AMCHITKA INDEPENDENT ASSESSMENT SCIENCE PLAN

Prepared for the Interagency Amchitka Policy Group

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* corrected for typographical and similar errors

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Cannikin Lake on an extraordinary weather day[1]

Acknowledgments

CRESP has developed this *Science Plan* in conjunction with DOE and stakeholders, at a series of public and scientific meetings, including at Fairbanks (February 2002), Dutch Harbor (March 2002), and Las Vegas (February and May 2003).

Many people participated in these meetings and we appreciate their contributions. We particularly acknowledge the contributions and critiques provided by the Interagency Amchitka Policy Group. It is clear to the PI that without the perseverance and good faith efforts of the leaders (and their colleagues) of the policy group to find common ground, this effort would have foundered. The ability of the Policy Group members to represent diverse interests, and yet imagine and then take hold of an agreed plan was and is impressive. Indeed, the input provided throughout the provision process by the group has dramatically improved the plan itself. The following individuals were especially important in the development of the *Science Plan*:

Runore Wycoff	National Nuclear Security Administration-Nevada
David Rogers	Alaska Department of Environmental Conservation
Robert Patrick	Aleutian/Pribilof Islands Association
Anne Morkill	United States Fish and Wildlife Service
Monica Sanchez	National Nuclear Security Administration-Nevada
Peter Sanders	National Nuclear Security Administration-Nevada
Ron King	Alaska Department of Environmental Conservation
Doug Dasher	Alaska Department of Environmental Conservation
Jenny Chapman	Desert Research Institute
Lee Younker	Lawrence Livermore National Laboratory

[1] http://www.nevadasurveyor.com/cannikin.htm

The PI also takes special note of the contributions of a series of CRESP-related researchers in the three years during which CRESP has struggled to bring the Amchitka subsurface issues under scientific discipline. Their contributions were diverse; the consistent underlying themes are persistence and the shared belief that differences about Amchitka just might be amenable to scientific resolution. Let me separate out two groups who now, in reality, belong together.

We are deeply dependent on our colleagues at the University of Alaska, Fairbanks; their capacities and credibility are key to this project. David Barnes led the UAF project when it was only an idea and built it into the first science research effort. He laid the groundwork. John Kelley was his sage mentor in this period. John Eichelberger (with Dave Barnes at his side) then showed both the national technical community and the Alaskan stakeholder communities that Amchitka is a major scientific challenge, that science can be the language of communication and that discourse and data could not only be friends but shed light. The effort to create the Letter of Intent (the event that made assurance that there would be to an independent scientific assessment official) is really the heir of this Eichelberger-led Workshop. And John then went on to turn this new commitment into a scientific program and into the first two iterations of this document. John sensed that the central focus of the effort was going to be biology and that his geo-physical work would provide longer-term clarity. He wisely recruited Larry Duffy to succeed him in the lead role. Many others at UAF have worked to make this document come whole (Steve Jewett, Jeff Freymueller and Sathy Naidu to name just three). And UAF will continue to be central to the actual project's success.

There is a second set of CRESP-related researchers who have worked tirelessly with their Alaskan colleagues. Dave Kosson may have logged the most miles and as always his scientific insight and breadth are key to CRESP quality. Joanna Burger and Mike Gochfeld are now challenging Dave Kosson in the miles traveled contest but have outdistanced us all in the number of words written and perceptively rewritten and in their relentless and synthetic efforts to competently develop the foundations and the data that now make this plan superb. Barry Friedlander logged many, many miles himself to make sure that CRESP stayed attentive and empathetic to evolving stakeholder concerns and how those concerns should shape our task. And many others (I think of Tom Leschine, Vikram Vyas and Panos Georgopoulos) have added key suggestions and more miles. Lisa Bliss was the cool and competent orchestrator of the process by which words become a readable plan.

The degree of commitment to making this plan come alive bears absolutely no relation to resources provided or personal scientific interests preserved. There would be no plan if those factors had played the major role. This is a scientific work of art by talented people who have come to believe that scientific hypotheses and protocols can generate data that will help us relate earlier models to the reality of what now are the issues posed by the Amchitka subsurface and to assure that we do what is needed (and don't do what is not needed) to track those issues for the peace of mind and the well-being of those diverse communities who are affected by the waters of Amchitka far into the future.

I. Executive Summary

Amchitka Island, situated in a tectonically and seismically active area in the Aleutian Island Chain, was the scene of three underground nuclear test shots:

Long Shot	1965	~80 kilotons
Milrow	1969	~1 megatons
Cannikin	1971	~ 5 megatons

Many concerns over earthquakes, pollution, and marine resources were voiced at the time of the testing. Initial surveys did not report evidence of radioactive contamination in the marine environment, and residual radionuclides were considered confined to the test cavities. At present, the U.S. Department of Energy (DOE) is moving to closure of contaminated sites and Long-term Stewardship nationwide, including Amchitka. Therefore it is desirable to reassess Amchitka's marine environment with respect to possible current or future transfer of radionuclides and other contaminants to the sea, to marine ecosystems, and particularly to sensitive or endangered species, foods harvested by Aleut fishermen, and seafood of commercial interest. It is also necessary to develop plans for the scope and frequency of the monitoring that will be needed in the Long-term Stewardship program.

The Department of Energy (DOE) and its stakeholders have agreed that an Independent Scientific Assessment of the Amchitka environment is necessary at this time, and this was cited in a formal Letter of Intent (June 2002).

Alaska Department of Environmental Conservation (ADEC) and DOE requested that the Consortium for Risk Evaluation with Stakeholder Participation (CRESP) take the lead role in organizing and implementing the *Amchitka Independent Assessment Science Plan (*hereinafter referred to as *Science Plan*). CRESP is a multi-university consortium of researchers dedicated to assisting DOE in the planning and prioritizing of its massive environmental management responsibilities, through the involvement of stakeholders at each step of the risk management process.

This document, the *Amchitka Independent Assessment Science Plan* sets forth a plan for scientific investigation of the hazards and risks associated with the Amchitka underground nuclear tests to achieve closure of the site by the US Department of Energy (DOE) and to plan for long-term stewardship of Amchitka as a National Wildlife Refuge under the management of the US Fish and Wildlife Service (USFWS). This draft Plan builds on prior studies: *Screening Risk Assessment for Possible Radionuclides in the Amchitka Marine Environment* (DOE 2002a) and *Modeling Groundwater Flow and Transport of Radionuclides at Amchitka Island's Underground Nuclear Tests: Milrow, Long Shot and Cannikin* (DOE 2002b). The Plan benefits from critiques provided by the National Nuclear Security Administration-Nevada (NNSA/NV), the Alaska Department of Environmental Conservation (ADEC), Aleutian/Pribilof Islands Association (A/PIA), and the US Fish and Wildlife Service (USFWS).

The *Science Plan* is organized into four major task groups:

1. The Marine Environment
2. Ocean Conditions
3. Geology and Hydrology
4. Stakeholder Dimensions

Each of these tasks has two or more subtasks. Each of the subtasks has been evaluated with respect to its priority status for DOE and for stakeholders. Those accorded high priority under both headings are considered the NNSA-NV Base while the remaining projects are part of the complete *Science Plan* as they form a "necklace" of interconnected tasks which will contribute significantly to the understanding of the Amchitka environment, its hazards, risks, and appropriate management and monitoring. A set of basic tasks has been assigned to funding through the NNSA-Nevada funding mechanism up to a limit of $3.1 million. Funding for the remaining tasks in the complete *Science Plan* will be sought from other sources in conjunction with the stakeholders.

Stakeholders and the DOE are concerned about whether release of radionuclides has occurred or whether it might eventually occur to the potential detriment of the ecology of the region and of human health. Barriers to radionuclide release include the depth of the shot cavity, the retention of some radionuclides in the glass breccia formed by the explosions, and subsurface rock that separates the shot cavities from the ocean. However, pathways through the faulted and fractured rock to the sea may occur.

Amchitka Island is unusual among the DOE's legacy sites of the Cold War in a number of ways:

- Underground nuclear explosions of exceptional size including the largest (*Cannikin*).
- Location within an actively deforming tectonic plate boundary characterized by frequent intense earthquake activity.
- Hydrology and the Ocean-Island interface.
- Remote location and difficulty of access.
- Proximity to Asia.
- Protected status as a National Wildlife Refuge with endangered species.
- Location within an important international fishery region.
- The marine environment supports the subsistence life style of indigenous people.

In accord with the wishes of the stakeholders and the US Department of Energy (DOE), it is desirable to move Amchitka expeditiously into long term stewardship, with appropriate monitoring and scientific investigations. Mechanisms should be in place to provide early warning of leakage of contaminants into the marine food web, and of the capacity to assess and communicate its significance. Management must be based on sound knowledge of the biological and physical characteristics of the natural system and the hazardous materials that have been deposited within it, as well as the pathways to human and ecologic receptors. While there has been recent modeling of groundwater flow, marine contamination, and health risks, great uncertainties remain. Independent verification of the models is hampered by the fact that details of the source term (identification and amount of radionuclides in the shot cavity) remain classified. There is limited information about contamination of the subsurface of the Amchitka sites or the nearby marine environment. During this time major advances have been made in the physical and biological sciences and the techniques available for studying contaminants in the environment. Scientific studies of the physical environment, radionuclides, and some biota were published by Merritt and Fuller (1977).

During the past decade there have been a number of studies on the distribution and biology of fish of commercial interest (Carlson et al. 1996, Hoag et al. 1997, Fritz and Lowe 1998, International Pacific Halibut Commission 1998, 2000, Ianelli et al. 2000, Lowe and Fritz 2000, Spencer et al. 2000, Witherell 2000). While these sources provide important baseline information on the marine ecosystem, and key species within it, they do not provide recent information on contaminants. It is the potential for radionuclides to have entered (or to enter in the future) the food chain that is of interest to a wide range of stakeholders. Baseline data on fish populations are key, however, to understanding population trends of these species within the Amchitka ecosystem. Moreover, the interpretation of the tectonic environment of the Aleutian region has undergone a revolution, facilitated by new technologies, and new information. There are a number of recent studies about the physical characteristics and currents in the vicinity of Amchitka (Reed and Stabeno 1994, Stabeno and Reed 1994, Roden 1995, U.S. Department of Commerce, Coast and Geodetic Survey 1995, Okkonen 1996).

Thus, there exists only a partial knowledge base for the Amchitka area from which to assess the hazards and risks or move forward to long-term stewardship. Understanding the biology of keystone species, and the physical environment, and ocean currents does not lead to understanding the potential of contaminants in biota not does it lead to predictability of significant risk from contaminants in biota (now or in the future). There must be a sound basis in empirical observation so that plans for stewardship of the site will be credible and will engender peace of mind among people who depend upon this region for food, and satisfy commercial fishing interests, resource trustees, and the broad environmental concerns of the general public. The projects of the *Science Plan (*see project timeline, Table 12) are designed to fill in the missing pieces, taking advantage of new sensing and analytic technology.

Objectives:

There is public and agency concern that residual radionuclides from nuclear tests may enter the marine food chain causing ecological and human health effects. The specific objectives of the *Science Plan* are:

- To determine whether or not current or future radionuclide releases from the shot cavities to the marine environment pose significant risks to human health and the ecosystem.
- To reduce uncertainty about the extent of the hazard and nature of the risks to human health and the ecosystem associated with any potential current or future radionuclide release to the marine environment, and the factors that may affect such risks.
- To devise and communicate an appropriate basis for a monitoring plan that would detect potential significant future risks to human health and the marine ecosystem as early as practical.

Central to this effort is sampling of marine biota, with particular reference to the food web and potential exposure to humans and other important ecological species, particularly those at high trophic levels. Selecting the locations for the marine sampling will be facilitated through sound understanding of the physical land/ocean system as well as understanding the marine life utilized by native populations. Baseline levels of radionuclide contaminants in the environment will also be established so that the detection and impact of future release can be assessed.

DISCLAIMER

This *Science Plan* is for the 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 or may arise from the Amchitka Nuclear Test shot activity (and not from other activities that have occurred on the island). The current *Science Plan* does not address surface hazards, direct exposures, nor risks to terrestrial organisms or to humans who may occupy Amchitka in the future for any purposes, except insofar as they may make use of marine resources.

It is understood that in the event that significant radionuclide contamination above background is detected in the physical or biological sampling, there will need to be substantial modifications and re-prioritizations of tasks and budgets.

A fully comprehensive approach to Amchitka would include an ecological risk assessment. The current *Science Plan* does not include a scope or funding for an ecological risk assessment, although data gathered, particularly in the biological sampling, will provide valuable input to an ecological risk assessment.

The costs of conducting the scientific assessment in a remote environment which no longer has land-based support facilities, and where the vagaries of weather may restrict field work, have been estimated to the best extent possible at this time. The ability to find and collect all of the identified organisms and physical data is contingent upon conditions encountered at the sampling sites, and researchers will need to exert expert judgment as to what can and cannot be accomplished safely. The CRESP project is planned as an independent scientific inquiry, with impartial science-based interpretation of data, openness to the public of both research processes and results, critical peer review by the scientific community and interactive participation by and scientific education opportunities for the resident Aleut community and other stakeholders. It is believed that, absent the discovery of serious leakage, the prerequisites for long term stewardship can be acquired within 3 years of initiation of the work outlined here. All data obtained in and by the project will be reviewed by and with stakeholders, will be made available to the public electronically and in hard copy, and will be published in the peer-reviewed scientific literature.

II. INTRODUCTION

Amchitka Island, situated in a tectonically and seismically active area in the mid-Aleutians, was the scene of three underground nuclear test shots:

Long Shot	1965	~80 kilotons
Milrow	1969	~1 megatons
Cannikin	1971	~5 megatons

Many concerns over earthquakes, pollution, and marine resources were voiced at the time of the testing. Initial surveys did not report evidence of radioactive contamination in the marine environment, and residual radionuclides were considered confined to the test cavities. At present, the U.S. Department of Energy (DOE) is moving to closure of contaminated sites and long term stewardship. Therefore it is necessary to reassess the marine environment with respect to possible current or future transfer of radionuclides and other contaminants to the sea, to marine ecosystems, and particularly to sensitive or endangered species, foods harvested by Aleut fishermen, and seafood of commercial interest. It is also necessary to develop plans for the scope and frequency of the monitoring that will be needed in the long term stewardship program.

The cause for stakeholder concern is the possibility of release to the marine environment of radioactive products from these nuclear tests to the potential detriment of the ecology of the region and of human health. Barriers to release are retention of some radionuclides in the glass breccia formed by the explosions and the rock that separates the shot cavities from the ocean. There is public and agency concern that residual radionuclides from nuclear tests may migrate through the fractured and faulted rock, carried by groundwater, and enter the marine food chain causing ecological and human health effects.

The specific objectives are:

- To determine whether or not current or future radionuclide releases from the shot cavities to the marine environment pose significant risks to human health and the ecosystem.
- To reduce uncertainty about the extent of the hazard and nature of the risks to human health and the ecosystem associated with any potential current or future radionuclide release to the marine environment and the factors that may affect such risks.
- To devise and communicate an appropriate monitoring plan that would detect potential significant future risks to human health and the marine ecosystem as early as practical.

Specific questions of concern are:

1. Which radionuclides should be looked for?
2. Which foods are consumed by Aleuts?

3. What levels of test-related contamination are found now or might be found in the future?
4. Would these levels pose a threat to human health or ecologic receptors?
5. How will we know if such threats arise in the future?

Amchitka Island is unusual among US legacy sites of the Cold War in a number of ways:

- Underground nuclear explosions of exceptional size including the largest (*Cannikin*) ever.
- Location within an actively deforming plate boundary characterized by intense earthquake activity.
- Remote location and difficulty of access.
- Proximity to Asia.
- Location within an important international fishery.
- Protected status as a National Wildlife Refuge with endangered species.
- Part of the marine environment that supports the subsistence life style of indigenous people and significant commercial fisheries.

This document, the *Amchitka Independent Assessment Science Plan*, sets forth a plan for scientific assessment of the hazards associated with the Amchitka underground nuclear tests to achieve closure of the site by the US Department of Energy (DOE) and Alaska Department of Environmental Conservation (ADEC), and to plan for long term stewardship as a National Wildlife Refuge under the management of the US Fish and Wildlife Service (USF&WS). This draft Plan builds on prior studies: *Screening Risk Assessment for Possible Radionuclides in the Amchitka Marine Environment* (DOE 2002a) and *Modeling Groundwater Flow and Transport of Radionuclides at Amchitka Island's Underground Nuclear Tests: Milrow, Long Shot and Cannikin* (DOE 2002b). The Plan benefits from critiques provided by the National Nuclear Security Administration-Nevada (NNSA/NV), the Alaska Department of Environmental Conservation (ADEC), Aleutian/Pribilof Islands Association, (A/PIA), and the US Fish and Wildlife Service.

The focus of the work is to establish a basis for reducing the uncertainties for risk assessment through prioritized examination of the physical, chemical, and biological context of the greater Amchitka system. The data will provide a basis for reducing important uncertainties in the groundwater modeling and screening risk assessment that is essential to evaluate the current situation and develop a long term stewardship plan. The latter focused on human health risk. An ecological risk assessment remains to be done, and the *Science Plan*, when fully executed, will contribute to this.

The Plan involves four major research tasks focusing on:

1. Sampling Physical and Biological Marine Environment
2. Ocean Conditions
3. Geology and Hydrology
4. Stakeholder Dimensions

The *Science Plan* was requested in a Letter of Intent (LOI) for Amchitka Island signed by the State of Alaska, Department of Environmental Conservation (ADEC) and U.S. Department of Energy, National Nuclear Security Administration, Nevada Operations Office (NNSA/NV) in June 2002. It is also discussed in the Performance Management Plan for the Amchitka Island Site drafted by NNSA/NV in July 2002. The AIASP is subject to approval by ADEC, NNSA/NV, the US Fish and Wildlife Service (USF&WS), which is the land manager, and the Aleutian and Pribilof Islands Association (A/PIA), which is the representative for Native stakeholders on this issue. Following acceptance of the base plan, the work will be managed independently by the Consortium for Risk Evaluation with Stakeholder Participation (CRESP) as further described in Section XII.

This document is based in part on discussions at a scientific workshop sponsored by CRESP in Fairbanks, Alaska in February 2002 (CRESP 2002), at a meeting of Aleut stakeholders sponsored by A/PIA in Dutch Harbor, Alaska in March 2002, at meetings at Desert Research Institute in Las Vegas (February and May 2003), by review of the draft *Screening Risk Assessment* (DOE 2002a) and draft *Groundwater Modeling Report* (DOE 2002b) and by comments from several agencies, A/PIA, and other stakeholders. It was the conclusion at these meetings that this plan is needed to evaluate the current situation and plan long-term monitoring.

Some participants at the Las Vegas meeting (19 February 2003) believe this plan is needed primarily to provide data to decide how the potential risk posed by the Amchitka site should be evaluated and managed in the short and long-term. Others hoped the plan would provide data to reduce uncertainty and verify existing analyses in the groundwater models and screening risk assessment, and to alleviate stakeholder concerns. At all the meetings, however, there was general consensus that a credible *Science Plan* would have the support of the interested parties.

A. CRESP AND PCCRARM

The Consortium for Risk Evaluation with Stakeholder Participation is a multi-university, scientific consortium that has conducted basic and applied research in a number of areas related to risk assessment and risk management for the Environmental Management Division of the Department of Energy (DOE-EM). Involvement of stakeholders in the understanding of concerns and contexts, the planning of data gathering, and the data interpretation, risk assessment, and prioritization of risk management options is central to CRESP's success. (Goldstein et al. 2000).

Figure 1: Adapted from the Presidential and Congressional Commission on Risk (1997)

CRESP's model is closely allied to the approach adopted by the Presidential/Congressional Commission on Risk Assessment and Risk Management (PCCRARM 1997) as depicted in Figure 1, in which an iterative process is established moving from Problem and Context definition to Risk Assessment (Risks), Management Options, Remediation Decision, Actions, Evaluation, and re-assessment of the problem and risks. Stakeholders are to be integral parts of each step in this decision process. This assures that the problem is defined by the parties (including regulators) in a manner relevant to the concerns of all stakeholders. The data gathered, risks assessed, and the outcomes will then be meaningful to the stakeholders.

The CRESP/PCCRARM approach is directly applicable to the Amchitka situation.

B. RISK ASSESSMENT AND UNCERTAINTIES

The primary emphasis of this *Science Plan* is on reducing uncertainties for Risk Assessment. Uncertainty intrudes at all stages in risk assessment because complete knowledge is seldom available. The unusual circumstances at Amchitka outlined previously result in high uncertainty. The recently completed *Screening Risk Assessment* (DOE 2002a has provided a framework for understanding risk and identifies areas of uncertainty. It focused only on human health from food chain contamination, with a limited set of assumptions. The proposed *Science Plan* goes beyond the SRA and will provide data to address many of its remaining uncertainties.

Risk assessment has been used in food and drug evaluation for 50 years and in environmental health for more than 30 years. The four-step risk assessment paradigm was codified by the National Research Council's 1983 volume *Risk Assessment in the Federal Process* (NRC 1983) which laid out the four key steps:

1. Hazard identification (what are the hazardous substances, receptors. and endpoints of concern)
2. Dose-response assessment (what magnitude of response is likely to be seen at particular doses).
3. Exposure assessment (how much of the hazard will reach sensitive organisms or organs).
4. Risk characterization (what is the probability that receptors will be exposed to sufficient dose to experience an particular probability of adverse effect).

Once risk estimates have been completed they are input into risk management decision making.

Hazard Identification: In risk assessment, efforts are made to characterize the source term. What hazardous substance(s) are present and in what quantity and chemical/physical form, are essential questions. At Amchitka the source term is classified, and one must infer the hazards from other experiences and documents (DOE 2002a). The Amchitka receptors have been defined by stakeholders as marine ecosystems including sensitive and endangered species, Native peoples, and more remotely, the public that purchases fish from commercial fisheries.

Not all stakeholders are receptors. One must consider a wide variety of endpoints, including death and population decline among marine organisms, leading to disruption of food chains and possible elimination (by emigration or extinction) of sensitive species. For humans exposed to radionuclides, a cancer risk assessment is most appropriate (NRC 1990). Because the source term is classified, uncertainties in the hazard assessment are higher than for most risk assessment contexts. Other contaminants also may occur in the marine ecosystem, adding to exposure and risk.

Dose-response Assessment: Establishing the relationship between dose and outcome usually relies on toxicologic and epidemiologic literature. Studies on the impacts of radiation on wildlife, both terrestrial and aquatic have been published, but much of the emphasis has been on the bioaccumulation and effects in terrestrial or fresh-water systems. Seymour and Nelson (1977) provided a review of radionuclides at Amchitka. Dose-response relationships for both externally and internally deposited radionuclides are available in several sources including EPA (1988,1998). Uncertainties in the dose response assessment arise mainly when data are not available from the system of concern. Some historical data are available from Amchitka (see Merritt and Fuller 1977); more data are available from the Aleutians and Pribilofs. Yet major uncertainties remain.

Exposure Assessment: Despite the presence of hazardous substances or conditions, organisms are not at risk if there is no exposure pathway. Lioy (1990) provided the popularly recognized general pathway for exposure assessment. Figure 2 is derived from the Lioy (1990) model as modified by Burger and Gochfeld (1996) for ecologic as well as human effects. Uncertainties arise because site specific data are not available for each of the transitions. Measuring radionuclide levels in individual organisms will greatly reduce uncertainty, at least for the present state. Geological and oceanographic measurements will reduce uncertainties that influence fate and transport. The extent to which native Aleut communities utilize Amchitka waters and resources is under study. The possibility of visitation and marine resource use by other island visitors such as refuge staff, military personnel, fishermen, and the general public will also be considered, but direct exposure from the terrestrial environment is beyond the scope of the *Science Plan*, although future visitors are likely to exploit some marine resources.

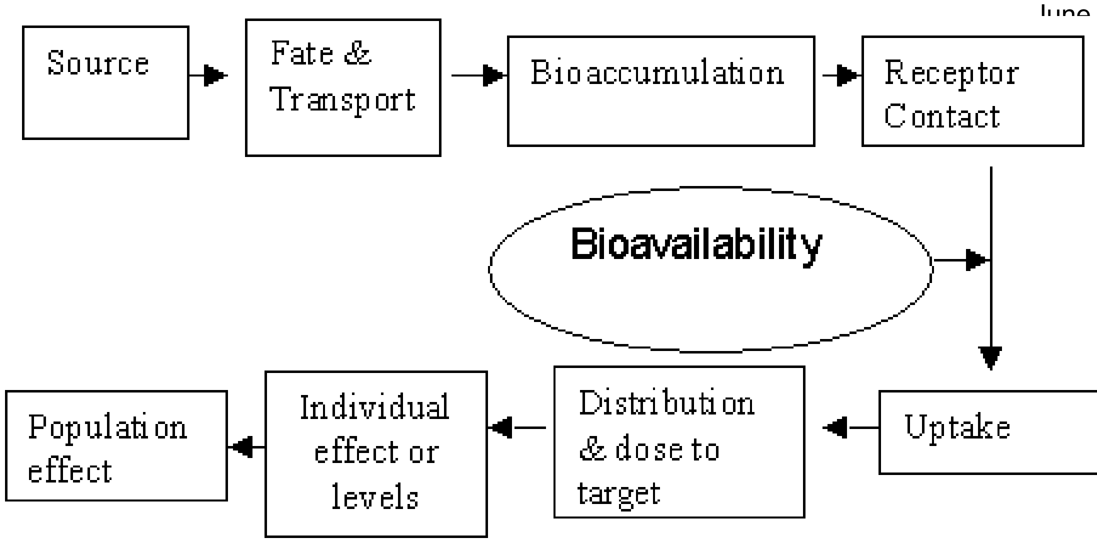


Figure 2: The movement of contaminants from source to receptors derived from Lioy (1990) and Burger and Gochfeld (1996). Individual effects are most important for humans and endangered species. Population effects are most important for other ecosystem outcomes.

Risk Characterization: The results from exposure assessment and dose-response analysis are combined to estimate the risk of various outcomes to the receptors of concern. There is a huge literature on human health risk from radionuclides. The National Academy of Sciences Committee on the Biological Effects of Ionizing Radiation, chaired by Arthur Upton of CRESP, provided a detailed risk characterization of low-level ionizing radiation exposure in the BEIR V report (NRC 1990). This has recently been updated (NCRP 2001). The uncertainties in the risk characterization are the product of uncertainties in the other risk assessment phases, hence are high at the present time. For radiation, risk from a particular source has to be compared to background risk from natural radiation (geologic and cosmic sources, NCRP 1992).

The relative contribution of fallout and other sources to ecological food chains was reviewed recently (Whicker and Pinder 2002). There are studies of terrestrial exposures going back to the Woodwell and Whittaker (1968) classical study of gamma radiation effects on plant communities. Exposure of various organisms and humans to fallout-contaminated soil has been reported by Whicker et al. (1996). Ecosystem dynamics (Hakonson and Whicker 1975), effects and exposure have been studied in terrestrial (Millard et al. 1990) and fresh-water ecosystems (Burger et al. 2001). A terrestrial food chain model (PATHWAY, Whicker and Kirchner 1987) has been extensively used. Factors influencing radionuclide uptake have been extensively studied in humans, but also in wildlife (Whicker et al.1965).

1. ECOLOGICAL RISK ASSESSMENT

Most risk assessment has been performed on human health endpoints, and the consideration of ecological risk has arisen relatively recently (reviewed by Burger 1997a), although there is a long history of research in ecotoxicology (Hoffman et al. 1995) and radioecology (Whicker and Schultz 1982). The National Research Council's Committee on Risk Assessment Methodology, chaired by Bernard Goldstein, undertook the challenge of applying the traditional human health risk assessment paradigm to ecological risk assessment (NRC 1993). Burger and Gochfeld (1996) emphasized the contrasts between these two domains of risk. In human health risk assessment we are usually concerned with one or a few specific endpoints affecting individuals. In ecological risk assessment the concern includes population numbers, food chain transfers, and ecosystem integrity (Burger and Gochfeld 1996). Ecological risk assessment must be conducted at varying temporal and spatial scales (Burger and Gochfeld 1992, Gochfeld and Burger 1993). Ecological risk assessment requires a system of monitoring selected media and indicator species, which becomes an essential component of any long term stewardship plan (Burger 2002a). This is directly applicable to Department of Energy sites in general (Burger 1999).

Much of the research in ecological risk assessment has focused on freshwater systems. Experimental studies in microcosms (aquaria) and mesocosms (small ponds) has focused on impacts of measured amounts of chemicals (particularly pesticides) on invertebrates and small fish (Linthurst et al. 1995). Less attention has been paid to terrestrial environments, although there is increasing interest on watersheds and "landscape" scale changes (Linthurst et al. 1995). There are applications to coral reefs and sea coasts, and ecological risk has been addressed in the Aleutians (Flint and Miles 2002). At the same time, ecological risk assessment has been applied to hazardous waste sites, with investigations of exposure, bioavailability, biomarkers, and a large variety of ecological health endpoints measured at the species and community level (Suter et al. 2000). Ecological indicators and risk modeling have also emerged as prominent disciplines (NRC 1991, Bartell et al. 1992), and have been applied to previous CRESP studies at Savannah River Site (Burger et al. 1998, 2001a,b), Oak Ridge (Bartell et al. 2002a,b), and Hanford (Kimberling et al. 2001). Quantitative studies of food webs (Burger et al. 2001c) and the transfer of pollutants across trophic levels is a central feature for ecological risk assessment.

There are significant challenges in how to interpret the concentrations of pollutants found in animal tissues (Beyer et al. 1996) and how to relate these to affects seen in animals and to possible effects in humans. The National Research Council (NRC 1979,1991) has examined how animals can be used to monitor pollutants and as sentinels for human health hazards. There have been a few attempts to link ecologic and human health (di Giulio and Monosson 1996). Ecological risk assessment can also form the basis for resource damage assessment on the one hand, and for the rehabilitation of ecologic damage on the other (Cairns 1995).

In a complex system, a variety of pathways exist from the environmental media (water, soil/sediment, air and food), through the uptake pathways (direct dermal or membrane contact, ingestion, inhalation or injection). These are illustrated in the Exposure Matrix (Table 1). Pathways of primary relevance to Amchitka are shown in boldface. The airborne deposition pathway delivers radionuclides and other contaminants from remote sources.

Table 1. Exposure Matrix for the Marine Ecosystem and Human Consumers at Amchitka (derived from Gochfeld 1986). Major pathways are shown in bold face. Airborne deposition is a potential confounding source of radionuclides.

	Water	Soil/sediment	Food	Air[b]
Direct contact	**Invertebrates, Aquatic vertebrates, Fish, Seabirds, Marine Mammals, Humans**	**Benthic organisms Flora-**	Not applicable in general	Airborne deposition on exposed organisms
Ingestion	**Invertebrates Fish, Seabirds[a] Marine Mammals**	**Benthic organisms, some terrestrial organisms**	**All organisms in food chain including humans**	Airborne deposition on exposed food items
Inhalation	Some aerosolization from ocean surface and surge zone	Inhalation of dust not applicable at Amchitka	Not applicable in general	All air-breathing organisms
Injection	Not applicable to Amchitka	Not applicable to Amchitka	Not applicable in general	Not applicable in general

a = seabirds are capable of drinking seawater and excreting the salt
b=historic airborne transport of "fallout" from nuclear tests and nuclear accidents would have delivered radionuclides to Amchitka and its marine ecosystems. This is a potential confounder for exposure to test shot radionuclides.

2. CATEGORIES OF UNCERTAINTIES:

Although the methodologies of risk assessment are basically deterministic, the results are subject to uncertainties that arise at all stages of the process. Uncertainties are a fact of life in risk assessment and risk management, and clear identification and communication of the magnitude and direction of the uncertainties is likely to be beneficial in risk communication.

There are two main categories of uncertainties that play a role in risk assessment, risk management, and risk communication.

1. Uncertainties due to intrinsic variability in the system. These can be understood and bounded by additional data, but cannot be eliminated.

2. Uncertainties due to lack of data or inadequate study designs. These can be reduced by improved study design and additional data.

The reduction of uncertainty, like many other aspects of risk management follows a marginal cost curve. That is, a small investment may result in substantial reduction of uncertainty, but a huge investment is needed to reduce or understand all aspects of uncertainty. Stakeholders can live with uncertainty when efforts are made to reduce it as much as feasible and to clarify the impact of residual uncertainty. The *Science Plan* is intended to accomplish this dual role.

Temporal Variation and Uncertainty*:* Ecological events in the Bering Sea and elsewhere operate on a variety of timeframes from hourly fluctuations of the tidal cycle to supra-annual variation in the El Nino/Southern Oscillations and in cycles induced by sunspots (Table 2). Thus a three year sampling regime can identify only some of the sources of variation, which nonetheless, must be considered in a long-term monitoring program.

Table 2. Time Scale Events Potentially Influencing the Bering Sea (modified from *The Bering Sea Ecosystem* Table 3.2; NRC 1996)

Temporal Period	**Phenomenon**
Hours	Tide cycle
Weeks	Storms
Seasonal	Solar declination
Annual	Variation in ice cover (ENSO related)
1+ years	Mesoscale ocean eddies (uncertain role)
3-7 years	El Niňo Southern Oscillation (ENSO) events
6-7 years	Mid-latitude atmospheric events
10+ years	“Regime shift”
11 years	Sunspots (uncertain role)
18.6 years	Lunar Declination
22 years	Sunspots (uncertain role)
Longer term	Climate change

*ENSO=El Niňo/Southern Oscillation – a global current/climate phenomenon

Figure 3a: Map of Alaska and Bering Sea showing entire Aleutian Chain

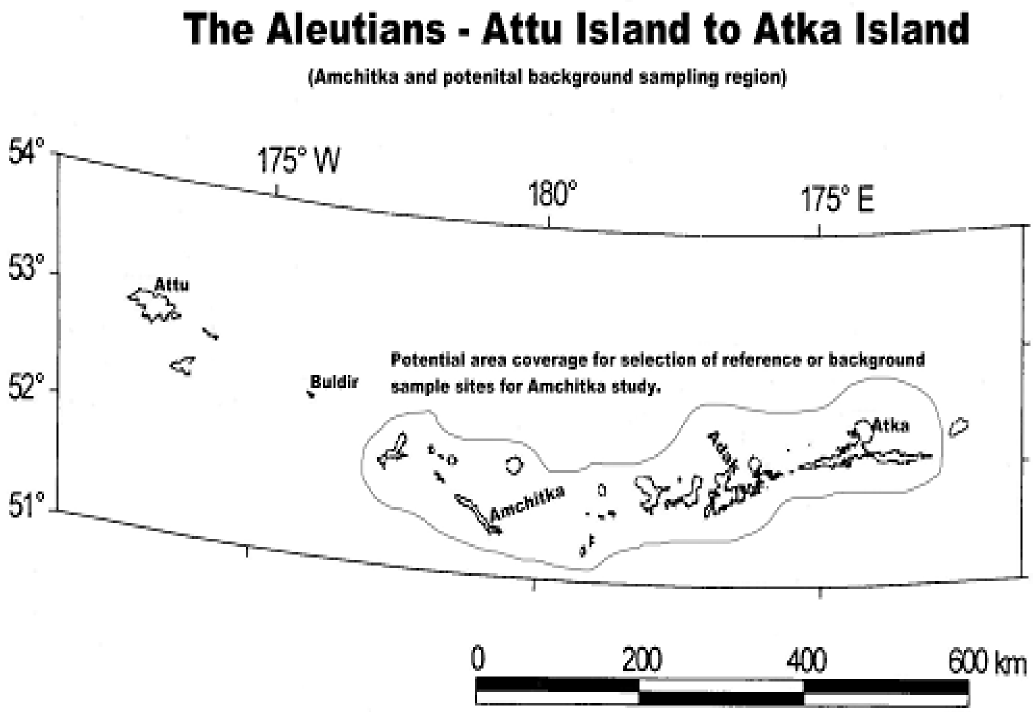


Figure 3b: Aleutian chain showing position of Amchitka.

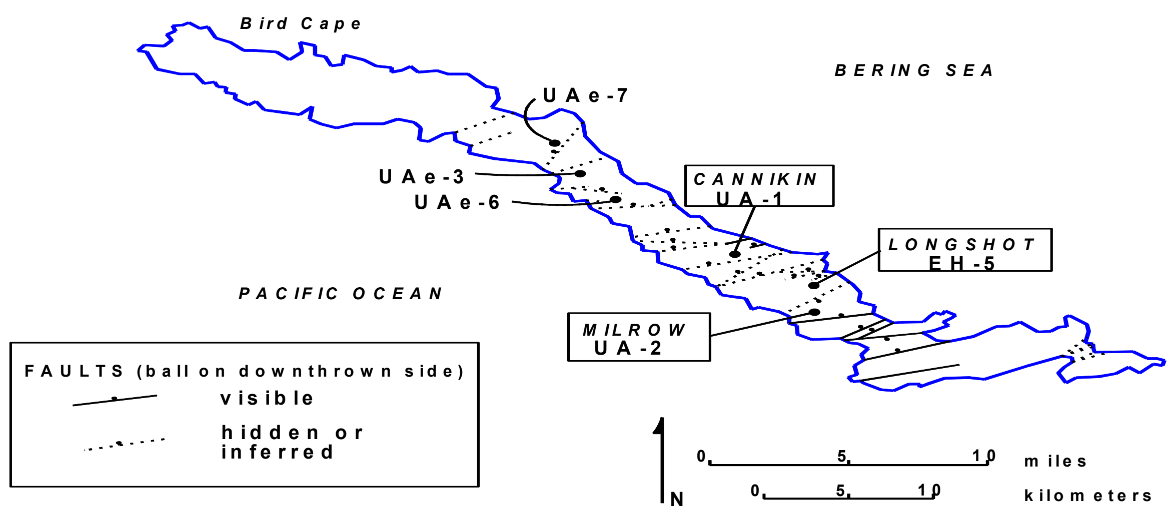


Figure 3c: Map of Amchitka Island showing the approximate location of each nuclear test and faults

C. LOCATION AND BACKGROUND

Amchitka Island is approximately 40 miles long and 1 to 4 miles wide, 1340 miles west-southwest of Anchorage, centered at 51.5 N latitude and 179 E longitude. It is the largest of the Rat Island Group (75, 212 acres). Annual precipitation is about 30 inches (Figs. 3a, 3b, 3c). The coastline is rugged with sea cliffs bordering sandy and gravel beaches. The eastern third of the island has isolated shallow ponds and maritime tundra meadows with relatively few plant taxa (Amudnsen 1977). The terrestrial flora includes a basal layer of mosses, lichens and liverworts, an herbaceous layer of ferns, grasses and sedges, and a shrubby layer of crowberry. The western third is mountainous (up to 1160 ft) with sparse vegetation. Many aspects of the Amchitka ecology are described in the "*Amchitka"* volume (Merritt and Fuller 1977).

