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Sediment and Radionuclide Transport in Rivers; Field Sampling Program, Cattaraugus and Buttermilk Creeks, New York

Annual Progress Report
October 1978 - September 1979

Prepared by Y. Onishi, W. H. Walters, R. M. Ecker

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ABSTRACT

This report describes FY-1979 analysis results on flow, sediment and radionuclide data collected in Cattaraugus, Buttermilk and Franks Creek, New York. The objective of the study is to investigate the radionuclide transport in these streams as a part of a continuing program to provide data required for application and verification of the Sediment and Radionuclide Transport Model (SERATRA). Radiological analyses were performed on sand, silt and clay size fractions of suspended and bed sediment, as well as for dissolved radionuclides. These include gamma-ray emitters plus ^{90}Sr, ^{238}Pu, $^{239-240}Pu$, ^{241}Am, ^{244}Cm and ^{3}H. Among radionuclides analyzed to date, a principal radionuclide found in the study area is ^{137}Cs. Distributions of ^{137}Cs associated with suspended and bed sediments have sharp peaks at the mouth of the Franks Creek, revealing the contribution of ^{137}Cs from the NFS site. Concentration of ^{137}Cs associated with a clay size fraction of suspended and bed sediments at the mouth of Franks Creek were 32.5 $\pm$ 1.5 and 134.0 $\pm$ 0.90 pCi/g, respectively. Cesium-134 and cobalt-60 associated with the bed sediment also have higher peaks at the mouth of Franks Creek. However, dissolved and particulate concentrations of other radionuclides analyzed under this study were generally very low and there is no clear evidence to indicate that these radionculides detected in this study area originated from the Nuclear Fuel Service site.

SUMMARY

This report describes FY-1979 results of the field sampling program performed on the Cattaragus, Buttermilk and Franks Creeks near the West Valley burial site (the Western New York Nuclear Service Center operated by the Nuclear Fuel Service Inc.), New York. The objective of this study is to investigate the radionuclide transport in these streams as a part of a continuing program to provide data required for application and verification of the Pacific Northwest Laboratory's (PNL) sediment and radionuclide transport model, SERATRA.

The program is divided into three phases: Phase 1, medium-flow condition; Phase 2, low-flow condition; and Phase 3, high flow condition. Under each of these three conditions, flow, sediment and radionuclide data in Cattaraugus, Buttermilk and Franks Creeks were collected and analyzed. Franks Creek receives runoff from the waste site of the Nuclear Fuel Service (NFS) Inc. and is a tributary of Buttermilk Creek which flows into Cattaraugus Creek. Cattaraugus Creek discharges into Lake Erie. Field data collection for Phases 1, 2 and 3 were performed during November 30 - December 5, 1977; September 20-27, 1978; and April 26-29, 1979, respectively.

Radiological analyses were performed on sand, silt and clay size fractions of suspended and bed sediment samples, as well as on filters, aluminum oxide and resin beds from filtering water samples. Radiological analyses were performed for primarily gamma-ray emitters; however, ^{90}Sr, ^{238}Pu, $^{239-240}Pu$, ^{241}Am, ^{244}Cm and ^{3}H were also analyzed for selected samples.

Among the radionuclides analyzed under Phase 2, a dominant radionuclide found in the study area is ^{137}Cs. Distributions of ^{137}Cs associated with suspended and bed sediments have sharp peaks at the mouth of Franks Creek, revealing the contributions of ^{137}Cs from the NFS into the Franks-Buttermilk-Cattaraugus Creek System. The maximum levels of ^{137}Cs associated with suspended and bed sediments at the mouth of Franks Creek were 32.5 $\pm$ 1.5 and 134.0 $\pm$ 0.90 pCi/g in a clay fraction of sediment. Gamma activity in water was very low for Phase 1 samples. Cesium-137 levels in water at the mouth

of Franks Creek vary from 0.194 ± 0.02 to 0.12 ± 0.10 pCi/ℓ and were not high enough to clearly distinguish them from background levels.

Cesium-134 and cobalt-60 remaining in the stream bed sediments also have their highest concentrations at the mouth of Franks Creek. However, levels of these two radionuclides adsorbed by suspended sediment and those in dissolved forms were near background or below detection levels.

Analyses of ^{238}Pu, $^{239-240}Pu$, ^{90}Sr, ^{241}Am, ^{244}Cm and ^{3}H were performed for Phase 1 samples. Dissolved and particulate concentrations of these radionuclides were generally very low and there is no clear evidence to indicate that these radionuclides detected in the study area originated from the NFS site.

During the Phase 3 field data collection, stream flow was monitored at nine temporary gaging stations and suspended sediment samples collected at seven of the locations. The gaging stations were established to provide detailed water and suspended sediment monitoring for a reach of Cattaraugas Creek from Bigelow Bridge (41.3 miles above Lake Erie) to a point about 900 ft below Frye Bridge (32.7 miles above Lake Erie). Five of the gages were located on tributary streams of the Cattaraugas Creek system and four on Cattaraugas Creek. The streamflow records provide input data for the hydraulic modeling of the creek system. The hydraulic modeling results will be used as input to SERATRA along with the suspended sediment data for the simulation of the water, sediment, and radionuclide movement.

ACKNOWLEDGMENTS

This report summarizes the results of research conducted by the Battelle Memorial Institute's Pacific Northwest Laboratory for the U.S. Nuclear Regulatory Commission on Cattaraugus and Buttermilk Creeks, New York, from October 1, 1978 to September 30, 1979. In addition to the authors of this report, significant contributions were made by R. G. Parkhurst for his field and laboratory expertise; S. M. Brown and E. M. Arnold for their efforts in the field; and, S. J. Phillips, and D. D. Hostetler for their scuba diving capabilities. The authors also wish to acknowledge the guidance and assistance provided by Dr. Phillip R. Reed of the U.S. Nuclear Regulatory Commission (NRC), Dr. R. H. Fakundiny, R. H. Fickies, and S. A. Mollelo of the New York State Geological Survey.

Support work for the project was performed uner a separate subcontract to Drs. William R. Schell and Thomas Sibley of the University of Washington, Laboratory of Radiation Ecology for radiological analyses.

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FIGURES

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PHASE 1 SAMPLING PROGRAM

RADIOLOGICAL ANALYSIS

Radiological analyses were performed on sand, silt and clay sized fractions of suspended sediment, bed sediment and water samples. Priority was given to gamma ray spectrometry analysis during the Phase 1 sampling program because of initial funding limitations and the relatively low costs of gamma ray spectrometry. Additional funding allowed the analysis of other radionuclides requiring radiochemical separation procedures, such as ^{90}Sr, ^{238}Pu, $^{239,240}Pu$, ^{241}Am and ^{244}Cm. However, the high costs of radiochemical separation did not warrant the analysis of all samples for non-gamma radionuclides. Results of the Phase 1 study are reported in Ecker and Onishi (1979).

United States Testing, Inc., a commercial laboratory located in Richland, Washington, performed the majority of the gamma ray spectrometry, ^{90}Sr, ^{238}Pu and ^{239}Pu analyses of the Phase 1 samples. The University of Washington, Laboratory of Radiation Ecology also performed some gamma ray spectrometry, plutonium and strontium analysis, in addition to performing ^{241}Am, ^{244}Cm, and tritium analyses. PNL's Physical Sciences Department performed gamma ray spectrometry analysis of one sample (FC-1).

Gamma ray spectrometry analysis was performed using Ge(Li) diode systems, except the one sample analyzed by PNL's Physical Sciences Department which utilized a large-volume NaI(Tl) multi-dimensional gamma ray spectrometer system in the coincidence and noncoincidence modes (Ecker and Onishi 1979).

Gamma ray spectrometry analysis by U.S. Testing, Inc. utilized a Canberra Model 7229 and 7248, Germanium-Lithium drifted diode and a Pulse Height Analyses (PHA) program for interpretation of the Ge(Li) spectra. The published detection limit of U.S. Testing's gamma ray spectrometry analysis is 0.07 pCi/g based on a 500 minute count and 40 g of sample. For a 200 minute count the detection limit is 0.1 pCi/g. The above detection limits do not apply to all samples analyzed, however, since the sample sizes were often less than 40 g. In many cases, the suspended sand fraction and bed clay fraction quantities were less than 1 g. In such cases, the detection limits increased dramatically and can be seen in the results of the gamma ray spectrometry analyses where the standard error (represented as ± two standard deviations) is much greater than the mean value reported.

A description of methods and procedures used by U.S. Testing, Inc., in their gamma emitters, plutonium and strontium analyses of Phase 1 samples were described in detail in Ecker and Onishi (1979).

A description of the analytical methods and procedures used by the University of Washington, Laboratory of Radiation Ecology in their gamma ray spectrometry, plutonium, strontium, americium and curium analyses of the Phase 1 samples were also described in Ecker and Onishi (1979).

GAMMA RAY SPECTROMETRY

Tables 1 and 2 are the results of gamma ray spectrometry analysis of radionuclides dissolved in water. Gamma ray spectrometry results of dissolved radionuclides are reported as the total activity of a particular radionuclide (Table 1) and as the activity associated with each of the three resin beds, aluminum oxide beds and 0.3 μm fiberglass filters (Table 2). Water samples were passed first through the filters, then through the aluminum oxide bed, and finally through resin (cation exchange) beds.

Transects BC-1 and CC-1 are the upstream control background stations on Buttermilk and Cattaraugus Creeks, as shown in Figure 1. Because these transects are upstream of the influence of the Nuclear Fuel Services, Inc. (NFS) complex at West Valley, New York, the radioactivity associated with the surface waters at these transects can be considered to be background. By comparing the gamma activity of water at the upstream control transects with the activity downstream of the NFS complex, one can, with a certain degree of confidence determine the influence of NFS facility on the radioactivity in Cattaraugus and Buttermilk Creeks.

Gamma Activity Associated With Water

Tables 1 and 2 are the results of gamma ray spectrometry analysis of radionuclides dissolved in water. In Table 2, the results are reported as the

TABLE 1. Gamma Ray Spectrometry - Radionuclides Dissolved in Water (pCi/ℓ)

		Cs-137	Cs-134	Co-60	ZrNb-95	Eu-155	Ce-144	Ce-141	Ra-224	Ra-226	Ru-106	K-40
FC-1	(1)	0.12 (0.10)	N.A.	N.D.	N.D.	N.D.	N.D.	N.A.	N.A.	N.D.	N.D.	N.D.
	(2)	0.194 (0.02)	0.005 (.002)	0.044 (.004)	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.527 (.05)	N.A.
BC-3		<.040	0.040 (.033)	<.0123	0.069 (.050)	<.050	N.D.	<.240	N.D.	<.064	<.210	6.97 (4.12)
BC-4	(1)	N.D.	N.A.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.42 (.15)	N.D.	N.D.
CC-1		0.122 (.104)	0.084 (.07)	<.074	0.092 (.065)	0.110 (.097)	<.119	<.009	N.D.	<.075	<.095	4.53 (2.72)
CC-3		<.028	0.049 (.032)	<.018	0.116 (.106)	0.263 (.234)	N.D.	<.064	N.D.	<.080	<.095	3.91 (.60)
CC-5		0.026 (.022)	<.083	<.003	0.048 (.037)	0.067 (.06)	<.059	<.026	N.D.	<.041	<.231	3.12 (2.0)
CC-9		<.049	0.079 (.063)	<.017	0.141 (.108)	0.172 (.063)	<.146	<.021	N.D.	0.114 (.063)	<.102	4.23 (2.67)

(1) University of Washington
(2) PNL

Remaining samples analyzed by U.S. Testing

N.D. Not Detected
N.A. Not Analyzed
( ) Two Standard Deviations

TABLE 2. Gamma Ray Spectrometry - Radionuclides Dissolved in Water (pCi/ℓ)

	Resin Beds			Aluminum Oxide Beds				
	R-1	R-2	R-3	Al-1	Al-2	Al-3	Filters	Total Activity
BC-3								
Ru 106	<.210	<.150	<.00632	<.151	<.084	N.D.	<.0127	less than
Ra 226	<.0636	<.0195	<.00138	<.0415	<.0168	<.0268	<.0582	less than
Cs 137	<.0403	<.0144	<.0004	<.0274	<.0121	<0.246	<.00171	less than
Cs 134	N.D.	<.0208	<.0020	<.0227	N.D.	N.D.	0.040 (.033)	0.040
K 40	2.86 (1.2)	<.263	0.882 (.605)	<.709	<.814	1.33 (1.1)	1.90 (0.73)	6.97
ZrNb 95	N.D.	<.0397	N.D.	N.D.	N.D.	<.0285	0.0686 (.050)	0.0686
Co 60	N.D.	<.0123	<0.0144	N.D.	N.D.	<.0016	N.D.	less than
Ce 141	N.D.	N.D.	N.D.	<.00905	<.240	<.0207	<.0285	less than
Eu 155	N.D.	N.D.	N.D.	N.D.	N.D.	<.0199	<.0505	less than
CC-1								
ZrNb 95	0.0758 (.06)	<.0473	<.529	<.0512	.0475	<.0714	0.0920 (.065)	0.1678
Eu 155	<.00136	<.0225	N.D.	<.0330	.0671	<.0823	0.110 (.097)	0.110
Ce 144	<.109	N.D.	N.D.	<.199	N.D.	N.D.	N.D.	less than
Ra 226	<.00703	<.0747	<.0232	N.D.	N.D.	<.00108	<.0348	less than
Cs 137	<.00931	<.00311	0.0458 (.036)	<.00763	.0330	0.0758 (.0703)	<.0200	0.1216
Cs 134	<.0384	<.0323	<.00379	<.0192	.0135	0.0839 (.0703)	<.0333	0.0839
Co 60	<.0176	N.D.	N.D.	<.0119	N.D.	<.0736	N.D.	less than
K 40	1.16 (.81)	N.D.	1.05 (.76)	<1.34	1.06	<.844	2.32 (.88)	3.48
Ce 141	N.D.	N.D.	<.00467	<.00866	N.D.	N.D.	N.D.	less than
Ru 106	N.D.	N.D.	N.D.	<.0181	.0952	<.0271	N.D.	less than
CC 3-3								
ZrNb 95	0.058 (.053)	<.0288	.585 (.053)	<.0862	.0585		<.0350	0.1165
Eu 155	0.0835 (.079)	N.D.	<.0492	0.180 (.15)	.00184		<.0176	0.2635
Cs 137	<.00506	<.0106	N.D.	N.D.	.00985		<.0273	less than
Cs 134	0.0488 (.032)	<.00318	<.0101	<.0406	.0479		<.00413	0.0488
Co 60	<.0179	<.00756	<.0129	N.D.	.00558		<.0116	less than
K 40	<.433	0.870 (.062)	0.668 (.062)	<.998	.945		2.37 (.703)	3.908
Ce 141	N.D.	<.0022	<.0140	N.D.	.0637		<.0184	less than
Ru 106	N.D.	<.0950	N.D.	<.0323	.141		N.D.	less than
Ra 226	N.D.	<.0255	N.D.	<.0800	.07965		<.0276	less than

TABLE 2. (Continued)

	Resin Beds			Aluminum Oxide Beds				
	R-1	R-2	R-3	Al-1	Al-2	Al-3	Filters	Total Activity
CC-5								
ZrNb 95	<.0283	N.D.	0.0478 (.037)	N.D.	<.0404	<.0658	<.0252	0.0478
Eu 155	<.0545	N.D.	0.0668 (.06)	<.0555	N.D.	<.0869	N.D.	0.0668
Ce 141	<.0259	N.D.	<.0118	<.0088	N.D.	<.0071	N.D.	less than
Ra 226	<.0213	N.D.	<.0318	<.0178	<.0408	<.0303	<.0266	less than
Cs 137	<.0134	<.0191	<.0096	<.0037	<.0161	<.0072	0.0260 (.022)	0.0260
Cs 134	<.0826	<.0203	<.0019	<.0092	<.0033	<.0282	<.0136	less than
K 40	<.384	0.582 (.44)	<.175	<.775	0.949 (.81)	<.0033	1.59 (.50)	3.12
Ce 144	N.D.	<.0588	N.D.	N.D.	N.D.	N.D.	N.D.	less than
Co 60	N.D.	<.0061	<.0009	N.D.	N.D.	<.0022	<.0026	less than
Ru 106	N.D.	N.D.	N.D.	<.231	N.D.	<.108	<.0555	less than
CC-9								
ZrNb 95	0.0607 (0.53)	0.0799 (.053)	N.D.	<.0187	N.D.	<.0949	<.0067	0.1406
Eu 155	<.0809	<.0720	N.D.	<.0254	<.0410	0.172 (.065)	N.D.	0.172
Ce 144	<.146	<.0650	<.0304	N.D.	N.D.	N.D.	N.D.	less than
Ce 141	<.0206	N.D.	N.D.	N.D.	N.D.	<.0006	<.0204	less than
Cs 137	<.0203	<.0039	<.0146	<.0237	<.0013	<.0492	<.0143	less than
Cs 134	<.0316	<.0259	<.0150	<.0103	<.0016	0.0791 (.063)	<.0213	0.0791
Co 60	<.0169	N.D.	<.0088	N.D.	<.0024	<.0021	N.D.	less than
K 40	0.881 (.722)	<.496	0.857 (.674)	<.612	<.0689	<.243	2.49 (.722)	4.23
Ru 106	N.D.	<.0024	<.0006	N.D.	<.0329	<.0255	<.1020	less than
Ra 226	N.D.	<.0010	<.0100	<.0101	<.0238	<.0322	0.114 (.063)	0.114

