Nevada
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Project

DOE/NV--624

Amchitka Island, Alaska
Special Sampling Project 1997

June 2000


Environmental Restoration
Division

U.S. Department of Energy
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AMCHITKA ISLAND, ALASKA SPECIAL SAMPLING PROJECT 1997

DOE Nevada Operations Office
Las Vegas, Nevada

July 2000

AMCHITKA ISLAND, ALASKA
SPECIAL SAMPLING PROJECT
1997

Submitted by: Signature Approved — 6/28/2000

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List of Acronyms and Abbreviations

A/PIA	Aleutian/Pribilof Islands Association
ADEC	Alaska Department of Environmental Conservation
AEC	U.S. Atomic Energy Commission
^{241}Am	Americium-241
^{243}Am	Americium-243
ATAG	Amchitka Technical Advisory Group
BKG	Background reference area sample transects
^{7}Be	Beryllium-7
°C	Degree(s) celsius
cm	Centimeter(s)
cm/yr	Centimeter(s) per year
CN	Cannikin sample transects
^{137}Cs	Cesium-137
DOE/NV	U.S. Department of Energy, Nevada Operations Office
DQO	Data Quality Objective(s)
EML	U.S. Department of Energy, Environmental Measurements Laboratory
EPA-R&IE	U.S. Environmental Protection Agency, Radiation and Indoor Environments National Laboratory
°F	Degree(s) Fahrenheit
fCi/g	Femtocurie(s)(10^{-15} Ci) per gram
ft	Foot (feet)
ft^2	Square foot (feet)
g	Gram(s)
gal	Gallon(s)
HERS, Inc.	Hanson Environmental Research Services, Inc.
in	Inch(es)
^{40}K	Potassium-40
keV	Kilo electron volts
kg	Kilogram(s)
km	Kilometer(s)
L	Liter(s)
LANL	Los Alamos National Laboratory
lb	Pound(s)

List of Acronyms and Abbreviations *(Continued)*

LS	Long Shot sample transects
LTHMP	Long-Term Hydrologic Monitoring Program
m	Meter(s)
m^2	Square meter(s)
MDA	Minimum Detectable Activity
MDC	Minimum Detectable Concentration
MeV	Million electron volt(s)
mi	Mile(s)
MR	Milrow sample transect(s)
mm	Millimeter(s)
μm	Micrometer(s)
μR	Microroentgen(s)
NaI	Sodium iodide
NIST	National Institute of Standards and Technology
oz	Ounce(s)
pCi/g	Picocurie(s)(10^{-12}Ci) per gram
pCi/L	Picocurie(s) per liter
ppm	Part(s) per million
^{238}Pu	Plutonium-238
^{239}Pu	Plutonium-239
$^{239+240}$Pu	Plutonium-239 and -240
^{242}Pu	Plutonium-242
SAP	Sampling and Analysis Plan
SD	Standard Deviation
SE	Standard Error
SGZ	Surface ground zero
SOP	Standard Operating Procedure(s)
SRM	Standard Reference Material
T_{eff}	Effective half-time
TIMS	Thermal ionization mass spectroscopy
wt	Weight

1.0 Introduction

1.1 Scope

In late 1996, the Long-Term Hydrological Monitoring Program (LTHMP) for Amchitka Island, Alaska, was expanded to include radiobiological sampling and analyses. This sampling event was implemented in early June 1997. The LTHMP sampling and the additional radiobiological sampling was performed by the U.S. Environmental Protection Agency Radiation and Indoor Environments National Laboratory (EPA-R&IE) through an interagency agreement with the U.S. Department of Energy, Nevada Operations Office (DOE/NV). Personnel from the Alaska Department of Environmental Conservation (ADEC); Aleutian/Pribilof Islands Association (A/PIA); Hanson Environmental Research Services, Inc. (HERS, Inc.); and Nuclear Military Monitoring (Greenpeace) also participated in the field sampling activities.

Amchitka Island lies in the western portion of the Aleutian Islands arc, near the International Date Line, and is one of the southernmost islands of the Rat Island Chain (Figure 1-1). Three underground nuclear tests were conducted on Amchitka Island between 1965 and 1971 (Projects Long Shot, Milrow, and Cannikin). Because of the use of Amchitka Island by the U.S. Atomic Energy Commission (AEC) as an underground nuclear test site and its designation as part of the Alaska Maritime National Wildlife Refuge, there has been sustained interest in the radioecology of the island.

Based on the results of a survey of selected aquatic biota on the island by Greenpeace in 1996, Greenpeace speculated that several long-lived man-made radionuclides were leaking into the surface environment from nuclear blast cavities several thousand feet below the surface of the island (Greenpeace, 1996). The radionuclides of interest identified by Greenpeace were primarily americium-241 (^{241}Am) and plutonium-239 and -240 ($^{239+240}$Pu). Subsequent to the issuance of their 1996 report, Greenpeace stated that ^{241}Am is the primary indicator of leakage from the cavity (Greenpeace, 1998).

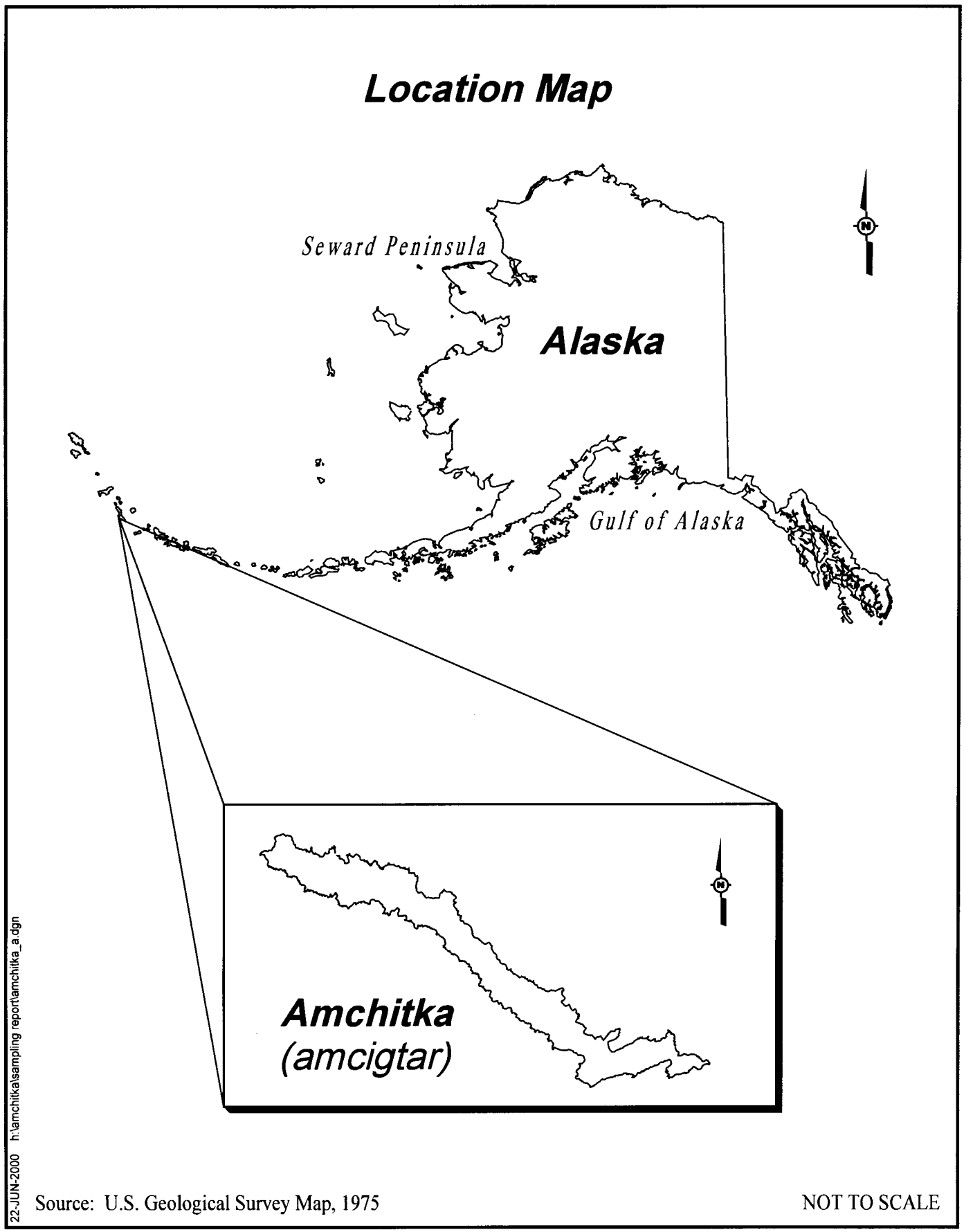


Figure 1-1
Location Map

The nuclides of interest as identified by Greenpeace, primarily beryllium-7 (^{7}Be), cesium-137 (^{137}Cs), $^{239+240}$Pu, and ^{241}Am, are also detectable throughout the environment as a result of worldwide fallout (Hanson, 1980).

In light of this, EPA-R&IE's routine surveillance of ground and surface waters under the LTHMP was expanded for 1997 to include selected sampling of aquatic biota and sediments based on decisions of the Amchitka Technical Advisory Group (ATAG). The additional samples were collected from streams, lakes, seeps, and marine tidal areas within the surface drainage basins surrounding surface ground zero (SGZ) at each of the three test sites. Aquatic plants and sediments from a geographically similar reference area in the central part of the island were also collected. Lichens were sampled at one location on Amchitka Island and on Adak Island (about 300 km [188 miles (mi)] ESE of Amchitka) to provide data on worldwide fallout deposition on surface environments.

1.2 Objectives

The extended radiobiological sampling program was developed from the Data Quality Objectives (DQO) meeting held in Anchorage, Alaska, with the stakeholders on February 4 and 5, 1997. The broad objectives of the sampling event were to collect and document radiological data concerning the possible presence and distribution of man-made radionuclides in the Amchitka Island environment, and to "note" sample locations for future study where the measured values of man-made radionuclides appeared to be inconsistent with worldwide fallout. With the exception of low levels (11 - 20 picocuries per liter [pCi/L]) of tritium (^{3}H) near the Long Shot Site SGZ, man-made radionuclides that can be attributed to the test cavities on the island have not been detected in the surface or near-surface environment of Amchitka Island. The tritium present in water samples from the Long Shot Site is attributed to contamination that occurred immediately following the Long Shot test in 1965 (EPA, 1996).

Although the special sampling plan was limited in scope because of time and logistic constraints, it was designed to answer two basic (ATAG) questions. First, what man-made radionuclides are detectable in the Amchitka Island surface environment? And second, is it possible to determine whether the source of any contaminants is worldwide fallout or a result of "leakage" from the underground nuclear detonation cavities? These questions were investigated by using the sampling and analysis methods as described in the *Amchitka, Alaska Special Sampling Project 1997 Sampling and Analysis Plan* (SAP) (EPA, 1997a), for the low-level determination of radionuclides in the environment and the collection of certain indicator species, particularly

freshwater mosses and algae, along with sediments directly associated with the biota samples. Lichen samples also were collected from Amchitka and Adak Islands to provide radionuclide concentration data that can be compared to data from other North American locations, particularly with respect to inputs from Chernobyl (Baskaran et al., 1991). Hydrological sampling was continued in similar format as in previous years to provide historical continuity and trend analysis.

The SAP was also designed to allow a basic statistical comparison of the analytical results between the reference area and the three sites, and between areas hydrologically upgradient of the SGZs and those downgradient. Additionally, a subset of the samples was collected and submitted to the Los Alamos National Laboratory (LANL) for "fingerprint" analysis of the $^{240}Pu/^{239}Pu$ ratio by thermal ionization mass spectroscopy (TIMS). The TIMS procedure is capable of measuring $^{240}Pu/^{239}Pu$ atom ratio to 0.07 percent precision and accuracy at the 95 percent confidence interval. Additional information on the LANL TIMS can be found in Perrin et al. (1985). Together this information will allow a first approximation of the radionuclide inventory, if present, in the media sampled and should also provide information concerning the most likely source of the radionuclides.

2.0 Sample Collection

2.1 Sample Location Selection

Sample locations were consistent with those proposed in the SAP as amended and approved by the ATAG at its April 21-22, 1997, meeting in Anchorage, with the proviso that field conditions on Amchitka Island would require consensus judgments in cases where adjustments to the SAP were indicated.

Transects of varying stream lengths were designated on stream courses in four drainages: three associated with the underground nuclear tests (Project Long Shot in October 1965, Project Milrow in October 1969, and Project Cannikin in November 1971) and a reference area located about 8 kilometers (km) (5 miles [mi]) northwest of the Cannikin ground zero (GZ). Transect length depended upon available biomass (about 3 kilograms [kg] [6.6 pounds {lb} weight]) required for radionuclide analyses of aquatic mosses, especially *Fontinalis neomexicanus* selected as the preferred sample type for consistency.

Four sample locations were designated within each transect: (A) at the key hydrological feature, such as an identified seep or confluence of a drainage from a GZ location; (B) a suitable stream section located contiguous with and upstream of the A location; and C and D, similar locations downstream of the A sampling point, and providing duplicate downstream samples.

