Entergy

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May 14, 2012

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, D.C. 20555

SUBJECT: Entergy Nuclear Operations, Inc.
Pilgrim Nuclear Power Station
Docket No.: 50-293
License No.: DPR-35

Annual Radiological Environmental Operating Report for January 1 through December 31, 2011

LETTER NUMBER: 2.12.038

Dear Sir or Madam:

In accordance with Pilgrim Technical Specification 5.6.2, Entergy Nuclear Operations, Inc submits the attached Annual Radiological Environmental Operating Report for January 1 through December 31, 2011.

This letter contains no commitments.

Should you have questions or require additional information, I can be contacted at (508) 830-8403.

Sincerely,

Joseph R. Lynch
Licensing Manager

FXM

Attachment: Pilgrim Annual Radiological Environmental Operating Report for January 1 through December 31, 2011

cc: U.S. Nuclear Regulatory Commission
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Attachment 1
Letter Number 2.12.038

Pilgrim Annual Radiological Environmental Operating Report
for January 1 through December 31, 2011

PILGRIM NUCLEAR POWER STATION

Facility Operating License DPR-35

Annual Radiological Environmental Operating Report

January 1 through December 31, 2011

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PILGRIM NUCLEAR POWER STATION
Facility Operating License DPR-35

ANNUAL RADIOLOGICAL ENVIRONMENTAL OPERATING REPORT

JANUARY 01 THROUGH DECEMBER 31, 2011

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INTRODUCTION

This report summarizes the results of the Entergy Nuclear Radiological Environmental Monitoring Program (REMP) conducted in the vicinity of Pilgrim Nuclear Power Station (PNPS) during the period from January 1 to December 31, 2011. This document has been prepared in accordance with the requirements of PNPS Technical Specifications section 5.6.2.

The REMP has been established to monitor the radiation and radioactivity released to the environment as a result of Pilgrim Station's operation. This program, initiated in August 1968, includes the collection, analysis, and evaluation of radiological data in order to assess the impact of Pilgrim Station on the environment and on the general public.

SAMPLING AND ANALYSIS

The environmental sampling media collected in the vicinity of PNPS and at distant locations include air particulate filters, charcoal cartridges, animal forage, vegetation, cranberries, seawater, sediment, Irish moss, shellfish, American lobster, and fishes.

During 2011, there were 1,271 samples collected from the atmospheric, aquatic, and terrestrial environments. In addition, 434 exposure measurements were obtained using environmental thermoluminescent dosimeters (TLDs).

A small number of inadvertent issues were encountered during 2011 in the collection of environmental samples in accordance with the PNPS Offsite Dose Calculation Manual (ODCM). Six out of 440 TLDs were unaccounted for during the quarterly retrieval process. However, the 434 TLDs that were collected provided the information necessary to assess ambient radiation levels in the vicinity of Pilgrim Station. Equipment failures and power outages resulted in a small number of instances in which lower than normal volumes were collected at the airborne sampling stations. In some cases, outages were of sufficient duration to yield no sample, and 581 of 581 air particulate and charcoal cartridges were collected and analyzed as required. A full description of any discrepancies encountered with the environmental monitoring program is presented in Appendix D of this report.

There were 1,327 analyses performed on the environmental media samples. Analyses were performed by the J.A. Fitzpatrick Environmental Laboratory in Fulton, New York. Samples were analyzed as required by the PNPS ODCM.

LAND USE CENSUS

The annual land use census in the vicinity of Pilgrim Station was conducted as required by the PNPS ODCM between August 25 and August 28, 2011. A total of 28 vegetable gardens having an area of more than 500 square feet were identified within five kilometers (three miles) of PNPS. No new milk or meat animals were located during the census. Of the 28 garden locations identified, samples were collected at or near three of the gardens as part of the environmental monitoring program. Other samples of natural vegetation were also collected in predicted high-deposition areas.

RADIOLOGICAL IMPACT TO THE ENVIRONMENT

During 2011, samples (except charcoal cartridges) collected as part of the REMP at Pilgrim Station continued to contain detectable amounts of naturally-occurring and man-made radioactive materials. No samples indicated any detectable radioactivity attributable to Pilgrim Station operations. Low-levels of radioactive Iodine-131 was detected in air samples and Irish moss collected in the March-April timeframe, but were attributed to the Japanese earthquake on 11-Mar-2011, that resulted in the release of radioactivity from the Fukushima power reactor site. Levels of I-131 detected around Pilgrim Station were observed in both indicator and control samples, and were similar to the concentrations of I-131 observed at other nuclear power plants throughout the USA during the same timeframe. Offsite ambient radiation measurements using environmental TLDs beyond the site boundary ranged between 43 and 77 milliRoentgens per year. The range of ambient radiation levels observed with the TLDs is consistent with natural background radiation levels for Massachusetts.

RADIOLOGICAL IMPACT TO THE GENERAL PUBLIC

During 2011, radiation doses to the general public as a result of Pilgrim Station's operation continued to be well below the federal limits and much less than the collective dose due to other sources of man-made (e.g., X-rays, medical, fallout) and naturally-occurring (e.g., cosmic, radon) radiation.

The calculated total body dose to the maximally exposed member of the general public from radioactive effluents and ambient radiation resulting from PNPS operations for 2011 was about 1.5 mrem for the year. This conservative estimate is well below the EPA's annual dose limit to any member of the general public and is a fraction of a percent of the typical dose received from natural and man-made radiation.

CONCLUSIONS

The 2011 Radiological Environmental Monitoring Program for Pilgrim Station resulted in the collection and analysis of hundreds of environmental samples and measurements. The data obtained were used to determine the impact of Pilgrim Station's operation on the environment and on the general public.

An evaluation of direct radiation measurements, environmental sample analyses, and dose calculations showed that all applicable federal criteria were met. Furthermore, radiation levels and resulting doses were a small fraction of those that are normally present due to natural and man-made background radiation.

Based on this information, there is no significant radiological impact on the environment or on the general public due to Pilgrim Station's operation.

1.0 INTRODUCTION

The Radiological Environmental Monitoring Program for 2011 performed by Entergy Nuclear Company for Pilgrim Nuclear Power Station (PNPS) is discussed in this report. Since the operation of a nuclear power plant results in the release of small amounts of radioactivity and low levels of radiation, the Nuclear Regulatory Commission (NRC) requires a program to be established to monitor radiation and radioactivity in the environment (Reference 1). This report, which is required to be published annually by Pilgrim Station's Technical Specifications section 5.6.2, summarizes the results of measurements of radiation and radioactivity in the environment in the vicinity of the Pilgrim Station and at distant locations during the period January 1 to December 31, 2011.

The Radiological Environmental Monitoring Program consists of taking radiation measurements and collecting samples from the environment, analyzing them for radioactivity content, and interpreting the results. With emphasis on the critical radiation exposure pathways to humans, samples from the aquatic, atmospheric, and terrestrial environments are collected. These samples include, but are not limited to: air, animal forage, vegetation, cranberries, seawater, sediment, Irish moss, shellfish, American lobster, and fish. Thermoluminescent dosimeters (TLDs) are placed in the environment to measure gamma radiation levels. The TLDs are processed and the environmental samples are analyzed to measure the very low levels of radiation and radioactivity present in the environment as a result of PNPS operation and other natural and man-made sources. These results are reviewed by PNPS's Chemistry staff and have been reported semiannually or annually to the Nuclear Regulatory Commission and others since 1972.

In order to more fully understand how a nuclear power plant impacts humans and the environment, background information on radiation and radioactivity, natural and man-made sources of radiation, reactor operations, radioactive effluent controls, and radiological impact on humans is provided. It is believed that this information will assist the reader in understanding the radiological impact on the environment and humans from the operation of Pilgrim Station.

1.1 Radiation and Radioactivity

All matter is made of atoms. An atom is the smallest part into which matter can be broken down and still maintain all its chemical properties. Nuclear radiation is energy, in the form of waves or particles that is given off by unstable, radioactive atoms.

Radioactive material exists naturally and has always been a part of our environment. The earth's crust, for example, contains radioactive uranium, radium, thorium, and potassium. Some radioactivity is a result of nuclear weapons testing. Examples of radioactive fallout that is normally present in environmental samples are cesium-137 and strontium-90. Some examples of radioactive materials released from a nuclear power plant are cesium-137, iodine-131, strontium-90, and cobalt-60.

Radiation is measured in units of millirem, much like temperature is measured in degrees. A millirem is a measure of the biological effect of the energy deposited in tissue. The natural and man-made radiation dose received in one year by the average American is about 620 mrem (References 2, 3, 4).

Radioactivity is measured in curies. A curie is that amount of radioactive material needed to produce 37,000,000,000 nuclear disintegrations per second. This is an extremely large amount of radioactivity in comparison to environmental radioactivity. That is why radioactivity in the environment is measured in picocuries. One picocurie is equal to one trillionth of a curie.

1.2 Sources of Radiation

As mentioned previously, naturally occurring radioactivity has always been a part of our environment. Table 1.2-1 shows the sources and doses of radiation from natural and man-made sources.

Table 1.2-1

Radiation Sources and Corresponding Doses [1]

NATURAL		MAN-MADE	
Source	Radiation Dose (millirem/year)	Source	Radiation Dose (millirem/year)
Internal, inhalation[2]	228	Medical[3]	300
External, space	33	Consumer[4]	13
Internal, ingestion	29	Industrial[5]	0.3
External, terrestrial	21	Occupational	0.5
		Weapons Fallout	< 1
		Nuclear Power Plants	< 1
Approximate Total	311	Approximate Total	314

(1) Information from NCRP Reports 160 and 94

(2) Primarily from airborne radon and its radioactive progeny

(3) Includes CT (147 millirem), nuclear medicine (77 mrem), interventional fluoroscopy (43 mrem) and conventional radiography and fluoroscopy (33 mrem)

(4) Primarily from cigarette smoking (4.6 mrem), commercial air travel (3.4 mrem), building materials (3.5 mrem), and mining and agriculture (0.8 mrem)

(5) Industrial, security, medical, educational, and research

Cosmic radiation from the sun and outer space penetrates the earth's atmosphere and continuously bombards us with rays and charged particles. Some of this cosmic radiation interacts with gases and particles in the atmosphere, making them radioactive in turn. These radioactive byproducts from cosmic ray bombardment are referred to as cosmogenic radionuclides. Isotopes such as beryllium-7 and carbon-14 are formed in this way. Exposure to cosmic and cosmogenic sources of radioactivity results in about 33 mrem of radiation dose per year.

Additionally, natural radioactivity is in our body and in the food we eat (about 29 millirem/yr), the ground we walk on (about 21 millirem/yr) and the air we breathe (about 228 millirem/yr). The majority of a person's annual dose results from exposure to radon and thoron in the air we breathe. These gases and their radioactive decay products arise from the decay of naturally occurring uranium, thorium and radium in the soil and building products such as brick, stone, and concrete. Radon and thoron levels vary greatly with location, primarily due to changes in the concentration of uranium and thorium in the soil. Residents at some locations in Colorado, New York, Pennsylvania, and New Jersey have a higher annual dose as a result of higher levels of radon/thoron gases in these areas. In total, these various sources of naturally-occurring radiation and radioactivity contribute to a total dose of about 311 mrem per year.

In addition to natural radiation, we are normally exposed to radiation from a number of man-made sources. The single largest doses from man-made sources result from therapeutic and diagnostic applications of x-rays and radiopharmaceuticals. The annual dose to an individual in the U.S. from medical and dental exposure is about 300 mrem. Consumer activities, such as smoking, commercial air travel, and building materials contribute about 13 mrem/yr. Much smaller doses result from weapons fallout (less than 1 mrem/yr) and nuclear power plants. Typically, the average person in the United States receives about 314 mrem per year from man-made sources. The collective dose from naturally-occurring and man-made sources results in a total dose of approximately 620 mrem/yr to the average American.

1.3 Nuclear Reactor Operations

Pilgrim Station generates about 700 megawatts of electricity at full power, which is enough electricity to supply the entire city of Boston, Massachusetts. Pilgrim Station is a boiling water reactor whose nuclear steam supply system was provided by General Electric Co. The nuclear station is located on a 1600-acre site about eight kilometers (five miles) east-southeast of the downtown area of Plymouth, Massachusetts. Commercial operation began in December 1972.

Pilgrim Station was operational during most of 2011, with the exception of the refueling outage in April-May, and a forced outage to repair a defective check valve in November. The resulting monthly capacity factors are presented in Table 1.3-1.

TABLE 1.3-1

PNPS OPERATING CAPACITY FACTOR DURING 2011
(Based on rated reactor thermal power of 2028 Megawatts-Thermal)

Month	Percent Capacity
January	99.4%
February	85.9%
March	95.4%
April	48.3%
May	39.9%
June	99.5%
July	98.9%
August	99.8%
September	98.8%
October	99.6%
November	72.4%
December	87.0%
Annual Average	85.5%

Nuclear-generated electricity is produced at Pilgrim Station by many of the same techniques used for conventional oil and coal-generated electricity. Both systems use heat to boil water to produce steam. The steam turns a turbine, which turns a generator, producing electricity. In both cases, the steam passes through a condenser where it changes back into water and recirculates back through the system. The cooling water source for Pilgrim Station is the Cape Cod Bay.

The key difference between Pilgrim's nuclear power and conventional power is the source of heat used to boil the water. Conventional plants burn fossil fuels in a boiler, while nuclear plants make use of uranium in a nuclear reactor.

Inside the reactor, a nuclear reaction called fission takes place. Particles, called neutrons, strike the nucleus of a uranium-235 atom, causing it to split into fragments called radioactive fission products. The splitting of the atoms releases both heat and more neutrons. The newly-released neutrons then collide with and split other uranium atoms, thus making more heat and releasing even more neutrons, and on and on until the uranium fuel is depleted or spent. This process is called a chain reaction.

The operation of a nuclear reactor results in the release of small amounts of radioactivity and low levels of radiation. The radioactivity originates from two major sources, radioactive fission products and radioactive activation products.

Radioactive fission products, as illustrated in Figure 1.3-1 (Reference 5), originate from the fissioning of the nuclear fuel. These fission products get into the reactor coolant from their release by minute amounts of uranium on the outside surfaces of the fuel cladding, by diffusion through the fuel pellets and cladding and, on occasion, through defects or failures in the fuel cladding. These fission products circulate along with the reactor coolant water and will deposit on the internal surfaces of pipes and equipment. The radioactive fission products on the pipes and equipment emit radiation. Examples of some fission products are krypton-85 (Kr-85), strontium-90 (Sr-90), iodine-131 (I-131), xenon-133 (Xe-133), and cesium-137 (Cs-137).

Nuclear Fission

Fission is the splitting of the uranium-235 atom by a neutron to release heat and more neutrons, creating a chain reaction. Radiation and fission products are by-products of the process.

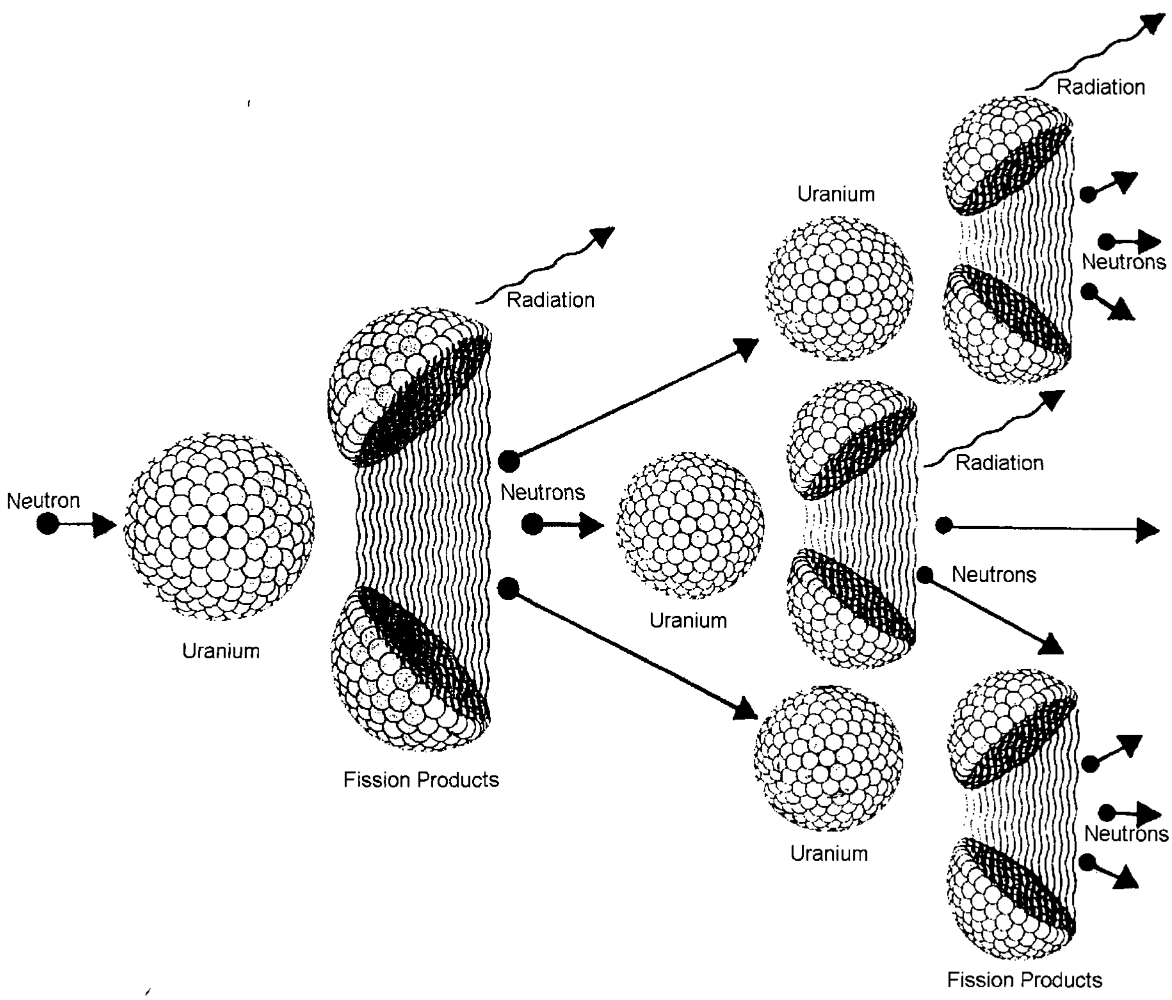


Figure 1.3-1
Radioactive Fission Product Formation

Radioactive activation products (see Figure 1.3-2), on the other hand, originate from two sources. The first is by neutron bombardment of the hydrogen, oxygen and other gas (helium, argon, nitrogen) molecules in the reactor cooling water. The second is a result of the fact that the internals of any piping system or component are subject to minute yet constant corrosion from the reactor cooling water. These minute metallic particles (for example: nickel, iron, cobalt, or magnesium) are transported through the reactor core into the fuel region, where neutrons may react with the nuclei of these particles, producing radioactive products. So, activation products are nothing more than ordinary naturally-occurring atoms that are made unstable or radioactive by neutron bombardment. These activation products circulate along with the reactor coolant water and will deposit on the internal surfaces of pipes and equipment. The radioactive activation products on the pipes and equipment emit radiation. Examples of some activation products are manganese-54 (Mn-54), iron-59 (Fe-59), cobalt-60 (Co-60), and zinc-65 (Zn-65).

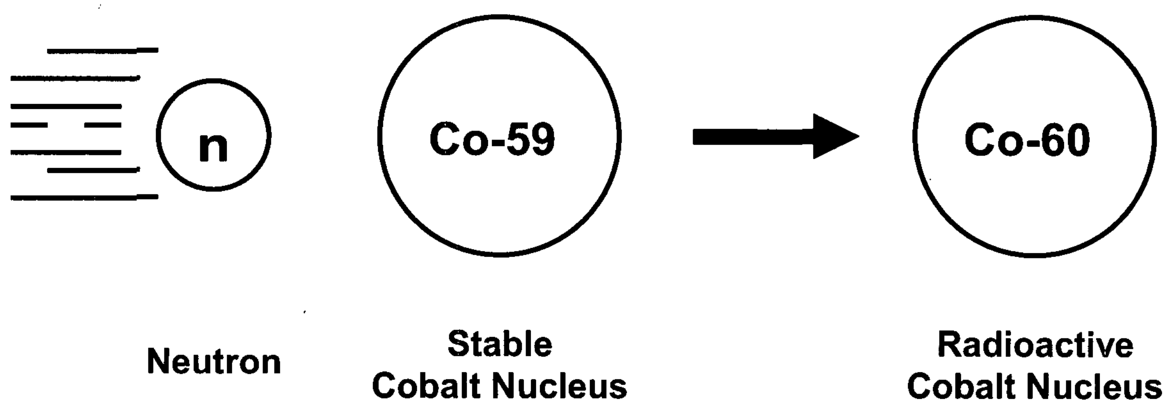


Figure 1.3-2
Radioactive Activation Product Formation

At Pilgrim Nuclear Power Station there are five independent protective barriers that confine these radioactive materials. These five barriers, which are shown in Figure 1.3-3 (Reference 5), are:

- fuel pellets;
- fuel cladding;
- reactor vessel and piping;
- primary containment (drywell and torus); and,
- secondary containment (reactor building).

SIMPLIFIED DIAGRAM OF A BOILING WATER REACTOR

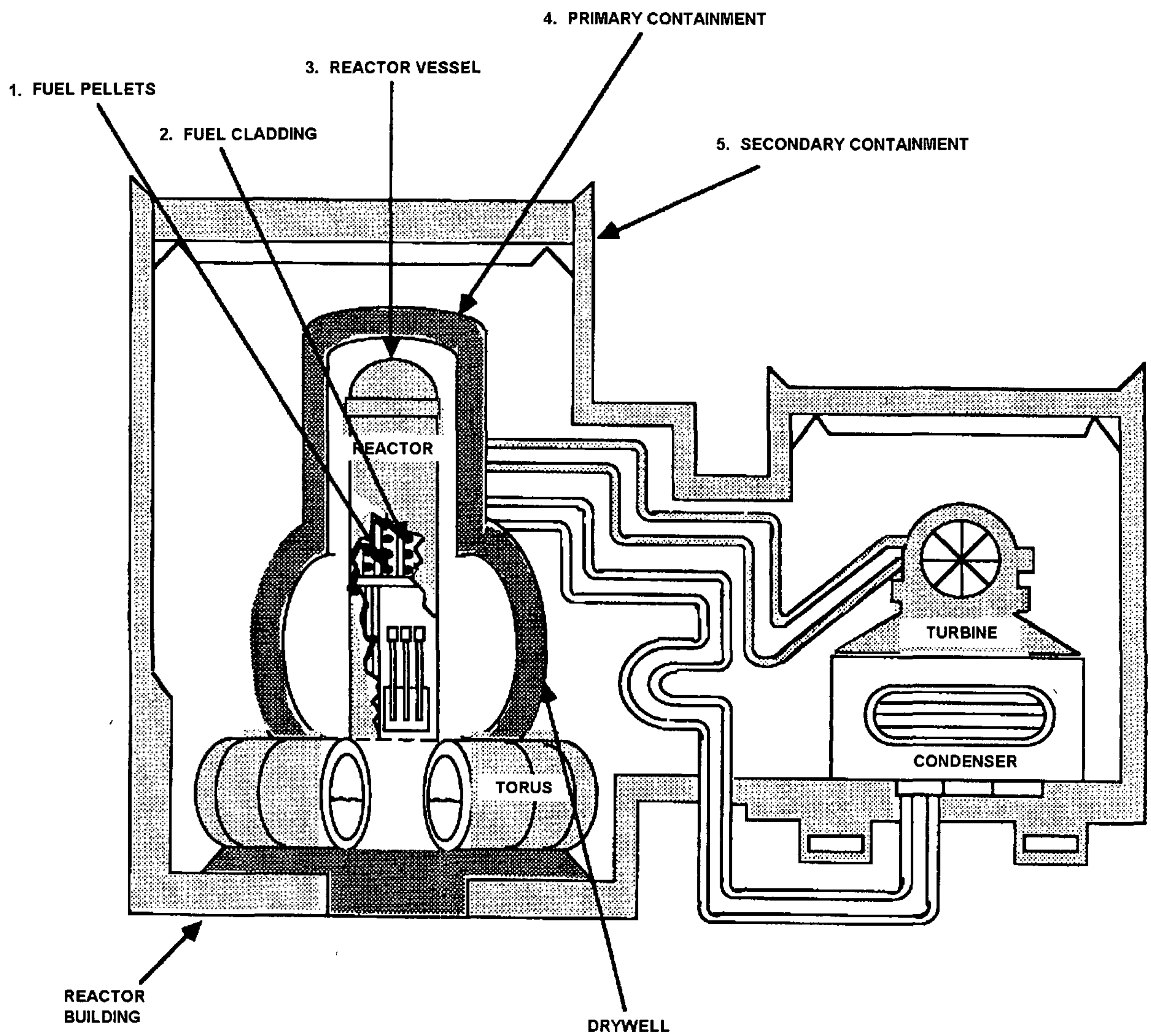


Figure 1.3-3
Barriers To Confine Radioactive Materials

The ceramic uranium fuel pellets provide the first barrier. Most of the radioactive fission products are either physically trapped or chemically bound between the uranium atoms, where they will remain. However, a few fission products that are volatile or gaseous may diffuse through the fuel pellets into small gaps between the pellets and the fuel cladding.

The second barrier, the fuel cladding, consists of zirconium alloy tubes that confine the fuel pellets. The small gaps between the fuel and the cladding contain the noble gases and volatile iodines that are types of radioactive fission products. This radioactivity can diffuse to a small extent through the fuel cladding into the reactor coolant water.

The third barrier consists of the reactor pressure vessel, steel piping and equipment that confine the reactor cooling water. The reactor pressure vessel, which holds the reactor fuel, is a 65-foot high by 19-foot diameter tank with steel walls about nine inches thick. This provides containment for radioactivity in the primary coolant and the reactor core. However, during the course of operations and maintenance, small amounts of radioactive fission and activation products can escape through valve leaks or upon breaching of the primary coolant system for maintenance.

The fourth barrier is the primary containment. This consists of the drywell and the torus. The drywell is a steel lined enclosure that is shaped like an inverted light bulb. An approximately five foot thick concrete wall encloses the drywell's steel pressure vessel. The torus is a donut-shaped pressure suppression chamber. The steel walls of the torus are nine feet in diameter with the donut itself having an outside diameter of about 130 feet. Small amounts of radioactivity may be released from primary containment during maintenance.

The fifth barrier is the secondary containment or reactor building. The reactor building is the concrete building that surrounds the primary containment. This barrier is an additional safety feature to contain radioactivity that may escape from the primary containment. This reactor building is equipped with a filtered ventilation system that is used when needed to reduce the radioactivity that escapes from the primary containment.

The five barriers confine most of the radioactive fission and activation products. However, small amounts of radioactivity do escape via mechanical failures and maintenance on valves, piping, and equipment associated with the reactor cooling water system. The small amounts of radioactive liquids and gases that do escape the various containment systems are further controlled by the liquid purification and ventilation filtration systems. Also, prior to a release to the environment, control systems exist to collect and purify the radioactive effluents in order to reduce releases to the environment to as low as is reasonably achievable. The control of radioactive effluents at Pilgrim Station will be discussed in more detail in the next section.

1.4 Radioactive Effluent Control

The small amounts of radioactive liquids and gases that might escape the five barriers are purified in the liquid and gaseous waste treatment systems, then monitored for radioactivity, and released only if the radioactivity levels are below the federal release limits.

Radioactivity released from the liquid effluent system to the environment is limited, controlled, and monitored by a variety of systems and procedures which include:

- reactor water cleanup system;
- liquid radwaste treatment system;
- sampling and analysis of the liquid radwaste tanks; and,
- liquid waste effluent discharge header radioactivity monitor.

The purpose of the reactor water cleanup system is to continuously purify the reactor cooling water by removing radioactive atoms and non-radioactive impurities that may become activated by neutron bombardment. A portion of the reactor coolant water is diverted from the primary coolant system and is directed through ion exchange resins where radioactive elements, dissolved and suspended in the water, are removed through chemical processes. The net effect is a substantial reduction of the radioactive material that is present in the primary coolant water and consequently the amount of radioactive material that might escape from the system.

Reactor cooling water that might escape the primary cooling system and other radioactive water sources are collected in floor and equipment drains. These drains direct this radioactive liquid waste to large holdup tanks. The liquid waste collected in the tanks is purified again using the liquid radwaste treatment system, which consists of a filter and ion exchange resins.

Processing of liquid radioactive waste results in large reductions of radioactive liquids discharged into Cape Cod Bay. Of all wastes processed through liquid radwaste treatment, 90 to 95 percent of all wastes are purified and the processed liquid is re-used in plant systems.

Prior to release, the radioactivity in the liquid radwaste tank is sampled and analyzed to determine if the level of radioactivity is below the release limits and to quantify the total amount of radioactive liquid effluent that would be released. If the levels are below the federal release limits, the tank is drained to the liquid effluent discharge header.

This liquid waste effluent discharge header is provided with a shielded radioactivity monitor. This detector is connected to a radiation level meter and a strip chart recorder in the Control Room. The radiation alarm is set so that the detector will alarm before radioactivity levels exceed the release limits. The liquid effluent discharge header has an isolation valve. If an alarm is received, the liquid effluent discharge valve will automatically close, thereby terminating the release to the Cape Cod Bay and preventing any liquid radioactivity from being released that may exceed the release limits. An audible alarm notifies the Control Room operator that this has occurred.

Some liquid waste sources which have a low potential for containing radioactivity, and/or may contain very low levels of contamination, may be discharged directly to the discharge canal without passing through the liquid radwaste discharge header. One such source of liquids is the neutralizing sump. However, prior to discharging such liquid wastes, the tank is thoroughly mixed and a representative sample is collected for analysis of radioactivity content prior to being discharged.

Another means for adjusting liquid effluent concentrations to below federal limits is by mixing plant cooling water from the condenser with the liquid effluents in the discharge canal. This larger volume of cooling water further dilutes the radioactivity levels far below the release limits.

The preceding discussion illustrates that many controls exist to reduce the radioactive liquid effluents released to the Cape Cod Bay to as far below the release limits as is reasonably achievable.

Radioactive releases from the radioactive gaseous effluent system to the environment are limited, controlled, and monitored by a variety of systems and procedures which include:

- reactor building ventilation system;
- reactor building vent effluent radioactivity monitor;
- sampling and analysis of reactor building vent effluents;
- standby gas treatment system;
- main stack effluent radioactivity monitor and sampling;
- sampling and analysis of main stack effluents;
- augmented off-gas system;
- steam jet air ejector (SJAE) monitor; and,
- off-gas radiation monitor.

The purpose of the reactor building ventilation system is to collect and exhaust reactor building air. Air collected from contaminated areas is filtered prior to combining it with air collected from other parts of the building. This combined airflow is then directed to the reactor building ventilation plenum that is located on the side of the reactor building. This plenum, which vents to the atmosphere, is equipped with a radiation detector. The radiation level meter and strip chart recorder for the reactor building vent effluent radioactivity monitor is located in the Control Room. To supplement the information continuously provided by the detector, air samples are taken periodically from the reactor building vent and are analyzed to quantify the total amount of tritium and radioactive gaseous and particulate effluents released.

If air containing elevated amounts of noble gases is routed past the reactor building vent's effluent radioactivity monitor, an alarm will alert the Control Room operators that release limits are being approached. The Control Room operators, according to procedure, will isolate the reactor building ventilation system and initiate the standby gas treatment system to remove airborne particulates and gaseous halogen radioactivity from the reactor building exhaust. This filtration assembly consists of high-efficiency particulate air filters and charcoal adsorber beds. The purified air is then directed to the main stack. The main stack has dilution flow that further reduces concentration levels of gaseous releases to the environment to as far below the release limits as is reasonably achievable.

The approximately 335 foot tall main stack has a special probe inside it that withdraws a portion of the air and passes it through a radioactivity monitoring system. This main stack effluent radioactivity monitoring system continuously samples radioactive particulates, iodines, and noble gases. Grab samples for a tritium analysis are also collected at this location. The system also contains radioactivity detectors that monitor the levels of radioactive noble gases in the stack flow and display the result on radiation level meters and strip chart recorders located in the Control Room. To supplement the information continuously provided by the detectors, the particulate, iodine, tritium, and gas samples are analyzed periodically to quantify the total amount of radioactive gaseous effluent being released.

The purpose of the augmented off-gas system is to reduce the radioactivity from the gases that are removed from the condenser. This purification system consists of two 30-minute holdup lines to reduce the radioactive gases with short half-lives, several charcoal adsorbers to remove radioactive iodines and further retard the short half-life gases, and offgas filters to remove radioactive particulates. The recombiner collects free hydrogen and oxygen gas and recombines them into water. This helps reduce the gaseous releases of short-lived isotopes of oxygen that have been made radioactive by neutron activation.

The radioactive off-gas from the condenser is then directed into a ventilation pipe to which the off-gas radiation monitors are attached. The radiation level meters and strip chart recorders for this detector are also located in the Control Room. If a radiation alarm setpoint is exceeded, an audible alarm will sound to alert the Control Room operators. In addition, the off-gas bypass and charcoal adsorber inlet valve will automatically re-direct the off-gas into the charcoal adsorbers if they are temporarily being bypassed. If the radioactivity levels are not returned to below the alarm setpoint within 13 minutes, the off-gas releases will be automatically isolated, thereby preventing any gaseous radioactivity from being released that may exceed the release limits.

