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DIVISION OF WASTE MANAGEMENT AND ENVIRONMENTAL PROTECTION

DRAFT SUPPLEMENT TO THE FINAL ENVIRONMENTAL ASSESSMENT RELATED TO THE PROPOSED PA'INA HAWAII, LLC UNDERWATER IRRADIATOR IN HONOLULU, HAWAII

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ACRONYMS/ABBREVIATIONS

CNWRA	Center for Nuclear Waste Regulatory Analyses
Co-60	Cobalt-60
Concerned Citizens	Concerned Citizens of Honolulu
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
E-beam	Electron-beam
EA	Environmental Assessment
EIS	Environmental Impact Statement
ERG	Emergency Response Guidebook
FAA	Federal Aviation Administration
FONSI	Finding of No Significant Impact
HDOT	Hawaii Department of Transportation
IAEA	International Atomic Energy Agency
ICAO	International Civil Aviation Organization
ISO	International Organization for Standardization
NEHRP	U.S. National Earthquake Hazard Reduction Program
NEPA	National Environmental Policy Act
NRC	U.S. Nuclear Regulatory Commission
Pa’ina	Pa’ina Hawaii, LLC
PDO	Property Damage Only
RAM	Radioactive material
RED	Radiological exposure device
RDD	Radiological dispersal device
USDA	U.S. Department of Agriculture
USGS	United States Geologic Survey

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1.0 INTRODUCTION

The staff of the U.S. Nuclear Regulatory Commission (NRC) has prepared this Draft Supplement to the Environmental Assessment (EA) for the proposed Pa'ina Hawaii, LLC (Pa'ina) underwater irradiator. This Draft Supplement assesses the environmental impacts from (1) transportation accidents involving shipments of cobalt-60 (Co-60) sources to and from Pa'ina's irradiator, (2) the alternative technology of electron-beam (e-beam) irradiation, and (3) construction and operation of a Co-60 irradiator at one of five alternative sites.

1.1 Background

By letter dated June 23, 2005, Pa'ina submitted an application to the NRC requesting a license to possess and use byproduct material in connection with a proposed underwater irradiator (Pa'ina, 2005). The proposed irradiator would use Co-60 to irradiate products for commercial, agricultural, and research purposes. The irradiator would be located on Palekona Street in Honolulu, Hawaii, adjacent to Honolulu International Airport.

The Atomic Energy Act of 1954 provides that an interested person may request a hearing in connection with certain proposed licensing actions. In this case, Concerned Citizens of Honolulu (Concerned Citizens) requested a hearing on Pa'ina's license application. On January 24, 2006, a three-judge Board from the NRC's Atomic Safety and Licensing Board Panel granted Concerned Citizens' hearing request. An Atomic Safety and Licensing Board is an adjudicatory body independent from the NRC Staff. Among their responsibilities, Boards preside over NRC licensing cases in which a hearing request has been submitted.

As a general matter, NRC regulations exempt irradiator licensing from the requirement, imposed by the National Environmental Policy Act (NEPA), that the NRC Staff prepare an EA or Environmental Impact Statement (EIS) to support a decision of whether to issue a license. Along with its hearing request, however, Concerned Citizens submitted contentions arguing that special circumstances existed such that the categorical exclusion could not be applied to Pa'ina's irradiator. Specifically, Concerned Citizens argued that, due to unique risks from aircraft crashes and certain natural phenomena at Pa'ina's proposed irradiator site, the NRC Staff must prepare an EA or EIS to support a decision of whether to issue Pa'ina a license.

The Board admitted Concerned Citizens' contentions challenging the categorical exclusion as applied to Pa'ina's proposed irradiator. This meant that the parties in this case—Pa'ina, Concerned Citizens, and the NRC Staff—would have been required to litigate the issues raised in those contentions. In order to resolve these admitted contentions, the NRC Staff and Concerned Citizens entered into a settlement agreement. As part of the settlement agreement, the NRC Staff agreed to prepare an EA for the proposed action. Although Pa'ina itself objected to the settlement agreement, the Board approved the agreement.

The NRC Staff issued a Draft EA on December 21, 2006. The Draft EA reflected the Staff's preliminary determination that issuing Pa'ina an NRC license would have no significant impact on the environment. After considering public comments on the Draft EA, on August 10, 2007 the Staff issued a Final EA and Finding of No Significant Impact (FONSI) for Pa'ina's proposed irradiator (NRC, 2007a). Based on the FONSI, and because the Staff had previously determined that Pa'ina's license application met all safety requirements in NRC regulations, the Staff issued Pa'ina a byproduct materials license on August 17, 2007 (NRC, 2007b).

As permitted under NRC regulations, Concerned Citizens filed contentions challenging the NRC Staff's analysis in the Final EA. Concerned Citizens' underlying claim was that in certain areas the Staff had not analyzed issues to the extent required under NEPA. The Board admitted certain portions of Concerned Citizens' contentions, while rejecting other portions. After the Board's rulings, the parties submitted evidence, including both testimony and exhibits, setting forth their positions on the issues raised in the admitted portions of Concerned Citizens' contentions. After considering this evidence, the Board dismissed additional portions of Concerned Citizens' contentions. However, the Board also found that there were three areas in which the Staff had not yet demonstrated that it complied with NEPA. Specifically, the Board found that the Staff needed to further consider (1) the environmental impacts of accidents that might occur during the transport of Co-60 sources to and from Pa'ina's irradiator, (2) e-beam technology as an alternative to Co-60 irradiation, and (3) alternative sites for Pa'ina's irradiator.

1.2 Purpose of this Supplement

This Draft Supplement to the EA for Pa'ina's irradiator addresses the three areas in which the Board found that the NRC Staff must perform additional analyses. The Draft Supplement is divided into three sections. The first section (Section 2) analyzes the environmental impacts of transportation accidents that might occur during the transport of Co-60 sources to and from Pa'ina's irradiator. The second section (Section 3) analyzes the environmental impacts of e-beam irradiation. The third section (Section 4) analyzes the environmental impacts associated with constructing and operating Pa'ina's irradiator at alternative sites.

1.3 Proposed Action

In June 2005, Pa'ina applied for an NRC license that would allow it to use sealed radioactive sources in an underwater irradiator. Pa'ina intends to use the irradiator for the production and research irradiation of food, cosmetic, and pharmaceutical products (Pa'ina, 2005).
The proposed irradiator would be located adjacent to Honolulu International Airport on Palekona Street near Lagoon Drive. The irradiator would primarily be used for phytosanitary treatment of fresh fruit and vegetables bound for the United States mainland from the Hawaiian Islands and similar products being imported to the Hawaiian Islands. The irradiator would also be used to irradiate cosmetic and pharmaceutical products. In addition, the irradiator would be used to conduct research and development projects and irradiate a wide range of other materials as specifically approved by the NRC on a case-by-case basis.

Pa'ina proposes to construct an underwater irradiator in which the sealed sources remain at the bottom of the irradiator pool at all times (i.e., approximately 12–18 feet below the pool surface). Human access to the sealed sources and the space subject to irradiation is not physically possible without entering the irradiator pool. The product to be irradiated is placed in a water-tight container (i.e., product bell) and lowered into the irradiator pool water.

Pa'ina's proposed irradiator was designed by Gray*Star, Inc. The irradiator can be used with two different types of radioactive Co-60 sealed source assemblies. Both source assemblies are doubly encapsulated. The inner capsule contains nickel-coated Co-60 metal slugs. This capsule is either stainless steel or zircalloy and has two welded end caps. The inner capsule is placed in the stainless steel outer capsule, which also has two welded end plugs. The Co-60 sealed source assemblies are of robust construction and meet NRC regulations applying to leak tests, corrosion, temperature shock, pressure, impact, vibration, puncture, and bending.

For more information regarding the proposed action, please refer to the Final EA (NRC, 2007a), which describes Pa'ina's proposal in detail.

2.0 TRANSPORTATION ACCIDENTS

2.1 Introduction

This section describes the environmental impacts of accidents associated with the transportation of Co-60 sources to and from Pa'ina's irradiator. This analysis first considers the probability and severity of accidents that might occur during the transportation of sources to and from Pa'ina's irradiator. This analysis then considers the environmental impacts that might result from transportation accidents.

Operation of the proposed Pa'ina irradiator would require the shipment of high activity Co-60 sources from manufacturers located in the United Kingdom (Reviss) or Canada (Nordion). It is estimated that the number of Co-60 shipments, including the return of used Co-60 sources to the manufacturer, would not exceed two per year. The annual shipments would consist of a single shipment of new Co-60 sources to the irradiator and a return shipment of depleted sources to the manufacturer, both using the same shipping package. These shipments could be made using a combination of marine, rail, and road transport. Planned shipments of Co-60 sources to and from Pa'ina's proposed irradiator would not involve air transport (Kohn, 2010). It is also unlikely that any future shipments would involve air transport, as the International Civil Aviation Organization (ICAO) has limited the quantity of Co-60 sources that can be shipped in a Type B package (the type of package in which Co-60 must be shipped) in a civil aircraft to 33,000 curies,[1] the equivalent of about two Co-60 "pencil" sources containing 13,000-14,000 curies each.[2] In contrast, a Type B package authorized for surface shipment, such as Nordion's Model F-294, can transport up to 360,000 curies in a single package.

2.2 Accident Rates for Large Truck Shipments

Data compiled by the U.S. Department of Transportation (DOT) on truck accident rates; property damage, hazardous materials releases, injuries, and fatalities resulting from truck accidents are based largely on the statistics developed for total commercial cargo shipments and hazardous materials shipments. It is difficult to estimate a precise accident rate for Co-60

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[1] In July 2001 the ICAO restricted the use of Type B containers for the transportation of radioactive nuclides by air to a maximum permitted load activity of 3,000 x A_1 or 100,000 x A_2, whichever is lower. This restriction incorporated the limits on air shipments of Type B packages adopted by the International Atomic Energy Agency in paragraph 416 of its 1996 Edition of Regulations for the Safe Transport of Radioactive Material. The maximum Co-60 load permitted for transportation by air in a Type B container is now 1.2 PBq (33 kCi).

[2] A typical Co-60 "pencil" source such as Norion's C-188 source can hold up to 14 thousand curies. The sources weigh approximately half a pound and are approximately 18 inches long and 0.45 inches in diameter. (*See* C-188 technical specifications at www.mds.nordion.com.)

truck shipments based solely on historic accident frequencies for radioactive materials shipments, including shipments of Co-60 sources. This stems from the fact that there have been relatively few radioactive materials (including Co-60) shipments by truck, when compared to the overall annual number of hazardous materials or general cargo truck shipments in the United States. Radioactive materials shipments have historically made up less than one percent of all hazardous materials shipments, and a much smaller percentage of the overall total of U.S. commercial cargo shipments (DOT *et al*., 2004). Additionally, during the past 30 years, there has never been a reported case of a release of the contents from a large Type B radioactive materials package[3] during either routine transportation or for shipments involved in an accident. As a result, there has never been an injury or fatality attributable to an accident involving a release from a large Type B radioactive materials shipping package. Based on the 30-year database accumulated for large Type B package shipments, the historical rate for truck accidents resulting in a release, injury, or fatality would be zero.

A more conservative estimate of the accident rate for Co-60 truck shipments comes from using the accident rates for large trucks compiled by the Federal Motor Carrier Safety Administration for the years 2006 through 2008, shown below in Table 1.

Table 1. Accident Rates for Large Trucks

Year	Fatal Crashes per 100 Million Vehicle Miles	Injury Crashes per 100 Million Vehicle Miles	Property Damage Only (PDO) Crashes per 100 Million Vehicle Miles
2008	1.64	28.0	130.8
2007	1.85	31.7	139.6
2006	1.95	34.5	128.9
2006- 2008 Average	1.8×10^{-8} fatalities/mile	9.4×10^{-7} injuries/mile	1.3×10^{-6} PDO /mile

Large Bus and Truck Crash Facts – 2008, Federal Motor Carrier Safety Administration, Analysis Division, FMCSA-RRA-10-043, published March 2010

As seen in Table 1, the average accident rate for large trucks ranges from 1.3×10^{-6} accidents per mile (accidents resulting only in property damage) to 1.8×10^{-8} accidents per mile (accidents resulting in a fatality from the impact force or fire occurring during the accident).

2.3 Requirement to Use Accident-Resistant Shipping Containers

[3] "Large Type B package," as used here, refers to packages that cannot be carried by a single individual.

Shipments of Co-60 to and from Pa'ina's irradiator would be made in accident-resistant Type B packages, certified by either the NRC for packages used solely for domestic shipments, or by DOT for packages used for import/export shipments. To be certified, the design of a Type B package must demonstrate its ability to withstand severe accident conditions, including impact, puncture, and fire. As a result, Co-60 sources are required to be transported in shipping packages that are heavy (up to 10 tons), with thick composite metal walls (up to a foot thick). These packages are closed using heavy metal lids, which are secured in place by multiple highly torqued bolts[4]. An example of a typical shipping package for Co-60 sources, with a height of about 52 inches, is shown in Figure 1. An additional measure of the robustness of the shipping package is the relative weight ratio of the empty package compared to its authorized contents. For the shipping package depicted, the weight ratio is about 500 to 1, with the empty shipping package weighing approximately 20,000 pounds and the authorized contents (radioactive Co-60 "pencil" sources) weighing 40 pounds.

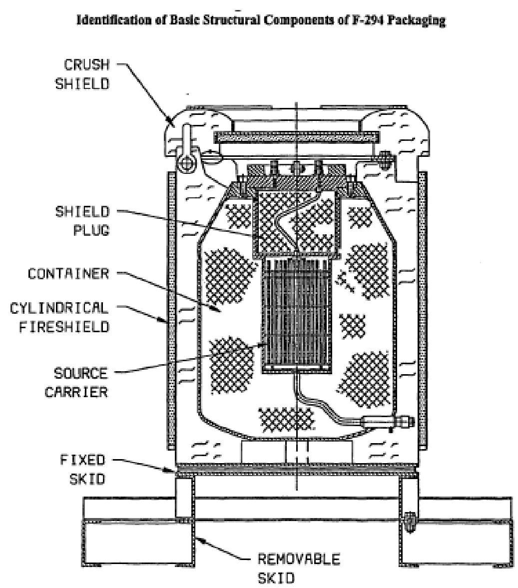

Figure 1. Model F-294 Shipping Package for Co-60 Sources

The packages are often shipped in International Organization for Standardization (ISO) containers, which could also provide additional protection during severe accidents (see Figure 2). The ISO containers would absorb some of the impact energy associated with a severe accident and potentially provide an additional barrier to the sources becoming exposed during the accident.

Although no specific studies have been conducted for how large Type B Co-60 shipping packages perform in severe accidents, a study completed for the NRC on Type B packages for spent nuclear fuel concluded that there would be no significant radiological hazard (impact) in 99.4% (994 of every 1000) of severe accidents (Lawrence Livermore National Laboratory, 1987). Because large Co-60 shipping packages share many of the characteristics of spent fuel

[4] A typical design for a Co-60 shipping package can be found in Directory of Certificates of Compliance for Radioactive Material Packages, (NUREG-0383, Volume 2, Revision 27), Certificate No: 9258.

casks—including thick, multi-layered, metallic walls; heavily bolted lids; and a large package-to-content weight ratio[5]— and are designed to withstand the same severe accident conditions (i.e., Type B package standards), it is reasonable to conclude that large irradiator packages will also survive a very high percentage of severe accidents (> 95%) without resulting in a significant radiological dose from either release of contents or loss of package shielding.

