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Developing a Health and Safety Plan for Hazardous Field Work in Remote Areas

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Developing health and safety plans (HASPs) is a common feature of occupational safety and health for many workplaces. Formal HASPs are a requirement for hazardous waste work, requiring the anticipation and identification of hazards and embodying the training, equipping, and evaluation of workers. Aside from OSHA, there are relatively few manuals or examples and virtually no papers that provide practical guidance in what a HASP should cover or how to create and implement one. Moreover, existing guidance refers to spatially circumscribed worksites. This article details development of a HASP to cover field researchers and ship personnel conducting scientific research in a remote area of the world (Amchitka Island in the western Aleutians), hundreds of kilometers from the nearest emergency room. It required characterizing the kinds of work to be performed and anticipating the hazards that could be encountered. It illustrates the meshing of a general HASP with a ship safety plan, a dive safety plan, and specialized topics, including stop-work authority, rock climbing, firearms, vehicle safety, and communication strategy. Remote area operations are a growing challenge facing the profession. An expedition of this sort requires extensive planning and experienced safety personnel and cannot rely on luck to ensure the safe return of participants.

Keywords HASP, hazardous materials, radiation safety, wilderness medicine, field research, ecological sampling

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INTRODUCTION

Health and Safety Plans (HASPs) are an organized and detailed means of scoping, defining, and controlling potential workplace health and safety hazards and are particularly important in uncontrolled environments.(1) HASPs require anticipation and identification of a wide range of potential hazards, and they detail the means for controlling hazards and minimizing exposure. A HASP is "a dynamic document that must be continually updated if and when new information is discovered."(1,p.x)

In the summer of 2004, the Consortium for Risk Evaluation with Stakeholder Participation (CRESP), conducted a three-phase research expedition for the Department of Energy in remote areas of the western Aleutian Islands to study possible radiological contamination of the marine environment from the underground nuclear tests conducted on Amchitka Island decades earlier (1965–1971) (Figure 1). The objective of this article is to describe the process by which the HASP was developed and implemented to minimize the risk of illness and injury to the senior scientists, university technicians, U.S. Navy personnel, Aleut fishermen, and ship's crew.

Although the authors had extensive experience with developing HASPs, particularly for hazardous waste site work, the remoteness of the expedition and the diversity of activities on ship, land, and sea, imposed some unusual challenges. We began the process with the consensus that a HASP was necessary for hazard recognition, control, and communication. Moreover, the discipline of developing the HASP would require us to fully anticipate hazards and provide for the protection of those involved in the expedition and to meet applicable regulations and laws. A HASP serves as both a training guide, a reference manual, and a contract acknowledged by all expedition participants. It is predicated on the underlying principle that occupational diseases and injuries are preventable and that good planning, careful oversight, training, participant responsibility, and evaluation and feedback combine to ensure that work is conducted safely.

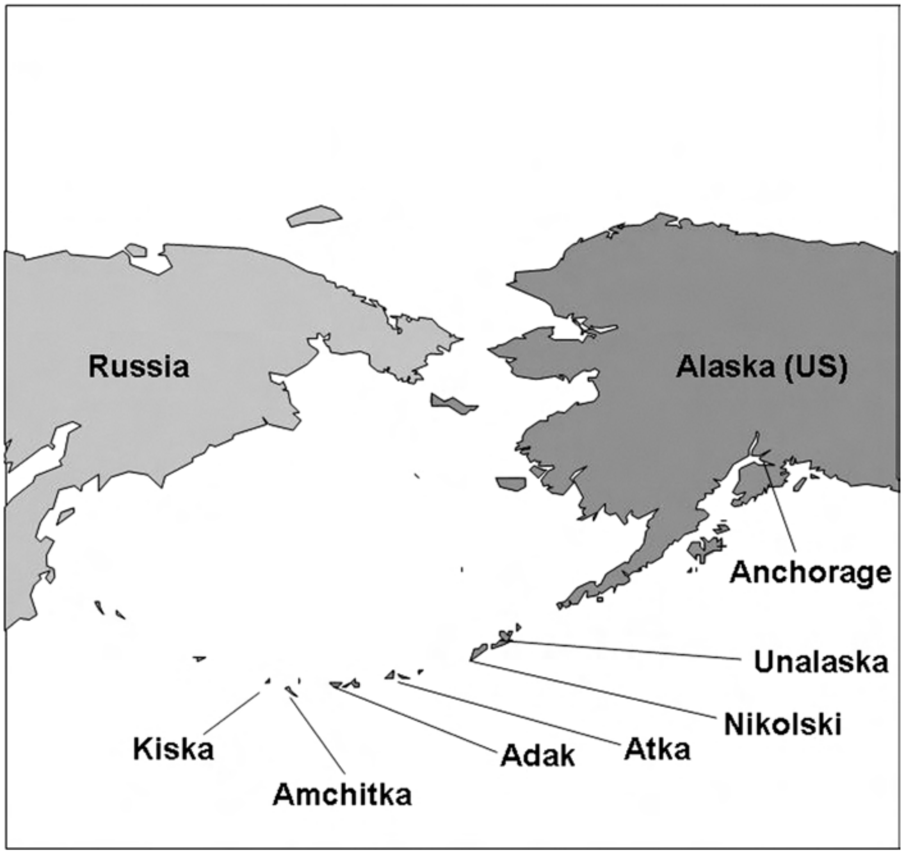

FIGURE 1. Map showing Aleutian Island chain and position of Amchitka and Kiska Islands relative to Anchorage. Nearest occupied village is at Adak; nearest city is at Dutch Harbor/Unalaska.

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The traditional HASP required by the Occupational Safety and Health Administration (OSHA) Hazardous Waste standard 1910.120 is designed for a fixed hazardous waste site on which three zones can be clearly delineated, allowing zones for staging, restricted entry, and decontamination. OSHA identifies lack of site-specific components as the main weaknesses in HASPs,[2] and we took that admonition seriously. Protecting field workers requires recognizing the full range of activities that may be performed, including some that are not traditionally recognized as hazardous waste work.[3] The changing work environment has been recognized as a priority area under the National Institute for Occupational Safety and Health (NIOSH) National Occupational Research Agenda (NORA). Industrial hygiene and occupational safety and health professionals are adapting to the changing work, moving from the relatively predictable factory workplace to the less easily controlled decentralized work environment. Remote area operations are one of those challenges.