Therefore, for both liquid and gaseous releases, radioactive effluent control systems exist to collect and purify the radioactive effluents in order to reduce releases to the environment to as low as is reasonably achievable. The effluents are always monitored, sampled and analyzed prior to release to make sure that radioactivity levels are below the release limits. If the release limits are being approached, isolation valves in some of the waste effluent lines will automatically shut to stop the release, or Control Room operators will implement procedures to ensure that federal regulatory limits are always met.

1.5 Radiological Impact on Humans

The final step in the effluent control process is the determination of the radiological dose impact to humans and comparison with the federal dose limits to the public. As mentioned previously, the purpose of continuous radiation monitoring and periodic sampling and analysis is to measure the quantities of radioactivity being released to determine compliance with the radioactivity release limits. This is the first stage for assessing releases to the environment.

Next, calculations of the dose impact to the general public from Pilgrim Station's radioactive effluents are performed. The purpose of these calculations is to periodically assess the doses to the general public resulting from radioactive effluents to ensure that these doses are being maintained as far below the federal dose limits as is reasonably achievable. This is the second stage for assessing releases to the environment.

The types and quantities of radioactive liquid and gaseous effluents released from Pilgrim Station during each given year are reported to the Nuclear Regulatory Commission annually. The 2011 Radioactive Effluents are provided in Appendix B and will be discussed in more detail in Section 3 of this report. These liquid and gaseous effluents were well below the federal release limits and were a small percentage of the PNPS ODCM effluent control limits.

These measurements of the physical and chemical nature of the effluents are used to determine how the radionuclides will interact with the environment and how they can result in radiation exposure to humans. The environmental interaction mechanisms depend upon factors such as the hydrological (water) and meteorological (atmospheric) characteristics in the area. Information on the water flow, wind speed, wind direction, and atmospheric mixing characteristics are used to estimate how radioactivity will distribute and disperse in the ocean and the atmosphere.

The most important type of information that is used to evaluate the radiological impact on humans is data on the use of the environment. Information on fish and shellfish consumption, boating usage, beach usage, locations of cows and goats, locations of residences, locations of gardens, drinking water supplies, and other usage information are utilized to estimate the amount of radiation and radioactivity received by the general public.

The radiation exposure pathway to humans is the path radioactivity takes from its release point at Pilgrim Station to its effect on man. The movement of radioactivity through the environment and its transport to humans is portrayed in Figure 1.5-1.

EXAMPLES OF PILGRIM STATION'S RADIATION EXPOSURE PATHWAYS

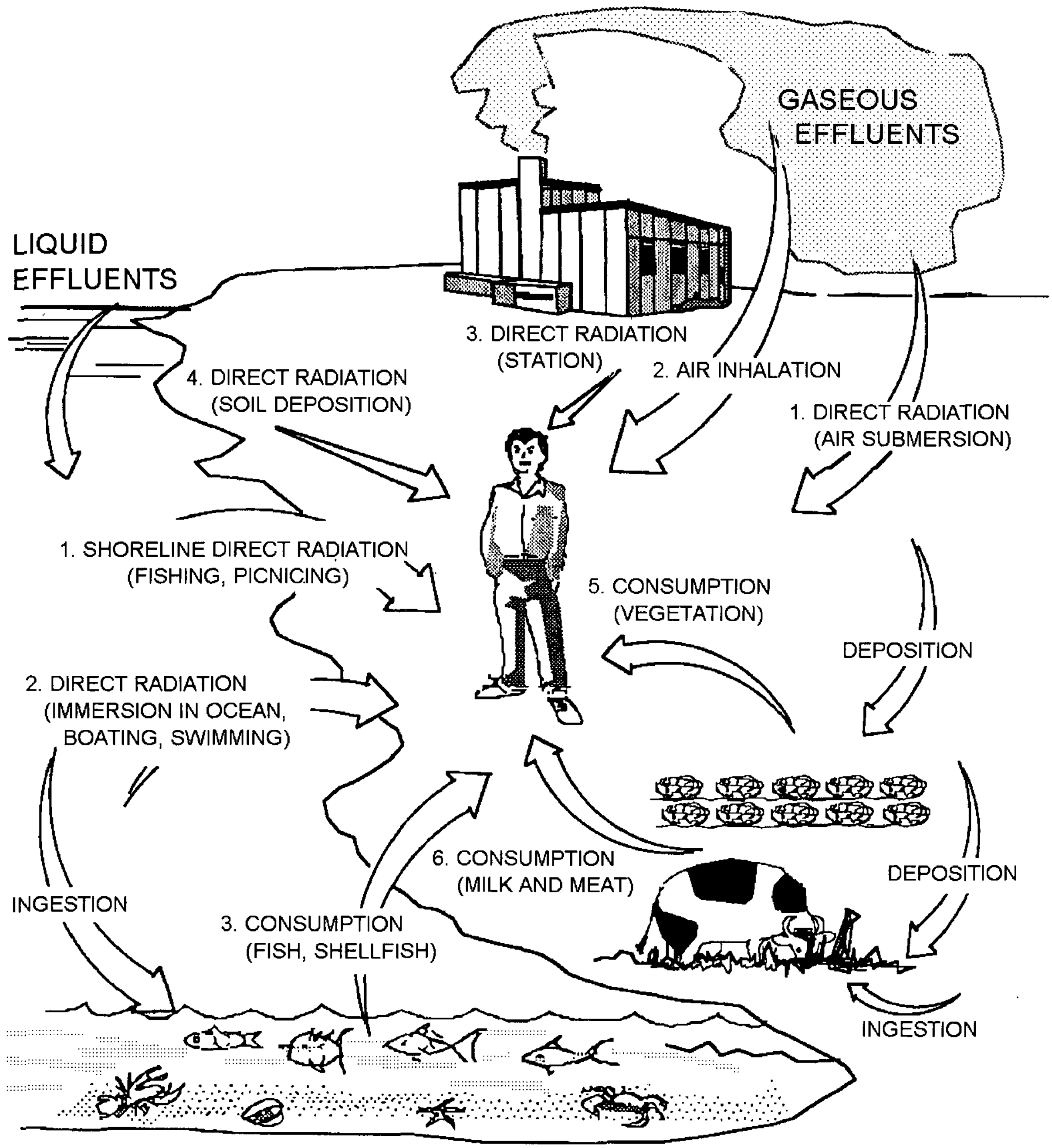


Figure 1.5-1
Radiation Exposure Pathways

There are three major ways in which liquid effluents affect humans:

- external radiation from liquid effluents that deposit and accumulate on the shoreline;
- external radiation from immersion in ocean water containing radioactive liquids; and,
- internal radiation from consumption of fish and shellfish containing radioactivity absorbed from the liquid effluents.

There are six major ways in which gaseous effluents affect humans:

- external radiation from an airborne plume of radioactivity;
- internal radiation from inhalation of airborne radioactivity;
- external radiation from deposition of radioactive effluents on soil;
- ambient (direct) radiation from contained sources at the power plant;
- internal radiation from consumption of vegetation containing radioactivity deposited on vegetation or absorbed from the soil due to ground deposition of radioactive effluents; and,
- internal radiation from consumption of milk and meat containing radioactivity deposited on forage that is eaten by cattle and other livestock.

In addition, ambient (direct) radiation emitted from contained sources of radioactivity at PNPS contributes to radiation exposure in the vicinity of the plant. Radioactive nitrogen-16 contained in the steam flowing through the turbine accounts for the majority of this "sky shine" radiation exposure immediately adjacent to the plant. Smaller amounts of ambient radiation result from low-level radioactive waste stored at the site prior to shipping and disposal.

To the extent possible, the radiological dose impact on humans is based on direct measurements of radiation and radioactivity in the environment. When PNPS-related activity is detected in samples that represent a plausible exposure pathway, the resulting dose from such exposure is assessed (see Appendix A). However, the operation of Pilgrim Nuclear Power Station results in releases of only small amounts of radioactivity, and, as a result of dilution in the atmosphere and ocean, even the most sensitive radioactivity measurement and analysis techniques cannot usually detect these tiny amounts of radioactivity above that which is naturally present in the environment. Therefore, radiation doses are calculated using radioactive effluent release data and computerized dose calculations that are based on very conservative NRC-recommended models that tend to result in over-estimates of resulting dose. These computerized dose calculations are performed by or for Entergy Nuclear personnel. These computer codes use the guidelines and methodology set forth by the NRC in Regulatory Guide 1.109 (Reference 6). The dose calculations are documented and described in detail in the Pilgrim Nuclear Power Station's Offsite Dose Calculation Manual (Reference 7), which has been reviewed by the NRC.

Monthly dose calculations are performed by PNPS personnel. It should be emphasized that because of the very conservative assumptions made in the computer code calculations, the maximum hypothetical dose to an individual is considerably higher than the dose that would actually be received by a real individual.

After dose calculations are performed, the results are compared to the federal dose limits for the public. The two federal agencies that are charged with the responsibility of protecting the public from radiation and radioactivity are the Nuclear Regulatory Commission (NRC) and the Environmental Protection Agency (EPA).

The NRC, in 10CFR 20.1301 (Reference 8) limits the levels of radiation to unrestricted areas resulting from the possession or use of radioactive materials such that they limit any individual to a dose of:

- less than or equal to 100 mrem per year to the total body.

In addition to this dose limit, the NRC has established design objectives for nuclear plant licensees. Conformance to these guidelines ensures that nuclear power reactor effluents are maintained as far below the legal limits as is reasonably achievable.

The NRC, in 10CFR 50 Appendix I (Reference 9) establishes design objectives for the dose to a member of the general public from radioactive material in liquid effluents released to unrestricted areas to be limited to:

- less than or equal to 3 mrem per year to the total body; and,
- less than or equal to 10 mrem per year to any organ.

The air dose due to release of noble gases in gaseous effluents is restricted to:

- less than or equal to 10 mrad per year for gamma radiation; and,
- less than or equal to 20 mrad per year for beta radiation.

The dose to a member of the general public from iodine-131, tritium, and all particulate radionuclides with half-lives greater than 8 days in gaseous effluents is limited to:

- less than or equal to 15 mrem per year to any organ.

The EPA, in 40CFR190.10 Subpart B (Reference 10), sets forth the environmental standards for the uranium fuel cycle. During normal operation, the annual dose to any member of the public from the entire uranium fuel cycle shall be limited to:

- less than or equal to 25 mrem per year to the total body;
- less than or equal to 75 mrem per year to the thyroid; and,
- less than or equal to 25 mrem per year to any other organ.

The summary of the 2011 radiological impact for Pilgrim Station and comparison with the EPA dose limits and guidelines, as well as a comparison with natural/man-made radiation levels, is presented in Section 3 of this report.

The third stage of assessing releases to the environment is the Radiological Environmental Monitoring Program (REMP). The description and results of the REMP at Pilgrim Nuclear Power Station during 2011 is discussed in Section 2 of this report.

2.0 RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM

2.1 Pre-Operational Monitoring Results

The Radiological Environmental Monitoring Program (REMP) at Pilgrim Nuclear Power Station was first initiated in August 1968, in the form of a pre-operational monitoring program prior to bringing the station on-line. The NRC's intent (Reference 11) with performing a pre-operational environmental monitoring program is to:

- measure background levels and their variations in the environment in the area surrounding the licensee's station; and,
- evaluate procedures, equipment, and techniques for monitoring radiation and radioactivity in the environment.

The pre-operational program (Reference 12) continued for approximately three and a half years, from August 1968 to June 1972. Examples of background radiation and radioactivity levels measured during this time period are as follows:

- Airborne Radioactivity Particulate Concentration (gross beta): 0.02 - 1.11 pCi/m^3;
- Ambient Radiation (TLDs): 4.2 - 22 micro-R/hr (37 - 190 mR/yr);
- Seawater Radioactivity Concentrations (gross beta): 12 - 31 pCi/liter;
- Fish Radioactivity Concentrations (gross beta): 2,200 - 11,300 pCi/kg;
- Milk Radioactive Cesium-137 Concentrations: 9.3 - 32 pCi/liter;
- Milk Radioactive Strontium-90 Concentrations: 4.7 - 17.6 pCi/liter;
- Cranberries Radioactive Cesium-137 Concentrations: 140 - 450 pCi/kg;
- Forage Radioactive Cesium-137 Concentrations: 150 - 290 pCi/kg.

This information from the pre-operational phase is used as a basis for evaluating changes in radiation and radioactivity levels in the vicinity of the plant following plant operation. In April 1972, just prior to initial reactor startup (June 12, 1972), Boston Edison Company implemented a comprehensive operational environmental monitoring program at Pilgrim Nuclear Power Station. This program (Reference 13) provides information on radioactivity and radiation levels in the environment for the purpose of:

- demonstrating that doses to the general public and levels of radioactivity in the environment are within established limits and legal requirements;
- monitoring the transfer and long-term buildup of specific radionuclides in the environment to revise the monitoring program and environmental models in response to changing conditions;
- checking the condition of the station's operation, the adequacy of operation in relation to the adequacy of containment, and the effectiveness of effluent treatment so as to provide a mechanism of determining unusual or unforeseen conditions and, where appropriate, to trigger special environmental monitoring studies;
- assessing the dose equivalent to the general public and the behavior of radioactivity released during the unlikely event of an accidental release; and,

- determining whether or not the radiological impact on the environment and humans is significant.

The Nuclear Regulatory Commission requires that Pilgrim Station provide monitoring of the plant environs for radioactivity that will be released as a result of normal operations, including anticipated operational occurrences, and from postulated accidents. The NRC has established guidelines (Reference 14) that specify an acceptable monitoring program. The PNPS Radiological Environmental Monitoring Program was designed to meet and exceed these guidelines. Guidance contained in the NRC's Radiological Assessment Branch Technical Position on Environmental Monitoring (Reference 15) has been used to improve the program. In addition, the program has incorporated the provisions of an agreement made with the Massachusetts Wildlife Federation (Reference 16). The program was supplemented by including improved analysis of shellfish and sediment at substantially higher sensitivity levels to verify the adequacy of effluent controls at Pilgrim Station.

2.2 Environmental Monitoring Locations

Sampling locations have been established by considering meteorology, population distribution, hydrology, and land use characteristics of the Plymouth area. The sampling locations are divided into two classes, indicator and control. Indicator locations are those that are expected to show effects from PNPS operations, if any exist. These locations were primarily selected on the basis of where the highest predicted environmental concentrations would occur. While the indicator locations are typically within a few kilometers of the plant, the control stations are generally located so as to be outside the influence of Pilgrim Station. They provide a basis on which to evaluate fluctuations at indicator locations relative to natural background radiation and natural radioactivity and fallout from prior nuclear weapons tests.

The environmental sampling media collected in the vicinity of Pilgrim Station during 2011 included air particulate filters, charcoal cartridges, animal forage, vegetation, cranberries, seawater, sediment, Irish moss, shellfish, American lobster, and fishes. The sampling medium, station description, station number, distance, and direction for indicator and control samples are listed in Table 2.2-1. These sampling locations are also displayed on the maps shown in Figures 2.2-1 through 2.2-6.

The radiation monitoring locations for the environmental TLDs are shown in Figures 2.2-1 through 2.2-4. The frequency of collection and types of radioactivity analysis are described in Pilgrim Station's ODCM, Sections 3/4.5.

The land-based (terrestrial) samples and monitoring devices are collected by Entergy personnel. The aquatic samples are collected by Marine Research, Inc. The radioactivity analysis of samples and the processing of the environmental TLDs are performed by Entergy's J.A. Fitzpatrick Environmental Laboratory.

The frequency, types, minimum number of samples, and maximum lower limits of detection (LLD) for the analytical measurements, are specified in the PNPS ODCM. During 2003, a revision was made to the PNPS ODCM to standardize it to the model program described in NUREG-1302 (Reference 14) and the Branch Technical Position of 1979 (Reference 15). In accordance with this standardization, a number of changes occurred regarding the types and frequencies of sample collections.

In regard to terrestrial REMP sampling, routine collection and analysis of soil samples was discontinued in lieu of the extensive network of environmental TLDs around PNPS, and the weekly collection of air samples at 11 locations. Such TLD monitoring and air sampling would provide an early indication of any potential deposition of radioactivity, and follow-up soil sampling could be performed on an as-needed basis. Also, with the loss of the indicator milk sample at the Plymouth

County Farm and the lack of a sufficient substitute location that could provide suitable volumes for analysis, it was deemed unnecessary to continue to collect and analyze control samples of milk. Consequently, routine milk sampling was also dropped from the terrestrial sampling program. NRC guidance (Reference 14) contains provisions for collection of vegetation and forage samples in lieu of milk sampling. Such samples have historically been collected near Pilgrim Station as part of the routine REMP program.

In the area of marine sampling, a number of the specialized sampling and analysis requirements implemented as part of the Agreement with the Massachusetts Wildlife Federation (Reference 16) for licensing of a second reactor at PNPS were dropped. This agreement, made in 1977, was predicated on the construction of a second nuclear unit, and was set to expire in 1987. However, since the specialized requirements were incorporated into the PNPS Technical Specifications at the time, the requirements were continued. When the ODCM was revised in 1999 in accordance with NRC Generic Letter 89-01, the sampling program description was relocated to the ODCM. When steps were taken in 2003 to standardize the PNPS ODCM to the NUREG-1302 model, the specialized marine sampling requirements were changed to those of the model program. These changes include the following:

- A sample of the surface layer of sediment is collected, as opposed to specialized depth-incremental sampling to 30 cm and subdividing cores into 2 cm increments.
- Standard LLD levels of about 150 to 180 pCi/kg were established for sediment, as opposed to the specialized LLDs of 50 pCi/kg.
- Specialized analysis of sediment for plutonium isotopes was removed.
- Sampling of Irish moss, shellfish, and fish was rescheduled to a semiannual period, as opposed to a specialized quarterly sampling interval.
- Analysis of only the edible portions of shellfish (mussels and clams), as opposed to specialized additional analysis of the shell portions.
- Standard LLD levels of 130 to 260 pCi/kg were established for edible portions of shellfish, as opposed to specialized LLDs of 5 pCi/kg.

The PNPS ODCM was revised in 2009. In conjunction with this revision, two changes were made to the environmental sampling program. Due to damage from past storms to the rocky areas at Manomet Point, there is no longer a harvestable population of blue mussels at this site. Several attempts have been made over the past years to collect samples from this location, but all efforts were unsuccessful. Because of unavailability of mussels at this location as a viable human foodchain exposure pathway, this location was dropped from the sampling program. The other change involved the twice per year sampling of Group II fishes in the vicinity of the PNPS discharge outfall, represented by species such as cunner and tautog. Because these fish tend to move away from the discharge jetty during colder months, they are not available for sampling at a six-month semi-annual sampling period. The sampling program was modified to reduce the sampling for Group II fishes to once per year, when they are available during warmer summer months.

Upon receipt of the analysis results from the analytical laboratories, the PNPS staff reviews the results. If the radioactivity concentrations are above the reporting levels, the NRC must be notified within 30 days. For radioactivity that is detected that is attributable to Pilgrim Station's operation, calculations are performed to determine the cumulative dose contribution for the current year. Depending upon the circumstances, a special study may also be completed (see Appendix A for 2011 special studies). Most importantly, if radioactivity levels in the environment become elevated as a result of the station's operation, an investigation is performed and corrective actions are recommended to reduce the amount of radioactivity to as far below the legal limits as is reasonably achievable.

The radiological environmental sampling locations are reviewed annually, and modified if necessary. A garden and milk animal census is performed every year to identify changes in the use of the environment in the vicinity of the station to permit modification of the monitoring and sampling locations. The results of the 2011 Garden and Milk Animal Census are reported in Appendix C.

The accuracy of the data obtained through Pilgrim Station's Radiological Environmental Monitoring Program is ensured through a comprehensive Quality Assurance (QA) programs. PNPS's QA program has been established to ensure confidence in the measurements and results of the radiological monitoring program through:

- Regular surveillances of the sampling and monitoring program;
- An annual audit of the analytical laboratory by the sponsor companies;
- Participation in cross-check programs;
- Use of blind duplicates for comparing separate analyses of the same sample; and,
- Spiked sample analyses by the analytical laboratory.

QA audits and inspections of the Radiological Environmental Monitoring Program are performed by the NRC, American Nuclear Insurers, and by the PNPS Quality Assurance Department.

The J.A. Fitzpatrick Environmental Laboratory conducts extensive quality assurance and quality control programs. The 2011 results of these programs are summarized in Appendix E. These results indicate that the analyses and measurements performed during 2011 exhibited acceptable precision and accuracy.

2.3 Interpretation of Radioactivity Analyses Results

The following pages summarize the analytical results of the environmental samples collected during 2011. Data for each environmental medium are included in a separate section. A table that summarizes the year's data for each type of medium follows a discussion of the sampling program and results. The unit of measurement for each medium is listed at the top of each table. The left hand column contains the radionuclides being reported, total number of analyses of that radionuclide, and the number of measurements that exceed ten times the yearly average for the control station(s). The latter are classified as "non-routine" measurements. The next column lists the Lower Limit of Detection (LLD) for those radionuclides that have detection capability requirements specified in the PNPS ODCM.

Those sampling stations within the range of influence of Pilgrim Station and which could conceivably be affected by its operation are called "indicator" stations. Distant stations, which are beyond plant influence, are called "control" stations. Ambient radiation monitoring stations are broken down into four separate zones to aid in data analysis.

For each sampling medium, each radionuclide is presented with a set of statistical parameters. This set of statistical parameters includes separate analyses for (1) the indicator stations, (2) the station having the highest annual mean concentration, and (3) the control stations. For each of these three groups of data, the following values are calculated:

- The mean value of detectable concentrations, including only those values above LLD;
- The standard deviation of the detectable measurements;
- The lowest and highest concentrations; and,
- The number of positive measurements (activity which is three times greater than the standard deviation), out of the total number of measurements.

Each single radioactivity measurement datum is based on a single measurement and is reported as a concentration plus or minus one standard deviation. The quoted uncertainty represents only the random uncertainty associated with the measurement of the radioactive decay process (counting statistics), and not the propagation of all possible uncertainties in the sampling and analysis process. A sample or measurement is considered to contain detectable radioactivity if the measured value (e.g., concentration) exceeds three times its associated standard deviation. For example, a vegetation sample with a cesium-137 concentration of 85 ± 21 pCi/kilogram would be considered "positive" (detectable Cs-137), whereas another sample with a concentration of 60 ± 32 pCi/kilogram would be considered "negative", indicating no detectable cesium-137. The latter sample may actually contain cesium-137, but the levels counted during its analysis were not significantly different than the background levels.

As an example of how to interpret data presented in the results tables, refer to the first entry on the table for air particulate filters (page 41). Gross beta (GR-B) analyses were performed on 581 routine samples. None of the samples exceeded ten times the average concentration at the control location. The lower limit of detection (LLD) required by the ODCM is 0.01 pCi/m^3.

For samples collected from the ten indicator stations, 528 out of 528 samples indicated detectable activity at the three-sigma (standard deviation) level. The mean concentration of gross beta activity in these 528 indicator station samples was 0.014 ± 0.005 (1.2E-2 ± 5.4E-3) pCi/m^3. Individual values ranged from 0.003 to 0.032 (3.0E-3 – 3.2E-2) pCi/m^3.

The monitoring station which yielded the highest mean concentration was station PB (Pedestrian Bridge), which yielded a mean concentration of 0.015 ± 0.0056 pCi/m^3, based on 53 observations.

Individual values ranged from 0.0040 to 0.032 pCi/m^3. Fifty-three of the fifty-three samples showed detectable activity at the three-sigma level.

At the control location, 53 out of 53 samples yielded detectable gross beta activity, for an average concentration of 0.014 ± 0.006 pCi/m^3. Individual samples at the control location ranged from 0.0040 to 0.034 pCi/m^3.

Referring to the last entry row in the table, analyses for cesium-137 (Cs-137) were performed 44 times (quarterly composites for 11 stations * 4 quarters). No samples exceeded ten times the mean control station concentration. The required LLD value Cs-137 in the PNPS ODCM is 0.06 pCi/m^3.

At the indicator stations, all 40 of the Cs-137 measurements were below the detection level. The same was true for the four measurements made on samples collected from the control location.

2.4 Ambient Radiation Measurements

The primary technique for measuring ambient radiation exposure in the vicinity of Pilgrim Station involves posting environmental thermoluminescent dosimeters (TLDs) at given monitoring locations and retrieving the TLDs after a specified time period. The TLDs are then taken to a laboratory and processed to determine the total amount of radiation exposure received over the period. Although TLDs can be used to monitor radiation exposure for short time periods, environmental TLDs are typically posted for periods of one to three months. Such TLD monitoring yields average exposure rate measurements over a relatively long time period. The PNPS environmental TLD monitoring program is based on a quarterly (three month) posting period, and a total of 110 locations are monitored using this technique. In addition, 27 of the 110 TLDs are located onsite, within the PNPS protected/restricted area, where the general public does not have access.

Out of the 440 TLDs (110 locations * 4 quarters) posted during 2011, 434 were retrieved and processed. Those TLDs missing from their monitoring locations were lost to storm damage, and/or building renovation, and their absence is discussed in Appendix D. The results for environmental TLDs located offsite, beyond the PNPS protected/restricted area fence, are presented in Table 2.4-1. Results from onsite TLDs posted within the restricted area are presented in Table 2.4-2. In addition to TLD results for individual locations, results from offsite TLDs were grouped according to geographic zone to determine average exposure rates as a function of distance. These results are summarized in Table 2.4-3. All of the listed exposure values represent continuous occupancy (2190 hr/qtr or 8760 hr/yr).

Annual exposure rates measured at locations beyond the PNPS protected area boundary ranged from 46 to 193 mR/yr. The average exposure rate at control locations greater than 15 km from Pilgrim Station (i.e., Zone 4) was 63.7 ± 6.8 mR/yr. When the 3-sigma confidence interval is calculated based on these control measurements, 99% of all measurements of background ambient exposure would be expected to be between 43 and 84 mR/yr. The results for all TLDs within 15 km (excluding those Zone 1 TLDs posted within the site boundary) ranged from 46 to 81 mR/yr, which compares favorably with the preoperational results of 37 - 190 mR/yr.

Inspection of onsite TLD results listed in Table 2.4-2 indicates that all of those TLDs located within the PNPS protected/restricted area yield exposure measurements higher than the average natural background. Such results are expected due to the close proximity of these locations to radiation sources onsite. The radionuclide nitrogen-16 (N-16) contained in steam flowing through the turbine accounts for most of the exposure onsite. Although this radioactivity is contained within the turbine and is not released to the atmosphere, the "sky shine" which occurs from the turbine increases the ambient radiation levels in areas near the turbine building.

A small number of offsite TLD locations in close proximity to the protected/restricted area indicated ambient radiation exposure above expected background levels. All of these locations are on Pilgrim Station controlled property, and experience exposure increases due to turbine sky shine (e.g., locations OA, TC, PB, and P01) and/or transit and storage of radwaste onsite (e.g., locations BLE and BLW). Due to heightened security measures following September 11 2001, members for the general public do not have access to such locations within the owner-controlled area.

One TLD, located in the basement of the Plymouth Memorial Hall, indicated an annual exposure of 77 mR in 2011. The higher exposure within the building at this location is due to the close proximity of stone building material, which contains higher levels of naturally-occurring radioactivity, as well as from the buildup of radon in this area of the building.

It should be noted that several of the TLDs used to calculate the Zone 1 averages presented in Table 2.4-3 are located on Pilgrim Station property. If the Zone 1 value is corrected for the near-site TLDs (those less than 0.6 km from the Reactor Building), the Zone 1 mean falls from a value of 77.0 ± 26.1 mR/yr to 65.9 ± 8.8 mR/yr. Additionally, exposure rates measured at areas beyond Entergy's control did not indicate any increase in ambient exposure from Pilgrim Station operation. For example, the annual exposure rate calculated from the two TLDs adjacent to the nearest offsite residence 0.80 kilometers (0.5 miles) southeast of the PNPS Reactor Building was 61.1 ± 8.4 mR/yr, which compares quite well with the average control location exposure of 63.7 ± 6.8 mR/yr.

In conclusion, measurements of ambient radiation exposure around Pilgrim Station do not indicate any significant increase in exposure levels. Although some increases in ambient radiation exposure level were apparent on Entergy property very close to Pilgrim Station, there were no measurable increases at areas beyond Entergy's control.

2.5 Air Particulate Filter Radioactivity Analyses

Airborne particulate radioactivity is sampled by drawing a stream of air through a glass fiber filter that has a very high efficiency for collecting airborne particulates. These samplers are operated continuously, and the resulting filters are collected weekly for analysis. Weekly filter samples are analyzed for gross beta radioactivity, and the filters are then composited on a quarterly basis for each location for gamma spectroscopy analysis. PNPS uses this technique to monitor 10 locations in the Plymouth area, along with the control location in East Weymouth.

Out of 583 filters (11 locations * 53 weeks), 581 samples were collected and analyzed during 2011. The two samples that appear to have been "missed" were actually in service for a two-week period when two of the sampling locations were inaccessible due to heavy snow during the week of 26-Jan-2011. There were also a few instances where power was lost or pumps failed during the course of the sampling period at some of the air sampling stations, resulting in lower than normal sample volumes. All of these discrepancies are noted in Appendix D.

The results of the analyses performed on these 581 filter samples are summarized in Table 2.5-1. Trend plots for the gross beta radioactivity levels at the near station, property line, and offsite airborne monitoring locations are shown in Figures 2.5-1, 2.5-2 and 2.5-3, respectively. Gross beta radioactivity was detected in 581 of the filter samples collected, including 53 of the 53 control location samples. This gross beta activity arises from naturally-occurring radionuclides such as radon decay daughter products. Naturally-occurring beryllium-7 was detected in 44 out of 44 of the quarterly composites analyzed with gamma spectroscopy. Naturally-occurring potassium-40 (K-40) was detected in 5 of 40 indicator samples, and in none of four control samples. No airborne radioactivity attributable to Pilgrim Station was detected in any of the samples collected during 2011, and results of any detectable naturally-occurring radioactivity were similar to those observed in the preoperational monitoring program.

2.6 Charcoal Cartridge Radioactivity Analyses

Airborne radioactive iodine is sampled by drawing a stream of air through a charcoal cartridge after it has passed through the high efficiency glass fiber filter. As is the case with the air particulate filters, these samplers are operated continuously, and the resulting cartridges are collected weekly for analysis. Weekly cartridge samples are analyzed for radioactive iodine. The same eleven locations monitored for airborne particulate radioactivity are also sampled for airborne radioiodine.

Out of 583 cartridges (11 locations * 53 weeks), 581 samples were collected and analyzed during 2011. The two samples that appear to have been "missed" were actually in service for a two-week period when two of the sampling locations were inaccessible due to heavy snow during the week of 26-Jan-2011. There were a few instances where power was lost or pumps failed during the course of the sampling period at some of the air sampling stations, resulting in lower than normal sample volumes. All of these discrepancies are noted in Appendix D. Despite such events during 2011, required LLDs were met on 581 of the 581 cartridges collected during 2011.

Several samples obtained from the 11 sampling locations during late March and April of 2011 identified detectable concentrations of airborne radioactive Iodine-131 that could be erroneously attributed to the operation of Pilgrim Station. Given the following facts, the detectable I-131 concentrations are not a result of Pilgrim Station operation:

- The quantities of radioactive I-131 in airborne effluents from Pilgrim Station during 2011 did not increase significantly compared to year 2010.
- Prior REMP sample results have not detected the presence of I-131 in charcoal cartridge samples.
- The concentrations being detected in the indicator samples were also identified in the control samples from East Weymouth, and are also consistent with levels detected in air samples collected by the EPA and other nuclear power plants in the northeast USA.

As such, the atypical detection of I-131 in both indicator and control samples is credibly attributed to the transport of airborne radioactivity released from the Fukushima Nuclear Power Plant in Japan following the March 11, 2011 Tohoku earthquake and is not related to the operations of Pilgrim Station.

The results of the analyses performed on these charcoal cartridges are summarized in Table 2.6-1. Aside from the I-131 attributed to the Fukushima event in March and April 2011, no other airborne radioactive iodine attributable to Pilgrim Station was detected in any of the charcoal cartridges collected.

2.7 Milk Radioactivity Analyses

In July 2002, the Plymouth County Farm ceased operation of its dairy facility. This was historically the only dairy facility near Pilgrim Station, and had been sampled continuously since Pilgrim Station began operation in 1972. Although attempts were made to obtain samples from an alternate indicator location within 5 miles as specified in NRC guidance (Reference 14), a suitable substitute location could not be found. Thus, milk collection at an indicator location was discontinued in July 2002, but control samples of milk continued to be collected and analyzed in the event an indicator location could be secured. In conjunction with the standardization of the ODCM during 2003, the decision was made to remove milk sampling from the PNPS Radiological Environmental Monitoring Program since suitable no milk sampling location existed in the vicinity of Pilgrim Station.

The nearest milk animals to Pilgrim Station are located at the Plimoth Plantation, approximately 2.5 miles west of PNPS, in a relatively upwind direction. Due to the limited number of milk animals available, this location is not able to provide the necessary volume of 4 gallons of milk every two weeks to facilitate the milk sampling program and meet the required detection sensitivities. Although milk sampling is not performed at Plimoth Plantation, effluent dose calculations are performed for this location assuming the presence of a milk ingestion pathway, as part of the annual Effluent and Waste Disposal Report (Reference 17).