N.D. Not detected

( ) ± two standard deviations

R-1 through R-3 Resin Beds

Al-1 through Al-3 Aluminum Oxide Beds

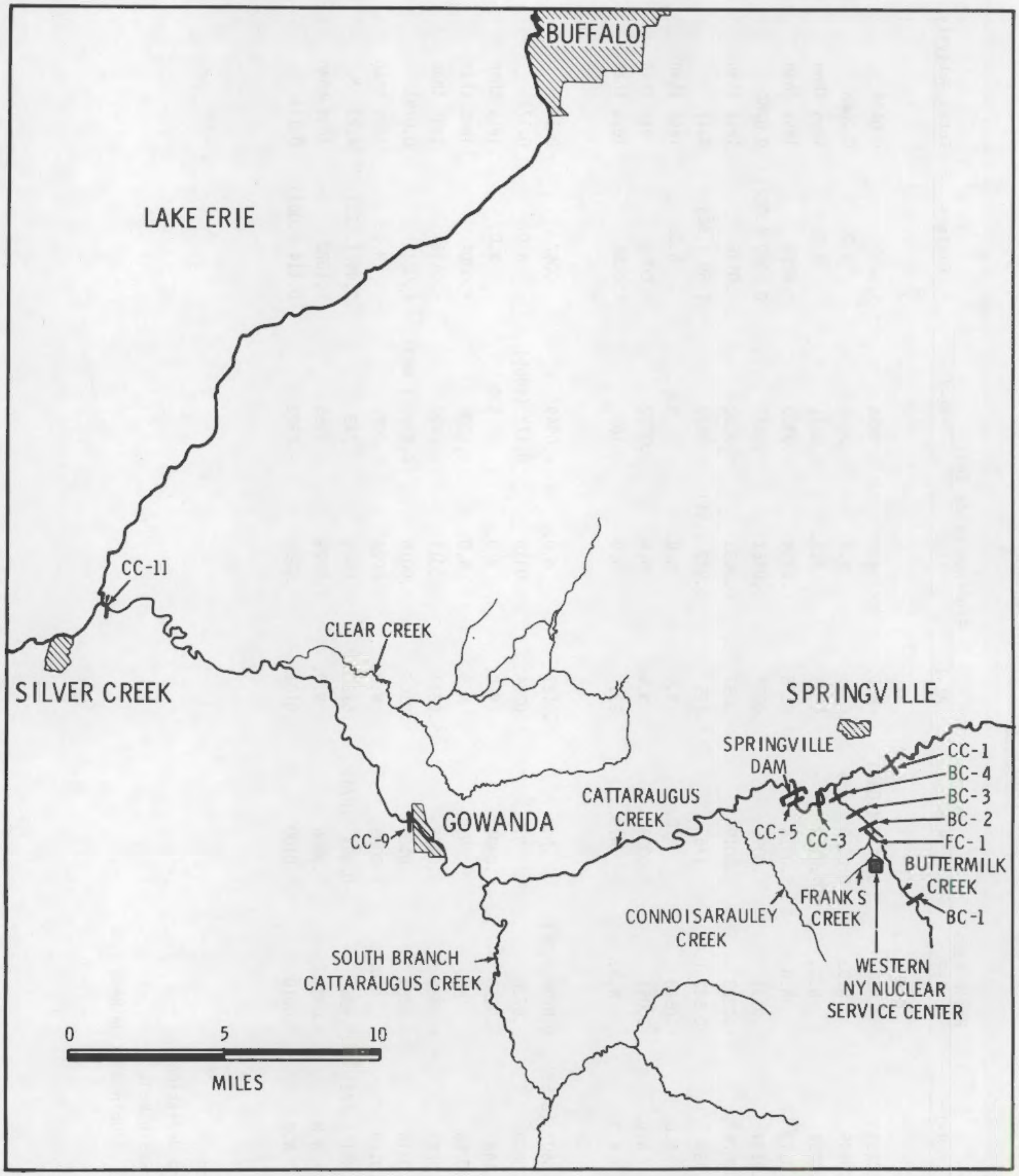

FIGURE 1. Franks-Buttermilk-Cattraugus Creek System with Sampling Locations

gamma activity associated with each of the resin beds, aluminum oxide beds, filters and total activity. The gamma activity in water was very low during the Phase 1 sampling program. Even ^{137}Cs levels in water were difficult to distinguish from the levels in the upstream control transect on Cattaraugus Creek. The counting errors as indicated by two standard deviations, in most cases, were very large compared with the reported likely value, even though some of the samples were counted for 2000 minutes. These large counting errors are not only a result of the low levels of activity, but also due to the size of the water sample taken. A different method for collection of large volume water samples, used during the Phase 2 sampling program, allowed larger water samples to be taken in the field and thus increased sensitivity.

Results of gamma ray spectrometry analysis in Cattaraugus and Buttermilk Creeks indicate that during the Phase 1 sampling program in November and December 1977, the principal gamma emitting radionuclide with levels downstream of the NFS complex was ^{137}Cs. However, even for Cesium-137, its levels in water were very low and in only a few cases were they above detection. Results of Phase 1 sample analyses reveal that the levels of gamma emitters other than ^{137}Cs, in a few cases, were greater in downstream samples than in background samples (e.g., ^{60}Co, ^{155}Eu, ^{144}Ce, ^{106}Ru and ^{95}Zr-Nb); but levels of these samples were too near the background levels, or the number of cases were too small in number to provide an accurate evaluation.

PLUTONIUM AND STRONTIUM ANALYSIS

Results of ^{238}Pu, $^{239,240}Pu$, and ^{90}Sr analyses of suspended sediment and bed sediment for Phase 1 are summarized in Tables 3 and 4. Only two water samples, FC-1 and BC-4 were analyzed for Pu and Sr for reasons stated previously. The ^{238}Pu and $^{239,240}Pu$ in water of Franks Creek (FC-1) were 0.0134 $\pm$ 0.0026 pCi/ℓ and 0.0020 $\pm$ 0.0010 pCi/ℓ, respectively. The levels in water of BC-4, Thomas Corners Bridge on Buttermilk Creek were 0.0154 $\pm$ 0.003 pCi/ℓ and 0.0038 $\pm$ 0.0015 pCi/ℓ, respectively.

Plutonium and Strontium in Suspended Sediment

Very few suspended sediment samples had detectable levels of ^{238}Pu, and all these were found in Franks Creek and Buttermilk Creek. The highest ^{238}Pu

TABLE 3. Strontium and Plutonium Attached to Suspended Sediment (pCi/g)

	^{238}Pu	$^{239-240}Pu$	^{90}Sr
FC-1(UW)			
Sand	N.A.	N.A.	N.D.
Silt	0.0074 (0.0007)	0.0013 (.0004)	<0.013
Clay	0.0344 (.0028)	0.0139 (.0017)	N.D.
BC-1(UW)			
Sand	N.A.	N.A.	N.A.
Silt	0.0153 (.0040)	0.0024 (.0023)	<0.029
Clay	N.A.	N.A.	N.A.
BC2-1			
Sand	0.0262 (.023)	<.00818	0.147 (.0044)
Silt	N.A.	N.A.	0.230 (.014)
Clay	N.D.	N.A.	1.02 (.18)
BC3-1			
Sand	N.D.	<1.58	<1.68
Silt	0.236 (.16)	<.107	1.15 (.066)
Clay	N.D.	<.0042	1.18 (.38)
BC4-1			
Sand	N.D.	<.0304	1.40 (1.0)
Silt	N.D.	<.003	2.27 (.092)
Clay	N.D.	<.019	1.06 (.31)
CC3-1/.2d			
Silt	<.024	0.0988 (.049)	2.40 (.12)
Clay	N.D.	N.D.	0.819 (.61)
CC3-1/.5d			
Sand	N.D.	N.D.	0.757 (.36)
Silt	N.D.	<.00478	0.354 (.038)
Clay	N.D.	<.017	1.01 (.56)
CC3-2			
Sand	N.D.	N.D.	<.64
CC5-1			
Sand	N.D.	N.D.	10.1 (4.5)
Silt	N.D.	N.D.	2.66 (.13)
Clay	N.D.	N.D.	0.770 (.28)
CC5-2/.5d			
Sand	N.D.	N.D.	7.21 (4.5)
Silt	N.D.	<.0013	1.84 (.092)
CC9-1			
Sand	<.00235	<.0163	0.717 (.33)
Silt	N.D.	N.D.	2.17 (.11)
Clay	N.D.	N.D.	0.931 (.45)
C11-1/.8d			
Silt	N.D.	<.0056	1.55 (.077)
Clay	N.D.	<.0398	0.788 (.56)

N.A. Not Analyzed
N.D. Not Detected
( ) ± one standard deviation

TABLE 4. Strontium and Plutonium Attached to Bed Sediment (pCi/g)

	^{238}Pu	$^{239,240}Pu$	^{90}Sr
FC-1(UW)			
Sand	0.0051 (.0009)	0.0030 (.0006)	<0.042
Silt	N.A.	N.A.	<0.022
Clay	0.0028 (.0009)	0.0003 (.0010)	<0.028
BC-1 (UW)			
Sand	0.0020 (.0004)	0.0006 (.0002)	<.013
Silt	0.0613 (0.0161)	0.0239 (0.0093)	<.03
Clay	0.0051 (0.0023)	<0.0014	N.D.
BC2-1			
Sand	N.D.	N.D.	0.0721 (0.045)
Silt	N.D.	N.D.	0.315 (0.045)
Clay	N.D.	<0.680	<0.592
BC3-1			
Sand	N.D.	<0.0008	0.237 (0.045)
Silt	<0.0681	<0.0487	0.234 (0.045)
Clay	N.D.	N.D.	3.38
BC4 Mixed Bed (UW)	0.0059 (.0018)	0.0065 (.0016)	N.A.
BC4-1			
Sand	N.D.	<0.284	<0.330
Clay	N.D.	<0.210	0.243 (0.045)
CC3 Mixed Bed (UW)	0.0039 (.0011)	0.0025 (.0010)	
CC3-1			
Sand	N.D.	N.D.	<0.030
Silt	N.D.	N.D.	0.0480 (.045)
Clay	N.D.	<0.473	<4.50
CC3-2			
Sand	N.D.	N.D.	<.0420
Silt	N.D.	N.D.	<0.0150
Clay	N.D.	<.0819	<1.22
CC9-1			
Sand	N.D.	<.00687	0.0841 (0.045)
Silt	N.D.	N.D.	0.0480 (0.045)
Clay	N.D.	N.D.	<0.287

N.A. Not Analyzed
N.D. Not Detected
( ) ± one standard deviation

value was found associated with the suspended silt fraction of BC3-1 (0.236 $\pm$ 0.16 pCi/g). At FC-1 the suspended silt and clay fractions had ^{238}Pu levels of 0.0074 $\pm$ 0.0008 pCi/g and 0.0344 $\pm$ 0.0028 pCi/g, respectively. Detectable levels of ^{238}Pu were also found in the suspended sand fraction of BC-2, station 1 and the suspended silt fraction of BC-1.

Detectable levels of $^{239,240}Pu$ in suspended sediment were found only at FC-1, BC-1 and near the surface of CC-3, station 1. The highest $^{239,240}Pu$ value of 0.0988 $\pm$ 0.049 pCi/g was found in the suspended sand fraction of CC-3, station 1. The suspended silt and clay fractions of FC-1 had $^{239,240}Pu$ levels of 0.0013 $\pm$ 0.0004 pCi/g and 0.0139 $\pm$ 0.0017 pCi/g, respectively.

Detectable levels of ^{90}Sr in suspended sediment were found at most transects. The highest recorded value was found in the suspended sand fraction of CC-5, station 1 in Springville Reservoir with a ^{90}Sr value of 10.1 $\pm$ 4.5 pCi/g.

Figure 2 is a comparison of ^{90}Sr levels in the suspended sand, silt and clay fractions of Phase 1 samples. The highest ^{90}Sr levels in suspended sediment were found in Springville Reservoir (CC-5) on Cattaraugus Creek. Strontium-90 levels in the suspended sediment of Cattaraugus Creek were as high or higher than those in suspended sediment of Buttermilk and Franks Creeks.

Plutonium and Strontium in Bed Sediment

Table 4 is a summary of ^{238}Pu, $^{239,240}Pu$ and ^{90}Sr levels in bed sediment of Cattaraugus and Buttermilk Creeks during the Phase 1 sampling program. Very few bed sediment samples had detectable levels of ^{238}Pu and $^{239,240}Pu$. The highest ^{238}Pu value was found in the bed silt fraction of BC-1 (0.0613 $\pm$ 0.0161 pCi/g). The bed sand fraction of FC-1, bed clay fraction of BC-1 and mixed bed sample of BC-4 had similar ^{238}Pu levels.

The only bed sediment samples with detectable levels of $^{239,240}Pu$ were found at FC-1, BC-4 (mixed bed), BC-1 and CC-3 mixed bed. The highest $^{239,240}Pu$ value of 0.0129 $\pm$ 0.D093 pCi/g was found in the bed silt fraction of BC-1, the upstream control transect on Buttermilk Creek. Strontium-90 levels in bed sediment varied from below detection to 0.315 $\pm$ 0.045 pCi/g. The highest value was found at BC-2, station 1 in the bed silt fraction.

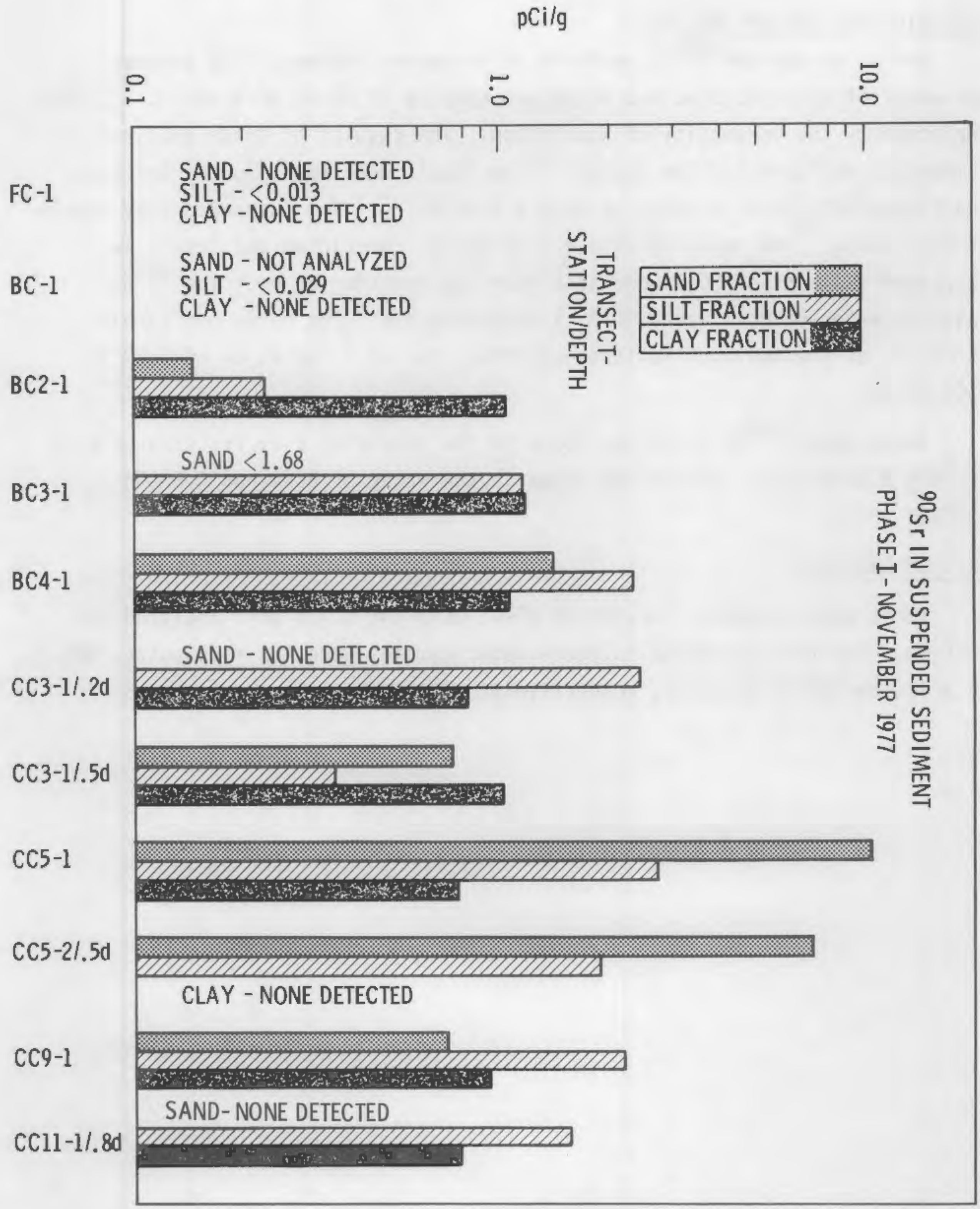

FIGURE 2. Strontium-90 in Suspended Sediment

AMERICIUM AND CURIUM ANALYSIS

Americium-241 and ^{244}Cm analysis of suspended sediment, bed sediment and water of FC-1 and BC-1 and mixed bed samples of BC-4, CC-3 and CC-11, were performed by the University of Washington. The results of these analyses are summarized in Table 5. The highest ^{241}Am levels were found in the bed clay fraction of BC-1 with a value of 1.00 ± 0.30 pCi/g. The suspended clay sample of BC-1 had a ^{241}Am value of 0.94 ± 0.31 pCi/g. Americium-241 levels in suspended sediment of FC-1 were less than the counting error. The ^{241}Am value in water of FC-1 was 0.00163 ± 0.00024 pCi/g. The mixed bed sample of CC-11, at the mouth of Cattaraugus Creek, had an ^{241}Am value of 0.28 ± 0.06 pCi/g.