This article recounts how we developed the HASP, documents some challenges of remote areas, raises questions for future remote investigations, and provides an outline (Table I) of the HASP itself. It draws on a review of hazards facing ecologic workers,[3] and on the University of Alaska–Fairbanks *Scientific Diving Safety Manual* (Table II).[4] It provides useful lessons learned on designing for safe investigation of remote areas and harsh environments. The entire HASP is available at: www.cresp.org (Amchitka Report Appendix 4.D).

LIABILITY AND SAFETY

A multi-university off-campus expedition imposes significant liability considerations that insurance risk managers must examine. In addition to personnel safety, concern was voiced whether specimens that were radiologically "hot" might contaminate the ship, causing costly cleanup. This topic was examined in detail by the scientists, and it was concluded that if marine organisms were alive it was not likely that they contained a sufficient body burden of radiation to harm persons who might handle the organism for a few minute, much less contaminate the ship. Nonetheless, it was considered both a safety and liability issue, as well as a matter of scientific interest, to screen all organisms with hand-held monitors for radioactivity before they were brought onboard the ship, or at least before they were processed in the hold of the ship. The development of the HASP also satisfied a requirement imposed by the lead university risk and claims manager. All expedition participants were employed by an entity that provided workers' compensation coverage. Only one compensable injury claim (for a torn tendon) was filed.

TABLE I. Outline for the CRESP-Amchitka Health and Safety Plan

1.0 General Project Information
- 1.1 Purpose of the Safety and Health Plan
- 1.2 Project Scope and Activities including
  - Group Assembly and Disassembly on Adak Island
  - General Maritime Operations and Authority of the *Ocean Explorer* Captain
  - Bathymetric Profile/CTD Scanning and Water and Sediment Sampling
  - Magnetotullerics and on Island Hydrogeological Work
  - Base Camp Construction and Operations
  - Biological Sampling
    - Rifle and Shotgun Safety
  - Climb Safety
  - On-ship laboratory dissection and preparation
  - Operation of Mobile Equipment
    - Medical Services
- 1.3 Management Structure, Key Project Personnel and Responsibilities, and Stop-Work Authority
- 1.4 Applicable Regulations
- 1.5 Disclaimer
- 1.6 Daily Coordination and Safety Meetings
- 1.7 Personal Medical Data
- 1.8 Emergency First Aid/CPR/AED Training

2.0 Hazard Analysis
- 2.1 Physical Hazards (including)
  - Shipboard operations and hazardous conditions
  - Small boat operations communication with the *Ocean Explorer*
  - Intertidal and on-island hazards including Rommel Stakes and unexploded ordnance
  - Adverse weather and hypothermia
  - Operation of All-Terrain Vehicles (ATVs)
  - Radiological Hazards including sample collection, handling, and scanning
- 2.3 Biological Hazards including microorganisms and dangerous animals.

3.0 Activity Safety Controls, Personal Protective Equipment and Training

4.0 Radiological Monitoring and Action Levels for personnel, specimens, and laboratory

5.0 Decontamination Procedures (deck and laboratory)

6.0 Dive Safety Procedures

7.0 Emergency Procedures

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DEVELOPING THE HASP

The approach to developing the HASP is shown in Figure 1. Two-headed arrows emphasize the iterative nature of the process and the importance of feedback. The first phase involved careful examination of documents on the potential contamination of the coastal and marine environments that would be visited on the expeditions.

Amchitka and Its Hazards

Amchitka Island in the western Aleutians, is about 1200 km west of Anchorage, Alaska. The U.S. Atomic Energy Commission, predecessor of the Department of Energy (DOE) conducted three underground nuclear tests on the island between 1965 and 1971. This is the most seismically and volcanically active region of the world,[5] and most of the Richter Scale 7 earthquakes each year occur in this area. After the blasts, Amchitka was left with three underground cavities. The DOE assumed that all the radioactive debris produced by the blasts had been trapped in the molten rock and were safely vitrified, but the possibility exists that some of the radionuclides would be carried by ground water through pores, fissures, or fractures in the rock, eventually reaching the sea floor and entering the marine food chain. In addition to this nuclear testing legacy, Amchitka had been a large military base; remaining hazards included buried chemical and asbestos waste sites (mostly sign posted), unexploded ordnance (UXO), and sharp pointed Rommel Stakes that had supported barbed wire barriers.

After the cleanup of the island surface in 2001, the Department of Energy (successor to the AEC) planned to terminate its responsibility for the island, which is part of the Alaska Maritime National Wildlife Refuge. A series of studies were conducted between 1965 and 1975, reporting relatively little radiation contamination, which was generally declining

TABLE II. Outline of the Scientific Diving Safety Manual

1.00	General Policy (including standards, regulations, responsibilities, records)
1.10	The Scientific Diving Standards
1.20	Operational Control
1.30	Consequences of Violation of Regulations
1.40	Record Maintenance
2.00	Diving Regulations for SCUBA (Open Circuit, Compressed Air)
3.00	Diving Equipment (specificiations, emergency maintenance, air quality assurance)
4.00	Entry-Level Training Requirements
5.00	Scientific Diver Certification (policies, requirements, certification, recertification)
6.00	Medical Standards
7.00	Other Diving Technology (advanced techniques not applicable to Amchitka project)
Appendices to Diving Plan	
1.	Diving Medical Exam Overview for the Examining Physician
2.	Medical Evaluation of Fitness for Scuba Diving Report
3.	Diving Medical History Form
4.	Recommended Physicians with Expertise in Diving Medicine
5.	Definition of Terms
6.	AAUS Diving Reciprocity Authorization Form
7.	Diving Emergency Management Procedures

Note: From May 2004 revision of *Scientific Diving Safety Manual*, "This document represents the minimal safety standards for scientific diving at the present day."