Marine transects were established at the outfalls of White Alice Creek (CN-4) below Cannikin GZ; Clevenger Creek (MR-4) below Milrow GZ; and at the mouth of the unidentified creek (BKG-2) agreed upon as the background stream. Three sample locations were designated at each of these: A, seaward of the outfall of the stream; and B, C, and D at suitable locations about 200-500 meters (m) on either side of the A location where the presence of the alga *Enteromorpha* and salinity measurements suggested the presence of freshwater seeps. A marine transect was not established below the Long Shot GZ because of no suitably defined drainage to the marine areas.

Sediment samples were collected within each sample location, and suspended fine material removed during washing of samples was captured by filtering washwater through sieves. Sediment samples in marine transects (CN-4, MR-4, and BKG-2) were collected above the high tide surge away from the coastal setting, as specified in the SAP.

Additional details concerning sampling location selection for each of the four areas are discussed below.

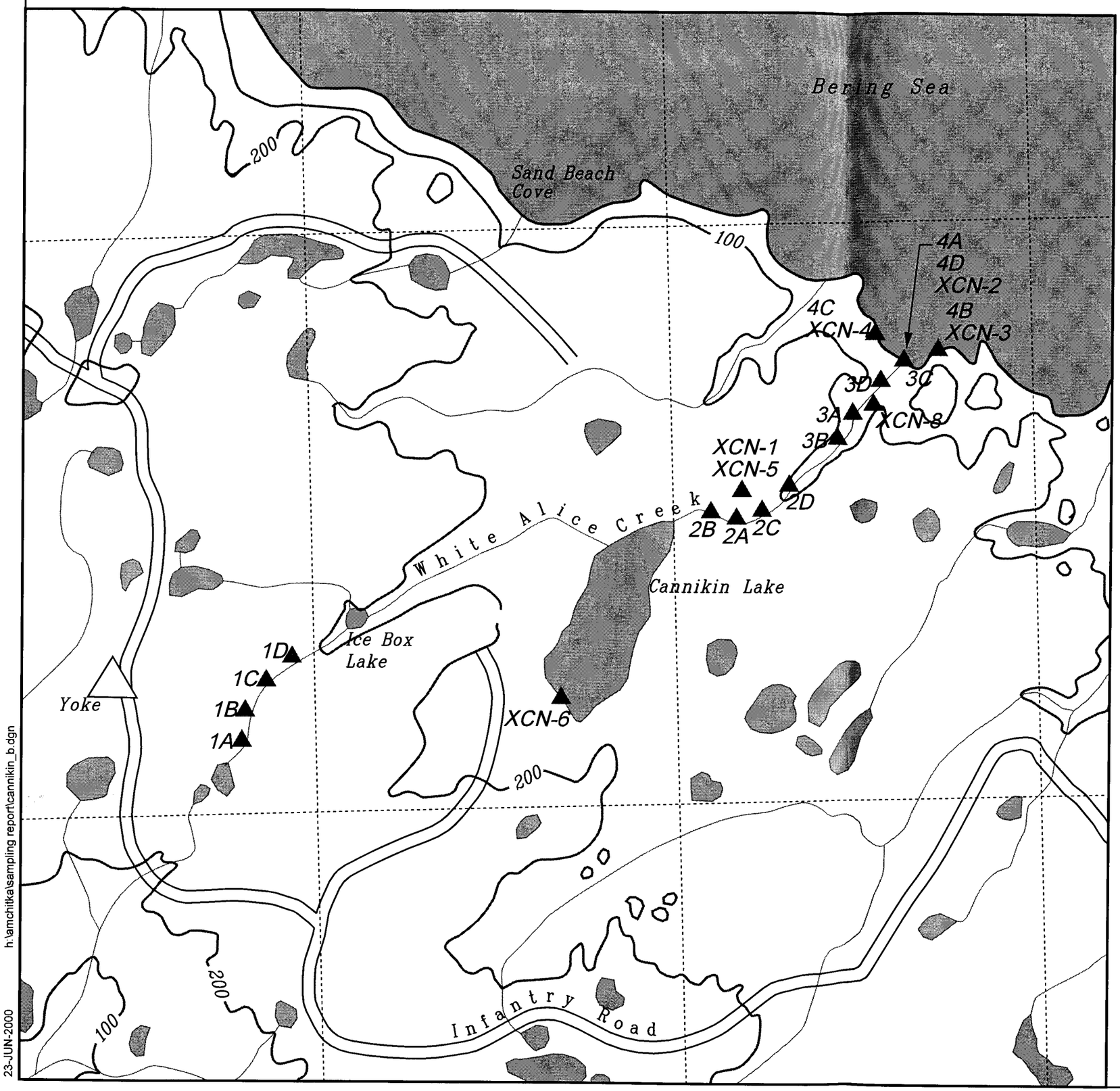
2.1.1 Cannikin

The White Alice Creek drainage of the Cannikin site was divided into four transect sampling zones: CN-1, the area above GZ on the North Fork of White Alice Creek; CN-2, the upper reach of White Alice Creek below Cannikin Lake; CN-3, the lower one-third of White Alice Creek below Cannikin Lake, including White Alice Falls; and CN-4, a marine transect centered on the outflow of White Alice Creek into the Bering Sea (Figure 2-1).

Transect CN-1 encompassed a narrow, deep drainage about 0.5 m wide eroded into peat and bordered by dense stands of sedge (*Carex lyngbyaei),* characteristic of many of the streams in the study area. The primary sample type (*Fontinalis neomexicanus)* was abundant. No hydraulic feature, such as a seep or tributary, was identified within the transect; therefore, sampling locations CN-1A, -1B, -1C, and -1D were established about midway between North Fork of White Alice Creek and Ice Box Lake.

Transect CN-2 was physically similar to CN-1, but was of lower water velocity and deep silt bottom, particularly in the upper portion just below the outlet of Cannikin Lake; hence, *Fontinalis* occurred in isolated patches and often with significant amounts of filamentous algae attached, which was removed during the cleaning process. It also included the location of Greenpeace 1996 sample #11, located in a backwater or oxbow of the main stream. Two different species of freshwater mosses were collected by Greenpeace at these sites (XCN-1 and XCN-5) and were designated by the Greenpeace representative as "individual samples."

Transect CN-3 was located in an area of increasing gradient and streamflow, with a series of small rapids and rocky streambed, terminating in White Alice Falls and tailrace to the Bering Sea. Location CN-3A was sited at a seep above White Alice Falls, as indicated by a 2.8 degrees celsius (°C) lower water temperature difference in the seep inflow compared with the mainstream. Seeps were suspected as possible leakage sites of underground waters containing radionuclides from the nuclear test cavity, as evidenced by lower water temperatures compared to the main stream. Location CN-3B was above the seep, CN-3D was below the seep, and CN-3C was below White Alice Falls in the outlet to the Bering Sea. The Falls was the area from



Location Map

Explanation

1A▲ Sample Location

Surface Ground Zero

Note

Grid Coordinates in Latitude/Longitude

Scale

0 250 500 Meters

0 1,000 2,000 Feet

Source: U.S. Geological Survey Map, 1975 (Modified)

h:\amchitka\sampling report\cannikin_b.dgn

23-JUN-2000

Figure 2-1
Cannikin Sample Locations

which Greenpeace #12 (1996) and XCN-8 (1997) were collected; -3C and -3D contained a mixture of *Fontinalis neomexicanus, Hygrohypnum bestii,* and *Brachythecium asperrimum* in order to obtain sufficient biomass.

Transect CN-4 was located on the rocky intertidal area of the Bering Sea at the mouth of White Alice Creek, where abundant marine algae of several species, particularly *Fucus distichus,* the targeted species, and *Enteromorpha intestinalis* provided ample samples. The latter species were "individual samples" designated by the Greenpeace representative XCN-2, -3, and -4. Seawater characteristics were variable due to inflows of freshwater at sampling locations.

2.1.2 Milrow

Low stream flows in the Clevenger Creek area required adjustment of Milrow transects (Figure 2-2) for effective study. Accordingly, consensus of the field party was reached in the following modifications to the SAP as agreed at the ATAG planning meeting in Anchorage on February 4 and 5, 1997:

A. Transect MR-1 was eliminated due to insufficient flow from Tent Lake.

B. Transect MR-2 was established on the drainage from Heart Lake and an unnamed group of lakes and ponds located southeast of Milrow GZ. Sampling location MR-2A was sited at the confluence of that drainage and Heart Lake effluent to form Clevenger Creek; sample location MR-2B above (east of) -2A; -2C and -2D were downstream of the confluence.

C. The MR-3 sampling transect was adjusted to include drainage from the ponds and lakes located downgradient of Heart Lake. Sampling location MR-3A was at the confluence of the drainage originating from the ponds and lakes and flowing southwest to Clevenger Creek; MR-3B was located above the confluence, and MR-3C and -3D were below.

2.1.3 Long Shot

As noted in the SAP, there is no clearly defined surface discharge from the Long Shot GZ, and therefore some improvisation was necessary in designation of transects (Figure 2-3). The rationale for the improvisations are clearly documented in the EPA sampling log.

Location Map

Explanation

2A▲ Sample Location

Milrow

Surface Ground Zero

Note

Grid Coordinates in Latitude/Longitude

Scale

0 250 500 Meters

0 1,000 2,000 Feet

Source: U.S. Geological Survey Map, 1975 (Modified)

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Figure 2-2
Milrow Sample Locations

650,000 m
179°10'00"
179°11'00"
179°12'00"
51°27'00"
51°26'00"
5,700,000 m
Square Bay
Round Lake
Bridge Creek
100
Infantry Road
Long Shot Pond
Long Shot Lake
1A
1B
1C
1D
Long Shot
XLS-1
2A
2B
2C
2D
Quonset Lake
Weed Lake
Clam Lake
Bill
h:\amchitka\sampling report\longshot_b.dgn
23-JUN-2000

Location Map

Explanation

1A ▲ Sample Location

Long Shot

Surface Ground Zero

Note

Grid Coordinates in Latitude/Longitude

Scale

0 250 500 Meters

0 1,000 2,000 Feet

Source: U.S. Geological Survey Map, 1975 (Modified)

Figure 2-3
Long Shot Sample Locations

In accordance with the SAP and ATAG guidelines, transect LS-1 consisted of the mud pits adjacent to Long Shot GZ, and sample sites LS-1A, -1B, -1C, and -1D were the individual mud pits, although both -1A and -1B were collected in the westernmost pit, labeled #3 in the SAP.

Transect LS-2 was established on the drainage from a lake to the southwest and downgradient of the Long Shot GZ, and south of the Greenpeace 1996 sample location #3. Sample LS-2A was collected at a poorly defined junction of the GP#3 and nearby small seeps (termed "soligenous bogs" by previous investigators, see Shacklette et al., 1969), with sample locations LS2-B above and LS2-C and -D downstream of that location and downstream (east) of the culvert under the Infantry Road.

2.1.4 Background Area

Selection of the Background Area was changed from either the Milepost 12 Creek or Ultra Creek (Option #2 and Option #3, respectively, in the SAP) locations to the unnamed creek that originates near Mile 16.6 on Infantry Road and discharges to the Pacific Ocean about 2 km southwest of Drillsite D. This satisfied the ATAG Option #1 for a location northwest of the Teal Creek Fault, as indicated by Gard (1977) (Figure 2-4).

Since there was no significant hydraulic feature (seep or influent stream) on the selected reach of stream, location BKG-1D was sited just below a small falls in the stream, and -1C, 1B, and 1A were established in that order upstream (Figure 2-4).

Transect BKG-2 was situated on the intertidal area centered on the outflow of the unnamed background creek, with locations BKG-2A and -2C near the outflow and -2B and -2D located west and east of the outflow, respectively.

2.2 Sample Collection

Temperature, pH, and conductivity measurements were taken at each sampling location prior to sample collection (Table 2-1) following procedures described in the LTHMP Standard Operating Procedure (SOP) 4.01 (EPA, 1996). Also, background radiation at the ground surface and one meter above the surface on the stream bank was measured with a handheld Ludlum microroentgen (µR) meter; no anomalous readings were observed at any one location. Measurements at the ground surface were usually one µR greater than at one meter above the surface; all values were within a range of 2-6 µR per hour.