1. THE BERING SEA ECOSYSTEM

The National Research Council published a report on *The Bering Sea Ecosystem* (NRC 1996) which addressed sustainability of marine resources in light of climate change and fishing pressure. It identified several major changes including:

1. Steller Sea Lion decline by 50-80%
2. Northern Fur Seal decline on Pribiloffs by 50% between 1950 and 1980
3. Harbor Seal decline by 90% since the 1970's in the Gulf of Alaska
4. Seabird declines in the Pribilofs and eastern Aleutians
5. Decline in whales and increase in Pollock

It reported that indigenous fishermen occasionally over-fished local resources. Commercial exploitation that began in the 18th century impacted resources sufficiently to cause starvation for local people. These fisheries over-fished flatfish and rockfish. Whale exploitation peaked in the 1950's to 1970's, and the elimination of whales is considered one factor in the population explosion of Pollock which became the dominant commercial species. About 25 species of fish, crustacea, and mollusks are considered important commercially (NRC 1996).

2. BIODIVERSITY AND AMCHITKA

Biodiversity has emerged as a major biological and social concern, and is particularly valued by Native American groups (Burger et al. 2000). The coastline is irregular and ringed with numerous rock spires, shallow reefs and extensive kelp beds that provide important habitat for marine invertebrates, fish, marine birds, and mammals. In general, primary production in coastal waters along the Aleutian chain is high, in the range of 200-250 grams of carbon per square meter per year (see Fig. 4 from Springer and McRoy 1993).

More than 130 bird species have been recorded on Amchitka Island, including the densest breeding Aleutian population of the endemic Aleutian Green-winged Teal, Aleutian Rock Sandpipers, and Gabrielson's Rock Ptarmigan. These birds in turn help support a diverse and dense population of avian predators in the Aleutians, including Bald Eagle, Peregrine Falcon, Gyrfalcon, Snowy Owl and Short-eared Owl. Principle marine bird species that feed in the intertidal and near shore marine zones include the Red-faced and Pelagic Cormorant, Common Eider, Glaucous-winged Gull, Arctic Tern, Aleutian Tern, Aleutian Green-winged Teal, Emperor Goose, Black Oystercatcher, and Rock Sandpiper (Kenyon, 1961). Marine mammals of the Amchitka littoral zone include the Sea Otter, Steller Sea Lion and Harbor Seal.

Of the 131 species of birds recorded on or near Amchitka, about 30 species breed (White et al. 1977), with the most abundant species being Rock Ptarmigan, Tufted Puffin, Green-winged Teal, Glaucous-winged Gull, Lapland Longspur and Snow Bunting. Breeding raptors include the Bald Eagle (currently being studied by R Anthony et al. 1999) and the Peregrine Falcon. Bird populations have increased greatly since the Kenyon's (1961) report, due mainly to the extermination of foxes which had been introduced by fur trappers centuries earlier. There are no native terrestrial mammals, but the Norway Rat still thrives on the island. Marine mammals include resident species (Sea Otter, Harbor Seal, Steller Sea Lion) and migrants such as Northern Fur Seals and various whales and porpoises.

Several species of anadromous fish spawn in the island's freshwater, including Pink, Sockeye, Silver Salmon, Dolly Varden, Threespine Stickleback, and Coast Range Sculpin, while about 90 fish species inhabit the surrounding marine environment (Crayton 2000).

It is the marine environment that is of greatest concern at this time because the natural and man-altered habitats and ecosystems provide potential pathways for radionuclide exposure to those who exploit marine resources.

D. HISTORY OF AMCHITKA

Human settlement in the Bering Sea dates back more than 10,000 years, and the land bridge exposed by lower sea levels during the late Pleistocene provided access for human migration from Asia to the Americas. Amchitka has supported a substantial human population, perhaps 1000 people or more (McCartney, 1977). Indigenous cultures of Beringia include in addition to Aleuts, Inupiat/Inuit and Yupik peoples, as well as the Koryaks and Chukchi of Siberia (NRC 1996). Vitus Bering's voyage in 1741 was followed by exploitation of mammals, extinction of Steller Sea Cow and depletion of otters, seals, and whales.

With Russian colonization of the Aleutian Islands and subsequent development of the commercial fur industry (Chevigny, 1998), the Aleut population declined precipitously due to disease and rapid depletion of resources, including the near-extinction of Sea Otters (Kenyon

1969). Some protection of fur-bearing animals was put in place with the 1991 Convention for the Preservation and Protection of Fur Seals. The region was purchased by the United States in 1867, and eventually some protection of fur-bearing animals was put in place. At the onset of World War II, the island contained only an abandoned Aleut village. This was destroyed by US forces so that it would not fall into enemy hands (Garfield and Cole, 1995). Inhabited Aleut villages of the region were also intentionally destroyed and their residents removed to camps in southeast Alaska, but non-Native civilian residents were allowed to remain in the region during the war years. Some villages have since been re-established, and while none are very close to Amchitka, Aleuts and the world at large derive food from the surrounding seas (http://www.st.nmfs.gov/st1/commercial/index.html). The Aleuts view this region as their historic home, and their future home.

1. CHRONOLOGY

1741	Vitus Bering's voyage opened the area for exploitation, mainly of marine mammals for the fur trade.
1750's	Petr Bashmakov's voyage for fur-bearers.
1761	Rat Island base established and persisted until 1763, including account of Amchitka and its human and avian residents.
1770	Foxes introduced to Aleutians to support fur trade.
1772-1776	Russian Dimitri Bragin recorded harvest of birds and mammals on Amchitka
1778-1780	Crew of *Aleksandr Nevskii* harvested 8000 fur seals, 642 sea otters and 1106 foxes from Amchitka (Kohlhoff 2002)
1799	Russian America Company given monopoly over fur harvesting.
1800	By this time most fur-bearer populations were seriously depleted and harvesting shifted to the southeast Aleutians.
1800's	Russians produced cycles of occupancy by forcibly moving Amchitkans to other islands, then returning them.
1849	End of continuous human occupancy.
1867	US Purchase

1900	Most whale, seal and Sea Otter populations reduced almost to extinction.
1911	Convention for the Preservation and Protection of Fur Seals signed to regulate the hunting of fur seals and halt the sea otter harvest.
1913	President William H. Taft signed Executive Order 1773 which created Aleutian Islands Reservation.
1931	First Sea Otter spotted at Amchitka after many years of absence.
1937	USFWS establishes Sea Otter observatory and scientific exploration greatly increased.
1940	Reservation renamed the Aleutian Islands National Wildlife Refuge. Management began in earnest as game wardens stationed on Amchitka Island to discourage Japanese fishing crews from poaching sea otters.
1943	U.S. military establishes base on Amchitka. By year-end about 15,000 troops were based there. 10,000 ft runway built.
1949	Aleutian Islands National Wildlife Refuge staff begins removal of introduced foxes on Amchitka Island to restore native bird species. This effort was completed in 1960.
1951	Military bases closed.
1952	Islands transferred from Department of Defense (DOD) to Department of Interior (DOI).
1959	A Distant Early Warning radar and communication site was operated on Amchitka Island until 1962.
1960	Environmental studies begin to assess impacts of forthcoming nuclear tests.
1960	Amchitka Island declared fox free, and native bird populations subsequently begin to rebound.
1965	*Long Shot* 80 kiloton test shot.
1967	Amchitka Bioenvironmental Program started and continued until 1973.

1971	*Cannikin* ~5 megaton test shot.
1973	AEC removes restrictions for Amchitka, while retaining administrative controls around the test sites themselves retained by AEC.
1973	Amchitka designated as part of the Aleutian Island International Biosphere Reserve by UNESCO, designed to encourage international research into preservation of plants and animals.
1976	U.S. Fish and Wildlife Service initiates endangered Aleutian Canada goose rearing-facility at Amchitka Island, which continued until 1980. Extensive sea otter research was also conducted during this period. .
1976	White and Risebrough (1977) report under auspices of Amchitka Bioenvironmental Program (focused on chlorinated hydrocarbons).
1977	Merritt and Fuller (1977) volume on prior research.
1980	Aleutian Islands National Wildlife Refuge is incorporated into the Alaska Maritime National Wildlife Refuge.
1986	DOD begins cleanup of World War II debris
1987	Department of Navy constructed and operated an over-the-horizon radar facility on Amchitka until 1993.
1991	USFWS initiates investigation of contaminants on Amchitka
1993-1998	Multi-agency field investigations to "identify sites of concern, human health and environmental risks and to explore possible cleanup options".
1996	Greenpeace report: *Nuclear Flashback: the Return to Amchitka*
1997-1998	DOE undertakes sampling in response to Greenpeace report.
2000	Crayton report on *Environmental Contaminants in Fauna Collected from Amchitka Island, Alaska*. "to provide the land manager (FWS Alaska Maritime National Wildlife Refuge) updated information about environmental contaminant levels in local fish and wildlife resources, and if possible, identify the contaminant sources." (Crayton 2000).

2001 Navy, Department of Energy, and Corps of Engineers removed nearly all remaining structures and remediated the drilling mud pits, landfills, and other surface contamination. Surveys and removal of unexploded ordnance is planned for 2005.

2001 DOE remediation of surface mudpits.

2002 Publicatoin of *Amchitka and the Bomb* by Kohlhoff

2. RECENT HISTORY

Amchitka is part of the Alaska Maritime National Wildlife Refuge, which includes the original Aleutian Islands Reservation. President William Taft established the reservation in 1913 to provide for a breeding ground for native seabirds, but one final statement in the Executive Order also stated that the establishment "shall not interfere with the use of the islands for lighthouse, military, or naval purposes." In World War II Amchitka served as a military base opposing the Japanese occupation of neighboring Kiska Island.

In the early 1960's the Atomic Energy Commission turned its attention to Amchitka as a possible place to conduct nuclear tests as part of the Vela Uniform project to study seismic signals. Subsequently, Amchitka was chosen for tests that were too large for the Nevada Test Site. Ground motion in Las Vegas had become a concern. The quest for suitable nuclear testing areas, the planning and implementation of the tests, and the controversies and legal action surrounding the Amchitka test shots, have been described in Kohlhoff's (2002) recent book. Questions arose about what tests were needed, what tests of a given size could be completed, and why use Amchitka (Younker 2002, Kohlhoff 2002). The remoteness of Amchitka, the nearby tectonic activity, and the proximity to the Soviet Union were all considered (Kohlhoff 2002). The *Long Shot* test was conducted in 1965 and *Milrow* in 1969 was conducted to see whether the island could withstand a large explosion. Since it appeared to do so, the nearly 5 megaton *Cannikin* test shot was planned in 1971 to test a warhead for the Spartan Missile of the Safeguard Missle Defense Program. Great public concern was voiced, with dire predictions regarding tsunamis, earthquakes, pollution and destruction of valuable marine resources. There was vigorous opposition by the Aleut and environmentalist communities, and formal protests from the governments of Japan and China (O'Neill, 1994; Kohlhoff, 2002).

Cannikin was unique in a number of ways. It was 1) the first major federal project under the National Environmental Policy Act of 1969 and was required to have an environmental impact statement; 2) the largest mined shaft in the United States, at the time, with a single elevator shaft of 6000 ft; 3) the longest diagnostic canister (264 feet); 4) the heaviest load (over 400 tons) lowered downhole (Younker 2002); 5) a very large cavity formed by the test @1000 ft. *Cannikin* required the use of many recording trailers located 2000 feet from ground zero, able to withstand a ground upheaval of 15 feet at shot time (Younker 2002). About a meter of uplift occurred along the adjacent Bering Sea Coast, leading Lebednik (1977) to conclude that "The lifting of some rock benches above the midlittoral areas as a result of the *Cannikin* test has resulted in a significant permanent reduction in area available to most littoral species." National and international attention was focused on Cannikin and its potential for both immediate and long term damage to the environment (Kohlhoff 2002).

In addition to the immediate and long-term consequences of the tests themselves, the infrastructure established to prepare for the tests left a variety of physical scars to heal over time, and contaminants requiring remediation. The Department of Energy has removed much of the infrastructure and completed the terrestrial remediation. After *Cannikin,* the seismic stations established on the islands for the purpose of studying the blast characteristics were removed.

An extensive effort was undertaken in 2001 by the Defense and Energy Departments to remove all structures and remediate surface contaminated sites. Amchitka Island is currently (2003) unoccupied and is managed by the U.S. Fish and Wildlife Service as a National Wildlife Refuge. The primary purposes of the Alaska Maritime National Wildlife Refuge are to conserve fish and wildlife populations in their natural diversity, and to provide a program of national and international scientific research on marine resources. The potential exists for future military re-occupation of Amchitka, but the long term stewardship plan and its associated monitoring program will be developed on the assumption that the island will remain a National Wildlife Refuge, open to public recreational and harvesting use. This *Science Plan* does not address exposure or risks to persons who may visit, work on, or occupy the island itself.

The region is tectonically active. The western Aleutian region, where the North Pacific plate subducts obliquely beneath North America at 7-8 cm/year, is one of the most volcanically and seismically active regions of the world (Jacob, 1984; Page et al., 1991). It was for the reason of high seismic activity that Amchitka was first selected for the 80 kt *Long Shot* test. The objective was to determine whether a nation wishing to clandestinely develop nuclear weapons could hide a nuclear explosion within intense natural seismicity. The test was conducted on October 29, 1965, shortly after a natural magnitude 8.7 event occurred nearby (sixth largest earthquake in the world in the 20th century), and little more than a year after a magnitude 9.2 event (second largest earthquake in the world in the 20th century) shook the eastern part of the same subduction zone.

The history of the region has been controversial both in regard to environmental policy and to Native civil rights. These events have produced obstacles to trust in the government's stewardship of the region, that only diligent regard for stakeholder participation in its future management can overcome. Accordingly, this *Science Plan* developed by CRESP, and its open development are part of a continuing resolve for transparency of process, wherein stakeholders can be fully informed and have input and involvement in actions that concern them, and wherein substantial independent academic support for the process is provided. The plan will be web accessible (www.cresp.org/amchitka.html) and comments and questions can be addressed to cresp@eohsi.rutgers.edu .

E. IMPORTANCE OF THE PROBLEM

Large quantities of radionuclides were sequestered in "puddle glass" in the shot cavities, while others (mainly lighter elements) were adhered to the surface of the chimney." Mobility for the former is generally low, while complex factors influence the mobility of the surface deposits (Dasher et al. 2002; DOE 2002b). The ground water model (DOE 2002b) used the conservative assumption that the surface deposits were readily soluble in ground water. The ground water modeling and the screening risk assessment identified uncertainties regarding mobilization and transport through the subsurface to the marine environment (DOE 2002a,b) and additional uncertainties involve bioconcentration and bioamplification through the food chain and potential dose to human and ecological receptors. The question of the potential risks presented by the Amchitka underground nuclear tests is important for the following reasons:

- The inventory of radioactive material deposited in the shot cavities and the resulting hydrological source term is significant (though specific information remains classified).
- The value of biological resources of the Amchitka area is high in cultural, commercial, and ecological terms.
- There is some stakeholder concern that disturbances in the physical environment could now or in the future accelerate the migration of radionuclides into the marine environment.

The DOE ground water model and risk assessment (DOE 2002a,b) made use of classified data on the source term. The qualitative identification of radionuclides of concern is essential. Stakeholders have reason to request that much more of the source information be declassified.

The reason for conducting nuclear tests underground was to limit the release of radiation to the atmosphere. The shift underground from atmospheric tests took place when it was recognized that radioactive fallout posed a risk to public health. Although few in number, the Amchitka tests include the largest underground test ever conducted by the US (*Cannikin*), and therefore a significant portion (~16%) of the total energy release from the underground testing program (Robbins et al; 1991; Norris and Arkin, 1998, and DOE 2000). Some release to the surface occurred at *Long Shot* and during drill back at *Cannikin*, but the leaks were not considered serious health threats (Seymour and Nelson 1977; Faller and Farmer 1998). There has, however, been increasing concern about the possibility of subsurface transport of radionuclides following nuclear tests (USDOE, 1997), particularly for tests conducted beneath the water table (Maxwell, et al, 2000). A Greenpeace (1996) study concluded that surface contamination had occurred, but

Dasher et al. (2002) did not confirm this. Except for surveys conducted after shots through the 1970’s, no systematic effort has been made at Amchitka to detect release of contaminated groundwater to the marine environment. Potential human and ecologic exposure through the marine food chain is more likely and probably more serious than exposure via terrestrial food chains. The *Screening Risk Assessment* (DOE 2002a) and groundwater modeling (DOE 2002b) have recently been conducted, providing substantial information while highlighting uncertainties. Regionally, the surrounding seas are extremely productive biologically (Fig. 4). They have long been used for subsistence fishing by the Aleut people, and over the last 30 years have come to comprise a major international commercial fishery. Even in the context of the biologically rich Aleutians, Amchitka Island itself stands out as an especially important part of the ecosystem. Its unusual expanse of gently rolling maritime tundra dotted with freshwater lakes, in contrast to the sea cliffs and desolate volcanic landscapes of many of the islands, supports dense bird populations with a diversity of species, some of which are shared with Asia and some with North America. Its similarly extensive intertidal zone served as a haven that permitted the survival of Sea Otters in the face of plundering during the 18^{th} and 19^{th} century and will no doubt serve a similar role for otters and other marine mammals during times of population stress in the future (Kenyon 1969, Kruse et al. 2001).

Primary productivity (measured in grams of carbon fixed per sq meter per year) is extremely high in the Bering Sea and along the Aleutian chain (Fig. 4). The marine food web at Amchitka and neighboring islands is extremely rich and diverse and supports migratory seabirds, marine mammals and pelagic fish. This productive food web can support extensive subsistence and commercial fisheries.

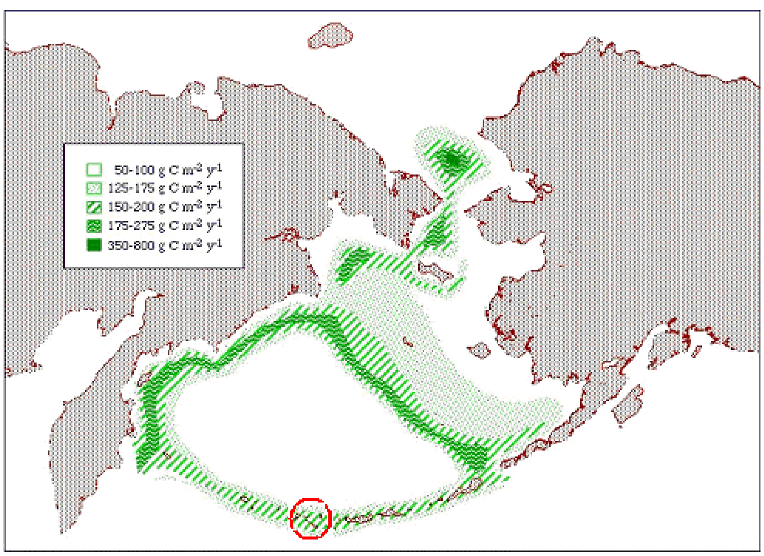


Figure 4: Shallow waters of the Aleutian volcanic ridge and edge of the continental shelf support robust biological productivity, here measured in grams of carbon per square meter per year. Amchitka Island is circled. From Springer et al (1996).

Basic changes in interpretation of the geology and geophysics of the area in the three decades since the last test demonstrate the plausibility that radionuclides could be transported from the shot cavities to the ocean (Eichelberger et al., 2002). East-west spreading (Ave Lallemont, 1996) of this portion of the island chain (Amchitka to Adak, perhaps centered at Amchitka Pass) at 2 cm/yr is opening fractures roughly perpendicular to the island axis, and therefore along the shortest distance to the sea (Fig. 3b). Indeed, the orientation of Amchitka at an angle to the general trend of the Aleutian chain appears to be due to extension and block rotation accompanying subduction with a faulted basin opening immediately north of the test site (Fig 5). Figure 5 illustrates the existing bathymetry information for the Amchitka Region. Figure 6 provides a schematic view of the collision of the Pacific Plate and North American Plate looking eastward. Figure 7 illustrates how the scientific investigations will interface with the presumed pathway of the radionuclides from source to receptors.

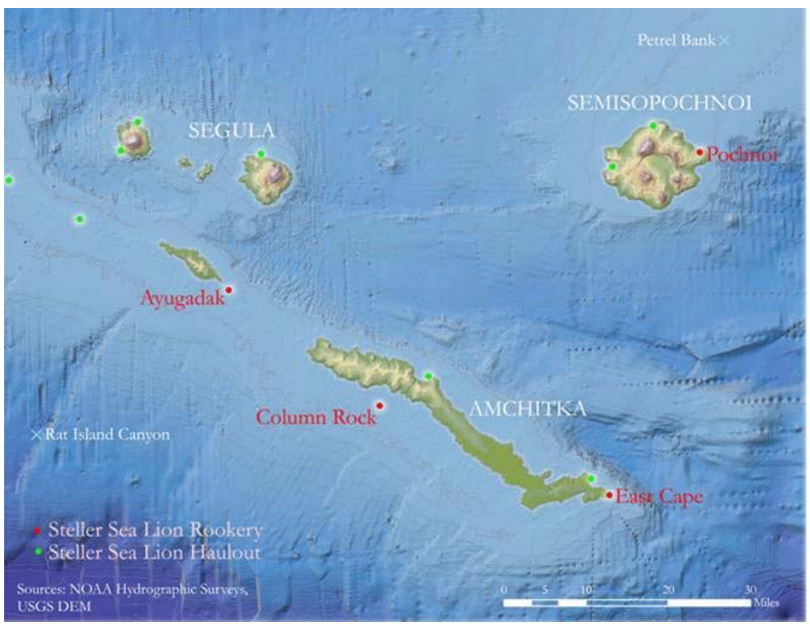


Figure 5: Bathymetric map for the Amchitka region.

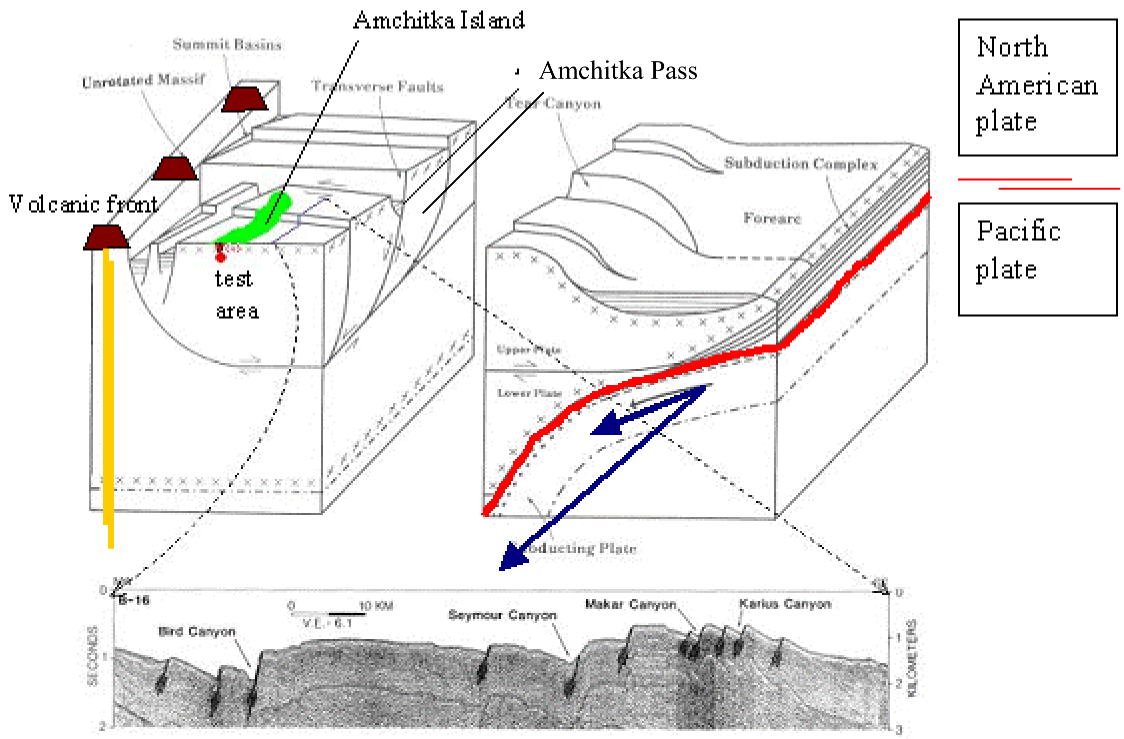


Figure 6: Schematic perspective view looking eastward, showing current concept of Amchitka Island (green) as part of a rotating and extending block in the Aleutian forearc. The Pacific plate is shifting westward, toward the reader, as well as thrusting downward beneath the North American Plate (blue arrows). The westward component of movement causes the thin edge of North America to splinter and drags those fragments westward. Deep basins are opening both north and east of Amchitka Island and the Amchitka block itself is broken by many down-to-the-west normal faults as shown in the accompanying seismic reflection profile. From Geist et al (1988).

F. PREVIOUS ENVIRONMENTAL SAMPLING EFFORTS AT AMCHITKA

The Amchitka Bioenvironmental Program (ABP), which began in 1967, conducted environmental studies until the AEC terminated activities at the site in 1973 (Merritt and Fuller 1977). During this period chemical residues were examined in terrestrial and marine species including herbivorous, omnivorous and carnivorous species (White and Risebrough 1977). The main findings focused on polychlorinated biphenyls (PCBs) and on the pesticide DDT and its metabolite DDE. The study concluded that although concentrations on Amchitka were not high enough to impair reproduction of the target species, they were higher than expected on a seemingly remote island, and, therefore, warranted further investigation.

In 1993 the USFWS compiled a *Summary of Site Contamination on Amchitka Island, Alaska (*USFWS 1993*)* which identified locations of contaminated sites and sources on the island, and a contractor prepared work plans and remedial investigation reports submitted to the Army Corps of Engineers (Crayton 2000). In 1996 and 1997 Greenpeace conducted a survey of radionuclides in mosses and reported that there were detectable levels of americium and plutonium, with a $^{239}Pu/^{240}Pu$ ratio suggestive of a test shot rather than fallout origin.

Pollution impacts reviewed by the NRC Committee (NRC 1996) included persistent organics, heavy metals, radioisotopes, and acid rain. The potential impact on long-lived organisms capable of bioaccumulating pollutants was considered significant, particularly since these species are harvested by humans and can transmit contaminants. Acknowledging the paucity of data, the Committee concluded "There is to date no hard evidence that these contaminants have significantly affected the Bering Sea ecosystem"(NRC 1996). Pollutants at sea were studied by the Arctic Monitoring Assessment Program (AMAP1993) and contamination on land was summarized by USFWS (1993).

In 1997 the USFWS (Crayton 2000) conducted additional studies of contaminants in Bald Eagle and Peregrine Falcon eggs, in tissues of Rock Ptarmigan, Green-winged Teal, Pelagic Cormorant, Tufted Puffin, Norway Rat, and in two fish species (Rock Greening and Pacific Cod collected on hook-and-line). PCBs, DDE, and polyaromatic hydrocarbon residues were detected in Bald Eagle eggs, and the eggs also contained detectable amounts of ten of the 17 inorganics analyzed (reported on a dry weight or dw basis). This included mercury levels between 0.8 and 0.9 ppm (dry weight, equivalent to about 0.12-0.17 ppm wet weight). These levels are within the range of other Pacific Rim sites (Burger and Gochfeld 1995, 2000b).The levels of aluminum (up to 106 ppm/dw) and strontium (up to 3.7 ppm dw) "were the highest detected in any collected avifauna specimens" (Crayton 2000). Pelagic Cormorants had up to 12.6 ppm(dw) mercury, equivalent to about 4 ppm (ww) of mercury in tissues. Mercury levels in Pacific Cod organs ranged up to 0.32 ppm(dw) and in Rock Greenling mercury in tissues ranged up to 0.35 ppm(dw), equivalent to about 0.1 ppm wet weight. Cadmium levels were also high in Rock Greenling ranging up to 3.7 ppm(dw), with a single outlier of 31 ppm (Crayton 2000). Lead levels in Amchitka birds and mammals were very low (mainly below detection level of 0.5 ppm), although Rock Greenling had up to 14 ppm (dw) in tissues. This is reassuring. The very high levels of lead detected in some Midway Island birds appeared to be due to direct contamination of young birds in nests close to buildings from which lead paint was chipping (Sileo and Fefer 1987, Burger and Gochfeld 2000a,b).

In his very comprehensive discussion of contaminants on Amchitka, Crayton (2000) points out that interpreting complex patterns of multiple contaminants in different tissues of different species from different trophic levels is challenging and that there are no standardized guidelines. Burger and Gochfeld have undertaken several analyses of metal patterns in bird feathers as a bioindicator of heavy metal pollution. In the Pacific Basin, Burger and Gochfeld (1995) established a biomonitoring program for using seabirds as top trophic level predators (Burger and Gochfeld 1999, 2000a,b, Burger et al. 1992, 2001d, Gochfeld et al. 1999). Comparisons between Johnston Island, a hazardous chemical storage site, and Oahu, Hawaii, showed a complex pattern of interspecific variation, with Oahu birds having higher levels of some metals than those from Johnston (Burger et al. 1992). Some species on Midway Island, however, had mercury levels (mean of 20 ppm dw) in the range known to cause adverse effects (Burger and Gochfeld 2000b).

Oil is a well-known contaminant of marine and coastal ecosystems, and the beaches of Amchitka are periodically subject to oil washed ashore from spills, while historically oil from the surface of the island (i.e. at Kirilof Point) has washed into the sea. Although oil is beyond the primary scope of the *Science Plan*, it can confound studies of other contaminants. Low level chronic oiling has been documented on beaches in the western Aleutians (Byrd et al. 1995). Hence visual inspection for oiling of birds and beaches will be conducted in the course of other studies, and archived tissues will be held for possible analysis of PAHs, since PAHs were widely detected in the Crayton (2000) study. PCBs, likewise, are ubiquitous pollutants that occur at moderate levels in Amchitka fauna (Estes et al. 1997). White and Risebrough (1977) concluded that there was probably a source on Amchitka from its past military use, while Anthony et al. (1999) suspected both past military use and atmospheric deposition as the main sources.

G. SCIENTIFIC APPROACH

To assess the risk from marine contamination posed by Amchitka it would be useful to know:

1. Current levels of radionuclides in the marine environment and food web – especially in those species that could cause the greatest radiation dose to human and ecological receptors;
2. The properties of radionuclides in the marine environment from the tests that can be distinguished from other potential sources;
3. The properties of the hydrogeologic system that constitute the fracture-dominated pathway between nuclear test shot cavities and the ocean; and
4. Processes for transfer, accumulation and attenuation of radionuclide concentrations in the hydrogeologic and marine systems.

If radioactive material reaches humans from the tests on Amchitka, it will have started as the contents of the shot cavity, the “source term”, traveled as a solute or colloidal suspension in groundwater through the subsurface rock to the ocean, become incorporated in the marine food chain, and been harvested and consumed by humans or other higher level vertebrates, the “receptor” (Fig. 7). The *Science Plan* proposes to characterize and sample, to the extent possible, the various steps in this path. Consumption of contaminated food by humans and other high-level species is the ultimate concern. However, detection of radionuclides in the marine environment and food chain does not necessarily indicate that the contamination originated from the Amchitka test shots. Other potential sources of radionuclide contamination in general include nuclear test fallout, sunken submarines and waste intentionally dumped at sea (Layton et al, 1997).

The Congressional Office of Technology Assessment (OTA 1995) studied the hazard resulting from the deliberate disposal of nuclear submarine cores and other nuclear waste mainly by the Soviet Union in the Arctic waters near Nova Zemlya and Kamchatka. The study concluded that no significant contamination had yet reached the Arctic or Bering Seas, "but future migration and impacts beyond Russian borders constitute a plausible scenario and deserve investigation" (OTA 1995).

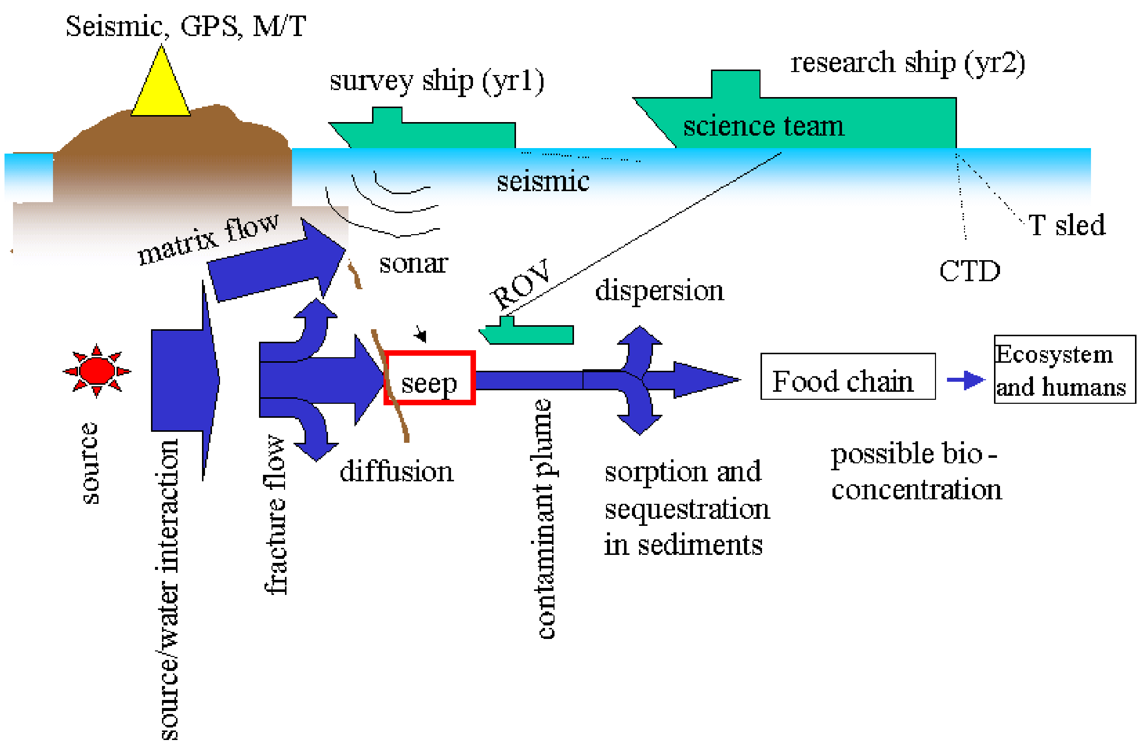


Figure 7: Relationship of scientific investigations to potential flow path of contaminants from source to receptor. CTD=conductivity/temperature/density probe GPS=Global positioning system MT=magnetotelluric ROV=remote operated vehicle

There are several foci for the *Science Plan*:

1. Characterization of the physical environment, together with contaminant transport models, to permit efficient, targeted sampling for radionuclide contamination
2. Analysis of human food, relevant components of the food web and the general biological environment for immediate confirmation of safety or warning of risk
3. Sampling strategy, analyses, and results for incorporation into or modification of existing contaminant transport and risk models to reduce the uncertainty in determining the rate, magnitude and risks associated with potential future radionuclide release.
4. Data collection to reduce uncertainties in the DOE's screening risk assessment and groundwater models. (DOE 2002a, b)
5. Identification of indicator species suitable for long-term monitoring.

The planning of the sampling approaches will be reviewed with stakeholders and sampling will be performed in collaboration with Aleut hunters and fishermen and Aleut student interns, where possible. The selection of food resource species for sampling and analysis will benefit from two projects currently underway at A/PIA, which will include laboratory analysis. Interviews with commercial fishermen and with other agencies will also influence the sampling. Results and recommendations based on these investigations will be presented in a way that is transparent, understandable, credible, timely, and responsive to stakeholders' interests and concerns.

The resulting data will be shared with the stakeholders, who will play a role in interpreting their significance, as well as published in the peer-reviewed literature.

H. CHEMICAL TRACERS AND RADIOLOGICAL SIGNATURE

Amchitka may be regarded as a large-scale tracer experiment that has been operating for over three decades. One purpose of the sampling program is to distinguish patterns of radionuclides found naturally in the marine environment, from patterns, unique signatures, that might be attributed to the test shots. Ascribing signatures to sources varies in difficulty, and in the case of Amchitka where the source data are classified; it is likely that the presence of any of the nuclear-detonation radionuclides (for example, plutonium isotopes, ^{241}Am) will be attributed to the test shots by many stakeholders in the absence of information to the contrary. Thus identification of specific isotopic composition will be important if radioactivity is detected. On the west coast of the United States it was observed that mussels sampled in areas of upwelling had ^{137}Cs and ^{241}Am levels significantly different than mussels samples elsewhere (Valette-Silver and Lauenstein, 1995).

The careful selection of chemical components to be traced is a key to the success of the investigation. A "signature" or signatures, for example, ratios reflecting relative abundance of isotopes of plutonium may be identified that is characteristic of the Amchitka sources and can be readily distinguished from other possible sources of nuclear contamination. Studies in the terrestrial environment by DOE and the State of Alaska (Dasher et al. 2002; Dasher et al. in prep) did not find any evidence of radionuclide leakage, other than that remaining from the 1965 *Long Shot* tritium release. A recent study (Dasher in preparation, 2003) identified anomalous $^{240}Pu/^{239}Pu$ ratios in the marine environment, but these appear to be widespread in the Bering Sea (Hameedi, et al., 1999). Whereas public health risk is a function of the total radionuclide burden in the food chain and population consumption patterns, the ability to mitigate the risk depends very much on the identification of sources. Of several radioisotopes that would have been released at Amchitka, tritium is likely to occur at higher levels than most others, despite its relatively short half- life.

For radionuclide activity or isotopic ratio to provide a good signature, it must:

- Originate from the source with sufficient activity.
- Have a half-life greater than 5 years so as to still be present in detectable amounts.
- Vary among possible sources in an amount that is large compared to analytical error.
- Have activity ratios with small standard deviations, otherwise propagation of errors make the ratio statistically meaningless.
- Be amenable to rapid, economical, and accurate determination.
- Be traceable across water, sediment, and biota samples to the highest levels of the food chain. This requires both detectable abundance and an absence of fractionation during transport. Isotope ratios will be usually more useful than activity ratios.