Figure 2. Model F-294 Shipping Packages for Cobalt-60 Sources in an ISO Container

It is also unlikely that a Co-60 sealed source would be breached even in a severe accident. Pa'ina's proposed irradiator is designed for use with two different types of radioactive Co-60 sealed source assemblies. Both source assembly designs are doubly encapsulated. The inner capsule, which contains the nickel-coated Co-60 metal slugs, is either stainless steel or zircalloy and has two welded end caps. The inner capsule is then placed in the stainless steel outer capsule, which also has two welded end plugs. In addition, the Co-60 sources are required to meet NRC performance requirements for use in irradiators (i.e., the requirements in 10 CFR 36.21),[6] and are required to be certified as "special form" for transportation under International Atomic Energy Agency (IAEA) or DOT regulations.[7] Special form certification requires that the sources be tested or evaluated to standards that simulate the impacts, thermal environment, and bending stresses that might be experienced during severe accidents.

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[5] For a spent fuel truck cask, the weight ratio of the cask to authorized contents is typically 10 to1. For a Co-60 package the weight ratio can be on the order of 500 to 1.

[6] 10 CFR 36.31 contains performance requirements for leak tests, corrosion, temperature shock, pressure, impact, vibration, puncture, and bending.

[7] See paragraphs 704–711 of IAEA's 1996 Edition of Regulations for the Safe Transport of Radioactive Material or 49 CFR 173.469 and 173.476 (DOT regulations).

2.4 Description of Environmental Impacts of Transportation Accidents

A transportation accident would not be expected to cause significant environmental impacts because of the low likelihood of an accident severe enough to cause a release of Co-60. Given that the number of Co-60 shipments, including the return of used Co-60 sources to the manufacturer, would not exceed two per year, and given that the road distance travelled from the Port of Honolulu to Pa'ina's proposed irradiator or to any alternative site is no more than 15 miles (see Section 4), the expected frequency of a large truck accident is approximately 3.9×10^{-5} accidents per year.

$$1.3 \times 10^{-6} \text{ accidents per mile} \times 15 \text{ miles/shipment} \times 2 \text{ shipments per year} = 3.9 \times 10^{-5} \text{ accidents per year} \quad (1)$$

Based on the design of the shipping package, it is estimated that less than five percent of accidents would have sufficient energy to breach a 10-ton Type B package used to ship Co-60 and result in either a release of contents or loss of package shielding. This represents an accident frequency of less than 2.0×10^{-6} accidents per year that could result in a release of contents or loss of shielding, or one accident every 500,000 years.

$$3.9 \times 10^{-5} \text{ accidents per year} \times .05 \text{ accidents that could be expected to breach a Type B container} = 2.0 \times 10^{-6} \text{ accidents per year} \quad (2)$$

In the very unlikely event that a release results from a severe accident, the impacts are expected to be short-lived and limited to a small area around the accident site. The primary hazards resulting from an accident severe enough to release Co-60 are the potential for a lethal injury from the impact force of the accident itself, and from direct radiation exposure to Co-60 sources that are released from the transportation shipping container.

Any accident severe enough to breach a 10-ton Co-60 package would likely result in fatality to the truck's driver. From Table 1, the likelihood of any fatality, including the truck driver and others involved in the accident, resulting from the crash of a large truck can be estimated as approximately 1.8×10^{-8} fatality per mile, or 5.4×10^{-7} fatality per year based on the proposed number of shipments needed to operate the Pa'ina irradiator and a maximum distance of 15 miles per shipment. This equates to approximately one fatality in 2 million years.

Direct radiation exposure to Co-60 sources that are released from a transportation shipping container could result in an individual receiving a significant dose. A person standing one meter from an unshielded Co-60 "pencil" source containing 14,000 curies would receive approximately 19,000 rem per hour (assuming specific gamma ray dose constant for Co-60 of 1.37 rem/hr at one meter). At this dose rate, an individual standing within one meter could receive an LD50/60 dose (500 rem)[8] in one to two minutes. The potential dose would depend on the amount of Co-60 exposed, the distance from the Co-60 source, exposure time, and intervening shielding. Any release of Co-60 sources from the package would not be expected to result in wide-spread

[8] The $LD_{50/60}$ is that dose at which 50%of the exposed population will die within 60 days. The $LD_{50/60}$ (with minimal supportive care) is 320–360 rem. $LD_{50/60}$ (with supportive medical treatment) is 480–540 rem. 100% mortality (with best available treatment) is 800 rem. (Adapted from NCRP Report No. 98 "Guidance on Radiation Received in Space Activities, NCRP, Bethesda, MD (1989).)

contamination, however, because the Co-60 sources consist of non-dispersible, metallic cobalt that is doubly encapsulated in stainless steel capsules.

Other impacts resulting from the release of Co-60 sources are expected to be short-lived and limited to a small area around the accident site. In the event of an accident, emergency responders arriving on the scene would be able to identify the contents of a Co-60 package either by examining the shipping papers that must accompany each shipment or by the label and identification number that must be affixed to the shipping package itself (see Figure 3).[9] In addition, emergency responders should be aware of any ongoing shipments, as shippers are required to notify states of impending shipments, and coordinate shipment information with affected states.[10]

In the event that the package label and identification number were obscured and the shipping papers were not available, responders could verify that the truck was carrying radioactive material from the truck's placard. In either case, emergency responders should be familiar with Guide 163 in DOT's 2008 Emergency Response Guidebook (ERG). The ERG recommends that, as an immediate precautionary measure, responders isolate the potential spill or leak area for at least 25 meters (75 feet) in all directions, stay upwind, and keep unauthorized personnel away. This action would decrease the likelihood and magnitude of exposure to the public should a source be released from its shipping package.

Figure 3. An Example of the Source Shipping Package Label and Identification Number Required for a Large Cobalt-60 Source Shipment

Any release of Co-60 sources from the package would be readily detectable as Co-60 is a strong gamma emitter and would not be expected to result in wide-spread contamination due to its non-dispersible nature. It is anticipated that emergency responders would consult with the source suppliers, or other emergency contact personnel identified on the shipping papers, about

[9] The requirements for labeling of radioactive material packages are in DOT regulations at 49 CFR 172.403; requirements for shipping papers are at 49 CFR 172 Subpart C.

[10] *Issuance of Order for Additional Security Measures on the Transportation of Radioactive Material of Concern* (July 19, 2005).

the best way to secure and recover any exposed sources.[11] Once the source is secured and recovered by emergency responders or other qualified parties, there should be no long-lasting environmental impact.

Accidents involving rail shipments of Co-60 across the United States also would not be expected to cause a significant environment impact. These shipments would take place no more than twice a year, and they would be made in packages meeting the stringent safety requirements for Co-60 shipping containers. As with truck shipments, in the event that a release results from a severe accident, the environmental impacts are expected to be short-lived and limited to a small area around the accident site. Additionally, as with truck shipments, the primary hazards resulting from the release of Co-60 in a severe rail transportation accident are the potential for a lethal injury from the impact force of the accident itself, and from direct radiation exposure to any Co-60 sources that may be released from the transportation shipping container. Once the source is secured and recovered by emergency responders or other qualified parties, there should be no long-lasting environmental impact.

Co-60 shipments would also involve marine shipments across the Pacific and/or the Atlantic Oceans. An accident during a marine segment of a Co-60 shipment to the Port of Honolulu would not be expected to cause a significant or long-lasting environment impact. In order to cause a release or loss of control of Co-60, a marine accident would have to generate sufficient forces on the shipping package to cause it to fail or cause the package to be lost overboard.

A research project on the marine shipment of radioactive material (RAM) conducted by the IAEA, published in July 2001,[12] reached the following conclusions:

1. Ship collisions and ship fires are infrequent events; most ship collisions and ship fires will not subject a RAM package being transported on the ship to any mechanical or thermal loads; the chance that a ship collision or ship fire will subject a RAM transport package to loads that might cause the package to fail is very small.

2. Should a ship collision or fire lead to the sinking of the RAM transport ship and thus to the loss of a RAM package into the ocean, the recovery of the package is likely if the loss occurs on the continental shelf (i.e., at depths of less than 200 meters). If, however, the package is not recovered, the rate of release of RAM from the package into ocean waters will be so slow that the radiation doses received by people who consume marine foods contaminated as a result of the accident will be negligible compared to background doses.

While the IAEA research project was based primarily on the marine transport of high-level waste and spent fuel, the project's conclusions are instructive when considering Co-60 shipments. These conclusions are instructive because (1) the IAEA project considered general marine accident data, (2) the Type B package designs for high-level waste and Co-60 are similar (as described earlier), and (3) the radioactive materials analyzed in the IAEA project are much more

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[11] An emergency contact is required on all shipping papers. 49 CFR 172.201(d).

[12] Severity, Probability and Risk of Accidents during Maritime Transport of Radioactive Material. Final report of a co-ordinated research project (1995-1000), IAEA-TECDOC-1231, published July 2001 (see page 60-61).

soluble and long-lived than Co-60. The IAEA project therefore supports the conclusion that the loss of a Co-60 package during a maritime accident is unlikely and that, in the event of such a loss, there would be no significant environmental impact.

Even if a Co-60 package were lost at sea, no release of Co-60 would occur unless seawater reached a Co-60 source, which could still be protected by both its shipping package and double encapsulation. If seawater reached a Co-60 source, the release rate and overall activity would be limited by the slow rate at which solid Co-60 corrodes. In addition, due to its short half-life, the radioactivity of the Co-60 would decrease by one-half approximately every five years. After 25 years, for example, the original activity of the Co-60 would be decreased by a factor of 32. In addition, any corroded Co-60 would be greatly diluted by the large quantity of sea water. For Co-60 that has not corroded, the seawater would provide shielding to humans and marine life.

2.5 Summary of Environmental Impacts of Transportation Accidents

An accident occurring during transport of Co-60 to Pa'ina's proposed irradiator would not be expected to cause significant environmental impacts because there is a low likelihood any accident would be severe enough to cause a release of Co-60. The very low likelihood of a release results from the small number of Co-60 shipments, the low accident rates for the modes of transportation used to ship Co-60, and the stringent safety requirements for Co-60 shipping packages. The proposed shipments of Co-60 would be made in accident-resistant Type B packages certified by the NRC or DOT. These packages would be certified to withstand severe accident conditions, including impact, puncture and fire.[13] In the very unlikely event that a release resulted from a severe accident, the environmental impacts are expected to be short-lived and limited to a small area around the accident site. The release of Co-60 sources would be readily detectable because Co-60 is a strong gamma emitter. Further, any release would not be expected to result in widespread contamination because Co-60 sources consist of non-dispersible, metallic Co-60 that is doubly encapsulated in stainless steel capsules. The primary hazards resulting from the release of Co-60 in a severe transportation accident are the potential for a lethal injury from the impact force of the accident itself, and from direct radiation exposure to any Co-60 sources that may be released from the transportation shipping container.

3.0 ALTERNATIVE TECHNOLOGY: ELECTRON-BEAM IRRADIATION

3.1 Introduction

This section describes the environmental impacts of an e-beam irradiator if it were located at Pa'ina's proposed site, which is adjacent to Honolulu International Airport on Palekona Street near Lagoon Drive. This analysis is presented to allow a comparison of the potential environmental impacts of an e-beam irradiator at the proposed site with the potential environmental impacts of a Co-60 irradiator at the proposed site. The summary at the end of this section includes a table comparing these impacts.

[13] Type B packages are designed to withstand hypothetical accident conditions that are intended to bound the physical impacts and thermal environments that might be experienced in real-life accidents. Type B package designs are reviewed and approved by the NRC under 10 CFR Part 71. For a more detailed description of the hypothetical accident conditions used in the approval of Type B shipping casks, see 10 CFR 71.73.

3.2 Description of Electron-Beam Irradiator Facility

As its name implies, an e-beam irradiator uses electron beams to irradiate food and other products for agricultural, commercial, research, and other purposes. In this type of irradiator, radiation is only generated when the accelerator is energized. No radiation is generated when the irradiator is not energized. Human access to the beam during operations is not physically possible without entering an interlocked shielded room. A schematic representation of an e-beam irradiation facility is shown in Figure 4. The dimensions of the self-contained facility vary depending on the amount of product that is processed; when large quantities of product are processed, larger warehouse facilities are needed. However, the size of the irradiator will remain the same. During operation, the product to be irradiated is placed in product carriers on a conveyor system, shown in Figure 5, and passed through the radiation field. The irradiator delivers a dose for the intended outcome. For insect disinfestations, doses are typically less than 1 kGy (100 krad), while doses between 1 and 10 kGy (100 and 1,000 krad) are typically used to control food-borne pathogens and to extend food shelf life (Miller, 2005). Product sterilization typically requires doses greater than 10 kGy (1,000 krad) (Miller, 2005).

An e-beam irradiator has two main components: a linear accelerator with a radiation shield and a material handling system (Miller, 2005). The linear accelerator, shown in Figure 6, generates and accelerates electrons to energies up to 7.5 MeV. An electron gun produces pulses of electrons that enter a series of resonant cavities in a magnetron, which is controlled by an automatic frequency control. The magnetron accelerates the pulses of electrons to the desired energy. Auxiliary systems provide a high vacuum inside the accelerator, as well as temperature control of its conducting surfaces. Power for the accelerator is supplied and controlled by a high-voltage power supply and a pulse-forming network.

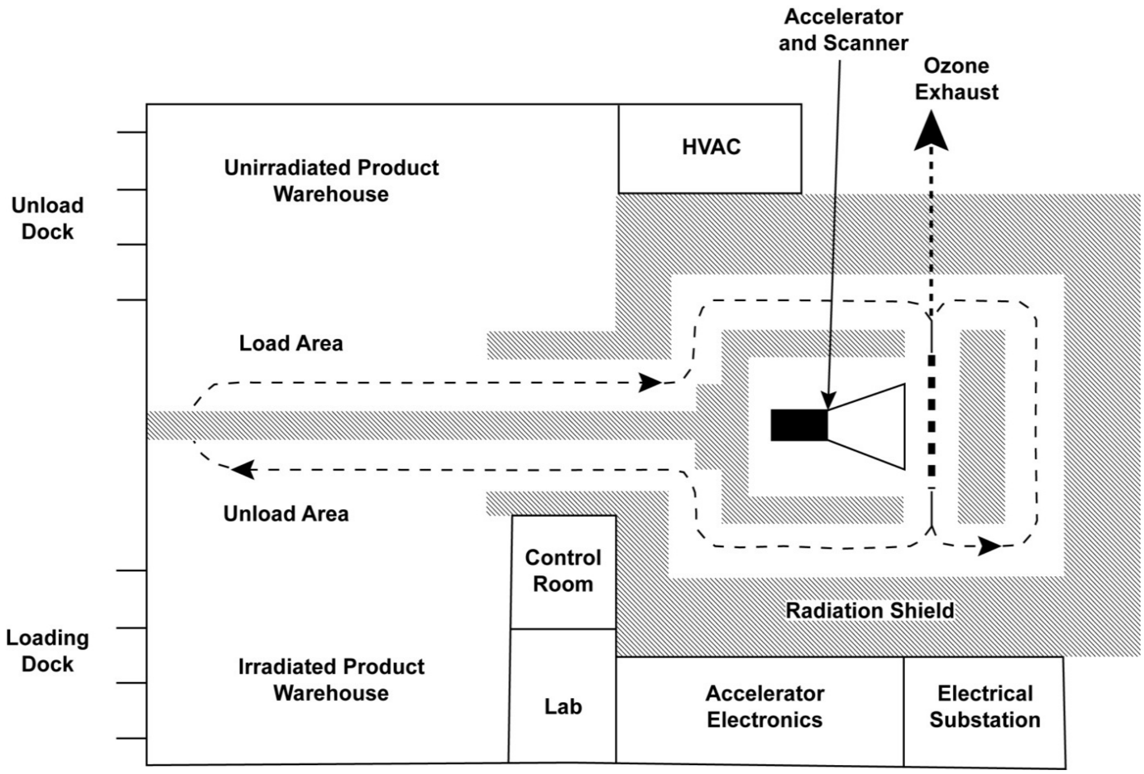

Figure 4. Schematic of an E-Beam Irradiator Facility (Adapted from Miller, 2005)

Figure 5. Product Conveyor System for an E-Beam Irradiator Facility Showing Product Carriers (Photo Courtesy of James Power, L-3 Communications)

The accelerated e-beam is controlled by a scan magnet and exits the accelerator system through the scan horn. The high-energy electrons then strike a high-density material such as tungsten or titanium that generates bremsstrahlung x-rays in all directions. The radiation shield absorbs the energy of those x-rays that are not travelling toward the product, thus creating an x-ray beam. The shield is made of high-density concrete with a thickness that reduces the radiation dose in unrestricted areas to below applicable regulatory limits.[14]

[14] In Hawaii, the State of Hawaii Department of Health sets regulatory limits applying to the radiation produced by e-beam irradiators. No NRC license is required to operate an e-beam irradiator because this type of irradiator does not use material regulated under the Atomic Energy Act.