As included in a provision in standard ODCM guidance in NUREG-1302 (Reference 13), sampling and analysis of vegetation from the offsite locations calculated to have the highest D/Q deposition factor can be performed in lieu of milk sampling. Such vegetation sampling has been routinely performed at Pilgrim Station as part of the radiological environmental monitoring program, and the results of this sampling are presented in Section 2.9.

2.8 Forage Radioactivity Analyses

Samples of animal forage (hay) had been collected in the past from the Plymouth County Farm, and from control locations in Bridgewater. However, due to the absence of any grazing animals within a five-mile radius of Pilgrim Station that are used for generation of food products (milk or meat), no samples of forage were collected during 2011. A number of wild vegetation samples were collected within a five mile radius of Pilgrim Station as part of the vegetable/vegetation sampling effort, and the results of this sampling would provide an indication of any radioactivity potentially entering the forage-milk or forage-meat pathways. Results of the vegetable/vegetation sampling effort are discussed in the following section.

2.9 Vegetable/Vegetation Radioactivity Analyses

Samples of vegetables and naturally-growing vegetation have historically been collected from the Plymouth County Farm and from the control locations in Bridgewater, Sandwich, and Norton. In addition, samples of vegetables or leafy vegetation were collected at or near a number of gardens identified during the Annual Land Use Census. Results of this census are discussed in Appendix C. In addition to these garden samples, naturally-growing vegetation is collected from locations yielding the highest D/Q deposition factors. All of the various samples of vegetables/vegetation are collected annually and analyzed by gamma spectroscopy.

Twenty-five samples of vegetables/vegetation were collected and analyzed as required during 2011. Results of the gamma analyses of these samples are summarized in Table 2.9-1. Naturally-occurring beryllium-7, potassium-40, radium-226, and actinium/thorium-228 were identified in most of the samples collected. Cesium-137 was also detected in six out of 18 samples of vegetation collected from indicator locations, and none of seven control samples collected, with concentrations ranging from non-detectable (<11 pCi/kg) up to 188 pCi/kg. The highest concentration of 188 pCi/kg was detected in a sample of natural vegetation collected from the Cleft Rock area of the Pine Hills south of PNPS. Although this Cs-137 result is outside of the normal range of <u>average</u> values expected for weapons-testing fallout (75 to 145 pCi/kg as projected from the pre-operational sampling program), the average Cs-137 concentration for the six samples of natural vegetation collected within 1 mile of Pilgrim Station was about 119 pCi/kg. It should be noted that natural vegetation samples collected in the 1990s often showed detectable Cs-137 from nuclear weapons tests up into the range of 300 to 400 pCi/kg, whereas soil samples often indicated concentrations in excess of 2000 pCi/kg. Cs-137 has a 30-year half-life, and measureable concentrations still remain in soil and vegetation as a result of atmospheric nuclear weapons testing performed during the 1950s through 1970s. Weekly particulate air filters collected from the Cleft Rock sampling station within a few yards of where the vegetation was sampled indicated no detectable Cs-137. A review of effluent data presented in Appendix B indicates that there were no measurable airborne releases of Cs-137 from Pilgrim Station during 2011 that could have attributed to this level. The sample with the highest level of Cs-137 also contained high levels of Ra-226, indicating appreciable soil content on the vegetation. This sample of natural vegetation was analyzed "as is" without any measure to clean the samples as normally would be performed prior to consuming vegetables, and would have detected any Cs-137 in soil adhering to those leaves collected. Certain species of plants such as sassafras are also known to concentrate chemical elements like cesium, and this higher-than-expected level is likely due to a combination of external soil contamination and bioconcentration in the leaves of the plants sampled. These levels are not believed to be indicative of any releases associated with Pilgrim Station. No radioactivity attributable to Pilgrim Station was detected in any of the vegetable/vegetation samples collected during 2011, and results of any detectable naturally-occurring radioactivity were similar to those observed in the preoperational monitoring program.

2.10 Cranberry Radioactivity Analyses

Samples of cranberries are normally collected from two bogs in the Plymouth area and from the control location in Kingston. Samples of cranberries are collected annually and analyzed by gamma spectroscopy. In 2011, the bog on Bartlett Road ceased harvesting operations, and a sample was collected from an alternate location along Beaver Dam Road. Samples were also not available from the historical control location in Halifax, and a substitute control sample was collected from a bog in Kingston. These discrepancies are noted in Appendix D.

Three samples of cranberries were collected and analyzed during 2011. Results of the gamma analyses of cranberry samples are summarized in Table 2.10-1. Cranberry samples collected during 2011 yielded detectable levels of naturally-occurring beryllium-7, potassium-40, radium-226, and actinium/thorium-228. No radioactivity attributable to Pilgrim Station was detected in any of the samples collected during 2011, and results of any detectable naturally-occurring radioactivity were similar to those observed in the preoperational monitoring program.

2.11 Soil Radioactivity Analyses

In the past, a survey of radioactivity in soil had been conducted once every three years at the 10 air sampling stations in the Plymouth area and the control location in East Weymouth. However, in conjunction with standardization of the ODCM during 2003, the soil survey effort was abandoned in favor of the extensive TLD monitoring effort at Pilgrim Station. Prior to ending the soil survey effort, there had been no apparent trends in radioactivity measurements at these locations.

2.12 Surface Water Radioactivity Analyses

Samples of surface water are routinely collected from the discharge canal, Bartlett Pond in Manomet and from the control location at Powder Point Bridge in Duxbury. Grab samples are collected weekly from the Bartlett Pond and Powder Point Bridge locations. Samples of surface water are composited every four weeks and analyzed by gamma spectroscopy and low-level iodine analysis. These monthly composites are further composited on a quarterly basis and tritium analysis is performed on this quarterly sample.

A total of 36 samples (3 locations * 12 sampling periods) of surface water were collected and analyzed as required during 2011. Results of the analyses of water samples are summarized in Table 2.12-1. Naturally-occurring potassium-40, radium-226, and actinium/thorium-228 were detected in several of the samples, especially those composed primarily of seawater. No radioactivity attributable to Pilgrim Station was detected in any of the samples collected during 2011, and results of any detectable naturally-occurring radioactivity were similar to those observed in the preoperational monitoring program.

In response to the Nuclear Energy Institute Groundwater Protection Initiative, Pilgrim Station installed a number of groundwater monitoring wells within the protected area in late 2007. Because all of these wells are onsite, they are not included in the offsite radiological monitoring program, and are not presented in this report. Details regarding Pilgrim Station's groundwater monitoring effort can be found in the Annual Radiological Effluent Release Report.

2.13 Sediment Radioactivity Analyses

Samples of sediment are routinely collected from the outfall area of the discharge canal and from three other locations in the Plymouth area (Manomet Point, Plymouth Harbor and Plymouth Beach), and from control locations in Duxbury and Marshfield. Samples are collected twice per year and are analyzed by gamma spectroscopy.

Twelve of twelve required samples of sediment were collected during 2011. Gamma analyses were performed on these samples. Results of the gamma analyses of sediment samples are summarized in Table 2.13-1. Naturally-occurring beryllium-7, potassium-40, radium-226, and actinium/thorium-228 were detected in a number of the samples. No radioactivity attributable to Pilgrim Station was detected in any of the samples collected during 2011, and results of any detectable naturally-occurring radioactivity were similar to those observed in the preoperational monitoring program.

2.14 Irish Moss Radioactivity Analyses

Samples of Irish moss are collected from the discharge canal outfall and two other locations in the Plymouth area (Manomet Point, Ellisville), and from a control location in Marshfield (Brant Rock). All samples are collected on a semiannual basis, and processed in the laboratory for gamma spectroscopy analysis.

Eight samples of Irish moss scheduled for collection during 2011 were obtained and analyzed. Results of the gamma analyses of these samples are summarized in Table 2.14-1. Naturally-occurring beryllium-7, potassium-40, radium-226, and actinium/thorium-228 were detected in a number of the samples. No radioactivity attributable to Pilgrim Station was detected in any of the samples collected during 2011, and results of any detectable naturally-occurring radioactivity were similar to those observed in the preoperational monitoring program.

Several samples of Irish moss obtained from the 4 sampling locations during mid-April of 2011 identified detectable concentrations of radioactive Iodine-131 that could be erroneously attributed to the operation of Pilgrim Station. Given the following facts, the detectable I-131 concentrations are not a result of Pilgrim Station operation:

- There was no detectable I-131 in liquid effluents released from Pilgrim Station during 2011.
- Prior REMP sample results have not detected the presence of I-131 in Irish moss samples.
- The concentrations being detected in the indicator samples were also identified in the control samples from Marshfield, and are also consistent with levels detected in marine algae collected by other nuclear power plants in the USA.

As such, the atypical detection of I-131 in both indicator and control samples is credibly attributed to the transport of airborne radioactivity released from the Fukushima Nuclear Power Plant in Japan following the March 11, 2011 Tohoku earthquake and is not related to the operations of Pilgrim Station.

It should be noted that the sample collected from the control location in Marshfield on 27-Sep-2011 also indicated the presence of I-131 at a concentration of 29.4 ± 10.9 pCi/kg. This sample was collected approximately six months after the Fukushima event, so the I-131detected was likely not related to Fukushima. Since the control location at Brant Rock is located 10.5 miles away, it is considered to be beyond the influence of Pilgrim Station. The Iodine-131 detected in the Sep-2011 sample is attributed to medically-administered I-131 discharged into municipal sewage systems feeding into the estuarine environments near Marshfield.

2.15 Shellfish Radioactivity Analyses

Samples of blue mussels, soft-shell clams and quahogs are collected from the discharge canal outfall and one other location in the Plymouth area (Plymouth Harbor), and from control locations in Duxbury and Marshfield. All samples are collected on a semiannual basis, and edible portions processed in the laboratory for gamma spectroscopy analysis.

Ten of the 10 required samples of shellfish meat scheduled for collection during 2011 were obtained and analyzed. Results of the gamma analyses of these samples are summarized in Table 2.15-1. Naturally-occurring potassium-40 and radium-226 were detected in a number of the samples. No radioactivity attributable to Pilgrim Station was detected in any of the samples collected during 2011, and results of any detectable naturally-occurring radioactivity were similar to those observed in the preoperational monitoring program.

2.16 Lobster Radioactivity Analyses

Samples of lobsters are routinely collected from the outfall area of the discharge canal and from control locations in Cape Cod Bay and Vineyard Sound. Samples are collected monthly from the discharge canal outfall from June through September and once annually from the control locations. All lobster samples are normally analyzed by gamma spectroscopy.

Five samples of lobsters were collected as required during 2011. Results of the gamma analyses of these samples are summarized in Table 2.16-1. Naturally-occurring potassium-40 and radium-226 were detected in a number of the samples. No radioactivity attributable to Pilgrim Station was detected in any of the samples collected during 2011, and results of any detectable naturally-occurring radioactivity were similar to those observed in the preoperational monitoring program.

2.17 Fish Radioactivity Analyses

Samples of fish are routinely collected from the area at the outfall of the discharge canal and from the control locations in Cape Cod Bay and Buzzard's Bay. Fish species are grouped into four major categories according to their biological requirements and mode of life. These major categories and the representative species are as follows:

- Group I - Bottom Oriented: Winter Flounder, Yellowtail Flounder
- Group II - Near-Bottom Distribution: Tautog, Cunner, Pollock, Atlantic Cod, Hake
- Group III - Anadromous: Alewife, Smelt, Striped Bass
- Group IV - Coastal Migratory: Bluefish, Herring, Menhaden, Mackerel

Group I fishes are sampled on a semiannual basis from the outfall area of the discharge canal, and on an annual basis from a control location. Group II, III, and IV fishes are sampled annually from the discharge canal outfall and control location. All samples of fish are analyzed by gamma spectroscopy.

Ten samples of fish were collected during 2011. Results of the gamma analyses of fish samples collected are summarized in Table 2.17-1. The only radionuclides detected in any of the samples were naturally-occurring potassium-40 and radium-226. No radioactivity attributable to Pilgrim Station was detected in any of the samples collected during 2011, and results of any detectable naturally-occurring radioactivity were similar to those observed in the preoperational monitoring program.

Table 2.2-1

Routine Radiological Environmental Sampling Locations
Pilgrim Nuclear Power Station, Plymouth, MA

Description	Code	Distance	Direction
Air Particulate Filters, Charcoal Cartridges			
Medical Building	WS	0.2 km	SSE
East Rocky Hill Road	ER	0.9 km	SE
West Rocky Hill Road	WR	0.8 km	WNW
Property Line	PL	0.5 km	NNW
Pedestrian Bridge	PB	0.2 km	N
Overlook Area	OA	0.1 km	W
East Breakwater	EB	0.5 km	ESE
Cleft Rock	CR	1.3 km	SSW
Plymouth Center	PC	6.7 km	W
Manomet Substation	MS	3.6 km	SSE
East Weymouth Control	EW	40 km	NW
Forage			
Plymouth County Farm	CF	5.6 km	W
Hansen Farm Control	HN	35 km	W
Vegetation			
Plymouth County Farm	CF	5.6 km	W
Hansen Farm Control	HN	35 km	W
Cranberries			
Bartlett Road Bog	BT	4.3 km	SSE
Beaverdam Road Bog	MR	3.4 km	S
Hollow Farm Bog Control	HF	16 km	WNW

Table 2.2-1 (continued)

Routine Radiological Environmental Sampling Locations
Pilgrim Nuclear Power Station, Plymouth, MA

Description	Code	Distance	Direction
Surface Water			
Discharge Canal	DIS	0.2 km	N
Bartlett Pond	BP	2.7 km	SE
Powder Point Control	PP	13 km	NNW
Sediment			
Discharge Canal Outfall	DIS	0.8 km	NE
Plymouth Harbor	Ply-H	4.1 km	W
Duxbury Bay Control	Dux-Bay	14 km	NNW
Plymouth Beach	PLB	4.0 km	WNW
Manomet Point	MP	3.3 km	ESE
Green Harbor Control	GH	16 km	NNW
Irish Moss			
Discharge Canal Outfall	DIS	0.7 km	NNE
Manomet Point	MP	4.0 km	ESE
Ellisville	EL	12 km	SSE
Brant Rock Control	BR	18 km	NNW
Shellfish			
Discharge Canal Outfall	DIS	0.7 km	NNE
Plymouth Harbor	Ply-H	4.1 km	W
Duxbury Bay Control	Dux-Bay	13 km	NNW
Manomet Point	MP	4.0 km	ESE
Green Harbor Control	GH	16 km	NNW
Lobster			
Discharge Canal Outfall	DIS	0.5 km	N
Plymouth Harbor	Ply-H	6.4 km	WNW
Duxbury Bay Control	Dux-Bay	11 km	NNW
Fishes			
Discharge Canal Outfall	DIS	0.5 km	N
Priest Cove Control	PC	48 km	SW
Jones River Control	JR	13 km	WNW
Vineyard Sound Control	MV	64 km	SSW
Buzzard's Bay Control	BB	40 km	SSW
Cape Cod Bay Control	CC-Bay	24 km	ESE

Table 2.4-1

Offsite Environmental TLD Results

TLD Station	TLD Location*	Quarterly Exposure - mR/quarter (Value ± Std.Dev.)				2011 Annual** Exposure mR/year
ID Description	Distance/Direction	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	
Zone 1 TLDs: 0-3 km	0-3 km	20.7 ± 7.0	19.1 ± 6.0	20.3 ± 8.0	16.9 ± 4.0	77.0 ± 26.1
BLW BOAT LAUNCH WEST	0.11 km E	38.6 ± 1.9	35.7 ± 2.3	39.5 ± 1.9	26.8 ± 1.3	140.7 ± 23.5
OA OVERLOOK AREA	0.15 km W	52.7 ± 1.5	43.0 ± 2.6	59.4 ± 4.9	37.4 ± 1.3	192.5 ± 39.8
TC HEALTH CLUB	0.15 km WSW	25.3 ± 1.4	21.5 ± 1.0	24.2 ± 1.4	18.4 ± 0.8	89.4 ± 12.6
BLE BOAT LAUNCH EAST	0.16 km ESE	34.8 ± 1.7	36.5 ± 1.5	37.8 ± 3.3	21.2 ± 0.7	130.4 ± 31.0
PB PEDESTRIAN BRIDGE	0.21 km N	31.5 ± 1.0	26.9 ± 1.5	30.1 ± 1.0	23.4 ± 0.8	111.9 ± 14.5
P01 SHOREFRONT SECURITY	0.22 km NNW	21.4 ± 1.1	18.6 ± 0.9	20.7 ± 0.7	17.2 ± 1.0	77.9 ± 7.9
WS MEDICAL BUILDING	0.23 km SSE	24.2 ± 1.1	21.9 ± 1.1	22.9 ± 0.8	19.7 ± 0.9	88.7 ± 7.8
CT PARKING LOT	0.31 km SE	22.1 ± 0.9	21.2 ± 1.2	23.3 ± 1.0	17.1 ± 0.6	83.6 ± 11.0
PA SHOREFRONT PARKING	0.35 km NNW	20.9 ± 0.7	18.7 ± 0.7	18.9 ± 0.8	17.5 ± 1.1	76.0 ± 6.0
A STATION A	0.37 km WSW	19.8 ± 1.3	17.4 ± 0.8	18.5 ± 0.8	15.1 ± 0.7	70.9 ± 8.2
F STATION F	0.43 km NW	18.6 ± 0.7	17.5 ± 0.8	18.8 ± 0.9	15.4 ± 0.9	70.3 ± 6.4
EB EAST BREAKWATER	0.44 km ESE	19.8 ± 0.6	17.8 ± 0.9	19.7 ± 0.9	16.1 ± 1.1	73.4 ± 7.1
B STATION B	0.44 km S	23.7 ± 1.0	22.3 ± 1.2	24.0 ± 0.8	18.5 ± 1.1	88.6 ± 10.3
PMT PNPS MET TOWER	0.44 km WNW	21.0 ± 0.9	19.5 ± 0.8	20.6 ± 1.1	16.9 ± 0.9	78.0 ± 7.6
H STATION H	0.47 km SW	18.3 ± 1.5	20.7 ± 0.8	21.7 ± 1.6	17.1 ± 0.8	77.8 ± 8.8
I STATION I	0.48 km WNW	19.2 ± 1.3	17.7 ± 0.9	18.7 ± 0.6	15.2 ± 0.6	70.8 ± 7.3
L STATION L	0.50 km ESE	20.4 ± 1.2	18.9 ± 1.1	20.4 ± 0.8	15.4 ± 0.7	75.0 ± 9.6
G STATION G	0.53 km W	18.9 ± 1.0	Missing	17.1 ± 0.6	15.6 ± 0.8	68.8 ± 7.0
D STATION D	0.54 km NNW	20.3 ± 0.6	19.0 ± 0.7	19.9 ± 1.2	16.5 ± 0.7	75.6 ± 7.1
PL PROPERTY LINE	0.54 km NW	18.5 ± 0.6	16.4 ± 0.9	16.1 ± 0.7	15.7 ± 1.0	66.7 ± 5.3
C STATION C	0.57 km ESE	20.0 ± 1.3	17.8 ± 0.7	18.1 ± 1.0	15.9 ± 0.8	71.8 ± 7.0
HB HALL'S BOG	0.63 km SE	18.8 ± 0.8	16.7 ± 0.7	16.7 ± 0.9	15.5 ± 0.8	67.7 ± 5.9
GH GREENWOOD HOUSE	0.65 km ESE	Missing	18.2 ± 0.8	18.6 ± 1.3	17.1 ± 0.8	71.8 ± 3.9
WR W ROCKY HILL ROAD	0.83 km WNW	22.1 ± 0.8	20.3 ± 0.9	20.6 ± 0.9	17.7 ± 0.8	80.7 ± 7.5
ER E ROCKY HILL ROAD	0.89 km SE	15.1 ± 0.7	12.7 ± 0.7	13.5 ± 0.6	13.3 ± 0.8	54.6 ± 4.3
MT MICROWAVE TOWER	1.03 km SSW	19.4 ± 1.3	17.8 ± 0.8	17.9 ± 0.9	15.8 ± 0.7	71.0 ± 6.1
CR CLEFT ROCK	1.27 km SSW	18.6 ± 0.7	17.0 ± 1.0	17.1 ± 0.7	15.9 ± 0.6	68.7 ± 4.7
BD BAYSHORE/GATE RD	1.34 km WNW	18.9 ± 0.6	17.9 ± 0.7	17.9 ± 0.8	16.1 ± 0.8	70.7 ± 4.9
MR MANOMET ROAD	1.38 km S	20.4 ± 0.8	19.4 ± 1.3	20.5 ± 1.2	16.3 ± 0.9	76.6 ± 8.1
DR DIRT ROAD	1.48 km SW	16.2 ± 0.8	15.5 ± 0.6	15.5 ± 0.9	13.7 ± 0.8	61.0 ± 4.6
EM EMERSON ROAD	1.53 km SSE	14.7 ± 0.8	16.1 ± 0.7	15.6 ± 1.0	17.1 ± 0.8	63.5 ± 4.3
EP EMERSON/PRISCILLA	1.55 km SE	15.6 ± 1.0	15.7 ± 0.7	15.6 ± 0.7	16.9 ± 1.2	63.8 ± 3.2
AR EDISON ACCESS ROAD	1.59 km SSE	17.1 ± 0.9	14.8 ± 0.7	15.2 ± 1.2	14.2 ± 0.6	61.4 ± 5.3
BS BAYSHORE	1.76 km W	20.8 ± 1.2	18.6 ± 0.9	20.1 ± 1.0	16.1 ± 0.8	75.6 ± 8.4
E STATION E	1.86 km S	18.2 ± 0.9	16.1 ± 0.9	17.6 ± 1.1	14.9 ± 1.0	66.7 ± 6.3
JG JOHN GAULEY	1.99 km W	18.9 ± 0.7	18.1 ± 0.7	18.8 ± 1.3	16.1 ± 0.6	71.9 ± 5.5
J STATION J	2.04 km SSE	18.4 ± 1.1	16.0 ± 0.7	16.8 ± 0.7	14.0 ± 1.3	65.1 ± 7.6
WH WHITEHORSE ROAD	2.09 km SSE	15.9 ± 0.6	17.0 ± 0.8	16.3 ± 0.7	17.5 ± 0.6	66.7 ± 3.2
RC PLYMOUTH YMCA	2.09 km WSW	19.1 ± 0.9	16.9 ± 0.8	18.4 ± 0.6	14.9 ± 0.9	69.3 ± 7.5
K STATION K	2.17 km S	16.8 ± 0.7	14.7 ± 0.7	14.5 ± 0.7	14.1 ± 0.7	60.1 ± 5.0
TT TAYLOR/THOMAS	2.26 km SE	14.8 ± 0.5	15.0 ± 1.0	16.8 ± 1.2	16.7 ± 0.8	63.3 ± 4.8
YV YANKEE VILLAGE	2.28 km WSW	19.5 ± 1.6	17.8 ± 0.9	20.0 ± 0.8	15.1 ± 0.6	72.5 ± 9.1
GN GOODWIN PROPERTY	2.38 km SW	13.8 ± 0.5	12.6 ± 0.5	13.6 ± 0.6	11.8 ± 0.8	51.7 ± 3.9
RW RIGHT OF WAY	2.83 km S	12.5 ± 0.6	12.6 ± 0.7	13.5 ± 1.7	14.2 ± 0.6	52.8 ± 3.7
TP TAYLOR/PEARL	2.98 km SE	14.2 ± 1.0	14.0 ± 0.7	13.3 ± 0.8	15.3 ± 0.6	56.8 ± 3.6

* Distance and direction are measured from centerline of Reactor Building to the monitoring location.

** Annual value is based on arithmetic mean of the observed quarterly values multiplied by four quarters/year.

Table 2.4-1 (continued)

Offsite Environmental TLD Results

TLD Station ID Description	TLD Location* Distance/Direction	Quarterly Exposure - mR/quarter (Value ± Std.Dev.) Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	2011 Annual** Exposure mR/year
Zone 2 TLDs: 3-8 km	3-8 km	16.0 ± 2.1	15.2 ± 1.8	15.0 ± 2.5	14.9 ± 1.6	61.2 ± 8.2
VR VALLEY ROAD	3.26 km SSW	15.2 ± 0.7	13.6 ± 0.6	12.8 ± 0.6	14.7 ± 0.6	56.3 ± 4.4
ME MANOMET ELEM	3.29 km SE	14.8 ± 0.5	15.0 ± 0.7	15.2 ± 0.7	16.3 ± 0.9	61.2 ± 3.1
WC WARREN/CLIFFORD	3.31 km W	17.4 ± 0.6	15.8 ± 0.7	17.1 ± 0.7	14.4 ± 0.8	64.6 ± 5.5
BB RT.3A/BARTLETT RD	3.33 km SSE	18.7 ± 1.2	16.2 ± 1.1	18.1 ± 0.7	15.1 ± 0.9	68.1 ± 7.0
MP MANOMET POINT	3.57 km SE	17.3 ± 0.7	14.6 ± 1.1	14.0 ± 0.7	15.7 ± 0.7	61.6 ± 6.1
MS MANOMET SUBSTATION	3.60 km SSE	19.9 ± 0.7	18.6 ± 0.9	19.3 ± 0.9	16.4 ± 0.7	74.1 ± 6.3
BW BEACHWOOD ROAD	3.93 km SE	14.1 ± 0.6	15.3 ± 0.9	15.2 ± 0.7	16.0 ± 0.9	60.7 ± 3.6
PT PINES ESTATE	4.44 km SSW	15.5 ± 1.3	14.0 ± 0.7	12.8 ± 0.6	14.4 ± 1.0	56.7 ± 4.9
EA EARL ROAD	4.60 km SSE	15.8 ± 0.7	14.4 ± 0.7	14.9 ± 1.0	13.3 ± 0.6	58.4 ± 4.4
SP S PLYMOUTH SUBST	4.62 km W	17.5 ± 0.6	15.8 ± 0.6	14.7 ± 0.8	16.7 ± 0.7	64.8 ± 5.0
RP ROUTE 3 OVERPASS	4.81 km SW	18.3 ± 1.1	16.3 ± 1.0	15.7 ± 0.5	16.9 ± 1.0	67.2 ± 4.9
RM RUSSELL MILLS RD	4.85 km WSW	17.0 ± 0.9	15.0 ± 0.8	14.4 ± 0.7	14.5 ± 0.6	60.9 ± 5.1
HD HILLDALE ROAD	5.18 km W	17.5 ± 1.1	17.0 ± 0.7	19.0 ± 1.2	14.6 ± 0.7	68.1 ± 7.5
MB MANOMET BEACH	5.43 km SSE	15.7 ± 0.8	15.7 ± 0.9	14.5 ± 0.6	Missing	61.3 ± 3.2
BR BEAVERDAM ROAD	5.52 km S	13.6 ± 0.6	15.8 ± 1.1	15.3 ± 0.6	16.8 ± 0.8	61.4 ± 5.6
PC PLYMOUTH CENTER	6.69 km W	13.2 ± 0.5	11.4 ± 0.7	10.6 ± 0.6	11.3 ± 0.5	46.4 ± 4.6
LD LONG POND/DREW RD	6.97 km WSW	15.6 ± 1.7	13.3 ± 0.6	13.7 ± 0.7	12.8 ± 0.6	55.3 ± 5.3
HR HYANNIS ROAD	7.33 km SSE	14.2 ± 0.9	14.4 ± 0.8	13.5 ± 0.8	15.1 ± 0.6	57.2 ± 3.0
SN SAQUISH NECK	7.58 km NNW	11.6 ± 0.5	12.4 ± 0.5	10.4 ± 0.5	12.2 ± 0.6	46.6 ± 3.8
MH MEMORIAL HALL	7.58 km WNW	18.7 ± 0.8	19.1 ± 0.9	19.5 ± 0.6	Missing	76.5 ± 2.5
CP COLLEGE POND	7.59 km SW	15.4 ± 0.5	15.7 ± 1.3	14.6 ± 0.6	15.6 ± 0.6	61.3 ± 2.7
Zone 3 TLDs: 8-15 km	8-15 km	14.5 ± 1.4	14.9 ± 1.8	14.3 ± 2.4	15.0 ± 1.2	58.8 ± 6.8
DW DEEP WATER POND	8.59 km W	17.7 ± 1.1	18.1 ± 1.8	16.5 ± 0.6	16.8 ± 1.0	69.1 ± 3.9
LP LONG POND ROAD	8.88 km SSW	14.4 ± 1.1	13.6 ± 0.7	12.4 ± 0.5	14.2 ± 0.7	54.6 ± 3.8
NP NORTH PLYMOUTH	9.38 km WNW	Missing	17.8 ± 0.8	20.2 ± 1.1	17.1 ± 0.9	73.5 ± 6.9
SS STANDISH SHORES	10.39 km NW	13.2 ± 0.5	14.6 ± 0.9	13.7 ± 0.6	15.1 ± 1.0	56.5 ± 3.8
EL ELLISVILLE ROAD	11.52 km SSE	13.8 ± 1.1	14.9 ± 0.8	14.7 ± 0.5	15.6 ± 0.7	58.9 ± 3.4
UC UP COLLEGE POND RD	11.78 km SW	14.1 ± 0.8	13.0 ± 0.6	12.6 ± 0.8	13.6 ± 0.5	53.2 ± 2.9
SH SACRED HEART	12.92 km W	14.6 ± 0.6	14.6 ± 0.9	13.8 ± 0.6	14.5 ± 0.6	57.4 ± 1.9
KC KING CAESAR ROAD	13.11 km NNW	13.0 ± 0.6	14.9 ± 1.1	13.6 ± 0.7	14.8 ± 1.2	56.2 ± 4.2
BE BOURNE ROAD	13.37 km S	14.9 ± 0.8	13.3 ± 0.7	12.5 ± 0.7	13.9 ± 0.9	54.6 ± 4.3
SA SHERMAN AIRPORT	13.43 km WSW	15.2 ± 0.7	14.6 ± 0.7	13.3 ± 0.7	14.2 ± 0.7	57.3 ± 3.5
Zone 4 TLDs: >15 km	>15 km	15.3 ± 1.4	16.6 ± 2.0	15.7 ± 1.9	16.0 ± 1.6	63.7 ± 6.8
CS CEDARVILLE SUBST	15.93 km S	15.2 ± 0.5	16.9 ± 0.9	15.7 ± 1.7	16.3 ± 0.9	64.1 ± 3.7
KS KINGSTON SUBST	16.15 km WNW	16.7 ± 1.2	16.3 ± 0.7	15.0 ± 1.2	15.7 ± 0.7	63.6 ± 3.5
LR LANDING ROAD	16.46 km NNW	14.6 ± 1.1	15.3 ± 0.8	15.0 ± 0.8	15.0 ± 0.6	59.9 ± 2.0
CW CHURCH/WEST	16.56 km NW	13.0 ± 0.7	13.5 ± 0.6	12.7 ± 0.6	13.6 ± 0.9	52.9 ± 2.2
MM MAIN/MEADOW	17.02 km WSW	16.7 ± 0.7	16.3 ± 0.8	15.5 ± 0.7	15.7 ± 1.1	64.1 ± 2.7
DMF DIV MARINE FISH	20.97 km SSE	16.3 ± 1.0	19.5 ± 0.9	18.1 ± 0.9	18.6 ± 0.7	72.5 ± 5.7
EW E WEYMOUTH SUBST	39.69 km NW	14.7 ± 0.6	18.6 ± 1.1	17.9 ± 1.1	17.1 ± 0.9	68.4 ± 7.1

* Distance and direction are measured from centerline of Reactor Building to the monitoring location.
** Annual value is based on arithmetic mean of the observed quarterly values multiplied by four quarters/year.