179°00'00"

179°01'00" 640,000 m

179°02'00"

5,710,000 m

51°31'00"

51°30'00"

Limpet Creek

Infantry Road

200

Site D

1A

1B

1C

1D

2D

2A

2B

2C

100

200

300

Falls Creek
(ciranarsgat)

Pacific Ocean

Location Map

Amchitka Island

Explanation

1A▲ Sample Location

Site D

Drill Site

Note

Grid Coordinates in Latitude/Longitude

Scale

0 250 500 Meters

0 1,000 2,000 Feet

Source: U.S. Geological Survey Map, 1975 (Modified)

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Figure 2-4
Reference Stream Sample Locations

Table 2-1
Amchitka Island Special Sampling Project
Sample Types and Environmental Measurements
(Page 1 of 3)

Sample	Sample Type (Species)	Temperature °C[a] (°F[b])	Conductivity ppm[c]	pH
Cannikin				
CN-1A	*Fontinalis neomexicanus*	10.5 (50.9)	120	8.01
CN-1B	*Fontinalis neomexicanus*	10.0 (50.0)	120	7.94
CN-1C	*Fontinalis neomexicanus*	8.8 (47.8)	120	7.83
CN-1D	*Fontinalis neomexicanus*	8.8 (47.8)	110	7.71
CN-2A	*Fontinalis neomexicanus*	9.9 (49.8)	310	8.23
CN-2B	*Fontinalis neomexicanus*	10.1 (50.2)	300	8.26
CN-2C	*Fontinalis neomexicanus*	9.8 (49.6)	290	8.26
CN-2D	*Fontinalis neomexicanus*	9.0 (48.2)	290	7.82
CN-3A	*Fontinalis neomexicanus*	11.4 (52.5)	210	8.40
CN-3B	*Fontinalis neomexicanus*	11.5 (52.7)	200	8.36
CN-3C	*Fontinalis neomexicanus/Hygrohypnum bestii/Brachythecium asperrimum*	8.6 (47.5)	200	7.94
CN-3D	*Fontinalis neomexicanus/Hygrohypnum bestii/Brachythecium asperrimum*	11.6 (52.9)	220	8.27
CN-4A	*Fucus distichus*	NA[d]	NA	NA
CN-4B	*Fucus distichus*	NA	NA	NA
CN-4C	*Fucus distichus*	NA	NA	NA
CN-4D	*Fucus distichus*	NA	NA	NA
XCN-1	*Fontinalis neomexicanus*	8.0 (46.4)	110	6.83
XCN-2	*Enteromorpha intestinalis*	NA	NA	NA
XCN-3	*Enteromorpha intestinalis*	NA	NA	NA
XCN-4	*Enteromorpha intestinalis*	NA	NA	NA
XCN-5	*Brachythecium sp.*	8.9 (48.0)	90	6.92
XCN-6	*Sphagnum squarrosum*	11.5 (52.7)	300	8.16
XCN-8	*Hygrohypnum bestii/ Brachythecium asperrimum*	8.6 (47.5)	190	8.15

Table 2-1
Amchitka Island Special Sampling Project
Sample Types and Environmental Measurements
(Page 2 of 3)

Sample	Sample Type (Species)	Temperature	Conductivity	pH
		°C[a] (°F[b])	ppm[c]	
Milrow				
MR-2A	*Fontinalis neomexicanus*	6.7 (44.1)	270	8.19
MR-2B	*Fontinalis neomexicanus*	7.4 (45.3)	140	7.83
MR-2C	*Fontinalis neomexicanus*	6.6 (43.9)	270	8.12
MR-2D	*Fontinalis neomexicanus*	6.8 (44.2)	270	8.11
MR-3A	*Fontinalis neomexicanus*	6.2 (43.2)	270	7.99
MR-3B	*Fontinalis neomexicanus*	6.9 (44.4)	280	7.91
MR-3C	*Fontinalis neomexicanus*	6.9 (44.4)	270	7.92
MR-3D	*Fontinalis neomexicanus*	6.9 (44.4)	260	7.97
MR-4A	*Fucus distichus*	NA	NA	NA
MR-4B	*Fucus distichus*	NA	NA	NA
MR-4C	*Fucus distichus*	NA	NA	NA
MR-4D	*Fucus distichus*	NA	NA	NA
Long Shot				
LS-1A	*Drepanocladus sp.*	8.6 (47.5)	150	8.07
LS-1B	*Drepanocladus sp.*	8.7 (47.7)	150	7.73
LS-1C	*Drepanocladus sp.*	8.4 (47.1)	150	8.22
LS-1D	*Drepanocladus sp.*	9.0 (48.2)	150	8.20
LS-2A	*Fontinalis neomexicanus*	8.9 (48.0)	90	7.13
LS-2B	*Fontinalis neomexicanus*	8.6 (47.5)	110	7.49
LS-2C	*Fontinalis neomexicanus*	9.8 (49.6)	100	7.26
LS-2D	*Fontinalis neomexicanus*	10.0 (50.0)	100	7.32
XLS-7	*Spirogyra sp.*	7.5 (45.5)	90	6.64

Table 2-1
Amchitka Island Special Sampling Project
Sample Types and Environmental Measurements
(Page 3 of 3)

Sample	Sample Type (Species)	Temperature	Conductivity	pH
		°C[a] (°F[b])	ppm[c]	
Reference Area				
BKG-1A	*Fontinalis neomexicanus*	7.6 (45.7)	110	7.44
BKG-1B	*Fontinalis neomexicanus*	7.5 (45.5)	110	7.45
BKG-1C	*Fontinalis neomexicanus*	7.5 (45.5)	110	7.57
BKG-1D	*Fontinalis neomexicanus*	7.4 (45.3)	100	7.68
BKG-2A	*Fucus distichus*	NA[d]	NA	NA
BKG-2B	*Fucus distichus*	NA	NA	NA
BKG-2C	*Fucus distichus*	NA	NA	NA
BKG-2D	*Fucus distichus*	NA	NA	NA

[a] Degrees Celsius
[b] Degrees Fahrenheit
[c] Parts per million
[d] Not applicable. Temperature, conductivity, and pH measurements not taken at location.

Emphasis was placed on collecting a few indicator species of freshwater moss, particularly *Fontinalis neomexicanus*, and the marine alga *Fucus distichus*, to avoid variability due to inter-specific differences in radionuclide concentration capability. This was accomplished with the exception of a mixed moss sample of *Fontinalis neomexicanus/Hygrohypnum bestii/ Brachythecium asperrimum* collected in the short segment of CN-3C below White Alice Falls and in a short rapids section of White Alice Creek above the Falls (CN-3D); collection of *Drepanocladus* sp. in Long Shot ponds (LS-1); and collection of *Sphagnum squarrosum* at the Cannikin Lake location. These alterations to the original proposed sampling scheme were documented with the rationale dictated by the nature of the aquatic habitats.

Sampling on transects was accomplished according to the SAP protocol with the objective to minimize the risk of cross-contamination between sampling points: (1) within a given drainage basin, samples were collected from the marine (or downstream) transect first, followed by the upstream transects; (2) within a transect, the downstream sample was collected first; and (3) the Long Shot Site was sampled last because of a history of tritium in water samples from that location.

Fucus distichus was the indicator species in marine transects and was plentiful in all sampling locations on the rock benches that characterized the intertidal zones. Individual plants were removed from their holdfast structure and snails, mussels, marine invertebrate egg masses, and dead material discarded prior to thorough rinsing in ambient seawater. Matching sediment samples for the marine transects were collected above the high tide surge region on the beaches to minimize oceanic influences on sediments from stream outflows. Procedures followed those set forth in SOP AM 97.02 (EPA, 1997b).

Freshwater moss samples were collected in a manner consistent with SOP AM 97.03 (EPA, 1997b) by gloved hands, gently lifting the long fronds of *Fontinalis* and other species to avoid disturbing underlying sediments. The samples were placed in plastic buckets and transported to the sample processing location downstream of collecting locations. Samples were then separated into individual fronds or other small aliquots and repeatedly rinsed in copious amounts of ambient stream water in large (40 liter [L]) tubs and then into smaller (10 L) containers as processed aliquots became smaller as extraneous material was removed to maintain sample quality. Sediment was retained as “fines” by filtering washwater through 2-millimeter (mm) and 100-micrometer (µm) screens and added to sediment samples from each location. Washing, scrubbing, and other cleaning of samples continued until washwater was

essentially clear, water was expressed by hand, and the aliquots were aggregated into a sample bag for that location. Plant fragments were collected during straining of washwater through the 0.64 centimeter (cm) and 2-mm screens and added to the sample. The sample bag was placed inside a second plastic bag that contained chain-of-custody documents and the bag sealed with tape for transport to the field laboratory. This field processing required an average of 45 minutes for most samples, with longer times required for samples that contained considerable sediment or unacceptable amounts of filamentous algae and other extraneous plant material. Longer processing times were necessary for moss samples from LS-1 and -2 and XCN-7 because of small standing crops, copious sediment, and considerable amounts of algae in those samples. A matching sediment sample was collected at or near each location where a freshwater moss sample was collected.

The mixed algae sample XCN-7 from the soligenous bog near the Long Shot GZ was collected by hand and using a 0.2 x 0.5-m piece of nylon screen to gently lift the algae and place it in a plastic bag. It was transported back to the field laboratory, where it was repeatedly rinsed in deionized water prior to being dried and further processed similar to other samples.

Eleven transects were established and from these 44 samples of aquatic mosses were collected, distributed among the sites as follows:

Cannikin	4 transects	16 samples
Milrow	3 transects	12 samples
Long Shot	2 transects	8 samples
Background	2 transects	8 samples

Eight “individual samples” were collected at the request of Greenpeace representatives, designated, and described as follows:

- XCN-1 - *Fontinalis neomexicanus* at the Greenpeace location Number 11 of 1996.
- XCN-2 - *Enteromorpha intestinalis,* a marine alga that becomes adapted to freshwater habitats, collected near Greenpeace locations Numbers 9 and 10 of 1996 and collected at *Fucus distichus* Sample Location CN-4 (vicinity of White Alice Creek discharge to the Bering Sea) in 1997.
- XCN-3 - *Enteromorpha intestinalis* collected on rock ledge 100 m east of above location, and near *Fucus distichus* Sample Location CN-4B.

- XCN-4 - *Enteromorpha intestinalis* collected on rock ledge 150 m west of above location and near *Fucus distichus* Sample Location CN-4C.

- XCN-5 - *Brachythecium salebrosum*, a semiaquatic moss that predominated at the Greenpeace location Number 11 of 1996.

- XCN-6 - *Sphagnum squarrosum* collected from inshore waters of Cannikin Lake.

- XCN-7 - Unidentified filamentous brown and green algae collected at the 1996 Greenpeace location Number 3 near the Long Shot Site.

- XCN-8 - *Hygrohypnum bestii/Brachythecium asperrimum* aquatic mosses collected by Greenpeace from the splash zone of White Alice Creek Falls, the same location as their 1996 sample #12.

Four 0.25-square meter (m^2) samples of the representative lichen component of the *Empetrum-Carex* lichen community that dominates much of the Amchitka Island terrestrial landscape were collected in the immediate vicinity of the U.S. Army Corps of Engineers base camp (established in 1997). *Cladina portentosa* var. *pacifica* was the dominant lichen species, with small amounts of *Cetraria spp., Thamnolia vermicularis,* and *Sphoroporus globosus.* Vascular plants and lichens each represented about 50 percent of total volume.

Two samples of lichens were collected on the west side of Lake Andrew on Adak Island, about 300 km east of Amchitka Island, on the return to Anchorage. *Cladina portentosa* var. *pacifica* was selectively collected from scattered patches, where it was heavily integrated with *Empetrum nigrum* and the moss *Aulocomnium palustre.*

2.3 Sample Preparation

Upon transfer of the custody to the field laboratory, samples were logged in according to protocol (SOP 97.05) and processed according to SOP 97.02 (sediment) or SOP 97.03 (plants) (EPA, 1997b). This included being accurately weighed in tared aluminum trays, and placed in preheated (100°C) drying ovens for sufficient time to attain constant dry weight; this varied from one day for algae (XCN-7) to a few days for most *Fucus distichus* samples. Wet, dry, and ash weights were recorded in laboratory notebooks, with dry and ash weights being the basis of choice for expressing concentrations of radionuclides (Table 2-2).

Dried plant samples were milled to pass a 2-mm screen, which produced a homogeneous powder suitable for sample splitting, easier handling by reducing sample volume, and in a more convenient form for subsequent ashing (425-450°C) prior to radionuclide analyses.

Sediment samples were processed according to SOP 97.02 (EPA, 1997b), which parallels that of moss and algae samples (SOP 97.03). Samples were sieved to pass a 2-mm screen in a wet slurry, dried to constant weight at 100°C and placed into a proper container for counting or archiving.

Lichen samples were individually separated to remove vascular plants, placed in tared aluminum pans and processed in the same manner as other plant samples. Samples from Adak were prepared off site by HERS Inc., and lichen samples were separated from other plants and shipped via air express to EPA-Las Vegas, where they were further processed according to appropriate EPA procedures.

