

# Long-Term Surveillance Plan for the Amchitka, Alaska, Site

July 2014

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## Abbreviations

ADEC	Alaska Department of Environmental Conservation
AEC	U.S. Atomic Energy Commission
ANCSA	Alaska Native Claims Settlement Act
APIA	Aleutian Pribilof Island Association
bgs	below ground surface
Btu	British thermal unit
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	<i>Code of Federal Regulations</i>
CRESP	Consortium for Risk Evaluation with Stakeholder Participation
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ft	feet
GEMS	Geospatial Environmental Management System
IC	institutional control
kt	kiloton
LM	DOE Office of Legacy Management
LMS	Legacy Management Support
LTHMP	Long-Term Hydrologic Monitoring Program
LTSP	Long-Term Surveillance Plan
MOU	Memorandum of Understanding
mt	megaton
Pu	plutonium
ROD	Record of Decision
SGZ	Surface Ground Zero
Sr	strontium
USC	<i>United States Code</i>
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey



## Executive Summary

This Long-Term Surveillance Plan (LTSP) describes how the U.S. Department of Energy's Office of Legacy Management (LM) intends to continue its mission to maintain protection of human health and the environment at the seven sites located on Amchitka Island, Alaska. The U.S. Government conducted three underground nuclear tests on Amchitka Island between 1965 and 1971. The U.S. Department of Defense, in conjunction with the U.S. Atomic Energy Commission (AEC), conducted the first nuclear test (Long Shot) 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 that AEC conducted to study the feasibility of detonating a much larger device. The final nuclear test (Cannikin), the largest United States underground test, was a weapons-related test.

Surface disturbances (11 drilling mud pits) associated with these tests have been remediated at seven sites on the island. Remediation was conducted to clean up drill cuttings contaminated with diesel-range organics, which remained from diesel fuel that was added to the drilling fluid during drilling operations. The remediated surface disturbances are called mud pit caps. At Long Shot, Milrow (the Milrow mud pits were transported to the Rifle Range site), and Cannikin, the mud pit caps comprise large volumes of earthen material that was removed from the boreholes during drilling of the three emplacement shafts at these sites. The Cannikin site has two mud pit caps. Three additional sites, Site D, Site E, and Site F, were investigated as potential future test sites, and at each of these sites exploratory test holes were drilled to determine subsurface geologic conditions. Large-diameter emplacement shafts were also drilled at Sites D and F but were not used. The earthen materials encapsulated beneath the mud pit caps at these seven sites are the drill cuttings from these emplacement shafts and exploratory test holes.

The deep, subsurface test cavities at Long Shot, Milrow, and Cannikin remain radioactive, and no feasible remediation technology has been identified.

LM inspected the seven mud pit caps in 2006 and 2011. During environmental sampling performed in 2011, LM collected samples of 14 marine species in the ocean waters adjacent to Amchitka and Adak Islands to analyze for Amchitka-test-related radioisotopes and to determine if the species were safe to eat. Both inspections and the environmental monitoring event were pursuant to the LTSP developed in 2008 and the 2011 Sampling Plan. This revised LTSP incorporates the knowledge gained from those actions and provides LM with information necessary for continued long-term stewardship of the Amchitka Island sites.

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## 1.0 Introduction

Amchitka Island is located near the far western end of the Aleutian Islands, approximately 1,340 miles west-southwest of Anchorage, Alaska (Figure 1). 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, multiple U.S. Government agencies have used Amchitka for a variety of military and research activities. From 1943 to 1950, it was used as a forward air base for the U.S. Armed Forces. During the late 1960s and early 1970s, the U.S. Department of Defense (DOD) and the U.S. Atomic Energy Commission (AEC) (predecessor agency to the U.S. Department of Energy [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) 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 that AEC conducted to study the feasibility of detonating a much larger device. The final nuclear test (Cannikin), the largest United States underground test, was weapons-related and was detonated on November 6, 1971. The fission products from the tests remain in and around the subsurface detonation cavities at each test location. Figure 2 shows the location on Amchitka Island of the three nuclear detonation sites and the seven mud pit caps.

In addition to the three underground nuclear test sites, six additional sites were considered as possible underground nuclear detonation sites. These sites were designated A, D, E, F, G, and H. Large-diameter emplacement holes were drilled at Sites D and F, but were not used. An exploratory hole was drilled at Site E. Site H was graded in preparation for drilling activities that did not occur. Sites A and G were located and staked, but no further preparation was made. It was estimated that drilling or preparation for drilling at Long Shot and Sites B (Milrow), C (Cannikin), D, E, F, and H disturbed approximately 195 acres. This area includes access roads and spoils-disposal areas (Merritt and Fuller 1977).

The three test sites and three additional sites that were investigated but never used for underground testing, Sites D, E, F, contained a total of 11 drilling mud pits that have previously affected the environment. The drill cuttings from the Milrow test were transported to a nearby site referred to as the Rifle Range site for disposal. DOE performed remediation activities in 2001 and consolidated these drilling pits into seven sites where the drilling muds were encapsulated into an engineered earthen containment cell called a mud pit cap. DOE's Office of Legacy Management (LM) is responsible for long-term surveillance and monitoring of the test-related sites on Amchitka. To simplify nomenclature of LM's sites on Amchitka Island, the seven mud pit caps (Long Shot site, Rifle Range site [Milrow cuttings], Cannikin North site, Cannikin South site, Site D, Site E, and Site F) and the three nuclear test sites (Long Shot, Milrow, and Cannikin) are collectively called LM's Amchitka Island sites.

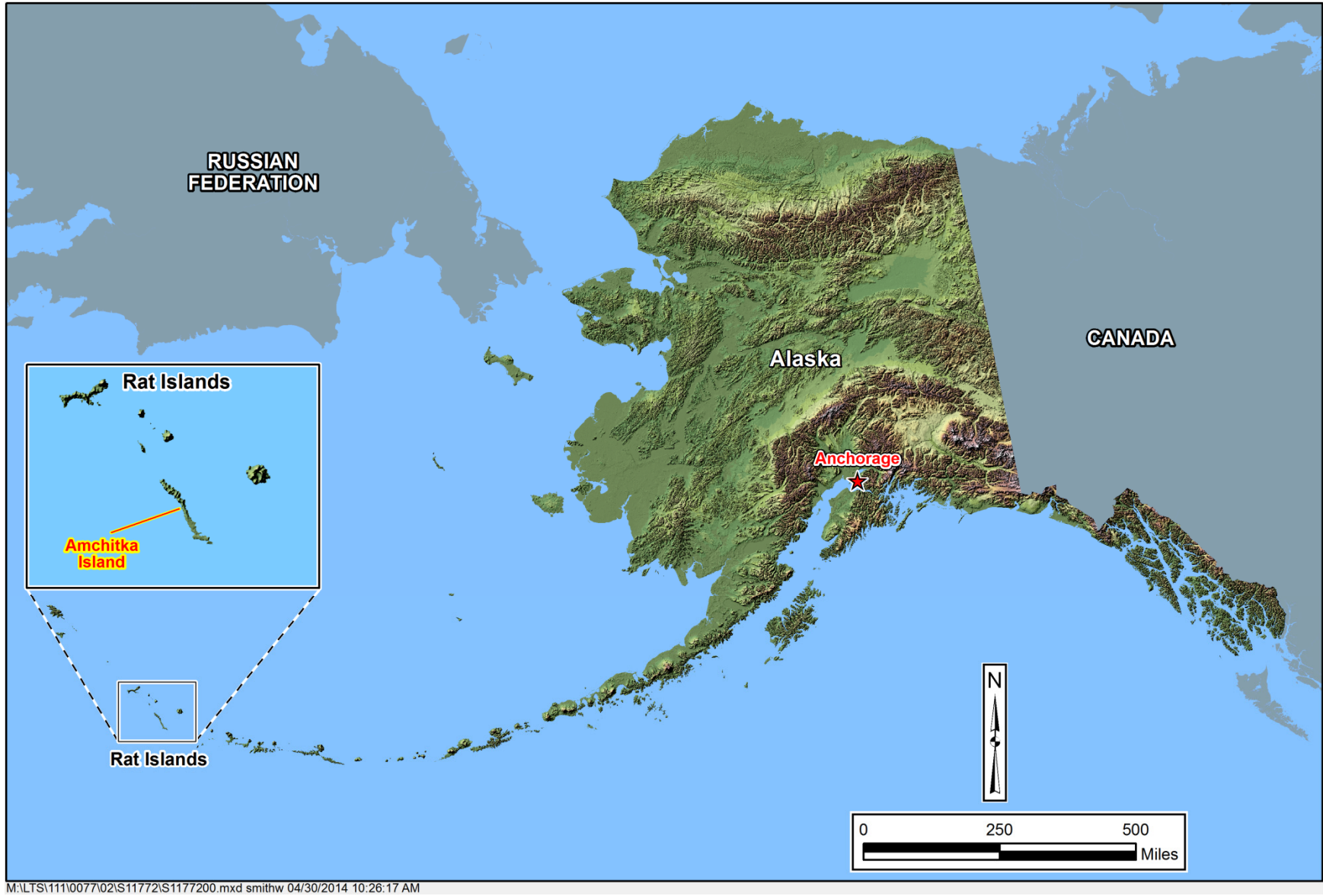


Figure 1. Amchitka Island Location



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Figure 2. Amchitka Island Sites

## 1.1 Purpose of the Amchitka, Alaska, Long-Term Surveillance Plan

Long-term surveillance refers to the performance of all activities necessary for protection of human health and the environment following cleanup, disposal, or stabilization at a site or part of a site. The LM documents *2011–2020 Strategic Plan* (DOE 2011b) and *Long-Term Stewardship Planning Guidance for Closure Sites* (DOE 2002a) provide guidance for these activities. This Long-Term Surveillance Plan (LTSP) explains how LM will fulfill its mission at the LM Amchitka Island sites and any future biological sampling on and adjacent to Amchitka Island and possibly nearby islands.

The following planning and reporting documents are relevant to LM's mission to maintain protection of human health and the environment at the Amchitka Island sites. Two plans and two reports provide direction in monitoring the environment of the sites, and the sampling report provides results of that monitoring. All plans and reports are on a 5-year cycle.

- **LTSP (this document):** The first LTSP came out in 2008. Thus, the next one was due in 2013, but a delay of the 2011 biological sampling results and subsequent biological sampling report delayed the LTSP revision. The LTSP Revision 1 will be issued in 2014. Revision 2 will be due in 2018. The LTSP describes how LM will fulfill its long-term obligation to manage residual hazards at the sites.
- **Post-Closure Monitoring and Inspection (PCM) Plan:** The first PCM Plan was issued in 2005; Revision 1 was issued in 2011, and LM will prepare Revision 2 in 2015. To ensure the integrity and effectiveness of remedial action, the mud pit caps will be inspected every 5 years pursuant to the LTSP. The PCM Plan provides guidance for inspecting the seven mud pit caps.
- **Post-Closure Monitoring and Inspection (PCM) Report:** The first PCM Report was issued in 2006, the second was issued in 2012, and the next one will be issued in 2017. Subsequent to the inspection, the PCM Report provides the summary of the work performed as part of the PCM Plan and provides recommendations for future maintenance issues the field inspection identified.
- **Sampling Plan for the Amchitka Site:** The first sampling plan was issued in March 2011. The intent of the plan is to describe the data collection and data management activities for collecting biological samples to determine if the seafood harvested for the Aleut diet is safe to eat. The next sampling plan is scheduled for 2016.
- **Amchitka Island, Alaska, Environmental Monitoring Report of Sampling Results:** The first results report was issued in 2013. The next one will come out in 2017 or 2018, depending on receipt of the analytical results.

### 1.1.1 Surveillance Objectives

This plan meets the following objectives:

- Describe how long-term surveillance will protect human health and the environment (Section 1.1.2).
- Collect and report inspection and monitoring data and comply with regulatory and other surveillance requirements (Sections 4.3 and 4.4).

- Maintain site records and information such that future custodians can continue to provide effective surveillance (Section 4.7).
- Plan for contingencies (Section 4.5).
- Provide a mechanism for stakeholder and regulator involvement (Section 1.1.3).
- Ensure that necessary institutional controls and physical controls are in place and effective (Section 2.4.2).

### **1.1.2 Protection of the Public and the Environment**

USFWS has management authority for Amchitka Island, a unit of the Alaska Maritime National Wildlife Refuge. Title 50 *Code of Federal Regulations* (CFR) Part 36.39(b)(1) states that “Amchitka Island—[is] closed to all public access, occupancy and use, unless specifically authorized by a special use permit issued jointly by the Refuge Manager and the U.S. Navy (Commanding Officer, Fleet Surveillance Support Command, Chesapeake, Virginia).” Therefore, access to Amchitka Island requires a special use permit from USFWS.

A Memorandum of Understanding (MOU) (USFWS 2010) between USFWS and LM establishes the roles and responsibilities of both agencies regarding site access, long-term surveillance activities, and use restrictions associated with LM’s Amchitka Island sites. Appendix B contains the MOU LM has with the USFWS. The primary use restriction is that a special use permit is required to access the island, and secondarily, excavation is prohibited in the areas of the Amchitka Island sites. Also, LM will review all applications from other government agencies for permanent-type uses (e.g., withdrawals, cooperative agreements, rights-of-way) for Amchitka Island (USFWS 2010).

LM has implemented institutional controls (ICs), including administrative, engineered, and physical (non-engineered) controls to prevent penetration of the nuclear test cavities and the mud pit caps at LM’s Amchitka Island sites. The definition of ICs is broadly interpreted to include the functional oversight by federal agencies (USFWS and DOE); engineered barriers (the disposal caps); and physical constructs (monuments and signs). This also includes periodic mud pit cap inspection and may include environmental monitoring as required. Section 2.4.2 provides additional discussion of ICs.

### **1.1.3 Criteria Used to Determine if Action Is Needed**

Mud pit cap failure as reported in the post-closure monitoring and inspection report, or the exceedance of dose limits to the public or environment, or an increase in radionuclide levels as determined by the environmental monitoring report will be criteria for determining action at LM’s Amchitka Island sites. LM will consult with the Alaska Department of Environmental Conservation (ADEC) and the Alaska stakeholders to develop indicator levels for subsistence users and an appropriate sampling and analysis strategy. Inspectors conducting the 5-year, onsite inspections will evaluate maintenance needs of the physical and institutional controls.

## 1.2 Authorities

Numerous statutes, regulations, and DOE policy and guidance documents constitute the framework for this plan. Sections 1.2.1 and 1.2.2 provide a discussion of the major authorities.

### 1.2.1 Executive Orders, DOE Orders, Guidance, Policies, and Commitments

In 1913, President Taft issued Executive Order 1733 to set aside the Aleutian Islands "...as a preserve and breeding ground for native birds..." The order also specified "the establishment of this order shall not interfere with the use of the islands for lighthouse, military or naval purposes..." This order allowed AEC and DOD use of the island as a site for the nuclear tests conducted in the mid-1960s to early 1970s. The Atomic Energy Act of 1954 (42 *United States Code* [USC] 2011) and related legislation provided AEC with authority to develop generally applicable standards for protecting the environment from radioactive materials.

Between 1986 and the present, DOE has entered into agreements with USFWS, ADEC, and the Aleutian Pribilof Island Association (APIA) to conduct work at the Amchitka Island sites. The MOU between USFWS and LM (USFWS 2010) has been updated twice since 1986, most recently on June 4, 2010. In 1999 the DOE Office of Environmental Management signed separate Agreements in Principle with ADEC (DOE 1999a) and APIA (DOE 1999b) to provide technical and financial support for the State's and APIA's efforts to maintain oversight of DOE's characterization and monitoring activities at Amchitka. The Agreements assure the State and APIA that DOE's characterization and monitoring activities are protective of human health and the environment and, more specifically, do not adversely affect the health and safety of APIA members.

The U.S. Environmental Protection Agency (EPA) performed a hazard assessment for Amchitka Island for possible placement on the National Priorities List. The hazard ranking score for the site was below the minimum score required for placement, and Amchitka was not placed on the National Priorities List (DOE 1998). The National Priorities scores were 12.06, 0.0, and 0.0 for Long Shot, Milrow, and Cannikin, respectively (DOE 1998). The primary reason for the Long Shot score was the "trace quantities of radioactivity [detected], principally tritium, in water and soil gas samples in the immediate vicinity of surface ground zero" following the test (Merritt and Fuller 1977). The minimum score for National Priorities List ranking is 28.5.

On February 11, 2011, DOE replaced Order 5400.5, *Radiation Protection of the Public and the Environment*, with Order 458.1, same title. Order 458.1 continues the requirements to protect the public and the environment against undue risk from radiation associated with radiological activities conducted under the control of the DOE pursuant to the Atomic Energy Act of 1954.

Table 1 summarizes other DOE orders related to the long-term stewardship process. DOE Order 430.1B, *Real Property and Asset Management*, specifies the management of real property and assets. DOE Order 454.1 and DOE Guide 454.1-1 specify the use of institutional controls for DOE real property. DOE Order 413.3-10A, *Program and Project Management for Acquisition of Capital Assets*, specifies a disciplined process for project management using the critical decision process.



Table 1. DOE Orders, Policy, and Guidance for Long-Term Surveillance at the Amchitka Site

Regulation or DOE Order	Summary
DOE Order 458.1	Replaced DOE Order 5400.5. Establishes the maximum total effective dose equivalent for exposure of the public to radiation ( $\leq 100$ millirem per year above background). <a href="https://www.directives.doe.gov/directives/0458.1-BOrder/view">https://www.directives.doe.gov/directives/0458.1-BOrder/view</a>
DOE Order 430.1B	Establishes approach for real property life-cycle asset management. <a href="https://www.directives.doe.gov/directives/0430.1-BOrder-b/view">https://www.directives.doe.gov/directives/0430.1-BOrder-b/view</a>
DOE Policy 454.1	Ensures that DOE will use institutional controls in the management of resources, facilities, and properties under its control. <a href="https://www.directives.doe.gov/directives/0454.1-APolicy/view">https://www.directives.doe.gov/directives/0454.1-APolicy/view</a>
DOE Guide 454.1-1	Provides information to assist DOE with what is necessary and acceptable for implementing DOE Policy 454.1. <a href="https://www.directives.doe.gov/directives/0454.1-EGuide-1/view">https://www.directives.doe.gov/directives/0454.1-EGuide-1/view</a>
DOE Order 413.3-10A	Establishes program management through the critical decision process. <a href="https://www.directives.doe.gov/directives/0413.3-BOrder/view">https://www.directives.doe.gov/directives/0413.3-BOrder/view</a>

After review of the documentation and condition of its Amchitka Island sites, DOE made the decision to transition the project from characterization activities to surveillance activities. LM assumed responsibility for long-term surveillance activities on October 1, 2006, as directed in a 2004 memorandum (DOE 2004). The LTSP developed in 2008 details how LM manages the Amchitka Island sites and is subject to future revisions or modifications (DOE 2008b). The 2008 LTSP provided the basis for LM's biological sampling program conducted in the ocean adjacent to Amchitka and Adak Islands in 2011 and the inspection of the Amchitka Island sites in 2011.

## 1.2.2 Legal and Regulatory Authorities

### 1.2.2.1 Federal Requirements

LM is responsible for the radioactive and other hazardous materials that DOE and AEC activities generated at the 10 Amchitka Island sites. LM manages the radioactive material at the sites under the authority of the Atomic Energy Act of 1954. It is LM's objective to conduct its long-term stewardship activities at Amchitka so that radiation exposure to members of the public are maintained within the limits established by DOE Order 5400.5, *Radiation Protection of the Public and the Environment* (to be replaced by DOE Order 458.1) and to control radioactive contamination through management of real and personal property. It is also LM's objective to protect the environment from radioactive contamination to the extent practicable.

Federal regulations for protection of threatened and endangered species and cultural resources are also applicable. The details are discussed further in Section 2.5.

Public Law 96-487 designated a portion of Amchitka as a wilderness area and further defined Alaska Native claims on portions of the island.

### 1.2.2.2 State Requirements

LM's Amchitka Island sites are not under the authority of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); however, ADEC and DOE agreed to a list of applicable or relevant and appropriate requirements for conducting remediation and for determining appropriate cleanup standards. This list is detailed in the *Remedial Action Work Plan Amchitka Island Mud Pit Closures* (DOE 2001a).

Surface cleanup of the Amchitka Island sites was conducted in 2001 under the State of Alaska's Contaminated Sites program (Title 18 *Alaska Administrative Code* Chapter 75, "Oil and Hazardous Substances Pollution Control"), and details of this remedial action are reported in the *Amchitka Island Surface Closure Report* (DOE 2003). In September 2004, ADEC accepted the surface cleanup as complete (ADEC 2004).

Subsequent to completion and ADEC's acceptance of surface closure activities, DOE prepared the *Subsurface Completion Report for Amchitka Underground Nuclear Test Sites: Long Shot, Milrow, and Cannikin* (DOE 2005a). In 2007, ADEC approved this report as a conditional closure with long-term surveillance and monitoring as an appropriate subsequent action (ADEC 2007).

Concurrently with ADEC's acceptance of the subsurface completion report, LM prepared a Record of Decision (ROD) as an ad hoc mechanism for ADEC and DOE to formalize acceptance of the work. The ROD summarized the surface closure activities and stated that DOE will conduct post-closure inspection and monitoring as described in the *Post-Closure Monitoring and Inspection Plan for Amchitka Island Mud Pit Release Sites* (DOE 2005b). Both ADEC and USFWS approved the ROD in August 2008.