Table 2.4-2

Onsite Environmental TLD Results

TLD Station	TLD Location*	Quarterly Exposure - mR/quarter (Value ± Std.Dev.)				2011 Annual** Exposure mR/year
ID Description	Distance/Direction	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	
Onsite TLDs						
P21 O&M/RXB. BREEZEWAY	50 m SE	28.9 ± 0.8	25.6 ± 1.1	29.5 ± 1.7	20.6 ± 0.8	104.6 ± 16.5
P24 EXEC.BUILDING	57 m W	52.1 ± 1.4	47.2 ± 1.6	59.6 ± 1.6	34.6 ± 1.1	193.5 ± 42.1
P04 FENCE-R SCREENHOUSE	66 m N	61.8 ± 2.4	68.2 ± 2.3	72.4 ± 5.0	48.3 ± 2.1	250.6 ± 42.6
P20 O&M - 2ND W WALL	67 m SE	36.3 ± 1.6	30.6 ± 1.9	42.7 ± 3.5	26.6 ± 2.3	136.3 ± 28.5
P25 EXEC.BUILDING LAWN	76 m WNW	47.5 ± 1.3	50.4 ± 2.0	55.6 ± 4.9	36.9 ± 2.0	190.5 ± 32.1
P05 FENCE-WATER TANK	81 m NNE	26.9 ± 1.4	25.0 ± 1.6	27.2 ± 1.5	21.1 ± 0.8	100.2 ± 11.5
P06 FENCE-OIL STORAGE	85 m NE	35.6 ± 1.0	30.7 ± 1.1	39.2 ± 1.6	29.5 ± 1.3	135.0 ± 18.2
P19 O&M - 2ND SW CORNER	86 m S	25.1 ± 0.9	21.5 ± 0.9	25.1 ± 0.9	18.9 ± 0.7	90.5 ± 12.2
P18 O&M - 1ST SW CORNER	90 m S	29.6 ± 2.2	29.7 ± 1.9	32.7 ± 2.5	23.9 ± 1.1	115.8 ± 15.3
P08 COMPRESSED GAS STOR	92 m E	36.7 ± 1.7	31.8 ± 2.2	40.9 ± 2.9	27.9 ± 1.7	137.3 ± 23.1
P03 FENCE-L SCREENHOUSE	100 m NW	40.0 ± 1.2	41.0 ± 1.9	44.6 ± 2.0	30.7 ± 3.1	156.3 ± 24.0
P17 FENCE-EXEC.BUILDING	107 m W	64.0 ± 2.5	59.1 ± 4.4	75.1 ± 4.3	44.2 ± 1.9	242.5 ± 51.8
P07 FENCE-INTAKE BAY	121 m ENE	31.8 ± 1.7	26.2 ± 1.8	34.0 ± 1.7	25.4 ± 1.4	117.4 ± 17.2
P23 O&M - 2ND S WALL	121 m SSE	25.9 ± 1.9	22.2 ± 1.0	26.8 ± 2.0	26.3 ± 0.9	101.2 ± 9.0
P26 FENCE-WAREHOUSE	134 m ESE	36.0 ± 1.2	31.3 ± 1.8	36.1 ± 1.8	23.5 ± 1.0	127.0 ± 23.9
P02 FENCE-SHOREFRONT	135 m NW	33.8 ± 0.9	30.5 ± 1.4	34.6 ± 1.6	23.3 ± 1.4	122.1 ± 20.8
P09 FENCE-W BOAT RAMP	136 m E	29.5 ± 1.4	Missing	34.3 ± 2.7	23.1 ± 1.0	115.9 ± 22.7
P22 O&M - 2ND N WALL	137 m SE	33.1 ± 1.3	27.7 ± 1.1	36.6 ± 2.7	18.7 ± 0.8	116.1 ± 31.4
P16 FENCE-W SWITCHYARD	172 m SW	92.4 ± 3.2	82.8 ± 2.7	107.6 ± 2.8	58.3 ± 3.9	341.2 ± 82.9
P11 FENCE-TCF GATE	183 m ESE	44.6 ± 2.0	60.0 ± 2.6	57.5 ± 2.7	31.2 ± 1.0	193.3 ± 53.3
P27 FENCE-TCF/BOAT RAMP	185 m ESE	25.1 ± 1.7	24.5 ± 1.0	24.5 ± 1.1	18.9 ± 0.8	93.0 ± 11.8
P12 FENCE-ACCESS GATE	202 m SE	27.4 ± 0.9	25.8 ± 1.5	28.4 ± 1.8	19.8 ± 0.9	101.4 ± 15.7
P15 FENCE-E SWITCHYARD	220 m S	29.2 ± 1.3	27.3 ± 1.0	29.1 ± 1.1	21.8 ± 0.9	107.4 ± 14.1
P10 FENCE-TCF/INTAKE BAY	223 m E	30.5 ± 1.7	29.5 ± 1.5	30.6 ± 1.0	21.3 ± 1.0	111.9 ± 18.2
P13 FENCE-MEDICAL BLDG.	224 m SSE	26.9 ± 2.3	25.2 ± 0.9	27.7 ± 1.0	20.0 ± 1.3	99.7 ± 14.2
P14 FENCE-BUTLER BLDG	228 m S	22.8 ± 0.7	21.5 ± 0.8	24.3 ± 0.9	17.5 ± 0.7	86.1 ± 11.8
P28 FENCE-TCF/PRKNG LOT	259 m ESE	91.5 ± 4.2	173.2 ± 7.5	120.9 ± 4.5	39.7 ± 2.5	425.3 ± 223.5

* Distance and direction are measured from centerline of Reactor Building to the monitoring location.

** Annual value is based on arithmetic mean of the observed quarterly values multiplied by four quarters/year.

Table 2.4-3

Average TLD Exposures By Distance Zone During 2011

Exposure Period	Average Exposure ± Standard Deviation: mR/period			
	Zone 1* 0-3 km	Zone 2 3-8 km	Zone 3 8-15 km	Zone 4 >15 km
Jan-Mar	20.7 ± 7.0	16.0 ± 2.1	14.5 ± 1.4	15.3 ± 1.4
Apr-Jun	19.1 ± 6.0	15.2 ± 1.8	14.9 ± 1.8	16.6 ± 2.0
Jul-Sep	20.3 ± 8.0	15.0 ± 2.5	14.3 ± 2.4	15.7 ± 1.9
Oct-Dec	16.9 ± 4.0	14.9 ± 1.6	15.0 ± 1.2	16.0 ± 1.6
Jan-Dec	77.0 ± 26.1**	61.2 ± 8.2	58.8 ± 6.8	63.7 ± 6.8

* Zone 1 extends from the PNPS restricted/protected area boundary outward to 3 kilometers (2 miles), and includes several TLDs located within the site boundary.

** When corrected for TLDs located within the site boundary, the Zone 1 annual average is calculated to be 65.9 ± 8.8 mR/yr.

Table 2.5-1
Air Particulate Filter Radioactivity Analyses

Radiological Environmental Program Summary
Pilgrim Nuclear Power Station, Plymouth, MA
(January - December 2011)

MEDIUM: Air Particulates (AP) UNITS: pCi/cubic meter

Radionuclide	No. Analyses Non-routine*	Required LLD	Indicator Stations Mean ± Std.Dev. Range Fraction>LLD	Station with Highest Mean Station: Mean ± Std.Dev. Range Fraction>LLD	Control Stations Mean ± Std.Dev. Range Fraction>LLD
Gross Beta	581 0	0.01	1.4E-2 ± 5.4E-3 3.0E-3 - 3.2E-2 528 / 528	PB: 1.5E-2 ± 5.6E-3 4.0E-3 - 3.2E-2 53 / 53	1.4E-2 ± 5.6E-3 4.0E-3 - 3.4E-2 53 / 53
Be-7	44 0		9.8E-2 ± 2.4E-2 4.1E-2 - 1.5E-1 40 / 40	WR: 1.2E-1 ± 2.0E-2 9.7E-2 - 1.4E-1 4 / 4	9.4E-2 ± 1.9E-2 7.8E-2 - 1.1E-1 4 / 4
K-40	44 0		5.9E-2 ± 9.9E-3 <LLD - 7.0E-2 5 / 40	PL: 7.0E-2 ± 1.7E-2 <LLD - 7.0E-2 1 / 4	<LLD <LLD 0 / 4
Ra-226	44 0		1.9E-2 ± 1.0E-2 <LLD - 1.9E-2 1 / 40	PC: 1.9E-2 ± 1.0E-2 <LLD - 1.9E-2 1 / 4	<LLD <LLD 0 / 4
Cs-134	44 0	0.05	<LLD <LLD 0 / 40	<LLD <LLD 0 / 4	<LLD <LLD 0 / 4
Cs-137	44 0	0.06	<LLD <LLD 0 / 40	<LLD <LLD 0 / 4	<LLD <LLD 0 / 4

* Non-Routine refers to those radionuclides that exceeded the Reporting Levels in ODCM Table 3.5-4.

Table 2.6-1
Charcoal Cartridge Radioactivity Analyses

Radiological Environmental Program Summary
Pilgrim Nuclear Power Station, Plymouth, MA
(January - December 2011)

MEDIUM: Charcoal Cartridge (CF) UNITS: pCi/cubic meter

Radionuclide	No. Analyses Non-routine*	Required LLD	Indicator Stations Mean ± Std.Dev. Range Fraction>LLD	Station with Highest Mean Station: Mean ± Std.Dev. Range Fraction>LLD	Control Stations Mean ± Std.Dev. Range Fraction>LLD
I-131	581 0	0.07	7.2E-2 ± 2.9E-2 <LLD - 1.2E-1 21 / 528	EB: 9.6E-2 ± 3.2E-2 <LLD - 1.2E-1 2 / 53	6.4E-2 ± 2.9E-2 <LLD - 9.3E-2 3 / 53

* Non-Routine refers to those radionuclides that exceeded the Reporting Levels in ODCM Table 3.5-4.

Table 2.7-1
Milk Radioactivity Analyses

Radiological Environmental Program Summary
Pilgrim Nuclear Power Station, Plymouth, MA
(January - December 2011)

No milk sampling was performed during 2011, as no suitable indicator locations for milk production were available for sampling within 5 miles of Pilgrim Station.

Table 2.8-1
Forage Radioactivity Analyses

Radiological Environmental Program Summary
Pilgrim Nuclear Power Station, Plymouth, MA
(January - December 2011)

No forage sampling was performed during 2011, as no grazing animals used for food products were available at any indicator locations within 5 miles of Pilgrim Station.

Table 2.9-1
Vegetable/Vegetation Radioactivity Analyses

Radiological Environmental Program Summary
Pilgrim Nuclear Power Station, Plymouth, MA
(January - December 2011)

MEDIUM: Vegetation (TF) UNITS: pCi/kg wet

Radionuclide	No. Analyses Non-routine*	Required LLD	Indicator Stations Mean ± Std.Dev. Range Fraction>LLD	Station with Highest Mean Station: Mean ± Std.Dev. Range Fraction>LLD	Control Stations Mean ± Std.Dev. Range Fraction>LLD
Be-7	25 0		3.1E+3 ± 1.8E+3 <LLD - 6.8E+3 12 / 18	PineHills: 6.3E+3 ± 2.1E+2 6.3E+3 - 6.3E+3 1 / 1	2.4E+3 ± 1.3E+3 <LLD - 3.5E+3 3 / 7
K-40	25 0		4.3E+3 ± 1.6E+3 2.1E+3 - 8.2E+3 18 / 18	HallsBog: 8.2E+3 ± 3.1E+2 8.2E+3 - 8.2E+3 1 / 1	3.8E+3 ± 1.9E+3 1.6E+3 - 7.3E+3 7 / 7
I-131	25 0	60	<LLD <LLD 0 / 18	<LLD <LLD 0 / 18	<LLD <LLD 0 / 7
Cs-134	25 0	60	<LLD <LLD 0 / 18	<LLD <LLD 0 / 18	<LLD <LLD 0 / 7
Cs-137	25 0	80	1.1E+2 ± 5.5E+1 <LLD - 1.9E+2 6 / 18	CleftRock: 1.4E+2 ± 3.7E+1 1.0E+2 - 1.9E+2 4 / 4	<LLD <LLD 0 / 7
Ra-226	25 0		5.7E+2 ± 4.0E+2 <LLD - 1.6E+3 17 / 18	Greenwood: 1.6E+3 ± 1.9E+2 1.6E+3 - 1.6E+3 1 / 1	3.3E+2 ± 3.1E+2 1.2E+2 - 8.8E+2 7 / 7
AcTh-228	25 0		1.8E+2 ± 2.1E+2 <LLD - 7.7E+2 11 / 18	Greenwood: 7.7E+2 ± 4.7E+1 7.7E+2 - 7.7E+2 1 / 1	1.5E+2 ± 1.1E+2 <LLD - 2.2E+2 3 / 7

* Non-Routine refers to those radionuclides that exceeded the Reporting Levels in ODCM Table 3.5-4.

Table 2.10-1
Cranberry Radioactivity Analyses

Radiological Environmental Program Summary
Pilgrim Nuclear Power Station, Plymouth, MA
(January - December 2011)

MEDIUM: Cranberries (CB) UNITS: pCi/kg wet

Radionuclide	No. Analyses Non-routine*	Required LLD	Indicator Stations Mean ± Std.Dev. Range Fraction>LLD	Station with Highest Mean Station: Mean ± Std.Dev. Range Fraction>LLD	Control Stations Mean ± Std.Dev. Range Fraction>LLD
Be-7	3 0		5.1E+2 ± 4.8E+2 1.7E+2 - 8.5E+2 2 / 2	BVDM: 8.5E+2 ± 6.9E+1 8.5E+2 - 8.5E+2 1 / 1	<LLD <LLD 0 / 1
K-40	3 0		1.2E+3 ± 2.9E+2 1.0E+3 - 1.4E+3 2 / 2	HollBog: 1.4E+3 ± 9.3E+1 1.4E+3 - 1.4E+3 1 / 1	1.4E+3 ± 9.3E+1 1.4E+3 - 1.4E+3 1 / 1
I-131	3 0	60	<LLD <LLD 0 / 1	<LLD <LLD 0 / 1	<LLD <LLD 0 / 1
Cs-134	3 0	60	<LLD <LLD 0 / 1	<LLD <LLD 0 / 1	<LLD <LLD 0 / 1
Cs-137	3 0	80	<LLD <LLD 0 / 1	<LLD <LLD 0 / 1	<LLD <LLD 0 / 1
Ra-226	3 0		1.4E+2 ± 6.3E+1 <LLD - 1.4E+2 1 / 2	HollBog: 4.4E+2 ± 8.8E+1 4.4E+2 - 4.4E+2 1 / 1	4.4E+2 ± 8.8E+1 4.4E+2 - 4.4E+2 1 / 1
AcTh-228	3 0		5.8E+1 ± 2.0E+1 <LLD - 5.8E+1 1 / 2	BVDM: 5.8E+1 ± 2.0E+1 5.8E+1 - 5.8E+1 1 / 1	5.6E+1 ± 1.6E+1 5.6E+1 - 5.6E+1 1 / 1

* Non-Routine refers to those radionuclides that exceeded the Reporting Levels in ODCM Table 3.5-4.

Table 2.12-1
Surface Water Radioactivity Analyses

Radiological Environmental Program Summary
Pilgrim Nuclear Power Station, Plymouth, MA
(January - December 2011)

MEDIUM: Surface Water (WS) UNITS: pCi/kg

Radionuclide	No. Analyses	Required	Indicator Stations	Station with Highest Mean	Control Stations
H-3	12 0	3000	<LLD <LLD 0 / 8	<LLD <LLD 0 / 4	<LLD <LLD 0 / 4
Be-7	36 0		<LLD <LLD 0 / 24	<LLD <LLD 0 / 12	<LLD <LLD 0 / 12
K-40	36 0		2.7E+2 ± 1.4E+2 4.5E+1 - 5.0E+2 24 / 24	PP: 5.1E+2 ± 9.6E+1 3.4E+2 - 6.2E+2 12 / 12	5.1E+2 ± 9.6E+1 3.4E+2 - 6.2E+2 12 / 12
Mn-54	36 0	15	<LLD <LLD 0 / 24	<LLD <LLD 0 / 12	<LLD <LLD 0 / 12
Fe-59	36 0	30	<LLD <LLD 0 / 24	<LLD <LLD 0 / 12	<LLD <LLD 0 / 12
Co-58	36 0	15	<LLD <LLD 0 / 24	<LLD <LLD 0 / 12	<LLD <LLD 0 / 12
Co-60	36 0	15	<LLD <LLD 0 / 24	<LLD <LLD 0 / 12	<LLD <LLD 0 / 12
Zn-65	36 0	30	<LLD <LLD 0 / 24	<LLD <LLD 0 / 12	<LLD <LLD 0 / 12
Zr-95	36 0	30	<LLD <LLD 0 / 24	<LLD <LLD 0 / 12	<LLD <LLD 0 / 12
Nb-95	36 0	15	<LLD <LLD 0 / 24	<LLD <LLD 0 / 12	<LLD <LLD 0 / 12
I-131	36 0	15	<LLD <LLD 0 / 24	<LLD <LLD 0 / 12	<LLD <LLD 0 / 12
Cs-134	36 0	15	<LLD <LLD 0 / 24	<LLD <LLD 0 / 12	<LLD <LLD 0 / 12
Cs-137	36 0	18	<LLD <LLD 0 / 24	<LLD <LLD 0 / 12	<LLD <LLD 0 / 12
Ba-140	36 0	60	<LLD <LLD 0 / 24	<LLD <LLD 0 / 12	<LLD <LLD 0 / 12
La-140	36 0	15	<LLD <LLD 0 / 24	<LLD <LLD 0 / 12	<LLD <LLD 0 / 12
Ra-226	36 0		8.6E+1 ± 2.5E+1 <LLD - 1.4E+2 22 / 24	PP: 1.0E+2 ± 3.7E+1 5.5E+1 - 1.6E+2 12 / 12	1.0E+2 ± 3.7E+1 5.5E+1 - 1.6E+2 12 / 12
AcTh-228	36 0		7.1E+0 ± 2.0E+0 <LLD - 8.8E+0 7 / 24	BP: 7.6E+0 ± 1.9E+0 <LLD - 8.7E+0 3 / 12	7.2E+0 ± 1.9E+0 <LLD - 8.9E+0 4 / 12

* Non-Routine refers to those radionuclides that exceeded the Reporting Levels in ODCM Table 3.5-4.

Table 2.13-1
Sediment Radioactivity Analyses

Radiological Environmental Program Summary
Pilgrim Nuclear Power Station, Plymouth, MA
(January - December 2011)

MEDIUM: Sediment (SE) UNITS: pCi/kg dry

Radionuclide	No. Analyses Non-routine*	Required LLD	Indicator Stations Mean ± Std.Dev. Range Fraction>LLD	Station with Highest Mean Station: Mean ± Std.Dev. Range Fraction>LLD	Control Stations Mean ± Std.Dev. Range Fraction>LLD
Be-7	12 0		3.7E+2 ± 1.4E+2 <LLD - 3.7E+2 1 / 8	DUX: 9.4E+2 ± 2.9E+2 7.6E+2 - 1.1E+3 2 / 2	7.1E+2 ± 4.5E+2 <LLD - 1.1E+3 3 / 4
K-40	12 0		1.2E+4 ± 3.0E+3 8.5E+3 - 1.8E+4 8 / 8	DUX: 1.4E+4 ± 9.8E+2 1.3E+4 - 1.4E+4 2 / 2	1.3E+4 ± 2.4E+3 9.2E+3 - 1.4E+4 4 / 4
Cs-134	12 0	150	<LLD <LLD 0 / 8	<LLD <LLD 0 / 2	<LLD <LLD 0 / 3
Cs-137	12 0	180	<LLD <LLD 0 / 8	<LLD <LLD 0 / 2	<LLD <LLD 0 / 3
Ra-226	12 0		8.5E+2 ± 2.9E+2 3.8E+2 - 1.3E+3 8 / 8	DUX: 1.4E+3 ± 3.3E+2 1.2E+3 - 1.5E+3 2 / 2	1.2E+3 ± 3.8E+2 7.8E+2 - 1.5E+3 4 / 4
AcTh-228	12 0		3.3E+2 ± 1.6E+2 2.2E+2 - 7.0E+2 8 / 8	DUX: 5.6E+2 ± 2.5E+2 3.9E+2 - 7.4E+2 2 / 2	4.9E+2 ± 2.2E+2 <LLD - 7.4E+2 3 / 4

* Non-Routine refers to those radionuclides that exceeded the Reporting Levels in ODCM Table 3.5-4.

Table 2.14-1
Irish Moss Radioactivity Analyses

Radiological Environmental Program Summary
Pilgrim Nuclear Power Station, Plymouth, MA
(January - December 2011)

MEDIUM: Irish Moss (AL) UNITS: pCi/kg wet

Radionuclide	No. Analyses Non-routine*	Required LLD	Indicator Stations Mean ± Std.Dev. Range Fraction>LLD	Station with Highest Mean Station: Mean ± Std.Dev. Range Fraction>LLD	Control Stations Mean ± Std.Dev. Range Fraction>LLD
Be-7	8 0		2.7E+2 ± 1.4E+2 1.3E+2 - 4.4E+2 6 / 6	EL: 2.8E+2 ± 2.3E+2 1.3E+2 - 4.4E+2 2 / 2	<LLD <LLD 0 / 2
K-40	8 0		6.2E+3 ± 1.1E+3 4.7E+3 - 7.5E+3 6 / 6	EL: 7.2E+3 ± 4.9E+2 6.9E+3 - 7.5E+3 2 / 2	5.9E+3 ± 7.3E+2 5.4E+3 - 6.4E+3 2 / 2
Mn-54	8 0	130	<LLD <LLD 0 / 6	<LLD <LLD 0 / 2	<LLD <LLD 0 / 2
Fe-59	8 0	260	<LLD <LLD 0 / 6	<LLD <LLD 0 / 2	<LLD <LLD 0 / 2
Co-58	8 0	130	<LLD <LLD 0 / 6	<LLD <LLD 0 / 2	<LLD <LLD 0 / 2
Co-60	8 0	130	<LLD <LLD 0 / 6	<LLD <LLD 0 / 2	<LLD <LLD 0 / 2
Zn-65	8 0	260	<LLD <LLD 0 / 6	<LLD <LLD 0 / 2	<LLD <LLD 0 / 2
I-131	8 0		2.8E+1 ± 8.3E+0 <LLD - 3.8E+1 3 / 6	DIS: 3.8E+1 ± 6.4E+0 <LLD - 3.8E+1 1 / 2	3.4E+1 ± 9.1E+0 2.9E+1 - 3.9E+1 2 / 2
Cs-134	8 0	130	<LLD <LLD 0 / 6	<LLD <LLD 0 / 2	<LLD <LLD 0 / 2
Cs-137	8 0	150	<LLD <LLD 0 / 6	<LLD <LLD 0 / 2	<LLD <LLD 0 / 2
Ra-226	8 0		2.9E+2 ± 1.2E+2 <LLD - 3.9E+2 4 / 6	MP: 3.6E+2 ± 9.1E+1 3.4E+2 - 3.9E+2 2 / 2	2.0E+2 ± 8.6E+1 <LLD - 2.0E+2 1 / 2
AcTh-228	8 0		5.0E+1 ± 1.5E+1 <LLD - 5.0E+1 1 / 6	5.0E+1 ± 1.5E+1 <LLD - 5.0E+1 1 / 2	<LLD <LLD 0 / 2

* Non-Routine refers to those radionuclides that exceeded the Reporting Levels in ODCM Table 3.5-4.

Table 2.15-1
Shellfish Radioactivity Analyses

Radiological Environmental Program Summary
Pilgrim Nuclear Power Station, Plymouth, MA
(January - December 2011)

MEDIUM: Shellfish (SF) UNITS: pCi/kg wet

Radionuclide	No. Analyses Non-routine*	Required LLD	Indicator Stations Mean ± Std.Dev. Range Fraction>LLD	Station with Highest Mean Station: Mean ± Std.Dev. Range Fraction>LLD	Control Stations Mean ± Std.Dev. Range Fraction>LLD
Be-7	10 0		<LLD <LLD 0 / 6	<LLD <LLD 0 / 4	<LLD <LLD 0 / 4
K-40	10 0		3.0E+3 ± 4.9E+2 2.6E+3 - 3.9E+3 6 / 6	GH: 3.8E+3 ± 9.2E+2 3.2E+3 - 4.4E+3 2 / 2	3.2E+3 ± 1.1E+3 1.9E+3 - 4.4E+3 4 / 4
Mn-54	10 0	130	<LLD <LLD 0 / 6	<LLD <LLD 0 / 4	<LLD <LLD 0 / 4
Fe-59	10 0	260	<LLD <LLD 0 / 6	<LLD <LLD 0 / 4	<LLD <LLD 0 / 4
Co-58	10 0	130	<LLD <LLD 0 / 6	<LLD <LLD 0 / 4	<LLD <LLD 0 / 4
Co-60	10 0	130	<LLD <LLD 0 / 6	<LLD <LLD 0 / 4	<LLD <LLD 0 / 4
Zn-65	10 0	260	<LLD <LLD 0 / 6	<LLD <LLD 0 / 4	<LLD <LLD 0 / 4
Cs-134	10 0	130	<LLD <LLD 0 / 6	<LLD <LLD 0 / 4	<LLD <LLD 0 / 4
Cs-137	10 0	150	<LLD <LLD 0 / 6	<LLD <LLD 0 / 4	<LLD <LLD 0 / 4
Ra-226	10 0		9.7E+2 ± 3.3E+2 <LLD - 1.2E+3 3 / 6	DIS: 1.2E+3 ± 4.4E+2 <LLD - 1.2E+3 1 / 2	6.5E+2 ± 3.6E+2 <LLD - 9.7E+2 3 / 4
AcTh-228	10 0		<LLD <LLD 0 / 6	<LLD <LLD 0 / 4	<LLD <LLD 0 / 4

* Non-Routine refers to those radionuclides that exceeded the Reporting Levels in ODCM Table 3.5-4.

Table 2.16-1
Lobster Radioactivity Analyses

Radiological Environmental Program Summary
Pilgrim Nuclear Power Station, Plymouth, MA
(January - December 2011)

MEDIUM: American Lobster (HA) UNITS: pCi/kg wet

Radionuclide	No. Analyses Non-routine*	Required LLD	Indicator Stations Mean ± Std.Dev. Range Fraction>LLD	Station with Highest Mean Station: Mean ± Std.Dev. Range Fraction>LLD	Control Stations Mean ± Std.Dev. Range Fraction>LLD
Be-7	5 0		<LLD <LLD 0 / 4	<LLD <LLD 0 / 4	<LLD <LLD 0 / 1
K-40	5 0		2.2E+3 ± 3.6E+2 1.8E+3 - 2.5E+3 4 / 4	CCBay: 3.3E+3 ± 3.1E+2 3.3E+3 - 3.3E+3 1 / 1	3.3E+3 ± 3.1E+2 3.3E+3 - 3.3E+3 1 / 1
Mn-54	5 0	130	<LLD <LLD 0 / 4	<LLD <LLD 0 / 4	<LLD <LLD 0 / 1
Fe-59	5 0	260	<LLD <LLD 0 / 4	<LLD <LLD 0 / 4	<LLD <LLD 0 / 1
Co-58	5 0	130	<LLD <LLD 0 / 4	<LLD <LLD 0 / 4	<LLD <LLD 0 / 1
Co-60	5 0	130	<LLD <LLD 0 / 4	<LLD <LLD 0 / 4	<LLD <LLD 0 / 1
Zn-65	5 0	260	<LLD <LLD 0 / 4	<LLD <LLD 0 / 4	<LLD <LLD 0 / 1
Cs-134	5 0	130	<LLD <LLD 0 / 4	<LLD <LLD 0 / 4	<LLD <LLD 0 / 1
Cs-137	5 0	150	<LLD <LLD 0 / 4	<LLD <LLD 0 / 4	<LLD <LLD 0 / 1
Ra-226	5 0		6.8E+2 ± 2.2E+2 <LLD - 6.8E+2 1 / 4	DIS: 6.8E+2 ± 2.2E+2 <LLD - 6.8E+2 1 / 4	<LLD <LLD 0 / 1
AcTh-228	5 0		<LLD <LLD 0 / 4	<LLD <LLD 0 / 4	<LLD <LLD 0 / 1

* Non-Routine refers to those radionuclides that exceeded the Reporting Levels in ODCM Table 3.5-4.

Table 2.17-1
Fish Radioactivity Analyses

Radiological Environmental Program Summary
Pilgrim Nuclear Power Station, Plymouth, MA
(January - December 2011)

MEDIUM: Fish (FH) UNITS: pCi/kg wet

Radionuclide	No. Analyses Non-routine*	Required LLD	Indicator Stations Mean ± Std.Dev. Range Fraction>LLD	Station with Highest Mean Station: Mean ± Std.Dev. Range Fraction>LLD	Control Stations Mean ± Std.Dev. Range Fraction>LLD
Be-7	10 0		<LLD <LLD 0 / 6	<LLD <LLD 0 / 5	<LLD <LLD 0 / 5
K-40	10 0		4.9E+3 ± 1.3E+3 3.7E+3 - 6.9E+3 5 / 5	CCBay: 5.4E+3 ± 7.1E+2 4.6E+3 - 5.8E+3 3 / 3	5.2E+3 ± 9.9E+2 3.8E+3 - 6.0E+3 5 / 5
Mn-54	10 0	130	<LLD <LLD 0 / 5	<LLD <LLD 0 / 5	<LLD <LLD 0 / 5
Fe-59	10 0	260	<LLD <LLD 0 / 5	<LLD <LLD 0 / 5	<LLD <LLD 0 / 5
Co-58	10 0	130	<LLD <LLD 0 / 5	<LLD <LLD 0 / 5	<LLD <LLD 0 / 5
Co-60	10 0	130	<LLD <LLD 0 / 5	<LLD <LLD 0 / 5	<LLD <LLD 0 / 5
Zn-65	10 0	260	<LLD <LLD 0 / 5	<LLD <LLD 0 / 5	<LLD <LLD 0 / 5
Cs-134	10 0	130	<LLD <LLD 0 / 5	<LLD <LLD 0 / 5	<LLD <LLD 0 / 5
Cs-137	10 0	150	<LLD <LLD 0 / 5	<LLD <LLD 0 / 5	<LLD <LLD 0 / 5
Ra-226	10 0		1.0E+3 ± 2.8E+2 <LLD - 1.1E+3 2 / 5	DIS: 1.0E+3 ± 2.8E+2 <LLD - 1.1E+3 2 / 5	8.7E+2 ± 3.4E+2 5.4E+2 - 1.3E+3 5 / 5
AcTh-228	10 0		<LLD <LLD 0 / 5	<LLD <LLD 0 / 5	<LLD <LLD 0 / 5

* Non-Routine refers to those radionuclides that exceeded the Reporting Levels in ODCM Table 3.5-4.

Figure 2.2-1

Environmental TLD Locations Within the PNPS Protected Area

TLD Station		Location*
Description	Code	Distance/Direction
TLDs Within Protected Area		
O&M/RXB. BREEZEWAY	P21	50 m SE
EXEC.BUILDING	P24	57 m W
FENCE-R SCREENHOUSE	P04	66 m N
O&M - 2ND W WALL	P20	67 m SE
EXEC.BUILDING LAWN	P25	76 m WNW
FENCE-WATER TANK	P05	81 m NNE
FENCE-OIL STORAGE	P06	85 m NE
O&M - 2ND SW CORNER	P19	86 m S
O&M - 1ST SW CORNER	P18	90 m S
COMPRESSED GAS STOR	P08	92 m E
FENCE-L SCREENHOUSE	P03	100 m NW
FENCE-EXEC.BUILDING	P17	107 m W
O&M - 2ND S WALL	P23	121 m ENE
FENCE-INTAKE BAY	P07	121 m SSE
FENCE-WAREHOUSE	P26	134 m ESE
FENCE-SHOREFRONT	P02	135 m NW
FENCE-W BOAT RAMP	P09	136 m E
O&M - 2ND N WALL	P22	137 m SE
FENCE-W SWITCHYARD	P16	172 m SW
FENCE-TCF GATE	P11	183 m ESE
FENCE-TCF/BOAT RAMP	P27	185 m ESE
FENCE-ACCESS GATE	P12	202 m SE
FENCE-E SWITCHYARD	P15	220 m S
FENCE-TCF/INTAKE BAY	P10	223 m E
FENCE-MEDICAL BLDG.	P13	224 m SSE
FENCE-BUTLER BLDG	P14	228 m S
FENCE-TCF/PRKNG LOT	P28	259 m ESE

* Distance and direction are measured from centerline of Reactor Building to the monitoring location.