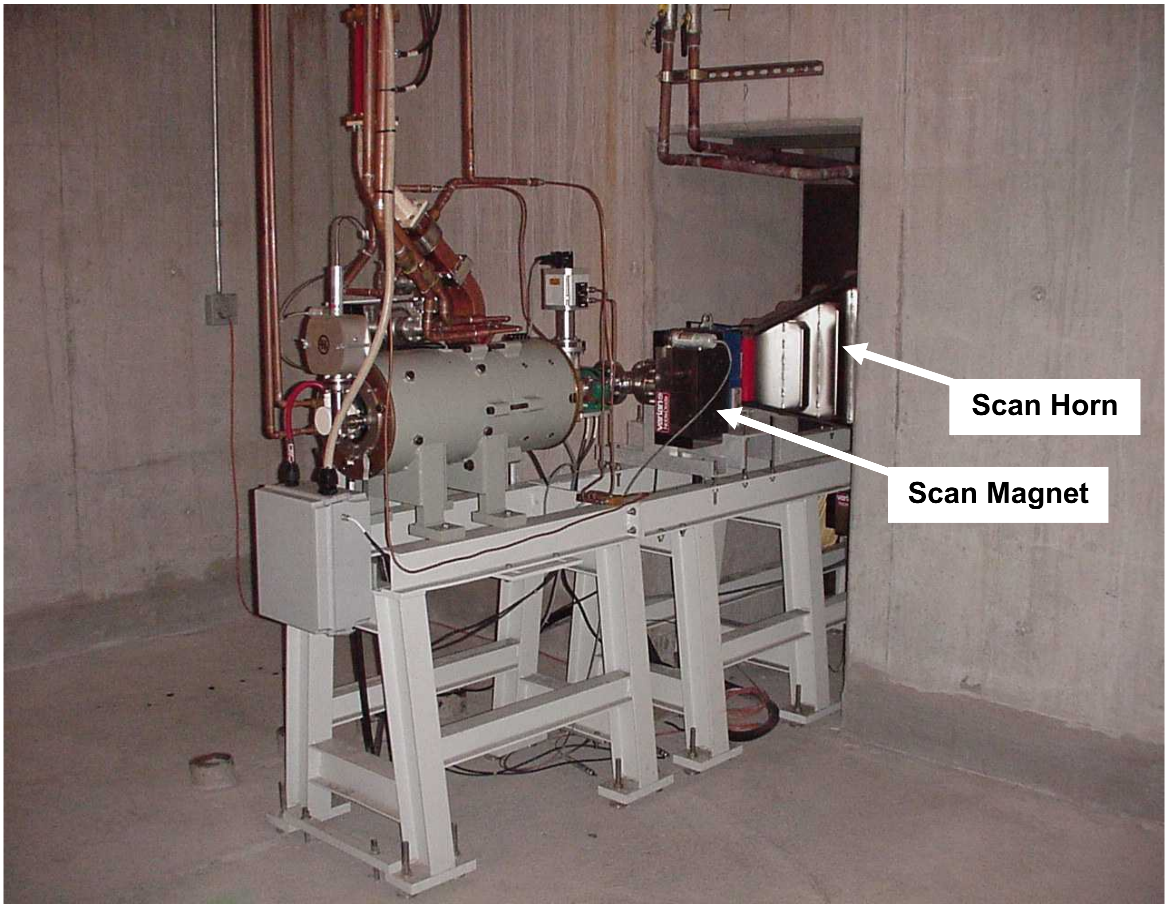

Figure 6. Linear Accelerator for an E-Beam Irradiator (Photo Courtesy of James Power, L-3 Communications)

An outside view of the shield is shown in Figure 7. Product irradiation takes place within the shielded room. Entry to the room and operation of the irradiator are interlocked such that if the door is opened, the accelerator immediately shuts off and radiation is no longer generated.

The product is passed through the x-ray beam using a material handling system as shown in Figure 5. The material handling system ensures that the product moves through the irradiation zone in a precisely controlled, constant manner for the type of product to be irradiated. The generated x-rays can penetrate 30 cm (12 in) into the product, producing a uniform distribution of radiation energy within that thickness of product.

Ozone is generated as radiation passes through air before reaching the product. Ozone is one of six criteria pollutants identified in the U.S. Environmental Protection Agency's National Ambient Air Quality Standards codified in 40 CFR Part 50. The limit for ozone in air is 0.075 parts per million (ppm). For the x-rays produced by an e-beam, ozone levels of up to 0.7 ppm can be expected (Miller, 2005). Thus, ozone must be removed from the irradiation chamber using a ventilation system.

According to Miller (2005), the e-beam facility can be operated by five workers [plant manager, radiation safety officer/quality control person, maintenance personnel (assumed to be two people), and clerical help (assumed to be one person)]. Depending on the amount of product being processed, additional workers are needed: a shift supervisor/plant operator and two to six product-handling personnel. If demand is very high, two or more shifts of these additional workers would be required. For a single shift, however, it is estimated that an average total of 10 employees would be required to operate the facility.

3.3 Environmental Impacts of the E-Beam Irradiator Facility

An e-beam irradiator would occupy a small percentage of existing industrial space adjacent to Honolulu International Airport. As shown in Figure 7, an e-beam irradiator facility is relatively small in size and requires construction activities that are common for industrial facilities, including grading, framing, and pouring concrete. Materials for shield construction are likely to be imported from the United States mainland. E-beam irradiator construction would not involve the use of hazardous or radioactive materials. In addition, facility construction would not restrict the use of land adjacent to the irradiator. After facility construction is complete, the accelerator is assembled from individual components (power supply, magnetron, scan magnet, scan horn).

In preparation of the EA for the Pa'ina irradiator, NRC Staff completed consultation requirements under Section 106 of the National Historic Preservation Act. The Hawaii State Historic Preservation Officer responded to NRC Staff that the proposed Pa'ina irradiator will have "no effect" on historic properties (Young, 2005). Because the e-beam irradiator would have essentially the same footprint as Pa'ina's proposed irradiator, would require similar types of construction activities, and would occupy the same location, the effects on historical and cultural resources are expected to be the same for both facilities during construction and operations. Therefore, the NRC Staff has determined that an e-beam irradiator would have no effect on historical and cultural resources during construction or operations.

Figure 7. View of the Shield During Construction of an E-Beam Irradiator Facility (Photo Courtesy of James Power, L-3 Communications)

During construction, noise at the site would increase because of increased vehicle traffic and construction activities. During operations, an e-beam irradiator would produce very little noticeable noise because the primary moving parts are the conveyor belt system, which is located within the building. There would be some additional noise from routine product truck shipments. Noise from an e-beam irradiator facility is expected to be negligible when compared to the other noise present at the proposed airport location. Therefore, the NRC Staff has determined that an e-beam irradiator would have small impacts on noise during construction and operations. The impacts would not be significantly different than those associated with construction and operation of a Co-60 irradiator.

During construction, diesel truck exhaust and dust generated by construction activities could have small, short-term effects on the local air quality. During operations the only regulated air effluent from an e-beam irradiator is ozone that is vented to the atmosphere during operation. Although ozone levels inside the shield are expected to be higher than the National Ambient Air Quality Standards level, the vented ozone is expected to be below the standard and have only a small effect on the environment. No airborne radioactive effluents are generated by an e-beam irradiator. Therefore, the NRC Staff has determined that an e-beam irradiator would have small impacts on air quality during operations. The impacts would not be significantly different than those associated with operation of a Co-60 irradiator.

An e-beam irradiator would be enclosed in an industrial-type, shielded building of similar size and color to other buildings in the vicinity of Honolulu International Airport. Therefore, the NRC has determined that an e-beam irradiator would have small impacts on visual quality during operations. The impacts would not be significantly different than those associated with operation of a Co-60 irradiator.

During construction, liquid effluents to state waters are not expected. Similarly, e-beam irradiators produce no liquid effluents to state waters during operations. Only small amounts of water (relative to general industrial users) would be needed to support the irradiator cooling system. No liquid radioactive effluents are generated by an e-beam irradiator. Therefore, the NRC Staff has determined that an e-beam irradiator would have small impacts on water quality or water use. The impacts would not be significantly different than those associated with operation of a Co-60 irradiator.

During operations, the e-beam irradiator will be required to maintain doses at the exterior of the building to below the requirements of State of Hawaii Department of Health, Hawaii Administrative Rules Chapter 40, Part 11–45–48(a)(2), which requires the maximum dose rate outside the facility to be below 0.02 mSv/hr (2 mrem/hr). Thus, it is unlikely that a member of the public could receive more than the public dose limit of 1 mSv/yr (100 mrem/yr) set by the State of Hawaii Department of Health, Hawaii Administrative Rules Chapter 40, Part 1–45–48(a)(1). Personnel within the facility would be located in the control room, lab, and warehouse areas, which are all outside of the shield as shown in Figure 4. Interlocks prevent personnel from entering or occupying the irradiation chamber during irradiator operation. Thus, it is unlikely that an employee could receive more than the occupational dose limit set by the State of Hawaii Department of Health, Hawaii Administrative Rules Chapter 40, Part 1–45–40(1)(A) of 50 mSv/yr (5,000 mrem/yr). Therefore, the NRC Staff has determined that an e-beam irradiator would have small impacts on public or occupational health. The impacts would not be significantly different than those associated with operation of a Co-60 irradiator. For comparison, as discussed in the EA for the Pa'ina Co-60 irradiator, the dose rate at the pool surface would be less than 0.01 mSv/h (1 mrem/h) and the dose to workers would be less than 10 percent of the regulatory limit of 1 mSv/yr (100 mrem/yr).

No transportation of radioactive material is required for operation of an e-beam irradiator. Therefore, there are no risks of accidents involving transportation of radioactive material associated with an e-beam irradiator. Depending on the demand for irradiation services, fruit-truck traffic may increase to and from the e-beam facility. The small number of workers needed to operate the facility would have only a small impact on local transportation. Therefore, the NRC Staff has determined that an e-beam irradiator would have small impacts on transportation. The impacts would not be significantly different than those associated with operation of a Co-60 irradiator.

No wastes are generated as part of e-beam irradiator operations. Nonradioactive, nonhazardous wastes, such as general trash or product waste from handling accidents, would be generated as part of normal operations. These wastes would be disposed of via established waste disposal pathways. Therefore, the NRC Staff has determined that an e-beam irradiator would have small impacts on waste management. The impacts would not be significantly different than those associated with operation of a Co-60 irradiator.

One difference between x-rays and sealed sources of gamma rays is that x-rays do not require a shielding storage pool. On the other hand, there is a substantial loss of energy (~92 percent) when electrons are converted to x-rays (Miller, 2005). Thus, operation of an e-beam irradiator can have a more significant impact with respect to energy consumption than pool-type irradiators that use sealed sources, assuming the same product volume throughput.

The socioeconomic impacts discussed in the Final EA (NRC, 2007a) apply regardless of whether a Co-60 or e-beam irradiator is used. For example, irradiator operation would provide Hawaiian sweet potato farmers with an effective and potentially cheaper alternative to fumigation with methyl bromide (U.S. Department of Agriculture (USDA), 2004). Likewise, banana farmers, and importers of fresh flowers and foliage could benefit economically from potentially cheaper treatment alternatives (USDA, 2006). In approving irradiation treatments for various types of produce, the Animal and Plant Health Inspection Service stated that such treatments would result in lower costs and increased flexibility for importers, gains U.S. consumers could realize through lower prices (USDA, 2006). However, low public acceptance of irradiated foods may limit the amount of product that is treated with radiation (Miller, 2005). For these reasons, the NRC Staff has determined that an e-beam irradiator, like a Co-60 irradiator, would have small impacts on socioeconomics.

An e-beam irradiator would also have small beneficial impacts to ecology by controlling invasive species. Invasive species are species that are non-native to the reference ecosystem and whose introduction causes economic, environmental, or human health harm (USDA, 2006). It is estimated that more than 2,500 insect species have been introduced to Hawaii and account for 98 percent of the pest species in the state (Pimentel, et al., 2005). In California, over 600 invasive pests account for 67 percent of all crop losses (Pimentel, et al., 2005). While an e-beam irradiator will not diminish the existing population of invasive species, like a Co-60 irradiator, it would be as one tool in preventing the further introduction and spread of invasive pests. Therefore, the NRC Staff has determined that an e-beam irradiator would have small impacts on ecology. The impacts would not be significantly different than those associated with operation of a Co-60 irradiator.

Finally, the NRC Staff considered impacts during decommissioning. An e-beam irradiator is expected to have no significant impacts during decommissioning for any resource areas due to its small size and the absence of any radioactive or hazardous materials. Parts of the irradiator may contain hazardous components (e.g., computer monitors, batteries); these would be disposed of through established disposal pathways. Demolition of the shield and building would not produce hazardous wastes. Therefore, the NRC Staff has determined that an e-beam irradiator would have small impacts during decommissioning. The impacts would not be significantly different than those associated with operation of a Co-60 irradiator.

3.4 Abnormal Events

The Final EA discussed the environmental impacts of abnormal events, including aviation accidents and natural phenomena (NRC, 2007a). In reviewing these impacts, the NRC Staff focused its review on the release of radioactive material that could have offsite consequences. The e-beam irradiator contains neither radioactive materials nor significant quantities of hazardous materials; consequently, no release of radioactive or hazardous materials from an e-beam irradiator would occur in the event of an aviation accident or natural phenomenon, and there would be no offsite consequences related to such materials. In addition, the e-beam could not be accidently activated in the event the building was damaged, because any type of power disruption would cause the e-beam to shut down. Therefore, the NRC Staff concludes that aviation accidents and natural phenomena would not have offsite environmental impacts.

The Final EA also discussed terrorism, defining threats, vulnerabilities, and consequences of the terrorist actions as they relate to Co-60 irradiators (NRC, 2007a, Appendix B). As stated in the Final EA (NRC, 2007a), the NRC currently assesses that there is a general, credible threat to NRC-licensed facilities and materials. Because an e-beam irradiator does not use NRC-licensed materials, this same type of threat would not apply to an e-beam irradiator. Additionally, the NRC Staff is not aware of any factors that would make e-beam irradiators a unique risk compared to industrial facilities generally. The NRC Staff therefore concludes that the likelihood of acts of terrorism directed toward an e-beam irradiator is small and would not result in off-site environmental impacts different from any other industrial facility.

3.5 Summary of Environmental Impacts of the E-Beam Irradiator Facility

The NRC Staff has prepared this section of the Draft Supplement to the EA to address the impacts of an alternative technology (e-beam irradiation) to the proposed action of licensing a Co-60 irradiator at Pa'ina's proposed site. As shown in Table 2, the NRC Staff has determined that the environmental impacts of an e-beam irradiator would be small for each resource area. Although an e-beam irradiator does not require the use of NRC-licensed material, the impacts of an e-beam irradiator would not be significantly different than those associated with a Co-60 irradiator. The NRC Staff has concluded that there would be small environmental impacts for this alternative action.

