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ENVIRONMENTAL STATEMENT

MASTER

CANNIKIN

TID-25735

JUNE 1971

UNITED STATES ATOMIC ENERGY COMMISSION

RESPONSIBLE OFFICIAL:

R. E. HOLLINGSWORTH
GENERAL MANAGER

ENVIRONMENTAL STATEMENT -- CANNIKIN

TABLE OF CONTENTS

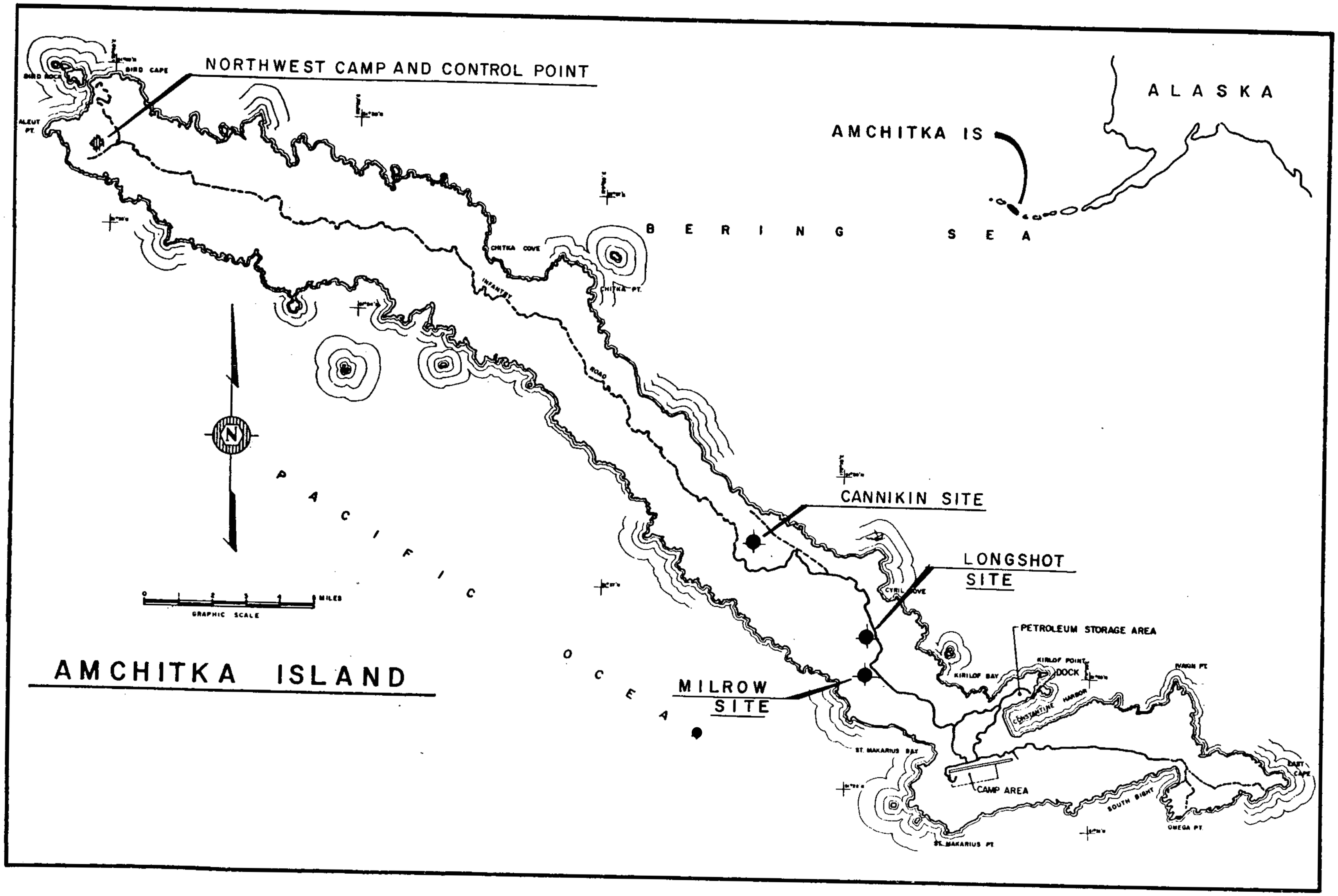

FIGURE 1

FIGURE 1

UNITED STATES ATOMIC ENERGY COMMISSION

FINAL ENVIRONMENTAL STATEMENT--CANNIKIN

JUNE 1971

Environmental Impact--Summary

CANNIKIN is a proposed underground nuclear test of less than five megatons to be fired about 6,000 feet underground in a fully stemmed hole on Amchitka Island, Alaska, in the autumn of 1971. It is a vital part of the U. S. weapons development program.

Preparatory to CANNIKIN, a test called MILROW, which had a yield of about one megaton, was conducted on Amchitka on October 2, 1969.[1] Its sole purpose was to obtain data concerning the physical and biological effects of a high-yield underground explosion upon the Amchitka environment, and to provide an experimental basis for prediction of CANNIKIN effects. MILROW behaved about as predicted and did not have any important long-term impact on the environment. The observed MILROW effects provided valued evidence that CANNIKIN can also be fired without important detrimental impact.

The principal environmental effects of CANNIKIN are those resulting from occupation of Amchitka by a work force of some hundreds of men.

The most probable effects of the CANNIKIN explosion itself should be localized, with little alteration to the surface conditions or any long-term damage to biological populations. However, both the most probable effects and the worst conceivable effects of CANNIKIN have been considered.

Like MILROW, CANNIKIN is expected to have only a minimal long-term impact on the environment. Radioactivity and heat will be trapped deep underground. The geologic siting, the depth of burst, and stemming procedures for CANNIKIN have been chosen to assure successful containment of the radioactivity underground, most of which will be trapped in a matrix of glass-like material formed from the condensed and solidified rock gases.

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[1]Merritt, M. L., USAEC Nevada Operations Office, Physical and Biological Effects - MILROW Event. Report NVO-79 (Springfield, Va. 22151: National Technical Information Service, U. S. Department of Commerce, December 1970).

Scientists and engineers do not conceive of any process by which a venting of radioactive material could occur. However, if those experts were completely wrong, the greatest conceivable venting would be a few percent of the total radioactivity produced by this experiment. In this case, using extremely cautious assumptions, the potential radiation doses would be below all of the radiation criteria set by the National Council on Radiation Protection and Measurements and the International Commission on Radiological Protection.

Radioactivity which is solidified in the rock-glass will be permanently held in place where it will gradually decay. Other radioactivity will tend to remain at the detonation point, since its transport from the cavity by groundwater will be very slow and inefficient, until it too has virtually disappeared by radioactive decay in the sub-surface environment. There is no foreseeable use of deep groundwater at this location, and the effects of the pocket of radioactivity will be nil. The worst conceivable release of radioactive groundwater would reach the sea commencing in two or three years, in which case, potential radiation doses would again be below all established radiation criteria, because of dilution by the sea water. It is not conceivable that CANNIKIN would cause release of underground radioactivity from the cavities which remain from the earlier MILROW and LONG SHOT tests.

A subsidence of 10 to 100 feet will probably remain at the surface over the explosion point. Rock and earthslides--processes which occur commonly on Amchitka as the result of natural forces--will be momentarily accelerated. Surface tears and cracks in the tundra and adjustments in drainage patterns associated with chimneying and surface subsidence in the area closest to surface zero are to be anticipated.

The rockfalls and earthslides along the island coast into the sea may affect some bird nesting sites. There are eight eagle nesting sites and two falcon nesting sites within range of possible cliff falls, but probably not more than one nesting site will be destroyed. There are numerous other nesting sites available to eagles and falcons. Also there are other species of birds on the island which would not be affected by the test. Moreover, the proposed autumn firing date avoids the bird nesting season entirely. The worst conceivable slide actions as a result of CANNIKIN would damage or destroy one site of archaeological interest plus the eight eagle nesting sites and two falcon nesting sites that are within about four miles. Slides of that magnitude would also affect bottom organisms but would not noticeably reduce the available food supply for fish or sea otters.

Very small and localized impact on the freshwater ecosystem of small lakes, ponds, and streams is anticipated. Dolly Varden char and salmon populations should not be affected. However, some minor loss of small scrapfish (threespine stickleback), and temporary reduction of plankton populations in ponds on the island near the surface zero are to be anticipated. As a worst case, threespine stickleback ranging in numbers up to a few thousand would be killed.

The anticipated impact on marine ecosystems is relatively small. Some sea otters, estimated at as many as 20 to 100, could suffer adverse effects due to overpressure, but the ecological impact on the total population (between 2,500 and 4,000) will be negligible in comparison to the impact of natural mortality and of decreases due to harvesting and transplanting (about 1,250 animals since 1967).

Some marine fish of commercially important species may be killed by shock, but the effects on the total fish populations and their food supplies will probably be undetectable. The predicted number of fish killed by the shock ranges from a probable estimate of a few to an unlikely estimate of between a few hundred and a few thousand.

No significant environmental impact can be expected from the seismic activity caused by the CANNIKIN test. The possibility of the CANNIKIN test "triggering" an earthquake with seismic energy comparable to or greater than that produced by the explosion itself is very unlikely. Since the understanding of earthquake mechanisms is still developing and is not yet sufficient for exact calculations, the possibility of such an occurrence cannot be ruled out. However, foremost seismologists have asserted that an explosion at Amchitka will not trigger a large earthquake (defined as one releasing as much or more seismic energy than the explosion itself) unless the occurrence of such an event is imminent, very near to the test site. In brief, the size and location of the CANNIKIN explosion, considered along with the size and frequency of naturally occurring earthquakes and the experience gained by observation of past nuclear detonations and aftershocks, combine to indicate that it is highly unlikely that the CANNIKIN explosion can, of itself, trigger a severe earthquake. Furthermore, the possibility of the CANNIKIN explosion or an earthquake causing a damaging tsunami (seismic sea wave) is even more unlikely.

It is important to emphasize that foremost seismologists have carefully weighed the possibility of triggered seismic motion in reaching their seismic predictions, taking into full consideration that, historically, the largest natural quake recorded near Amchitka had a Richter magnitude of about 8 and did not cause a damaging tsunami.

The effects of CANNIKIN upon man are expected to be nil. About 200 people will remain on the island during the shot. They will be 23 miles away in structures designed to withstand more than the predicted motion. The next nearest populated areas will be at military bases on Adak and Shemya, about 200 miles away; people at those locations will barely feel the motion.

Other unavoidable environmental effects relate to construction activities, including road work, campsite development, drilling operations, the use of borrow pits, and some off-road traffic by tracked vehicles. The AEC and the Department of the Interior are developing plans to assure that areas disturbed by AEC activities at Amchitka will be restored to a satisfactory condition before the AEC leaves that site.

PART I

BACKGROUND

CANNIKIN--WHAT AND WHY

CANNIKIN is an underground nuclear test which is a vital part of the weapons development program of the United States. While its yield (less than 5 megatons*) will be somewhat larger than that of the MILROW test conducted on Amchitka on October 2, 1969, the physical effects of CANNIKIN will be sufficiently comparable so that its safety and environmental impact can be predicted with confidence. For purposes of reference, a test of 5 megatons at Amchitka would have a body-wave magnitude on the Richter scale of about 7.0. This test is presently planned for the autumn of 1971 at a depth of about 6,000 feet.

WHY AMCHITKA?

In 1966, it appeared that the Department of Defense (DOD) would soon ask the AEC to design nuclear explosives of yields larger than could be safely tested at the existing Nevada Test Site, the limitations there being ground motion and its effect on high-rise buildings in Las Vegas. The AEC's Nevada Operations Office and its contractors and the weapons laboratories (Los Alamos Scientific Laboratory, Lawrence Radiation Laboratory, and Sandia Laboratories) began to look for supplemental test sites. The basic criteria were that the sites have geology proper for the proposed tests and for containment of resulting radioactivity and that the sites be sufficiently remote to give reasonable assurance of safety. Other sites were evaluated in the western United States, Alaska, and elsewhere. After screening, three sites remained that were considered possibly satisfactory. These were: (1) Northwest of the Brooks Range in Alaska, near Cape Beaufort; (2) Central Nevada, north of the existing NTS; and (3) Amchitka Island.

At Cape Beaufort, it appeared that there would be ecological problems; for instance, important caribou calving grounds were in the proximity. In addition, because it is almost inaccessible except by air, and since weather there is very adverse, it would be extremely difficult and costly to prepare and operate a site in that area.

* A megaton is equivalent to 1,000,000 tons of chemical explosive.

Of the two remaining sites, each had its own problems. The Central Nevada Supplemental Test Site, as it is now called, which is effectively equidistant from Las Vegas, Reno, and Salt Lake City from the standpoint of ground motion, has limitations to its use because of predicted ground motion effects on high-rise buildings in those cities and on vulnerable buildings in closer towns and ranches. The choice of Amchitka necessitated careful review along biological and seismic lines; however, its selection provided the very great advantage of remoteness from human populations, the ability to be supplied by sea at all seasons, and the existence of repairable airfields, facilities, and roads remaining from World War II.

Since Amchitka Island is not located in the Arctic, its weather is relatively mild. It can be supplied by sea during all seasons. Construction operations there do not contend with the hostile weather and permafrost which prevail in northwestern Alaska.

GEOLOGIC HISTORY

Amchitka Island consists of submarine and subaerial volcanic rocks and volcanic debris.

The oldest rocks, those in which the CANNIKIN device is to be detonated, consist mainly of altered fragmental volcanic debris with a few submarine lava flows which were deposited about 50 million years ago. This episode was followed by local submarine volcanic activity which left lava flows and obsidian breccias. This was followed shortly by another episode of volcanism which took place elsewhere but dumped coarse-grained submarine mudflows in this area about 37 to 38 million years ago.

About 16 million years ago, uplift, erosion, and faulting took place accompanied by intrusion of a large granitic mass. This appears to have been a general age of intrusive activity throughout the Aleutian Arc, of which Amchitka is a part.

This intrusive episode was closely followed by intrusion of another large granitic mass about 12-14 million years ago which broke through to the surface and built a volcano which was entirely above sea level near the west end of the island. Subsequent to this, minor intrusions of basalt occurred about 10 million years ago which represent the last local igneous activity.

During the Pleistocene epoch, in the last few million years, fluctuations in sea level, both higher and lower than present, caused bevelling of terraces around and across the island. Minor faulting continued into the Pleistocene but appears to have ceased prior to the last glacial stage.

The island is surrounded by a terrace cut at present sea level which is believed to have been eroded during the past 4,000 to 5,000 years. This suggests that the island platform has not had significant vertical movement or tilting for at least that length of time.

NATURAL HISTORY

Throughout most of its length, the Aleutian Island Arc consists of a mountainous ridge of volcanic materials flanked on the north by a chain of active and quiescent volcanoes and on the south by the submarine Aleutian Terrace and Aleutian Trench. Amchitka itself has no volcanoes. It is in the Rat Island group of the western Aleutian Islands, at latitude 51.5°N, longitude 179°E, approximately 1,400 miles WSW of Anchorage and 2,500 miles WNW of Seattle. Amchitka is about 42 miles long and varies from 2 to 4 miles in width. The western third of the island is mountainous, up to 1,200 feet elevation; the eastern two-thirds is less than 600 feet above sea level.

The landscape is treeless, an archetype of a maritime tundra system. The climate differs from that of arctic and many alpine tundras in that it is more uniform throughout the year, and that there is a high humidity. It is windy at all seasons and it has no permafrost. Dominant factors influencing the distribution of plant communities are temperature regimes, drainage, soil type, and wind erosion. In the mountain and plateau country of the western third of the island, vegetation is largely restricted to stream bottoms and more or less flat areas protected from the wind. The eastern third of the island is characterized by lowlands with numerous shallow lakes and ponds with little or no drainage collections, everywhere covered by vegetation, giving way in the higher central third to areas of more integrated drainage and greater wind erosion, with fewer lakes and with patches of lag gravel interrupting the cover. The better drained ridge tops and slopes are covered with a crowberry-lichen-grass community and the poorly drained lowlands are dominated by sedges. Beach plant communities are composed of grasses and salt-resistant succulents.

Generally, and especially in the boggy areas, plant productivity exceeds decay and has produced peat in the flats that is at many places several meters thick.

Natural revegetation of disturbed areas on Amchitka is strongly dependent on drainage and may be limited by a lack of nutrients. For example, berms around Quonset huts remaining from military occupation occurring from 1942 to 1951 are nicely covered with grass, but numerous pits dug for gun emplacements or lookout points are full of water and show few signs of natural recovery.

The barrenness of the land is reflected in the fauna. The only permanent land-dwelling mammal on the island is the Norway rat. Fish food organisms of lakes and streams live to a large extent on a detritus economy. The highest tropic level in the lakes is represented by the Dolly Varden, stickleback, and sculpin. The only other fish found inland are a few silver, pink, and sockeye salmon which spawn in the early autumn. One hundred species of birds have been identified. Birds of special interest are the bald eagle, endangered in the southern states but common in Alaska; the emperor goose, which winters on Amchitka; the winter wren; the song sparrow, rare due to rat predation; and the peregrine falcon, endangered elsewhere.

In recent years and until 1971, no Aleutian Canada geese have bred on the island. This rare type of Canada goose is known to breed only on Buldir Island and has been extirpated from other Aleutian Islands, presumably by predation by introduced foxes. However, the Department of the Interior, having considered Amchitka a suitable location for the reestablishment of breeding populations of these geese, transplanted 75 of them to the island in March 1971.

The marine waters surrounding Amchitka have a high biological productivity, as is characteristic of the north Pacific. The in-shore waters support a dense flora of attached algae, including extensive intertidal kelp beds. The invertebrate fauna is rich in species, but in shallow waters some of the larger benthic forms such as sea urchins that would be expected to be abundant are scarce due to heavy predation by otters.

Prior to the establishment of the AEC's bioenvironmental program on Amchitka, the U. S. possessed little information on the commercial fishery resources of the Amchitka region, except for Pacific salmon. North American fishery industries still do not fish the waters of the more distant Aleutians except recently a few king crab fishermen have fished isolated spots in the western Aleutians. The open seas of that region are fished by the Japanese and Russians.

Five species of Pacific salmon migrate through the waters bordering Amchitka. These include the sockeye or red salmon (Oncorhynchus nerka), pink or humpback salmon (O. gorbuscha), chum or dog salmon (O. keta), Chinook or spring salmon (O. tshawytsha), and the silver or coho salmon (O. kisutch). The salmon that frequent the Amchitka area are not homogeneous populations, but represent mixed stocks.

Some migrate to western Alaskan waters for spawning and others go to streams of the Asian coast. Approximately 90 percent of the sockeye originate from Alaskan spawning streams, and 10 percent come from Asian waters. The Alaskan stock is mostly from spawning areas in the Bristol Bay and neighboring areas. About 90 percent of the chum salmon originate from the Siberian Arctic coast; the remainder are primarily from western Alaska with a few coming from areas bordering the Gulf of Alaska. The other three species of Pacific salmon do not occur in significant numbers in the vicinity of Amchitka.

The Pacific ocean perch (Sebastes alutus) is another marine fish of commercial importance which is found in the western Aleutian region. Considerable numbers of this species are common at depths of over 100 fathoms in the vicinity of Amchitka during their summer feeding period of April-May to September. Commercially significant numbers of this species have been detected by exploratory trawling conducted by the University of Washington Fisheries Research Institute under the Amchitka Bioenvironmental Program.

Pacific halibut (Hippoglossus stenolepis) is the most important bottom fish in the area. It also is probably the most available commercial fish near Amchitka's shores in the summer and fall. Limited survey data indicate that considerable numbers of immature halibut inhabit the in-shore waters around Amchitka during the summer months. This species spawns along the edge of the continental shelf, and all known spawning areas are far east of Amchitka. On the Bering side of the Island, between 20 and 40 fathoms, there appears to be a nursery area for several species of fish including halibut and Pacific cod. Only a few adult Pacific cod have been taken by exploratory trawling, and they are most abundant at about 50 fathoms. Exploratory fishing indicates that the rock greenling is by far the most abundant in-shore fish. This species is not of commercial importance, but it is an important food item of the sea otters.

Exploratory sampling for crabs has not located any commercially important populations immediately around Amchitka.