This LTSP details the implementation of actions outlined in the above reports and constitutes formal agreement between LM and ADEC concerning the required long-term surveillance actions for LM's Amchitka Island sites.

Table 2 lists the primary environmental laws and regulatory programs relevant to the Amchitka surface remediation.

Table 2. Significant Environmental Laws and Regulatory Programs

Act/Regulation	Reference
Atomic Energy Act of 1954	42 USC. 2011
Wildlife and Fisheries	50 CFR 36.39
CERCLA	42 USC. 9620, 40 CFR 300
Clean Water Act	33 USC. 1251 et seq., 40 CFR 330 Appendix A
Resource Conservation and Recovery Act	42 USC. 6901 et seq., 40 CFR 262 subparts A-C
Wilderness Management Act	16 USC. 1131
Endangered Species Act	16 USC. 1531-1534
National Historic Preservation Act	16 USC. 470, 36 CFR 63, 36 CFR 800
Conservation and Protection of Alaska Fish and Game	Alaska Statutes: 16.20
Environmental Conservation	Alaska Statutes: 46.03
Hazardous Substance Release Control	Alaska Statutes: 46.09
Alaska Oil and Gas Conservation Commission	<i>Alaska Administrative Code</i> : Title 18, Chapter 25
Solid Waste Management	<i>Alaska Administrative Code</i> : Title 18, Chapter 60
Water Quality Standards	<i>Alaska Administrative Code</i> : Title 18, Chapter 70
Oil and Other Hazardous Substances Pollution Control	<i>Alaska Administrative Code</i> : Title 18, Chapter 75
Underground Storage Tanks	<i>Alaska Administrative Code</i> : Title 18, Chapter 78
Drinking Water	<i>Alaska Administrative Code</i> : Title 18, Chapter 80

CFR = Code of Federal Regulations

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## 2.0 Amchitka Island

### 2.1 Location Information

Amchitka is the largest island in the Rat Island Group of the Aleutian Island chain. It is 1,340 statute miles west-southwest of Anchorage, Alaska, and 870 miles east of Petropavlovsk, Kamchatka, Russia. It is bounded by the Bering Sea to the north and the Pacific Ocean to the south.

#### 2.1.1 Physical Description of Amchitka Island

The island is 42 miles long and varies from 1 to 4 miles in width. The total land area is approximately 116 square miles. Amchitka has a rugged coastline, steep cliffs, few sandy beaches, and only one harbor (Constantine). The eastern portion of the island consists of rolling hills dotted with shallow ponds; drainages and rubble ridges are more prominent in the central portion. The west-central region is mountainous, with elevations ranging from about 50 feet (ft) above sea level at the tops of sea cliffs to over 1,100 ft in the interior. The western portion is a barren rocky plateau shaped by high winds and erosion (Merritt and Fuller 1977). Figure 3 shows the general topography of Amchitka Island.

#### 2.1.2 Legal Descriptions and Surveys

Amchitka Island is located at latitude 51°21' to 51°39.5' N and longitude 178° 37' to 179° 28' E (Merritt and Fuller 1977). It lies between Township 98 South, Range 230 West and Township 102 South, Range 230 West of the Seward Meridian.

## 2.2 Land Ownership and Use

### 2.2.1 National Maritime Wildlife Refuge and Wilderness Designation

Amchitka Island was included in the purchase of Alaska by Secretary of State William Seward on March 30, 1867. President Taft included Amchitka Island in the Aleutian Islands Reservation, which later became the Alaska Maritime National Wildlife Refuge. The island is public land under the jurisdiction of the U.S. Department of Interior, USFWS, for the benefit of the United States of America. The central portion of the island was designated as part of the Aleutian Island Wilderness area under Public Law 96-487. Figure 4 shows the USFWS wildlife and wilderness areas.

#### 2.2.2 DOE Use

LM retains responsibility for those areas agreed to in the 2001 Letter of Agreement between USFWS, U.S. Army Corps of Engineers, U.S. Department of Navy, ADEC, APIA, and DOE (DOE 2001b). The 2010 MOU between USFWS and DOE (USFWS 2010) established the roles and responsibilities of both agencies regarding site access, long-term surveillance activities, and use restrictions at Amchitka. As detailed in the USFWS *Remedial Action/Removal Action Environmental Assessment Finding of No Significant Impact* (USFWS 2000), LM has responsibility for only portions of the island where nuclear testing occurred or at sites



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Figure 3. Topographic Contours, Amchitka Island

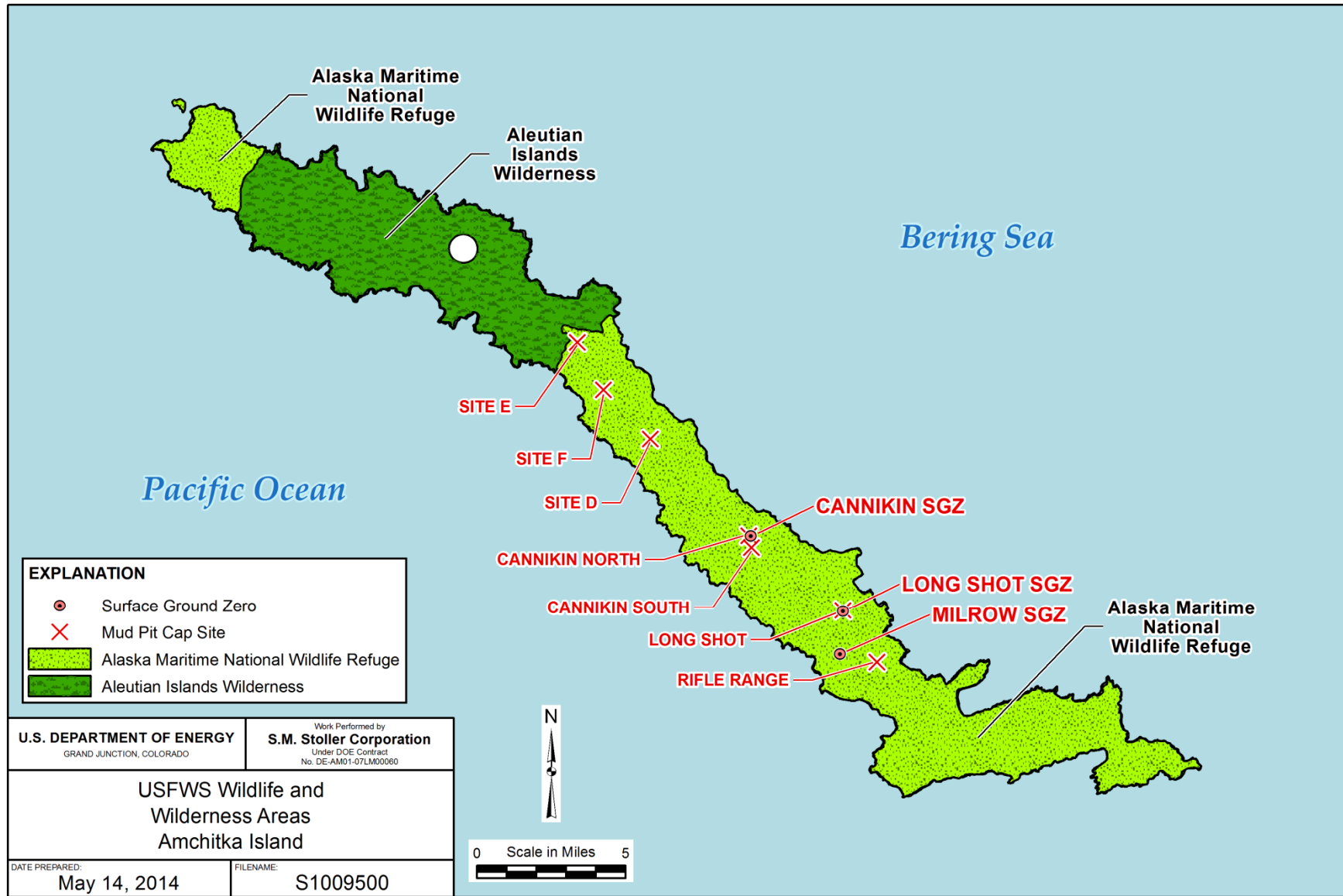


Figure 4. USFWS Wildlife and Wilderness Areas Amchitka Island

where hydrologic testing occurred in preparation for future nuclear testing (LM's Amchitka Island sites). Other federal agencies also have remediation responsibilities on the island.

### **2.2.3 Potential Native Claims**

A unique aspect of the Alaska Native population is that a large percentage still relies on traditional hunting, fishing, and gathering as a basis for their food supply. This has led to years of discussion, legislation, and lawsuits over how to protect and allocate resources among conflicting subsistence, commercial, and sport users (Mertz 1991).

The Alaska National Interest Lands Conservation Act (PL 96-487, 1980) in conjunction with the Alaska Native Claims Settlement Act (ANCSA) (PL 92-203, 1971, as amended) established certain rights for recognized Alaska Natives, including a requirement that rural residents be given priority for subsistence harvests on certain federal lands.

To reconcile differences with previous legislation, ANCSA created 12 regional native corporations, one regional corporation for nonpermanent resident natives, and 220 village corporations. In exchange for relinquishing all aboriginal claims and any aboriginal hunting rights, these corporations were given 44 million acres of land and 1 billion dollars. Part of these agreements allowed the corporations to select claims on federally owned land with a certain portion of wilderness areas eligible for claims (Stadium Group 2003). Currently, there are 68 conveyed and 4 selected claims under ANCSA Section 14(h)(1) on Amchitka Island (The Aleut Corporation). Other small islands around Amchitka also have conveyed 14(h)(1) claims (USFWS 2013a). Figure 5 shows the land status of Amchitka Island, including refuge, existing wilderness, and selected and conveyed land of the Aleut Corporation. These claims are cemetery and historical sites and, if conveyed, come with covenants that restrict activity; settlement would not be permitted. If these claims are conveyed, additional institutional controls would not be necessary.

### **2.2.4 Recreational, Subsistence, and Commercial Use**

The remote location and weather conditions limit the use of Amchitka Island and surrounding waters for recreational use. However, there have been some landings on the island that were apparently for the purpose of recreation. The surrounding waters are fished commercially but are rarely used for subsistence fishing. In 2004 the USFWS interview program recorded 51 landings on the island. If these landings were to become more frequent, the probability would increase for disturbance of the remediated sites. Institutional controls will aid in protection of these sites.

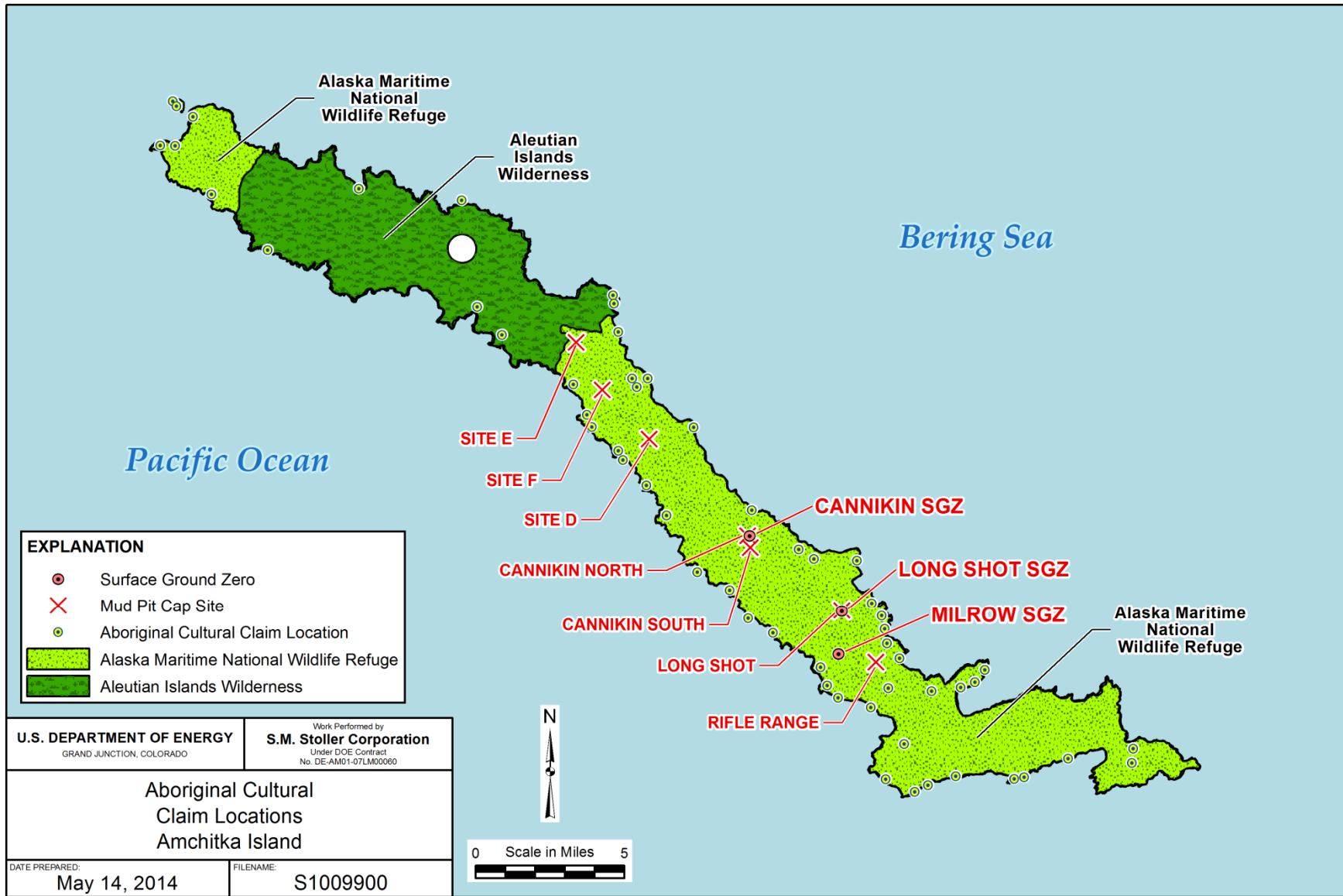
## **2.3 Mineral, Water, and Surface Rights**

Pyritic (iron ore) zones have been located on the western portion of Amchitka. According to provisions in the Alaska National Interest Lands Conservation Act, these deposits are open for leasing; however, production is unlikely because the area is designated as a wildlife refuge.

USFWS currently retains water rights.

Upon settlement of the Native claims, surface rights will change and will require further evaluation.





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Figure 5. Aboriginal Cultural Claim Locations, Amchitka Island

## 2.4 Easements and Access Rights

### 2.4.1 DOE Areas of Responsibility and Restrictions

The 2010 MOU between USFWS and LM (USFWS 2010) and 50 CFR 36.39(b)(1) restrict access to the island without a special use permit and LM notification. Details regarding appropriate restrictions have yet to be determined.

### 2.4.2 Physical and Institutional Controls

Several ICs are currently implemented at the LM Amchitka Island sites to protect human health and the environment from contaminated surface and subsurface areas. As discussed in Section 1.1.2, without a special use permit from USFWS, access to the island is prohibited. DOE has previously established ICs for the three detonation sites. Appendix A provides figures showing the ICs for these three sites. A bronze plaque at each surface ground zero (SGZ) location provides IC information (see Appendix A). The following ICs are in place for the Amchitka Island sites:

- DOD retains the right to use the island, if determined necessary, for national defense purposes.
- USFWS is the landowner and maintains all mineral rights for the island.
- LM's Amchitka Island sites are located in the Aleutian Maritime National Wildlife Reserve under the jurisdiction of USFWS. Administrative control is achieved by prohibiting access to the island except for activities granted under a special use permit.
- A bronze plaque was mounted onto a concrete monument and placed at SGZ for Long Shot, Milrow, and Cannikin. Each plaque explained the event and restrictions that apply to the nearby area. The restrictions on the bronze plaques are provided in Appendix A and read as follows:

**Long Shot:** “No excavation, drilling, and/or removal of materials is permitted without U.S. Government approval, between the ground surface and minus 3,000 feet below mean sea level and out to a horizontal distance of 1,000 feet from the surface ground zero location ...”

**Milrow:** “No excavation, drilling, and/or removal of materials is permitted, without U.S. Government approval, between the ground surface and minus 5,000 feet below mean sea level and out to a horizontal distance of 1,000 feet from the surface ground zero location ...”

**Cannikin:** “No excavation, drilling, and/or removal of materials is permitted without U.S. Government approval between ground surface and minus 6,200 feet below mean sea level and out to a horizontal distance of 3,000 feet from the surface ground zero location ...”

LM is working with USFWS to establish the appropriate level of institutional control that is needed for LM's four other Amchitka Island sites—D, E, F, and the Rifle Range. LM will issue a separate document that discusses institutional controls at LM's Amchitka Island sites in 2014.

### **2.4.3 Access by Other Federal, State, or Private Entities**

LM does not foresee any need to restrict use of the island for research, data collection, or other activities, provided users are given notice of restrictions designed to avoid disturbance of surface restoration and subsurface contamination.

## **2.5 Threatened and Endangered Species**

### **2.5.1 Federal Listings**

The purpose of the Endangered Species Act is to conserve threatened and endangered species and their ecosystems. A species is considered endangered if it is in danger of extinction throughout all or a significant portion of its range.

Two federal agencies, the National Marine Fisheries Service and USFWS, are responsible for maintaining lists of species that meet the definition of threatened or endangered under the Endangered Species Act. The National Marine Fisheries Service is responsible for maintaining the endangered species list for marine species and managing those species once they are listed. USFWS is responsible for maintaining the endangered species list for terrestrial and freshwater species and managing those species once they are listed.

The Steller sea lion and the northern sea otter are currently the only federally recognized threatened or endangered animal species that inhabit Amchitka Island. A portion of Amchitka has been designated as critical habitat for the Steller sea lion, which has established rookeries in the area. There are no federally listed or candidate plant species on Amchitka.

The Steller sea lion was first listed as threatened in 1990. In 1997, the species was reclassified into two distinct population segments under the Endangered Species Act. The reclassification was based on biological information collected since the species was listed as threatened in 1990. The Steller sea lion population segment west of Longitude 144°W was reclassified as endangered; the listing for the remainder of the U.S. Steller sea lion population remained as threatened (NOAA 2013). The two sea lion rookeries on Amchitka Island cannot be approached within 3 nautical miles by a vessel or within one-half statutory mile by land (USFWS 2013b).

The northern sea otter was first listed on August 9, 2005. It is currently designated as threatened in the southwest area of Alaska that includes the Aleutian Islands, Alaska Peninsula coast, and Kodiak Archipelago.

### **2.5.2 State Listings**

The State of Alaska has a category called Special Status Species. This list includes the Steller sea lion as an endangered species and the northern sea otter (southwest Alaska population) as a threatened species (ADFG 2013).

### 2.5.3 Critical Habitats

Critical habitats are defined by the Endangered Species Act (16 USC 1531–1534) as:

(i) The specific areas within the geographical area occupied by a species, at the time it is listed in accordance with the Act, on which are found those physical or biological features (I) essential to the conservation of the species and (II) that may require special management considerations or protection; and (ii) specific areas outside the geographical area occupied by a species at the time it is listed, upon a determination that such areas are essential for the conservation of the species. “Conservation” is defined in section 3 as meaning the use of all methods and procedures needed to bring the species to the point at which listing under the Act is no longer necessary. The primary regulatory effect of critical habitat is the section 7(a)(2) requirement that Federal agencies shall insure that any action they authorize, fund, or carry out is not likely to result in the destruction or adverse modification of designated critical habitat.

The Steller sea lion and the northern sea otter both have critical habitats designated on Amchitka Island. In October 2009, USFWS designated northern sea otter critical habitat for this distinct population segment. Amchitka Island is in Unit 1—Western Aleutian of the Southwest Alaska distinct population segment (USFWS 2013b). The Steller sea lion critical habitat location on Amchitka is presented in Table 3 and shown on Figure 6.

*Table 3. Amchitka Island Steller Sea Lion Critical Habitat*

Critical Habitat	From		To		NOAA Chart	Notes
	Lat.	Long.	Lat.	Long.		
	51° 22.5'N	179° 28.0'E	51° 21.5'N	179° 25.0'E	16440	East Cape
	51° 32.5'N	178° 49.5'E			16440	Column Rocks

NOAA = National Oceanic and Atmospheric Administration

### 2.6 Cultural Resources

USFWS has the responsibility for managing Amchitka, which is part of the Alaska Maritime National Wildlife Refuge. LM has no responsibility for the cultural resources on the island, other than training its employees regarding protection and preservation of these resources. Most of the cultural resources that are on the island coincide with the Native claims (Section 2.2.3) depicted on Figure 5 and are on the coastal portions of the island. LM activity on the island will be restricted in those areas USFWS designates as having culturally sensitive resources.

Prior to departing in 2011 for the inspection of the LM Amchitka Island sites, inspection team personnel met in Anchorage with Debbie Corbett, the USFWS Regional Historic Preservation Officer, for cultural awareness training. The training covered a broad spectrum of Aleutian Island archaeological information. The U.S. Army Corps of Engineers also provided unexploded ordnance training in case inspection team members encountered unexploded ordnance, remnants of when the U.S. military occupied the island.

## 2.7 Site History

Amchitka has a long and varied history. During the last 2,500 years, Amchitka has been, at various times, home to the Aleut people. Because of modern interest in the island, Amchitka has been the site of several major archaeological expeditions and has a rich and diverse modern history. Figure 7 is a timeline of Amchitka Island’s history starting in the mid-19th century that chronicles the modern occupation of the island.