The activity or isotope values will depend on the nuclear device design and especially the activity ratios, as well as their fate in different physical, biologic and chemical environments.

An additional approach to identifying the source of radionuclides will be evaluation of an appropriate reference site remote from Amchitka. Adak Island is being considered for this role. Adak is located in the central Aleutians about 155 miles from Amchitka, and has similar intertidal zones with many of the same species that we anticipate collecting at Amchitka. Its biodiversity and contaminants have been studied. It is also logistically suitable with an airfield and accommodations. Other possible reference sites will be discussed with stakeholders. If the pattern of radionuclides in biota were similar between Amchitka and the reference site, it would suggest a more global source of contamination such as natural marine sources or fallout from nuclear testing. In addition, levels observed in the environmental samples can be compared to those obtained at other sites, such as the arctic and mid-latitudes (Alexander et al., 1994; Cooper et al., 1998; Hamilton et a., 1996). Levels that are substantially elevated may then bear further examination.

In the following section, we consider the processes that may be involved in transport of radionuclides from source to receptor. It should be emphasized that in many cases the work proposed would not have been possible even a few years ago. The following developments have proven especially important:

- Enormous increase in the computing power and data storage capacity of computers that can be taken into the field.
- Application of Global Positioning System (GPS) technology so that chemical and physical observations can be instantaneously tied to their position in space and time.
- Improvement in environmental sensors and introduction of digital telemetry and satellite technology that make possible acquisition of real time data from remote stand-alone monitoring points in the field.
- Improvements in the acquisition, and manipulation as images, of sonar data.
- Vast improvements in the diversity and power of tools for marine investigations generally.
- Proliferation of techniques of microbeam chemical and isotopic analysis.
- Compilation of databases relevant to evaluation of the test site.
- Improved understanding of ecosystems and ecological and human health risk.
- Improved sensitivity to understanding and including the perspectives of multiple stakeholders.

These developments make a comprehensive initiative to understand the natural system represented by Amchitka both timely and likely to succeed.

III. THE CONTAMINANT PATH

Understanding the risk from radionuclides to humans and other receptors in the Amchitka marine ecosystem involves understanding how the contaminants can move from the source (shot cavities) through the hydrogeological setting of the island of Amchitka to release to seawater and sediments, and then through the marine food web to high level consumers. It involves the source term, the geology, geochemistry groundwater movement, inshore oceanography, and the abiotic and biotic environment of the coastal ecosystem. Finally humans are intimately connected to this food web.

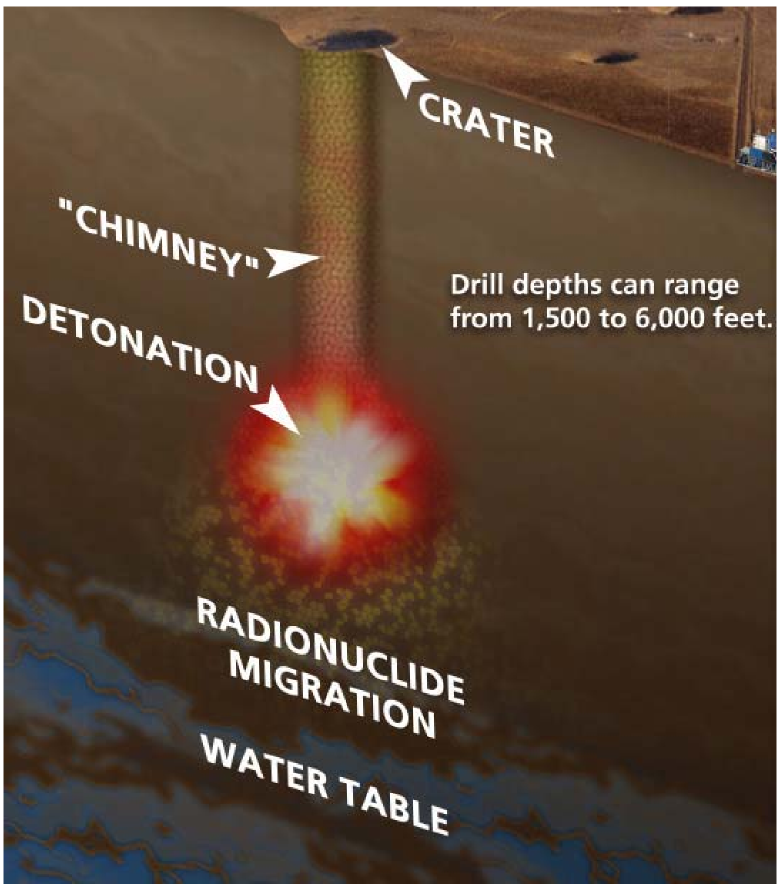


Figure 8: Schematic diagram of an underground nuclear test, shown as a cut-away view through the underground. A cavity is created at the detonation point and overlying material collapses into it, creating a chimney of rubble, often leading to a crater at the land surface (courtesy NNSA-NV).

A. SOURCE TERM

In an underground test, intense heat from the blast melts rock adjacent to the device, creating a cavity with a pool of molten rock on its floor (Fig. 8; Laczniak et al., 1996). Rapid cooling of the molten rock turns it to glass, just as molten rock becomes glass following a volcanic eruption. Successive collapse of blocks from the roof over a period of hours or days yields a block-filled "chimney" extending to the surface (DOE 2002b). The cavity eventually contains both the cooled "glass" and collapsed blocks.

Products of nuclear reaction are thoroughly mixed into the rock melted by the explosion. As the rock cools some of the radioactive material will reside in glass from the melt pool that collected on the floor of the cavity (Smith, 1995). Other radionuclides including ^{3}H (tritium), ^{137}Cs, ^{90}Sr, ^{14}C, ^{129}I and others may have a sizeable percentage residing outside of the melt glass, hence in a much more mobile form. Though not thermodynamically stable in a strict sense, glass can persist for long geologic time scales, sequestering the radionuclides within it. Volcanic glass is subject to slow dissolution in groundwater at rates that have been experimentally determined. It is also subject to mechanical breakdown and transport as colloidal material. Such a mechanism is less well understood but is hypothesized to have resulted in the transport of plutonium at the Nevada Test Site (Kersting et al, 1999) at rates that, if similar conditions existed at Amchitka, may have plausibly carried shot material away from the cavity. Other chemical reactions may also be responsible for, or contribute to, the more rapid than expected movement of Pu in groundwater (Haschke, et al., 2000). Dissolution of glass is a function of pH of groundwater and increases with temperature, which may remain significantly elevated in the shot region for many years after a test shot (Maxwell et al, 2000). Colloidal transport probably depends strongly on the physical state of the source, local geochemistry, and the extent to which the flow is in fractures rather than filtered through the source and host rock matrix. Different components of the contaminant source will tend to migrate at different rates as a function of physical and chemical characteristics, and different radionuclides have different rates of decay, so the temperature dependence of the radioactive character of flow from the shot cavity will be quite complex.

B. ROCK ENVELOPE

Understanding the hydrology, how groundwater moves through the subsurface, is fundamental at Amchitka. Fluid flow through the rock envelope surrounding the shot cavities can be thought of as occurring by two mechanisms. In porous flow, the fluid moves through interconnected void spaces, which gives the rock matrix permeability. Such flow generally obeys Darcy's Law, wherein the flux rate is proportional to the permeability of the rock and the pressure gradient. In contrast, fracture flow occurs in continuous physical discontinuities in the rocks. The flow rate is a function of the pressure gradient and the physical characteristics of the fracture, such as width and surface roughness (e.g., Carrigan et al. 1996). Fracture flow may vary from comparatively rapid flow through distinct channels to lower flow that approximates porous media flow, depending on the nature of fractured geologic materials through which flow is occurring. Buoyancy forces that affect the flow trajectory arise due to fluid temperature (Maxwell et al, 2000) and composition (salinity) as compared to ambient groundwater. In slow diffuse, porous flow will readily mix with ocean water when it reaches the sea. Fracture flow can produce point sources of release feeding contaminant plumes with locally relatively high concentrations of radionuclides. In reality, there may be a continuum from porous flow, which follows discontinuities around grains, to fracture flow which follows discontinuities around multiple grains. Stakeholders are particularly concerned that there may exist distinct fractures in the form of active faults, which would provide fast pathways for release.

Faults are a special case of fractures that are subject to repeated displacement. In some cases, faults would be expected to favor transmissivity over the simple fracture case because mineral deposits that would normally accumulate and impede flow would be repeatedly ruptured, and because a fault develops a thick damage zone that a simple fracture lacks (e.g., Faunt, 1997; Lopez et al, 1995; Caine and Forster, 1999). In other cases, the motion along the fault plane results in creation of a fine grained, low permeability, fault gouge that inhibits ground water flow (Smith et al. 1990; Caine et al. 1996; Evans et al 1997).

An additional consideration pertains to normal faults of the kind that cut the Amchitka test area. These develop approximately perpendicular to the direction of extension of the crust, which is the direction of least principal stress. In an extensional regime the stress perpendicular to the fault plane is low and therefore the threshold fluid pressure required for open pathways is low (Hickman et al, 1997).

Not all the contaminant that is released from the source will reach the sea. Some will diffuse through the fracture walls into the rock matrix where flow velocities are much lower. Also, contaminants will be sorbed onto mineral surfaces - hence, as a practical matter the matrix will “store” the contaminant, but may also release them to flow in the future due to changes in concentration or quake-induced pore-pressure changes.

C. GROUNDWATER FLOW

Groundwater flow is mainly driven by hydrologic recharge from rain falling on the island and by the density contrast between freshwater and seawater (Fig. 9). Most rainfall runs off into surface waters, but some percolates through vegetation and the surface. This gives rise to a freshwater lens beneath the island that tapers toward the sea, with the highest flow velocities expected to be near the base of this zone. Saltwater beneath this lens may be relatively stagnant, though even there the substantial island-arc geothermal gradient or residual heat from the tests may drive fluid circulation. Because density contrasts due to varying salinity are an important influence of flow patterns, it is therefore important to know the position of the freshwater/saltwater interface with respect to the shot cavities. Except where the subsurface flow field is perturbed by faults or thermal anomalies, the interval between the shoreline and the intersection of the salt/fresh groundwater surface with the seafloor is the likely zone for submarine seepage.

Much of the groundwater flow in the relatively impermeable volcanic formations of Amchitka can be expected to occur in fractures rather than through the matrix of the rock, producing vigorous discharge to the submarine environment (e.g., Montlucon et al, 2001; Borisenko, 2001). Over time, the flow of groundwater through fractures is accompanied by mineral deposition, which tends to seal the pathways. Faulting, however, can keep them open. It is known that active normal faults can be efficient conduits for hydrologic flow (Hickman et al, 1997). The Amchitka test area is cut by such faults, as is evident in both the surface geology (Gard, 1977) and marine seismic reflection lines (Geist et al, 1988). Faulting occurs because the region is extending at about 2cm/yr. To identify active faults that may intersect a shot cavity may identify likely pathways for leakage to the sea. There is detailed geological information on the location of faults on the island, though not on their rates of motion. Information on their offshore extensions is scant. There is a reverse movement as well; tidal oscillations in groundwater levels occur at Amchitka (Fenske, 1972). This tidal groundwater interaction may result in an increase in mixing of the radionuclides in the aquifer and affect the transfer rate of radionuclides to the marine waters (Li et al., 1999). It is likely that cross-shore and along-shore interactions exist as well.

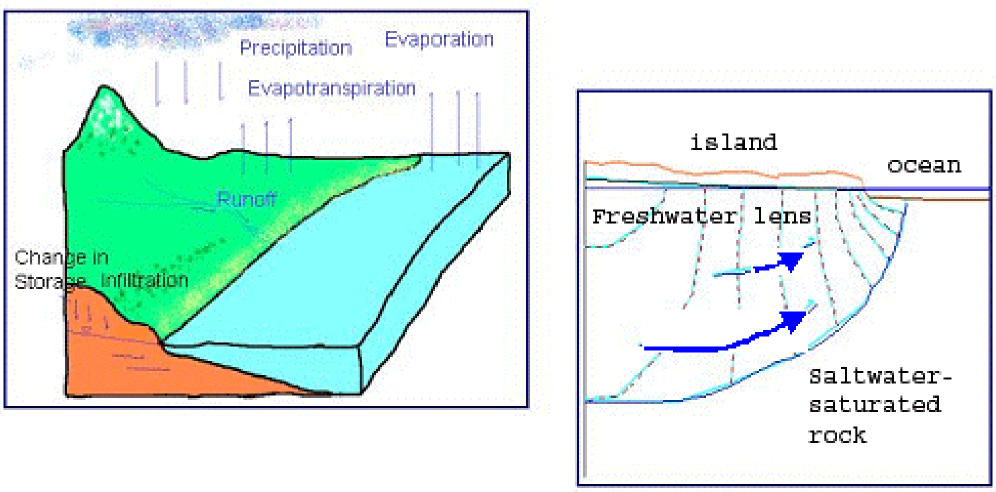


Figure 9: Generic cross section through a shoreline showing hydrologic processes and the expected freshwater lens.

We need to be able to understand Amchitka as a complex assemblage of blocks that are moving in different directions in response to the large-scale stresses imposed on them by oblique subduction. The faults that bound these blocks are likely paths for fluid flow. This behavior is supported by observations during the nuclear tests (AEC video record):

1. Coastal uplift along the entire fault-bounded block in which the *Cannikin* test was detonated.
2. Blast-induced motion, consistent with the geologic record, on the Teal Creek fault just north of *Cannikin*.
3. Ejection of ground water from faults during the *Cannikin* test.

Six survey points on Amchitka were observed by GPS in 2001 by the UAF/CRESP team. One of these sites had been occupied with high precision instrumentation previously, in 1997. This provided a measurement of displacement over a 4-year period that verified our modern concept of the tectonics of the region, and shows that Amchitka lies on a part of arc crust that is being torn off from North America (Fig. 10). It also demonstrates that this displacement is ongoing now.

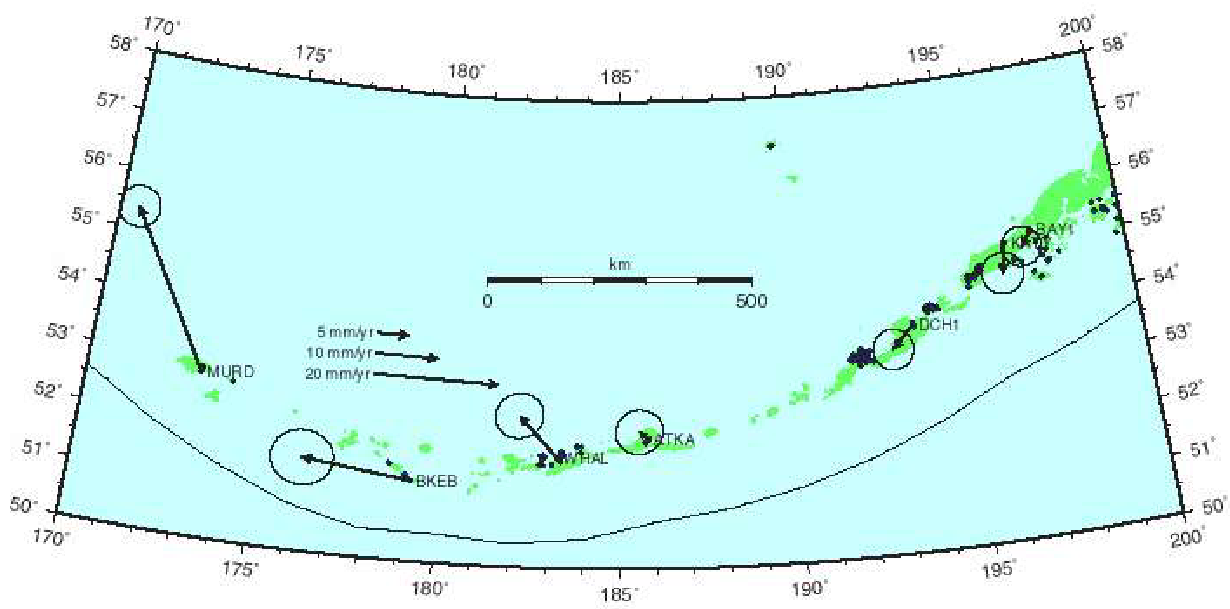


Figure 10: Existing site motion vectors for the Aleutian arc relative to North America, including new measurements acquired in 2001 for Amchitka (BKEB). (Data compiled by J. Freymueller, UAF, 2002)

The above data and seafloor topography suggest that Amchitka Pass may be a major tear in the arc. Rifting associated with the pass could easily overlap with the test area. That such is the case is suggested by a preliminary examination of radar satellite imagery (Fig. 11) that shows 2 cm of vertical displacement across a normal fault that cuts the island near the *Milrow* test site. This displacement was measured by analyzing radar images taken 1.6 years apart. Such tectonic activity operates on a time scale of millennia.

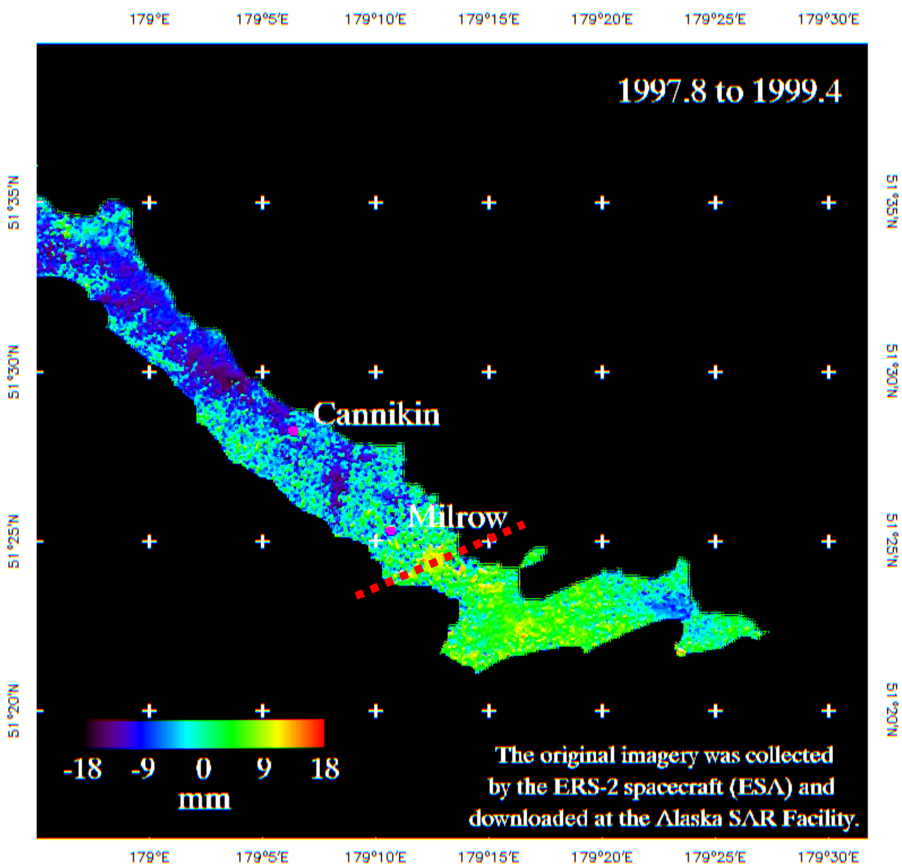


Figure 11: Repeat pass synthetic aperture radar interferogram (InSAR) suggesting 2 cm of SE-side up displacement along a NE-trending normal fault near the *Milrow* test during a 1.6 year period (courtesy of E. Price, UAF). The satellite measures the change in surface position in the satellite's "look" direction.

A common technique in assessing groundwater contamination is to drill hydrologic monitoring wells. This permits sampling of groundwater *in situ* as well as determination of hydrologic properties of the reservoir. Where multiple wells are drilled, it is possible to define a contaminant plume extending downstream from the source of contamination, and to track its progress. However, this approach is very complex and may require many wells and a long time to characterize flow in fractured geologic strata. We have considered this very direct approach to the problem of contaminant transport at Amchitka, but currently reject it for the following reasons:

- Costs are prohibitive, as multiple wells would be needed for each shot, and each borehole would cost well in excess of $1 million.

- Drilling represents a substantial intrusion of people, noise, potential pollution, and infrastructure needed for support of drilling, all of which are highly undesirable in the wildlife refuge.
- If a comprehensive marine sampling program is initiated, drilling would not be necessary.

It is possible that data forthcoming in the proposed study showing human or ecological risks may necessitate reexamination of this conclusion, but the case for benefits of direct sampling of groundwater will have to be compelling because the cost will be very high.

D. MARINE ENVIRONMENT- PHYSICAL

Once contaminated groundwater emerges from the flank of the Amchitka massif into the ocean, it will mix with seawater, and depending on physical and biological conditions is likely to be rapidly diluted. The contaminants may be accumulated on sediments, diluted, or taken up by living organisms either from the water or sediments. If a flow emerges from an orifice on a fault, analogous to a spring on dry land, there will be a distinct plume of contaminated water that trails downstream in the ocean current. Understanding the nature and pathway of that dispersion becomes fundamentally important. Will it disperse uniformly or will it, in addition to mixing, be attenuated-through sorption on suspended particulates in the water column? Particulates may then settle on the ocean floor resulting in contaminated sediments. Contaminants may thus be sequestered in the short or long term, or may be available for uptake by biota. The *Screening Risk Assessment* (DOE 2002a) considered a kelp-bed scenario as one model that would retard the rapid dilution/dispersion of contaminants. However, it did not consider sediments or kelp as a mechanism for localized accumulation of radionuclides. Site specific data are needed to validate the models.

Table 3 lists naturally occurring radionuclides in sea water which will influence the detection level for contamination above background.

Table 3. List of naturally occurring radionuclides in sea water (average concentrations (pCi/L) in seawater based on data in Clark (1989).

Radionuclide	Concentration (pCi/L)
K-40	320
H-3	0.6–3.0
Rb-87	2.9
U-234	1.3
U-238	1.2
C-14	0.2
Ra-226	.04-.045
Rn-222	.02
Ra-228	.001-.1
Pb-210	.001-.068
U-235	.005
Po-210	.006-.042
Th-228	.0002–.003
Th-230	.00006–.0014
Th-232	.00001–.0008
1 pCi = 0.037 becquerels	

Source: Adapted from Clark (1989)

E. MARINE ENVIRONMENT – BIOLOGICAL

The Amchitka and its adjacent waters contain a wide diversity of wildlife, including fish such as the Walleye Pollock, Pacific Cod, Herring, flatfishes (e.g. Halibut), Rockfishes, Pacific Salmon (particularly Chum, Pink, Coho and Sockeye Salmon), shellfish, crabs (including Snow, Red King and Brown (Golden) King crabs), birds (seabirds, waterfowl, and raptors), and marine mammals (Steller Sea Lions, Harbor Seals, Northern Fur Seals, Killer Whales, Gray Whales, Sea Otters, and porpoises), to mention just a few. This array of vertebrate species is of particular interest to Aleuts, commercial fisheries, resource trustees and the public. It is supported by a diverse food web base of algae, plankton, small invertebrates and larval fish. The productive kelp bed ecosystems around Amchitka support abundant near shore fishes (Estes, 1996; Estes, 1978). The proximity of the kelp beds to the potential discharge of radionuclides may make this near shore area highly vulnerable. While there has been recent sampling of freshwater biota on Amchitka Island itself (Dasher et al. 2002), there has been relatively little sampling of the marine environment since the 1970s (Merritt and Fuller 1977; CRESP 2002). Marine mammals, particularly Sea Otters and Sea Lions, have been well-studied over the past 40 years (Kenyon 1969, Kruse et al. 2001, Baskaran et al. 2003). Following the description of the avifauna at

Amchitka by Kenyon (1961), studies by White et al. (1977) estimated populations of all species. U.S. Fish and Wildlife personnel documented changes in the biological diversity and numbers of birds at Amchitka following removal of introduced foxes (Alaska Maritime National Wildlife Refuge, unpublished data).

The biological sampling will adhere to the *DOE Technical Standard – A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota,* which, however, will require new information to be collected as that standard lacks assessment values for the marine environment. The presence of threatened and endangered species at Amchitka necessitates the use of the site-specific biota dose assessment rather than just a general screening. Previous freshwater and terrestrial sampling on Amchitka did not find evidence of underground nuclear test radionuclides, except low amounts of ^3H remaining in the groundwater and surface waters at *Long Shot* from the 1965 seepage event (Faller and Farmer 1997, Dasher et al. 2002, AMAP 2002).

The marine environment, however, is different from the terrestrial in that the potential exists for radionuclides from the test shots to be carried to the marine environment by freshwater through seeps along faults or fractures, or by diffuse flow. The exact location of where these seeps or discharges may meet the marine environment, and thus the exposure pathway through the food chain to high level consumers (large fish, birds, marine mammals and humans), is extremely important to assess or predict. Moreover because this is an area of extensive tectonic movement and seismic activity, pathways to the surface and ocean may change in the future.

The main concern for the marine environment is the possibility that now, or at some point in the future, releases of radionuclides from the test sites will contaminate the marine food web, affecting the ecosystem, sensitive organisms, and humans who rely on these organisms for food. Modeling suggests that releases could occur in a time frame of 10 to 3000 years (DOE 2002b AMAP 2003). Similarly, the amount and extent, both spatially and temporally, of such release is highly uncertain, and the impact of such leakage on the marine ecosystem and safety of human food resources is therefore highly uncertain.

A key data gap that requires examination is to ensure that there is currently no detectable release that would pose an ecological or human health risk, and to design a biomonitoring and surveillance plan that will ensure early warning of any potential risk to receptors in the future. The data obtained at this time is an essential baseline against which future contaminant levels will be compared.

The proposed sampling regime is aimed at reducing the uncertainties in the human and ecological risk assessments, and at establishing baseline conditions and monitoring requirements for the long term stewardship plan. In the event radionuclides or other contaminants are detected in target biota at levels above those in reference sites, interpretation will require review of the extensive and growing literature on the effects of ionizing radiation in general and specific radioisotopes on plants, microorganisms, invertebrates and vertebrates.

1. HUMANS AND FOOD WEBS

A major advancement in our understanding of the potential risks at Amchitka was the *Screening Risk Assessment* (DOE 2002a), which provided models for predicting possible discharge of radionuclides into the marine environment, and impacts under several scenarios. The *Screening Risk Assessment* identified many uncertainties. The data collected from the marine environment under this *Science Plan* will allow for an overall reduction in the uncertainties encountered in the *Screening Risk Assessment* (DOE 2002a), which assumed rapid dilution rather than site-specific information which may include localized accumulation in sediments or biota. The human health risk screening scenarios did not have site-specific information on radionuclide levels in water or foods (DOE 2002a), both of which are essential for credible, site-specific risk scenarios. Reducing uncertainties in the scenarios is an essential task to assure Native communities, commercial fisheries, and resource trustees that the food derived from environment around Amchitka is safe.

Further, the *Screening Risk Assessment* examined only risk to humans (DOE 2002a), not to other ecological receptors, which are of interest to the Aleuts, to natural resource trustees, and indeed to the nation. To the Aleut people, a clean environment equals clean food resources (R. Patrick, Personnel communication March 2003). The data collected on species in the marine environment will allow for ecological risk assessments to the species themselves, and to organisms that consume them. Understanding the potential risk to marine food webs independently of the risk to human consumers is an important consideration, and implementation of the *Science Plan* will reduce uncertainties in these assessments.

The recent Amchitka Long-term Stewardship Workshop held in Fairbanks (CRESP 2002) identified the role of biota in the transfer of radionuclides as the highest priority for marine science in the Amchitka ecosystem. This requires examining radionuclide levels in biota and movements through the food web. It is critical for the state of Alaska to have information that will allow it to protect the environment and human health in the region (Brown 2002).

Once in the marine environment, radionuclides and other contaminants enter the food web, effectively moving from one trophic level to another, eventually reaching the larger marine organisms that are consumed by humans, including resident Aleuts and distant people who purchase commercial fish of Aleutian origin (see Fig. 12). Plants and animals that are low on the food chain take up contaminants through contact with seawater and sediments; those higher on the food chain take up contaminants from their prey items.

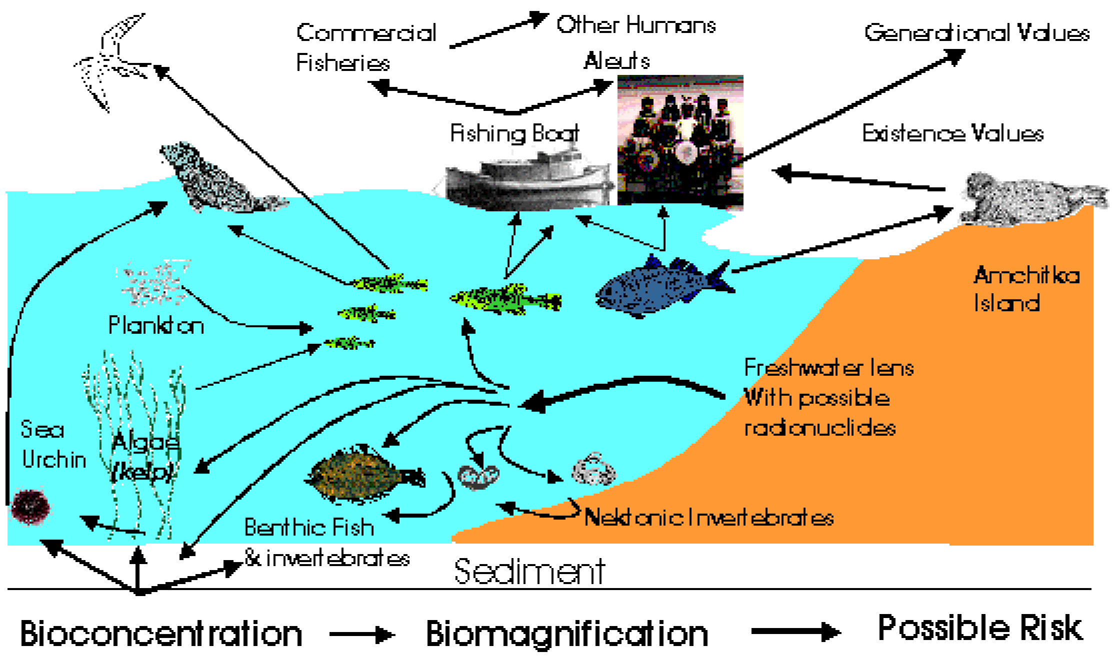


Figure 12: Through the process of bioaccumulation, bioconcentration and biomagnification, radionuclides can move through the food chain to higher trophic levels, including humans. Concern should include not only present and future risk to receptors, but existence values and Intergenerational factors. (Copyright Joanna Burger)

If radionuclides occur in the water or sediment, exposure for marine organisms can occur through several pathways:

1. direct external exposure to sedentary organisms living on or near the location of a submarine groundwater discharge (such as sessile invertebrates and kelp);
2. direct exposure of biota from uptake of radionuclides that have accumulated in sediments;
3. direct external and internal exposure to mobile organisms moving in and around the discharge area (some mobile invertebrates, some small fish);
4. direct exposure to migratory organisms moving through the area of release (such as migratory fish, marine mammals, and birds);
5. indirect exposure of non-migratory organisms that prey on organisms that are directly exposed;

6. indirect exposure of larger, migratory organisms (such as migratory marine mammals, seabirds, or larger fish), and
7. indirect offshore exposure of migratory organisms to prey that were directly exposed but have moved away from the source. Thus organisms containing radionuclides may be found close to a discharge source, or remotely.

Humans, as one potential receptor, are exposed mainly when they eat marine plants, invertebrates, fish, marine mammals and birds that were indirectly exposed. There is also a remote potential for direct human external exposure through contact with contaminated water or sediments, or work on the island itself. The *Screening Risk Assessment* addressed only internal exposure through the ingestion of marine foods, but humans might also receive external exposure from working with fishing gear if it had entered the plume, from diving in a plume, or from the handling of marine foods or craft items. Although both the probability and magnitude of such exposures are likely to be low, they will be addressed in the Health and Safety Plan for site workers, and will be considered in risk communications for site users. These pathways represent routes of exposure for organisms within the marine ecosystem, and thereby represent key indicators for the system.

Several different processes must be taken into account when examining the movement of contaminants, such as radionuclides, through food chains. These processes include dilution, settling, sequestration in sediments, and chemical and physical factors influencing bioavailability, bioaccumulation, bioconcentration and biomagnification (also known as biological amplification). Dilution refers to the decreasing concentrations with time or distance from the source. Ideally, concentration decreases as an exponential function of distance. The DOE *Screening Risk Assessment* models for possible radionuclides in the Amchitka marine environment assumed uniform and instantaneous dilution (DOE 2002a). However, organisms living directly over a release of radionuclides will receive the full dose. Dilution can also occur over time depending on whether the contaminant escapes as a single peak or slowly over time. Thus it is essential not to only assume immediate dilution at the site of a potential seep (see DOE 2002a), since there could be immediate uptake by organisms residing at the interface. Moreover, the CORMIX model run as described in the *Screening Risk Assessment* did not address unsteady flow, actual (though little studied) kelp bed hydrodynamics, or partitioning of radionuclides between particulate and dissolved material into consideration, (David Rogers, pers. comm.).

2. BIOAVAILABILITY, BIOACCUMULATION AND BIOMAGNIFICATION

Bioavailability refers to the ability of a contaminant to be released from the matrix and taken up by organisms that contact or ingest it. Bioaccumulation refers to the uptake and incorporation of radionuclides and other contaminants in the tissues of organisms. The amount taken into the body can exceed the amount excreted or eliminated, resulting in an increasing concentration over time. Biomagnification refers to the increasing concentrations of contaminants in organisms at

higher trophic levels. Each organism ingests the contaminants in their prey and stores them in tissues, thus increasing the exposure to creatures that eat them.
Several terms are used to describe the transfer of contaminants (or nutrients) from abiotic media to biota or from one organism to another. The following terminology is appropriate:

- Bioaccumulation is defined as the net accumulation of a contaminant in an organism from all sources, including water, air, and solids (e.g. foods, sediment, fine particulates) in the environment.
- Bioconcentration is defined as the net accumulation of a contaminant in and on an organism from the water only.
- Biomagnification occurs when there is an increase in the contaminant from one trophic level to another due to accumulation from food, relative to organism size.

Bioconcentration is the first step in the movement of contaminants into organisms of the food chain. Not all organisms take up radionuclides, or store them, at the same rate. It is the biochemical, rather than radiologic, properties that influence the behavior of radionuclides in the body. Hydrogen is found in all tissues and cells, hence tritium can distribute uniformly through the body. Cesium behaves somewhat like potassium and is likewise quite mobile in the body, distributing itself in many soft tissues. Strontium behaves like calcium and is stored preferentially in bony structures. Iodine isotopes are preferentially concentrated by the thyroid which actively extracts iodine from blood. Other radionuclides have properties which either allow them to distribute in the whole body or to concentrate in particular tissues.

Biomagnification is one of three outcomes for the movement of contaminants, like radionuclides, into the food web. It is characteristic of many organic pollutants that concentrate in lipids or many heavy metals that bind to proteins. However, a contaminant may also remain similar in predator and prey or it may decrease with increasing trophic level (Newman 1998). Tritium is an example of a radionuclide that can potentially stay the same or decrease with increasing trophic level (Whicker and Schultz 1982).

Long-lived organisms are able to accumulate contaminants in their tissues over time, leading eventually to potential adverse effects. On the other hand, if exposure occurs early in life resulting in a body burden of a contaminant, growth dilution may occur, where the contaminant concentration decreases over time as the tissue volume in which the contaminant is sequestered increases. Conversely, recent work with Sea Otter skulls has indicated that ^{210}Pb in skulls collected from Amchitka Island were significantly higher in the 1950s compared to the 1990s (Baskaran et al. 2003). In addition, several other factors must be integrated into the sampling regime, including the relative sensitivity of early developmental stages, differential species uptake and susceptibility (some algae take up higher levels of radionuclides than other species), and habitat vulnerability (bottom-dwelling species may be more vulnerable if they are close to seeps or the freshwater/salt water lens). Acute lethal doses to ionizing radiation, and presumably sublethal effects, vary with species groups. Mammals are most vulnerable, followed by birds, higher plants, fish, crustaceans, and then mollusks (AMAP 2003). While the *Science Plan* focuses on radionuclides as the primary contaminants of concern, it must be recognized that other contaminants can also pose a risk to humans and other receptors. In this regard, mercury is of particular concern because it bioaccumulates, it is highly toxic, and it is of particular interest for subsistence peoples (Rothschild and Duffy 2002, Jewett et al. 2003).

3. RECEPTORS OF CONCERN

While the potential exposure of the entire marine ecosystem is of interest, some endpoints in the food chain are of greater interest, primarily high trophic level organisms (such as large predatory fish, marine mammals, seabirds, humans). Non-human receptors of particular concern are federally endangered or threatened species (a number of marine mammals) and migratory species (such as birds, large predatory fish). The U.S. Fish and Wildlife Service has control and responsibility for the Alaska Maritime National Wildlife Refuge, including most of the endangered and threatened species residing there. A major and successful rehabilitation program was undertaken for the Aleutian Canada Goose, formerly listed as endangered. The National Marine Fisheries (NMFS) is responsible for managing and protecting the endangered Steller Sea Lion as well as whales and seals, including the Northern Fur Seal. Sea Lion breeding habitat is located on the National Wildlife Refuge, but access, control and enforcement is the responsibility of NMFS. The decline of marine mammals has been extensively reviewed (NRC 1996). Contaminants were considered to play a minor role in the decline, while competition from the expanding commercial fishery has reduced food availability.

Species that are at the top of their food chains are of particular interest, including Halibut, seals, cormorants and Sea Otters. The current decline of sea otters in the Aleutians and their status as a candidate species under the Endangered Species Act (65 FR 67343) is added reason for concern and justification for including sea otters as a Receptor of Concern. Further, high latitude ecosystems are more vulnerable than temperate or tropical systems, because food chains are generally shorter, and there are fewer species at each trophic level (Burger 1997b). A classical simple food chain is represented by Sea Otters, which typically eat primarily one organism (Green Sea Urchin, Baskaran et al. 2003), and the urchins eat primarily kelp. However, since the 1969's the Sea Otters at Amchitka have shifted to a diet much higher in volume of fish than Sea Urchins (Estes, 1978). Also mollusks and crabs may make up a larger part of their diet than previously thought.