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by 1975.[6] However, native communities represented by the Aleutian/Pribilof Island Association, the U.S. Fish and Wildlife Service (USFWS), and the State of Alaska were concerned that leakage may have occurred during the ensuing decades. These concerns were echoed by the State of Alaska.[7]

In 2001, these stakeholders prevailed on the DOE to resolve the uncertainty by commissioning an independent scientific assessment of the Amchitka marine environment. This was planned and carried out by the Consortium for Risk Evaluation with Stakeholder Participation (CRESP), a multiuniversity, multidisciplinary scientific consortium The planning began with a stakeholder meeting in Fairbanks in February 2002.[8−10] Over the next 15 months CRESP developed an elaborate multipronged scientific plan to investigate the biological and physical environment and to interact with various stakeholder communities.[11−13] The Amchitka plan was approved in summer 2003 by four signatories (DOE, AHEC, USFWS, and APIA) and planning began for the field expeditions to be launched in 2004.

The HASP development began with the three "Ps": principles, personnel, and procedures, and included emphasis on redundancy, contingency, and cost-effectivness. All parties agreed that health and safety issues were paramount. The lead scientific personnel were then identified and tasked with determining each of the field tasks and describing the procedures and equipment that would be required. Guidance provided by chapters in *Protecting Personnel at Hazardous Waste Sites*[14] offered a useful starting point, but much new ground was covered in planning for Amchitka. We benefited from Auerbach's *Wilderness Medicine*[15] with chapters covering many of the problems we might encounter. Four topics are covered below: (1) Characterizing Field Operations and Anticipating Hazards, (2) Developing the HASP, (3) implementation of the HASP, and (4) Discussion and Evaluation.

The process for developing a HASP is quite general, but tailoring it to the conditions and hazards that might be encountered on a marine expedition required an iterative interaction among the senior investigators and the principal investigator. This examination and re-examination of tasks, hazards, and conditions allowed each investigator to sharpen their understanding of conditions and to write up procedures for minimizing adverse outcomes.

Characterizing Field Operations and Anticipating Hazards

Safety considerations and operational specifications figured prominently in the selection of the ship, a 50 m commercial trawler, but this was not part of the written HASP. CRESP examined safety records and captain credentials, as well as the physical configuration of the vessel. An important part of the HASP was to develop a comprehensive picture of all the activities that would be part of the expedition. This required review of the *Science Plan*[11] and consultation with the senior scientists and others who had worked on Amchitka.

More than 10 types of operation were identified in the HASP (Table III). Phase I included a magnetotelluric (MT) survey with transects across all three of the nuclear test sites. MT measures the earth's impedance to naturally occurring electromagnetic waves, providing information on subterranean geologic features and the depth of the freshwater-saltwater interface. This involved establishing a campsite and transporting heavy equipment in backpacks across the uneven tundra.

TABLE III. Hazard Assessment for Activies of the Amchitka Research

Activity	Venue	Hazards and Conditions	Controls	Personal Protective Equipment
Phase I				
Bathymetry	Ship	Crane	Alertness, avoidance	Helmet Life jackets
Freshwater probe and water/sediment collecting	Ship	Crane Specimens	Alertness, avoidance Radiation screening	Helmet Life jackets
Magnetotellurics	Land	Camping Hypothermia Load-carrying vehicles Shock	Camp design Survival gear Improved load distribution Seat belts and helmets Warnings	Warm clothing and sleeping bags Helmets seat belts
Phase II				
Intertidal kelp and invertebrates	Ship to shore	Ship-to-skiff Skiff-to-shore Slippery rocks Terrain Hypothermia	Alertness Avoidance	Helmets Walking sticks Nonskid soles on thermal waders Thermal gear
Benthic kelp, invertebrates, fish	Skiffs Underwater	Ship-to-skiff Diving Entanglements Spines Wind, waves, surge	Alertness Weather condition assessments	Dry suits Knives
Fish	Ship Skiffs	Ship-to-skiff Hooks, spines	Survival gear in skiffs	Non-skid soles
Sea birds	Skiffs Land	Ship-to-skiff Firearms Terrain Sea cliffs Vehicles	Firearm safety protocol Speed limits	Helmets Seat belts
Eagle	Land	Terrain Climbing Falls	Climb assessment Equipment assessment Belay procedure	Helmets Ropes and harness
Sample preparation	Ship	Cuts (Noise)[A]	Alertness Sharpen knives repeatedly Rubber nonskid mats on floor Frequent cleanup	Aprons Safety glasses Rubber and steel mesh gloves Hearing protection
Phase III				
Commercial fishing	NOAA trawler	Ship Crane Spines	Adhere to ship safety procedures Crane alertness	Helmet Life jacket Mesh gloves

Notes: All activities involved slips, trips, and falls on the ship. All controls included initial training and safety briefings, which are not included in the table.
[A]The hazardous exposure to noise in the "laboratory" adjacent to the ship's engine room was not anticipated.

Phase I also included shipboard activities: bathymetry, side-scan sonar, conductivity, temperature, density probes, and collection of water and sediment samples, several of which required frequent use of the ship's crane.

Phase II included mainly the collection of biological specimens (kelp, invertebrates, fish, and sea birds) on land, in the intertidal, and under the sea, and the preparation of specimens in a laboratory on the ship. Phase III involved a CRESP researcher stationed on a NOAA trawler for the collection of fish representative of commercial fisheries.

Table III lists the main activities, locations, hazards, controls, and personnel protections. Exposure to icy winds, sporadic gales, and late spring snow storms posed a constant hypothermia concern. Particularly, during Phase I (early

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June) loading and unloading of vehicles, skiffs (small boats), and equipment by the ship's crane was a common hazard. Transferring from ship to skiffs and from skiffs to shore was dangerous; high winds frequently restricted this activity. Slips, trips, and falls on ship and on land; encounters with UXO; handling of firearms (needed to collect seabirds for analysis); and use of vehicles and boats were all identified for the HASP. Finally, cold water diving in a remote area was a nearly daily hazard. Divers worked out of skiffs always with a buddy under the water and a tender in the skiff. For Phase II of the expedition the trawler converted its fish factory hold into a laboratory where specimens were processed and frozen for eventual shipment back to Rutgers University.