Amchitka’s modern history is well documented in a number of sources. Merritt and Fuller (1977) provide abundant information on the physical and ecological setting of Amchitka in *The Environment of Amchitka Island, Alaska*. O’Neill (1994) and Kohlhoff (2002) have written about the underground nuclear tests at the site for the general public, including the societal aspects of the testing.

### 2.7.1 AEC Nuclear Tests

The U.S. Government conducted three underground nuclear tests on Amchitka Island between 1965 and 1971 (DOE 2000a). Long Shot (80 kiloton [kt] yield) was detonated on October 29, 1965. Milrow (about 1 megaton [mt]) was detonated on October 2, 1969. Cannikin (less than 5 mt) was detonated on November 6, 1971. In addition to the three sites that were used for underground nuclear testing, drilling occurred at three other sites (D, E, and F) where nuclear testing was considered but was not performed. Figure 8 through Figure 10 show schematic cross sections of the three nuclear test sites and pertinent features, and Table 4 shows details of the tests.

Table 4. Amchitka Nuclear Test Summary

Name	Date	Yield	Seismic Activity <sup>a</sup>	Purpose	Detonation Depth	Locations (Latitude and Longitude)
Long Shot	10/29/65	80 kt	Mb 6.1	Vela Uniform Program <sup>b</sup>	2,300 ft below ground surface (bgs)	51.424°N 179.179°E
Milrow	10/02/69	About 1 mt	Mb 6.5	Weapons related	3,996 ft bgs	51.403°N 179.179°E
Cannikin	11/06/71	Less than 5 mt	Mb 6.8	Weapons Related	5,879 ft bgs	51.456°N 179.102°E

<sup>a</sup> Seismic information on tests from the earthquake database at the National Earthquake Information Center. The Mb magnitude is based on the amplitudes of short-period P waves and is typically the magnitude used to describe the yield of the tests.

<sup>b</sup> Vela Uniform was a series of underground nuclear tests carried out to obtain data to differentiate between underground nuclear detonations and earthquakes.

Statistic source: DOE 2006b.



Figure 6. Rookeries and Critical Habitat, Amchitka Island

# Amchitka, Alaska, Site Timeline

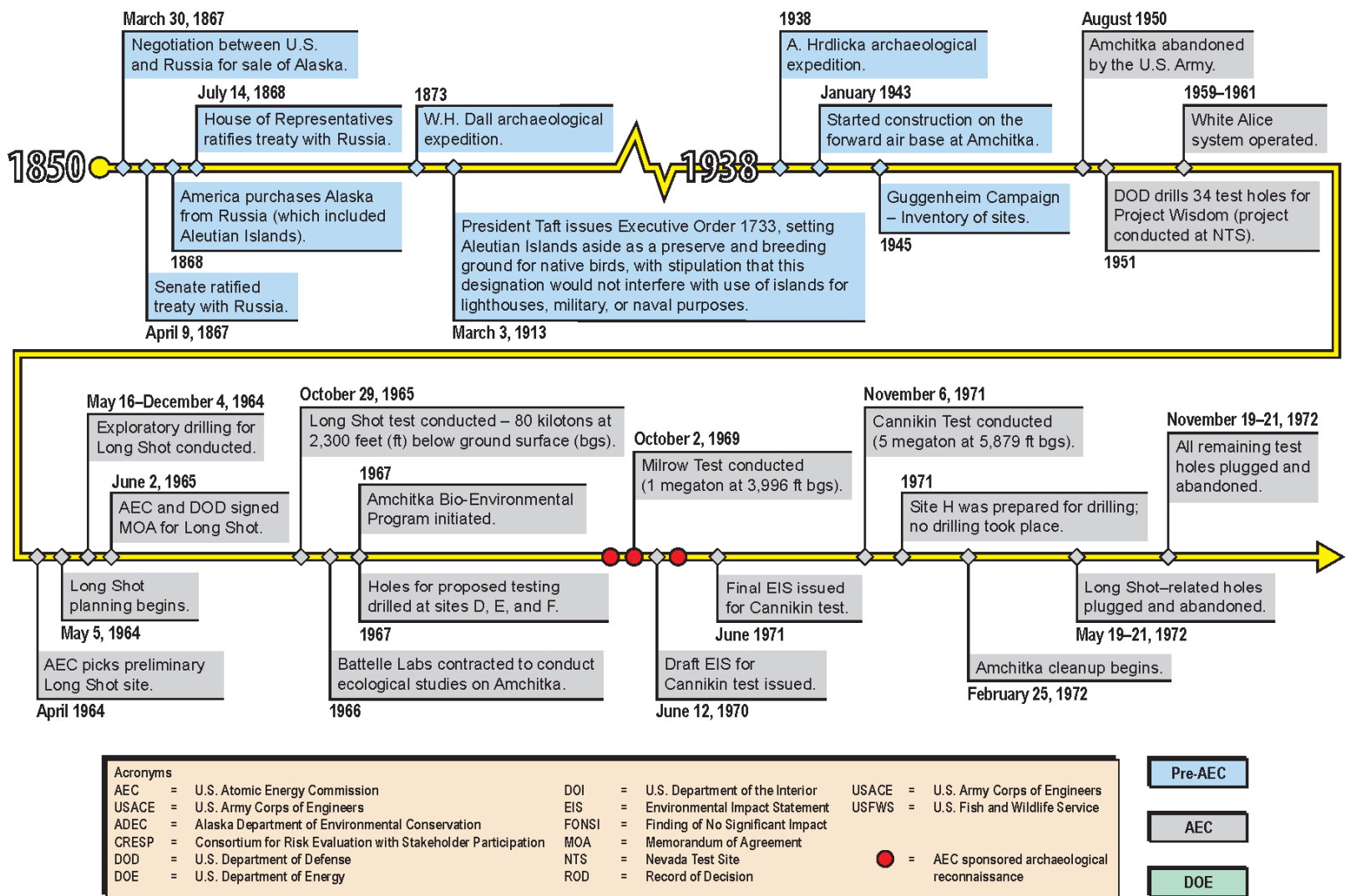


Figure 7. Historical Timeline

## Amchitka, Alaska, Site Timeline (continued)

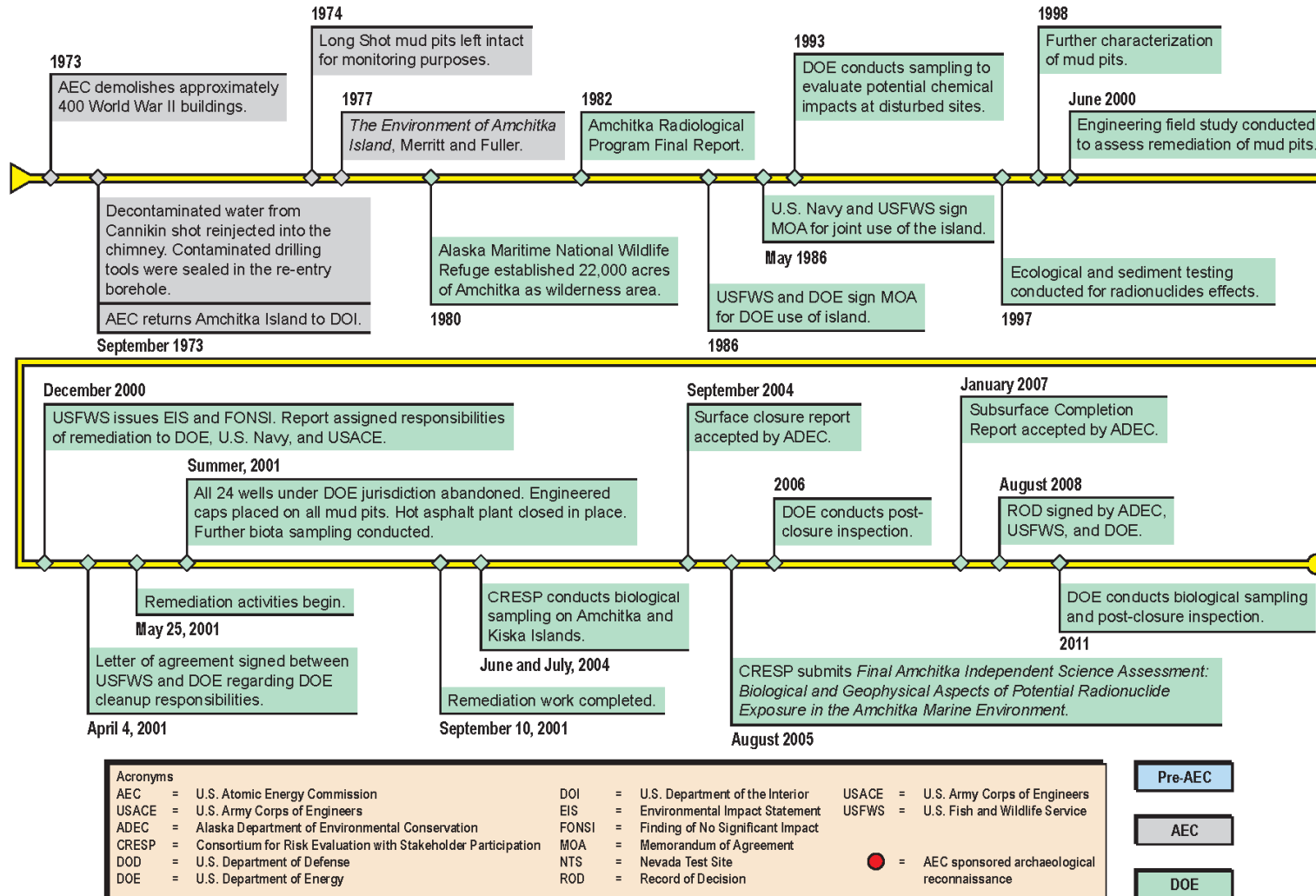
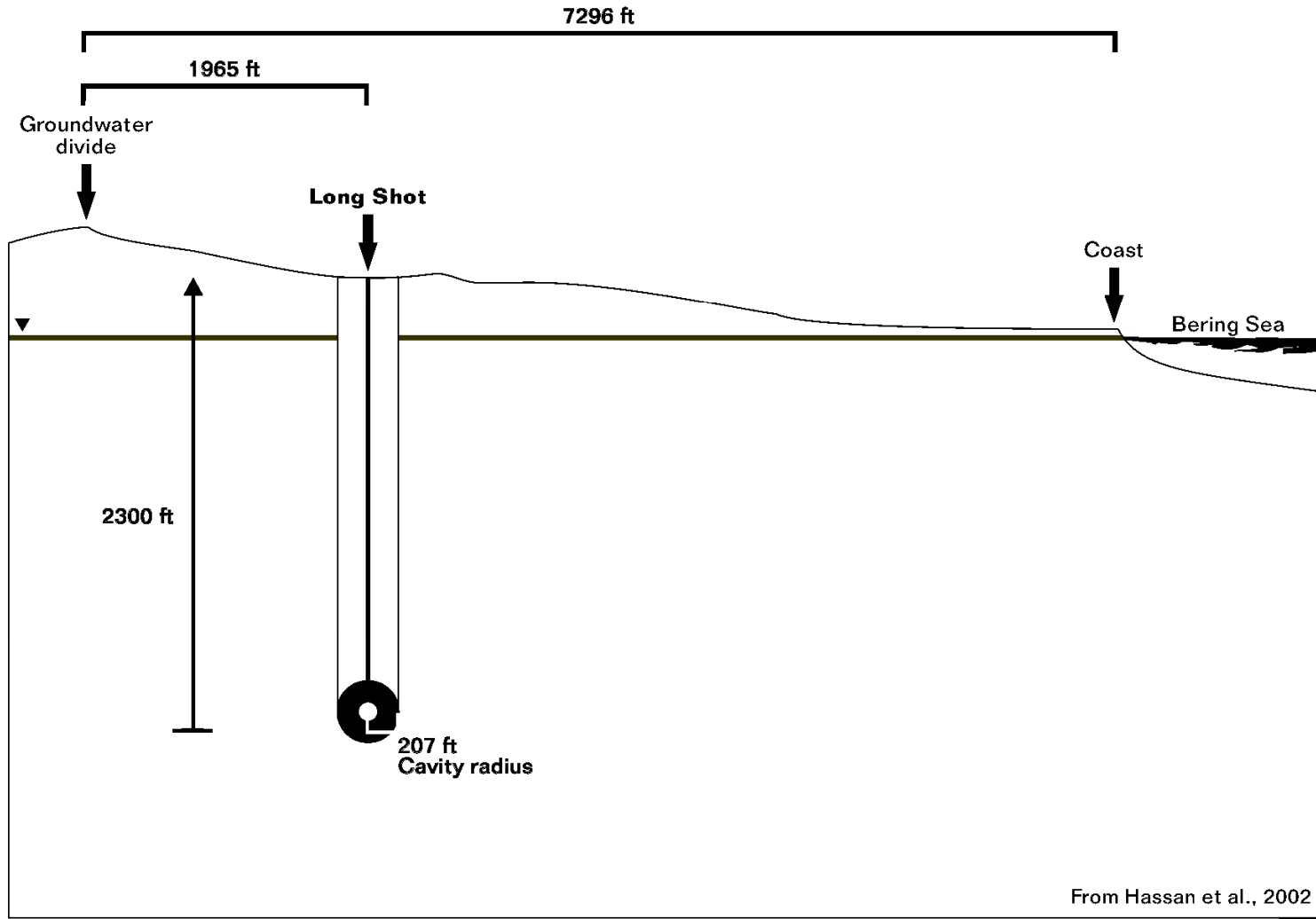


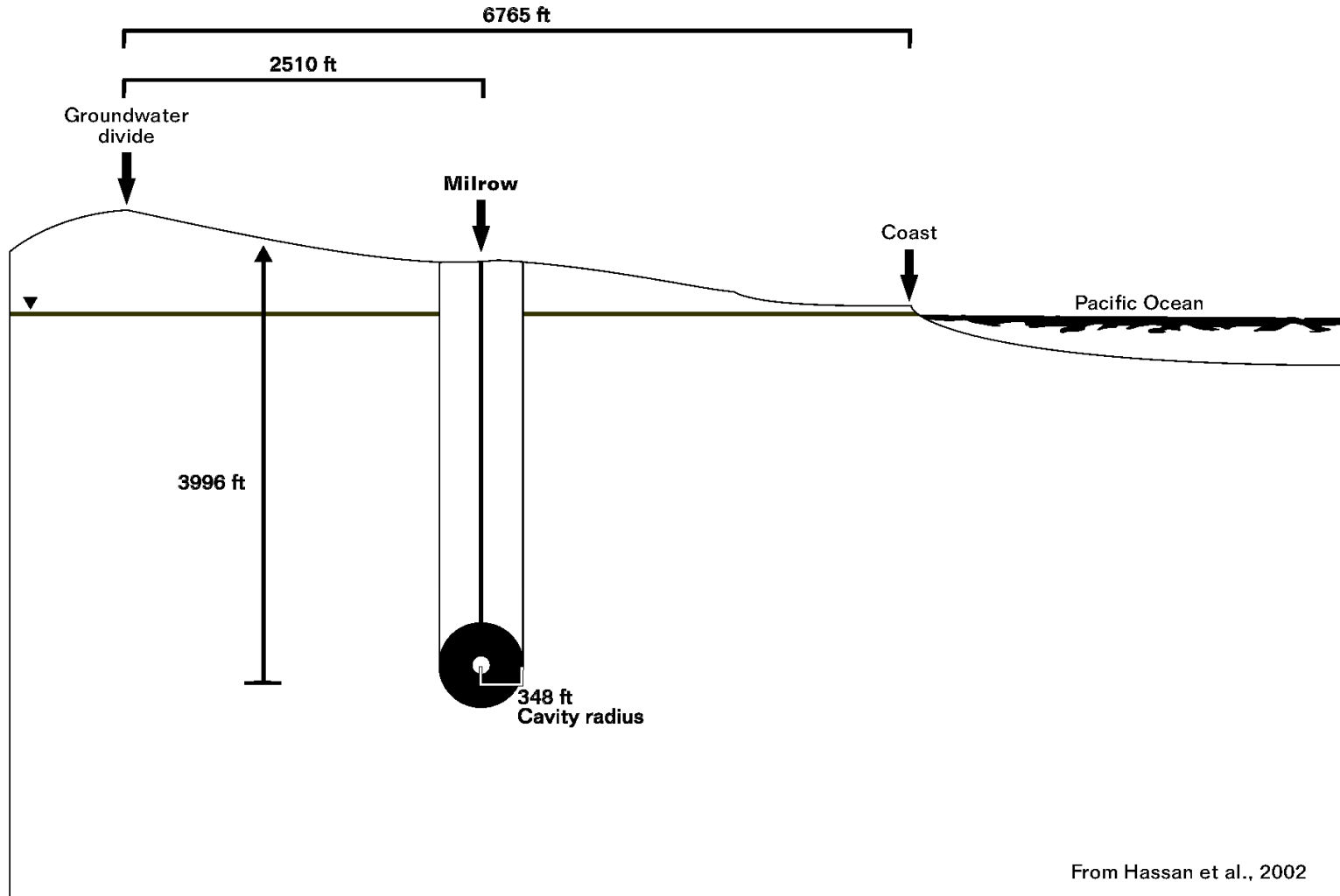
Figure 7 (continued). Historical Timeline





From Hassan et al., 2002

Figure 8. Schematic Cross Section of the Long Shot Test



From Hassan et al., 2002

Figure 9. Schematic Cross Section of the Milrow Test

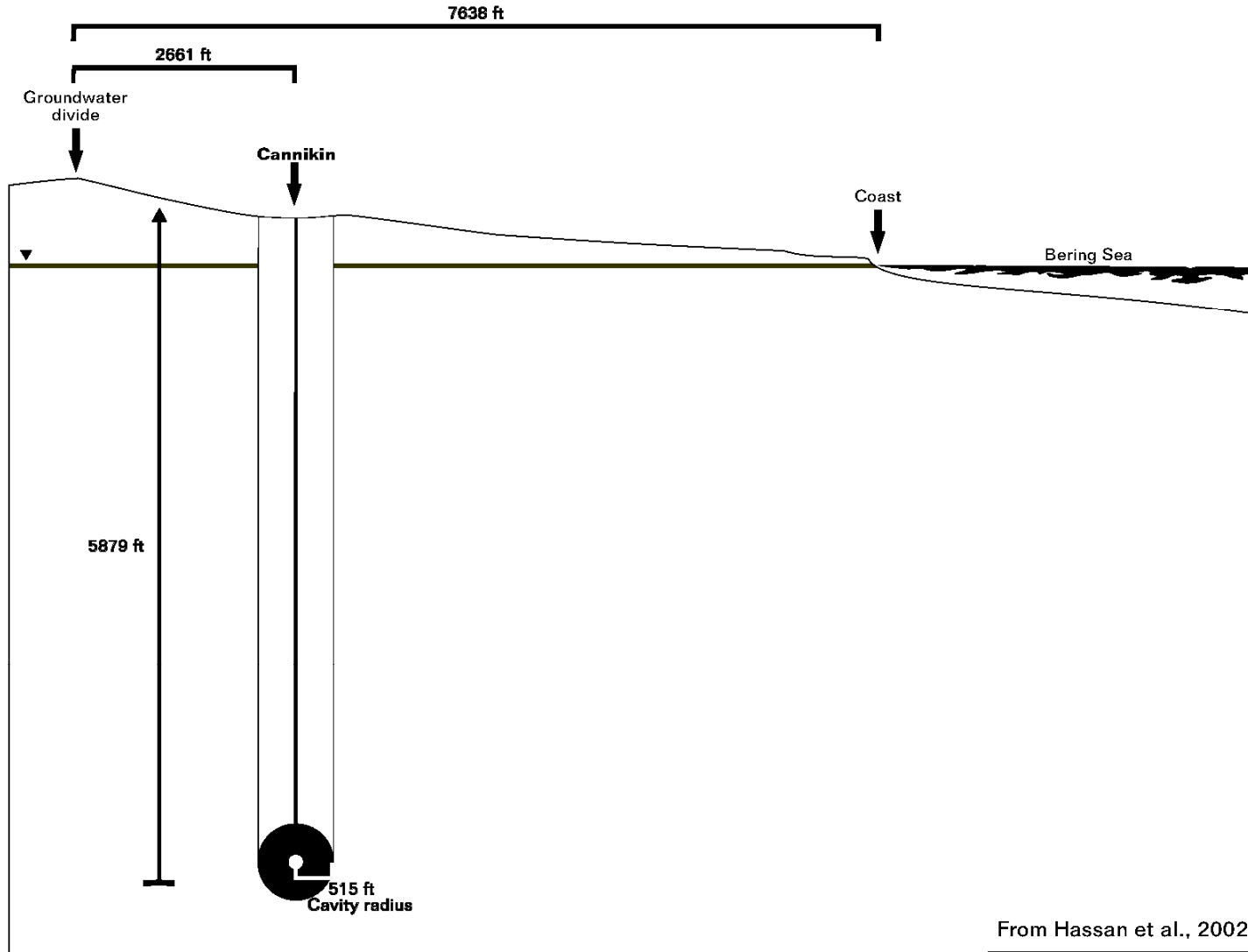


Figure 10. Schematic Cross Section of the Cannikin Test

## **2.7.2 Other Federal Military Activities**

In late January and early February 1943, the U.S. Army Air Corps occupied Amchitka in response to the Japanese occupation of the islands of Attu and Kiska, about 250 miles and 60 miles, respectively, northwest of Amchitka. The Air Corps occupied the island until 1950. In 1951, DOD drilled exploratory test holes for a proposed nuclear test later conducted in Nevada. From 1959 through 1964, the Air Force used the island as part of the White Alice systems. From 1988 until closure of the base in 1992, the Navy used the island for a Relocatable Over the Horizon Radar station.