The highest ^{244}Cm value was found in the suspended clay fraction of FC-1 (1.29 ± 0.08 pCi/g). Curium-244 value in the water of BC-4 was 0.00004 ± 0.00002 pCi/ℓ.

TRITIUM ANALYSIS

Three water samples, located at BC-4, CC-3 and CC-11 were analyzed for tritium. The tritium levels in these water samples were 461 ± 35 pCi/ℓ, 305 ± 36 pCi/ℓ and 206 ± 32 pCi/ℓ, respectively.

TABLE 5. Americium-241 and Curium-244 Analysis Performed by the University of Washington (pCi/g for particulates and pCi/ℓ for dissolved radionuclides)

	^{241}Am	^{244}Cm
FC-1		
Suspended Sand	NA	NA
Suspended Silt	<0.06	0.05 (0.01)
Suspended Clay	<0.18	1.29 (0.08)
Bed Sand	0.40 (0.07)	0.28 (0.02)
Bed Silt	0.23 (0.06)	0.24 (0.02)
Bed Clay	0.74 (0.13)	0.30 (0.03)
Water	0.00163 (0.00024)	<0.00002
BC-1		
Suspended Sand	NA	NA
Suspended Silt	0.47 (0.13)	0.50 (0.04)
Suspended Clay	0.91 (0.31)	0.64 (0.05)
Bed Sand	0.26 (0.04)	0.29 (0.03)
Bed Silt	0.28 (0.13)	0.24 (0.03)
Bed Clay	1.00 (0.30)	0.59 (0.04)
BC-4		
Mixed Bed	0.20 (0.04)	0.29 (0.03)
Water	<0.00046	0.00004 (0.00002)
CC-3		
Mixed Bed	<0.04	<0.01
CC-11		
Mixed Bed	0.28 (0.06)	0.18 (0.02)

N.A. Not analyzed due to insufficient quantity of sample
( ) ± one standard deviation

PHASE 2 SAMPLING PROGRAM

RADIOLOGICAL ANALYSIS

Similar to the Phase 1 Program, radiological analyses were performed on sand, silt and clay size fractions of suspended sediment and bed sediment; and for water. All radiological counting was performed by the University of Washington, Laboratory of Radiation Ecology.

Particulate radionuclides described by three sediment size fractions (sand, silt and clay) of suspended and bed sediments counted by the University of Washington, are shown in Tables 6 and 7. Sampling locations are shown in Figure 1.

Based on the percentage of each sediment size fraction for both suspended and bed sediments, weighted-average particulate radionuclide concentrations were calculated and results are shown in Tables 8 and 9. Changes of suspended particulate radionuclide concentrations associated with sand, silt, clay and composite suspended sediment with respect to the river locations are shown in Figures 3 through 8. Vertical lines in these figures indicate the range of two standard deviations. Each cesium-137 distribution associated with clay, silt and composites sediments shown in Figure 3, has a sharp peak at the mouth of the Franks Creek, revealing the introduction of ^{137}Cs from NFS into the Buttermilk-Cattaraugus Creek system. This figure also indicates that ^{137}Cs associated with clay has consistantly a several times higher concentration than one associated with silt at the same location. This may be due to a higher exchange capacity of clay as compared to silt's capacity. Uranium-235 associated with the composite sediment also reveals a small peak at FC-1 as shown in Figure 4. Cesium-134, radium-226, thorium-228 and thorium-232 do not show any discernible peaks releated to radionuclides released to Buttermilk-Cattaraugus Creek system from the Franks Creek, as shown in Figures 5 through 8.

Similarly, particulate radionuclides associated with sand, silt, clay and composite sediment in the river bed are shown in Figures 9 through 15. Cesium-137, shown in Figure 9, clearly indicates that concentrations in Erdmans Brook (which is a tributary of Franks Creek closest to the NFS disposal site) and Franks Creek are the highest for all the three sediment size fractions as

TABLE 6. Gamma Ray Spectrometry Analysis--Radionuclides Adsorbed by Suspended Sediment, Phase 2, counted by the University of Washington

Station	Sample Wt. g	^{137}Cs pCi/g	^{134}Cs pCi/g	^{60}Co pCi/g	^{40}K pCi/g	^{226}Ra pCi/g	^{232}Th pCi/g	^{228}Th pCi/g	^{235}U pCi/g	^{238}U pCi/g	^{241}Am pCi/g	^{125}Sb pCi/g	^{207}Bi pCi/g	^{102m}Rh pCi/g	^{101}Rh pCi/g	^{155}Eu pCi/g	^{65}Zn pCi/g	^{54}Mn pCi/g	^{144}Ce pCi/g	Others pCi/g
Background																				
Silt	4.6	0.89 (0.39)	0.42 (0.31)		21.9 (12.3)	1.68 ( )	3.95 (1.17)	1.89 (0.55)		4.76 (4.65)						0.96 (0.76)			3.57 (1.93)	
Clay	2.6	2.57 (0.73)			41.5 (1.5)			1.24 (0.76)												
FC-1																				
Silt	8.7	11.7 (0.60)	0.34 (0.13)		21.9 (5.0)	0.80 (0.21)	1.31 (0.73)	0.98 (0.25)												
Clay	3.4	32.5 (1.5)			27.4 (17.1)			2.54 (0.74)	0.65 (0.57)											
BC-1																				
Silt	10.9	0.13 (0.13)			14.7 (4.1)	0.93 (0.17)	1.42 (0.56)	1.32 (0.22)	0.11 (0.11)								0.53 (0.37)			
Clay	2.3	0.66 (0.31)			39.9 (9.1)	1.73 (0.38)	2.63 (1.16)	2.40 (0.47)		4.19 (2.30)										^{210}Pb- 9.67 (8.04)
BC-4																				
Silt	59.6	2.06 (0.14)			20.0 (2.6)	1.06 (0.10)	1.03 (0.26)	1.35 (0.13)	0.14 (0.08)	2.35 (0.96)										
Clay	17.7	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
CC-1																				
Silt	14.0	0.35 (0.19)			17.5 (5.0)	0.77 (0.19)	1.11 (0.57)	1.18 (0.24)	0.19 (0.12)		0.39 (0.29)				0.09 (0.04)				18.8 (13.3)	
Clay	3.4	1.10 (0.41)			32.4 (10.9)	1.16 (0.47)		1.54 (0.53)												
CC 3/1 Top																				
Silt	6.9	1.16 (0.30)		1.13 (1.03)		1.23 (0.30)	1.45 (0.92)	1.25 (0.39)	0.39 (0.28)											
Clay	1.8	2.80 (0.98)	0.84 (0.71)		39.9 (32.7)		3.34 (3.26)	3.47 (1.38)												
CC 3/1 Bottom																				
Silt	10.1	1.76 (0.38)	0.30 (0.21)		25.7 (7.2)	0.76 (0.24)	1.75 (0.84)	1.42 (0.35)												
Clay	4.5	2.88 (0.50)			36.7 (13.4)	1.15 (0.50)		1.82 (0.57)	0.49 (0.42)											
CC 3/2																				
Silt	19.3	1.71 (0.27)			24.5 (5.3)	1.11 (0.20)		1.80 (0.27)	0.26 (0.15)	1.95 (1.79)			0.162 (0.099)			0.359 (0.323)				
Clay	5.5	4.29 (0.45)			33.8 (10.6)	1.03 (0.34)	2.62 (1.02)	1.86 (0.45)									0.171 (0.105)			
CC 3/3																				
Silt	15.3	1.72 (0.20)			20.3 (3.4)	0.77 (0.13)	0.92 (0.34)	0.98 (0.16)	0.13 (0.08)											
Clay	2.1	5.00 (0.95)			31.8 (15.8)			2.42 (0.89)												

TABLE 6. (Continued)

Station	Sample Wt. g	^{137}Cs pCi/g	^{134}Cs pCi/g	^{60}Co pCi/g	^{40}K pCi/g	^{226}Ra pCi/g	^{232}Th pCi/g	^{228}Th pCi/g	^{235}U pCi/g	^{238}U pCi/g	^{241}Am pCi/g	^{125}Sb pCi/g	^{207}Bi pCi/g	^{102m}Rh pCi/g	^{101}Rh pCi/g	^{155}Eu pCi/g	^{65}Zn pCi/g	^{54}Mn pCi/g	^{144}Ce pCi/g	Others pCi/g
CC 5/1																				
Silt	34.4	1.17			19.5	0.96	0.95	1.38	0.15	1.15						0.14				
		(0.13)			(2.4)	(0.09)	(0.27)	(0.12)	(0.05)	(0.58)						(0.11)				
Clay	4.1	2.84			9.7	0.83	0.90	0.91	0.14	1.99										
		(0.21)			(2.3)	(0.10)	(0.27)	(0.12)	(0.06)	(0.75)										
CC 5/2 Top																				
Silt	16.0	1.01			19.3	0.85	0.79	1.33	0.17											
		(0.23)			(4.8)	(0.17)	(0.53)	(0.23)	(0.11)											
Clay	3.0	2.09			37.5	1.00		2.38												
		(0.57)			(11.3)	(0.72)		(0.60)												
CC 5/2 Mid-depth																				
Silt	20.7	1.15			21.1	1.15	1.36	1.46	0.22	1.72										
		(0.14)			(3.0)	(0.12)	(0.31)	(0.15)	(0.09)	(1.09)										
Clay	4.0	2.15			32.9	1.57	1.61	1.82				1.39				0.91				
		(0.49)			(14.2)	(0.48)	(1.47)	(0.62)				(0.88)				(0.88)				
CC 5/2 Bottom																				
Silt	44.4	1.11			19.0	0.92	1.13	1.35	0.13											
		(0.15)			(2.8)	(0.11)	(0.32)	(0.14)	(0.06)											
Clay	4.8	2.07			40.0	1.14	1.96	1.92	0.30	4.37										
		(0.41)			(0.90)	(0.36)	(1.01)	(0.42)	(0.21)	(2.23)										
CC 5/3																				
Silt	20.7	1.20			17.4	1.00	1.04	1.15	0.15											
		(0.23)			(3.9)	(0.17)	(0.52)	(0.22)	(0.09)											
Clay	2.1	2.36			31.1			2.43												
		(0.69)			(14.6)			(0.84)												
CC 9																				
Silt	24.3	1.85			25.7	0.87	1.43	1.48	0.21	2.12					0.07			0.17		
		(0.22)			(4.3)	(0.15)	(0.49)	(0.21)	(0.12)	(1.41)					(0.05)			(0.15)		
Clay	8.3	2.74			27.0	1.11	1.37	1.61	0.25											
		(0.34)			(5.6)	(0.21)	(0.59)	(0.28)	(0.14)											
CC 11 Top																				
Silt	12.9	1.41			19.0	1.10	1.20	0.98	0.18											
		(0.20)			(3.6)	(0.14)	(0.44)	(0.18)	(0.09)											
Clay	3.0	2.51			33.8	1.46	1.80	2.01						0.49						
		(0.59)			(11.9)	(0.72)	(1.66)	(0.63)						(0.35)						
CC 11 Bottom																				
Silt	20.5	1.82			19.2	1.02	1.36	1.44	0.17	1.00						0.22				
		(0.20)			(3.1)	(0.13)	(0.36)	(0.17)	(0.08)	(0.72)						(0.14)				
Clay	3.2	2.71			21.1		2.77	2.54												
		(0.57)			(16.8)		(1.56)	(0.80)												

N.A. - Not analyzed.
Blanks indicate a radionuclide level was below detection.
( ) parentheses represent two standard deviations.

TABLE 7. Gamma Ray Spectrometry Analysis--Radionuclides Adsorbed by Bed Sediment Phase 2, Counted by the University of Washington

Station Fraction	%	^{137}Cs pCi/g	^{134}Cs pCi/g	^{60}Co pCi/g	^{40}K pCi/g	^{226}Ra pCi/g	^{232}Th pCi/g	^{228}Th pCi/g	^{235}U pCi/g	^{238}U pCi/g	^{241}Am pCi/g	^{125}Sb pCi/g	^{207}Bi pCi/g	^{102m}Rh pCi/g	^{101}Rh pCi/g	^{57}Cr pCi/g	^{155}Eu pCi/g	^{65}Zn pCi/g	^{54}Mn pCi/g	Other pCi/g
FC-1																				
Sand	74.5	27.7	0.47	0.44	14.1	0.51	0.47	0.59	0.08	0.91										
		(0.50)	(0.07)	(0.08)	(2.0)	(0.09)	(0.32)	(0.11)	(0.06)	(0.59)										
Silt	23.2	28.6	0.52	0.45	15.5	0.84	0.62	1.04	0.16	0.82			0.11							
		(0.60)	(0.08)	(0.08)	(2.2)	(0.11)	(0.42)	(0.13)	(0.08)	(0.72)			(0.07)							
Clay	2.3	134.0	2.81	1.91	39.2	1.74	2.22	2.31	0.57	3.57		1.84		0.25						
		(0.90)	(1.46)	(0.14)	(3.4)	(0.18)	(0.63)	(0.22)	(0.14)	(1.52)		(0.59)		(0.20)						
Erdmans Brook																				
Coarse Sand	32.5	72.1	1.24	0.59	14.5	0.78	0.56	0.84	0.18	1.63	0.25		0.13	0.12	0.04					
		(0.50)	(0.06)	(0.05)	(1.3)	(0.08)	(0.32)	(0.10)	(0.06)	(0.72)	(0.22)		(0.05)	(0.06)	(0.03)					
Med. Sand	21.8	43.7	0.85	0.64	13.6	0.71	1.01	0.82	0.16	1.33		0.84	0.13							
		(0.40)	(0.06)	(0.06)	(1.5)	(0.08)	(0.26)	(0.09)	(0.06)	(0.69)		(0.07)	(0.05)							
Fine Sand	8.3	21.3	0.42	0.39	12.0	0.57	0.51	0.65		0.88		0.42								
		(0.50)	(0.07)	(0.08)	(2.1)	(0.10)	(0.35)	(0.12)		(0.85)		(0.08)								
Silt	32.4	29.5	0.66	0.54	15.2	1.03	0.82	1.14	0.20	1.22		0.62	0.33	0.15		83.1				
		(0.40)	(0.06)	(0.06)	(1.8)	(0.08)	(0.27)	(0.10)	(0.06)	(0.74)		(0.07)	(0.11)	(0.06)		(52.5)				
Clay	5.1	112.0	2.58	1.61	35.7	1.30	1.81	2.07	0.20	1.94		2.25		0.09						
		(1.0)	(0.14)	(0.15)	(3.0)	(0.17)	(0.61)	(0.20)	(0.11)	(0.91)		(0.17)		(0.05)						
BC-1																				
Sand	98.4		0.05		11.7	0.61	0.73	0.67	0.10	0.86							0.19			
			(0.02)		(1.4)	(0.05)	(0.14)	(0.07)	(0.04)	(0.49)							(0.08)			
Silt	1.5	0.10	0.04		11.9	0.91	0.88	0.97	1.10	1.48										
		(0.04)	(0.03)		(1.4)	(0.06)	(0.14)	(0.07)	(0.04)	(0.47)										
Clay	0.09				59.3		4.17	3.05	2.02											
					(34.9)		(3.61)	(1.61)	(1.05)											
BC-4																				
Sand	95.8	11.2	0.21	0.14	10.6	0.45	0.31	0.48	0.07	0.57				0.08						
		(0.20)	(0.03)	(0.03)	(1.14)	(0.05)	(0.17)	(0.06)	(0.03)	(0.32)				(0.04)						
Silt	4.0	15.2	0.27	0.19	11.3	0.77	0.90	0.93	0.11	0.63		0.25		0.07	0.05					
		(0.30)	(0.04)	(0.05)	(1.30)	(0.07)	(0.21)	(0.08)	(0.04)	(0.42)		(0.07)		(0.06)	(0.02)					
Clay	0.2	108.0	1.87		34.7	2.26	6.17	3.28												
		(2.8)	(0.48)		(18.0)	(1.00)	(2.54)	(1.08)												
CC-1																				
Sand	98.7	0.19			9.40	0.36	0.37	0.43	0.05											
		(0.04)			(1.09)	(0.04)	(0.09)	(0.04)	(0.02)											
Silt	1.3	0.98		0.07	11.5	0.92	0.96	0.97	0.15	1.98				0.05			0.18			
		(0.09)		(0.06)	(2.0)	(0.08)	(0.19)	(0.09)	(0.06)	(0.71)				(0.04)			(0.12)			
Clay	0.04	14.8		0.90	27.7	1.95		3.10	0.68											
		(1.7)		(0.87)	(16.9)	(1.00)		(1.00)	(0.61)											
CC-3/1																				
Sand	79.3	2.04	0.05		9.93	0.44	0.43	0.44	0.07	0.50										
		(0.16)	(0.04)		(1.67)	(0.06)	(0.18)	(0.07)	(0.04)	(0.38)										
Silt	20.4	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.			
Clay	0.4	21.8			33.7	1.68		2.26	0.33						0.14					
		(1.5)			(9.7)	(0.40)		(0.53)	(0.26)						(0.13)					

TABLE 7. (Continued)

