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Environmental Sampling Plan for the Amchitka, Alaska, Site and Adak Island 2016 Sampling Event

April 2016

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Appendix A Long Shot All Hot Spot Seawater Sample Locations
Appendix B Seawater Sampling Information

Abbreviations

3-D	three-dimensional
ADEC	Alaska Department of Environmental Conservation
AEC	U.S. Atomic Energy Commission
ANOVA	analysis of variance (statistical test)
APIA	Aleutian Pribilof Islands Association
Bq/L	becquerel per liter
Bq/m^3	becquerel per cubic meter
CRESP	Consortium for Risk Evaluation with Stakeholder Participation II
CTD	conductivity, temperature, and depth (measurements)
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DQOs	data quality objectives
L	liter
LM	Office of Legacy Management
LTHMP	Long-Term Hydrological Monitoring Program
LTSP	Long-Term Surveillance Plan
m	meter
m^3	cubic meter
mBq/L	millibecquerel per liter
MOUs	memoranda of understanding
pCi/L	picocurie per liter
UAF	University of Alaska Fairbanks
USFWS	U.S. Fish and Wildlife Service

Radionuclide Symbols

^{134}Cs	cesium-134
^{137}Cs	cesium-137
^{3}H	tritium
^{239}Pu	plutonium-239
^{240}Pu	plutonium-240

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1.0 Introduction

In its implementation of the *Long-Term Surveillance Plan for the U.S. Department of Energy Amchitka, Alaska, Site* (DOE 2014) (LTSP), the U.S. Department of Energy (DOE) Office of Legacy Management (LM) prepared this sampling plan to describe the data collection and data management activities that will be conducted as indicated in the LTSP. The sampling activities described in this plan are to be implemented in 2016.

1.1 Background

Amchitka Island is near the far western end of the Aleutian Islands, approximately 1,340 miles west-southwest of Anchorage, Alaska. It is part of the Aleutian Islands Unit of the Alaska Maritime National Wildlife Refuge, which is administered by the U.S. Fish and Wildlife Service (USFWS). Since World War II, Amchitka Island has been used by multiple U.S. government agencies for various military and research activities. From 1943 to 1950, it was used as a forward air base for the U.S. Armed Forces. During the middle 1960s and early 1970s, the U.S. Department of Defense (DOD) and the U.S. Atomic Energy Commission (AEC) (predecessor agency to DOE) used a portion of the island as a site for underground nuclear tests. During the late 1980s and early 1990s, the U.S. Navy constructed and operated a radar station on the island.

Three underground nuclear tests were conducted on Amchitka Island. DOD, in conjunction with AEC, conducted the first nuclear test (named Long Shot) in 1965 to provide data that would improve the United States' capability of detecting underground nuclear explosions. The second nuclear test (Milrow) was a weapons-related test conducted by AEC in 1969 as a means to study the feasibility of detonating a much larger device. Cannikin, the third nuclear test on Amchitka Island and the largest underground nuclear test conducted in the United States, was a weapons-related test conducted on November 6, 1971. With the exception of anomalous concentrations of tritium (^3H) detected in surface water shortly after the Long Shot test, radioactive fission products from the tests remain in the subsurface at each test location.

1.2 Purpose of the 2016 Sampling Event

The purpose of this sampling plan is to carry out LM's responsibility—described in the LTSP for the Amchitka Island site and its reference site of Adak, Alaska—to further assess the possibility that selected residual radionuclides from nuclear tests may enter the marine food chain, resulting in potential ecological and human health effects. Previous scientific studies were performed on and around Amchitka Island that were similar in purpose to this plan. Some of these activities are described below.

The Environment of Amchitka Island, Alaska (Merritt and Fuller 1977), a multidisciplinary work, provides a concise review of the geology, ecology, and radionuclides in air, water, and biota with an emphasis on "the search for and identity of radionuclides of Amchitka Island origin in the samples and [contributing] to the general knowledge of the distribution of radionuclides in the environment." This evaluation showed that no radionuclides had escaped from the underground sites of the three nuclear detonations at Amchitka Island except for trace quantities of radionuclides, principally tritium, in water and soil gas samples taken in the immediate vicinity of the Long Shot test.

The Amchitka Radiobiological Program began in 1970 and continued through 1979. The program's principal objective was to collect biological and environmental samples for radiobiological analyses and to determine the extent of radionuclide contamination from worldwide atmospheric fallout and from the detonation of the three underground nuclear tests on Amchitka Island. Leakage of radionuclides from the underground test sites would be suspected if the amount of contamination were significantly greater than could be attributed to worldwide fallout or if an unexpected assemblage of radionuclides were detected. In the *Amchitka Radiobiological Program Final Report July 1970 to December 1979* (DOE 1982), it was determined that no radionuclides from the underground sites were detected, except for ^{3}H from the Long Shot test, which produced increased ^{3}H concentrations in surface water and freshwater plants near the site.

Another DOE program that monitored Amchitka Island radioactivity levels in groundwater was the Off-Site Environmental Monitoring Program for the Nevada Test Site and Other Test Areas Used for Underground Nuclear Detonations. Amchitka Island monitoring under this program began in 1977, and since then, sampling has occurred intermittently. Samples were taken from 1977 through 1989, in 1991, in 1993, in 1997, and in 2001. The U.S. Environmental Protection Agency carried out this program and monitored Amchitka Island to measure levels and trends of radioactivity in the offsite environment surrounding testing areas to ensure that radioactive levels comply with existing radiation protection levels.

Over time, the program became known as the Long-Term Hydrological Monitoring Program (LTHMP). In 1997, the LTHMP at Amchitka Island was expanded to include radiobiological sampling and analyses. This change was based on the results of a survey of selected aquatic biota that Greenpeace conducted on the island (Greenpeace 1996). Greenpeace speculated that several long-lived man-made radionuclides were leaking into the surface environment from nuclear test cavities several thousand feet (ft) below the surface of the island (DOE 2000). Briefly summarized, the results of the 1997 LTHMP radiobiological sampling indicated there was no evidence for leakage from the underground test cavities into the terrestrial or freshwater environments on Amchitka Island (DOE 2000; Dasher et al. 2002).

In 2004, the Consortium for Risk Evaluation with Stakeholder Participation II (CRESP), a group of independent universities, composed the *Amchitka Independent Science Assessment: Biological and Geophysical Aspects of Potential Radionuclide Exposures in the Amchitka Marine Environment* (CRESP 2005). CRESP found that radionuclide levels in marine resources were too low to put people or the environment at risk.

In 2011, a sampling event conducted by DOE addressed the safety of seafood consumption by paying particular attention to available diet information and considering the species included in the diet and portions consumed (DOE 2013). The diet information was used as the basis for the collection of samples and subsequent data interpretation including risk estimates. The risk estimates for the 2011 sampling event indicated that life-long consumption of subsistence seafood from Amchitka and Adak Islands yields a potential risk of below 1×10^{-5}, which is considered safe by the Alaska Department of Environmental Conservation (ADEC).

For the samples collected during the upcoming 2016 sampling event, DOE has selected laboratory analytical methods with low detection limits to measure the baseline activities of radionuclides in sampled biota and seawater.

2.0 Project Goals

The collection of biota samples for cesium-134 (^{134}Cs), cesium-137 (^{137}Cs), plutonium-239 (^{239}Pu), plutonium-240 (^{240}Pu), and freshwater and seawater samples for ^{134}Cs, ^{137}Cs, and ^{3}H is the primary objective of the 2016 sampling effort. These sampling activities are specified in the LTSP and agreed to by the Alaska Department of Environmental Conservation. The laboratory analytical method detection limits that will be used in the 2016 samples are lower than those used previously. The lower detection limits should provide data to enable DOE to delineate background activity concentrations of the radionuclides of interest included for analyses as part of the 2016 plan. Data from the 2016 sampling event will be used to assess if leakage from blast cavities can be detected and provide baseline activity concentrations that will support quantitative statistical trending analysis with previous and future sampling results. Sampling conducted in 2016 and beyond will include the objective of assessing the statistical trends of activity concentrations in biota and ocean water.

2.1 Specific Objectives for the 2016 Sampling Event

Consistent with the discussion in the LTSP and subsequent discussions with the various stakeholders, ADEC, the U.S. Fish and Wildlife Service, and the Aleutian Pribilof Islands Association (APIA), the primary objective of the 2016 sampling event will include the collection of both water and tissue data in response to the objective of determining leakage from the test cavities, with a specific focus on seawater sampling of the area of potential leakage off of Long Shot as defined in the Amchitka groundwater model (Hassan et al. 2002). The hydrologic model indicated that the shortest leakage arrival times could occur at the Long Shot test site.

Additionally, results from the leakage assessment will provide information on food safety. Prior assessment results have demonstrated that subsistence foods available on and around Amchitka have not been adversely impacted by radionuclides associated with the underground nuclear tests. If sufficient monitoring is conducted and does not identify radionuclide seepage from the test sites, then it can be concluded that the subsistence foods remain safe with respect to test-related radionuclides.

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3.0 Project Organization

LM's mission is to manage post-closure responsibilities and ensure the long-term protection of human health and the environment. LM implements its environmental-stewardship mission on Amchitka Island via contracts, work orders, cooperative agreements, and memoranda of understanding (MOUs) with private entities and government agencies. The Organizational Chart for the 2016 environmental sampling event is shown in Figure 1.

LM retains Navarro Research and Engineering, Inc. (Navarro), as its Legacy Management Support Services contractor. Navarro is a privately owned corporation headquartered in Oak Ridge, Tennessee. Navarro uses the most current management tools to plan the work scope, execute project tasks, measure progress throughout the performance of the project, and provide timely reports with regard to schedule and cost. Navarro helps DOE plan and execute the Amchitka Island work scope and will continue that function through 2017.

LM retains Argonne National Laboratory through a work order to help develop the environmental sampling plan and provide technical support with data analysis and other technical issues, as required.

LM also retains Lawrence Livermore National Laboratory through a work order to provide support in the radionuclide analysis of the environmental samples collected in 2016.

LM has given a financial assistance grant to APIA to support participation in Amchitka activities. APIA is an important component of the LM mission at Amchitka Island because APIA represents the interests of, and communicates with, the Aleut people and ADEC. APIA actively participates in developing important aspects of work scope related to the LM mission on Amchitka Island, participates in regular planning meetings, and will assist with sample collection during the 2016 sampling event.

LM has given a financial assistance grant to ADEC to support participation in Amchitka activities and regularly meets with ADEC's Division of Spill Prevention and Response. ADEC collaborates with the University of Alaska Fairbanks (UAF) to plan the sampling campaigns and recommend improvements to the LM sampling plan. UAF will also participate in sample collection during the 2016 sampling event.

LM has an MOU with USFWS. Amchitka Island is within the Aleutian Island Unit of the Alaska Maritime National Wildlife Refuge established in 1980 by President Carter. It was previously dedicated as a wildlife reserve created through an executive order by President William Howard Taft in 1913. The purpose of the MOU between LM and USFWS is to define the roles and responsibilities of both agencies, specify the means of access and egress to Amchitka Island, and explain how LM will exercise institutional controls. USFWS will issue access permits to LM in conjunction with the periodic monitoring and sampling events.

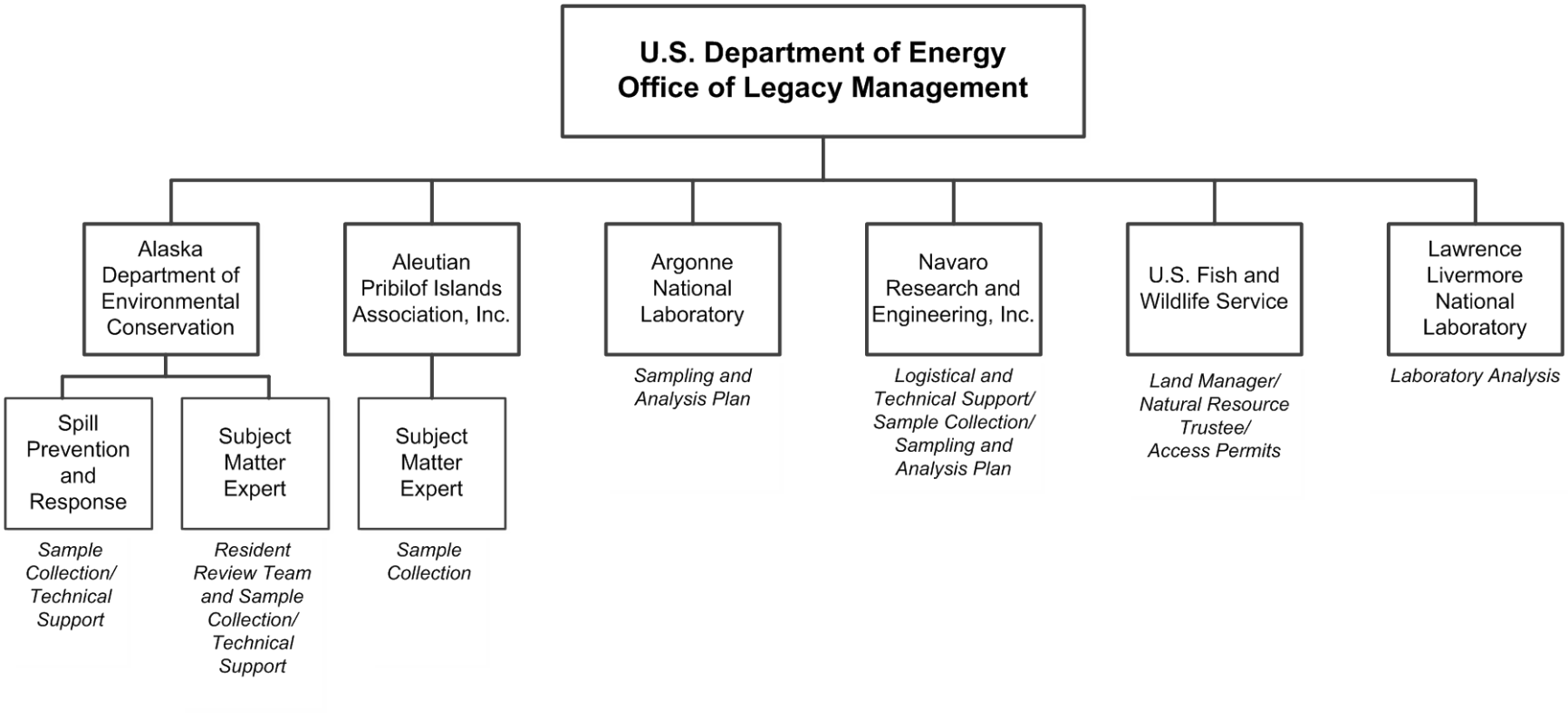

Figure 1. Organization Chart

4.0 Data Quality Objectives

Radioactive material remains in the subsurface environment in and adjacent to the test cavities at the three test sites on Amchitka Island. The data quality objectives (DQOs) described in this section provide a strategic planning approach that would generate adequate quantity and quality of data to support decisions regarding indications of leakage of the radioactive material from the test cavities. The seven steps that embody the planning for the collection of data are discussed in Section 4.1.