## 3.0 Baseline Conditions

### 3.1 Geology and Hydrology

Geology, hydrology, and oceanography have been studied extensively at Amchitka because of the nuclear testing done on the island. Most of this work was done in the 1960s and 1970s and is documented in numerous U.S. Geological Survey (USGS) publications from the period generally referred to as the USGS 474 Series.

#### 3.1.1 Geology

The island is of volcanic origin, consisting of andesite surface lavas and submarine angular volcanic fragments, pillow lavas, and granodiorite intrusions. Most of the island contains only a thin, discontinuous veneer of unconsolidated sediments overlying the volcanic bedrock. Although Amchitka's origin is volcanic, there is no volcanic vent on the island, and an eruption has not occurred in Holocene time (the last 10,000 years). The nearest active volcanoes are on Semisopochnoi and Little Sitkin, about 40 miles and 20 miles, respectively, north-northeast of Amchitka, and both erupted in the 20th century (Little Sitkin erupted in 1900 and Semisopochnoi erupted in 1987). Over most of the island, organic soils, including peat, overlie the unconsolidated sediments. The island has numerous east-northeast-trending normal faults with modest displacement as shown on Figure 11.

Figure 12 is a geologic cross section along the long axis of Amchitka Island.

Amchitka lies in the western portion of the Aleutian arc, a prominent geologic/oceanographic feature of importance in determining the stability of the island. Although geologists have long recognized that Amchitka lies along an active volcanic area, frequent earthquakes are what brought nuclear testing to Amchitka initially. AEC was attempting to determine if current-day (1964) seismic equipment could detect the difference between an earthquake and an underground nuclear test. A magnitude 8.7 earthquake occurred just off the coast of Amchitka on February 4, 1965. In October of that year, Long Shot was detonated for comparison.

During the early work on the island, plate tectonics, first proposed in 1929, was not an accepted theory in geology. By the mid-1970s, in part due to work regarding formation of the Aleutian Islands, data supported the plate tectonics concept and explained the mechanism for continental drift that had been proposed earlier in the twentieth century. The Aleutian Islands are an expression of the collision of the North American and Pacific tectonic plates. When two ocean plates meet, one plate is forced beneath the other (subduction); in this case, the Pacific plate is forced under the North American plate. In the Aleutians, the subduction increases with the westward curvature of the Aleutian arc. The western Aleutians are surface expressions of the broken crustal blocks and are rotating clockwise away from the arc. Amchitka Island, as part of the Aleutian arc, is moving westward at a rate of approximately 2 centimeters (0.8 inch) per year (Eichelberger et al. 2002). This movement, along with the volcanic activity and earthquakes, indicates that the island is in a geologically active area. The routine occurrence of seismic activity in the area has raised concern over the stability of the test cavities (Eichelberger et al. 2002). However, since the tests, several earthquakes with magnitude greater than 6.7 have occurred, and no adverse effects have been detected.

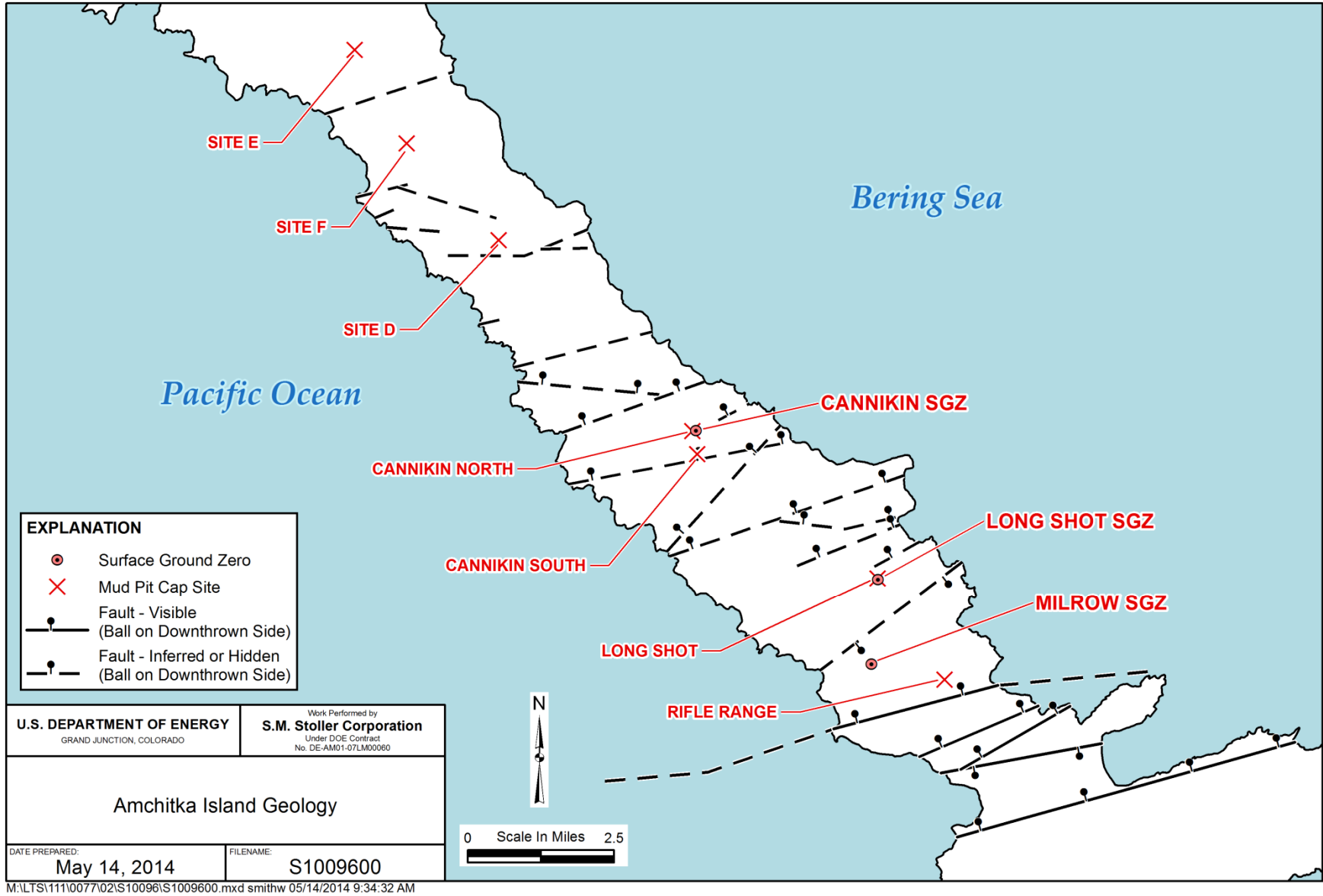
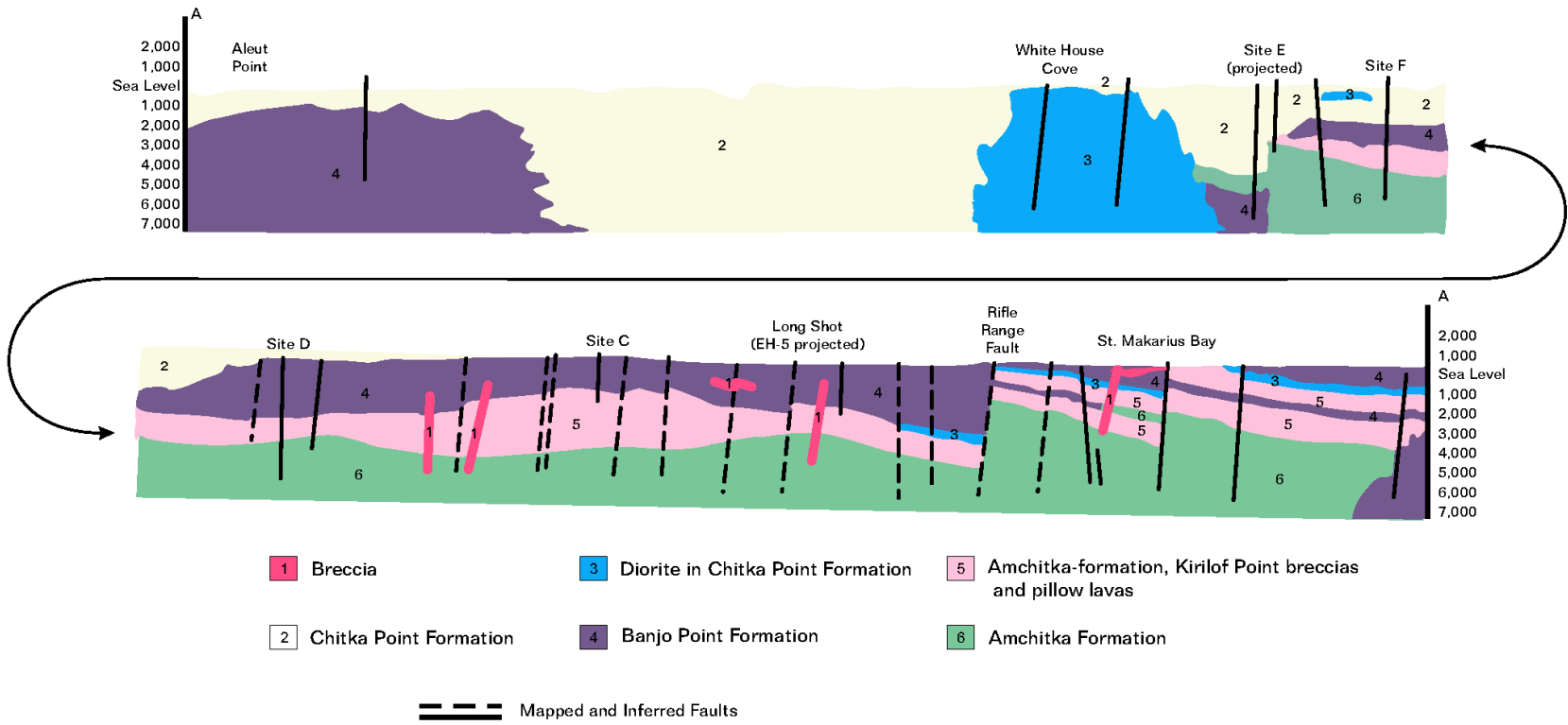


Figure 11. Amchitka Island Geology



From: Carr et al. 1971

Figure 12. Geologic Cross Section of Amchitka Island

More-detailed discussions of the geology are available in Coats (1962); Carr and Quinlivan (1969); Carr et al. (1969); Anderson (1971); Carr et al. (1971); and Avé Lallemant et al. (2000).

### 3.1.2 Hydrology

Amchitka is covered with hundreds of small, shallow ponds up to 330 ft wide and up to 10 ft deep. The smaller ponds are considerably shallower, typically ranging from 12 to 20 inches deep. Ponds are most numerous on the eastern two-thirds of the island (approximately 26 ponds per square mile), where they have developed above marine terraces and are confined by thick vegetation and peat. Many lakes in this region lack a definite inlet or outlet. Fewer ponds are present on the western third of the island, where they typically occupy bedrock depressions. Larger pond sediments are either floc (suspension of low-density detrital organic material) over gravel, organic silts over gravel, or clean gravel. The bottoms of smaller ponds are usually composed of peat or fine sediment covered with floc. Watersheds on Amchitka Island are generally limited to 1 to 3 miles in length, because all streams drain perpendicular to the long axis of the island into either the Bering Sea or the Pacific Ocean. Streams on the eastern part of the island flow slowly through tundra-covered watersheds, range from 3 to 10 ft wide, are up to 12 inches deep, and are characterized by low gradients and low flow velocities. Streams in the central and western regions range from 6 to 13 ft wide and are up to 14 inches deep. Most of the streams in the island flow year-round. During relatively dry periods, stream flows are sustained by base flow from soils and the underlying weathered bedrock; surface runoff and base flow contribute to flows during wet periods.

The hydrogeology beneath the surface of Amchitka Island is governed by the dynamics of the seawater intrusion typical of islands. The groundwater system consists of a freshwater lens floating on seawater. To sustain this lens, there must be active groundwater circulation. Rainfall that infiltrates is fresher and less dense than the underlying seawater. Continued recharge results in the buildup of a lens of fresh water floating above the seawater and the flow of fresh water from the center of the island outward to the ocean. Groundwater flow is generally characterized by recharge along a shallow water table, downward flow in the interior of the island, and upward flow approaching the coast, with freshwater discharge in seeps along the ocean floor. The nearly saturated subsurface conditions, combined with low hydraulic conductivity and high rainfall, lead to significant runoff and the development of shallow groundwater zones that rapidly discharge water in springs and seeps rather than allow deep infiltration. Data collected from shallow and deep boreholes on Amchitka confirm this conceptual flow model (Chapman 2006).

## 3.2 Ecology

Amchitka's coastline is rugged, with sea cliffs, isolated sandy and gravel beaches, and grassy slopes. The lowest elevations are on the eastern third of the island and are characterized by isolated, shallow ponds and heavily vegetated drainages. The central portion of the island has higher elevations, is more prone to wind erosion, and has fewer lakes. The westernmost 3 miles of the island are barren. The area contains a windswept, rocky plateau with sparse vegetation, except for areas (e.g., stream drainages) protected from the wind. The average surface elevation at the western end of the island is approximately 800 ft. The highest elevation on the island is approximately 1,160 ft (Merritt and Fuller 1977).



Amchitka is characterized by a pronounced maritime climate, including frequent storms, strong winds, and cloudy skies. There is no prevailing wind on Amchitka, although during the summer months the winds are generally out of the southwest. The mean wind speed between December and February is 30 miles per hour; between March and May it is 26 miles per hour, between June and August it is 22 miles per hour, and between September and November it is 27 miles per hour. The maximum recorded wind velocity on Amchitka is 115 miles per hour. The ocean moderates temperatures, which average 31 °F in January and 48 °F in August. Annual precipitation is about 33 inches, including approximately 71 inches of snow (Merritt and Fuller 1977). The conversion of snowpack to inches of water is dependent on several variables, such as area of cover and density. As a rule of thumb, 10 inches of snow is equivalent to about 1 inch of water.

### **3.2.1 Terrestrial**

The island's topography defines two broad vegetation categories: wetland tundra and upland tundra. Wetland communities cover much of the low-lying southeastern half of the island; upland communities dominate the slopes in the northwestern half.

Raptors, seabirds, shorebirds, waterfowl, and upland game birds represent the 131 species of birds recorded on and near the island; approximately 30 species breed on the island. Among other species commonly found on the island are the bald eagle, peregrine falcon, and Aleutian cackling goose.

The only mammal on Amchitka is the Norway rat, believed to have been introduced on the island during World War II (Merritt and Fuller 1977). In 1921, fox were introduced on the island under a fox-farming permit. Because of the fox's impact on island bird populations, USFWS started an eradication program, and by 1960 all the fox, along with feral cats and dogs from World War II were removed (USFWS 2000).

The numerous freshwater ponds on the island support a few fish species. Dolly Varden, a salmonid, and three species of stickleback are present in both a landlocked and an anadromous (i.e., migrating up streams from the ocean to spawn in fresh water) form (USFWS 2000).

### **3.2.2 Wetlands**

Wetlands are areas that are inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soils. Although Alaska has not designated specific regions of Amchitka as wetlands, they cover much of the southeastern lowlands. Wetland tundra plant communities include shallow ponds and extensive meadows. Although some of the island's ponds do not contain vascular plants, many support emergent plant communities composed of Arctic rush, sedges, shortawn foxtail, and burrweed (USFWS 2000).

### **3.2.3 Marine**

The marine algal flora of Amchitka is diverse; about 120 algal species have been reported from the island coast. Zonation within the algal community is related to exposure, and characteristic assemblages occur throughout the intertidal and shallow subtidal regions.

Numerous waterfowl species, such as green-winged teal, mallard, and red-throated loons, are year-round residents. Marine bird species occupy many nesting sites around the perimeter of the island.

A number of marine mammals occur in or migrate through the area of Amchitka. The northern sea otter and harbor seal are commonly seen on the island. Steller sea lions are permanent residents.

The marine fisheries resources of the Aleutian Islands are abundant and diverse. Ninety-two fish species have been described in Amchitka's nearshore environment (USFWS 2000).

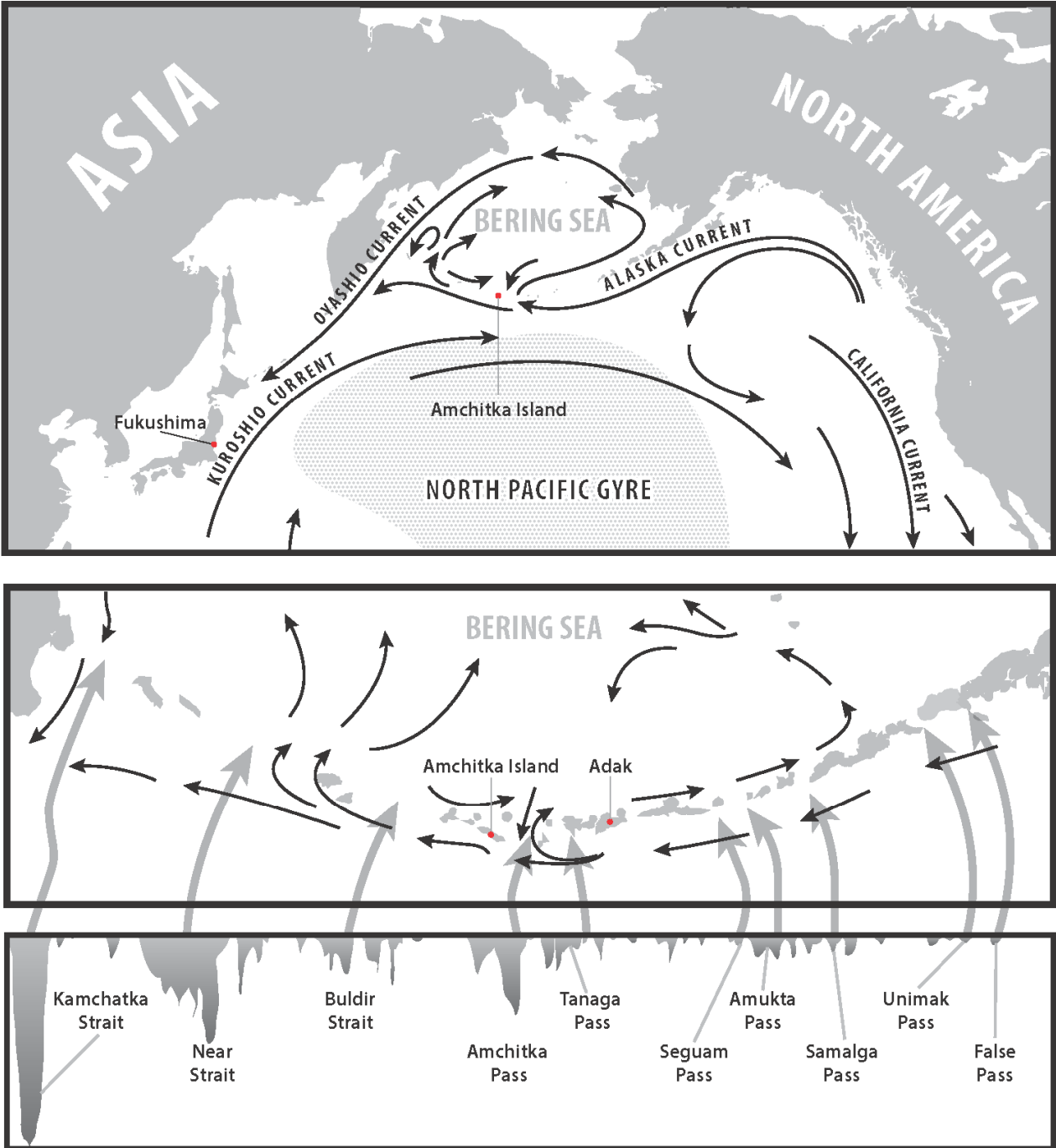
### **3.3 Oceanography**

The Aleutian Ridge is an elongate, curved rim that rises from the sea floor, extends westward from the Bering Shelf, and separates the Pacific Ocean from the Bering Sea. Along the ridge are 167 named and over 300 unnamed islands that rise above sea level and form the Aleutian Islands. Amchitka Island, situated near the western end of the Aleutian chain, is an elongate, narrow landmass between Amchitka Pass and Oglala Pass. Amchitka Pass is one of only three deep passes in the Aleutians, although all 14 passes allow significant flow between the North Pacific and the Bering Sea. Although there is a general flow pattern in the Bering Sea, influenced by the northward inflow of relatively fresh, warmer water from the Alaskan Stream, and exiting with southward flow forming the Kamchatka Current, inside the basin, complex subcurrents and flows are present (Loughlin and Ohtani 1999).

Reed and Stabeno (1999) determined in the early 1990s that Amchitka Pass has bidirectional flow, that is, northward (inflow) on the eastern side of the pass and southward (outflow) on the western side. This results in complex currents around Amchitka Island, partially influenced by the presence of Bowers Ridge, a northward extension of the Aleutian Arc. Due to the complex topography of the sea floor in the region, a number of convoluted, highly variable currents exist in and around the waters bordering Amchitka (DOE 2003). Figure 13 shows regional ocean currents of the western Aleutian Islands.