Table 2. Comparison of Environmental Impacts for a Cobalt-60 Irradiator and an Electron-Beam Irradiator		
Resource Area	**Cobalt-60 Irradiator**	**Electron-Beam Irradiator**
Land Use	Small	Small
Historical and Cultural Resources	Small	Small
Noise	Small	Small
Air Quality	Small	Small
Visual Resources	Small	Small
Water Quality	Small	Small
Public and Occupational Health	Small	Small
Transportation	Small	Small
Waste Management	Small	Small
Socioeconomics	Small	Small
Ecology	Small	Small
Abnormal Events	Small	Small

4.0 ALTERNATIVE SITES ANALYSIS

4.1 Introduction

This section describes the potential environmental impacts of the Co-60 irradiator, if constructed and operated as described in the proposed action, but if located at alternative sites. This analysis is presented to allow a comparison of the potential impacts of the irradiator at the proposed site with the potential impacts of the irradiator at alternative sites. This analysis considers environmental impacts from irradiator construction and normal operations, as well as impacts from aircraft crashes, natural phenomena, and terrorism.

4.2 Selection and Description of Alternative Sites

Five locations were identified as alternatives to the proposed site at 134 Palekona Street, Honolulu, Hawaii 96819. These alternative sites were selected with input from Pa'ina and based on each site's ability to meet the need of the proposed action. As stated in "The Need for the Proposed Action" in the Final EA (NRC, 2007a), the irradiator should be centrally located on Oahu for treatment of Hawaiian products for export as well as products for import to Hawaii. The locations of the five alternative sites are described below and listed in Table 3. All six sites are shown in Figure 8.

<u>(1) 3209 Ualena Street, Honolulu, HI 96819</u>

The Ualena Street site is located 2.5 km (1.5 mi) north-northeast of the proposed site in an existing industrial area on airport property. This site is close to the Port of Honolulu and has an existing warehouse that could be used for the irradiator.

(2) 92-1860 Kunia Road, Kunia, HI 96759

The Kunia Road site is located 21.3 km (13.2 mi) northwest of the proposed site in a developed agricultural area that had been used, until recently, as the Fresh Del Monte Produce Inc. pineapple plantation and fruit packing facility.

(3) 99-941/99-951 Halawa Valley Street, Aiea, HI 96701

The Halawa Valley Street site is located 6.9 km (4.3 mi) north-northwest of the proposed site in an existing industrial area that currently houses the Honolulu animal quarantine facilities. This site is close to the Port of Honolulu.

(4) 1849 Auiki Street, Honolulu, HI 96819

The Auiki Street site is located 3.6 km (2.2 mi) east-northeast of the proposed site in an existing industrial area that currently houses the Honolulu plant quarantine facilities. This site is close to the Port of Honolulu.

(5) 5 Sand Island Access Road, Honolulu, HI 96819

The Sand Island Access Road site is located 3.3 km (2.0 mi) east of the proposed site in an existing industrial area that currently includes the former Kapalama Military Reservation. This site is close to the Port of Honolulu and is undergoing redevelopment as part of harbor expansion projects.

Table 3. Alternative Site Distance and Direction from Proposed Pa'ina Site

Site No. and Location	Distance From Proposed Site km (mi)	Direction From Proposed Site
(1) 3209 Ualena Street, Honolulu, HI 96819	2.5 (1.5)	NNE
(2) 92-1860 Kunia Road, Kunia, HI 96759	21.3 (13.2)	NW
(3) 99-941/99-951 Halawa Valley Street, Aiea, HI 96701	6.9 (4.3)	NNW
(4) 1849 Auiki Street, Honolulu, HI 69819	3.6 (2.2)	ENE
(5) 5 Sand Island Access Road, Honolulu, HI 96819	3.3 (2.0)	E

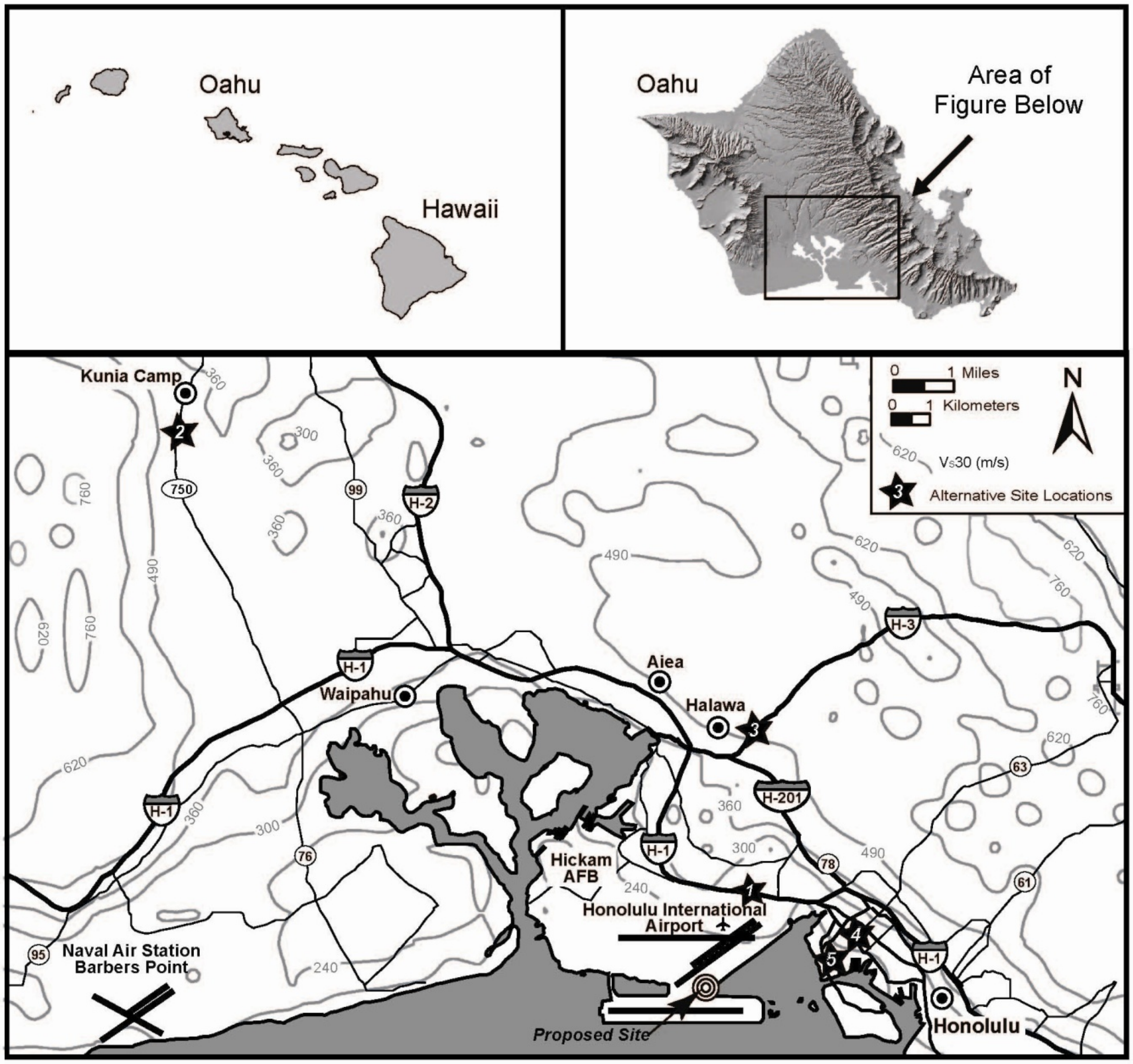

Figure 8. Maps and a Digital Elevation Model Showing the Location of the Proposed Site and Five Alternative Sites on Oahu

4.3 Environmental Impacts of Construction and Normal Operations

Environmental impacts of the proposed irradiator at the alternative sites during construction and normal operations are expected to be very similar to the anticipated impacts of the irradiator at the proposed site. Each of the proposed alternative sites is within a developed industrial or agricultural area. Prior to construction, Pa'ina would be required to obtain necessary local permits that would ensure that the proposed site is properly zoned for an irradiator. The proposed irradiator is expected to have no significant impacts during construction for any resource area due to its small size and the limited nature of construction activities. Relative impacts of construction activities at the Sand Island Access Road and Auiki Street sites would likely be minimal because areas near these sites are currently part of the Oahu Commercial Harbors 2020 Master Plan, which proposes several construction, demolition, and redevelopment projects (Hawaii Department of Transportation (HDOT), 1997). The proposed irradiator would occupy a small percentage of existing space at each of the alternative sites. As with the proposed site, there are no known land use restrictions that would be created by construction and operation of the proposed Pa'ina irradiator at the alternative sites; therefore no impacts to land use are expected. The proposed irradiator would produce very little noticeable noise as the primary moving parts are the overhead hoist and trolley system and the routine product deliveries via truck; therefore no significant noise impacts are expected. There are no air effluents from the proposed irradiator; therefore no significant impacts to air quality are expected. The proposed irradiator would be enclosed in an industrial-type building of similar size and color to other buildings at the alternative sites; therefore no significant visual impacts are expected. The NRC Staff finds that the proposed irradiator would have no significant impacts on land use, noise, air quality, or visual quality during operation. Also, due to the location of the alternative sites within developed areas and/or extensively urbanized areas, NRC Staff finds that the proposed irradiator would have no effect on historical and cultural resources or threatened and endangered species.

In the Final EA (NRC, 2007a), NRC Staff found that Pa'ina's irradiator would have no significant impacts on water quality or water use at the proposed site because no liquid effluents would be released to State waters, only small amounts of water (relative to general industrial users) would be needed to maintain the water level in the pool after it is filled, and there is a low likelihood of either radioactively contaminated or uncontaminated leaks. These conclusions are also valid for the alternative sites because the general design and operation of the irradiator would be the same regardless of where the irradiator is built. Therefore, NRC Staff finds that the proposed irradiator would have no significant impacts on water quality or water use at the alternative sites.

The NRC Staff also found that at the proposed site Pa'ina's irradiator would have no significant impact on public or occupational health because the expected doses would be well below regulatory standards (NRC, 2007a). Staff estimated that the maximum dose at the pool surface would be well below 1 millirem/hour. Also, due to the location of personnel and operational practices of the irradiator, Staff found it was unlikely that an employee could receive more than the occupational dose limit (5,000 millirem/year). NRC Staff found that the expected dose rate approximately 20-25 feet from the pool edge and the expected dose rates outside the building would be indistinguishable from background radiation. Therefore, NRC Staff concluded that it is unlikely a member of the public could receive more than the public limit (100 millirem/year). These findings are also valid for the alternative sites because the design and operation of the irradiator would be the same. Therefore, NRC Staff finds that the proposed irradiator would have no significant impacts on public or occupational health at the alternative sites.

The NRC Staff found that the proposed irradiator would have no significant impacts from transportation of the sources or additional products during normal operations (NRC, 2007a). Using RADTRAN 5.6, staff estimated that the maximum dose for a full initial shipment would be 3.7×10^{-2} millirem/year. For this calculation, the staff assumed each source contained the maximum allowable activity and that there would be 10 sources per cask, one cask per shipment, and six total shipments. These findings are also valid for the alternative sites because the dose to the maximum exposed individual is not dependent on the transportation routes. The dose to the maximum exposed individual is dependent on the source size and the speed of the shipping vehicle, which is not expected to vary significantly for the alternative sites. Following initial source loading, yearly Co-60 shipments would consist of a single shipment of new Co-60 sources to the irradiator and a return shipment of depleted sources to the manufacturer, both using the same shipping package. The maximum yearly dose for these continuing shipments is expected to be less than the 3.7×10^{-2} millirem/year dose calculated for the initial shipment since there would be fewer shipments per year and potentially fewer sources in each shipment. Therefore, NRC Staff finds that the proposed irradiator would have no significant impacts from transportation of the sources to and from the alternative sites during normal operations.

In Section 2 of this document, the Staff discusses impacts associated with accidents involving the transportation of sources to and from the proposed site and certain alternative sites. As discussed in Section 2, there is a low likelihood any transportation accident would be severe enough to cause a release of Co-60. In the unlikely case of such an event, the impact to the environment would be small because the source is not dispersible and emergency response personnel would likely secure the source, eliminating any lasting impacts. Therefore, NRC Staff finds that the proposed irradiator would have no significant impacts from normal transportation of the sources or additional products or from accidents involving transportation of the sources at the alternative sites.

In the Final EA (NRC, 2007a), NRC Staff found that the proposed irradiator would have no significant impacts on socioeconomics. The proposed irradiator was expected to potentially have small beneficial impacts to socioeconomics because it would provide Hawaiian sweet potato farmers with an effective and potentially cheaper alternative to fumigation with methyl bromide (USDA, 2004). Similarly, it was determined that banana farmers, and importers of fresh flowers and foliage could benefit economically from potentially cheaper treatment alternatives (USDA, 2006). The Final EA noted that the U.S. Department of Agriculture, Animal and Plant Health Inspection Service stated the result of irradiation treatments would be lower costs and increased flexibility for importers and that gains could be realized by U.S. consumers through lower prices (USDA, 2006). These findings are also valid for the alternative sites, which are all located on Oahu and so would achieve the same small socioeconomic benefits. Therefore, NRC Staff finds that the proposed irradiator would have no significant impacts on socioeconomics at the alternative sites.

In the Final EA (NRC, 2007a), NRC Staff also found that the proposed irradiator would have no significant impacts on ecology. The proposed irradiator was expected to have small beneficial impacts to ecology in regard to controlling invasive species whose introduction could cause economic, environmental, or human health harm. The proposed irradiator is seen as one tool in preventing the further introduction and spread of invasive pests. The Final EA noted that The Hawaii Department of Agriculture stated that an additional irradiator would be a benefit to the "preventative release" program whereby fruit fly pupae are sterilized to prevent the establishment of the fruit fly in California (Wong, 2006). These findings are also valid for the alternative sites, which are all located on Oahu, and so would control the same invasive species. Therefore, NRC Staff finds that the proposed irradiator would have no significant impacts on ecology at the alternative sites.

4.4 Environmental Impacts of Aircraft Crashes

In the Final EA (NRC, 2007a), the NRC Staff considered the potential environmental impacts of an aircraft crash into Pa'ina's proposed irradiator site and determined that an aircraft crash into the proposed site is not expected to cause any significant environmental impact. This is due in part to the low probability an aircraft will crash into the proposed site. However, even if an aircraft did crash into the proposed site, it is not plausible that the crash would cause any impact other than a temporary increase in the dose rate directly above the irradiator pool. An aircraft crash into the proposed site would not cause Co-60 to be dispersed or otherwise released into the environment.

In this Draft Supplement, the Staff considers the potential environmental impacts of an aircraft crash into an irradiator at each of the five alternative sites. Using the same methodology applied to the proposed site, the Staff estimates the probability an aircraft will crash into each alternative site. (This methodology employs conservative assumptions that result in aircraft crash frequency being overestimated to some extent for both the proposed site and the alternative sites.) The Staff also considers the impacts of such a crash.

As discussed below, the probability an aircraft will crash into any of the alternative sites is somewhat less than the probability an aircraft will crash into the proposed site, which is adjacent to Honolulu International Airport. The impacts of a crash into any of the alternative sites, however, are expected to be the same as those involving a crash into the proposed site. As explained in the Final EA, and as discussed below, an aircraft crash into Pa'ina's irradiator is not expected to cause any significant environmental impact, regardless of where the irradiator is located.

