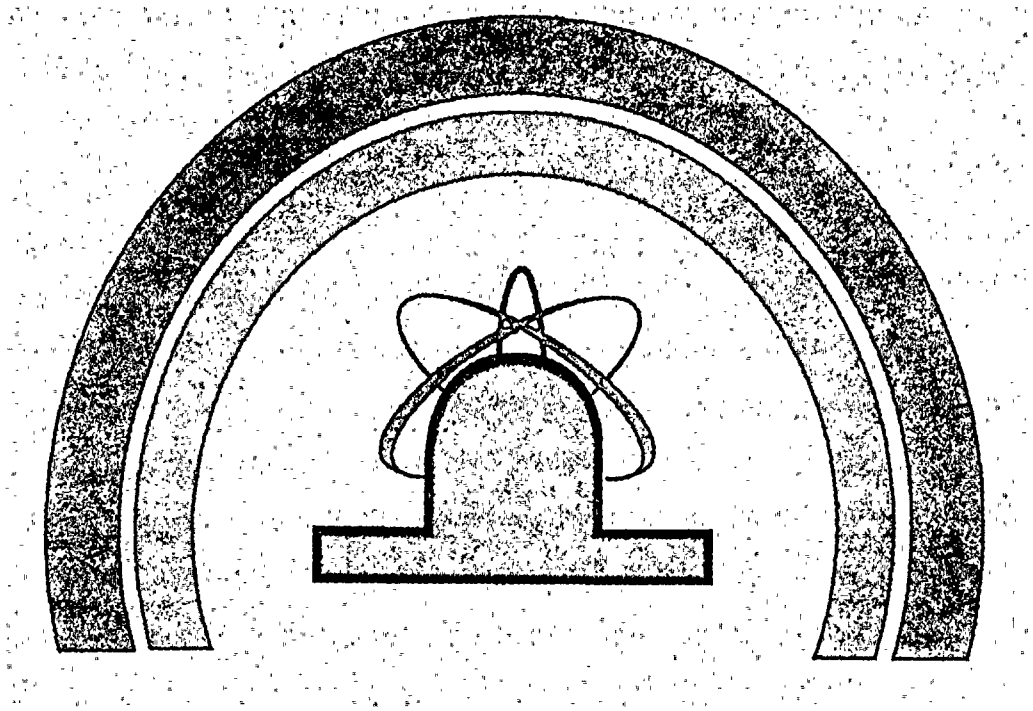
RADIOLOGICAL ENVIRONMENTAL OPERATING REPORT

1996



HARRIS NUCLEAR PLANT

CAROLINA POWER & LIGHT

Harris Energy & Environmental Center

Carolina Power & Light Company

New Hill, North Carolina

RADIOLOGICAL ENVIRONMENTAL OPERATING REPORT

FOR THE

SHEARON HARRIS NUCLEAR POWER PLANT

JANUARY 1 THROUGH DECEMBER 31, 1996

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EXECUTIVE SUMMARY

The Harris Nuclear Plant is operated by Carolina Power & Light Company under a license granted by the Nuclear Regulatory Commission. Provisions of the Nuclear Regulatory Commission's Regulatory Guide 4.8, Harris Nuclear Plant Technical Specifications, and the Harris Nuclear Plant Offsite Dose Calculation Manual establish the requirements of the Radiological Environmental Monitoring Program. This report provides the results of the Radiological Environmental Monitoring program from January 1, 1996 through December 31, 1996.

The Radiological Environmental Monitoring program was established in 1982. Radiation and radioactivity in various environmental media have been monitored for more than 14 years, including 5 years prior to commencing operation. Monitoring is also provided for control locations which would not be impacted by operations of the Harris Nuclear Plant. Using these control locations and data collected prior to operation allows comparison of data collected at locations near the Harris Nuclear Plant which could potentially be impacted by its operations.

Radiation levels show no significant change from pre-operational radiation levels. Monitoring results for environmental media are summarized as follows:

- Air- monitoring results are similar or less than the concentrations of radioactivity from pre-operation monitoring. These observations are also consistent with past operational data.
- Milk monitoring results are similar to all the past years where no I-131 concentrations were detected.
- Terrestrial vegetation includes various crops collected during a growing season.
- Aquatic organism monitoring includes fish and benthic organisms.
- Surface (and drinking) water results indicate no detectable gamma-emitting radionuclides or I-131.
- External radiation dose showed no measurable change from pre-operational data.

The continued operation of the Harris Nuclear Plant has not significantly contributed radiation or the presence of radioactivity in the environmental media monitored. The measured concentrations of radioactivity and radiation are well within applicable regulatory limits.

INTRODUCTION TO NUCLEAR OPERATIONS

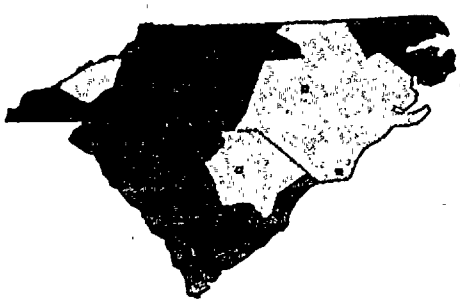

Figure 1: CP&L SERVICE AREA

Carolina Power & Light Company (CP&L) operates an integrated electrical system serving more than one million customers in North Carolina and South Carolina. A system map is provided (Figure #1) that illustrates the area served and the location of the nuclear generating units including the Harris (Blue), Brunswick (Green), and Robinson (Brown) Nuclear Plants. The service area is more than 30,000 square miles and has a population of more than 3,500,000 people.

The energy sources for electrical generation include coal, fuel oil, natural gas, hydro-power, and nuclear fuel. No one energy source is best. Each fuel source has merits and disadvantages. Fossil fuels pose issues associated with clean air including emissions of sulfur dioxide and oxides of nitrogen. Both natural gas and hydro-power are in limited supply.

Nuclear energy is a vital component in a diversified energy mix. In 1996 nuclear energy supplied 38% of CP&L's total electrical generation. This nuclear component was generated from four units including the Harris Nuclear Plant. The remaining energy sources were primarily from coal-fired generation, and a very small contribution from oil, natural gas and hydro-power.

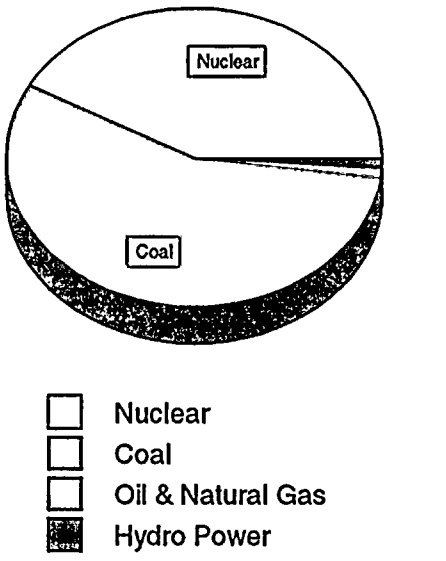

Figure 2: 1996 ENERGY SOURCES

BENEFITS OF NUCLEAR POWER

Nuclear energy is a viable, clean, safe, and readily available source of energy. The operation of the Harris Nuclear Plant results in a very small impact on the environment. Nuclear generation serves a vital role in the operation of the Carolina Power & Light system as well as in the nations electrical needs. Nuclear energy currently supplies more than twenty percent of the nation's electrical energy. It is an important source of electrical energy now and is meeting the growing electrical needs for the future

Nuclear energy has the following advantages over other fuel sources:

- The fuel is uranium which is relatively inexpensive when compared with the fuels of coal, natural gas, and fuel oil.
- Emissions from nuclear stations do not include sulfur dioxide, oxides of nitrogen, or carbon dioxide. Sulfur dioxide is well known as a significant contributor to acid rain leading to acidification of streams and lakes. Oxides of nitrogen play a key role in the formation of ozone which is a significant pollutant in urbanized air quality. Finally carbon dioxide is a significant green house gas.
- Nuclear energy is safe. Nuclear power in the United states has an excellent safety record, starting with the first commercial nuclear plant in 1957.

To better understand this source of energy, a basic understanding of radiation, it's effects, risk assessment, and reactor operation follow.

RADIATION AND RADIOACTIVITY

The Atom

All matter consists of **atoms.** An atom is the smallest unit into which an element can be divided and still retain its identity as that element. An atom is made up of a number of different particles. These particles are **protons, neutrons, and electrons.** Each proton is positively charged (+). Each neutron has no charge. And the electron is negatively charged (-). The heavier particles including protons and neutrons are found in the center of the atom in a very small cluster referred to as the **nucleus.** (The term nuclear refers to this nucleus.) Nearly all the mass of the atom is found in the nucleus. Electrons orbit the nucleus. Since the atom is electrically neutral (no charge) the number of protons and electrons in the atom are equal. See Figure 3 a conceptional drawing of an atom. The electrons (red) are shown in orbit around the nucleus. The protons (green), and the neutrons (black) are shown in the nucleus at the center of the atom.

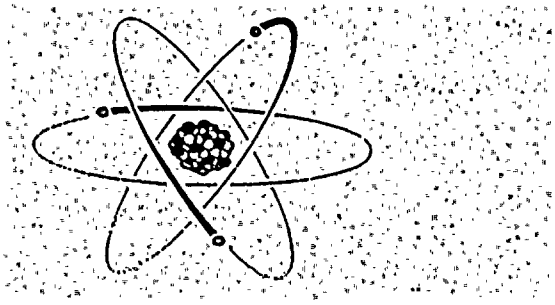

Figure 3: The Atom

Elements, Isotopes, and Radionuclides

Simple substances that can not be decomposed in any chemical reaction are known as **elements.** Hydrogen, oxygen, iron, chlorine, and uranium are examples of elements. The atoms of such

Hydrogen, oxygen, iron, chlorine, and uranium are examples of elements. The atoms of such elements differ in the number of protons (also know as the atomic number) in their nucleus. For example the number of protons in each example above is 1 for hydrogen, 8 for oxygen, 26 for iron, 17 for chlorine, and 92 for uranium. The number of neutrons in the nucleus may vary in atoms of the same element. Atoms that contain the same number of protons but a different number of neutrons are referred to as **isotopes** of that element. An example is the element hydrogen which has three isotopes -- one with no neutrons, a second with one neutron, an the third with two neutrons. Isotopes can be unstable (also referred to as **radioactive**), which means they will readily transform to another isotope and are called **radionuclides**. Of more than one thousand known isotopes less than twenty-five percent are considered stable. It is important to remember that a significant number of radioactive isotopes occur naturally.

When referring to isotopes of an element, it is common to refer to the element by the symbol for it's name (or the name) followed by the total number of protons and neutrons; for example H-3 or hydrogen-3 describing an atom with one proton and two neutrons.

Radiation

Radiation is defined as the conveyance of energy through space. This conveyance may occur in the form of particles, waves, or photons. Some common forms of radiation are sunlight, microwaves or radio waves. These are all examples of non-ionizing radiation. **Ionizing radiation** differs in its interaction with matter because its energy is capable of removing an electron from the outer part of an atom resulting in the remaining atom being positively charged and a free electron. There are two types of ionizing radiation -- particulate radiation and electromagnetic radiation. **Particulate radiations** are energetic particles which will travel in a straight line if unhindered. Three types of particulate radiation of interest in nuclear energy, those being beta particles which are high-energy electrons (not part of an atom), neutrons, and alpha particles which consist of two protons and two neutrons. **Electromagnetic Radiations** are high-energy waves (or photons) which have no apparent mass (not a particle). There are two types of electromagnetic radiation of interest which are gamma rays and X-rays. **Gamma rays** have their origin in the nucleus of the atom. **X-rays** have their origin in the stored energy of the electrons orbiting the nucleus. There are many important differences in the behavior of these radiations which will be discussed in the later sections.