### **3.4 Previous Investigations**

Amchitka Island has been the subject of many studies. During the 1960s and 1970s, both before and after the underground nuclear tests were conducted, scientists carried out extensive investigations of the environment on Amchitka Island. Data collected from these investigations include information on the geology, hydrology, climate, geomorphology, and the land and marine biota of the island as well as information on environmental contaminants and the effects of nuclear testing. Some of these studies and investigations are summarized and discussed in the following sections.



Modified from Hunt and Stabeno, 2005

Figure 13. Regional Ocean Currents

### **3.4.1 The Environment of Amchitka Island**

The Amchitka Bioenvironmental Program (Merritt and Fuller 1977) was developed in support of the Amchitka Island underground nuclear tests, specifically the Milrow and Cannikin tests. The objectives of the program were to conduct appropriate field and laboratory studies to predict, evaluate, and document the effects that the nuclear tests might have on the bioenvironment of Amchitka Island and to recommend measures for minimizing these effects. The program began in 1967, after the Long Shot test but before the Milrow test in 1969. It concluded in 1973, following completion of the Cannikin test.

The studies conducted under this program included climate, geology, hydrology, and biota. The Merritt and Fuller (1971) report presents a summary of these studies in a series of individual papers within the report, which are grouped into major sections on the land, the sea, marine mammals, and environmental contaminants. The report also includes a summary of the island setting (geographic, geologic, hydrologic, weather and climate, prehistoric human occupation, and previous scientific investigations) and a paper summarizing the observed and measured effects of the nuclear tests on the island.

### **3.4.2 Ecological Consequences of Nuclear Testing**

The detonations at Milrow and Cannikin and related activities resulted in the loss of or damage to terrestrial habitat totaling approximately 1.5 percent of the total area of Amchitka Island (Fuller and Kirkwood 1977). A number of lakes and streams were temporarily affected by site activities but recovered quickly. Several freshwater areas of the island were irreversibly impacted, however, including channel alteration along one stream and the creation of a new lake. An intertidal bench was displaced to a level above the intertidal zone.

Localized terrestrial, freshwater, and marine ecosystem habitat losses were minor and had no permanent effects on the associated biotic populations. No plant or animal population on or around the island was lost or endangered, although substantial numbers of sea otters and freshwater and marine fish were killed by the Cannikin detonation. However, post-test studies indicated that these populations recovered quickly (Fuller and Kirkwood 1977).

The detonations also produced scattered terrain disturbances around the island, some of which were severe in localized areas. In these instances, the landscape was visibly altered, and may remain so for decades or even centuries.

### **3.4.3 Radionuclides in Air, Water, and Biota**

Air, water, and biological samples were collected before and after the three underground nuclear detonations at Amchitka Island and were analyzed for natural and fallout radionuclides by gamma spectrometry (Seymour and Nelson 1977). Selected samples were also analyzed for tritium, iron-55, and strontium (Sr)-90. The primary objective of this study was to identify the origin of the fallout radionuclides (i.e., the Amchitka Island detonations, natural background, or other sources).

Samples from 81 types of organisms were collected and analyzed for radionuclides potentially available to humans through the food web from areas likely to be contaminated if radionuclides

seeped from the detonation sites. The studies showed that there was no escape of radionuclides from the detonation sites except for trace amounts, primarily tritium, in water and soil gas samples from the immediate vicinity of the SGZ for the Long Shot test. In general, radionuclide values for Amchitka Island samples were similar to those from comparable samples from other geographical areas.

The University of Washington College of Fisheries in Seattle, Washington, conducted radiobiological studies on Amchitka from 1969 to 1979. The final annual report (DOE 1982) concluded:

Conclusions from the results of the recent analyses are a reiteration of the results stated in Nelson and Seymour (1975); namely, “(1) no new radionuclides are present; (2) the most abundant radionuclides are naturally occurring beryllium-7 ( $^7\text{Be}$ ) and potassium-40 ( $^{40}\text{K}$ ); (3) the trace quantities of fission products and induced radionuclides are from world fallout; and (4) a trace of  $^3\text{H}$  contamination remains in some Long Shot ponds, as previously reported.” It is concluded from the results of analyses of samples collected between September 1969, and December 1978 as reported in this and the eight previous progress reports, that there were no radionuclides of Milrow or Cannikin origin in the water, plants, or animals of Amchitka Island.

These studies included some of the same marine species sampled in later studies as well other biota from the marine environment.

### **3.4.4 Marine Fish Communities**

The Fisheries Research Institute of the University of Washington studied and evaluated the impact of the Milrow and Cannikin tests on marine fish off Amchitka Island from the summer of 1967 to the fall of 1973 (Simenstad et al. 1977). Information was collected on 92 fish species taken from marine waters around Amchitka Island, not only providing information to support the nuclear testing efforts, but also significantly expanding the knowledge of the Aleutian marine fish communities.

The pressure waves resulting from the nuclear detonations, particularly Cannikin, killed large numbers of several species of fish in offshore waters and changed marine habitat through uplifting of some rock benches. The effects were short term, however, with no detectable effects on the fish populations observed within a year after the Cannikin detonation. Because the total area of marine habitat affected by the tests was a small fraction of the total habitat around the island, the overall effect of the tests on the Amchitka Island marine ecosystem was temporary.

### **3.4.5 Aquatic Ecology**

The freshwater ponds and streams on Amchitka Island support few species of vertebrates and invertebrates. However, these waters do support six species of freshwater fish, including pink and silver salmon, which use the streams for spawning (Valdez et al. 1977).

The Milrow and Cannikin detonations significantly affected ponds and streams within about 1.2 miles of SGZ at each site. Ponds were drained by fissuring or tilting, and stream channels were altered. Local fish populations were adversely impacted by terrain alterations and pressure waves generated by the detonations. Habitat alterations were not permanent. Fish populations fully recovered within 5 years of each test.

Preparations for the nuclear tests also had deleterious effects on the freshwater vertebrates and invertebrates. Drilling mud released and/or spilled into streams and ponds smothered the macroinvertebrates, which in turn depressed fish populations because of the absence of food organisms. The populations have recovered, and there are no known lasting impacts from the mud.

### **3.4.6 Avifaunal Investigations**

Bird populations on and near Amchitka Island were studied between 1967 and 1973 to determine species composition, ecological distribution, density, productivity, and seasonal movements. A total of 131 species were recorded, and evidence of breeding for 28 species was obtained (White et al. 1977). The investigators predicted that the impacts of the Milrow and Cannikin nuclear testing could include habitat and nest-site destruction, destruction of birds, and accidental release of radionuclides. These predictions led to two recommendations regarding conduct of the tests. The first recommendation was to not conduct the tests during the height of the breeding season, when the greatest number of birds would be affected. The second was to conduct the tests during the winter months (November to February) to eliminate possible radionuclide transport by fall migrants and birds resident on Amchitka during the summer.

No actual direct effects of the Milrow test were detected in any bird populations. The immediate, actual results of the Cannikin test, however, were 15 test-related bird deaths, the loss of two peregrine falcon aeries that involved only one pair of falcons, additional damage to a falcon aerie originally damaged by Milrow, the loss of six bald eagle nests, and damage to one eagle nest. The long-term effects of the tests could not be assessed at the time of the study, but a baseline of data was established for future studies.

### **3.4.7 Tritium Sampling**

Tritium activity has been monitored in surface water and shallow groundwater on Amchitka Island from 1965 to the present under various programs. Following the Long Shot detonation, anomalous concentrations of tritium were found in the vicinity of SGZ 27 days after the original test (Castagnola 1969). The main activity front of radioactive gases reached the surface roughly 6 months or more after the Long Shot detonation. At least 3.5 years after the Long Shot test, anomalous concentrations of tritium in water existed in several surface waters in the vicinity of Long Shot SGZ, reaching a maximum observed concentration of about 5,000 tritium units (approximately 16,000 picocuries per liter) in September 1966.

The EPA drinking water standard for tritium is 20,000 picocuries per liter. Tritium levels in some of the groundwater and surface water samples collected by EPA in 1997 (Faller and Farmer 1998) remain above background levels but well below the current safe drinking water levels. At locations around the Long Shot SGZ, tritium concentrations continue to decrease faster than would be expected from tritium decay alone, indicating that dilution is also a factor. Dasher et al. (2000) noted that tritium measurements taken since the Long Shot detonation indicate that radioactive gases escaped to the near surface shortly after the detonation but do not indicate long-term movement from the contaminated groundwater to the Long Shot SGZ surface environment.

In addition to the fact that tritium concentrations are declining faster than would be predicted from the rate of decay alone, hydrologic measurements at Amchitka indicate a downward flow for recharge water to a freshwater/saline water zone where movement occurs laterally. With the exception of a brief pathway from Long Shot immediately after the test that has since been flushed out, the results of hydrological tests indicate that there is no complete exposure pathway from the subsurface radionuclide source areas beneath the island to the shallow groundwater beneath or to surface water on the island (Claassen 1978; Fenske 1972; Wheatcraft 1995).

### 3.4.8 Investigation of Radionuclides in Ecosystems

In 1996, the Greenpeace organization reported that radionuclides associated with the three Amchitka Island underground nuclear test sites were leaking into the surface environments on the island (Miller 1996). This report was based on limited sampling and analysis of selected biota on the island. In response to this report, radioecological studies of Amchitka freshwater and marine environments were conducted in 1997 and 1998 under the auspices of the Amchitka Technical Advisory Group, which consisted of representatives from DOE, ADEC, EPA, USFWS, University of Alaska-Fairbanks, APIA, Greenpeace, Los Alamos National Laboratory, and other stakeholders.

Sampling transects of varying lengths were established on stream courses in four drainages, three associated with the underground test sites and a single reference location 8 kilometers (5 miles) upgradient from each major test location (Dasher et al. 2004). Four biota sampling sites were designated within each stream transect, and representative plant and sediment samples were collected at each. Marine transects for sampling marine algae were located at the outfalls of the streams. Sediment samples were obtained at each sampling location. In 1998, the same four stream drainages were resampled as well as four additional drainages on Amchitka. Three new stream transects on nearby Adak Island and at Cold Bay on the Alaska Peninsula were also added to the 1998 survey. In addition, 76 upland soil cores (100 square centimeters [15.5 square inches]) and 34 lichen samples (0.25 square meter [2.7 square ft]) were collected at 11 locations on Amchitka and at 3 sites each on Adak Island and at Cold Bay. All samples were analyzed for gamma- and alpha-emitters by conventional radioanalytical methods at three different laboratories. In addition, plutonium-240 ( $^{240}\text{Pu}$ ) and  $^{239}\text{Pu}$  ratios were determined by thermal ionization mass spectrometry, and low-level tritium enrichment analyses were performed on selected surface water and precipitation samples.

DOE contracted with EPA's Environmental Monitoring Systems Laboratory in Las Vegas, Nevada, to perform the sampling and radiological testing. Analytical results were comparable between the 1997 and 1998 surveys and the various laboratories, and results indicated that worldwide fallout was the major source of radionuclides in surface environments of Amchitka Island. No indications were found suggesting "leakage" of radionuclides from the deep underground test cavities to the surface environment. EPA's Amchitka Island Special Sampling Study 1997 reached the following conclusion: "Comparison of cesium-137 ( $^{137}\text{Cs}$ ) 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" (DOE 2000b). Dasher et al. (2000) concluded that the elevated levels were associated with global fallout rather than the Amchitka tests.

### 3.4.9 Long-Term Hydrologic Monitoring Program

A long-term hydrologic monitoring network was established on Amchitka Island in 1967 to document the effect of the underground nuclear testing on the island. Before 1972, groundwater and surface water sampling at the Nevada National Security Site (formerly called the Nevada Test Site) and offsite areas, including Amchitka Island, was conducted by the U.S. Public Health Service, USGS, AEC, and various contractor organizations. In 1972, DOE began a program called the Off-Site Environmental Monitoring Program for the Nevada Test Site and Other Test Areas Used for Underground Nuclear Detonations, which monitored Amchitka radioactivity levels in groundwater. Amchitka 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 Long-Term Hydrologic Monitoring Program (LTHMP), which was funded by the DOE National Nuclear Security Administration Nevada Site Office and operated by the EPA Radiation and Indoor Environments National Laboratory in Las Vegas, was created in 1972 to measure levels and trends of radioactivity in the offsite environment surrounding testing areas to ensure that radioactivity levels comply with existing radiation protection standards.

The LTHMP for Amchitka Island consisted of biennial sampling and analyzing surface water and groundwater samples during odd years from the Long Shot, Milrow, and Cannikin test sites and from other locations on the island designated as background (sampling was not conducted in 1995, however, due to budget restrictions). Tritium and gamma-spectral analyses were routinely performed, and new water sources were also initially analyzed for strontium-89 ( $^{89}\text{Sr}$ ) and  $^{90}\text{Sr}$ , radium-226,  $^{238}\text{Pu}$  and  $^{239}\text{Pu}$ , and uranium isotopes.

Since long-term hydrologic monitoring commenced on Amchitka, no radionuclides attributable to the three underground test sites have been observed, with the exception of tritium from the Long Shot site. Concentrations of tritium at Long Shot have been steadily declining, however, and are below the EPA drinking water standard. Monitoring under the LTHMP last occurred in 2001.

### 3.4.10 Groundwater Modeling

The purpose of the 2002 groundwater modeling effort (DOE 2002b) was to provide information needed to conduct a human-health risk assessment of the potential hazard posed by the three underground nuclear tests on Amchitka. The modeling focused on subsurface transport of radionuclides from the underground detonation cavities and their movement through the groundwater system to the point where they seep from the ocean floor into the marine environment.

Conceptual models for flow and transport for the tests were developed. A multiparameter uncertainty analysis was performed to address uncertainty in the supporting data, and separate sensitivity analyses were evaluated for specific conceptual uncertainties. The final modeling assumes that groundwater moves predominantly through fractures in the rock and considers multiple realizations of the flow field by drawing values of hydraulic conductivity, recharge, and porosity from their distributions. An additional separate sensitivity case was also presented addressing uncertainty in the matrix diffusion process.



The final model calibrations depict a deeper freshwater-saltwater transition zone on the Bering Sea side of the island, as compared to the Pacific side. Transport results indicate that radionuclide movement at Long Shot is much faster than at Milrow and Cannikin. This faster rate results from the shallower depth of the Long Shot cavity compared to the depths of the other two test cavities. Long Shot is above the freshwater-saltwater transition zone in all realizations, whereas Milrow and Cannikin tend to be within or below the transition zone. Below the transition zone, the flow path toward the seafloor is lengthened, and groundwater velocities are much slower. The arrival time of the peaks of mass flux and concentration for tritium was on the order of 20 to 30 years for Long Shot and 100 to 125 years for Milrow and Cannikin. This led to higher mass fluxes and concentrations breaking through at Long Shot than at Cannikin or Milrow, particularly due to the process of radioactive decay reducing mass as time proceeds (DOE 2002b).

The groundwater model results included a mean (expected) value and a standard deviation (measure of uncertainty). The standard deviation was large as a result of uncertainties in parameter values and their variability in the subsurface. The most significant uncertain parameter was found to be the porosity assigned to the fracture system. Uncertainty in the freshwater-saltwater transition zone location also led to large variation in transport results from one realization to the next. The Consortium for Risk Evaluation with Stakeholder Participation (CRESP) independent science study provided new data regarding both porosity and the location of the transition zone. These data, along with new bathymetric profiles, were used to verify the Amchitka groundwater models, revise and update the model parameter distributions, and reduce uncertainty in the model results (Hassan and Chapman 2006).

Through a series of analyses, it was found that the new data provided by CRESP were consistent with the conceptual framework and range of parameter values used in the 2002 groundwater flow and transport model. The 2002 model was verified through a number of components. First, the high-resolution bathymetric data obtained by CRESP (2005) closely matched the profiles used in the models. Second, the posterior distributions for recharge, hydraulic conductivity, and their ratio (all constrained by the transition zone location information from CRESP), are encompassed within the original prior distributions used in the 2002 model, verifying that the original distributions were wide enough to include the new data. Third, the updated flow solution results in an ensemble mean that matches the head and chemistry data within one standard deviation of the original models. When the new data provided better control on parameter ranges, the wide uncertainty range was trimmed from both sides, resulting in a new set of possible solutions encompassed within the original set of possible solutions. Though the CRESP data indicate a deeper transition zone at Milrow than indicated by site chemistry data, the possibility of a deeper transition zone was accounted for in the 2002 model by the wide range of recharge and hydraulic conductivity considered.

In 2006, the models were updated with the new CRESP data, and the resulting groundwater fluxes had the same distribution as the original models. A dramatic reduction in uncertainty was achieved by conditioning on all available data sets. The 2006 modeling assumes that groundwater moves predominantly through fractures in the rock and considers multiple realizations of the flow field by drawing values of hydraulic conductivity, recharge, and porosity from the fracture distributions. An additional separate sensitivity case was also presented addressing uncertainty in the matrix diffusion process.

The parameter distributions cover a much narrower range than originally used in the 2002 model. Using the new porosity profiles from CRESP (2005) results in very slow flow velocities, orders of magnitude slower than the velocities produced by the 2002 model. With the new porosities, radionuclides require thousands of years to reach the seafloor. No breakthrough resulted for any of the three sites within the 2000-year model time frame in the updated model, despite ignoring all retardation mechanisms (sorption, radionuclide trapping in glass, matrix diffusion, and radioactive decay). In the 2002 model, the standard deviation of mass flux was larger than the mean, implying that the lower limit for radionuclide mass flux was essentially zero. This value is now indicated by the CRESP data, and was included in the possibilities presented by Hassan and Chapman (2006).

### **3.4.11 Independent Assessment**

At the request of the State of Alaska, DOE funded CRESP to conduct an independent assessment of potential hazards and risks to marine resources of the Amchitka littoral zone and surrounding marine environment and their consumers, both animal and human, that have resulted or may arise from the Amchitka nuclear tests and not from other activities that have occurred on the island (CRESP 2003).

Commencing in 2003, CRESP, a group of universities, performed an independent evaluation of possible contamination at Amchitka and specifically to determine (1) whether marine biota consumed either as part of a subsistence diet or taken by commercial fishing is safe and (2) which organisms would be useful for long-term monitoring. The CRESP field sampling was conducted in 2004, and the report was completed in 2005. An addendum to the report was prepared in 2006 (CRESP 2006). One of the conclusions from the CRESP study was “The foods consumed by humans are safe with respect to radionuclides, and levels of radionuclides are well below published human health risk guidance levels” (CRESP 2005).

### **3.4.12 Environmental Monitoring Program**

Following the CRESP evaluation and results, DOE, in collaboration with ADEC, USFWS, APIA, University of Alaska-Fairbanks, and Argonne National Laboratory, set about continuing to evaluate selected marine and terrestrial biota. Their collective work resulted in the *Sampling Plan for the Amchitka, Alaska, Site 2011 Sampling Event* (DOE 2011a) that outlined four sets of data quality objectives that provided the rationale for the 2011 sampling effort. The first set provides supporting information for the biota sampling event. The second set provides the rationale for using biota data from the first objective for input into the RESRAD-BIOTA code to analyze the potential ecological risks from the radionuclides of interest. The third set supports the collection of tritium data in seawater. The fourth set supports the collection of star reindeer lichen and soil beneath the lichen and marine sediment. The subsequent report, *Amchitka Island, Alaska Monitoring Report 2011 Sampling Results* (DOE 2013), summarizes the work that was performed in the collection of the data to meet these data quality objectives, presents the results of the laboratory analyses from all the samples collected, and provides an evaluation of the ecological health of the Amchitka and Adak environments.

Results of the 2011 environmental sampling did not identify any test-related radionuclide seepage into the terrestrial or marine environments. Based on the 2011 data collected for Amchitka and Adak, seafood harvested at Amchitka and Adak are considered safe for

consumption at the intake levels for the five diets evaluated. These results confirmed the results of earlier investigations, which showed that subsistence- and commercial-catch seafood is safe for human consumption.

### 3.5 Remedial Actions

The surface and subsurface remedial activities at Amchitka are addressed separately due to the nature of the available technology and the residual radioactivity. Surface remediation has been completed; for the subsurface, it was determined that long-term monitoring is the most effective alternative because no feasible technology has been identified to remove the residual radioactivity from the test cavities.

#### 3.5.1 Surface

Surface water, sediment, and biological data were collected periodically from 1971 through 2004 to determine any effect from AEC activities on the island and its biota. To date, these data indicate no significant impact from the AEC testing.

A total of 11 drilling mud pits (at the six locations) are located at the Long Shot, Milrow (Rifle Range), and Cannikin nuclear test sites and at drill sites D, E, and F. An asphalt (hot mix) plant was located at Charlie Runway. All mud pits have been reclaimed by encapsulating the drill cuttings into an engineered mud pit cap, and the results were accepted by the State of Alaska. Results of DOE sampling indicate that the shallow groundwater was not affected by the drilling mud, and no cleanup of shallow groundwater is necessary (DOE 2000c).

##### 3.5.1.1 AEC Activities

In 1972 and 1973, AEC conducted site demobilization and restoration activities that consisted of:

- Plugging, sealing, and capping drill holes.
- Disposing of contaminated fluids, equipment, and materials off-island.
- Removing and disposing of all AEC-associated buildings, equipment, and associated surface facilities.
- Contouring and revegetating disturbed areas.
- Placing the material and equipment that became contaminated during Cannikin re-entry into the re-entry borehole.