Sea otters (Enhydra lutris) were once widely distributed along the Pacific coast of North America from the western Aleutians to southern California. Following the discovery of the outer Aleutian Islands with their rich population of sea otters by the Russian Bering expedition in 1741, Russian fur hunters soon began exploiting the Aleutians' otters for the Oriental market. Intensive and unregulated fur hunting by the Russians and, later, by the Americans, almost extirpated the species. In 1911, they were placed under protection by an international treaty and subsequently there was a gradual recovery of the otters starting from a few small groups that had escaped the fur hunters. One such group survived on Amchitka. The Amchitka population increased at a rate of about 10 percent per year, reaching a peak of about 4,500 in the early 1940's.[1] There was then a decline in the sea otter population, probably because they had depleted their natural food supplies. Recent counts by visual and photographic methods have indicated that the current population is between 2,500 and 4,000 and apparently is no longer declining. Otters are now harvested in that region by the State of Alaska, utilizing carefully controlled game management practices. They have been harvested from Amchitka since 1962. Through 1970, 901 had been harvested from Amchitka for fur.

The common harbor or hair seal (Phoca vitulina) and Steller sea lion (Eumetopius jubata) are indigeous to the in-shore waters of Amchitka. The total sea lion population has been estimated to be about 750 animals and the harbor seal population to be about 350. Because they feed on salmon, there is a State of Alaska bounty on the harbor seal in parts of western Alaska.

The Pribilof Islands in the Bering Sea are the breeding grounds for the fur seals (Callorhinus ursinus). This valuable fur-bearing animal is protected by international treaty. Controlled harvests are conducted on the Pribilof Islands as well as on several Russian islands. Migration from the Pribilofs starts as a mass movement in November. After departure, they move singly or in small groups, some of which pass by the general area of Amchitka. They move into southern waters for the winter, about 30 percent going to Asian waters and the rest to American waters. The return (northward) migration begins in April and May with arrival back in the Pribilofs occurring throughout the summer.

Five species of whales of commercial importance inhabit the north Pacific and the Bering Sea. These include the fin whale (Balaenoptera physalus), sei whale (B. borealis), blue whale (B. musculus), humpback whale (Megaptera novaeanquliaae), and the sperm whale (Physeter catodon). Each of these species can be expected to occasionally frequent the off-shore waters of Amchitka.

Commercial Harvests of Fish and Marine Mammals

Japan is the only nation that fishes for salmon on the high seas; and the Japanese commonly fish the waters in the general vicinity of Amchitka, from May through August, with the bulk of the harvest in

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[1]Kenyon, K. W. The Sea Otter in the Eastern Pacific Ocean. U.S. Department of Interior, Bureau of Sport Fisheries and Wildlife, North American Fauna, Publication No. 68, August 1970.

this area being made before mid-June. American fishermen take salmon from in-shore Alaskan waters when the fish are returning to their home streams for spawning. This does not include fishing in the outer Aleutians. Similarly, the Russians and Japanese, as well as the Canadians, have land-based fisheries along their coasts which capture the returning adult fish. The foreign land-based fisheries are all many hundreds of miles distant from Amchitka. The sockeye is the most valuable and most abundant salmon to both the Alaskan and Japanese fisheries.

The Russians and Japanese also fish with trawls for bottom fish in the north Pacific along the Aleutian chain. The most important species taken by this method are halibut, ocean perch, cod, and flounder. Other species include sole, pollock, plaice, sable fish, herring, and various species of rockfishes. The Pacific halibut is undoubtedly the most important bottom fish in the Amchitka area.

The Alaskan king crab fishery is centered around the Alaska Peninsula and Kodiak region. Until recently, the crab fishermen did not venture to the outer Aleutian area. At the present, a few Alaskan crab fishermen trap during the crab season on Petrel Bank, in the vicinity of Shemya, and in the area between Adak and Amchitka. The Asian bottom trawlers pick up some crabs and shrimp in their searches for bottom fish.

The Japanese and Russians still hunt whales in the Pacific. They harvest in the western Aleutian region from spring until mid-autumn.

SEA OTTER TRANSPLANTS

Although the sea otters have made a remarkable population recovery in certain selected areas by natural recolonization, they have not recolonized other suitable habitat areas and perhaps they never would naturally recolonize some of the desirable areas that they once occupied. A logical solution is to recolonize suitable habitats by transplanting small colonies from areas of high population density. Attempts to transplant otters from Amchitka to other Alaskan habitats were started in 1951 by U. S. Bureau of Sport Fisheries and Wildlife (BSF&W) biologists. Early attempts were not very successful; by 1966, a total of about 60 animals had been successfully moved. Since 1968, the AEC has cooperated with the Alaska Department of Fish and Game by providing logistical support for the transplanting program, using improved methods for capturing and handling. By this cooperative effort, during 1968, 359 animals were transplanted to six locations in southeastern Alaska and one location in the Pribilof Islands. The 1969 transplant of 116 animals was distributed between one location each in Washington and southern Alaska. (Four of the animals were delivered to the Point Defiance Aquarium near Tacoma, Washington, where physiological and behavioral studies of sea otters are in progress.)

Some of those animals delivered to Alaska in 1969 were subsequently provided to British Columbia by the State of Alaska. In 1970, 59 otters were transplanted to the coasts of Oregon and Washington; additional animals will be taken to Oregon during 1971.

HISTORY OF USE OF AMCHITKA BY MAN

Amchitka has had a long history of human disturbance. The impact of the aboriginal Aleuts was small, but discovery of the Aleutians and Komandorskis by the Russians in the 1740's was followed by a period of extensive fur hunting that led to a decimation of the Aleut population and the near extinction of the sea otter and fur seal. The principal recent events influencing the ecology systems of the island are the following:

1911	An international treaty protecting the sea otter and fur seal was concluded. (Amchitka had one of the remnant populations of sea otters.) (The treaty was terminated in 1941. A new agreement protecting fur seals was concluded in 1957.)
1913	Executive Order 1733 established the Aleutian Islands National Wildlife Refuge (Amchitka was included). It included provision that use of the specified area as a wildlife refuge should not interfere with use of the islands for military purposes.
1921	Blue fox farming was introduced, under lease agreement with Atka natives. The U. S. Department of the Interior, Bureau of Sport Fisheries and Wildlife, reports that foxes were trapped at least through 1936.
1942-1951	Amchitka was occupied by U. S. military forces (reportedly as many as 10,000 men at peak period). The Norway rat was inadvertently introduced during this occupation. Many hundreds of small buildings were erected and still remain on the island in various stages of disintegration. An extensive system of roads and trails remains.

1951-1957	A fox and rat eradication program was carried out by the Department of the Interior, using strychnine and "1080." Foxes were eradicated and the rat population reduced. Dogs and cats abandoned upon departure of World War II forces disappeared from natural causes. The bald eagle population declined somewhat as a result of poisoning operations, but is reported to have recovered by 1959.
1958-1959	A WHITE ALICE radar station was operated by Western Electric Company for the Department of Defense.
1962	A program of sea otter harvesting was initiated by the Alaska Department of Fish and Game to reduce and regulate the otter population.
October 1965	LONG SHOT, a Department of Defense-sponsored underground nuclear test, was carried out. Bioenvironmental surveys were done.
1967	Drilling and construction activities were initiated in preparation for AEC underground nuclear testing. A program of bioenvironmental studies was started.
October 1969	MILROW was detonated.

PART II

IMPACT ON THE ENVIRONMENT

RADIOACTIVITY--ATMOSPHERIC AND SURFACE

The CANNIKIN emplacement conditions are designed to assure containment of radioactive explosion products deep within the rock below Amchitka.

This section contains a discussion of the prior experience at Amchitka and Nevada followed by a description of how the CANNIKIN site was selected and designed to provide for containment.

Amchitka Containment Experience

There have been two nuclear detonations on Amchitka Island, Alaska: LONG SHOT (about 80 kilotons (KT*)) on October 29, 1965; and MILROW (about one megaton) on October 2, 1969. To date, no radioactivity from MILROW has been observed. Air sampling instruments located in two concentric rings around the MILROW surface zero location were operated at detonation time and shortly thereafter to monitor for possible gamma radiation, but no radioactivity appeared. Since then, a few plankton hauls in the seas around Amchitka and many samples from land-surface waters and near-shore ocean waters were analyzed for radioactivity. No levels of radioactivity above background were found. There will be similar monitoring, sampling, and analysis after CANNIKIN.

There was no immediate release of radioactivity from the LONG SHOT test. About one month after the test, however, anomalous levels of tritium were detected in three small ponds on the north edge of the surface zero pad and in drainage ditches from those ponds.

In order to determine how this tritium might be reaching the surface, exploratory drilling was conducted at several locations around the LONG SHOT surface zero point during the summer months of 1969. Levels of tritium above background were found in these shallow wells out to about 900 feet from the emplacement hole. However, no tritium above background was found in surface water beyond about 500 feet from the emplacement hole. On the basis of this information, the most likely explanation for the appearance of this tritium is gradual seepage from the top of the chimney upward through the stemming material inside the cased hole to a break in the hole casing and then upward outside the cased hole to the surface, with accumulation beneath the

* A kiloton is equivalent to 1,000 tons of chemical explosive.

emplacement pad. The fact that no tritium seepage has been observed at the MILROW site is explainable in part because the MILROW emplacement was much deeper (4,000 feet as compared to 2,350 feet).

The tritium mentioned above, which was observed in local ponds at LONG SHOT, was at levels far below the Radioactivity Concentration Guides (RCG's) for water and hence was of no significant ecological impact. Trace amounts of radioactive noble gases were also detected over LONG SHOT, and the possibility exists that trace amounts may yet become detectable at the MILROW site. However, because noble gases are biologically inert and would be in very low concentrations, they would pose no environmental hazard. No leakage of tritium or radioactive noble gases is expected for CANNIKIN; behavior comparable to MILROW is likely. Even the extreme case would be expected to be no more than a gradual upward seepage similar to that experienced on LONG SHOT.

Because tritium seepage was observed after LONG SHOT, a brief description of tritium and its biological behavior may be useful to the reader:

Tritium, a radioactive isotope of hydrogen, emits a weak beta particle when it undergoes radioactive decay. It has a radioactive half-life of 12.3 years. Tritium in minute amounts is distributed essentially everywhere that water or hydrogen occurs. Its main sources are nuclear reactors, nuclear detonations, and nuclear fuel reprocessing plants. Lesser sources are wastes from research laboratories and even luminescent dials. It is also produced by natural processes, and has been present in the biosphere in trace amounts throughout the period that life has existed on the earth. Its production by natural processes amounts to about 4 to 8 megacuries of tritium per year. Before the advent of the nuclear age, the natural rates of production and decay caused there to be a steady $3x18^{-18}$ grams of tritium per gram of stable hydrogen (.01 pCi/ml).

The current level of tritium in fresh waters on Amchitka Island, with the exception of the mud ponds contaminated with tritium from LONG SHOT, is about 10^{-16} grams of tritium per gram of stable hydrogen (0.3x0-0.6 pCi/ml). This level is common to that region.

If some tritium were to be released to the environment from the CANNIKIN detonation site which is more than a mile below the surface, it would escape as water or else would rapidly be converted to water. If it escaped, it would be dispersed like ordinary water, paralleling the circulation of other water in the vicinity of the site of emission, whether it be on the ground surface such as the mud ponds at the

LONG SHOT site, or in the inter-tidal zone. Thus, in addition to losing its radioactive potency with time due to radioactive decay, any tritium that should reach the surface would be rapidly diluted by the water in which it would become dispersed. The highest level observed in the ponds directly above the LONG SHOT site where leakage did occur was 17 pCi/ml which is only about 1/60th of the Radioactivity Concentration Guide (RCG) for water that would be suitable as the sole lifetime source of water for the general public (1,000 pCi/ml). The tritium level in the LONG SHOT mud ponds now fluctuates with rainfall in season, and the highest recent measurement in the ponds was about 7 pCi/ml measured in December 1970.

Studies of fish, shellfish, and other food organisms have shown no evidence that a mechanism might exist whereby the specific activity of tritium (ratio of tritium to nonradioactive hydrogen) increases in transfer from diet to tissues.[1] Due to the heavier atomic weight of tritium as compared to natural hydrogen, there ordinarily is a discrimination against tritium in those reactions involving the transfer of hydrogen. There is a tendency for it to remain behind in biochemical reactions such as those whereby hydrogen is transferred into organic materials, but gradually, the tritium content of any organism will reach equilibrium with the tritium in its environment. This has been demonstrated by biological experiments. For example, experiments conducted more than 15 years ago at the AEC's Hanford Plant showed that if small fish were maintained in water containing tritium oxide and then moved to an uncontaminated environment, half of the tritium was eliminated from the fish within about 24 minutes.[2]

In brief, experimental evidence indicates that tritium in water does not have any tendency to accumulate in specific tissues or to concentrate as a result of food chain processes; for CANNIKIN it does not pose any potential danger to fisheries or to the public at large.

Nevada Containment Experience

All of the experience which has been accumulated by the AEC in providing for the containment of underground nuclear tests has contributed to the development of sound test containment procedures. Hence, it is relevant to mention containment experience at Nevada.

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[1]U.S. Council on Environmental Quality, First Annual Report of the Council on Environmental Quality, August 1970.

[2]Foster, R. F., Annual Progress Report of Biology Research for 1954. Report H.W.-35917 (Richland, Washington: Hanford Atomic Products Incorporated, 1955), pp. 98-103.

From the signing of the limited test ban treaty in 1963 to the end of 1970, there were 230 announced U. S. underground nuclear explosions at the Nevada Test Site and elsewhere, including five Plowshare cratering tests. Of the non-Plowshare tests, 17 inadvertently leaked radioactivity detectable off-site. Thirteen of the 17 were tunnel experiments and/or experiments involving open lines of sight part way through the stemming (the material used to refill the emplacement hole). The remaining four tests which leaked were fully buried in vertical shafts. Only one of these four had a yield of over 20 KT.

Each time a leak of radioactivity has occurred, there has been careful investigation in an effort to learn the cause so that leaks from similar causes can be avoided. For instance, after a large leak occurred during the BANEBERRY test on December 18, 1970, further testing was delayed for six months to allow for a thorough investigation of the incident. Investigation of the BANEBERRY venting indicated that it could basically be attributed to stronger than normal coupling of energy into the ground due to an unexpectedly high water content at the test depth.

BANEBERRY was fired in Yucca Flats at the Nevada Test Site, at a relatively shallow depth, in an area where experience indicated that an explosion at the BANEBERRY yield level and depth of burial would be entirely contained underground. Geological and physical data obtained during two earlier successful low-yield tests very near to the BANEBERRY site (one had been 2,000 feet to the north and the other about the same distance to the east) had indicated the suitability of the BANEBERRY site.

Studies made after the test revealed that within a limited region around the BANEBERRY emplacement position the rock has an unusually high water content filling almost all of its pore space. This is considered to be the major reason for the BANEBERRY venting of explosion products. Varying underground water content can have a marked effect on coupling of explosive energy to the ground. This comes about both directly, through the presence of the water itself, and indirectly, through filling of the porous volume which would otherwise tend to cushion the force of the explosion. In both ways, increasing water content tends to increase the effective force of an explosion. If the water content and the degree of saturation of the material surrounding BANEBERRY had been recognized, the test would have been fired at a greater depth or a different location. The BANEBERRY containment failure resulted not from water per se, but from the presence of excessive water at a position where it was not expected.

However, the BANEBERRY experience has no direct bearing on CANNIKIN; emplacement for the latter event will follow already well-proved guidelines for deep, high-yield tests which presume a saturated medium.

While low-yield tests at relatively shallow depths of burial are normally fired in unsaturated rock, every test of yield greater than about 200 KT has been fired below the static water table in essentially fully water-saturated rock, with completely successful containment. Emplacement conditions are designed to take account of the presence of water-saturated rock at the greatest depths. The rock medium surrounding CANNIKIN is fully water-saturated, as it was at the sites of the LONG SHOT and MILROW explosions under Amchitka. (It is interesting to note, however, that the actual percent water content is about one-third of that at BANEBERRY.) The nature of the rock medium is better known than for almost any previously drilled emplacement site. Mining operations at the emplacement position, together with exploration of the medium through two supplementary drill holes located within a few hundred feet of the main hole, have yielded ample data to establish a reliable description of the material and formation characteristics.

Experience with the containment of larger yield tests is particularly pertinent. No leaks or ventings have accompanied any of the large yield, deeply buried explosions. There have been 13 underground tests of 200 KT or greater, all fully stemmed. None of these 13 tests and, in fact, no experiment having a yield greater than 50 KT, has leaked radioactivity detectable off-site. As a matter of fact, drill-back operations following megaton tests at Nevada have shown that explosion-produced radioactivity is first encountered at about half of the emplacement depth, even when those tests have chimneyed to the surface. Empirically based calculations indicate that for the CANNIKIN containment situation, the chance of prompt venting of mixed fission products in quantity is remote. The soundness of these calculations is borne out by test and drill-back experience under similar conditions of yield, depth, and medium.

CANNIKIN Containment

The CANNIKIN detonation will derive part of its energy from fission and part from fusion. Therefore, it will form a complex mixture of fission products as well as tritium and various induced radioactivities. At the beginning, these are in a cavity where they are intimately mixed with molten rock and rock gases. As the cavity expands, the internal pressure and temperature drop and the more refractory and chemically active isotopes combine with the gaseous compounds and condense and solidify to form a glass-like material inside the cavity. On collapse of the cavity and formation of the rubble chimney, pressures drop still more and only a few isotopes remain at all free to migrate outwards as gases or in solution.

In order to assure containment of radioactivity, it is necessary to provide proper rock types, adequate distance from faults, sufficient depth for the yield, and adequate stemming. Selection of specific emplacement sites for each of these tests on Amchitka Island was made on the recommendation of the U. S. Geological Survey (USGS). A vast amount of geological knowledge about Amchitka has been developed and evaluated in detail. Much of this was acquired during the drilling and testing of exploratory holes prior to selecting the final emplacement sites for LONG SHOT, MILROW, and CANNIKIN.

Since 1966, the USGS has expended more than 40 man-years of effort on geological and hydrological studies at Amchitka, at a cost of over $1,300,000. A major consideration in any geologic investigation for underground nuclear test purposes concerns the location, depth attitude, and history of large faults or fractures near the proposed test location. Prime attention is given to identifying known and inferred faults by surface geologic mapping prior to selecting the site of an exploratory hole. During the drilling of exploratory holes, the progress is continuously monitored by well site geologists who observe the rock cuttings returned by the drilling process to establish correlation of underground strata with surface geology. They also remain alert to any changes in lithologic or hydrologic conditions apparent or suggested through close observation and interpretation of drilling records, geophysical logging, or other data.

When an exploratory hole has been shown to be in an acceptable location, free of structural anomalies, and at the required depth for containment in a medium having suitable physical and engineering properties, the larger emplacement hole may be drilled. Again, careful attention is given to a comparison of the geology and hydrology of these adjacent locations until the hole and emplacement chambers are complete.

The total costs for drilling and testing seven of these exploration holes at Amchitka including logging, cementing, casing as needed, and personnel support are estimated at approximately $20 million.

It was only after this exhaustive geologic study and site exploration that it was decided that the most suitable site for emplacement of the CANNIKIN test device had been located. The CANNIKIN site is 3,300 feet south of the Teal Creek Fault and 2,800 feet north of a suspected fault expressed only as a lineament on aerial photographs. The CANNIKIN depth of burst has been selected so as to assure containment; its selection was made after full consideration of experience gained in Nevada, and is based on the geology of the location and the yield at the test.