Radioactivity

Radionuclides are atoms that are unstable and will eventually reach a stable state through a process know as radioactive decay. This process results in the emission of energy or energetic particles from the nucleus of the unstable atom. The process may occur in a single step or may be composed of a series of steps to various radioisotopes. When this process proceeds through a series of steps it is called a **radioactive decay series.**

There are at least three natural radioactive-decay series which are the thorium, neptunium, and

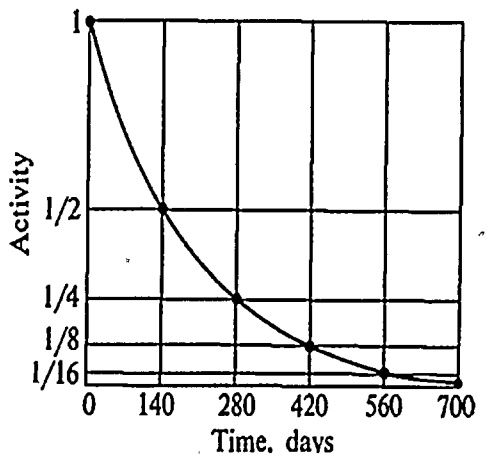

Figure 4: Radioactive Decay

the uranium series. These radioactive decay series as well as naturally occurring K(potassium)-40, C(carbon)-14, H(hydrogen)-3 are significant contributors to background radiation levels, which are addressed in greater detail later.

The rate at which atoms undergo radioactive decay varies greatly. A common expression of the tendency for radioactive decay is the half-life associated with a particular isotope. The half-life is the amount of time required for one-half of the number of atoms for an isotope to experience radioactive decay. The longer the half-life the less likely an atom will experience radioactive decay in a fixed time interval. Half-lives vary from extemely small fractions of a second (billionths) to millions of years. Figure 4 illustrates an isotope with a 140-day half-life. Note that the activity decreases by half in 140 days, and then by half again the next 140 days and thereafter.

RADIATION INTERACTION WITH MATTER

Ionization

As alpha, beta, gamma, and X-ray radiation interact with matter they impart part or all of their energy to the matter in a single interaction. It may require many interactions to absorb the energy of a single particle or photon of radiation. One of the most common ways energy is dissipated is ionization. As we discussed earlier this results in the creation of a positively charged atom and a free electron. The positively charged atom and the free electron are referred to as a charged pair. The creation of the charged pair is one of the primary contributions to damage of biological systems.

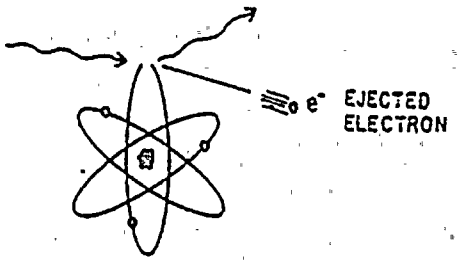

Figure 5: Ionization

Radiation Ranges

Each type of radiation we have discussed interacts with the matter they travel through differently because of the different characteristics of each radiation.

Alpha particles are composed of two protons and two neutrons. This is the heaviest particulate radiation with a positive charge of two (two protons). The alpha particle is the slowest of the radiations we will review with a speed of no more than 20,000 miles per second. As a result of these characteristics the alpha travels only a few centimeters (or inches) in air and is readily stopped by a sheet of paper. The alpha leaves it's energy in a short distance characterized by a great many ionizations.

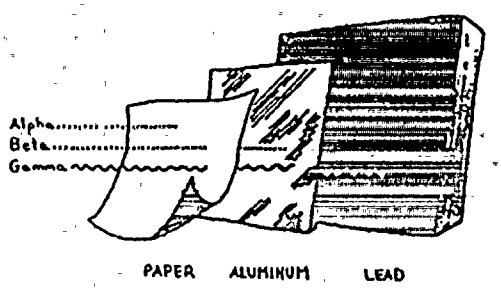

Figure 6: Radiation Ranges & Shielding

Beta particles are basically a very high-energy electron. Beta particles have a negative charge. It is a very light particle, with a mass of about one two-thousandth of a proton (or about one eight-thousandth of an alpha particle). Beta particles are very fast, approaching the speed of light. Due to their speed and lower charge, the beta particles travel several meters (or yards) in air and are readily stopped by a small piece of metal or other dense material. The beta particle leaves its energy in many ionizations but with the ionizations distributed along a much longer path of travel.

Gamma rays are photons (or energy waves, not a charged particle). Like light (also a photon) it travels at a speed of approximately 186,000 miles per second. The gamma ray travels much larger distances without interacting. When the gamma ray interacts with matter it creates very high-energy electrons similar to beta particles which in turn create ionizations as their energy is dissipated. Due to these differences the gamma ray travels much greater distances before its energy is dissipated. To dissipate the energy of a gamma ray several inches of lead are required.

RADIATION QUALITIES AND UNITS OF MEASURE

There are numerous qualities and units used to describe radiation and radioactivity and their effects. Those used in this report relate to activity, absorbed dose, and dose equivalent. It is also common to express numbers in scientific notation or use prefixes with the number denoting the number of zeros (0) before or after the decimal. A few examples are provided below.

Prefix	Number Represented	Number in Scientific Notation
pico	.000000000001	$1x10^{-12}$
nano	.000000001	$1x10^{-9}$
micro	.000001	$1x10^{-6}$
milli	.001	$1x10^{-3}$
centi	.01	$1x10^{-2}$
kilo	1,000.	$1x10^{3}$
mega	1,000,000.	$1x10^{6}$

Activity is the number of radioactive transformations (decays, disintegrations) that occur in a fixed time interval. The unit used to express activity is the **curie**. The curie is defined as 37,000,000,000 disintegrations per second; also expressed as $3.7x10^{10}$ s^{-1}. A curie is a unit of activity, not an amount of material or the number of atoms. The amount of material or number of atoms necessary to produce a curie of activity vary over a very wide range. Atoms with very long half-lives would require many more atoms to produce a curie of activity versus atoms with short half-lives.

Absorbed dose describes the energy absorbed per unit of mass of tissue. The unit used to express absorbed dose is the **rad** (radiation absorbed dose). One rad is an absorbed radiation dose of 100 ergs(a measure of a very small amount of energy) per gram. The rad can be used with all types of radiation including X-rays, gamma-rays, and particulate radiations. The absorbed dose can be measured with various radiation-detection instruments which allows the assessment of damage to biological systems subjected to radiation and radioactive materials.

Dose equivalent is an expression of the biological effect of the radiation on tissue. The unit used to express absorbed dose equivalent is the **rem**. Dose equivalent is obtained by multiplying the absorbed dose (expressed in rad) by a **quality factor** (QF) for the type of radiation being considered.

$$\underline{\text{Dose equivalent}} = \underline{\text{absorbed dose}} \text{ X } \underline{\text{quality factor}}$$

Some types of radiation create more biological damage due to the extent of ionization in small areas. From our discussion of alpha particles, the intense ionizations caused by the alpha particle results in a much higher Quality Factor for this radiation. This relationship for quality factors and

different radiations we have discussed is illustrated below

Table 1

Quality Factors for Various Radiations

Radiation	Quality Factor
Gamma-rays	1
X-rays	1
Beta Particles	1
Alpha Particles	20

SOURCES OF RADIATION

Background Radiation

Radiation occurs naturally and is an everyday fact of our existence. Mankind has always lived with radiation and radioactive materials and will continue to in the future. The radiation that occurs naturally is referred to as **background radiation.** Mankind experiences two types of radiation dose: first is radiation that originates outside the body and is called **external radiation,** and the second is radiation that originates inside the body and is called **internal radiation.** External radiation comes from the earth, the atmosphere, and every structure(buildings) around us as well as a source referred to as **cosmic radiation** which is generated in the stars throughout the galaxy including our own sun.

Cosmic radiation is composed of gamma-rays (some of very high energy) and many different types of energetic particulate radiation. Some of the particulate forms of radiation include neutrons, alpha particles, and heavy particles (including nuclei). These high-energy cosmic radiations have the capability to interact with other atoms on earth and generate new isotopes. As we have already discussed, some of these may be radioactive. Common examples of radionuclides formed from cosmic radiations are carbon-14 and tritium (H-3). The atmosphere around the earth serves as an effective shield causing much of the energy of cosmic radiations to be dissipated prior to reaching the surface of the earth. However, each of us may receive a dose equivalent, due external cosmic radiation, to 20 to 50 mrem (.020 to .050 rem) annually. The actual dose is influenced by the elevation we live. Higher elevations provide less shielding and therefore the doses are higher. A single plane flight can also contribute to our dose from cosmic radiations. The average passenger could expect to receive a dose of 2.8 mrem (.0028 rem) per flight.

Another important contributor to external absorbed dose is **terrestrial radiation.** This is the

radiation from the earth itself, and the air around each of us. The sources of terrestrial radiation include the thorium, neptunium, and the uranium decay series as well as potassium-40. The absorbed dose varies about 15 to 140 mrem (.015 to .140 rem) annually. However there are a very few areas that these terrestrial absorbed doses exceed 800 mrem each year.

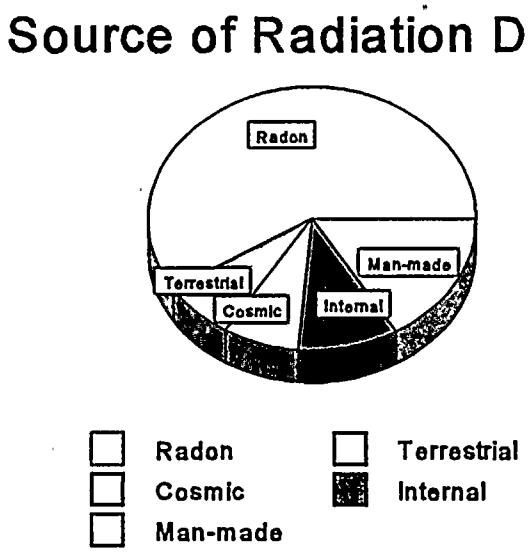

Figure 7: Radiation Sources (BIER V)

One of the most important sources of dose is that contributed by internal radiations. These radionuclides are part of our body, the air we have breathed, or the food we have consumed. One if the most significant contributors is **radon**. Radon is a radioactive gas that is part of the uranium decay series. Radon's concentration varies greatly based upon the geology of each community, but is found in soils and rock everywhere. If it is allowed to concentrate in a building, the dose from radon can be increased significantly. Normally radon does not pose a significant health threat. Since radon is an alpha particle emitter, inhaling radon gas makes the lung our greatest concern (IE the alpha does not travel far but has a high quality factor for the affected tissue). The health effect of breathing radon is an increased risk of lung cancer.

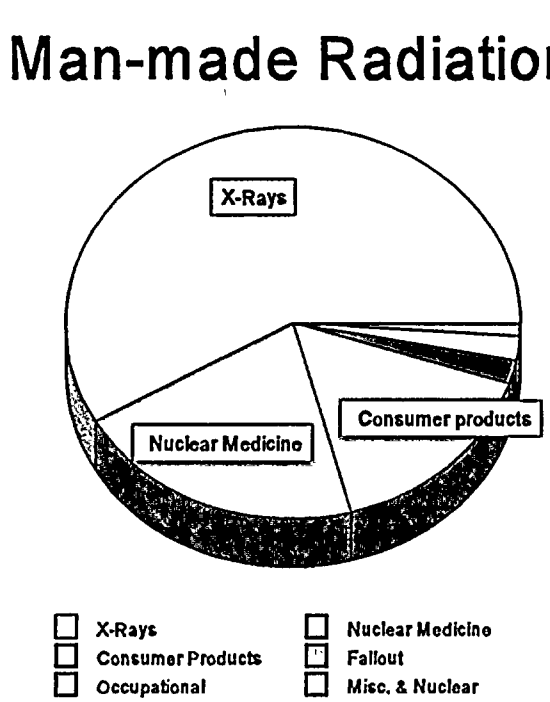

Figure 8: Man-Made Radiation Sources (BIER V)

Man-made radiations are important to completing our understanding of sources of radiation. An important aspect in discussing man-made radiation is the benefit man derives from the use of these. Medical uses of radiation are the major contributor, including diagnostic X-ray, and nuclear medical treatment. Consumer products such as televisions, display screens, smoke detectors, and many other devices are the next most important class of man-made radiations. Fallout from prior weapons testing is now a small contributor to total radiation dose. Occupational exposure is also a factor from the medical, manufacturing, and nuclear industries. Finally, contributions from nuclear plant operations represent less that 1% of the man-made radiations for the average member of the general public. The data presented in figure 8 illustrates the importance of the different sources of man-made radiation for the average member of the public.