Table 2-2
Amchitka Island Special Sampling Project
Dry Weights, Ash Weights, and Ash/Dry Ratios
(Page 1 of 3)

Sample	Sample Type (Species)	Dry Weight g[a] (oz[b])	Ash Weight g (oz)	Ash/Dry Ratio
Cannikin				
CN-1A	*Fontinalis neomexicanus*	551.0 (19.44)	40.1 (1.41)	0.073
CN-1B	*Fontinalis neomexicanus*	566.7 (19.99)	41.4 (1.46)	0.073
CN-1C	*Fontinalis neomexicanus*	558.2 (19.69)	45.0 (1.59)	0.081
CN-1D	*Fontinalis neomexicanus*	591.5 (20.86)	43.0 (1.52)	0.073
CN-2A	*Fontinalis neomexicanus*	347.4 (12.25)	43.8 (1.54)	0.126
CN-2B	*Fontinalis neomexicanus*	432.3 (15.25)	52.0 (1.83)	0.120
CN-2C	*Fontinalis neomexicanus*	400.0 (14.11)	47.9 (1.69)	0.120
CN-2D	*Fontinalis neomexicanus*	430.8 (15.20)	51.8 (1.83)	0.120
CN-3A	*Fontinalis neomexicanus*	161.7 (5.70)	14.8 (0.52)	0.092
CN-3B	*Fontinalis neomexicanus*	289.4 (10.21)	37.9 (1.34)	0.131
CN-3C	*Fontinalis neomexicanus/Hygrohypnum bestii/Brachythecium asperrimum*	339.7 (11.98)	48.1 (1.70)	0.142
CN-3D	*Fontinalis neomexicanus/Hygrohypnum bestii/Brachythecium asperrimum*	402.2 (14.19)	46.0 (1.62)	0.114
CN-4A	*Fucus distichus*	449.7 (15.86)	81.6 (2.88)	0.181
CN-4B	*Fucus distichus*	456.4 (16.10)	112.2 (3.96)	0.246
CN-4C	*Fucus distichus*	497.4 (17.55)	139.1 (4.91)	0.280
CN-4D[c]	*Fucus distichus*	467.0 (16.47)	85.7[c] (3.02)	0.183
XCN-1	*Fontinalis neomexicanus*	127.6 (4.50)	9.0 (0.32)	0.071
XCN-2	*Enteromorpha intestinalis*	333.5 (11.76)	62.0 (2.19)	0.186
XCN-3	*Enteromorpha intestinalis*	314.9 (11.11)	80.1 (2.83)	0.254
XCN-4	*Enteromorpha intestinalis*	406.6 (14.34)	156.2 (5.51)	0.384
XCN-5	*Brachythecium sp.*	289.2 (10.20)	21.4 (0.75)	0.074
XCN-6	*Sphagnum squarrosum*	454.8 (16.04)	81.2 (2.86)	0.179
XCN-8	*Hygrohypnum bestii/ Brachythecium asperrimum*	405.4 (14.30)	47.1 (1.66)	0.116

Table 2-2
Amchitka Island Special Sampling Project
Dry Weights, Ash Weights, and Ash/Dry Ratios
(Page 2 of 3)

Sample	Sample Type (Species)	Dry Weight g[a] (oz[b])	Ash Weight g (oz)	Ash/Dry Ratio
Milrow				
MR-2A	*Fontinalis neomexicanus*	534.4 (18.85)	38.4 (1.35)	0.072
MR-2B	*Fontinalis neomexicanus*	380.0 (13.40)	23.8 (0.84)	0.063
MR-2C	*Fontinalis neomexicanus*	502.6 (17.73)	38.0 (1.34)	0.076
MR-2D	*Fontinalis neomexicanus*	490.2 (17.29)	40.8 (1.44)	0.083
MR-3A	*Fontinalis neomexicanus*	494.7 (17.45)	60.1 (2.12)	0.121
MR-3B	*Fontinalis neomexicanus*	577.8 (20.38)	66.0 (2.33)	0.114
MR-3C	*Fontinalis neomexicanus*	379.4 (13.38)	48.0 (1.69)	0.127
MR-3D	*Fontinalis neomexicanus*	443.7 (15.65)	36.7 (1.29)	0.083
MR-4A	*Fucus distichus*	610.0 (21.52)	114.5 (4.04)	0.188
MR-4B	*Fucus distichus*	639.4 (22.55)	151.8 (5.35)	0.237
MR-4C	*Fucus distichus*	616.9 (21.76)	183.5 (6.47)	0.297
MR-4D[c]	*Fucus distichus*	620.3 (21.88)	118.2[c] (4.17)	0.191
Long Shot				
LS-1A	*Drepanocladus sp.*	219.3 (7.74)	27.0 (0.95)	0.123
LS-1B	*Drepanocladus sp.*	241.7 (8.53)	23.4 (0.83)	0.097
LS-1C	*Drepanocladus sp.*	191.0 (6.74)	22.4 (0.79)	0.117
LS-1D	*Drepanocladus sp.*	245.0 (8.64)	25.9 (0.91)	0.106
LS-2A	*Fontinalis neomexicanus*	258.7 (9.13)	27.4 (0.97)	0.106
LS-2B	*Fontinalis neomexicanus*	70.4 (2.48)	4.4 (0.16)	0.063
LS-2C	*Fontinalis neomexicanus*	451.8 (15.94)	47.9 (1.69)	0.106
LS-2D	*Fontinalis neomexicanus*	501.8 (17.70)	52.5 (1.85)	0.105
XLS-7	*Spirogyra sp.*	51.3 (1.81)	21.0 (0.74)	0.409

Table 2-2
Amchitka Island Special Sampling Project
Dry Weights, Ash Weights, and Ash/Dry Ratios
(Page 3 of 3)

Sample	Sample Type (Species)	Dry Weight g[a] (oz[b])	Ash Weight g (oz)	Ash/Dry Ratio
Reference Area				
BKG-1A	*Fontinalis neomexicanus*	541.2 (19.09)	30.4 (1.07)	0.056
BKG-1B	*Fontinalis neomexicanus*	473.2 (16.69)	24.3 (0.86)	0.051
BKG-1C	*Fontinalis neomexicanus*	592.3 (20.89)	28.0 (0.99)	0.047
BKG-1D	*Fontinalis neomexicanus*	487.1 (17.18)	35.0 (1.23)	0.072
BKG-2A	*Fucus distichus*	468.2 (16.52)	109.9 (3.88)	0.235
BKG-2B	*Fucus distichus*	548.7 (19.35)	159.6 (5.63)	0.291
BKG-2C	*Fucus distichus*	493.5 (17.41)	134.3 (4.74)	0.272
BKG-2D[c]	*Fucus distichus*	662.7 (23.38)	125.3[c] (4.42)	0.189

[a] Gram(s)
[b] Ounce(s)
[c] The furnace malfunctioned during ashing of this sample, which fused the sample due to the high temperature and may have significantly changed the cesium content and ash weight of the sample.

3.0 Analytical Results

3.1 Gamma-Ray Analytical Results

Concentrations of gamma-emitting radionuclides (e.g., ^{137}Cs) are usually expressed as picocuries (10^{-12} Ci) per gram of sample, while alpha-emitting radionuclides (e.g., $^{239+240}$Pu) are considerably (often 1,000 times) lower in concentration than gamma emitters and are usually expressed as femtocuries (10^{-15} Ci) per gram of sample. Both units have been used in this report to expedite comparison between samples and transects.

Results of gamma-ray analyses of the ashed samples expressed as picocuries (10^{-12} Ci) per gram dry weight basis are presented in Figure 3-1 and Table 3-1. Beryllium-7, potassium-40 (^{40}K), and ^{137}Cs were identified consistently. All identifications of ^{241}Am were made with the System 9 thin-window detector. Beryllium-7 and ^{40}K were observed in all of the samples analyzed, and ^{137}Cs was observed in all except the marine *Enteromorpha* samples XCN-3 and XCN-4.

Several radionuclides that were frequently reported by the peak search/nuclide identification software were dismissed because of their short half-lives (e.g., cadmium-109 [^{109}Cd], cerium-141 [^{141}Ce], yttrium-88 [^{88}Y], and niobium-95 [^{95}Nd]). Uranium-235 was frequently reported, but has strongly interfering lines from radon-226 (^{226}Ra) and lead-214 (^{214}Pb) (radon daughter) at 186 kiloelectron volts (keV) and 143 keV, respectively. Therefore, the EPA made a further requirement that the 163 keV gamma-ray be observable in any spectrum in order for ^{235}U to be positively identified. This occurred only in the MR-2C sample (ID #723427), in which the concentration was found to be 0.031 ± 0.059 pCi/g ash, with an Minimum Detectable Concentration (MDC) of 0.029 pCi/g ash.

The long-lived fission product tin-126 (^{126}Sn) was also frequently reported on the basis of lines at 63 keV and 86 keV. These peaks can be attributed to a gamma-ray of ^{234}Th (daughter of naturally-occurring ^{238}U) and an x-ray of ^{214}Pb, respectively, so the presence of ^{126}Sn is not certain.

Long-lived metastable rhenium-186 (^{186}mRe), a neutron activation product, was reported in some samples on the basis of peaks at 52 keV and 59 keV. Lead-214 (^{214}Pb) has a disputed weak gamma-ray at 51 keV (as does ^{239}Pu) and ^{241}Am has a distinct gamma-ray at 59 keV. No determination of ^{186}mRe could be made.

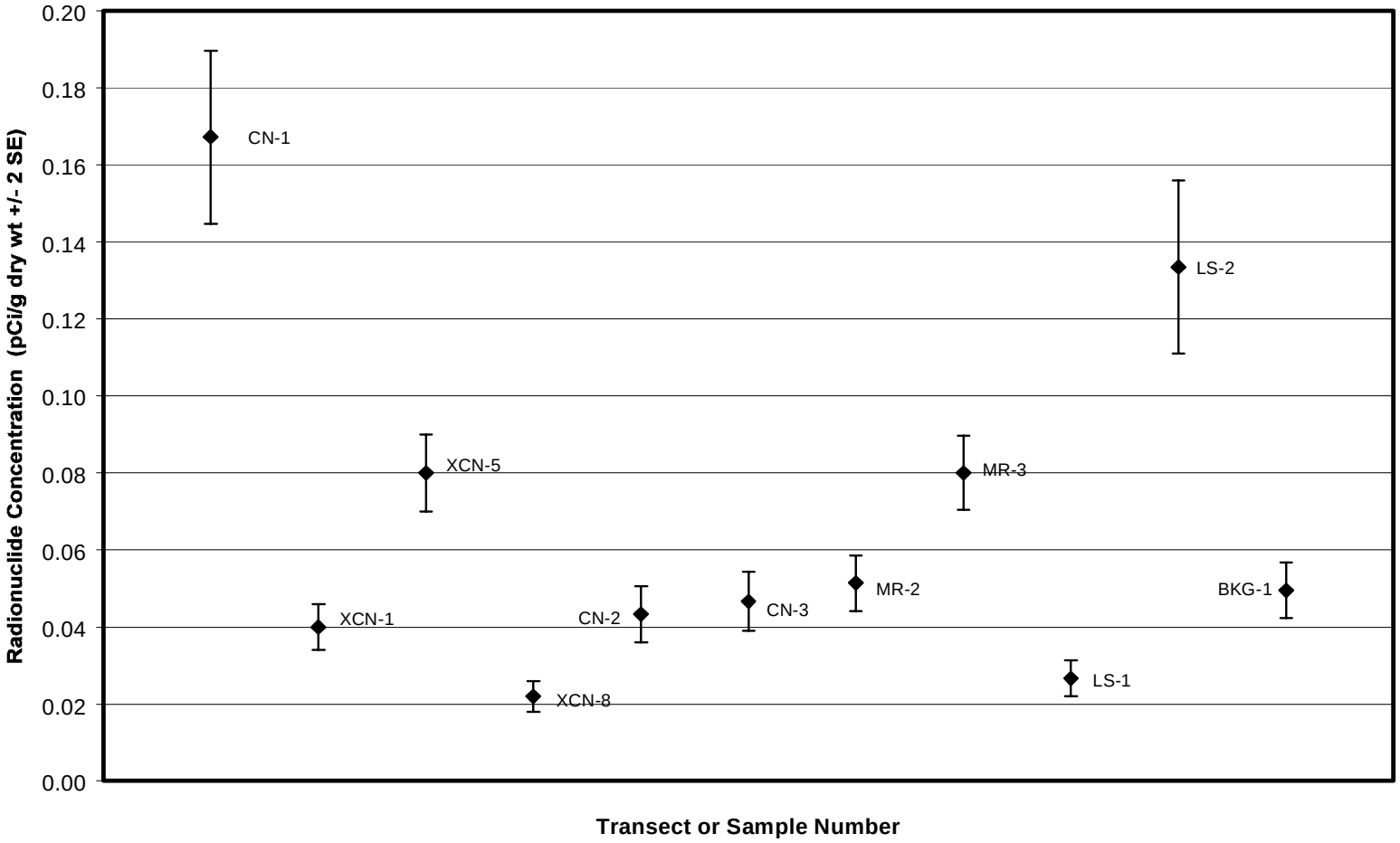

Figure 3-1
Cesium-137 Concentrations (pCi/g dry wt ± 2 SE)
in Freshwater Moss (principally *Fontinalis neomexicanus*) Collected
at Amchitka Island 1997 Transects and "Individual Samples" (XCN values)

Table 3-1
Amchitka Island Special Sampling Event
Gamma-Emitting Radionuclides in Biota
(Page 1 of 2)