At the time of these AEC activities, there was a requirement for continued monitoring of surface waters in the area of the Long Shot site, and the mud pits at Long Shot were left intact for that purpose. The AEC *Summary Report Amchitka Demobilization and Restoration Activities* (AEC 1974) details the demobilization, cleanup, and restoration of AEC's operations on Amchitka Island. The AEC's drilling contractor's report *Abandonment of Drilled Holes Amchitka Island, Alaska* details the plan for abandonment of the 38 holes drilled and used by AEC on Amchitka (Fenix and Scisson 1972).

### 3.5.1.2 DOE Activities

In addition to all the previous investigations that were performed in support of the Amchitka bioenvironmental assessment (Section 3.4), DOE conducted additional targeted site characterization investigations in 1993, 1997, 1998, and 2000. Drilling operations for the three large-diameter emplacement holes and numerous small-diameter instrument and hydrologic test holes generated large volumes of drilling mud, which consisted of a mixture of rock cuttings, bentonite, diesel fuel, and other compounds, including chrome lignosulfonate. DOE submitted the 1998 drilling mud samples for chemical analysis to determine the proper method of disposal for this material.

The 1998 chemical analysis of the drilling mud indicated that all drilling mud pits contained concentrations of diesel-range organics, low levels of polychlorinated biphenyls (PCBs), and chromium. The only contaminants of concern with concentrations above ADEC cleanup levels within each mud pit were diesel-range organics. Mean concentrations of contaminants in ponded water overlying the drilling mud pits were well below applicable ecological criteria in all drilling mud pits. Sampling of the surface water drainages of each drill site revealed that contaminants within the sediment affected by drilling mud were diesel-range organics and PCBs. The investigation in June of 2000 involved gathering chemical data on the shallow groundwater downgradient of the drilling mud pits. Sampling results indicated that drilling mud did not affect the shallow groundwater, and no cleanup of shallow groundwater is necessary (DOE 2000d).

In 1997, the LTHMP (Section 3.4.9) 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 manmade radionuclides were leaking into the surface environment from nuclear test cavities several thousand feet below the surface of the island (DOE 2000d). The results of the 1997 LTHMP radiobiological sampling indicated there was no evidence of leakage from the underground test cavities into the terrestrial or freshwater environments on Amchitka (DOE 2000d; Dasher et al. 2000).

USFWS in 2000 was the lead agency for coordinating National Environmental Policy Act compliance of the multi-agency cleanup effort on Amchitka Island and prepared an Environmental Assessment to (1) address the potential cumulative impacts associated with the wide scope of cleanup activities being proposed by the various federal agencies conducting cleanup on the Island and (2) facilitate the development of mitigation measures to be included in special use permits issued to each action-agency. USFWS issued a Remedial/Removal Action Environmental Assessment and Finding of No Significant Impact (FONSI) for all past U.S. military activities (e.g., World War II bases, nuclear test explosions, Navy surveillance operations, and U.S Army Corp of Engineers military cleanup operations) on Amchitka Island (USFWS 2000). That document assigned specific areas of responsibility to each of the entities that have used Amchitka since 1945. The FONSI provided the regulatory mechanism for allowing remediation of the Amchitka Island sites.

DOE remediated the 11 drilling mud pits and the asphalt plant in 2001. The remediation work consolidated the 11 drilling mud pits into seven locations where the drill cuttings were placed into engineered mud pit caps, which were capped first with a geosynthetic material and then with native earthen materials. Figure 14 depicts a schematic cross section of a mud pit cap. The Milrow drilling mud pits were relocated to a site referred to as the Rifle Range site, and the Cannikin site has two mud pit caps designated Cannikin North and Cannikin South. Details of that remedial action are reported in the *Amchitka Island Surface Closure Report* (DOE 2003). In September 2004, ADEC accepted the surface cleanup as complete.

In addition to remediation of the 11 drilling mud pits, the asphalt plant that was located adjacent to Charlie Runway was also remediated. The two underground storage tanks were located side-by-side about 22 ft apart and had a storage capacity of approximately 25,000 gallons each (DOE 2003). Historical records suggest that the tanks held asphalt used in constructing and maintaining the nearby runways. A sample of one of the tanks was collected in 1995 and was analyzed for metals, total halogens, PCBs, hydrocarbons, and British thermal unit (Btu) content (USACE 1996). Hydrocarbons were the only analytes present above detection limits: 309,000 parts per million (30.9 percent) and 124,000 parts per million (12.4 percent) of “unknown petroleum” compounds per tank. The Btu content was 18,000 Btu per pound. No associated piping or distribution system was observed during the remediation of the asphalt plant. Approximately 17,430 gallons of water were treated at the Drill Site D water treatment plant, and 6,953 gallons of used oil and 3,923 gallons of water from the tanks were transported to Alaska Pollution Control, Inc., in Palmer, Alaska, for reclamation. The two tanks were filled with native soil and left in place.

These surface remediation activities are documented in the *Amchitka Island Surface Closure Report* (DOE 2003), which was submitted to the State in April 2004. ADEC approved this report in September 2004 and stated in their acceptance letter, September 27, 2004, that it was ADEC’s “understanding that DOE is conducting the environmental response actions for surface impacts at Amchitka consistent with CERCLA and the National Contingency Plan” and “a proposed plan and record of decision (ROD) are being, or will be, developed” (ADEC 2004). The surface ROD was not a CERCLA-type ROD, but an ad hoc mechanism for ADEC and LM to formalize acceptance of the work.

The plan and ROD mentioned in the ADEC acceptance letter became one document, the *Record of Decision (ROD) for Amchitka Surface Closure, Alaska* (DOE 2008a). DOE prepared the ROD in agreement with both ADEC and DOE to formalize acceptance of the work. The ROD summarized the surface closure activities and stated that LM would conduct post-closure inspection and monitoring as described in the *Post-Closure Monitoring and Inspection Plan for Amchitka Island Mud Pit Release Sites* (DOE 2005b). Both ADEC and USFWS approved the ROD in August 2008.

In 2005, the DOE National Nuclear Security Administration Nevada Site Office submitted a *Draft Screening Risk Assessment for Possible Radionuclides in the Amchitka Marine Environment* (DOE 2005c) assessing possible human health effects from testing at Amchitka. ADEC indicated in a letter that they have reservations about the 2005 draft and suggested it remain as a pre-decisional draft document (Halverson 2006).

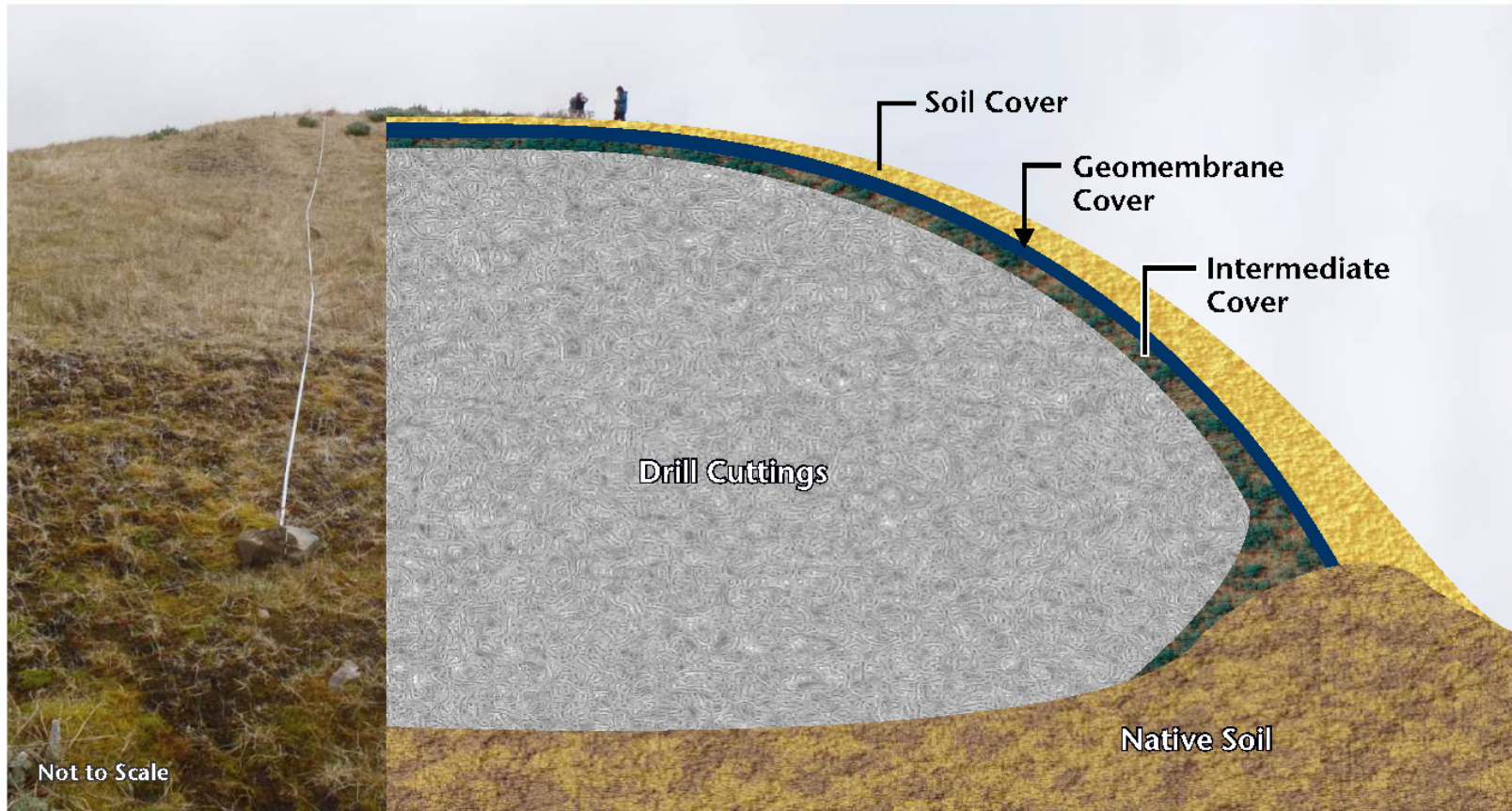


Figure 14. Schematic Cross Section of a Mud Pit Cap

### 3.5.2 Subsurface

The deep subsurface at each nuclear test site remains contaminated with fission products as a result of the underground detonations. Figure 15 depicts the formation history of a nuclear explosive cavity and chimney. No remedy is known for the radioactivity that remains from the blast deep in the subsurface. Because no remedy is known and because past nuclear testing has created an environmental liability, DOE prepared the *Subsurface Completion Report for Amchitka Underground Nuclear Test Sites: Long Shot, Milrow, and Cannikin* (DOE 2005a), which provides a recommendation of no further remedial action and a long-term surveillance strategy for the subsurface (DOE 2006b). ADEC accepted this report in January 2007 (ADEC 2007), stating “the department concurs No Further Remedial Action Planned (a.k.a. conditional closure) with LTSM [long-term surveillance and monitoring] is appropriate for the Amchitka Underground Nuclear Test Sites.”

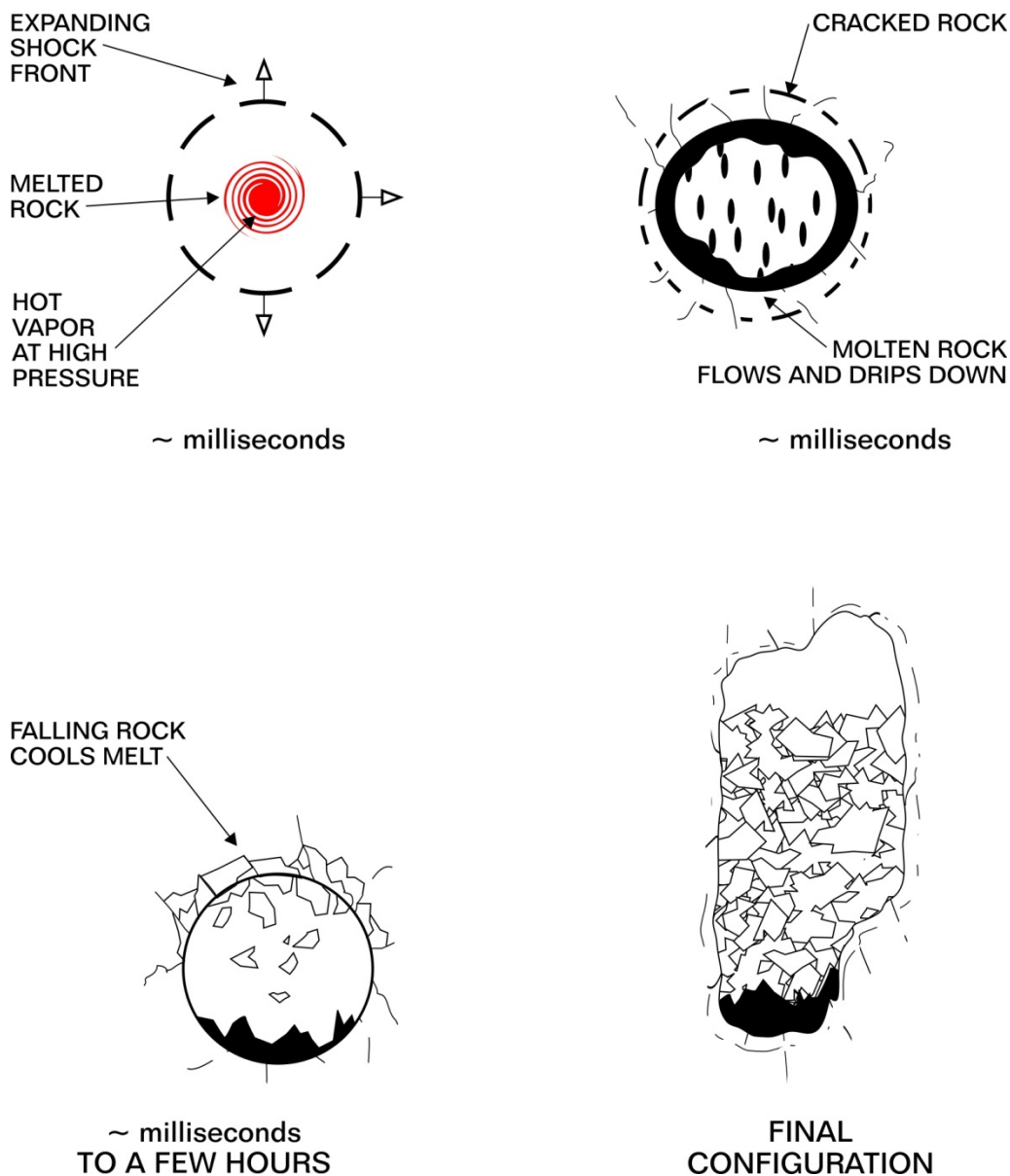


Figure 15. Formation History of a Nuclear Explosive Cavity and Chimney



### 3.5.3 Groundwater Monitoring Wells

During 1972 and 1973 site reclamation efforts, a number of test-related wells were plugged and abandoned, leaving only the wells identified as part of the LTHMP. These wells, locations, depths, and abandonment method are identified in the Subsurface Completion Report (DOE 2006b). In 2001, DOE performed final plugging and abandonment of the LTHMP wells. Of the 24 monitoring wells, 16 were plugged and abandoned, 2 had steel protective casings installed, and 6 were either not found (under water) or the well structure and casing had deteriorated to the point that plugging the well was not needed or possible. Details associated with each well are also described in the Subsurface Completion Report (DOE 2006b). Finally, in 2011 LM plugged and abandoned the two wells that had steel protective casings around them at the Long Shot site. LM currently has no groundwater monitoring wells or any other type of well or test hole on Amchitka Island.

### 3.6 Current Understanding of the Environment

No remedy is known for the radioactive fission products remaining within the cavities formed from the nuclear detonations. Numerous and extensive environmental and biological studies have been conducted on and around Amchitka since the early 1970s to detect leakage via the most likely pathway, groundwater transport and discharge into the ocean, as depicted in the conceptual model presented in Figure 16. No study concluded that test-related radionuclides have migrated from the test cavities. Other than naturally occurring radiation, detected radiation in the environment is likely from atmospheric nuclear-test fallout or ocean dumping.

“There has been essentially no escape of radionuclides from the sites of the Long Shot, Milrow, and Cannikin underground nuclear detonations. Radionuclide values for Amchitka samples are similar to those for comparable samples from other geographical areas. The only radioactivity of Amchitka nuclear test origin that was detected consisted of trace quantities of radionuclides, principally tritium, in water and soil gas samples in the immediate vicinity of surface ground zero for the Long Shot detonation” (Merritt and Fuller 1977). Subsequent results from long-term monitoring of groundwater and shallow surface waters by EPA show that detected tritium concentrations are declining faster than would be estimated from radioactive decay alone.



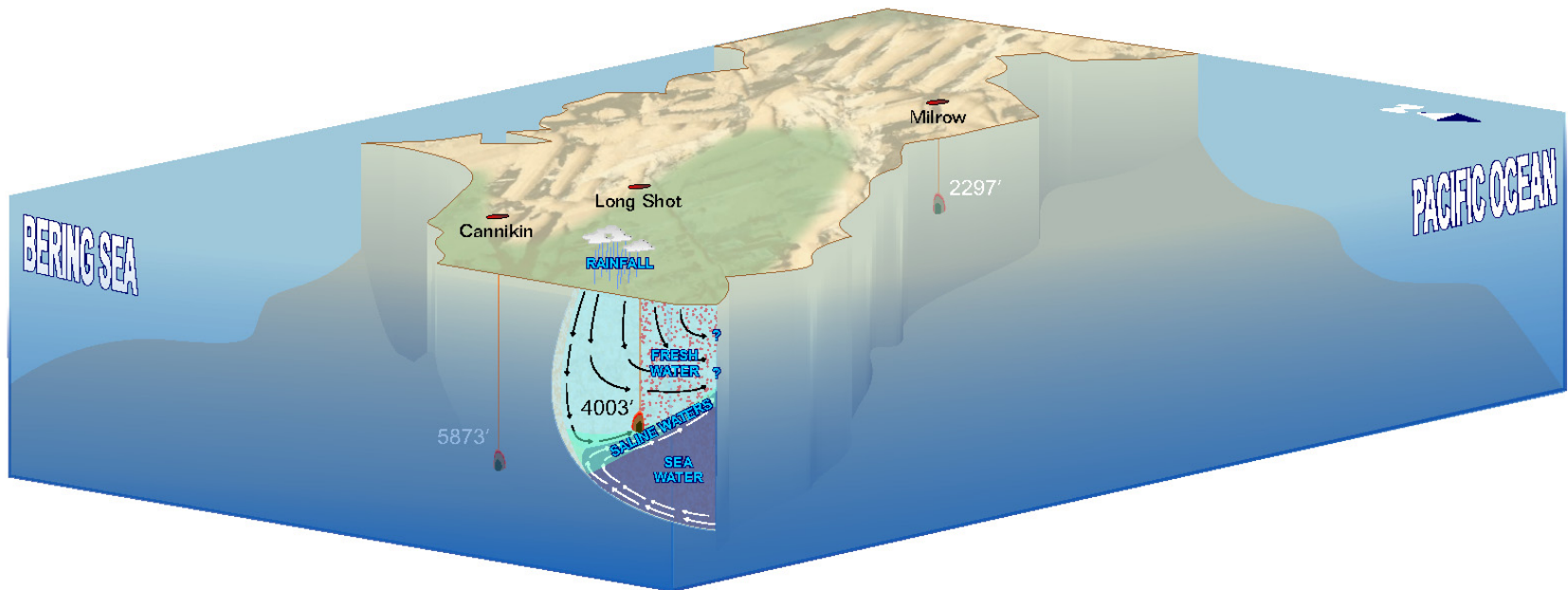


Figure 16. Idealized Conceptual Model

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## 4.0 Amchitka Island Long-Term Surveillance

### 4.1 Surveillance

The LM Amchitka Island sites are currently being inspected every 5 years since remedial actions were completed in 2001. Results of the inspections in 2006 and 2011 have indicated that the mud pits are in good condition and are performing as designed. The requirements for these inspection activities are detailed in the *Post-Closure Monitoring and Inspection Plan for Amchitka Island Mud Pit Release Sites* (DOE 2005b and 2011c), and the inspection results are detailed in *Amchitka Island Mud Pit Sites Post-Closure Monitoring and Inspection Report Amchitka Island, Alaska* (DOE 2006a and 2012). The next inspection is planned for 2016, and the details for this inspection will be similar to those of the previous inspections but specifically identified in the post-closure monitoring and inspection plan that LM will prepare for the 2016 inspection event. The next biological sampling event is also planned for 2016. LM will prepare a biological sampling plan, which will be approved by ADEC, specifically for the 2016 event.

Institutional controls serve to inform visitors of previous activities on the island and to prevent penetration of the nuclear test cavities and caps covering the mud pits at the sites. In the past, DOE has relied on the remoteness of the island for a measure of protection, but with the increase in commercial fishing activity in the area, additional controls are required. LM will establish a combination of institutional, engineered, and physical controls, including notifications, engineered barriers, and administrative mechanisms, to help ensure that previous remedial actions taken at LM's 10 Amchitka Island sites resulted in conditions that remain protective of human health and the environment. In 2014, LM will issue a separate document that discusses institutional controls at the Amchitka Island sites.