HEALTH EFFECTS OF RADIATION

The effects of ionizing radiation has been of concern to the scientific community for several decades. The oldest body established to study radiations biological effects dates from at least 1928 with the establishment of the International Commission on Radiological Protection. Much of our knowledge is based upon very high doses from animal experiments, accidents handling radioactive materials, and war time nuclear weapons use and its survivors. It has been a classical problem of how to relate doses at these levels to much lower medical use (although some treatments are designed to deliver high dose) and occupational radiation levels. Environmental levels of radiation represent even greater challenges because of the extemely low doses compared with medical and occupational levels. Experiments with animals represent additional challenges because they may not accurately represent human biological responses to radiation.

Radiations biological effects are classified as **somatic** and **genetic** (or hereditary). Somatic effects are observed in the individual receiving the radiation dose. Genetic effects are observed in the decedents of the individual receiving the radiation dose.

Somatic effects can be classified as **acute** or **chronic**. Acute effects occur within a short time (days) after the dose is received. Generally acute effects require very high doses. Blood changes have been observed in the range of 25 to 50 rem (or 50,000 mrem). Other acute effects can be expected at even higher doses. Our knowledge of this level of dose are the survivors of nuclear weapons, accidents, and planned medical treatments. These dose levels are more than 500 times normal environmental background radiation. For this reason, these effects are not important to a discussion of environmental radiation.

Chronic effects are generally used to refer to effects that are observed a long period of time and these have also been referred to as **delayed effects**. The effects are also generally associated with radiation dose received over a long period know as **chronic exposure**. However is not necessary for the exposure to occur over a long period. The most important chronic effect is cancer. There are numerous forms of cancer. The rate of cancer in individuals at low doses (at occupational or environmental levels) has not been observed directly. "Cancers induced by radiation are indistinguishable from those occurring naturally; hence, their existence can be inferred only on the basis of statistical excess above the natural incidence." The current practice is to use observations at a much higher dose to establish the rate of cancers at that dose and then assume that the rate of cancers must be proportional to the lower dose. This has created a scientific disagreement, because some scientists believe this method over estimates the cancer risk from low doses of radiation. However this appears to be a conservative assumption. Some risk exists but it is believed to be a small risk of cancer at occupational levels. The Committee of the Biological Effect of Ionizing Radiation further states "It is by no means clear whether dose rates of gamma or X-rays of about 100 mrad per year are in any way detrimental to exposed people....." Environmental radiation levels are in the range of 100 mrad per year or less as we have discussed.

Genetic radiation effect occur when radiation changes the genetic material in cells. As we have discussed the process of ionization removes electrons from the atom. These electrons are

sometimes necessary in the creation of chemical bonds. If the bonds are part of the genetic material of the cell, it could result in changed genetic material (mutations). Radiation is just one of several agents that contribute to genetic change. Chemicals including those that occur naturally are a significant contributor to genetic mutations. Background radiation levels only provide a minor contribution to total mutations. To double the general mutation (from all sources) rate would require a dose of 50 to 250 rem (or 50,000 to 250,000 mrem). This is approximately 500 to 2,500 times the normal environmental background of about 100 mrem.

GENERAL HEALTH RISK

Every human activity has risk associated with it. The air we breath, the food we eat, where we live or work all have different risks. Many times our perception of these risks is quite different than the real risk of an activity. There was widespread fear and misunderstanding regarding the fire and safety hazard from electricity early this century. Now electricity is accepted as part of our daily existence. Radiation is unique in that it can not be seen, felt, smelled, or detected by any of the human senses. It is detected by instruments or laboratory analysis specially designed to detect radiation. Thus it is understandable to be wary of something we can not readily sense and may not have a personal knowledge about. There are other similar hazards we tend to accept such as micro-wave radiations, carbon monoxide in the operation of some furnaces and our vehicles due to our familiarity with these.

A common was of expressing risk is a reduction of life expectancy from a particular activity. Below you will find a table of common activities and the associated reduction in life expectancy

Table 2

REDUCTION IN AVERAGE LIFE EXPECTANCY

ACTIVITY	REDUCTION IN LIFE EXPECTANCY
CIGARETTE SMOKING 2 PACKS/DAY	10 YEARS
CIGARETTE SMOKING 1 PACK/DAY	7 YEARS
HEART DISEASE	5.8 YEARS
LIVING IN CITY VERSUS RURAL	5 YEARS
OVERWEIGHT 30 %	3.6 YEARS
CANCER	2.7 YEARS
COMMERCIAL NUCLEAR POWER	12 MINUTES

NUCLEAR POWER PLANT OPERATIONS

The primary difference between a nuclear generating station and fossil generating station is the source of heat or thermal energy. The steam turbine, condenser, condensate and feed water systems are much the same. The uranium fuel within the nuclear reactor is the source of heat or energy in the nuclear generating station.

Nuclear Fission

Certain heavy radionuclides are known to naturally undergo a special form of radioactive decay, called spontaneous fission. Spontaneous **fission** means the nuclei of these radioisotopes literally split into two or three new nuclei (also known a fission fragments) and a few free neutrons(not in a nucleus). The protons and neutrons are shared between these new nuclei. One isotope of Uranium known a U-235 is known to undergo fission. The other more common isotope of Uranium known as U-238 does not fission so easily.

Fission can also be stimulated by neutrons interacting with the nucleus of these atoms. Simply stated a neutron reaches the nucleus and produces fission fragments, free neutrons, and heat. Fission of Uranium produces more than one neutron per fission. Therefore; if there is enough uranium, especially U-235, present is it possible to produce more fissions and keep the process going or cause more and more fissions to occur. When the rate of fission initiated is self sustaining or increasing a **chain reaction** has been established. It is this sustained chain reaction and the energy produced that produces the heat needed to generate steam for electrical generation.

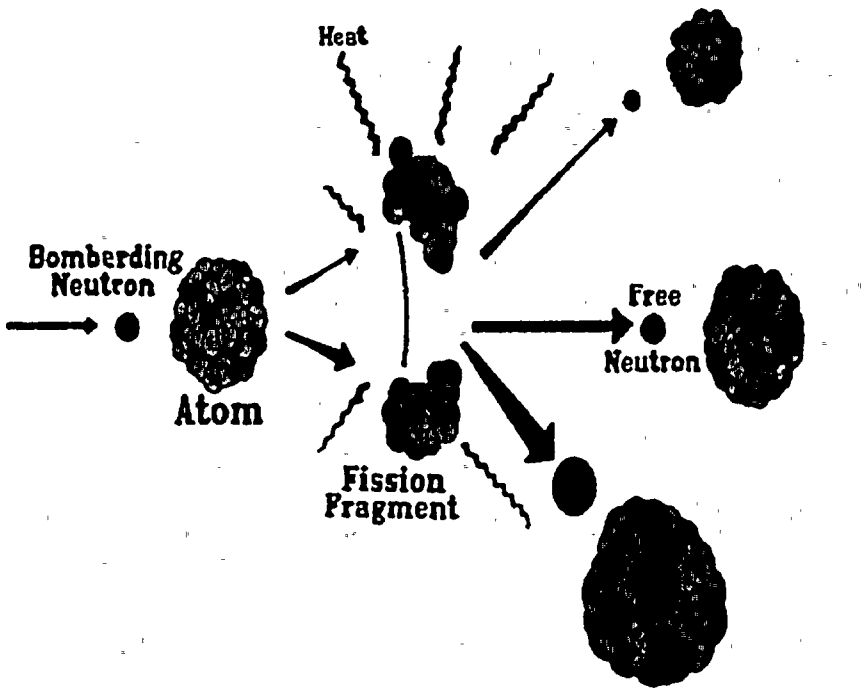

Figure 9: Nuclear Fission

Uranium Fuel

Uranium is mined from the earth the same as many minerals are as an ore. This uranium ore is then taken to a mill to concentrate the uranium. The extraction process for uranium uses acids to dissolve the uranium and separate it from the ore. This uranium is then **converted** chemically to a gas uranium hexafloride (in chemical notation UF_6) While in this form it is possible to separate the lighter U-235 from the heavier U-238. This process of separation is called **gaseous diffusion.** The reason for separation is to allow more of the U-235 to be included in the fuels used in commercial reactors. We have already discussed that U-235 fissions more readily that U-238. This process that increases the amount of U-235 is also referred to as **enrichment.** After enrichment this gas is chemically converted to uranium dioxide (in chemical notation UO_2). At this point the uranium dioxide is a gray powder. The next process takes this powder and under high pressure, and temperature creates a ceramic pellet of uranium dioxide. This process is part of the **fuel fabrication.** The fuel fabricator also ensures that each fuel pellet also has the proper amount of U-235 and U-238. The additional U-235 added is referred to as the percent enrichment which for commercial reactors is about 6% of the total uranium in the fuel. These fuel pellets are placed into long tubes of zirconium alloy or **fuel rods.** These rods of uranium fuel are then placed with other such fuel rods into a **fuel assembly.** This fuel assembly is the basic unit that is shipped to the nuclear power plant. It is important to note that the entire process of making nuclear fuel is carefully controlled to ensure the quality of the nuclear fuel.

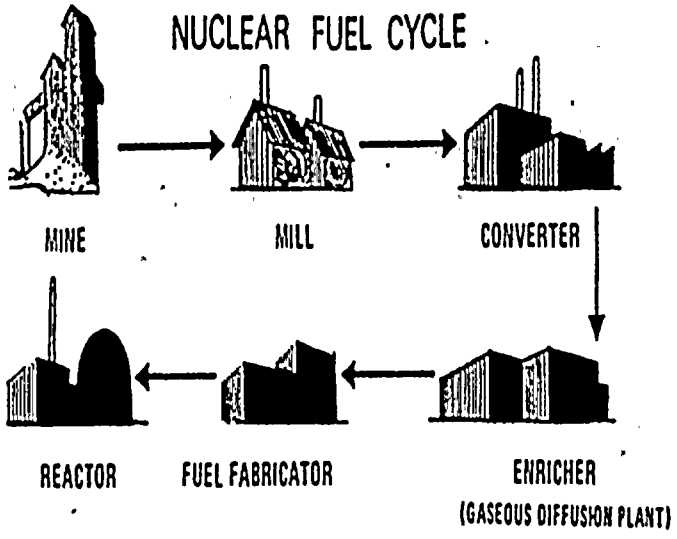

Figure 10: The Nuclear Fuel Cycle

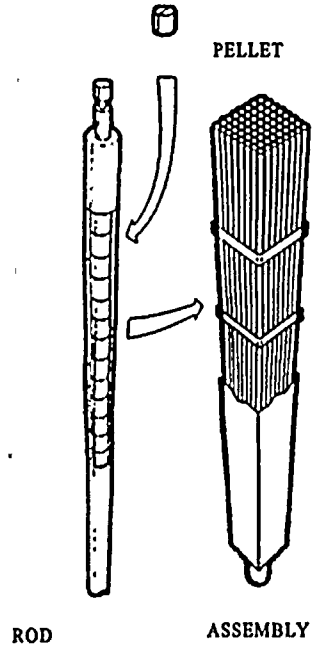

Figure 11: Fuel Pellets, Rods & Assemblies

PLANT SYSTEMS

System Summary

There are four (4) grouping of major plant systems and these are the reactor, the turbine generator, the condensate and feed water systems, and various support systems including various emergency systems. The reactor and its nuclear fuel is the source of heat to generate high pressure steam. The turbine is a large rotating fan like machine that the steam causes to rotate. The turbine is connected to an electrical generator which produces a rotating magnetic field. Electricity is generated in winding of metallic conductors around this magnetic field and then transmitted to the electrical transmission system and from there to the customers in the service area and sold to neighboring utilities.