Station Fraction	%	^{137}Cs pCi/g	^{134}Cs pCi/g	^{60}Co pCi/g	^{40}K pCi/g	^{226}Ra pCi/g	^{212}Th pCi/g	^{228}Th pCi/g	^{235}U pCi/g	^{238}U pCi/g	^{241}Am pCi/g	^{125}Sb pCi/g	^{207}Bi pCi/g	^{102m}Rh pCi/g	^{101}Rh pCi/g	^{57}Cr pCi/g	^{155}Eu pCi/g	^{65}Zn pCi/g	^{54}Mn pCi/g	Other pCi/g
CC-3/2																				
Sand	99.3	1.15	0.29		9.67	0.38	0.44	0.43	0.10	0.45										
		(0.07)	(0.27)		(1.21)	(0.04)	(0.11)	(0.05)	(0.03)	(0.41)										
Silt	0.7	2.11	0.12		10.9	0.89	1.04	0.87	0.11									0.29		
		(0.21)	(0.06)		(2.5)	(0.11)	(0.30)	(0.13)	(0.06)									(0.22)		
Clay	0.02	14.0	1.75			4.96		5.33							1.12		5.62			
		(2.4)	(1.57)			(3.37)		(3.02)							(0.83)		(3.99)			
CC-3/3																				
Sand	95.2	1.14			9.82	0.38	0.37	0.42	0.08	0.49										
		(0.07)			(1.15)	(0.04)	(0.11)	(0.05)	(0.03)	(0.40)										
Silt	4.4	27.6	0.61		13.4	1.05	0.71	1.13	0.19								0.13			
		(0.50)	(0.07)		(2.20)	(0.11)	(0.36)	(0.13)	(0.08)								(0.09)			
Clay	0.4	134.0	2.98	1.59	34.0	1.83	2.20	2.40	0.22											
		(2.1)	(0.28)	(0.27)	(5.3)	(0.33)	(1.19)	(0.40)	(0.20)											
CC-5/1																				
Sand	5.1	1.16			7.29			0.63	0.18			0.43								
		(0.25)			(4.42)			(0.25)	(0.14)			(0.40)								
Silt	85.4	1.79			15.1	1.03	1.06	1.20	0.15	1.93					0.05		0.20			
		(0.19)			(3.1)	(0.12)	(0.32)	(0.16)	(0.08)	(1.06)					(0.04)		(0.19)			
Clay	9.5	5.40			37.5	1.63	2.32	2.15	0.45	3.40										
		(0.42)			(5.8)	(0.22)	(0.64)	(0.28)	(0.16)	(1.87)										
CC-5/2																				
Sand	1.3	1.50	0.35		14.9		1.61	1.13	0.43											
		(0.32)	(0.17)		(9.6)		(1.00)	(0.44)	(0.32)											
Silt	88.7	1.23			14.6	0.99	1.06	1.15	0.17											
		(0.14)			(2.7)	(0.10)	(0.31)	(0.13)	(0.06)											
Clay	9.9	3.35			28.2	1.48	1.08	1.99	0.21										0.27	
		(0.37)			(5.0)	(0.19)	(0.56)	(0.25)	(0.10)										(0.17)	
CC-5/3																				
Sand	0.4	1.16				2.23	3.57	1.87	1.08								0.95			
		(0.65)				(1.13)	(1.85)	(1.10)	(0.81)								(0.73)			
Silt	86.6	1.14			14.9	1.03	0.69	1.26	0.17	1.21							0.17			^{144}Ce-0.56
		(0.14)			(2.6)	(0.10)	(0.28)	(0.14)	(0.66)	(0.84)							(0.15)			(0.39)
Clay	13.1	3.44		0.27	25.7	1.73	1.91	2.10	0.23	3.06					0.06					^{144}Ce-0.67
		(0.37)		(0.17)	(4.7)	(0.20)	(0.54)	(0.27)	(0.10)	(1.16)					(0.05)					(0.65)
CC-9																				
Sand	98.4	0.34			11.7	0.42	0.44	0.36		1.01										
		(0.06)			(1.8)	(0.06)	(0.17)	(0.08)		(0.55)										
Silt	1.5	0.65			12.8	0.89	0.79	0.93	0.11	0.85										
		(0.10)			(2.1)	(0.08)	(0.23)	(0.10)	(0.05)	(0.51)										
Clay	0.1	3.37			34.4	4.04	5.05	3.07	0.99						0.03					
		(0.72)			(21.8)	(0.80)	(2.31)	(0.97)	(0.75)						(0.02)					
CC-11																				
Sand	21.7	0.23			10.2	0.38	0.40	0.39	0.08											
		(0.05)			(1.4)	(0.05)	(0.13)	(0.06)	(0.03)											
Silt	72.0	0.67			12.8	0.72	0.86	1.06	0.61	1.15	0.18	0.05				0.13				
		(0.10)			(2.1)	(0.08)	(0.21)	(0.10)	(0.43)	(0.49)	(0.12)	(0.04)				(0.10)				
Clay	6.3	3.29			32.4	1.51	2.33	2.34	0.27	3.15						0.34			0.26	^{210}Pb-7.21
		(0.30)			(5.0)	(0.19)	(0.52)	(0.25)	(0.13)	(1.65)						(0.30)			(0.19)	(6.77)

N.A. - Not analyzed
Blanks indicate a radionuclide level was below detection
( ) parentheses represent two standard deviations

TABLE 8. Suspended Particulate Radionuclides of Gamma Emitters

Location	PCi/g in Suspended Sediment																
	Am 241	Bi 207	Co 60	Cs 134	Cs 137	Ce 144	K 40	Mn 54	Ra 226	Rh 101	Rh 102m	Th 228	Th 232	U 235	U 238	Zn 65	Eu 155
Background				0.42 (0.31)	1.46 (0.50)	3.57 (1.93)	28.2 (8.3)		1.68			1.62 (0.61)	3.95 (1.17)		4.76 (4.85)		0.96 (0.76)
BC-1					0.21 (0.16)		18.2 (4.8)		1.02 (0.20)			1.44 (0.25)	1.56 (0.64)	0.11 (0.11)	4.19 (2.30)	0.53 (0.37)	
CC-1	0.39 (0.29)				0.48 (0.23)	18.8 (13.3)	19.8 (6.0)		0.82 (0.24)	0.09 (0.04)		1.21 (0.29)	1.11 (0.57)	0.19 (0.12)			
FC-1				0.34 (0.13)	17.4 (0.85)		23.2 (8.3)		0.80 (0.21)			1.40 (0.32)	1.31 (0.73)	0.65 (0.57)			
BC-4					2.06 (0.14)		20.0 (2.6)		1.06 (0.10)			1.35 (0.13)	1.03 (0.26)	0.14 (0.08)	2.35 (0.96)		
CC-3/1/Top			1.13 (1.03)	0.18 (0.15)	1.49 (0.43)		8.14 (6.67)		1.23 (0.30)			1.68 (0.58)	1.82 (1.38)	0.39 (0.28)			
CC-3/1/Bottom				0.30 (0.21)	2.07 (0.41)		28.71 (8.98)		0.87 (0.31)			1.52 (0.41)	1.75 (0.84)	0.15 (0.05)			
CC-3/2		0.162 (0.099)			2.25 (0.31)		26.20 (6.39)		1.07 (.228)			1.81 (0.31)	0.59 (0.23)	0.26 (0.15)	1.95 (1.79)	0.17 (0.105)	0.36 (0.32)
CC-3/3					2.10 (0.29)		21.40 (4.83)		0.77 (0.13)			1.14 (0.24)	0.92 (0.34)	0.13 (0.08)			
CC-5/1					1.35 (0.14)		18.43 (2.38)		0.945 (0.09)			1.33 (0.12)	0.94 (0.27)	0.15 (0.05)	1.24 (0.60)		0.14 (0.11)
CC-5/2/Top					1.19 (0.27)		22.28 (5.86)		0.873 (0.26)			1.50 (0.30)	0.79 (0.53)	0.17 (0.11)			
CC-5/2/Mid					1.27 (0.18)		22.54 (4.40)		1.20 (0.165)			1.50 (0.20)	1.39 (0.45)	0.22 (0.09)	1.72 (1.09)		0.12 (0.11)
CC-5/2/Bottom					1.12 (0.18)		21.02 (2.60)		0.939 (0.134)			1.40 (0.17)	1.21 (0.38)	0.15 (0.07)	0.41 (0.22)		
CC-5/3					1.30 (0.27)		18.62 (4.87)		1.00 (0.17)			1.26 (0.27)	1.04 (0.52)	0.15 (0.09)			
CC-9					2.04 (0.25)		25.45 (4.52)	0.17 (0.15)	0.910 (0.16)	0.07 (0.05)		1.74 (0.22)	1.38 (0.50)	0.22 (0.12)	2.12 (1.41)		
CC-11/Top					1.61 (0.27)		21.71 (5.15)		1.16 (0.249)		0.093 (0.06)	1.17 (0.26)	1.30 (0.67)	0.18 (0.09)			
CC-11/Bottom					1.93 (0.25)		19.36 (4.93)		1.02 (0.13)			1.58 (0.25)	1.54 (0.52)	0.17 (0.08)	1.00 (0.72)		0.22 (0.14)

Blanks indicate a radionuclide level was below detection
Parentheses ( ) represents two standard deviations

TABLE 9. Weighted Average of Concentrations of Particulate Radionuclides of Gamma Emitters in River Bed

Location	PCi/g in Bed Sediment																			
	Am 241	Bi 207	Ce 144	Co 60	Cs 134	Cs 137	Cr 57	Eu 155	K 40	Mn 54	Po 210	Ra 226	Rh 101	Rh 102m	Th 228	Th 232	U 235	U 238	Sb 125	Zn 65
BC-1					0.049 (0.039)	.001 (.0006)		0.19 (0.08)	11.7 (1.4)			0.61 (0.05)		0.08 (0.04)	0.67 (0.07)	0.73 (0.14)	0.10 (0.04)	0.86 (0.89)		
CC-1				0.0013 (0.0008)		0.206 (0.041)		0.0023 (0.0015)	9.4 (1.1)			0.368 (0.040)		0.0006 (0.0005)	0.438 (0.04)	0.377 (0.09)	0.05 (0.02)	0.025 (0.009)		
Erdmans Brook	0.25 (0.22)	0.20 (0.07)		0.62 (0.06)	0.97 (0.07)	47.0 (0.44)	26.92 (17.01)		15.4 (1.7)			0.86 (0.09)	0.013 (0.009)	0.092 (0.042)	0.98 (0.10)	0.80 (0.31)	0.168 (0.05)	1.386 (0.74)	0.533 (0.053)	
FC-1		0.026 (0.016)		0.48 (0.08)	0.54 (0.10)	30.4 (0.53)			15.0 (2.1)			0.61 (0.10)		0.006 (0.005)	0.73 (0.12)	0.55 (0.35)	0.11 (0.07)	0.95 (0.64)	0.042 (0.014)	
BC-4				0.14 (0.03)	0.21 (0.03)	11.6 (0.21)			10.6 (1.14)			0.466 (0.05)	0.002 (0.0008)	0.079 (0.04)	0.50 (0.06)	0.345 (0.176)	0.07 (0.03)	0.571 (0.32)	0.01 (.002)	
CC-3/1					0.039 (0.031)	1.70 (0.14)			8.00 (1.363)			0.355 (0.05)	0.0005 (0.0005)		0.357 (0.057)	0.34 (0.14)	0.051 (0.03)	0.396 (0.30)		
CC-3/2					0.29 (0.27)	1.16 (0.07)		0.001 (0.0008)	9.67 (1.22)			0.384 (0.04)	0.0002 (0.0001)		0.434 (0.05)	0.44 (0.11)	0.10 (0.03)	0.446 (0.407)		0.002 (0.0015)
CC-3/3				0.0064 (0.0011)	0.038 (0.004)	2.30 (0.09)		0.005 (0.003)	10.07 (1.21)			0.415 (0.04)			0.459 (0.05)	0.392 (0.12)	0.085 (0.03)	0.466 (0.38)		
CC-5/1						2.10 (0.21)		0.170 (0.162)	16.82 (3.42)			1.034 (0.123)	0.05 (0.04)		1.26 (0.175)	1.12 (0.33)	0.180 (0.09)	1.971 (1.08)		
CC-5/2					0.004 (0.002)	1.44 (0.17)			15.93 (3.01)	0.026 (0.016)		1.024 (0.107)			1.23 (0.145)	1.068 (0.34)	0.177 (0.067)			
CC-5/3			0.57 (0.42)	0.035 (0.022)		1.44 (0.17)		0.151 (0.132)	16.27 (2.86)			1.127 (0.117)	0.007 (0.006)		1.373 (0.16)	0.862 (0.32)	0.181 (0.58)	1.448 (0.879)	0.021 (0.020)	
CC-9						0.34 (0.06)			11.73 (1.82)			0.430 (0.06)			0.371 (0.08)	0.45 (0.17)	0.002 (0.0015)	1.00 (0.548)		
CC-11						0.74 (0.10)	0.115 (0.09)		13.47 (2.13)	0.016 (0.011)		0.695 (0.08)			0.995 (0.10)	0.852 (0.21)	0.473 (0.324)	1.026 (0.456)	0.036 (0.028)	

No sand data for BC-1 (C_s 137)
No sand, silt data for CC-5/2, CC-11, (Mn54)
No sand data for BC-4, CC-3/1, 3/2, 5/3, 9, Rh_{101}

Blanks indicate a radionuclide level was below detection
Parentheses ( ) represents two standard deviations

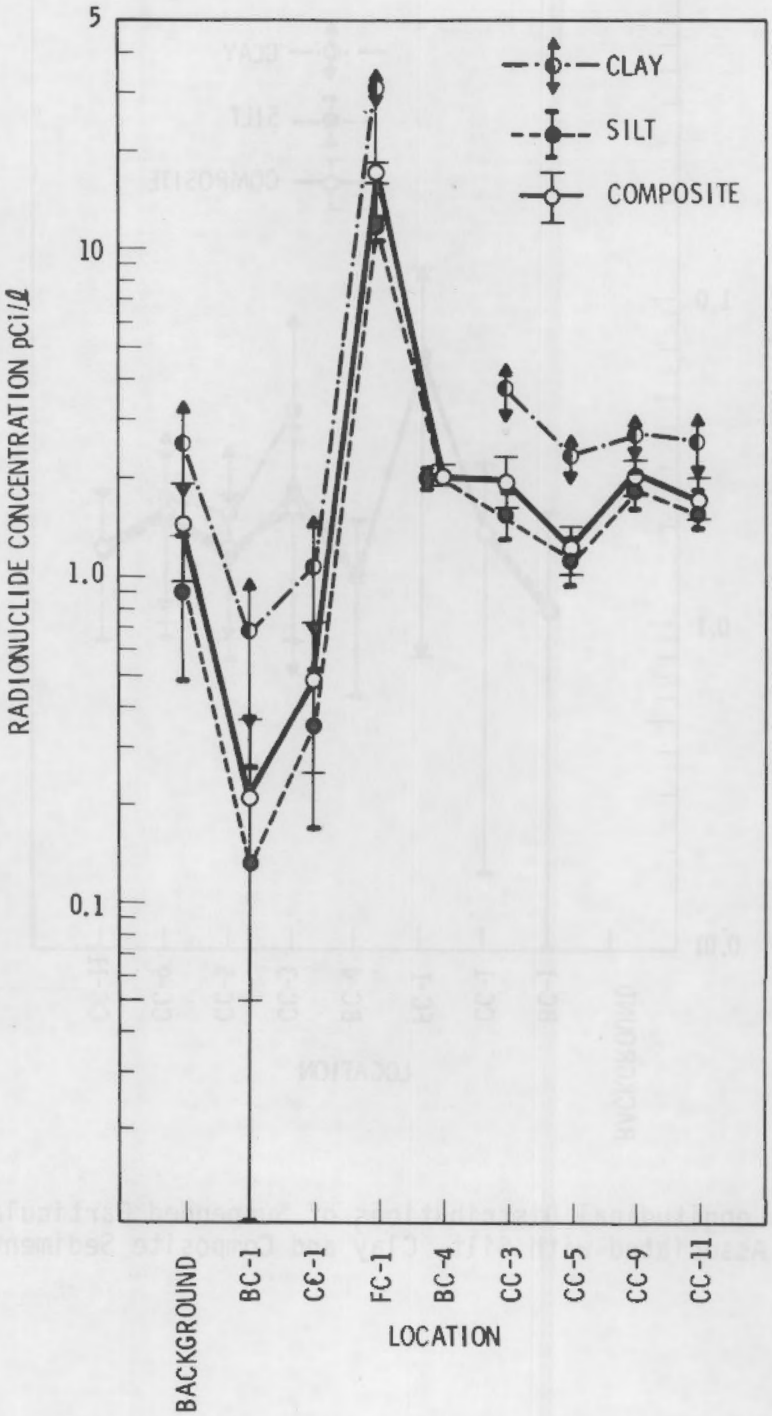

FIGURE 3. Longitudinal Distributions of Suspended Particulate ^{137}Cs Associated with Silt, Clay and Composite Sediment