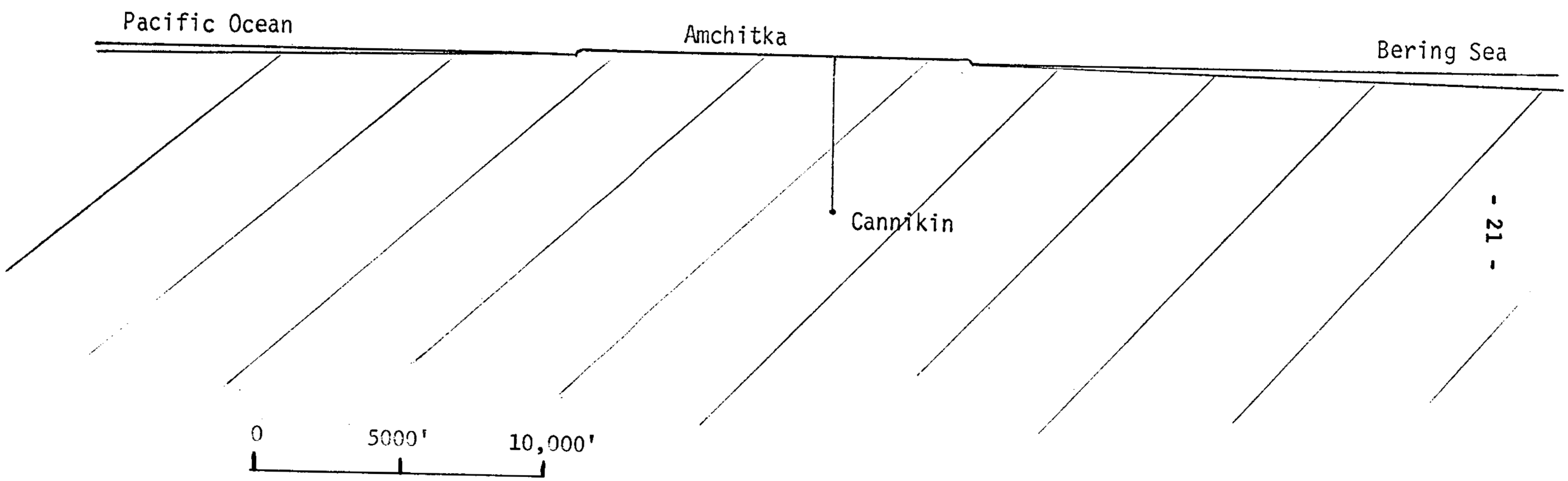
The CANNIKIN explosive will be emplaced in a cavity of 26-foot radius, at a depth of 5,875 feet, at the bottom of a 90-inch drill hole which has been cased to an inside diameter of 54 inches. The annulus between the casing and the hole has been filled with cement. After the device is emplaced, the hole will be stemmed (i.e., filled) from the top of the cavity to the surface of the ground with sand, pea gravel, and plastic plugs. Most of the stemming will be pea gravel, but sand plugs 100 feet thick will be placed near the surface and at depths of about 1,000 feet, 2,000 feet, and 3,000 feet. In addition, the bottom 250 feet of stemming will be sand. The sand plugs are less permeable than the pea gravel and act to stop the diffusion of gaseous products up the drill hole. Such diffusion is further inhibited by two plastic plugs, each about 40 feet thick, one of which will be cast near the surface and another about 1,500 feet above the explosion point. The lower plastic plug not only inhibits the flow of gas, but also acts as a platform to help support the stemming material. All of the electric cables from the device to the surface will have sealed sections to prevent gaseous products from reaching the ground surface by passing through the cables. The "cable blocks" will be buried in the lower plastic plug to preclude any flow of gas within the cable through the blocks, then out into the stemming material above.

Some days or weeks after the CANNIKIN test is conducted, it may be necessary to drill a small diameter hole to the explosion cavity so that a sample of the radioactive material can be obtained. If that drill-back is done, the latest drilling equipment and procedures will be utilized, insuring control of radioactivity. A small amount of radioactive gas may pass through the blowout preventers on the drilling equipment. This gas will be filtered and released and will not present a radiological hazard.

RADIOACTIVITY--GROUNDWATER

The top of the CANNIKIN emplacement hole is on a flat knoll 200 feet above sea level and 4,500 feet from the Bering Sea. The width of Amchitka at this location is about three miles. Figure 2 is a diagrammatic cross-section through Amchitka Island and the surrounding sea bed, drawn approximately to scale. The explosion point is at a minimum slant distance of 7,400 feet from the nearest sea coast.

Most of the precipitation collects temporarily in lakes, turf, and the underlying peat, and subsequently drains to the ocean via streams. Runoff during and after storms suggests that the underlying rocks are relatively impermeable or are saturated to the surface.



SCHEMATIC CROSS SECTION OF CANNIKIN EMPLACEMENT

FIGURE 2

Hydrologic testing at an exploratory hole near the CANNIKIN site indicates that only the rock units in the upper part of the hole are sufficiently permeable to permit significant groundwater movement outward and upward toward the ocean. Groundwater movement at greater depth is extremely slow. Water samples were taken at various depths for age dating by the carbon-14 method. One sample was recovered with sufficient carbonate for age dating. The uncorrected age determined from this sample from 3,150 feet was about 11,000 years. (The age is probably over 9,000 years.) The age and location of this sample and the determined downward flow of groundwater imply extremely slow movement of any groundwater at the depth of the CANNIKIN site.

The existing hydrological regime will be disturbed locally by the CANNIKIN test. (All activities in connection with this project are expected to comply with the requirements of the Federal Water Pollution Control Act, as amended by the Water Quality Act of 1970.) After CANNIKIN, the roof of the cavity produced is expected to collapse. Most of the radioactive material associated with the detonation will be incorporated into and trapped in rock melt, or will be adsorbed onto the surfaces of rock material. Most material will therefore be essentially retained in the bottom of the explosion zone. The volatile fission products and tritium are exceptions. The remainder of the cavity and the chimney above it will be filled with broken and partially recompacted rock, resulting from the collapse. This will very probably extend to the surface and result in a subsidence crater or sink. Test experience has shown that this subsidence does not provide open paths for escape of radioactivity to the surface.

After the CANNIKIN test, water will flow toward, rather than away from, the cavity until for all practical purposes the pre-shot hydrological conditions are reestablished, a process estimated to take about one year. The filling of the void space will take place by several mechanisms.

1. A mixture of fresh and saline water will enter the cavity by interstitial migration into the cracks and fractures created by the explosion. At this location the lower portion of the chimney and the cavity are expected to be in saline groundwater.

2. Groundwater will enter the cavity from overlying water-bearing zones and will percolate down through the chimney rubble.

3. Surface water and precipitation draining into the subsidence sink will also percolate down through the chimney rubble. It is expected that the subsidence sink will capture the drainage from WHITE ALICE Creek and this flow will be a contributor to the cavity infill.

The overall net effect will be that of downward and inward flow until the preshot conditions are reestablished. Only after this can contaminated water tend to flow away from the cavity toward the sea.

Those radionuclides not trapped in the solidified rock melt will be susceptible to migration in groundwater. Only an insignificant fraction of the trapped radionuclides will be slowly leached from the surfaces of the fused rock. The most volatile radionuclides (mostly xenon, krypton, and some iodine) will migrate upward, filter through the chimney rubble, and deposit their radionuclide daughters (cesium, barium, rubidium, and strontium) on the rubble surfaces. This migration is inhibited by the downward flow and flushing action of water in the chimney. Some tritium will be among the gases. Tritiated water vapor will condense and return to the cavity along with the downward-moving water. Data from test locations in Nevada show that the concentration of tritium in water decreases sharply with increasing height above the shot point.

Tritiated water is not expected to reach the surface of the subsidence sink. None had been detected from MILROW as late as a year and a half after the test. The point of origin of the by-products of the explosion, together with the direction of groundwater flow, will result in the highest concentration of radionuclides in the groundwater being at the bottom of the cavity.

Tritium in water is of more concern than other radioactive materials since it will migrate at nearly the same velocity as the natural groundwater. Tritium radioactivity decays continuously with a half-life of 12.3 years. Other radioactive materials not fixed in the rock melt will be retarded by adsorption on rock surfaces and will not migrate beyond a short distance from the cavity-chimney system.

Analysis of the groundwater situation expected after the CANNIKIN test postulates the most probable mechanism (1.) by which the groundwater can migrate to the sea. Two other less likely mechanisms (2. and 3.) are also presented. The three mechanisms are described below:

1. What is now considered to be the most likely mode of circulation involves downward movement of water into the cavity and outward migration through cracks, crevices, and interstitial pores in the rock to the sea. The driving force for this circulation is the hydraulic head from the water in the chimney extending up to the

natural water table some 100 feet below the land surface. The nearest potential discharge point would be between the shoreline and to about a quarter of a mile offshore in the Bering Sea. The migration would take a thousand years or more. By that time, the tritium in the discharge water would have decayed to a concentration well below the present background in the Bering Sea.

2. A second mechanism which is much less probable involves the vertical mixing of water within the cavity-chimney region due to thermal diffusion caused by the higher temperature in the cavity. Although the water in the cavity is expected to be heated, a substantial rise in the temperature would be required to upset the inherent density stability. The infilling water produces a cooling effect as does the transfer of heat into the rubble and surrounding media. The cooling effect reduces the driving force. Estimates indicate that such circulation would be small and that its effect would be reduced by the continual opposition from the overall downward movement of water. At most, this is a short-term process in terms of the years involved, but may cause, at least initially, some small fraction of the tritiated water to move upward in the chimney rubble. The increased permeability in the upper levels offers a path for the migration of the water to the sea through a combination of flow through cracks and crevices and interstitial pores in the rocks. This process is estimated to take over a hundred years and to result in the discharge of tritiated water at about the same concentration as the Radioactivity Concentration Guide (RCG) for water. This discharge area would be localized in the downgradient side of the island (Bering Sea) from the shoreline to about a quarter of a mile offshore.

3. A third mechanism involves the very unlikely assumption that the water within the cavity-chimney system becomes completely mixed, coupled with a second unlikely assumption that the flow through the rock occurs only through a system of interconnecting fractures. Estimates using these assumptions indicate contaminated water would reach the sea in about two or three years after the cavity was filled--or some three years after the explosion. This would introduce tritiated water into the ocean with an initial concentration about 1,200 times that of the RCG for water. Because of the very small seepage rate, such flow would continue to flush out tritium-bearing water

for many years. However, either the effect of radioactive decay or that of dilution by new groundwater, acting separately, would act to reduce the tritium concentration of the cavity water to the RCG level in a time of about 130 years; groundwater dilution and radioactive decay acting together will reduce the tritium concentration to the RCG level in perhaps 60 or 70 years. The assumptions of this model also imply a sharp reduction in adsorption surface and, therefore, at some later time other radionuclides such as strontium, cesium, ruthenium, and antimony would also be introduced into the ocean in concentrations higher than the RCG.

The point should be made that even if this extreme case were to exist, dilution of that water by the sea water would take place rapidly. With the seeping water being swept up by the passing ocean current and mixed through tidal action and wave action, oceanographers have estimated that there would be an effective dilution factor of about 100,000 within a few hours. In this manner, the sea water tritium[1] would quickly dilute to levels comparable to those **freshwater** levels acceptable for lifetime use by humans.

A long-term water sampling program to monitor and document radioactivity on and near the island will be continued by the USGS following the detonation. Water samples will be collected annually from lakes and streams in the vicinity of the LONG SHOT, MILROW, and CANNIKIN sites, as well as background samples near the base camp and at other selected points along the island. In addition, sea-water samples will be obtained from various depths at locations offshore from the three test sites, as well as background samples at more remote sites. All samples will be analyzed for tritium, and any suspect readings will result in more detailed analysis. Annual reports will be distributed describing the results of the surveys.

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[1]The RCG for drinking water is used because there are no standards for sea water per se or for fish and shellfish except as they are used for food.

THE AMCHITKA BIOENVIRONMENTAL PROGRAM [1]

Under contract with AEC Nevada Operations Office, Battelle Columbus Laboratory initiated ecological studies on Amchitka in 1967. The investigations are being carried out with the assistance of scientists from several universities, the Smithsonian Institution, the Fish and Wildlife Service (U. S. Department of the Interior), and the National Marine Fisheries Service (U. S. Department of Commerce).

This Amchitka bioenvironmental program is designed to:

Characterize the ecological features of the island and surrounding waters;

Predict, document, and evaluate the effects of nuclear testing activities on the biota and the environment;

Recommend measures for minimizing adverse effects of nuclear testing activities on the biota and the environment; and

Identify needs and recommend methods for environmental restoration of areas disturbed by AEC activities.

Bioenvironmental Studies

The program includes studies of the soils and ecological studies of the terrestrial vegetation, avian population, freshwater streams and lakes, and of the marine environment surrounding the island. Also included are an archeological survey and radioecological studies of the terrestrial, freshwater, and marine environment.

Numerous sites of archaeological interest are present on the island, but no systematic attempt to explore and interpret the prehistory of Amchitka had been made prior to the present operations. A team of

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[1] The Amchitka bioenvironmental program was the subject of a symposium conducted during the annual meeting of the Ecological Society at Bloomington, Indiana, in August 1970. (See June 15, 1971, Special Issue BIOSCIENCE, Volume 21, No. 12.)

professional archaeologists has now surveyed the island for evidence of early human occupation. Seventy-eight sites have been identified along the sea coast, and six of these have been carefully excavated to find artifacts and determine information contained in them. This work was done in compliance with the Antiquities Act of 1906.

The objectives of the soil studies are to characterize the major soil types of Amchitka, and to identify and define the physical characteristics of shock sensitive soils. Effects of expected ground shock upon the mass movement and alterations in soil conditions have been predicted. After detonation, effects will be documented and correlated to predictions. Soil characteristics have also been evaluated relative to assisting in reclamation of disturbed areas.

The plant studies have developed baseline information concerning the vegetation of the island. Plots have been established for long-term investigations of the effects of man's past and present activities on the terrestrial plant communities. The feasibility of and best methods for revegetating areas that have been disturbed during site preparation and testing activities are also being investigated.

The avian ecology studies are designed to determine the kinds and numbers of birds on the island. Their habitats have been identified, breeding periods and nesting sites have been determined, and food habits of more important species have been determined. Predictions have been made of the impact of testing activities upon the bird life for the different times of the year. Subsequent to the test, studies will be conducted to evaluate the effects. Special emphasis is devoted to endangered species, such as the bald eagle and the peregrine falcon, and to species that are used for food by man.

The freshwater studies are designed to determine the limnological characteristics of Amchitka's lakes, ponds, and streams. The food habits and breeding cycles have been determined for all species of freshwater fish, including detailed studies of salmon spawning activities on the island. Certain streams and lakes have been selected for intensive studies to estimate abundance, distribution, movement, growth, survival, and mortality of natural fish populations. The abundance and seasonal cycles of fish-food organisms have been studied and natural variations in plankton populations and primary productivity are being documented. Predictions have been made of the effects of the nuclear testing activities upon the freshwater organisms and these predictions will be tested by post-detonation studies.

In support of the marine program, existing information on the most important commercial species of marine fishes and mammals that are harvested around Amchitka has been compiled and summarized. These data include information on the seasonal patterns of fishing effort, fishing sites, catch statistics, life histories, and migratory habits of the species of major commercial importance. Some exploratory fishing has been conducted in search of possible unexploited fishery resources and nursery grounds of commercially important species near Amchitka, and to develop additional information on the migratory patterns of valuable species. Baseline physical oceanographic information has determined current patterns and water mass transport rates relative to the Amchitka region. Detailed ecological studies of the Bering Sea and Pacific Ocean waters nearest to the test area have included chemical analysis of water, primary productivity measurements, plankton studies, and investigations of the attached algae and in-shore benthic fauna. Particular emphasis has been devoted to evaluating the distribution and abundance of the sea otters' food organisms. Predictions have been made of test effects, and, subsequent to the test, studies will be conducted to document and evaluate any effects. This effort will include observations for kills due to shock effects and for any sub-marine fault movements. Also, specimens will be collected for radiochemical analysis.

The objectives of the marine mammal investigations include surveys of the marine mammal population of the general area, and special studies of the sea otters. The sea otter studies include population surveys, evaluations of sea otter population dynamics, experiments to determine the physiological effects of shock waves, and investigations of the animals' behavior as may be related to the test activities. Predictions have been made of test effects and subsequent studies will be conducted to identify and evaluate effects from the test.

The radioecology effort includes documentation of the background levels of specific radionuclides present in the soils, water, plants and animals, resulting from natural and worldwide fallout sources. Food chains whereby certain radioactive materials could be transferred to man or other important species in the remote case of a venting have been identified.

Marine Food Chains

Although the CANNIKIN test is designed so that the venting of underground radioactivity is extremely unlikely, as a precautionary measure, attention has been given to the possible consequences if the maximum credible prompt release (venting) of a few percent of the total radioactivity were to occur soon after the detonation. Since there are no permanent human inhabitants either on Amchitka or the nearest islands, the principal question about the fate of vented radionuclides is that of contaminating marine life, especially fish that are used as food by man. The Battelle Columbus Laboratory has developed mathematical models and computer programs to predict the dispersion of radionuclides in the sea, uptake by marine organisms, and ultimately the internal radiation dose to man consuming the sea food.[1]

These mathematical models and computer programs were used to make calculations for the MILROW test.

These modeling calculations were based on assumptions all of which were cautious to the point of being extremely unlikely:

> That all vented radionuclides would reach the sea by a predicted fallout pattern and by runoff of fallout from the land to the sea;
>
> That all of the radionuclides would remain within the volume of water in which they were deposited;
>
> That all of man's food fish would remain in this volume of sea water until caught and eaten so that the radionuclides in their bodies would have reached an equilibrium level; and
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> That man would consume this food at a rate of 66 pounds per year commencing 30 days after the detonation and continuing throughout his lifetime.

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[1]Bloom, S. G. and Raines, G. E., Simulation Studies as Related to the Ecological Effects of Underground Testing of Nuclear Devices on Amchitka Island: Annual Progress Report. Amchitka Bioenvironmental Program. Report BMI-171-118 (Columbus, Ohio: Battelle Memorial Institute, February 1969).

Bloom, S. G. and Raines, G. E., A Preliminary Mathematical Model for Predicting the Transport of Radionuclides in the Marine Environment. Amchitka Bioenvironmental Program. Report BMI-171-123 (Columbus, Ohio: Battelle Memorial Institute, November 20, 1969).

Bloom, S. G. and Raines, G. E., Simulation Studies as Related to the Ecological Effects of Underground Testing of Nuclear Devices on Amchitka: Annual Progress Report July 1, 1969 - June 30, 1970. Amchitka Bioenvironmental Program. Report BMI-171-138 (Columbus, Ohio: Battelle Memorial Institute, In Press).

On the basis of this modeling calculation, the overall total dose that was hypothetically possible to man under these assumed conditions was only 1.10 rem to time infinity. It is of special interest that of this total the cumulative hypothetical tritium dose for 50 years totaled only 1.6×10^{-7} rem.

Similar calculations are being done for CANNIKIN as source-term data is developed for the CANNIKIN device.

It is anticipated that the results of these comparable but more complete calculations for the CANNIKIN case will not be substantially different from the results of the MILROW calculations. Because of the relatively slow rates of groundwater migration, application of similar mathematical modeling and computer calculations to hypothetical mechanisms for transport of groundwater to the sea would necessarily result in predictions of dose much smaller than the predictions described above for the venting model.

SUMMARY OF MILROW BIOENVIRONMENTAL PREDICTIONS

Prior to MILROW, existing bioenvironmental conditions in the terrestrial, freshwater, and marine ecosystems were documented. Studies began immediately following the MILROW test to determine prompt effects. These studies are continuing to detect any latent or delayed effects.

On the basis of two years of bioenvironmental studies and experience in other nuclear test programs--especially the LONG SHOT test on Amchitka in October 1965--the following predictions were made by the Battelle Columbus Laboratory of the probable bioenvironmental effects of firing the MILROW test in October 1969:

> "Since the MILROW test is designed to make it improbable that any radioactivity will be released by prompt venting or seepage to the freshwater, terrestrial, and marine ecosystems, a radiation hazard is not predicted. However, if venting should occur, the hazard would not be as great in October as if it occurred during the period of May through September. By October, the bird nesting season is over, the peak of the commercial fisheries has passed, and few salmon are in the waters off Amchitka. Emperor geese winter at Amchitka, numbering several hundred in October and subsequently building up to a maximum of around 10,000 in mid-winter. The only commercial fisheries remaining active near Amchitka in October would be for halibut and other bottom fish.

"Effects of overpressure in the marine ecosystem, if the device produces the shock and other seismic effects predicted, are expected to be minor. Overpressure pulses may cause lung damage to sea otters that are in the water off the south coast near surface zero. Perhaps 5 to 10 otters could be so affected. Temporary habitat disturbances of sea otters and some fish species may result. These effects will be less hazardous during October than at other periods such as spring and summer when marine species of fish are more numerous and are reproducing or late winter when environmental conditions are less favorable for sea otter survival than during the remainder of the year.

