
$^{238,240}Pu$	9.1 E-08±7%
^{134}Cs	1.09 E-05±5%
^{137}Cs	7.38 E-04±3%
$^{134}Cs(Cs_2PtCl_6)$	
$^{137}Cs(Cs_2PtCl_6)$	
^{55}Fe	
^{60}Co	2.6 E-06±10%
^{63}Ni	4.35 E-05±3%
^{14}C(total)	3.6 E-04±5%
$^{14}CO_3^{2-}$(INORG)	5.8 E-06±5%
^{129}I	
^{234}U	2.3 E-08±14%
^{235}U	6 E-10±92%
^{238}U	1.5 E-08±18%
^{241}Am	
$^{232}Th(^{212}Pb)$	<7 E-07
^{22}Na	1.22 E-06±20%
^{133}Ba	<8 E-07
^{54}Mn	
^{106}Ru	
^{125}Sb	
G Beta	1.44 E-01±3% µCi/g
G Beta	6.7 E-04±3% µCi/ml
G Alpha	<5 E-05 µCi/g
G Alpha	<2 E-07 µCi/ml
^{40}K	<1.1 E-07

* G. Beta and G. Alpha measured in both µCi/g and µCi/ml modes.

TRENCH #14 Well 14-1A
(Collected 9-20-77)

	Dissolved (μCi/ml)	Suspended (μCi/g)	Suspended (μCi/ml)
^{3}HHO	4.27 E-02±3%		
^{90}Sr	1.10 E-04±6%	3.2 E-03±7%	
^{238}Pu	1.0 E-08±22%	8.4 E-03±11%	2.2 E-07±11%
$^{239.240}Pu$	< 1.9 E-10	9 E-05±28%	2.4 E-09±28%
^{134}Cs	2.6 E-06±12%	2.3 E-04±39%	6 E-08±39%
^{137}Cs	1.71 E-05±4%	9.9 E-04 10%	2.6 E-08 10%
$^{134}Cs(Cs_2PtCl_6)$	2.49 E-06±4%		
$^{137}Cs(Cs_2PtCl_6)$	1.91 E-05±3%		
^{55}Fe	4.6 E-07±26%	3.2 E-03±29%	
^{60}Co	1.8 E-07±55%	2.5 E-04±32%	7 E-09±32%
^{63}Ni	1.38 E-05±3%	< 7 E-04	
^{14}C(total)	6.4 E-05±5%		
$^{14}CO_3^{2-}$(INORG)	1.1 E-05±5%		
^{129}I			
^{234}U	< 6 E-09	1.09E-04±17%	2.9 E-09±17%
^{235}U	< 3 E-09	< 7 E-07	< 1.8 E-11
^{238}U	5 E-09±44%	1.9 E-04±13%	5.0 E-09±13%
^{241}Am	< 3 E-09		
$^{232}Th(^{212}Pb)$	< 3 E-07	2.7 E-03±44%	
^{22}Na	< 1.9 E-07	< 7 E-04	< 1.8 E-08
^{133}Ba	< 2 E-07	< 8 E-04	< 2 E-08
^{54}Mn			
^{106}Ru		< 9 E-04	< 2 E-08
^{125}Sb			
G. Beta	1.71 E-04±4%	< 3 E-02	< 8 E-07
G. Alpha	2 E-07	< 4 E-02	< 1.1 E-06
^{40}K	< 6 E-06	< 5 E-03	< 1.3 E-07

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16. ABSTRACT *(200 words or less)*

The scope of this research program includes several basic parts: a surface water program, a geomorphic and erosion study, a trench water study, and a soil analysis study. The study involved the collection of surface water data, a geomorphic study and mapping of a 4.1 km reach of Buttermilk Creek and adjacent areas within the drainage basin, the analysis of water samples collected from waste burial trenches, and the analysis of soil samples collected from a research trench near the burial site. Buttermilk Creek Valley is being actively subjected to erosion by a combination of fluvial transport, lateral channel scour processes, transport on alluvial fans, and landsliding. Local ponding may contribute to landsliding and slumping by bringing moisture contents close to the liquid limit of the soil. Tests indicate that the soil in which the waste is buried has been subjected to a load greater than the present day overburden loading. The theoretical depth limit to which cracks can penetrate in the soil is approximately 50 feet.

17. KEY WORDS AND DOCUMENT ANALYSIS

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17a. DESCRIPTORS

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