Sample	Beryllium-7		Potassium-40		Cesium-137	
	Ash (pCi/g[a] ± 2σ[b])	Dry (pCi/g ± 2σ)	Ash (pCi/g ± 2σ)	Dry (pCi/g ± 2σ)	Ash (pCi/g ± 2σ)	Dry (pCi/g ± 2σ)
Cannikin						
CN-1A	35.8 ± 5.4	2.61 ± 0.39	106.7 ± 11.2	7.77 ± 0.82	2.53 ± 0.34	0.18 ± 0.03
CN-1B	29.7 ± 4.4	2.17 ± 0.32	107.5 ± 11.2	7.85 ± 0.82	2.21 ± 0.3	0.16 ± 0.02
CN-1B DUP	31.2 ± 4.8	2.28 ± 0.36	113.4 ± 11.8	8.28 ± 0.86	2.32 ± 0.32	0.17 ± 0.02
CN-1C	32.3 ± 4.8	2.60 ± 0.39	109.6 ± 11.6	8.84 ± 0.94	1.93 ± 0.26	0.16 ± 0.02
CN-1D[d]	11.6 ± 0.46	0.84 ± 0.03	106.7 ± 4.26	7.78 ± 0.31	2.52 ± 0.1	0.18 ± 0.007
CN-2A	68.6 ± 10.2	8.65 ± 1.29	43.9 ± 4.6	5.53 ± 0.58	0.29 ± 0.06	0.04 ± 0.008
CN-2B	62.8 ± 9.4	7.55 ± 1.13	47.4 ± 5.0	5.70 ± 0.60	0.33 ± 0.06	0.04 ± 0.007
CN-2C	69.9 ± 10.4	8.37 ± 1.25	50.7 ± 5.4	6.1 ± 0.65	0.43 ± 0.06	0.05 ± 0.007
CN-2D	31.0 ± 1.24	3.73 ± 0.15	48.9 ± 1.96	5.88 ± 0.24	0.35 ± 0.05	0.04 ± 0.006
CN-3A	51.5 ± 9.2	4.71 ± 0.84	68.8 ± 7.2	6.30 ± 0.66	0.33 ± 0.06	0.03 ± 0.005
CN-3B	72.7 ± 10.8	9.52 ± 1.41	36.7 ± 4.0	4.81 ± 0.52	0.33 ± 0.06	0.04 ± 0.008
CN-3C	67.5 ± 10.0	9.56 ± 1.42	40.4 ± 4.2	5.72 ± 0.60	0.51 ± 0.08	0.07 ± 0.01
CN-3D	33 ± 1.32	3.77 ± 0.15	51.6 ± 2.1	5.90 ± 0.24	0.33 ± 0.05	0.04 ± 0.006
CN-4A	0.48 ± 0.02	0.09 ± 0.004	178.9 ± 18.6	32.5 ± 3.4	0.07 ± 0.02	0.01 ± 0.003
CN-4B	0.8 ± 0.2	0.20 ± 0.05	152.9 ± 16.0	37.6 ± 3.9	0.06 ± 0.02	0.01 ± 0.003
CN-4C	1.7 ± 0.4	0.48 ± 0.08	131.2 ± 13.6	36.7 ± 3.8	0.04 ± 0.02	0.01 ± 0.003
CN-4D	< mdc[c]	< mdc	173.3± 3.5	31.8 ± 0.64	0.14 ± 0.04	0.03 ± 0.007
XCN-1	82.0 ± 11.8	5.78 ± 0.83	83.7 ± 8.8	5.90 ± 0.62	0.55 ± 0.08	0.04 ± 0.006
XCN-2	1.7 ± 0.4	0.32 ± 0.07	103.0 ± 10.8	19.1 ± 2.0	0.49 ± 0.08	0.09 ± 0.014
XCN-3	2.9 ± 0.6	0.74 ± 0.15	69.9 ± 7.4	17.8 ± 1.88	< 0.03	< .008
XCN-4	3.9 ± 0.8	1.50 ± 0.26	48.7 ± 5.2	18.7 ± 2.0	< 0.03	< .012
XCN-5	100.7 ± 15	7.45 ± 1.11	114.0 ± 12.0	8.44 ± 0.89	1.06 ± 0.14	0.08 ± 0.01
XCN-6	84.9 ± 12.8	15.2 ± 2.29	29.8 ± 3.2	5.32 ± 0.57	0.26 ± 0.06	0.05 ± 0.01
XCN-8	107.7 ± 15.6	12.5 ± 1.81	29.8 ± 3.2	3.46 ± 0.37	0.19 ± 0.04	0.02 ± 0.005
XCN-8 DUP	112.7 ± 16.8	13.10 ± 1.96	32.0 ± 3.4	3.72 ± 0.40	0.19 ± 0.04	0.022 ± 0.004
Milrow						
MR-2A	24 ± 3.4	1.73 ± 0.24	83.9 ± 8.8	6.03 ± 0.63	0.69 ± 0.1	0.05 ± 0.007
MR-2A DUP	23.8 ± 3.6	1.71 ± 0.26	84.5 ± 8.9	6.08 ± 0.64	0.73 ± 0.1	0.052 ± 0.008
MR-2B	28.7 ± 4.8	1.80 ± 0.30	118.0 ± 12.4	7.39 ± 0.78	1.51 ± 0.22	0.09 ± 0.01
MR-2C	21.8 ± 3.2	1.65 ± 0.24	68.4 ± 7.2	5.17 ± 0.54	0.43 ± 0.06	0.03 ± 0.005
MR-2C DUP	21.9 ± 3.4	1.66 ± 0.26	68.6 ± 7.2	5.20 ± 0.54	0.46 ± 0.08	0.035 ± 0.006
MR-2D	10.8 ± 0.64	0.90 ± 0.05	62.4 ± 2.5	5.20 ± 0.21	0.52 ± 0.06	0.04 ± 0.005
MR-3A	14.4 ± 2.2	1.75 ± 0.27	67.1 ± 7.0	8.15 ± 0.85	0.68 ± 0.1	0.08 ± 0.01
MR-3B	18.4 ± 2.8	2.10 ± 0.32	59.9 ± 6.4	6.84 ± 0.73	0.58 ± 0.08	0.07 ± 0.009
MR-3C	18.3 ± 2.8	2.32 ± 0.35	67.9 ± 7.2	8.59 ± 0.91	0.68 ± 0.1	0.09 ± 0.01
MR-3D	17.8 ± 0.72	1.47 ± 0.06	112.8 ± 4.5	9.36 ± 0.37	0.96 ± 0.08	0.08 ± 0.006
MR-4A	2.5 ± 0.4	0.47 ± 0.08	168.1 ± 17.4	31.6 ± 3.27	0.08 ± 0.02	0.02 ± 0.003

Table 3-1
Amchitka Island Special Sampling Event
Gamma-Emitting Radionuclides in Biota
(Page 2 of 2)

Sample	Beryllium-7		Potassium-40		Cesium-137	
	Ash (pCi/g[a] ± 2σ[b])	Dry (pCi/g ± 2σ)	Ash (pCi/g ± 2σ)	Dry (pCi/g ± 2σ)	Ash (pCi/g ± 2σ)	Dry (pCi/g ± 2σ)
MR-4B	1.7 ± 0.4	0.40 ± 0.10	178.6 ± 18.6	42.4 ± 4.42	0.05 ± 0.02	0.01 ± 0.003
MR-4C	2.3 ± 0.4	0.68 ± 0.12	129.1 ± 13.4	38.4 ± 4.0	0.04 ± 0.02	0.01 ± 0.004
MR-4D	1.1 ± 0.28	0.21 ± 0.05	173.9 ± 3.5	33.1 ± 0.66	0.08 ± 0.03	0.01 ± 0.006
Long Shot						
LS-1A	112.8 ± 18.6	13.9 ± 2.29	34.1 ± 3.6	4.20 ± 0.44	0.21 ± 0.04	0.03 ± 0.005
LS-1B	172.7 ± 25.8	16.7 ± 2.5	51.9 ± 5.4	5.02 ± 0.52	0.17 ± 0.04	0.02 ± 0.004
LS-1C	223.7 ± 39.2	26.2 ± 4.6	36.7 ± 3.8	4.30 ± 0.45	0.23 ± 0.04	0.03 ± 0.005
LS-1D	106.1 ± 2.12	11.2 ± 0.22	78.8 ± 3.2	8.34 ± 0.33	0.36 ± 0.07	0.04 ± 0.008
LS-2A	19.8 ± 3.0	2.10 ± 0.32	36.4 ± 3.8	3.86 ± 0.4	1.67 ± 0.24	0.18 ± 0.03
LS-2B	30.2 ± 5.4	1.89 ± 0.34	91.8 ± 9.6	5.74 ± 0.6	1.73 ± 0.26	0.11 ± 0.02
LS-2C	35.2 ± 5.2	3.73 ± 0.55	68.1 ± 7.2	7.22 ± 0.76	1.15 ± 0.16	0.12 ± 0.02
LS-2C DUP	36.1 ± 5.4	3.84 ± 0.58	68.6 ± 7.2	7.29 ± 0.76	1.16 ± 0.16	0.124 ± 0.02
LS-2D	16.6 ± 0.66	1.74 ± 0.07	67.5 ± 2.7	7.06 ± 0.28	1.38 ± 0.08	0.14 ± 0.009
XLS-7	10.1 ± 1.8	4.13 ± 0.74	8.5 ± 1.0	3.48 ± 0.41	2.29 ± 0.36	0.94 ± 0.15
Reference Area						
BKG-1A	31.2 ± 4.8	1.75 ± 0.27	128.3 ± 13.4	7.21 ± 0.75	0.84 ± 0.12	0.05 ± 0.007
B K G - 1 A DUP	31.4 ± 4.6	1.76 ± 0.26	124.8 ± 13.0	7.01 ± 0.74	0.85 ± 0.12	0.048 ± 0.006
BKG-1B	36.6 ± 5.6	1.88 ± 0.29	123.9 ± 13.0	6.36 ± 0.67	0.94 ± 0.14	0.05 ± 0.007
BKG-1C	44.8 ± 7.8	2.12 ± 0.37	131.9 ± 13.8	6.24 ± 0.65	1.14 ± 0.18	0.05 ± 0.009
BKG-1D	7.8 ± 0.46	0.56 ± 0.03	79.9 ± 3.2	8.1 ± 0.32	0.84 ± 0.07	0.06 ± 0.005
BKG-2A	0.6 ± 0.2	0.14 ± 0.05	166.2 ± 17.2	39.0 ± 4.04	0.08 ± 0.02	0.02 ± 0.003
BKG-2B	0.9 ± 0.2	0.26 ± 0.06	152.5 ± 15.8	44.4 ± 4.6	0.04 ± 0.02	0.01 ± 0.003
BKG-2C	1.6 ± 0.4	0.44 ± 0.08	139 ± 14.6	37.8 ± 3.97	0.04 ± 0.02	0.01 ± 0.003
BKG-2D	1.0 ± 0.42	0.19 ± 0.08	174.9 ± 3.5	33.1 ± 0.66	0.24 ± 0.04	0.05 ± 0.008

[a] Picocurie(s) per gram
[b] Two sigma counting error
[c] Minimum detectable concentration
[d] "D" samples were analyzed by LANL personnel

Several gamma and x-rays from nuclides of the ^{232}Th and ^{238}U series were identified, and made up the majority of all observed peaks in the spectra. However, because the samples were taken from an aqueous environment, it is unlikely that the nuclides of the ^{232}Th series were in equilibrium. The strongly gamma and x-ray emitting daughters of ^{238}U follow the decay of the well-known emanating gas ^{222}Rn, and cannot be used to determine quantities of parent nuclides in the chain. Reliable gamma-rays are emitted by palladium (^{234}Pa) in the decay chain $^{238}U \rightarrow ^{234}Th \rightarrow ^{234}Pa$, but it is not known what the equilibrium condition of the ^{234}Th ($t_{1/2}$ = 24 days) was at the time of collection. The determination of these series nuclides by gamma-ray analysis is outside the scope of this project and their presence is reported for information only.

3.2 Alpha Spectroscopy Analytical Results

Analytical results of $^{239+240}$Pu, ^{238}Pu, and ^{241}Am in the ashed samples expressed as femtocuries (10^{-15} Ci) per gram dry weight are presented in Figures 3-2 and 3-3, and Table 3-2. Plutonium-238 concentrations were near the detectable limit of analysis and precluded realistic comparison of samples or transects; therefore, those results were not included. Additional analytical details for the transuranic elements of interest are given below.

Plutonium: No samples were lost in analysis; however, because of low tracer recovery five samples (MR-2A, MR-2B, MR-3C, XCN-3 and CN-4A) were counted for 2,000 minutes (33 hours) to reduce analytical uncertainty. Results from the 2,000-minute count are reported and the original 1,000-minute (17 hours) count retained for comparison. Tracer yields on the entire sample set were quite variable, ranging from approximately 10 percent to 90 percent. Later batches generally had better average yields. The long count times (about 100 times longer than usually performed at a commercial laboratory) were prescribed to obtain reliable results.

Americium: To achieve adequate resolution between the energetically-similar ^{243}Am tracer peak (5276 keV) and ^{241}Am (5486 keV) the sample-to-detector distance was increased, slightly lowering overall counting efficiency. A counting time of 1,500 minutes (25 hours) was used for all but one set of samples. As with the plutonium analyses, tracer recovery was variable. One quality control sample was rejected because of inadequate tracer recovery (EML Method Spike 9609 Soil: Batch #1) and two samples had yields less than 10 percent (BKG-1A and LS-2C) but were considered acceptable.