"Ground shock from the MILROW event will affect the terrestrial and freshwater ecosystems in close proximity to the test site. A potential detrimental effect is the loss of nesting sites on sea stacks and cliff areas for birds such as the bald eagle and peregrine falcon. One eagle nest is 1.7 miles from surface zero; four more are 2-3 miles from it. The potential hazards to resident populations will be reduced by testing during October, after birds have completed their nesting and after juvenile salmon have migrated to sea. Testing when the soil moisture content is low will minimize changes such as bank slumping, debris slides, and liquefaction of mineral soils.

"The major changes that will be produced in the Amchitka ecosystems by the MILROW event probably have already occurred. These are the changes associated with construction and site preparation activities. Some of these changes may be mitigated after the test by revegetation efforts."

SUMMARY OF MILROW BIOENVIRONMENTAL EXPERIENCE[1]

Experiments were conducted during MILROW to aid in predicting biological effects from a future test of greater yield. Sea otters, freshwater fish, ocean fish, and crabs were placed in experimental pens in their natural habitats to study their responses to shock forces from MILROW. Following the detonation, survey parties reconnoitered the area around the test site by helicopter, boat, and on foot to search for any dead or injured fish, marine mammals, or birds. These surveys started a few hours after the shot and continued for several days. No casualties

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[1]Kirkwood, James B., Bioenvironmental Safety Studies, Amchitka Island, Alaska: MILROW D+2 Months Report. Amchitka Bioenvironmental Program. Report BMI-171-126 (Columbus, Ohio: Battelle Memorial Institute, March 20, 1970).

were observed in unconfined populations of sea otters, sea lions, or harbor seals. A group of up to about 15 harbor seals were observed on rocks in a cove on the Pacific Coastline, about two miles from MILROW surface zero, a few days before the test. These animals were photographed at the same location a few hours post-MILROW, and were observed to have suffered no adverse effects from the test. One dead porpoise was found that had died due to a rib puncturing a lung; cause of the fracture could not be determined. The only casualties in freshwater habitats were some of the small stickleback fish in two ponds half a mile from surface zero. No dead or injured birds were found.

None of the marine fish or crabs maintained in holding pens during the detonation were harmed. One sea otter that had been confined to a test pen floating in the sea 9,200 feet from the MILROW surface zero was found dead after the shot. Autopsy of this otter did not reveal any shock injury; in fact, no cause of death could be determined. (It is possible that the animal succumbed to the stress of handling and confinement--a reaction commonly encountered when otters are in captivity.) There were 24 additional otters in the test pens. Of these, four escaped before their recovery from the pens. Observation of the 20 remaining otters indicated that all survived and were in good health. Four of these 20 sea otters were sacrificed three days after MILROW to learn if any physical damage had been inflicted as a result of the test. None was detected.

Disturbances of the land surfaces caused by MILROW were largely confined to the area within a two-mile radius of surface zero. With few exceptions, the disruptions of the organic vegetation mat were confined to a 3,000-foot radius around surface zero. Disruption of the drainage system was that caused by the general surface subsidence within about 1,500 feet of surface zero. Rockfalls and peat and debris slides occurred along the coast mainly at sites which had been weakened by natural processes such as wave erosion and frost action. About 3,800 cubic yards of material fell along the coast on the Pacific side of Amchitka. About 10,000 cubic yards of rockfall occurred on the Bering Sea side. Most of this latter total can be accounted for by one slide in a place where, judging from preshot observations, the headland has been subject to large natural rockfalls during past years. No eagle or peregrine falcon nests were destroyed. There were also slides on cut banks along a road beside the harbor.

As described above, scientific observation of two previous nuclear explosions has shown very little damage to fish and animal populations and very little disturbance of the landscape. Design of the CANNIKIN experiment is such that its physical effects on Amchitka will be roughly comparable to those of MILROW.

PREDICTIONS OF EFFECTS FROM CANNIKIN (The following predictions are based in part on the assumption that the CANNIKIN test would be done in the autumn.)

Radioactivity

The CANNIKIN test is designed to retain activity underground and the chance of prompt release of radioactivity to the biosphere is remote. Groundwater will gradually transport activity away from the explosion source and may eventually discharge to the ocean with tritium concentrations near to present background levels for the Bering Sea.

Upon reaching the sea floor interface, dilution would further reduce the tritium concentration. Other isotopes are retarded by sorption and will be below maximum concentration levels before reaching the sea. Radioisotopes of noble gases will seep to the earth's surface and be rapidly dissipated to levels well below applicable RCG's.

Terrestrial Ecosystems

The main impact on the terrestrial ecosystem will be the occurrence of rock and earthslides along coastal areas and the possible resultant effects on bird nesting habitats. About 14,000 cubic yards of rock and peat materials were dislocated by MILROW. Because the yield of CANNIKIN will be larger and because the instability of the soils in the CANNIKIN area will be greater, the disturbances of rock and peat will probably be more extensive. Numerous massive slumps of fossile sand dune materials may occur along the Bering Sea shoreline, near the CANNIKIN site. If there were severe damage to sea stack and sea cliff nesting areas of bald eagles and peregrine falcons, it could affect their reproductive success in subsequent breeding seasons. Ornithologists estimated that 55 pairs of bald eagles and 19 pairs of peregrine falcons nested on Amchitka during 1970. The numbers of eagle and falcon nests counted in 1970 within four miles from CANNIKIN surface zero are as follows:

DISTANCE FROM SURFACE ZERO (MILES)	NUMBER OF NESTS	
	BALD EAGLES	PEREGRINE FALCONS
0 to 1	0	0
1 to 2	2	1
2 to 3	3	1
3 to 4	3	0

Based on MILROW, rockfalls could occur to a distance of four miles from CANNIKIN. Extrapolation from MILROW experience indicates that CANNIKIN may damage one or two eagle or falcon nesting sites so severely that they would be unsuitable as future nesting locations. This amount of damage to nesting sites would not affect the reproduction potential or populations of their species, nor should there be any measurable effects on population density or reproduction potential of the other avian species as a result of the CANNIKIN test.

Rockfalls may also cause damage to one archaeological site situated on a cliff edge near the CANNIKIN site.

It is probable that a saucer-shaped surface depression will form above the CANNIKIN emplacement location as it did in the case of MILROW (see Appendix). It could be as large as about 4,000 feet in diameter from crest to crest, and anywhere from a few feet to 100 feet deep at the center. As on MILROW, this will cause numerous circumferential tears and cracks in the turf.

Topographic changes resulting from CANNIKIN will alter soil drainage in some locations and this will cause changes in some plant community structures, but this is not expected to be extensive. As during MILROW, the most spectacular effects on vegetation should be the disturbance of moss mounds by ground shock effects. However, because of differences in the composition and distribution of plant communities, CANNIKIN will affect fewer moss mounds than MILROW.

Freshwater Ecosystems

Amchitka Island contributes very little to salmon fisheries. Pink salmon are the most abundant species of salmon on Amchitka and silver salmon are encountered occasionally. Red salmon are rare. Freshwater and intertidal spawning is well distributed around the island, but only a small number of fish are found. This is probably because the streams are small and their drainages short.

Experience gained during MILROW and LONG SHOT, coupled with the water overpressure pulse predictions, indicates that the CANNIKIN test should not affect Dolly Varden char, or salmon populations on the island. Salmon have been found in 21 streams; four of the streams warrant special attention because of their proximity to the CANNIKIN site. All four streams supported spawning pink salmon during surveys conducted during 1970; the nearest redd was 1.7 miles from surface zero. In these four streams, only a total of

31 pink salmon and 9 redds were observed during the 1970 spawning season. (Two of the four streams also had lesser numbers of silver salmon.) One of these streams, Bridge Creek, three miles from surface zero, also contained spawning salmon during 1969 but it is not known whether or not the other three streams support an odd-year run. It should be noted that pink salmon always have a two-year life cycle. Dolly Varden char have been found in 34 streams on Amchitka, including the four streams mentioned above. Although it is not possible to predict with confidence the effects that shock from the detonation may have on fish in these streams, it is encouraging to note that Dolly Varden confined to live boxes in ponds 2,500 feet from surface zero in LONG SHOT and 2,000 feet in MILROW survived those detonations without apparent harm. It is possible that some fish in the closest streams will be injured or killed by CANNIKIN shock effects, but at worst this would affect only a small fraction (1-10% depending on species) of the total island populations.

Some small scrapfish (threespine sticklebacks) will be killed in some of the lakes adjacent to the CANNIKIN surface zero. Since the lakes that will be affected are few and not nursery areas for salmons smolts, this effect is considered of minor importance. Changes of plankton levels in nearby ponds may occur, but this would be transient and not a problem.

Minor changes in drainage patterns are expected and draining of one or two ponds is possible; this will result in changes in the standing crops of several species of plants and animals in these bodies of water. No major salmon or Dolly Varden spawning or rearing areas would be affected.

As far as the overall freshwater ecosystem is concerned, the principal ecological effects of CANNIKIN are likely to be produced during site construction and operations where sediments, and possibly escaped waste materials, may be carried by natural drainage pathways into nearby streams and ponds. While some waste materials have reached streams and ponds, extensive efforts are being made to minimize such mishaps.

Marine Ecosystems

Field studies which included observations during the MILROW test have shown that for the CANNIKIN test the effects of overpressure in the marine ecosystem should be expected to be minor.

Sea Otters

Estimates of the total population of sea otters at Amchitka vary depending upon when and under what conditions the counts were made. During the period of 1969 to 1970, otter counts ranged from 2,500 to 4,000.

Overpressures greater than 100 psi may rupture sea otter tympanic membranes (eardrums) which ultimately can be expected to cause death in otters so affected if they are unable to dive for food. Overpressures of this magnitude at the sea floor may extend out to radii of about five miles from CANNIKIN; however, at any given location, the overpressure depends on water depth and decreases to zero at the surface. The number of otters within a five-mile radius, of course, differs from time to time, but estimates based on counts have ranged from 200 to 700, including the pertinent sections of both the Bering and Pacific coasts.

Typically during mid-day, otters intersperse dives for food-gathering with periods of grooming and rest on the surface. Again, estimates vary about the fraction of animals that might be down on the sea floor during mid-day; on a typical autumn day, in the area of interest--the latest estimates range from 10% to 15%.

Combining these latter two estimates yields a prediction that 20 to 100 sea otters might be exposed to overpressures from CANNIKIN that could be severe enough to rupture their eardrums and ultimately result in their death. To place this prediction in perspective, it should be noted that during the period 1962 through July 1970, the Alaska Department of Fish and Game killed 901 Amchitka sea otters for their pelts. This is in accord with conventional game management practices as a means of keeping animal populations in balance with their food supply. Insofar as can be determined, the removal of about 1,250 sea otters from Amchitka since 1967, in transplants, harvests, and for experimental use, has not had a prejudicial effect on their population. Therefore, even if shock effects of CANNIKIN should cause some mortality as discussed above, the net effect on the Amchitka population should not be of long duration.

Sea Lions and Harbor Seals

The Amchitka sea lion and harbor seal populations are not expected to be affected by CANNIKIN. During the fall, most of the sea lions are at hauling-out areas too far from surface zero to suffer any adverse effects from ground motion or overpressure (e.g., at

Column Rocks, some 13 miles distant in the Pacific, or at Ivakin Point about 14 miles away, on the Bering coast). Small groups of harbor seals may be somewhat closer to surface zero. If a few such individuals should be killed by ground motion or overpressure from CANNIKIN, early restoration of the island seal population would be anticipated by normal population growth of groups beyond the range of damage.

Commercial Fisheries

Bioenvironmental program scientists are confident that populations of commercial fish and shellfish species will not be endangered from CANNIKIN. There is uncertainty, however, as to the extent to which overpressure and underpressure pulses in the sea could cause injury to fish. Those species such as cod and rockfish having air bladders that are not connected to the alimentary canal are considered to be the most vulnerable to abrupt pressure changes. Fortunately, the most important commercial species of rockfish, the Pacific ocean perch, migrates to deeper water in the fall (about 150 fathoms) and will probably be out of the area of greatest risk. Estimates of pressure effects to ocean fish range from the most probable expectation that only a few fish, primarily cod and rockfish species, will be killed, to the unlikely possibility that casualities may include: hundreds of fish in the near-shore area such as Pacific cod and dusky rockfish; a few salmon in deeper off-shore water; hundreds of fish such as Atka, mackerel, lantern fish, rockfish, and smelt in mid-water, off-shore areas; and thousands of rockfish and Pacific cod in off-shore bottom areas. In any event, the possible losses would be localized close to Amchitka Island.

Construction Activities

The area of Amchitka is about 114 square miles or 73,000 acres. The Department of the Interior's resident biologist estimates that 950 acres of land have been disturbed by various operational activities associated with preparation for MILROW and CANNIKIN. These activities include road building and improving, drill-site development, and the development of material supply areas. The disturbance includes 79 acres of lake and 7.5 miles of stream pollution, mostly from spills or leaks of drilling mud. During the early phases of construction, there was some illegal disturbance of middens despite warnings and some off-road disturbance by tracked vehicles.

Approximately half of the disturbed 950 acres is on land used previously for roads, aircraft taxiways, or borrow pits by the military during World War II. About 500 acres are new disturbances--0.7% of the island area.

The AEC-constructed camp facilities were designed for an initial population of 500 men and later enlarged to accommodate the peak population of 774 men on September 8, 1969. At MILROW shot-time, 137 men were at the northwest camp and Control Point. The peak population for CANNIKIN is expected to be around 740, and the population at shot-time is expected to be around 200.

The AEC has also put into use various World War II and LONG SHOT facilities after renovation. These include two aircraft hangars, several small warehouses, trailer and office units, roads, the airstrip, dock facilities, fuel storage tanks, water, and sewage systems. The main road network necessary to support the program follows the route of a World War II road and jeep trail along the length of the island, although some new branch roads have been constructed to support the current test program.

The garbage disposal area is on the site of a World War II pit--a four-acre combination burn and cut-and-fill operation. For sewage disposal, the AEC constructed aerated sewage lagoons to service all facilities on the island. Locations and methods were approved by the resident representatives of the Fish and Wildlife Service.

All of the support facilities which have been built at Amchitka for the test operations have been designed in anticipation of the ground motion to which they would be subjected during tests. Facilities containing fluids will be contained at safe levels or emptied before the test if there is a serious possibility of damage which could lead to a leak or spill. As an additional precaution, containment berms have been constructed around bulk storage tanks.

Drinking water for the main camp is taken from a spring just north of the main airstrip. Water from this source is carried to the drill sites. Drinking water for the northwest camp and Control Point is obtained from a rehabilitated World War II dammed spring. Drilling and construction water is taken from nearby lakes under the guidance and approval of the Fish and Wildlife Service representative on the island. At no time has the Amchitka potable water supply been contaminated from any of the AEC operations, except for small amounts of silt entering the system when new facilities were added and, briefly, at the time of the MILROW test. The drilling operations have caused some damage to freshwater streams inadvertently. In part, this happened when oil was introduced as a supplemental drilling fluid but this use was discontinued after 1968. The streams so damaged are recovering satisfactorily.

Field representatives of the AEC and the Department of the Interior at Amchitka have developed plans for measures to be carried out so that Amchitka Island will be restored to a satisfactory condition before the AEC leaves that site.

After the successful completion of CANNIKIN, the AEC intends to vacate Amchitka, leaving that island as nearly as possible in the condition in which it was found to be in 1967. All debris created on Amchitka as a result of the AEC's activities will be removed from the island or buried in a location that has been designated for that purpose. All structures erected on Amchitka by the AEC will be removed except for specific buildings which the Department of the Interior wishes left in place. Existing paved areas such as the airport runways, taxiways, and roads will be left in place. Some buildings and debris left at Amchitka as a result of the World War II activities will have been removed by the AEC incidental to its general cleanup activities. To the extent feasible, areas that have been disturbed through AEC activities will be restored by leveling or contouring, and reseeding. Restoration methods and plant species to be used for revegetation will be selected with the approval of U. S. Fish and Wildlife Service representatives.

Other Effects

In considering the possible effects of CANNIKIN, it was determined that the U. S. Army had disposed of a large number of containers of mustard gas and Lewisite in 1947 by dumping them at sea near Attu Island at a distance of about 240 miles from Amchitka. There was the question of whether CANNIKIN might cause these materials to be released to the ocean. At a distance of about 240 miles, the CANNIKIN explosion will appear as a simple seismic wave with no significant disturbance of the sea floor. Since the disturbance will be minimal at the location of the mustard gas and Lewisite containers, the CANNIKIN test should have no effect upon those containers. It should be noted that there have been three earthquakes of magnitude 7.0 or greater in the Aleutian Islands west of Amchitka since 1947. Each of these seismic disturbances has probably subjected the containers to motions larger than those which will occur in connection with CANNIKIN.

In 1967, the Advanced Research Projects Agency (ARPA) of the Department of Defense attempted an experiment in which about 2,300 tons of high explosive was to be detonated in the sea at a water depth of about 4,000 feet but not at the sea floor. For this experiment, the obsolete cargo ship Robert Louis Stevenson, loaded with the 2,300 tons of explosives, was fuzed to detonate at the desired depth by hydrostatic pressure. The ship was towed to a position about 32 miles west of Amchitka and released, and the sea cocks opened so that the ship would sink. Actually the ship did not sink as rapidly as expected and it drifted so that it sank in only about 2,800 feet of water at a location that is about 30 miles from the CANNIKIN site and did not detonate. Subsequently, the U. S. Navy attempted unsuccessfully to detonate the high explosive in the Stevenson's hulk using large (2,000 pound) depth bombs exploded nearby. After studying the situation and testing the type fuzes that were involved, the Navy concluded that the hydrostatic fuzes had become inert and that, hence, the materials in the Stevenson's hulk were no longer a potential explosive hazard. Therefore, the explosives in the Stevenson's hulk are not vulnerable to the effects of CANNIKIN.

BIOENVIRONMENTAL PROGRAM FOR CANNIKIN

A shot-time and long-term post-shot program has been established to document environmental effects and to form a scientific basis for improving our predictive capability. This program will include the collection and radiological analysis of environmental samples to assure the AEC and the public that if any release of radioactivity should occur, it will be detected and appropriate action taken.

CANNIKIN Sampling[1]

The collection of biological and environmental samples at Amchitka for radiological analyses was started in 1967, more than two years prior to the MILROW detonation, and will be continued on a regular basis for about one year following the CANNIKIN event. Thereafter, routine sampling will be continued for a few more years on a reduced basis. There is also a limited amount of information from samples collected in 1964 before the LONG SHOT detonation. One objective of these efforts has been to detect and document the kinds and amounts of radionuclides already present and to determine if these concentrations differ significantly from natural background variations or from levels expected from worldwide fallout.

The sampling program in the past has concentrated on the vicinity of the nuclear tests LONG SHOT and MILROW, but has also included areas remote from these sites to obtain control data. The spectrum of samples includes, among other things, water from ponds, streams, groundwater sources, the ocean and precipitation, air filter samples, and soils. Samples of terrestrial plants include lichens, mosses, sedges, grasses, and forbs. Land and shore animals sampled include

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[1]Ewing, R. A.; Howes, J. E.; and Vogt, J. R., Radionuclide and Stable Element Analyses of Environmental Samples from Amchitka Island, Alaska: Annual Progress Report, Amchitka Bioenvironmental Program, Report BMI-171-110 (Columbus, Ohio: Battelle Memorial Institute, November 1968).

Isakson, John S. and Seymour, Allyn H., Radiometric and Elemental Analyses of Marine Organisms from Amchitka, Alaska: Annual Progress Report July 1, 1967 - June 30, 1968, Amchitka Bioenvironmental Program. Report BMI-171-113 (University of Washington: Fisheries Research Institute, September 26, 1968).

Nakatani, Roy E. and Seymour, Allyn H., LONG SHOT Bioenvironmental Safety Program, Final Report. Report RL-1385-1 (University of Washington: Laboratory of Radiation Ecology, October 27, 1967).

Held, Edward E., Amchitka Radiobiological Program Progress Report - April 1, 1971, Report NVO-269-11 (University of Washington: Laboratory of Radiation Ecology, In Preparation).

Koranda, John J., et al, Radiological Studies of Amchitka Island, Aleutian Islands, Alaska, II, Gamma - Emitting Radionuclides in the Terrestrial Environment. Report UCRL-50786 (Livermore: University of California, Lawrence Radiation Laboratory, December 8, 1969).