Food safety, specifically the consumption of subsistence seafood, has already been addressed in previous sampling events, the most recent of which was the 2011 sampling event completed by LM. The data from the 2011 sampling event and those of previous sampling events indicate that life-long consumption of seafood harvested near Amchitka Island is safe with respect to radionuclides.

The 2011 sampling event conducted by LM addressed the safety of seafood consumption by paying particular attention to available diet information and considering the species included in the diet and portions consumed. The diet information was used as the basis for the collection of samples and subsequent data interpretation including risk estimates. The risk estimates for the 2011 sampling event indicated that life-long consumption of subsistence seafood from Amchitka and Adak Islands yields a potential risk of below 1×10^{-5}, which is considered safe by ADEC. These risk estimates are expected to remain the same (i.e., safe) for a number of years based on the data collected to date and on the project hydrologic model, which showed that the potential for leakage from the test cavities is low, with potential breakthrough of radionuclides from the test sites as far out as 2,200 years in the future. The 2016 sampling event will provide new results to compare against the safe levels already found in 2011. As long as radionuclides from the test sites do not seep into the aquatic or terrestrial environments, the Amchitka Island sites radionuclides cannot adversely affect food safety.

The 2016 sampling event will include collection of seawater, freshwater, and biota data in response to the objective of determining leakage from the test cavities.

4.1 DQOs for Environmental Sampling

The seven steps associated with the development of the DQOs for the environmental sampling effort are presented below.

4.1.1 State the Problem

Radioactive materials remain in the subsurface cavities of the three test sites on Amchitka Island. Groundwater flow and transport modeling studies previously conducted for the three test sites on Amchitka Island indicate that breakthrough of radionuclides from the three test cavities could begin at the seafloor within 10 years of release from the cavity. However, the distribution of first-arrival times extends from 10 years to 2,200 years, and beyond (Hassan et al. 2002). In addition, the hydrologic model indicated that the shortest arrival times could occur at the Long Shot test site. Monitoring results are needed to provide another layer of information, beyond modeling results, to assure that site conditions remain protective of human health and the environment. The monitoring results will be used to assess whether leakage from the detonation cavities is indicated or not.

Seawater samples were collected along inferred offshore fault traces in 2011 and analyzed for ^{3}H. These ^{3}H data were incorporated into a baseline of information that will be trended against future (2016 and beyond) data. Results from the 2011 monitoring indicate that ^{3}H concentrations in seawater are low, similar to North Pacific regional concentrations (i.e., at no greater than 0.104 becquerel per liter (Bq/L) (2.8 picocuries per liter [pCi/L]) (DOE 2013). Therefore, no leakage has been indicated to date.

Biota sample concentrations in 2011 indicated that radionuclide levels were protective of the subsistence diet and were similar to levels found at the background reference location (Adak Island) (DOE 2013); 2016 data will be collected from resident fish species and rockweed identified in Table 1 to determine if there has been any statistically significant change in concentration. If increases are found, they could be an indication of possible leakage of radionuclides from the test cavities.

Following the atmospheric releases from the Fukushima Daiichi nuclear power plant in March 2011, the Amchitka Working Group questioned whether these releases might affect the ability to interpret background activity concentrations of target radionuclides from the Amchitka 2016 sampling event. To determine to what extent this direct release of radioactive materials into the atmosphere and seawater might be contributing to the background radiation on Amchitka and Adak Islands, semiquantitative gamma spectrometry measurements will be made during the data validation process. Therefore, all environmental samples collected are being tested for ^{134}Cs.

Table 1. Sample Types and Radionuclides Selected for Analysis

Sample Type	Cesium-134	Cesium-137	Plutonium-239	Plutonium-240	Tritium
Greenling (*Hexagrammos* spp.)[a]	X	X	X	X	NA
Rockfish (*Sebastes* spp.)[a]	X	X	X	X	NA
Irish lord (*Hemilepidotus* spp.)[a]	X	X	X	X	NA
Rockweed (*Fucus distichus*)[a]	X	X	X	X	NA
Dolly Varden (*Salvelinus malma*)[b]	X	X	X	X	NA
Seawater[a]	X	X	X	X	X[c]
Freshwater[b]	X	X	X	X	X

Notes:
[a] Collected from offshore at all three test sites and North and South Adak.
[b] Collected from Cannikin Lake and an Adak Island lake.
[c] Collected from offshore at all three test sites and North and South Adak and from offshore Long Shot Site.
Abbreviation:
NA = not applicable
spp. = species (more than one)

4.1.2 Identify the Decision

Data from water samples for the selected indicator nuclides (^{3}H and $^{134}Cs/^{137}Cs$) will be used to determine if leakage is indicated from the Long Shot area of potential release and for developing a baseline for future comparisons and trending analysis. The data will also be compared against North Pacific regional data.

Indicator nuclides (^{134}Cs, ^{137}Cs, ^{239}Pu, and ^{240}Pu) will be analyzed from biota collected to compare against 2011 data. As stated previously, these data will serve to provide affirmation of food safety in addition to providing an indication of leakage.

Indicator nuclides (^{3}H, ^{134}Cs, ^{137}Cs, ^{239}Pu, and ^{240}Pu) will be analyzed from seawater samples collected from all five transect locations and the freshwater samples from the two island lakes to compare analytical results to the biota and water samples.

Transect locations are defined as the near-shore areas of the Long Shot, Milrow, Cannikin, Adak North and Adak South locations. The area of the transect where biota and seawater samples will be collected extends from the shoreline to approximately 1,000 ft from the shoreline for approximately 3 miles along the shoreline. A seawater sample will be collected at approximately 1-mile increments over the 3-mile extent of each transect. Biota samples will be collected from the same general area the seawater samples are being collected from. Freshwater samples will be collected opportunistically from both island lakes.

4.1.3 Identify the Inputs to the Decision

The indication of potential leakage from water samples is addressed by:

- Collecting seawater samples from near-shore locations from all five transect locations and adjacent to the Long Shot test site and analyzing the samples for ^{3}H, ^{134}Cs, ^{137}Cs, ^{239}Pu, and ^{240}Pu.
- Collecting a freshwater sample from Cannikin Lake on Amchitka Island and an Adak Island lake and analyzing the samples for ^{3}H, ^{134}Cs, and ^{137}Cs.
- Collecting Dolly Varden fish from Cannikin Lake on Amchitka Island and an Adak Island lake and analyzing the samples for ^{134}Cs, ^{137}Cs, ^{239}Pu, and ^{240}Pu.
- Ensuring that laboratory methods are adequately sensitive to detect 0.01 Bq/L (0.3 pCi/L) or lower ^{3}H levels.
- Identifying North Pacific regional seawater data for ^{3}H, ^{134}Cs, and ^{137}Cs to compare to sample concentrations from Amchitka Island sites and Adak sites.
- Finding that Long Shot hot spot sample results for ^{3}H and or ^{137}Cs are equal to or exceed 200 millibecquerel per liter (mBq/L) (5.4 pCi/L) or 8 becquerel per cubic meter (Bq/m^3) (216 pCi/m^3), respectively.
- Collecting rockweed algae and greenling, rockfish, and Irish lords fish as indicator resident species to identify potential seepage and accumulation of test-related radionuclides. The fish species will be collected by hook-and-line catch off the coastline of the three Amchitka Island sites and off the north and south coastline of Adak Island (Table 2).
- In 2016, focusing on obtaining concentrations of ^{134}Cs, ^{137}Cs, ^{239}Pu, and ^{240}Pu in the biota samples collected.
- Ensuring an adequate number of samples from both Amchitka Island sites and Adak Island sites (Table 3).
- Sampling from appropriate locations (Figure 2 through Figure 5).
- Ensuring adequately sensitive analytical methods and detection limits.

Table 2. Sample Collection Philosophy

Sample to be Collected	Hook-and-Line, Fish Trap, or Netting	Collected by Hand from Land	From Vessel/Skiff/Inflatable
Greenling, rockfish, and Irish lord[a]	X	NA	X
Rockweed[a]	NA	X	X
Dolly Varden[b]	X	NA	X
Seawater[a]	NA	NA	X
Freshwater[b]	NA	X	NA

Notes:
[a] Collected from offshore at all three test sites and North and South Adak.
[b] Collected from Cannikin Lake and an Adak Island lake.
Abbreviation:
NA = not applicable

Table 3. Field Collection Sampling Requirements

Sampling Area/Type	Sample Wet Weight Needed (kg)	Average Weight per Species per Sample (kg)	Number of Specimens Required for Sample Weight Requirement[a]	Cannikin	Long Shot		Milrow	Adak North	Adak South	Total Number of Sample Locations
Ocean/Species										
Greenling	1	~0.5	1–3	10	10		10	10	10	50
Rockfish	1	~0.5	1–3	10	10		10	10	10	50
Irish lord	1	~0.5	1–3	10	10		10	10	10	50
									Total number of samples	**150**
Ocean/Seawater[b]										
Offshore	NA	NA	NA	3	43	4[c]	3	3	3	59
									Total number of samples	**59**
Marine Littoral Zone/Species										
Rockweed	5	~0.5	10	10	10		10	10	10	50
									Total number of samples	**50**
Terrestrial/Species										
Dolly Varden – Cannikin Lake and Adak Island lake	1	~0.25	12							2
									Total number of samples	**2**
Terrestrial/Freshwater[b]										
Cannikin Lake and an Adak Island lake										2
									Total number of samples	**2**
									TOTAL NUMBER OF SAMPLES TO BE COLLECTED	**263**

Notes:
[a] The number of fish per sample requirement is to collect enough fish of the same species so that when all the fish have been composited the total weight is 1 kilogram.
[b] Sample size is 1 L amber bottle and 20 L carboy.
[c] Duplicate samples.
Abbreviations:
kg = kilogram
NA = not applicable