4.4.1 Estimation of Annual Frequency of Aircraft Crashes at Five Alternative Sites

Flight Paths to Honolulu International Airport

The airspace above Honolulu International Airport is designated as Class B airspace, which extends 37 km (20 nautical mi) outward. All aircraft within this airspace will be under air traffic control for safety advisories and separation. No aircraft is allowed to enter the Class B airspace unless cleared by the air traffic control. There are several airways leading to Honolulu International Airport: V4, V8–21, V20, V2, and V12–15. An aircraft either landing at or departing from Honolulu International Airport will follow one of these designated airways. All of the airways approach either from east or west of Oahu or from the ocean. None of these airways approach Honolulu International Airport from the north, thus not overflying the island and the mountains (National Aeronautical Charting Office, 2006). As can be seen in Figure 8, an aircraft landing or taking off from Honolulu International Airport will come close to three alternative sites: Ualena Street, Auiki Street, and Sand Island Access Road, and may overfly them. However, such aircraft will not be near the alternative sites at Kunia Road or Halawa Valley Street.

Arrivals and Departures from Honolulu International Airport

The layout of the runways at Honolulu International Airport is shown in Figure 9. An aircraft approaching Honolulu International Airport to land aligns with the assigned runway several miles away from the landing end of the runway (AirNav LLC, 2010). None of the landing approaches are near the alternative sites at Halawa Valley Street or Kunia Road. Additionally, an aircraft in a "missed approach" (i.e., fails to land and performs a "go-around") will climb and take either a left turn or a right turn, depending on the runway, so that the aircraft always proceeds toward the ocean for its next attempt for landing as instructed by air traffic control (AirNav LLC, 2010). Again, these procedures for go-around at Honolulu International Airport bring all aircraft in a missed approach away from the alternative sites at Halawa Valley Street or Kunia Road.

An aircraft departing from Runway 4L/4R or 8L/8R generally will complete a right turn toward the ocean within 3.7 km (2 nautical mi) from the departure end of the runway (AirNav LLC, 2010). Similarly, an aircraft departing from Runway 26L/26R or 22L/22R will turn left toward the ocean within 3.7 km (2 nautical mi) from the departure end of the runway (AirNav LLC, 2010). However, small aircraft taking off from Runway 4L or 4R and bound for the eastern part of Oahu or other islands east of Oahu may follow Highway H-1. Additionally, small aircraft heading west may follow a route north of Pearl Harbor.

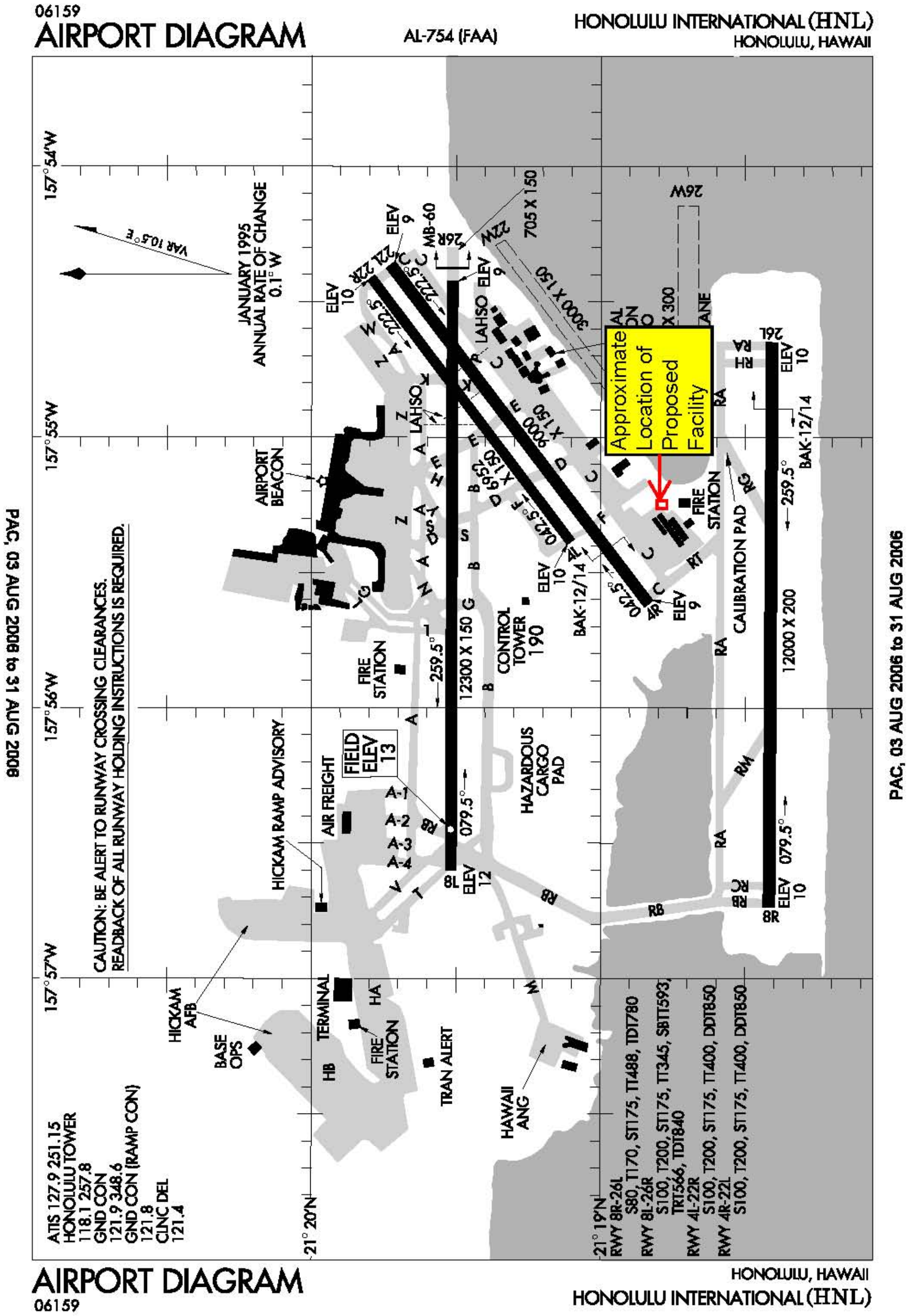

Figure 9. Layout of Honolulu International Airport Showing Runways (National Aeronautical Charting Office, 2007)

Similarly, small aircraft approaching from the east may follow Highway H-1 or follow the route north of Pearl Harbor if approaching from the west to land at Runway 22R or 22L. Therefore, an aircraft departing from or landing at Honolulu International Airport is not likely to be near the alternative sites at Halawa Valley Street or Kunia Road.

Annual Aircraft Crash Frequency at the Alternative Sites

The annual frequency of an aircraft crashing into an irradiator facility located at any of the alternative sites is estimated using the methodology given in Section 3.5.1.4 of NUREG–0800 (NRC, 1981). According to NUREG–0800 (NRC, 1981), the annual frequency of an aircraft crashing into a facility, P_A, located at some distance from an airport is the product of three terms: (i) the probability per square mile of an aircraft crash, (ii) the number of aircraft performing landings or takeoffs per year, and (iii) the effective area of the facility. This is expressed mathematically as

$$P_A = \sum_{i=1}^{L} \sum_{j=1}^{M} C_j \, N_{ij} \, A_j \qquad (3)$$

where,

M	=	number of different types of aircraft using the airport
L	=	number of flight trajectories affecting the facility
C_j	=	probability per square mile of a crash per aircraft movement for the j^{th} aircraft
N_{ij}	=	number of aircraft movements per year by the j^{th} aircraft along the i^{th} flight path
A_j	=	effective area of the facility for the j^{th} aircraft

In the following sections, these terms are discussed and the basis for the values used is provided.

Aircraft Operations at Honolulu International Airport and around the Kunia Site

The “Final Topical Report on the Effects of Potential Aviation Accidents and Natural Phenomena at the Proposed Pa’ina Hawaii, LLC, Irradiator Facility” (Center for Nuclear Waste Regulatory Analyses (CNWRA), 2007) used information on the number of aircraft operations at Honolulu International Airport from the Federal Aviation Administration (FAA, 2006). The 2006 FAA document is the most recent FAA information on the number of aircraft operations at Honolulu International Airport and, therefore, has been used here to assess aviation-related hazards. Recent information from the State of Hawaii (2010) shows the total number of aircraft operations at Honolulu International Airport is decreasing (from 317,317 in 2006 to 286,593 in 2008). Assuming that the trend continues, using information of 2006 aircraft operations will result in conservative estimates of aircraft crash frequency.

Additionally, the approach used in CNWRA (2007) is also used here to partition the annual number of operations to each runway at Honolulu International Airport. Table 4 shows the annual operations at each runway at Honolulu International Airport, adapted from CNWRA (2007). The data in Table 4 assumes that the number of landings at a runway is equal to the number of takeoffs from that runway, as in CNWRA (2007). It should be noted that there are two seaplane lanes at Honolulu International Airport–8W/26W and 4W/22W. Many sightseeing seaplane flights originate and terminate at Honolulu International Airport. These seaplane flights, although under visual flight rule, will be under air traffic control (HDOT, 2010). No separate information is available for the number of seaplane flights. The annual number of these operations is included in the general aviation operations at Honolulu International Airport (HDOT, 2010). Consequently, the annual number of general aviation operations at each runway, as given in Table 4, also includes a portion of total seaplane operations.

Table 4. Annual Operations for Each Type of Aircraft (Takeoff or Landing) at Honolulu International Airport

	Runway							
Aircraft Type	**8L**	**26R**	**8R**	**26L**	**4R**	**22L**	**4L**	**22R**
Air Carrier	59,496	19,832	22,476	7,492	37,020	12,340	13,222	4,406
Air Taxi	16,226	5,408	6,130	2,042	10,096	3,364	3,606	1,202
General Aviation, Turboprop	28,126	9,374	10,624	3,540	17,500	5,834	6,250	2,082
Military Aircraft	5,408	1,802	2,042	680	3,364	1,122	1,202	400

There are no formal military training routes on the island of Oahu. Alert Area A-311 near Wheeler Army Airfield is identified for helicopter training. Wheeler Army Airfield, near the site at Kunia Road, experiences an average of 6,500 movements (arrivals, departure, or overflights) per month. Ninety percent of these are helicopter flights (U.S. Army Environmental Command, 2008).

Dillingham Airfield near the site at Kunia Road is open to civilian visual flight rule only during the daytime. Extensive glider operations and parachute jumping operations take place at this airfield at both ends of the runway. Parachutists normally exit the aircraft upwind of the airport. During strong wind conditions, they may exit 3.7 km (2 nautical mi) from the drop zone; however, parachutes may open directly above the airport and adjacent beach area during light and no wind conditions. As the site at Kunia Road is more than 16 km (10 mi) away from Dillingham Airfield, operations at Dillingham Airfield do not significantly affect the aviation-related crash frequency at the site at Kunia Road.

Information from HDOT shows that helicopter routes are close to the Kunia Road site (HDOT, 2010). To arrive at a conservative estimate of hazard probability, it has been assumed that these helicopter flights are local flights over the site, that is, intentional flights over the site. Additionally, based on the U.S. Department of Energy (DOE) Standard (DOE, 1996), which was used in preparing the Final EA (NRC, 2007a and CNWRA, 2007), it has been assumed that all helicopter flights will be within 0.4 km (0.25 mi) on both sides of flight centerline, which is assumed to be located above the irradiator facility at the Kunia Road site. This is a very conservative assumption as it assumes every flight is within a narrow zone of 0.8 km (0.5 mi) wide.

Based on information from U.S. Army Environmental Command (2008), approximately 78,000 flights may go over the Kunia Road site in a year. Of those flights, 72,000 flights will be by helicopter. To be conservative, 6,500 annual flights were assumed to be from general aviation turboprop type aircraft.

Effective Area of the Irradiator Facility

The effective area of the proposed irradiator facility for each aircraft type is taken from CNWRA (2007) and is given in Table 5. As defined in CNWRA (2007), the effective area of a facility is the ground surface area surrounding the facility such that any unobstructed aircraft would affect the facility if it were to crash within that area. The impact could be either by direct fly-in or skid into the facility (DOE, 1996). As noted in CNWRA (2007), information used to estimate the effective area of the facility came from DOE (1996). As used in CNWRA (2007), all general aviation aircraft are assumed to be turboprop type, which gives the largest effective area and, therefore, adds conservatism to the hazard estimation. Similarly, all military aircraft are assumed to be high-performance fighter aircraft, which also adds conservatism to the estimated hazard, as these aircraft are more prone to crash than multiengine large aircraft. Unlike small fighter aircraft, multiengine large aircraft can still fly if an engine becomes inoperable during flight.

Because flights near the Kunia Road site are primarily made by helicopters, the effective area of the irradiator facility for helicopters is also estimated and is given in Table 5. Basic parameters necessary to estimate the effective area for helicopters are taken from the DOE Standard (DOE, 1996).

Table 5. Estimated Effective Area of the Facility for Each Type of Aircraft

Aircraft Type	Effective Facility Area	
	km^2	mi^2
Air Carrier	0.03905	0.01506
Air Taxi	0.03233	0.01247
General Aviation, Turboprop	0.00724	0.00279
Military Aircraft	0.01119*/0.01628†	0.00431*/0.00628†
Helicopter	0.00150	0.00058

*Takeoff
†Landing

It should be noted that it would not always possible for an aircraft to skid the entire distance to the irradiator, as given in the standard (DOE, 1996). Other nearby structures would impede the skid of the aircraft. For example, there are several structures in close proximity to the sites at Ualena Street, Auiki Street, Sand Island Access Road, and Halawa Valley Street. These structures would prevent an aircraft from skidding the entire distance and reaching the irradiator facility (Figure 10 through 14). Consequently, the effective area given in Table 5 is overestimated. Although the standard (DOE, 1996) allows credit for such cases, in order to be conservative no such credit was taken in this analysis. This is the same approach that was taken in CNWRA (2007).

<u>Crash Rates for Aircraft from NUREG–0800</u>

The probability of a fatal crash, C_j, per square mile per aircraft movement depends on the type of aircraft and the distance from the end of a runway. NUREG–0800 (NRC, 1981) provides the value of C_j for broad classes of aircraft. Values of C_j appropriate for the aircraft type relevant to this report are given in Table 6. It should be noted that in this analysis, it has been assumed that all military aircraft are high-performance small aircraft (e.g., fighter aircraft such as, F-15s, F-16s, etc.) belonging to U.S. Air Force.

4.4.1.1 Estimated Annual Crash Frequency at Alternative Sites

The following discussion provides an assessment of the probability of an aircraft crash into the proposed irradiator facility located at each alternative site while attempting to land at or take off from each runway at Honolulu International Airport. This discussion also assesses the probability of a helicopter crash into the proposed irradiator facility located at the Kunia Road site.