Norway rats, rock ptarmigan, Lapland long-spurs, emperor geese and black oyster catchers. Fresh water organisms include Dolly Varden trout, sticklebacks, and periphyton. Among the many marine organisms sampled are sea otters; seals; sockeye, chum, pink, and silver salmon; rock sole, halibut, Alaska pollock, ocean perch, Pacific cod, greenling, crab, euphausids, amphipods, scallops, mussels, snails, squid, sea urchins, sea stars, algae, and plankton.

Representative specimens of these samples, including different specific tissues such as flesh and bone, have been radiologically analyzed; some of the samples have been preserved and are being held in case additional analysis is warranted in the future.

From results of the samples analyzed, it has been concluded that the radionuclides detected were naturally occurring, resulting from worldwide fallout or were carried to the area by oceanic currents. The exception is tritium which is slowly seeping in very low concentrations into mud ponds at the site of LONG SHOT. Except for tritium in LONG SHOT mud ponds, the concentrations of the radionuclides found are within the range of values reported for similar samples from other parts of the northern hemisphere.

Post-CANNIKIN Sampling

The Western Environmental Research Laboratory (formerly Southwestern Radiological Health Laboratory of the U.S. Public Health Service) of the Environmental Protection Agency will operate an air sampling network extending from Shemya and Adak Islands in the western Aleutians to Annette Island in southeastern Alaska. These air samplers will be operated continuously on a 24-hour filter change regimen starting about three weeks before the planned date of detonation and the sampling will be continued for at least two weeks after the detonation. All filters will be scanned for gross radioactivity and any that measure above background levels will be further analyzed for specific radionuclides. Selected foods will be collected from markets and analyzed for radioactivity. EPA radiation health personnel equipped with radiation dosimeters and external radiation survey instruments will be stationed at selected sites in Alaska during the CANNIKIN test period. In addition to activities at the ground stations, EPA scientists will monitor the atmosphere using special aircraft flying over the test area immediately after the detonation and they will be prepared to follow and delineate any radioactive release to the air.

The AEC will continue periodic sampling and analyses for at least several years after CANNIKIN to ascertain if the radionuclides from all nuclear tests at Amchitka remain adequately contained underground.

PART III

COORDINATION AND REVIEW PROCEDURES

COORDINATION

Before seeking Presidential approval to use Amchitka Island for the conduct of certain high yield tests, the AEC consulted various interested federal departments and agencies, including the Department of the Interior. Presidential authorization to proceed with an initial survey of Amchitka Island as a possible supplemental test site was received in August 1966. Planning for operations at Amchitka was also coordinated with the State of Alaska, initially in 1966 and subsequently as plans were developed. In December 1966, after the completion and review of this survey, the Commission received Presidential approval to develop the Amchitka supplemental test site. In each of the fiscal years 1968, 1969, and 1970, AEC's appropriation requests to Congress explicitly included funds for the use of Amchitka Island as a supplemental test site.

Since receiving authorization to use Amchitka Island, the AEC has coordinated its Amchitka activities with the Department of the Interior through the Fish and Wildlife Service which manages the Aleutian Islands Wildlife Refuge. In order to protect Amchitka, as part of the Aleutian Islands National Wildlife Refuge, the AEC obtained the services of two refuge biologists and one research biologist from the Department of the Interior. The AEC also obtained the assistance from the Department of Commerce, National Marine Fisheries Service, to maintain cognizance over and furnish advice regarding commercial fisheries aspects of our activities. (Prior to the start of the AEC operations on the island, the Department of the Interior did not maintain personnel on the island full-time, although some short-term ecological studies had been conducted there earlier.) One or the other of the Bureau of Sport Fisheries and Wildlife (BSF&W) refuge biologists is in residence on the island at all times. His responsibility is to advise AEC engineering and construction personnel on measures for minimizing disturbance of the ecosystems and for preserving Refuge values. The role of the research biologists is to maintain technical liaison between the Department of the Interior, AEC Nevada Operations Office, and Battelle Columbus Laboratory on matters pertaining to the bioenvironmental program.

REVIEW PROCEDURES

In order to uncover potential safety problems and predict the effects upon the environment of the CANNIKIN test, the Atomic Energy Commission has utilized the best scientific talent it could bring to bear, both from within and from outside the Commission. It has utilized the services of private contractors, of the universities, and of other governmental agencies such as the U. S. Geological Survey; the National Ocean Survey (formerly the U. S. Coast and Geodetic Survey) and the Air Resources Laboratory, both of the National Oceanic and Atmospheric Administration (NOAA) (formerly ESSA); and the Environmental Protection Agency. The outputs of these efforts have been coordinated and compiled by an effects evaluation scientist specifically assigned for the CANNIKIN test. The resulting compilations have been reviewed by the Manager of the AEC Nevada Operations Office with the assistance of three scientific advisors from the Los Alamos Scientific Laboratory, the Lawrence Radiation Laboratory, and the Sandia Laboratories.

The Atomic Energy Commission has also utilized the advice and counsel of a number of independently recognized experts from a variety of pertinent scientific disciplines. For CANNIKIN, a Standing Panel of Consultants for the AEC has performed a review of the effects predicted on the geology, groundwater, ecology, and natural and man-made structures from ground motion and radiation hazards. In addition, because of the seismic nature of the Aleutians, the Special Panel for Seismology has reviewed the programs which the Atomic Energy Commission has conducted to study the seismological effects of CANNIKIN. For the most part, these experts were selected from candidates recommended by the National Academy of Sciences. The Panel of Consultants as well as the Special Consultants were made up of individuals from such organizations and institutions as the U. S. Geological Survey, University of California, University of Illinois, St. Louis University, University of Nevada, Washington State University, University of Michigan, Columbia University, California Institute of Technology, Palo Alto Medical Clinic, Scripps Institution of Oceanography, Sheppard T. Powell and Associates, and Shannon and Wilson, Inc. They represented such disciplines and subdisciplines as radiobiology, soil mechanics, structural engineering, geophysics, hydrology, radiation medicine, ecology, geology, oceanography, tsunaminology, seismology, and hydrogeology.

Finally, before detonation authority is obtained, the expected environmental effects will be reviewed by the Under Secretaries Committee of the National Security Council. This Committee will in turn make its recommendations to the President. The State Department, the Department of Defense, the Joint Chiefs of Staff, and the Central Intelligence Agency are represented on this Committee, along with the Assistant to the President for National Security Affairs. The Arms Control and Disarmament Agency, the Office of Management and Budget, the Council on Environmental Quality, the Atomic Energy Commission, and the Department of the Interior will act in an advisory capacity to the Committee.

PART IV

ALTERNATIVES

Throughout the CANNIKIN project development a number of alternatives were considered in relation to the test and the Amchitka site. The need for the CANNIKIN test has been stated as vital to the U. S. weapons development program and the alternative sites for the tests have been described briefly in Part I. Although the preparations for the CANNIKIN test began in 1966, more than three years before the passage of the National Environmental Policy Act of 1969 (NEPA), environmental matters were of major importance during the consideration of all alternatives concerning the test. Alternatives to the proposed CANNIKIN action that were examined carefully are as follows:

1. Not Testing This Particular Device -- This alternative would severely hamper the development of nuclear weapons technology of prime significance to our national security requirements.

2. Testing The Device At Another Location -- Other sites in the U. S. were considered. Two were evaluated in detail; one in Central Nevada, the other in northwestern Alaska. Amchitka was chosen because of its isolation, reasonable accessibility, and because tests to be executed there could be expected to have minimal impact on the environment.

3. Testing A Smaller Yield Device -- This alternative would not obtain the information needed from the CANNIKIN test.

4. Delaying The CANNIKIN Test For More Study of Environmental Matters -- Amchitka environmental matters have been studied since early 1967 and all of the planned pre-test investigations have been completed to determine the adequacy of the Amchitka site and the anticipated environmental impact. To delay CANNIKIN would serve no useful purpose and would impede an important weapon development program.

PART V

SHORT-TERM USES AND LONG-TERM PRODUCTIVITY

Most of the present human activities on Amchitka Island are related to preparations for the CANNIKIN test. The scientific studies associated with the program have contributed significantly to knowledge of the earth, of atmospheric and marine sciences, of the island's flora and fauna, and of its archaeology. Neither the supporting activities nor the test itself will significantly alter the fish and wildlife populations or their food supplies, or the general productivity of the island. Beyond successful completion of the CANNIKIN test, the AEC does not have any plans for future underground nuclear testing on Amchitka, although this does not preclude such plans should a future need arise.

In brief, short-term use of Amchitka Island as a testing site will not interfere with long-term use of the island as a wildlife refuge.

PART VI

IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF NATURAL RESOURCES

Project CANNIKIN will not commit any natural, mineral, or fuel resources. The pocket of radioactivity left beneath the detonation point will limit the use of the underground water and the rubble in the chimney for many years to come; however, these are at great depth and have no presently known value that would merit economic development. Use of the land surface directly above the CANNIKIN detonation point may be limited to test-related studies for some indefinite time into the future.

APPENDIX

This appendix provides a technical discussion in some detail of the various effects related to ground motion produced by underground nuclear testing. It should be noted that there is considerable experience in this area. On the basis of this experience, it appears that no significant environmental impact can be expected from ground motion, earthquake, or tsunami effects related to the CANNIKIN test. A more detailed account of the processes described in this appendix can be found in a separate summary report.[1]

EFFECTS RELATED TO GROUND MOTION

An explosion of known size set off in a known environment underground has predictable results in terms of ground displacement and vibration. Experience with the two previous explosions at Amchitka, LONG SHOT and MILROW, interpreted in the light of underground test experience at Nevada, makes it possible to calculate the ground motion effects of CANNIKIN to the degree of accuracy that is needed for evaluation of the environmental impact.

Ground motion is the direct cause of several environmental effects. First, of course, is the direct mechanical effect on structures, nearby or at distances. Buildings on the island itself may experience minor damage, but these include only relic structures from the war-time military occupation and buildings incidental to the test operation.

Second is the short-term environmental effect of killing small fractions of the local population of birds, fish, and animals. Since there will be no land animals, other than perhaps a few rats, in the region of strong ground shock, their injury is not an issue. There is a remote possibility that birds settled on the ground near the detonation site might be killed, but birds are not normally attracted to that region and the presence of more than a few appears quite unlikely. There is a possibility that a few fish or marine animals could be caught in a rockslide at the coast. The pressure pulse in streams and the ocean could result in damage to fish or aquatic life. In the shallow lakes near the test point, it is expected that some sticklebacks will be lost. In the ocean, it is anticipated that only fish near the bottom and close to the shore of the island could be affected. These effects are short-term because the small fraction of the population injured or killed will be restored in a relatively short time by natural reproduction. Short-term effects may also include transient raising or lowering of water levels in lakes, temporary changes in stream flow rates, and temporary muddying of streams and lakes by disturbances of bottom sediments or collapse of stream banks.

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[1] USAEC Nevada Operations Office, Technical Discussions of Off-Site Safety Programs for Underground Nuclear Detonations. Report NVO-40 (Springfield, Va. 22151: National Technical Information Service, U.S. Department of Commerce, May 1969).

Also, there are several longer term environmental effects. The possibility of longer term effects on the biological environment through such motion-related effects as disturbance of stream channels, drainage of lakes, and the like has been investigated. Another potential longer term effect which may be anticipated, on the basis of the MILROW experience, is the permanent vertical displacement of shallow intertidal marine terraces. On such intertidal benches, permanent upward displacement of only a few inches can result in the elimination of certain marine flora and, probably, some associated fauna in the displaced area. Early estimates suggest that it may take three years or more for the small disturbed area to reach a new biotic equilibrium; i.e., for plants and animals suited to the new environmental conditions to become established.

Thorough studies of these effects have been made, and the documentation is available on request. Review of all of the experience and analysis bearing on the environmental effects of CANNIKIN is now in process, and will continue up to the time of the test. The sources of the data are varied, and range through detailed instrumental measurements of ground motion at all distances, through direct and photographic observation of surface motion and displacement, to long-term searches for evidence of changes in the bioecology or seismicity of the Aleutian area following the MILROW test.

Cavity and Collapse

Burial of the CANNIKIN explosive at a depth of almost 6,000 feet shields the surface environment from violent, direct impact; the detonation's intense forces are dissipated far beneath the island. The most immediate effect of the release of energy from the explosion is creation of a region of extremely high temperature and pressure, containing the vaporized remains of the device itself together with some of the surrounding rock. The consequent enormous forces push material away in all directions, so that within a period of about one second after the detonation of CANNIKIN a cavity a few hundred feet in radius will exist around its emplacement position. Eventually, after a period which cannot be predicted exactly but which may be a day or so, the unsupported rock arch above the cavity will collapse, creating a rubble-filled "chimney" extending upward for thousands of feet and probably all the way to the ground surface. Experience with many deeply buried nuclear explosions in Nevada as well as two at Amchitka shows that the material in the chimney, though extensively fractured, does not provide open paths for escape of radioactive residue to the surface.

Local Surface Displacement

Formation of the cavity and the subsequent collapse will result in a permanent change in the contour of the ground surface. A saucer-shaped depression usually occurs, and for CANNIKIN is expected to be perhaps 4,000 feet in diameter from crest to crest and anywhere from a few feet to more than 100 feet deep. Because of the random nature of the collapse process, the shape of this subsidence is not exactly predictable, but disruption of the ground surface within it will probably take place. Surrounding the subsidence, the ground is uplifted as a consequence of displacement of rock by the explosion-produced underground cavity. This uplift will amount to a maximum of about five feet just outside the limits of the central subsidence and will taper off very gradually with increasing distance, producing a slight tilt in the ground surface and thus some rearrangement of the local water runoff and pooling characteristics. The latter effect, while noticeable to a distance of a few miles, will not significantly disturb the plant and animal population.

Forces resulting from the explosion may also cause motion along local zones of weakness in the island rock--"faults." Offset along faults near major tests in Nevada has amounted to several feet, producing an abrupt step at the surface. While neither previous test at Amchitka has resulted in a fault offset of more than one foot, it is assumed, as an extreme case, that CANNIKIN might result in greater displacement--perhaps up to three feet or so. This displacement could run along the surface trace of the fault for the whole length of its traversal of the island and on for a mile or two into the sea floor, but there will be no consequence other than local disturbances of surface water flow and, of course, tearing of tundra along the line of slippage. Any significant vertical displacement of the flat marine terrace in the intertidal and the shallow subtidal zones will effect marine plants and animals in the area. Sea floor displacement due either to local fault motion or the broad uplift described before will be too limited in extent to produce any sea wave motion other than minor local effects (see the section on tsunamis).

Residual Crustal Strain

Distortion produced in rock of the earth's crust as a result of the cavity displacement is measurable out to considerable distances. It is quite large near the cavity, but falls off rapidly with distance, and at locations farther from the explosion site than 100 miles or so, it is no greater in amplitude than the cyclic distortion--about one unit of distortion per 100 million units of length--caused by rotation of the earth in the sun's and moon's gravitational fields (i.e., earth tide).[1] This distortion (technically called "strain") has no direct effect of any significance, either near or at a distance, except as it may be involved in triggering of earthquakes. This subject is taken up below in the section on earthquakes.

[1]See, for example, the papers collected in Aldredge, L. R., ed. Earthquake Research in ESSA, 1969-1970. ESSA Technical Report ERL 182-ESL 11, U.S. Department of Commerce, July 1970.

Dynamic Motion

Vibrational waves set up by the explosion will move outward in all directions through the ground, producing shaking at the surface similar to that produced by an earthquake of Richter magnitude slightly below 7.0. This motion, while strongly felt by personnel at the Control Point on Amchitka and detectable by a sensitive seismometer anywhere on earth, will not be perceptible to persons at any centers of population farther away than the military bases at Shemya and Adak in the Aleutians. No structural damage is expected other than minor effects to some of the buildings on Amchitka itself. Amplitudes of velocity and acceleration at surface ground zero will not reach higher values than they did in the MILROW test in 1969, but the region of strong motion on Amchitka will cover a somewhat greater area than for MILROW.

This motion will produce a few marked immediate effects--water in streams and ponds near ground zero will be thrown into the air. In MILROW this resulted in the stranding on land of some of the stickleback fish population. A few miles of coastline near the test point will be subject to disturbance to cliffs and banks. Largely, this will amount to no more than collapse of soil from under the fringe of tundra in amounts of a few cubic feet; but there may be isolated instances of collapse of as much as a few thousand cubic yards of material from the higher cliffs.

As the motion from the explosion impinges on water in lakes or the sea along the coasts near the test point, it will create a momentary sharp rise and fall in pressure. This effect killed stickleback in two ponds near MILROW.

EARTHQUAKES

Seismic Background

The Aleutian Island chain is a region of intense seismic activity. In a typical year, several earthquakes of magnitude 6 or greater occur in the Rat and Delarof island groups around Amchitka, with a great number of small quakes. The reason for this high concentration of seismic activity in the Aleutians--and along most other shores of the Pacific--is coming to be generally understood in terms of the spreading sea floor model.[1] According to this understanding, hot plastic rock emerges from a system of mid-oceanic ridges in the east-central Pacific and spreads out to form a new crustal material. Being constantly fed in this way, the North Pacific Ocean floor slides as one continuous plate toward the northwest at a rate of about an inch per year. The plate

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[1] Isacks, F.; Oliver, J.; and Sykes, L. Seismology and the New Global Tectonics. Journal of Geophysical Research 73, No. 18, September 1968.

impacts at its leading edge along the Aleutian chain, the Kamchatka Peninsula, the Kurils, and the Japanese Islands. The moving crustal material then turns downward and is reabsorbed into the underlying mantle, a process accompanied by the buildup and release of enormous stresses. The sliding of crustal material beneath the island arcs is not smooth and regular, but erratic, with motion first in one place and then another. The stress release events taking place in this process are manifested as earthquakes.

The Aleutian Arc appears to be divided into several rather well-defined regions in which recent groups of earthquake events have taken place--typically, these have occurred as a great earthquake followed by a series of aftershocks confined within definite boundaries. In each case, the zone of aftershocks is believed to coincide with the region of residual ground displacement caused by the main quake, and with the general extent of the fault slip associated with the main quake itself.

In the local region about Amchitka (from longitude 176°E to 178°W), the record shows that there has been one earthquake of magnitude 7 or greater every five to ten years since 1900 and there have been ten times as many of magnitude 6 or greater.[1] This average rate of occurrence, continuing into the future, implies almost one chance in 100 that there will be an earthquake as big as or bigger than CANNIKIN in the vicinity of Amchitka in any two-week period. For the whole of the Aleutian Islands and Alaskan Peninsula, the probability is higher, more like one in 20. Thus, the occurrence of an earthquake after CANNIKIN from completely natural causes is quite possible.

At this rate of occurrence of earthquakes in the Aleutians, it is reasonable to expect that any potential for earthquake triggering in the Amchitka area, at a level of sensitivity commensurate with the potential affect of the CANNIKIN explosion, is fairly well exploited through the action of natural events. In other words, with respect to possible triggering, CANNIKIN will be no more than a slight perturbation to natural processes.

Ground Motion from Secondary Effects

After the initial shock and the creation of the subterranean cavern of several hundred feet diameter, it is anticipated that rock will collapse into this cavern after a period of hours or days. This will result eventually in a surface subsidence of perhaps 10 to 100 feet in

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[1]Data furnished by National Earthquake Information Center, National Ocean Survey, U. S. Department of Commerce.

depth. During the intervening period, rockfalls within the cavity will result in additional ground signals. Such signals have been observed from underground nuclear tests and are recognizable as such in that they are small and occur very close to the detonation point. In addition, there are aftershocks which follow the larger yield underground nuclear tests and which have the characteristics of small earthquakes with separate hypocenters a few miles from the explosion point. The environmental effect of these small events will be nil.

Triggered Ground Motion

The suggestion has been made that ground motion and strain effects resulting from an underground nuclear explosion might trigger an earthquake producing ground motion much stronger than that from the explosion itself. Unlike the more direct explosive effects, the process by which such an earthquake might be triggered is not yet subject to exact analysis and calculation.