After the steam has spent most all of its energy in the turbine, water vapor remains and must be recovered for reuse. The water vapor is recovered as water in a condenser. The condenser is a large system of tubes that are water cooled. The water used to cool the condenser is one of the most visible features at any power plant. Either large quantities of water are used or a cooling tower is used. After the steam has been recovered as water it is returned through a system of pumps, piping and heaters to the steam generator. The process of reusing this water and steam in a continuing cycle is referred to as the **steam cycle.**

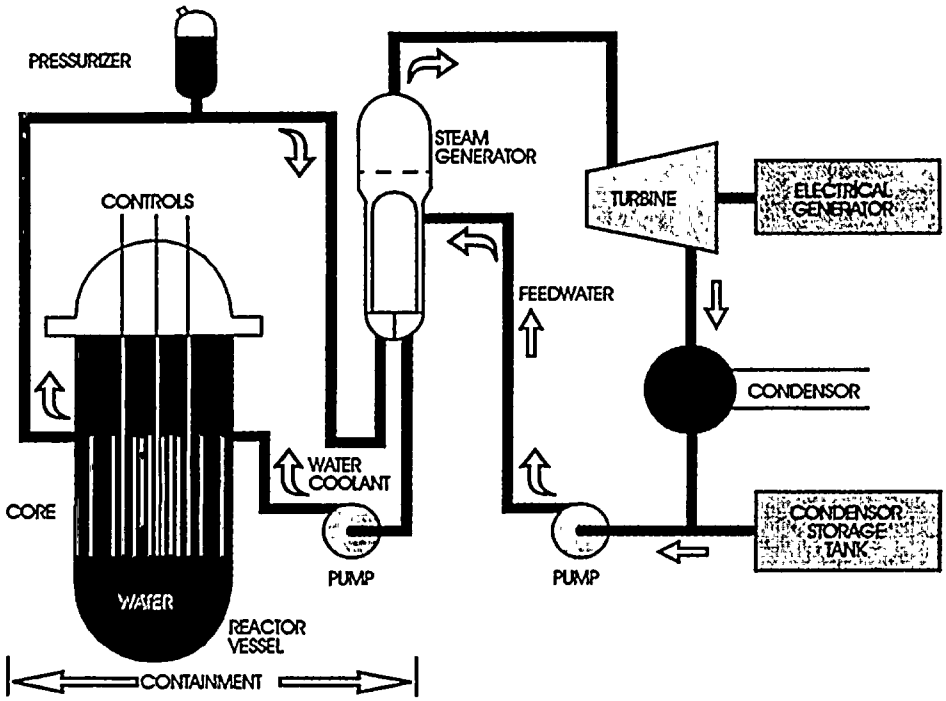

Figure 12: Major Plant Systems for The Pressurized Water Reactor

Reactor Types and the Reactor Vessel

There are approximately 180 commercial nuclear reactors being used to generate electricity in the United States today. Of these, there are two basic types of reactor in use today, the **Pressurized Water Reactor** (PWR) and the **Boiling Water Reactor** (BWR). The basic difference is the point where steam is formed. The boiling water reactor forms steam in the reactor while the pressurized water reactor forms steam through a separate heat exchanger called a steam generator. The Harris Plant is a Pressurized Water Reactor (PWR). There are other types of reactors used for research and military purposes.

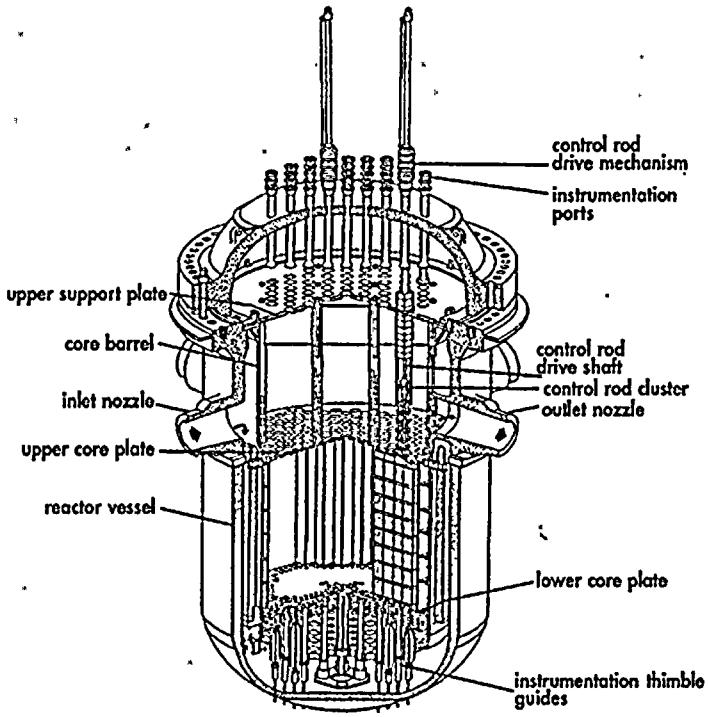

Figure 13: Reactor Vessel

The collection of fuel assemblies is referred to as the **reactor core**. The Harris Plant has 157 fuel assemblies in the reactor core. The reactor core, the controls, instrumentation as well as other components are located in the reactor vessel. The components vary greatly by reactor type. The reactor vessel is a specially designed container which supports all of the components. The reactor vessel varies in wall thickness from 4.87 inches of steel on the lower head to 7.75 inches of steel at the core elevation with a stainless steel lining.

The rate of nuclear fission is controlled by neutron absorbing materials. One of the most common materials used is an isotope of boron known as boron-10 (B-10). Also control rods are used that are made of other materials including indium and cadmium. By controlling how much of the control rods are inserted in the reactor core the rate of nuclear fission is controlled. The Harris Plant has 52 control rods.

The boiling water reactor generates steam with a significant water fraction and this steam must have this water removed. The reactor vessel for the boiling water reactor contains a steam separator which removes most of the water fraction. After treatment by the steam separator the steam passes through a steam dryer to remove additional water. The water removed by the steam separator and dryer is returned to the water in the reactor vessel. The boiling water reactor also has a special pair of recirculating pumps that provide additional control of steam generation and reactor power.

The pressurized water reactor does not generate steam in the reactor. The reactor vessel is pressurized to prevent boiling from occurring in the reactor or the reactor vessel. Steam is generated in a heat exchanger called the steam generator. The steam and the water from which

steam is generated is a separate water system from reactor water or reactor coolant. This separate water system is referred to as **secondary system** while the reactor's water system is referred to as the **primary system.** In the pressurized water reactor it is this secondary water that steam is made from and recycled through the condenser and feedwater system. This water is returned to the steam generator.

The PWR steam generators serve as the point of steam production. The reactor water of primary system is not allowed to boil or produce steam. This primary system water (or coolant) is circulated to the steam generators and back to the reactor in a continuous cycle. While in the steam generator the primary coolant(or water) transfers some of it's heat or energy to the secondary coolant(water) by heating the secondary coolant and making steam with the secondary coolant. It is important to note that there is no exchange of water between the primary coolant and the secondary coolant. This process is made possible because the pressure in the primary(reactor) systems are maintained at a point which prevents boiling in the reactor.

The pressurizer is the system that supports regulation of reactor pressure. The pressurizer is a vessel partly filled with water and is in free exchange with the water in the reactor and primary systems. The pressurizer also allows for the volumetric expansion of the primary coolant(water) as the reactor starts up, while maintaining the pressure of the reactor

Sources of Radioactive Materials In Reactor Operation

There are two primary means that radioactive materials are produced in reactor operation which are:

- Fission produces two or more fission fragments in each fission. These fission fragments become the nuclei of new atoms as **fission products.** As we have already discussed many atoms are radioactive as is the case with these fission fragments. Example of these isotopes are iodine-131 (I-131), strontium-90 (Sr-90), cesium-137 (Cs-137), as well as others.
- Activation of normally stable nuclei occurs in the neutron field in the reactor. This occurs because neutrons are absorbed by the nucleus of an atom and a new isotope of that atom is created. The new isotopes may be radioactive. Examples of these isotopes include tritium (H-3) and cobalt-60 (Co-60). These radionuclei are referred to as **activation products.**

The sources of radioactive emissions from nuclear power operations are the treatment of water from the reactor systems, and the treatment of air in the buildings that house plant systems. Each of these emissions is managed to reduce the emissions to levels that are considered as low as reasonably achievable. The radiological monitoring program is designed to assess the impacts of these emissions even though they are acknowledged to be small contributors to background radiation

Barriers to Release of Radioactive Materials

There are several barriers to release of radioactive materials. In order these are:

- the ceramic fuel pellet itself.
- the zirconium cladding of the fuel rod
- the reactor vessel and it's associated piping
- the containment building

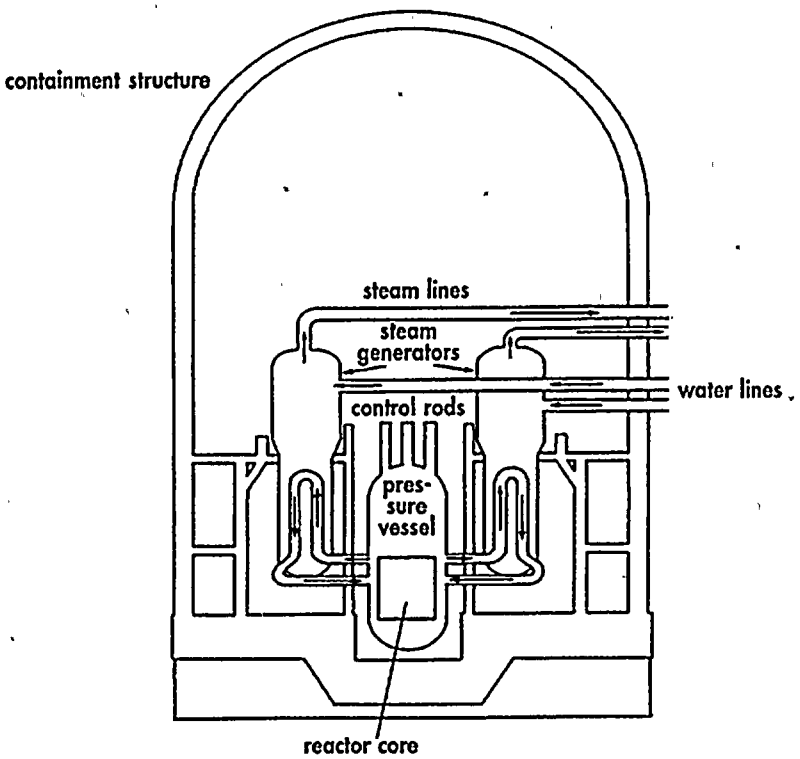

Figure 14:

The fuel, fuel rods, and the reactor vessel have already been discussed. The **containment** building is illustrated in figure 14. The containment houses the reactor core, the reactor vessel and it's associated piping, reactor coolant pumps and the pressurizer.

This containment is maintained at a pressure lower than the pressure outside the building. This is accomplished by a system of fans and filter systems the treat the air inside the secondary containment; thus, any air leakage would be into the secondary containment from the outside. The air coming from secondary containment is all filtered and treated prior to discharge.