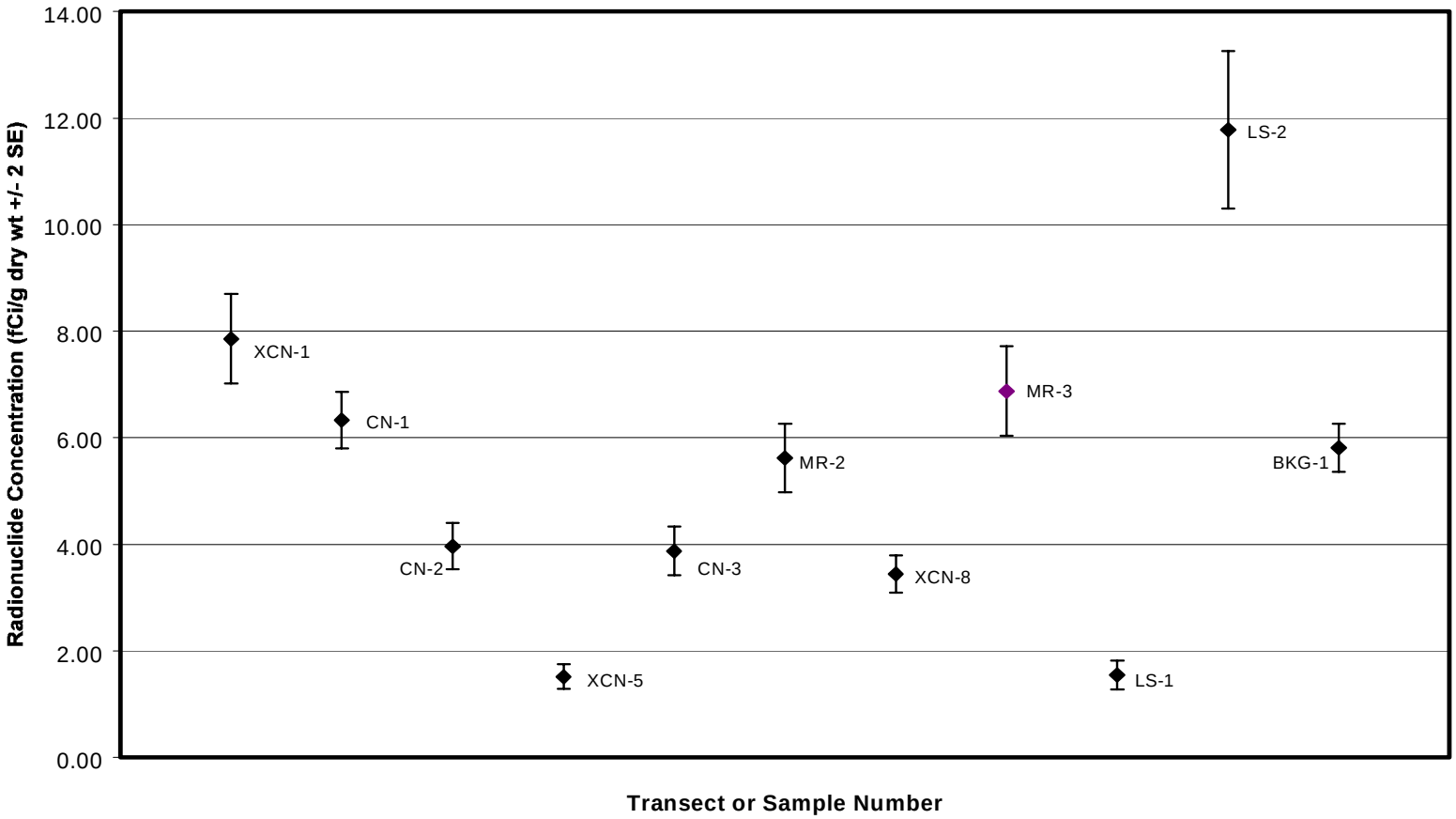

Figure 3-2
Plutonium-239+-240 Concentrations (fCi/g dry wt ± 2 SE)
in Freshwater Moss (principally *Fontinalis neomexicanus*) Collected
at Amchitka Island 1997 Transects and "Individual Samples" (XCN values)

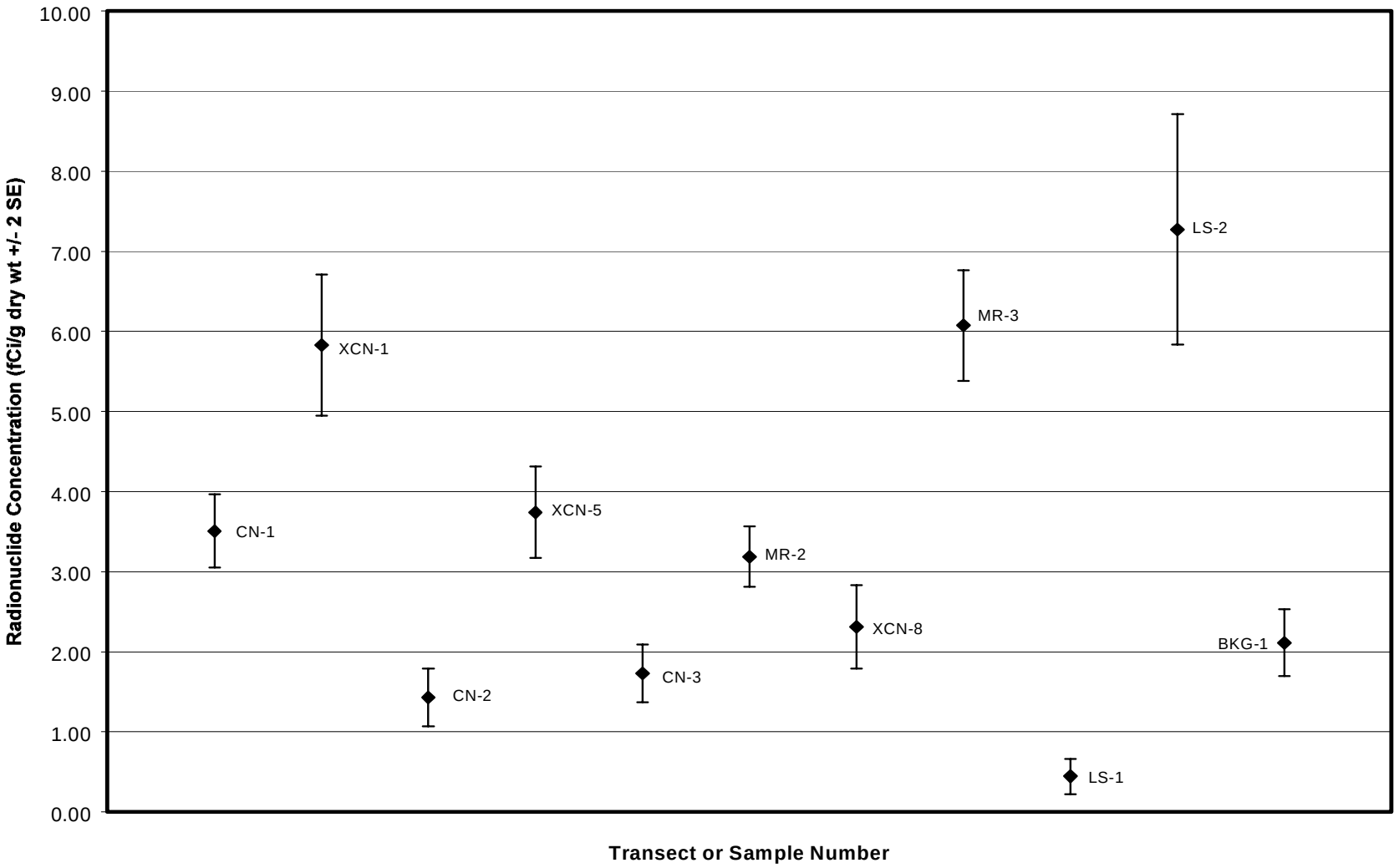

Figure 3-3
Americium-241 Concentrations (fCi/g dry wt ± 2 SE)
in Freshwater Moss (principally *Fontinalis neomexicanus*) Collected at
Amchitka Island 1997 Transects and "Individual Samples" (XCN values)

Table 3-2
Amchitka Island Special Sampling Event
Alpha-Emitting Radionuclides in Biota
(Page 1 of 2)

Sample	Plutonium-239,240		Plutonium-238		Americium-241	
	Ash	Dry	Ash	Dry	Ash	Dry
	(fCi/g[a] ± 2σ[b])	(fCi/g ± 2σ)	(fCi/g ± 2σ)	(fCi/g ± 2σ)	(fCi/g ± 2σ)	(fCi/g ± 2σ)
Cannikin						
CN-1A	88.2 ± 7.16	6.42 ± 0.52	2.7 ± 0.8	0.2 ± 0.06	54.6 ± 7.13	3.97 ± 0.52
CN-1B	78.2 ± 6.83	5.71 ± 0.5	2.7 ± 0.8	0.2 ± 0.06	42 ± 5.63	3.07 ± 0.41
CN-1C	85.3 ± 7.03	6.88 ± 0.57	3.4 ± 1.0	0.27 ± 0.08	43.2 ± 5.41	3.48 ± 0.44
CN-1D	57.5 ± 0.95	4.18 ± 0.07	NR[c]	NR	< 23.9	< 1.74
CN-2A	33.5 ± 3.88	4.22 ± 0.49	1.1 ± 0.6	0.14 ± 0.08	11.8 ± 3.5	1.49 ± 0.44
CN-2A DUP	32.9 ± 3.8	4.1 ± 0.4	0.8 ± 0.6	0.1 ± 0.08	NR*	NR
CN-2B	36.1 ± 3.85	4.34 ± 0.46	1.2 ± 0.6	0.14 ± 0.07	13.9 ± 3.07	1.67 ± 0.37
CN-2C	26.8 ± 3.08	3.21 ± 0.37	0.7 ± 0.4	0.08 ± 0.05	9.37 ± 2.22	1.12 ± 0.27
CN-2D	28.18 ± 0.76	3.39 ± 0.09	NR	NR	< 10.7	< 1.28
CN-3A	42.4 ± 5.3	3.88 ± 0.49	1.7 ± 1.0	0.16 ± 0.09	15.8 ± 3.72	1.45 ± 0.34
CN-3B	26.6 ± 3.49	3.48 ± 0.46	1.2 ± 0.6	0.16 ± 0.08	14.6 ± 2.78	1.91 ± 0.36
CN-3B DUP	28.5 ± 3.8	3.7 ± 0.4	< 0.5	< 0.1	NR	NR
CN-3C	31.5 ± 3.4	4.46 ± 0.48	0.9 ± 0.6	0.13 ± 0.09	12.9 ± 2.7	1.83 ± 0.38
CN-3D	30.9 ± 0.4	3.53 ± 0.05	NR	NR	< 18.0	< 2.06
CN-4A	7.0 ± 1.58	1.27 ± 0.29	< 1.0	< 0.2	6.21 ± 2.28	1.13 ± 0.41
CN-4B	3.22 ± 1.09	0.79 ± 0.27	< 0.3	< 0.1	< 1.7	< 0.4
CN-4C	8.36 ± 1.66	2.34 ± 0.46	< 0.3	< 0.1	2.27 ± 1.05	0.63 ± 0.29
CN-4D	5.8 ± 0.16	1.06 ± 0.03	NR	NR	< 7.9	< 1.45
XCN-1	111.5 ± 11.9	7.86 ± 0.84	4.8 ± 2.2	0.34 ± 0.16	82.7 ± 12.4	5.83 ± 0.88
XCN-2	2.87 ± 1.36	0.53 ± 0.25	< 0.8	< 0.1	3.14 ± 1.69	0.58 ± 0.31
XCN-3	5.39 ± 1.61	1.37 ± 0.41	< 1.1	< 0.3	3.01 ± 1.12	0.77 ± 0.29
XCN-4	5.83 ± 1.31	2.24 ± 0.5	0.4 ± 0.4	0.15 ± 0.16	2.3 ± 1.49	0.88 ± 0.57
XCN-5	20.5 ± 3.16	1.52 ± 0.23	< 0.5	< 0.04	50.5 ± 7.7	3.74 ± 0.57
XCN-6	19.4 ± 5.52	3.46 ± 0.99	< 1.1	< 0.2	6.25 ± 2.65	1.12 ± 0.47
XCN-8	29.7 ± 3.04	3.45 ± 0.35	1.2 ± 0.6	0.14 ± 0.07	19.9 ± 4.51	2.31 ± 0.52
Milrow						
MR-2A	71.8 ± 8.75	5.16 ± 0.63	2.2 ± 1.2	0.16 ± 0.09	47.6 ± 4.85	3.42 ± 0.35
MR-2B	75.4 ± 9.16	4.72 ± 0.57	3.7 ± 1.2	0.23 ± 0.08	48.7 ± 5.71	3.05 ± 0.36
MR-2C	92.3 ± 9.48	6.98 ± 0.72	3.0 ± 1.2	0.23 ± 0.09	40.9 ± 5.57	3.09 ± 0.42
MR-2D	81.3 ± 0.67	6.77 ± 0.06	NR	NR	46.2 ± 32.2	3.84 ± 2.68
MR-3A	61.1 ± 7.29	7.42 ± 0.89	1.9 ± 1.0	0.23 ± 0.12	55.6 ± 6.88	6.75 ± 0.84
MR-3B	51.7 ± 5.72	5.91 ± 0.65	1.8 ± 0.8	0.21 ± 0.09	43.5 ± 5.65	4.97 ± 0.65
MR-3C	57.7 ± 7.76	7.3 ± 0.98	1.5 ± 1.0	0.19 ± 0.13	51.4 ± 4.67	6.5 ± 0.59
MR-3D	111.9 ± 2.89	9.24 ± 0.24	NR	NR	< 240.5	< 20.0
MR-4A	11.4 ± 2.28	2.14 ± 0.43	0.5 ± 0.4	0.09 ± 0.08	3.7 ± 1.85	0.69 ± 0.35