Amchitka Island needs enforceable controls to ensure continued safety and security. DOE will rely on USFWS for primary oversight, since USFWS is the land manager. USFWS oversight will not lessen DOE's responsibility for its Amchitka test sites. LM will work in federal partnership with USFWS for the safety and security at the test sites.

There is no likely scenario in which subsistence or commercial fishermen accessing the island would be of concern. Activities at Constantine Harbor dock are well away from LM locations. LM will provide information to USFWS detailing each LM location requiring restrictions.

There is no need for LM to be notified of all activities on the island, but any actions that require land surface penetration anywhere on the island would be of interest to LM. Although LM has no objection to use of the island for research and other purposes, caution requires that LM review any request for surface disturbance to ensure that the proposed action is well away from sensitive test areas. The current MOU between LM and USFWS (USFWS 2010) states that USFWS will prohibit all excavation in the areas formerly used for nuclear testing on Amchitka Island. To provide additional notification at each test location, a monument stating the restriction is placed directly over the test cavity.

LM wants to ensure that no activity is allowed in certain areas. LM has installed controls in the form of engineered caps for the mud pits. The mud pits are included in the restricted areas to ensure that they are protected from surface disturbance and penetration by users of the island.

The subsurface test cavities present the most significant contamination deep under the island that must be protected from accidental or intentional penetration.

If Native land claims are settled, USFWS will notify LM of parcels to be placed into Native custody; if necessary, LM can develop legal language that protects LM locations on Amchitka Island.

The public can call the 24-hour numbers monitored at the LM office in Grand Junction, Colorado (970-248-6070 or 877-695-5322), to request information about the site or to notify LM of site concerns.

## **4.2 USGS Seismic Surveillance**

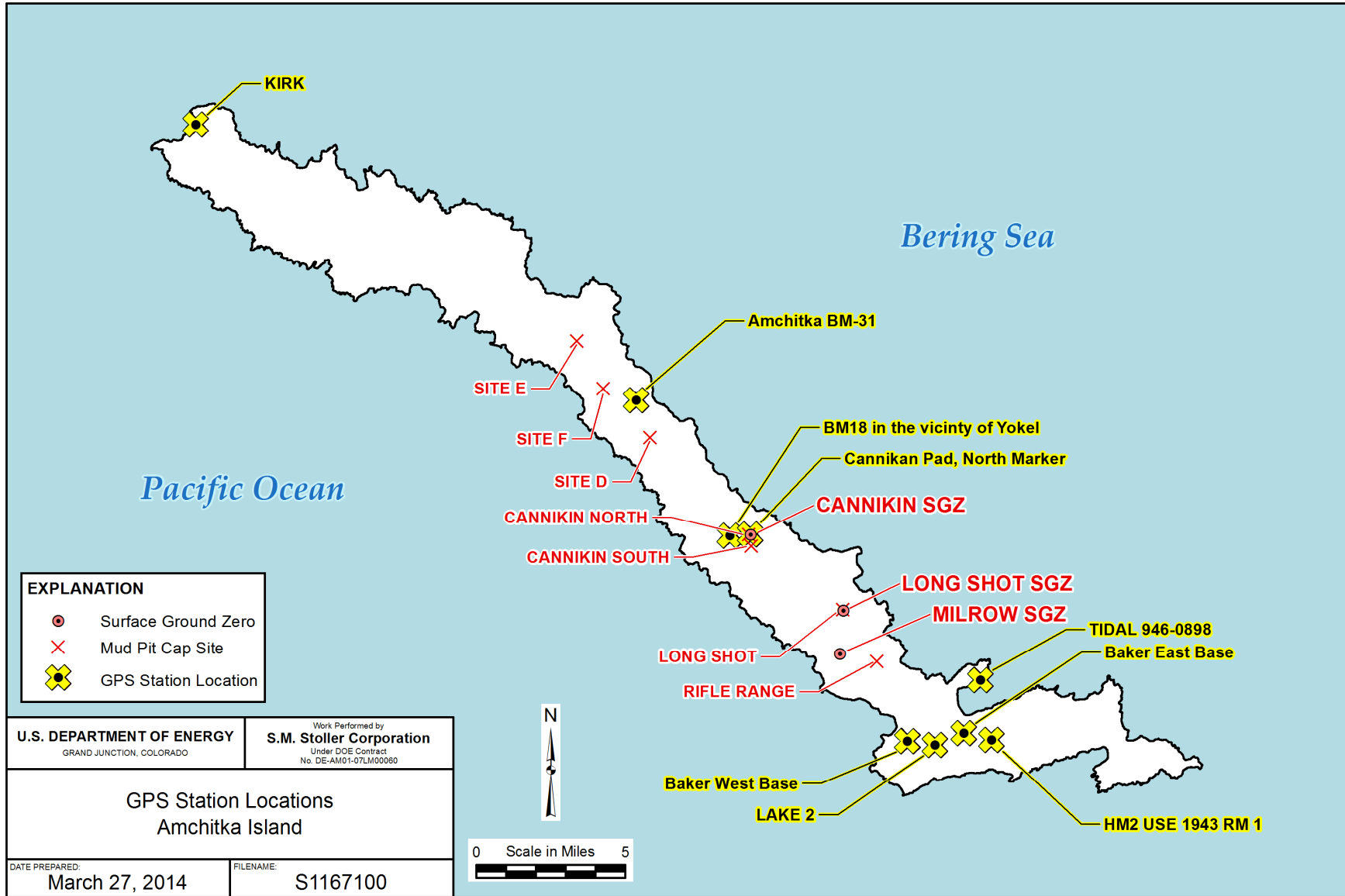
With direction from LM, the USGS Alaska Volcano Observatory will perform the following activities beginning in 2014:

1. Attempt to repair the AMKA VSAT station on Amchitka Island in 2014 and download the GPS data from that station. While on-island, personnel will complete a full site reconnaissance of the island for future visits.
2. If the AMKA VSAT station on Amchitka Island can be brought back online in 2014, light duty maintenance at the station will be performed annually. This includes annual payment for the satellite telecommunications utilized to support the data link.
3. Reestablish geodetic campaign network when time and personnel are available or at least during the 5-year visits (next major visit is scheduled for 2016). Figure 17 depicts the GPS stations on Amchitka Island.
4. Large-scale maintenance at the Amchitka Island VSAT site once every 5 years, including but not limited to full battery replacement, dish replacement, and radome (next major visit is scheduled for 2016).
5. General scientific interpretation, evaluation, and report of tectonic setting and current deformation and seismic activity in the Amchitka area as it pertains to structural integrity of the island. Possible development of a conditional “alarm” (e.g., an occurrence of an earthquake of magnitude X within radius Y [of Amchitka] could lead to possible ground cracks and warrant observation and investigation).

## **4.3 Permits**

LM will submit a special use permit application (50 CFR 36.39) to USFWS to obtain authorization to conduct inspection activities on Amchitka Island.

LM will also obtain the appropriate permit or permission from USFWS, Alaska Department of Fish and Game, International Pacific Halibut Commission, Aleut Corporation, and other entities that may be involved in LM’s continuing performance of long-term inspection and monitoring activities as part of this LTSP or ancillary plans such as the monitoring and inspection or environmental monitoring plans.



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Figure 17. GPS Station Locations, Amchitka Island

## 4.4 Mud Pit Monitoring and Inspection Plan

The monitoring and inspection plan outlines the specific monitoring and inspection requirements for the LM Amchitka Island sites and provides the procedures for conducting the inspections. Also included in that plan is any additional scope of work that may be required while inspectors perform LM's primary mission. In the past, this additional scope has included sampling the U.S. Navy's reclaimed sewage lagoon pond and repairing the USGS's seismic station on Amchitka.

During routine site inspections, LM will inspect the engineered mud pit caps as detailed in the *Post-Closure Monitoring and Inspection Plan for Amchitka Island Mud Pit Release Sites* (DOE 2005b and 2011c). Typically, a detailed inspection of the seven mud pit caps entails walking around and over each mud pit cap to determine integrity of the cover and surrounding erosion protection features that were designed to maximize mud pit cap integrity. The inspection will also include a detailed evaluation of the vegetation on the cover.

## 4.5 Environmental Monitoring Plan

The environmental monitoring plan outlines the specific monitoring requirements for the LM biological sampling on and in the ocean surrounding Amchitka Island and other predetermined islands. LM will perform biological sampling as detailed in the sampling plan specifically developed to meet the goals of LM, ADEC, and Amchitka stakeholders and would be similar in nature to the plan LM prepared in 2011: *Sampling Plan for the Amchitka, Alaska, Site 2011 Sampling Event* (DOE 2011a).

## 4.6 Follow-Up Inspection

LM will determine the need for follow-up inspections on the basis of observation, scientific data, and recommendations of LM personnel with expertise in the appropriate areas.

### 4.6.1 Criteria for Follow-Up Inspections

LM may conduct follow-up inspections if the following occurs:

- A condition is identified during the routine site inspection or other site visit that requires personnel or equipment with specific expertise or function to return to the site to evaluate and repair the condition; or
- A citizen, employee, or federal, state, or local agency notifies LM that conditions at the site are substantially changed.

Once a condition or concern is identified at the site, LM will evaluate the information and decide how to respond with an appropriate action.

Specific conditions that may necessitate a follow-up inspection include major earthquakes, unauthorized intrusion, violation of institutional controls, vandalism, or the need to revisit the site to evaluate, define, or conduct maintenance tasks.

If an incident or activity threatens or compromises institutional controls or poses a risk of exposure to or release of known contaminants, LM may, as appropriate, notify USFWS and ADEC, begin the LM occurrence notification process (DOE Order 232.2), respond with an immediate follow-up inspection, and begin emergency measures to contain or prevent dispersion of contaminants. At any time, LM may request the assistance of State and federal authorities based in Alaska and local authorities based in Adak to confirm the seriousness of a condition at the site before scheduling a follow-up inspection or initiating other action.

#### **4.6.2 Criteria for Follow-Up Environmental Monitoring**

If a recognized standard for ingestion is exceeded or an increasing trend of radionuclide levels is indicated, LM will consult with ADEC, APIA, and USFWS about appropriate action.

### **4.7 Periodic Review of the LTSP**

Currently, LM inspects the Amchitka Island sites every 5 years and, based on that inspection, updates the LTSP. Any needed changes can be incorporated into a revision of this plan. Changes will be made to this LTSP in consultation with ADEC, APIA, and USFWS.

### **4.8 Records and Data Management**

To support post-remediation monitoring of the Amchitka Island sites, LM maintains records at the LM office in Grand Junction, Colorado, and at the LM Business Center in Morgantown, West Virginia. These records contain critical information required to protect human health and the environment, manage land and assets, protect the legal interests of DOE and the public, and mitigate community impacts resulting from the cleanup of legacy waste. The collection includes site historical records about the detonation and its environmental remediation and stewardship. Field and laboratory data are stored in a protected, active, environmental database. LM will manage all records in accordance with the following requirements:

- 44 USC 29, “Records Management by the Archivist of the United States and by the Administrator of General Services,” January 4, 2012, available online at [http://www.law.cornell.edu/uscode/pdf/lii\\_usc\\_TI\\_44.pdf](http://www.law.cornell.edu/uscode/pdf/lii_usc_TI_44.pdf), accessed May 8, 2014.
- 44 USC 31, “Records Management by Federal Agencies,” January 4, 2012, available online at [http://www.law.cornell.edu/uscode/pdf/lii\\_usc\\_TI\\_44.pdf](http://www.law.cornell.edu/uscode/pdf/lii_usc_TI_44.pdf), accessed May 8, 2014.
- 44 USC 33, “Disposal of Records,” January 4, 2012, available online at [http://www.law.cornell.edu/uscode/pdf/lii\\_usc\\_TI\\_44.pdf](http://www.law.cornell.edu/uscode/pdf/lii_usc_TI_44.pdf), accessed May 8, 2014.
- 36 CFR 1220–1239, Chapter 12, Subchapter B, “Records Management.”
- DOE Order 243.1B, *Records Management Program*, March 11, 2013, available online at <https://www.directives.doe.gov/directives-documents/0243.1-BOrder-B-admchg1>, accessed May 8, 2014.
- *LM Records Management Manual* (LMS/POL/S04327).

## 4.9 Geospatial Environmental Management System (GEMS)

GEMS provides a dynamic mapping and environmental monitoring data display for the DOE sites. Stakeholders can use GEMS to view a map of the site, photographs, and monitoring data. Some Amchitka data are currently in the database and online; validation of the remaining data is in process. These data are accessible on the LM home page at <http://www.lm.doe.gov/>. Click **LM Sites Map**; under **LM Sites** on the right side of the map, select **Amchitka Site**. Select **Amchitka Mapping and Monitoring (GEMS)** and follow the instructions.

## 4.10 Quality Assurance/Quality Control

Programmatic quality assurance for all LM activities is based on DOE Order 414.1D, *Quality Assurance*. The DOE order is embodied in the Legacy Management Support (LMS) *Quality Assurance Manual* (LMS/POL/S04320).

## 4.11 Health and Safety

The health and safety program is based on 10 CFR 851, “Worker Safety and Health Program,” and 10 CFR 835, “Occupational Radiation Protection.” The LMS program is based on these regulations and embodied in the LMS *Health and Safety Manual* (LMS/POL/S04321), which identifies the policies and requirements that apply to all work performed within the LMS contract.

## 4.12 Public Participation Plan

Promoting public involvement in the surveillance process at the Amchitka site ensures that citizens’ concerns are addressed and that relevant public information is provided. Active citizen involvement also promotes understanding of, and encourages informed participation in, the project by the general public. LM encourages public participation by providing site information to stakeholders via LM’s Internet website, providing documents to the public, and conducting public meetings for residents of the region.

### 4.12.1 Meetings

#### 4.12.1.1 Briefings for Tribal, State, and Local Officials

LM will continue to hold briefings with APIA, which represents regional tribes, and with state and local officials, as needed, to discuss new data trends or DOE activities.

#### 4.12.1.2 Meetings with Regional Tribes and Citizen Groups

LM will hold public meetings with regional stakeholder groups to address community concerns or issues as needed.

#### 4.12.1.3 Public Meetings

LM will hold additional public meetings as needed.



### 4.12.2 Information Repository

To facilitate public understanding of LM's activities, LM will continue to maintain an information repository at the APIA office in Anchorage, Alaska. Copies of key documents are kept in the information repository and at the LM office in Grand Junction, Colorado. The information repository addresses are:

Aleutian Pribilof Islands Association, Inc.  
131 East International Airport Rd.  
Anchorage, Alaska 99518  
Phone: (907) 276-2700  
Fax: (907) 279-4351  
E-mail: [apiai@apiai.org](mailto:apiai@apiai.org)

U.S. Department of Energy Office of Legacy Management  
2597 Legacy Way  
Grand Junction, CO 81503  
Phone: (970) 248-6000  
Fax: (970) 248-6040  
E-mail: [lm.records@gjo.doe.gov](mailto:lm.records@gjo.doe.gov)

Appendix D, Selected Bibliography of Amchitka-Related Papers, contains selected references relative to the Amchitka, Alaska, Site.

### 4.12.3 Website

LM maintains a webpage for the Amchitka site, and key documents are available online. The LM website address is <http://www.lm.doe.gov/>. To access site documents, follow the steps described in Section 4.9 to open the Amchitka webpage, then select **Site Documents and Links**.

### 4.12.4 News Releases and Editorials

LM will issue news releases and community advisories to announce public meetings regarding LM documents or activities as required.

### 4.12.5 Information Contacts

The purpose of the contact effort is to ensure that public and key community leaders, including federal, state, tribal, and local government officials, are kept informed of site activities and status changes. Contact information is maintained for the following:

- APIA
- Federal, state, and local elected officials.
- ADEC
- USFWS
- Interest groups and interested citizens.

The key information contacts are listed in Appendix C.

### **4.13 Budget and Funding**

At federal sites such as the LM Amchitka Island sites, the authority to ensure long-term implementation of programs to protect human health and the environment originates in the U.S. Congress and is delegated to an appropriate federal agency, in this case DOE.

LM recognizes the significance of maintaining adequate funding levels for long-term surveillance and, if required, maintenance. Funding is also a major concern of the stakeholders. LM will request adequate funds to implement this LTSP through the annual appropriation process.

## 5.0 References

36 CFR 1220–1239, Chapter 12, Subchapter B. National Archives and Records Administration, “Records Management,” *Code of Federal Regulations*.

50 CFR 36.39 Subpart F. U.S. Department of the Interior, U.S. Fish and Wildlife Service, Alaska National Wildlife Refuges, “Refuge Specific Regulations,” *Code of Federal Regulations*.

16 USC 470. *United States Code*, Title 16, Chapter 1A, Subchapter II, Section 470, “National Historic Preservation Act.”

16 USC 1531 et seq. *United States Code*, Title 16, Chapter 35, “Endangered Species,” Sections 1531 et seq.

42 USC 2011. *United States Code*, Title 42, Chapter 23, Division A, Subchapter I, Part 2011, “Atomic Energy Act of 1954.”

44 USC 29. *United States Code*, Title 44, Chapter 29, “Records Management by the Archivist of the United States and by the Administrator of General Services.”

44 USC 31. *United States Code*, Title 44, Chapter 31, “Records Management by Federal Agencies.”

44 USC 33. *United States Code*, Title 44, Chapter 33, “Disposal of Records.”

18 AAC 75.325. *Alaska Administrative Code*, Title 18, Chapter 75, Section 325, “Site Cleanup Rules: Purpose, Applicability, and General Provisions.”

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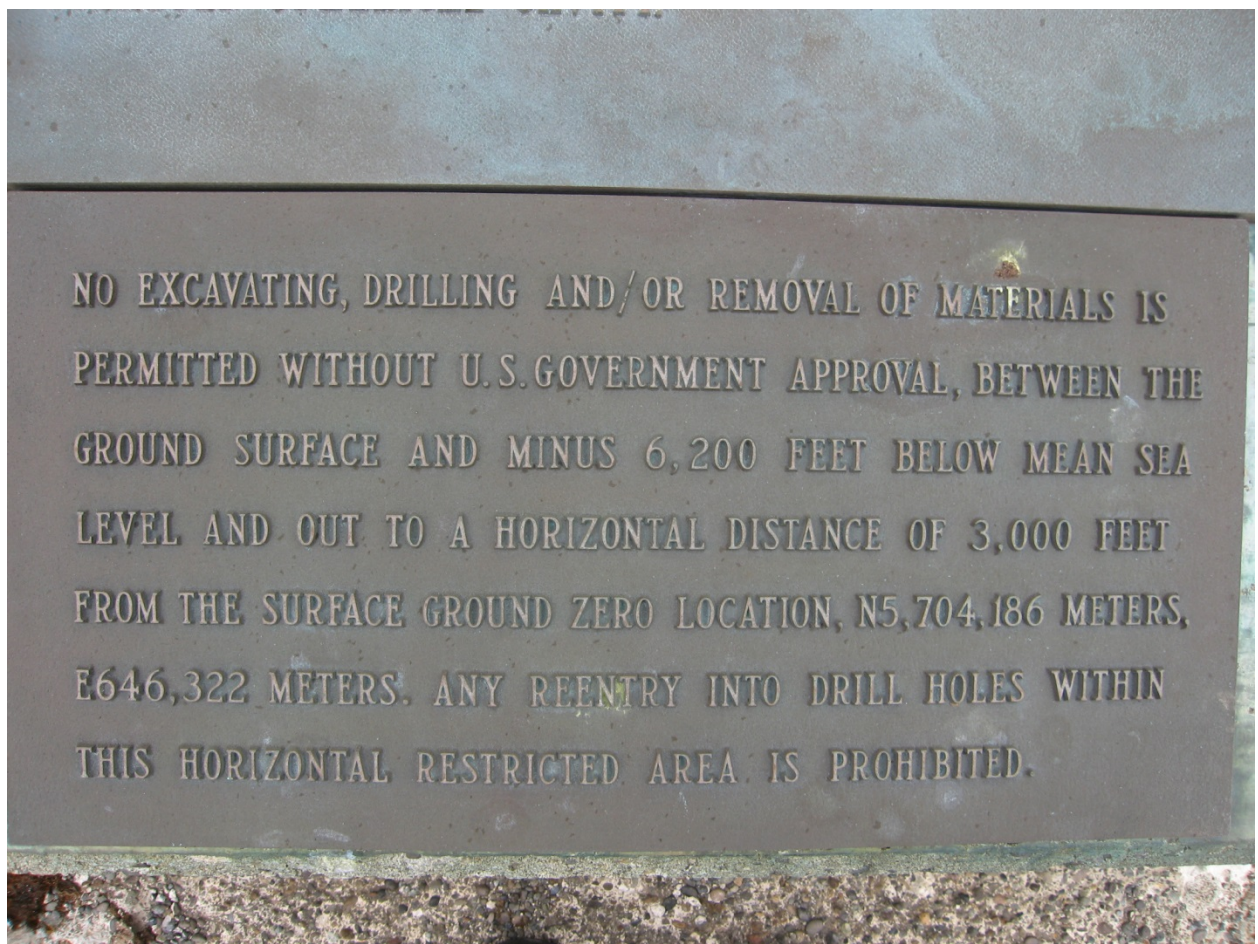
## **Appendix A**

### **Institutional Controls for LM's Amchitka Island Sites**

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*Cannikin Site Ground Zero Marker*