Nearly 25 species of shore and seabirds nest on Amchitka Island or neighboring islands, and forage mainly on small and medium-sized fish in the surrounding waters. At least eight species are common breeders on the island (Kenyon 1961, Sowls et al. 1978). The seabirds breed in social groups known as "colonies". Although some of the seabird colonies are located at the far end of the island from the nuclear test "shots", these distances are well within the normal foraging range of nesting seabirds. Species such as gulls, auklets, murres, puffins, cormorants and eiders normally feed relatively close to coastal or island areas, while fulmars and kittiwakes normally feed in the open ocean (Sowls et al, 1978). Bald Eagles are prominent predators and scavengers of the littoral zone of Amchitka.

The Native communities, as well as the Aleutian/Pribilof Islands Association, have a commitment to preserving the native ecosystems on Bering Sea and Aleutian Islands including Amchitka. This commitment includes the organisms that live in the marine environment. The communities are interested in the well-being of the organisms, as well as their subsistence values. This is an important cultural value that must be respected and incorporated into the study design (Patrick 2002).

Among humans in Alaska, Aleuts have the greatest risk of exposure to contaminants because of their subsistence on "seafood" from the Bering Sea and North Pacific. They derive the majority of their food from the inshore waters and littoral zone. This includes consumption of marine plants, invertebrates (e.g., crabs and mollusks), fish, and seals and Sea Lions.

Commercial fishing is another route by which human exposure is possible, although most consumers would derive only a small percentage of their diet from the Amchitka vicinity. Any finding of significant radionuclide contamination could be economically serious to the North Pacific and Bering Sea fishing industry. The main Alaska "groundfish" are shown in Table 4.

Table 4. Alaska ground fishery data by species for 2001.

	% of 2001 catch	% of 2001 $ value
Walleye Pollock	74%	69%
Pacific Cod	11%	17%
Flatfish	9%	4%
Atka Mackerel	3%	3%
Rockfish	2%	1%
Sablefish	1%	6%

Source: National Marine Fisheries Service-Alaska Fisheries Science Center (NMFS 2003).

IV. LONG TERM STEWARDSHIP

Wherever there is a legacy of contamination, long term stewardship is an essential aspect of land management and of ensuring the future well-being of humans and ecosystems. Such stewardship is an important component of environmental management for the DOE because of residual radioactive waste – particularly long-lived isotopes (Crowley and Ahearne 2002), where current technology does not allow a definitive treatment, or where long-lived radioisotopes must be sequestered, stabilized and secured. Accordingly, DOE recognizes the necessity for long term stewardship into the indefinite future for some of its sites with residual hazards (DOE 1999, 2001). This is particularly true where the radioactive contamination is in the subsurface, and not amenable to remediation (NRC 2000). A number of informational needs and tools are required for adequately developing the monitoring and surveillance necessary for long term stewardship (Probst and McGovern 1998). Further there are a number of technical and institutional limitations to ensuring the long-term health and safety of humans and the environment at DOE sites with residual contamination (NRC 2000). Providing a sound scientific basis and characterization for the current situation is a crucial step in developing adequate long term stewardship.

Stewardship must be an active iterative process. The transition to stewardship establishes both engineering and administrative controls, the latter of which must put in place social mechanisms for conveying information about and assuring integrity of the former. The NRC (2000) panel suggested that present-day decisions on the extent of site remediation should be guided by expectations about the ability of engineered and institutional controls to perform through time as required to protect against future release or migration of residual site contamination. In the case of Amchitka, early warning is the key to assessing whether radionuclide migration and bioaccumulation may be occurring, and whether it is sufficient to pose a risk. This may allow assurance that foods derived from the environment are safe, and that the marine ecosystem is not jeopardized. The importance of Amchitka and its flora/fauna, to the Aleut communities, commercial fisheries, and resource trustees cannot be underestimated - and long term stewardship planning must be central throughout the process.

While developing the long term stewardship plan for Amchitka is not the purview of the Amchitka *Science Plan*, the plan must provide a basis for planning the long-term monitoring component of stewardship. Thus, the tasks are designed to fill data gaps required to develop a long-term monitoring plan that meets the needs of the Aleut communities, U.S. Fish and Wildlife Service, Alaskan Department of Environmental Conservation, commercial fisheries, and a variety of other stakeholders. Moreover, the CRESP Oversight Committee is committed to ensuring that monitoring needs are a central consideration during the execution of each project, and that sufficient discussion about the long term stewardship implications occurs between and among the personnel leading each task and stakeholders.

It is essential that long term monitoring goes hand-in-hand with all aspects of the Amchitka *Science Plan*, and that insights and recommendations about long term stewardship be provided to all interested parties throughout the process. The transition to long term stewardship does not start with the end of the *Science Plan*, but at the beginning so that it forms the basis for the work.

V. QUALITY ASSURANCE AND DATA QUALITY OBJECTIVES

All environmental sampling and monitoring projects used in making management or regulatory decisions must have a Quality Assurance Project Plan (QAPP) which establishes, among other things, the Data Quality Objectives (DQO). Quality assurance refers to all the actions taken to ensure that a program or system adheres to standards, procedures, and performance requirements, such that the program can achieve its goals, and those who use its results can do so with confidence in the integrity and accuracy of the data and the quality of the product. QA extends through the lifecycle of the data including not only data-gathering, analysis, and presentation, but updates and documentation.

The Environmental Protection Agency has established Data Quality Objectives as an essential task for all programs generating data that may be used for risk assessment or risk management or regulation. This includes planning "the type, quantity, and quality of the data" (EPA 1994). DQO advance "the goal of EPA and the regulated community to minimize expenditures related to data collection by eliminating unnecessary, duplicative, or overly precise data". At the same time, the data collected should have sufficient quality and quantity to support defensible decision making. The most efficient way to accomplish both of these goals is to establish criteria for defensible decision making before the study begins, and then develop a data collection design based on these criteria

The DQO fits directly into the Risk Assessment and Risk Management Framework advanced by the Presidential Congressional Commission on Risk Assessment and Risk Management (see Fig. 1; PCCRARM 1997). "The DQO Process enables data users and relevant technical experts to participate in data collection planning and to specify their particular needs prior to data collection. The DQO process fosters communication among all participants, one of the central tenets of quality management practices (EPA 1994)." The PCCRARM approach provides a framework for the overall quality assurance of the *Science Plan*. It requires the interaction of stakeholders at all phases of the process from establishing the context and framing the question, to the specifics of sampling design, data gathering, analysis, interpretation and implementation. The framework is iterative; as new information arrives, the premises and approaches are re-examined and modified. This is the first step of quality assurance---assuring that the data to be gathered address the concerns voiced in the first place
(i.e. the relevance of the study).

A. DATA QUALITY OBJECTIVES PROCESS

The Amchitka *Science Plan* will follow the DQO process which EPA(2000a) defines as a strategic planning approach based on the Scientific Method that is used to prepare for a data collection activity. It provides a systematic procedure for defining the criteria that a data collection design should satisfy, including when to collect samples, where to collect samples, the tolerable level of decision errors for the study, and how many samples to collect. This will be linked to other important QA components such as chain-of-custody and data verification and management. The DQO process has seven steps executed in sequence (Tables 5 and 6); it is intrinsically iterative, such that each step requires re-evaluation of the previous steps (EPA 1994).

A critical application of the DQO process to the *Science Plan* will be the selection of radionuclides for analysis and the ascertainment of detection limits by different methodologies.

The general process is as follows:

Table 5. The Data Quality Objective Process (EPA 1994)

STEP	DESCRIPTION
1. State the problem	Concisely describe the problem to be studied. Review prior studies and existing information to gain a sufficient understanding to define the problem.
2. Identify the decision	Identify what questions the study will attempt to resolve, and what actions may result.
3. Identify the inputs to the decision	Identify the information that needs to be obtained and the measurements that need to be taken to resolve the decision statement.
4. Define the study boundaries	Specify the time periods and spatial area to which decisions will apply. Determine when and where data should be collected.
5. Develop a decision rule	Define the statistical parameter of interest, specify the action level, and integrate the previous DQO outputs into a single statement that describes the logical basis for choosing among alternative actions.
6. Specify tolerable limits on decision errors	Define the decision maker's tolerable decision error rates based on a consideration of the consequences of making an incorrect decision.
7. Optimize the design	Evaluate information from the previous steps and generate alternative data collection designs. Choose the most resource-effective design that meets all DQOs.

An Example of the possible application of this DQO process to the Amchitka *Science Plan* follows in Table 6.

Table 6. The Data Quality Objective Process applied to Amchitka (EPA 1993, 2000)

STEP	DESCRIPTION
1. State the problem	There is public and agency concern that residual radionuclides from nuclear tests may enter the marine food chain, causing ecological and human health effects now or in the future.
2. Identify the decisions	The Amchitka study will identify whether there is current evidence of radionuclides from the tests in the marine food web, as well as the likelihood of current or future human food chain contamination. It will identify needs for future monitoring to incorporate into the long term stewardship plan. It will help verify models and reduce uncertainty regarding whether there is statistically significant evidence of release or increased risk. It will identify needs for future monitoring to incorporate into the long term stewardship plan.
3. Identify the inputs to the decision	Several major types of information are needed: a. Contaminant levels in biota of the marine food web and the main species of human-exposure concern. b. Clarification of receptors (human and ecologic) and exposure pathways c. Hydrogeologic assessment of source and pathways to the marine environment d. Temporal/spatial predictions of future pathways
4. Define the study boundaries	Data will initially be collected over a two year time period (2004 and 2005) for comparison with previously available data from the 1970's and more recent marine studies. Projections will be made regarding future sampling needs. The sampling will be conducted at two points along the Amchitka coastline corresponding to areas of maximum likelihood for past or future discharge.
5. Develop a decision rule	The Planning Committee will determine parameters of interest. The analytes of interest are a variety of radionuclides including natural isotopes of radium and radon, fallout isotopes, and products associated with the nuclear testing, including but not limited to: ^{237}Pu ^{238}Pu ^{239}Pu ^{240}Pu ^{241}Am ^{137}Cs, ^{127}I ^{129}I ^{90}Sr ^{60}Co ^{237}Np and tritium.
6. Specify tolerable limits on decision errors	A decision error rate is the probability of making an incorrect decision based on data that inaccurately estimate the true state of nature. This will be a primary focus of the Planning Committee which must consider the consequences of decisions involving current exposure and excessive or inadequate future monitoring.
7. Optimize the design	This study will proceed with three years of collection data, an initial year to develop methods and a second sampling year. The third year design will be informed by the results of the initial year to assure the most efficient use of resources and to validate preliminary findings

Table 7 outlines a decision approach to intervention. Column 1 identifies the presence or absence of evidence that a radionuclide discharge is occurring. Columns 2 and 3 indicate whether radionuclides are detected in high or low trophic level organisms (those most likely to be directly consumed by humans). Column 4 indicates whether remediation or interdiction options should be considered. Columns 5,6,7 indicate whether exclusion of subsistence and commercial harvesting, issuance of advisories, or future monitoring, are appropriate interventions.

Table 7. Decision matrix relating saltwater/freshwater interface and radionuclide detection to risk management options

1. Physical Evidence of radionuclide discharge	2. High trophic level Tests +	3. Low trophic level Test +	4. Remediation Interdiction	5. Exclusion	6. Advisories	7. Monitoring
Yes	Yes	Yes	Consider	Yes	Yes	Frequent
Yes	Yes	No	Consider	Consider	Yes	Frequent
Yes	No	No	Consider	Consider	No	Frequent
No	Yes	Yes	No	Consider	Yes	Frequent
No	Yes	No	No	Consider	Yes	Frequent
No	No	No	No	No	No	Less often

+ = If the organisms test positive.

VI. HEALTH AND SAFETY PLAN

All fieldwork entails hazardous conditions that are more difficult to predict and control than more typical forms of stationary, indoor employment. Ideally the risks to research workers and crew should not exceed the anticipated public health risks from the residual radiation. Every effort must be made to train and protect all personnel to minimize the risk of illness or injury. A designated health and safety officer should be identified during field work, and laboratory work should conform to OSHA requirements for laboratory safety. Work on research vessels operating in remote areas requires emergency medical (trained EMT) personnel on board in direct communication with land-based physicians. A survey of 122 shipboard medical cases indicated that 20% required evacuation or vessel diversion (Barss and Hall 1990). A Health and Safety Plan will be prepared to identify hazards, serve as a training manual, identify resources, provide evacuation plans, and conform to requirements. The Occupational Safety and Health Administrations standard for Hazardous waste operations and emergency response (29 CFR 1910.120 (www.osha.gov/pls/oshaweb/owadisp.show_documenHazardous) Waste (HAZWOPERS CFR 1910.120) guidance on the preparation and dissemination of a HASP and the Research Vessel Safety Standards will be followed.

Each task and subtask coordinator will be responsible for identifying hazards and preventive strategies and equipment. Attention will be paid to shipboard safety, diving and boat safety, and radiation safety. An appropriate radiation-safety course will be provided to field and laboratory personnel who may come in contact with radioactive material. Stephen Jewett, PhD, a member of the University of Alaska Diving Control Board and the NSF Office of Polar Programs Diving Control Board, will serve as the dive safety officer. Michael Gochfeld, MD, PhD, an occupational physician, will review the health and safety plans.

VII. RELATIONSHIP OF THIS PROJECT TO PREVIOUS WORK

There is a large body of literature on radionuclides in Arctic and Subartic environments (OTA 1995). A number of previous studies on the Amchitka environment have been published and will be used as a reference base for comparing future findings generated by the *Science Plan*. Merritt and Fuller (1977) edited a multi-authored compendium of research under the Amchitka Bioenvironmental Program. This provided the history and geomorphology of the island, including chapters on terrestrial and marine ecology. Of particular relevance is the chapter on radionuclides by Seymour and Nelson (1977), and on PCBs by White and Risebrough (1977), as well as the chapter on ecological consequences (Fuller and Kirkwood 1977).

The Department of Energy has supported development, by the Desert Research Institute, of a stochastically based groundwater flow and contaminant transport model for Amchitka Island (DOE 2002b). The groundwater flow model addresses density-driven flow characteristic of island hydrology. A stochastic modeling approach, Monte Carlo analysis, was used to address the uncertainty in hydraulic conductivity, recharge, fracture porosity, and macro-dispersivity. The statistical properties defining each probability density function were estimated from previous studies, from modeling, and from literature. With the results from the groundwater model, the conceptual transport model estimates the maximum and minimum boundaries of possible sub-sea seepage zones as well as the travel time required for key radionuclides to reach these zones.

Based on the groundwater modeling, DOE commissioned the *Screening Risk Assessment for Possible Radionuclides in the Amchitka Marine Environment* (October 2002 draft; DOE 2002a). While that document, as well as the groundwater model (DOE 2002b), are still under review, they provide valuable information for the *Science Plan* and future planning. The document examined a series of scenarios for exposure to radionuclides from *Cannikin*, *Long Shot* and *Milrow* which include:

Scenarios 1 and 4: Fish subsistence diet (1: no kelp/4: kelp)
Scenario 2 and 5: Marine mammals subsistence diet (2:no kelp/5: kelp)
Scenario 3 and 6: Commercial catch diet (3: no kelp/6: kelp)
Scenario 7: Fish subsistence diet for the Aleut culture and communication area
Scenario 8: Marine mammal subsistence for the Aleut culture and communication area
Scenario 9: Commercial catch diet for the Aleut culture and communication area

For each scenario the report considered a base case and a groundwater modeling sensitivity case. The role of kelp in influencing the trapping of radionuclides was demonstrated. The assumption of rapid dissipation, precluding any localized buildup of radionuclides may be realistic under some circumstances, but was non-conservative. Each of these models reflect extensive work and each identifies extensive uncertainties. A major limitation is that the source terms remain classified, which limits independent verification.

The greatest benefit of these conceptual models to the planned field studies that will result in a monitoring program for the island is the identification of the most sensitive system properties. Knowing which properties are most sensitive will facilitate focusing the field effort on decreasing the uncertainty in radionuclide transport times and locations of possible sea floor discharge. For example, results from the groundwater model (DOE 2002b) indicate that the ratio of recharge to hydraulic conductivity is one of the most sensitive parameters. Results from a field program to obtain the data necessary for a water balance may decrease the uncertainty in these parameters allowing for a more carefully defined zone of possible groundwater seepage. Similarly, the analysis identifies the position of the shot cavities relative to the saltwater/freshwater interface as of critical importance. Consequently, a geophysical survey is planned to map the interface in the subsurface.

Although Fuller and Kirkwood (1977) reported that there was no loss of habitat to terrestrial, freshwater, or marine ecosystems, they did note that a substantial number of Sea Otters, freshwater fish, and marine organisms were killed by the *Cannikin* detonation, presumably by the immediate shock of the detonation. These populations recuperated quickly because of reproduction and recruitment (Fuller and Kirkwood 1977). Physical disturbance on Amchitka itself resulted from terrestrial activities, including infrastructure and terrain disturbance (still evident in the mid-1970's), creation of berms (subsequently used for nesting by some birds), and introduction of non-native fish and plants.

There were some shifts in the marine environment, including a shift in the fault line in the intertidal rock bench at Duck Cove (Pacific coast side of *Milrow*). There were also some coastal rockfalls and turf falls following *Cannikin*. These changes apparently resulted in local die-offs and changes in the algae populations (Lepednik and Palmisano 1977, O'Clair 1977). Fuller and Kirkwood (1977) were optimistic about the recovery of these resources.

VIII. EXPECTED OUTCOMES

The majority of the *Science Plan* is focused on field studies that will improve our understanding of the complexity of how radionuclides may be moving (now or in the future) through the Island subsurface into the marine environment, through the food web, and possibly to human receptors. The research will focus on uncertainties in the groundwater modeling and the *Screening Risk Assessment* (DOE 2002b,a), and will include direct observation of food chain concentrations of radionuclides, and will model formulation based on physical oceanography, geology and hydrology. It is expected that these complex field studies will provide data on: (1) whether Amchitka is releasing radionuclides into the marine environment, (2) the current levels of radionuclides in the marine environment and food web surrounding Amchitka to establish a baseline, (3) whether any radionuclides detected are related to Amchitka releases, and (4) will provide a foundation for the long-term monitoring component of the stewardship of the Island, and for risk management and risk communication.

To develop a meaningful Long-term monitoring plan, significant amounts of interconnected data are required. For example, selection of areas to be sampled biologically is dependent upon identifying or predicting the freshwater/salt water interface zones in the subsurface. The boundaries of these zones require extensive knowledge about how the groundwater moves through the Island's subsurface. Groundwater flow (and radionuclide travel time) is controlled by the position of the interface (as well as the structure of the subsurface) between the fresh water (resulting from recharge on the Island surface) and the denser salt water. Radionuclide travel times are also dependent on the interaction of the different radionuclides of concern with the subsurface geological material in contact with flowing groundwater. Since the Island's subsurface is fractured and faulted, the flow path that the groundwater takes through this material is another controlling factor on both the radionuclide travel time and on the location of groundwater seeps. Given the high seismic activity of the region, the flow paths and potential discharge zones and fluxes may change with time.

It is anticipated that the resulting long term monitoring plan will be a dynamic plan. Uncertainty in sensitive parameters will be continually reduced as data are gathered in accordance with the planned field program outlined in this *Science Plan* and as data are gathered during long term stewardship. As more is known about the Island's subsurface and the surrounding marine environment, the sampling strategies may change. A long term stewardship plan should reflect this dynamic process and should define the process by which decisions are made on sampling strategy. CRESP researchers have significant experience in the areas of long term stewardship planning and in decision making under conditions of uncertainty. This expertise will provide input to DOE and other stakeholders for development of a plan for the Island that strives to be affordable and achievable. Obviously, stakeholder participation is paramount in planning, in the field research program, and in monitoring the Island during long term stewardship. We anticipate Aleut (and possibly other stakeholders) participation in field sampling both during the initial determination of the baseline and during long-term monitoring. Results from these programs will be presented to all stakeholders on a regular basis, as well as to the peer-reviewed literature.

IX. PRIORITIZATION OF TASKS AND SUBTASKS

In developing this complex scientific assessment, CRESP identified three levels of priorities which generally apply to investigations of contamination, hazard, and human and ecological risk.

1. Projects that **must** be accomplished to meet stakeholder needs, including compliance with regulations, standards, or compliance agreements.
2. Projects that **should** be accomplished to address stakeholder concerns and to plan long-term monitoring.
3. Projects that are indirectly related to investigation of DOE residual contamination, but **will provide useful** information for understanding the Amchitka environment and interpreting long-term monitoring results.

There are currently no regulatory compliance agreements affecting the subsurface or marine environment.

Each of the tasks or projects can contribute to understanding in one or more ways:

1. Help locate or target appropriate areas for sampling the marine environment.
2. Facilitate risk communication with stakeholders.
3. Reduce the uncertainty in the groundwater modeling and/or the screening risk assessment.
4. Contribute to the plan for long-term monitoring.

CRESP recognizes that different stakeholders including A/PIA, ADEC and USFWS may have different priorities or more extensive priorities than currently envisioned by DOE. Based on CRESP experience and technical expertise, on discussions in Las Vegas (February and May 2003), and the subsequent comments from DOE-Nevada, A/PIA, USFWS, and ADEC, there are several considerations in setting criteria for prioritization.

A. CLARIFICATION OF CRITERIA FOR PRIORITIZATION

For each task or component of task: How will it help develop a plan for current marine ecosystem sampling, uncertainty reduction, risk communication and/or future monitoring?

1. Probability that if successful the results will reduce important uncertainties to an important extent.
2. Probability that the project will be successful in generating useful data
    a. At all
    b. Within a reasonable time frame
    c. At a reasonable cost
3. Relevance of the project and results to stakeholders

   a. Communicability and clarity
   b. Will results be reassuring (if risk is negligible)?
   c. Will results lead to appropriate actions?
4. Would the project have a higher priority if it were recast?

This revision of the *Science Plan* (June 24, 2003) lists each of the tasks and the various subtasks, and indicates how each can contribute to the major areas. Note that there have been some changes from the enumeration of Tasks in the Feb 13, 2003 draft. The work plan is broken down into four "Tasks", and these are divided into subtasks (Table 8). For each an estimate is given of its contribution to 1) targeting the biologic sampling, 2) risk communication to stakeholders, 3) uncertainty reduction in the ground water models and risk assessment, and 4) usefulness for long-term monitoring. The right hand column of Table 8 gives the priority ranking agreed on at the Las Vegas meeting (Feb 20, 2003). Tasks and subtasks identified by bold face are considered the highest priority of the *Science Plan.* The remaining projects provide a coherent framework for understanding the current and future potential for migration, exposure and risk. Although DOE feels these tasks will do little to reduce uncertainties in the groundwater model and screening risk assessment (NNSA-NV pers comm.) some of these are of great interest to stakeholders.

A conceptual model for the interrelationship among the tasks and their relation to the potential migration of radionuclides from source to receptor is shown in Figure 13.

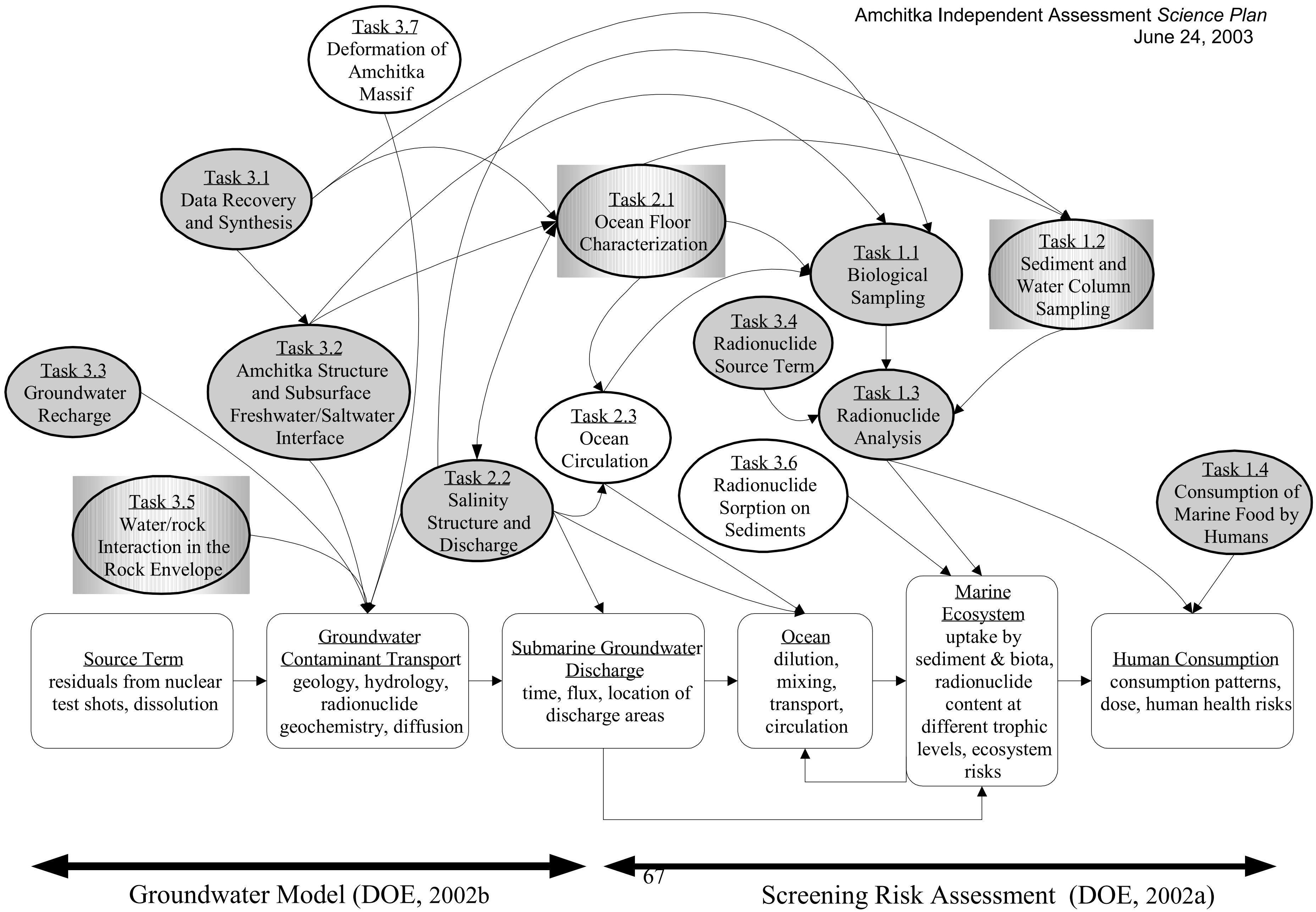
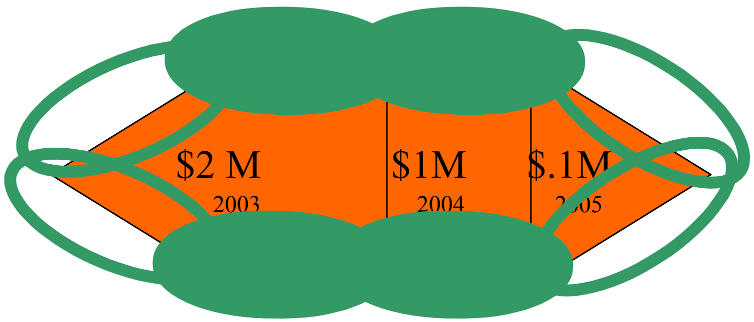


Figure 13. Conceptual model relating proposed tasks to reduction of uncertainties in Groundwater Model and Screening Risk Assessme

Commentary on the Conceptual Model and Plan Funding and Management

It is important to note what the conceptual model does and does not tell us about how to prioritize the work to be done through this plan and how that prioritization may need to be converted into ways to separate out elements of the plan in both funding and management. The Conceptual Model tells us how tasks are related to each other and to the reduction of uncertainties.



The complete assessment of Amchitka is conditional not only on the availability of full funding from a variety of sources, but on preliminary findings and logistical constraints. A set of basic tasks has been identified for the NNSA-NV funding mechanism totaling $3.1 million, and the tasks assigned to this are identified in Section XI and Table 9. Some of the preliminary findings funded by this mechanism should help focus and clarify approaches and priorities needed for the full assessment of Amchitka. In any event, it will be necessary to define a clear path forward by September 2003.

Once the *Science Plan* is approved by the parties identified in the Letter of Intent, and the priorities refined, the PI will enter into discussions with the Task coordinators regarding the actual budget and the magnitude of each task that can be accomplished with existing or anticipated funding. At that time an assessment will be made as to whether to additional funding sources alter the scope of projects and/or allow other subtasks to be initiated.

There is an extremely important caveat to be entered in this discussion: Were researchers to discover major sources of contamination, there would need to be a reorientation of all activities and of the methods used to address them.

Table 8. Tasks and Subtasks of the *Science Plan* with references to the categories for prioritization. Boldface indicates a task assigned a high priority.

	Helps spatial Targeting of biological sampling	**Useful for Risk communication**	**Uncertainty reduction for SRA & GW models**	**Long-term monitoring component of stewardship**	**Las Vegas meeting Final Ranking May 1-2, 2003**
Task 1: Sampling the Marine Environment					
1.1 Biological Sampling					
1.1.1 Preliminary 2003	Develop methods and QA	Low	Validates methodology and QA verification in advance of main sampling effort		High
1.1.2 Main Sampling 2004-2005		**Yes**	**Moderate to High**	**Yes**	**Highest**
1.1.3 Biodiversity	Yes	Yes	Not directly	Yes	Medium (Will do if possible)
1.1.4 Bioaccumulation factors	No	Yes	Useful for SRA	Yes	Medium
1.2 Sediment and Water Column sampling					
1.2.1 Water Column	Low probability	Moderate	Verification of salinity structure and presence of groundwater discharge, mixing and dilution.	Baseline	Medium

	Helps spatial Targeting of biological sampling	**Useful for Risk communication**	**Uncertainty reduction for SRA & GW models**	**Long-term monitoring component of stewardship**	**Las Vegas meeting Final Ranking May 1-2, 2003**
1.2.2 Sediment	Moderate probability	Moderate	May indicate local radionuclide accumulation; provide temporal history of discharge; provide indication of non-Amchitka radionuclide sources	Baseline	Medium
1.2.3 Physical analysis of sediment: granulometry	No	Low	Provides basis for comparison with other results	No	Low interest to DOE Moderate to stakeholders
1.3 Radionuclide Analysis of marine samples	**Yes for subsequent years**	**Yes**	**Yes**	**Yes**	**Highest**
1.3.1 Radionuclide analysis of biota	**Yes, iteratively**	**Yes**	**Low if negative, high if positive**	**Yes**	**Highest**
1.3.2 Radionuclide analysis of water and sediment	Yes	Yes	Low if negative, high if positive. Shows potential Re: sediments; may indicate other sources.	Maybe	Medium for sediment; Low for water (except medium for H3, medium for H3 in water)

	Helps spatial Targeting of biological sampling	**Useful for Risk communication**	**Uncertainty reduction for SRA & GW models**	**Long-term monitoring component of stewardship**	**Las Vegas meeting Final Ranking May 1-2, 2003**
1.4 Consumption of marine food by humans	**Helps select target species High**	**High Targets risk communication needs**	**Provides input for choice of target species and basis for exposure and risk assessment**	**Useful baseline**	**High**
Task 2—Ocean Conditions			**Yes for both models**		
2.1 Ocean floor physical characterization (including bathymetry)	**Moderate, could identify concentration areas**	**Low-moderate**	**Moderate for SRA. Utility based in part on Task 3.1; some bathymetry may support other tasks.**	**May help select monitoring areas**	**Moderate (Contingent on 3.1)**
2.2 Salinity structure and discharge	**Yes if freshwater lens identified**	**Moderate**	**High for groundwater and SRA**	**May help select monitoring areas**	**High**
2.3 Ocean circulation	Yes, if positive	Moderate	May indicate areas where remote discharge may result in transport of radionuclides to biologically sensitive areas (accumulation high productivity); helps estimate dilution and dispersion for groundwater discharge	Moderate	Low
Task 3 Geology and Hydrology					
3.1 Data Recovery and Synthesis		**Yes**	**Yes**	**Yes**	**High**
3.2 Subsurface freshwater/saltwater interface	**Yes if discharge zone identified**	**Low**	**Yes**	**Yes**	**High**
3.3 Ground water recharge	**No**	**Yes**	**Yes—both Ground Water and SRA**	**Yes**	**High**

	Helps spatial Targeting of biological sampling	Useful for Risk communication	Uncertainty reduction for SRA & GW models	Long-term monitoring component of stewardship	Las Vegas meeting Final Ranking May 1-2, 2003
3.4 Radionuclide content of the test area	**Low. Provides geologic basis for selecting sampling area**	**Yes**	**Yes for both models. Provides basis for radionuclide analysis in Task 1.3**	**No**	**High (Signature would verify whether contaminants are from Amchitka)**
3.5 Water/rock interaction	No	No	Yes for GW model	No	Medium
3.6 Radionuclide sorption on sediments	No	No	Yes for SRA model, if it affects GW model asssumptions.	No	Low
3.7 Deformation of Amchitka	No	Yes	Yes-role of seismicity	Seismic monitoring station	Moderate
Task 4 Stakeholder Dimensions					
4.1 Stakeholder participation	Yes	Yes		Important	
4.2 Monitoring component of long term stewardship	**N/a**	**Yes**		**Essential**	**High**

X. NNSA FUNDING

This *Science Plan* has identified a number of tasks and subtasks of varying scope and urgency which together provide an comprehensive picture of the Amchitka environment, and an integrate understanding of potential impacts from the nuclear test shots. The tasks will provide information important to risk assessment and risk management, including long-term monitoring of the Amchitka environment.

This section identifies those tasks agreed on for initial support through the NNSA-NV funding mechanism. Other funding is being sought for the remaining tasks. Some funding will come from in-kind support including ship time provided by collaborating agencies, for example, the proposed collecting of specimens by USFWS in 2003 (Task 1.1).

Table 9 lists the agreed upon tasks and optimizes the assignment of tasks for NNSA-NV funding based on $3.1 million dollars currently allotted. It is expected that during the detailed planning of projects, including the temporal sequencing of start dates, there may be some cost savings. In addition, we hope/anticipate other support will augment the NNSA-NV funding. Tasks will be added as additional funding is identified.

Whereas the entire plan identifies the necessary scientific investigation, the NNSA-NV's current funding limitations require assignment of certain components of the plan to this funding mechanism, so that the first year of the project can receive funding beginning June 1st 2003, as originally planned. Delay in starting the scientific assessment will limit the information available for closure planning. Implementation of the plan met with the approval of the Alaska Department of Environmental Conservation, the U.S. Fish and Wildlife Service, the Aleutian/Pribilof Islands Association, and the National Nuclear Security Administration---Nevada reviewers. The Plan benefited from written critiques provided by these agencies. At the May 1 & 2nd meeting, the four parties acknowledged that the April 25th 2003 document was generally responsive to their earlier comments, and responsive to the need for a scientific assessment of the Amchitka marine ecosystem and food chain. Additional changes were made to responds to comments made/ agreed and/or sent after the May 1-2 meeting.

Table 9 lists all tasks in two categories. The first column is the total projected budget from the project scoping. The second is the amount of funding assigned to the NNSA-NV funding mechanism. The third is the funding to be sought from Other Sources. Initiation of many of the NNSA-NV tasks is essential during the 2003 summer field season so that logistical planning, QA/AC documentation, and integration can occur before the main field sampling season of 2004.

Table 9.

Overall *Science Plan* Budget (revised June 24, 2003)

Preliminary cost estimates from project scoping (all estimates in thousands of dollars)
Funding apportionment reflecting Las Vegas meeting (May 1-2, 2003) and conference call of June 20, 2003

TASKS	**TASK TITLES**	**TOTAL** *Science Plan*	**NNSA-NV** Funding Mechanism	**Other** Sources	**Notes**
	Management, peer review, and data evaluation	$1,421	$495	$926	
	Shiptime--current best estimate	$900	$400	$500	
1.1.1	Biological---initial sampling 2003	$41	$41	$0	
1.1.2	Biological---main sampling 2004-2005	$675	$530	$145	
1.1.3	Biodiversity	$45		$45	
1.1.4	Bioconcentration/bioaccumulation	$56		$56	
1.2.1	Physical sampling-water	$33	$33	$0	
1.2.2	Sediment sampling	$66		$66	
1.2.3	Physical aspects of sediment: granulometry	$45		$45	+
1.3.1	Laboratory analysis---biota	$1,339	$1,071	$268	
1.3.2	Radionuclides in Sediment and Water	$300	$0	$300	*
1.4	Food consumption-human	$88		$88	
2.1	Ocean floor structure	$950		$950	
2.2	Salinity structure	$150		$150	
2.3	Ocean circulation	$1,041		$1,041	
3.1	Data recovery	$150	$150	$0	
3.2	Subsurface interface	$223		$223	
3.3	Groundwater recharge	$400	$35	$365	
3.4	Radionuclide source term	$155	$100	$55	
3.5	Water/rock interaction	$45	$45	$0	
3.6	Sorption to sediment	$49		$49	
3.7	Seismic monitoring	$1,814		$1,814	
4.1	Stakeholder involvement	$245		$245	
4.2	Synthesis for long-term monitoring	$63		$63	
	Available for redistribution or re-allocation	0	$200	-$200	#
	SUBTOTALS FOR EACH SOURCE	**$10,294**	**$3,100**	**$7,194**	

This budgetary scope does not include allowance for weather or logistic delays beyond the control of the investigators. A reasonable contingency estimate would be about 10% of the total cost, bringing the current overall estimate for the Science Plan to $11, 323 thousands.

The changes to the May 28th version of Table 9 of the *Science Plan* are indicated by notes in the right hand column.

\+ Indicates corrected renumbering and renaming of the Task on "Physical Aspects of Sediment: granulometry".

* Indicates renaming of the task to match the text, and the agreed on change eliminating NNSA funding. $30K of "Other Sources" funding will come from CRESP carry forward and will thus allow early study to evaluate which radionuclides, including tritium, should be sampled.

\# Captures designation of $200 K to fully fund tasks as needed or to fund additional tasks.

XI. TASKS

The following tasks reflect the work that is required to address the major uncertainties and data gaps concerning the physical and biological environment in the ecosystem of Amchitka Island.. These tasks involve:

1. Marine Environment
2. Ocean conditions,
3. Amchitka Geology and Hydrology
4. Human dimensions.

Each of these major tasks has several subtasks that address particular data needs.