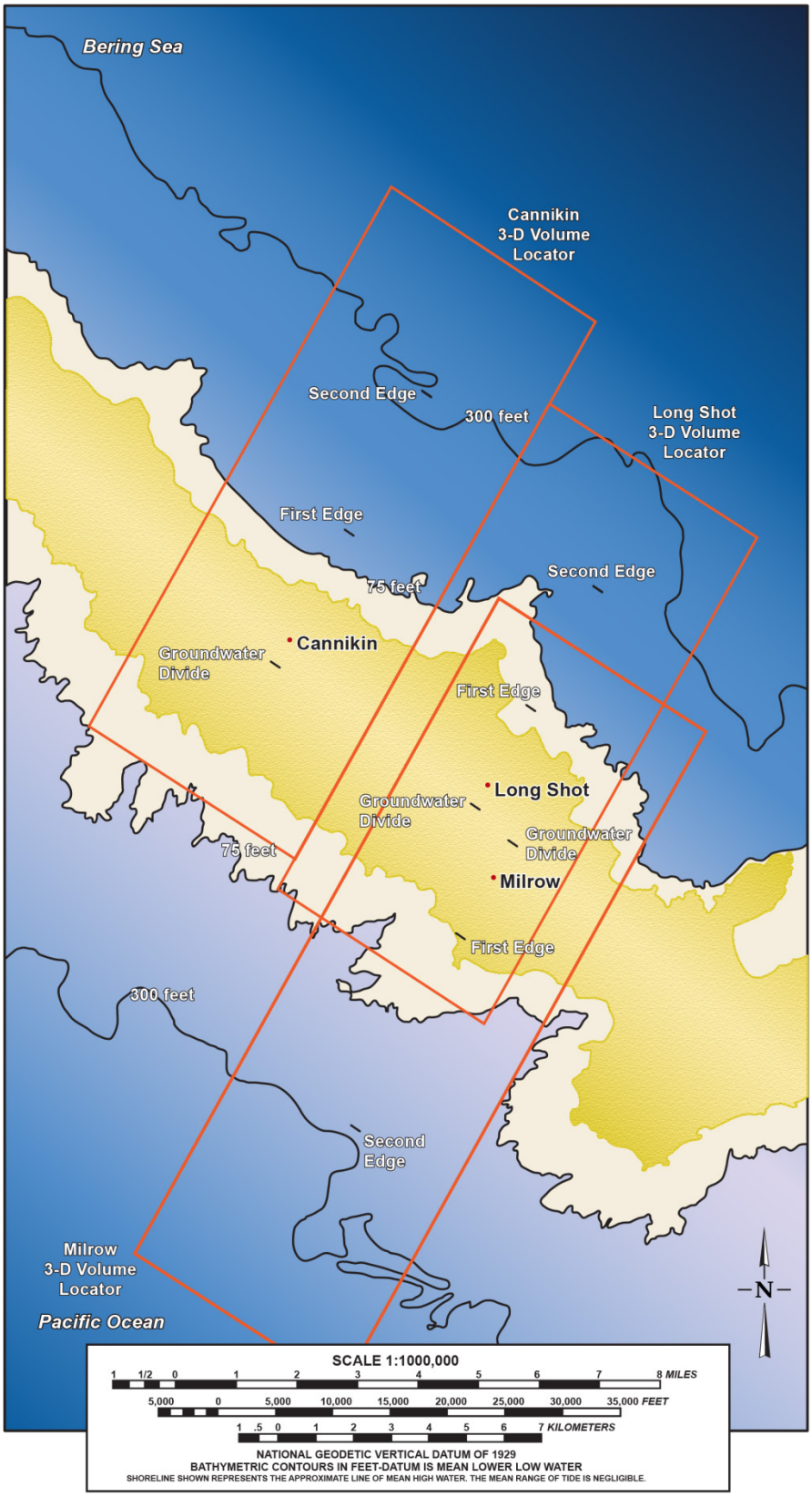

Figure 2. Locations of 3-D Volumes for the Three Areas of Potential Release

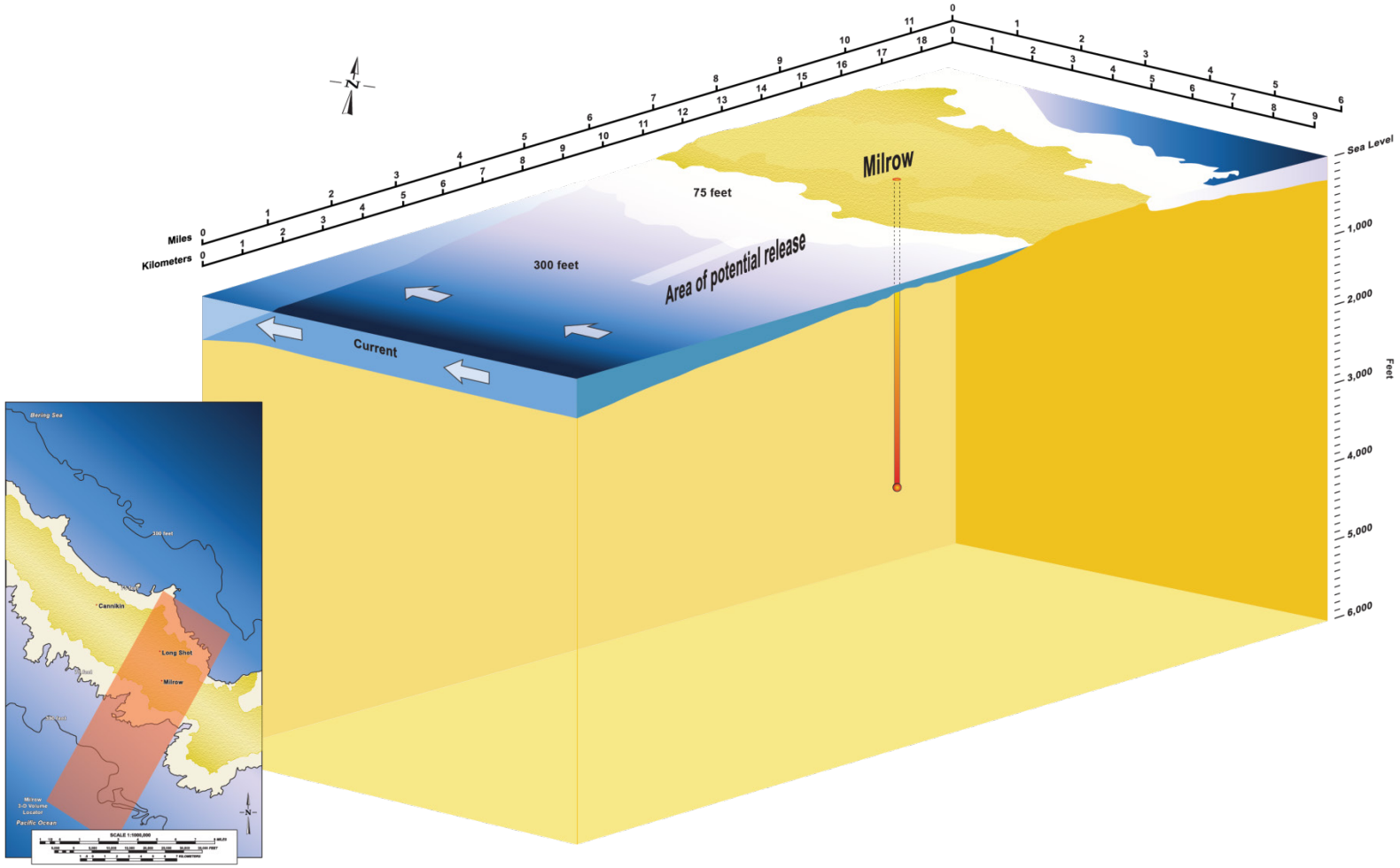

Figure 3. 3-D Volume Cutaway for Milrow

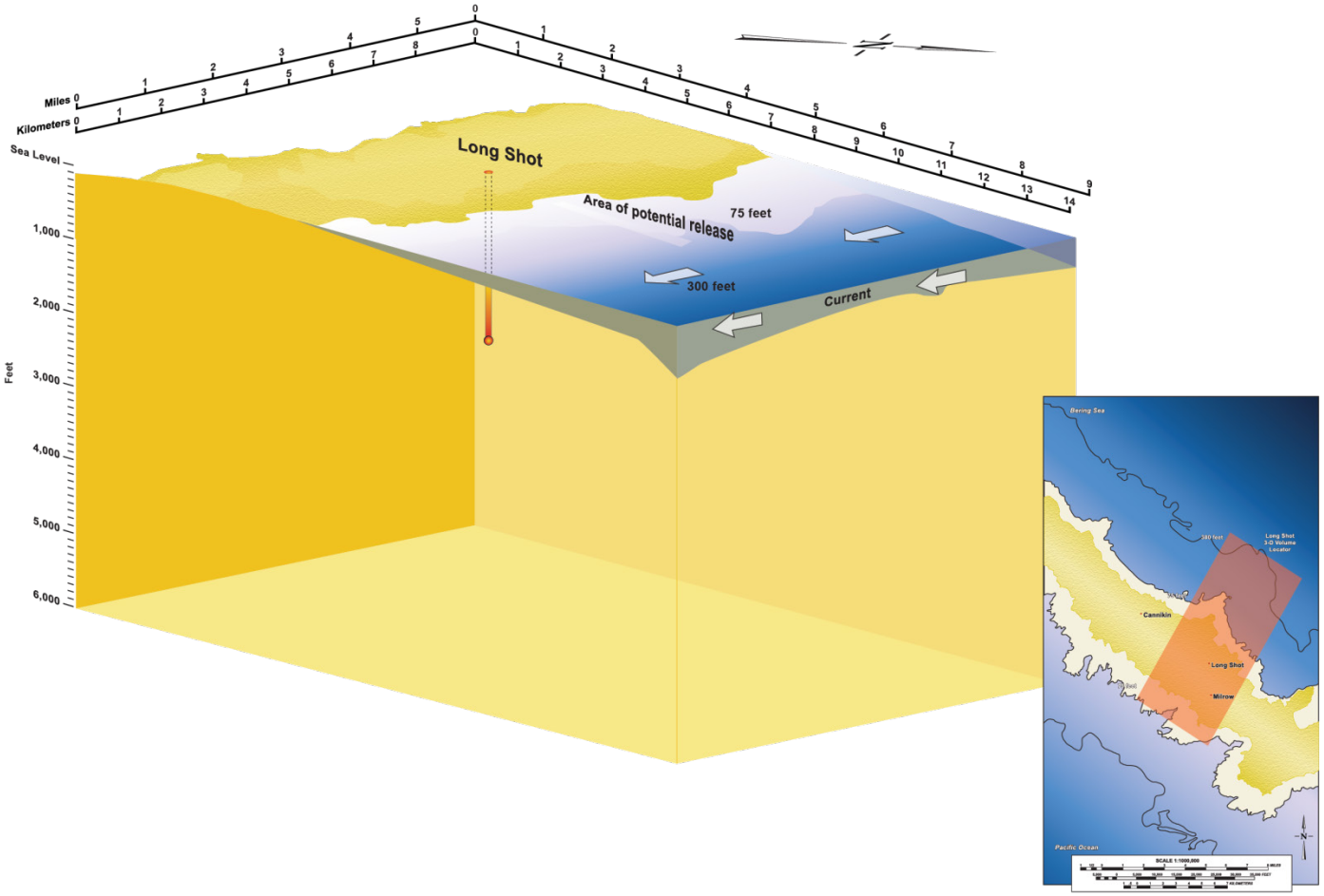

Figure 4. 3-D Volume Cutaway for Long Shot

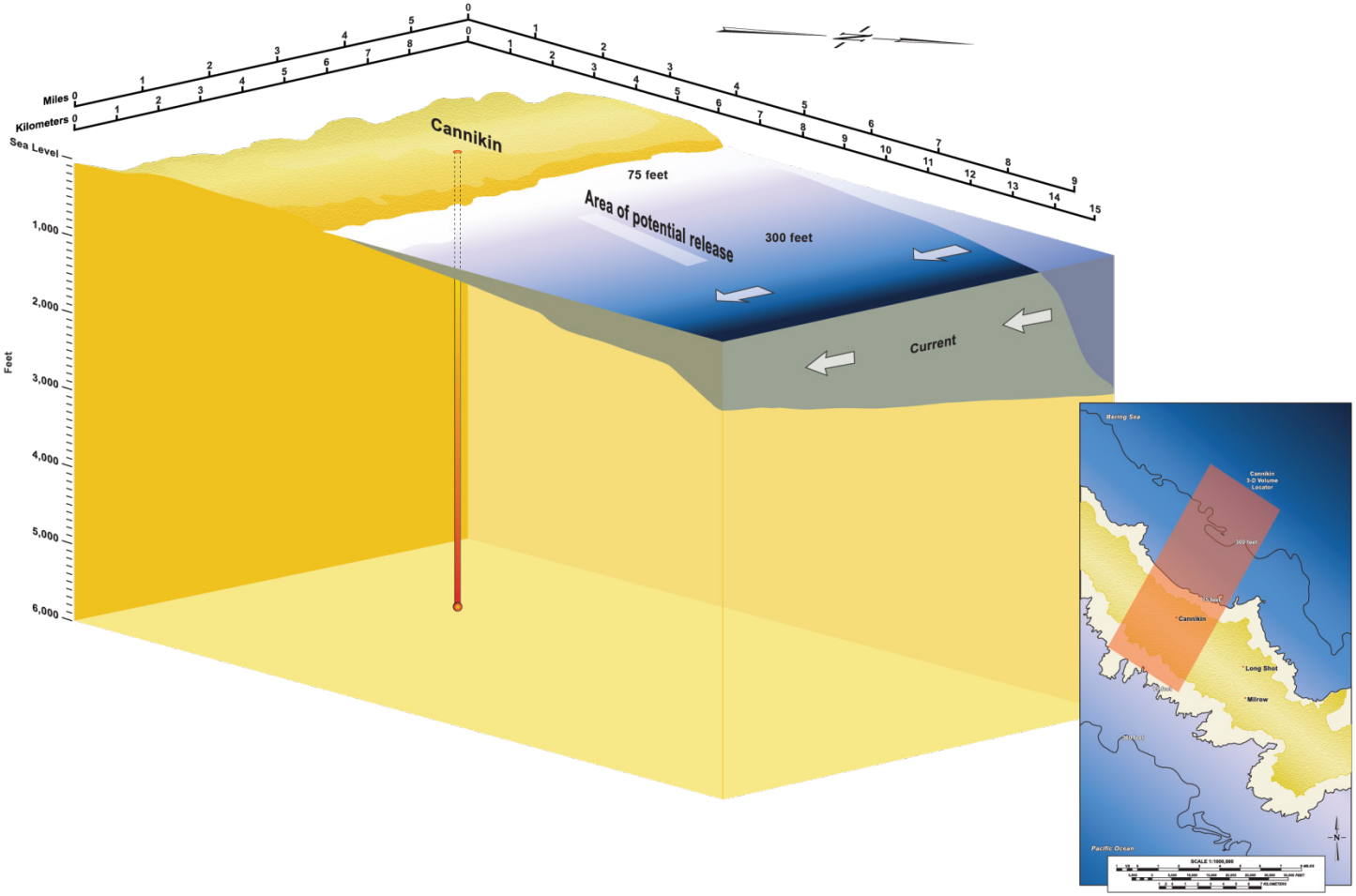

Figure 5. 3-D Volume Cutaway for Cannikin

4.1.4 Define the Study Boundaries

The Long Shot area of potential release boundary where seawater samples are proposed to be collected is presented in Figure 2. Comparison seawater samples will also be collected from all three detonation sites (Long Shot, Milrow, and Cannikin) and the reference area (Adak North and Adak South) and tested for the same radionuclides. In Figure 2, a first and second edge are depicted where the computer model predicts the distribution of the location of the plume edges (first and second edge) would be on the bathymetric profile; the first and second edge are equivalent to the computer model-predicted plume after accounting for matrix diffusion effects.

For the biota tissue sampling locations, in order to provide continuity and efficiency in data interpretation, the sampling locations at Amchitka and Adak Islands for 2016 will be the same as those sampled in 2011. Upon review, to support the planning for the 2016 sampling event, these sampling locations are still considered optimal.

4.1.5 Develop a Decision Rule

In the event that the Long Shot site seawater concentrations for ^{3}H and/or ^{137}Cs are detected respectively at concentrations of 200 mBq/L (5.4 pCi/L) or 8 Bq/m^3 (216 pCi/m^3) or greater, the working group will convene to discuss follow-up actions or investigations. If Long Shot seawater ^{3}H and ^{137}Cs concentrations are less than a priori established hot spot concentrations, the observed concentrations of ^{3}H, ^{134}Cs, and ^{137}Cs will be compared to North Pacific Regional data. A compilation of available data from various literature sources will be conducted to establish representative North Pacific regional values for use on this project. For ^{3}H, 2016 data will also be compared with 2011 ^{3}H data collected offshore from Cannikin.

If ^{3}H, ^{134}Cs, and ^{137}Cs concentrations in seawater from Long Shot are similar to North Pacific regional data, no further activity will be undertaken until the next sampling event. Radionuclide data collected will be documented in the project database as initial baseline concentrations. If the Amchitka Island sites radionuclide data are statistically higher than the North Pacific regional data but lower than the established hot spot concentration values, the working group will convene to discuss possible follow-up actions or investigations.

Radionuclide concentrations from rockweed and three fish species (greenling, rockfish, and Irish lord tissue) will be compared among sites and between years using analysis of variance (ANOVA), a statistical test used to test whether means (in this case, average concentrations) differ between two or more groups. Consistent with standard practice in the scientific community, a significance level of α (alpha) = 0.05 (5%) will be applied.

Because two independent (or explanatory) variables will be tested, location/island (Amchitka vs. Adak) and years (2016 vs. 2011), a two-way ANOVA will be applied. If this analysis yields a significant result (indicating that the mean activity concentrations from at least one of the group differ significantly from the others) a Tukey multiple comparisons test will be used to determine which group differs (e.g., 2016 ≠ 2011, Amchitka ≠ Adak, or both). Biota data and corresponding ANOVA test results will be evaluated as follows:

1. If the radionuclide concentrations measured in 2016 from the Amchitka Island sites are the same or lower than those measured in 2011 for rockweed, greenling, rockfish, and

Irish lord, the results would support a determination that leakage from the test cavities is not indicated. The 2016 data would be used to compare against future data.