Many of the tasks that ecological workers encounter at hazardous waste sites include habitat characterization, sampling, capturing, preparing, and transporting organisms, and collecting soil, sediment, and water samples.[3] This involved deployment of a variety of equipment that needed to be packed either on vehicles or skiffs or carried by personnel. Unlike most hazardous waste sites, accessing the coastline of Amchitka for biological sampling of the shore and intertidal proved challenging and dangerous. Access from land involved long walks over undulating, boggy tundra and climbs down steep, unstable hillsides. Access from the sea was complicated by floating kelp, partially exposed rock tables, and crashing waves. Climbing in and out of skiffs was a particularly dangerous activity, requiring appropriate equipment, timing, and care. Climbing over wet rocks, made slick by growing algae, was identified as a hazard in advance and was addressed in the HASP, which required buddies, urged caution, and recommended the use of nonskid footgear, walking sticks for support, and hard hats.

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DEVELOPING THE HASP DOCUMENT

Once the prospective work was characterized and hazards identified, the outline of the HASP was organized, and authors were assigned writing responsibilities for each paragraph. Each element of Table I had to be addressed. It was recognized that safety considerations might make it very difficult for the expeditions to achieve all objectives, particularly if the weather was unfavorable, as indeed it often was.

Although Amchitka field work was not, strictly speaking, hazardous waste work, we considered the elements of a HASP embodied in OSHA's Hazardous Waste Worker Operations (HAZWOPER) Standard (CFR 1910.120).[2] The DOE's own HASP guidelines are parallel to the OSHA guidance.[16] The Amchitka HASP followed a somewhat different format but included the relevant sections, as well as additional sections specific to the expedition.

The process for developing the HASP is illustrated in Figure 2. The senior scientists were identified, and C.V. was designated the Expedition Manager with responsibility for logistics and for radiation safety. M.G., a certified occupational physician, was designated the Expedition Health and Safety Director. S.J, the University of Alaska-Fairbanks (UAF) Dive Safety Officer, assumed responsibility for the dive safety program and the selection and training of the diver team. J.B., as the expedition leader, was responsible for balancing the collecting requirements against weather and safety concerns and shifting priorities depending on previous successes or failures and changing weather. C.P., in New Jersey, assumed overall responsibility for possible dangers and damage. It was agreed that the ship captain would have the final say over safety issues involving the mother ship or the deployment of any skiffs. Identifying these lines of authority in the HASP facilitated the day-to-day decision making that enhanced the productivity of the expedition, while maintaining vigilance over health and safety matters.

The project leaders were all senior investigators with many years of experience leading field expeditions, often in remote areas. They characterized activities in detail and then, in joint discussions, reviewed potential hazards and identified relevant safety documents, standards, or guidelines. This provided several documents to include in the HASP, either by text or by reference. The main components were the OSHA HAZWOPER Standard (CFR 1910.120), the UAF *Scientific Diving Safety Manual* (Table II),[4] and the ship safety plan issued by the parent company, B&N Fisheries. With these documents as background, the authors reviewed the expedition objectives, the activities on land and sea, and the equipment they would need.

Developing the HASP was an iterative process. It was reviewed by the team leaders, revised, and sent electronically to all expedition participants requesting verification of receipt. This gave the team leaders the opportunity to address questions and obtain additional input. The document was then modified to incorporate suggestions and then distributed. Additional modifications were made as experience in the field accumulated. Key aspects of plan development are described below.

Medical Clearance

Work in remote areas on difficult terrain or under the water for long hours, often involving intense physical exertion, imposes physical demands. Team leaders were required to make this clear to all team members, and each participant (except the U.S. Navy employees) completed a health certification form that was reviewed by the physician. Based on this review, certain individuals were asked to provide written clearance from their personal physicians, who were provided with a brief description of the expedition and anticipated physical requirements. Persons requiring medication were reminded to have sufficient quantity on hand.

Stop Work Authority

An important feature of any HASP is to have clearly designated authority even if these have to be a matrix. Of particular importance was the stop-work authority ultimately vested in a single person,[17] in this case, the ship captain. This requirement was echoed by the principal investigator and the Department of Risk Managemant and Insurance of Rutgers