TASK 1 SAMPLING THE MARINE ENVIRONMENT

TASK 1.1 BIOLOGICAL SAMPLING

TASK COORDINATORS: Stephen Jewett (UAF) and Joanna Burger (Rutgers)

QUESTIONS:

1. Are the food resources potentially harvested by subsistence, recreational or commercial fisheries "safe" to eat currently?
2. Is the biota of the Amchitka environment currently contaminated by anthropogenic pollutants, from test shots; if not what are the baseline levels of contaminants?
3. Are levels of contaminants high enough to pose harm to any species or interfere with the dynamics of the ecosystem?
4. What are the current risks and the appropriate risk scenarios?
5. What species are appropriate as indicators for long-term monitoring?
6. What is the biodiversity at the target and reference sites?
7. What are the ecospecific bioconcentration factors (BCF) and bioaccumulation factors (BAF) that should be incorporated in future ecological risk assessments?

UNCERTAINTIES ADDRESSED:

1. Current distribution of radiologic contaminants in components of the marine ecosystem that can be used in predicting or modeling risk and in validating existing models.
2. Concentrations of contaminants in lower trophic level organisms that will influence exposure at higher trophic levels.
   (a) Levels of contaminants (regardless of source) and whether they are at a sufficient level to pose a health risk to organisms or humans who consume them?
   (b) Levels of contaminants sufficient to influence biodiversity or ecological risk.

DATA NEEDED: Concentrations of radionuclides and other contaminants in biota including plant, invertebrate and vertebrate organisms that represent indicator components of the marine ecosystem, as well as potential human foods for consumers of subsistence, recreational, or commercial resources. Data will be obtained from target and reference sites. A biodiversity baseline should be established and the bioconcentration and bioaccumulation factors applicable to the Amchitka ecosystem should be assessed.

Subtask 1.1.1 Preliminary Sampling in 2003

During the summer of 2003 preliminary sampling of selected marine biota will be obtained by personnel of the USFWS, who will visit Amchitka during the first week of September. A sampling protocol will be developed and field tested. Specimens will be submitted with appropriate chain of custody. These preliminary samples will allow the testing of QA/QC procedures in the field and laboratory, and to assure readiness for the definitive sampling regime to be conducted during 2004. This project will also be coordinated with sampling being conducted under the auspices of A/PIA.

Subtask 1.1.2 Main sampling effort 2004-2005

Most of the information provided below refers to sampling efforts to be conducted in 2004 at both target and reference site(s). In 2005 additional testing will be focused on area or biota suggested by review of the 2004 data.

BACKGROUND

To assure Native Communities, the U.S. Fish & Wildlife Service and the Alaskan Department of Environmental Conservation, as well as other stakeholders, that there are currently no risks to organisms residing around Amchitka Island and to consumers of these organisms, and to provide a baseline for future studies, it is necessary to: 1) examine radionuclide levels in marine plants and animals near Amchitka Island and at one or more reference sites, 2) compare current levels with those in Amchitka organisms from the 1960s and 1970s (Merritt and Fuller 1977), from the early 1990's (Crayton 2000), and with data from other parts of the Aleutians; 3) test for food chain biomagnification by sampling organisms at different trophic levels, 4) model radionuclide transfer in selected food webs (Burger et al. 2001c) of biological interest (e.g. Steller Sea Lions, seals, Sea Otters, large predatory fish), and 5) assess the risk to humans (see below) and ecosystems. The data will provide a valuable baseline for future biomonitoring and assessment plans. These data are essential to providing peace of mind to all residents of Alaska, to the Native Communities, and to the world at large that consumes commercial seafood from the region. Further, sampling of both the marine environment and foods should be done in collaboration with people of the Aleutian/Pribilof area and this project will be coordinated with ongoing field studies under the auspices of A/PIA.

A fundamental premise of CRESP is the involvement of stakeholders in all phases of the risk assessment and management process. This has been memorialized in the diagram of the Presidential/Congressional Committee on Risk Assessment and Risk Management (PCCRARM 1997 (see introduction and Fig. 1). Involving Native Communities and other stakeholders will improve the quality of the biological sampling, the quality of the bioindicators selected, and assure that the results will be relevant to community concerns. The *Long-term Stewardship Workshop* held in Fairbanks (Feb 2002; CRESP 2002) identified the role of biota in the transfer of radionuclides as the highest priority for marine science in the Amchitka ecosystem, as well as for human health risk assessment (CRESP 2002). The marine science group of the Feb 2002 workshop recognized the importance of analyzing radionuclides in a number of different compartments or species groups, including 1) sedentary and sessile organisms, 2) Rockfish, 3) Atka Mackerel, and 4) dietary and subsistence foods. Further, identification of key pathways of radionuclide transfer in the food chain was a high priority. Such food chains include: 1)kelp-urchin-otter; 2) small fish (such as salmon)-Pollock-Steller Sea Lion (endangered); and 3) invertebrates -small fish-Halibut-human. Within fish species, larval and juvenile stages occupy lower trophic levels than adults (Hart 1973, DiCosimo 1998).

WORKPLAN

Using the above-mentioned advice, we will conduct an extensive marine sampling plan (Table 9). In addition we will conduct baseline biodiversity sampling (Subtask 1.1.3) for macroflora and macrofauna at the collection sites, including the reference sites. This information will be important for considering the suitability of the sampling strategy and will enable the future monitoring program to detect significant changes in biodiversity. In addition we will conduct stable isotope sampling for oxygen and nitrogen isotopic ratios, as a means of validating trophic levels of collected specimens. We have previously used this technique successfully with Raccoons at Savannah River Site (Gaines et al 2002) and with Common Terns in New England (Nisbet et al. 2002).

Marine sampling will be conducted to determine the extent of radionuclide contamination in biota (see Fig. 14). The overall objective is to determine if there is currently any contamination due to the testing at Amchitka, and if so, whether the levels pose a risk now, or to future generations, and secondly to establish baseline values. Further, due to the presence of several threatened and sensitive marine vertebrates that live or migrate through the system, as well as local fauna, it is important to assess the potential risk to ecological receptors, as well as human health.

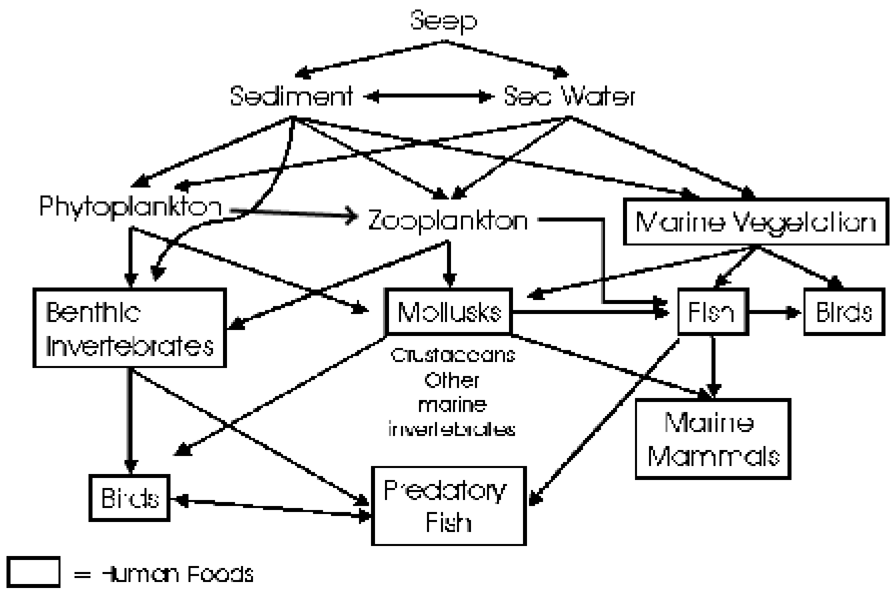


Figure 14. Pathways of radionuclide transfer from seeps to sediment and seawater and thence through micro- and macro-invertebrates to higher trophic levels. Entities enclosed in boxes are those consumed by humans for food (original drawing by J. Burger 2003).

The overarching concern of the communities within the region, natural resource trustees, commercial fishermen, and other stakeholders is for the safety of current and future subsistence and commercial marine foods. However, human foods represent the top part of the marine food web (see Fig.14), and thus are of interest for all three purposes (assessing marine ecosystems, assessing foods of Aleuts to the 7th generation, assessing safety of commercial fishery).

Several species of birds (geese, eiders, gulls, eagles) are high level predators in the marine environment. Eiders are sought for food and therefore bridge human and ecological risk. Human and ecological health may require some determination of tissue levels of contaminants (Burger et al., 1998; Harvey et al., 1995), but the initial plan is to collect eggs of these species, which can provide an indication of adult contamination.

It is not possible to sample all species, so certain bioindicator species will be selected. Preferably these should provide both ecologic and human health information. They should be recognizable and relevant to the stakeholders, and should be obtainable in a cost-effective manner (Burger and Gochfeld 1996). The sampling regime shown below (Table 10) is tentative. It is subject to modification by the three main receptor or stakeholder groups: Aleuts, commercial fisheries, natural resource trustees. Moreover, it is planned that Aleut and commercial fishers will participate in the sampling regime to assure that species obtained reflect species they are actually likely to capture. Modifications will be made in public meetings and in discussions with appropriate elders/officials.

These should include the Aleutian/Pribilof Island Association (A/PIA), Alaska Native Health Board, Alaska Department of Environmental Conservation (ADEC), Alaska Department of Natural Resources, Institute for Circumpolar Health Studies, U.S. Environmental Protection Agency (EPA), U.S. Fish and Wildlife Service (USFWS), National Oceanic and Atmospheric Administration (NOAA), Alaska Department of Health and Social Services, commercial fishing interests, and other interested parties. Partly this task was discussed by Jewett (2002) at the February 2002 Long-term Stewardship Workshop, and reflected a May 1998 meeting with several of the above-mentioned stakeholders.

Species selection: As mentioned above, the preliminary list of species to be sampled were selected based on discussions and presentations at the CRESP Long-term Stewardship Workshop in Fairbanks (CRESP 2002), papers and comments on Aleut diet by R. Patrick (Patrick 2002), C. Hild (pers. comm.) and S. Jewett (Jewett 2002), and information on commercial fisheries (NMFS 2003). Pollock represent 74 % of the Alaska groundfish fishery, and Pacific Cod represents 11 % (AFSC 2003). It is expected that amendments to this table (Table 9) will occur upon review by stakeholder groups and with information from the food use pattern surveys in four western Aleutian villages currently underway by A/PIA. In addition, preliminary onsite experience will indicate which of the species can be obtained consistently and in adequate numbers.

These species were selected because of their role in Aleutian diets, commercial fisheries, and ecosystem food webs, and to allow comparison with the data from 1965-1975 (Jewett 2002 and pers. comm., Bartell et al, 1999, Hild, pers. comm., Merritt and Fuller 1977). The human dietary data from Bartell et al (1999) is site-specific, was collected at three times of the year, and indicated that the most important marine foods were Sea Lion (ranked number one), Halibut, Salmon and Harbor Seal.

A variety of potential fish species has been listed in Table 10. Based on preliminary discussion it is anticipated to sample Dusky Rockfish, Rock Greenling, and Sculpin as indicators of nearshore bottom or column feeders. Atka Mackerel spawn locally and are both an important commercial species as well as prey for seabirds, seals and Sea Lions. Pacific Cod and Pacific Halibut are important for commercial and subsistence fisheries. Pacific salmon (Pink Salmon, Coho Salmon) and Dolly Varden, spawn in freshwater creeks in the fall on Amchitka, but then go to sea for the rest of their development, hence spend little time in the local littoral zone.

Bald Eagles are top-level predators on the Amchitka littoral ecosystem. The distribution and bioaccumulation of contaminants has been extensively studied in Bald Eagles in the Aleutians. At the suggestion of the USFWS (Anne Morkill), one egg will be taken from 10 two-egg clutches to analyze for a suite of contaminants including radionuclides. This work will be coordinated with ongoing studies of the Amchitka eagles by Robert Anthony. Adding Bald Eagle to the sampling regime will afford additional useful information since the Bald Eagle has been an endangered species and is the United States National Emblem. Bald Eagles on Amchitka are non-migratory and nest along the coast of the island and feed on both terrestrial and marine mammals, birds, and fish. The eagles have been documented (Anthony et al. 1999) to consume 26 species of birds (comprising about 60% of the diet), 30% mammals (including Sea Otter pups), and 10% fish (particularly Rock Greenling and Pacific Cod).

The Emperor Goose winters on Amchitka and migrates to the mainland where it is an important food source for native hunters. However, it is mostly absent in the summer, so at the suggestion of the USFWS (Morkill, pers. Comm.), Sea Lettuce (*Ulva*), one of main foods of the wintering geese, will be sampled.

Because of the difficulties associated with sampling, such a range of species, under the harsh environmental conditions around Amchitka, it may not be possible to obtain all the samples from all areas. Thus the final sampling scheme may not be balanced. The sampling regime is based on one target site and one reference site. In the event significant radionuclides are detected in certain species it may be necessary to obtain additional samples.

Table 10. Bioindicator sampling regime: Shown are the organisms to be sampled. Number of each species refer to the numbers of POOLS obtained from each of the sample sites and the reference site, on each sampling occasion. Specimens will be collected by researchers, by commercial fisheries, and by Aleut hunters, fishers, and interns. It is anticipated that for most species, pools will comprise 5 individuals (shown in parentheses), a typical procedure advocated by EPA Guidance Document (EPA 2000b). Species designated "probably omit" will probably be dropped from the regime based on preliminary discussions with USFWS, A/PIA and ADEC. The species selection will be modified after additional discussions with stakeholders.

SAMPLING METHODS		Research Ship	Commercial fishery	Aleuts
PROPORTION OF SAMPLE		40%	20%	40%
SPECIES	TROPHIC LEVEL			
Kelps (Browns)[a,d,e] *Fucus, Alaria, Laminaria,Hedophyllum*	Primary Producer	20 (5)		
Sea Lettuce[g] *(Ulva)*	Primary Producer	20 (5)		
Giant Chiton[a] *Cryptochiton stelleri*	Grazer	Probably omit		
Green Sea Urchin[a,d,e] *Strongylocentrotus polyacanthus*	Grazer	10 (5)		
Blue Mussel[a,e] *Mytilus trossulus*	Filter Feeder	unavailable		
Basket Star[a,e] *Gorgonocephalus caryi*	Filter Feeder	5 (5)		
Rock Jingle[a] *Pododesmus macroschisma*	Filter Feeder	5 (5)		
Red King Crab[a,c,e] *Paralithodes camtschaticus*	Predator		5 (5)	
Brown King Crab[a,c,e] *Lithodes aequispinus*	Predator		20 (5)	
Dusky Rockfish[a,e] *Sebastes ciliatus*	Predator			40 (10)
Pacific Ocean Perch[a,c,e] *Sebastes alutus*	Predator	40(10)	10 (5)	
Pacific Salmon[a,b,c,e] *Oncorhynchus* spp.	Predator	Probably omit		
Dolly Varden *Salvelinus malma*	Predator	20 (5) Probably omit	20 (5)	
Atka Mackerel[c,e] *Pleurogrammus monopterygius*	Predator	20 (5)	40	
Rock Greenling[a,e] *Hexagrammos lagocephalus*	Predator			40 (10)
Walleye Pollock[a,b,c,e] *Theragra chalcogramma*	Predator		20	10
Pacific Cod[a,b,c,e] *Gadus macrocephalus*	Predator		60	60
Pacific Halibut[a,b,c,e] *Hippoglussus stenolepis*	Predator		60	20

Turbot[c,e] = Arrowtooth Flounder *Atheresthes stomias*	Predator		20	
Sculpin[a,e] Cottidae	Predator			
Common Eider[b] *Somateria mollissima*	Predator Scavenger	20 eggs[g]		20
Glaucous-winged Gull[b,e] *Larus glaucescens*	Predator Scavenger	20 eggs[g]		20(eggs)
Bald Eagle Eggs [g] *Haliaeetus leucocephalus*	Predator	15 h		
Norway Rat *Rattus norvegicus*	Omnivorous	20 (5)		
Harbor Seal[b] *Phoca vitulina*	Predator			Up to 10
Steller Sea Lion[b] *Eumetopias jubatus*	Predator			Up to 10
Sea Otter[b,d,e] *Enhydra lutris*	Predator			Up to 10

a. samples collected by CRESP from research ship.
b. samples collected by Aleuts, or their designee (based on dietary information of Aleuts, C. Hild, pers. comm), in collaboration with CRESP. List to be modified after meetings with A/PIA.
c. samples collected by commercial fishermen or designee, in collaboration with CRESP.
d. because of its role in the kelp-urchin-otter food chain
e. for comparison with 1965-1975 samples (Jewett, CRESP workshop, 2002).
f. juvenile Pollock are a nodal species in the food web and a major prey item for many higher trophic level carnivores (Brodeur et al. 2002).
g. Of interest to US Fish and Wildlife Service
h. Collated by US Fish and Wildlife Service

Sampling locations: Choosing the locations for the biological sampling is crucial. The Oversight Team will use expert judgment in locating the biological sampling sites. As a preliminary plan three sites will be considered, one in closest proximity to each of the test shots. Further localization will be done in conjunction with the quest for the salt water/freshwater interface or salinity surveys. It is desirable that the interface be sought to support the site selection. The most likely direction of release to the marine environment from *Long Shot* and *Cannikin* is to the Bering Sea, while from *Milrow* it is to the Pacific, probably near Duck Cove. Hence preliminary attention will focus on the Bering Sea coast of the island at the three points that are closest to the test shots. This will be coordinated with the water and sediment sampling (Task 1.2). Preliminary sampling will be done at all three points with nearshore and offshore sampling at each point. Additional sampling at a to-be-determined nearshore and offshore reference point may also be conducted, bringing the total number of sampling points to eight. Information from physical studies as well as the preliminary findings will be used to narrow the focus for full scale sampling to one or two of the sites. Expert discussions will also help choose between the *Long Shot* (shallowest) and *Cannikin* (deepest, largest) to determine the most likely location for radionuclides to have entered the sea.

Reference Site: In the event that radionuclides are detected it will be necessary to consider a reference site in the Aleutians. The reference site should be sufficiently remote from Amchitka to be free of any test shot influence, yet sufficiently close to share its fauna and flora. There are zoogeographical breaks between the eastern and western Aleutians and between the Aleutians and the Pribilofs (Kenyon 1961). The reference site should be free of radioactive contamination and accessible to study.

Sampling Protocol: Selection of species to sample to assess whether there is currently any release of radionuclides into the marine environment, and to set-up a long-term biomonitoring plan to provide early warning of any potential release, is key to the Amchitka *Science Plan* and eventual closure and long-term monitoring (Burger 1999). The sampling scheme shown above is designed to provide information on marine food chains to assess both ecosystem health and human health. Prior to beginning collection appropriate permits will be obtained from the U.S. Fish and Wildlife Service, Alaska Department of Fish and Game, and the local/tribal administration. Sampling may be adjusted where threatened or endangered species are involved.

Samples will be obtained from three sources: research ship sampling, Aleut subsistence fishers and hunters, and commercial fisheries. Aleut subsistence sampling will be done in collaboration with A/PIA, employing native hunters, fishers, and Aleut student interns, and is dependent on their collections. Their knowledge base concerning both the biology of the species, and the use of these foods by their people, is essential to the success of the sampling scheme. Commercial fish samples will be obtained from commercial fishing boats operating near Amchitka. Fillets (and where possible liver and bone) samples will be taken from fish of commercial interest and some whole fish will be analyzed as well. Arrangements will be made in advance with the appropriate fishing vessels to obtain samples.

A detailed sampling protocol will be prepared and all collectors (senior, technicians, interns) will be briefed on sampling procedures including health and safety and chain-of-custody. The protocol will cover site selection, biologic and physical sampling, preparation including sieving and preservation, labeling, data entry, storage and transport. A separate protocol will be prepared for the laboratory procedures including specimen handling, tracking, and archiving and for analysis and quality control. Each sample will be labeled with chemically resistant plastic and ink and will contain the date, time, GPS coordinates, depth, sampling device, and name of collector, and will be placed in the container. It will be linked to a chain of custody form affixed to the outside of the container.

Biological collections in the intertidal will be done by hand, and in the shallow subtidal zone by van Veen grabs and scuba. Deeper samples will be collected using a remote operated vehicle (ROV), a variety of dredges and trawls, and rod and reel. All scuba diving will be conducted at no-decompression depths and will generally not exceed 20 m. All diving will adhere to standards established by the American Academy of Underwater Sciences. Samples will be collected in duplicate, with emphasis on areas of known faults, seeps, or at saltwater/freshwater interfaces, because of the higher potential for bioaccumulation and detection of radionuclides. Once on site, the sampling regime will be adjusted after availability and prevalence of different species have been assessed. On land, bird eggs will be collected by hand from nests. Norway Rats will be trapped. Rats have been suggested as a target species because there are data from the 1960's and 1970's. Marine mammal sampling will be coordinated with the USFWS Marine Mammal Management Office which contracts with native hunters.

Samples will be processed initially on the ship, and further preparation and dissection will be done at UAF. Split samples will then be sent to other participating laboratories for analysis and QA/QC intercomparisons for radionuclides. Other contaminants of particular interest in marine ecosystems, such as metals (e.g. mercury) and organics (e.g.PCBs) will be archived for analysis under other programs.

All protocols for collection of samples will follow appropriate federal and state permits, and university Animal Review Board approvals. A hazardous materials safety protocol will be followed for underwater and shipboard sample handling. All voucher specimens and any remaining samples will be archived at the University of Alaska.

Analyses will conform to EPA and DOE EML protocols for radionuclide analysis (Erickson and Chieco, 1997; U.S. EPA, 2000) , taking advantage of existing environmental reference standards (Inn et al., 1996).

Subtask 1.1.3. Biodiversity

Biodiversity is of both biological and social interest (Wilson 1988). Native American groups, including the Aleuts, often have a high degree of concern and respect for ecological integrity and biodiversity per se, as well as for the resources it provides (Burger et al. 2000). Biodiversity will be examined at the same sites used for biological sampling (Task 1.1.2). Where feasible permanent transects will be established and photography used to document the habitat and organisms at fixed intervals along the transect. A variety of sampling techniques will be required suited to the different depths, slopes, substrates, wave action, and tides. Grabs, cores, and dredges will be deployed from boats, from remote operated vehicles (ROVs), or directly by SCUBA divers. On rocky substrates small organisms will be obtained by vacuuming, and crusting organisms will be removed by chiseling as needed. In intertidal and supratidal areas specimens will be collected by hand. Specimens will be collected to the depth realistically accessible to subsistence fishing or commercial fishing. Distance from shore will be determined at the next planning stage.

Samples will be archived for sorting and for preliminary identification to higher order taxa. More refined identifications will be deferred. The fauna is generally rich in sponges, soft corals, bryozoans, hydroids, and tunicates. Issues of quadrat size, sampling devices, sieve sizes and quantity of collection will be incorporated into a sampling strategy plan.

Subtask 1.1.4. Estimating Bioconcentration and Bioaccumulation Factors

Knowledge of the bioconcentration of contaminants from water and the bioaccumulation of contaminants from prey organisms, is valuable for documenting food chain processes and estimating exposure to higher trophic levels including humans. Procedures for collection of samples to estimate BCF's and BAF's require careful sampling of water, sediment, and biota.

- Seawater samples both filtered and unfiltered will be analyzed for denominator values. This will also clarify how the radionuclides may be partitioned in the water.
- Invertebrates and small marine vertebrates will be analyzed as whole body samples.
- From marine mammals, samples of teeth and bone will be obtained for analysis of bone seeking radionuclides, such as ^{90}Sr and $^{239+240}$Pu.
- Additional physical variables will include date , time. water temperature, salinity, depth, and tide cycle.
- Additional biotic information to be recorded are species, size, age, sex and reproductive status.
- Pooled samples will be homogeneous with regard to as many of these variables as feasible.

To strengthen the ecological assessment it will be appropriate to collect blood and tissue samples for biomarker analysis, including gene arrays, as currently done at other DOE sites contaminated with radionuclides (Trabidou and Florou 2002, Hsie et al. 1996, INEEL pers comm.). These samples will be archived in appropriate freezers, pending collaboration with these other DOE-supported research programs.

Data Management: All records and results of analyses will be entered into a geospatial references database (coordinated with Task 3.1) and made available over the Internet to researchers, Native communities, commercial fisheries, natural resource trustees, and other interested parties. Copies of the data will also be made available to US AMAP representatives for submittal to the AMAP and IAEAD international radioactivity bases. Analyses of results will be published in the peer-reviewed literature. Maps showing contoured concentration levels of diagnostic pollutants will be produced and made available to the public.

Radionuclides: The selection of analytes and analytical methods is addressed under Task 1.3. A detailed laboratory protocol for sample preparation, handling, analysis, and data reporting will be prepared as part of the detailed Quality Assurance Project Plan

The overall objective of the biological sampling is to reduce uncertainties for risk assessments involving radionuclide transfer through the food web around Amchitka Island, including those species harvested by Aleuts and commercial fisheries. Uncertainties that will be reduced or bounded include, among others:

1. Site specific data on absence or presence of radionuclide levels at all trophic levels in the marine ecosystem, and in all major habitats will be obtained.

2. Site specific data on the distribution and variance of any possible radionuclide contaminants in marine organisms in the food web, including those leading directly to humans will be obtained. These results will be used to advance the risk assessment process.

3. Site specific data on biodiversity, and on the distribution of the sample organisms with respect to depth. This would help validate to one of the assumptions of the human health Screening Risk Assessment, DOE (2002a). Estes (1978) indicated that macroalgae covers the solid rock substrate to depths greater than 25 meters. Macroalgae, not just the kelp species, are important to the hydrodynamic modeling and to the ecological and human health risk assessment.

5. Site specific data on radionuclides will be compared to the data from the 1970s, and will be used as a baseline for future biomonitoring and early detection of possible future problems. However, there are difficulties with this comparison, particularly the loss of short-lived isotopes. Subsequent to 1971, there were airborne emissions from Chinese atmospheric nuclear tests, as well as from the Chernobyl disaster. Moreover, the Soviet Union continued to dump nuclear wastes in the marine environment of the North Pacific Ocean up through the early 1990's. Data exist from Amchitka for the early 1990's (Crayton 2000), and consideration will be given to comparison with other studies that have occurred in the last 10 years in the North Pacific Ocean, the Arctic and other sites within the Northern Hemisphere.

6. Site specific data on radionuclides will be used to model food chain biotransformation.

7. Site specific data on radionuclides in the biota and water (and sediment) can be used to compute bioaccumulation factors (BAF) and bioconcentration factors (BCF) that are specific to Amchitka Island. These will be compared with factors used in the *Screening Risk Assessment* (DOE 2002a)

8. With the site-specific data, BCFs can be computed for organisms that are sedentary or remain in the region for several days or weeks, as opposed to assuming that marine mammals remain in the plume for no more than a few days (as in the screening risk assessment).

9. Specific data on whether similar species collected by the ship sampling contain the same levels (or lack thereof) of radionuclides will be compared to those found in the foods collected by the Aleuts and in commercial fishery samples.

TASK 1.2 PHYSICAL MARINE ENVIRONMENT

TEAM COORDINATOR: Sathy Naidu (UAF)

QUESTION:

a. Is the abiotic marine environment contaminated with Amchitka radionuclides now?
b. If not, what are the baseline concentrations of contaminants so that leakage can be identified in the future?

UNCERTAINTIES ADDRESSED:

1. The current radionuclide content of sediments and the water column in the areas where groundwater discharge from the Amchitka test shots is expected.
2. Background concentrations of radionuclides in comparable sediments and water columns.
3. Determination of whether or not ocean floor sediments in the Amchitka vicinity are accumulating or attenuating radionuclides from the Amchitka test shots.

DATA NEEDED: Radionuclide content of samples of water and sediment.

EXPECTED RESULTS:
Determination of whether release is occurring.
If it is occurring, the sediment samples may yield a temporal history.
Establishment of a baseline for long-term monitoring.
Establishment of a spatial and temporal sampling protocol.

BACKGROUND
To assess whether Amchitka has in the past or is currently releasing radionuclides and to recognize releases in the future, it is necessary to know a) the background burden of radionuclides in the environment, b) establish baseline measurements of radionuclides in the vicinity of Amchitka and c) identify signature isotopes or isotope ratios by which releases from Amchitka sources can be distinguished from other sources (e.g., atmospheric testing or nuclear reactor incidents). The background burden of key radionuclides in the arctic environment may be established from published data (Seymour and Nelson, 1977; Cooper et al., 2000 and references therein). Establishment of a baseline for the Amchitka vicinity requires sampling water and sediments at locations where submarine freshwater discharge originating from the test shot locations is expected and from a suitable analogous control site where impact from the test shots is not expected. Four general sampling areas, one corresponding to the expected discharge area from each of the three test shots and one control area will be identified. Each sampling area will be further subdivided into areas of relatively high biological productivity (e.g., shallow water areas) and low biological productivity (e.g., deep water areas). Additional sampling may be carried out at locations where other observations (e.g., salinity, nutrient, geologic/sea floor structural data) indicate or suggest the location of high flux of water through sea floor seeps (e.g., freshwater springs) within the expected discharge areas.

Task 1.2.1 Water samples

We assume that the overall area of interest for the project will be extended over the Bering Sea side of the Amchitka Island, and the North Pacific side of the island. Water samples will be taken from near the submarine floor at locations showing signs of freshwater discharge within the areas of expected discharge originating from the test shots. Specific sampling locations will be guided by the salinity and nitrate determinations using towed instrumentation, maps of sea floor structure and extension of onshore faults, and the hydrogeologic study by Hassan et al (2002).

Sites for collecting water samples will be selected based on the field observations from the CTD (conductivity/temperature/density) or SeaSoar tows (Task 2.2). At this time it is difficult to predict how many of the above sites will be located. However, we anticipate collecting two sets of water samples. One set of samples will be from at least 80 locations for the salinity and nitrate measurements. These samples will be from four specific areas: three areas off each of the three onshore test shot locations and one from a control site. We propose to select one near shore and another farther offshore target locations (as justified earlier) for intense sampling from each of the above four areas (total 8 target locations). We propose to collect 10 samples from each of the target locations, providing a total of 80 water samples. These water samples at the identified sites will be collected using remotely triggered Niskin bottles on the CTD rosette. The sampling areas will include where the real-time measurements indicate temperature, salinity and/or nitrate anomalies, which are strong indications of freshwater discharge from submarine seepages (Capone and Bautista, 1985; Capone and Slater, 1990). The assistance of scuba divers may be used to obtain samples from suspected seep locations. To the extent possible, diagnostic analyses will be conducted on board ship so as to focus the domain of groundwater discharge areas in near real time and to verify data from the remote instrument measurements. The samples will be collected, as mentioned above, with the rosette on the CTD.

Additional seawater samples will be collected (Ikeuchi et al., 1999, Holtzendorff et al. 2000) from the 8 target sites, particularly in the environmentally-sensitive nearshore kelp beds, for subsequent analysis of radionuclides (Task 1.3.2). These samples will have to be in large volumes (up to 300 L), to identify the underground nuclear test-derived isotopes (e.g., ^{3}H, ^{137}Cs, ^{90}Sr, $^{238, 239, 240, 241}Pu$, ^{241}Am, ^{60}Co, $^{127, 129}I$, ^{237}Np). Samples will be pre-concentrated, on board the ship, the radionuclides from the large water samples. To send the bulky (300 L) water samples to the analytical laboratory will not be preferred as the samples may lose their original integrity during transit. Initial shipboard processing of the water samples also minimizes the cost of handling and forwarding the large water samples. The pre-concentration of the radionuclides in the water samples will be accomplished according to the widely known methods, involving filtering in situ of up to 300 L of water samples through individual Mn cartridge, using peristaltic, vacuum and submersible pumps. The cartridges thus obtained (with the radionuclides encapsulated in them) will then be forwarded by courier service to the designated analytical laboratory for the radionuclide measurements (Task 1.3).

Expected results: a) validation of remote salinity, temperature and nitrate measurements, b) determination of water column concentrations of radionuclides, c) focusing areas for biological sampling, e) understanding of dilution rates for groundwater discharge.

1.2.2 Sediment Sampling

We propose to collect sediment samples from the Amchitka margin for a number of reasons. Sea floor sediments are an important habitat parameter (substrate and particulate carbon food source) in determining the composition of macrophyte and benthic organisms (Feder et al., 1994, and references therein). Additionally marine sediments, which act as an initial sink for particle-reactive trace elements and radionuclides (Naidu et al., 2001), could be a major source of contaminants to benthos and higher trophic organisms having a link to the bottom dwellers. Upon entering the marine environment, many radionuclides of concern will be partitioned between the water and particulate matter in water (Duursma et al, 1996; Fisher et al, 1983; Whicker et al. 1982). Particle-reactive radionuclides are susceptible to concentration in sediments by scavenging and sequestering by phyllosilicates (clay minerals) and ferri- and manganic oxides and hydroxides, involving processes such as cation exchange, adsorption and/or co-precipitation (Robinson 1962, Fuhrman et al. 2001,Zachara et al. 2002, among numerous others). If there is any discharge of particle-reactive radionuclides into the Amchitka shelf, either from submarine seeps or land stream runoff, it is to be expected that the nuclides will be scavenged relatively quickly by the smectitic clays present in abundance in the Aleutian shelf region (Naidu et al. 1995). Smectite, which has one of the highest cation exchange capacities, is the principal clay mineral derived from weathering of the basaltic-andesitic rocks of the Amchitka Island. Radionuclides may also be present in the sediment pore water and outflows as primary or secondary colloids or as organic complexes (Kersting et al. 1999, Bates et al. 1992). Marine sediments provide a matrix for trapping radionuclides, allowing for determination of a time history of radionuclide release reflected by stratification within sediment cores. Additionally, sediments may serve either a natural mitigating role, in sequestering contaminants before they are dispersed or transported by ocean currents, or may enhance bioaccumulation by local retention prior to uptake by biota. Desorption of various radionuclides from sediments to the water column should also be considered (Sanchez et al, 1986). Thus, the sediment data will be useful in characterization of the benthic substrate habitat as related to Task 1.1, and to better understand the control of sediments in the distribution and concentration of radionuclides (Task 1.3).

We propose to collect sea floor sediment samples from various locations where water and benthic samples are collected. As in case of the water samples, sediment sampling will be obtained in four specific areas: three areas off each of the three onshore test shot locations and one from a reference site. We propose to select one near shore and another farther offshore target locations (as justified earlier) for intense sampling from each of the above four areas (total 8 target locations). We further propose to collect 10 samples from each of the 8 target locations, providing a total of 80 sediment grab samples. Supplemental samples will be collected from proven freshwater seepage and non-seepage areas, following the results of the CTD and SeaSoar surveys. These sediment samples will be collected by a van Veen grab (0.1 m^3) or scuba diving as appropriate. The near shore seabed surrounding Amchitka Island is a high-energy region, comprised predominantly of gravel with minor mud and sand. In most cases this will preclude sediment coring. If areas of interest contain thick accumulations of mud and sand, then up to 1-meter long sediment cores will be collected by gravity coring. In such a case we will obtain at least one representative core sample from each of the 8 target areas. Stratigraphic sampling of such cores will allow for the investigation of historical changes in radionuclide deposition to the seabed from any source.

Splits of the sediment samples will be made available for analyses of grain size distribution and organic carbon content (Task 1.4.1), and for radionuclides (Task 1.3) and investigations relating to the radionuclide sorption (Task 3.6).

Expected results: a) radionuclide concentrations in sediments located in areas of expected freshwater discharge and comparable background areas, b) assessment of the potential for local sediments to attenuate radionuclide discharge to the marine environment, c) potentially, temporal history of radionuclide discharge and deposition (if intact core samples are obtained).

Subtask 1.2.3 Physical Properties of Sediments: Granulometry

QUESTION:

1. Is there lateral variation in sediments of the Amchitka margin based on granulometry and organic carbon contents?

UNCERTAINTIES ADDRESSED:

1. As the nature of the sediment derived from land can vary regionally along the coast and are modified by marine hydraulic action along and across the shelf, it is to be expected that there will be lateral variations in offshore sediment granulometry.
2. The nearshore of Amchitka has patches of marine macrophyte beds, which can contribute to regional differences in particulate organic carbon contents in nearshore sediments

DATA NEEDED: Analyses of the sediment grain size distribution and organic carbon contents

WORK PLAN:
Grain size distributions of all the 80 samples of sea floor sediments, collected from the 8 target areas (Task 1.3), will be analyzed by the combined sieve-pipette method and the size distribution will be expressed in terms of the conventional statistical grain size parameters (mean size, sorting, etc.). Splits of all the above sediments will also be analyzed for their organic carbon contents, using an isotope ratio mass spectrometer (IRMS) located at the University of Alaska Fairbanks. The latter analysis, which will be on carbonate-free dry sediments, will provide simultaneous data on the contents of organic carbon (OC), nitrogen (N), and their stable isotopes ($\delta^{13}C$ and $\delta^{15}N$) and OC/N ratios, which will be useful to determine the sources of organic matter in the study area at no additional cost to the project. The procedure for the above analysis is outlined in Naidu et al. (2000).

TASK 1.3 RADIONUCLIDE ANALYSIS OF MARINE SAMPLES

TASK LEADER: Rod Hand (INEEL) and CRESP

QUESTIONS:

1. What are the radionuclide contents of biota, sediment and water column samples?

2. What is the groundwater component of sea water column samples?

UNCERTAINTIES ADDRESSED:
1. Radionuclide content of biota, sediment and water samples for isotopes potentially originating from Amchitka test shots.
2. Likelihood that observed isotopes originated from Amchitka test shots.
3. Dilution and mixing of ground water with seawater.

DATA NEEDED: Screening level gross alpha and beta analysis of biota, sediment and water column samples; Screening level gamma speciation on biota, sediment and water column samples. Isotope speciation for selected radionuclides on a subset of samples. Analysis for specific isotopes indicative of groundwater.

BACKGROUND:

Radionuclide analysis for indications of impact from the Amchitka test shots will be conducted on biota, sediment and water column samples. Table 11 provides a list of isotopes and their analysis approach. All biological samples will need to be reduced (wet digestion or muffle furnace) prior to alpha or beta analysis. Sediment samples also will require digestion prior to analysis. Specific methodologies will be identified and validated during development of the implementation plan. In order to conserve costs, samples will be screened for gross alpha and beta activity and gamma speciation. A fraction of the samples (i.e., 10%) will be subject to specific isotope speciation for alpha and beta emitters. Selection of samples for isotope speciation will be based on screening results.

Table 11. Radionuclide analysis and estimated costs per sample.