A panel of eminent scientists and engineers, (Special Panel for Seismology mentioned in Part III) acting as consultants to the AEC, have examined this specific question with extreme care. Their comments are directly pertinent:

> "Although a general theory of the mechanism by which an underground explosion causes earthquakes to occur has not been developed, the experience gained in NTS (Nevada Test Site), CNTS (Central Nevada Test Site), and STS (Supplemental Test Site) supports the conclusion that an explosion will not trigger a large earthquake (defined as one releasing as much or more seismic energy than the explosion itself) unless the event is detonated near a fault on which an earthquake of this magnitude is imminent."

Triggered Volcanic Activity

Amchitka itself has not been volcanic for over a million years. There are active and quiescent volcanoes in a line to the north of Amchitka including Kiska, Segula, Little Sitkin, Semisopochnoi, Gareloi, and Tanaga, within 150 miles. Volcanism is believed to be caused by the same plate tectonics that gives rise to seismicity, and there are occasional temporal associations of the two. Nevertheless, very few of even the larger earthquakes are associated with volcanic eruptions. For example, neither the 1964 Prince William Sound earthquake (M_s=8.5) nor the 1965 Rat Island earthquake (M_s=7.8) was followed by volcanic activity. Since the most likely method of triggering a volcano is by relief of stress by means of an earthquake, and since earthquakes are seldom associated with volcanic eruptions, the probability of triggering an eruption is less than that of triggering an earthquake.

Experience with Past Tests

Most existing experience is from large underground explosions in Nevada. Many aftershocks have been observed there from the largest tests, but these always occur fairly close to the explosion site--within a range of less than 10 miles for clearly test-related events--although there is a suggestion that some small quakes were triggered out to about 25 miles from the FAULTLESS test.[1] By and large, these small quakes--always observed to be much lower in energy release than the nuclear explosive which triggers them--can reasonably be said to have been induced by the explosion, since they would not have been expected to occur naturally at that time and with that frequency. This type of event differs from the premature triggering of a large natural earthquake (having more seismic energy than the explosion itself), which has never been observed from an underground nuclear test.[2]

Observations before and after the MILROW test showed no detectable change in the rate or position of occurrence of natural earthquakes. A normal number of fairly large quakes--magnitudes 5 and 6--occurred near Amchitka both before and after MILROW during 1969, and many more of lesser magnitude were detected. MILROW did produce a few hundred small aftershocks within a range of a few miles, but this number was small in comparison with the number that had been expected and ceased about 37 hours after the detonation at the time of cavity subsidence.

Figure 3 affords a simplified presentation of information from the worldwide earthquake reporting net comparing the Aleutian earthquakes during the three months immediately prior to MILROW with Aleutian earthquakes during the three months immediately after MILROW. The average number of Aleutian earthquakes per three-month period based on 5 1/2 years of observations is also given for comparison. Although the numbers of earthquakes in the higher magnitude ranges are too few to provide statistically significant data, they do indicate no significant change in Aleutian seismicity between pre-test and post-test three-month intervals.

Thus the MILROW experience gave no indication of an increased sensitivity to aftershock activity in Amchitka over that in Nevada, and, in fact, the number of local aftershocks which did occur was less than had been expected from Nevada experience. It is expected that the only observable effect from CANNIKIN will, again, be a cluster of small aftershocks in the vicinity of the explosion site.

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[1]Hamilton, R. M., et al. Seismic Activity and Faulting Associated With A Large Underground Nuclear Explosion. Science Vol. 166, No. 3905, October 1969.

[2]Engdahl, E. R. and Tarr, A. C. Aleutian Seismic Program-MILROW Seismic Effects. U. S. Coast and Geodetic Survey. Special Report CGS-746-102 (Springfield, Va. 22151: National Technical Information Service, U. S. Department of Commerce, May 1970)

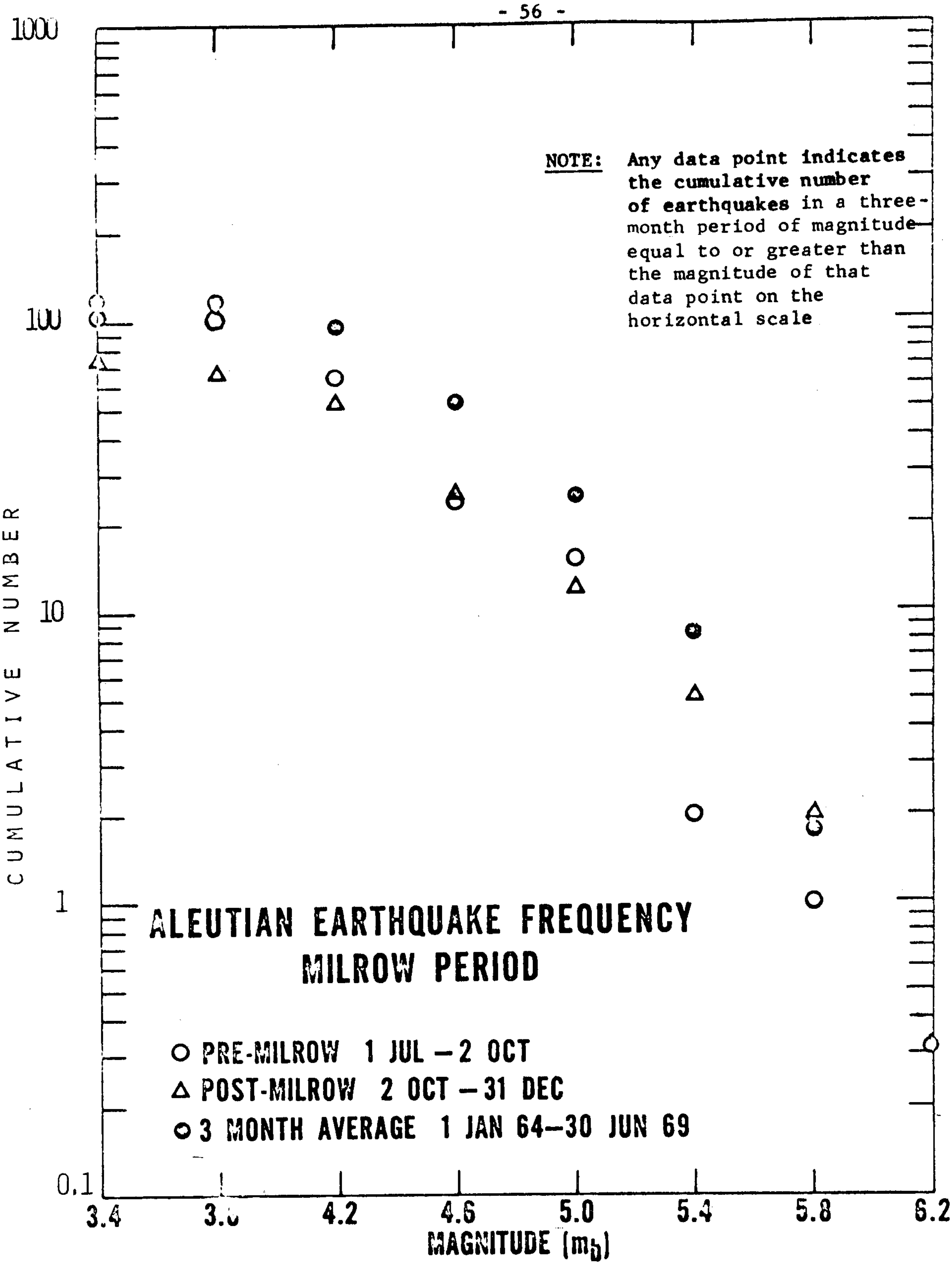
1000
100
10
1
0.1
CUMULATIVE NUMBER
NOTE: Any data point indicates the cumulative number of earthquakes in a three-month period of magnitude equal to or greater than the magnitude of that data point on the horizontal scale
ALEUTIAN EARTHQUAKE FREQUENCY
MILROW PERIOD
○ PRE-MILROW 1 JUL – 2 OCT
△ POST-MILROW 2 OCT – 31 DEC
⊙ 3 MONTH AVERAGE 1 JAN 64–30 JUN 69
3.4
4.2
4.6
5.0
5.4
5.8
6.2
MAGNITUDE (mb)

FIGURE 3

TSUNAMIS

Underground testing at Amchitka raises an issue not encountered in Nevada testing: the possibility of creating a significant seismic sea wave (tsunami). Large tsunamis can travel the breadth of the Pacific and cause severe damage thousands of miles from their sources.

It is now believed that the principal mechanism of wave generation is uplift or subsidence of the sea floor directly involved in earthquake source motion. This is especially true of large, destructive tsunamis, which involve very large volumes of displacement--the earthquake at Prince William Sound, Alaska, in 1964, involved uplift of the shelf bordering the Gulf of Alaska by an average distance of about six feet, over a total area of some 40,000 square miles. The resulting tsunami caused destruction throughout the source region and down the coast as far as California.

As pointed out above, the direct sea floor uplift produced by the CANNIKIN explosion will be too small to produce a substantial wave even along the shores of Amchitka. While several small tsunamis have resulted from undersea landslides, acoustic profiling of the slopes of the Aleutian Trench and of the Bering Sea near Amchitka has revealed no large deposits of sedimentary material, so that such a tsunami source is not credible for that area.

Following the line of reasoning set forth earlier, it appears highly improbable that CANNIKIN will trigger a major earthquake, although the possibility cannot categorically be denied. If such an event should take place, it would be indistinguishable in character from a natural earthquake, and it would probably be confined to a discrete block of the Aleutian chain, west of Amchitka Pass which includes Amchitka, the Rat, and the Near Islands. The wave-generating potential of such an earthquake would not be expected to be different from that of other large quakes in the same region.

Historically, the western sector of the Aleutians has not been a source of damaging tsunamis--although several large earthquakes have recently occurred there, there is no record of a destructive tsunami originating in that region. The last important seismic event in the area was the Rat Island earthquake of February 1965 of Richter magnitude, almost 8, whose epicenter was within 30 miles of Amchitka and whose principal fracture and zone of aftershocks extended through the whole Rat Island-Near Island part of the island chain. Although waves of substantial height were observed locally, no significant waves reached Japan or Hawaii. This behavior contrasts markedly with the effects of earthquakes farther east in the Aleutians, three of which have generated waves causing substantial damage in Hawaii in recent history. While it is not wholly understood, the relatively nontsunamigenic character of western Aleutian earthquakes may have some rational basis in evidence--the motion of the spreading sea floor is directly toward the eastern part of the island chain, but is more nearly tangent to the western islands near Amchitka. Thus, a smaller tendency toward buckling and upthrust is implied in the west than in the east. This view is supported by the existence in the western Aleutians of a plurality of relict marine terraces that exhibit little evidence of tilting or unconformity--in contrast to marked relative terrace displacement well to the east of Amchitka Pass in the coastal areas from Prince William Sound to Kodiak Island. This distinction suggests a long-term vertical stability of the Rat and Near Islands consistent with the lack of sigificant tsunami activity. An investigation of the terraces in the eastern Aleutians is being carried out by the USGS.

The very small displacements observed during the MILROW test have confirmed that local ground motion caused by a large underground test will not cause significant water waves. Three types of wave observations--portable tide gages, deep-sea wave recorders, and shallow-water wave gages--were conducted. No permanent dislocations of the sea floor were observed. The deep-sea wave recorders observed no waves exceeding 3/8 of an inch, and the shallow-water gages, which could detect waves as small as 1/8 of an inch, recorded no unusual signals.

During the CANNIKIN test, coordination between the CANNIKIN Control Point and the Alaskan Regional Tsunami Warning System, operated by the National Ocean Survey of NOAA at their Palmer, Alaska, Seismological Observatory will be accomplished through a teletype communication channel which will be in operation at detonation time.

CONCLUSION

The triggering by CANNIKIN of earthquake-produced ground motion comparable to or greater than that produced by the explosion itself is very unlikely. Should this highly unlikely event occur, the triggered earthquake would plausibly involve only the western Aleutians, near Amchitka, and thus would pose no direct threat to populated areas, the closest other than Amchitka itself being military bases 200 miles away. Further, it is reasonable to suppose that any triggered quake would be somewhat smaller because of premature release than if it had occurred later, in the natural course of events, after additional buildup of stress.

It is worth reiterating that although the possibility of CANNIKIN's causing premature release of a large quake cannot be absolutely ruled out, it is extremely unlikely. Because the understanding of earthquake mechanisms is still developing, and is not subject to exact calculation, the possibility of occurrence of this event is regarded with some range of opinion among the most eminent seismologists. None, however, assert that it is at all likely or that its occurrence near a population center is plausible.

With regard to sea waves (tsunamis) initiated by natural earthquakes, there is no recorded case of a destructive tsunami originating in the western Aleutians, and any postulated CANNIKIN-triggered quake would not be expected to differ from natural precedent. Thus, a sequence of two events, both of which are contrary to expectation, would be necessary to bring about damage from a tsunami: first, a major quake would have to be triggered; second, that quake would have to behave contrary to all prior experience for the western Aleutians and generate an important tsunami. In this light, the risk of tsunami damage consequent upon the CANNIKIN test appears to be negligible.

In order to be assured of having all possible information in hand that could add to knowledge of the seismic and tsunamigenic character of the western Aleutians, active investigations of the geology and seismicity of that region are being pursued. A program of calculations to predict the generation and propagation of a postulated tsunami originating there is being supported. While the latter calculations are not necessary to the CANNIKIN test, they will be available well in advance of that test and will provide supplementary useful information.

NOTE: In the unlikely event that the Project CANNIKIN detonation should cause damages to property or injury to persons, the Atomic Energy Act of 1954, as amended, authorizes the Atomic Energy Commission to compensate for the losses under Section 167 of the Act. The Commission has authority to pay immediately any such loss of $5,000 or less. Payment of any claims in excess are handled through Commission certification to the Congress. To date, this arrangement has been adequate for dealing with any damages resulting from the underground testing program.

In addition, the Commission has indemnity authority by reason of the Price-Anderson legislation (Section 170) of the Atomic Energy Act, and the indemnity agreements thereunder which are in force, to pay $500,000,000 for claims for liability arising out of a nuclear incident, as provided in the Act. There has been no occasion to utilize this authority in the testing program.

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ANNEX

Comments from Federal and
Other Agencies and AEC's Responses

Received in AEC on 8/3/70.

United States Department of the Interior

OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

July 16, 1970

Mr. John A. Erlewine
Assistant General Manager for Operations
U. S. Atomic Energy Commission
Washington, D. C. 20545

Dear Mr. Erlewine:

As requested in your letter of June 17, we have reviewed the draft environmental impact statement for the CANNIKIN nuclear test, Amchitka Island, Alaska, and offer the following comments:

(1) The statement estimates that tritium will be discharged into the ocean at a level close to the maximum permissible concentration for water, beginning 145 years after the CANNIKIN event, and that this discharge will be diluted by 10^5 by the longshore currents (page 13 of the draft). Does this dilution factor account for the accumulation of tritium in the longshore currents that may result from groundwater discharges from the MILROW and LONGSHOT events? If it does not, we believe it should and the potential CANNIKIN discharge evaluated in this light.

(2) Because tritium from the LONGSHOT event was found in surface ponds, we believe that water samples should be collected, following the CANNIKIN event, from water geysers that may occur over or near the "ground zero" sites of the MILROW and LONGSHOT events. Analyses should be made to determine whether such geysers are allowing the movement of radionuclides from these previous events from the subsurface to the surface environment. Analyses should be made for fission and fusion-activation by-products in addition to tritium and the noble gases. We do not find in the draft statement that such sampling and analyses are planned.

(3) Careful and continued monitoring of the radioactivity in the marine environment and especially in fishes of the Amchitka area should be maintained in cooperation with the Department of the Interior, in order to insure that there is no contamination of commercial fishery products. In the unlikely event that contamination did occur, we must be aware of it and prepared to reassure the American public of the safety of fishery products moving into the market.

(4) We do not believe that the anticipated possible loss of up to 20 sea otters from the native population of 2, 500 would be of any lasting significance. It may be possible to minimize the possibility of these small losses; however, by having harvest or transplant stock collected from near the test site if any animals are taken for those purposes within a few months prior to the tests. Also, the contemplated sea otter research program may provide us with techniques for luring or driving the animals from the test area at shot time.

(5) The draft statement refers to man-made containment structures, such as sewage treatment facilities, drilling mud pits and fuel oil tanks on the Island. Although the statement makes little reference to these facilities, we assume that proper precautions have or will be taken to prevent possible failure due to the seismic shock from the CANNIKIN test.

(6) Although the conclusion that CANNIKIN is unlikely to trigger a seismic event as large as or larger than the nuclear event is valid, some of the statements leading to that conclusion are not entirely correct and may be misleading. It should be pointed out, however, that additional background studies on regional tectonics and marine geology are underway and final evaluations of the feasibility of the CANNIKIN event should not be made until the results of these studies have been assessed.

(7) The Aleut Indian League, during their last annual meeting in Anchorage, passed a resolution opposing any atomic blasting in the "Aleut Country" which is all of the Aleutian Chain. We suggest that their President, Carl Moses, of Unalaska, Alaska be given an opportunity to review this environmental statement.

Cooperation between this Department and the Atomic Energy Commission with regard to the past nuclear tests on Amchitka Island and in preparation for the CANNIKIN test has been effective toward balancing our various interests. We look forward to continuing cooperation in this regard.

We appreciate the opportunity to review this statement.

Sincerely yours,

John Quarles

John R. Quarles, Jr.
Assistant to the Secretary for Policy
Planning and Research

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

Mr. John R. Quarles, Jr.
Assistant to the Secretary
for Policy Planning and Research
U. S. Department of the Interior
Washington, D.C. 20240

Dear Mr. Quarles:

Thank you for your comments of July 16, 1970 on AEC's Draft Environmental Statement - CANNIKIN. Taking your comments in the numbered sequence of your letter, we have accommodated each as follows:

1. Beginning on page 20 of the final statement (enclosed) a more detailed and quantitative analysis of the different mechanisms and time scales by which tritiated water could be discharged into the Bering Sea is presented. You will note that we predict that tritiated water will most likely require about 1,000 years to reach the Bering Sea at which time the radioactive level will be less than the Bering Sea background. This prediction is based on known geology and hydrology of Amchitka and has the concurrence of the U. S. Geological Survey. You will note also other analyses are exhibited in the environmental statement and are based on very unlikely presumptions that could lead to more rapid discharge to the Bering Sea. However, even under the worst presumed conditions the dilution of the Sea would reduce radioactivity concentrations to levels that are far below the limits established for fresh water. In fact, of course, the Bering Sea is not fresh water and is not used for human consumption and oceans in general are not concerned with fresh water standards.

2. As you know, an intensive environmental monitoring and analysis program, including water monitoring at the Long Shot and MILROW sites is continuing on Amchitka and will be appropriately documented following CANNIKIN, similar to that provided following the MILROW event (enclosed). The U. S. Geological Survey water monitoring and general environmental monitoring programs are summarized on pages 41 and 42, respectively, of the environmental statement.

3. We agree on the desirability of the biological environmental monitoring programs and have included general summaries of our arrangements for continuing these activities on pages 41 and 42 of the environmental statement.

4. We agree on the desirability of minimizing the injury or loss to the sea otter population of Amchitka and have indicated on page 11 of the environmental statement some of the considerations that should minimize such impact. We are also working closely with the Department of Interior and with the Alaska Department of Interior and with the Alaska Department of Fish and Game in this regard.

5. The construction activities section of the environmental statement has been expanded to summarize the AEC's protective measures to prevent or minimize any ground motion damage to support facilities and civil works.

6. We have continued to collect and analyze seismic information and have had our contractors and consultants review the CANNIKIN environmental statement to assure that it reflects a consensus of expert opinion. If there are further specific questions regarding our statement on seismicity and triggering, we will be pleased to give them consideration.

7. The President of the Aleut Indian League was forwarded copies of the draft environmental statement on August 7, 1970 as you requested. We are also providing him with copies of the final statement.

For your information we are forwarding copies of our CANNIKIN environmental statement, comments that we received on the draft statement and AEC's response to the comments.

We are pleased to have received the Department of Interior's comments.

Sincerely,

John A. Erlewine

John A. Erlewine, Assistant
General Manager for Operations

Enclosures:
As stated

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
WASHINGTON, D.C. 20201

OFFICE OF THE SECRETARY

OCT 14 1970

Mr. John A. Erlewine
Assistant General Manager
for Operations
U.S. Atomic Energy Commission
Washington, D.C. 20545

Dear Mr. Erlewine:

Mr. Roger Strelow has referred your letter of June 17, 1970, to me requesting comments on the environmental impact of the proposed CANNIKIN test scheduled for fall of 1971. These comments were requested based on the Commission's procedures for implementing the provisions of the National Environmental Policy Act of 1969.