Figure 2.2-1 (continued)
Environmental TLD Locations Within the PNPS Protected Area

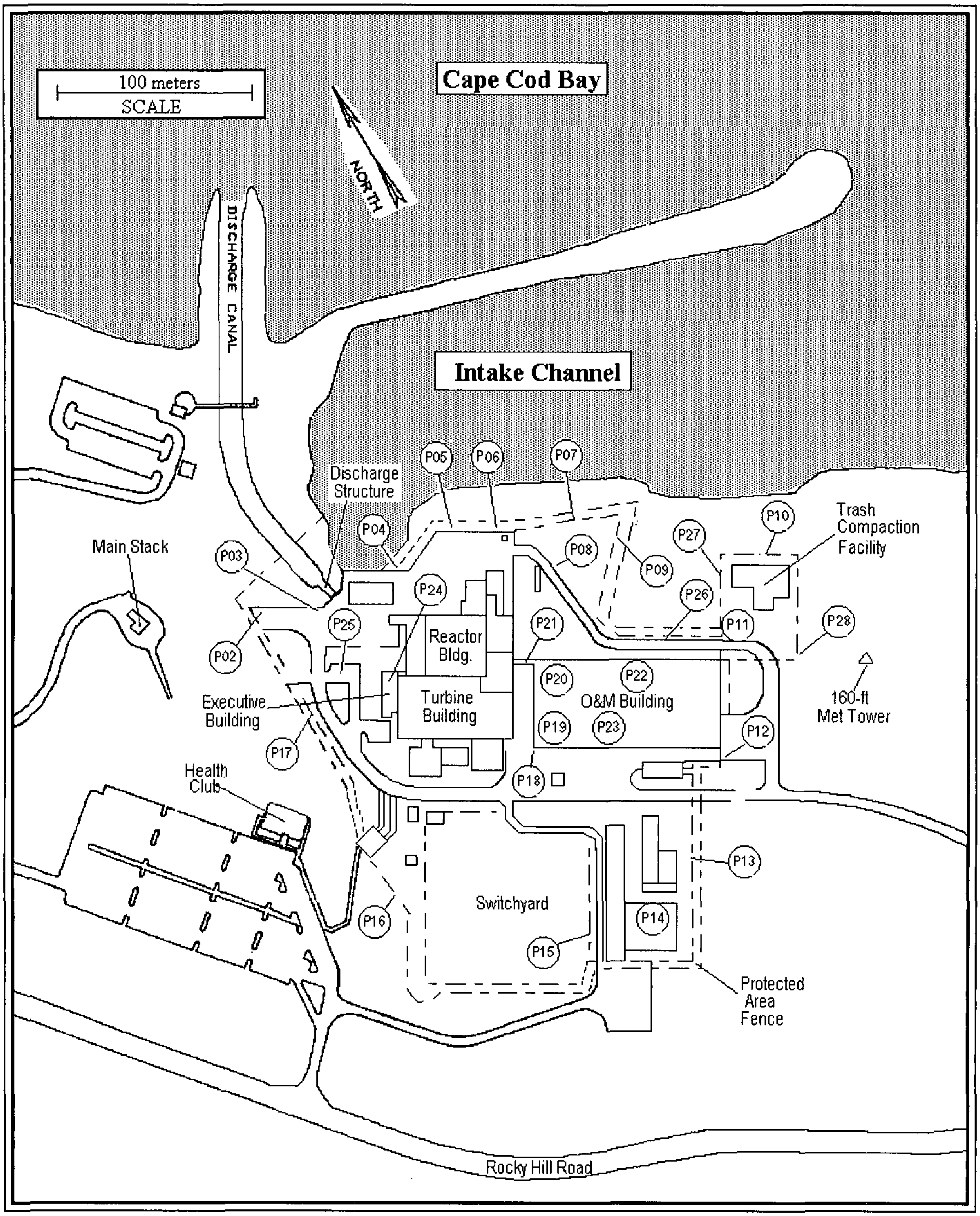


Figure 2.2-2

TLD and Air Sampling Locations: Within 1 Kilometer

TLD Station		Location*	Air Sampling Station		Location*
Description	Code	Distance/Direction	Description	Code	Distance/Direction
Zone 1 TLDs: 0-3 km					
BOAT LAUNCH WEST	BLW	0.11 km E	OVERLOOK AREA	OA	0.15 km W
OVERLOOK AREA	OA	0.15 km W	PEDESTRIAN BRIDGE	PB	0.21 km N
HEALTH CLUB	TC	0.15 km WSW	MEDICAL BUILDING	WS	0.23 km SSE
BOAT LAUNCH EAST	BLE	0.16 km ESE	EAST BREAKWATER	EB	0.44 km ESE
PEDESTRIAN BRIDGE	PB	0.21 km N	PROPERTY LINE	PL	0.54 km NNW
SHOREFRONT SECURITY	P01	0.22 km NNW	W ROCKY HILL ROAD	WR	0.83 km WNW
MEDICAL BUILDING	WS	0.23 km SSE	E ROCKY HILL ROAD	ER	0.89 km SE
PARKING LOT	CT	0.31 km SE			
SHOREFRONT PARKING	PA	0.35 km NNW			
STATION A	A	0.37 km WSW			
STATION F	F	0.43 km NW			
STATION B	B	0.44 km S			
EAST BREAKWATER	EB	0.44 km ESE			
PNPS MET TOWER	PMT	0.44 km WNW			
STATION H	H	0.47 km SW			
STATION I	I	0.48 km WNW			
STATION L	L	0.50 km ESE			
STATION G	G	0.53 km W			
STATION D	D	0.54 km NW			
PROPERTY LINE	PL	0.54 km NNW			
STATION C	C	0.57 km ESE			
HALL'S BOG	HB	0.63 km SE			
GREENWOOD HOUSE	GH	0.65 km ESE			
W ROCKY HILL ROAD	WR	0.83 km WNW			
E ROCKY HILL ROAD	ER	0.89 km SE			

Figure 2.2-2 (continued)

TLD and Air Sampling Locations: Within 1 Kilometer

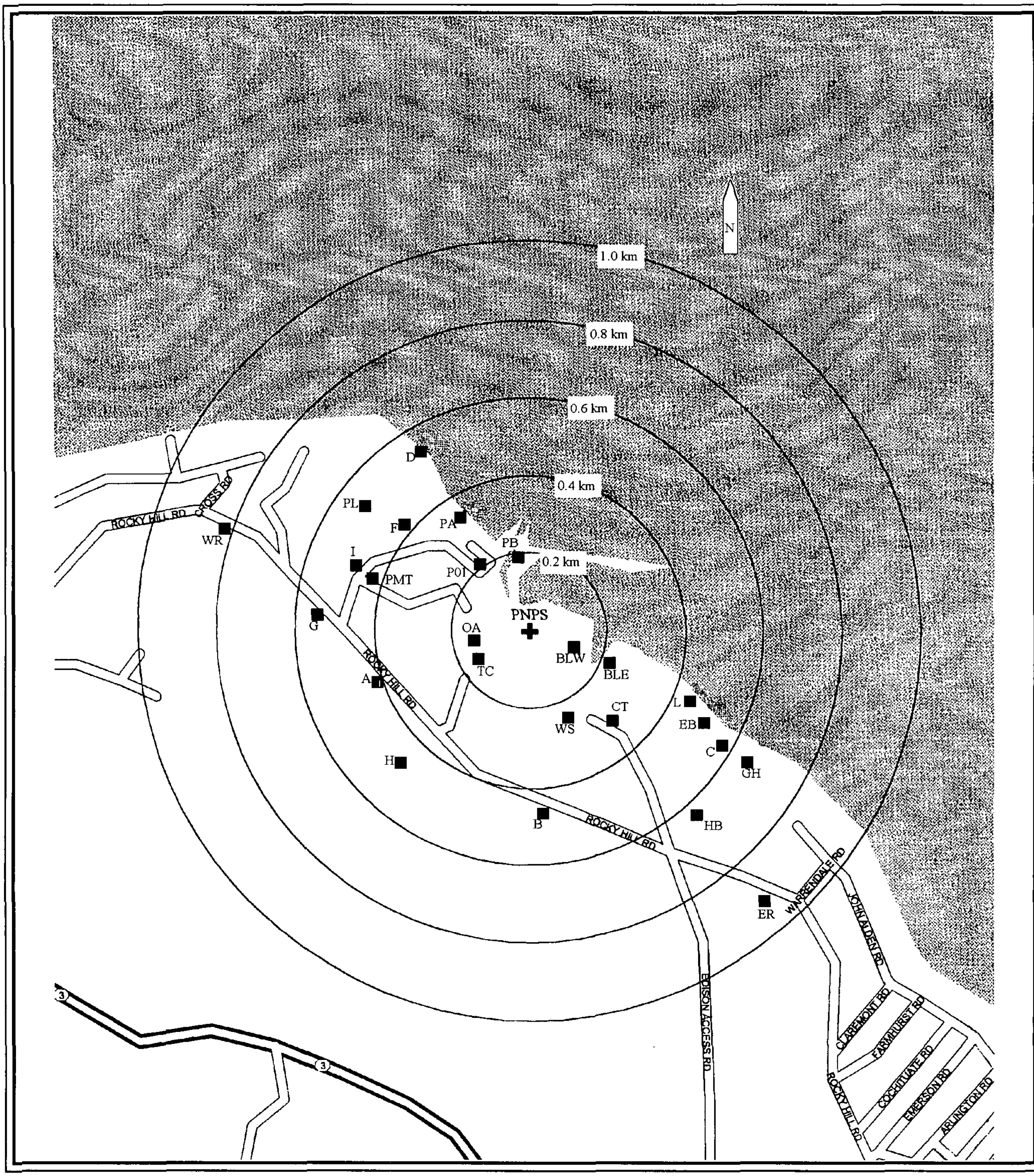


Figure 2.2-3

TLD and Air Sampling Locations: 1 to 5 Kilometers

TLD Station		Location*	Air Sampling Station		Location*
Description	Code	Distance/Direction	Description	Code	Distance/Direction
Zone 1 TLDs: 0-3 km					
MICROWAVE TOWER	MT	1.03 km SSW	CLEFT ROCK	CR	1.27 km SSW
CLEFT ROCK	CR	1.27 km SSW	MANOMET SUBSTATION	MS	3.60 km SSE
BAYSHORE/GATE RD	BD	1.34 km WNW			
MANOMET ROAD	MR	1.38 km S			
DIRT ROAD	DR	1.48 km SW			
EMERSON ROAD	EM	1.53 km SSE			
EMERSON/PRISCILLA	EP	1.55 km SE			
EDISON ACCESS ROAD	AR	1.59 km SSE			
BAYSHORE	BS	1.76 km W			
STATION E	E	1.86 km S			
JOHN GAULEY	JG	1.99 km W			
STATION J	J	2.04 km SSE			
WHITEHORSE ROAD	WH	2.09 km SSE			
PLYMOUTH YMCA	RC	2.09 km WSW			
STATION K	K	2.17 km S			
TAYLOR/THOMAS	TT	2.26 km SE			
YANKEE VILLAGE	YV	2.28 km WSW			
GOODWIN PROPERTY	GN	2.38 km SW			
RIGHT OF WAY	RW	2.83 km S			
TAYLOR/PEARL	TP	2.98 km SE			
Zone 2 TLDs: 3-8 km					
VALLEY ROAD	VR	3.26 km SSW			
MANOMET ELEM	ME	3.29 km SE			
WARREN/CLIFFORD	WC	3.31 km W			
RT.3A/BARTLETT RD	BB	3.33 km SSE			
MANOMET POINT	MP	3.57 km SE			
MANOMET SUBSTATION	MS	3.60 km SSE			
BEACHWOOD ROAD	BW	3.93 km SE			
PINES ESTATE	PT	4.44 km SSW			
EARL ROAD	EA	4.60 km SSE			
S PLYMOUTH SUBST	SP	4.62 km W			
ROUTE 3 OVERPASS	RP	4.81 km SW			
RUSSELL MILLS RD	RM	4.85 km WSW			

* Distance and direction are measured from centerline of Reactor Building to the monitoring location.

Figure 2.2-3 (continued)

TLD and Air Sampling Locations: 1 to 5 Kilometers

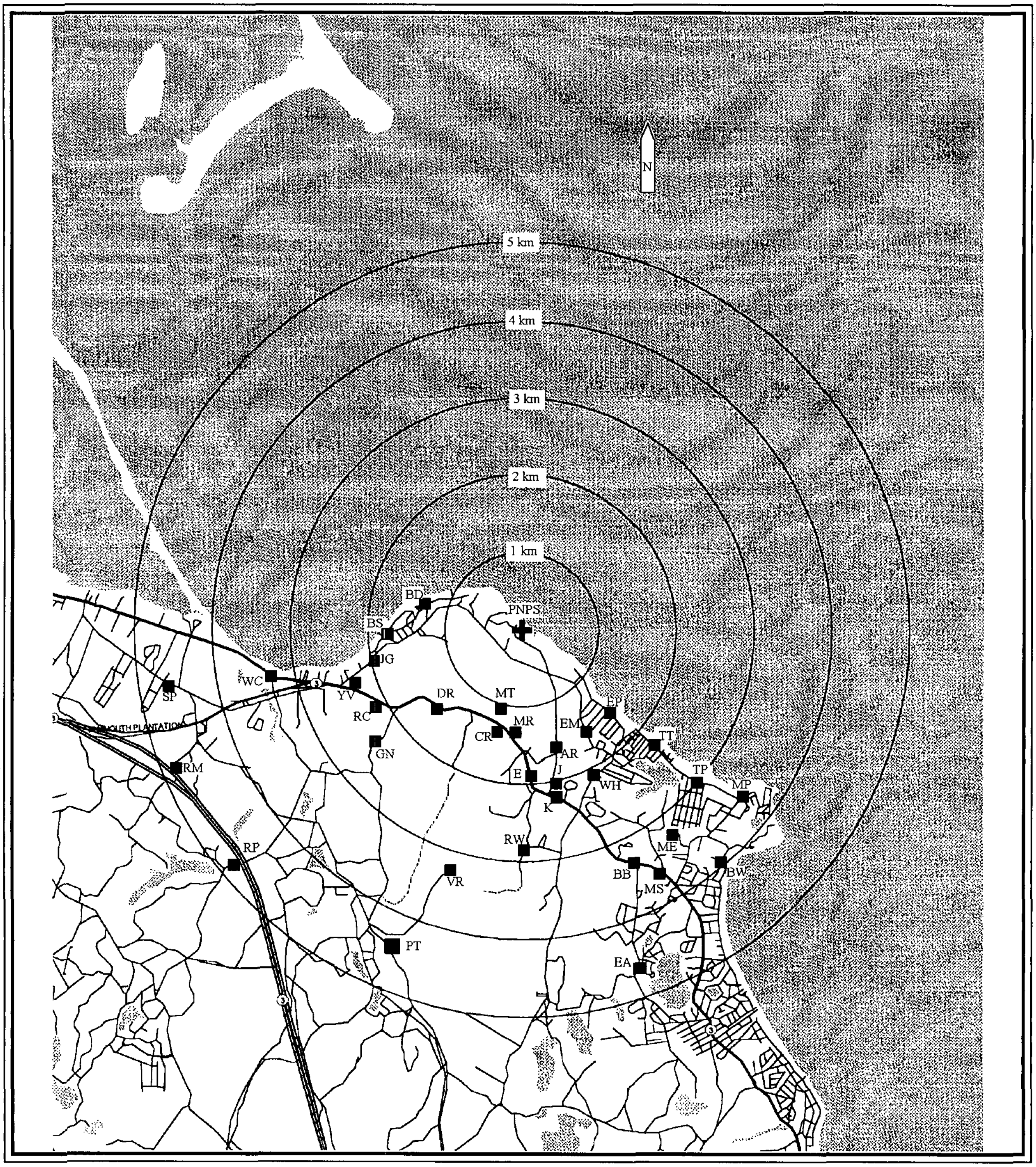


Figure 2.2-4

TLD and Air Sampling Locations: 5 to 25 Kilometers

TLD Station		Location*	Air Sampling Station		Location*
Description	Code	Distance/Direction	Description	Code	Distance/Direction
Zone 2 TLDs: 3-8 km					
HILLDALE ROAD	HD	5.18 km W	PLYMOUTH CENTER	PC	6.69 km W
MANOMET BEACH	MB	5.43 km SSE			
BEAVER DAM ROAD	BR	5.52 km S			
PLYMOUTH CENTER	PC	6.69 km W			
LONG POND/DREW RD	LD	6.97 km WSW			
HYANNIS ROAD	HR	7.33 km SSE			
MEMORIAL HALL	MH	7.58 km WNW			
SAQUISH NECK	SN	7.58 km NNW			
COLLEGE POND	CP	7.59 km SW			
Zone 3 TLDs: 8-15 km					
DEEP WATER POND	DW	8.59 km W			
LONG POND ROAD	LP	8.88 km SSW			
NORTH PLYMOUTH	NP	9.38 km WNW			
STANDISH SHORES	SS	10.39 km NW			
ELLISVILLE ROAD	EL	11.52 km SSE			
UP COLLEGE POND RD	UC	11.78 km SW			
SACRED HEART	SH	12.92 km W			
KING CAESAR ROAD	KC	13.11 km NNW			
BOURNE ROAD	BE	13.37 km S			
SHERMAN AIRPORT	SA	13.43 km WSW			
Zone 4 TLDs: >15 km					
CEDARVILLE SUBST	CS	15.93 km S			
KINGSTON SUBST	KS	16.15 km WNW			
LANDING ROAD	LR	16.46 km NNW			
CHURCH/WEST	CW	16.56 km NW			
MAIN/MEADOW	MM	17.02 km WSW			
DIV MARINE FISH	DMF	20.97 km SSE			

* Distance and direction are measured from centerline of Reactor Building to the monitoring location.

Figure 2.2-4 (continued)

TLD and Air Sampling Locations: 5 to 25 Kilometers

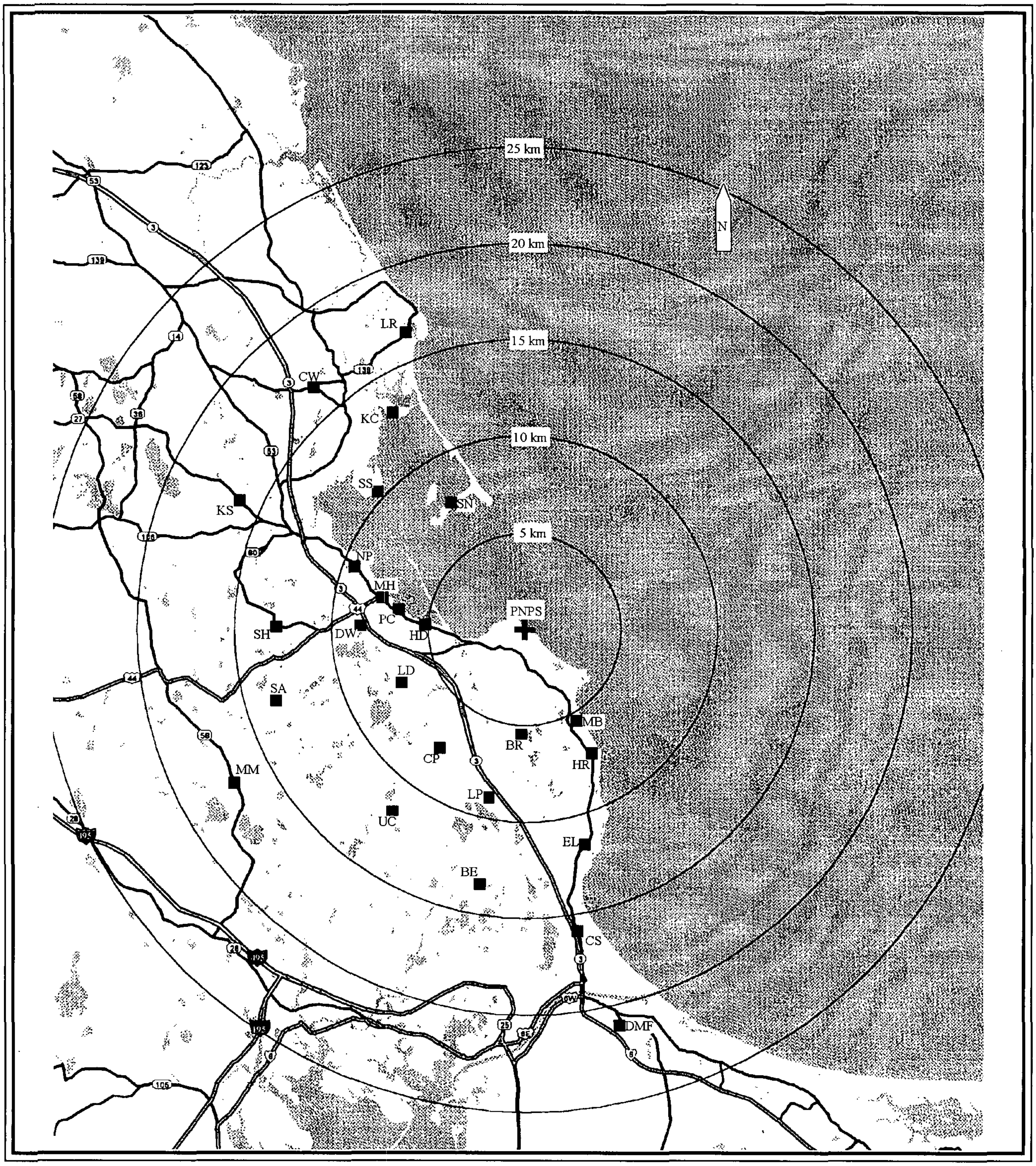


Figure 2.2-5

Terrestrial and Aquatic Sampling Locations

Description	Code	Distance/Direction*	Description	Code	Distance/Direction*
FORAGE			SURFACE WATER		
Plymouth County Farm	CF	5.6 km W	Discharge Canal	DIS	0.2 km N
Bridgewater Control	BF	31 km W	Bartlett Pond	BP	2.7 km SE
Hanson Farm Control	HN	34 km W	Powder Point Control	PP	13 km NNW
			SEDIMENT		
			Discharge Canal Outfall	DIS	0.8 km NE
			Plymouth Beach	PLB	4.0 km W
			Manomet Point	MP	3.3 km ESE
VEGETABLES/VEGETATION			Plymouth Harbor	PLY-H	4.1 km W
Site Boundary C	BC	0.5 km SW	Duxbury Bay Control	DUX-BAY	14 km NNW
Site Boundary B	BB	0.5 km ESE	Green Harbor Control	GH	16 km NNW
Rocky Hill Road	RH	0.9 km SE			
Site Boundary D	Bd	1.1 km S	IRISH MOSS		
Site Boundary A	BA	1.5 km SSW	Discharge Canal Outfall	DIS	0.7 km NNE
Clay Hill Road	CH	1.6 km W	Manomet Point	MP	4.0 km ESE
Brook Road	BK	2.9 km SSE	Ellisville	EL	12 km SSE
Beaver Dam Road	BD	3.4 km S	Brant Rock Control	BK	18 km NNW
Plymouth County Farm	CF	5.6 km W			
Hanson Farm Control	HN	34 km W	SHELLFISH		
Norton Control	NC	50 km W	Discharge Canal Outfall	DIS	0.7 km NNE
			Plymouth Harbor	PLY-H	4.1 km W
CRANBERRIES			Manomet Point	MP	4.0 km ESE
Bartlett Road Bog	BT	4.3 km SSE	Duxbury Bay Control	DUX-BAY	13 km NNW
Beaverdam Road Bog	MR	3.4 km S	Powder Point Control	PP	13 km NNW
Hollow Farm Bog Control	HF	16 km WNW	Green Harbor Control	GH	16 km NNW
			LOBSTER		
			Discharge Canal Outfall	DIS	0.5 km N
			Plymouth Beach	PLB	4.0 km W
			Plymouth Harbor	PLY-H	6.4 km WNW
			Duxbury Bay Control	DUX-BAY	11 km NNW
			FISHES		
			Discharge Canal Outfall	DIS	0.5 km N
			Plymouth Beach	PLB	4.0 km W
			Jones River Control	JR	13 km WNW
			Cape Cod Bay Control	CC-BAY	24 km ESE
			N River-Hanover Control	NR	24 km NNW
			Cataumet Control	CA	32 km SSW
			Provincetown Control	PT	32 km NE
			Buzzards Bay Control	BB	40 km SSW
			Priest Cove Control	PC	48 km SW
			Nantucket Sound Control	NS	48 km SSE
			Atlantic Ocean Control	AO	48 km E
			Vineyard Sound Control	MV	64 km SSW

* Distance and direction are measured from the centerline of the reactor to the sampling/monitoring location.

Figure 2.2-5 (continued)

Terrestrial and Aquatic Sampling Locations

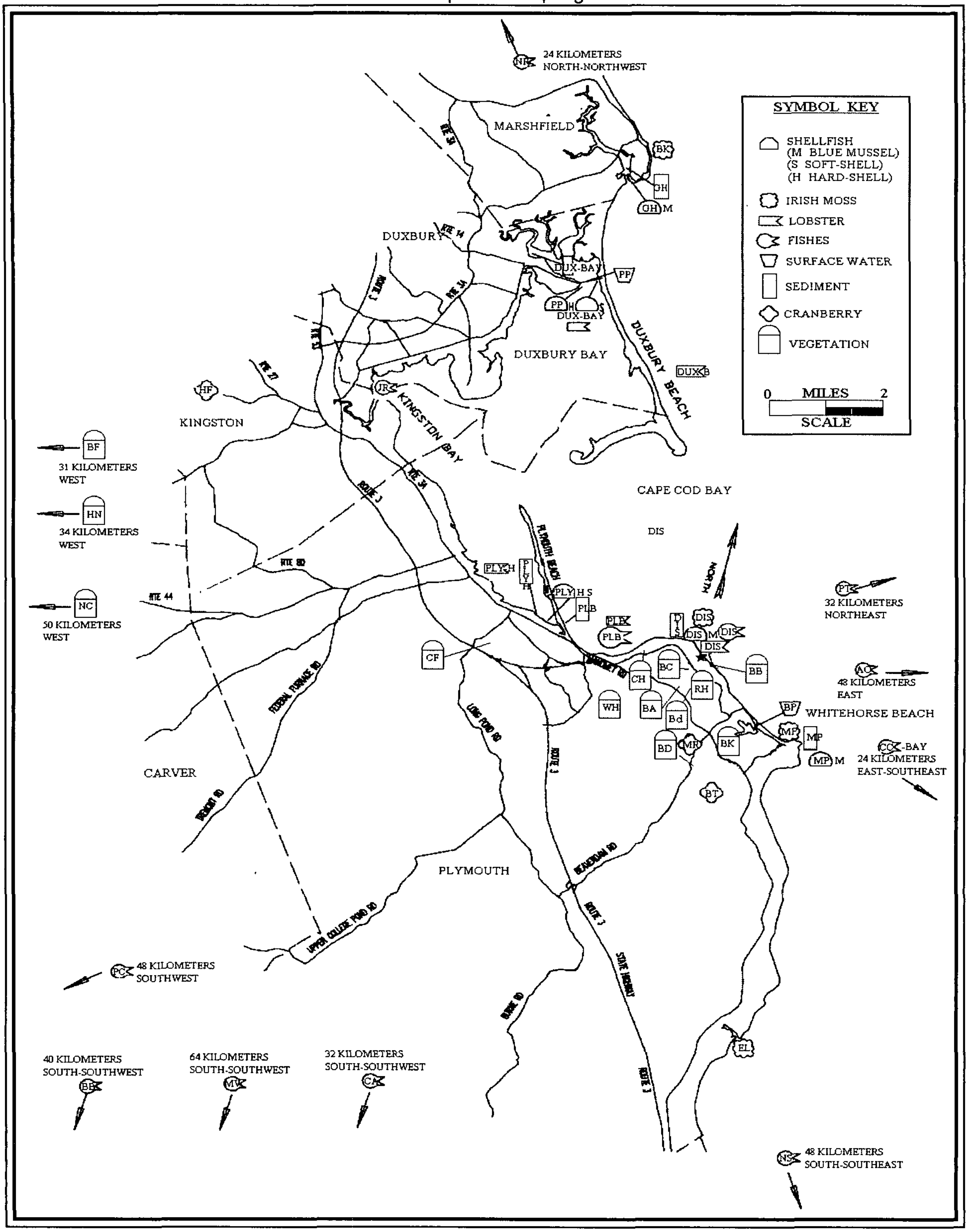


Figure 2.2-6

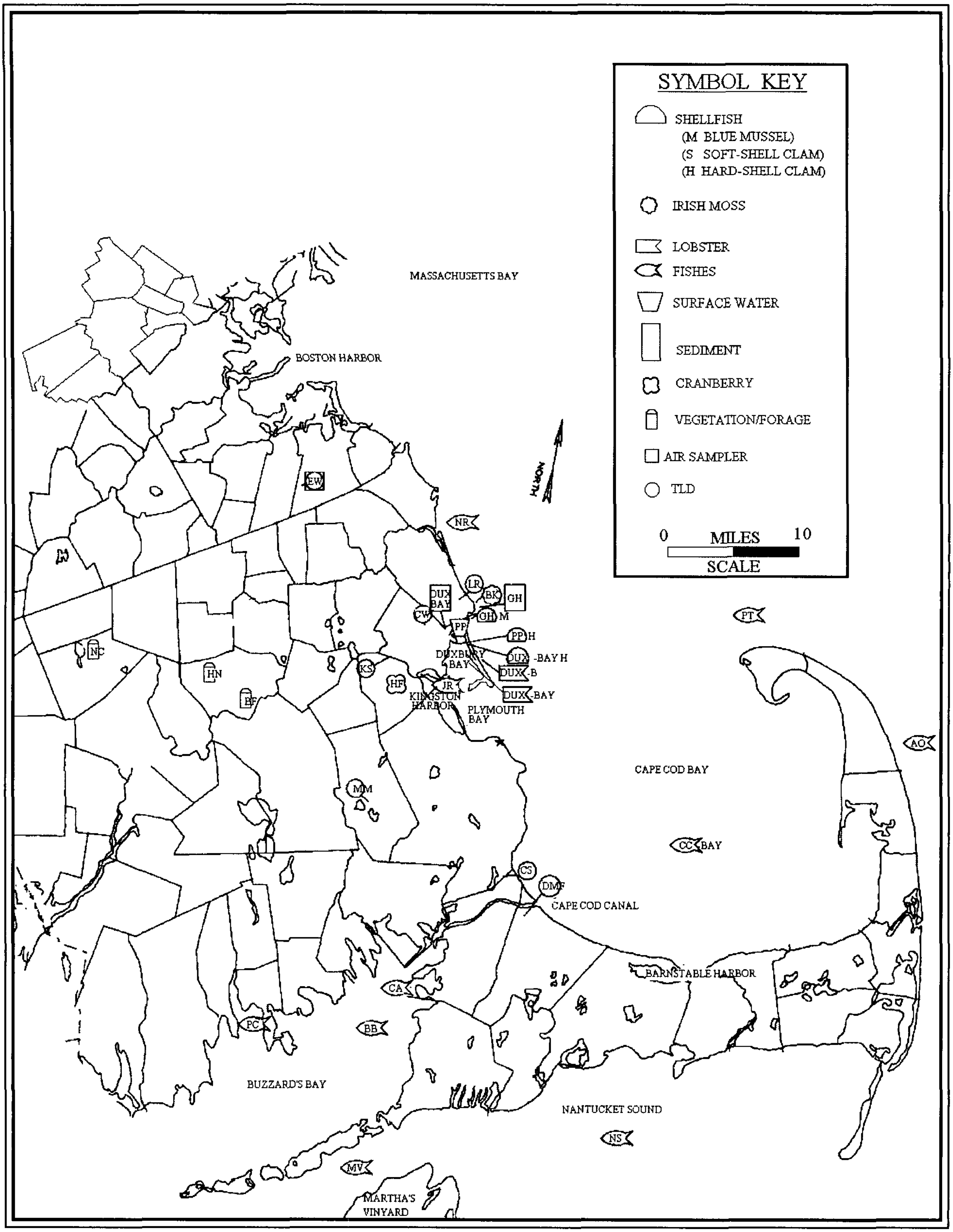
Environmental Sampling And Measurement Control Locations

Description	Code	Distance/Direction*	Description	Code	Distance/Direction*
TLD			SURFACE WATER		
Cedarville Substation	CS	16 km S	Powder Point Control	PP	13 km NNW
Kingston Substation	KS	16 km WNW			
Landing Road	LR	16 km NNW	SEDIMENT		
Church & West Street	CW	17 km NW	Duxbury Bay Control	DUX-BAY	14 km NNW
Main & Meadow Street	MM	17 km WSW	Green Harbor Control	GH	16 km NNW
Div. Marine Fisheries	DMF	21 km SSE			
East Weymouth Substation	EW	40 km NW	IRISH MOSS		
			Brant Rock Control	BK	18 km NNW
AIR SAMPLER					
East Weymouth Substation	EW	40 km NW	SHELLFISH		
			Duxbury Bay Control	DUX-BAY	13 km NNW
FORAGE			Powder Point Control	PP	13 km NNW
Bridgewater Control	BF	31 km W	Green Harbor Control	GH	16 km NNW
Hanson Farm Control	HN	34 km W			
			LOBSTER		
VEGETABLES/VEGETATION			Duxbury Bay Control	DUX-BAY	11 km NNW
Hanson Farm Control	HN	34 km W			
Norton Control	NC	50 km W	FISHES		
			Jones River Control	JR	13 km WNW
			Cape Cod Bay Control	CC-BAY	24 km ESE
CRANBERRIES			N River-Hanover Control	NR	24 km NNW
Hollow Farm Bog Control	HF	16 km WNW	Cataumet Control	CA	32 km SSW
			Provincetown Control	PT	32 km NE
			Buzzards Bay Control	BB	40 km SSW
			Priest Cove Control	PC	48 km SW
			Nantucket Sound Control	NS	48 km SSE
			Atlantic Ocean Control	AO	48 km E
			Vineyard Sound Control	MV	64 km SSW

* Distance and direction are measured from the centerline of the reactor to the sampling/monitoring location.