REACTOR SAFETY

There are several points regarding nuclear safety that are important to understand and these are:

- Commercial nuclear generating station can not explode as a nuclear weapon. The uranium for weapons is highly enriched and must be carefully timed and configured to create an explosion. The uranium in commercial generating stations is low enrichment and can not be configured to create a nuclear explosion.
- The **reactor control system** regulates the power output of the reactor by controlling the rate of nuclear fission. This is accomplished by inserting or withdrawing control rods or by the addition of neutron absorbing materials. A special safety system is part of the reactor control system call the **reactor protection system** which will cause the control rods to be quickly inserted. This insertion causes to nuclear chain reaction to stop. There are numerous sensors that measure different plant conditions that would cause the reactor protection system to activate.
- There are several emergency systems that provide adequate cooling and water to the reactor in the event these are required. Should there be breakage of piping carrying water to the reactor this is referred to as a Loss of Coolant. These systems are activated upon a drop in reactor pressure or a low level of water in the reactor. The exact activation varies by reactor type. These systems that delivery this supplemental source of water are referred to as the **Emergency Core Cooling System.** There are even backup systems to the individual Emergency Core Cooling Systems. This practice is referred to as defense in depth. Safety is not dependent on any one device but is a system of several backups.

The Harris Nuclear Plant is designed to be a safe means of generating electrical power. This level of safety is further enhanced through the discipline of operation provided by a well qualified and trained staff. Ongoing training is provided to the staff to ensure a high quality performance from each member of the plant staff. Although the requirements are high for the staff, reactor operators and senior reactor operators must also pass a rigorous license examination by the Nuclear Regulatory Commission on a regular basis. These examinations test knowledge of plant systems, design, procedures, problem solving, regulatory requirements, and the ability to function as a team responding to plant conditions.

RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM

PURPOSE AND REQUIREMENTS FOR THE RADIOLOGICAL MONITORING PROGRAM

Although the operation of a nuclear generating station may result in the raising of background radiation only a small amount, it is important to measure these emissions of radioactivity and radiation to access their impact on the surrounding populations. The purpose of the radiological monitoring program is to measure accumulation of radioactivity in the environments, to determine whether this radioactivity is the result of operations of the Harris Plant, and to assess the potential dose to the off-site population based on the cumulative measurements of radioactivity of plant origin. Radiological monitoring programs provide an additional verification of the radiological controls of nuclear generating stations.

The radiological monitoring program was established in 1982 and continues to collect samples and evaluate them for 14 years.

Requirements are established for the radiological monitoring program as follows:

- Technical Specifications
- Off-Site Dose Calculation Manual(ODCM)
- various procedures

Additional guidance regarding the radiological monitoring program may be found in the following:

- NRC Regulatory Guide 1.109
- NRC Regulatory Guide 4.13
- NRC Regulatory Guide 4.15

General Site Description

The Harris Nuclear Plant consists of a pressurized water reactor with a design rating of 860 MWe (Mega Watts electric) Commercial production was initiated on January 3, 1987. The Harris Nuclear Plant is located in southwest Wake County, North Carolina. The site is along U.S. route 1 approximately sixteen (16) miles southwest of Raleigh, North Carolina and is displayed on the map of central North Carolina (Figure 15). The site is also approximately fifteen (15) miles northeast of Sanford, North Carolina.The nearest community is New Hill which is north of the site.

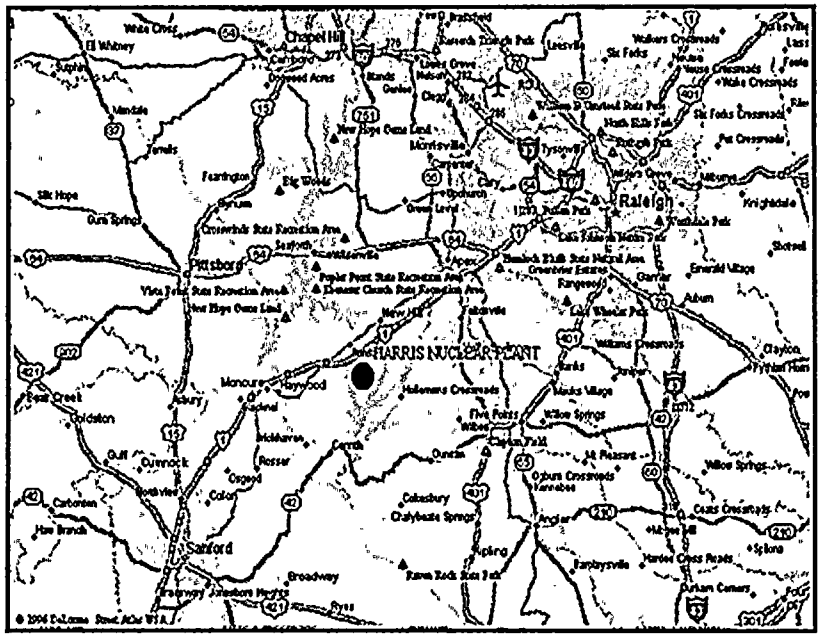

Figure 15 Location of Harris Nuclear Plant

Harris Lake is adjacent to the plant itself and is the source of cooling tower makeup water. The lake was impounded in the construction of Harris Plant. The lake is fed by Buckhorn Creek and is approximately 4,000 acres in area. The main dam is approximately 4.7 miles south of the site. The primary discharges to Harris Lake from the plant are surface runoff, cooling tower blow down, and radiological waste process systems.

Fishing, boating, and swimming are popular activities on Harris Lake and other nearby lakes. Carolina Power & Light encourages the recreational use of the lake and adjoining lands through a variety of agreements with state and local goverment. One of these agreements is the gamelands agreement encouraging hunting.

Within a five mile radius most of the land is wooded with only a few residences and limited agricultural activity. There are no non company industrial structures or residences on the plant site. The chief use of the land is for production of timber and pulp fiber.

Within a ten mile radius the area would be considered rural with significant populations in Apex, Holly Springs, and Fuquay-Varina. Currently these communities are experiencing significant growth.

Within a fifty mile radius much of the land is used in agricultural production. Significant crops include corn, soybeans, and tobacco. Livestock is also an important component with significant production in cattle, hogs, poultry, and dairy products.

Consumption of drinking water, food crops, and fish are sample media that are examples of ingestion pathways for exposure.

RADIOLOGICAL MONITORING PROGRAM QUALITY ASSURANCE

A required component of the environmental radiological monitoring program is the Quality Assurance Program. The standards for the quality assurance program are established in the NRC Regulatory Guide 4.15, "Quality Assurance for Radiological Monitoring Programs. The purpose of the quality assurance program is to "(1) to identify deficiencies in the sampling and measurement processes to those responsible for these operations so that corrective action can be taken, and (2) to obtain some measure of confidence in the results of the monitoring programs in order to assure the regulatory agencies and the public that the results are valid."(NRC Regulatory Guide 4.15 B Pg. 4.15-2) This provides the opportunity to implement corrective actions that address possible deficiencies. Examples of the activities of the quality assurance program include:

- regular review of sample collection and records
- regular review of laboratory procedures and methods
- participation in the Analytics, Inc. Environmental Cross-Check Program, which provides an independent assessment of the quality of laboratory results.
- the use of known concentrations of radioactivity in test samples by the laboratory to ensure consistent quality results on an ongoing basis.

RADIOLOGICAL MONITORING PROGRAM GENERAL DESCRIPTION

Although the contribution to background radiation is small, we have established this program to measure the exposure pathways to man. An exposure pathway describes the source of the radiological exposure. The primary forms of radiological emissions from the plant are airborne and liquid discharge. The following pathways are monitored; external dose, ingestion of radioactive materials, and the inhalation of radioactive material. Specific methods and different environmental media are required to assess each pathway. Below in Table 3 is a list of the media used to assess each of these pathways.

Table 3

Media Used to Assess Exposure Pathways to Man

Pathway of Exposure to Man	Media Sampled
External Dose	Thermoluminescent Dosimetry(TLD) Shoreline Sediment
Ingestion	Aquatic Vegetation Drinking Water Food Crops Fish Ground Water Milk Surface Water
Inhalation	Air Samples (Particulate & Radioiodine)

Sampling Locations

Sampling locations are chosen based upon meteorological factors, preoperation monitoring, and results of the land use surveys. A number of locations are selected as controls. Control stations are selected because they are unaffected by the operation of the plant. Sample locations may be seen in figures 16 and 17. A description of each sample location may be found in Table 4.

Radiological Sampling Locations

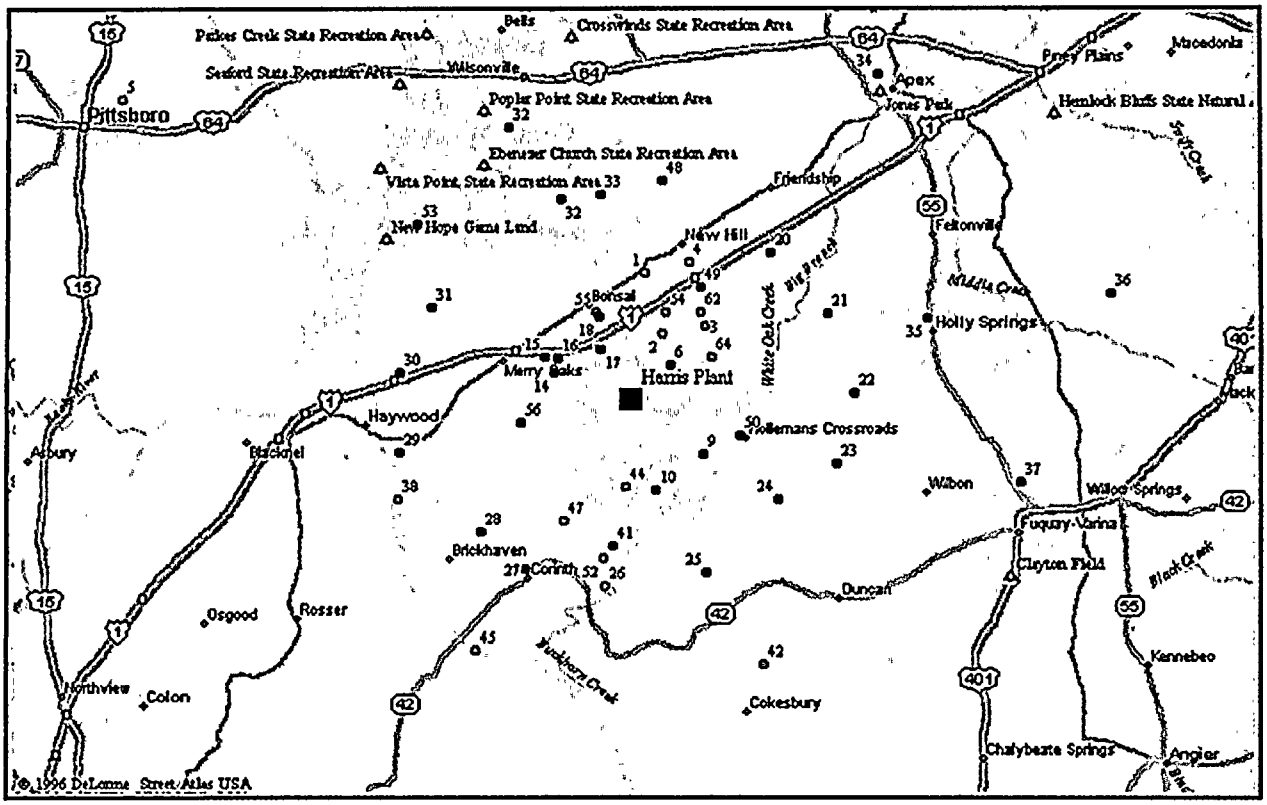

Figure 16: Radiological Sampling Locations (Distant from Plant) (Scale 1 inch = 3.9 miles)

Thermoluninescent dosimeter and shoreline sediment locations(only) are displayed in black, ingestion and waterborne pathways in blue, and inhalation or air sampling stations in red.