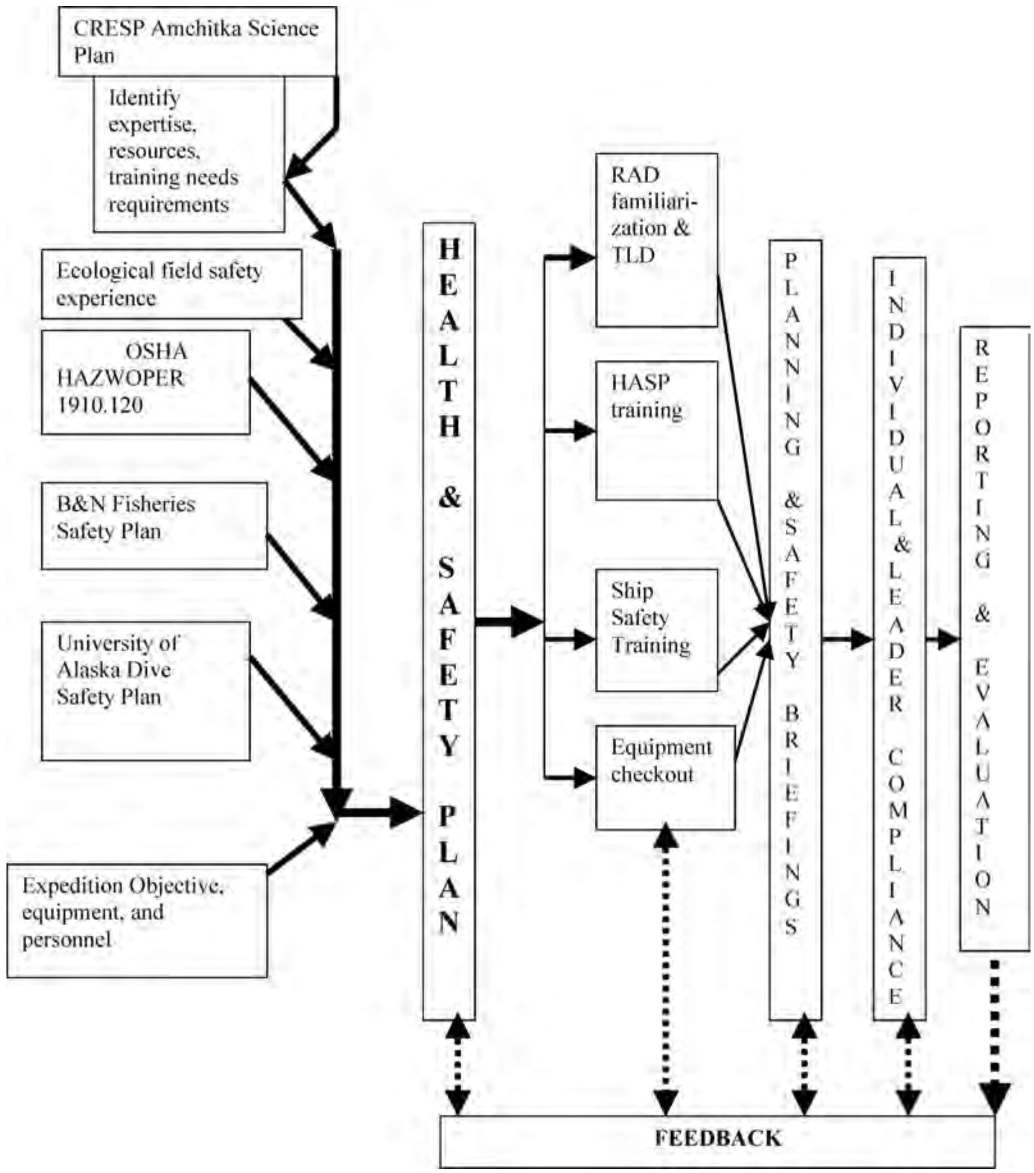

FIGURE 2. The process of developing the HASP began with the Science Plan and the research elements that it defined. The second step was to identify the expertise available for planning and implementation, the resources that were required, any training needs and compliance requirements, as well as related documents. The two-headed dotted arrows show the importance of feedback and iteration at all phases of plan implementation.

University as essential for finding supplemental insurance coverage for the project. However, the safety officer and each team leader had stop work authority for their units as well. Once in the field, operational decisions always included safety concerns and were made on a daily basis or more often.

Radiation Dosimetry and Monitoring

Amchitka was after all a nuclear test site, and the rationale for the Amchitka expeditions stemmed from concern by Native communities, the State of Alaska, and the U.S. Fish and Wildlife Service over possible radiation leakage to the marine environment. Despite reassurance from DOE's National Nuclear Safety Administration (Nevada), which had jurisdiction over Amchitka, it was prudent to plan for the possibility that the expedition might encounter radioactivity above background. There had been no studies since the 1970s, and the ground water model[18] predicted that breakthrough might already have occurred. Detecting such seepage was one of the expedition objectives. Although the risk assessment model,[19] which assumed immediate dilution to negligible levels, could have been adduced as a basis for complacency, the document used questionable assumptions. The CRESP investigators considered it prudent to assume that there might be unacceptably high ("hot") radiation levels at some points on the sea floor or that "hot" biota might be handled.

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Health physicists at Rutgers University concluded that any potential exposure would be below the threshold at which the University would require badging (thermoluminiescent dosimetry badges, TLD) or radiation worker training. Although only four of the participants were from Rutgers University, this advice was considered appropriate for all personnel. However, the HASP authors agreed that because this was a research expedition, all participants would wear TLD badges for the duration of their participation on the expedition. And, as a control, each person would wear a second TLD badge for an equivalent period of time after the expedition. We achieved total cooperation for the first part and 86% cooperation for the control badges. Additionally, all water, sediment, and biota samples were screened with hand-held survey meters (model 2241-2; Ludlum Measurement Inc., Sweetwater, Texas), with an alpha, beta, gamma detector (model 44-9; Ludlum), gamma scintillator (model 44-10; Ludlum), before being brought into the laboratory. A detailed account of the radiation health planning, implementation, and results, is provided separately.[20]

Emergency Planning and Evacuation

Planning for emergency evacuation from Amchitka in the case of serious disease, injury, or diving accident was a major stumbling block. A monetary contingency reserve was held for this eventuality (which fortunately was not needed), but the logistics were nonetheless daunting. The HASP included a detailed listing of emergency contact information in the case of medical or diving emergency, but no facility was nearby.

Amchitka has an all-weather airstrip but no navigation lights or controls. The airstrip was subject to frequent fog conditions that would have made landing aircraft problematic. The nearest airport was at Adak, a distance of 280 km. However, no aircraft were regularly berthed at Adak, nor at Dutch Harbor, so the nearest source of air evacuation would likely have been at Anchorage, about 3 hours away by jet and 6 hours by prop plane. Kiska, which occupied a week's activity, was an additional 140 km to the west. The nearest dive recompression chamber was at Anchorage. If air evacuation were impossible, it would take the ship about 14 hours to reach the active airbase at Adak, from which air evacuation would require several more hours.