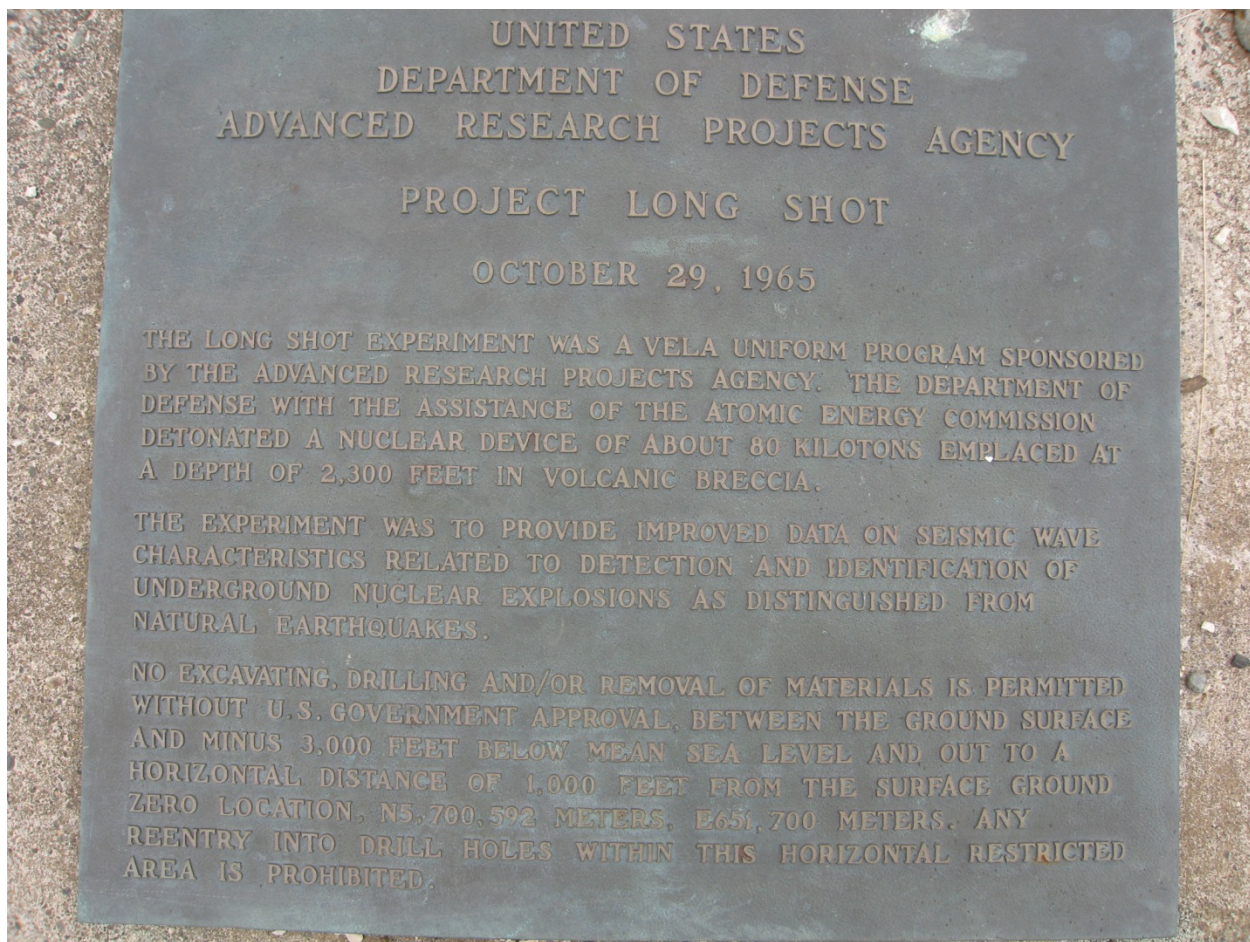


*Cannikin Site Ground Zero Marker*



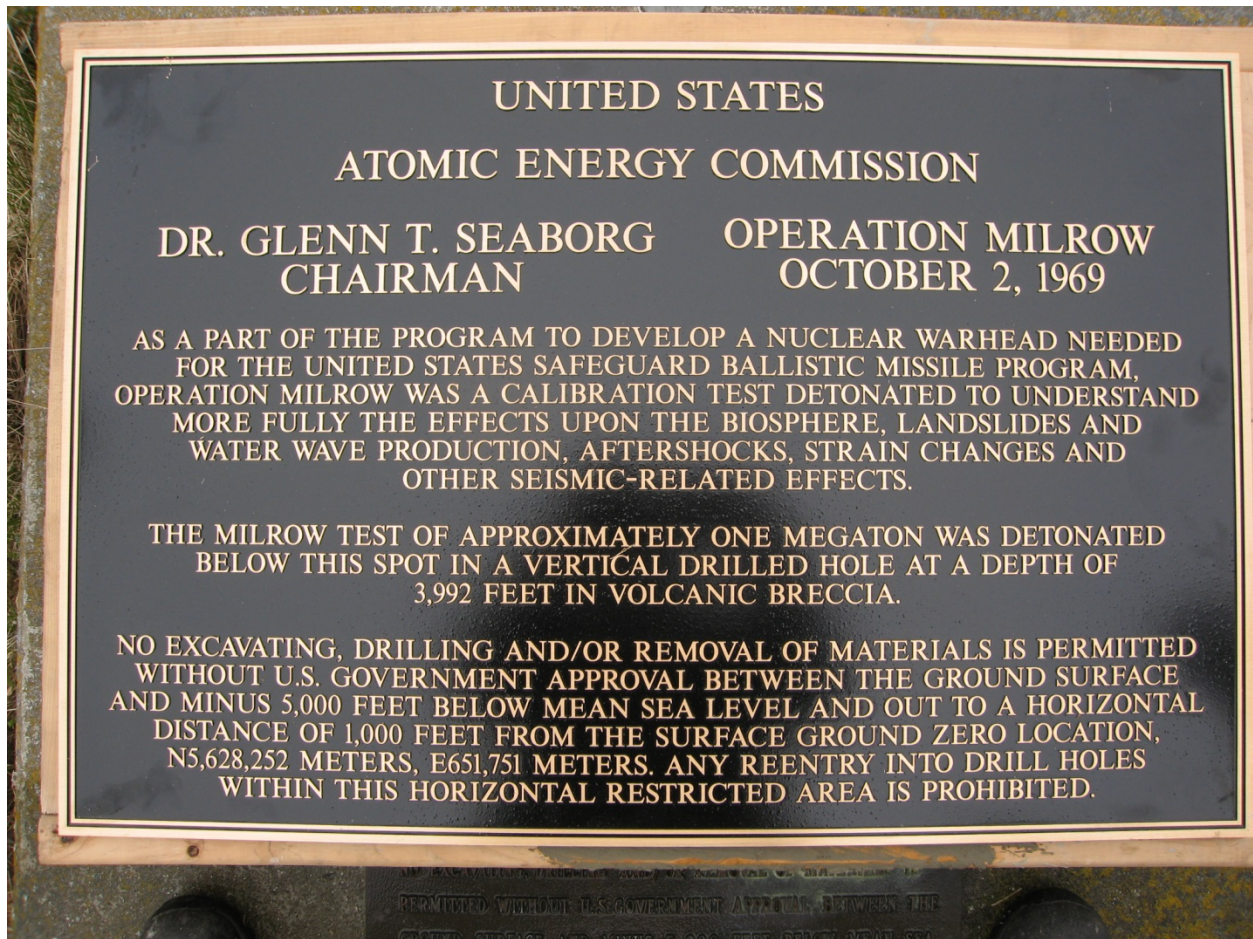


*Cannikin Site Ground Zero Marker*



*Long Shot Site Ground Zero Marker*





*Milrow Site Ground Zero Marker*

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## **Appendix B**

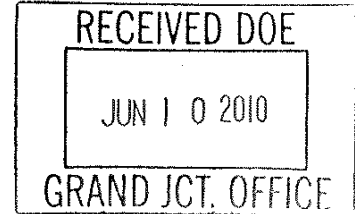
### **Memorandum of Understanding**

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## MEMORANDUM OF UNDERSTANDING (MOU)

Involving the U.S. Department of Energy's Use and Future Interest in Amchitka Island  
(Alaska Maritime National Wildlife Refuge), Alaska.

Between the U.S. Department of the Interior, Fish & Wildlife Service (USFWS),  
and the U.S. Department of Energy (DOE), Office of Legacy Management(LM).



### I. Introduction

This agreement between the U.S. Department of Interior, Fish & Wildlife Service (USFWS) and the U.S. Department of Energy (DOE), Office of Legacy Management (LM) establishes the roles and responsibilities of both agencies regarding site access, long-term surveillance and maintenance (LTS&M) activities, and use restrictions surrounding the former nuclear-test sites on Amchitka Island, Alaska. The USFWS has management authority for Amchitka Island. LM will conduct periodic site visits to Amchitka Island in conjunction with its LTS&M mission.

### II. Objectives

#### A. USFWS

1. Conserve fish and wildlife populations and habitats in their natural diversity including, but not limited to marine mammals, marine birds, and other migratory birds.
2. Fulfill international treaty obligations of the United States with respect to fish and wildlife and their habitats.
3. Provide, in a manner consistent with the first two objectives, the opportunity for continued subsistence uses by local residents.
4. Conduct scientific study of marine resources.
5. Protect water quality and quantity.
6. Protect and manage endangered species.
7. Manage wilderness, as established by Alaska National Interest Lands Conservation Act (ANILCA).
8. Preserve historical and archaeological sites.

#### B. LM

1. Maintain vehicular access to each former nuclear test site.

2. Conduct periodic inspections, assessments and maintenance of mud-pit caps, test-site placards, drill-hole integrity, and perform environmental monitoring on and around the island, in conjunction with its LTS&M mission.

### III. Authorities

- A. Executive Order No. 1733, dated March 3, 1913.
- B. Proclamation No. 2416, dated July 25, 1940.
- C. The Alaska National Interest Lands Conservation Act (P.L. 96-487), dated December 2, 1980.
- D. The Atomic Energy Act of 1954, as amended (42 U.S.C. 2011 et seq.)
- E. Department of Energy Organization Act of 1977 (42 U.S.C 7257).
- F. The Economy Act of 1932, as amended (31 U.S.C. 1535).

### IV. WHEREAS, the USFWS has management authority for Amchitka Island, a unit of the Alaska Maritime National Wildlife Refuge; and

WHEREAS, Amchitka Island has been used for underground nuclear testing by the United States Atomic Energy Commission, a predecessor agency to the DOE;

NOW, THEREFORE, it is mutually agreed that the LM and USFWS will cooperate in the following ways:

#### A. LM & USFWS will

1. Cooperate during planning and execution of LM's *Long Term Surveillance and Maintenance Plan* for Amchitka Island.

#### B. USFWS will

1. Allow LM to review and comment on all applications from other government agencies for permanent-type uses (e.g., withdrawals, cooperative agreements, rights of way) for Amchitka.
2. Cooperate with LM by issuing special-use permits to allow road maintenance, radiological monitoring, the collection of environmental samples, and maintenance of institutional controls, as appropriate.
3. Prohibit all excavation in the areas formerly used for nuclear testing on Amchitka Island.
4. Designate the Aleutian Islands Unit Manager as the point of contact for routine interagency correspondence.

C. LM will

1. Submit to USFWS any proposals for and results of future environmental inspection or monitoring on Amchitka Island. Such proposals will be subject to a determination of compatibility with refuge purposes and compliance with applicable environmental laws and regulations.
2. Protect wildlife and wilderness values.
3. Designate a Site Manager as the point of contact for routine interagency correspondence.

D. RESOLUTION OF DISAGREEMENTS

Nothing herein is intended to conflict with current LM or USFWS directives. If the terms of this agreement are inconsistent with existing directives of either of the agencies entering into this agreement, then those portions of this agreement which are determined to be inconsistent shall be invalid, but the remaining terms and conditions not affected by the inconsistency shall remain in full force and effect. At the first opportunity for review of the agreement, all necessary changes will be accomplished either by an amendment to this agreement or by entering into a new agreement, whichever is deemed expedient to the interest of both parties.

Disputes shall be resolved pursuant to applicable provisions of the Business Rules for Intragovernmental Transactions delineated in the Treasury Financial Manual, Vol. 1, Bulletin 2007-03, Section VII (Resolving Intragovernmental Disputes and Major Differences).

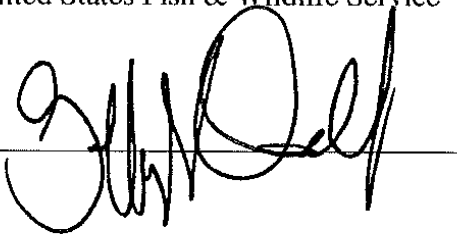
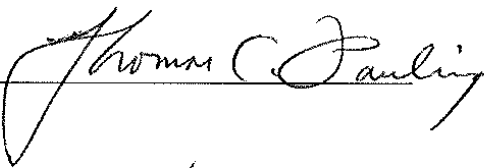
V. PROVISION:

The parties to this agreement agree to be responsible for damages to their own property and injuries to their own employees/volunteers, except for damages/injuries resulting from the fault or negligence of the other party. Any claim for damage to property or persons made against the Government will be pursued in accordance with the provision of the Federal Tort Claims Act.

VI. This MOU will become effective upon signature by both parties. The responsibilities assumed by each of the cooperating parties are contingent upon funds being available from which the expenditures legally may be met. Amendments to this MOU may be proposed at any time by either signatory and shall be effective upon approval by both. This MOU may be terminated by either party 90 days after written notification by one party to the other.

Thomas C. Pauling, Environment Team Lead  
Office of Legacy Management  
United States Department of Energy

Geoff Haskett, Regional Director  
Alaska Region  
United States Fish & Wildlife Service



Date: 04/28/2010

Date: 6/2/10



## **Appendix C**

### **Contact List—Amchitka, Alaska, Site**

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<b>DOE Office of Legacy Management</b>	
Dave Geiser Director, LM-1 U.S. Department of Energy 1000 Independence Ave., SW Washington, DC 20585 Phone: (202) 586-8324 E-mail: <a href="mailto:david.geiser@hq.doe.gov">david.geiser@hq.doe.gov</a>	April Gil Environment Team Lead U.S. Department of Energy 2597 Legacy Way Grand Junction, Colorado 81503 Phone: (970) 248-6020 E-mail: <a href="mailto:april.gil@lm.doe.gov">april.gil@lm.doe.gov</a>
Mark Kautsky LM Site Lead 2597 Legacy Way Grand Junction, CO 81503 Phone: (970) 248-6018 E-mail: <a href="mailto:mark.kautsky@lm.doe.gov">mark.kautsky@lm.doe.gov</a>	Paul Darr Amchitka Project Manager S.M. Stoller Corporation 2597 Legacy Way Grand Junction, Colorado 81503 Phone: (970) 248-7666 E-mail: <a href="mailto:paul.darr@lm.doe.gov">paul.darr@lm.doe.gov</a>
<b>U.S. Fish and Wildlife Service</b>	
Merry Maxwell Regional Permits Coordinator FUDS Alaska Maritime NWR U.S. Fish and Wildlife Service 1011 East Tudor Road Anchorage, Alaska 99503 (907)786-3379	Tim Pucinski US Fish and Wildlife Service 1011 East Tudor Road Anchorage, Alaska 99503 (907) 786 3464
<b>Alaska Department of Environmental Conservation</b>	
John Halverson Environmental Program Manager Alaska Department of Environmental Conservation 555 Cordova Street Anchorage, Alaska 99501 Phone: (907) 269-7545 Fax: (907) 269-7649 E-mail: <a href="mailto:John_Halverson@dec.state.ak.us">John_Halverson@dec.state.ak.us</a>	Meredith Savage Alaska Dept. of Environmental Conservation Contaminated Sites Program 555 Cordova Street Anchorage, AK 99501 (907) 269-7578 <a href="mailto:Meredith.savage@alaska.gov">Meredith.savage@alaska.gov</a>
<b>Federal Elected Officials</b>	
The Honorable Lisa Murkowski Senator United States Senate 709 Hart Senate Building Washington, DC 20510 Phone: (202) 224-6665	The Honorable Mark Begich Senator United States Senate 111 Russell Senate Office Building Washington, DC 20510 Phone: (202) 224-3004 Fax: (202) 224-2354
The Honorable Don Young Representative U.S. House of Representatives 2314 Rayburn House Office Building Washington, DC 20515 Phone: (202) 225-5765 Fax: (202) 225-0425	

<b>State Elected Officials</b>	
The Honorable Sean Parnell Governor of Alaska P.O. Box 110001 Juneau, Alaska 99811-0001 Phone: (907) 465-3500 Fax: (907) 465-3532	The Honorable Lyman Hoffman Senator State Capitol, Room 514 Juneau, Alaska 99801-1182 Phone: (907) 465-4453 Fax: (907) 465-4523
The Honorable Bryce Edgmon Representative State Capitol, Room 411 Juneau, AK 99801-1182 Phone: (907) 465-4942 Fax: (907) 465-4589	
<b>Local Elected Officials</b>	
Mayor Shirley Marquart City Hall P.O. Box 610 Unalaska, Alaska 99685 Phone: (907) 581-1251  Christopher Maly P.O. Box 47070 Atka, AK 99547 Phone: (907) 839-2233	Mayor Tom Spitler P.O. Box 2011 Adak, Alaska 99571 Phone: (907) 592-4513  Nikolski Village Council Nikolski, Alaska 99638 Phone: (907) 576-2205
<b>Environmental/Interest Groups</b>	
Bruce Wright Senior Scientist Aleutian Pribilof Islands Association 1131 E. International Airport Rd. Anchorage, AK 99518-1408 Phone: (907) 222-4260 Fax: (907) 279-4351 E-mail: <a href="mailto:brucew@api.ai.org">brucew@api.ai.org</a>	Douglas H. Dasher, P.E., Ph.D. University of Alaska Fairbanks Research Professional V School of Fisheries and Ocean Sciences 905 N. Koyukuk 245 O'Neill Building P.O. Box 757220 Fairbanks, AK 99775-7220 Office Phone: (907) 474-6840 Cell Phone: (907) 347-7779 Office: Irving II, Room 132
Stephen C. Jewett, Ph.D. University of Alaska Fairbanks Research Professor School of Fisheries and Ocean Sciences 905 N. Koyukuk 245 O'Neill Bldg. P.O. Box 757220 Fairbanks. AK 99775-7550 Office Phone: (907)-474-7841 Cell Phone: (970)-744-8743 Fax: (907)-474-7204 Office: 126 O'Neill Bldg.	Ken Selby Aleutian Pribilof Islands Association 1131 E. International Airport Road Anchorage, AK 99518 (907) 222-4217

## **Appendix D**

### **Selected Bibliography of Amchitka-Related Papers**

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## **On Stakeholder Involvement:**

Burger, J., M. Gochfeld, D.S. Kosson, C.W. Powers, B. Friedlander, J. Eichelberger, D. Barnes, L.K. Duffy, S.C. Jewett, and C.D. Volz. 2005. Science, policy, and stakeholders: developing a consensus science plan for Amchitka Island, Aleutians, Alaska. *Environmental Management* 35:557-568.

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Burger, J., M. Gochfeld, D.S. Kosson, C.W. Powers, B. Friedlander, M. Stabin, D. Favret, S. Jewett, D. Snigaroff, R. Snigaroff, T. Stamm, J. Weston, D. Volz, and C. Jeitner. 2007. Radionuclides in marine fishes and birds from Amchitka and Kiska Islands in the Aleutians: establishing a baseline. (PROOF) *Health Physics* 92:265-279.

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Powers, C.W., J. Burger, D. Kosson, M. Gochfeld, and D. Barnes. eds. 2005. *Biological and Geophysical Aspects of Potential Radionuclide Exposure in the Amchitka Marine Environment*. CRESP, Piscataway, New Jersey.

Powers, C.W., J. Burger, K. Kosson, and M. Gochfeld. 2006. Addendum to final report: *Biological and Geophysical Aspects of Potential Radionuclide Exposure in the Amchitka Marine Environment*. CRESP, Piscataway, New Jersey.

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<p>Douglas Dasher School of Fisheries and Ocean Sciences University of Alaska Fairbanks P.O. Box 757220 Fairbanks, AK 99775-7220 (907) 474-6840 dhdasher@alaska.edu</p>
<p>John Halverson, Program Manager Alaska Dept. of Environmental Conservation Contaminated Sites Program 555 Cordova Street Anchorage, AK 99501 (907) 269-7545 john.halverson@alaska.gov</p>
<p>Stephen C. Jewett Institute of Marine Science University of Alaska Fairbanks Fairbanks, AK 99775-7220 (907) 474-7841 scjewett@alaska.edu</p>
<p>Merry Maxwell Regional Permits Coordinator FUDS coordinator Alaska Maritime NWR US Fish and Wildlife Service 1011 East Tudor Road Anchorage, Alaska 99503 (907) 786 3379 merry_maxwell@fws.gov</p>
<p>Tim Pucinski US Fish and Wildlife Service 1011 East Tudor Road Anchorage, Alaska 99503 (907) 786 3464</p>
<p>Meredith Savage Alaska Dept. of Environmental Conservation Contaminated Sites Program 555 Cordova Street Anchorage, AK 99501 (907) 269-7578 Meredith.savage@alaska.gov</p>
<p>Ken Selby Aleutian Pribilof Islands Association 1131 E. International Airport Road Anchorage, AK 99518 (907) 222-4217</p>

Bruce Wright  
Aleutian Pribilof Islands Association  
1131 E. International Airport Rd.  
Anchorage, AK 99518-1408  
(907) 222-4260  
brucew@apiai.org

U.S. Department of Energy  
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