<u>Ualena Street Site</u>

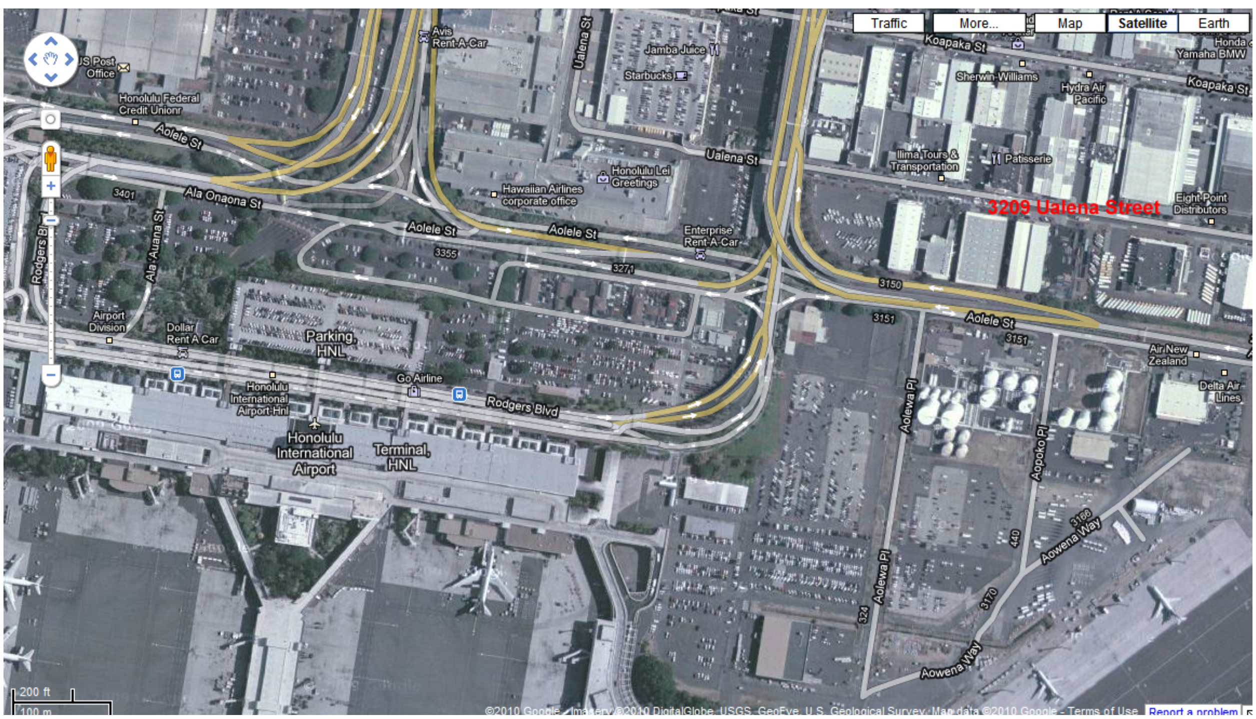

Figure 10. Aerial View of the Ualena Street Site

The distance of the Ualena Street site from the end of each runway at Honolulu International Airport is given in Table 7. Based on this distance and discussion of aircraft operations at each runway with respect to location of this site, as given below, the appropriate crash rate was selected from Table 6 and was used to estimate the annual aviation-related hazard at this alternative site. As can be seen in Figure 10, there are large structures near the Ualena Street site. Consequently, the full skid distance (e.g., 432 m (1,440 ft) for air carriers and air taxis), as considered in estimating the effective area of the facility, is a conservative estimate because no credit for nearby structures was taken in this analysis.

Table 6. Values of a Crash Rate C_j from NUREG-0800*

Distance from End of Runway km (mi)	Probability of a Fatal Crash Per Square Mile Per Aircraft Movement		
	Air Carrier	**General Aviation**	**U.S. Air Force**
0–1.6 (0–1)	16.7×10^{-8}	84×10^{-8}	5.7×10^{-8}
1.6–3.2 (1–2)	4.0×10^{-8}	15×10^{-8}	2.3×10^{-8}
3.2–4.8 (2–3)	9.6×10^{-9}	6.2×10^{-8}	1.1×10^{-8}
4.8–6.4 (3–4)	6.8×10^{-9}	3.8×10^{-8}	4.2×10^{-9}
6.4–8.0 (4–5)	2.7×10^{-9}	1.2×10^{-8}	4.0×10^{-9}
8.0–9.6 (5–6)	10	No data available	No data available
9.6–11.2 (6–7)	0	No data available	No data available
11.2–12.8 (7–8)	0	No data available	No data available
12.8–14.4 (8–9)	1.4×10^{-9}	No data available	No data available
14.4–16.0 (9–10)	1.2×10^{-9}	No data available	No data available

*U.S. Nuclear Regulatory Commission (NRC). NUREG–0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants. Standard Review Plan Section 3.5.1.6—Aircraft Hazards." Washington, DC: NRC. June 1981.

Table 7. Distance of Runway Ends at Honolulu International Airport to Alternative Site at Ualena Street, Honolulu, Hawaii

Runway	Landing End km (mi)	Departure End km (mi)
8L	3.3 (2.0)	1.1 (0.7)
26R	1.1 (0.7)	3.3 (2.0)
8R	4.7 (2.9)	3.1 (1.9)
26L	3.1 (1.9)	4.7 (2.9)
4R	2.7 (1.7)	1.0 (0.6)
22L	1.0 (0.6)	2.7 (1.7)
4L	2.1 (1.3)	0.8 (0.5)
22R	0.8 (0.5)	2.1 (1.3)

Runway 8L

The Ualena Street site is located north (away from the ocean) of the departure end of Runway 8L in a direction perpendicular to this runway centerline (Figure 10). As discussed in Section 4.4.1- Arrivals and Departures from Honolulu International Airport, an aircraft after takeoff from this runway will turn toward the ocean within 3.7 km (2 nautical mi) of the departure end. Therefore, it is not likely that an aircraft will reach this site while taking off from this runway; however, the annual frequency has been estimated to be conservative.

As discussed in CNWRA (2007), wide-body aircraft would land on this runway and exit at taxiway S or H, near the overseas terminal. However, nearly all narrow-body aircraft in inter-island operations would exit the runway at either taxiway L or G to expedite arriving at the inter-island terminal of the airport. This practice effectively shortens the 3,749 m (12,300 ft) runway to approximately 1,525 m (5,000 ft) from the Runway 8L threshold (Barnes, et al., 2001). An aircraft landing at this runway and skidding from the runway while decelerating toward this alternative site would have to pass through the airport terminal buildings and several other buildings to reach the irradiator facility (Figure 9). The probability of an aircraft crashing into this alternative site while attempting to land at this runway is, therefore, negligible. DOE Standard (1996) also supports the conclusion that the probability of crash while landing at this runway is negligible.

<u>Runway 26R</u>
The Ualena Street site is north of this runway centerline. During takeoff roll, the aircraft travels away from this site. Therefore, the probability of a crash into this alternative site during takeoff from this runway is negligible. DOE Standard (1996) also supports the conclusion that the probability of crash during takeoff from this runway is negligible. Accordingly, when assessing aviation hazards for purposes of this study, we have estimated only the contribution of aircraft landing at this runway.

<u>Runway 8R</u>
This runway is the preferred departure runway for wide-body aircraft. Aircraft make a right turn to a crosswind leg after takeoff to reach the assigned route, which would bring the aircraft in a direction opposite the facility. However, to be conservative, the annual aviation-related hazard during takeoff from this runway has been estimated. It is not feasible that aircraft landing at this runway could reach the facility because the aircraft would have to skid across a taxiway, other structures, and terminal buildings to reach the Ualena Street site. Crash location probabilities, as given in the DOE Standard (DOE, 1996), support this conclusion.

<u>Runway 26L</u>
An aircraft on its takeoff roll on this runway is unlikely to skid into the Ualena Street site because it would have to skid to the right across two runways and through terminal buildings to reach the site. The probability of an aircraft crash involving the proposed facility during takeoff is, therefore, negligible. DOE Standard (1996) also supports the conclusion that the probability of crash during takeoff from this runway is negligible.

The probability of an aircraft crashing into the Ualena Street site while landing at this runway is low because the distance between the runway threshold and the site is 3 km (1.9 mi) and the site is close to the terminal buildings. To be conservative, the annual frequency of crash at this site includes this contribution.

<u>Runway 4L</u>
The Ualena Street site is beyond the departure end of this runway. An aircraft landing at this runway and skidding toward the Ualena Street site will have to go through the terminal buildings to reach the site. Therefore, the probability of a crash into this site while landing at this runway is negligible. Crash location probabilities, as given in the DOE Standard (DOE, 1996), support this conclusion. The probability of a crash during takeoff from this runway has been included in estimating the annual frequency of aviation-related hazards.

<u>Runway 22R</u>
The Ualena Street site is behind the landing end of this runway. During takeoff from this runway, an aircraft will travel away from the site. Therefore, the probability of a crash into this site while landing at this runway is negligible. DOE Standard (1996) also supports the conclusion that the probability of crash while landing at this runway is negligible. The annual

frequency of aviation-related hazard at this site includes contribution from aircraft landing at this runway.

Runway 4R
The Ualena Street site is beyond the departure end of this runway. An aircraft landing at this runway and skidding toward the Ualena Street site will have to go through the terminal buildings to reach the site. Therefore, the probability of a crash into this site while landing at this runway is negligible. DOE Standard (1996) also supports the conclusion that the probability of crash while landing at this runway is negligible. The probability of a crash during takeoff from this runway has been included in estimating the annual frequency of aviation-related hazard.

Runway 22L
The Ualena Street site is behind the landing end of this runway. During takeoff from this runway, an aircraft will travel away from the Ualena Street site. Therefore, the probability of a crash into this site during takeoff from this runway is negligible. DOE Standard (1996) also supports the conclusion that the probability of crash during takeoff from this runway is negligible. Potential contribution of aircraft landing at this runway has been estimated.

Auiki Street and Sand Island Access Road Sites

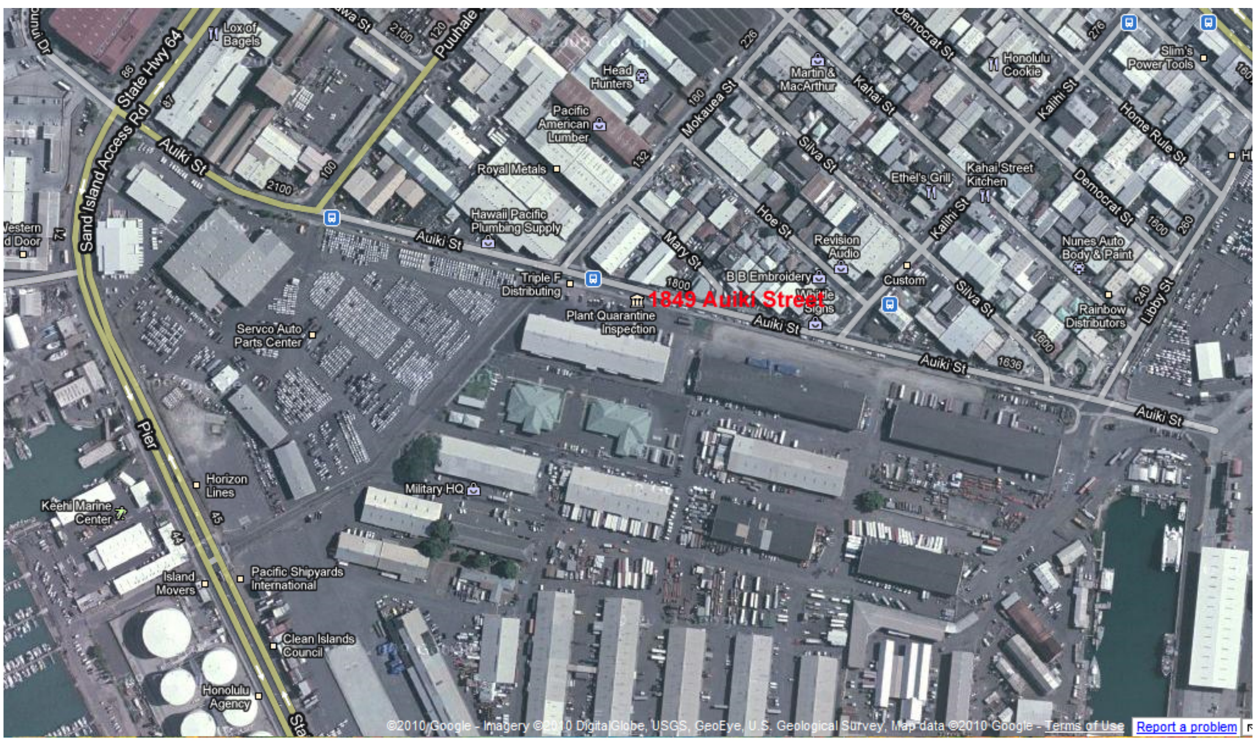

Figure 11. Aerial View of the Auiki Street Site

Figure 12. Aerial view of the Sand Island Access Road Site

The distance of the Auiki Street and Sand Island Access Road sites from each runway at Honolulu International Airport is given in Table 8. Based on this distance and a discussion of aircraft operations at each runway with respect to this site, as given below, the appropriate crash rate from Table 6 was used to estimate the annual aviation-related hazard at these alternative sites. As can be seen in Figures 11 and 12, there are large structures near the Auiki Street and Sand Island Access Road sites. Consequently, the full skid distance [e.g., 432 m (1,440 ft) for air carriers and air taxis], as considered in estimating the effective area of the facility, is an overestimation. To be conservative, and to be consistent with the approach taken in CNWRA (2007), no credit for nearby structures was taken in this analysis.

Table 8. Distance of Runway Ends at Honolulu International Airport to Alternative Sites at Auiki Street and Sand Island Access Road, Honolulu, Hawaii

	Auiki Street Site		Sand Island Access Site	
Runway	**Landing End km (mi)**	**Departure End km (mi)**	**Landing End km (mi)**	**Departure End km (mi)**
8L	5.7 (3.6)	2.1 (1.3)	5.7 (3.6)	2.1 (1.3)
26R	2.1 (1.3)	5.7 (3.6)	2.1 (1.3)	5.7 (3.6)
8R	6.3 (3.9)	3.0 (1.9)	6.0 (3.7)	2.5 (1.6)
26L	3.0 (1.9)	6.3 (3.9)	2.5 (1.6)	6.0 (3.7)
4R	4.3 (2.7)	2.1 (1.3)	4.0 (2.5)	2.3 (1.4)
22L	2.1 (1.3)	4.3 (2.7)	2.3 (1.4)	4.0 (2.5)
4L	3.8 (2.4)	2.3 (1.4)	3.5 (2.2)	2.4 (1.5)
22R	2.3 (1.4)	3.8 (2.4)	2.4 (1.5)	3.5 (2.2)

Runway 8L
The Auiki Street and Sand Island Access Road sites are located almost directly in line with the runway, at the opposite side of Keehi Lagoon. As discussed in Section 4.4.1 - Arrivals and Departures from Honolulu International Airport, an aircraft during takeoff from Runway 8L will turn toward the ocean and may overfly these sites. Consequently, the annual aviation-related hazard has been estimated. An aircraft landing at this runway and skidding toward these sites must cross Keehi Lagoon to reach the sites. Therefore, the probability of an aircraft crash into these alternative sites while attempting to land at the Runway 8L is negligible. DOE Standard (1996) also supports the conclusion that the probability of crash while landing at this runway is negligible.

Runway 26R
The Auiki Street and Sand Island Access Road sites are behind the runway threshold at the other side of Keehi Lagoon. During takeoff roll, the aircraft travels away from these sites. Therefore, the probability of a crash into these sites while taking off from this runway is negligible. DOE Standard (1996) also supports the conclusion that the probability of crash during takeoff from this runway is negligible. When landing at Runway 26R, an aircraft may overfly these sites. The probability of a crash landing on this runway has been included in estimating the annual frequency.

Runway 8R
The Auiki Street and Sand Island Access Road sites are somewhat north of this runway centerline at the other side of Keehi Lagoon. Although an aircraft taking off from this runway may not directly overfly these sites as it takes a right turn toward the ocean after taking off from Runway 8R, in order to be conservative the annual frequency of aviation-related hazard during takeoff has been computed. An aircraft landing on this runway will have to skid across Keehi Lagoon to reach these sites. Therefore, the probability of an aircraft crashing into these alternative sites while landing at Runway 8R is negligible. DOE Standard (1996) also supports the conclusion that the probability of crash while landing at this runway is negligible.

Runway 26L
An aircraft attempting to land at Runway 26L will already be aligned with the runway when the aircraft passes these sites for a successful landing; otherwise, the aircraft will be following a missed approach procedure of going back toward the ocean. Consequently, it is not likely that the aircraft will overfly the Auiki Street and Sand Island Access Road sites. To be conservative, however, the annual aviation-related hazard during landing at Runway 26L has been estimated. An aircraft during takeoff from this runway will be travelling away from these sites and the probability of a crash during takeoff from this runway will be negligible. DOE Standard (1996) also supports the conclusion that the probability of crash during takeoff from this runway is negligible.