Ship Safety

The *Ocean Explorer* had an elaborate safety plan, including man-overboard procedures and evacuation in case of sinking, fire, or collision. All participants were required to learn these procedures and to practice donning an emergency evacuation suit. All activities on deck required wearing a life jacket or flotation coat. However, there are many other hazardous areas on a ship such as cranes, overhead obstructions, stairwells, raised ledges, and hatch covers that are made more dangerous by pitching actions in high wave conditions. Daily safety briefings included identifying any near-miss activities and advising all personnel. All personnel were instructed to be observant and cautious about where they placed equipment. The safety and health officers regularly toured the public areas of the ship to identify obstructions resulting from field activities or maintenance.

Dive Safety

The University of Alaska-Fairbanks (UAF) is an organizational member of the American Academy of Underwater Sciences and, as such, must adhere to strict research dive safety guidelines. Although diving activity was controlled according to guidelines in the UAF *Scientific Diving Safety Manual*,[4] diving was still the most potentially hazardous activity occurring regularly on the biological expedition. Weather conditions produced dangerous underwater surges as well as above-water hazards (getting in and out of skiffs, and off and on the ship). Entanglement with underwater kelp or perhaps with rope, netting, or wire debris from former island operations was also a potential hazard. Many dive opportunities were cancelled or curtailed due to changing wind conditions. Because there was no dive recompression chamber within a reasonable distance, the original diving plan was modified to adhere to "no decompression" diving. Most work was done in the 5–18 m range. Decompression illness is still a problem for shallow water operations, and the team was particularly cautious to remain well within the dive-time guidelines for these depths.

Skiff Safety

As mentioned above, transferring from the ship to the skiffs was potentially dangerous whether accomplished by ladder down the side of the ship or on the rear 45° ramp, which was made slippery by waves. All persons entering skiffs had to wear safety vests or coats. In all dive operations a member of the ship's crew remained on the skiff over the divers as a tender. At least two radios accompanied each skiff, and regular radio contact with the ship was required even though the skiffs were almost always in sight of the ship.

Vehicle Safety

Vehicle accidents are a leading cause of occupational injury and death. The land vehicles consisted of four off-road vehicles capable of operating at 80 kph. Many of the roads on Amchitka still had excellent pavement or were all-weather gravel. The roads on the island were graded and in remarkably good condition considering that they had not been maintained for 3 years. Because research sites were as much as 20 km from the harbor, extensive driving was required. Drivers were instructed to maintain a speed limit of 50 kph and to maintain distance between vehicles to avoid flying gravel. Two vehicles were fitted with plexiglass windscreens to protect against flying objects. Off-road operations across the tundra were strongly discouraged by the USFWS and were kept to a minimum. Users of vehicles were required to wear eye protection and helmets at all times; compliance was monitored and was very high. When vehicles were operated in tandem, drivers were instructed to maintain a separation of about 100 m.

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Climbing Safety

The bald eagle is an endangered species of concern to the USFWS, and CRESP was requested to analyze samples of eagle eggs or chicks for radionculides and metals. Eagles nest on cliff ledges, steep unstable slopes, and rock pinnacles along the Amchitka and Kiska coasts. Accessing nests required trained and experienced climbers, and although the HASP did not provide details on climb safety, it embodied standard climbing safety requirements.[21] C.D.V. had received additional training in mountaineering search and rescue, which facilitated developing the HASP. All climbing sessions involved detailed planning and visual inspection of the proposed route, examination of equipment by two climbers, attention to environmental conditions, and standard belaying plans and communication. All personal protective equipment (PPE) was used according to manufacturer's recommendations. No incidents resulted from climbing, although the down climbing process to retrieve a sick eagle chick on Kiska Island took over 3 hours to accomplish safely.

Unexploded Ordnance and Rommel Stakes

Unexploded ordnance poses a problem at hazardous waste sites on military reservations.[22] Although the Department of Defense and Department of Energy had tried to remove contamination, debris, and ordnance from Amchitka, there remained the possibility of unexploded ordnance half buried in the boggy tundra. This was even more of a hazard on Kiska, which had not had a concerted surface cleanup. Rommel stakes, sharp-pointed steel rods that had once supported fences of concertina wire, were widespread on Amchitka. Although most stood nearly a meter high, there were many small, pointed spikes hidden in the tundra vegetation. All team members were instructed on the pattern of Rommel stake placement and the potential hazards and were told to strictly avoid working in the line of stakes where the hidden points were likely to occur. Magnetotelluric team members, who spent all of their time hiking across the Island, wore boots with metal shanks. Nonetheless one boot penetration (fortunately without injury) did occur.

Magnetotelluric operations required digging trenches, and the HASP specified that all paths and all digging areas be inspected visually and scanned with metal detectors. This was to be repeated frequently as holes were being dug. The HASP also described the potential electrical shock hazard from the high amperage batteries used during MT operations and how to prevent it.

Weapons Safety

Sea birds and marine mammals are preferred subsistence foods in the villages of the Aleutian Islands, therefore it was deemed necessary to collect seabirds. This was accomplished mainly by the Aleut hunters using their personal shotguns and hunting in traditional manner to to obtain representative samples. The HASP stipulated that weapons and ammunition would be stored in a locked firearms cabinet. Other details on transporting weapons unloaded were included. However, the requirement for eye and hearing protection in the HASP was not followed routinely under field conditions. The HASP recognized the need to coordinate shooting activities but did not foresee having two shooters in a skiff. In the field it was determined that only one shooter could fire at a time. A lead shooter was assigned in each collecting situation; the second shooter was designated to dispatch wounded birds if needed.

Organisms

Many scientific expeditions are likely to encounter or specificly seek organisms (animals, plants, microorganisms) that can cause harm either through spines, venom, or infectious agents. The HASP authors discussed this with members of previous expeditions and determined that the Aleutians are remarkably free of biting insects, venomous snakes, toxic algal blooms, and dangerous marine organisms. Even the sea urchins targeted for collection at Amchitka have short, blunt spines. The only biological hazard covered in the HASP was the potential for entanglement in kelp and the handling of rats that were trapped. (These situations could constitute part of a major section in a HASP developed for work in a tropical region.)