2. If the Amchitka Island sites radionuclide concentrations measured in 2016 are higher than those measured in 2011 concentrations, but equal to or lower than corresponding 2016 Adak concentrations, these results would also support a conclusion that leakage from the test cavities is not indicated. The 2016 data would be compared against future data.
3. Finally, if radionuclide concentrations measured in biota from 2016 at Amchitka Island sites are higher than those measured in 2011 for rockweed, greenling, rockfish, and Irish lord, and higher than corresponding 2016 Adak data, the Amchitka Working Group will be notified to discuss the need for follow-up activities. These activities could include confirmatory reanalysis of samples and/or obtaining additional samples for analysis.

4.1.6 Specify Tolerance Limits on Decision Errors

The sampling plan is designed to support decisions for population estimates of radionuclide concentrations at a 95% confidence level. This confidence level in turn is used to determine the 95% confidence interval, the range of values or interval around the mean within which the true mean is expected to fall with the specified (95%) probability. Depending on the comparison (e.g., Amchitka 2016 vs. Amchitka 2011), a sample mean falling outside of (greater than) the specified 95% confidence interval might provide evidence of increased radionuclide concentrations and potential leakage from the test sites. However, such a result could also indicate sampling or measurement error, thereby warranting further evaluation and follow-up as described in Step 3 above (Section 4.1.5).

4.1.7 Optimize the Design

Power analyses, or statistical power calculations, are often used in experimental design. To optimize the 2016 sampling design, power analyses were performed to estimate required sample sizes based on historical (2011) results and expected or biologically relevant changes in the data. Power analysis for biological samples was performed for ^{137}Cs and two matrices (rockfish and rockweed) using the means and standard deviations reported in the 2011 Biological Monitoring Report (DOE 2013). For water samples, ^{3}H was considered. Power estimates were made using *GPower* v3.1 (http://www.gpower.hhu.de/).

For the biota samples, power was estimated using the two-way ANOVA (comparing islands and years for 2011 and 2016). Assumptions included equal variance, normal errors, and independence of replicates. Based on the variance in the 2011 data, and depending on the expected increase or change, the assumption of equal variance might be violated. If this is the case, the power estimates may underestimate the required sample size, which was a factor that was accounted for in the ultimate determination (Table 3). For ^{3}H in water samples, the power analysis was based on a two-way *t*-test assuming independent means and unequal variance (variance was conservatively assumed equal to the mean). Results of the power analyses (recommended sample sizes) support the sample sizes documented in Table 3.

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5.0 Sampling Elements

The following sampling elements will be described and developed for implementation in 2016 and be in accordance with the DQOs in Section 4.0 of this sampling plan.

5.1 Analytes

Analytes for the biota samples will be ^{134}Cs, ^{137}Cs, ^{239}Pu, and ^{240}Pu. Seawater and freshwater samples will be analyzed for ^{3}H, ^{134}Cs, and ^{137}Cs. Table 4 lists the analytes and the corresponding detection limits achieved by the analytical methods given.

Table 4. Laboratory Method and Estimated Minimum Detection Activity

Analytes	Laboratory Method	Estimated MDA (Bq)	A Priori MDC (Bq/kg-wet weight)[a]		
			Based on 100 g Sample	Based on 1,000 g Sample	Based on 5,000 g Sample
Biological Samples					
^{134}Cs	Gamma spectroscopy	0.3	3	0.3	0.06
^{137}Cs	Gamma spectroscopy	0.3	3	0.3	0.06
^{239}Pu	Quad ICP-MS	0.008	0.08	0.008	0.0016
^{240}Pu	Quad ICP-MS	0.02	0.2	0.02	0.004
^{239}Pu	AMS	0.00001	0.0001	0.00001	0.000002
^{240}Pu	AMS	0.00003	0.0003	0.00003	0.000006
Seawater and Freshwater Samples					
^{134}Cs	Gamma spectroscopy (SAGe)	0.006[b]	0.3[b]		
^{137}Cs	Gamma spectroscopy (SAGe)	0.003[b]	0.15[b]		
^{3}H	Electrolytic enrichment followed by gas proportional counting	0.01184[c]			

Notes:

[a] On the basis of the analytical methods identified in this table, a sample size of 0.1 kg on wet-weight basis is indicated to be adequate for the radionuclide concentrations of interest (see Table 1); however, to provide ample sample size and further optimize laboratory efficiency, a nominal sample size of 1 kg will be considered, as field conditions allow. Sample sizes indicated on Table 3 are considered realistic.

[b] Based on a 20-liter sample (Bq/m^3).

[c] Bq/L.

Abbreviations:

AMS = accelerator mass spectrometry
ICP-MS = inductively coupled mass spectrometry
g = gram
MDA = minimum detectable activity
MDC = minimum detectable concentration

5.2 Biota Sampling Locations and Sample Nomenclature

Figure 2 shows the proposed environmental sampling locations for Amchitka Island sites. Figure 6 and Figure 7 show the proposed environmental sampling locations for Adak Island, the

reference sampling location. For the Amchitka Island sample collection, each sampling location consists of two separate sample areas, the shoreline transect and the portion of the 3-D volume for each of the three areas of potential release (Cannikin, Milrow and Long Shot). For each sampling location, the shoreline transect extends for approximately 3 miles along the shoreline.

Sampling personnel working in skiffs will employ hook-and-line fishing, fish traps, or netting for sampling the shoreline transects. Hook and line fishing, fish traps, or netting will also occur from the ship in offshore areas. In addition, the terrestrial sampling will take place along the shoreline transects where sampling for algae will occur. Marine algae may also be collected from the skiff.

Figure 6 shows the locations for North Adak, and Figure 7 shows the locations for South Adak. The same general areas where samples were collected in 2011 will be sampled again in 2016. Sample areas along North Adak will take place from Blind Point on the east to Finger Bay on the west and includes Blind Cove and Scabbard Bay. Sample areas along South Adak include the entire Boot Bay area.

A standard labeling system will be followed for all specimens. The labels will take the following form:

[*Species or sample type*]-[*Site*]- [*Sample Number*]-[*Depth*]-[*Duplicate*]

Table 5 shows the labeling system to be used for sample identification.

Table 5. Labeling System

Sample Type	Sample Identification
Greenling (*Hexagrammos* spp.)	GREN-K (Kelp); GREN-R (Rock)
Rockfish (*Sebastes* spp.)	ROCK-B (Black); ROCK-D (Dusky)
Irish lord (*Hemilepidotus* spp.)	ILOR-R (Red); ILOR-Y (Yellow)
Rockweed (*Fucus distichus*)	FUCU
Dolly Varden (*Salvelinus malma*)	DOLL
Seawater	SEAW
Freshwater	FRES
Site Location	**Location Identifier**
Amchitka Island	AI
Adak Island	AD
Cannikin	CN
Long Shot	LS
Milrow	ML
Adak, North	AN
Adak, South	AS
Sample Number	
Sample Number	1 through 10
Depth	
Shallow	SH
Deep	DE
Duplicate	
Duplicate	DUP

Abbreviation:
spp. = species (more than one)

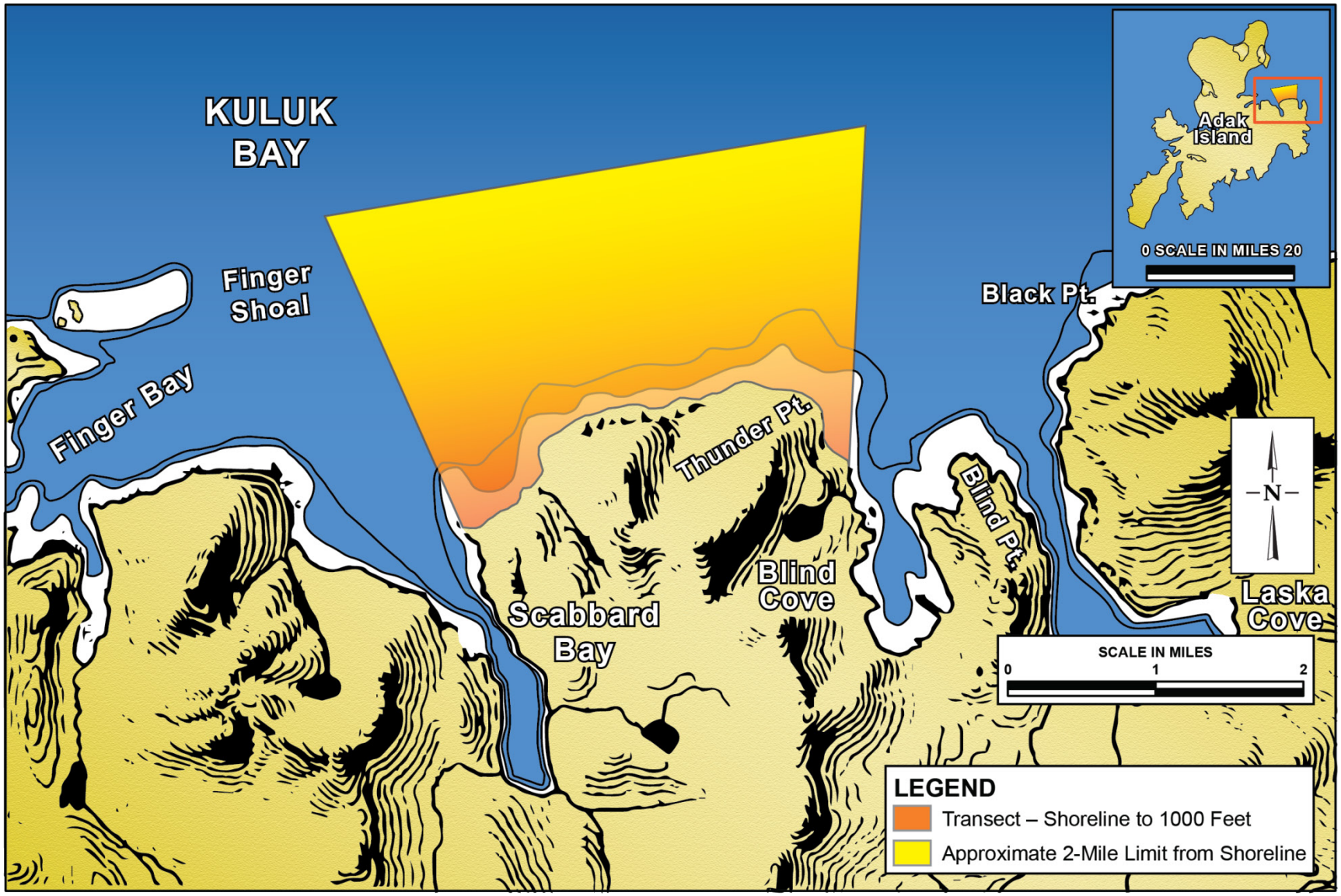

Figure 6. Background Reference Site: Adak Island (North), Alaska

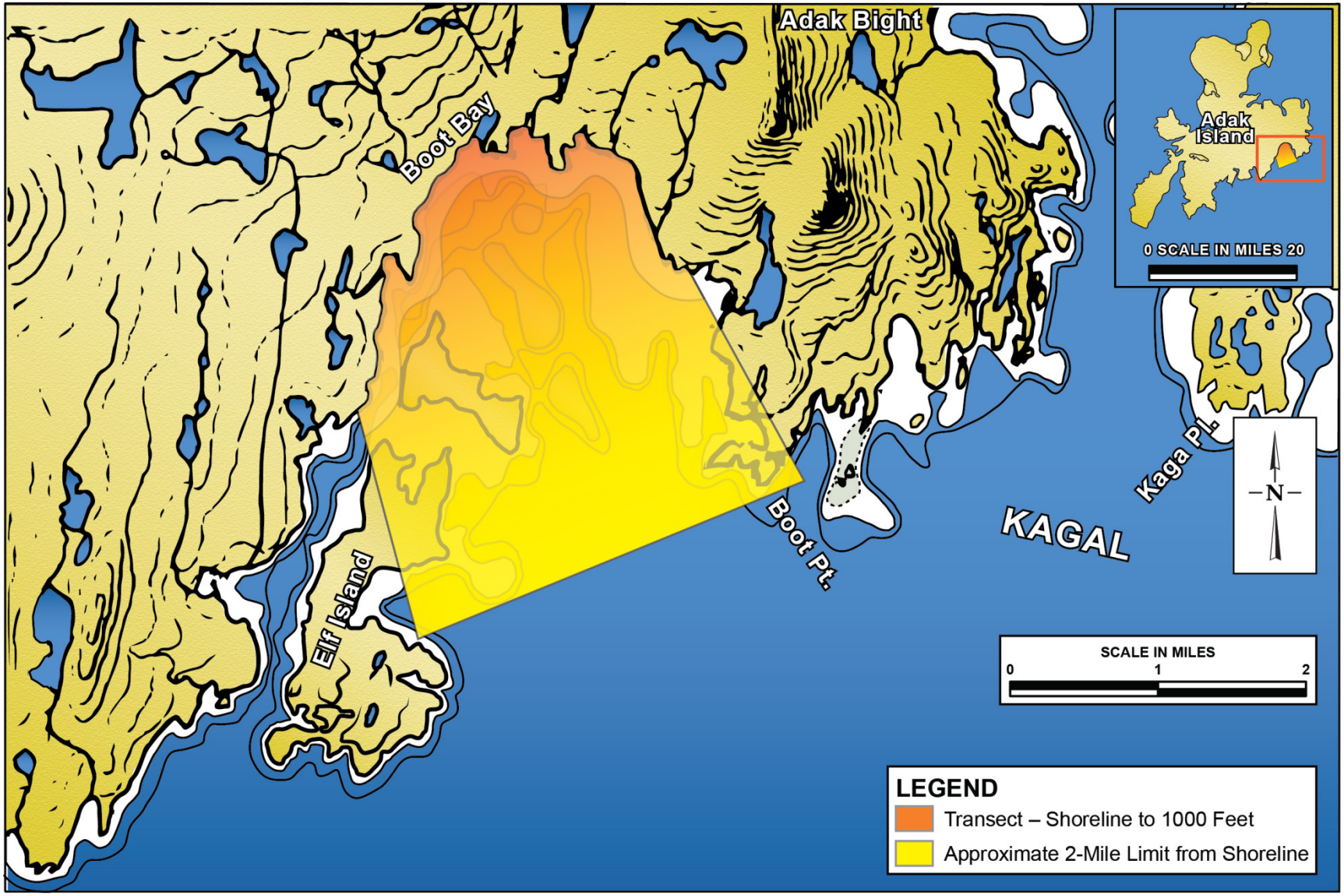

Figure 7. Background Reference Site: Adak Island (South), Alaska

For example:

- Shoreline sample collection personnel collect Rockweed from Cannikin. The entire plant is bagged and labeled "FUCU-CN-1."
- The sample collection personnel collect three black rockfish, four kelp greenlings, and seven Red Irish lords from the Long Shot site. The sample preparation personnel keep approximately 1 kilogram of each of the three species of fish caught and bag each species individually and label each bag as:
  - Rockfish, Black – "ROCK-B-LS-1."
  - Greenlings, Kelp – "GREN-K-LS-1."
  - Irish Lords, Red – "ILOR-R-LS-1."
- The charter vessel has moved to another location offshore of the Long Shot site and the sample collection personnel collect one dusky rockfish, three rock greenlings, and four yellow Irish lords. The sample preparation personnel keep the whole fish with a combined mass greater than 1 kilogram and label each bag as:
  - Rockfish, Dusky – "ROCK-D-LS-2."
  - Greenlings, Rock – "GREN-R-LS-2."
  - Irish Lords, Yellow – "ILOR-Y-LS-2."
- The charter vessel has moved to yet another location offshore of the Long Shot site and the sample collection personnel collect one black rockfish, three kelp greenlings, and four yellow Irish lords. The sample preparation personnel keep approximately 1 kilogram of each of the three species of fish caught and bag each species individually and label each bag as:
  - Rockfish, Black – "ROCK-B-LS-3."
  - Greenlings, Kelp – "GREN-K-LS-3."
  - Irish Lords, Yellow – "ILOR-Y-LS-3."
- Sample collection personnel collect five Dolly Varden from a lake on Amchitka Island. All five fish are bagged together and labeled "DOLL-AI-1."
- Sample collection personnel collecting seawater samples off the Long Shot site should refer to Table 7, second column, for location identification. All seawater samples from Long Shot are deep (e.g., LS-3-DE, LS-7-DE, LS-8-DE and so forth).
- Sample collection personnel collect a freshwater sample from Cannikin Lake. This sample is labeled "FRES-AI-1-SH."

5.3 Number and Size of Biota Samples

Biota samples will consist of freshwater landlocked Dolly Varden and marine waters greenling (kelp or rock) but will also contain rockfish (black or dusky) and Irish lords (red or yellow). Table 3 summarizes the number of samples for each species to be collected at the specified sampling locations. Table 3 also specifies the approximate wet weight needed to achieve the minimum detectable concentrations. All processed fish and algae samples will be frozen.

5.4 Field Sampling Methods

Table 6 summarizes the field sampling and handling procedures for the samples collected in 2016. The exact location of each sampling site will be noted using a GPS from the skiffs or from wherever the sampling team obtains the sample.

Field duplicates will be collected at a frequency of 10% for seawater samples. Field duplicates will be processed by the laboratory in the same way as all other samples.

5.4.1 Seawater Sampling Procedure from Vessel or Skiff

Seawater will be sampled from off the coastline of the Long Shot site and at each of the five transects sampled.

5.4.1.1 Long Shot Seawater Sampling

Seawater will be sampled from off the coastline of the Long Shot site to determine if leakage from the blast cavity might be occurring. In order to assess the possibility of leakage from the Long Shot cavity, a rotating panel design is used to determine the number of sample locations required off the coastline of Long Shot (McDonald, 2003). To have an 80% probability of locating an elliptical hot spot within the rectangle shown in Figure 8, with a height-to-width ratio of 0.2, oriented at an unknown angle, using point samples arranged in a triangular grid pattern, a maximum spacing of 580 ft between samples is needed. It is estimated that a random selection of 40 stations covering from the first edge to the furthest edge of the rectangular sampling area during each of LM's Amchitka environmental assessment survey for the next four surveys (2016, 2022, 2026, and 2031) will be required. Figure 8 shows the hot spot sample locations off the coast line of the Long Shot site, and Figure 9 is a more detailed depiction of the hot spot sample locations with the 2016 sample locations highlighted in blue. Appendix A includes the coordinates of all 126 hot spot sample locations, and Table 7 shows the Sample ID and locations of the 40 samples to be collected in 2016. If a proposed 2016 sample location cannot be sampled, an alternate sample location can be used from Appendix A and renumbered with an unused Sample ID from Table 7.

The per-sample volume requirement for the Long Shot seawater samples is 20 L. An ECO water sampler, or equivalent, with a six-bottle configuration (4 L/bottle capacity) will be deployed from the deck of the vessel to the desired depth. Appendix B provides information on the ECO water sampler and the portable instrumentation winch designed to optimize for real-time conductivity, temperature, and depth (CTD) measurements and water sample profiling to the desired anticipated depths off the coast of the Long Shot site. The CTD sampling process is described in more detail in Section 5.4.2.

Table 6. Field Sampling Procedures

	Species	Where	How Collected	Collection Procedure	Onboard Ship Handling	Comment
1.	Greenling (*Hexagrammos* spp.), rockfish (*Sebastes* spp.), and Irish lord (*Hemilepidotus* spp.)	Near-shore subtidal and offshore at all three test sites and North and South Adak	Hook-and-line, fish trap, or netting from charter vessel or skiff	For each transect, individual fish species are collected, though several fish may have to be composited to make up the 1 kg sample size. Because the sex typically cannot be readily determined when fish samples are harvested, the sampling objective is to minimize the size effect by compositing fish of similar size classes.	Once the fish are returned to the main vessel, they will be placed in a holding cooler for processing. Each fish will have its taxonomic identification checked, sex determined (if possible), length measured (total or fork length, dependent on the fish species) in centimeters (cm), and weight recorded in grams (g). Samples will be placed in plastic bags and labeled accordingly as one composite sample and kept frozen.	Radionuclide concentrations in fish can vary within a species, based on the size, age, and sex of the fish
2.	Rockweed (*Fucus distichus*)	Intertidal at all three test sites and North and South Adak	Sampling personnel from skiff	For each transect, three individual samples of the whole plants weighing approximately 5 kg each will be collected and composited. Epibiotic growth and residual sedimentary debris will be removed by shaking fronds in local seawater or onboard vessel in a large tub of seawater.	Onboard ship, composites will be placed separately in plastic bags, labeled, and frozen.	This alga is a good integrator of many radionuclides in the marine environment
3.	Dolly Varden (*Salvelinus malma*)	Cannikin Lake and an Adak Island lake	Hook-and-line, fish trap, or netting	The goal for one sample depending upon number and size of fish collected is 12 fish per lake.	Once the fish are returned to the main vessel, they will be placed in a holding tank for processing. Each fish will have its taxonomic identification checked, sex determined (if possible), length measured (total or fork length, dependent on the fish species) in centimeters, and weight recorded in grams. Samples will be placed in plastic bags and labeled accordingly as one composite sample and kept frozen.	Dolly Varden is to be sampled to determine long-term trends in ^{137}Cs and for statistical comparison with Dolly Varden from Adak Island lake (background)
4	Seawater	Offshore at all three test sites and North and South Adak	Sampling personnel from aboard charter vessel or skiff	Sample collection personnel will use an ECO water sampler, or equivalent, to fill a 20 L carboy per sample and a 1 L amber bottle. The carboy and bottle will be clean and dry, with good caps. Seawater collection from vessel or skiff is described in detail in Section 5.4.1. Duplicates will be collected only from Long Shot.	Container numbers will be recorded on original field data sheets, and information will be recorded on the container label. Samples will be unfiltered, and there must be no preservatives used. The samples will be kept cool.	Seawater samples will be collected from near the ocean bottom from the deck of the vessel off the coastline of Long Shot and from each of the five transects to determine if leakage is occurring and to compare to biota sample results
5.	Freshwater	Cannikin Lake and an Adak Island lake	Sampling personnel from land	Sample collection personnel will use a peristaltic pump to fill two 20 L carboys half full and a 1 L amber glass full. The carboys and bottle will be clean and dry, with good caps. Once back at the ship, the two half-full carboys will be combined into one 20 L carboy.	Container numbers will be recorded on original field data sheets, and information will be recorded on the bottle label. Samples will be unfiltered, and there must be no preservatives used. The samples will be kept cool.	Freshwater sample will be collected by hand from Cannikin Lake and an Adak Island lake to compare to seawater results