Runway 4L
An aircraft during takeoff from this runway can overfly the Auiki Street and Sand Island Access Road sites. Therefore, the annual aviation-related hazard for these alternative sites has been estimated. An aircraft attempting to land at this runway will be aligned with the runway and will not overfly these sites. Therefore, the probability of crash into these alternative sites while landing at this runway is negligible. The DOE Standard also (1996) supports the conclusion that the probability of crash while landing at Runway 4L is negligible.

Runway 22R
An aircraft landing at this runway can overfly the Auiki Street and Sand Island Access Road sites. The annual aviation-related hazard during landing has been computed. An aircraft, during takeoff from this runway, will travel away from these sites. Therefore, the probability of crash into these alternative sites during takeoff from this runway is negligible. DOE Standard (1996) also supports the conclusion that the probability of crash during takeoff from this runway is negligible.

Runway 4R
An aircraft during takeoff from this runway can overfly the Auiki Street and Sand Island Access Road sites. Therefore, the annual aviation-related hazard during takeoff has been estimated. An aircraft attempting to land on this runway will be aligned with the runway and will not overfly these sites. Therefore, the probability of crashing into these sites while landing at this runway is negligible. The DOE Standard (1996) supports the conclusion that the probability of crash while landing at Runway 4R is negligible.

Runway 22L
An aircraft landing at this runway can overfly the Auiki Street and Sand Island Access Road sites. Therefore, the annual frequency of aviation-related hazards during landing has been estimated. On the other hand, an aircraft during takeoff from this runway will travel away from these sites. Therefore, the probability of crashing into these alternative sites during takeoff from this runway is negligible. DOE Standard (1996) also supports the conclusion that the probability of crash during takeoff from this runway is negligible.

Halawa Valley Street Site

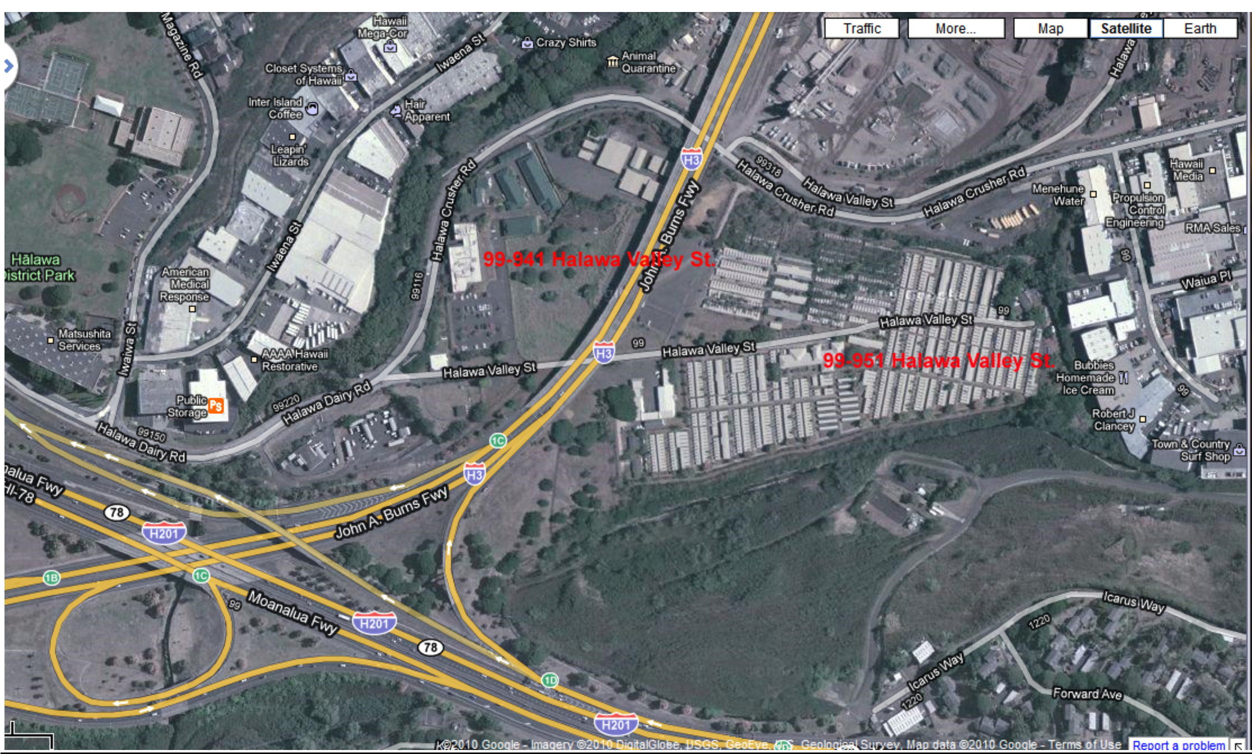

Figure 13. Aerial View of the Halawa Valley Street Site

The distance from the end of each runway at Honolulu International Airport is given in Table 9. Based on this distance and discussion of aircraft operations at each runway with respect to location of the site, as given below, the appropriate crash rate from Table 6 was selected to estimate the annual aviation-related hazard at this alternative site. Figure 13 shows large structures near the Halawa Valley Street site. Consequently, the full skid distance [e.g., 432 m (1,440 ft) for air carriers and air taxis], as considered in estimating the effective area of the facility, is conservative because no credit for nearby structures was taken in this analysis. This follows the approach taken in CNWRA (2007).

Table 9. Distance of Runway Ends at Honolulu International Airport to Alternative Site at Halawa Valley Street, Aiea, Hawaii

Runway	Landing End km (mi)	Departure End km (mi)
8L	6.5 (4.1)	5.3 (3.3)
26R	5.3 (3.3)	6.5 (4.1)
8R	8.3 (5.2)	7.3 (4.6)
26L	7.3 (4.6)	8.3 (5.2)
4R	6.8 (4.2)	5.0 (3.1)
22L	5.0 (3.1)	6.8 (4.2)
4L	6.2 (3.8)	4.8 (3.0)
22R	4.8 (3.0)	6.2 (3.8)

Runways 8L/26R

The Halawa Valley Street site is approximately 6.4 km (4 mi) in a direction perpendicular to the runway centerline toward the inland mountain region. As discussed previously, there are no designated airways near the site. An aircraft landing at these runways will be aligned with the runway some distance away from the runway threshold. In a missed approach, the aircraft will turn toward the ocean, away from this site. Additionally, an aircraft during takeoff from these runways will have the site behind it. The aircraft will turn toward the ocean to join the designated airway for the destination. Therefore, the probability of an aircraft crash into this alternative site during landing or takeoff from these runways is negligible. The crash location probability given in the DOE Standard (DOE, 1996) supports this conclusion.

Runways 8R/26L

The Halawa Valley Street site is approximately 8.0 km (5 mi) in a direction perpendicular to the runway centerline toward the inland mountain region. There are no designated airways near the site to bring aircraft routinely over the site. An aircraft landing at these runways will be aligned with the runway some distance away from the runway threshold. As dictated by the Honolulu International Airport procedure, an aircraft in a missed approach will turn toward the ocean, away from this site. Additionally, an aircraft taking off from these runways will have the site behind it. The aircraft will turn toward the ocean to join the designated airway for the destination. Therefore, the probability of an aircraft crashing into this alternative site during landing or takeoff from Runways 8R and 26L is negligible. The DOE Standard (1996) also supports the conclusion that the probability of a crash during landing or takeoff from these runways is negligible.

Runway 4L

An aircraft landing at Runway 4L will have to travel approximately 6.4 km (4 mi) to reach the Halawa Valley Street site. While skidding toward the site, it must pass through terminal buildings, highways, and several built-up areas. Therefore, the probability of an aircraft crashing into this alternative site while landing at this runway is negligible. The DOE Standard (1996) also supports the conclusion that the probability of crash while landing at this runway is negligible.

An aircraft during takeoff from the departure end of Runway 4L will be approximately 6.4 km (4 mi) from the Halawa Valley Street site. As per the departure procedure at Honolulu International Airport, the aircraft will turn toward the ocean, away from the site, or follow H-1 freeway or a route north of Pearl Harbor. None of these routes brings an aircraft over the site. To be conservative, however, the annual frequency of aviation-related hazard for the Halawa Valley Street site has been estimated for takeoffs from Runway 4L assuming that the crashing aircraft can somehow reach the site.

<u>Runway 22R</u>
An aircraft will be aligned with the runway at some distance from the runway threshold while landing at Runway 22R. Additionally, the aircraft will reach this runway by flying along freeway H-1 or the route north of Pearl Harbor. Both of these routes are south of the Halawa Valley Street site; however, to be conservative, the contribution of an aircraft landing at this runway has been estimated. In addition, the aircraft will travel away from the site toward the ocean while taking off from Runway 22R. Therefore, the probability of an aircraft crash into the Halawa Valley Street site during takeoff from this runway is negligible. The DOE Standard (1996) also supports the conclusion that the probability of crash while taking off from this runway is negligible.

<u>Runway 4R</u>
An aircraft landing at Runway 4R will be approximately 6.4 km (4 mi) from the Halawa Valley Street site. While skidding toward the site, it must pass through the terminal buildings, highways, and several built-up areas. Therefore, the probability of an aircraft crashing into this alternative site while landing at this runway is negligible. The DOE Standard (1996) also supports the conclusion that the probability of crash while landing at this runway is negligible.

An aircraft will be approximately 6.4 km (4 mi) from the Halawa Valley Street site during takeoff from the departure end of Runway 4R. The departure procedure at Honolulu International Airport will direct the aircraft toward the ocean, away from the site. To be conservative, however, the annual aviation-related hazard for the Halawa Valley Street site has been estimated during takeoff from Runway 4L assuming that the aircraft can somehow reach the site.

<u>Runway 22L</u>
An aircraft landing at Runway 22L will be aligned with the runway at some distance from the runway threshold. Moreover, the aircraft will not generally fly north of freeway H-1 or along routes near Pearl Harbor to reach this runway. Nonetheless, the contribution of aircraft landing at this runway has been estimated. Additionally, the aircraft will travel away from the Halawa Valley Street site toward the ocean during takeoff from Runway 22L. Therefore, the probability of an aircraft crashing into this alternative site during takeoff from this runway is negligible. The DOE Standard (1996) also supports the conclusion that the probability of crash during takeoff from this runway is negligible.

Kunia Road Site

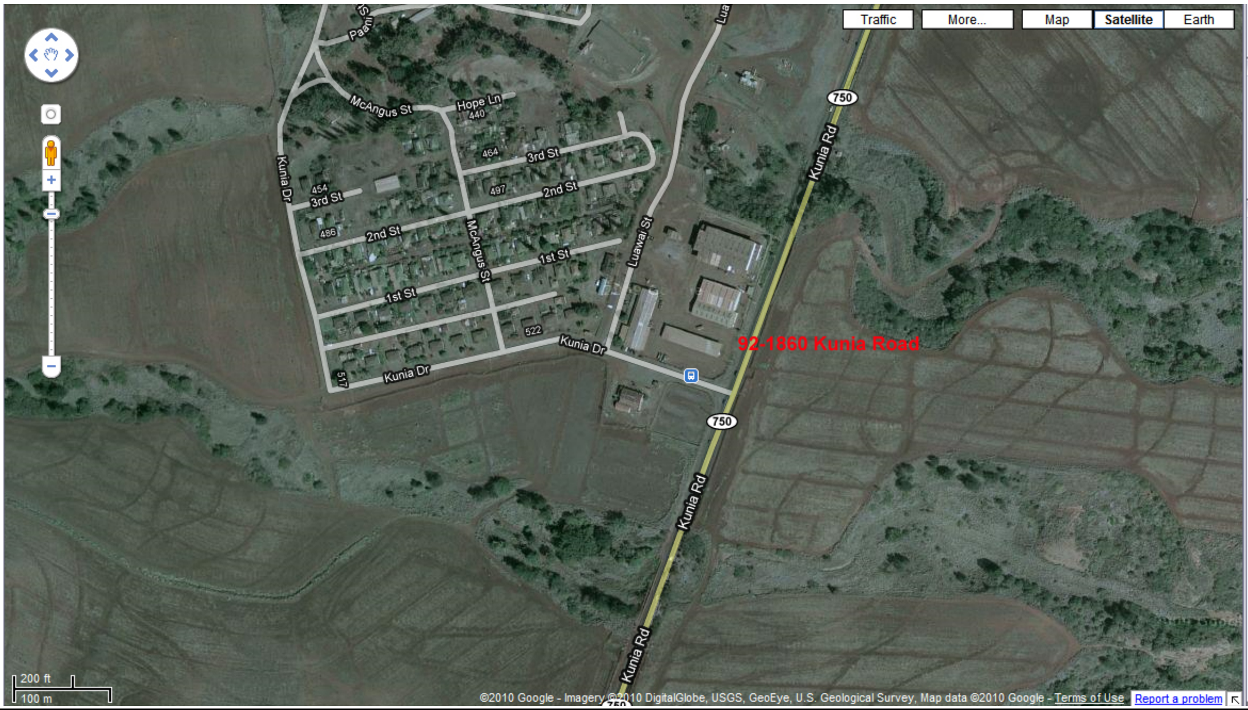

Figure 14. Aerial View of the Kunia Road Site

Because the runways at Honolulu International Airport and Dillingham Airfield are more than 16 km (10 mi) from the Kunia Road site, flights taking off or landing at these airfields will add a negligible contribution to the total annual crash frequency at this site.

The DOE Standard gives the crash rate for helicopters as 2.5×10^{-6} per flight. Based on the information from the Hawaii Department of Transportation (2010), the average flight length has been estimated to be approximately 32 km (20 mi) from Dillingham Airfield at North to Harbor View at South. Using Equation 5-3 of DOE (1996), the annual frequency of aviation-related hazards for the Kunia Road site is estimated to be 1.07×10^{-5}. As discussed in Section 4.4.1, Aircraft Operations at Honolulu International Airport and around the Kunia Site, 6,500 annual overflights by general aviation turboprop aircraft were assumed in addition to 70,200 helicopter overflights.

4.4.2 Environmental Impacts due to Aviation-Related Crashes

The estimated annual frequency of aviation-related hazards for the proposed site and each alternative site is presented in Table 10.

Table 10. Estimated Annual Crash Frequency at Alternative Sites						
Site	**Ualena Street**	**Auiki Street**	**Sand Island Street**	**Halawa Valley Street**	**Kunia Street**	**Proposed Site**
Cumulative annual crash frequency	3.2×10^{-4}	8.3×10^{-5}	8.3×10^{-5}	6.3×10^{-6}	1.1×10^{-5}	2.1×10^{-4}

As reflected in Table 10, the aircraft crash frequency is highest for the proposed site (2.1×10^{-4}) and lowest for the alternative site on Halawa Valley Street (6.3×10^{-6}). The Ualena Street site has an annual crash frequency (3.2×10^{-4}) closest to that of the proposed site. It should be noted that, although the proposed site has an annual crash frequency higher than that for any of the five alternative sites, the annual probability of a crash into the proposed site is nonetheless low, at 2.1×10^{-4}, or approximately 1 in 5000.