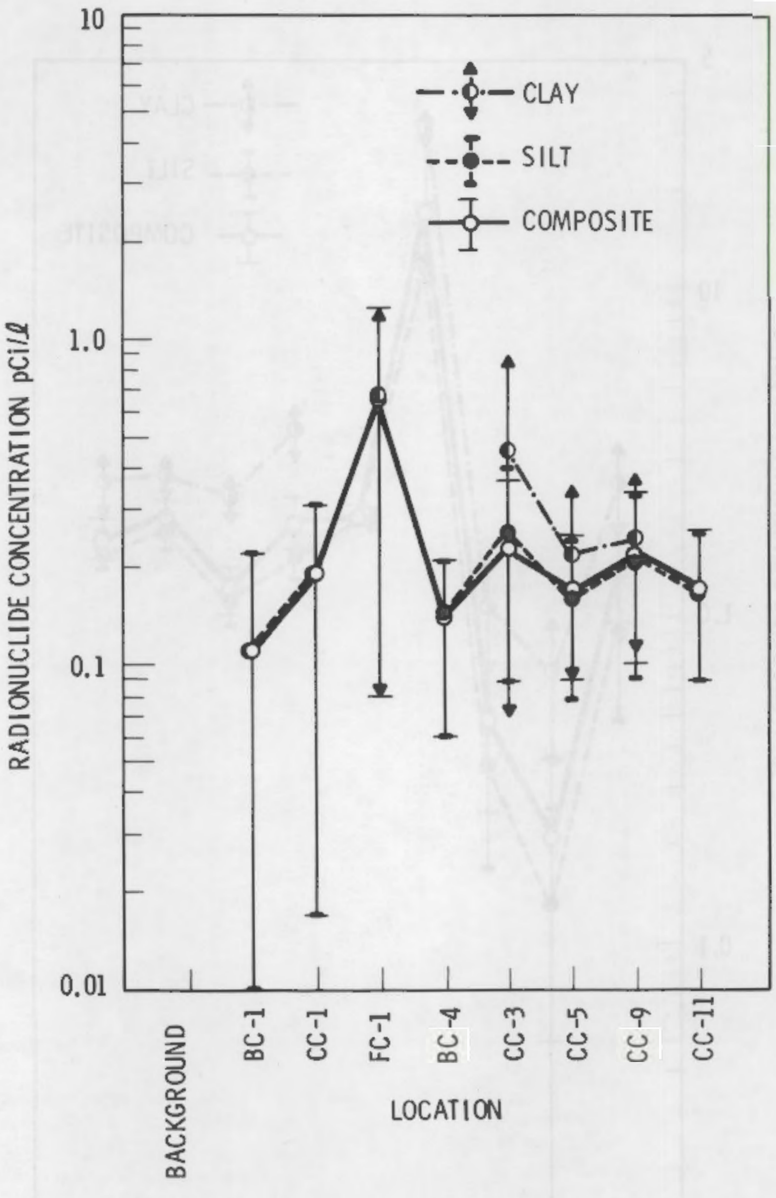

FIGURE 4. Longitudinal Distributions of Suspended Particulate ^{235}U Associated with Silt, Clay and Composite Sediment

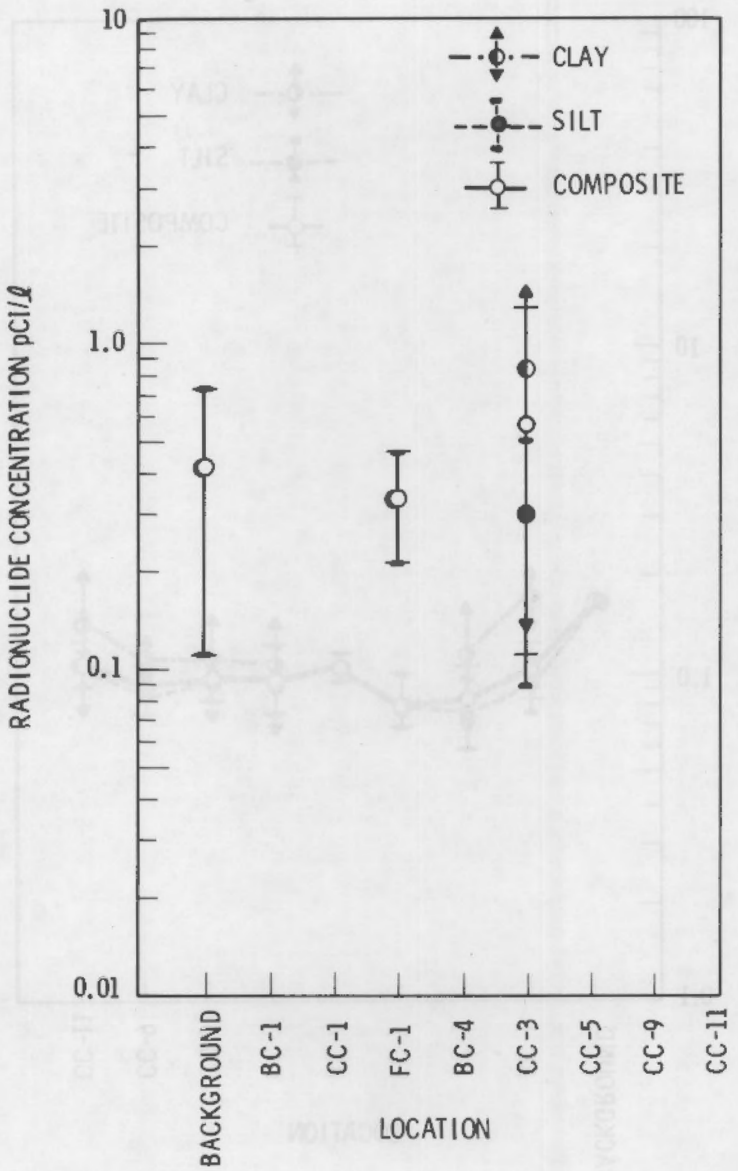

FIGURE 5. Longitudinal Distributions of Suspended Particulate ^{134}Cs Associated with Silt, Clay and Composite Sediment

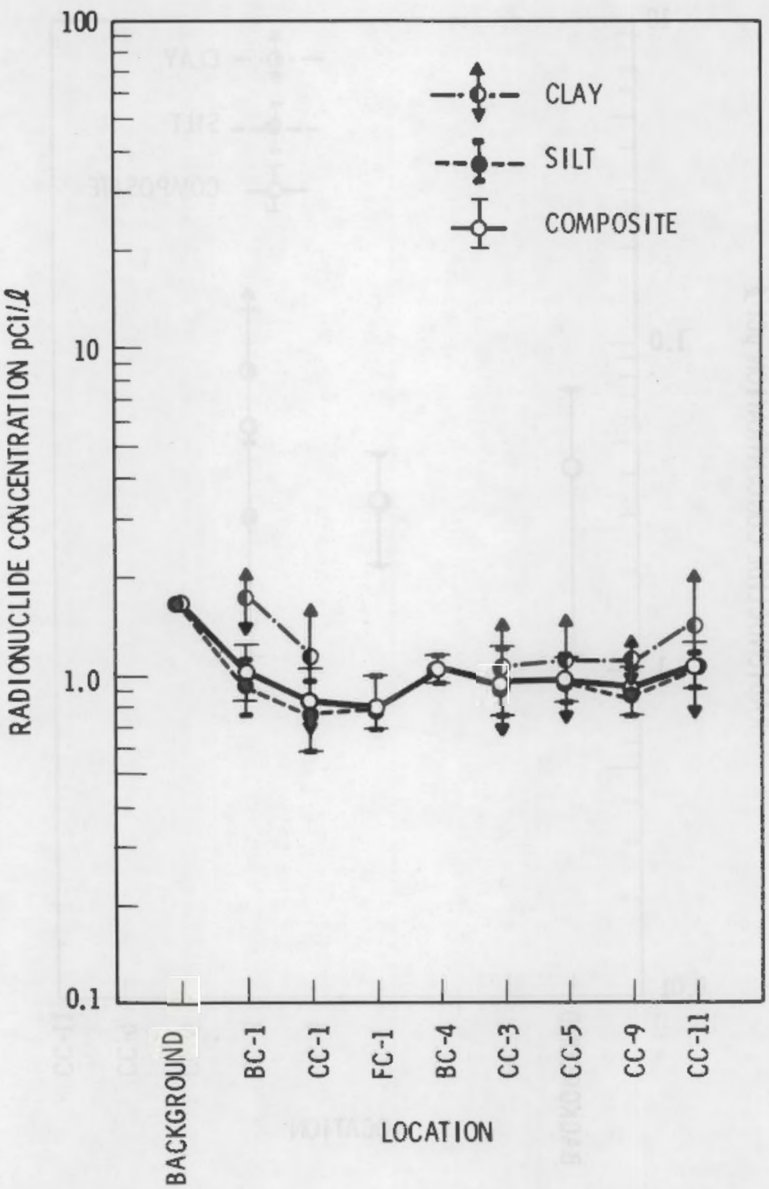

FIGURE 6. Longitudinal Distributions of Suspended Particulate ^{226}Ra Associated with Silt, Clay and Composite Sediment

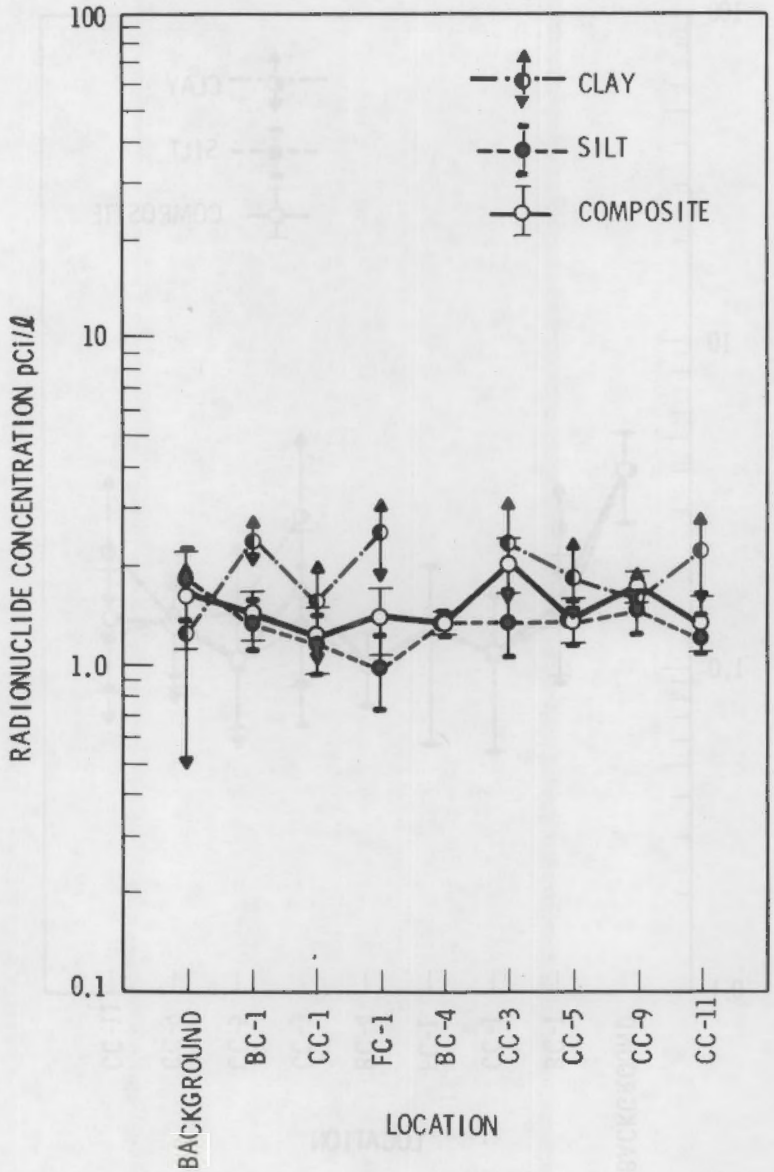

FIGURE 7. Longitudinal Distributions of Suspended Particulate ^{228}Th Associated with Silt, Clay and Composite Sediment

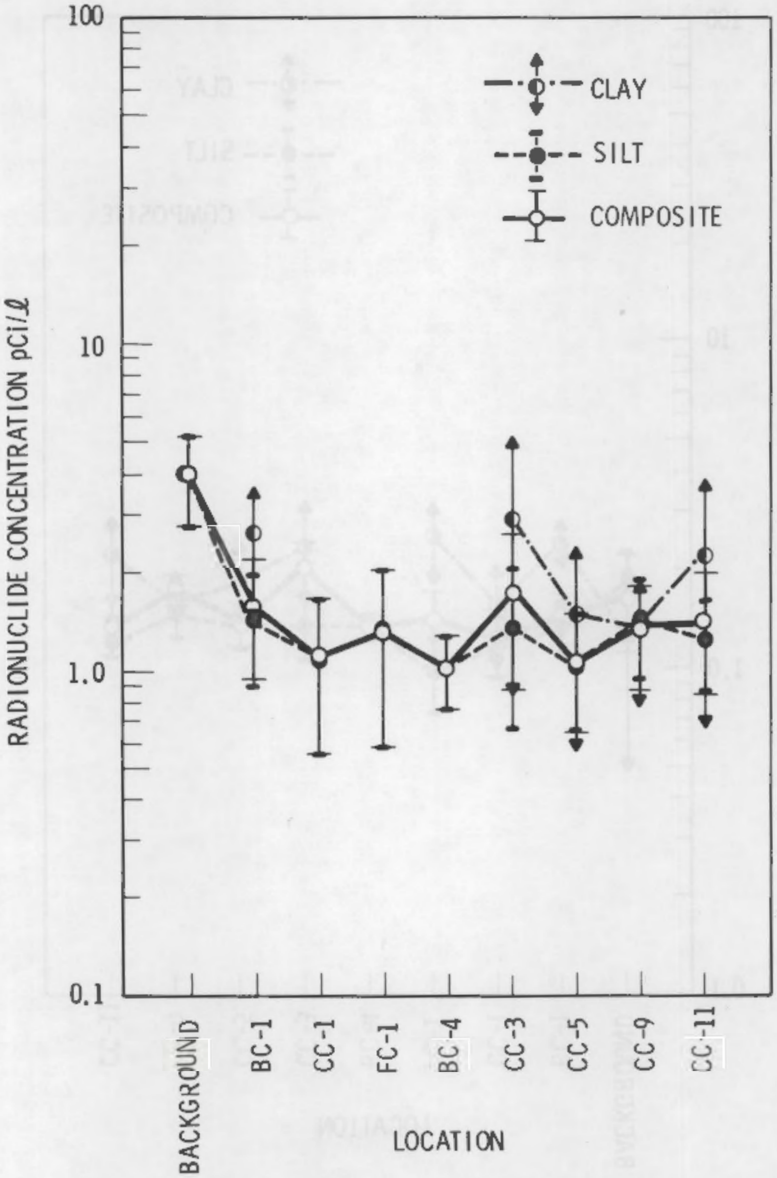

FIGURE 8. Longitudinal Distributions of Suspended Particulate ^{232}Th Associated with Silt, Clay and Composite Sediment

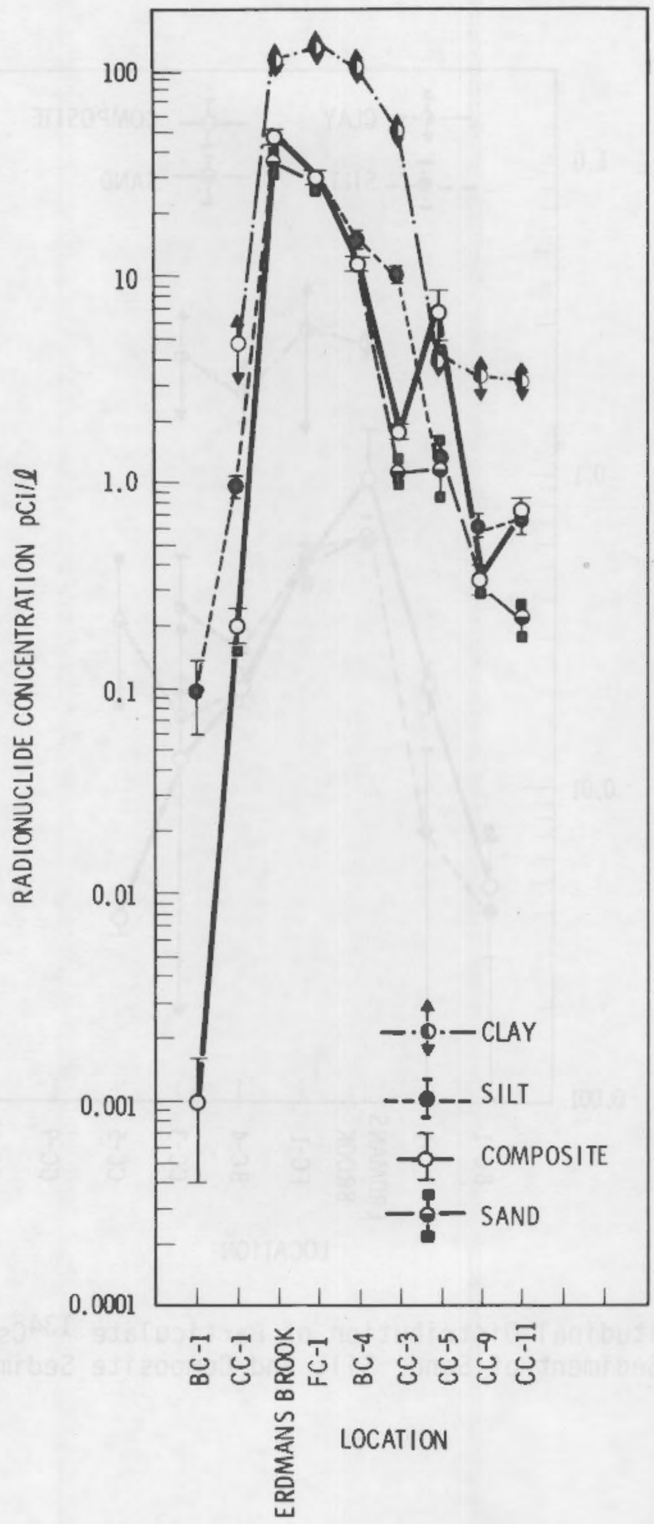

FIGURE 9. Longitudinal Distribution of Particulate ^{137}Cs Associated with Bed Sediment of Sand, Silt, Clay and Composite Sediment