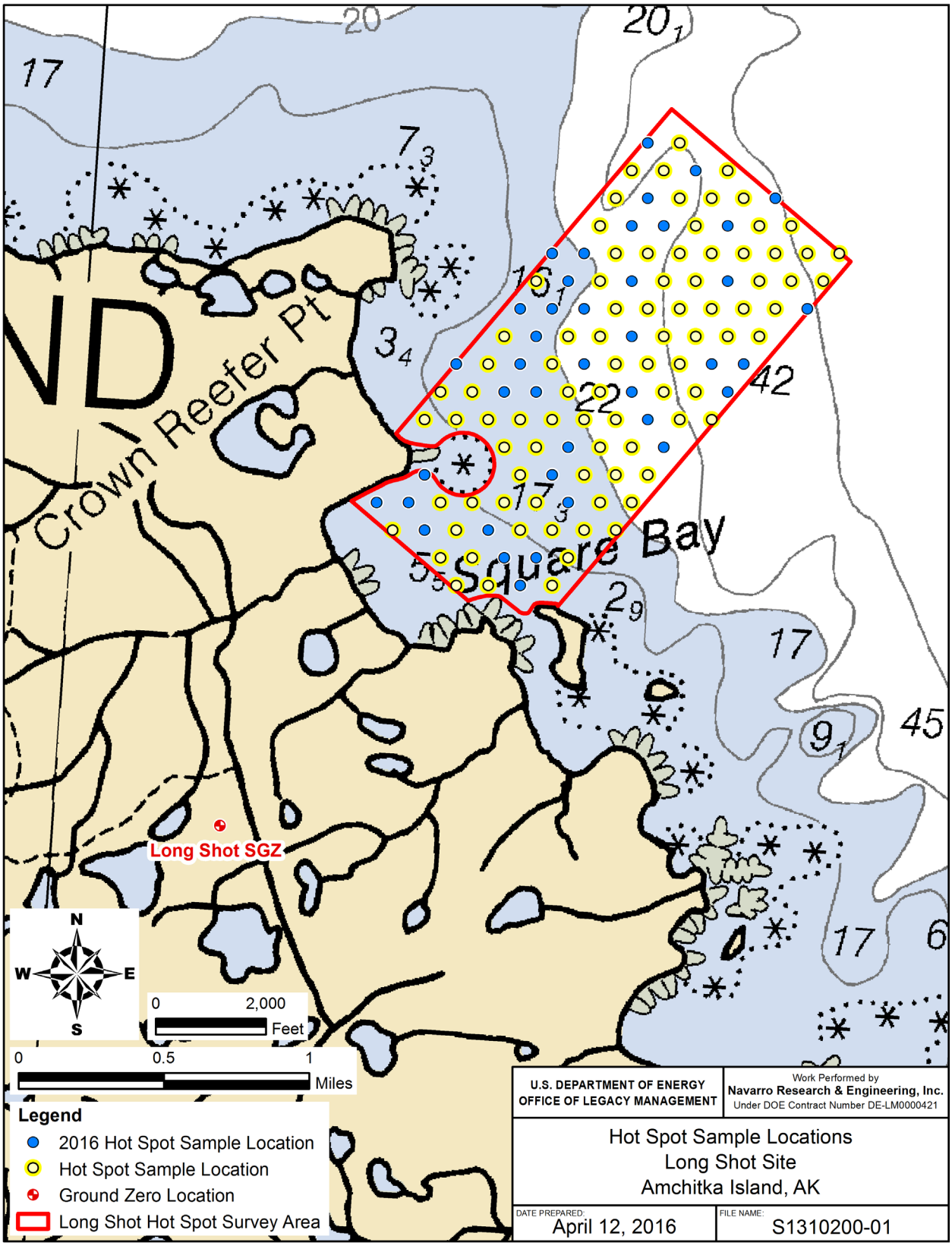

Figure 8. Long Shot Hot Spot Seawater Sample Locations

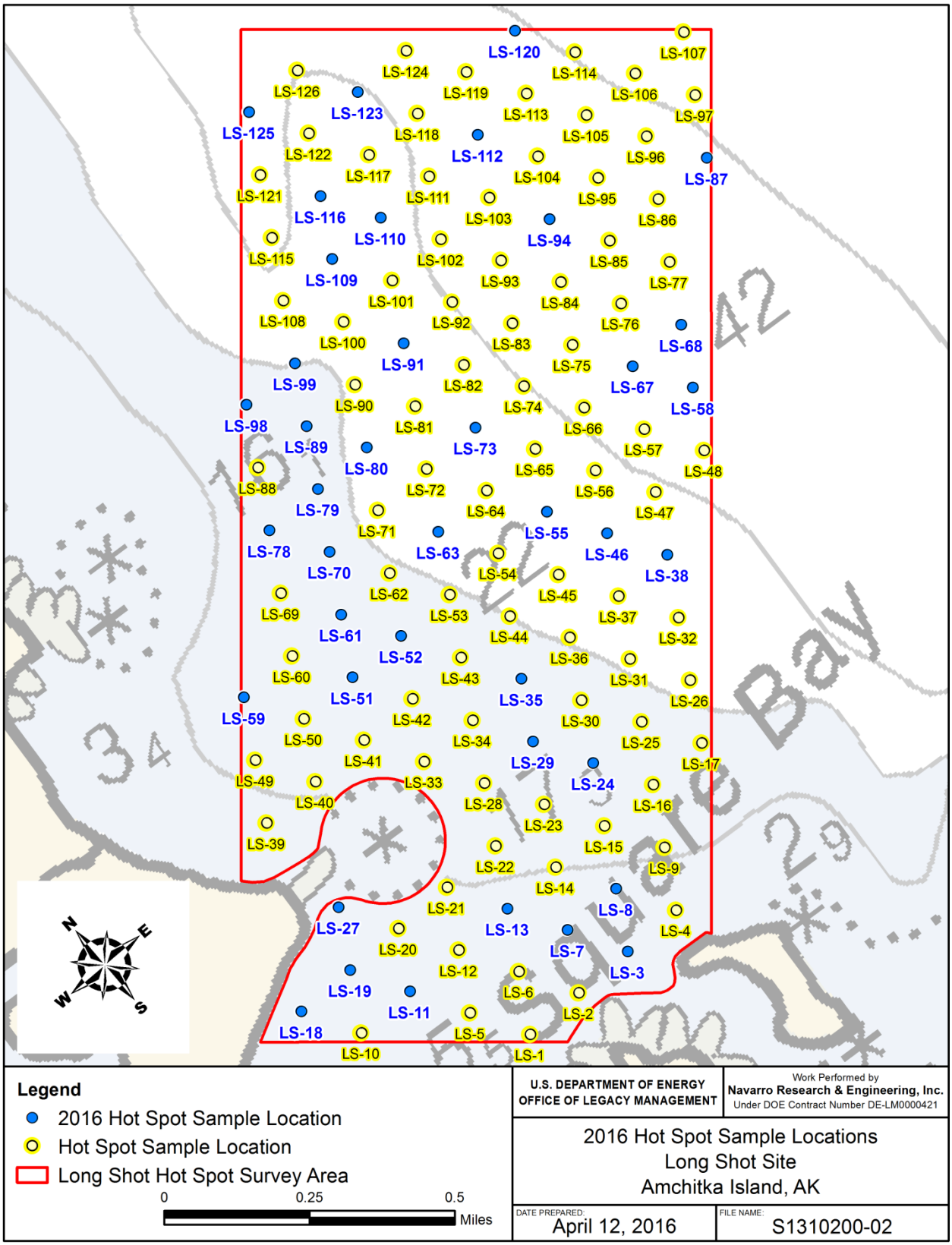

Figure 9. Long Shot Hot Spot Seawater Sample Identification Locations

Table 7. 2016 Long Shot Hot Spot Seawater Sample Coordinates

No. of Sample	Location SAP_2016	Latitude Decimal Degrees	Longitude Decimal Degrees
1	LS-3	51.4494912	179.2025663
2	LS-7	51.4508103	179.2011517
3	LS-8	51.4509162	179.2036874
4	LS-11	51.4519174	179.1946656
5	LS-13	51.4521294	179.1997371
6	LS-18	51.4531303	179.1907150
7	LS-19	51.4532364	179.1932507
8	LS-24	51.4537661	179.2059297
9	LS-27	51.4546615	179.1943716
10	LS-29	51.4550853	179.2045151
11	LS-35	51.4565103	179.2056364
12	LS-38	51.4568274	179.2132444
13	LS-46	51.4581467	179.2118299
14	LS-51	51.4590427	179.2002708
15	LS-52	51.4591486	179.2028069
16	LS-55	51.4594659	179.2104154
17	LS-58	51.4597828	179.2180239
18	LS-59	51.4602558	179.1963197
19	LS-61	51.4604677	179.2013921
20	LS-63	51.4606794	179.2064645
21	LS-67	51.4611021	179.2166095
22	LS-68	51.4612076	179.2191457
23	LS-70	51.4618927	179.2025134
24	LS-73	51.4622101	179.2101223
25	LS-78	51.4632118	179.2010984
26	LS-79	51.4633177	179.2036348
27	LS-80	51.4634235	179.2061711
28	LS-87	51.4641627	179.2239261
29	LS-89	51.4647427	179.2047562
30	LS-91	51.4649542	179.2098291
31	LS-94	51.4652711	179.2174386
32	LS-98	51.4660618	179.2033412
33	LS-99	51.4661677	179.2058778
34	LS-109	51.4676984	179.2095360
35	LS-110	51.4678041	179.2120726
36	LS-112	51.4680153	179.2171459
37	LS-116	51.4691233	179.2106577
38	LS-120	51.4695456	179.2208047
39	LS-123	51.4706539	179.2143164
40	LS-125	51.4718675	179.2103646

At each seawater sampling site, seawater samples will be collected approximately 5 meters (m) off the bottom. Depending on marine conditions, hazards, and water depth, the sampling may take place from the deck of the charter vessel or a smaller skiff. An inline filter may be used to reduce fine-grained particles from entering the sample containers. Sample containers will be 20 L carboys. In addition, a 1 L amber bottle will also be filled, unfiltered, for ^{3}H analysis.

All sample containers will be labeled with the sample number, location code, and date and wrapped with clear tape prior to field sampling. The sampling location will be confirmed to within 50 m (150 ft) with nondifferential GPS. The actual station depth will be confirmed with a depth finder on the boat. The appropriate number of Niskin bottles will be set for sampling at approximately 5 m (15 ft) off the bottom on a single line with a messenger to trip both bottles. The recovered Niskin bottles will be anchored to a holding board after the seawater samples are collected.

5.4.1.2 Transect Seawater Sampling

Seawater from each transect will be sampled to compare results to biota sampling results. Depending on marine conditions, hazards, and water depth, the sampling may take place from the deck of the charter vessel or a smaller skiff. If the large support vessel cannot access a station or transect site, the seawater sampling will be conducted from a small skiff. A 4 L or larger Niskin bottle(s) attached to a rope or wireline will be used to collect the seawater sample. Niskin bottle closing is triggered by a weighted messenger slid down the line. After retrieval, the seawater samples are composited on the skiff as necessary to make up the 20 L sample. Sample containers will be 20 L carboys. In addition, a 1 L amber bottle will also be filled, unfiltered, for ^{3}H analysis.

For the 1 L unfiltered amber bottle, sample transfer will occur outdoors as follows (adapted from the University of Miami Tritium Laboratory's (2009) advice on ^{3}H sampling):

a. Do not wear a wristwatch, compass, or similar device with luminescent dials or "beta" lights while taking samples.

b. Keep the Niskin bottle sealed, and withdraw the sample through the sampling tube on the side.

c. Rinse the bottle with sample water, and then fill the bottle using the tube near the bottom, slowly withdrawing as you fill it to leave air in the neck of the bottle, allowing for pressure changes during air shipment. Minimize air contamination.

d. Replace the cap, and screw it on tightly.

e. Record the bottle number and information on the field data sheets, double-checking it against the bottle label.

f. Wrap the bottle cap clockwise with electrical tape to help secure the cap for shipment.

g. Once sampling is completed, wrap the bottles in bubble wrap, and pack them securely.

h. Store the water sample at ~4° Celsius.

i. Initiate the chain-of-custody form when the sample enters storage.

j. Collect a field duplicate for every 10 samples in accordance with the procedures above.

5.4.2 Conductivity, Temperature, and Depth Sampling

The field seawater sampling activities will consist of obtaining a CTD instrument profile down the water column from surface to the water sampling point. An altimeter to measure distance from the bottom of the CTD instrument to the sea bed floor will also be used. Other sensor instruments, such as a pH meter, may also be included to measure additional water-column characteristics.

The CTD instrument will be deployed as part of a water sampling rosette of Niskin sampling bottles using the vessel's A-frame, crane, or suitably designed davit off the stern or side of the vessel on an electromechanical wireline allowing for deployment and recovery of the instrument. This provides for real-time data transmission between the CTD/rosette controller and computer. This allows the CTD profile to be observed during deployment and for immediate collection of the water sample when the desired distance from the seafloor has been achieved. The CTD instrument will be deployed and recovered from a stable deck stand allowing for ease of collection of the water samples.

The electromechanical cabling on the wench is connected by slip-ring to the CTD/rosette controller and computer-operated within an enclosed section of the vessel that provides for visual and audio communication with the operator during the winch deployment. See generic diagram in the attached ECO water sampler model SBE 55 brochure.

The instruments being considered for use are the ECO models ECO Winch, SBE 55, SBE 25 (CTD), and SBE 33 (controller), though these may be replaced with other similar instruments suitable for the same operations. Attachment A provides information on the SBE 55 and ECO Winch.

The vessel operator must provide experienced personnel for supporting the deployment operations, including a winch operator. Proper operational space deployment and storage of the CTD/rosette controller and winch (deck connections and electrical connections) for deck operations must be provided. Interior vessel facilities must be provided for the CTD/rosette operation controller and computer.

Vessel operators should provide information on prior experience with deployment and personnel support for CTD/rosette controller and winch deployment operations.

5.4.3 Freshwater Sampling Procedure

A sample of fresh water will be collected from Cannikin Lake and an Adak Island lake (the primary fish collection on Adak Island). The sample volume requirement for the freshwater sample from the lake is 20 L. A peristaltic pump, controller box, and associated tubing will be deployed from the shore to collect the sample. An inline filter may be used to reduce fine-grained particles from entering the sample containers. Sample containers will be 20 L carboys. In addition, a 1 L unfiltered water sample will be collected in an amber glass bottle, for ^{3}H analysis. A peristaltic pump may be used to collect the samples. To facilitate transport back to the ship, two 20 L carboys will be half-filled for easier handling and transport back to the ship. Once back at the ship, the two half-filled carboys will be combined into one 20 L carboy.

5.5 Laboratory Sample Handling and Analytical Methods

The samples will be sent to two laboratories for analysis. With the exception of the seawater samples, the majority of the samples will be sent to the Lawrence Livermore National Laboratory. The seawater samples will be sent to the University of Miami Tritium Laboratory for ^{3}H analysis. Generally, environmental samples will be labeled and sealed in plastic bags and frozen. Seawater and freshwater samples will be labeled and sealed in their respective sample containers.

5.6 Data Interpretation and Use

Data obtained from the analysis of environmental samples from the 2016 sampling event will be reviewed against quality assurance and quality control requirements and validated accordingly for inclusion in LM's database for the Amchitka Island project.

Representative statistics from applicable subsets of data, including the range, maximum, mean, and 95% upper confidence level, will be generated and compiled. Associated statistical information (e.g., standard deviation) will also be documented.

5.6.1 Environmental Data

Data statistics for the environmental samples collected for each of the site areas will be reviewed against previous data sets to determine whether the data are comparable to levels previously reported.

Initial observations or conclusions will be documented in the data report and used in the planning for the next sampling event (in 2021 or sooner as the results dictate).

5.6.2 Tritium Data from Seawater

The data collected will be documented in the database as initial baseline data. Comparisons will be made to the 2011 results and to literature data for the North Pacific region.

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6.0 Sampling Schedule

Table 8 presents the schedule for performing the on-island and environmental sampling tasks in 2016. No dates are provided as the actual schedule will depend upon the availability of the chartered vessel at the time of procurement. The window for this work will tentatively be from mid-May to early July 2016. The chartered vessel will depart its home port and travel to Adak, Alaska. Adak will be the pickup and drop-off point for the environmental sampling team.

Table 8. 2016 Schedule for Environmental Sampling

Task	Number of Days
Pick up Environmental Sampling Team	0
Charter vessel cruise from Adak to Amchitka	1
Perform operations off Cannikin site	4
Perform operations off Long Shot site	4
Perform operations off Milrow site	4
Charter vessel cruise from Amchitka to Adak	1
Perform operations off North Adak	4
Perform operations off South Adak	4
Charter vessel returns to Adak and drops off Sampling Team	0
Total number of days ship is required	**22**
Adak Island sampling	2

Commercial airline service is only available from Anchorage to Adak twice a week on Thursday and Sunday. A typical schedule will be as follows. The Environmental Sampling Team will arrive in Adak on a Thursday. Personnel and equipment will be transported from the airport to the pier, where the chartered vessel will be tied up and waiting to board passengers and equipment. Once passengers have boarded and equipment has been loaded onto the ship, the ship will get underway for the approximately 20-hour transit time from Adak to Amchitka Island. Upon arrival at Amchitka Island, the vessel will perform environmental sampling offshore of the Cannikin Site, then proceed to the Long shot site, and finally cruise over to the Milrow site. Once Amchitka Island sites have been sampled, the charter vessel will proceed to Adak Island to begin sampling the two locations there. Collection of Dolly Varden from a lake on Adak Island will be performed at the end of the project.

Regardless of where the environmental sampling starts or finishes, the chartered vessel is scheduled to be back in Adak approximately 22 days after the start date.

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7.0 References

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Appendix A

Long Shot All Hot Spot Seawater Sample Locations

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X	Y	Surface	Label	Type	Latitude	Longitude	Random_ Unique	Sap_ Location_2016
2,186,163.03	200,601.28	Floor	LS-1	Hotspot	51.44927932	179.1974951	84	
2,186,742.70	200,601.28	Floor	LS-2	Hotspot	51.44938528	179.2000307	77	
2,187,322.38	200,601.28	Floor	LS-3	Hotspot	51.44949118	179.2025663	35	YES
2,187,902.05	200,601.28	Floor	LS-4	Hotspot	51.44959703	179.2051019	85	
2,185,873.20	201,103.29	Floor	LS-5	Hotspot	51.45059838	179.1960804	92	
2,186,452.87	201,103.29	Floor	LS-6	Hotspot	51.45070437	179.1986161	64	
2,187,032.54	201,103.29	Floor	LS-7	Hotspot	51.4508103	179.2011517	27	YES
2,187,612.21	201,103.29	Floor	LS-8	Hotspot	51.45091618	179.2036874	40	YES
2,188,191.88	201,103.29	Floor	LS-9	Hotspot	51.451022	179.206223	72	
2,185,003.69	201,605.29	Floor	LS-10	Hotspot	51.45181134	179.1921299	125	
2,185,583.36	201,605.29	Floor	LS-11	Hotspot	51.45191741	179.1946656	25	YES
2,186,163.03	201,605.29	Floor	LS-12	Hotspot	51.45202343	179.1972013	111	
2,186,742.70	201,605.29	Floor	LS-13	Hotspot	51.4521294	179.1997371	18	YES
2,187,322.38	201,605.29	Floor	LS-14	Hotspot	51.45223531	179.2022728	61	
2,187,902.05	201,605.29	Floor	LS-15	Hotspot	51.45234116	179.2048085	126	
2,188,481.72	201,605.29	Floor	LS-16	Hotspot	51.45244696	179.2073443	87	
2,189,061.39	201,605.29	Floor	LS-17	Hotspot	51.4525527	179.20988	118	
2,184,713.86	202,107.30	Floor	LS-18	Hotspot	51.45313033	179.190715	29	YES
2,185,293.53	202,107.30	Floor	LS-19	Hotspot	51.45323643	179.1932507	10	YES
2,185,873.20	202,107.30	Floor	LS-20	Hotspot	51.45334248	179.1957865	121	
2,186,452.87	202,107.30	Floor	LS-21	Hotspot	51.45344848	179.1983223	69	
2,187,032.54	202,107.30	Floor	LS-22	Hotspot	51.45355442	179.2008581	101	
2,187,612.21	202,107.30	Floor	LS-23	Hotspot	51.4536603	179.2033939	105	
2,188,191.88	202,107.30	Floor	LS-24	Hotspot	51.45376613	179.2059297	1	YES
2,188,771.55	202,107.30	Floor	LS-25	Hotspot	51.45387191	179.2084656	41	
2,189,351.22	202,107.30	Floor	LS-26	Hotspot	51.45397762	179.2110014	46	
2,185,583.36	202,609.31	Floor	LS-27	Hotspot	51.45466152	179.1943716	2	YES
2,187,322.38	202,609.31	Floor	LS-28	Hotspot	51.45497943	179.2019792	123	
2,187,902.05	202,609.31	Floor	LS-29	Hotspot	51.45508529	179.2045151	30	YES
2,188,481.72	202,609.31	Floor	LS-30	Hotspot	51.4551911	179.207051	49	
2,189,061.39	202,609.31	Floor	LS-31	Hotspot	51.45529684	179.209587	65	
2,189,641.06	202,609.31	Floor	LS-32	Hotspot	51.45540253	179.2121229	103	
2,187,032.54	203,111.32	Floor	LS-33	Hotspot	51.45629854	179.2005645	93	
2,187,612.21	203,111.32	Floor	LS-34	Hotspot	51.45640443	179.2031004	99	
2,188,191.88	203,111.32	Floor	LS-35	Hotspot	51.45651027	179.2056364	31	YES
2,188,771.55	203,111.32	Floor	LS-36	Hotspot	51.45661605	179.2081724	89	
2,189,351.22	203,111.32	Floor	LS-37	Hotspot	51.45672177	179.2107084	51	
2,189,930.89	203,111.32	Floor	LS-38	Hotspot	51.45682744	179.2132444	23	YES
2,185,583.36	203,613.33	Floor	LS-39	Hotspot	51.45740562	179.1940776	63	
2,186,163.03	203,613.33	Floor	LS-40	Hotspot	51.45751166	179.1966136	58	
2,186,742.70	203,613.33	Floor	LS-41	Hotspot	51.45761764	179.1991496	82	
2,187,322.38	203,613.33	Floor	LS-42	Hotspot	51.45772356	179.2016857	55	