Communications

Communication is a major issue in field operations, and the ship was well equipped with a backup system. During Phase I, a satellite phone was used on the island. In Phases I and II, all field and boat parties were required to have two VHF phones to communicate with the ship, which provided long-distance, line-of-sight communication although it was sometimes necessary to climb to a high point to achieve communication. Two-way radios with a 2-km range were used within the land parties.

The communication system was reviewed each day in Phase I and II, and the ship's crew made sure that all parties leaving the ship were adequately equipped.

A regular radio check-in schedule was required at 4-hr intervals.

At morning health and safety briefings, the location (including map coordinates) of all collection points were discussed. The expedition manager, the captain, and at least two team leaders knew each day where all personnel were deployed. Dive logs, field activity logs, and laboratory logs were kept.

IMPLEMENTATION OF HASP

About a week prior to departure, an electronic copy of the HASP was sent to all participants by e-mail with an admonition to familiarize themselves with all aspects of the plan prior to attending a briefing. As part of redundancy, the HASP required both a top-down and bottom-up responsibility. Each senior investigator was responsible for their team, and each individual was responsible for their own health and safety and that of their immediate co-workers. Other aspects are discussed below.

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Training

Training is basic to any health and safety enterprise[23] and includes familiarization, hazard identification, requirements and responsibilities, acknowledgement, and, in many cases, reinforcement. The HASP required all personnel to have first aid training, but the expedition leaders required all personnel to attend a Basic Life Support course. In addition, divers were required to be trained in cardiopulmonary recuscitation (CPR) as well as Oxygen First Aid for Scuba Diving Injuries. The health and safety officers held Advanced Life Support certificates. Prior to boarding the *Ocean Explorer*, all personnel participated in a briefing that reviewed the HASP, the individual and team responsibilities, emergency procedures, safety involving boats, vehicles, and firearms. Although the HASP did not require rad-worker training for CRESP participants, the leaders did incorporate a level of radiation familiarity in the training program.

On-Site Briefing

Participants during each phase were required to attend a safety briefing based on the HASP, on the day prior to embarkation. All aspects of the HASP were reviewed, and the delineation of lines of authority was explained. The HASP included the "right to refuse hazardous assignments." All participants were told that they had the right to exercise personal judgment if a planned activity appeared unacceptably hazardous. Moreover, all team leaders were reminded that the ship captain had the final authority over whether it was safe to launch field teams from the ship. A second training was conducted by the captain on the ship, which included learning to don emergency survival suits. A reporting system was developed for all incidents on the ship and off.

All program participants were required to sign an acknowledgement that they had read the HASP, agree to abide by outlined procedures and that they had an opportunity to discuss questions with Gochfeld/Volz. Daily briefings provided the opportunity to review incidents or near-misses, new operations, and reinforce safety principles.

DISCUSSION

Incidents

Although there were no major safety breaches, there were several injuries. Particularly dangerous were the narrow stairs on the ship that too frequently were obstructed by gear. Crane operation required personnel on deck particularly when boats, cargo, and vehicles were being lowered. Positioning cargo as it was raised and lowered through the hatch, brought staff into proximity with heavy swinging objects and the potential for crush injuries. Although hard hats were specified and used, the HASP did not adequately foresee and address this hazardous activity.

When the expedition's first phase first arrived at Amchitka, the need to unload tons of equipment and supplies for the land-based operations, in the face of imminent bad weather, resulted in inattention, the location of the overhead crane, and some had to be reminded to wear hard hats, since the 25-kg crane hook could be deadly. Although the ship's crew members were experienced in loading/unloading operations, some scientists (including some HASP authors) were seeing this for the first time. A load shifting incident did occur during Phase I unloading, but fortunately only equipment was lost, with no personnel injuries. This resulted in:

- The immediate cessation of all unloading operations both above and below deck.
- An investigation to determine the cause of the accident. It was concluded that the accident resulted from a combination of two factors. First, there was not adequate shrink-wrapping around and over the top of the equipment at the top of the pallet. Second, the shore hand should not have pulled the pallet toward shore but should have indicated to the crane operator to extend the crane boom farther so that the pallet could have been positioned further from the edge of the dock.
- Calling an impromptu meeting of all crew involved in unloading operations.
- Detailing to all crew members the accident and the causes of the accident.
- Informing offloading crew to slow down, decrease the height of loads, ensure that all loads are shrink-wrapped to their full height, including over the top of the load; when on shore to signal to the crane operator to indicate the desired placement of the pallet.

Note: The HASP was revised to cover details of safe handling of palletized equipment and crane operations, and this was included in subsequent briefings and in Phase II training.

Deploying and retrieving the skiffs was often challenging, whether climbing up and down a vertical rope ladder or scrambling up the 45° sloping ramp at the rear of the ship. Wave action made this hazardous and was a frequent cause of curtailed field activities. The captain often had to terminate planned activities when entering or leaving the skiffs was too dangerous. One moderate back injury occurred when a field worker skidded on the slick ramp while returning to the ship.

Operations on land were difficult due to the very irregular and spongy terrain. Carrying heavy loads and negotiating steep slopes through the tall grass over hidden rocks resulted in falls and sprains. Although the authors of the HASP had not previously set foot on Amchitka, there was ample warning from other expedition participants and other scientists about the difficulty of working on the island and surrounding waters. The HASP anticipated some of these difficulties, but only in generalities. Several falls were recorded, including a fall among rocks at Kiska that caused a tendon injury subsequently requiring surgery.

Fatigue is well established as a contributing factor to occupational injury. With 20 hours of daylight on Amchitka, it was enticing to work long hours on land and then spend additional hours on the ship processing specimens long into the night. The HASP did not anticipate that circadian rhythm

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would be affected in this manner, and many team members got less than the optimum amount of sleep.

Work in the ship laboratory involved the use of sharp knives to dissect specimens. On a pitching boat this was occasionally too dangerous to continue; no injuries occurred. Gloves (both latex and nitrile were available) were used at all times, as much to protect the specimens as to protect the workers from irritant, allergenic, or infectious materials. Wire mesh gloves proved useful to restrain slippery specimens as well as deflecting sharp knives.