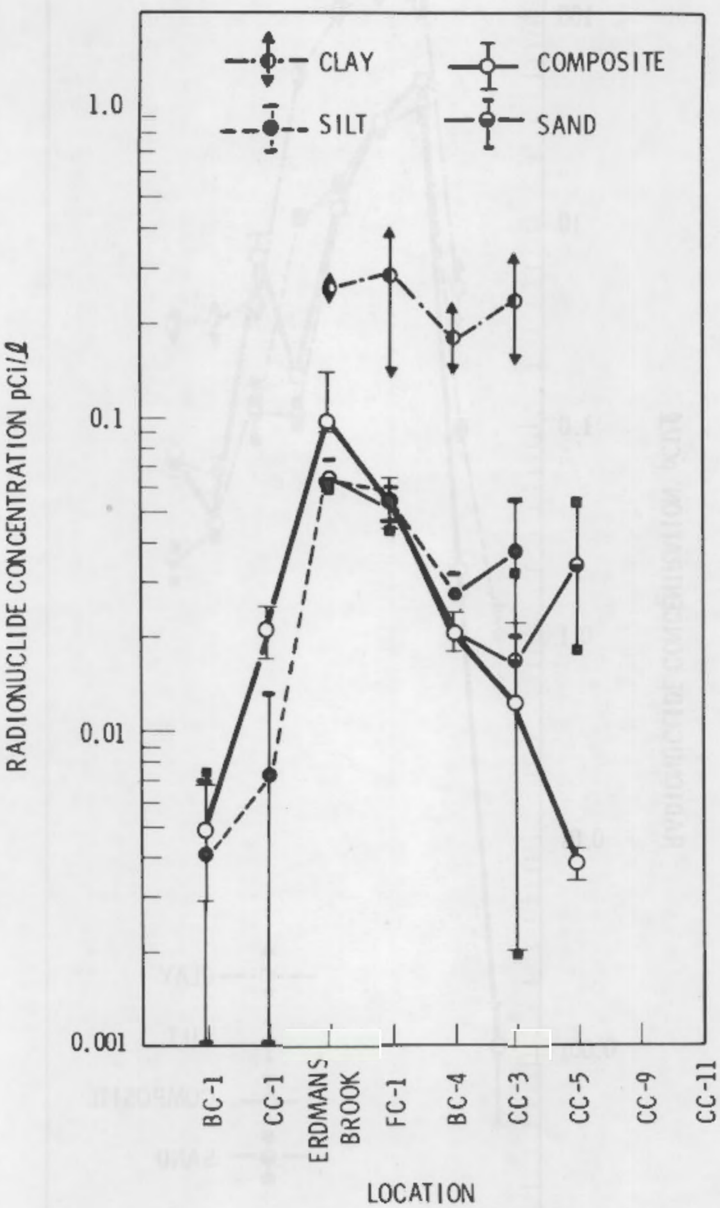

FIGURE 10. Longitudinal Distribution of Particulate ^{134}Cs Associated with Bed Sediment of Sand, Silt and Composite Sediment

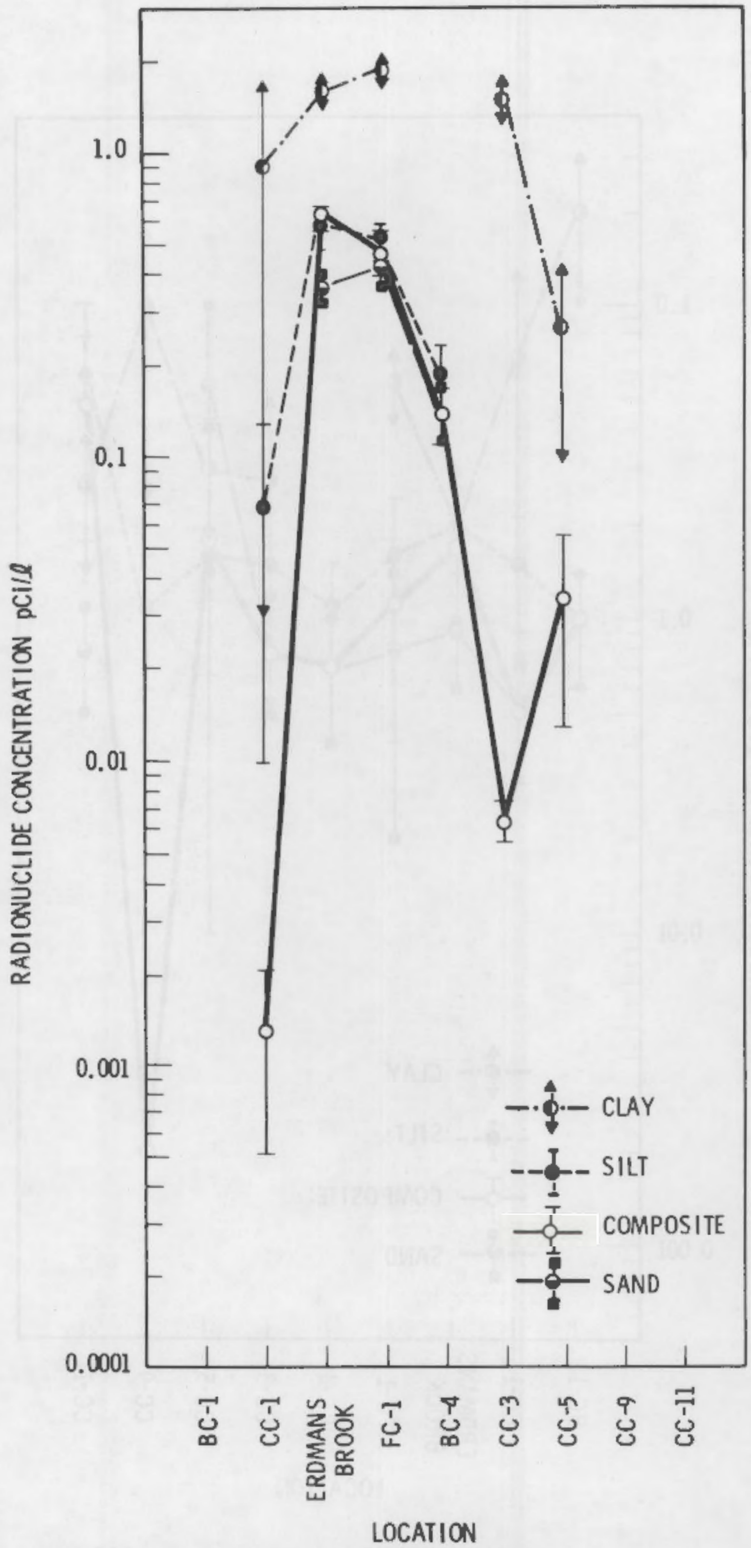

FIGURE 11. Longitudinal Distribution of Particulate ^{60}Co Associated with Bed Sediment of Sand, Silt, Clay and Composite Sediment

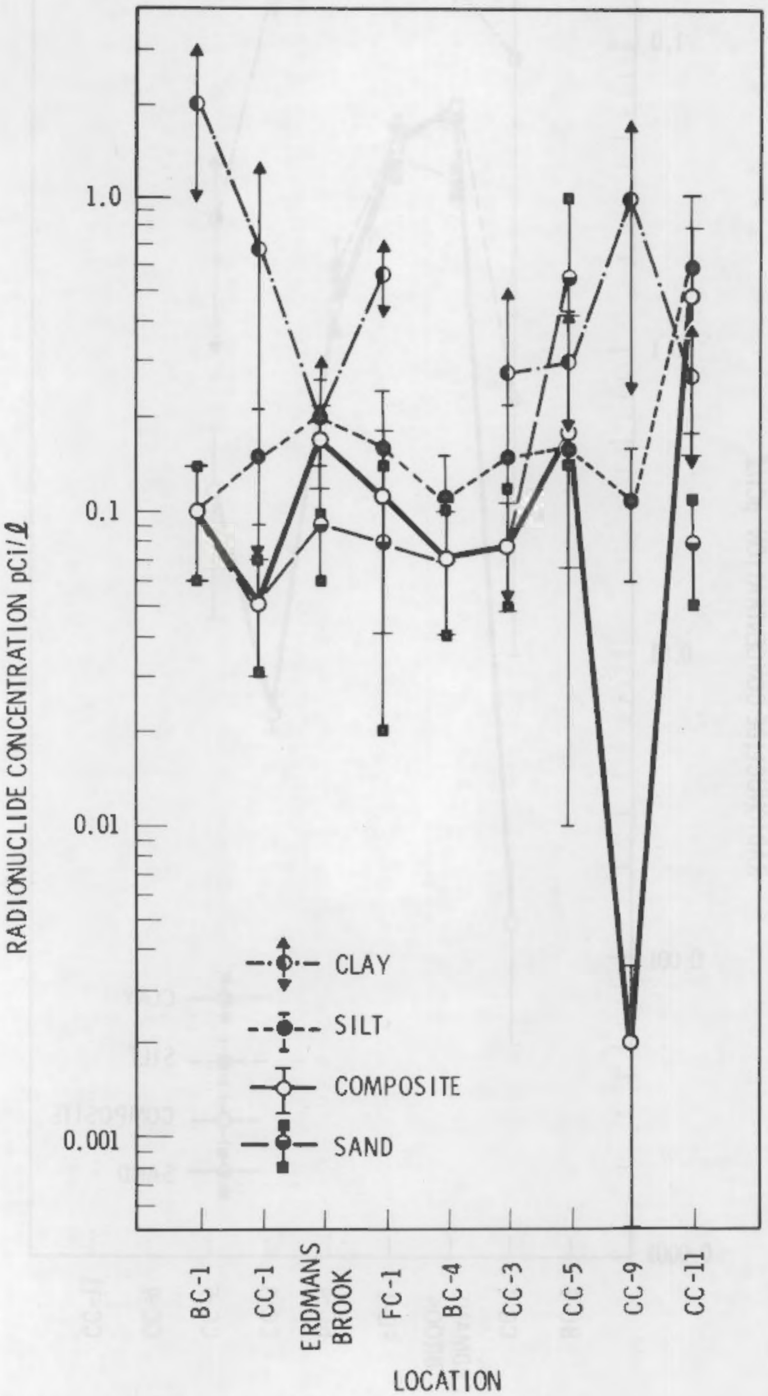

FIGURE 12. Longitudinal Distribution of Particulate ^{235}U Associated with Bed Sediment of Sand, Silt, Clay and Composite Sediment

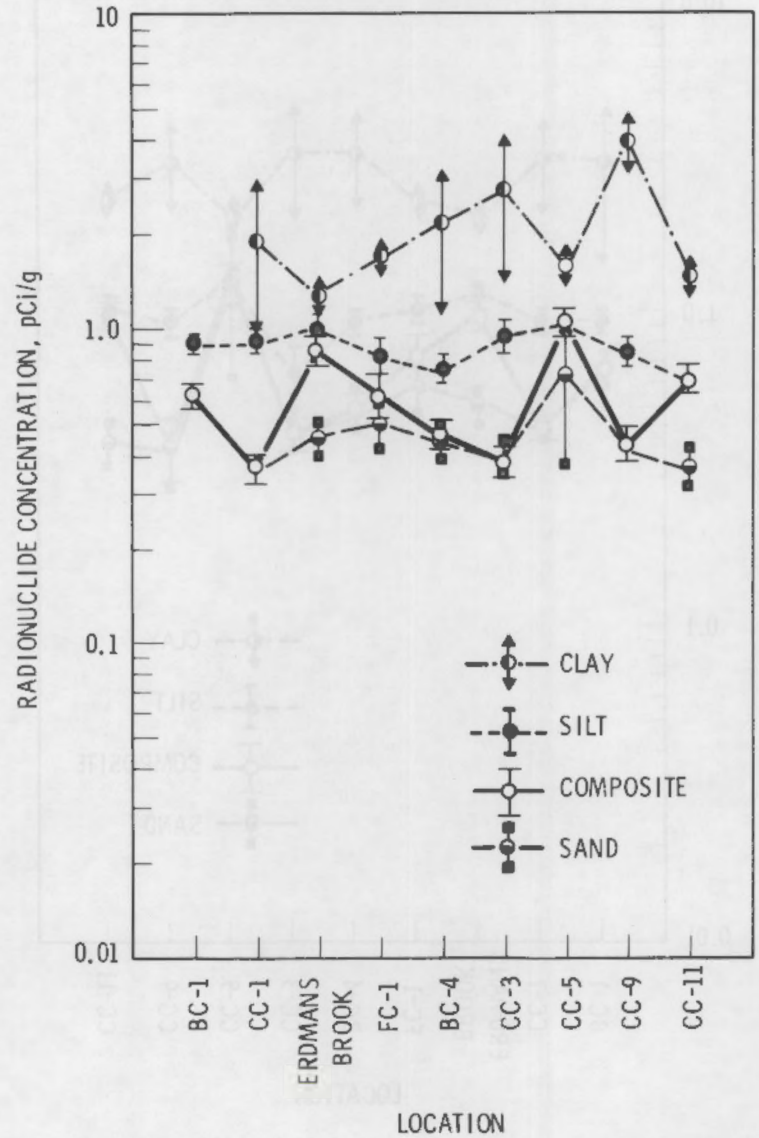

FIGURE 13. Longitudinal Distribution of Particulate ^{226}Ra Associated with Bed Sediment of Sand, Silt, Clay and Composite Sediment

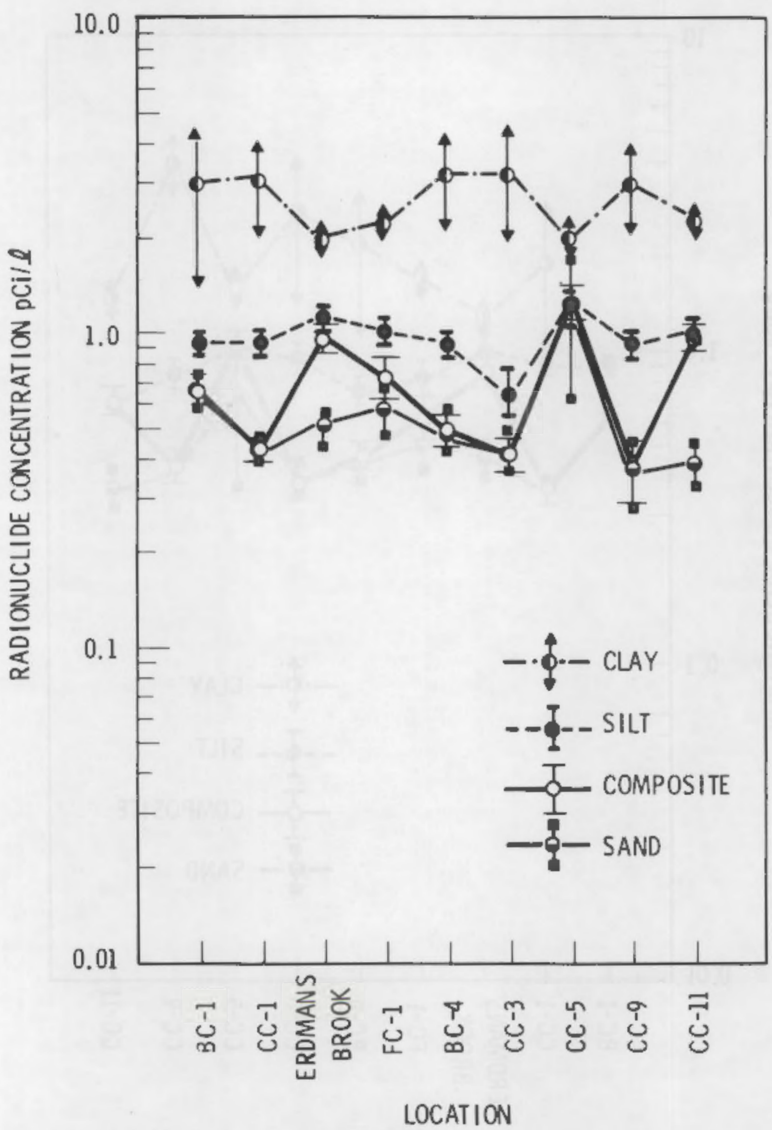

FIGURE 14. Longitudinal Distribution of Particulate ^{228}Th Associated with Bed Sediment of Sand, Silt, Clay and Composite Sediment