Stations 1 through 5, and 26 inculde air sampling and thermoluminsent dosimeters.

Sample Types	Sample Locations
Air Cartridge & Patriculate	1-5, 26,47(RED)
Shoreline Sediment	26,41
Ground Water	39,57-60(BLUE)
Drinking Water	38, 40(BLUE)
Surface Water	26, 38, 40 (BLUE)
Thermoluminscent Dosimeter	1-37, 48-50, 53, 56, 63 (BLACK EXCEPT AT SHARED LOCATIONS)
Milk	5, 42 (BLUE)
Fish	44, 45(BLUE)
Food Products	5, 54, 55, 62, 64 (BLUE)
Aquatic Vegetation & Bottom Sediment	41, 45, 46, 52

Radiological Sampling Locations

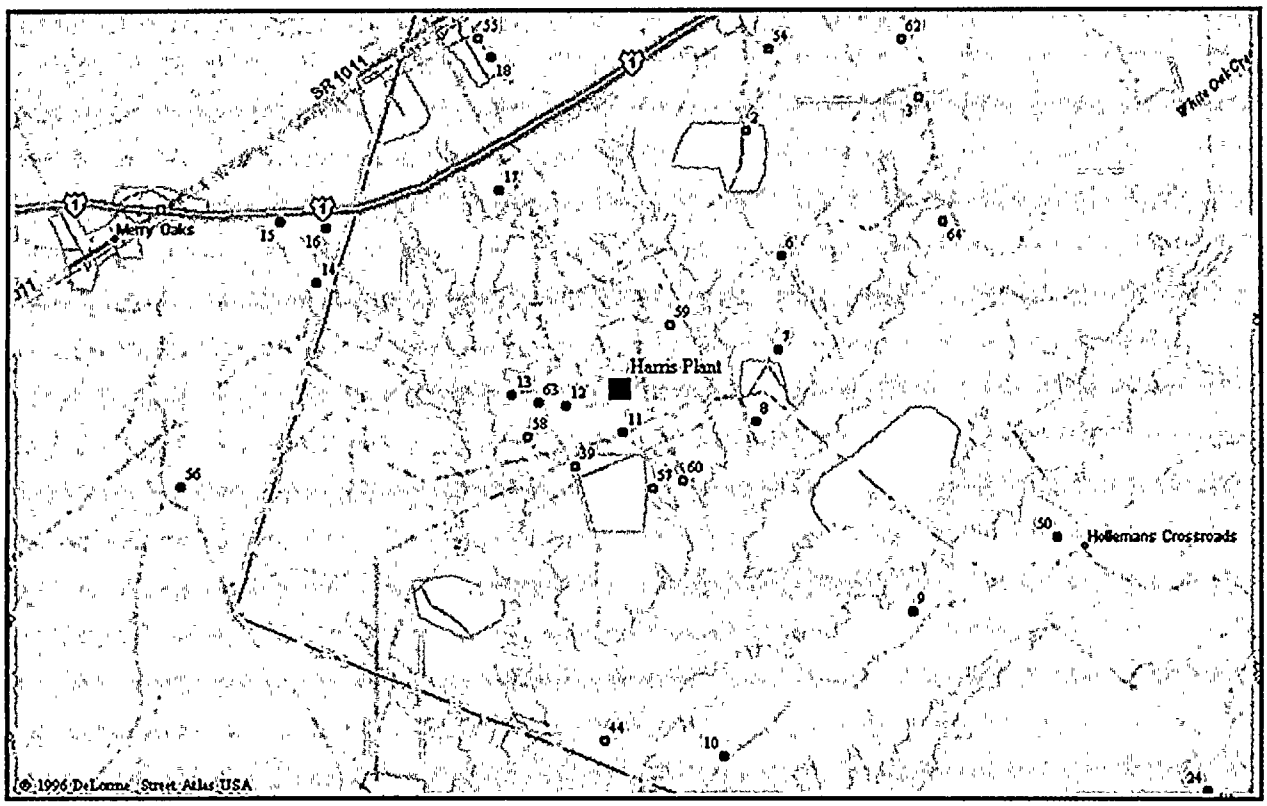

Figure 17 Radiological Sampling Locations (Nearest Plant) (Scale 1 inch = 1 miles)

Thermoluninescent dosimeter and shoreline sediment locations(only) are displayed in black, ingestion and waterborne pathways in blue, and inhalation or air sampling stations in red.

Stations 1 through 5, and 26 inculde air sampling and thermoluminsent dosimeters.

Sample Types	Sample Locations
Air Cartridge & Patriculate	1-5, 26,47(RED)
Shorcline Sediment	26,41
Ground Water	39,57-60(BLUE)
Drinking Water	38, 40(BLUE)
Surface Water	26, 38, 40 (BLUE)
Thermoluminscent Dosimeter	1-37, 48-50, 53, 56, 63 (BLACK EXCEPT SHARED LOCATION)
Milk	5, 42 (BLUE)
Fish	44, 45(BLUE)
Food Products	5, 54, 55, 62, 64 (BLUE)
Aquatic Vegetation & Bottom Sediment	41, 45, 46, 52

Table 4

Harris Nuclear Plant

Radiological Monitoring Sampling Locations

Sample Type	Location & Description	Frequency	Sample Size	Analysis
Air Cartridge (AC)	1--2.6 miles N 2--1.4 miles NNE 4--3.1 miles NNE 5--13.4 miles WNW--Pittsboro* 26--4.7 miles S 47--3.4 miles SSW	Weekly or as required by dust loading	30,000 ft^3 (900 m^3)	Iodine
Air Particulate (AP)	1--2.6 miles N 2--1.4 miles NNE 4--3.1 miles NNE 5--13.4 miles WNW--Pittsboro* 26--4.7 miles S 47--3.4 miles SSW	Weekly or as required by dust loading	30,000 ft^3 (900 m^3)	Gross Beta (Weekly) Composite Gamma (Quarterly)
Fish (FI)	44--Site varies in Harris Lake 45--Site varies in Cape Fear River*	Semiannual (In Season)	1 kg (wet) Free Swimmers & Bottom Feeders	Gamma
Drinking Water (DW)	38--6.2 miles WSW* 40--17.2 miles SSE Lillington 51--Water Treatment Plant (On Site)	Weekly Monthly Composite	8 liters	I-131, Gamma Tritium Gross Beta
Groundwater (GW)	39--.07 miles SSW 57--.04 miles SSW 58--.5 miles WSW 59--.5 miles NNE 60--.5 miles ESE	Quarterly	8 liters	Gamma Tritium
Milk(MK)	5— 18.2 miles WNW Manco Dairy* 42--7.0 miles SSE Maple Knoll Dairy	Semimonthly	8 liters	I-131 Gamma
Shoreline Sediment (SS)	26--4.6 miles S 41--3.8 miles S	Semiannual	500 grams	Gamma
Surface Water (SW)	26--4.7 miles S 38--6.2 miles WSW * 40--17.2 miles SSE Lillington	Weekly Monthly Composite	8 liters	I-131, Gamma Tritium Gross Beta
Aquatic Vegetation	26--4.7 miles S 41--3.8 miles S 61--2.5 miles E	Annually	500 grams	Gamma
Bottom Sediment (SD)	52--3.8 miles S	Semiannual	500 grams	Gamma
Food Products (FP)	5--18.0 miles NNW--Pittsboro* 54--1.7 miles NNE--Wilkins or Morris 55--2.0 miles NNW--L. L. Goodwin 62--2.3 miles NE--Lee 64--1.8 miles ENE-Michael	Monthly during growing season when milk samples not performed	500 grams	Gamma

* Control Stations

Table 4 (Continued)

Harris Nuclear Plant

Radiological Monitoring Sampling Locations

Sample Type	Location & Description	Frequency	Sample Size	Analysis
Thermoluminescent Dosimetry (TLD)	1--2.6 miles N 2-1.4 miles NNE 3--2.6 miles ENE 4--3.1 miles NNE 5--13.4 miles WNW--Pittsboro* 6--0.8 mile NE 7-0.7 mile E 8--0.6 mile ESE 9--2.2 miles SE 10--2.2 miles SSE 11-0.6 mile S 12--0.9 mile SSW 13--0.7 mile WSW 14--1.5 miles W 15--2.0 miles W 16--1.9 miles WNW 17--1.5 miles NW 18--1.4 miles NNW 19--5.0 miles NNE 20--4.5 miles NE 21--4.8 miles ENE 22 --4.3 miles E 23 --4.8 miles ESE 24--4.0 miles SE 25--4.7 miles SSE 26--4.7 miles S 27--4.8 miles SW 28--4.8 miles SSW 29--5.7 miles WSW 30--5.6 miles W 31--4.7 miles WNW 32--6.4 miles NNW 33--4.5 miles NNW 34--8.7 miles NE--Apex 35--6.9 miles E--Holly Springs 36--10.9 miles E 37--9.2 miles ESE--Fuquay-Varina 48--4.5 miles N 49--2.5 miles NNE 50--2.6 miles ESE 53--5.8 miles NW 56--3.0 miles WSW 63--0.6 mile S'W	Quarterly	Not Applicable	TLD Reading

* Control Stations

SUMMARY OF RADIOLOGICAL MONITORING PROGRAM

This report presents the results of the Radiological Environmental Monitoring Program conducted during 1996 for the Shearon Harris Nuclear Power Plant (SHNPP) and fulfills the reporting requirements of Technical Specifications 6.9.1.3. The program was conducted in accordance with Operational Requirement 3.12.1 in the Off-Site Dose Calculation Manual (ODCM), and applicable procedures.

Approximately 1060 samples of 11 different media types from indicator stations were compared to approximately 340 control samples. Control stations are locations that are unaffected by plant operations. In approximately 99 percent of the indicator samples there was no difference from the activities observed in the corresponding control samples.

Radioactivity in environmental samples attributed to plant operations in 1996 are as follows:

Environmental Media	Radionuclide	Location of w/Highest Annual Mean	Activity and Occurrence	Maximum Individual Dose (mrem/yr)
Surface Water	H-3	Harris Lake	4,750 pCi/L (12/12)	No ingestion pathway. No dose calculated.
Fish	H-3	Harris Lake	See above. Assumes H-3 equilibrium between lake water and fish tissue.	0.01 Total Body

The radiological environmental data indicates that SHNPP operations in 1996 had no significant impact on the environment or public health and safety.

A statistical summary of all the data for 1996 has been compiled and summarized in Table 5.

The only plant-derived activity detected within the scope of the Radiological Environmental Monitoring Program (see Data Summary Table 5) has been tritium activity in Harris Lake water at an average concentration of 4.75 E+3 pCi/L for 1996. Tritium activity (4.55 E+2 pCi/L) was observed only one (1) out of twelve (12) times at Lillington, N.C., located 17 miles downstream on the Cape Fear River. This is the first public drinking water location below the Harris Lake discharge spillway. No plant-related gamma activity has been detected in fish collected from Harris Lake or in the water samples from Lillington, N.C.