When the laboratory area was inspected in Seattle, prior to engaging the ship, the engines were not operating. A completely unanticipated hazard, therefore, was the noise exposure in the laboratory that was adjacent to the engine room. Although we did not carry a sound level meter, experience indicated that the work stations closest to the engine room exceeded 90 dB. Fortunately, the ship carried hearing protectors, which were then required at those stations. Most preparations were done at stations more than 10 m from the engine room and, insofar as possible, laboratory work was scheduled when the ship was not moving and the engines were still.

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EVALUATION

In the western Aleutians we encountered a complicated mix of physical and biological hazards, with difficult terrain and stormy seas. We were far from any support base with a long latency before anyone could reach a hospital or recompression chamber.

Despite fielding more than 20 personnel for 10 to 23 days on a ship, often in stormy conditions on land and under the water, there were no serious injuries or illnesses, although one musculoskeletal injury (the torn tendon) required elective surgical repair at a later date.

It would be good to report that all personnel adhered to all safety guidelines at all times, but university researchers are notorious for individuality. Transgressions were generally minor and were quickly noted and corrected; consequences were minor as well. We noted that some of the most serious transgressions were on the part of the U.S. Navy personnel, particularly when it came to the use of vehicles on shore.

HASPs and Luck

When the expedition safely returned to Adak, we were congratulated on our “good luck” in not sustaining injuries. However, occupational injuries are not generally due to “bad luck,” but rather to bad planning or bad operations. A HASP does not rely on luck. Rather, it is a blueprint for eliminating, insofar as possible, luck as a factor. We relied on careful planning rather than good luck to minimize the likelihood of adverse events, and we relied on careful planning to minimize the impact of adverse events.. Indeed, the occupational safety and health profession operates on the principle that good planning minimizes the likelihood of so-called bad luck intervening and reduces consequences when it happens.

Moreover, accidents are likely to occur when good judgment is suspended, when the desire to maximize productivity sends people into harms way, and when chances are taken. Even though the likelihood of harm may be low on any particular outing, the cumulative effect of multiple outings increases the likelihood that an adverse event occurs. The authors of the CRESP HASP were aware of this principle and, with the strong support of the principal investigator, it was clear that safety would never be jeopardized if there were a question about the ability of a field team to depart and/or return to the ship safely. All land parties carried survival gear in case return to the ship was delayed. The captain assumed primary responsibility for determining whether sea conditions allowed safe loading and unloading of skiffs. High winds made it difficult to lift the inflatable skiffs from the deck to the sea and waves made entering and leaving the skiffs dangerous. The ship crew performed admirably, considering that their experience as trawl fishermen did not generally include skiff and research operations.

Because weather was a major primary safety factor to be considered on any day, we watched the weather closely, relying on the local experience of the captain, on the limited weather communications available, and on the experience and wisdom of our Aleut team whose lives and livelihood depend on reading weather sign. We benefited repeatedly from their wisdom for they mixed an enthusiasm for field work with careful observation of wind and waves. Although we had not written this into our field plan, we came to rely on their judgement. We conclude that a HASP for remote operations should provide for and encourage reliance on local expertise.

Processing the complex weather information allowed us to make good decisions about moving the ship from a bad weather location to a better weather location, and even though we had foul weather or fog almost every day, good decisions allowed us to capitalize on intervals of fair weather. So, overall we lost only about 20% of collecting days completely, and lost only 1 day when waves were too severe to allow processing in the laboratory. In effect, the expedition made its own weather.

Lessons Learned: Why a HASP?

Development of a formal HASP, although not specifically required for such an expedition, forced us to identify a wide variety of potential hazards and to address each of them (Table III). Although this expedition investigated a Department of Energy site with certain unique environmental features,[24] the experience and example of developing and implementing a site-specific HASP is generalizable. A significant criticism of hazardous waste HASPs is that their authors merely copy OSHA guidance text without determining the unique features of each site.[2] Although developing the document CRESP HASP entailed a substantial professional effort in advance, it increased the confidence of all leaders, that all participants were versed in the hazards and responsibilities. It proved valuable to have established in advance a clear delineation of the different health and safety responsibilities, lines of authority, participation in decisions, and stop-work authority.

Although the signed certifications that people had read the HASP conferred little legal protection, the certification required acknowledgement of the importance of safety. Moreover, the repeated statement on the "right to refuse hazardous assignment," one of the historic OSHA controversies,[25] made it clear that personnel safety was always the highest consideration. Although OSHA states that this right is limited to situations where a worker believes in "good faith" that there is imminent danger of death or serious injury, the CRESP statement above is more general. Delineating the clear lines of authority and identifying the shipboard personnel who would be involved in the day-to-day or even hour-to-hour planning, led to smooth cooperation in the field, mutual respect, and maximization of productivity, as evidenced by success in meeting the various specimen quotas, even in the face of highly variable weather conditions.

The HASP was prepared with the input of all researchers, taking advantage of their field experience and knowledge of conditions in the Aleutian Islands. We reviewed HASP guidance provided by OSHA,[2] as recommended by DOE,[26] as well as unpublished HASPs from companies involved in waste site studies or remediation. In the end, however, we needed to improvise (largely from our field experience and analysis of field conditions).

Preparing the HASP also made us better quartermasters, identifying the kinds of equipment needed for safety, particularly from the elements. This was routine for the Dive Safety and Climbing Safety plans, but would not have been routine for those planning work in the intertidal or on land. By paying attention to slips and falls in writing the HASP, we were able to purchase appropriate equipment to minimize such events. The wet, algae-covered rocks were particularly hazardous, and anticipating this resulted in purchasing clamp on cleats to provide secure footing. We rarely said, "I wish I'd thought of that." In conclusion, we endorse and recommend development of a formal HASP as a heuristic, training, and legal mechanism for enhancing personnel safety in remote locations and harsh environments. The HASP and related documents (including the reports on the scientific results) are available at www.cresp.org under "The Amchitka Report."[27]

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