X	Y	Surface	Label	Type	Latitude	Longitude	Random_ Unique	Sap_ Location_2016
2,187,902.05	203,613.33	Floor	LS-43	Hotspot	51.45782942	179.2042217	106	
2,188,481.72	203,613.33	Floor	LS-44	Hotspot	51.45793523	179.2067578	96	
2,189,061.39	203,613.33	Floor	LS-45	Hotspot	51.45804099	179.2092938	43	
2,189,641.06	203,613.33	Floor	LS-46	Hotspot	51.45814669	179.2118299	24	YES
2,190,220.73	203,613.33	Floor	LS-47	Hotspot	51.45825233	179.214366	116	
2,190,800.40	203,613.33	Floor	LS-48	Hotspot	51.45835792	179.2169021	112	
2,185,873.20	204,115.34	Floor	LS-49	Hotspot	51.4588307	179.1951986	62	
2,186,452.87	204,115.34	Floor	LS-50	Hotspot	51.45893671	179.1977347	56	
2,187,032.54	204,115.34	Floor	LS-51	Hotspot	51.45904267	179.2002708	3	YES
2,187,612.21	204,115.34	Floor	LS-52	Hotspot	51.45914856	179.2028069	8	YES
2,188,191.88	204,115.34	Floor	LS-53	Hotspot	51.4592544	179.2053431	59	
2,188,771.55	204,115.34	Floor	LS-54	Hotspot	51.45936019	179.2078792	76	
2,189,351.22	204,115.34	Floor	LS-55	Hotspot	51.45946592	179.2104154	37	YES
2,189,930.89	204,115.34	Floor	LS-56	Hotspot	51.45957159	179.2129515	60	
2,190,510.56	204,115.34	Floor	LS-57	Hotspot	51.45967721	179.2154877	120	
2,191,090.23	204,115.34	Floor	LS-58	Hotspot	51.45978277	179.2180239	19	YES
2,186,163.03	204,617.35	Floor	LS-59	Hotspot	51.46025577	179.1963197	20	YES
2,186,742.70	204,617.35	Floor	LS-60	Hotspot	51.46036176	179.1988559	90	
2,187,322.38	204,617.35	Floor	LS-61	Hotspot	51.46046769	179.2013921	32	YES
2,187,902.05	204,617.35	Floor	LS-62	Hotspot	51.46057356	179.2039283	94	
2,188,481.72	204,617.35	Floor	LS-63	Hotspot	51.46067937	179.2064645	14	YES
2,189,061.39	204,617.35	Floor	LS-64	Hotspot	51.46078514	179.2090007	44	
2,189,641.06	204,617.35	Floor	LS-65	Hotspot	51.46089084	179.2115369	80	
2,190,220.73	204,617.35	Floor	LS-66	Hotspot	51.46099649	179.2140732	53	
2,190,800.40	204,617.35	Floor	LS-67	Hotspot	51.46110208	179.2166095	4	YES
2,191,380.07	204,617.35	Floor	LS-68	Hotspot	51.46120762	179.2191457	28	YES
2,187,032.54	205,119.36	Floor	LS-69	Hotspot	51.46178679	179.1999771	113	
2,187,612.21	205,119.36	Floor	LS-70	Hotspot	51.46189269	179.2025134	7	YES
2,188,191.88	205,119.36	Floor	LS-71	Hotspot	51.46199854	179.2050497	73	
2,188,771.55	205,119.36	Floor	LS-72	Hotspot	51.46210433	179.207586	88	
2,189,351.22	205,119.36	Floor	LS-73	Hotspot	51.46221007	179.2101223	5	YES
2,189,930.89	205,119.36	Floor	LS-74	Hotspot	51.46231575	179.2126586	107	
2,190,510.56	205,119.36	Floor	LS-75	Hotspot	51.46242137	179.2151949	104	
2,191,090.23	205,119.36	Floor	LS-76	Hotspot	51.46252694	179.2177313	110	
2,191,669.91	205,119.36	Floor	LS-77	Hotspot	51.46263246	179.2202676	45	
2,187,322.38	205,621.37	Floor	LS-78	Hotspot	51.46321181	179.2010984	33	YES
2,187,902.05	205,621.37	Floor	LS-79	Hotspot	51.46331769	179.2036348	39	YES
2,188,481.72	205,621.37	Floor	LS-80	Hotspot	51.46342352	179.2061711	6	YES
2,189,061.39	205,621.37	Floor	LS-81	Hotspot	51.46352928	179.2087075	102	
2,189,641.06	205,621.37	Floor	LS-82	Hotspot	51.46363499	179.2112439	50	
2,190,220.73	205,621.37	Floor	LS-83	Hotspot	51.46374065	179.2137803	66	
2,190,800.40	205,621.37	Floor	LS-84	Hotspot	51.46384625	179.2163167	54	

X	Y	Surface	Label	Type	Latitude	Longitude	Random_ Unique	Sap_ Location_2016
2,191,380.07	205,621.37	Floor	LS-85	Hotspot	51.46395179	179.2188532	114	
2,191,959.74	205,621.37	Floor	LS-86	Hotspot	51.46405728	179.2213896	115	
2,192,539.41	205,621.37	Floor	LS-87	Hotspot	51.46416271	179.2239261	13	YES
2,187,612.21	206,123.38	Floor	LS-88	Hotspot	51.46463683	179.2022198	74	
2,188,191.88	206,123.38	Floor	LS-89	Hotspot	51.46474268	179.2047562	11	YES
2,188,771.55	206,123.38	Floor	LS-90	Hotspot	51.46484848	179.2072927	108	
2,189,351.22	206,123.38	Floor	LS-91	Hotspot	51.46495422	179.2098291	17	YES
2,189,930.89	206,123.38	Floor	LS-92	Hotspot	51.46505991	179.2123656	83	
2,190,510.56	206,123.38	Floor	LS-93	Hotspot	51.46516554	179.2149021	117	
2,191,090.23	206,123.38	Floor	LS-94	Hotspot	51.46527111	179.2174386	9	YES
2,191,669.91	206,123.38	Floor	LS-95	Hotspot	51.46537663	179.2199751	91	
2,192,249.58	206,123.38	Floor	LS-96	Hotspot	51.4654821	179.2225116	78	
2,192,829.25	206,123.38	Floor	LS-97	Hotspot	51.4655875	179.2250482	124	
2,187,902.05	206,625.39	Floor	LS-98	Hotspot	51.46606183	179.2033412	34	YES
2,188,481.72	206,625.39	Floor	LS-99	Hotspot	51.46616766	179.2058778	26	YES
2,189,061.39	206,625.39	Floor	LS-100	Hotspot	51.46627343	179.2084143	75	
2,189,641.06	206,625.39	Floor	LS-101	Hotspot	51.46637915	179.2109508	86	
2,190,220.73	206,625.39	Floor	LS-102	Hotspot	51.46648481	179.2134874	109	
2,190,800.40	206,625.39	Floor	LS-103	Hotspot	51.46659042	179.216024	79	
2,191,380.07	206,625.39	Floor	LS-104	Hotspot	51.46669597	179.2185606	100	
2,191,959.74	206,625.39	Floor	LS-105	Hotspot	51.46680146	179.2210972	47	
2,192,539.41	206,625.39	Floor	LS-106	Hotspot	51.4669069	179.2236338	97	
2,193,119.08	206,625.39	Floor	LS-107	Hotspot	51.46701228	179.2261704	70	
2,188,771.55	207,127.40	Floor	LS-108	Hotspot	51.46759263	179.2069994	71	
2,189,351.22	207,127.40	Floor	LS-109	Hotspot	51.46769837	179.209536	21	YES
2,189,930.89	207,127.40	Floor	LS-110	Hotspot	51.46780407	179.2120726	36	YES
2,190,510.56	207,127.40	Floor	LS-111	Hotspot	51.46790971	179.2146093	52	
2,191,090.23	207,127.40	Floor	LS-112	Hotspot	51.46801529	179.2171459	38	YES
2,191,669.91	207,127.40	Floor	LS-113	Hotspot	51.46812081	179.2196826	42	
2,192,249.58	207,127.40	Floor	LS-114	Hotspot	51.46822628	179.2222193	67	
2,189,061.39	207,629.41	Floor	LS-115	Hotspot	51.46901758	179.208121	48	
2,189,641.06	207,629.41	Floor	LS-116	Hotspot	51.46912331	179.2106577	22	YES
2,190,220.73	207,629.41	Floor	LS-117	Hotspot	51.46922898	179.2131945	122	
2,190,800.40	207,629.41	Floor	LS-118	Hotspot	51.46933459	179.2157312	68	
2,191,380.07	207,629.41	Floor	LS-119	Hotspot	51.46944014	179.2182679	98	
2,191,959.74	207,629.41	Floor	LS-120	Hotspot	51.46954565	179.2208047	15	YES
2,189,351.22	208,131.42	Floor	LS-121	Hotspot	51.47044253	179.2092428	95	
2,189,930.89	208,131.42	Floor	LS-122	Hotspot	51.47054823	179.2117796	81	
2,190,510.56	208,131.42	Floor	LS-123	Hotspot	51.47065387	179.2143164	12	YES
2,191,090.23	208,131.42	Floor	LS-124	Hotspot	51.47075946	179.2168532	119	
2,189,641.06	208,633.43	Floor	LS-125	Hotspot	51.47186746	179.2103646	16	YES
2,190,220.73	208,633.43	Floor	LS-126	Hotspot	51.47197314	179.2129015	57	

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Appendix B

Seawater Sampling Information

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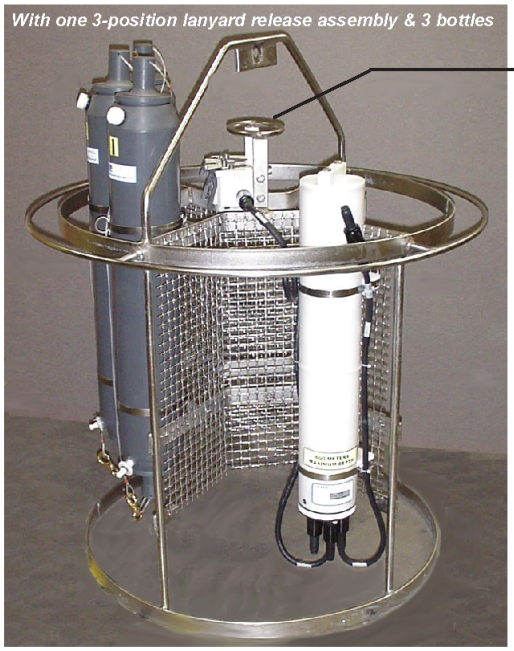
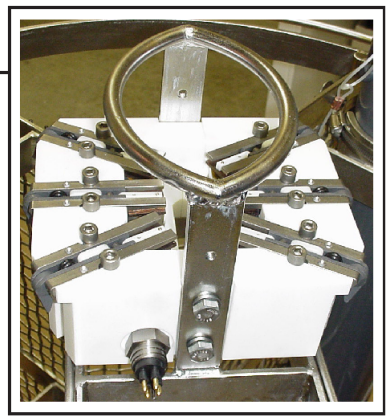
ECO Water Sampler

SBE 55



With one 3-position lanyard release assembly & 3 bottles



Configured with two 3-position lanyard release assemblies (for 6 bottles)

SUMMARY

- Small, lightweight, robust water sampler package with open structure for better flushing and less drag
- Three or six 4-liter bottles
- Integrates with Sea-Bird CTDs
- Autonomous (pre-programmed) or real-time data acquisition and water sampling; bottle firing in any order
- Depths to 600 meters

DESCRIPTION

The ECO is the ideal small-boat water sampler for coastal, estuarine, and large lake ecological monitoring. The ECO is light and economical and can be integrated with an SBE 19, 19*plus*, 19*plus* V2, 25, 25*plus*, or 49* CTD. It is available in a three- or six-bottle configuration with 4-liter ECO sample bottles, uniquely designed for the ECO. The ECO can operate autonomously on internal batteries and be programmed to close bottles at selected depths, allowing deployment using non-electrical wire or line. It also can be used with an SBE 33 Carousel Deck Unit for real-time CTD data acquisition and water sampling. Real-time operation requires an electro-mechanical cable and slip-ring equipped winch.
(*Note: SBE 49 integration for real-time operation only.)