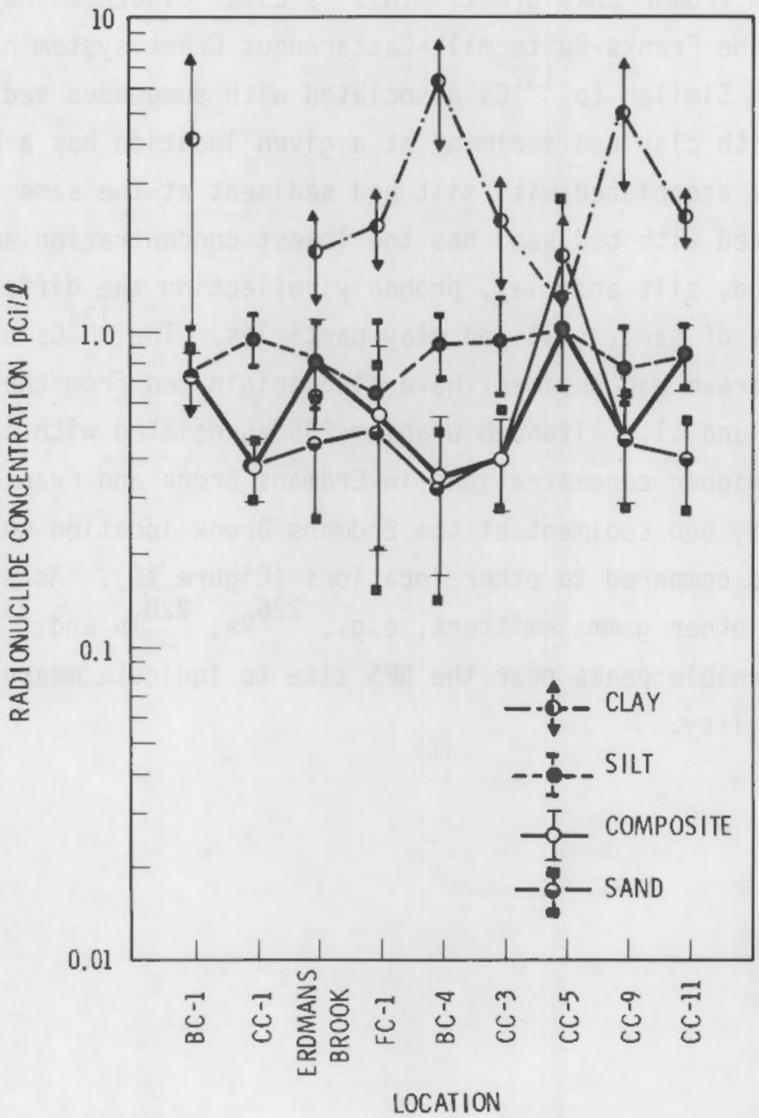

FIGURE 15. Longitudinal Distributions of Particulate ^{232}Th Associated with Bed Sediment of Sand, Silt, Clay and Composite Sediment

well as the composite bed sediment. Cesium-137 concentrations in the riverbed decrease downstream from Franks Creek. This is clear evidence that most of ^{137}Cs existing in the Franks-Buttermilk-Cattaraugus Creek system has come from the NFS site. Similar to ^{137}Cs associated with suspended sediment, ^{137}Cs associated with clay bed sediment at a given location has a higher concentration than one associated with silt bed sediment at the same location. Cesium-137 associated with bed sand has the lowest concentration among those associated with sand, silt and clay, probably reflecting the differences in exchange capacities of sand, silt and clay particles. The ^{134}Cs and ^{60}Co remaining in the stream bed sediment have also originated from the NFS site, as shown in Figure 10 and 11. Although uranium-235 associated with composite bed sediment also has higher concentrations in Erdmans Brook and Franks Creek, ^{235}U associated with clay bed sediment at the Erdmans Brook location shows the smallest concentrations compared to other locations (Figure 12). As shown in Figures 12 through 15 other gamma emitters, e.g., ^{226}Ra, ^{228}Th and ^{232}Th, do not have clearly discernible peaks near the NFS site to indicate measurable input from the waste facility.

PHASE 3 SAMPLING PROGRAM

During FY-1979, a hydrologic analysis for Phase 3 was performed. However, no radiological analysis for Phase 3 has been conducted yet.

HYDROLOGIC DATA COLLECTION

Purpose of Monitoring Effort

The purpose of the hydrological monitoring task is to provide input data of the actual flow conditions during the sampling period for unsteady state flow modeling. The results of the unsteady state flow computations will provide hydraulic input data for the sediment-contaminant model SERATRA. The collected hydrologic data include river stage readings versus time at temporary gage locations, vertical velocity measurements, channel cross-section surveys, and water surface slopes.

Certain sediment data are required as input to SERATRA and were collected simultaneously with the gage readings. These data are wash load concentrations (clay and silt fractions) and channel bed material samples (sand fractions). Wash load concentrations versus time are required at all primary channel network and tributary inflow points. Bed material samples are necessary for the determination of sand size fraction distribution.

The primary stream system under study consists of a length of Buttermilk Creek that extends from the mouth of Franks Creek at the NFS facilities to its confluence with Cattaraugas Creek which is about 12,500 feet of channel. The length of Cattaraugas extends 39 miles downstream to its outlet at Lake Erie. This is the assumed pathway of radionuclide migration for surface waters. In order to simplify model verification, a short reach of Buttermilk and Cattaraugas Creek system about 10 miles long was selected for detailed monitoring. The reach extends from just above the confluence with Buttermilk Creek to just upstream of Connoisarauley Creek. This reduces the number of tributaries that require monitoring to two which are Spring Brook and Spooner Creek.

Hydrographs of water discharge versus time are required at all significant inflow points of the selected reaches of Cattaraugas and Buttermilk Creeks.

The channel geometry will be determined from the cross-sectional surveys and the channel slope measured from USGS topographic maps. Using these data the unsteady flow model will generate water depths and average cross-sectional velocities at specified points along the channel length for input into SERATRA. The wash load sediment concentration versus time and bed material size distribution data are not required for the unsteady flow modeling but will be input data for SERATRA.

CATTARAUGAS CREEK WATERSHED

Location

Cattaraugus Creek flows in a westerly direction through the Zoar Valley and empties into Lake Erie about 27 miles southwest of Buffalo, New York. The principal community on Cattaraugas Creek is Gowanda, New York which is located about 19 stream miles upstream from Lake Erie. The confluence of Buttermilk Creek is 20 miles further upstream from Gowanda. The total drainage area of the watershed is 564 square miles.

The watershed area upstream of Buttermilk Creek includes 218 square miles and above Gowanda about 432 square miles.

Geomorphology

The Cattaraugas Creek watershed in Western New York lies within the Allegheny Plateau physiographic province. The pre-glacial erosional surface of the watershed was dissected upland with deeply incised valleys. Many of the valleys have been buried by a considerable volume of glacial deposits with the result that much of the present drainage is post-glacial and bedrock valleys which have depth and direction varying from the present valleys.

The present course of Buttermilk Creek is incised into glacial deposits and recent alluvium which fill a deep pre-glacial bedrock gorge. The channel pattern in the vicinity of its confluence with Franks Creek is that of a braided stream where at low flows there will be multiple channels.

At low flows Buttermilk Creek discharge follows a meandering underfit channel pattern among the alluvial islands within its narrow flood plain. At many locations the bankline is poorly defined and unstable. Evidence of very recent bank caving exists at some locations. Two primary causes generally assumed to be responsible for a braided condition are (1) a sediment load which exceeds the transport capacity of the stream, and (2) a steep channel slope, which tends to produce a wide shallow channel where bars and islands easily form.

At about the mid-point of the reach between the Franks Creek outlet and the confluence with Cattaraugas Creek the channel begins to establish a meandering plan geometry. Bendway development gives an S-shaped appearance which increases in size as the confluence with Cattaraugas Creek is approached. Meandering is a trading process of erosion and deposition. Material is eroded from the concave banklines of bendways and deposited on point bars (convex banklines) over a period of time. For easily erodible banks this process leads to a noticeable migration of the bendways over a period of years.

Cattaraugas Creek from the mouth of Buttermilk Creek to its outlet at Lake Erie has a meandering plan view geometry. There are reaches where alluvial islands and bars are present which cause a braided appearance at low flows. For the most part these multi-channeled reaches appear to have remained stable where the islands and bars tend to remain in their general location. Some islands lie adjacent to a bankline and have well-established vegetation. Many of the point bars are clear of established vegetation indicating prolonged inundation during the high water season or growth of the alluvial bar area. Both of these phenomena usually work in concert which is probably the case for Cattaraugas Creek.

Near Lake Erie the Cattaraugas Creek flood plain is much wider and terraces are prevalent. Numerous meander scrolls are evident in the cleared agricultural lands and can be determined by the difference in soil type and moisture content. Other cutoff bendways of more recent origin are in the form of oxbow lakes which may receive flow from the creek during spring floods. It is difficult to determine if the meandering process is very active without a sequence of aerial photos and mapping covering a sufficient time period, however, the presence of erosion control structures at a bridge near Gowanda indicates meandering may still be active enough to introduce significant quantities of sediment into the streamflow.

Hydrology

The Nuclear Fuels Service Center is located within an area that normally receives enough monthly precipitation to provide surplus water runoff throughout the year. Small quantitites of water that are withdrawn from the groundwater by farm, public, and private wells is replenished through natural percolation. Therefore, the natural water supply is more than adequate to supply the needs of the center and area. The water supply for the center is provided by surface runoff collected in two lakes in the southern portion of the center. These two lakes periodically release controlled water discharges to Buttermilk Creek at two separate inflow points about one-half mile apart and about two miles upstream from the Franks Creek confluence. The releases from these lakes superimpose a small wave disturbance on the stage hydrograph for time periods of 2 to 3 hours. A major portion of the water collected within the center will be returned to the drainage network and enter Lake Erie by way of Cattaraugus Creek. The extreme flow events for Buttermilk Creek are of short duration of hours or a few days. A report by Dana et al. (1979) discusses the USGS gage records on Buttermilk Creek from 1968 to 1973. They summarized the flow hydrograph characteristics for Buttermilk Creek as follows:

> "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.)."

The high discharge events are much higher than the mean daily flow which indicates that the high discharge events are on the order of several hours in duration. The highest discharge recorded for the period of record is $110.65m^3$/sec or 3896.5 cfs (Dana et al. 1979).

The only one gaging station on Cattaraugus Creek is located at Gowanda, New York. The watershed area upstream of the gage is 432 square miles. Annual peak discharge records received from the USGS Water Resources Division, Albany, New York, indicate that the maximum peak dishcarge of 34,600 cfs occurred on March 7, 1956 for the period of record from 1911 to 1975. The high discharges normally occur during the spring season from snowmelt coupled with rainfall.

HYDROLOGIC DATA COLLECTION

The routing of water and sediment through the Buttermilk-Cattaraugus Creek system will require monitoring the water discharge and suspended sediment concentrations at all significant inflow points. Because of the size (564 square miles) and complexity, including 16 significant tributaries from Buttermilk Creek to Lake Erie, a sub-basin area of the watershed in the immediate vicinity of NFS was selected for "more detailed" hydrologic monitoring. The area includes a 12,500 ft reach of Buttermilk Creek from just upstream of Franks Creek to its confluence with Cattaraugus Creek. The reach of Cattaraugus Creek is about 8 streamlength miles and begins at Bigelow Bridge upstream of the Buttermilk Creek confluence and extends downstream past Springville Dam to a point about 800 ft below Frye Bridge. A map of the study area and gage locations is shown in Figure 16. Two tributaries, Spooner Creek and Spring Brook, have significant drainage areas and are included as inflow points for water and sediment. Springville Dam and reservoir are located about 2.5 miles downstream from the mouth of Buttermilk Creek and act as an intermediate control section. The reservoir serves only as pondage for the small hydroelectric plant at the dam but does trap large quantities of sediment. Flow depth over the spillway was monitored and total flow was measured at a section about 1500 ft downstream of the dam. The difference between the flow over the spillway and the total discharge measured downstream will provide an estimate of the water passing through the turbines.

An automatic water stage recorder has been established by the New York State Geological Survey at Thomas Corners Bridge over Buttermilk Creek. This gage provided continuous stage and time data for the monitoring period and serves as a check on upstream gage readings. Periodic surges of flow occur on Buttermilk Creek due to controlled reservoir releases upstream from the NFS ponds and last for about 2 to 3 hr. Because of the difficulty of minute by minute monitoring of the upstream inflow point on Buttermilk Creek by field

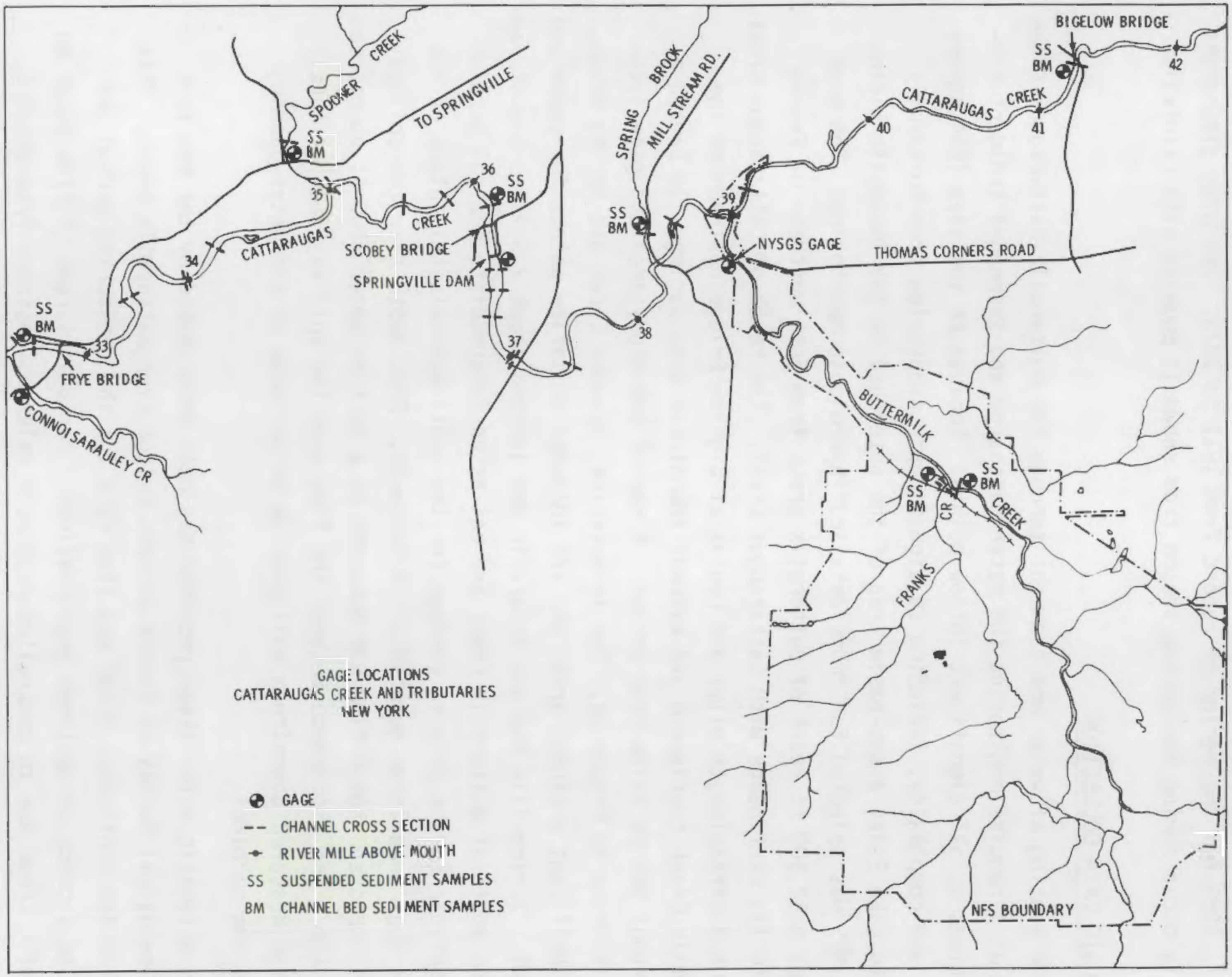

FIGURE 16. Gage Locations of Cattaraugas Creek and Tributaries, New York

personnel, the continuous record of the Thomas Corners Bridge gage was used to insure all surges were accounted for. During the monitoring period only one surge occurred and gage readings taken at the upstream inflow point corresponds very closely with those at Thomas Corners Bridge. An instream discharge measurement was also obtained at the peak of the surge.

Suspended sediment samples are required at all inflow points on Cattaraugus and Buttermilk Creeks. Samples were also taken immediately below the dam and at the outflow point below Frye Bridge as a check on the amount of sediment being transported through the system. Bed material samples are required at these locations to determine a size distribution of the sand available for transport. This information together with the water discharge will be used to compute channel bed material transport rates.

Stream Gage Network

Establishment of Gages

The staff gages were fabricated in the field using 3/4 in. galvanized pipe in lengths of 4 ft. One inch wide masking tape was used to outline 1 in. divisions with black and red spray paint as shown in Figure 17. The painted pipe sections were driven into the stream bed about 2 ft and tied back with 1/8 in. cable or nylon rope for stability.

Monitoring of Gages

Beginning at 0730 on April 26, 1979 the reading of all gages in the study area commenced. The readings were taken by field personnel including the gage at Connoisarauley Creek which is very near the Frye Bridge gaging station. The auxiliary gage at South Branch Cattaraugus Creek proved to be too far downstream to effectively monitor, therefore, only two readings area available for that location. The gage readings are tabulated in Tables 10 through 17 for all monitored gages.