The Southwestern Radiological Health Laboratory of our Bureau of Radiological Health has prepared a staff report on the public health aspects of this proposed test based on the information contained in the Draft Environmental Statement - CANNIKIN submitted to this Department for review. This staff report is herewith formally submitted as our response to your request.

We appreciate the opportunity to comment on the Draft Environmental Statement - CANNIKIN. Please advise if this Department can be of further assistance in this matter.

Sincerely yours,

Roger O. Egeberg, M.D.
Assistant Secretary
for Health and Scientific Affairs

Enclosure

SWRHL STAFF REPORT

ON

JUNE 12, 1970

DRAFT ENVIRONMENTAL STATEMENT

CANNIKIN

by

Southwestern Radiological Health Laboratory

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Public Health Service

Environmental Health Service

September 18, 1970

INTRODUCTION AND CONCLUSIONS

The Draft Environmental Statement - Cannikin dated June 12, 1970, which was submitted by the U.S. Atomic Energy Commission to the Department of Health, Education, and Welfare, has been reviewed by members of the staff of the Southwestern Radiological Health Laboratory, Bureau of Radiological Health, Public Health Service (SWRHL, BRH, PHS). This staff report is limited to consideration of radioactivity released to the surface and to ground water and bioenvironmental effects related to radioactivity. It is directly responsive to the requirements placed on Federal agencies by the National Environmental Policy Act of 1969 and, as such, is intended to state the position of the Department of Health, Education, and Welfare.

The Department of Health, Education, and Welfare, as it relates to this Statement, is concerned with radioactivity and its impact on the health of the public. We did not have the precise information available in the Environmental Statement upon which to make our evaluation; in particular it did not contain sufficient information concerning the credibility of various types of releases of radioactivity. Therefore, conservative assumptions were used in this evaluation which insured, from a public health viewpoint, that all pertinent factors related to environmental impact have been adequately evaluated. In addition to the information contained in the Environmental Statement general information from the Longshot and Milrow Events and technical reports at the Southwestern Radiological Health Laboratory were utilized. Since it was stated that the yield is somewhat larger than Milrow (about 1 Mt), it was assumed that the Cannikin test is a typical underground test with a yield between one and ten megatons, and that the device yield will be largely fusion with a maximum fission yield in the kiloton range.

The principal conclusions of this review are as follows:

1. The Cannikin test will not adversely affect the health and welfare of the population, nor should there be a major impact on the environment of Amchitka Island. The probability of any event time release, much less one which would result in concentrations of radioactivity in populated areas above appropriate Federal Radiation Council guides or Atomic Energy Commission standards (3,4), is very low.

2. The Environmental Statement would be much more useful and its conclusions more credible if calculation techniques, parameters and rationale used in calculation, and conclusions from past experience were referenced to appropriate sources.

3. The off-site radiological safety program should be mentioned and described in the Statement.

4. Pertinent information should be forwarded to the Department of Health, Education, and Welfare as it becomes available in order to allow a continuous review until the execution of the test and for at least a year thereafter.

DISCUSSION

St. Paul and Umnak Island are the nearest uncontrolled population areas to Amchitka, the testing area. These Islands are about 500 miles from

Amchitka. The military bases on Adak, Attu, and Shemya are about 200 miles distant. The personnel remaining on Amchitka during the Cannikin test will be directly related to the event and under the direct supervision of the Test Manger. They will be located in a specially designed control point 23 miles from surface ground zero . An indication of the isolation of the area is that the nearest significant milk production is in the Palmer area (near Anchorage) more than a thousand miles away (9).

A review of venting phenomenology by Rapp (10) of the Lawrence Radiation Laboratory indicates a minimum burial depth of less than 6,000 feet (as given in the Statement) for containment of a test up to 10 Mt in yield. Rapp indicates that his technique will not determine the depth at which venting will occur, but rather a depth below which venting will not occur (10).

A study by Los Alamos Scientific Laboratory indicates that if the ratio of the depth of burial to the radius of the cavity is greater than seven, there will not be a prompt release of radioactivity. This ratio is about ten or greater for the Cannikin test, even allowing for a yield of 10 Mt and uncertainties in the medium where the device is buried (radius calculation based on references 11, 12, and 13). The measure of containment success is illustrated by the fact that since 1963 only 10 of approximately 200 standard vertical shaft events have released radioactivity of any consequence. Only one of these was above 20 kt (i.e., it was in the low-intermediate class), and the release from it was associated with seepage[a]. Of the twelve events over 200 kt (including Milrow), none have released any detectable radioactivity at shot time (11).

A general review of ground water contamination and transport (based on references 14, 15, 16 and 17) indicated results similar to those in the Environmental Statement.

The only expected releases of radioactivity to the biosphere are tritium at levels in the range of the concentration guides (3 μCi/l for individuals) in ground water diffusing into the ocean about one century after the event and possibly tritium in surface water at concentrations significantly lower than the guides several months after the event. The latter possibility is based on Longshot experience.

It is improbable that there will be any environmental release of radioactivity associated with event time activities (i.e., venting or seepage). Thus, no radiological bioenvironmental effects are expected. The low concentrations of tritiated water that may seep or diffuse into the ocean or to the surface at ground zero should not produce any measurable biological effects.

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[a]This test took place in carbonate rock, which produced large volumes of carbon dioxide. Carbon dioxide, unlike water, does not condense at the chimney temperature and pressure conditions. Thus, the cavity pressure did not fall, as normally occurs in a water environment, and non-condensable gases containing predominantly radioactive noble gases percolated through the chimney to the surface.

Although an event time release is not expected, a small release related to seepage is within the realm of possibility. A release similar to that of the Nash (1) or Pin Stripe (2, 18) Events, conducted at the Nevada Test Site, presents a credible estimate of the type of release that could occur from Cannikin. The Nash (1) Event is an example of seepage due to a large volume of non-condensable gasses and the Pin Stripe Event (2, 18) is used as an example of a minor venting. The analogy of Cannikin to these events is predicated on the assumption that Cannikin will be a minimum fission device (several kt or less).

The Nash Event resulted in external gamma readings of less than 1 mR/hr (cloud passage; not deposition) at 40 miles (1). Fresh fission products (including radioiodine isotopes) were not detected off-site (approximately 40 miles) with regard to this event.

The Pin Stripe Event resulted in external gamma readings of about 8 mR/hr (cloud passage) at about 40 miles from the detonation point. Iodine-131 concentrations in milk were about 4800 pCi/l and 170 pCi/l at 65 and 105 miles, respectively, from the detonation point.

Even if a release similar to or greater than these examples were to occur, we would not expect any measurable biological effects (4, 20, 21). The distance to populated areas for the Cannikin test is roughly an order of magnitude greater than for the referenced events. Thus, using a distance squared scaling factor for the effluent concentrations, the resulting doses would be several orders of magnitude less than those for the referenced events. Also the probability of effluent passing over a populated area is small, considering that the populated areas cover only a small fraction of the 360° arc.

In addition to the previously noted populations, there is commercial fishing in the area by Russian and Japanese fleets (19). Consideration of the fishing crews and/or their catch does not change the aforementioned statements of effects.

The event planning will include a safety program similar to that for Milrow (9) where SWRHL/PHS personnel were available at the closest populated locations with several personnel also aboard ships in the area. The individuals are equipped to monitor radioactive effluent, should unexpected circumstances occur. The safety program conducted by SWRHL also includes planning for protective action enactment (18).

GEOLOGICAL

The geology of Amchitka has not been evaluated as it may be affected by the detonation of Cannikin. The U.S. Geological Survey has the expertise in this area and the data from their evaluation are used as they may apply to the movement and distribution of radioactivity.

SEISMOLOGICAL

The environmental effect of ground motion from the detonation is provided by the U.S. Coast and Geodetic Survey. Since this type of environmental effect is outside our technical capability to review, they have not been included. We utilize the information provided by the U.S. Coast and Geodetic Survey in planning our Off-Site Radiological Safety Program.

ATMOSPHERIC AND SURFACE RELEASE OF RADIOACTIVITY

The likelihood of venting was considered from the standpoint of (a) historical or empirical information from past events, (b) from the more theoretical standpoint of cavity and chimney formation, and (c) cratering/venting phenomenology or consideration of the rarefaction wave and gas acceleration, and flow through interstitial spaces. These evaluations were performed through use of historical records and the papers by Rapp (10) Germain and Kahn (11), Chapin (12), and others as referenced. A basic difference between the historic and phenomenology approaches is that the historic approach, although based on experience, does not explain why things happen. The phenomenology approach attempts to explain the phenomenon of venting and the physical reasons for it occurring and, thus, is more adaptable to event yields greater than those for which actual experience has been obtained.

The analysis was based on a yield range of 1-5 Mt for Cannikin. A yield of 10 Mt was also considered. Cannikin will be the largest underground nuclear explosive ever detonated in the U.S. testing program. The evaluation techniques used (10, 11, 12) are thus based on events with smaller yields, but they are based on a range of yield and should be relevant. Extrapolation to higher magnitudes always entails uncertainties--although nuclear testing experience to date indicates a higher degree of integrity of containment for high yield shots versus low yield shots (kiloton range) (10, 11).

Empirical Historic Approach: The U.S. testing program has contained numerous underground tests with various yields from essentially zero to over one megaton. The design of the tests varies from those located in vertical shafts or tunnels with experimental designs requiring line-of-sight pipes (closed subsequent to the device detonation either by auxilliary explosives or the shock wave from the device) to devices emplaced in vertical shafts where the shaft is completely stemmed (10, 11, 22).

A number of events in the past have vented--inadvertently released radioactivity at the time of the detonation. These ventings have been in part due to inadequate burial depth, as well as the design of associated experiments and other factors. The capability of containing underground nuclear detonations has not only improved with time (a greater fraction of the events of a given yield prior to and including 1963 vented than after 1963), but it has been noted that events with a low yield, 0-20 kt, have a higher probability of venting than those with a higher yield (10, 11).

The inadvertent releases can be categorized by the physical phenomena of the nature of the release--seepage and "prompt" or dynamic venting. Prompt venting is associated with considerable thermal and kinetic energy with the release resulting from ground fissures and/or stemming failure. Seepage, which is more probable than prompt venting, is a result of radioactive gases filtering through the chimney rubble to the surface. Whereas, prompt venting results in an essentially non-fractionated radioactive effluent, in the course of seepage the non-gaseous isotopes are retained by filtration and absorption and the release is largely composed of noble gases (10, 11, 22). Even in the case of prompt ventings, the releases have been only a few percent of the total inventory; whereas, for seepage the effluent is not only fractionated, but much lower in quantity (22).

The measure of containment success is illustrated by the fact that since 1963 only 10 of approximately 200 standard vertical shaft events have released radioactivity of any consequence. Only one of these was above 20 kt (i.e., it was in the low-intermediate class); and the release from it was associated with seepage[a]. Of the twelve events in the intermediate category (200-1,000 kt and some slightly over 1,000 kt) none have released any detectable radioactivity at shot time (11).

Cavity Radius and Chimney Formation: Higgins and Butkovich (13) derived the basic equation indicating that the cavity radius is a function of a materials constant and the cube root of the device yield. The product of the above parameters is divided by the overburden pressure taken to a power dependent on the adiabatic expansion coefficient of the rock.

[a]This test took place in carbonate rock, which produced large volumes of carbon dioxide. Carbon dioxide, unlike water, does not condense at the chimney temperature and pressure conditions. Thus, the cavity pressure did not fall, as normally occurs in a water environment, and non-condensable gases containing predominantly radioactive noble gases percolated through the chimney to the surface (10, 11).

Boardman, et al. (23), indicated that an earlier version of this relationship, where the overburden pressure was taken to a constant power, predicted cavity radius within ± 20%.

Chapin (12) indicated a further modification of the basic equation by noting the adiabatic expansion coefficient was not constant with pressure as Higgins and Butkovich have assumed (13). Chapin (12) also included a parameter to account for the fact that the cavity doesn't always continue to expand until the cavity pressure reaches the overburden pressure (24). Chapin's (12) approach indicates cavity radii about 10% less than that for Higgins and Butkovich (13) for the Cannikin Event. Using Higgins and Butkovich equations, the cavity radius for even a 10 Mt device is slightly less than one-tenth of the burial depth assuming a granite medium which should be representative of the Cannikin environment which has been identified as basaltic volcanic breccia (14).

A study of past events by the Los Alamos Scientific Laboratory indicates that a ratio of burial depth to the cavity radius of 7 is sufficient for containment. The above calculations indicate a ratio of greater than 10 for a yield of 10 Mt. Uncertainties concerning the actual medium do not cause this ratio to deviate significantly below 10.

Teller, et al. (25) indicates an approach the same as that of Higgins and Butkovich (13).

Based on the collapse of Longshot and Milrow and several events at the Nevada Test Site, it would appear that Cannikin will probably chimney to the surface and collapse. This will present a path for possible seepage of radioactivity to the surface. But, Rapp (10) and Germain and Kahn (11) have indicated that the requirements for burial depth to prevent dynamic venting, for events above ten to tens of kilotons, result in a sufficient depth of chimney material to prevent seepage to the surface.

Germain and Kahn (11) concluded that there is some concern for seepage from low yield events (less than 5 kt), but there is remarkable success for higher yield events--especially when the scaled depth of burial is over 350 (SDOB = Depth in ft. divided by the cube root of the yield in kt). Assuming 1 Mt for Cannikin. the SDOB is 600 ($6,000/1,000^{1/3}$; whereas, for 5 Mt it is 350.

<u>Prompt-Venting Phenomenology</u>: Rapp (10) presents venting mechanisms in terms of two categories: (1) prompt-venting prior to chimney formation and (2) mechanisms which operate during and following chimney formation. The first mechanism relates to the mechanics of cratering where the burial depth is not sufficient for the expanding cavity gases to reach a point of dynamic equilibrium with the containing environment. This phenomenon, termed gas acceleration, has been described as the process by which the cavity grows asymmetrically toward the surface (10). The second category relates to effluent transfer along paths existing through the shock-deformed media (covered in previous section).

Basically Rapp's analysis of prompt-venting, "gas acceleration," is summarized as follows (10):

1. Containment will be achieved if the rarefaction or decompression wave does not return from the surface to the cavity prior to the end of cavity growth.

2. Although it is not presently possible to define the critical timing (depth) of rarefaction wave and cavity growth to result in venting, it is possible to define the depth corresponding to a given yield and geological environment below which no significant gas acceleration phase of cavity growth occurs.

Thus, although this technique will not indicate a minimum burial depth for containment, it should indicate a depth below which containment is assured (10, 11). This criterion indicates burial depths of 3300, 4300, or 5600 feet, respectively, for a 1, 5 or 10 Mt device in granite. The burial depths for other media; such as, Lewis Shale and Pictured Cliffs Sandstone are less.

GROUND WATER TRANSPORT OF RADIOACTIVITY

The AEC Environmental Statement indicates that the ground water flow-rates for Amchitka at the Cannikin depth are very low and that there is poor vertical communication between strata. Also, there is an indication that there is limited knowledge of the actual ground water flow rates. There are numerous reports and papers available on transport of radio-activity by underground water, but we feel the lack of specific information available to us for this specific event environment does not merit their use (reports by Isotopes, Inc., USGS, LRL, Hazleton-Nuclear Science Corp., etc.).

A rough approximation of ground water contamination and transport can be obtained by assuming the tritium is diluted in water in the cavity and chimney and then that this mass is transported through ground water flow (gives results similar to use of the fractured radius). Although significant quantities of ^{90}Sr and ^{137}Cs are not trapped in the melt in the bottom of the cavity[a], sorption or chemical reactions are such that they are essentially retained in the vicinity of the cavity (15, 16, 25). By use of this method and assuming a 5 Mt event and tritium production of 10^8 curies the initial concentration of tritium in the chimney water is estimated to be three orders of magnitude above the concentration guide of 3 μCi/l for individuals in the general population (3). Assuming the chimney filled with water instantaneously (time reference to the tritium half-life) and no further dilution occurs, this requires about 140 years for decay to the concentration guide.

Assuming that the shortest path from the Cannikin environment to the ocean is about seven thousand feet (the shore line is not a vertical shelf down to six thousand feet--the depth of burial) a transport rate of one-tenth foot per day would require 200 years for transport to the ocean. A transport rate of one foot per day would only take about 20 years.

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[a]The half-lives of their gaseous precursors are such that a large fraction of the ^{90}Sr and ^{137}Cs is formed after most of the cavity melt is formed (17).

The ocean currents and tidal action should result in several orders of magnitude of dilution in a very short distance from the point of diffusion or permeation of any tritiated water into the ocean. Thus, even if water should reach the ocean at levels above the concentration guides, no measurable biological effects are expected.

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UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

Roger O. Egeberg, M.D.
Assistant Secretary for Health
and Scientific Affairs
Department of Health, Education and Welfare

Dear Dr. Egeberg:

Thank you for the Department of Health, Education and Welfare's comments of October 14, 1970 on AEC's Draft Environmental Statement - CANNIKIN. We have since had an opportunity to revise the CANNIKIN Environmental Statement (Enclosure 1), taking into account the comments of Federal and State agencies. For your information, I enclose copies of the final CANNIKIN Environmental Statement, of the comments received on the Draft Statement and of AEC's response to the comments.

We believe that HEW's analysis confirmed that of the AEC with respect to environmental effects and we appreciate that your analysis was necessarily made broader in scope than would have been the case if we were able to publish the anticipated yield. We have treated HEW's principal conclusions as follows, in the sequential order of the SWHRL Staff Report, page 2:

(1) HEW's conclusion confirms that of the AEC.

(2) We agree on the desirability of appropriate referencing of important information sources to substantiate the conclusions of the environmental statement. We have included AEC's "Physical and Biological Effects - MILROW Event" (NVO-79) (copy enclosed) which is also liberally references as the most appropriate reference to the CANNIKIN Environmental Statement. We believe that these references, plus those contained in HEW's SWHRL Staff Report, considerably strengthen and support the conclusions of the CANNIKIN Environmental Statement.

(3) Additional information has been added to pages 13 through 17, and to page 24, in response to similar comments from both Department of HEW and of Interior. These additions summarize our predictions with respect to radioactivity

in the environment and describe the general features of the water and environmental monitoring programs. These monitoring programs were begun prior to MILROW and are to be continued well beyond the CANNIKIN test. We do not expect that the offsite radiological safety program could itself result in any significant environmental impact; therefore, we have only elaborated its general features in the CANNIKIN Environmental Statement. However, the radiological safety program will be similar to that of the MILROW exercise, modified by any unique CANNIKIN requirements, and it will assure ourselves and the public of detection and appropriate countermeasures if any unexpected release of radioactivity should occur. As further information, we enclose copies of the "On-Island and Off-Island Radiological Safety," plan.

As a general reference on AEC's Amchitka safety program management and on the organizations and their respective missions, we suggest TID-25180, "Underground Nuclear Testing" copies of which are enclosed for your information.

(4) CANNIKIN program information pertinent to bioenvironmental considerations will continue to be published and made available to the Department of Health, Education and Welfare and to the public. The NVO-79 report, previously mentioned, is the most recent of the Amchitka bioenvironmental summaries.

Sincerely,

John A. Erlewine

John A. Erlewine, Assistant
General Manager for Operations

Enclosures:
1. Final CANNIKIN Environmental Statement
2. Draft Statement Comments, with AEC responses
3. Physical and Biological Effects - MILROW Event
4. TID-25180 Underground Nuclear Testing
5. Appendix C - On-Island and Off-Island Radiological Safety

June 8, 1971

Mr. Timothy Atkeson
Council on Environmental Quality
722 Jackson Place, N.W.
Washington, D.C. 20006

Dear Mr. Atkeson:

Enclosed for your files and other action as appropriate, are ten copies of comments prepared by the National Ocean Survey, National Oceanic and Atmospheric Administration, pertaining to the environmental impact statement entitled 'AEC --- Cannikin' submitted by the Atomic Energy Commission. Referenced statement was referred in draft to this department last year at a time when we were not yet equipped to insure screening by all subtendent agency or the Department of Commerce. The National Ocean Survey only recently came into possession of a copy and because of its area of expertise, requested the opportunity to comment, belated though these comments might be, for inclusion in the public record. I believe this matter was recently discussed with you by the Deputy Assistant Secretary for Environmental Affairs, and that you granted your consent for this late submission.