Figure 2.2-6 (continued)

Environmental Sampling And Measurement Control Locations



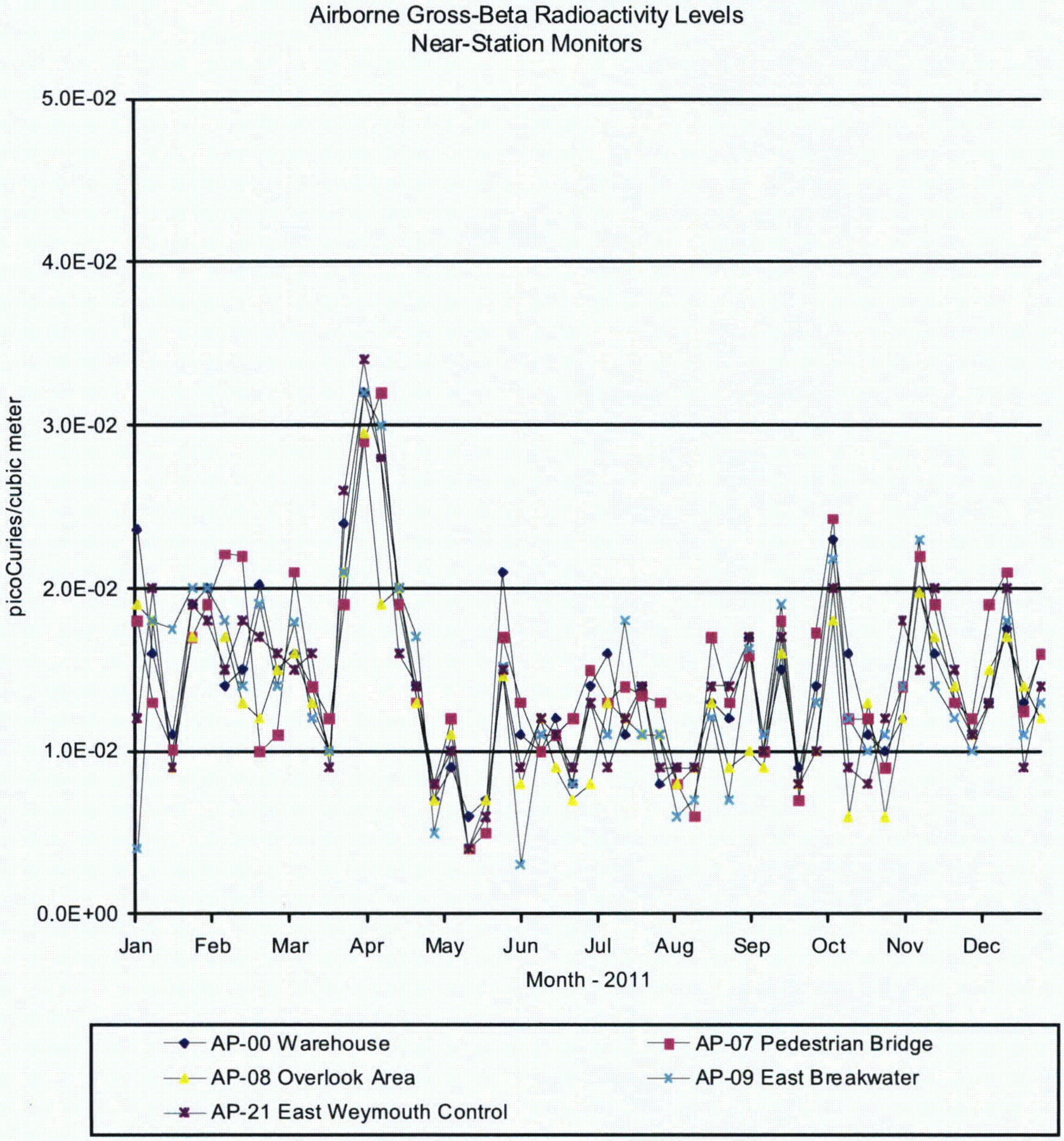


Figure 2.5-1
Airborne Gross-Beta Radioactivity Levels: Near Station Monitors

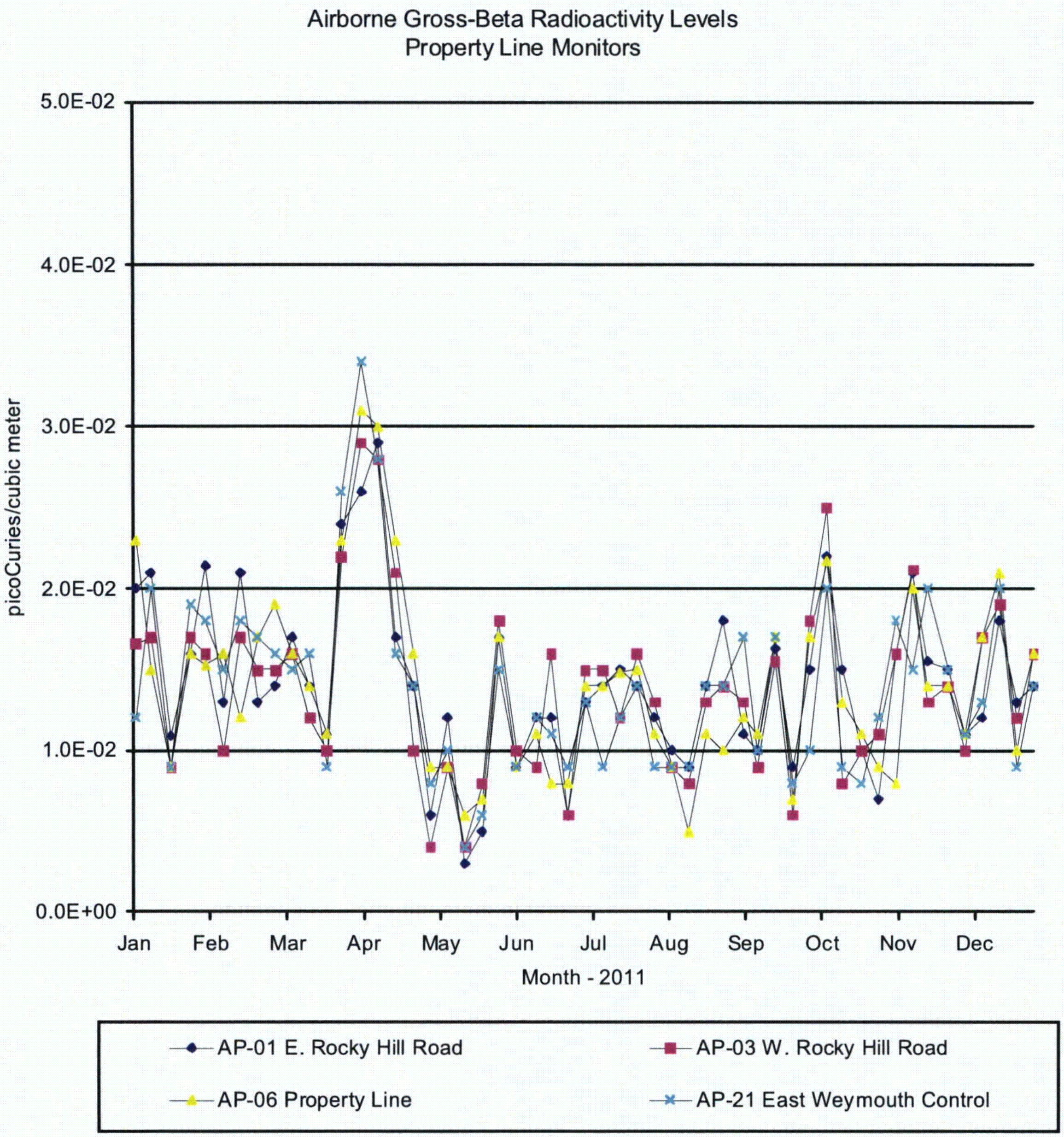


Figure 2.5-2
Airborne Gross-Beta Radioactivity Levels: Property Line Monitors

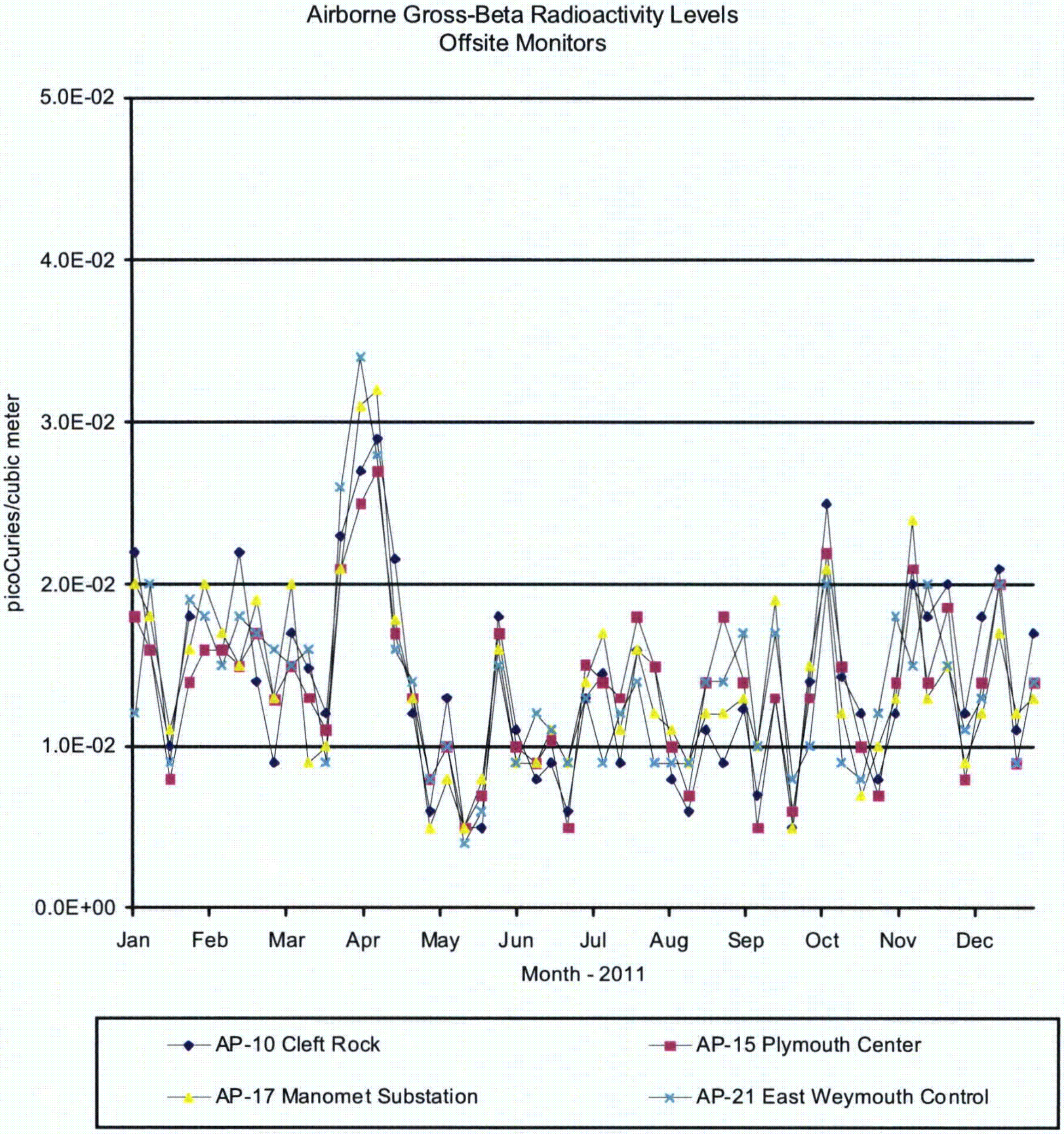


Figure 2.5-3
Airborne Gross-Beta Radioactivity Levels: Offsite Monitors

3.0 SUMMARY OF RADIOLOGICAL IMPACT ON HUMANS

The radiological impact to humans from the Pilgrim Station's radioactive liquid and gaseous releases has been estimated using two methods:

- calculations based on measurements of plant effluents; and
- calculations based on measurements of environmental samples.

The first method utilizes data from the radioactive effluents (measured at the point of release) together with conservative models that calculate the dispersion and transport of radioactivity through the environment to humans (Reference 7). The second method is based on actual measurements of radioactivity in the environmental samples and on dose conversion factors recommended by the Nuclear Regulatory Commission. The measured types and quantities of radioactive liquid and gaseous effluents released from Pilgrim Station during 2011 were reported to the Nuclear Regulatory Commission, copies of which are provided in Appendix B. The measured levels of radioactivity in the environmental samples that required dose calculations are listed in Appendix A.

The maximum individual dose from liquid effluents was calculated using the following radiation exposure pathways:

- shoreline external radiation during fishing and recreation at the Pilgrim Station Shorefront;
- external radiation from the ocean during boating and swimming; and
- ingestion of fish and shellfish.

For gaseous effluents, the maximum individual dose was calculated using the following radiation exposure pathways:

- external radiation from cloud shine and submersion in gaseous effluents;
- inhalation of airborne radioactivity;
- external radiation from soil deposition;
- consumption of vegetables; and
- consumption of milk and meat.

The results from the dose calculations based on PNPS operations are presented in Table 3.0-1. The dose assessment data presented were taken from the "Radioactive Effluent Release Report" for the period of January 1 through December 31, 2011 (Reference 17).

Table 3.0-1

Radiation Doses from 2011 Pilgrim Station Operations

Receptor	Maximum Individual Dose From Exposure Pathway - mrem/yr			
	Gaseous Effluents*	Liquid Effluents	Ambient Radiation**	Total
Total Body	0.029	0.00032	1.5	1.5
Thyroid	0.040	0.000043	1.5	1.5
Max. Organ	0.081	0.0012	1.5	1.6

* Gaseous effluent exposure pathway includes combined dose from particulates, iodines and tritium in addition to noble gases, calculated at the nearest residence.

** Ambient radiation dose for the hypothetical maximum-exposed individual at a location on PNPS property yielding highest ambient radiation exposure value as measured with TLDs.

Two federal agencies establish dose limits to protect the public from radiation and radioactivity. The Nuclear Regulatory Commission (NRC) specifies a whole body dose limit of 100 mrem/yr to be received by the maximum exposed member of the general public. This limit is set forth in Section 1301, Part 20, Title 10, of the U.S. Code of Federal Regulations (10CFR20). By comparison, the Environmental Protection Agency (EPA) limits the annual whole body dose to 25 mrem/yr, which is specified in Section 10, Part 190, Title 40, of the Code of Federal Regulations (40CFR190).

Another useful "gauge" of radiation exposure is provided by the amount of dose a typical individual receives each year from natural and man-made sources of radiation. Such radiation doses are summarized in Table 1.2-1. The typical American receives about 620 mrem/yr from such sources.

As can be seen from the doses resulting from Pilgrim Station Operations during 2011, all values are well within the federal limits specified by the NRC and EPA. In addition, the calculated doses from PNPS operation represent only a fraction of a percent of doses from natural and man-made radiation.

In conclusion, the radiological impact of Pilgrim Station operations, whether based on actual environmental measurements or calculations made from effluent releases, would yield doses well within any federal dose limits set by the NRC or EPA. Such doses represent only a small percentage of the typical annual dose received from natural and man-made sources of radiation.

4.0 REFERENCES

1) United States of America, Code of Federal Regulations, Title 10, Part 50, Appendix A Criteria 64.

2) Donald T. Oakley, "Natural Radiation Exposure in the United States." U. S. Environmental Protection Agency, ORP/SID 72-1, June 1972.

3) National Council on Radiation Protection and Measurements, Report No. 93, "Ionizing Radiation Exposures of the Population of the United States," September 1987.

4) United States Nuclear Regulatory Commission, Regulatory Guide 8.29, "Instructions Concerning Risks from Occupational Radiation Exposure," Revision 0, July 1981.

5) Boston Edison Company, "Pilgrim Station" Public Information Brochure 100M, WNTHP, September 1989.

6) United States Nuclear Regulatory Commission, Regulatory Guide 1.109, "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I," Revision 1, October 1977.

7) Pilgrim Nuclear Power Station Offsite Dose Calculation Manual, Revision 9, June 2003.

8) United States of America, Code of Federal Regulations, Title 10, Part 20.1301.

9) United States of America, Code of Federal Regulations, Title 10, Part 50, Appendix I.

10) United States of America, Code of Federal Regulations, Title 40, Part 190.

11) United States Nuclear Regulatory Commission, Regulatory Guide 4.1, "Program for Monitoring Radioactivity in the Environs of Nuclear Power Plants," Revision 1, April 1975.

12) ICN/Tracerlab, "Pilgrim Nuclear Power Station Pre-operational Environmental Radiation Survey Program, Quarterly Reports," August 1968 to June 1972.

13) International Commission of Radiological Protection, Publication No. 43, "Principles of Monitoring for the Radiation Protection of the Population," May 1984.

14) United States Nuclear Regulatory Commission, NUREG-1302, "Offsite Dose Calculation Manual Guidance: Standard Radiological Effluent Controls for Boiling Water Reactors," April 1991.

15) United States Nuclear Regulatory Commission, Branch Technical Position, "An Acceptable Radiological Environmental Monitoring Program," Revision 1, November 1979.

16) Settlement Agreement Between Massachusetts Wildlife Federation and Boston Edison Company Relating to Offsite Radiological Monitoring - June 9, 1977.

17) Pilgrim Nuclear Power Station, "Annual Radioactive Effluent Release Report", May 2011.

APPENDIX A

SPECIAL STUDIES

None of the samples collected as part of the radiological environmental monitoring program during 2011 indicated any detectable radioactivity attributable to Pilgrim Station operations. Therefore, no special dose analyses were performed.

APPENDIX B

Effluent Release Information

Table B.1
Pilgrim Nuclear Power Station
Annual Radioactive Effluent Release Report
Supplemental Information
January-December 2011

FACILITY: PILGRIM NUCLEAR POWER STATION **LICENSE: DPR-35**

1. REGULATORY LIMITS	
a. Fission and activation gases:	500 mrem/yr total body and 3000 mrem/yr for skin at site boundary
b,c. Iodines, particulates with half-life: >8 days, tritium	1500 mrem/yr to any organ at site boundary
d. Liquid effluents:	0.06 mrem/month for whole body and 0.2 mrem/month for any organ (without radwaste treatment)
2. EFFLUENT CONCENTRATION LIMITS	
a. Fission and activation gases:	10CFR20 Appendix B Table II
b. Iodines:	10CFR20 Appendix B Table II
c. Particulates with half-life > 8 days:	10CFR20 Appendix B Table II
d. Liquid effluents:	2E-04 μCi/mL for entrained noble gases; 10CFR20 Appendix B Table II values for all other radionuclides
3. AVERAGE ENERGY	Not Applicable
4. MEASUREMENTS AND APPROXIMATIONS OF TOTAL RADIOACTIVITY	
a. Fission and activation gases: b. Iodines: c. Particulates: d. Liquid effluents:	High purity germanium gamma spectroscopy for all gamma emitters; radiochemistry analysis for H-3, Fe-55 (liquid effluents), Sr-89, and Sr-90

5. BATCH RELEASES	Jan-Mar 2011	Apr-Jun 2011	Jul-Sep 2011	Oct-Dec 2011	Jan-Dec 2011
a. Liquid Effluents					
1. Total number of releases:	12	14	0	3	29
2. Total time period (minutes):	1.31E+03	1.29E+03	N/A	3.48E+02	2.95E+03
3. Maximum time period (minutes):	1.52E+02	1.50E+02	N/A	1.35E+02	1.52E+02
4. Average time period (minutes):	1.09E+02	9.22E+01	N/A	1.16E+02	1.02E+02
5. Minimum time period (minutes):	8.30E+01	7.70E+01	N/A	1.05E+02	7.70E+01
6. Average stream flow during periods of release of effluents into a flowing stream (Liters/min):	1.19E+06	9.61E+05	N/A	1.19E+06	1.09E+06
b. Gaseous Effluents	None	None	None	None	None
6. ABNORMAL RELEASES					
a. Liquid Effluents	None	None	None	None	None
b. Gaseous Effluents	None	None	None	None	None

Table B.2-A
Pilgrim Nuclear Power Station
Annual Radioactive Effluent Release Report
Gaseous Effluents - Summation of All Releases
January-December 2011

RELEASE PERIOD	Jan-Mar 2011	Apr-Jun 2011	Jul-Sep 2011	Oct-Dec 2011	Jan-Dec 2011	Est. Total Error
A. FISSION AND ACTIVATION GASES						
Total Release: Ci	6.46E+00	3.52E-01	1.78E-01	4.56E+00	1.15E+01	±22%
Average Release Rate: μCi/sec	8.19E-01	4.46E-02	2.26E-02	5.78E-01	3.66E-01	
Percent of Effluent Control Limit*	*	*	*	*	*	
B. IODINE-131						
Total Iodine-131 Release: Ci	6.69E-04	3.47E-04	2.03E-04	1.47E-04	1.37E-03	±20%
Average Release Rate: μCi/sec	8.49E-05	4.40E-05	2.58E-05	1.86E-05	4.33E-05	
Percent of Effluent Control Limit*	*	*	*	*	*	
C. PARTICULATES WITH HALF-LIVES > 8 DAYS						
Total Release: Ci	1.76E-03	5.55E-04	2.56E-04	1.17E-04	2.69E-03	±21%
Average Release Rate: μCi/sec	2.23E-04	7.04E-05	3.24E-05	1.49E-05	8.52E-05	
Percent of Effluent Control Limit*	*	*	*	*	*	
Gross Alpha Radioactivity: Ci	NDA	NDA	NDA	NDA	NDA	
D. TRITIUM						
Total Release: Ci	1.01E+01	5.88E+00	1.35E+01	8.46E+00	3.80E+01	±20%
Average Release Rate: μCi/sec	1.29E+00	7.46E-01	1.72E+00	1.07E+00	1.20E+00	
Percent of Effluent Control Limit*	*	*	*	*	*	
E. CARBON-14						
Total Release: Ci	1.99E+00	1.34E+00	2.15E+00	1.88E+00	7.36E+00	N/A
Average Release Rate: μCi/sec	2.53E-01	1.70E-01	2.73E-01	2.38E-01	2.33E-01	
Percent of Effluent Control Limit*	*	*	*	*	*	

Notes for Table B.2-A:

* Percent of Effluent Control Limit values based on dose assessments are provided in Section 6 of the Annual Radioactive Effluent Release Report.

1. NDA stands for No Detectable Activity.
2. LLD for airborne gross alpha activity listed as NDA is 1E-11 μCi/cc.
3. N/A stands for not applicable.

Table B.2-B
Pilgrim Nuclear Power Station
Annual Radioactive Effluent Release Report
Gaseous Effluents – Elevated Release
January-December 2011

CONTINUOUS MODE RELEASES FROM ELEVATED RELEASE POINT					
Nuclide Released	Jan-Mar 2011	Apr-Jun 2011	Jul-Sep 2011	Oct-Dec 2011	Jan-Dec 2011
1. FISSION AND ACTIVATION GASES: Ci					
Ar-41	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-85m	9.47E-03	7.15E-02	0.00E+00	0.00E+00	8.10E-02
Kr-87	2.79E-02	0.00E+00	0.00E+00	0.00E+00	2.79E-02
Kr-88	1.68E-02	0.00E+00	0.00E+00	0.00E+00	1.68E-02
Xe-131m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-133	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-133m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-135	5.84E-03	0.00E+00	0.00E+00	1.07E-01	1.13E-01
Xe-135m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-137	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-138	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total for Period	6.00E-02	7.15E-02	0.00E+00	1.07E-01	2.39E-01
2. IODINES: Ci					
I-131	2.47E-05	1.93E-05	1.57E-05	1.48E-05	7.44E-05
I-133	3.95E-05	2.30E-05	1.78E-05	4.40E-06	8.47E-05
Total for Period	6.42E-05	4.23E-05	3.35E-05	1.92E-05	1.59E-04
3. PARTICULATES WITH HALF-LIVES > 8 DAYS: Ci					
Cr-51	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mn-54	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Fe-59	0.00E+00	6.88E-07	0.00E+00	0.00E+00	6.88E-07
Co-58	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Co-60	0.00E+00	1.02E-06	0.00E+00	0.00E+00	1.02E-06
Zn-65	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-89	0.00E+00	0.00E+00	9.37E-07	0.00E+00	9.37E-07
Sr-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-103	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-134	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-137	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba/La-140	0.00E+00	0.00E+00	2.50E-06	0.00E+00	2.50E-06
Total for Period	0.00E+00	1.71E-06	3.44E-06	0.00E+00	5.14E-06
4. TRITIUM: Ci					
H-3	3.15E-02	2.48E-02	4.87E-02	2.76E-02	1.33E-01
5. CARBON-14: Ci					
C-14	1.93E+00	1.30E+00	2.09E+00	1.82E+00	7.14E+00

Notes for Table B.2-B:

1. N/A stands for not applicable.
2. NDA stands for No Detectable Activity.
3. LLDs for airborne radionuclides listed as NDA are as follows:
   - Fission Gases: 1E-04 μCi/cc
   - Iodines: 1E-12 μCi/cc
   - Particulates: 1E-11 μCi/cc

Table B.2-B (continued)
Pilgrim Nuclear Power Station
Annual Radioactive Effluent Release Report
Gaseous Effluents – Elevated Release
January-December 2011

BATCH MODE RELEASES FROM ELEVATED RELEASE POINT					
Nuclide Released	Jan-Mar 2011	Apr-Jun 2011	Jul-Sep 2011	Oct-Dec 2011	Jan-Dec 2011
1. FISSION AND ACTIVATION GASES: Ci					
Ar-41	N/A	N/A	N/A	N/A	N/A
Kr-85	N/A	N/A	N/A	N/A	N/A
Kr-85m	N/A	N/A	N/A	N/A	N/A
Kr-87	N/A	N/A	N/A	N/A	N/A
Kr-88	N/A	N/A	N/A	N/A	N/A
Xe-131m	N/A	N/A	N/A	N/A	N/A
Xe-133	N/A	N/A	N/A	N/A	N/A
Xe-133m	N/A	N/A	N/A	N/A	N/A
Xe-135	N/A	N/A	N/A	N/A	N/A
Xe-135m	N/A	N/A	N/A	N/A	N/A
Xe-137	N/A	N/A	N/A	N/A	N/A
Xe-138	N/A	N/A	N/A	N/A	N/A
Total for period	N/A	N/A	N/A	N/A	N/A
2. IODINES: Ci					
I-131	N/A	N/A	N/A	N/A	N/A
I-133	N/A	N/A	N/A	N/A	N/A
Total for period	N/A	N/A	N/A	N/A	N/A
3. PARTICULATES WITH HALF-LIVES > 8 DAYS: Ci					
Cr-51	N/A	N/A	N/A	N/A	N/A
Mn-54	N/A	N/A	N/A	N/A	N/A
Fe-59	N/A	N/A	N/A	N/A	N/A
Co-58	N/A	N/A	N/A	N/A	N/A
Co-60	N/A	N/A	N/A	N/A	N/A
Zn-65	N/A	N/A	N/A	N/A	N/A
Sr-89	N/A	N/A	N/A	N/A	N/A
Sr-90	N/A	N/A	N/A	N/A	N/A
Ru-103	N/A	N/A	N/A	N/A	N/A
Cs-134	N/A	N/A	N/A	N/A	N/A
Cs-137	N/A	N/A	N/A	N/A	N/A
Ba/La-140	N/A	N/A	N/A	N/A	N/A
Total for period	N/A	N/A	N/A	N/A	N/A
4. TRITIUM: Ci					
H-3	N/A	N/A	N/A	N/A	N/A
5. CARBON-14: Ci					
C-14	N/A	N/A	N/A	N/A	N/A

Notes for Table B.2-B:

1. N/A stands for not applicable.
2. NDA stands for No Detectable Activity.
3. LLDs for airborne radionuclides listed as NDA are as follows:
   - Fission Gases: 1E-04 μCi/cc
   - Iodines: 1E-12 μCi/cc
   - Particulates: 1E-11 μCi/cc

Table B.2-C
Pilgrim Nuclear Power Station
Annual Radioactive Effluent Release Report
Gaseous Effluents – Ground-Level Release
January-December 2011

CONTINUOUS MODE RELEASES FROM GROUND-LEVEL RELEASE POINT					
Nuclide Released	Jan-Mar 2011	Apr-Jun 2011	Jul-Sep 2011	Oct-Dec 2011	Jan-Dec 2011
1. FISSION AND ACTIVATION GASES: Ci					
Ar-41	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-85m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-87	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-88	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-131m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-133	0.00E+00	0.00E+00	0.00E+00	1.71E+00	1.71E+00
Xe-133m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-135	1.66E+00	2.80E-01	1.78E-01	2.74E+00	4.87E+00
Xe-135m	1.75E-01	0.00E+00	0.00E+00	0.00E+00	1.75E-01
Xe-137	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-138	4.56E+00	0.00E+00	0.00E+00	0.00E+00	4.56E+00
Total for period	6.40E+00	2.80E-01	1.78E-01	4.45E+00	1.13E+01
2. IODINES: Ci					
I-131	6.45E-04	3.27E-04	1.88E-04	1.32E-04	1.29E-03
I-133	1.97E-03	5.42E-04	4.46E-04	2.97E-04	3.25E-03
Total for period	2.61E-03	8.69E-04	6.34E-04	4.29E-04	4.54E-03
3. PARTICULATES WITH HALF-LIVES > 8 DAYS: Ci					
Cr-51	0.00E+00	2.95E-05	0.00E+00	0.00E+00	2.95E-05
Mn-54	2.78E-06	2.44E-06	5.62E-07	0.00E+00	5.78E-06
Fe-59	2.23E-06	4.48E-05	2.42E-06	1.27E-06	5.07E-05
Co-58	0.00E+00	4.43E-06	0.00E+00	0.00E+00	4.43E-06
Co-60	2.93E-06	8.53E-05	1.05E-05	0.00E+00	9.87E-05
Zn-65	0.00E+00	2.48E-05	0.00E+00	0.00E+00	2.48E-05
Sr-89	0.00E+00	3.56E-05	4.38E-05	3.25E-05	1.12E-04
Sr-90	0.00E+00	0.00E+00	1.27E-06	0.00E+00	1.27E-06
Ru-103	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-134	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-137	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba/La-140	1.75E-03	3.27E-04	1.94E-04	8.36E-05	2.36E-03
Total for period	1.76E-03	5.53E-04	2.52E-04	1.17E-04	2.68E-03
4. TRITIUM: Ci					
H-3	1.01E+01	5.85E+00	1.35E+01	8.44E+00	3.79E+01
5. CARBON-14: Ci					
C-14	5.98E-02	4.02E-02	6.46E-02	5.63E-02	2.21E-01

Notes for Table B.2-C:

1. N/A stands for not applicable.
2. NDA stands for No Detectable Activity.
3. LLDs for airborne radionuclides listed as NDA are as follows:
   - Fission Gases: 1E-04 µCi/cc
   - Iodines: 1E-12 µCi/cc
   - Particulates: 1E-11 µCi/cc

Table B.2-C (continued)
Pilgrim Nuclear Power Station
Annual Radioactive Effluent Release Report
Gaseous Effluents – Ground-Level Release
January-December 2011

BATCH MODE RELEASES FROM GROUND-LEVEL RELEASE POINT					
Nuclide Released	Jan-Mar 2011	Apr-Jun 2011	Jul-Sep 2011	Oct-Dec 2011	Jan-Dec 2011
1. FISSION AND ACTIVATION GASES: Ci					
Ar-41	N/A	N/A	N/A	N/A	N/A
Kr-85	N/A	N/A	N/A	N/A	N/A
Kr-85m	N/A	N/A	N/A	N/A	N/A
Kr-87	N/A	N/A	N/A	N/A	N/A
Kr-88	N/A	N/A	N/A	N/A	N/A
Xe-131m	N/A	N/A	N/A	N/A	N/A
Xe-133	N/A	N/A	N/A	N/A	N/A
Xe-133m	N/A	N/A	N/A	N/A	N/A
Xe-135	N/A	N/A	N/A	N/A	N/A
Xe-135m	N/A	N/A	N/A	N/A	N/A
Xe-137	N/A	N/A	N/A	N/A	N/A
Xe-138	N/A	N/A	N/A	N/A	N/A
Total for period	N/A	N/A	N/A	N/A	N/A
2. IODINES: Ci					
I-131	N/A	N/A	N/A	N/A	N/A
I-133	N/A	N/A	N/A	N/A	N/A
Total for period	N/A	N/A	N/A	N/A	N/A
3. PARTICULATES WITH HALF-LIVES > 8 DAYS: Ci					
Cr-51	N/A	N/A	N/A	N/A	N/A
Mn-54	N/A	N/A	N/A	N/A	N/A
Fe-59	N/A	N/A	N/A	N/A	N/A
Co-58	N/A	N/A	N/A	N/A	N/A
Co-60	N/A	N/A	N/A	N/A	N/A
Zn-65	N/A	N/A	N/A	N/A	N/A
Sr-89	N/A	N/A	N/A	N/A	N/A
Sr-90	N/A	N/A	N/A	N/A	N/A
Ru-103	N/A	N/A	N/A	N/A	N/A
Cs-134	N/A	N/A	N/A	N/A	N/A
Cs-137	N/A	N/A	N/A	N/A	N/A
Ba/La-140	N/A	N/A	N/A	N/A	N/A
Total for period	N/A	N/A	N/A	N/A	N/A
4. TRITIUM: Ci					
H-3	N/A	N/A	N/A	N/A	N/A
5. CARBON-14: Ci					
C-14	N/A	N/A	N/A	N/A	N/A

Notes for Table B.2-C:

1. N/A stands for not applicable.
2. NDA stands for No Detectable Activity.
3. LLDs for airborne radionuclides listed as NDA are as follows:
   - Fission Gases: 1E-04 μCi/cc
   - Iodines: 1E-12 μCi/cc
   - Particulates: 1E-11 μCi/cc

Table B.3-A
Pilgrim Nuclear Power Station
Annual Radioactive Effluent Release Report
Liquid Effluents - Summation of All Releases
January-December 2011

RELEASE PERIOD	Jan-Mar 2011	Apr-Jun 2011	Jul-Sep 2011	Oct-Dec 2011	Jan-Dec 2011	Est. Total Error
A. FISSION AND ACTIVATION PRODUCTS						
Total Release (not including tritium, gases, alpha): Ci	7.87E-05	3.68E-03	N/A	NDA	3.75E-03	±12%
Average Diluted Concentration During Period: μCi/mL	5.18E-13	3.00E-11	N/A	NDA	6.46E-12	
Percent of Effluent Concentration Limit*	4.62E-05%	3.24E-04%	N/A	0.00E+00%	8.03E-05%	
B. TRITIUM						
Total Release: Ci	1.58E-01	4.22E+00	N/A	5.18E-02	4.43E+00	±9.4%
Average Diluted Concentration During Period: μCi/mL	1.04E-09	3.45E-08	N/A	3.37E-10	7.62E-09	
Percent of Effluent Concentration Limit*	1.04E-04%	3.45E-03%	N/A	3.37E-05%	7.62E-04%	
C. DISSOLVED AND ENTRAINED GASES						
Total Release: Ci	NDA	NDA	N/A	NDA	NDA	±16%
Average Diluted Concentration During Period: μCi/mL	NDA	NDA	N/A	NDA	NDA	
Percent of Effluent Concentration Limit*	0.00E+00%	0.00E+00%	N/A	0.00E+00%	0.00E+00%	
D. GROSS ALPHA RADIOACTIVITY						
Total Release: Ci	N/A	NDA	N/A	NDA	NDA	±34%
E. VOLUME OF WASTE RELEASED PRIOR TO DILUTION						
Waste Volume: Liters	3.96E+05	7.42E+05	N/A	1.00E+05	1.24E+06	±5.7%
F. VOLUME OF DILUTION WATER USED DURING PERIOD						
Dilution Volume: Liters	1.52E+11	1.22E+11	1.53E+11	1.54E+11	5.82E+11	±10%

Notes for Table B.3-A:

* Additional percent of Effluent Control Limit values based on dose assessments are provided in Section 6 of the Annual Radioactive Effluent Release Report.