Water Discharge Measurements

Velocity measurements at specified intervals across the cross-section are required in order to determine the water discharge for the range of water

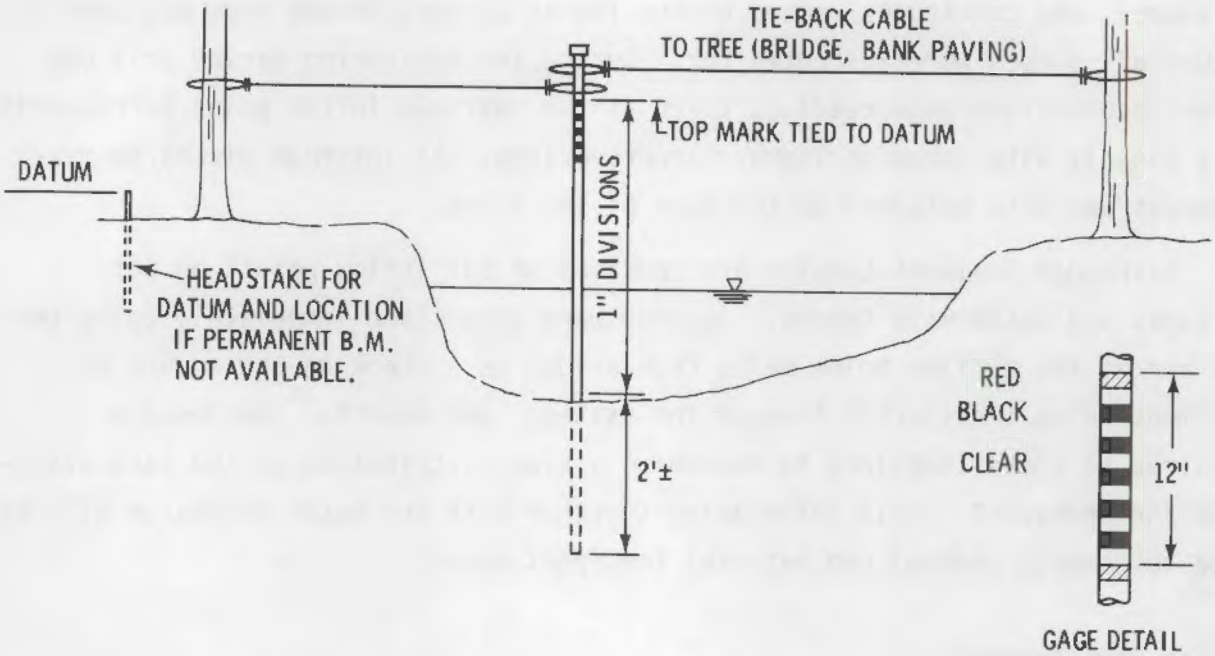

FIGURE 17. Typical Staff Gage Installation for Recording Changes in Water Surface Elevation

surface elevations during the monitoring period. The velocity measurements together with the cross-sectional area and water surface slope will determine the water discharge and channel roughness. These data would then be used to develop discharge hydrographs for each gage location. The discharge hydrographs would be used as input at all inflow points for the unsteady state flow modeling.

Sediment Sampling

Five suspended sediment samples were collected in plastic 1 liter bottles at each inflow and outflow point and below the dam. The number of samples was limited by project costs but it is believed that enough samples were collected to determine the changes in sediment inflow. One bed material sample was collected at the sampling points by scooping materials from the bed at two or three locations along the discharge range. The wash load samples are tabulated in Table 18. Table 19 is a summary of collected data for all gage locations.

TABLE 10. Water Surface Stages, Connoisarauley Creek

Location: Gage at left bank tied to bridge Wingwall about 0.4 miles upstream of Cattaraugas Creek

Datum: Top of gage = 100.0 ft. (arbitrary)

Date	Time	Stage	Remarks
4/26/79	0745	96.92	
	1102	96.92	
	1438	96.92	
	2020	96.92	Light rain
	2203	96.92	Light rain
	2325	96.92	Light rain
4/27/79	0140	96.92	
	0305	97.00	
	0435	96.96	Light rain
	0610	97.00	
	0748	97.04	
	0952	97.04	
	1108	97.13	
	1420	97.08	
	1626	97.08	
	1750	97.08	
	2137	97.04	
	2320	97.04	
4/28/79	0141	97.00	
	0335	97.00	
	0506	97.00	
	0745	97.00	
	0930	97.00	
	1110	97.00	
	1440	97.00	
	1750	96.96	Light rain
	2150	96.96	
	2310	96.96	
4/29/79	0100	97.00	
	0245	97.00	
	0444	96.96	
	0655	96.96	

TABLE 11. Water Surface Stages, Spooner Creek

Location: Gage at left bank under Zoar Valley Road Bridge
0.5 miles upstream of Cattaraugas Creek

Datum: Top of gage = 100.0 ft. (arbitrary)

Date	Time	Stage	Remarks
4/26/79	0730	97.21	Wind 5-10 mph (est.)
	1053	97.21	Wind 0-5 mph (est.)
	1415	97.21	Wind 5-10 mph (est.)
	2000	97.17	Light rain
	2150	97.17	Light rain
	2335	97.21	Light rain
4/27/79	0125	97.21	
	0255	97.21	Light rain
	0440	97.21	Light rain
	0620	97.25	
	0755	97.29	
	0940	97.29	Light rain
	1056	97.25	
	1400	97.29	
	1615	97.25	
	1740	97.25	
	2120	97.25	
	2300	97.29	
4/28/79	0100	97.33	
	0320	97.29	
	0455	97.29	
	0730	97.25	
	0915	97.25	
	1105	97.25	
	1330	97.25	
	1730	97.21	Light rain
	2145	97.21	
	2250	97.25	
4/29/79	0050	97.29	
	0230	97.29	
	0430	97.29	
	0646	97.25	

TABLE 12. Water Surface Stages, Spring Brook

Location: Gage at center of channel about 1000 ft upstream of Cattaraugas Creek

Datum: Top of gage = 100.0 ft. (arbitrary)

Date	Time	Stage	Remarks
4/26/79	0833	97.67	
	1142	97.67	
	1525	97.67	
	2100	97.62	Light rain
	2240	97.62	Light rain
4/27/79	0055	97.62	
	0215	97.67	
	0355	97.62	Light rain
	0520	97.67	Light rain
	0655	97.71	Light rain
	0820	97.71	
	1028	97.71	
	1215	97.75	
	1515	97.75	
	1704	97.71	
	2050	97.71	
	2215	97.71	
	2359	97.71	
4/28/79	0230	97.67	
	0425	97.67	
	0540	97.67	
	0815	97.67	
	1003	97.67	
	1145	97.67	
	1410	97.61	
	1830	96.67	Light rain
	2225	96.67	
	2340	97.61	
4/29/79	0135	97.67	
	0325	97.61	
	0515	97.67	
	0730	96.57	

TABLE 13. Water Surface Stages, Franks Creek

Location: Gage at left wall of railroad culvert barrel about 150 ft upstream of Buttermilk Creek at sampling station FC-1.

Datum: Top of gage = 100.0 ft. (arbitrary)

Date	Time	Stage	Remarks
4/26/79	0940	97.33	wind 5-10 mph (est.)
	1035	97.33	
	1135	97.33	
	1230	97.33	
	1330	97.33	
	1430	97.33	
	1500	97.33	
	1730	97.33	
	1830	97.33	
	1930	97.33	
	2030	97.33	Light rain
	2130	97.37	
	2230	97.33	Heavy rain
	2330	97.37	Rain stopped
4/27/79	0030	97.33	
	1030	97.33	
	0230	97.37	
	0330	97.33	
	0350	97.33	Light rain
	0410	97.33	Rain stopped
	0430	97.33	Light rain
	0500	97.33	Light rain
	0530	97.37	Light rain
	0600	97.37	Light rain
	0630	97.42	Steady rain increased sediment load
	0945	97.46	
	1100	97.46	
	1200	97.50	
	1300	97.50	
	1400	97.50	
	1505	97.50	
	1605	97.50	
	1707	97.50	
	1800	97.50	
	1900	97.46	
	1953	97.45	

TABLE 13. Continued

Date	Time	Stage	Remarks
4/27/79	2110	97.46	
	2200	97.46	
	2300	97.42	
4/28/79	0000	97.42	
	0100	97.42	
	0200	97.42	
	0300	97.42	
	0400	97.42	
	0500	97.37	
	0600	97.37	
	0700	97.37	
	0827	97.37	Warm and sunny Light breeze
	0920	97.37	
	1035	97.37	
	1125	97.37	
	1225	97.37	Cloudy
	1325	97.37	
	1425	97.37	
	1530	97.37	
	1630	97.37	Intermittant rain
	1730	97.42	Steady light rain
	1830	97.42	Raining
	1930	97.42	Rain stopped
	2030	97.42	
	2130	97.42	
	2230	97.42	Cloud cover breaking up
	2330	97.42	
4/29/79	0030	97.42	
	0130	97.42	
	0200	97.42	
	0330	97.42	
	0600	97.42	

TABLE 14. Water Surface Stages, Buttermilk Creek

Location: Gage at left bank about 150 ft upstream of Franks Creek and about 12,500 ft upstream of Cattaraugas Creek at station BC-1A.

Datum: Top of gage = 100.0 ft. (arbitrary)

Date	Time	Stage	Remarks
4/26/79	0930	95.71	
	1030	95.71	
	1100	95.71	
	1140	95.71	
	1205	95.71	
	1230	95.71	
	1300	95.71	
	1330	95.71	
	1400	95.71	
	1430	95.71	
	1500	95.71	
	1530	95.71	
	1600	95.71	
	1730	95.71	
	1830	95.71	
	1930	95.71	
	2030	95.71	Light rain
	2130	95.71	Intermittent rain
	2230	95.71	Heavy rain
	2330	95.71	Rain stopped
4/27/79	0030	95.71	
	0130	95.71	
	0230	95.71	
	0330	95.71	
	0350	no reading	Light rain
	0410	no reading	Rain stopped
	0430	95.75	Light rain
	0500	95.75	Light rain
	0530	95.75	Light rain
	0600	95.75	Light rain
	0630	95.75	Very light rain
	0945	95.92	Steady rain increased sediment load
	1100	95.92	
	1200	96.00	
	1300	96.00	
	1400	96.04	
	1505	96.04	
4/27/79	1600	96.04	
	1705	96.00	

TABLE 14. Continued

Date	Time	Stage	Remarks
	1730	96.42	
	1737	96.50	
	1739	96.54	
	1741	96.58	
	1745	96.58	
	1758	96.50	
	1815	96.54	
	1830	96.54	
	1855	96.54	
	1917	96.54	
	1934	96.54	
	1955	96.04	
	2020	95.96	
	2110	95.87	
	2130	95.87	
	2200	95.87	
	2300	95.87	
4/28/79	0000	95.83	
	0100	95.83	
	0200	95.79	
	0300	95.79	
	0400	95.79	
	0500	95.79	
	0600	95.79	
	0700	95.79	
	0830	95.79	
	0925	95.79	
	1030	95.79	
	1128	95.79	
	1230	95.79	
	1330	95.79	Cloudy
	1430	95.79	
	1540	95.79	
	1630	95.79	Intermittent rain
	1730	95.79	Steady light rain
	1830	95.79	Rain continuing
	1930	95.79	Rain stopped
	2030	95.79	
	2130	95.79	
	2230	95.79	Cloud cover breaking up
	2330	95.79	
4/29/79	0030	95.79	
	0130	95.79	
	0200	95.79	
	0330	95.79	
	0602	95.79	

TABLE 15. Water Surface Stages, Cattaraugas Creek at Scobey Bridge

Location: Gage at right bank about 500 ft downstream of Scobey Hill Road Bridge 36.15 miles upstream of Lake Erie

Datum: Top of gage = 100.0 ft. (arbitrary)

Date	Time	Stage	Remarks
4/26/79	0812	94.83	
	1126	94.83	
	1510	94.83	
	2045	94.83	
	2225	94.83	
4/27/79	0020	94.83	
	0155	94.83	
	0320	94.83	
	0505	94.87	Light rain
	0635	94.87	Light rain
	0816	94.92	
	1014	94.96	
	1201	95.04	Raining
	1500	95.21	
	1645	95.17	
	2150	95.21	
	2325	95.17	
4/28/79	0215	95.17	
	0415	94.17	
	0530	95.17	
	0755	95.12	
	0945	95.12	
	1130	95.08	
	1335	95.04	
	1815	95.00	Light rain
	2205	94.96	
	2320	94.92	
4/29/79	0125	94.96	
	0310	94.92	
	0506	94.96	
	0715	94.96	

TABLE 16. Water Surface Stages. Springville Dam - Cattaraugas Creek

Location: Gage attached to steel ladder in forebay of power plant 36.4 miles upstream of Lake Erie near sampling station CC-5.

Datum: Top of gage = 0.0 ft. (level with spillway crest)

Date	Time	Stage	Remarks
4/26/69	0800	0.25	
	1117	0.25	
	1456	0.25	
	2040	0.25	Light rain
	2218	0.25	Light rain
4/27/79	0035	0.25	Light rain
	0330	0.21	
	0515	0.25	Light rain
	0640	0.33	Light rain
	0822	0.38	
	1005	0.29	
	1153	0.38	
	1445	0.50	
	1655	0.50	
	1845	0.50	
	2200	0.54	
	2335	0.50	
4/28/79	0155	0.58	
	0405	0.58	
	0525	0.54	
	0805	0.42	
	0905	0.42	
	1133	0.42	
	1402	0.42	
	1800	0.33	Light rain
	2215	0.38	
	2325	0.33	
4/29/79	D120	0.33	
	0300	0.33	
	0459	0.33	
	0715	0.21	

TABLE 17. Water Surface Stages, Cattaraugas Creek at Bigelow Bridge

Location: Gage at right bank under bridge 41.3 miles upstream of Lake Erie at sampling station CC-1.

Datum: Top of gage = 100.0 ft. (arbitrary)

Date	Time	Stage	Remarks
4/26/69	0845	95.79	
	1150	95.79	
	1538	95.79	
	2125	95.79	Light rain
	2252	95.79	Light rain
4/27/79	0105	95.79	
	0225	95.79	
	0405	95.83	Light rain
	0530	95.83	Light rain
	0700	95.83	Light rain
	0835	95.87	
	1040	95.92	Light rain
	1223	95.96	
	1530	96.04	
	1710	96.04	
	2100	96.08	
	2227	96.12	
4/28/79	0015	96.12	
	0250	96.08	
	0437	96.04	
	0550	96.04	
	0825	96.00	
	1010	96.00	
	1200	95.96	
	1420	96.96	
	1845	95.87	Light rain
	2235	95.92	
	2250	95.92	
4/29/79	0200	95.96	
	0335	95.87	
	0523	95.87	
	0740	95.87	

TABLE 18. Suspended Sediment Samples

(Wash Load Only)

Location	Sample No.	Date	Time	Stage	Concentration (mg/ℓ)
Franks Creek (FC-1)	1	4-26	1635	97.33	60.0
	2	4-27	1100	97.46	238.0
	3	4-28	0920	97.37	88.3
	4	4-28	1425	97.37	84.0
	5	4-29	0556	97.42	128.2
Buttermilk Creek (BC-1A)	1	4-26	1637	95.71	3.7
	2	4-27	1100	95.92	31.4
	3	4-28	0925	95.79	8.3
	4	4-28	1430	95.79	1.4
	5	4-29	0559	95.79	8.4
Cattaraugas Creek at Bigelow Bridge (CC-1)	1	4-26	1538	95.79	4.05
	2	4-27	1530	76.04	28.0
	3	4-28	0250	96.08	49.8
	4	4-28	1845	95.87	27.2
	5	4-29	0035	95.87	3.8
Cataraugas Creek at Scobey Bridge	1	4-26	1510	94.83	13.7
	2	4-27	1500	95.31	37.9
	3	4-28	0215	95.17	39.6
	4	4-28	1815	95.00	15.6
	5	4-29	0310	94.92	4.4
Cattaraugas Creek at Frye Bridge	1	4-26	1428	94.83	3.2
	2	4-27	1410	95.04	17.6
	3	4-28	0135	95.17	44.8
	4	4-28	1745	94.96	24.3
	5	4-29	0240	94.92	4.2

TABLE 18. Continued

Location	Sample No.	Date	Time	Stage	Concentration (mg/ℓ)
Spring Brook	1	4-26	1525	94.67	127.2
	2	4-27	1515	97.75	199.8
	3	4-28	0230	97.67	212.1
	4	4-28	1820	97.67	191.8
	5	4-29	0325	97.61	132.4
Spooner Creek	1	4-26	1415	97.21	28.2
	2	4-27	1400	97.29	11.4
	3	4-28	0100	97.33	31.4
	4	4-28	1730	97.21	5.2
	5	4-29	0230	97.29	(a)

(a) sample container damaged in shipment

TABLE 19. Data Summary

GAGE LOCATION	STAGE	VELOCITY	CROSS SECTION	WATER SURFACE SLOPE	SUSPENDED SEDIMENT	CHANNEL BED SEDIMENT	REMARKS
FRANKS CREEK	●	●	●		●	●	INFLOW
BUTTERMILK CREEK	●	●	●	●	●	●	INFLOW
THOMAS CORNERS BRIDGE	● (1)						INTERMEDIATE GAGE BUTTERMILK CREEK
BIGELOW BRIDGE	●	●	●	●	●	●	INFLOW
SPRINGVILLE DAM	● (2)						CONTROL SECTION AND RESERVOIR
SCOBEY BRIDGE	●	●	●	●	●	●	INTERMEDIATE GAGE DOWNSTREAM OF DAM
FRYE BRIDGE	●	●	●	●	●	●	OUTFLOW
SPRING BROOK	●	●	●	●	●	●	INFLOW
SPOONER CREEK	●	●	●	●	●	●	INFLOW
CONNOISARAULEY CREEK	●	●	●	●			INFLOW-AUXILIARY GAGE (3)
SOUTH BRANCH CATTARAUGAS CREEK	●	●	●	●			INFLOW-AUXILIARY GAGE (3)

1. NEW YORK STATE GEOLOGICAL SURVEY AUTOMATIC STAGE RECORDER.
2. DEPTH OF FLOW OVER SPILLWAY.
3. AUXILIARY GAGES TO MONITOR FLOW FROM TYPICAL LARGE TRIBUTARY BASINS.

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This report describes FY-1979 analysis results on flow, sediment and radionuclide data collected in Cattaraugus, Buttermilk and Franks Creek, New York. The objective of this study is to investigate the radionuclide transport in these streams as part of a continuing program to provide data required for application and verification of the Sediment and Radionuclide Transport Model (SERATRA). Radiological analyses were performed on sand, silt and clay size fractions of suspended and bed sediment, as well as for dissolved radionuclides.

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