Table 3-2
Amchitka Island Special Sampling Event
Alpha-Emitting Radionuclides in Biota
(Page 2 of 2)

Sample	Plutonium-239,240		Plutonium-238		Americium-241	
	Ash	Dry	Ash	Dry	Ash	Dry
	(fCi/g[a] ± 2σ[b])	(fCi/g ± 2σ)	(fCi/g ± 2σ)	(fCi/g ± 2σ)	(fCi/g ± 2σ)	(fCi/g ± 2σ)
MR-4B	9.74 ± 1.9	2.31 ± 0.45	< 0.3	< 0.07	1.58 ± 0.85	0.38 ± 0.2
MR-4B DUP	11.3 ± 2.0	2.7 ± 0.4	0.4 ± 0.4	0.1 ± 0.08	NR	NR
MR-4C	5.45 ± 1.24	1.62 ± 0.37	< 0.3	< 0.089	2.16 ± 0.82	0.64 ± 0.24
MR-4D	12.4 ± 0.62	2.37 ± 0.12	NR	NR	< 29.8	< 5.69
Long Shot						
LS-1A	9.71 ± 1.96	1.2 ± 0.24	< 0.5	< 0.062	4.34 ± 1.72	0.53 ± 0.21
LS-1B	13.1 ± 2.43	1.27 ± 0.24	0.9 ± 0.8	0.09 ± 0.08	3.04 ± 1.73	0.29 ± 0.17
LS-1C	18.7 ± 2.78	2.19 ± 0.33	0.9 ± 0.6	0.11 ± 0.07	4.34 ± 2.4	0.51 ± 0.28
LS-1D	21.3 ± 0.47	2.25 ± 0.05	NR	NR	< 76.9	< 8.15
LS-2A	122.0 ± 10.1	12.9 ± 1.07	4.7 ± 1.4	0.5 ± 0.15	74.3 ± 12.6	7.87 ± 1.34
LS-2B	247.9 ± 28.5	15.5 ± 1.78	8.1 ± 4.6	0.51 ± 0.29	96.5 ± 15.8	6.03 ± 0.99
LS-2C	65.6 ± 14.9	6.95 ± 1.58	2.1 ± 2.2	0.22 ± 0.23	74.7 ± 18.8	7.92 ± 1.99
LS-2D	63.0 ± 0.77	6.6 ± 0.08	NR	NR	18.8 ± 14	1.97 ± 1.47
XLS-7	227.0 ± 16.1	92.9 ± 6.59	4.7 ± 1.4	1.92 ± 0.57	125.6 ± 10.8	51.4 ± 4.42
XLS-7 DUP	226.3 ± 16.4	92.5 ± 6.8	7.6 ± 1.8	3.1 ± 0.8	NR	NR
Reference Area						
BKG-1A	108.8 ± 8.38	6.11 ± 0.47	3.2 ± 1.0	0.18 ± 0.06	33.3 ± 10.5	1.87 ± 0.59
BKG-1B	115.1 ± 9.33	5.91 ± 0.48	4.0 ± 1.2	0.21 ± 0.06	38.1 ± 5.86	1.96 ± 0.3
B K G - 1 B DUP	105.3 ± 8.6	5.4 ± 0.4	4.0 ± 1.2	0.20 ± 0.06	NR	NR
BKG-1C	123.6 ± 9.79	5.84 ± 0.46	2.9 ± 1	0.14 ± 0.05	53.1 ± 7.52	2.51 ± 0.36
BKG-1D	55.4 ± 0.72	3.97 ± 0.05	NR	NR	50.6 ± 33.6	3.63 ± 2.41
BKG-2A	4.34 ± 1.1	1.02 ± 0.26	< 0.3	< 0.071	1.84 ± 0.74	0.43 ± 0.17
BKG-2B	6.67 ± 1.49	1.94 ± 0.43	< 0.5	< 0.1	1.26 ± 0.68	0.37 ± 0.2
B K G - 2 B DUP	6.2 ± 1.4	1.8 ± 0.4	0.5 ± 0.4	0.1 ± 0.12	NR	NR
BKG-2C	6.12 ± 1.67	1.67 ± 0.45	0.5 ±0.4	0.14 ± 0.11	1.55 ± 0.8	0.42 ± 0.22
BKG-2D	9.4 ± 0.61	1.78 ± 0.12	NR	NR	< 14.6	< 2.76

[a] Femtocurie(s) per gram
[b] Two sigma counting error
[c] Not reported
[d] D samples were analyzed by LANL personnel

An independent data audit of EPA and LANL laboratory procedures was conducted by representatives of ADEC, A/PIA, and Greenpeace during 1997-1999 to assure acceptability of the data in this report. Emphasis was placed on verification of ^{241}Am analyses, which were confirmed by reanalyses of 12 ashed aquatic moss samples by the State of Washington Department of Environmental Health for that radionuclide. The intercomparison is shown in Table 3-3.

These results are comparable (linear regression [$r^2 = 0.64$]) within normal analytical variations and considered to be evidence of equitable analytical performance.

Table 3-3
Comparison of ^{241}Am by Alpha Spectrometric Analyses of 12 Amchitka Island Aquatic Moss Samples by EPA-LV and State of Washington Department of Environmental Health Laboratory

Sample Number	EPA/LV		SW/DEH	
	fCi/g ash ± 1 σ	MDC	fCi/g ash ± 1 σ	MDA
XCN-8	19.9 ± 2.3	1.1	16 ± 11[a]	17
CN-1A	54.6 ± 3.6	0.5	44 ± 14	14
CN-1B	42.0 ± 2.8	0.4	26 ± 12	15
CN-1C	43.2 ± 2.7	0.4	36 ± 13	14
CN-2A	11.8 ± 1.8	1.3	4.2 ± 9.5[a]	17
CN-2B	13.9 ± 1.5	0.8	3 ± 11[a]	21
CN-2C	9.4 ± 1.1	0.8	3 ± 12[a]	22
CN-3C	12.9 ± 1.3	0.4	4 ± 10[a]	19
MR-3A	55.6 ± 3.4	0.7	85 ± 20	18
MR-3C	51.4 ± 2.3	0.1	35 ± 15	24
LS-2A	74.3 ± 6.3	3.3	35 ± 23	32
LS-2C	74.7 ± 9.4	8.2	51 ± 16	18

[a] Values are below MDA.

3.3 Thermal Ionization Mass Spectrometry (TIMS) Results

Eight aquatic moss (primarily *Fontinalis*), three marine alga (*Fucus*) and 11 stream and marine sediment samples were analyzed by LANL for gamma emitters, ^{241}Am, $^{239+240}$Pu , and ^{240}Pu/^{239}Pu atom ratios, the latter using TIMS methodology. Those results yielded an average ^{241}Am concentration in aquatic moss of 21.3 ± 17.9 fCi/g ash, which correlated well with the EPA and SW/DEH results (38.6 ± 24.3 and 28.5 ± 24.7 fCi/g ash, respectively). The ^{240}Pu/^{239}Pu ratio in freshwater moss averaged 0.189 ± 0.006 and in marine *Fucus* was 0.217 ± 0.016; the global mean ratio for worldwide fallout is reported to be 0.176 ± 0.014 (SD) (Hardy et al., 1973; Krey et al., 1976).

LANL also used TIMS in the analysis of Greenpeace 1996 sample numbers 3, 11, 12 (Greenpeace, 1996) which were reported to be "moss" collected from a seep near Long Shot GZ, "moss/algae" collected from a seep adjacent to White Alice Creek near the 1997 Sample CN-3A location, and "moss/algae" collected in White Alice Creek at the falls (1997 Sample CN-3C). Results are presented in Table 3-4 and all three values are consistent with ratios widely reported for worldwide fallout (Krey et al., 1976) that range from 0.12 to 0.21 around the world and average 0.176 ± 0.014 (SD) (Hardy, et al., 1973).

Table 3-4
$^{239+240}$Pu Concentrations (pCi/g ash) in Greenpeace 1996 Samples and ^{240}Pu/^{239}Pu Atom Ratios Determined by TIMS Methodology

Sample Number	Sample wt (g)	$^{239+240}$Pu pCi/g* ash by Alpha	$^{239+240}$Pu pCi/g* ash by TIMS	^{240}Pu/^{239}Pu Atom Ratio by TIMS
Greenpeace 3	10.5849	0.214 ± 0.008	0.204 ± 0.003	0.185 ± 0.003
Greenpeace 11	14.2352	0.018 ± 0.003	0.023 ± 0.001	0.192 ± 0.009
Greenpeace 12	20.6134	0.032 ± 0.006	0.037 ± 0.001	0.188 ± 0.005

* = Errors are reported at the 1σ level based on counting statistics.

3.4 Tritium in Surface Waters

Surface water and groundwater samples were collected from 32 wells, tundra holes, and surface waters during June 1997 as a continuation of the EPA's LTAMP begun in 1965 following the Long Shot underground nuclear test (Faller and Farmer, 1998). The samples were initially screened by gamma-counting (EPA SOP NRA 2.17) to identify and quantify a large number of anthropogenic radionuclides, particularly ^{137}Cs, for which the screening level was 5 pCi/L during

a 100-minute count. No man-made gamma-ray emitting radionuclides were detected by this method.

Conventional tritium analysis (EPA SOP NRA 1.14) was performed to screen the water samples and only one sample (Long Shot Well GZ No. l) was above the tritium screening level of 400 pCi/L; the other 41 samples were processed according to the ^{3}H enrichment method (EPA SOP NRA 1.07). These results showed that tritium concentrations on Amchitka Island continued a decreasing trend due to radioactive decay and dilution established from prior LTHMP sampling (Faller and Farmer, 1998).

4.0 Summary and Conclusions

Measurements of gamma- and alpha-emitting radionuclides in mosses and algae (Tables 3-2, 3-3, and 3-4) collected at 44 locations within 11 sampling transects in 4 major drainage systems on Amchitka Island during June 1997 provide the basis for the following conclusions:

1. Comparison of ^{137}Cs concentrations in the marine alga *Fucus distichus* from Bering Sea and North Pacific Ocean transects (CN-4, MR-4, and BKG-2) at Amchitka Island stream discharges show no differences in the mean and standard deviation values, as follows:

   CN-4 (n=3): 0.012 ± 0.002 pCi/g dry weight
   MR-4 (n=3): 0.013 ±0.002 pCi/g dry weight
   BKG-2 (n=3): 0.014 ±0.005 pCi/g dry weight

2. Cesium-137 concentrations in the marine alga *Enteromorpha intestinalis* in freshwater intertidal environments from CN-4 transect on the Bering Sea coast were below the MDA, with the exception of one sample containing 0.091 ± 0.014 pCi/g dry wt.

3. There were no differences in ^{137}Cs, $^{239+240}$Pu, or ^{241}Am concentrations in samples of mixed *Fontinalis neomexicanus/Hygrohypnum bestii* mosses collected at, above, and below the confluence of the Greenpeace 1996 seep location #12 on White Alice Creek (Transect CN-3) (Table 4-1).

Table 4-1
Radionuclide Concentrations in Fresh Water Moss Samples in Transect CN-3

Sample No.	^{137}Cs (pCi/g)[a]	$^{239+240}$Pu (fCi/g)[a]	^{241}Am (fCi/g)[a]
CN-3A (at seep)	0.030	3.9	1.4
CN-3B (above seep)	0.043	3.5	1.9
CN-3C (below seep)	0.072	4.5	1.8
CN-3D (below seep)	0.038	3.5	ND[b]
Means ± SD (n=4) =	0.048 ± 0.021	3.8 ± 0.47	1.7 ± 0.26

[a] Note difference in units.
[b] Below Minimum Detectable Activity

4. There were no differences in ^{137}Cs, $^{239+240}Pu$, or ^{241}Am concentrations in *Fontinalis neomexicanus/Hygrohypnum bestii* moss samples collected at, above, and below the confluence of Greenpeace 1966 seep location #11 on White Alice Creek (Transect CN-2) (Table 4-2).

Table 4-2
Radionuclide Concentrations in Fresh Water Moss Samples in Transect CN-2

Sample No.	^{137}Cs (pCi/g)[a]	$^{239+240}Pu$ (fCi/g)[a]	^{241}Am (fCi/g)[a]
CN-2A (at seep)	0.037	4.2	1.5
CN-2B (above seep)	0.040	4.3	1.7
CN-2C (below seep)	0.051	3.2	1.1
CN-2D (below seep)	0.042	3.4	1.2
Means ± SD (n=4) =	0.042 ± 0.006	3.8 ± 0.55	1.4 ± 0.28

[a] Note difference in units.

5. Cesium-137 concentrations (pCi/g dry weight) in *Fontinalis neomexicanus* samples from North Fork of White Alice Creek (Transect CN-1) were slightly greater (Mean ± SD, n=4 = 0.171 ± 0.015 pCi/g) than those from lower reaches of White Alice Creek (Transects CN-2 and CN-3; Means (pCi/g) ± SDs (n=4): 0.042 ± 0.006 and 0.048 ± 0.021 pCi/g, respectively) but not significantly so.