1. N/A stands for not applicable.
2. NDA stands for No Detectable Activity.
3. LLD for dissolved and entrained gases listed as NDA is 1E-05 μCi/mL.
4. LLD for liquid gross alpha activity listed as NDA is 1E-07 μCi/mL.

Table B.3-B
Pilgrim Nuclear Power Station
Annual Radioactive Effluent Release Report
Liquid Effluents
January-December 2011

CONTINUOUS MODE RELEASES					
Nuclide Released	Jan-Mar 2011	Apr-Jun 2011	Jul-Sep 2011	Oct-Dec 2011	Jan-Dec 2011
1. FISSION AND ACTIVATION PRODUCTS: Ci					
Cr-51	N/A	N/A	N/A	N/A	N/A
Mn-54	N/A	N/A	N/A	N/A	N/A
Fe-55	N/A	N/A	N/A	N/A	N/A
Fe-59	N/A	N/A	N/A	N/A	N/A
Co-58	N/A	N/A	N/A	N/A	N/A
Co-60	N/A	N/A	N/A	N/A	N/A
Zn-65	N/A	N/A	N/A	N/A	N/A
Zn-69m	N/A	N/A	N/A	N/A	N/A
Sr-89	N/A	N/A	N/A	N/A	N/A
Sr-90	N/A	N/A	N/A	N/A	N/A
Zr/Nb-95	N/A	N/A	N/A	N/A	N/A
Mo/Tc-99	N/A	N/A	N/A	N/A	N/A
Ag-110m	N/A	N/A	N/A	N/A	N/A
Sb-124	N/A	N/A	N/A	N/A	N/A
I-131	N/A	N/A	N/A	N/A	N/A
I-133	N/A	N/A	N/A	N/A	N/A
Cs-134	N/A	N/A	N/A	N/A	N/A
Cs-137	N/A	N/A	N/A	N/A	N/A
Ba/La-140	N/A	N/A	N/A	N/A	N/A
Ce-141	N/A	N/A	N/A	N/A	N/A
Total for period	N/A	N/A	N/A	N/A	N/A
2. DISSOLVED AND ENTRAINED GASES: Ci					
Xe-133	N/A	N/A	N/A	N/A	N/A
Xe-135	N/A	N/A	N/A	N/A	N/A
Total for period	N/A	N/A	N/A	N/A	N/A

Notes for Table B.3-B:

1. N/A stands for not applicable.
2. NDA stands for No Detectable Activity.
3. LLDs for liquid radionuclides listed as NDA are as follows:

Strontium:	5E-08 μCi/mL
Iodines:	1E-06 μCi/mL
Noble Gases:	1E-05 μCi/mL
All Others:	5E-07 μCi/mL

Table B.3-B (continued)
Pilgrim Nuclear Power Station
Annual Radioactive Effluent Release Report
Liquid Effluents
January-December 2011

BATCH MODE RELEASES					
Nuclide Released	Jan-Mar 2011	Apr-Jun 2011	Jul-Sep 2011	Oct-Dec 2011	Jan-Dec 2011
1. FISSION AND ACTIVATION PRODUCTS: Ci					
Na-24	4.56E-06	NDA	N/A	NDA	4.56E-06
Cr-51	NDA	1.00E-03	N/A	NDA	1.00E-03
Mn-54	3.86E-06	1.30E-03	N/A	NDA	1.30E-03
Fe-55	NDA	NDA	N/A	NDA	NDA
Fe-59	NDA	2.32E-04	N/A	NDA	2.32E-04
Co-58	NDA	1.04E-04	N/A	NDA	1.04E-04
Co-60	2.41E-07	8.49E-04	N/A	NDA	8.49E-04
Zn-65	NDA	1.54E-04	N/A	NDA	1.54E-04
Zn-69m	NDA	NDA	N/A	NDA	NDA
Sr-89	8.43E-08	NDA	N/A	NDA	8.43E-08
Sr-90	NDA	NDA	N/A	NDA	NDA
Zr/Nb-95	NDA	8.66E-06	N/A	NDA	8.66E-06
Mo/Tc-99	NDA	NDA	N/A	NDA	NDA
Ag-110m	NDA	2.37E-05	N/A	NDA	2.37E-05
Sb-124	NDA	NDA	N/A	NDA	NDA
I-131	NDA	NDA	N/A	NDA	NDA
I-133	NDA	NDA	N/A	NDA	NDA
Cs-134	NDA	NDA	N/A	NDA	NDA
Cs-137	7.00E-05	4.81E-06	N/A	NDA	7.48E-05
Ba/La-140	NDA	NDA	N/A	NDA	NDA
Ce-141	NDA	NDA	N/A	NDA	NDA
Ce-144	NDA	NDA	N/A	NDA	NDA
Total for period	7.87E-05	3.68E-03	N/A	NDA	3.75E-03
2. DISSOLVED AND ENTRAINED GASES: Ci					
Xe-133	NDA	NDA	N/A	NDA	NDA
Xe-135	NDA	NDA	N/A	NDA	NDA
Total for period	NDA	NDA	N/A	NDA	NDA

Notes for Table B.3-B:

1. N/A stands for not applicable.
2. NDA stands for No Detectable Activity.
3. LLDs for liquid radionuclides listed as NDA are as follows:
   - Strontium: 5E-08 μCi/mL
   - Iodines: 1E-06 μCi/mL
   - Noble Gases: 1E-05 μCi/mL
   - All Others: 5E-07 μCi/mL

APPENDIX C

LAND USE CENSUS RESULTS

The annual land use census for gardens and milk and meat animals in the vicinity of Pilgrim Station was performed between August 25 and August 28, 2011. The census was conducted by driving along each improved road/street in the Plymouth area within 5 kilometers (3 miles) of Pilgrim Station to survey for visible gardens with an area of greater than 500 square feet. In compass sectors where no gardens were identified within 5 km (SSW, WNW, NW, and NNW sectors), the survey was extended to 8 km (5 mi). A total of 28 gardens were identified in the vicinity of Pilgrim Station. In addition, the Town of Plymouth Animal Inspector was contacted for information regarding milk and meat animals.

Atmospheric deposition (D/Q) values at the locations of the identified gardens were compared to those for the existing sampling program locations. These comparisons enabled PNPS personnel to ascertain the best locations for monitoring for releases of airborne radionuclides. Gardens yielding higher D/Q values than those currently in the sampling program were also sampled as part of the radiological environmental monitoring program.

Based on assessment of the gardens identified during the 2011 land use census, samples of garden-grown vegetables or naturally-growing vegetation (e.g. grass, leaves from bushes or trees, etc.) were collected at or near the closest gardens in each of the following landward compass sectors. These locations, and their distance and direction relative to the PNPS Reactor Building, are as follows:

Rocky Hill Road	0.9 km SE
Rocky Hill Road	1.8 km SSE
Clay Hill Road	1.6 km W

Additional samples of naturally-growing vegetation were collected at the site boundary in the ESE and SE sectors to monitor for atmospheric deposition in the vicinity of the nearest resident in the SE sector.

In addition to these special sampling locations identified and sampled in conjunction with the 2011 land use census, samples were also collected at or near the Plymouth County Farm (5.6 km W), and from control locations in Bridgewater (31 km W), Sandwich (21 km SSE), and Norton (49 km W).

Samples of naturally-growing vegetation were also collected in the vicinity of the site boundary locations yielding the highest deposition (D/Q) factors for each of the two release points. These locations, and their distance and direction relative to the PNPS Reactor Building, are as follows:

Highest Main Stack D/Q:	1.5 km SSW
Highest Reactor Building Vent D/Q:	0.5 km ESE
2nd highest D/Q, both release points:	1.1 km S

No new milk or meat animals were identified during the land use census. In addition, the Town of Plymouth Animal Inspector stated that their office is not aware of any animals at locations other than the Plimoth Plantation. Although milk sampling is not performed at Plimoth Plantation, effluent dose calculations are performed for this location assuming the presence of a milk ingestion pathway, as part of the Annual Radioactive Effluent Release Report (Reference 17).

APPENDIX D

ENVIRONMENTAL MONITORING PROGRAM DISCREPANCIES

There were a number of instances during 2011 in which inadvertent issues were encountered in the collection of environmental samples. All of these issues were minor in nature and did not have an adverse effect on the results or integrity of the monitoring program. Details of these various problems are given below.

During 2011, five offsite thermoluminescent dosimeters (TLD) and one onsite TLD were not recovered from their assigned locations during the quarterly retrieval process. Degradation of the plastic cages housing the TLDs resulted in the loss of the following TLDs: Greenwood House - GH (Qtr 1), North Plymouth - NP (Qtr 1), Station G (Qtr 2), Manomet Beach – MB (Qtr 4), and Memorial Hall – MH (Qtr 4). In these cases, the plastic cage holding the TLD were replaced and a new TLD posted. In situations involving suspected vandalism, the TLD cages were relocated to be less conspicuous, or raised up in height to deter further vandalism. The onsite TLD on the fence near the Trash Compaction Facility (P18) was lost during the second quarter due to weather-related degradation of the sample cage. Despite these losses, the 434 TLDs that were collected (98.6%) allowed for adequate assessment of the ambient radiation levels in the vicinity of Pilgrim Station.

Within the air sampling program, there were a few instances in which continuous sampling was interrupted at the eleven airborne sampling locations during 2011. Most of these interruptions were due to short-term power losses and were sporadic and of limited duration (less than 24 hours out of the weekly sampling period). Such events did not have any significant impact on the scope and purpose of the sampling program, and lower limits of detection (LLDs) were met for both airborne particulates and iodine-131 on 581 of the 581 filters/cartridges collected.

Out of 583 filters (11 locations * 53 weeks), 581 samples were collected and analyzed during 2011. The two samples that appear to have been "missed" were actually in service for a two-week period when sampling locations CR and OA were inaccessible due to heavy snow during the week of 26-Jan-2011. The particulate filters and charcoal cartridges were collected during the following week and the filters were analyzed based on the two week service time. All required LLDs were achieved on these samples.

The configuration of air samplers that had been in use at Pilgrim Station since the early 1980s, was replaced between June and August of 2011. Both the pumps and dry gas meters were replaced, and operating experience since changing over to the new configuration has been favorable. Although the occurrence of pump failures and gas meter problems have been largely eliminated, the new configuration is still subject to trips of the ground fault interrupt circuit (GFCI). Many of these problems were encountered at air samplers located at the East Breakwater and Pedestrian Bridge. Both of these locations are immediately adjacent to the shoreline and are subject to significant wind-blown salt water, and are prone to tripping of the GFCI. The following table contains a listing of larger problems encountered with air sampling stations during 2011, many of which resulted in loss of more than 24 hours in a sampling period.

Location	Sampling Period	Sampling Hours Lost	Problem Description
PB	12/28/10 to 01/04/10	34 of 168	GFCI outlet tripped during storm; reset
EB	01/11 to 01/18	124 of 196	GFCI outlet tripped during storm; reset
CR OA	01/26 to 02/08	No Hours Lost	Sampling station inaccessible due to heavy snow; filters left on for 2-week period, with no interruption of sampling; all required LLDs were achieved.
PB	05/03 to 05/10	65 of 169	Power supply to sampling station interrupted during planned load shed testing of electrical systems during RFO

Location	Sampling Period	Sampling Hours Lost	Problem Description
PB	06/21 to 06/28	101 of 168	Pump seized, resulting in trip of circuit breaker; replaced pump and reset breaker
ER	08/23 to 08/30	42 of 168	Power supply to sampling station was damaged by storm; power out at time of filter collection, but was repaired 09/02
ER	08/30 to 09/07	70 of 190	Power supply to sampling station was damaged by storm during previous week; power restored 09/02
PB	10/25 to 11/01	55 of 168	GFCI outlet tripped during storm; reset

There were three occurrences during 2011 in which the particulate filter was mispositioned in the air filter sampling head, resulting in partial bypassing of the flow around the filter media. Although the particulate filter was partially bypassed, most particulate activity would have been captured in the charcoal cartridge. Such instances of filter bypass occurred at EB (Week 1, 12/28/10 to 01/04/11); at ER (Week 23, 05/31 to 06/07); and at WR (Week 47, 11/15 to 11/21). Only the EB filter collected during Week 1 appeared to have a lower-than-normal level of gross beta activity when compared to other samples collected during the same week. The two instances involving ER and WR contained normal gross beta activity, suggesting minimal bypass. Sampling technicians were instructed to more carefully inspect filter holders before deployment into the field.

Despite the lower-than-normal sampling volumes in the various instances involving power interruptions and equipment failures, required LLDs were met on 581 of the 581 particulate filters, and 581 of the 581 of the iodine cartridges collected during 2011. When viewed collectively during the entire year of 2011, the following sampling recoveries were achieved in the airborne sampling program:

Location	Recovery	Location	Recovery	Location	Recovery
WS	99.9%	PB	97.0%	PC	100.0%
ER	98.7%	OA	99.8%	MS	99.9%
WR	99.9%	EB	98.5%	EW	99.9%
PL	99.9%	CR	100.0%		

An alternate location had to be found for sampling control vegetable samples in the Bridgewater area. In past years, samples had been collected at the Bridgewater County Farm, associated with the Bridgewater Correctional Facility. Due to loss of state funding for garden projects during 2006, no garden was grown. An alternate location was found at the Hanson Farm in Bridgewater, located in the same compass sector, and at approximately the same distance as the Bridgewater County Farm. Additional samples of naturally-occurring vegetation were collected from distant control locations in Sandwich and Norton. As expected for control samples, vegetables and vegetation collected at these locations only contained naturally-occurring radioactivity (Be-7, K-40, and Ac/Th-228).

Some problems were encountered in collection of crop samples during 2011. Crops which had normally been sampled in the past (lettuce, tomatoes, potatoes, and onions) were not grown at the Plymouth County Farm (CF) during 2011. Leafy material from pumpkin plants and corn plants were substituted for the lettuce to analyze for surface deposition of radioactivity on edible plants. Samples of squash, tomatoes, cucumbers, zucchini, and grape leaves were also collected from two other locations in the immediate vicinity of Pilgrim Station. No radionuclides attributed to PNPS operations were detected in any of the samples.

Naturally-growing leafy vegetation (grass, leaves from trees and bushes, etc.) was collected near some gardens identified during the annual land use census. Due to the unavailability of crops grown in several of these gardens, these substitute samples were collected as near as practicable to the gardens of interest. No radionuclides attributed to PNPS operations were detected in any of the samples. Additional details regarding the land use census can be found in Appendix C of this report.

The cranberry bog at Pine Street Bog in Halifax was not in production during 2011, so a sample could not be obtained from this location. A substitute sample was collected from a bog (Hollow Bog) in Kingston, beyond the influence of Pilgrim Station. In addition, the cranberry bog along Bartlett Road suspended operation during 2011, and was not producing cranberries. Samples were collected from two separate indicator locations located along Beaverdam Road.

The peristaltic pump in the composite sampler is insufficient to overcome the lift head from the canal into the small laboratory in the base of the footbridge. Therefore, an auxiliary lift pump is suspended into the canal, and provides a feed of water into the laboratory, which is then sampled by the composite sampler. Failure of the auxiliary lift pump during the following periods led to interruption in supply water to the composite sampler: 12/28/10 to 01/04/11; 01/10 to 01/18; and 11/21 to 11/29. In all of these instances, a grab sample was collected from the discharge canal to substitute for the missing composite sample. None of these failures occurred during periods when liquid radwaste discharges were being performed.

An additional problem was encountered with the programming of the composite sampler to collect a fixed volume of sample every 30 minutes, sufficient to provide a targeted volume of approximately 5 gallons each week. The program failed to properly reinitiate following weekly composite collection, and resulted in a 1-gallon sample during the week of 11/8 to 11/15, instead of the anticipated 5-gallon sample. Proper operation was restored when the composite sampler was reprogrammed. In this instance of low composite sample volume, a grab sample was collected from the discharge canal to substitute for the missing composite sample.

In summary, the various problems encountered in collecting and analyzing environmental samples during 2011 were relatively minor when viewed in the context of the entire monitoring program. These discrepancies were promptly corrected when issue was identified. None of the discrepancies resulted in an adverse impact on the overall monitoring program.

APPENDIX E

J.A. FITZPATRICK INTERLABORATORY COMPARISON PROGRAM

E.1 Program Description

The J.A. Fitzpatrick Environmental Laboratory participates in an Interlaboratory Comparison Program. The Interlaboratory Comparison Program includes sample media for which samples are routinely collected and for which comparison samples are commercially available. Participation in an Interlaboratory Comparison Program ensures that independent checks on the precision and accuracy of the measurement of radioactive material in the environmental samples are performed as part of the Quality Assurance Program for environmental monitoring. To fulfill the requirement for an Interlaboratory Comparison Program, the James A. FitzPatrick Nuclear Power Plant (JAF) Environmental Laboratory has engaged the services of Eckert & Ziegler Analytics, Incorporated in Atlanta, Georgia.

Analytics supplies sample media as blind sample spikes, which contain certified levels of radioactivity unknown to the analysis laboratory. These samples are prepared and analyzed by the JAF Environmental Laboratory using standard laboratory procedures. Analytics issues a statistical summary report of the results. The JAF Environmental Laboratory uses predetermined acceptance criteria methodology for evaluating the laboratory's performance.

The JAF Environmental Laboratory also analyzes laboratory blanks. The analysis of laboratory blanks provides a means to detect and measure radioactive contamination of analytical samples. The analysis of analytical blanks also provides information on the adequacy of background subtraction. Laboratory blank results are analyzed using control charts.

E.2 Program Schedule

SAMPLE MEDIA	LABORATORY ANALYSIS	SAMPLE PROVIDER ANALYTICS
Water	Gross Beta	3
Water	Tritium	5
Water	I-131	4
Water	Mixed Gamma	4
Air	Gross Beta	3
Air	I-131	4
Air	Mixed Gamma	2
Milk	I-131	3
Milk	Mixed Gamma	3
Soil	Mixed Gamma	1
Vegetation	Mixed Gamma	2
TOTAL SAMPLE INVENTORY		34

E.3 Acceptance Criteria

Each sample result is evaluated to determine the accuracy and precision of the laboratory's analysis result. The sample evaluation method is discussed below.

E.3.1 Sample Results Evaluation

Samples provided by Analytics are evaluated using what is specified as the NRC method. This method is based on the calculation of the ratio of results reported by the participating laboratory (QC result) to the Vendor Laboratory Known value (reference result).

An Environmental Laboratory analytical result is evaluated using the following calculation:

The value for the error resolution is calculated.

$$\text{Error Resolution} = \frac{\text{Reference Result}}{\text{Reference Results Error (1 sigma)}}$$

Using the appropriate row under the Error Resolution column in Table E.3-1, a corresponding Ratio of Agreement interval is given.

The value for the ratio is then calculated.

$$\text{Ratio of agreement} = \frac{\text{QC Result}}{\text{Reference Result}}$$

If the value falls within the agreement interval, the result is acceptable.

TABLE E.3-1

ERROR RESOLUTION	RATIO OF AGREEMENT
< 4	No Comparison
4 to 7	0.5-2.0
8 to 15	0.6-1.66
16 to 50	0.75-1.33
51 to 200	0.8-1.25
>200	0.85-1.18

This acceptance test is generally referred to as the "NRC" method. The acceptance criteria are contained in Procedure EN-CY-102. The NRC method generally results in an acceptance range of approximately ± 25% of the Known value when applied to sample results from the Eckert & Ziegler Analytics Interlaboratory Comparison Program. This method is used as the procedurally required assessment method and requires the generation of a deviation from QA/QC program report when results are unacceptable.

E.4 Program Results Summary

The Interlaboratory Comparison Program numerical results are provided on Section E.4.2.

E.4.1 Eckert & Ziegler Analytics QA Samples Results

Thirty-four QA blind spike samples were analyzed as part of Analytics 2011 Interlaboratory Comparison Program. The following sample media were evaluated as part of the comparison program.

- Air Charcoal Cartridge: I-131
- Air Particulate Filter: Gross Beta, Mixed Gamma Emitters
- Water: Gross Beta, Tritium, I-131, Mixed Gamma Emitters
- Milk: I-131, Mixed Gamma Emitters
- Vegetation: Mixed Gamma Emitters
- Soil: Mixed Gamma Emitters

The JAF Environmental Laboratory performed 133 individual analyses on the 34 QA samples. Of the 133 analyses performed, 133 were in agreement using the NRC acceptance criteria for a 100% agreement ratio.

There were no nonconformities in the 2011 program.

E.4.2 Numerical Results Tables

Data tables in this section were obtained from Section 8 of the annual QA Report for the J.A. Fitzpatrick Environmental Laboratory.

Table E.4-1
INTERLABORATORY INTERCOMPARISON PROGRAM
Gross Beta Analysis of Air Particulate Filter

DATE	SAMPLE ID NO.	MEDIUM	ANALYSIS	JAF ELAB RESULTS pCi ±1 sigma	REFERENCE LAB* pCi ±1 sigma	RATIO (1)
06/16/2011	E7633-05	Air Particulate Filter	Gross Beta	9.32E+01 ± 1.36E+00 9.11E+01 ± 1.34E+00 9.17E+01 ± 1.35E+00 Mean = 9.20E+01 ± 7.79E-01	8.55E+01 ± 1.43E+00	1.08 A
06/16/2011	E7618-09	Air Particulate Filter	Gross Beta	7.61E+01 ± 1.20E+00 7.93E+01 ± 1.30E+00 7.64E+01 ± 1.20E+00 Mean = 7.73E+01 ± 7.10E-01	7.29E+01 ± 1.22E+00	1.06 A
12/08/2011	E8254-05	Air Particulate Filter	Gross Beta	1.01E+02 ± 2.74E+00 9.96E+01 ± 2.72E+00 1.01E+02 ± 2.74E+00 9.98E+01 ± 2.72E+00 9.89E+01 ± 2.71E+00 9.79E+01 ± 2.69E+00 1.05E+02 ± 2.78E+00 1.08E+02 ± 2.81E+00 9.97E+01 ± 2.70E+00 9.14E+01 ± 2.69E+00 9.14E+01 ± 2.71E+00 9.81E+01 ± 2.79E+00 Mean = 9.94E+01 ± 8.00E-01	8.96E+01 ± 1.50E+00	1.11 A

(1) Ratio = Reported/Analytics. A=Acceptable
* Sample provided by Analytics, Inc. U=Unacceptable

Table E.4-1 (Continued)
I-131 Gamma Analysis of Air Charcoal

DATE	SAMPLE ID NO.	MEDIUM	ANALYSIS	JAF ELAB RESULTS pCi ±1 sigma	REFERENCE LAB* pCi ±1 sigma	RATIO (1)
03/17/2011	E7437-09	Air Charcoal Cartridge	I-131	9.63E+01 ± 3.30E+00 9.73E+01 ± 1.50E+00 9.80E+01 ± 3.20E+00 Mean = 9.72E+01 ± 1.57E+00	9.62E+01 ± 1.61E+00	1.01 A
06/16/2011	E7636-05	Air Charcoal Cartridge	I-131	9.53E+01 ± 2.70E+00 1.00E+02 ± 2.70E+00 8.61E+01 ± 2.80E+00 Mean = 9.38E+01 ± 1.57E+00	8.67E+01 ± 1.45E+00	1.08 A
09/15/2011	E8125-05	Air Charcoal Cartridge	I-131	8.05E+01 ± 3.00E+00 8.32E+01 ± 3.20E+00 8.40E+01 ± 3.10E+00 Mean = 8.26E+01 ± 1.80E+00	8.05E+01 ± 1.34E+00	1.03 A
09/15/2011	E8127-09	Air Charcoal Cartridge	I-131	7.23E+01 ± 4.30E+00 7.21E+01 ± 4.50E+00 8.06E+01 ± 4.60E+00 Mean = 7.50E+01 ± 2.60E+00	8.05E+01 ± 1.34E+00	0.93 A

(1) Ratio = Reported/Analytics. A=Acceptable
* Sample provided by Analytics, Inc. U=Unacceptable

Table E.4-1 (Continued)
Gross Beta Analysis of Water

DATE	SAMPLE ID NO.	MEDIUM	ANALYSIS	JAF ELAB RESULTS pCi/liter ±1 sigma	REFERENCE LAB* pCi/liter ±1 sigma	RATIO (1)
03/17/2011	E7479-05	Water	Gross Beta	2.51E+02 ± 2.50E+00 2.52E+02 ± 2.50E+00 2.54E+02 ± 2.50E+00 2.55E+02 ± 2.50E+00 Mean = 2.53E+02 ± 1.30E+00	2.47E+02 ± 4.13E+00	1.02 A
06/16/2011	E7638-05	Water	Gross Beta	2.33E+02 ± 2.40E+00 2.32E+02 ± 2.40E+00 2.34E+02 ± 2.40E+00 Mean = 2.33E+02 ± 1.39E+00	2.51E+02 ± 4.18E+00	0.93 A
09/15/2011	E8126-05	Water	Gross Beta	2.54E+02 ± 3.30E+00 2.57E+02 ± 3.30E+00 2.50E+02 ± 3.30E+00 Mean = 2.54E+02 ± 1.90E+00	2.49E+02 ± 4.16E+00	1.02 A

(1) Ratio = Reported/Analytics. A=Acceptable
* Sample provided by Analytics, Inc. U=Unacceptable

Table E.4-1 (Continued)
Tritium Analysis of Water

DATE	SAMPLE ID NO.	MEDIUM	ANALYSIS	JAF ELAB RESULTS pCi/liter ±1 sigma	REFERENCE LAB* pCi/liter ±1 sigma	RATIO (1)
03/17/2011	E7476-05	Water	H-3	4.31E+03 ± 1.63E+02 4.67E+03 ± 1.66E+02 4.65E+03 ± 1.66E+02 Mean = 4.55E+03 ± 9.50E+01	4.53E+03 ± 7.57E+01	1.00 A
06/16/2011	E7632-05	Water	H-3	8.33E+02 ± 1.34E+02 9.23E+02 ± 1.35E+02 9.08E+02 ± 1.35E+02 Mean = 8.88E+02 ± 7.78E+01	9.05E+02 ± 1.51E+01	0.98 A
09/15/2011	E8121-05	Water	H-3	9.15E+02 ± 1.31E+02 1.00E+03 ± 1.32E+02 9.57E+02 ± 1.32E+02 Mean = 9.58E+02 ± 7.60E+01	7.92E+02 ± 1.32E+02	1.21 A
12/08/2011	E8181-09	Water	H-3	1.06E+04 ± 2.09E+02 1.02E+04 ± 2.08E+02 1.01E+04 ± 2.11E+02 Mean = 1.03E+04 ± 1.21E+02	1.09E+04 ± 1.82E+02	0.94 A
12/08/2011	E8182-09	Water	H-3	1.03E+04 ± 2.06E+02 1.03E+04 ± 2.08E+02 1.01E+04 ± 2.10E+02 Mean = 1.03E+04 ± 1.20E+02	1.09E+04 ± 1.82E+02	0.94 A

(1) Ratio = Reported/Analytics. A=Acceptable
* Sample provided by Analytics, Inc. U=Unacceptable

Table E.4-1 (Continued)
INTERLABORATORY INTERCOMPARISON PROGRAM
Gamma Analysis of Air Particulate Filter

DATE	SAMPLE ID NO.	MEDIUM	ANALYSIS	JAF ELAB RESULTS pCi ±1 sigma	REFERENCE LAB* pCi ±1 sigma	RATIO (1)
03/17/2011	E7478-05	Air Particulate Filter	Cr-51	2.21E+02 ± 1.59E+01 2.24E+02 ± 1.80E+01 2.33E+02 ± 1.37E+01 Mean = 2.26E+02 ± 9.22E+00	2.30E+02 ± 3.84E+00	0.98 A
			Cs-134	1.17E+02 ± 4.50E+00 1.11E+02 ± 4.90E+00 1.15E+02 ± 3.80E+00 Mean = 1.14E+02 ± 2.55E+00	1.01E+02 ± 1.68E+00	1.13 A
			Cs-137	1.69E+02 ± 4.50E+00 1.59E+02 ± 4.80E+00 1.65E+02 ± 3.80E+00 Mean = 1.64E+02 ± 2.52E+00	1.58E+02 ± 2.64E+00	1.04 A
			Co-58	9.00E+01 ± 3.50E+00 8.40E+01 ± 4.10E+00 9.00E+01 ± 3.20E+00 Mean = 8.81E+01 ± 2.08E+00	8.73E+01 ± 1.46E+00	1.01 A
			Mn-54	2.11E+02 ± 5.20E+00 2.21E+02 ± 5.80E+00 2.18E+02 ± 4.50E+00 Mean = 2.17E+02 ± 2.98E+00	2.05E+02 ± 3.43E+00	1.06 A
			Fe-59	1.44E+02 ± 5.20E+00 1.38E+02 ± 6.10E+00 1.56E+02 ± 4.60E+00 Mean = 1.46E+02 ± 3.09E+00	1.34E+02 ± 2.24E+00	1.09 A
			Zn-65	2.26E+02 ± 8.80E+00 2.12E+02 ± 9.80E+00 2.08E+02 ± 7.60E+00 Mean = 2.15E+02 ± 5.04E+00	2.01E+02 ± 3.36E+00	1.07 A
			Co-60	1.27E+02 ± 3.40E+00 1.32E+02 ± 3.80E+00 1.30E+02 ± 2.90E+00 Mean = 1.30E+02 ± 1.94E+00	1.32E+02 ± 2.21E+00	0.98 A

(1) Ratio = Reported/Analytics.
* Sample provided by Analytics, Inc.

A=Acceptable
U=Unacceptable

Table E.4-1 (Continued)
INTERLABORATORY INTERCOMPARISON PROGRAM
Gamma Analysis of Air Particulate Filter

DATE	SAMPLE ID NO.	MEDIUM	ANALYSIS	JAF ELAB RESULTS pCi ±1 sigma	REFERENCE LAB* pCi ±1 sigma	RATIO (1)
09/15/2011	E8123-05	Air Particulate Filter	Ce-141	6.84E+01 ± 2.80E+00	6.96E+01 ± 1.16E+00	1.02 A
				7.11E+01 ± 2.70E+00		
				7.35E+01 ± 2.80E+00		
				Mean = 7.10E+01 ± 1.60E+00		
			Cr-51	2.17E+02 ± 1.84E+01	2.36E+02 ± 3.94E+00	0.96 A
				2.32E+02 ± 1.79E+01		
				2.28E+02 ± 1.80E+01		
				Mean = 2.26E+02 ± 1.05E+01		
			Cs-134	1.15E+02 ± 8.70E+00	1.34E+02 ± 2.23E+00	0.85 A
				1.15E+02 ± 8.50E+00		
				1.11E+02 ± 8.20E+00		
				Mean = 1.14E+02 ± 4.89E+00		
			Cs-137	1.24E+02 ± 4.30E+00	1.19E+02 ± 1.98E+00	0.99 A
				1.14E+02 ± 4.20E+00		
				1.15E+02 ± 4.00E+00		
				Mean = 1.18E+02 ± 2.41E+00		
			Co-58	1.04E+02 ± 4.10E+00	1.02E+02 ± 1.70E+00	1.05 A
				1.08E+02 ± 4.10E+00		
				1.08E+02 ± 4.00E+00		
				Mean = 1.07E+02 ± 2.35E+00		
			Mn-54	1.75E+02 ± 5.20E+00	1.57E+02 ± 2.63E+00	1.11 A
				1.67E+02 ± 5.10E+00		
				1.79E+02 ± 4.80E+00		
				Mean = 1.74E+02 ± 2.91E+00		
			Fe-59	6.17E+01 ± 4.90E+00	5.72E+01 ± 9.55E-01	1.13 A
				6.86E+01 ± 4.80E+00		
				6.35E+01 ± 4.30E+00		
				Mean = 6.46E+01 ± 2.70E+00		
			Zn-65	1.97E+02 ± 1.01E+01	1.88E+02 ± 3.14E+00	1.13 A
				2.18E+02 ± 9.80E+00		
				2.25E+02 ± 9.00E+00		
				Mean = 2.13E+02 ± 5.57E+00		
			Co-60	1.61E+02 ± 4.20E+00	1.64E+02 ± 2.74E+00	0.98 A
				1.59E+02 ± 4.10E+00		
				1.64E+02 ± 3.90E+00		
				Mean = 1.61E+02 ± 2.35E+00		

(1) Ratio = Reported/Analytics.
* Sample provided by Analytics, Inc.