TABLE 5

RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM DATA SUMMARY

Shearon Harris Nuclear Power Plant
Wake County, North Carolina

Docket Number: STN 50-400
Calendar Year: 1996

Medium or Pathway Sampled or Measured (Unit of Measurement)	Type and Total No. of Measurements Performed	Typical Lower Limit of Detection (LLD) [1]	All Indicator Locations Mean [2] Range	Location w/Highest Annual Mean Name, Distance, and Direction	Location w/Highest Annual Mean Mean [2] Range	Control Locations Mean [2] Range
Air Cartridge (pCi/m³)	I-131 318	2.2E-2	All less than LLD		All less than LLD	All less than LLD
Air Particulate (pCi/m³)	Gross Beta 318	1.0E-3	1.74E-2 (265/265) 6.99E-3 - 2.82E-2	Dixie Pipeline 2.6 miles N	1.88E-2 (53/53) 1.09E-2 - 2.82E-2	1.88E-2 (53/53) 1.19E-2 - 2.84E-2
	Gamma 24	Refer to Table 6	All less than LLD		All less than LLD	All less than LLD
Drinking Water[4] (pCi/l)	I-131 106	1.0E+0	All less than LLD		All less than LLD	All less than LLD
	Gross Beta 24	1.0E+0	3.70E+0 (12/12) 2.75E+0 - 4.97E+0	Lillington Cape Fear River 17.2 miles SSE	3.70E+0 (12/12) 2.75E+0 - 4.97E+0	3.68E+0 (12/12) 2.75E+0 - 4.61 E+0
	Gamma 24	Refer to Table 6	All less than LLD	All less than LLD		All less than LLD
	Tritium 24	3.25E+2 (14/24)[6] 1.00E+3 (10/24)[6]	4.55 E+2 (1/12) Single Value	Lillington Cape Fear River 17.2 miles SSE	4.55 E+2 (1/12) Single Value	All less than LLD
Fish Bottom-Feeders (pCi/g, wet)	Gamma 4	Refer to Table 6	All less than LLD		All less than LLD	All less than LLD
Free-Swimmers (pCi/g, wet)	Gamma 8	Refer to Table 6	All less than LLD		All less than LLD	All less than LLD

TABLE 5 (cont.)

RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM DATA SUMMARY

Shearon Harris Nuclear Power Plant
Wake County, North Carolina

Docket Number: STN 50-400
Calendar Year: 1996

Medium or Pathway Sampled or Measured (Unit of Measurement)	Type and Total No. of Measurements Performed	Typical Lower Limit of Detection (LLD) [1]	All Indicator Locations Mean [2] Range	Location w/Highest Annual Mean Name, Distance, and Direction	Mean [2] Range	Control Locations Mean [2] Range
Food Crop (pCi/g, wet)	Gamma 13[3]	Refer to Table 6	All less than LLD		All less than LLD	All less than LLD
Groundwater (pCi/l)	Gamma 20	Refer to Table 6	All less than LLD		All less than LLD	No control
	Tritium 20	3.25E+2 (15/20) [4] 1.00E+3 (5/20)[4]	7.91 E+2 (3/20) 7.43 E+2 - 8.40 E+2	North Bank ESW Intake 0.5 mile WSW	7.91 E+2 (3/20) 7.43 E+2 - 8.40 E+2	No control
Milk (pCi/l)	I-131 48[3]	1.0E+0	All less than LLD		All less than LLD	All less than LLD
	Gamma 48[3]	Refer to Table 6	All less than LLD		All less than LLD	All less than LLD
Shoreline Sediments (pCi/g, dry)	Gamma 8	Refer to Table 6	All less than LLD		All less than LLD	No control
Surface Water[4] (pCi/l)	I-131 106	1.0E+0	All less than LLD		All less than LLD	All less than LLD
	Gross Beta 36	1.0E+0	3.32E+0 (24/24) 2.37E+0 - 4.97E+0	Lillington Cape Fear River 17.2 miles SSE	3.70E+0 (12/12) 2.75E+0 - 4.97E+0	3.68E+0 (12/12) 2.75E+0 - 4.61E+0
	Gamma 36	Refer to Table 6	All less than LLD		All less than LLD	All less than LLD
	Tritium 36	3.25E+2 (14/36)[4] 1.00E+3(22/36)[4]	4.75E+3 (13/24) 4.55E+2 - 6.65E+3	Harris Lake 4.7 miles S	4.75E+3 (12/12) 3.86E+3 - 6.65E+3	All less than LLD
Direct Radiation (mR/qtr)[5]	TLD 163[3]		1.22E+1 (159/159) 1.12E+1 - 1.34E+1	Apex at Jones Park 8.7 miles NE-Apex	1.77E+1 (3/3) 1.35E+1 - 2.59E+1	1.60E+1 (4/4) 1.53E+1 - 1.68E+1

FOOTNOTES TO TABLE 5

1. The Lower Limit of Detection (LLD) is the smallest concentration of radioactive material in a sample that will yield a net count above system background which will be detected with 95 percent probability and with only 5 percent probability of falsely concluding that a blank observation represents a "real" signal. Due to counting statistics and varying volumes, occasionally lower LLDs are achieved.

2. Mean and range are based on detectable measurements only. The fractions of all samples with detectable activities at specific locations are indicated in parentheses.

3. Missing samples are discussed in Missed Samples and Analyses.

4. Although quarterly composite samples are required, monthly composite samples are used to provide more frequent and sensitive analyses.

5. TLD exposure is reported in milliroentgen (mR) per 90-day period (quarter) beginning in 1995. This is the exposure standard used to compare data to the Nuclear Regulatory Commission (NRC).

6. Tritium Lower Limit of Detection (LLD) was 1.0 E+3 pCi/L for five out of twelve months in 1996 (January-May); however, the LLD was lowered to 3.25 E+2 pCi/L in June 1996 for samples that typically demonstrate activity less than the LLD. The LLD was lowered at the request of the plants in order to maintain comparable LLD and result values with the state (N.C. and S.C.) Agencies' laboratories.

INTERPRETATIONS AND CONCLUSIONS

Air Monitoring

All 318 air cartridge samples from indicator and control stations had I-131 activities which were less than the LLD of 1.5 E-2 pCi/m^3. I-131 was detected in air samples for a six-week period following the Chernobyl incident in April 1986. With this exception, no I-131 has been detected in air samples collected from 1987 through 1996, which is the entire operating history of the plant.

Gross beta activity was detectable in all airborne particulate samples from the five indicator locations. The 265 samples had an average concentration of 1.74E-2 pCi/m^3, a value similar to preoperational data of 2.0 E-2 pCi/m^3. Similar gross beta activities were observed at the control location in Pittsboro which had an average concentration of 1.88E-2 pCi/m^3 in 53 samples. These concentrations are typical of the natural environment and are not attributed to plant operations. Figures 18 through 22 provide a graphic representation of the gross beta activity at the indicator locations compared to the control location for the period January through December 1996.

No plant-related gamma activity was detected in quarterly composite filter samples from either the indicator or control locations. Typical LLDs for air particulates are contained in Table 6.

Drinking Water

None of the 53 drinking water samples collected at the Lillington Municipal water supply nor the 53 control samples collected from the Cape Fear River above the Buckhorn Dam contained detectable I-131 activity (< 1.0 E+0 pCi/L) during 1996. This has been the experience for the preoperational and operational period with the exception of 1986 when the fallout from Chernobyl was detected.

The average annual gross beta concentrations at the indicator and control locations were similar with activities of 3.70 pCi/L and 3.68 pCi/L, respectively, similar to the preoperational average of 4.00 pCi/L. These activities are attributed to the natural environment and are not attributed to plant operations. Figure 23 provides graphic representation of the gross beta activity during 1996 for Location 40 (Lillington).

Analyses for gamma-emitting radionuclides indicated all concentrations were less than the lower limit of detection for drinking water. Table 6 contains typical LLD values for gamma-emitting radionuclides in drinking water.

Tritium concentrations in all but one (one out of twelve samples) of the Lillington Municipal Water Supply samples were less than the lower limit of detection (325 pCi/L) (see Footnotes to Table 5, Footnote 6). The one sample that exhibited tritium activity (455 pCi/L) was the monthly composite for September 1996 (after hurricane Fran). The next month (October 1996) the tritium concentration was less than the LLD (< 302 pCi/L).

Fish

Analyses for gamma-emitting radionuclides in two samples of bottom-feeding fish and in four samples of free-swimming species (sunfish and largemouth bass) from the indicator location, Harris Lake, revealed no detectable activity for 1996 consistent with the data for 1989-1995. During the Chernobyl period, Cs-134, 137 were detected in both control and indicator samples.

Fish are considered to be in equilibrium with the tritium activity in the lake and the most exposed individual (an adult) would have to consume approximately 46 pounds (lbs.) of fish a year (21 kg fish/yr.). The total body dose to the maximum exposed adult individual due to tritium was calculated by Regulatory Guide 1.109, Equation A-1, to be 0.01 mrem/year.

Equation A-1

$$R_{aipj} = C_{ip}\, U_{ap}\, D_{aipj}$$

where as:

R_{aipj}	=	total body dose in mrem/yr of H-3
C_{ip}	=	concentration of nuclide (H-3) in pCi/kg = pCi/L
U_{ap}	=	maximum exposed individual's consumption (Reg. Guide 1.109 Table E-5) (approx. 46 lbs. of fish/yr. = 21 kg of fish/yr.)
D_{aipj}	=	ingestion dose factor for total body of individual in U_{ap} in mrem/pCi (Reg. Guide 1.109 Table E-11)

The dose due to tritium in the fish was also calculated using the adult as the maximum exposed individual with the exposure to the liver, the result was the same. The total body dose and dose to the liver (ingestion dose factor - Reg. Guide 1.109 Table E-13) for the exposed individual being a child consuming approximately 15 lbs. of fish a year (6.9 kg fish/yr.) Reg. Guide 1.109 Table E-5) calculates to be 0.007 mrem/year.

Surface Water

Surface water samples were collected and analyzed weekly for I-131. Water samples collected during 1996 contained no detectable I-131 (LLD < 1.0E+0 pCi/L) as they have been since plant operations began in 1987.

Average gross beta concentrations at the indicator and control locations were 3.32 E+0 pCi/L and 3.68 E+0 pCi/L, respectively in 1996, indicating no adverse influence from plant operations (See Figure 24).

Surface water samples were analyzed for gamma-emitting radionuclides and tritium. All concentrations of man-made gamma-emitters were less than their respective lower limits of detection (see Table 6).

The annual average tritium concentration in Harris Lake was 4.75 E+3 pCi/L with minimum and maximum values of 3.86 E+3 pCi/L and 6.65 E+3 pCi/L, respectively. The Harris Lake tritium activity showed a significant decline in tritium concentration compared to 8.0 E+3 pCi/L in 1995 (see Figure 25).

Groundwater

Groundwater samples are collected on site at SHNPP and analyzed for gamma-emitting radionuclides and tritium. Concentrations of the gamma radionuclides were all less than their respective lower limits of detection during 1996. Therefore, there appears to be no downwelling of activity. No tritium or gamma-emitter activity has been observed over the period from 1985-1995. Tritium activity was detected in groundwater 58 (0.5 mile WSW Sector N Bank ESW Intake) three out of four quarters in 1996, above the lower limit at detection (< 325 pCi/L). No activity was observed in first quarter 1996, which had an LLD of 1000 pCi/L. The tritium LLD activity for pre-operational samples through first quarter 1996 was 1000 pCi/L and from second quarter (June) 1996 through December 1996 the LLD activity was decreased to 325 pCi/L. The

groundwater wells are all abandoned wells and are not a water supply for drinking or irrigation; therefore, there is no radiological dose via this pathway.

Milk

During 1996 as in all past years with the exception of the Chernobyl period, no I-131 concentrations were detected in milk samples throughout the entire year. There were also no other gamma-emitting radionuclides from plant operations detected in the milk. The only detectable gamma-emitting nuclide identified in each milk sample was potassium-40 (K-40). This is a natural occuring nuclide in any living organism or product of. The K-40 concentrations in milk range from 1.18E+3 pCi/L - 2.11E+3 pCi/L for the control location and 1.23E+3 pCi/L - 2.19E+3 pCi/L for the indicator sample location.

Shoreline Sediment

Shoreline sediment samples were collected (1) opposite the discharge structure and (2) near the main dam in 1996. No plant-related radioactivity has been observed in either sample 1994-1996. No long-term trends are readily identifiable.

Food Crops

In addition to milk sampling, a food product sampling program was maintained. Various crops were collected during a growing season which basically continued year round. The species selected were primarily broad-leaf vegetables most sensitive to direct fallout of airborne radioactive particulates. Crops sampled in 1996 included turnip greens, cabbage, collards, tomatoes, and mustard greens. Gamma spectrometry analyses of the food crops detected no plant-related activity in 12 samples from indicator locations collected in 1996.