6. Filamentous algae sample XLS-7 from a soligenous bog (seep) near Greenpeace 1996 #3 location contained a ^{137}Cs concentration of 0.939 ± 0.144 (2 SD) pCi/g dry weight. No other comparable samples were collected from other habitats or locations. However, this value is only 7.1 times the ^{137}Cs concentration in *Fontinalis neomexicanus* in the nearby transect LS-2 and at the lower end of the wide range of concentration factors (400 to 4,000) reported for algae species collected under both large-scale experimental conditions and field conditions (Williams and Swanson, 1958; Pendleton and Hanson, 1958). Also, this value is within the range of ^{137}Cs values reported in freshwater aufwuchs and filamentous algae from several streams such as MP 12 Creek and mouth of the North Fork of White Alice Creek during 1972-1979 (Sibley and Tornberg, 1982; Table 17).

Higher concentrations of transuranic nuclides in algae relative to vascular plants have usually been observed in several field studies of pond ecosystems (Kuzo et al., 1983) compared to flowing freshwater systems. This is due to the importance of sorption of these nuclides on algal material and settling of sestonic (both living and dead components of the environment) on this component having large surface-to-volume ratios. In soligenous bogs (seeps) such as the XLS-7 sample site, high Concentration Ratios (CRs) are to be expected due to the aquatic system being impounded and thereby accumulating materials from runoff.

Concentrations of ^{137}Cs, $^{239+240}Pu$, and ^{241}Am (means ± 2 SE) are graphically presented in Figures 3-1, 3-2, and 3-3, to allow expeditious comparison of the values presented in Tables 3-1 and 3-3. It is immediately apparent that: (1) transect CN-1 values for ^{137}Cs are significantly higher than most other transects, with the exception of LS-2; (2) transect LS-2 values for $^{239+240}Pu$ are more variable, ranging from upper ranges to much above those values for other transects; and (3) the 95 percent (± 2 SE) range of values for the BKG-1 transect in all three radionuclides was medial to those of the other transects, indicating that results of the 1997 sampling exercise on Amchitka Island suggest that all radionuclides detected in the effort are ascribable to worldwide fallout and occur in amounts of minor concern from a radiological health standpoint.

Special Samples XCN-1, XCN-5, and XCN-8 were collected from White Alice Creek at the locations of "seeps" proposed by Greenpeace to be originating from underground and downgradient from the Cannikin GZ and, therefore, candidates for indicating radionuclide leakage, particularly ^{241}Am. Results from this exercise show that ^{137}Cs, $^{239+240}Pu$, and ^{241}Am concentrations at all three locations are within the range as values from other transects and are concluded to represent single values illustrating the ubiquity of worldwide fallout in the Amchitka Island environs.

As with previous radioecological investigations conducted during the past 40 years in a variety of environments slightly higher than average concentrations of various radionuclides occurred at certain locations on Amchitka Island (Table 4-3). There was no consistent pattern to transect location relative to test GZs. Transect LS-2 was 150 to 500 m south and downgradient northwest of Long Shot GZ; CN-1 was 500 to 700 m upgradient (west) of Cannikin GZ; MR-3 was 1,500 m downgradient (east) of Milrow GZ; and BKG-1 was 8,000 m upgradient (northwest) of Cannikin GZ and west of several fault lines. These slightly higher values are ascribed to common environmental factors encountered in radioecological field studies.

Table 4-3
Sampling Locations on Amchitka Island with Elevated Radionuclide Concentrations in Freshwater Mosses and Algae

Location	fCi/g Dry Weight ± 2σ		
	^{137}Cs	$^{239+240}$Pu	^{241}Am
XLS-7*	939	93	51
LS-2[a]	135 ± 45	11.5 ± 5.0	7.5 ± 0.7
CN-1[a]	165 ± 15	5.9 ± 0.8	3.5 ± 0.5
MR-3[a]	75 ± 10	6.9 ± 1.0	6.0 ± 0.1
BKG-1[a]	50 ± 5.0	5.9 ± 0.2	2.3 ± .03

*Single algae sample; therefore, no sampling statistics.
[a]Mean ± SD of 3 replicate samples per transect.

The data provided in this report provide the basis for concluding that radionuclide concentrations in Amchitka Island aquatic ecosystems are consistent with worldwide fallout levels and give no indication of surface leakage of radioactivity from subterranean sources. Fingerprinting of plutonium isotopes in the samples provides further evidence of worldwide fallout as their source.

Four 0.25-m^2 samples of lichens were collected near the Amchitka Island 1997 base camp and two opportunistic samples were collected in the vicinity of Lake Andrew on Adak Island 155 nautical miles ESE of Amchitka Island. The Amchitka Island samples were components of the *Empetrum-Carex*-lichen carpet on Amchitka Island, and vascular plants (which comprised about 50 percent by volume of the individual samples) were separated from lichens before further processing. *Cladina portentosa* var. *pacifica* was the dominant lichen species, with minor amounts of *Thamnolia vermicularis, Cetraria islandica,* and *Sphaerophorus globosus.*

The Adak lichen samples were principally *Cladina portentosa var. pacifica* selectively collected from the *Empetrum-Aulocomnium* carpet at that location. Further hand-processing removed the moss and vascular plant components, which comprised 15 and 19 percent by weight of the total samples, prior to further processing. Cesium-137 concentrations in these lichen samples were as follows:

Amchitka Island #1 - 0.065 ± 0.012 (2σ) pCi/g dry wt.
Amchitka Island #2 - 0.063 ± 0.010 (2σ) pCi/g dry wt.
Amchitka Island #3 - 0.074 ± 0.012 (2σ) pCi/g dry wt.
Amchitka Island #4 - 0.062 ± 0.010 (2σ) pCi/g dry wt.
Mean ± SD = 0.066 ± 0.005 (2σ) pCi/g dry wt.

Adak #1 - 0.24 ± 0.02 (2σ) pCi/g dry wt.
Duplicate - 0.24 ± 0.02 (2σ) pCi/g dry wt.
Adak #2 - 0.24 ± 0.02 (2σ) pCi/g dry wt.
Mean ± SD = 0.24 ± 0.0 pCi/g dry wt.

Concentrations of ^{7}Be and ^{40}K are of ancillary interest due to their natural occurrence and indicator of sample measurement consistency. Coefficients of variation (SD ÷ Mean) ranged from 5 - 8 percent.

Ratios of $^{7}Be/^{137}Cs$ in all samples were consistent within a range of 60 to 70, with a mean of 66 ± 4, indicating good analytical agreement for the two radionuclides. Differences between radionuclide concentrations at the two locations are attributed to differing rainfall (144 centimeters per year [cm/yr] at Adak, 83 cm/yr at Amchitka Island [Armstrong, 1977]).

Gamma spectrometric analyses of the lichen samples provided comparative data with lichens collected previously on Amchitka Island (Koranda and Martin, 1973; Seymour and Nelson, 1977; Sibley and Tornberg, 1982), elsewhere in Alaska (Hanson and Eberhardt, 1973 and Hanson, 1982) and northern Canada (Taylor, et al., 1985). Lichens of various species were sampled during September 1967, August 1968, and August 1970 (Koranda and Martin, 1973) during major test series by China (Carter and Moghissi, 1977) and from late 1970-1979 as part of the Amchitka Island environmental program by the University of Washington (Sibley and Tornberg, 1982). Effective half-times (T_{eff}) of ^{137}Cs in samples compared within and between sampling regimens ranged from 2.6 to 3.4 years, similar to values reported by Taylor, et al. (1985) at southerly locations (50° N latitude) in a study of T_{eff} versus latitude in northern Canada.

Various lichen species were sampled in the earlier Amchitka Island programs, usually not specified as to species or degree of separation from vascular plant components. Amundsen (1977) listed *Cladonia* (= *Cladina*) *pacifica* as the major lichen species in Cover-Frequency Indices for four major plant community types, and Everett (1977) stated that large areas of relatively poorly-drained uplands or raised marine terraces on Amchitka Island were vegetated by sedges, lichens (primarily *C. pacifica*) and grasses. Koranda and Martin (1973) sampled *C. rangiferina* almost exclusively at several Alaskan locations, including Amchitka Island.

A complicating factor in calculating effective half-times of radionuclides in Amchitka Island ecosystems during the 1970s is the geographic situation of the island. Located at 51°N, 179°E,

fallout would be expected to be at a maximum from detonations at Lop Nor (China) and worldwide fallout that is annually transferred to the troposphere through the breaks in the tropopause located at 40° N and 40° S latitudes. Thus, the rates of fallout on Amchitka Island may have varied severalfold within a year during the 1970s due to such contributions. This may account for the substantial variability in radionuclide concentrations reported for samples of the same species collected at different times of the year; however, some variability in those values is probably due to ecological and biological factors that affect the metabolic rate of organisms. Similar conclusions were reported by Seymour and Nelson (1977).

Lichen samples also provide a means to determining the possible influence of radioactive contamination from the Chernobyl nuclear power plant in the Former Soviet Union in April 1986. Previous studies (Baskaran et al., 1991; Strandberg, 1997; Taylor et al., 1988; and White et al., 1986) emphasized ^{134}Cs concentrations as a measure of Chernobyl contamination by assuming a $^{134}Cs/^{137}Cs$ ratio of 0.4 (Strandberg, 1997) to 0.55 (Baskaran et al., 1991) at the time of the accident and subsequent physical decay; the half-life of ^{134}Cs is 2.06 years. Thus, only 0.025 of ^{134}Cs originating from Chernobyl would have been present in our samples; it was therefore not surprising that it was not detectable in the 3,600-minute (60-hour) counting time used for the lichen samples discussed above. Cesium-134 was not detected in an extensive series of lichen samples collected at Cape Thompson (Project Chariot) in 1993 (DOE/NV, 1994).

Americium-241 is of interest in this study as a possible measure of surface contamination that might originate from the underground nuclear tests on Amchitka Island. This radionuclide is also a constituent of worldwide fallout and has been reported in very low concentrations in northern Alaska, along with the other transuranic nuclides ^{238}Pu, and $^{239+240}Pu$ (Hanson, 1980; DOE/NV, 1994). Ratios of ^{241}Am to ^{137}Cs in lichens from northern Alaska were 0.0035 ± 0.00037 in 1976 compared to 0.014 ± 0.002 for $^{239,240}Pu/^{137}Cs$, suggesting very low levels were anticipated in 1997 samples, particularly in aquatic environments. The United Nations Scientific Committee on the Effects of Atomic Radiation (1993) reported a population-weighted deposition density for $^{241}Am/^{90}Sr$ of 0.0077 (upon decay of ^{241}Pu); and 1.6 for $^{137}Cs/^{90}Sr$ in worldwide fallout. This would equal a $^{241}Am/^{137}Cs$ ratio of 0.0048 for estimates of ^{241}Am in the 1997 samples and accounts for its undetectability in most of the aquatic samples; the lichen samples have not yet been analyzed by alpha spectrometry.

The above values for ^{137}Cs were measured by gamma spectrometry and the $^{239+240}Pu$ and ^{241}Am values were derived by alpha spectrometry to compare these results with those reported in past

radioecological studies of Amchitka Island (Sibley and Tornberg, 1982). Measurement of transuranic elements by gamma analyses, as reported by Greenpeace (1996), make difficult comparison with countless other studies of transuranic elements in the environment that have been conducted in circumpolar regions during the past 30 years that clearly show that ^{241}Am and other transuranic elements from worldwide fallout are present in most ecosystems, and are routinely measured by alpha spectroscopy methods.

Measurement of ^{241}Am by counting of its 59.5 keV gamma rays (36 percent abundance) has been suggested as an expeditious means of determination without the conventional complex alpha spectrometric procedures (Byrne and Komosa, 1993). However, the most promising approach in this method involves leaching ashed samples with 8 molar nitric acid and co-precipitation with calcium oxalate to compensate for the much higher background for gamma spectroscopy than for alpha spectroscopy. However, most analyses of transuranic radionuclides are still conducted by alpha spectroscopy due to its greater sensitivity and reliability for determining small concentrations that are usually found in environmental samples.

5.0 Summary

The objectives of this special sampling project as stated earlier in this report were to answer the questions (1) what man-made radionuclides are detectable in the Amchitka Island surface environment; and (2) is it possible to determine whether the source of any contaminants is worldwide fallout or a result of leakage from the underground detonation cavities?

The data presented in this report are typical of worldwide fallout radionuclides routinely measured in environmental studies, such as ^{137}Cs, ^{238}Pu, $^{239+240}Pu$, and ^{241}Am, as well as ^{7}Be and ^{40}K from natural sources. There were no unusual or unexpected sources of radionuclides in 44 samples of aquatic mosses and marine algae collected from 11 transects on four streams located in three underground test site watersheds and a background location, nor in eight aquatic moss, marine algae and freshwater algae "individual samples" collected in locations that were suspected by Greenpeace to be sources of underground leakage from underground nuclear test cavities.

Sensitive TIMS analyses of aquatic mosses, marine algae, and stream and marine sediment samples provided further confirmation of worldwide fallout as the source of Amchitka Island radionuclides by presence of $^{240}Pu/^{239}Pu$ ratios consistent with most other reports.

Interlaboratory comparisons of radionuclide analyses for ^{241}Am by EPA-LV, LANL, and State of Washington Department of Environmental Health yielded comparable consistent results. The data provide the basis for concluding that worldwide fallout occurs throughout Amchitka Island environs and there is no evidence of leakage of radionuclides from underground test locations other than tritium from Long Shot, which has long been recognized and monitored; it continues a decreasing trend due to radioactive decay and dilution.

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