Further, the probability that an aircraft will crash into the irradiator does not reflect the potential for release or dispersal of radioactive Co-60 sources. This holds true regardless of whether the irradiator is located at the proposed site or at an alternative site. The Co-60 sources used in a pool irradiator are located near the bottom of the pool, under approximately 3.6–5.4 m (12–16 ft) of water. These sources are doubly encapsulated and have been tested to withstand large forces. Although an aircraft crash would generate a very large force, a significant portion of this force would be absorbed by the irradiator building and other ground-level structures. Additionally, many aircraft flying into or departing from Honolulu International Airport have engines that are larger than the irradiator pool, meaning that an engine could not enter the pool and damage a source. Even if an aircraft component were to enter the irradiator pool, it is not plausible that the component would exert enough force to both breach the pool liner and damage the Co-60 sources. Further, even if the pool liner were breached and shielding water drained from the irradiator, the resulting dose would be in the form of a well-collimated beam directly above the pool. This beam would not significantly affect persons or the environment.

It is also expected that an aviation accident would be accompanied by a jet fuel fire. Because jet fuel is lighter than water, it would burn on the top of the irradiator pool, causing minimum water evaporation. Although the maximum flame temperature of burning jet fuel is 2,200 F (Turns, 2000), the melting point of cobalt is 2,723 F (Bolz *et al*, 1973). Further, the source assemblies have been tested to withstand temperatures up to 1,475 F for 1 hour (MDS Nordian, 2002).

Based on these considerations, the NRC Staff finds that aircraft crashes at the alternative sites would have no significant impacts on public health and safety.

4.5 Environmental Impacts due to Natural Phenomena

4.5.1 Earthquakes

The "Final Topical Report on the Effects of Potential Aviation Accidents and Natural Phenomena at the Proposed Pa'ina Hawaii, LLC, Irradiator Facility" (CNWRA, 2007) concluded that any environmental impacts from earthquakes affecting the proposed site would be negligible. This analysis was based on the geological history of Hawaii, historical data on the number and severity of earthquakes in Hawaii, and United States Geologic Survey (USGS) probabilistic seismic hazard maps.

Impacts of earthquakes are felt over large regions, tens to hundreds of square kilometers in area. Because the alternative sites are all located relatively close to the originally proposed site and to each other, the earthquake analysis provided in CNWRA (2007) is valid for all five sites. In summary, the analysis in CNWRA (2007) showed that Oahu has not experienced anything more than Modified Mercalli Intensity Force VI damage from historical earthquakes. In addition, based on the USGS probabilistic seismic hazard map for Hawaii, which is based on a 2-percent probability of exceedence in 50 years, the estimated peak horizontal ground acceleration is less than 0.30 g. The only differences among the five alternative sites and the proposed site are soil conditions, which could locally amplify or deamplify seismic ground motions.

NRC Staff consulted USGS V_s30 data to assess potential site response at the five alternative site locations. V_s30 refers to the average shear-wave velocity in the first 30 m of subsoil, which serves as a measure of soil rigidity. It is a widely used parameter for classifying sites as a way to predict their potential to amplify seismic ground motions. The U.S. National Earthquake Hazard Reduction Program (NEHRP) soil classes are a useful way of grouping sites according to potential for site amplification. Soil classes A through E are categorized according to specific V_s30 profiles. Table 11 describes the NEHRP site classes, associated soil profiles, and V_s30 characteristics.

Under the NEHRP hierarchy, locations designated as Site Class A are least susceptible to seismic amplification, while Site Class E locations are most susceptible. Class E also represents site locations that could be most susceptible to liquefaction and, therefore, have the greatest likelihood of experiencing severe earthquake-related structural damage.

Table 11. National Earthquake Hazard Reduction Program Site Class Definitions

		Average Properties in Top 30 m (100 ft) (as per 2000 International Building Code Section 1615.1.5) Soil Shear Wave Velocity, V_s*	
Site Class	**Soil Profile Name**	**m/s**	**ft/s**
A	Hard Rock	$V_s > 1524$	$V_s > 5000$
B	Rock	$762 < V_s \leq 1524$	$2500 < V_s \leq 5000$
C	Very dense soil and soft rock	$366 < V_s \leq 762$	$1200 < V_s \leq 2500$
D	Stiff soil profile	$183 < V_s \leq 366$	$600 < V_s \leq 1200$
E	Soft soil profile	$V_s < 183$	$V_s < 600$

*University of Utah Seismograph Stations. "NEHRP Site Class." 2010. <http://www.seis.utah.edu/urban/nehrp.shtml> (12 October 2010).

The NEHRP Site Classifications for the alternative sites and proposed site were determined utilizing USGS V_s30 data, as illustrated in Figure 8 (the base map in Figure 8 includes contours of V_S30 values derived from the U.S. Geological Survey Global V_s30 map server). The soil classification for the proposed site and the five alternative sites is given in Table 12.

The USGS earthquake hazard maps, including those for Hawaii, were developed assuming relatively firm bedrock conditions (Site Class B) with average V_s30 values of 760 m/s (2500 ft/s). Thus, because of the soft rock and stiff soils at all the sites, the predicted probabilistic ground motions from the USGS hazard maps would likely be amplified. Amplification of the peak ground accelerations from the USGS probabilistic seismic hazard map for Hawaii (which, as stated above, is based on a 2-percent probability of exceedence in 50 years) would result in peak horizontal ground accelerations of less than 0.60 g. Based on the suite of empirical relationships that correlate peak ground acceleration with the Modified Mercalli Intensities at the epicenter summarized in Linkimer (2008), peak ground accelerations up to 0.6 g would yield Modified Mercalli Intensity Force VI damage, which is consistent with past observations of earthquake damage from historical earthquakes on Oahu.

According to the USGS, Modified Mercalli Intensity Force VI damage is “Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage is slight.” Thus, earthquake ground motions at the alternative sites would be insufficient to cause substantial damage to the proposed facility and would not produce forces at the proposed facility necessary to dislodge Co-60 sources from the pools.

Table 12. Alternative Site and Proposed Site National Earthquake Hazard Reduction Program (NEHRP) Classification

Site	NEHRP Class*
(1) Ualena Street	D
(2) Kunia Road	C
(3) Halawa Valley Street	C
(4) Auiki Street	D
(5) Sand Island Access Road	D
Proposed Site - 100-134 Palekona St, Honolulu 96819	D

*USGS. “Global V_s30 Map Server—Earthquake Hazard Program.” 2010. <http://earthquake. usgs.gov/hazards/ apps/vs30/> (11 October 2010).

Moreover, because none of the alternative sites is located in a NEHRP Class E zone, it is unlikely that liquefaction and corresponding structural damage to the irradiator at these sites would occur. As in the original analysis, this conclusion assumes that Pa’ina’s irradiator will be designed and constructed in accordance with applicable industry codes. Compliance with these requirements will mitigate the consequences of a seismic event, including liquefaction. Therefore, based on the assessment contained in the Topical Report (CNWRA, 2007) as well as the analysis provided in this document, environmental impacts from a seismically-induced radiological accident would be small at the alternative sites. As discussed in CNWRA (2007), even in the unlikely event that the facility is damaged by earthquakes, the sources will remain in place, as the proposed facility is not mechanically connected to the source assemblies. Additionally, as just discussed, the irradiator pool will be installed in a manner that will mitigate the consequences of a seismic event, including liquefaction.

The forces generated during an earthquake are not strong enough to remove a source assembly from the bottom of the pool, and the source assemblies would be shielded throughout the event. Thus, the probability of an earthquake dislodging the source assemblies from the pool and causing them to be exposed unshielded at the surface is negligible.

4.5.2 Tsunami

The Topical Report (CNWRA, 2007) determined that the projected wave velocities associated with the largest historical tsunamis at the proposed site would not be sufficient to remove a source assembly from the bottom of the pool. The source assembly would remain stationary even if the facility had sustained enough damage to destroy the rack system holding the source and the source plenum. Additionally, the proposed site is outside of the official tsunami evacuation zone based on Oahu Civil Defense maps, which were updated in 2010 (City and County of Honolulu, 2010a). The evacuation zone includes both the inundation zone as well as a buffer area to ensure public safety. The inundation zone is defined as the maximum area tsunami waves would be expected to reach in a worst-case tsunami event (City and County of Honolulu, 2010b).

Alternative sites 1, 2, and 3—the sites on Ualena Street, Kunia Road, and Halawa Valley Street—are located at elevations higher than the proposed site and thus they would be at a reduced risk from a tsunami. Furthermore, all three of these sites, as well as the proposed site and site 4 on Auiki Street, are located outside the tsunami evacuation zone (Table 13). Therefore, environmental impacts to the facility at any of these alternative sites due to a tsunami would be small, because these four alternative sites are situated at elevations above maximum wave heights produced from a tsunami. Only Site 5, which is located on the Sand Island Access Road, is situated within the tsunami evacuation zone (City and County of Honolulu, 2010a). As with the proposed site, however, the probability of a large tsunami removing a Co-60 source from Site 5 is negligible.

Table 13. Elevations of the Alternative and Proposed Sites and Location within Tsunami Evacuation Zone*

Site	Elevation m (ft)	Located within Tsunami Evacuation Zone
1. Ualena Street	4.3 (14)	No
2. Kunia Road	255 (838)	No
3. Halawa Valley Street	21-35 (70-116)	No
4. Auiki Street	1.8 (6)	No
5. Sand Island Access Road	1.8 (6)	Yes
Proposed Site. 100-134 Palekona St , Honolulu 96819	1.8 (6)	No

*EarthTools. "Find Elevation/Height Above Sea Level." 2010. <http://www.earthtools.org/> (11 October 2010).

4.5.3 Hurricanes

The Final EA (NRC, 2007a) concluded that wave velocity associated with a hurricane's storm surge is significantly less than that associated with a tsunami. The tsunami analysis discussed in the Topical Report (CNWRA, 2007) appropriately bounds safety concerns at the proposed site related to storm surges associated with tropical cyclones. Since the 1950s, there have been a number of hurricanes that have passed near Oahu, but none has produced a storm surge that would pose a hazard to the proposed facility.

Furthermore, the analysis in section 3.2.2 of the Topical Report (CNWRA, 2007) concluded that even an extremely rare large tsunami, much larger than any of the largest historical tsunamis to strike Oahu would not be sufficient to remove a source assembly from the bottom of the pool, even if the facility has sustained enough damage that the source holding equipment and source plenum were destroyed. Consequently, the probability of a storm surge associated with a hurricane resulting in the release of a Co-60 source at the five alternative sites is also considered negligible.

4.5.4 Summary of Environmental Impacts at Alternative Sites due to Natural Phenomena

The NRC Staff finds that the probability of an earthquake, tsunami, or hurricane dislodging the source assemblies from the pool and causing them to be exposed unshielded at the surface is negligible at any of the five alternative sites. Even in the unlikely event the assemblies were exposed, the resulting increased dose would be in the form of a well-collimated beam directly above the irradiator pool. Accordingly, the NRC Staff concludes that the environmental impacts associated with earthquakes, tsunamis, or hurricanes at the five alternative sites are small.

4.6 Environmental Impacts at Alternative Sites due to Terrorism

The Final EA discusses potential impacts of terrorist attacks on the proposed irradiator facility (NRC, 2007a, Appendix B). The analysis in the Final EA was based in part on the Radiation Source Protection and Security Task Force Report to the President and Congress, dated August 15, 2006 (NRC, 2006). In this Report the NRC provided recommendations to the President and Congress relating to the security of radiation sources in the United States from potential terrorist threats. These potential threats included acts of sabotage, theft, or use of a radiation source in a radiological dispersal device (RDD) or radiological exposure device (RED).

The Final EA (NRC, 2007a, Appendix B) defines threats, vulnerabilities, and consequences of terrorist actions as they relate to irradiator facilities. The NRC currently assesses that there is a general, credible threat to NRC-licensed facilities and materials. This threat, and the effects from any terrorist action directed at an irradiator, does not change appreciably by selection of an alternative site. As with the proposed site, the consequences of radiological sabotage involving an alternative site are expected to be small. The consequences are expected to be similar to those at the proposed site because the irradiator's features—including the passive nature and location of the sources, the irradiator design, and the irradiator construction—are not changed by site selection. For theft and diversion terrorist threat scenarios involving alternative sites, the consequences are also similar in that a source could be taken anywhere and used malevolently in an RDD or RED.

Since the publication of the Final EA (NRC, 2007a), a second Task Force Report to the President and Congress (NRC, 2010), dated August 11, 2010, reported on the NRC's reevaluation of the list of risk-significant radioactive sources and the associated threshold quantities warranting enhanced security and protection. The Task Force assessed the adequacy of the NRC's prior evaluations in light of the evolving threat environment. The Task Force also achieved Federal concurrence on the definitions of a significant RDD and a significant RED and used those definitions in its reevaluation. The reevaluation considers consequences of concern beyond prompt fatalities and deterministic effects (based on the IAEA Code of Conduct), including economic, social, and psychological consequences, with consideration of radioactive materials worldwide (IAEA, 2004).

As stated in the Task Force Report, the principal consequence of an RDD is economic loss, the amount of which is primarily driven by time-consuming and costly decontamination and environmental cleanup efforts, which are highly dependent on the cleanup level selected. The report concludes that that no changes should be made to the existing list of 16 radionuclides and associated established threshold quantities, which includes Co-60 used in irradiators like that proposed by Pa'ina. In addition, the report does not make any recommendations that additional security or protective measures are needed above the existing regulatory requirements and the voluntary enhanced security and protection measures that are already in place or being implemented.

Accordingly, the NRC Staff concludes that any act of terrorism involving an underwater irradiator at one of the five alternative sites would have environmental impacts similar to those described in the Final EA (NRC, 2007a). The same protective strategies that will have to be employed at Pa'ina's proposed site would, if used at an alternative site, reduce the risk from a terrorist attack to an acceptable level, thereby reducing the potential for the facility to be considered an attractive target.

4.7 Summary - Alternative Sites Analysis

The NRC Staff has prepared this section of the Draft Supplement to the EA to address the environmental impacts of the Co-60 irradiator, if constructed and operated as described in the proposed action, but if located at alternative sites. The NRC Staff has determined that the environmental impacts of a Co-60 irradiator would be small for each resource area during normal construction and operation. The NRC Staff has also found that impacts from aircraft crashes, natural phenomena (earthquakes, tsunamis, and hurricanes), and acts of terrorism would be small and would not be significantly different than those associated with the proposed site. For these reasons, the NRC Staff concludes that the environmental impacts at alternative sites generally would be similar to those at the proposed site and the five other sites the Staff considered. The Staff therefore finds no reason to expand its alternative sites analysis beyond five sites.

5.0 AGENCIES AND PERSONS CONSULTED

No additional discussions or consultations with outside agencies or persons have been conducted in the development of this Draft Supplement to the EA. Comments submitted in response to the issuance of this Draft Supplement will be considered by the NRC Staff in preparation of the Final Supplement to the EA.

6.0 CONCLUSION

As discussed in Section 1.2 – Purpose of this Supplement, NRC Staff has prepared this Draft Supplement to the EA to address the three areas in which the Board found that the NRC Staff was to perform additional analyses. The NRC Staff has prepared this Draft Supplement to the EA in order to address (1) the environmental impacts of accidents that might occur during the transport of Co-60 sources to and from Pa'ina's irradiator, (2) electron-beam technology as an alternative to Co-60 irradiation, and (3) alternative sites for Pa'ina's irradiator. On the basis of the Final EA (NRC, 2007a) and this Draft Supplement to the EA, NRC has concluded that there are no significant environmental impacts associated with the proposed action.

7.0 SOURCES USED

This Draft Supplement to the EA was prepared by Johari Moore, Project Manager, in the Office of Federal and State Materials and Environmental Management Programs; with technical input from Earl Easton, Senior Technical Advisor for Transportation, in the Office of Nuclear Material Safety and Safeguards; and Fritz Sturz, Senior Safeguards Technical Analyst, in the Office of Nuclear Security and Incident Response. Additionally, the Center for Nuclear Waste Regulatory Analyses provided technical support for the electron-beam, aircraft crash hazard, and natural phenomena analyses under NRC Contract No.: NRC–41–09–011.

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