Analysis	**Approach**	**Estimated cost per sample**
Gross alpha/beta	Digestion + liquid scintillation or gas proportional detection	$300
Gamma Screening	NaI or HP Ge detection	$200
^{3}H	Gas proportional detection	$300
Alpha Speciation*	Digestion/prep + alpha spectroscopy	$1500
$^{238,239,240,241}Pu$		
$^{234,236,238}U$		
^{241}Am		
^{237}Np		

Gamma Speciation	HP Ge spectroscopy	$300
^{137}Cs		
^{152}Eu*		
^{60}Co*		
^{90}Sr	^{90}Y equilibrium	$750

*Alpha speciation will be confined to a small subset of samples, as DOE believes there is little chance that these isotopes from nuclear testing at Amchitka would be seen (NNSA-NV pers comm.).

1.3.1 Quantification of Radionuclides in Biota

It is anticipated that approximately 1000 biota samples (mainly pooled) will be subject to gross alpha/beta screening and gamma screening from the Summer 2004 sampling. Approximately 200 samples will result from the Summer 2005 confirmatory sampling. Methods selection and validation will occur using representative samples obtained during Summer 2003, and in coordination with development of the implementation plan for 2004. Thus, 25-50 samples will be subject to screening analysis during Fall 2003. Approximately 10 samples will be subject to specific isotope speciation and quantification (alpha, beta and gamma). Initial detection limits will be estimated based on back calculation from health risk thresholds, incorporation of a safety factor to allow detection before risk thresholds are exceeded, and consideration of anticipated background levels. Detection limits for the analysis of Summer 2004 samples will be established based on both the initial estimates and experience with the validation samples from 2003.

1.3.2 Quantification of Radionuclides in Sediment and Water Samples

Planned sediment and water sampling will result in 80 samples from each medium for gross alpha/beta analysis and gamma screening, for a total of 160 samples. It is estimated that 20% of these samples will be subject to detailed isotope speciation (alpha and gamma) and 20% of these will have Sr-90 quantification.

TASK 1.4 CONSUMPTION OF MARINE FOOD BY HUMANS

TEAM COORDINATOR: Kari Hamrick (UAA) and J. Burger (Rutgers University)

A/PIA COLLABORATOR: Robert Patrick.

QUESTIONS:
1. Is there a dietary pathway for radionuclides from Amchitka to reach people at levels of public health significance?
2. Does nutritional status influence exposure or response to dietary radionuclides.

UNCERTAINTIES ADDRESSED:

1. What is the variation in consumption patterns between Aleut villages?
2. How will these variations affect the exposure assessment?

DATA NEEDED: Analysis of food selection, preparation, and consumption patterns.

BACKGROUND:
Communities in the Aleutian and Pribilof Islands desire specific information on the benefits and risks of their diet that includes both traditional subsistence foods and store-bought items. The first step toward understanding diet and the associated health effects is to conduct a comprehensive dietary intake assessment at the community level. Traditional foods in the diet contribute to both significant nutritional benefits and possible contaminant exposure. Accurate food consumption information assists with the estimation of contaminant and nutrient intakes. There is little information about the radionuclide and nutrient composition of "as consumed" foods in Aleutian/Pribilof Island communities. Consumption studies are beneficial for helping communities prioritize species and particular tissues for contaminant analyses. This information is essential in a risk-benefit evaluation of traditional foods for specific communities.

Foods from the land and sea have been nourishing Alaska Natives for thousands of years. They nourish the body, spirit and community. The process of obtaining subsistence foods gives a person tasty food, exercise, fresh air, a chance to be with family, and something to share. These contributions are tangible examples of important cultural and social values. Dietary assessment instruments used in research settings are able to measure individual intake of foods or nutrients as well as overall energy intake. Twenty-four hour recalls and food frequency questionnaires are two instruments that are commonly used for this purpose. However, these instruments do not assess the importance of traditional foods, concerns about food safety, typical processing and cooking techniques and cultural distribution of harvested animals. Recent information (news, government advisories) on contaminants may have caused significant changes in the diets of Aleutian/Pribilof Islands residents. These dietary changes need to be quantified in communities that have already participated in food consumption surveys.

A dietary assessment has been completed for one Aleut community. This provided very valuable information on the dietary behaviors of Atka residents and emphasized the importance of obtaining comprehensive intake studies by season and for different islands. The Aleutian/Pribilof Island Association (APIA) recently received an Environmental Justice grant from the National Institutes of Health/ National Institute for Environmental Health Sciences. This grant provides funding to conduct a dietary intake study in St. Paul Island and follow-up dietary information from Atka. The final report is being reviewed by the participating communities and will be available for distribution in summer 2003. In addition, APIA has received a Resolve grant (Citizens Monitoring and Technical Assessment Fund) that funds dietary intake studies in both Unalaska and Nikolski. The dietary intake results for the Resolve communities will be complete by late summer 2003.

PREVIOUS STUDIES: DIETARY INTAKE DATA FOR ALEUTIANS:

A dietary intake study was conducted among residents of Atka from June 1998 to April 1999. The goals of the study were to assess the potential exposure to environmental contaminants in traditional, local foods, and determine the nutritional quality of consumed foods. Dietary intake field surveys were conducted over three time points to evaluate total nutrient intakes using a 24-hour recall, and usual intakes of selected foods using seasonal food frequency information (Bartell et al, 1999).

Mean energy and nutrient intake of 34 interviews revealed that most nutrients were in ample supply and exceeded recommendations for the general US population. For all age-sex groups, protein, iron, selenium, vitamin A, vitamin E, vitamin C, most B vitamins and phosporus intakes were adequate or high. However, mean intakes of several other nutrients were below recommendations, including calcium, fiber, folate, and magnesium, pantothenic acid and zinc (Bartell et al., 1999).

Traditional meats are of high quality, high quantity, and high variety make a substantial contribution to the diets by adding, which are all important to good health. Based on the 24-hour recalls from the Atka study, 66% of meats consumed were Native meats. Food frequency questionnaire data indicated that the most abundantly consumed traditional foods in all seasons combined were reindeer, sea lion, salmon, halibut, seal, bidarkis, cod, octopus, birds, wild rice, and other local fish. The most frequently consumed non-traditional meats include beef, chicken, chicken eggs, spam, hot dogs and hot pockets.

Studies are required to assess the effects of cooking and processing of traditional foods on both nutrient content and contaminant levels. The dietary assessment results compiled for all dietary assessments conducted in the Aleutian/Pribilof Islands will assist researchers in prioritizing species and tissues for the biological sampling regime.

Objectives

The objective of this study is to use a dietary assessment not only as a measure of intake and nutrition, but also as a tool for engaging public discussion about subsistence preference, dietary changes, health changes, and community priorities and concerns. Recent discussions with A/PIA representatives established that the most important communities for obtaining dietary data relevant to Amchitka are the Western Aleutian villages, which include Unalaska, Nikolski, Atka and Adak. Of those villages, Adak is the only community that does not have dietary intake data completed or in process.

The purpose of the dietary assessment is to help guide stakeholder research and provide a model for long-term tracking of traditional and non-traditional food consumption trends.

The specific aims of the dietary assessment are:

1. To document the diet of Adak village, including types and quantities of foods consumed.
2. To provide an assessment of the nutritional, cultural and physical benefits of a traditional subsistence diet in Adak, Atka, Nikolski and Unalaska (Western Aleutians villages).
3. To assess the most common methods of cooking and processing of traditional foods to evaluate the potential effects on radionuclide levels in each Western Aleutian village.
4. To provide interpretation and application of all dietary assessment results conducted in the Aleutian/Pribilof Islands and to apply the results within the context of risk assessment and long term stewardship activities.

WORK PLAN

Food frequency questionnaire (Specific Aim 1):

A semi-quantitative food frequency questionnaire (FFQ) will be performed once for approximately 50 individuals residing in Adak to assess the frequency (e.g. daily, weekly, monthly, yearly) and quantity with which traditional and market food items are consumed during a one-year time period. The list of traditional and market foods for the Core questionnaire (ATDP) was developed by a Diet Survey Development Advisory Board at Alaska Native Health Board to guide the process and survey development. Any interested party was invited to participate in this committee. The survey instrument includes categories of foods from all regions in Alaska, seasonal versus year-round consumption patterns, usual portion size, self-reported heights and weights, self-reported concerns regarding traditional and store-bought foods, and questions on the spiritual, cultural, and economic significance of traditional foods.

In addition, an addendum survey was developed in participation with community representatives, A/PIA project leader, and A/PIA nutritionist. The addendum survey includes 51 additional traditional foods found specifically in the Aleutian/Pribilof Islands. Both the Core and addendum surveys have been used in St. Paul, Nikolski, Unalaska, as well as 13 communities throughout the interior, arctic/subarctic and southeastern Alaska.

Information on past, current, or future fishing activity in the Amchitka area will be obtained.

Key informant interviews (Specific Aims 2 & 3):

An ethnographic study of food-related beliefs and behaviors among Aleuts would help to describe the prevalent beliefs surrounding diet and health among Aleut communities in order to better understand the use of traditional/subsistence foods and to develop appropriate dietary guidelines as a part of a risk/benefit assessment. This approach will be extremely useful and complement the more structured data being collected on the dietary intakes and patterns.

In-depth interviews will form the centerpiece for the ethnography. Field guides will be used to direct the interviews. The field guides will be on general themes related to the importance of harvesting and preparation of indigenous foods, perceptions of the relationship of diet, health and wellness, and concerns about food safety and the impact of contaminants in subsistence foods to the individual, community and culture. Free listing, pile sorting and ranking methodologies will also be used for the qualitative analysis. Other questions to be answered with this investigation include:

- trading and sharing practices,
- age and gender differences of subsistence harvest distribution,
- use of subsistence food parts depending on region, season and climate,
- anatomical or physical anomalies of animals harvested.

Key informants will be selected from each community that participated in a dietary intake assessment. In all, we will interview a minimum of 15 residents from each site, or a total of 60 respondents. The following participants will be eligible for the study: a) married, b) >25 years of age, c) current participation in subsistence activities, and d) >5 years residency in community. Results from the ethnographic study will be analyzed with the dietary consumption data from each community to provide a holistic view of diet behavior and how actual or perceived contamination of the subsistence food supply could impact food selection.

Interpretation & application for long term stewardship (Specific Aim 4):
It is essential for interpretation and application of these dietary assessment results that studies in the Aleutians be compared with other dietary intake efforts in Alaska and Canada. The nutritionists at the Institute for Circumpolar Health Studies (ICHS), University of Alaska Anchorage, have been involved with all the dietary assessment studies conducted or ongoing in the Aleutian/Pribilof Islands. Therefore, ICHS has the expertise as well as the institutional history to facilitate these analyses and to work with the CRESP team and participating communities to apply the results within the context of risk assessment and long term stewardship activities.

Results from the consumption surveys and key informant interviews will be shared with A/PIA and participating communities during community presentations. The goal of these presentations will be to engage public discussion about traditional diet, and formulate recommendations for appropriate ways to use the dietary results for risk exposure and involvement of the community in long term stewardship activities. Results will be incorporated into a peer-reviewed article for the scientific literature.

TASK 2 OCEAN CONDITIONS

TASK 2.1: OCEAN FLOOR CHARACTERIZATION

Question: What is the position and form of faults and fault zones as they extend from the test sites onto the sea floor?
Data needed: High resolution bathymetry and backscatter, sub-bottom reflection profiles.

Uncertainties Addressed:
1. What are the structural connections between the shot cavities and the seafloor, that may serve as pathways for groundwater migration and discharge?
2. Where do these structural connections intersect the seafloor?
3. Where have sediments accumulated?

Team coordinator: Jennifer Reynolds, UAF and John Lindsay, NOAA

A moderately detailed contour map of the seafloor in the immediate proximity of Amchitka was constructed in the late 1960s. It shows offshore extensions of some of the fault scarps mapped on the island, and provides an indication of water depths around the island. While some bathymetric data were collected by Nichols and Perry [with radio-network based navigation for their 1966 map series (D.Scholl, pers. comm.), other data in the NOS database for this region are lead-line soundings of 1930s vintage, with locations by dead reckoning. It is difficult to characterize even the 1960s data in terms of resolution, and indeed any mapping using modern narrow-beam sonar and navigational techniques will be an improvement. The bathymetry data hint at fault scarps and other structures, but there is large uncertainty arising from whether some of these are an artifact of the data and where they are actually located. GLORIA imagery is suggestive of fresh faults and landslides (Fig. 15) but far better resolution is now possible.

One component of the planned marine effort is the making of new maps of the seafloor (Fig. 9, 10). Reasons for this priority are:

1. The location and geometry of the offshore fault structures needs to be much better defined. This information will enable us to extend the map of the geologic structure of the island offshore, and to predict likely sites for groundwater discharge. Both the bathymetry and backscatter (pseudo-sidescan) data will be necessary for this purpose. A sub-bottom profiler may will be operated simultaneously with the sonar mapping system, to collect high-resolution profiles of the shallow sediment stratigraphy and fault structures. This will reveal what faults displace the uppermost, youngest sediments and therefore are the most recently active.
2. The information about the seabed in the existing map is patchy and inadequate for characterization of sediment distribution and bottom type (mud, sand, boulders, etc). These issues are relevant for developing the sediment sampling strategy, determining patterns of bottom currents, locating habitats for different types of biological communities of target species to be sampled, and potentially locating fresh-water

seeps by their influence on seafloor characteristics. The side-scan mapping is primarily directed at this need.

101Because of the need for specialized equipment and expertise, the seafloor mapping will be contracted to a commercial mapping company. Acquisition of a high-resolution bathymetric map will require installation of tide gauges on Amchitka Island for a period of at least two months in order to get reliable local tidal corrections. The cost of mapping is related to the number of transects; offshore transects are farther apart than nearshore.

Figure 15a.

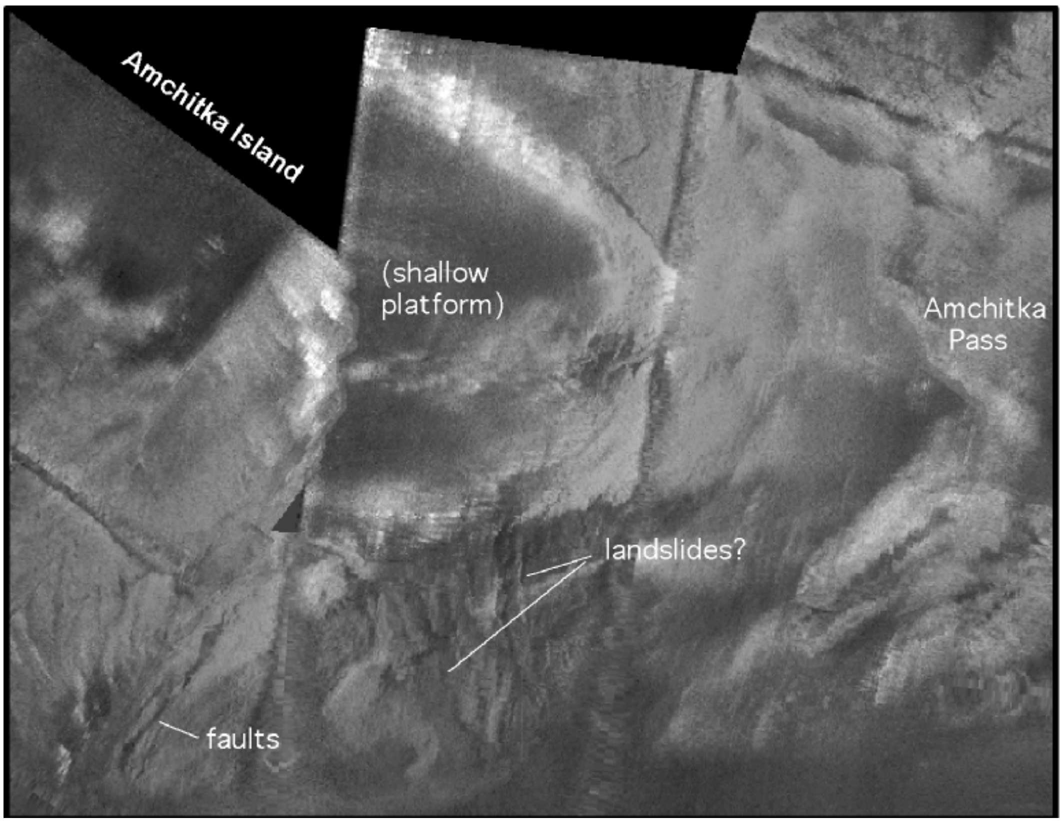
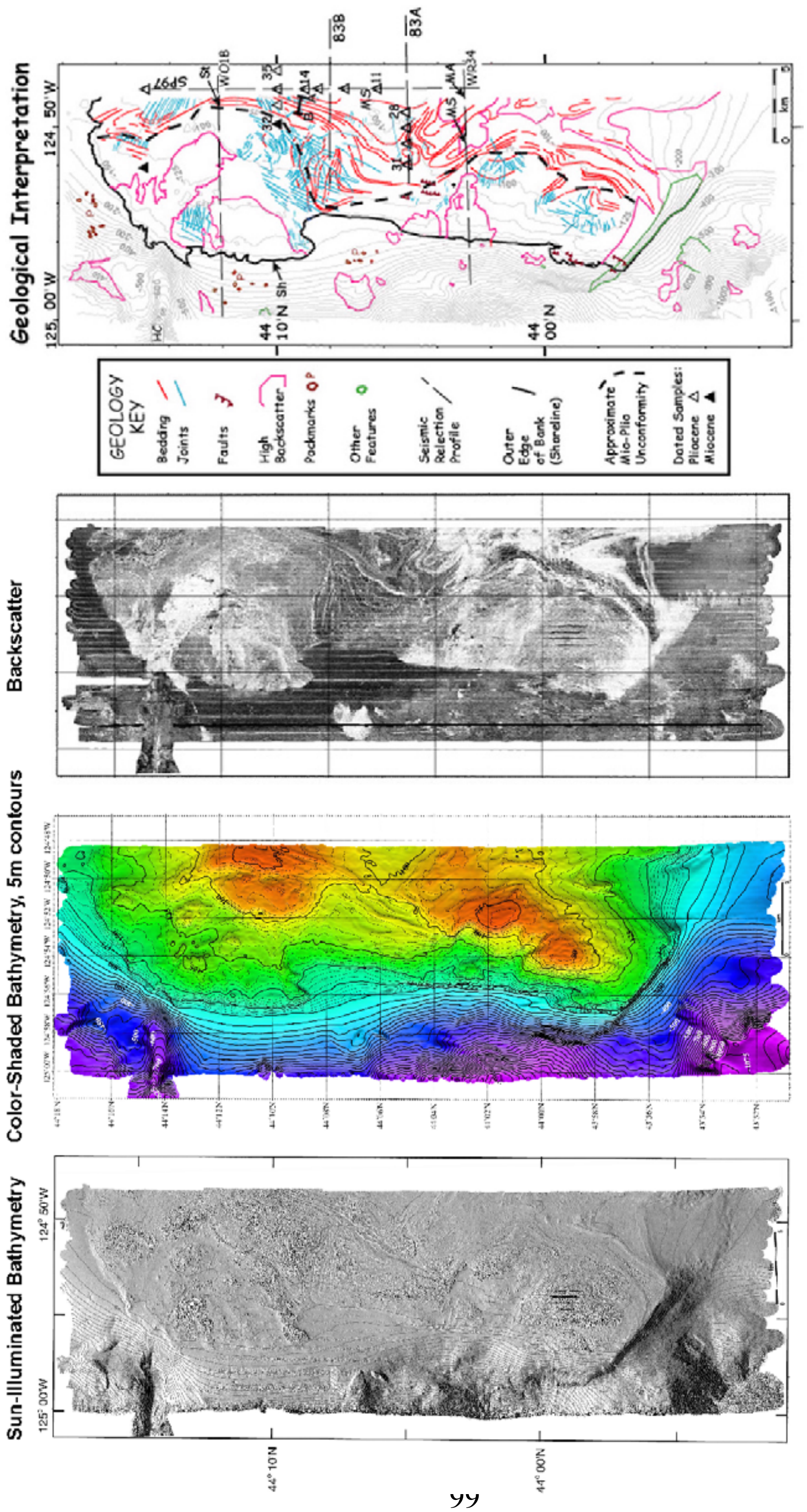


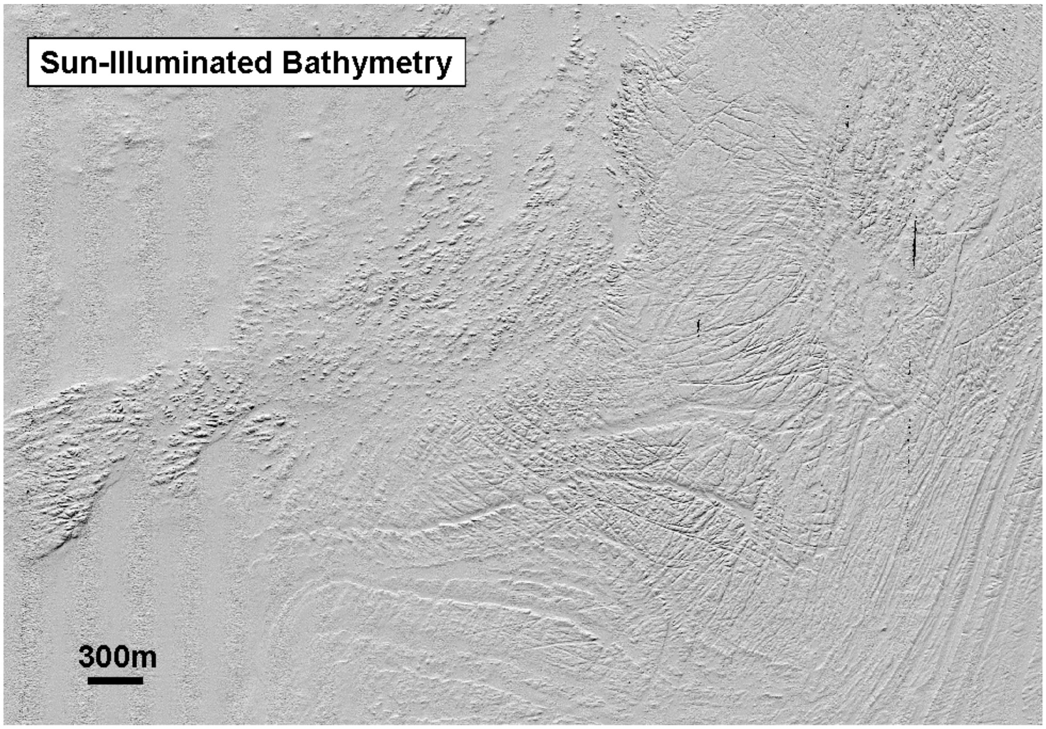
Figure 15: a) GLORIA side-scan imagery of the ocean floor off the southeast tip of Amchitka Island, suggesting fresh faulting and landslide structures well offshore from the island.

Figure 15: b) Example of high-resolution sea floor imagery from another wave-cut platform in forearc terrain (Heceta Bank, Oregon), and geologic interpretation based on the seafloor maps, seismic data, and geologic sampling, showing faults, joint sets, bedding planes, and contacts between geologic formations [Embley et al, 2003];

Figure 15: c) Details of the Heceta Bank bathymetry and backscatter maps, gridded at 5m cell size. These data are similar to the swath mapping data that we propose to collect around Amchitka.

Figure 15b


Geological Interpretation
125° 00'W
124° 50'W
44° 10'N
44° 00'N
GEOLOGY KEY
Bedding
Joints
Faults
High Backscatter
Pockmarks
Other Features
Seismic Reflection Profile
Outer Edge of Bank (Shoreline)
Approximate Mio-Plio Unconformity
Dated Samples:
Pliocene
Miocene
Backscatter
Color-Shaded Bathymetry, 5m contours
Sun-Illuminated Bathymetry



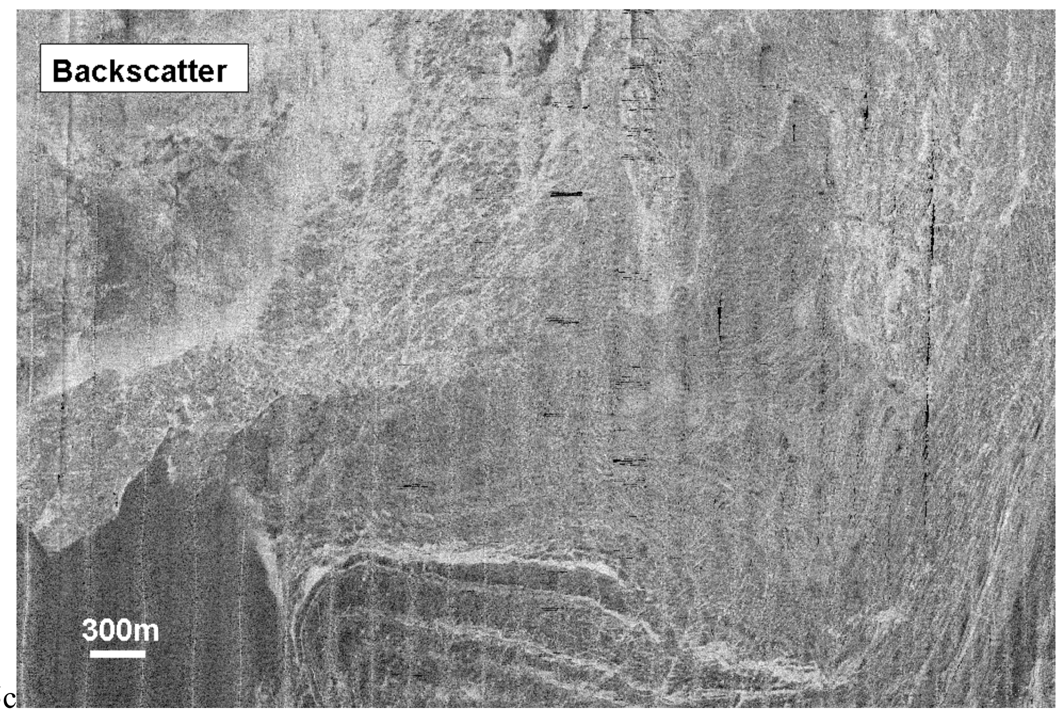


Figure 15c

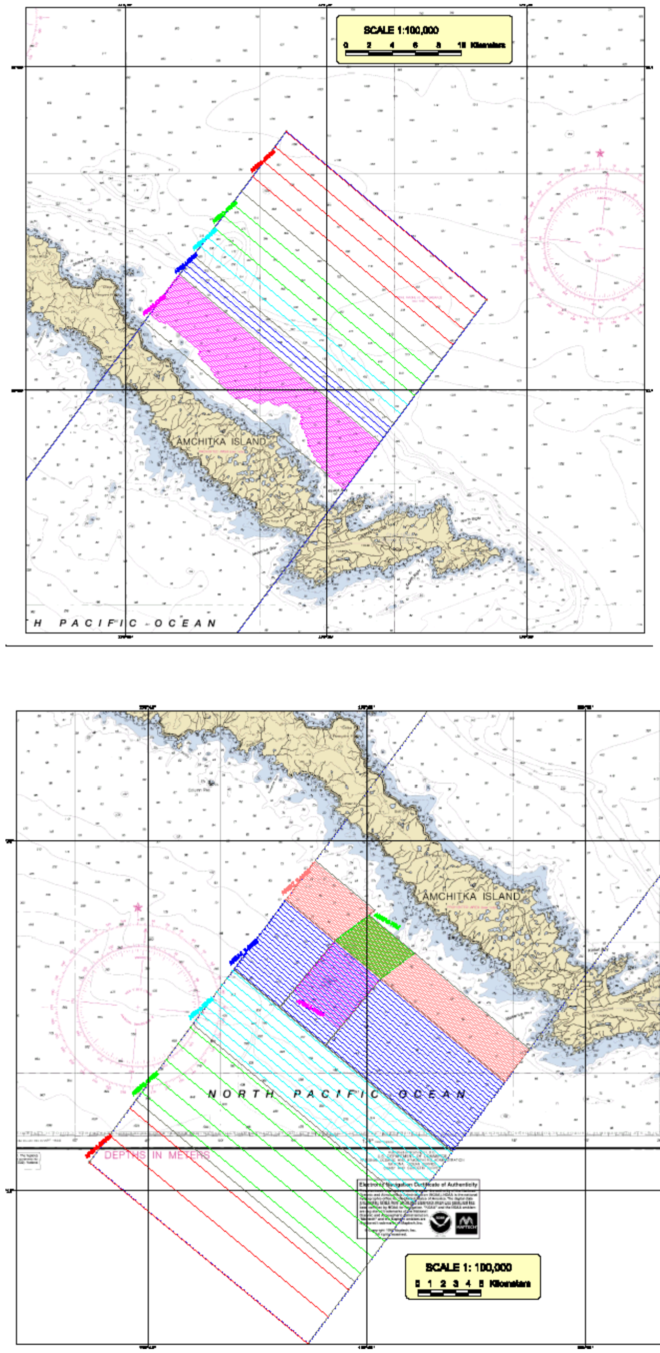


Figure 16: Planned coverage of seafloor bathymetry survey surrounding Amchitka test area. Color changes indicate changes in spacing of swaths, required by changes in water depth. Shallow water requires close spacing. The short dimension of the survey spans the test area while the long dimension extends to where sea floor elevation is equivalent to that of the deepest shot cavity.

Expected result: Delineation of young faults on the basis of surface morphology, acoustic backscatter, and near-surface reflection profiling. Sea bed characterization with general distribution of sediment types. Base map for *in situ* investigation of possible submarine seeps.

Milestones:
1. Selection of commercial mapping company, negotiation of a formal contract, schedule mapping operations. Winter, 2003-2004.
2. Collection and processing of multibeam swath mapping data, including bathymetry and backscatter, as a collaboration between the mapping company and geologists on this project. Summer, 2004.
3. Collection and processing of subbottom reflection profiling data, as a collaboration between the mapping company and geologists on this project. Summer, 2004.
4. Identification of fault zones, individual faults (primary and secondary) and any indications of whether they have moved recently, lithologic contacts on the seafloor, locations of anomalous seabed morphology or backscatter, regions of significant sediment cover and probable sediment types.
5. Extend the geologic map of the island to offshore regions, based on the new mapping data and existing sea bed samples, as well as the regional geologic framework [e.g., Scholl et al., 1987].

TASK 2.2 SALINITY STRUCTURE AND DISCHARGE

TEAM COORDINATOR: Johnson and Whitledge (UAF)

QUESTIONS:
1. Where is freshwater groundwater originating from the Amchitka test shots flowing into the ocean?
2. What is the extent of dilution and mixing occurring for the freshwater discharged through the sea floor?

UNCERTAINTIES ADDRESSED:
1. Location, flux and mixing of discharged groundwater in the marine environment?

DATA NEEDED:
Conductivity, temperature and density measurements as a function of water depth and location in the areas of anticipated groundwater discharge from the test shot areas.

BACKGROUND
An effort will be made to locate and directly sample (Task 1.2) both diffuse and localized groundwater (freshwater) discharges flows on Amchitka's submarine flank. Localized discharge seeps are analogous to springs on a subaerial mountain, and are a reasonable place to look for contamination. However, it will be uncertain whether located seeps originate from the test shot locations and what fraction of the overall discharge from the test shot locations that they represent. Hence, a balanced approach will be pursued to establish the general areas of diffuse

groundwater discharge likely to originate from proximity of the test shots and potential seeps contained within these diffuse areas. Even if these flows are free of test-derived radionuclides, they will nevertheless provide valuable insight into conditions within the island's hydrologic regime, such as age of groundwater and hence flow rate, temperature conditions, pH, etc. These sites have the potential to serve as critical monitoring points as part of long term stewardship, once closure is achieved. Identification of seeps is challenging, but in recent years, much scientific effort has been devoted to finding and sampling high-temperature hydrothermal vents on the mid-ocean ridges (Humphris et al., 1995). In this case, we will seek to define low temperature hydrothermal vents (e.g., Thomson et al, 1995; Wheat et al, 1997; Mottl et al, 1998) when anomalies are observed from broader salinity structure determinations used to establish areas of diffuse discharge.

Based upon present understanding, the strongest flows are expected to emanate along active faults oriented perpendicular to the least principal stress. Faults may also serve as natural boundaries for diffuse discharge areas. These general considerations will focus a more concentrated search. The primary evidence to constrain the search area are a) results from the DRI groundwater modeling study, b) evaluation of previously obtained geologic data (Task 3.1), c) the Amchitka structure and determination of the subsurface freshwater/saltwater interface and associated tellurmetric data (Task 3.2), and d) seafloor bathymetry (Task 2.1). These data will likely yield multiple linear target areas a few hundred meters wide by several kilometers in length.

The standard technique to find outflows in target areas is to conduct a conductivity-temperature-depth (CTD) survey, which relies on the chemical and thermal contrast between normal ocean water and water containing an admixed component of warm, low-salinity seep outflows. The measurements are precise and produced in real time, so that extensive areas can be surveyed rapidly and subtle anomalies detected. In practice the CTD (conductivity/salinity, temperature, density) is raised and lowered while being towed along a fault or scarp. If there is little relief in basement features, the CTD instrument will be towed close to the seafloor aided in part with an altimeter, thus allowing the CTD to be within meters of the seafloor. Additional sensors will be attached to the CTD. These instruments include a TV camera, and a rosette comprised of 12 individual fluid samplers. Fluids captured in the fluid samplers will be analyzed for a host of elements including radioactive products, thus providing the foundation for either background levels or the concentration and types of contaminates.

The CTD and SeaSoar data collected on board the ship and stored on computer disks will be analyzed post-cruise. The high resolution, three-dimensional measurements will be used to construct maps of the water masses in the nearshore of the study area, to identify site specific regions with relatively low salinity, higher temperature and nitrate (tell-tale for seepage), and to estimate along- and cross-shelf distributions of seepage waters from the Amchitka Island. Additionally, the high resolution SeaSoar data will be used to explore the mixing dynamics of water masses because some of the processes of interest likely occur at small spatial scales not easily resolvable by the traditional CTD sampling alone. In all these efforts the CTD and SeaSoar data will be combined.

Expected result: Identify sites for intensive biological sampling that will allow us to establish baseline concentrations and/or detect leakage for a future monitoring phase. Maps showing the three-dimensional distributions of salinity, temperature and nitrate concentrations of water masses for the study area. Direct observation of the discharge and dilution/mixing of groundwater.

Milestones:
2003: Development of implementation plan

2004: Field CTD measurements and analysis

TASK 2.3 OCEAN CIRCULATION

TEAM COORDINATORS: Mark Johnson and Zygmunt Kowalik (UAF)

QUESTIONS:

1. If submarine discharge of radionuclides originating from the Amchitka test shots occurs, to what extent will they be dispersed and where will they impact?
2. Will ocean and near shore currents transport discharged radionuclides to areas of high biological productivity where bioaccumulation may occur?
   Data: Ocean circulation and mixing patterns originating from the areas of freshwater submarine discharge from the test shots and until either dilution to extinction or deposition in areas of high biological productivity (e.g., shallow, near shore areas)

UNCERTAINTIES ADDRESSED:

1. Potential for rapid dilution and dispersion assumed in DOE risk assessment or potential for radionuclide transport and accumulation in areas of high biological productivity.
2. Refinement in biological sampling areas if deposition and accumulation areas are identified.

DATA NEEDED: Data on tidal flows, semi-permanent currents, large-scale eddies, storms, and annual cycles on surface and subsurface waters of the Amchitka environs and Amchitka Pass, suitable for modeling local and regional circulation.

BACKGROUND

Freshwater input from Amchitka Island, and any leaked radionuclides, will enter the marine ecosystem both to the north and south of Amchitka Island in proximity to the test shot sites. If radionuclide discharge occurs, it is important to know where the contaminants will be transported, the rates of dilution and if areas of localized accumulation exist. This is the basic problem of a contaminant plume in a fluid, and is amenable to both empirical observations and modeling.

Radionuclides entering the marine environment in the vicinity of Amchitka Island would encounter a complex mixing and transport regime. Water motion in the region of Amchitka Island is a superposition of three main regimes: a) trapped circulation around the island caused by tides and density distribution, b) semi-permanent motion through the Amchitka Pass, which brings North Pacific water into the Bering Sea and vice versa, and c) time dependent motion due to frequent storm surges.

The mixing conditions (rapid/slow dilutions) are the function of water motion, and motion in the shallow water will be forced by the tides and the wind stress. Therefore, it is important through initial observations to determine the locations of the front between the well-mixed water close to the island and the stratified waters at some distance from the island. Although, we will focus our investigation on local transport from the expected areas of discharge, we still need to understand how the local motion is influenced by the larger scale motion.

The dynamics in the shallow water around Amchitka Island are mainly related to tides. Tides around the Aleutian Islands, over the shelf break, and between the islands are still insufficiently determined (Kowalik, 1999). Tidally generated, shelf-trapped waves at the shelf break, and large tidal currents between Aleutian Islands, generate strong nonlinear effects, resulting in complicated spectra of the tidal motion. The basic tidal constituents, through nonlinear interactions, generate long-term and short-term oscillations and residual currents. The role of tides in the exchange of the water between the North Pacific Ocean and the Bering Sea is especially important (see Fig.16) Due to strong tidal currents, permanent residual motion has been established between islands (Kowalik 1999) influencing exchange between the North Pacific and Bering Sea. All of these factors will influence how any contaminants released from the island will move, how quickly they will dissipate, and whether local concentrations may occur.

Although oceanographic data for this region are sparse, it is expected that water circulation, and any transport of leaked radionuclides, will be clockwise around Amchitka Island. Mixing, turbulence, and storm events will result in near-shore residence times of generally less than one month. In the near shore region, the extensive kelp communities may have an influence on the flow structure of the bottom boundary layer. Farther offshore, it is especially important to understand that a major boundary current (Alaskan Stream) flows along the North Pacific flank of the Aleutian/Komandorski Island chain. On the Bering Sea side a relatively weak, eastward flow occurs (Roden, 1995). The transport in these currents is usually evaluated from the measured distribution of density, therefore little is known about the rates and the variations in these currents. The surface pattern of motion in the Alaska Stream is known quite well from the satellite-tracked drifting buoys (Stabeno and Reed 1994). The eastward flow in the Bering Sea and westward flow in the North Pacific are connected through the deep passes such as Amchitka Pass (1800m deep), where interaction between the Pacific and Bering Sea takes place. Roden (1995) analyzed the hydrochemical and hydrophysical conditions in this Pass and concluded that they are different from both the Bering Sea and the North Pacific. The differences are due to a well-mixed layer between 1200 and 1800m induced by strong tidal flow over highly complex bottom topography. In Amchitka Pass, Reed (1990) reported the results from year-long measurements of the currents at one station located in the eastern part of the Pass.