One copy of the National Ocean Survey comments, together with a copy of this memorandum is being addressed to the Assistant Director for Regulation, Atomic Energy Commission.

Sincerely,

Sidney R. Galler
Deputy Assistant Secretary
for Environmental Affairs

Enclosure

FBMahoney/SRGaller:jg:6/8/71
SRG/Sub. & Chron
cc: Mr. Christopher L. Henderson/
Ass't Dir. for
Regulation, AEC. (1 copy
attach.)
Env.Work.Gp.
Wakelin
White
Brennan
M. Butler

National Oceanic and Atmospheric Administration
Rockville, Md. 20852

National Ocean Survey

Date: MAY 19 1971

Reply to Attn of: C2

Subject: Environmental Impact 102 (2) (C) Statement Entitled "AEC - Cannikin"

To: Assistant Administrator for Plans and Programs
Attention: AS5

Recent active investigations of the geologic, seismic, and tsunamigenic character of the Aleutians, with particular emphasis on the Amchitka Island region, support the anticipated effects from the underground nuclear explosion CANNIKIN outlined in the Draft Environmental Statement.

The National Ocean Survey (NOS), with the support of the Atomic Energy Commission (AEC), has been a particularly active participant in these investigations. For many years, NOS has operated a network of seismic stations in Alaska and on Adak Island in the Aleutians as part of the Tsunami Warning Program for the Circum-Pacific seismic belt. Since May 1969, this network has been expanded to include eleven additional reliable continuously monitoring seismic stations; eight high-frequency, high-gain seismographs on Amchitka and the neighboring islands; three broader-band instruments at Granite Mountain in Western Alaska and on the islands of Shemya and Unimak in the Aleutians. Within the next few weeks, six additional instruments will be installed on Amchitka for a total of eleven detectors on the island proper, nine of which will be within 15 km of Cannikin ground-zero.

Basic data derived from this network are routinely collected, reduced to accurate estimates of event hypocenters and magnitudes, and summarized in a monthly bulletin for the benefit of the entire scientific community. These data have been instrumental in establishing a more precise definition of the seismic zone in the immediate vicinity of Amchitka Island. Shallow earthquakes are found to occur south of the trench axis and along a diffuse, gently dipping zone extending from the south slope of the ridge to a point just north of the ridge crest. The spatial distribution of these shallow shocks also appears to be strongly correlated with structural features having expression in the bathymetry of the ridge. Deeper earthquakes are found to occur along a steeply dipping seismic zone extending northward from the ridge crest to depths in excess of 200 kilometers just beyond the volcanic arc. Earthquakes less than 20 kilometers in focal depth beneath Amchitka Island proper are few in number and very small suggesting that this region may act independently of the major seismic zone below.

These results have important consequences to future testing on Amchitka and the interpretations of seismic effects from the LONGSHOT and MILROW explosions. No aftershocks were detected at teleseismic distances from either LONGSHOT or MILROW. Close-in seismic monitoring for MILROW, however, did reveal a very low level ($<$magnitude 3.0) of shallow-focus aftershock generation within a zone not more than three miles in radius from ground-zero that terminated abruptly with the cavity collapse, 37 hours after detonation. The spatial distribution and radiation pattern of the more accurately located aftershocks suggest that they are related to local geological readjustments. It is highly relevant that this activity was at least two orders of magnitude smaller in size and number than that induced by similar explosions in Nevada, such as BENHAM. These results, geologic evidence, and the very low level of natural seismic activity in the immediate vicinity of the island all point to a lower level of ambient tectonic stress in the upper crust beneath Amchitka. Since explosion-induced aftershocks are believed to be related to the ambient tectonic stress, are small, of short duration, and occur in the immediate vicinity of the explosion, they are not believed to constitute a hazard to the major fault zone under Amchitka Island.

The careful monitoring of natural earthquake patterns preceding and following MILROW by NOS revealed no evidence for any significant spatial or temporal changes in the natural seismicity. The low-level natural seismic activity detected over the past year near Amchitka is apparently a continuation of pre-MILROW patterns. Larger earthquakes continue to occur predominantly to the east of Amchitka in the Amchitka Pass-Delarof Islands region. Focal mechanism solutions completed on a number of these events indicate a continuation of previously existing patterns. It is highly relevant to the triggering problem that none of these larger nearby events produced any apparent increase in seismicity in the immediate vicinity of Amchitka Island. A magnitude 6.0 earthquake occurring about 160 kilometers from Amchitka on the south wall of the Aleutian Trench on February 27, 1970, was accompanied by hundreds of small aftershocks apparently originating from a very small source region.

For CANNIKIN, the expanded seismic network will have a two-fold purpose: (1) to obtain a complete description of explosion-related aftershocks and their relation to the natural seismic patterns, (2) to monitor the major fault zone beneath Amchitka Island and establish the level of activity of extremely small events both post- and pre-shot.

Before MILROW, it was predicted that the only possibility of producing a damaging tsunami was by virtue of an earthquake being triggered of magnitude considerably greater than the magnitude of the seismic effects attributable to MILROW itself. Permanent doming of the ground surface at and around surface zero and/or displacements on faults of one-three feet would produce waves of several inches height locally but would probably not be detected at Adak or Shemya, the next nearest populated points. The results from MILROW show that no large aftershocks occurred and the local ground motions, which were in the order of a half foot at the shore line, did not cause measurable waves.

The National Ocean Survey has at this time a considerable body of data bearing on the problems of explosion-related effects which supports but is not reflected in the Draft Environmental Statement. These results have been reported at scientific meetings and have been made available to the AEC (e.g., Explosion Effects and Earthquakes in the Amchitka Island Region--Engdahl, E. R., a paper presented at the Sixty-Sixth Annual Meeting of the Seismological Society of America, Riverside, California, March 1971), and a scientific paper for a professional journal is now in preparation.

In summary, the National Ocean Survey believes the Environmental Impact Statement, "AEC - Cannikin" as related to earthquakes and tsunamis, is very definitive and represents the results of many years of research and investigations conducted by the AEC and its contractors. NOS is in agreement with these statements and has a few recommendations to offer.

In commenting on the extremely small likelihood for interaction between detonations and a major earthquake, specific reference should be made to observed data from previous detonations in Nevada, South Pacific, and the Aleutians. To support many of the statements and conclusions in seismology and tsunamis, referral documents should be cited because much of the background data are not readily available to reviewers or interested parties. The environmental statement should be more definitive about the expected magnitude of Cannikin. Slightly above 6.5 is not adequate for reviewers to appraise the magnitude range for aftershocks and the potential for tsunami generation.

Gordon Lill

Gordon G. Lill
Deputy Director
National Ocean Survey

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

Dr. Sidney R. Galler
Deputy Assistant Secretary
for Environmental Affairs
Department of Commerce
Washington, D. C. 20230

Dear Dr. Galler:

We have received a copy of your June 8 letter to Mr. Timothy Atkeson, Council on Environmental Quality, which enclosed copies of the comments of the National Ocean Survey. We have included in the final statement a bibliography of referral documents. Thank you for the support of our conclusions.

Enclosed are copies of AEC's final Cannikin Environmental Statement along with the comments received on the draft statement and AEC's response to the comments.

Sincerely,

John A. Erlewine
Assistant General Manager
for Operations

Enclosure:
Cannikin Statement

OFFICE OF THE ASSISTANT SECRETARY OF DEFENSE
WASHINGTON, D. C. 20301

HEALTH AND
ENVIRONMENT

21 JUL 1970

Mr. John A. Erlewine
Assistant General Manager for Operations
Atomic Energy Commission
Washington, D. C. 20545

Dear Mr. Erlewine:

A review has been made of the environmental statement on the CANNIKIN Test as requested by your letter of 17 June 1970.

The Department of Defense considers that the statement adequately treats all environmental aspects of the proposed test. We are in agreement with the Atomic Energy Commission's assessment of hazards dealing with local ground effects, triggering of earthquakes, and generation of tsunamis.

The following specific comments are provided:

1. Page 2, paragraph 4. Substitute for "...provide extremely positive assurance..." the phrase "indicate that it is highly unlikely."

2. Page A-1, paragraph 2. While the first sentence in this paragraph is correct, the second sentence is not if related to the first, or concerned with damage to animals in the proximity of the shot. At large ranges or teleseismic distances the explosion will produce shocks like those from an earthquake with little probable effect on animals. At close ranges the shocks will have accelerations and displacements which could break legs. It is noted that there will probably be no animals near ground zero at shot time.

3. Page A-4, paragraph 5. Substitute for "...provide extremely positive assurance..." the phrase "indicate that it is highly unlikely."

4. Page A-6, paragraph 1. It is suggested that the remainder of the paragraph following, "earthquakes," in line 4 be deleted. This is considered extraneous material and does not contribute to the statement.

5. Page A-9, paragraph 2, line 10. Strike remainder of paragraph after "Hawaii." The remaining sentences add nothing factual.

It seems clear that Amchitka is, on balance, the best available site for conduct of the test and that the alternative of not testing is unacceptable on important grounds of national security.

Louis M. Rousselot

Louis M. Rousselot, M.D., F.A.C.S.
Deputy Assistant Secretary

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

Louis M. Rousselot, M.D.
Deputy Assistant Director
Office of Assistant Secretary of Defense
Department of Defense

Dear Dr. Rousselot:

Thank you for your comments of July 21, 1970, on AEC's Draft Environmental Statement - CANNIKIN. We have accommodated your comments 1, 2, and 3 in our Final CANNIKIN Environmental Statement.

We have not made the deletions suggested in your comments numbered 4 and 5. While the spreading sea floor model does not, of course, provide quantitative seismic data specific to Amchitka, or permit prediction of seismic effects, nevertheless it does, in the opinion of other seismologists, constitute a rational explanation of the general seismicity in the Aleutians, is consistent with the existence of ancient marine terraces in the Western Aleutians which exhibit little evidence of tilting (as contrasted from those in the Eastern Aleutians) and it leads to conclusions with respect to the low tsunami probabilities in the Western Aleutians that are consistent with experience. For your information we are enclosing copies of the CANNIKIN Environmental Statement, the comments that we received on the draft statement and AEC's response to the comments.

We are pleased to have received the Department of Defense comments.

Sincerely,

John A. Erlewine

John A. Erlewine, Assistant
General Manager for Operations

Enclosures:
As stated

DEPARTMENT OF STATE

Washington, D.C. 20520

July 28, 1970

Mr. John A. Erlewine
Assistant General Manager
for Operations
Atomic Energy Commission
Washington, D. C. 20545

Dear Mr. Erlewine:

With reference to your letter of June 17, 1970, transmitting the AEC draft environmental statement on the CANNIKIN test scheduled for the fall of 1971, this Department has reviewed the statement and has but one comment to submit relating to the environmental impact of the proposed test. Recalling the criticisms made in the overseas press and foreign governmental fora on project Milrow, we believe it would be in our own interests to give further discussion on the environmental statement to what are the probabilities and nature of any effects from the test being felt in other countries - particularly Canada, Japan and Russia.

Other aspects of the test, particularly those relating to foreign policy, will be discussed in the National Security Council's Under Secretaries' Committee.

Sincerely,

William C. Salmon

William C. Salmon
Acting Director
Office of Environmental Affairs

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

Mr. William C. Salmon
Acting Director
Office of Environmental Affairs
U. S. Department of State
Washington, D. C. 20520

Dear Mr. Salmon:

Responding to your comments of July 28, 1970 on the Atomic Energy Commission's Draft Environmental Statement - CANNIKIN, this is to advise you of several actions we have taken to further confirm the probabilities and nature of CANNIKIN effects on the environment.

First, we have updated past test experience from both the Nevada Test Site and Amchitka, with particular emphasis on the MILROW test, as indicators of the nature and probable magnitude of environmental effects from CANNIKIN. Secondly, we have carefully reviewed all of the comments received on our draft statement and have reevaluated and revised our final statement accordingly to clarify and answer additional environmental questions appropriate to this statement, and to reconfirm the quantitative predictions that we expect from the CANNIKIN test. Thirdly, we have continued development of our public information programs for both the foreign and domestic public. Although the public information program is outside the scope of the environmental statement, it is important to note publicly that such information plans have been actively developed in parallel with the test program and with the environmental statement. It is further noteworthy that the CANNIKIN Environmental Statement and the comments received on the draft statement are being made available to the public in advance of the CANNIKIN test, pursuant to the requirements of the National Environmental Policy Act.

As part of our international information program, we expect also to provide copies of the CANNIKIN Environmental Statement to all foreign governments on request, and to provide additional environmental information and briefings to those foreign government officials who have particularly important interests in the CANNIKIN test. For further details on both foreign and domestic information plans on CANNIKIN, please refer to the Interagency CANNIKIN Task Force - International Relations and Public Affairs Subcommittee on which Mr. H. C. Handyside, is the State Department representative.

In answer to your question on the probability and nature of any CANNIKIN effects which might be felt in other countries, it may be useful to summarize here our conclusions on such effects as seismic and ground motion, tsunamis and radioactive release. You will note that a peak ground motion equivalent to an earthquake of Richter magnitude slightly below 7.0 will be felt at the Amchitka site, and that vibrational waves will be detectable with seismometers anywhere on earth; however, ground motion will not be perceptible to persons at any population centers farther away than the military bases at Shemya and Adak, about 200 miles distant. Following the initial explosion and consequent creation of an underground cavity, rock falls into the cavity will produce additional ground signals which will be small, will be centered about the detonation point, and will only be noticeable to persons locally or with very sensitive seismometers elsewhere. Aftershocks, which have the characteristics of small earthquakes with separate hypocenters and which can reasonably be attributed to the underground explosion, are expected to occur for several days following CANNIKIN, are expected to be clustered fairly close to the explosion site (10-25 miles), and are expected to be substantially smaller in magnitude than the test itself (i.e., in the range of 1/100 to 1/10).

Damage to building structures due to direct ground motion, cavity collapse or rock falls and to aftershocks, will be minor and confined entirely to test-related or relic structures on the Island of Amchitka itself. These predictions of ground motion and seismic effects are based on searching analysis of the site and the planned test, with frequent reference to past test experience both at Amchitka and at our Nevada Test Site.

As for tsunamis, we conclude that the Western Aleutians have not produced damaging tsunamis in the past and that the relatively small sea floor displacement and the local ground motion in connection with CANNIKIN will not be sufficient to induce significant water waves or tsunamis. Our conclusions with respect to tsunamis are supported by experience. U. S. Coast and Geodetic Survey records show that there have been four natural earthquakes of more than magnitude 7.7 within 150 miles of Amchitka since 1900, and that there is an average of 2 or more earthquakes of magnitude 6.0 or greater each year, yet none of these have generated a serious tsunami. As a second, and less important consideration, a tsunami caused by an undersea landslide (small tsunamis have resulted from such subterranean landslides elsewhere) is not considered a threat at Amchitka since acoustic profiling in that region has not revealed any large deposits of sedimentary material which would be requisite for such a postulation. The MILROW

Test, which was about 6.5 Richter magnitude, did not produce any wave motion different from normal, although the instrumentation was capable of measuring waves of less than one inch.

The probability of CANNIKIN triggering a damaging earthquake - defined as an earthquake equal to or larger in seismic magnitude than the event itself - has been studied carefully by the AEC and its laboratories and consultants and by scientists who are independent of the AEC, and we have concluded that an explosion will not trigger a large earthquake unless it is detonated on or near a fault on which an earthquake of that magnitude is imminent. Considering the CANNIKIN event and the geologic and seismic features of the Amchitka site, we conclude that such triggering is very unlikely. It is very difficult to visualize how CANNIKIN could uniquely lead to sudden and unexpected release of tectonic energy that would not otherwise have happened. Since natural earthquakes of magnitude 7 or greater occur once every five to ten years, and since earthquakes of magnitude 6 and greater are occurring about two times annually in the Amchitka area, it appears that any potential for earthquake triggering is fairly well exploited through natural events whether CANNIKIN is fired or not. The possibility of triggering was also studied in detail before the MILROW event in 1969, which produced a Richter magnitude of about 6.5; yet, and I am sure you will note from the environmental statement, MILROW did not measurably alter either the magnitude or frequency of earthquakes in the Amchitka region.

With respect to the possibility of release of radioactivity to the environment, the AEC and its contractors have carefully designed the emplacement and analysed the containment conservatively and have coordinated with other government agencies to conclude that the possibility of prompt venting is very remote. Further, any tritium radioactivity that might be transported and released later through ground water will most probably be discharged to the ocean on the order of 1000 years hence and at a radioactive level well below the present background in the Bering Sea. Other radionuclides will be contained or entrapped in the substrata near the detonation point where the effects will be nil and radioactive decay will steadily reduce the levels to insignificance without affecting the surface environment.

You may wish to refer to the above summaries and to the enclosed CANNIKIN Environmental Statement which includes the comments received on the draft statement and AEC's response to the comments, in your liaison with foreign governments on CANNIKIN.

Sincerely,

John A. Erlewine

John A. Erlewine, Assistant
General Manager for Operations

Enclosures:
1. CANNIKIN Environmental Statement
2. Comments Received on the Draft Statement
3. AEC's Response to the Comments

OFFICE OF THE SECRETARY OF TRANSPORTATION
WASHINGTON, D.C. 20590

ASSISTANT SECRETARY

July 22, 1970

Mr. John A. Erlewine
Assistant General Manager
for Operations
Atomic Energy Commission
Washington, D.C. 20545

Dear Mr. Erlewine:

This is in response to your letter of June 17, 1970 to Mr. Legate of this Department.

The Coast Guard has pointed out that there is a petroleum storage area near Constantine Harbor, approximately 9 1/2 miles from the proposed test site. While the potential impact of the nuclear test on this storage area may have been adequately considered, the draft statement does not discuss that consideration in specific terms. In view of the possibility of pollution resulting from any disturbance of the storage area, it would appear to be desirable to include in the statement specific comments concerning the potential impact, including the exact products in storage, the type of storage facilities, and the prediction of any effect caused by the proposed test.

Thank you for this opportunity to comment.

Sincerely,

J. D. Braman
Assistant Secretary for
Environment and Urban Systems

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

Mr. J. D. Braman
Assistant Secretary for
Environment and Urban Systems
Department of Transportation
Washington, D.C. 20590

Dear Mr. Braman:

Thank you for your comments of July 22, 1970 on AEC's Draft Environmental Statement - CANNIKIN.

We have noted your concern with the petroleum storage area at Constantine Harbor and we are exercising both design and operating precautions to protect against loss from the storage tanks during the CANNIKIN test, as noted in the construction activities section of the enclosed CANNIKIN Environmental Statement.

Thank you for your assistance.

Sincerely,

John A. Erlewine

John A. Erlewine
Assistant General Manager
for Operations

Enclosure:
CANNIKIN Environmental Statement
w/Comments Received on Draft
Statement and AEC Response to
Comments

EXECUTIVE CHAMBERS

HONOLULU

JOHN A. BURNS
GOVERNOR

July 14, 1970

Dear Mr. Hollingsworth:

Thank you for your letter of June 17, 1970 requesting our comments to a draft of an environmental statement on the proposed CANNIKIN test to be conducted in 1971 at Amchitka Island, Alaska. We have studied the draft of the proposed statement and find it to be complete and comprehensive in the scope of the environmental factors which may be involved during this test.

We are vitally interested and we would appreciate your sending us any further information the Atomic Energy Commission may provide state and local officials regarding AEC activities and plans.

With warm personal regards. May the Almighty be with you and yours always.

Sincerely,

John A. Burns

Mr. R. E. Hollingsworth
General Manager
U. S. Atomic Energy Commission
Washington, D.C. 20545

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

Honorable John A. Burns
Governor of Hawaii
Honolulu, Hawaii

Dear Governor Burns:

Thank you for your letter of July 14, 1970 commenting on the Atomic Energy Commission's Draft Environmental Statement - CANNIKIN. Since that time we have revised the statement taking into account the comments.

For your information, enclosed are copies of the CANNIKIN Environmental Statement, the comments received on the draft and AEC's response to the comments.

Thank you for your assistance.

Sincerely,

John A. Erlewine

John A. Erlewine, Assistant
General Manager for Operations

Enclosure:
As stated

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