The bottle closing mechanism is a magnetically actuated lanyard release latch derived from the SBE 32 Carousel Water Sampler, with a long history of reliability and ease-of-use. Lanyards are rigged to hold bottles open when attached to the release latches. A pressure-proof electromagnet is energized on command to trigger a lanyard release, allowing the bottle to close. The ECO has one or two 3-position lanyard release assemblies. Each release assembly is connected to the ECO's Electronics Control Module by a separate cable, allowing easy do-it-yourself expansion from a three- to a six-bottle system.

The ECO includes the Electronics Control Module (ECM), one or two lanyard release assemblies, three or six 4-liter ECO sample bottles mounted in saddle brackets and fastened with band clamps, stainless steel guard frame with integral lifting bail, and mesh panels for mounting the ECM, CTD, and other sensors that may be integrated with the CTD (e.g., dissolved oxygen sensor, fluorometer, turbidity sensor, etc.). CTD mounting brackets and interface cable, auxiliary sensors, and (for real-time operation) SBE 33 Carousel Deck Unit are ordered separately.

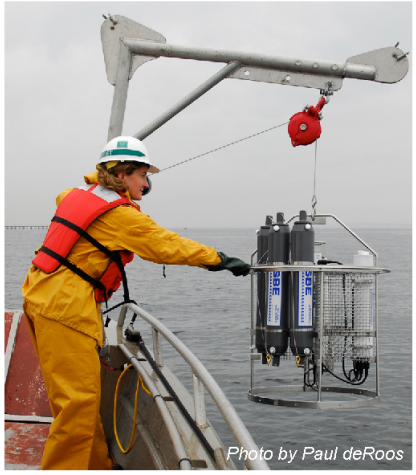


Photo by Paul deRoos

SOFTWARE

Seasoft© V2, our complete Windows software package, is included at no extra charge. Seasoft's modular programs include:

- Seaterm, SeatermAF, SeatermV2 – terminal programs for setup and data upload.
- Seasave V7 – real-time data acquisition and simultaneous keyboard control of bottle firing.
- SBE Data Processing – filtering, aligning, averaging, and display of CTD and auxiliary sensor data and derived variables.

Sea-Bird Electronics, Inc.
13431 NE 20th Street, Bellevue, Washington 98005 USA
Website: www.seabird.com

Email: seabird@seabird.com
Telephone: +1 425-643-9866
Fax: +1 425-643-9954

ECO Water Sampler

SBE 55

WATER SAMPLER CONTROL

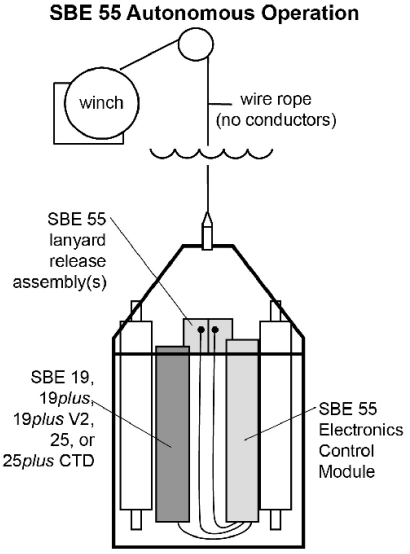
Autonomous Operation (wire rope only, no electromechanical cable required)

The ECO's Electronics Control Module provides power to and programmable control of the water sampler:

- With an SBE 19, 19*plus*, 19*plus* V2, 25, or 25*plus* CTD, the ECO monitors pressure data and fires bottles at user-programmed pressures or depths. It also records bottle number, firing confirmation, and 5 scans of instrument data for each bottle.
- Without a CTD, the ECO fires bottles at user-programmed elapsed times, and records bottle number and firing confirmation for each bottle fired.

At the end of a cast, data from the CTD and the bottle summary file from the ECO are uploaded using the software provided. Nine high-quality alkaline D-size cells (LR-20) provide several months of daily operation (rechargeable Ni-MH batteries also available).

SBE 55 Autonomous Operation

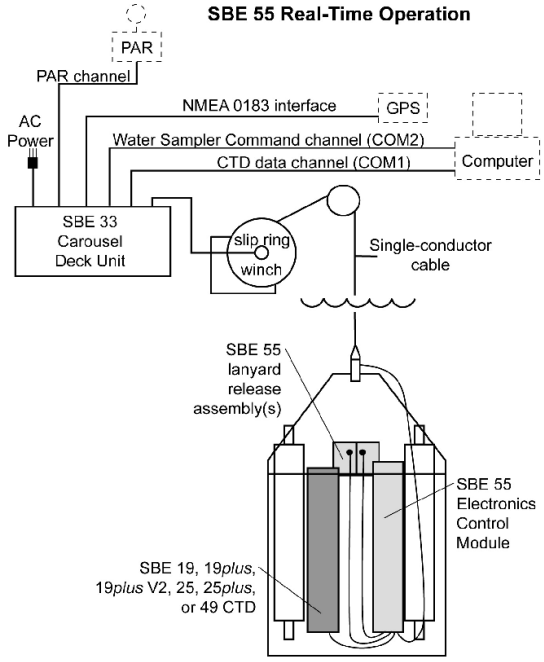


Real-Time Operation via Electromechanical Cable

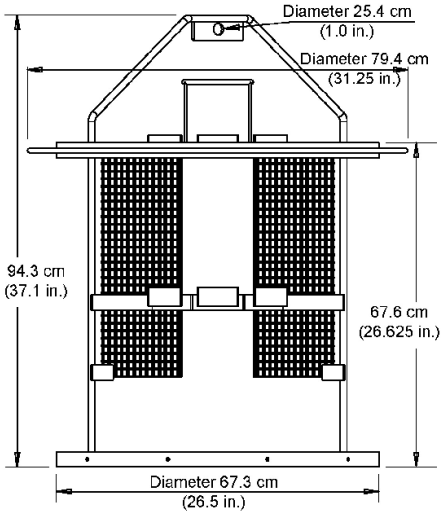
The ECO's Electronics Control Module can be connected to a winch cable for real-time use. Users can switch from autonomous to real-time operation at any time by connecting the winch cable to the ECM, and connecting the SBE 33 Carousel Deck Unit to AC power and the winch slip rings. This enables real-time CTD data acquisition and water sampler control from your computer keyboard or Deck Unit panel controls:

- With an SBE 19, 19*plus*, 19*plus* V2, 25, 25*plus*, or 49 CTD, the SBE 33 provides power and real-time control to the ECO, as well as power and real-time telemetry for the CTD and auxiliary sensors.
- Without a CTD, the SBE 33 provides power and real-time control to the ECO.

SBE 55 Real-Time Operation



SPECIFICATIONS



Depth Rating: 600 meters

Materials: 316 stainless steel, titanium, anodized aluminum, plastic

Weight in air:

Without CTD or bottles – 30 kg (67 lbs)
With SBE 19plus & three* ***empty*** *4-liter bottles* – 51 kg (113 lbs)
With SBE 19plus & six* ***empty*** *4-liter bottles* – 60 kg (133 lbs)
With SBE 19plus & six* ***full*** *4-liter bottles* – 84 kg (185 lbs)
*Note: 19*plus* and 19*plus* V2 weights are identical

Winch Cable Compatibility: Single or multi-core armored cable up to 10,000 meters long with inner core resistance of 0 - 350 ohms

04/13

Sea-Bird Electronics, Inc.
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Website: www.seabird.com

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Telephone: +1 425-643-9866
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Tel: +1 425-869-1834
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www.soundocean.com

ECO Winch

Portable Instrumentation Winch

STANDARD FEAURES

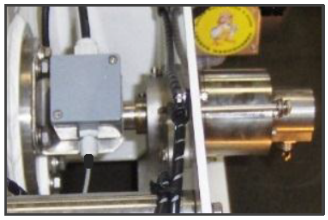
- Diamond screw level wind for 1/8 in. (3.2 mm) cable
- Electronic dynamic braking
- Automatic safety brake
- Cabled remote control with backlit speed & payout display
- Variable speed control
- Carry handles & lifting rings
- Aluminum frame and drum with epoxy powder coat finish
- Stainless steel shafts, bearings and hardware

OPTIONS

- 1 H.P. 110 VAC motor /drive
- 1 H.P. 220 VAC motor /drive
- 2 H.P. 220 VAC motor /drive
- Alternate drive sprocket for lower speed and higher line pull
- Two pass oceanographic slip ring with waterproof connector
- Single conductor armored CTD cable or 7x19 strand stainless steel wire rope
- Display units in feet & ft./min. or meters & m/sec.
- ECO Sheave, 8 in. (20 cm) for 1/8 in. (3.2 mm) dia. wire
- Marine canvas fitted cover
- Modular components of SOSI's small boat Instrument Handling System (IHS)

The ECO Winch design is optimized for real time CTD and water sample profiling from small boats or vessels of opportunity, to depths of 1000 meters or less. The ECO Winch's modular frame, drum, and level wind supports either a 1 horsepower (.75 kW) or 2 horsepower (1.5 kW) motor, brake and drive assembly. The motor options, in combination with standard or optional "low gear" drive sprockets, provide a wide range of line speed and line pull capability. The ECO Winch provides excellent bi-directional speed control for safe deck operations and gives operators real time cable awareness, allowing good control of the instrumentation underwater. The ECO Winch also serves many applications, both marine and land-based, that do not require real time data, by omitting the slip ring and substituting 1/8 in. (3.2mm) wire rope for the electro-mechanical CTD cable.

The slip ring option (right) includes a 2-pass slip ring in an environmentally sealed stainless steel housing with wet-pluggable under-water connector, and a waterproof junction box containing the winch cable-to-slip ring termination.



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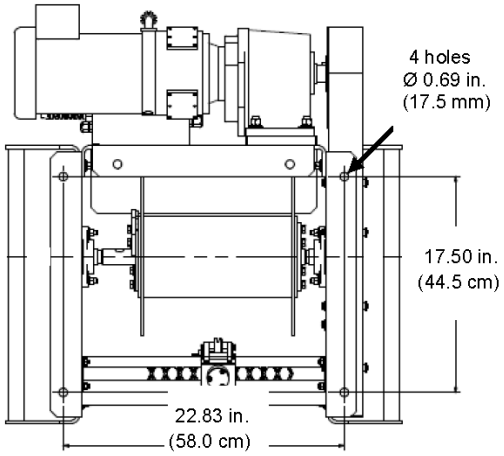
SPECIFICATIONS

Overall Dimensions:

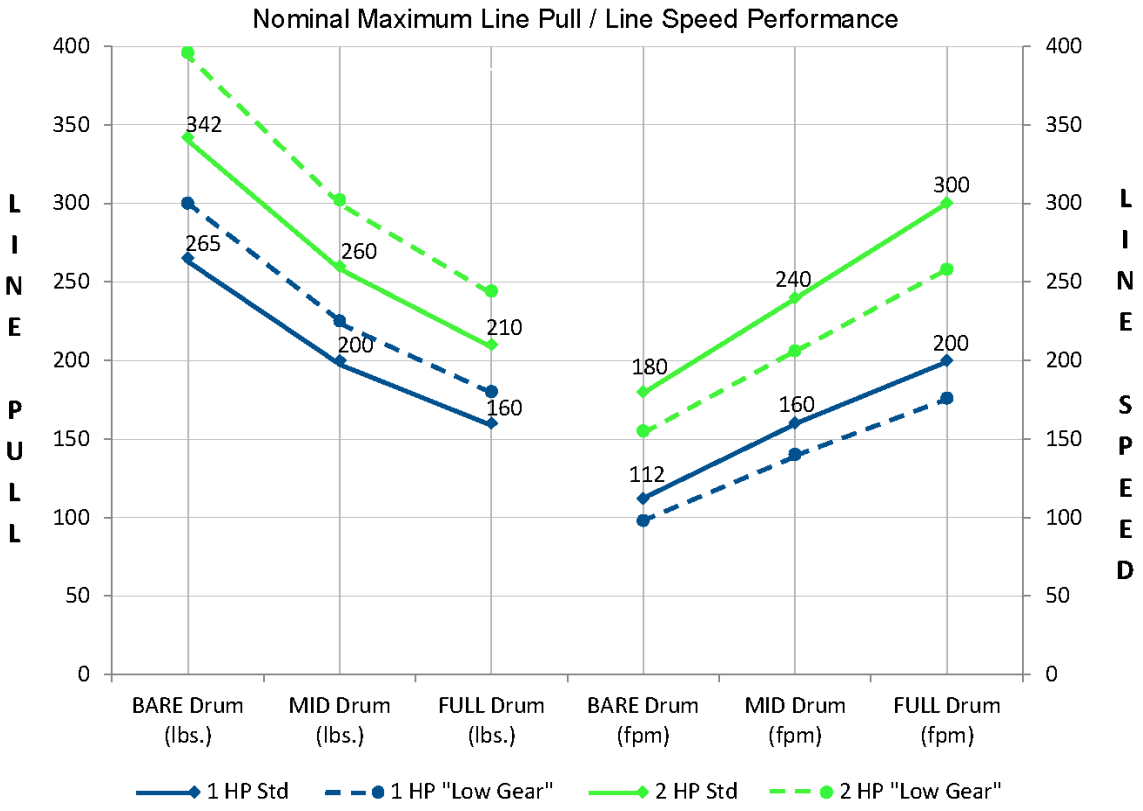
Width:	31.3 in. (80 cm)
Length:	32.2 in. (82 cm)
Height (remote pendant not in holder):	20.4 in. (52 cm)
Drum flange diameter:	12.88 in. (32.7 cm)
Drum core diameter:	6.625 in. (16.8 cm)
Drum width between flanges:	12.06 in. (30.6 cm)
Drum capacity (1/8 in. (3.3 mm) cable):	3300 feet (1100 m)
Weight (without cable):	1 HP = 165 lbs. (75 kg)
	2 HP = 195 lbs. (89 kg)

Input Power Options:
1 HP: 108-132 VAC single phase, 48-62 Hz, 2.0 kVA
1 HP: 208-240 VAC single phase, 48-62 Hz, 2.2 kVA
2 HP: 208-240 VAC single phase, 48-62 Hz, 3.1 kVA
2 HP: 208-240 VAC three phase, 48-62 Hz, 3.3 kVA



Bottom view mounting holes

Specifications subject to change without notice



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