The average northward transport was modulated by the diurnal and semidiurnal tidal currents. Salinity and temperature profiles taken in the Amchitka Pass were used to perform geostrophic calculation of the currents based on the density distribution (Reed and Stabeno 1999). These calculations lead to a different pattern of the transport. Along with the northward transport on the eastern side of Amchitka Pass, the southward directed transport exists on the western side of Amchitka Pass. This general flow pattern often changes due to the transit of the Alaskan Stream eddy south of the Pass (Okkonen 1996), or southward shifts in the path of the Alaskan Stream (Stabeno and Reed 1994). The satellite-tracked buoys also revealed eddy-like motion in the central portion of the Pass. The images taken from the satellite display an intricate flow pattern in the surface layer in Amchitka Pass (Fig. 17). It should be stressed that bathymetry in the passages is very sparse, and this uncertain knowledge of bathymetry together with the presence of the many islands and passages complicate both the observations and modeling in the Amchitka Island area.

Assessment of the pathways for dispersion of contaminants will involve nested studies of the motion around Amchitka Island, starting from close proximity to the Island and continuing into Amchitka Pass and the region of the Alaskan Stream. The major thrust is measurements and numerical modeling of the dynamic processes around Amchitka Island. Acoustic Doppler Current Profiles (ADCP) and CTD (conductivity/salinity, temperature, and density data are needed to gain a better understanding of the ocean circulation patterns that would transport and disperse contaminants. Moored current meters will also be deployed. Satellite-based AVHRR imagery will be examined to further elucidate circulation paths. The primary purpose of the measurements is delineation of the tidal front location around Amchitka Island. The measurements will establish natural boundary between the shallow domain of stronger mixing and transport and the deeper domain, where the density stratification defines the transport processes.

WORK PLAN:
We plan shipboard observations during summer and year-long in situ oceanographic measurements. Measurements will be organized in two phases.

Phase I: a) shipboard observations of the local bathymetry for the numerical model, for accurate placement of current meter moorings, and for making hydrographic measurements to the ocean floor b) make observations of the local, time-dependent currents near shore using an acoustic Doppler current profiler (for comparison with model) c) make closely spaced (5km or less) hydrographic measurements along transects to infer water mass boundaries and likely spreading pathways

Phase II: a) deploy two current-meter moorings to the north and south of Amchitka Island at likely discharge locations to measure year-long currents and tides, b) recover moorings and compare yearlong measurements with model, c) redeploy current meter moorings as necessary for continued model validation and confirmation of contaminant pathways. The two moorings will be profiling moorings for making high vertical resolution measurements. Yearlong deployments will help determine whether mixing in the winter is sufficiently strong to completely mix the water surrounding Amchitka into the surrounding waters of the Bering Sea and north Pacific Ocean.

Models for local and regional ocean circulation will be developed with the aid of an improved database on bathymetry and circulation, to describe the role of atmospheric and oceanographic phenomena on residence times and paths of potential radionuclide transport (Kowalik and Murty, 1993). This information will be critical to formulating a response, should release occur.

Phase III: In the modeling task we plan the following steps: a) build a low resolution numerical model of the Bering Sea and Northern Pacific Ocean; b) build a mesoscale model to include Amchitka Island, Amchitka Pass and surrounding islands; c) build a high resolution numerical model around Amchitka Island. The purpose of these investigations will be achieved through the high resolution model. This model's open boundary conditions ought to be prescribed either from the larger scale models or observations. The larger scale models for the tides, density and wind driven motion will play the major role in this process. The measurements will serve important role of validation of the computed current and density fields.

The measurements and the models will be used to: a) describe the dominant tidal flows to estimate residence times for water around Amchitka; b) describe the role of the semi-permanent currents which flow through Amchitka Pass in and out of the Bering Sea; c) describe the role of the large scale eddies in the mixing processes in Amchitka Pass; d) describe the role of the annual cycle from wind forcing to update estimates of residence times; e) describe the role of storms on the regional ocean and their effect on residence times and pathways

Expected Results

The following critical information will be delivered from circulation/flow studies: a) direction and rate of dilution/dispersion from areas of groundwater discharge, b) potential for currents to carry groundwater discharge back towards shore or areas of high biological productivity.

The project is planned for the three-year period.

2003-04
Development and testing 2-D model for the Bering Sea and nearby Northern Pacific.
Development and testing 2-D model around Amchitka Island.
Introductory testing and development of a high resolution 3-D model around Amchitka Island. Open boundary condition for this model will taken from the 2-D models and from available data on the density and wind-driven forcing.

Analyze bathymetry for best location of moored current meter moorings. Design and construct MMP-profiling moorings for deployment to north and south of Amchitka.

2004 -05
Further development of the high resolution model and testing against available data.

Recover two MMP-profiling oceanographic moorings. Analyze data and provide data for validation of numerical model. Analyze data for assessment of tidal trapping and storm driving mixing.

2005-06
Continue with development of the 3-D model in the Amchitka Island domain and in the larger domain by including exchange processes between Bering Sea and North Pacific.

Continue analysis of mooring data for detailed estimates of summer vs. winter mixing, analysis of tidal currents, and model validation. Develop conceptual model of the annual cycle of currents around Amchitka Island.

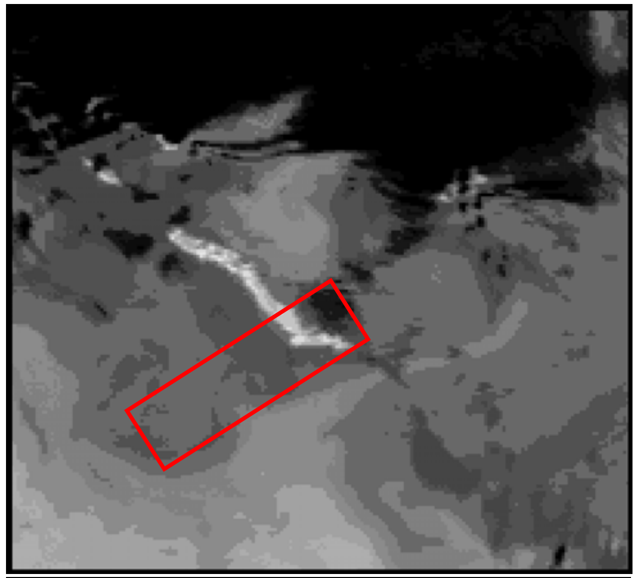


Figure 17: Satellite image showing warm Pacific water (light gray) flowing through Amchitka Pass southeast of Amchitka Island (white strip) and mixing with cold Bering Sea water (black). Approximate area of proposed bathymetric survey is shown in rectangle.

TASK 3: AMCHITKA GEOLOGY AND HYDROLOGY

TASK 3.1 AMCHITKA DATA RECOVERY AND SYNTHESIS

TEAM COORDINATOR: Frank Manheim (USGS)

QUESTIONS:

1. What archival information on Amchitka geology and bathymetry is available that can be made available to Amchitka researchers and synthesized to address current data needs?
2. To what extent is currently available bathymetry suitable to meet needs for planned field sampling and surveying activities?
3. What other geospatial data relevant to current assessment and long term stewardship can be recovered from earlier data sources (reports, maps, charts etc)?
4. How can historic data be linked to current and future data?

UNCERTAINTIES ADDRESSED:

1. Integration of past studies to define specific field sampling areas
2. Evaluate and make available prior bathymetry for Amchitka.

DATA NEEDED: Digitization and synthesis of data and reports from prior studies in USGS archives.

BACKGROUND:
Many maps and much data have already been obtained for the Amchitka land and marine system. The *Science Plan* will generate much additional data. Appropriate representation in a geospatial data base will provide the greatest flexibility for data analysis, modeling, and prediction. It will also provide the basis for communicating data from all phases to the public, through web access.

The U.S. Geological Survey (USGS) Library at National Headquarters in Reston Virginia contains hundreds of documents and maps compiled to prepare for the three underground nuclear explosions on Amchitka Island from 1965 through 1971, as well as post-test monitoring and synthesis reports, and relevant external studies. The majority of the studies were produced by USGS scientists as reports to the Atomic Energy Commission. USGS field work including radioactive monitoring continued through 1973, and syntheses were published into the 1980's. These documents provide the earth science and hydrologic background upon which the recent hydrologic modeling report by Desert Research Institute (DOE 2002b). Full availability of these data is needed for future studies designed to determine the status of possible radioactive leakage from the underground test strata. This cooperative proposal does not include new field data acquisition, but could include integration of data of more recent origin.

The proposed recovery and synthesis project will utilize the Reston archives as well as ancillary materials available at the USGS Center in Menlo Park (especially marine geophysical data). It will digitize, organize, and to the extent feasible, synthesize the most important elements of the data. The project would be conducted by a combination of USGS, CRESP, and other groups. The goal will be to develop a web site on which a combination of raw and synthesized data will be systematically placed as it is developed. The project would begin as soon as agreement among key participants and logistic arrangements can be achieved. The initial effort would last to one year, but emphasis will be placed on generating as much information as possible in the first six months to make useful information available to DOE and the stakeholders. Maintenance and updating of the data base and web site should be included in the DOE's long term stewardship planning. .

Principal data types to be recovered

Priority data pertinent to the search for pathways, exposure and risk, include the following items: a more specific order of priority would be developed on commencement of the project.

- Marine geophysical (seismic) studies, and bathymetric maps.
- Aeromagnetic survey maps and structural syntheses.
- Gravity maps
- Topographic, surficial geologic, and soils maps, including post-test changes
- Geologic and hydrologic studies based on boreholes: these include petrologic, chemical, and mineralogical analyses, geophysical logs, various pumping, pressure testing, permeability/transmissibility studies, geophysical logs, water chemistry analyses, and hydrologic modeling.
- Post-test radiological monitoring
- Post-test drilling, thermal, radioactivity and other studies at *Cannikin* site.
- Biodiversity and species distribution
- Contaminant survey data in water, sediment, biota
- Radiobiological post-test surveys

A more specific order of priorities will be developed in conjunction with stakeholders.

Other studies that should receive attention include but are not limited to botanical and biological surveys, earthquake, and climatological studies, and sedimentary geology, mainly associated with glacial and interglacial deposits. Note: shallow fault systems show different patterns than deeper fault and fracture patterns, which are regarded as the most critical for potential transport of radionuclide transport.
Work plan and targets

How the data are presented and integrated will make a great deal of difference in how effectively they can be used. The data retrieval should therefore be carefully attuned to the purposes of the CRESP –sponsored studies.

a) *Reston work phase*. We understand that qualified students (that may include native Alaskans) may be available to take a key role in the project. They would come to Reston for several weeks to acquire or enhance skills with special scanning techniques, advanced OCR software that can automatically separate and process text, tables, and graphics; databasing; and graphic techniques. They would copy and scan materials to bring back to Alaska to continue processing. This work would be guided by Robert Evans and Jeffrey Meunier.
b) *Bulk scan:* key (perhaps all) documents would be image-scanned and made available in PDF format. Large, high-resolution scanners are available to scan maps at Reston. Fast, advanced OCR-capable scanners should be purchased (Alaska & USGS-Reston).
c) *Digitization of geophysical and geological maps*: After consultation and analysis, digitization of geophysical, geological (including fault), and bathymetric maps would be undertaken. These offer key data, for which optimum presentation pose non-trivial tasks that require careful assessment of goals and methods, given the time and staff constraints.

A USGS public-domain autovectorization application is available and can be taken to Alaska.

d) *Digitization and databasing of borehole geologic and hydrologic data*. Achieving full use of these valuable data will require both image scanning and OCR scanning and special software. For electrical logs assistance by Denver staff who have special logging software (these applications cost >$10,000) might be sought; manual log digitization would probably be too slow. USGS CMG/EMRT has developed a broad-capacity database system in Microsoft Access, which has a user interface permitting persons with minimal Access skills to directly view queries in Excel spreadsheets. J. Meunier can serve as database manager, coordinating with training student assistants in data entry and basic Access skills.
The database system is portable, applicable to standard Access software, and can be used for other data integration purposes as well.

e) *GIS mapping, synthesis:* the usefulness of the archival data will depend in part on the way diverse data are combined and made available. Hopefully, expertise may be available in Alaska.

Milestones

- Initiation of data recovery and synthesis May 2003
- Inventory of data – June 2003
- 75% completion of data digitization – August 2003
- Draft synthesis report – September 2003
- On-going synthesis through May 2004

TASK 3.2 AMCHITKA STRUCTURE AND DETERMINATION OF SUBSURFACE FRESHWATER/SALTWATER INTERFACE.

TEAM COORDINATOR: Herbert A. Pierce (USGS)

QUESTIONS:

1. What is the location of the subsurface freshwater/saltwater interface on-shore and off-shore in the vicinity of the test shots?
2. What are the locations of fractures and faults adjacent to and extending seaward from the test shot locations?
3. What are the horizontal ratios of anisotropy, secondary porosity values, and strike directions as a function of depth for each of the test shot locations?

UNCERTAINTIES ADDRESSED:

1. Focusing of marine areas for biological sampling based on likely freshwater discharge areas.
2. Location of freshwater/saltwater interface.
3. Groundwater transport model parameterization (anisotropy, porosity)
4. Groundwater transport model conceptual model (fracture locations, strike directions)

DATA NEEDED: Onshore and offshore tensor magnetotelluric and audiomagnetotellurics surveys

BACKGROUND:
Understanding the fractures and faults adjacent to and seaward of below-ground tests on Amchitka Island are critical to constrain the scope of radiobiological sampling to the areas where freshwater discharge from the cavities and chimneys is likely to occur. It is proposed that magnetotelluric (MT) and audio-magnetotelluric (AMT) soundings both onshore and offshore be completed to provide, impedance and phase data, electrical cross-sections, horizontal ratios of anisotropy, secondary porosity values, strike directions at each frequency as well as indications of how the strike directions vary with depth. These primary and secondary data will provide information about how sub-surface faults and fractures affect the groundwater flow near the three test sites. This information can then be used in conjunction with the digitization, synthesis, and construction of a GIS database of existing USGS and other data to improve the groundwater flow models and provide online access to the data for all interested parties.

AMT and MT data are required to map the test cavities, chimneys, and the depth of the zone of dispersion (freshwater-saltwater boundary). Both techniques are required because targets range from the near surface to over 2 km below ground. Depending upon the frequencies collected AMT data are generally useful for the upper kilometer and MT data are useful for 0.5 km to more than 10 km below the surface.

Onshore work:

Four weeks of field-work are required to allow for the characterization of the top 2+ km from the islands groundwater divide across the three ground zeros (GZ) to the ocean. This will require deploying a variety of sensing equipment (Fig. 18a). In addition, another eight weeks of office time are required to process the data into the Society of Exploration Geophysicists (SEG) standard electronic data interchange (EDI) format and produce the plots, maps, sounding curves, rose diagrams, and electrical sections. We anticipate collecting at least 60 combined AMT-MT soundings on three grids with a station spacing of 500x500 m. Of these 75% of the stations will be seaward of the GZs. The grid will allow plan view resistivity maps to be constructed at various frequencies (depth slices) and for 2-D electrical cross-sections to be constructed both transversely and longitudinally to the islands axes within the grid. That is a minimum of 20 soundings per test site. These data should be extended offshore to include the suspected discharge areas.

Figure 18a: From top left to right (5) E-field electrodes, (3) H-field sensors, battery pack, receiver case, cables, receiver, GPS antenna, software, electrical section plots, palm pilot IR receiver controller, plan view plots of resistivity. This equipment has been used throughout the world in all environments wet and dry, hot and cold.

Offshore work:

Because of the difficulty and hence expense of collecting offshore resistivity data only 30 stations are proposed for a total of 10 stations per test site (Fig. 18b,c). These sites would complement and augment the onshore sites and would be integrated into the onshore electromagnetic (EM) database to provide information about the electrical nature of the rocks offshore. These stations would allow the continuation of the onshore electrical sections into the near-shore where fresh water presumably discharges from the island into the ocean.

Figure 18b: Deploying offshore version of EM gear. Tips of the long poles contain the E-field electrodes.

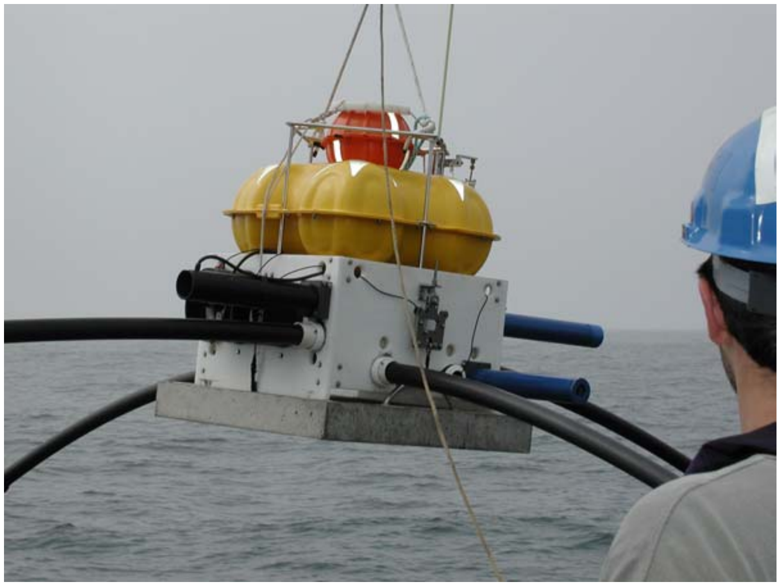


Figure 18c: Close up of the offshore EM gear. Blue rods are the H-field sensors, black rods spread the E-field electrodes, and yellow box contains the receiver.

The offshore work like the onshore work will provide major strike directions and variations with depth to help guide the sampling of marine biota and improve the groundwater flow models by mapping the potential flow paths for groundwater provided by faults and fractures, layering, and map the non-smooth nature of the zone of dispersion. The EM techniques should provide information on how the strike directions change with increasing depth. These data are critical because of the heterogeneous nature of volcanic blocks, the tectonically rotated nature of the volcanic blocks, and the man-made fractures introduced by the testing. Some of the uncertainty in the groundwater flow models can be addressed by completing these surveys.

TASK 3.3 GROUNDWATER RECHARGE

TEAM COORDINATORS: David Barnes and Daqing Yang (UAF)
QUESTIONS:

1. What is the typical annual recharge rate on Amchitka Island?
2. Given the measured value of recharge, what is the configuration and depth of the interface between the saltwater and freshwater?

UNCERTAINTIES ADDRESSED

1. The value of recharge used in the DRI Groundwater Model.
2. Position of the interface between saltwater and freshwater.

DATA NEEDED:

We will have direct measurements of precipitation and streamflow as a function of time. The time dependent values for evapotranspiration and recharge will be calculated. Modeling results will provide estimates of the depth to the interface as a function of location.

BACKGROUND

The location of the working points of each underground test on Amchitka Island will influence the rate of movement of radionuclides to the marine environment. The rate radionuclides are moving from a working point below the interface between the saltwater and the freshwater to the marine environment will most likely be much slower than the rate of radionuclide movement for a working point located above the interface. On Amchitka Island, the depth of this interface as a function of space is not known with any certainty. One of the key parameters required for estimating the depth of the interface is the amount of recharge to the freshwater aquifer in the watersheds where the tests took place.

WORKPLAN

The classical method of determining the recharge is by performing a water balance for the location in question. Parameters required for a water balance include precipitation, evapotranspiration, and runoff. Methods of determining these parameters include precipitation gauging, streamflow monitoring, evaporation measurements, etc. Performing these measurements on Amchitka Island presents challenges due to the Island's unique climate conditions and its relative isolation. High winds make accurate rain and snow gauging a challenge. Rain gauging instruments will be carefully chosen and the location for the instruments selected to reduce the errors induced by these conditions. Significant shallow flow emanating as springs complicates accurately measuring the runoff flow rate. These springs can be measured and included in the flux calculations. For these calculations, a survey of the springs is required over the island and the flow rates of the springs will need to be measured at different times (dry and wet seasons if possible). The location of the island complicates retrieval of the data and operation and maintenance of the equipment. For these efforts we hope to engage the help of the Aleutian residents who are closer to the Island.

The research outlined in this *Science Plan* will be completed in three years (two field seasons). The first field season will be devoted to identifying likely locations for equipment, installing some of the instruments, and for surveying the chosen watershed to identify surface water features. The remaining equipment will be installed and measurements will be taken during the second field season. This time frame allows for approximately two years of data accumulation. Obviously, longer measurement periods will result in more precise water balance calculations. However, it is possible to understand and quantify the important components/basic characteristics of a water balance based with only a few years worth of observation and analysis. Long-term climate data are available over the island. We will compare precipitation and temperature data (we collect) with historical records to determine if our study years/seasons are wet/dry/normal. This comparison will allow us to assess how representative the water balance results are to past measurements.

As in most water balances in wet climates, recharge is much smaller than precipitation and runoff. The accuracy of the water balance observations/calculations will be improved by collecting high-quality runoff data through frequent direct streamflow observation during the peak flow seasons. To improve precipitation data quality, density gauge network will be installed and bias adjustments for gauge precipitation measurements will be made.

The resulting value for recharge will be used with an appropriate numerical model to estimate the possible location of the interface between the saltwater and freshwater and how this interface is affected by changes in the recharge rate as a function of time. The design and installation of the monitoring system should be completed by the end of the second field season and will be linked to seismic and geodetic monitoring, as discussed below.

The position of the interface between the saltwater and the relatively less dense fresh water in the Island's subsurface is a sensitive parameter in the DRI groundwater model. A better understanding of the spatial distribution of this interface will both decrease the uncertainty in the groundwater model as well as aid any future monitoring program planned for the Island.

Expected Results

By the completion of this project we expect to have a weather station and stream gauges in place on the Island and approximately two years of data required to determine the amount of recharge occurring on the Island. We also expect to have better understanding of the position of the interface between the saltwater and the freshwater. We anticipate that we will be able to secure additional funding from other sources to continue gathering data in support of long term stewardship after the end of this initial funding.

Milestones
2003:

- Select equipment.
- Determine how to power the instruments and how to store and teleport data.
- Test instruments, power system, data storage and teleporting system.
- Characterize the watershed to be monitored using existing information.
- Select possible locations of instruments from existing information.
- Gather data from existing information for numerical model.

2004:

- Make the final select of the locations for the instruments while on the Island.
- Begin installing the instruments.
- Collect and analyze data.
- Gather surface water measurements.
- Build numerical model.

2005:

- Finish installing the instruments
- Collect and analyze data.
- Make necessary changes to instruments.
- Gather surface water measurements.
- Calibrate numerical model.
- Analyze results and estimate depth to interface.

TASK 3.4 RADIONUCLIDE CONTENT OF THE TEST AREA: THE SOURCE TERM

TEAM COORDINATORS: David W. Layton and David K. Smith (LLNL)

QUESTIONS:

a. What radioactive material was deposited by the tests?
b. Which radionuclides should be analyzed for in biota, sediment and water samples?
c. Can impacts from Amchitka test shots on the marine environment be distinguished from other sources of radionuclide contamination?

UNCERTAINTIES ADDRESSED:

1. Most effective suite of radionuclide analyses for biota, sediment and water samples.
2. Distinguishing radionuclide contributions from Amchitka from other sources in the marine environment.

DATA NEEDED: Information on Amchitka nuclear tests.

BACKGROUND:
The residual radionuclide inventory of the three Amchitka underground nuclear tests has been quantified but remains classified to protect nuclear weapons design information (Goishi et al., 1995). In the case of *Cannikin*, a drill-back operation was conducted and core recovered from the cavity itself. Much is therefore known about the physical and chemical form of the source (Claasen et al, 1978). The *Milrow* and *Cannikin* tests were conducted by Lawrence Livermore National Laboratory (LLNL). A much more comprehensive data base, including long-term results from sampling in monitoring wells, exists for the Nevada Test Site (NTS), and was considered by DRI in the groundwater model (DOE 2002b). Mechanisms and rates of contaminant transport at NTS are the subject of active investigation under the Underground Test Area Project (UGTA) at LLNL. We are therefore requesting guidance from LLNL to bound the radionuclide source term for the Amchitka tests, as well as to suggest an appropriate analytical strategy to detect radionuclides of concern based on their knowledge of the Amchitka tests and more recent experience with radionuclide migration at NTS (e.g., Kersting et al, 1999). If any of the indicator species are present in concentrations above background levels, then we will seek LLNL's further advice in interpreting whether or not the Amchitka tests are a likely source.

In this regard, it is important to recognize two things about a possible finding of anomalous levels of contaminants. First, there are numerous other sources of radionuclide contamination in the North Pacific (Layton et al., 1997). For this reason, detection of anthropogenic radionuclide signatures does not automatically implicate the Amchitka site. However, given that identification of the source is a key to risk assessment and risk management; it should be noted that isotope ratios have proven to be a useful technique for fingerprinting unique nuclear sources. Second, levels of contamination that are detectable may be well below what would pose a risk to the environment and to humans. Thus, identification of leakage of radionuclides from the Amchitka test site does not by itself mean that a serious problem exists. However, the detection of leakage from the test cavities would afford a means to interrogate the controls on radionuclide mobility and provides a means of monitoring for changes in those conditions, as well as optimizing a long-term strategy for biological monitoring.

Expected result: Analytical strategy for detecting the release of radionuclides from the tests and, if present, its significance.

Milestones**:**

2003

- Finalize list of source term radionuclides of significance for human health and analysis in biota, sediment and water samples
- Assist in the development of and provide review of the implementing steps for the science program

2004

- Participate in data analysis from initial field sampling
- Participate in planning for 2005 sampling efforts

2005

- Participate in data analysis from 2005 field sampling

TASK 3.5 WATER/ROCK INTERACTION IN THE ROCK ENVELOPE

TEAM COORDINATOR: David Barnes (UAF)

QUESTIONS:

1. What are the effective diffusion coefficients for the dominant rock types?
2. What are the partitioning coefficients for key radionuclides on the dominant rock types?
3. How significant of a factor is diffusion on the movement of radionuclides through the subsurface?

UNCERTAINTIES ADDRESSED:

1. The values of effective diffusion and sorption used in the DRI Groundwater Model.
2. Expected mass flux of radionuclides into the ocean with time.

DATA NEEDED: Effective diffusion coefficients for the dominant rock types and the partitioning coefficients for key radionuclides onto these materials.

BACKGROUND:
Evaluation of the risk posed by the Amchitka tests must be based on transport modeling, which in turn depends upon knowing the fate of contaminants in fractured rock. Contaminant movement through fractured rock, as in the case of Amchitka Island, may be influenced by the diffusion of contaminants from the fractures into the surrounding formation rock. Sorption also influences the movement of contaminants through the subsurface. Contaminant movement by advection in the fractures and movement by diffusion into the matrix rock are both affected by sorption. A better understanding of the possible diffusion of radionuclides into the subsurface matrix rock on Amchitka is required to both decrease the uncertainty in the DRI Groundwater Model as well as for long term stewardship. The goal of this study is to determine the effective diffusion coefficients (including sorption) of key radionuclides into the different predominant types of matrix rock found in the Island's subsurface. The results of this research will both decrease the uncertainty in the DRI Groundwater Model and provide a better understanding of the movement of radionuclides through the subsurface, which is required for long term stewardship.

Brown (pers. Comm.) conducted a comprehensive investigation of the sorption and diffusion of Pb(II) and ^{137}Cs onto Amchitka native materials. Results from this testing showed Pb to be strongly adsorbed to both breccia and basalt with Cs was only weakly sorbed to both material. The diffusion rate of Pb was much less than the diffusion rate of Cs. These tests were conducted in a high ionic strength synthetic ground water over a wide pH range (6 to 9). Assumption were made as to the applicability of the results from these two radionuclides to other radionuclides associated with the Amchitka underground nuclear testing and were incorporated into the DOE modeling effort (Chapman, 2001). To reach the goal of decreasing the uncertainty in the DRI

Groundwater model as well as to aid long term stewardship, additional studies beyond Brown (1997) are required to have a better understanding of the magnitude of the diffusive fluxes.

According to the sensitivity analysis conducted on key transport parameters in the DRI Groundwater Model (DOE 2002b), the matrix diffusion parameter is a sensitive parameter. However, the DRI Groundwater Model does not treat the matrix diffusion coefficient as a random variable dependent on the radionuclide and geologic strata due to the lack of available data (DOE 2002b). It is well known that sorption and diffusion characteristics are different for each element and are dependent upon the type of sorbent. To be more specific, the effective diffusion coefficient is a property of the matrix rock's porosity and tortuosity. Thus, owing to the uniqueness of these parameters to the material, the precision of any model is compromised by relying on literature values of effective diffusion coefficients.

In addition to decreasing the uncertainty in the model, gaining a better understanding of the nature of radionuclide diffusion into subsurface rock on Amchitka provides needed information for decision makers concerned with long term stewardship. With this information more informed sample planning could take place. For example, if diffusion of radionuclides into the matrix rock is occurring in the subsurface, then the result will be a decrease in the magnitude of the mass flux entering the ocean at any time. In comparison, if diffusion is not a factor, then the mass flux into the ocean will be greater. This type of information is required for proper monitoring. Currently, information that is available on diffusion into the Island's subsurface rock indicates that diffusion of radionuclides is possible. While the testing that has occurred is a valid first step, more comprehensive information is required.

Expected Results
By the completion of this project we will better understand how diffusion influences the mass flux of radionuclides from the shot cavities into the ocean. This information both aids the DRI Groundwater model as well as long term stewardship.

Milestones
2003-2004:

- Develop testing methodology.
- Locate core from the Island that is in different storage locations (some core is stored at UAF).
- Identify the rock types to be tested.
- Cut the rock cores into the configurations required for testing.
- Perform batch sorption tests with stable isotopes of key radionuclides.

2004-2005

- Perform diffusion tests.
- Analyze results.
- Document results.

TASK 3.6 RADIONUCLIDE SORPTION ON SEDIMENTS

TEAM COORDINATOR: Sathy Naidu (UAF)

QUESTIONS:
What is the capacity of the clays deposited around Amchitka Island to scavenge, by adsorption, particle-reactive radionuclides discharged into the marine environment from the Amchitka shots?

UNCERTAINTIES ADDRESSED:
Determination of whether or not ocean floor clays in the Amchitka vicinity are a sink for radionuclides.

DATA NEEDED:
Estimates, from controlled laboratory experiments, of the adsorptive capacity of a representative particle–reactive radionuclide (^{137}Cs) for marine clays deposited around Amchitka Island.

BACKGROUND:
The fate of dissolved or colloidal-bound radionuclides subsequent to their discharge into the marine environment depends on several possible complicated biogeochemical processes. However, it is likely that most of the particle-reactive radionuclides will initially be relatively quickly sequestered from sea water by scavenging by clays, organic particles, and/or are co-precipitated in ferri- and manganic oxides and hydroxides, and/or as organic chelates (Robinson 1962, Bates et al. 1992, Kersting et al. 1999, Fuhrman et al. 2001, Zachara et al. 2002). However, little is known about the processes of scavenging as it can involve several interacting environmental factors, natures of a matrix of particles and their surface characteristics, and a knowledge of the type and state of the radionuclide involved. It is generally assumed that one of the primary scavenging process is by adsorption of radionuclide on clay minerals (Robinson, 1962). We hypothesize that the radionuclides originating from the Amchitka shots and subsequently discharged into the marine environment by surface seepage and/or submarine seepage will be susceptible to quick adsorption by marine clays. Thus, clays depositing on the sea floor could be an effective primary sink for the radionuclides. It is possible that radionuclides subsequently released from post-depositional desorption to the water column (Sanchez et al. 1986) could bioaccumulate in benthic organisms or transferred to higher trophic organisms.

The basis of our hypothesis lies on the fact that the marine clays in the vicinity of Amchitka Island are dominated by smectite clay mineral (Naidu et al., 1995). Smectite, which has one of the highest ion exchange capacities, is expected to have a high potential for adsorbing radionuclides. Clarifying the role of the above clays in sequestering radionuclides will be prerequisite for understanding the fate of the radionuclides, which are discharged into the marine environment from the Amchitka shots. It is, therefore, proposed to estimate the adsorptive capacity of the smectitic clays of the Amchitka margin.

The adsorptive capacity of the Amchitka marine clays for radionuclides will be estimated by controlled laboratory experiments and expressed as adsorption coefficient distribution. For the purpose of our study the term adsorption will be restricted to the general reaction of a radionuclide in a solute with clay surface, rather than several possible solute-particle interactions. Additionally, our estimation of the adsorptive capacity will be limited to calculations of the distribution coefficient, K_D, for radiocesium, a nuclide which is assumed will serve as a suitable representative proxy for all radionuclides originating from the Amchitka shots. We prefer to choose radiocesium, because ^{137}Cs, is one of the high-yield fission products expected from the Amchitka nuclear underground tests and which can be entrained in any submarine freshwater seepage and land run off that might be occurring.

WORK PLAN:
For our investigations we intend to follow the methods outlined in Zachara et al. (2002). In brief, our experiments will include treatments of known activities of ^{134}Cs (half-life 2.05 yrs) or ^{137}Cs (half-life 30.1 yrs) dissolved in different concentrations of saline water with milligram quantities of the Kamchitka marine clays, followed by time-series monitoring of the radiocesium activities in the solute and clay particles. The radiocesium activities will be measured by high resolution gamma spectrometry at the University of Alaska, Fairbanks. The experiment will be conducted under a range of pH, temperature and salinity conditions of the water and particle concentrations. The clay size (< 4um size) will be separated from gross sediments by centrifugation or settling.

To the extent possible the experiments will be kept simple (saline solutions made up of NaCl), but closely mimicking the salient environmental conditions in the Amchitka margin as far as the above experimental parameters are concerned. The experiments could be extended to onshore soil clays and taking into consideration conditions prevailing there, to compare adsorption capacities of clays between freshwater and marine regions. As we intend to conduct the experiments on clay samples collected from representative regions of the Amchitka margin, it will be necessary to normalize results of our experiments to any regional differences in the clay mineral compositions of the particles. Therefore, we will estimate the relative abundances of the clay mineral types (smectite %) using X-ray analysis on splits of all the clay samples involved in the experiments. The steps for the clay mineral analysis are enumerated in Naidu et al. (1995).

Expected results: a) calculated distribution coefficient, K_D, for Amchitka clay-radiocesium reactions, which will provide a measure of the potential adsorptive/scavenging capacity of the clays for radionuclides originating from the nuclear shots, b) The above data will provide a basis to model the marine biogeochemical fate of the radionuclides, extent of entrainment and circulation of radionuclides in water (Task 2.3), and to predict the potential for bioaccumulation of the radionuclides (Task 1.1).

TASK 3.7 DEFORMATION OF THE AMCHITKA MASSIF

TASK COORDINATOR: Jeff Freymueller (UAF)

QUESTION:
1. What is the motion of crustal blocks within the Amchitka region, which faults are active, and what is the current orientation of the stress field?
2. What is the status of the faults in close proximity to the test sites?

UNCERTAINTIES ADDRESSED:
1. Detection of fault activity near the test shot cavities contributes to predicting the likelihood and timing of migration of radionuclides to the sea.
2. Measurement of strain averaged over time periods of 1000s of years will inform the long term Stewardship planning process.

DATA NEEDED: Determination of earthquake locations and source mechanisms; high-precision geodetic measurements; quantitative geological strain measurements.

BACKGROUND:
If active faults are cutting across Amchitka close to the test cavities, risk assessors would assume that radionuclides could reach the marine environment. The behavior of the faults across the island are highly uncertain, and these clearly have the potential to change flow characteristics; hence understanding activity patterns is important to the risk process, and long-term monitoring of activity will trigger other risk management activities.

Faults, especially active faults, can be preferred pathways for fluid flow. Amchitka lies in a tectonically active zone, of rapid extension of the Aleutian arc, and is cut by faults of unknown activity. This was unknown at the time of the nuclear tests (1965-1971), and it is unknown today how much extension occurs across the island and how much occurs in Amchitka Pass, east of the island, but the total extension rate between Amchitka and Adak to the east is comparable to the total extension rate across the western Lower 48, which produced the Basin and Range Province, and is roughly an order of magnitude higher than the extension rate across Yucca Mountain or the Nevada Test Site. The test shots on Amchitka were located close to faults, several of which reach the surface (see Fig. 3b). Future slip on these faults may open pathways for radionuclide migration. The proposed seismic measurements will establish a means to identify when these faults are active, and are necessary for determining when additional marine environment monitoring will be required in the future.

The regional stress field on Amchitka and local perturbations to it control which fractures in the earth may be open or closed, potentially establishing a preferential direction for fluid flow in a system dominated by fracture flow. Fractures perpendicular to the maximum principal compressional stress direction will remain closed unless fluid pressures within them are high enough to exceed this stress. Fractures perpendicular to the minimum principal compressional stress direction will be open at much lower fluid pressures, and if that minimum stress is actually extensional then fractures could remain open without any significant fluid pressure (Hickman et al, 1997). Fractures that are active faults are favorable pathways because their stress state is close to failure and because repeated rupture counteracts the tendency for mineral deposition to seal fractures. During the *Cannikin test*, water was expelled from some faults that slipped in response to explosion. Knowledge of fault positions, orientations, and motions permits derivation of the stress field driving these motions. This, in turn, allows prediction of what faults are likely to provide fluid flow paths and hence will help to constrain the search for seeps. These measurements will also allow us to, for the first time, make an informed estimate of the likelihood, over the long stewardship period, of significant nearby earthquakes that could perturb the stress field and flow pattern.

To predict likely pathways for fluid flow and be able to make an informed assessment of the likelihood that faults will act as pathways for rapid fluid flow to the environment, we require a knowledge of the dynamics of the system. We know the locations of the major faults that cut the island, but we do not know which faults are active, nor how fast the active faults move, nor how often they break, nor in general at what rate tectonic stress accumulates. To gain this understanding, we will install a combined seismic and Global Positioning System (GPS) network. The network will provide the following:

1. Definition of planes of microseismicity that illuminate currently active faults.
2. Rates and directions of deformation in response to existing tectonic stresses (e.g., Freymueller et al, 1999).
3. Calculation of earthquake source mechanisms that will reveal stress directions (e.g., Gephart and Forsyth, 1984).