A=Acceptable
U=Unacceptable

Table E.4-1 (Continued)
INTERLABORATORY INTERCOMPARISON PROGRAM
Gamma Analysis of Soil

DATE	SAMPLE ID NO.	MEDIUM	ANALYSIS	JAF ELAB RESULTS pCi/g ±1 sigma	REFERENCE LAB* pCi/g ±1 sigma	RATIO (1)
06/16/2011	E7635-05	Soil	Ce-141	1.89E-01 ± 2.20E-02 1.89E-01 ± 2.00E-02 1.93E-01 ± 2.09E-02 Mean = 1.90E-01 ± 1.21E-02	1.54E-01 ± 2.57E-03	1.24 A
			Cr-51	3.16E-01 ± 9.66E-03 3.65E-01 ± 9.37E-03 3.42E-01 ± 9.45E-03 Mean = 3.41E-01 ± 5.48E-03	3.97E-01 ± 6.63E-03	0.86 A
			Cs-134	3.58E-01 ± 3.38E-03 3.63E-01 ± 3.32E-03 3.49E-01 ± 3.86E-03 Mean = 3.57E-01 ± 2.04E-03	3.66E-01 ± 6.10E-03	0.97 A
			Cs-137	3.08E-01 ± 1.90E-02 3.54E-01 ± 1.90E-02 3.47E-01 ± 2.09E-02 Mean = 3.36E-01 ± 1.13E-02	3.55E-01 ± 5.93E-03	0.95 A
			Co-58	2.92E-01 ± 1.78E-02 2.95E-01 ± 1.74E-02 2.90E-01 ± 1.95E-02 Mean = 2.92E-01 ± 1.05E-02	2.92E-01 ± 4.88E-03	1.00 A
			Mn-54	3.04E-01 ± 1.74E-02 2.81E-01 ± 1.70E-02 2.85E-01 ± 1.98E-02 Mean = 2.90E-01 ± 1.05E-02	2.66E-01 ± 4.44E-03	1.09 A
			Fe-59	2.33E-01 ± 1.96E-02 2.53E-01 ± 2.07E-02 2.48E-01 ± 2.28E-02 Mean = 2.45E-01 ± 1.22E-02	2.38E-01 ± 3.97E-03	1.03 A
			Zn-65	5.22E-01 ± 3.25E-02 5.57E-01 ± 3.39E-02 5.53E-01 ± 3.85E-02 Mean = 5.44E-01 ± 2.02E-02	5.02E-01 ± 8.39E-03	1.08 A
			Co-60	4.02E-01 ± 1.46E-02 3.86E-01 ± 1.49E-02 3.69E-01 ± 1.65E-02 Mean = 3.86E-01 ± 8.87E-03	3.75E-01 ± 6.26E-03	1.03 A

(1) Ratio = Reported/Analytics. A=Acceptable
* Sample provided by Analytics, Inc. U=Unacceptable

Table E.4-1 (Continued)
INTERLABORATORY INTERCOMPARISON PROGRAM
Gamma Analysis of Vegetation

DATE	SAMPLE ID NO.	MEDIUM	ANALYSIS	JAF ELAB RESULTS pCi/g ±1 sigma		REFERENCE LAB* pCi/g ±1 sigma	RATIO (1)
06/16/2011	E7637-05	Vegetation	Ce-141		2.74E-01 ± 1.29E-02	3.07E-01 ± 5.13E-03	0.92 A
					2.70E-01 ± 1.52E-02		
					3.04E-01 ± 1.36E-02		
				Mean =	2.83E-01 ± 8.04E-03		
			Cr-51		7.39E-01 ± 7.34E-02	7.92E-01 ± 1.32E-02	1.00 A
					7.67E-01 ± 8.79E-02		
					8.63E-01 ± 7.11E-02		
				Mean =	7.90E-01 ± 4.49E-02		
			Cs-134		6.64E-01 ± 3.52E-02	7.29E-01 ± 1.22E-02	0.89 A
					6.60E-01 ± 4.13E-03		
					6.29E-01 ± 2.84E-03		
				Mean =	6.51E-01 ± 1.19E-02		
			Cs-137		4.94E-01 ± 1.63E-02	5.30E-01 ± 8.86E-03	0.95 A
					5.06E-01 ± 1.91E-02		
					5.11E-01 ± 1.52E-02		
				Mean =	5.04E-01 ± 9.78E-03		
			Co-58		5.79E-01 ± 1.71E-02	5.83E-01 ± 9.73E-03	0.99 A
					5.56E-01 ± 1.92E-02		
					5.95E-01 ± 1.54E-02		
				Mean =	5.77E-01 ± 9.99E-03		
			Mn-54		5.20E-01 ± 1.66E-02	5.30E-01 ± 8.85E-03	0.96 A
					5.12E-01 ± 1.93E-02		
					4.87E-01 ± 1.48E-02		
				Mean =	5.06E-01 ± 9.82E-03		
			Fe-59		4.87E-01 ± 1.89E-02	4.74E-01 ± 7.91E-03	1.03 A
					5.14E-01 ± 2.30E-02		
					4.70E-01 ± 1.67E-02		
				Mean =	4.90E-01 ± 1.14E-02		
			Zn-65		1.10E+00 ± 3.70E-02	1.00E+00 ± 1.67E-02	1.01 A
					9.41E-01 ± 4.33E-02		
					9.83E-01 ± 3.14E-02		
				Mean =	1.01E+00 ± 2.17E-02		
			Co-60		7.18E-01 ± 1.52E-02	7.48E-01 ± 1.25E-02	0.94 A
					7.16E-01 ± 1.74E-02		
					6.80E-01 ± 1.30E-02		
				Mean =	7.05E-01 ± 8.84E-03		

(1) Ratio = Reported/Analytics. A=Acceptable
* Sample provided by Analytics, Inc. U=Unacceptable

Table E.4-1 (Continued)
INTERLABORATORY INTERCOMPARISON PROGRAM
Gamma Analysis of Vegetation

DATE	SAMPLE ID NO.	MEDIUM	ANALYSIS	JAF ELAB RESULTS pCi/g ±1 sigma	REFERENCE LAB* pCi/g ±1 sigma	RATIO (1)
09/15/2011	E8128-09	Vegetation	Ce-141	1.51E-01 ± 1.34E-02 1.67E-01 ± 1.73E-02 1.63E-01 ± 1.48E-02 Mean = 1.60E-01 ± 8.81E-03	1.69E-01 ± 2.82E-03	0.95 A
			Cr-51	6.32E-01 ± 8.21E-02 5.53E-01 ± 1.14E-01 6.62E-01 ± 9.49E-03 Mean = 6.16E-01 ± 4.69E-02	5.73E-01 ± 9.57E-03	1.07 A
			Cs-134	3.32E-01 ± 2.88E-02 3.43E-01 ± 3.18E-02 2.71E-01 ± 3.27E-02 Mean = 3.15E-01 ± 1.80E-02	3.25E-01 ± 5.42E-03	0.97 A
			Cs-137	2.99E-01 ± 1.41E-02 2.56E-01 ± 1.61E-02 2.81E-01 ± 1.59E-02 Mean = 2.79E-01 ± 8.89E-03	2.88E-01 ± 4.81E-03	0.97 A
			Co-58	2.73E-01 ± 1.44E-02 2.56E-01 ± 1.61E-02 2.58E-01 ± 1.64E-02 Mean = 2.62E-01 ± 9.04E-03	2.47E-01 ± 4.12E-03	1.06 A
			Mn-54	4.00E-01 ± 1.57E-02 4.30E-01 ± 1.98E-02 3.66E-01 ± 1.89E-02 Mean = 3.99E-01 ± 1.05E-02	3.82E-01 ± 6.38E-03	1.04 A
			Fe-59	1.58E-01 ± 1.64E-02 1.55E-01 ± 2.13E-02 1.09E-01 ± 1.93E-02 Mean = 1.41E-01 ± 1.10E-02	1.39E-01 ± 2.32E-03	1.01 A
			Zn-65	4.19E-01 ± 2.89E-02 4.93E-01 ± 3.85E-02 4.77E-01 ± 3.56E-02 Mean = 4.63E-01 ± 2.00E-02	4.57E-01 ± 7.63E-03	1.01 A
			Co-60	3.88E-01 ± 1.26E-02 3.66E-01 ± 1.52E-02 3.95E-01 ± 1.51E-02 Mean = 3.83E-01 ± 8.29E-03	3.97E-01 ± 6.64E-03	0.96 A

(1) Ratio = Reported/Analytics. A=Acceptable
* Sample provided by Analytics, Inc. U=Unacceptable

Table E.4-1 (Continued)
INTERLABORATORY INTERCOMPARISON PROGRAM
Gamma Analysis of Milk

DATE	SAMPLE ID NO.	MEDIUM	ANALYSIS	JAF ELAB RESULTS pCi/liter ±1 sigma	REFERENCE LAB* pCi/liter ±1 sigma	RATIO (1)
03/17/2011	E7438-09	Milk	Cr-51	2.64E+02 ± 4.13E+01	2.98E+02 ± 4.98E+00	0.97 A
				3.12E+02 ± 2.32E+01		
				2.95E+02 ± 5.59E+01		
				Mean = 2.90E+02 ± 1.60E+01		
			Cs-134	1.35E+02 ± 7.50E+00	1.30E+02 ± 2.18E+00	1.04 A
				1.33E+02 ± 4.70E+00		
				1.36E+02 ± 9.80E+00		
				Mean = 1.35E+02 ± 3.10E+00		
			Cs-137	2.06E+02 ± 8.80E+00	2.05E+02 ± 3.43E+00	1.03 A
				2.08E+02 ± 5.00E+00		
				2.19E+02 ± 1.06E+01		
				Mean = 2.11E+02 ± 3.50E+00		
			Co-58	1.26E+02 ± 7.20E+00	1.13E+02 ± 1.89E+00	1.07 A
				1.22E+02 ± 4.00E+00		
				1.16E+02 ± 9.30E+00		
				Mean = 1.21E+02 ± 2.90E+00		
			Mn-54	2.82E+02 ± 1.00E+01	2.66E+02 ± 4.45E+00	1.05 A
				2.75E+02 ± 5.60E+00		
				2.79E+02 ± 1.20E+01		
				Mean = 2.79E+02 ± 5.50E+00		
			Fe-59	1.74E+02 ± 1.07E+01	1.75E+02 ± 2.91E+00	1.06 A
				1.84E+02 ± 6.00E+00		
				1.98E+02 ± 1.40E+01		
				Mean = 1.85E+02 ± 6.20E+00		
			Zn-65	2.75E+02 ± 1.71E+01	2.61E+02 ± 4.36E+00	1.13 A
				2.87E+02 ± 9.60E+00		
				3.24E+02 ± 2.13E+01		
				Mean = 2.95E+02 ± 9.60E+00		
			Co-60	1.84E+02 ± 6.60E+00	1.72E+02 ± 2.87E+00	1.00 A
				1.69E+02 ± 3.60E+00		
				1.61E+02 ± 7.80E+00		
				Mean = 1.71E+02 ± 3.60E+00		
			I-131	1.08E+02 ± 8.40E+00	9.69E+01 ± 1.62E+00	1.07 A
				1.04E+02 ± 4.50E+00		
				9.75E+01 ± 9.50E+00		
				Mean = 1.03E+02 ± 4.50E+00		
			I-131**	9.54E+01 ± 6.50E+00	9.69E+01 ± 1.62E+00	1.00 A
				1.03E+02 ± 2.60E+00		
				9.18E+01 ± 3.60E+00		
				Mean = 9.67E+01 ± 2.60E+00		

(1) Ratio = Reported/Analytics. A=Acceptable
* Sample provided by Analytics, Inc. U=Unacceptable
** Result determined by Resin Extraction/Gamma Spectral Analysis.

Table E.4-1 (Continued)
INTERLABORATORY INTERCOMPARISON PROGRAM
Gamma Analysis of Milk

DATE	SAMPLE ID NO.	MEDIUM	ANALYSIS	JAF ELAB RESULTS pCi/liter ±1 sigma	REFERENCE LAB* pCi/liter ±1 sigma	RATIO (1)
06/16/2011	E7634-05	Milk	Ce-141	8.61E+01 ± 5.92E+00 8.57E+01 ± 7.98E+00 8.47E+01 ± 7.23E+00 Mean = 8.55E+01 ± 4.10E+00	7.99E+01 ± 1.33E+00	1.07 A
			Cr-51	2.09E+02 ± 2.64E+01 2.21E+02 ± 4.24E+01 2.38E+02 ± 3.70E+01 Mean = 2.23E+02 ± 2.07E+01	2.06E+02 ± 3.44E+00	1.08 A
			Cs-134	1.81E+02 ± 9.37E+00 1.79E+02 ± 1.25E+01 1.59E+02 ± 1.31E+01 Mean = 1.73E+02 ± 6.80E+00	1.90E+02 ± 3.17E+00	0.91 A
			Cs-137	1.35E+02 ± 4.67E+00 1.45E+02 ± 6.51E+00 1.36E+02 ± 6.38E+00 Mean = 1.39E+02 ± 3.41E+00	1.38E+02 ± 2.30E+00	1.00 A
			Co-58	1.58E+02 ± 4.86E+00 1.53E+02 ± 6.56E+00 1.53E+02 ± 6.98E+00 Mean = 1.55E+02 ± 3.58E+00	1.52E+02 ± 2.53E+00	1.02 A
			Mn-54	1.36E+02 ± 4.79E+00 1.41E+02 ± 6.81E+00 1.38E+02 ± 6.46E+00 Mean = 1.38E+02 ± 3.51E+00	1.38E+02 ± 2.30E+00	1.00 A
			Fe-59	1.33E+02 ± 5.64E+00 1.45E+02 ± 8.64E+00 1.27E+02 ± 7.70E+00 Mean = 1.35E+02 ± 4.29E+00	1.23E+02 ± 2.06E+00	1.10 A
			Zn-65	2.66E+02 ± 9.97E+00 2.62E+02 ± 1.44E+01 2.61E+02 ± 1.38E+01 Mean = 2.63E+02 ± 7.43E+00	2.61E+02 ± 4.35E+00	1.01 A
			Co-60	1.96E+02 ± 4.09E+00 1.96E+02 ± 5.91E+00 2.05E+02 ± 5.69E+00 Mean = 1.99E+02 ± 3.06E+00	1.95E+02 ± 3.25E+00	1.02 A
			I-131	1.12E+02 ± 5.24E+00 9.23E+01 ± 7.65E+00 1.01E+02 ± 8.95E+00 Mean = 1.02E+02 ± 4.30E+00	1.03E+02 ± 1.72E+00	0.99 A
			I-131**	9.23E+01 ± 1.18E+00 8.98E+01 ± 1.68E+00 9.25E+01 ± 1.26E+00 Mean = 9.15E+01 ± 8.03E-01	1.03E+02 ± 1.72E+00	0.89 A

(1) Ratio = Reported/Analytics.
* Sample provided by Analytics, Inc.
** Result determined by Resin Extraction/Gamma Spectral Analysis.

A=Acceptable
U=Unacceptable

Table E.4-1 (Continued)
INTERLABORATORY INTERCOMPARISON PROGRAM
Gamma Analysis of Milk

DATE	SAMPLE ID NO.	MEDIUM	ANALYSIS	JAF ELAB RESULTS pCi/liter ±1 sigma	REFERENCE LAB* pCi/liter ±1 sigma	RATIO (1)
09/15/2011	E8124-05	Milk	Ce-141	7.92E+01 ± 7.50E+00 6.47E+01 ± 5.20E+00 6.98E+01 ± 6.40E+00 Mean = 7.12E+01 ± 3.72E+00	6.67E+01 ± 1.11E+00	1.07 A
			Cr-51	1.87E+02 ± 3.55E+01 2.43E+02 ± 2.58E+01 2.24E+02 ± 2.93E+01 Mean = 2.18E+02 ± 1.76E+01	2.26E+02 ± 3.78E+00	0.96 A
			Cs-134	1.12E+02 ± 1.17E+01 1.24E+02 ± 8.50E+00 1.16E+02 ± 9.50E+00 Mean = 1.17E+02 ± 5.77E+00	1.28E+02 ± 2.14E+00	0.92 A
			Cs-137	1.11E+02 ± 6.00E+00 1.11E+02 ± 4.50E+00 1.15E+02 ± 4.90E+00 Mean = 1.12E+02 ± 2.99E+00	1.14E+02 ± 1.90E+00	0.99 A
			Co-58	1.04E+02 ± 5.80E+00 1.07E+02 ± 4.40E+00 9.31E+01 ± 4.50E+00 Mean = 1.01E+02 ± 2.85E+00	9.75E+01 ± 1.63E+00	1.04 A
			Mn-54	1.68E+02 ± 6.90E+00 1.57E+02 ± 5.10E+00 1.54E+02 ± 5.60E+00 Mean = 1.60E+02 ± 3.42E+00	1.51E+02 ± 2.52E+00	1.06 A
			Fe-59	6.19E+01 ± 7.00E+00 6.58E+01 ± 4.90E+00 5.52E+01 ± 5.40E+00 Mean = 6.10E+01 ± 3.37E+00	5.48E+01 ± 9.15E-01	1.11 A
			Zn-65	1.94E+02 ± 1.36E+01 1.91E+02 ± 9.40E+00 1.99E+02 ± 1.06E+01 Mean = 1.95E+02 ± 6.55E+00	1.80E+02 ± 3.01E+00	1.08 A
			Co-60	1.59E+02 ± 5.30E+00 1.65E+02 ± 4.10E+00 1.55E+02 ± 4.40E+00 Mean = 1.60E+02 ± 2.67E+00	1.57E+02 ± 2.62E+00	1.02 A
			I-131	8.69E+01 ± 6.60E+00 9.79E+01 ± 5.30E+00 9.77E+01 ± 5.80E+00 Mean = 9.42E+01 ± 3.42E+00	8.92E+01 ± 1.49E+00	1.06 A
			I-131**	7.98E+01 ± 1.10E+00 7.95E+01 ± 1.00E+00 7.85E+01 ± 1.60E+00 Mean = 7.93E+01 ± 7.28E-01	8.92E+01 ± 1.49E+00	0.89 A

(1) Ratio = Reported/Analytics.
A=Acceptable
U=Unacceptable

* Sample provided by Analytics, Inc.

** Result determined by Resin Extraction/Gamma Spectral Analysis.

Table E.4-1 (Continued)
INTERLABORATORY INTERCOMPARISON PROGRAM
Gamma Analysis of Water

DATE	SAMPLE ID NO.	MEDIUM	ANALYSIS	JAF ELAB RESULTS pCi/liter ±1 sigma	REFERENCE LAB* pCi/liter ±1 sigma	RATIO (1)
03/17/2011	E7477-05	Water	Cr-51	1.86E+02 ± 1.85E+01 2.05E+02 ± 1.00E+01 2.22E+02 ± 2.57E+01 Mean = 2.04E+02 ± 1.11E+01	1.96E+02 ± 3.27E+00	1.04 A
			Cs-134	9.40E+01 ± 3.32E+00 9.20E+01 ± 2.32E+00 9.10E+01 ± 5.06E+00 Mean = 9.22E+01 ± 2.16E+00	8.56E+01 ± 1.43E+00	1.08 A
			Cs-137	1.43E+02 ± 3.86E+00 1.42E+02 ± 2.49E+00 1.34E+02 ± 5.55E+00 Mean = 1.40E+02 ± 2.40E+00	1.35E+02 ± 2.25E+00	1.04 A
			Co-58	8.10E+01 ± 2.96E+00 7.70E+01 ± 1.97E+00 7.40E+01 ± 4.54E+00 Mean = 7.72E+01 ± 1.92E+00	7.44E+01 ± 1.24E+00	1.04 A
			Mn-54	1.87E+02 ± 4.33E+00 1.83E+02 ± 2.82E+00 1.89E+02 ± 6.38E+00 Mean = 1.86E+02 ± 2.74E+00	1.75E+02 ± 2.92E+00	1.06 A
			Fe-59	1.21E+02 ± 4.09E+00 1.28E+02 ± 2.83E+00 1.15E+02 ± 6.22E+00 Mean = 1.21E+02 ± 2.65E+00	1.15E+02 ± 1.91E+00	1.05 A
			Zn-65	1.98E+02 ± 7.05E+00 1.91E+02 ± 4.62E+00 1.87E+02 ± 1.03E+01 Mean = 1.92E+02 ± 4.44E+00	1.72E+02 ± 2.87E+00	1.12 A
			Co-60	1.17E+02 ± 2.65E+00 1.15E+02 ± 1.80E+00 1.16E+02 ± 3.97E+00 Mean = 1.16E+02 ± 1.70E+00	1.13E+02 ± 1.88E+00	1.03 A
			I-131	9.26E+01 ± 3.25E+00 9.59E+01 ± 2.12E+00 9.53E+01 ± 4.53E+00 Mean = 9.46E+01 ± 1.99E+00	9.40E+01 ± 1.57E+00	1.01 A
			I-131**	9.00E+01 ± 9.50E-01 8.41E+01 ± 2.19E+00 9.09E+01 ± 2.14E+00 Mean = 8.83E+01 ± 1.07E+00	9.40E+01 ± 1.57E+00	0.94 A

(1) Ratio = Reported/Analytics. A=Acceptable
* Sample provided by Analytics, Inc. U=Unacceptable
** Result determined by Resin Extraction/Gamma Spectral Analysis.

Table E.4-1 (Continued)
INTERLABORATORY INTERCOMPARISON PROGRAM
Gamma Analysis of Water

DATE	SAMPLE ID NO.	MEDIUM	ANALYSIS	JAF ELAB RESULTS pCi/liter ±1 sigma	REFERENCE LAB* pCi/liter ±1 sigma	RATIO (1)
06/16/2011	E7617-09	Water	Ce-141	9.16E+01 ± 7.08E+00 9.17E+01 ± 7.37E+00 8.77E+01 ± 7.26E+00 8.70E+01 ± 7.68E+00 Mean = 8.96E+01 ± 4.26E+00	9.35E+01 ± 1.56E+00	0.95 A
			Cr-51	1.97E+02 ± 3.18E+01 1.83E+02 ± 3.68E+01 2.67E+02 ± 3.21E+01 2.77E+02 ± 4.54E+01 Mean = 2.31E+02 ± 2.22E+01	2.41E+02 ± 4.03E+00	0.96 A
			Cs-134	2.11E+02 ± 1.18E+01 2.22E+02 ± 1.16E+01 2.08E+02 ± 1.06E+01 2.25E+02 ± 1.39E+01 Mean = 2.17E+02 ± 7.20E+00	2.22E+02 ± 3.71E+00	0.98 A
			Cs-137	1.68E+02 ± 5.77E+00 1.56E+02 ± 5.73E+00 1.64E+02 ± 5.25E+00 1.56E+02 ± 6.66E+00 Mean = 1.61E+02 ± 3.50E+00	1.61E+02 ± 2.70E+00	1.00 A
			Co-58	1.90E+02 ± 6.17E+00 1.75E+02 ± 5.95E+00 1.88E+02 ± 5.93E+00 1.83E+02 ± 7.07E+00 Mean = 1.84E+02 ± 3.70E+00	1.77E+02 ± 2.96E+00	1.04 A
			Mn-54	1.65E+02 ± 5.71E+00 1.83E+02 ± 6.12E+00 1.69E+02 ± 5.41E+00 1.74E+02 ± 7.25E+00 Mean = 1.73E+02 ± 3.70E+00	1.61E+02 ± 2.69E+00	1.07 A
			Fe-59	1.57E+02 ± 6.81E+00 1.45E+02 ± 6.86E+00 1.73E+02 ± 8.93E+00 1.55E+02 ± 6.68E+00 Mean = 1.58E+02 ± 4.40E+00	1.44E+02 ± 2.41E+00	1.10 A
			Zn-65	3.16E+02 ± 1.24E+01 2.98E+02 ± 1.21E+01 3.23E+02 ± 1.20E+01 3.16E+02 ± 1.53E+01 Mean = 3.13E+02 ± 7.70E+00	3.05E+02 ± 5.09E+00	1.03 A
			Co-60	2.26E+02 ± 5.07E+00 2.32E+02 ± 5.17E+00 2.43E+02 ± 4.79E+00 2.25E+02 ± 6.21E+00 Mean = 2.32E+02 ± 3.20E+00	2.28E+02 ± 3.80E+00	1.02 A
			I-131	1.10E+02 ± 7.24E+00 1.01E+02 ± 7.44E+00 1.06E+02 ± 7.37E+00 1.15E+02 ± 9.22E+00 Mean = 1.08E+02 ± 3.90E+00	1.01E+02 ± 1.68E+00	1.07 A
			I-131**	9.73E+01 ± 1.33E+00 9.78E+01 ± 1.52E+00 9.43E+01 ± 1.47E+00 Mean = 9.65E+01 ± 8.33E-01	1.01E+02 ± 1.68E+00	0.96 A

(1) Ratio = Reported/Analytics. A=Acceptable
* Sample provided by Analytics, Inc. U=Unacceptable
** Result determined by Resin Extraction/Gamma Spectral Analysis.

Table E.4-1 (Continued)
INTERLABORATORY INTERCOMPARISON PROGRAM
Gamma Analysis of Water

DATE	SAMPLE ID NO.	MEDIUM	ANALYSIS	JAF ELAB RESULTS pCi/liter ±1 sigma	REFERENCE LAB* pCi/liter ±1 sigma	RATIO (1)
09/15/2011	E8122-05	Water	Ce-141	4.75E+01 ± 4.70E+00 5.28E+01 ± 4.90E+00 5.99E+01 ± 4.20E+00 Mean = 5.34E+01 ± 2.70E+00	5.32E+01 ± 8.88E-01	1.00 A
			Cr-51	1.65E+02 ± 2.39E+01 1.75E+02 ± 2.35E+01 1.84E+02 ± 1.98E+01 Mean = 1.75E+02 ± 1.30E+01	1.80E+02 ± 3.01E+00	0.97 A
			Cs-134	9.86E+01 ± 7.00E+00 8.86E+01 ± 7.80E+00 9.75E+01 ± 6.70E+00 Mean = 9.49E+01 ± 4.10E+00	1.02E+02 ± 1.71E+00	0.93 A
			Cs-137	9.10E+01 ± 3.70E+00 9.41E+01 ± 4.50E+00 8.80E+01 ± 3.50E+00 Mean = 9.10E+01 ± 4.10E+00	9.07E+01 ± 1.51E+00	1.00 A
			Co-58	7.59E+01 ± 3.60E+00 8.37E+01 ± 4.40E+00 8.43E+01 ± 3.40E+00 Mean = 8.13E+01 ± 2.20E+00	7.77E+01 ± 1.30E+00	1.05 A
			Mn-54	1.17E+02 ± 4.30E+00 1.18E+02 ± 4.90E+00 1.28E+02 ± 3.90E+00 Mean = 1.21E+02 ± 2.50E+00	1.20E+02 ± 2.01E+00	1.01 A
			Fe-59	5.17E+01 ± 3.80E+00 4.44E+01 ± 4.30E+00 4.73E+01 ± 3.60E+00 Mean = 4.78E+01 ± 2.30E+00	4.37E+01 ± 7.30E-01	1.09 A
			Zn-65	1.49E+02 ± 7.90E+00 1.43E+02 ± 8.90E+00 1.48E+02 ± 7.00E+00 Mean = 1.47E+02 ± 4.60E+00	1.44E+02 ± 2.40E+00	1.02 A
			Co-60	1.24E+02 ± 3.30E+00 1.22E+02 ± 3.80E+00 1.23E+02 ± 3.00E+00 Mean = 1.23E+02 ± 1.90E+00	1.25E+02 ± 2.09E+00	0.98 A
			I-131	8.59E+01 ± 4.50E+00 8.20E+01 ± 5.20E+00 7.91E+01 ± 4.10E+00 Mean = 8.23E+01 ± 2.70E+00	7.99E+01 ± 1.33E+00	1.03 A
			I-131**	7.93E+01 ± 1.00E+00 7.61E+01 ± 1.30E+00 7.63E+01 ± 1.30E+00 Mean = 6.72E+01 ± 7.00E-01	7.99E+01 ± 1.33E+00	0.84 A

(1) Ratio = Reported/Analytics. A=Acceptable
* Sample provided by Analytics, Inc. U=Unacceptable
** Result determined by Resin Extraction/Gamma Spectral Analysis.

Table E.4-1 (Continued)
INTERLABORATORY INTERCOMPARISON PROGRAM
Gamma Analysis of Water

DATE	SAMPLE ID NO.	MEDIUM	ANALYSIS	JAF ELAB RESULTS pCi/liter ±1 sigma	REFERENCE LAB* pCi/liter ±1 sigma	RATIO (1)
12/08/2011	E8183-09	Water	Cr-51	5.01E+02 ± 4.08E+01	5.66E+02 ± 9.45E+00	0.99 A
				6.12E+02 ± 3.81E+01		
				5.66E+02 ± 3.61E+01		
				5.89E+02 ± 3.49E+01		
				5.46E+02 ± 3.77E+01		
				Mean = 5.63E+02 ± 2.55E+01		
			Cs-134	1.59E+02 ± 1.34E+01	1.71E+02 ± 2.86E+00	0.99 A
				1.68E+02 ± 1.17E+01		
				1.70E+02 ± 9.30E+00		
				1.78E+02 ± 1.08E+01		
				1.74E+02 ± 1.07E+01		
				Mean = 1.70E+02 ± 7.60E+00		
			Cs-137	2.16E+02 ± 7.50E+00	2.10E+02 ± 3.50E+00	1.03 A
				2.13E+02 ± 6.70E+00		
				2.09E+02 ± 5.70E+00		
				2.12E+02 ± 6.00E+00		
				2.28E+02 ± 6.50E+00		
				Mean = 2.16E+02 ± 4.40E+00		
			Co-58	2.29E+02 ± 7.80E+00	2.21E+02 ± 3.69E+00	1.04 A
				2.36E+02 ± 7.00E+00		
				2.24E+02 ± 5.70E+00		
				2.21E+02 ± 6.30E+00		
				2.37E+02 ± 6.50E+00		
				Mean = 2.29E+02 ± 4.50E+00		
			Mn-54	2.49E+02 ± 8.10E+00	2.41E+02 ± 4.02E+00	1.08 A
				2.64E+02 ± 7.20E+00		
				2.69E+02 ± 6.20E+00		
				2.61E+02 ± 6.60E+00		
				2.62E+02 ± 6.90E+00		
				Mean = 2.61E+02 ± 4.80E+00		
			Fe-59	2.14E+02 ± 8.50E+00	1.83E+02 ± 3.06E+00	1.11 A
				2.03E+02 ± 7.73E+01		
				2.03E+02 ± 6.40E+00		
				2.04E+02 ± 7.00E+00		
				1.88E+02 ± 7.30E+00		
				Mean = 2.02E+02 ± 4.90E+00		
			Zn-65	3.20E+02 ± 1.44E+01	2.91E+02 ± 4.87E+00	1.08 A
				3.11E+02 ± 1.27E+01		
				3.30E+02 ± 1.03E+01		
				3.06E+02 ± 1.13E+01		
				3.07E+02 ± 1.22E+01		
				Mean = 3.15E+02 ± 8.30E+00		
			Co-60	2.86E+02 ± 6.50E+00	2.70E+02 ± 4.51E+00	1.06 A
				2.87E+02 ± 5.70E+00		
				2.82E+02 ± 4.80E+00		
				2.88E+02 ± 5.20E+00		
				2.87E+02 ± 5.50E+00		
				Mean = 2.86E+02 ± 3.80E+00		
			I-131	9.25E+01 ± 5.50E+00	8.87E+01 ± 1.48E+00	1.05 A
				1.00E+02 ± 5.30E+00		
				9.96E+01 ± 5.50E+00		
				8.49E+01 ± 5.40E+00		
				8.66E+01 ± 5.60E+00		
				Mean = 9.27E+01 ± 3.60E+00		
			I-131**	1.07E+02 ± 1.90E+00	8.87E+01 ± 1.48E+00	1.25 A
				1.16E+02 ± 2.10E+00		
				1.08E+02 ± 2.80E+00		
				1.11E+02 ± 2.50E+00		
				Mean = 1.11E+02 ± 1.30E+00		

(1) Ratio = Reported/Analytics. A=Acceptable U=Unacceptable
* Sample provided by Analytics, Inc.
** Result determined by Resin Extraction/Gamma Spectral Analysis.

E.5 References

E.5.1 Radioactivity and Radiochemistry, The Counting Room: Special Edition, 1994 Caretaker Publications, Atlanta, Georgia.

E.5.2 Data Reduction and Error Analysis for the Physical Sciences, Bevington P.R., McGraw Hill, New York (1969).