In addition, re-analysis of the seismic records from the tests using modern techniques may significantly improve locations of induced seismic events and reveal which faults were activated by the shots and how far from the shot points they were activated. Results of the MT survey may provide complementary data if fault zones contain saltwater; such faults would appear as planes of high conductivity. Active fault structures will be remapped and analyzed using modern quantitative structural analysis (ave Lallemant, 1996). Fault offsets will be measured and dated, complementing the GPS data with strain data that average over a longer time interval of thousands to tens of thousands of years.

A seismic monitoring network was put in place for a short time before and during the testing period. The network was removed after the tests. Although these data are not useless, data quality is far from modern standards. Other than in this brief period, this entire region of the western Aleutians has not been instrumented. The lack of local instruments means that earthquakes smaller than magnitude 4.5-5 are never detected, and uncertainties in earthquake locations are of the order of 20 km or more. This makes it virtually impossible to locate active faults, except those that rupture in major to great earthquakes larger than magnitude 7.

WORK PLAN:
Active faults and fault activity can be located at Amchitka by deploying a network of seismic stations across the region, which will be capable of locating the small earthquakes that are much more frequent than large ones, and which may reveal faults that could create pathways for migration of radionuclides to the sea. In order to provide information on fault locations in time for other tasks of this project to use, data from this network must be telemetered off the island. Although requiring a larger initiation capital investment than on-site data storage, telemetry will also significantly reduce the cost of data analysis, as all data from the Amchitka network can be included in the normal Alaska Volcano Observatory (AVO) and Alaska Earthquake Information Center (AEIC) operations.

A seven-station telemetered seismic and geodetic net (Fig. 19, 20) is proposed for establishment on Amchitka and the neighboring islands, with a satellite communications terminal (VSAT) located there as well. Three-dimensional earthquake locations require a minimum of 4 seismic stations recording each event, and earthquake locations improve in accuracy with additional stations. The sites on adjacent islands are needed to give the array necessary breadth. Data will be recorded and analyzed as it is acquired at the UAF/GI Seismology Laboratory in Fairbanks. The network will provide extremely sensitive detection of earthquake activity under Amchitka.

At a minimum, two seismic stations on Amchitka would be needed to provide reassurance to stakeholders that seismic events can be localized.

A somewhat more extensive network was installed in an analogous environment, the Adak region, by AVO during the summer of 1999. Figure 21 shows that two years' of data from this network clearly delineate zones of high activity.

Summary of main sub-tasks under 3.7

1. Install and operate seismic network to monitor seismicity to identify locations and lengths of active faults.
2. Install and operate GPS network to monitor deformation; rapid deformation means high earthquake potential.
3. Remap and analyze active fault structures using quantitative structural analysis.
4. In stewardship phase: assess the extent of "shaking" and possible change to flow field in the event of earthquake or eruption.

The geophysical network installed during this assessment will become an integral component of the subsequent stewardship phase, following in-place closure of the site. In the case of a large nearby earthquake or volcanic eruption, it will be possible to immediately assess the extent of shaking and deformation that could disrupt the shot cavities and groundwater flow paths, and hence gauge whether a field response is required.

Expected result: Geophysical definition of likely fracture flow paths. Installation of an observing network that will remain in place for monitoring during long term stewardship.

The monitoring system will reduce uncertainty in the future, by identifying activity along critical faults where radionuclide migration might occur. This can be a trigger for activating monitoring of the abiotic and biotic marine environment.

Milestones
Spring 2004:
Purchase and prepare seismic station equipment for field
Purchase and prepare GPS equipment for field deployment
Purchase and prepare VSAT remote terminal for field deployment
Purchase and prepare power system for VSAT

Summer 2004:
Test VSAT uplink in Fairbanks
Deploy GPS and seismic network with VSAT uplink
Survey previously existing GPS points on Amchitka island
Update seismic network acquisition to bring in seismic data, begin analyzing data
Update GPS analysis system to handle incoming GPS data, begin analyzing data

Locating earthquakes and analyzing incoming seismic data is a steady, ongoing process once the network is installed. Earthquakes will be located, and focal mechanisms or moment tensors estimated for the larger events, on an ongoing basis.

Fall 2004:
Analyze data from existing GPS survey points, calculate displacements since 2001.

Winter/Spring 2005:
Calculate preliminary deformation model based on 2001-2004 displacements
Prepare initial summary report on seismicity and observed deformation; focus on any unusual characteristics.

Summer 2005:
Service and fine tune GPS and seismic network on Amchitka
Pick up any data not successfully telemetered.

Fall/Winter 2005:
Analyze any non-telemetered data

Spring 2005:
Prepare second summary report on seismicity and observed deformation; focus on any unusual characteristics.

Fall 2005/Winter 2006:
Analyze seismicity map
Calculate regional stress model using focal mechanisms/moment tensors
Calculate strain rates from all GPS data; make preliminary assessment of potential fault slip rates

Spring 2006:
Write project summary report

Figure 19: A telemetered geophysical station on Umnak Island recently installed by AVO, of the type to be employed for the Amchitka net. The geophone is buried in the ground and connected to the hut by a cable. The hut houses the GPS antenna and electronics for GPS, seismic, and telemetry. Power is supplied by solar cells. Such stations can operate unattended for up 5 years. (Photo: S Moran, USGS). Equipment placement will take into account the strong winds.

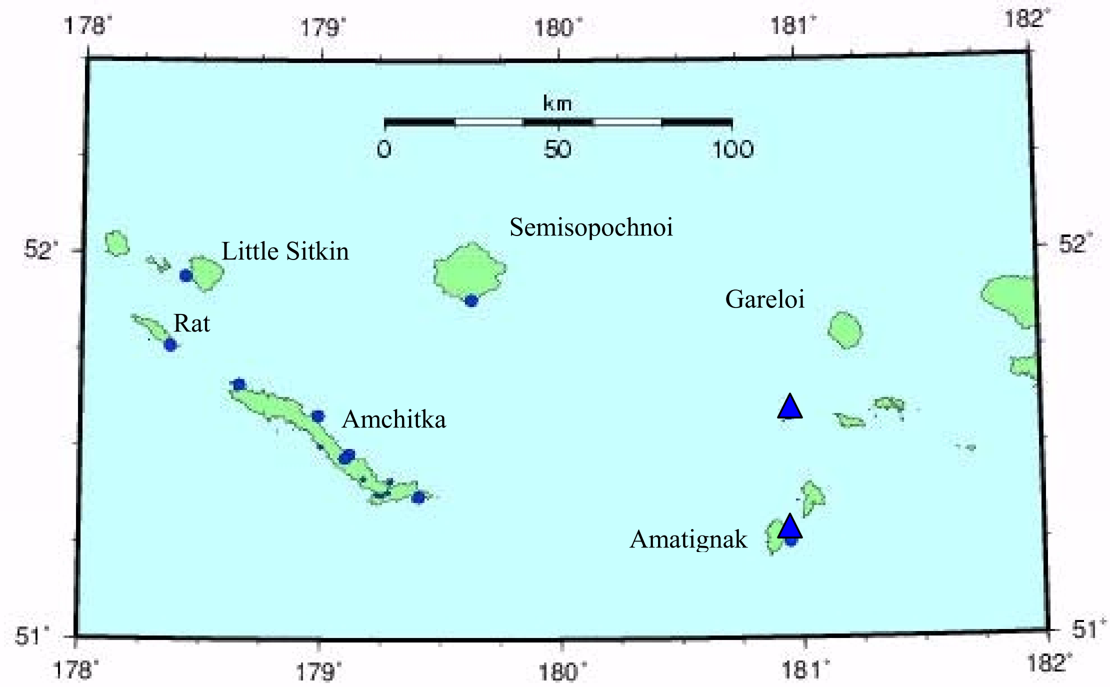


Figure 20: Proposed sites for seismic and GPS array. Blue dots show locations of planned telemetered stations with digital broadband, strong motion seismic instruments, and continuous GPS. Blue triangles will be bench marks occupied periodically to detect spreading across Amchitka Pass.

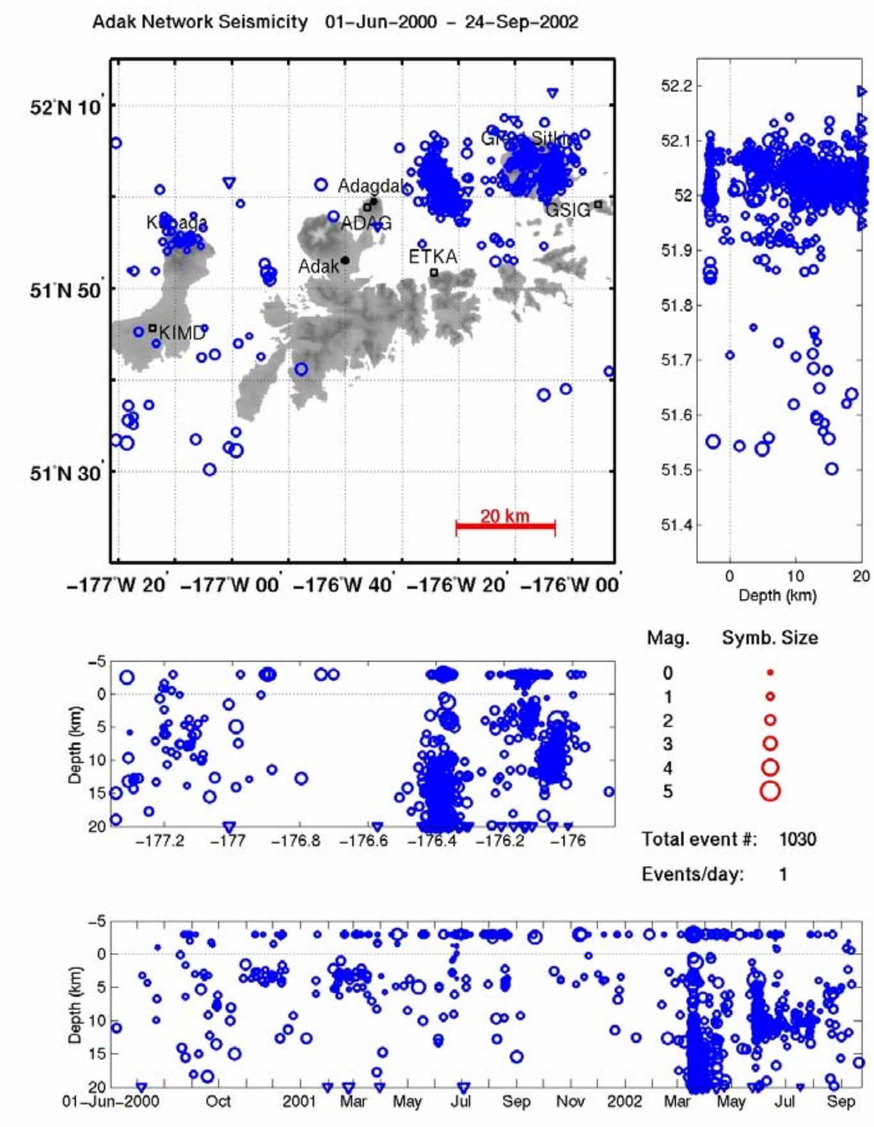


Figure 21: Earthquake locations from the Alaska Volcano Observatory's Adak network for the period 2000 to 2002, showing the high rate of seismicity typical of the Aleutians. In this case most of the seismicity is related to shallow magma bodies and their associated hydrothermal systems (courtesy of Alaska Volano Observatory).

TASK 4 STAKEHOLDER DIMENSIONS

TASK 4.1 STAKEHOLDER PARTICIPATION

TEAM COORDINATORS: CRESP
COORDINATOR FOR EDUCATIONAL PROGRAMS: Larry Duffy (UAF)

QUESTION:
1. How shall Aleut communities and other stakeholders be involved in the *Science Plan*?
2. What are the stakeholders' main concerns?
3. What kinds of information are needed to keep stakeholders informed of the process?
4. What are the needs for establishing a credible monitoring program?

UNCERTAINTIES ADDRESSED:
1. Level of involvement of stakeholders at different stages of the planning, implementation and interpretation?
2. Main stakeholder concerns regarding hazards, exposures, risk, and risk management?
3. Communication needs and methods?

DATA NEEDS: information on needs of the Aleut community, natural resource trustees , fisheries, and other stakeholders to allow them to participate in all aspects of the implementation of the *Science Plan*.

BACKGROUND:
Stakeholder participation in the planning and conduct of the project is essential to the appropriate design, credibility, and therefore the usefulness of conclusions drawn. In addition, an educated and involved resident population is the key ingredient to maintaining government resolve in stewardship over the long term (NRC 2000). DOE has recognized the importance of transparency and stakeholder involvement (Omenn 2001).

Stakeholder participation involves a range of communities, notably the Aleut Communities, resource trustees, commercial fisheries, and the public. It is critical to have all of these groups involved at all stages. All participated in the CRESP Workshop (Feb 2002) and in the subsequent Technical and Public Briefings in Dec 2002 in Anchorage. Continued involvement of all parties is essential to the design, implementation, and interpretation of the *Science Plan*. Further, extensive efforts will be made to make all data, analyses and interpretations available to those who are interested.

The project will promote participation by the Aleut community through two paths:
1. Periodic workshops to develop plans for research, review progress, and discuss results, and
2. Internships for Aleut students who show an interest in and aptitude for science.

The objective of the internship program will be to give students maximum hands-on exposure to how Earth, marine, and biological sciences are done. This will be conducted in consultation with village school systems, with the goal of providing this experience to about ten students during the life of the project.

The precise methodology used to involve the full range of Aleut Native communities and other stakeholders will vary, and will be fully developed in conjunction with each individual group. It is important to involve all interests at every stage in the *Science Plan*.

EXPECTED RESULT:
1. Peace of mind for affected people through active participation in the assessment and subsequent monitoring process.
2. Expanded opportunities for developing interest in careers in science for young people of the region.
3. Greater involvement of the resident population in management of their environment.

TASK 4.2 LONG-TERM MONITORING

TEAM COORDINATOR: CRESP

QUESTIONS:
1. What long-term monitoring would be appropriate for the Amchitka site to identify when and if additional contamination is occurring, to determine whether it poses a risk to humans or other consumers?
2. How should Amchitka's long-term monitoring be integrated and maintained in the stewardship plan?

UNCERTAINTIES ADDRESSED:
1. Determining baseline data needed for the long-term monitoring plan?

DATA NEEDS: Results from Tasks 1-3 and previous studies.

BACKGROUND
One assumption in developing this plan is that no evidence of significant release of test shot radionuclides will be found, and so the focus must then turn immediately to developing the capability for early detection of release in the future. (If significant current leakage is found, then a longer-term and more expansive scientific study may be needed.) The tasks listed above will provide the means to decide where and how periodic or real-time monitoring should be conducted. Even if our study determines that the risk of leakage is low, peace-of-mind for the residents of the region will require some long-term monitoring. This may be as simple as the annual taking of a water sample or a food species. But given advances in sensor technology and telemetry, it is likely that some sort of stand-alone remote instrumentation can be devised that will require infrequent attention and involve little by way of operating cost, yet report an array of

variables from multiple sites in real time. Planning such a system will require careful consideration of the following issues:

1. What are the concerns of residents and resource users?
2. What is the technical feasibility, including accuracy, reliability, and cost?
3. How does this conform to the national policy on stewardship of nuclear legacy sites.

In additional to a monitoring program, consideration must be given to the potential establishment of exclusionary zones, advisories on harvesting of subsistence foods, and/or special approaches to wildlife management to mitigate any hazard. In the matter of long term stewardship, which is longer than our accustomed timeframe of thought, it will be of paramount importance to realize that Amchitka is not uninhabitable, it is merely uninhabited.

Careful attention will be paid to the record of successes and failures at other contaminated sites. Of paramount importance will be the wishes and concerns of the Aleut people, natural resource trustees, and the public, but we will seek and be informed by the views of a variety of other stakeholders as well. What information do the stakeholders want and how do they want it presented in order to feel that they will have adequate warning of problems?

A generic template for addressing this task exists in the form of a report by the National Research Council (NRC 2000). The task will be to apply these general considerations to the specific circumstances of Amchitka.

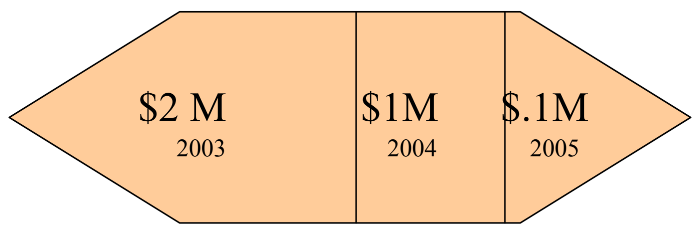
Expected result: Identification of actions needed for closure in place and institutional arrangements for long term stewardship.

XII. MANAGEMENT AND OVERSIGHT

As indicated in the introduction to this document, the CRESP Amchitka Oversight Committee believes that the objectives of the Letter of Intent (June 2002) signed by officials from the Department of Energy and the State of Alaska can fully be achieved by a well-planned and managed scientific effort that involves all the tasks of the *Science Plan* which is comprised of both the base tasks to be funded by NNSA-NV as well as the other tasks identified in this document and summarized in Table 9. The base NNSA-NV resources will support the initial effort to be managed by CRESP and they will flow through the CRESP grant or in other ways be directly overseen by CRESP and its PI. A similarly clear role for CRESP in the management of part or all of the remaining tasks cannot meaningfully be defined at this time. There remains, however, an important managerial challenge if it becomes necessary effectively to link this base funding work and its early start with other funding and the tasks it supports.

Since the resources to support the initial tasks can, be expected to be available over the three-year period of work envisaged in this document beginning in the early summer of 2003, we turn first to the way in which that program, funded by NNSA-NV resources, will be managed. Later in this section we explore ways to manage this program when this base is augmented with the complete *Science Plan*.

Managing the NNSA-NV Base



The NNSA-NV supported project (with approximately $3.1 million in DOE financial resources) will be managed by CRESP and implemented by a science team drawn from Consortium universities and/or consultants from those universities except where additional specific skills, information and/or scientific assets[2] are needed. But there are three separate managerial processes to describe in respect of the management of just the base itself. The Letter of Intent (LOI) describes one of those processes, the process whereby the *Science Plan* itself is approved.

<u>The Role of the *Interagency Amchitka Policy Group (IAPG):*</u> This document is being submitted to the *Interagency Amchitka Policy Group (IAPG)*, an entity which as a group is advisory but is made up of officials of those agencies which must, to meet the requirements of the LOI, each

[2] Such as ocean-going research vessels and the like. For a variety of managerial reasons, it is the hope of the CRESP PI that many assets and skills involved with the delivery of researchers to the research sites at Amchitka can be secured from cooperating governmental entities who have already worked out logistical and liability issues for the work they now do and would, then, perform as part of the major 2004 effort.

approve the *Science Plan* before it is implemented to meet the purposes of the LOI.[3] This group has now met three times in the past 12 months and provides an important forum through which the individual agencies can determine how best to comment on this *Science Plan.*

As clearly intended by the LOI, we support the idea that this Interagency Amchita Policy Group stay in existence and provide advice and counsel and provide a forum for commentary on progress and work on the entire scientific effort. There is one specific time at which broad, ongoing review will be particularly useful. In the Fall of 2003, plans must be finalized to convert what has been learned from the small scale field work done in the summer of 2003 to guide the major field effort scheduled for the summer of 2004. As described earlier, the success of this project depends on a well-organized summer project in the summer of 2004 with follow up and confirmation in the summer of 2005. This will allow a targeted completion date of the work product envisaged by the LOI by December of 2005. If the path forward for the project later includes other related governmental agencies whose collaboration becomes integral to the organization and implementation of a larger plan, we propose that those additional agencies be included as additional entities named as ex officio members of the IAPG.

CRESP has long promised that when the *Science Plan* has taken shape, it would also be reviewed with a broader group of stakeholders, particularly in Alaska. We believe the current draft of the scientific plan has sufficient specificity to warrant *a broader stakeholder review* in the near term. Following the approval of the LOI-specified agencies, a specific effort will be made later in June to distribute this document and to seek input and response that can guide specific implementation.[4]

When approval of the *Science Plan* is achieved from the LOI-specified agencies, there will begin active management and implementation of the plan under the auspices of *CRESP*. *CRESP* was selected specifically to assure that the scientific work is done independently and with competence. CRESP is a research consortium funded by DOE and, since the resources of the base ($3.1M) are to be provided as part of that research grant, it is the *CRESP PI* who is ultimately responsible for this work and work product.[5] CRESP is, however, actually managed

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[3] *The Letter of Intent (see Appendix I) includes the following statement: "The Consortium for Risk Evaluation and Stakeholder Participation (CRESP) will develop a plan that will be agreed to and accepted by the ADEC, A/PIA, USF&W and DOE. The agreed upon CRESP sponsored plan will establish the framework for a scientific assessment providing a basis for long-term stewardship."*

[4] CRESP was founded on the principle that stakeholders have a crucial role in framing the scientific questions that can shape the inquiries that inform effective environmental management. The initial workshop (February 2002) provided that frame. Now, as our plan moves toward initial studies and planning for implementation, stakeholder advice will again be important.

[5] CRESP is an organization of the Institute for Responsible Management, a 501-c3 organization that officially receives DOE grant funding and provides funding to its consortium members primarily through subawards to member universities but also through subcontracts and consultant contracts with specific technical people, agencies and capabilities.

on a day-to-day basis by a Management Board of CRESP researchers, three of whose members are members of the *CRESP Amchitka Oversight Committee*, the group that is responsible for the development of this document. The Management Board will receive this document at a June 20 meeting after/when it is approved by both CRESP and the entities named in the LOI, CRESP would then be in a position to receive the implementing funds expected to be made available to it in each of three fiscal years, 2003 to 2005.

The Role of the *CRESP Amchitka Oversight Committee (CAOC):* The *CRESP Amchitka Oversight Committee (CAOC)* is a combined group of lead CRESP Lower 48 researchers and managers and their counterparts at the University of Alaska. They have effectively become the minds, hands and legs of the Amchitka science definition process. We believe that the active and collaborative participation of this group throughout the three years of this project is essential to its success. It has taken time to define this group and it has really jelled only in the late winter of 2003. Some additions to it may be made as the project evolves. We hope, however, that there will not be a loss of any of these members, as we believe that after a long effort we have been able to define and recruit a team capable of providing the needed research leadership, of functioning together to provide substantive technical oversight to the project itself. Since, particularly in the late summer and fall of 2003, there will be evolution in our technical understanding of issues relevant to the Amchitka subsurface and waters, that will lead to some redefinition and reorientation of specific aspects of the base (NNSA-NV) project, it is essential that there be a group working together in this way to oversee this project.

The CAOC possesses broad technical understanding and local experience. Assuming that the complete *Science Plan* is funded – and as the summer of 2004 approaches - the CAOC skills and knowledge needs to be able to provide coordination and collaboration among even more diverse entities and disciplines. For the base project to succeed, it must be resolutely pursued in accordance with a well-defined timeline and scope. The CAOC will be responsible for providing the needed input to the CRESP PI to be certain that the base projects are integrated and well sequenced. On the other hand, we do not believe that the technically complete product sought by the LOI cannot be achieved by the resources now anticipated to be made available by NNSA-NV. That is why the CAOC will – in parallel with its oversight of the base project – need to achieve effective integration and even sequencing of all activities especially if complete/significant administrative and financial managerial control are dispersed. The additional activities could be provided by or to a single source and/or funded by diverse sources through multiple entities that are related to, but not operating "under", the CAOC. To achieve clear and coherent direction in a situation where a designated set of controlled activities are enhanced and improved by collaborative work actually managed by others is a significant challenge The CAOC committee will give that overall direction and be the frequently convened sounding board for the larger effort.

Although the CAOC will provide coordination, there must in addition be line responsibilities tied to fiscal discipline to assure that the specific tasks are developed and implemented as defined projects that achieve defined work products in the proper sequence. These responsibilities will flow as follows:

<u>CRESP Oversight:</u> The PI of CRESP provides the overall management authority and links the tasks to the resources provided to achieve them[6]. The CRESP HQ staff, under his direction, will provide administrative and financial functions consistent with the grant

The CRESP PI will depend on technical management of the totality of the base tasks in two groups. Those that utilize the biological sciences will be managed by Joanna Burger. Those involving the physical sciences will be managed by David Kosson.[7] It is currently anticipated that the CRESP PI will designate Joanna Burger Ph.D. as the overall technical manager of the major near-Island on-site research effort to take place in the summer of 2004 and that Michael Gochfeld, MD, Ph.D. will be responsible for health and safety decisions in accordance with the health and safety plan and lab analysis oversight.[8]

The *Science Plan* designates researchers who are responsible for specific tasks within the base. When these tasks are undertaken at the University of Alaska, Fairbanks, they will be a part of a single subaward to the university for which Lawrence Duffy is the PI and David Barnes is the co-PI. At other institutions, such as at INEEL or LLNL, there will again be a single primary point of contact.

Finally, we anticipate that there may well be, particularly beginning in September 2003 and extending to September 2004, major logistical and managerial tasks whose performance is essential to achieve effective coordination of very diverse kinds of activity and work done by multiple institutions. To the extent that those activities are general and not geographically specific, the structure already discussed (the CRESP PI, CRESP HQ) can be effective. But even to carry out the base itself, there will be a series of coordinative tasks in Alaska itself where managerial judgment, the ability to work across diverse interests and institutions (including the ability to keep diverse stakeholders apprised of developments) in Anchorage, Fairbanks, Homer and Juneau, etc. may well need to be organized and managed by some extra-UAF mechanism not tied to an academic schedule or even institutionally to UAF. We have made provision for some such managerial role and plan to identify some organization or person to play it by the end of the

[6] The actual mechanisms will differ because different university and government entities will receive core funds authorized by PI in diverse ways. In situations where the line responsibility is in a participating CRESP consortium university, a subaward to the university (for which there is typically a single subawardee university PI) will be made. Where the entity is a federal government entity, distribution of funds to the federal entity may not actually be made by CRESP, but authorized by it. In some cases, it may be more efficient to compensate individual researchers through consulting contracts managed by the CRESP PI.

[7] This distinction between biological and physical sciences will not always apply when, for example, measurement management is at issue but these two researchers have extensive experience in collaboratively managing these overlaps).

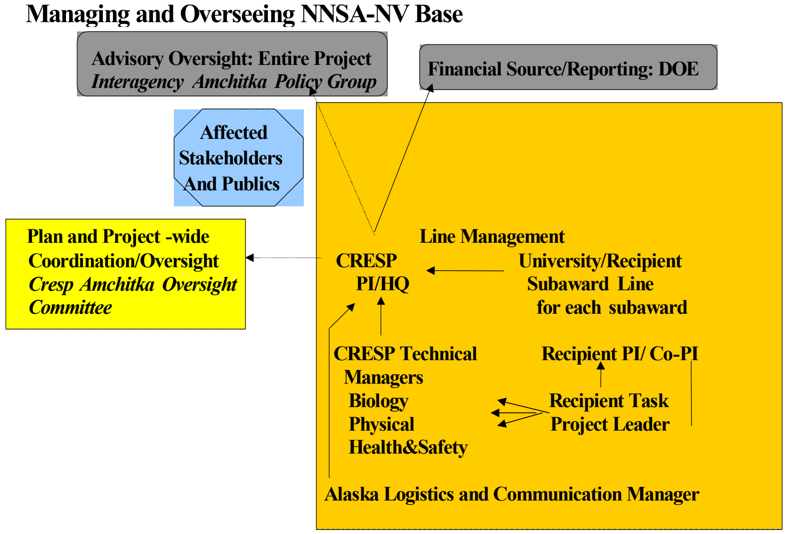
[8] Under Dr. Gochfeld's direction, the actual implementation of the plan would operate effectively only if the skill set of participating scientists allows coverage of relevant health and safety contingencies. For example diving safety would be managed by the UAF's Steve Jewitt.

summer of 2003 and that logistical role could extend to the administrative management of diverse projects at the Island in the summer of 2004.

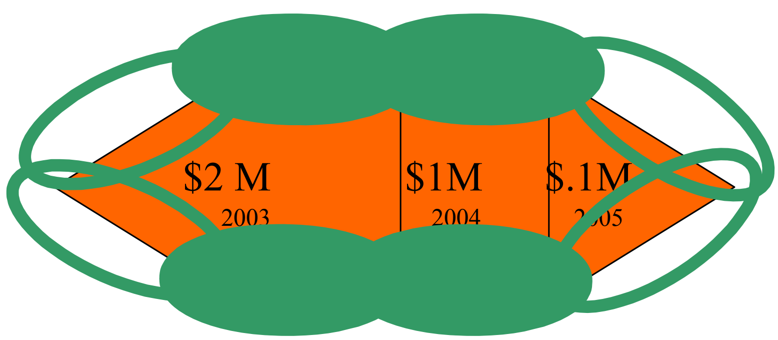
We have captured these base managerial and oversight relationships in a simple diagram.

Figure 22:

Managing and Overseeing NNSA-NV Base



Managing the Complete Program:



Again, optimally it will emerge that these base task projects will not only be augmented by additional projects but in some cases the activities will be directly integrated to the work of the base projects. One example is that when planning to budget for and manage the base projects, we have assumed a modest cost for a sea-going vessel just adequate to support the diverse tasks planned for the summer of 2004 and an even more modest expenditure for the summer of 2005. The sampling plan is limited and many samples will not be analyzed unless there is a finding that specifically justifies/requires that additional sample measurement is done. In each of these cases, were funding to be provided to all activities, then the infrastructure cost of what CRESP now plans to do in its base funded work would be reduced since the base budget would support only partial and not the total costs associated. The flow of funding which has allowed the evolution of a better definition of Aleut consumption patterns could be extended to augment the current plan's approach to linking sampling to consumption and thereby enhance the quality and durability of that sampling process. Should, for example, it be a NOAA vessel that carries the research effort to Amchitka, and additional bathymetric data is to be obtained, it is likely that funding could be found to utilize NOAA's digitalized video tape capability to assure that the information developed from the work in the base projects are effectively depicted in ways that quickly build a foundation for its distribution to Aleut communities and/or to a permanent living repository of information at UAF. These process would help CRESP meet its risk communication responsibilities in the process of defining the technical basis for a stewardship plan and in much more publicly-understandable formats than would be allowed by base funding alive.

If the base plan is agreed in early June, and the complete *Science Plan* of additional projects which constitute the complete *SciencePlan* were to be supported by Fall, 2003, there would likely emerge an integrated plan. As noted earlier, we believe the Interagency Amchitka Policy Group could usefully be expanded (through full or ex officio membership) to become a/the forum for this broader collaboration. Alternatively, or in addition, the CRESP Amchitka Oversight Committee could be expanded to include these additional collaborators at the research scientist level.

If asked, CRESP will play a variety of roles to help facilitate definition, management, administration or oversight of full plan activities. As is seen in this document, CRESP has already defined what we believe to be a complete *Science Plan* that would achieve the objectives of LOI and has winnowed the base activities and budget to meet currently anticipated revenue.[9]

CRESP has a stake in, and believes it can within the scope of the LOI legitimately work to support, the most rapid possible development of an approach that helps garner the resources for the complete Science Program. We hope that with or without its direct involvement, the complete technical base for Amchitka's stewardship plan will be built.

[9] We want to note for the record again that at no point are we aware of any effort actually to link the cost of work actually defined in the LOI for Amchitka to a funding level, let alone to the level currently being budgeted by DOE. We know of no work scope for this assessment project that has ever been less than twice the amount budgeted by DOE.

Table 12: Amchitka *Science Plan* Timeline

		2003 Jun-Sep	**2003 Oct-Dec**	**2004 Jan-Mar**	**2004 Apr-Jun**	**2004 July-Sep**	**2004 Oct-Dec**	**2005 Jan-Mar**	**2005 Apr-Jun**	**2005 July-Sep**	**2005 Oct-Dec**
Task 1	**SAMPLING THE MARINE ENVIRONMENT**										
1.1	Biological Sampling										
1.1.1	Preliminary Sampling	Plan-coll	Analyze								
1.1.2	Main sampling			Plan	Plan	Collect	Analyze	Analyze	Plan	Collect	Analyze/report
1.1.3	Biodiversity			Plan		Collect	Analyze			Collect	Report
1.1.4	Bioaccumulation					Collect	Analyze	Report			
1.2	Physical Marine Environment										
1.2.1	Water Samples					Collect	Analyze				Report
1.2.2	Sediment Sampling					Collect	Analyze				Report
1.2.3	Physical Analysis of Sedimnt					Collect	Analyze				
1.3	Radionuclide Analysis										
1.3.1	Biota						Analyze	Analyze	Analyze		Analyze
1.3.2	Water/sediment									Analyze	
1.4	Human Food	Collect	Collect			Collect	Analyze				Report
Task 2	**OCEANOGRAPHY**										
2.1	Ocean floor mapping			Plan	Plan	Collect	Collect	Collect	Collect	Collect	Report
2.2	Salinity structure		Plan			Collect	Analyze				Report
2.3	Ocean circulation	Model	Deploy	Analyze		Collect	Analyze	Model	Model	Model	Report

		2003 Jun-Sep	2003 Oct-Dec	2004 Jan-Mar	2004 Apr-Jun	2004 July-Sep	2004 Oct-Dec	2005 Jan-Mar	2005 Apr-Jun	2005 July-Sep	2005 Oct-Dec
Task 3	**GEOLOGY/HYDROLOGY**										
3.1	Data recovery and synthesis	Data recovery and synthesis			Report						
3.2	Subsurface interface		Plan	Plan	Plan	Collect	Analyze			Collect	Report
3.3	Groundwater recharge		Plan	Plan	Select	Install	Data	Analyze	Model	Install	Analyze/report
3.4	Radionuclides at source		Plan	Analyze	Plan			Analyze	Plan		Analyze
3.5	Water/rock interaction		Develop	Find core	Analyze	Test	Test	Analyze	Report		
3.6	Sorption on sediments			Plan	Plan	Test	Test	Test	Analyze	Report	
3.7	Deformation of Amchitka			Plan	Purchase	Deploy	Analyze	Calculate	Model	Analyze	Report
Task 4	**STAKEHOLDER DIMENSIONS**										
4.1	Stakeholder interactions	Meetings-planning		Meetings-planning		Interns in field and lab		Meetings-Planning		Risk communication	
4.2	Long-term monitoring needs	Planning	Date review				Date review	Indicators selection		Analyze	Report
MANAGEMENT AND OVERSIGHT		Ongoing activity through out project cycle									

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APPENDIX 1

LETTER OF INTENT
for Amchitka Island

PURPOSE/VISION:

This Letter of Intent documents a commitment by the State of Alaska, Department of Environmental Conservation (ADEC) and the U.S. Department of Energy, National Nuclear Security Administration, Nevada Operations Office (NNSA/NV) Environmental Management (EM) program to achieve closure and long-term stewardship for the Amchitka Island Site.

The Letter of Intent recognizes that the long-standing working relationship between ADEC and NNSA/NV EM has resulted in closure of the Project Chariot site, and the substantial completion of surface closure of the Amchitka Island site.

The Amchitka Island site is part of the Alaska Maritime National Wildlife Refuge and is managed by the United States Fish and Wildlife Service (USFWS). In addition, the Aleutian/Pribilof Island Association (A/PIA) has cultural and subsistence interests both on the island and in the marine region surrounding Amchitka.

PRINCIPLES:

- NNSA/NV EM and its contractors will continue to ensure that all of their activities are conducted in accordance with Integrated Safety Management principles, compliant with applicable state and federal regulations, and are protective of human health and the environment. Closure of a small site, which includes the closure in place of the underground test sites at Amchitka and a reduction in risk uncertainty will be the primary focus of this activity.

- NNSA/NV EM will work with ADEC, A/PIA, USFWS, and other stakeholders to take all necessary steps to reach agreement on closure in place and stewardship requirements.

- ADEC will continue its long-standing partnership with the NNSA/NV EM program to ensure state regulator goals and objectives are met. ADEC will provide proactive, appropriately focused, and timely review and comment of all applicable documents.

- Closure and Stewardship activities for Amchitka Island will be focused on the following:

  - The Consortium for Risk Evaluation and Stakeholder Participation (CRESP) will develop a plan that will be agreed to and accepted by the ADEC, A/PIA, USF&W and DOE. The agreed upon CRESP sponsored plan will establish the framework for a scientific assessment providing a basis for long-term stewardship.

  - CRESP will be allowed to perform its activities independently.

- The CRESP independent assessment and DOE groundwater model verification will be completed by FY2005.
- DOE's support of this assessment will be focused on the model verification and reduction of risk uncertainty aspects during this phase of the assessment.
- CRESP's Principal Investigator will keep DOE, ADEC, A/PIA, USF&W and other stakeholders regularly apprised of the status of the progress on the activities identified in the agreed upon plan through routine briefings.
- DOE will complete the subsurface groundwater modeling and risk assessment in FY 2003 and will be providing the products/results to ADEC, A/PIA, and USF&W for review, and to CRESP program for incorporation into its work.
- A long-term stewardship plan will be reviewed every five years to ensure human health and the environment are adequately protected.
- Establish an agreement with ADEC, A/PIA and USF&W on long-term stewardship of Amchitka Islands underground nuclear test sites that will enable closure in place to proceed, while verification of the models through proof of concept is completed.
- NNSA/EM, ADEC, A/PIA and USF&W agree that closure in place is contingent upon the results of the actions required by this Letter of Intent. If land use changes significantly from the current conditions then the new land use activities will be evaluated to determine changes to human and ecological risk, DOE will work with stakeholders to determine a path forward.

• NNSA/NV EM will continue to support a stakeholder involvement program included in the existing AIPs (i.e., ADEC and A/PIA agreements) to ensure the public is appropriately involved in providing advice and recommendations regarding activities as stated in this letter of intent. To assist in this effort, the principal parties will act as an informal policy review group to discuss the assessment and work on reaching agreement on closure in place and long-term stewardship.

• NNSA/NV EM, ADEC, A/PIA and USF&W will continue to evaluate opportunities to improve cost and schedule performance of agreement activities.

• NNSA/NV EM considers this Letter of Intent, together with achievement of the items delineated above, to meet the objectives called for in the President's fiscal year 2003 budget request for sites to reach new agreements with state and federal regulators to reach closure in place and implement long-term stewardship.

We, the undersigned, are committed to work together to implement this letter of intent and to seek additional opportunities to achieve closure by reduction of risk uncertainty and establish a long-term stewardship program.

Carl P. Gertz, P.E.
Assistant Manager
for Environmental Management

5/31/02
Date

Kathleen A. Carlson
Manager

5/31/02
Date

Michele Brown, Commissioner
Alaska Department of
Environmental Conservation

6/3/02
Date

Jessie H. Roberson
Assistant Secretary
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6/12/02
Date