External Radiation Exposure

Thermoluminescent dosimeters (TLDs) were used to monitor ambient radiation exposures in the plant environs. The average quarterly exposure from the indicator locations was 12.2 mR and 16.0 mR from the control station. The highest indicator location was 8.7 miles NE of the plant and averaged 17.7 mR/qtr. The differences among these locations is attributed to variations in soils and local geology and are not the result of plant operations.

Comparison of the quarterly TLD exposure within approximately 2 miles (inner ring) of the plant with that at approximately 5 miles (outer ring) is presented in Figure 26; these data illustrate that the inner and outer rings are approximately equal.

MISSED SAMPLES AND ANALYSES

Air Cartridge and Air Particulates

Low air sample volumes were collected from locations AC/AP-1, AC/AP-2, AC/AP-5, and AC/AP-47 during the week of September 9, 1996, due to hurricane Fran.

Food Crops

Food crops were not available for sampling during January, February, March, April, and May.

Milks

A new dairy was added in January 1996 to replace the Strow Dairy (Mk-5 Pittsboro - Control) that ceased operations in December 1995. The new dairy is the Manco Dairy of Pittsboro (Mk-5) and is located in the WNW sector at 18.2 miles from the plant.

TLDs

Seven of a possible 170 TLD samples were missing during 1996 due to vandalism. They were:

First Quarter	-	TLDs 16, 20, and 34 were missing in the field.
Second Quarter	-	TLD 17 was missing in the field due to road construction with the widening of the highway. TLD was relocated across the road.
Third Quarter	-	TLD 9 was missing in the field.

Fourth Quarter - TLDs 15 and 17 were missing in the field. TLD 17 missing due to additional highway construction on the opposite side of the road. It was moved further out from the highway construction, but still within the range of acceptable coordinates (0.10 mile).

ANALYTICAL PROCEDURES

Gross Beta

Gross beta radioactivity measurements are made utilizing a Tennelec Low-Background Alpha/Beta Counting System. The LLD for air particulates is approximately 1.0E-3 pCi/m^3 for SHNPP samples. Air particulate samples are mounted in 2-inch stainless steel planchets and counted directly.

Gross beta activity in drinking and surface waters is determined by evaporating 1 liter of the sample and counting a planchet on a Tennelec Low-Background Alpha/Beta Counting System for 50 minutes. Typical LLD for gross beta is 1.0E+0 pCi/L.

Tritium

Liquid samples requiring tritium analysis are treated with a small amount of sodium hydroxide and potassium permanganate crystals and then distilled. Five milliliters of the distillate are mixed with thirteen milliliters of liquid scintillation cocktail and counted in a liquid scintillation counter. Samples which routinely demonstrate activity less than the lower limit of detection count for 500 minutes with an approximate LLD of 325 pCi/L and samples that typically exhibit activity count for 60 minutes with an approximate LLD of 1000 pCi/L. The tritium LLD was lowered at the request of the plants (see Footnotes to Table 5, Number 6).

Iodine-131

Iodine-131 airborne concentrations are analyzed by the intrinsic germanium (Ge) spectrometry systems. The cartridges are placed on the detector, and each charcoal cartridge is counted individually with an LLD 2.2 E-2 pCi/m^3.

Iodine-131 in milk and drinking water is determined by an instrumental method. Analysis involves passing 4 liters over an anion exchange resin and direct gamma analysis of the resin with an intrinsic Ge detector. The LLD using the Ge detector is approximately 1.0 E+0 pCi/L using a 25,000-second count time.

Gamma Spectrometry

Gamma spectrum analysis utilizes intrinsic germanium detectors with thin aluminum windows housed in steel and lead shields. The analyzer system is the Canberra Nuclear 9900 Gamma Spectroscopy System. Table 6 summarizes LLD values derived from instrument sensitivity based upon a blank sample background.

Air particulate filter quarterly composites are placed in a Petri dish and analyzed directly for 1,000 seconds.

Liquid samples, except milk, are boiled down to a small volume, transferred to a PB-50 beaker and analyzed for 7,000 seconds. One-liter milk samples are analyzed in a Marinelli beaker for 25,000 seconds.

Shoreline sediments are dried, weighed, and then analyzed in a Marinelli beaker for 1,500 seconds.

Food crop and aquatic vegetation samples are weighed as sampled and analyzed in a Marinelli beaker for 7,500 seconds.

Fish samples are cleaned, dressed, and placed in a Marinelli beaker for analysis for 1,500 seconds.

Thermoluminescent Dosimetry

Each area monitoring station includes a TLD packet which is a polyethylene bag containing three calcium sulfate phosphors contained in a Panasonic UD-814 badge. The TLD is lighttight and the bag is weather-resistant.

Dosimeters are machine annealed before field placement. Following exposure in the field, each dosimeter is read utilizing a Panasonic TLD reader. This instrument integrates the light photons emitted from traps as the dosimeter is heated above 150EC. The photons from the lower-energy traps are automatically eliminated through a preheat cycle. Calibration is checked regularly using dosimeters irradiated to known doses. Prior to the measurement of each dosimeter, the instrument is checked through use of an internal constant light source as a secondary standard.

The exposure reported is corrected for exposure received in transit and during storage through the use of control dosimeters.

Interlaboratory Comparison Program

The Radiochemistry Laboratory at the Harris Energy & Environmental Center in New Hill, North Carolina, provides radioanalytical services for CP&L's nuclear plant radiological environmental surveillance programs. In fulfillment of ODCM Operational Requirements, the laboratory is a participant in the Analytics, Inc., Environmental Cross-Check Program and uses its performance in this program as a major determinant of the accuracy and precision of its analytical results. The change in vendors for the Interlaboratory Program was due to the EPA Environmental Cross-Check Program's termination as of December 31, 1995.

During 1996, 81 analyses were completed on 16 samples representing five major environmental media (i.e., water, milk, air filters, soil, and air cartridges). Data on the known activities and the standard deviations for the 81 analyses have been received from Analytics, Inc. A comparison of the average of our reported values with the Analytics, Inc., known activity and its standard deviation is provided below:

Standard Deviation From Known Activity	Percent of Analyses
≤1 Standard Deviation	61
≤2 Standard Deviation	85
≤3 Standard Deviation	94

Five of 81 analyses exceeded the 3 sigma action level. This was a gross alpha/beta in water from First Quarter 1996 Gross Alpha/Beta in Water (E0658-72) and three gammas from Second Quarter 1996 Gamma in Water (E0734-72) and an Air Filter gamma (E0737-72).

The gross alpha/beta results were investigated by the following means: 1) rechecked counts and efficiency used, 2) instrument efficiency was verified and checked against 1995's efficiency, 3) samples had been disposed of so a recount was unobtainable, 4) reanalyzed an aliquot of remaining original sample, and 5) spiked the sample-recovery was also high; therefore, the investigation did not determine a reason for the erroneous result. The laboratory also participates in a Radiochemistry Effluent Interlaboratory Comparison Program (vendor - Analytics, Inc.) which checks our performance (accuracy and precision) on Gross Alpha/Beta, Sr-89/90, and

Fe-55. The Gross Alpha/Beta results for 1996 were within Analytics, Inc.'s acceptable criteria range. The three gamma results that exceeded the three sigma value in the second quarter were within acceptable range in the Third Quarter 1996 Cross-Check sample.

Lower Limits of Detection

All samples analyzed met the LLD required by the ODCM.

TABLE 6
TYPICAL LOWER LIMITS OF DETECTION (A PRIORI)
GAMMA SPECTROMETRY

Drinking Water/Surface Water/Groundwater Samples	
Isotope	**LLD (pCi/L)**
Mn-54	6
Co-58	6
Fe-59	14
Co-60	8
Zn-65	13
Zr-Nb-95	6
I-131	1.0*
Cs-134	7
Cs-137	7
Ba-La-140	8
Other Expected Gamma Emitters	3 to 311
Air Particulates (Quarterly Composite)	
Isotope	**LLD (pCi/m^3)**
I-131	0.045
Cs-134	0.001
Cs-137	0.001
Other Expected Gamma Emitters	0.001 to 0.043
Milk	
Isotope	**LLD (pCi/L)**
I-131	1.0*
Cs-134	10
Cs-137	9
Other Expected Gamma Emitters	6 to 587

*Instrumental analysis of resin concentrates of samples.

TABLE 6 (continued)
TYPICAL LOWER LIMITS OF DETECTION (A PRIORI)
GAMMA SPECTROMETRY

Sediment	
Isotope	**LLD (pCi/kg dry)**
Cs-134	69
Cs-137	71
Other Expected Gamma Emitters	41 to 1518
Fish	
Isotope	**LLD (pCi/kg wet)**
Mn-54	54
Co-58	40
Fe-59	119
Co-60	67
Zn-65	75
Cs-134	74
Cs-137	64
Other Expected Gamma Emitters	36 to 1429
Food Products and Vegetation	
Isotope	**LLD (pCi/kg wet)**
I-131	41 pCi/kg (wet)
Cs-134	34
Cs-137	34
Other Expected Gamma Emitters	22 to 1811

LAND-USE CENSUS
PURPOSE OF THE LAND-USE CENSUS

The land-use census identifies the pathways (or routes) that radioactive material may reach the general populations near commercial nuclear generating stations. This is accomplished by completing studies each year that identify how the surrounding lands are used by the population. A comprehensive census of the use of the land within a five mile distance of the plant is completed during the growing season each year. This information is used for dose assessment and to identify changes to the stations sampled and the type of samples. These results ensure that the Radiological Environmental Monitoring Program (REMP) is based upon current data regarding human activity in the vicinity of the plant. Therefore the purpose of the land-use census is both to ensure the monitoring program is current as well as provide data for the calculation of estimated radiation exposure.

The pathways that are evaluated are:

- Ingestion Pathway - Results from eating food crops that may have radioactive materials deposited on them, incorporated radioactive materials from the soil or atmosphere. Another pathway is through drinking milk from local cows or goats if these are present. The grass used to feed these animals may have incorporated or had deposited on it radioactive materials that can be transferred to the milk.
- Direct Radiation Exposure Pathway- Results from deposition of radioactive materials on the ground or from passage of these radioactive materials in the air.
- Inhalation Pathway- Results from breathing radioactive materials transported in the air.

Methodology

The following must be identified within the five (5) mile radius of the plant for each of the sixteen meteorological sectors (compass direction the winds may blow, for example NNE [North North East]):

- The nearest resident
- The nearest garden of greater that 500 square feet, producing broadleaf vegetables
- The nearest milk animal

The primary method is visual inspection from roadside within the five (5) mile radius, with the exception of the Military Ocean Terminal. This information is supplemented with data from aerial photographs, information from county extension agents, and farm supply businesses.

1996 Land-Use Census Results

The 1996 and 1995 results of the survey for the nearest resident, garden, milk and meat animals in each sector are compared in Table 7.

The nearest resident in each sector remained the same from 1995 to 1996. No gardens were located within 5 miles of the plant for the E, S, and SW sectors. The only substantive change in meat animals was the loss of chickens in the ESE sector. The dairy in the N sector 2.2 miles from the plant ceased operation in 1995. A dairy in the SSE sector 7.0 miles from the plant which had been a participant in the REMP as an additional sampling site became the indicator location for this exposure pathway.

TABLE 7

LAND-USE CENSUS COMPARISON (1995-1996)
NEAREST PATHWAY (MILES)

SECTOR	RESIDENT		GARDEN		MEAT ANIMAL		MILK ANIMAL	
	1996	1995	1996	1995	1996	1995	1996	1995
N	2.2	2.2	2.2	2.2	2.2	2.2	---	---
NNE	1.9	1.9	1.9	1.9	2.2	2.2	---	---
NE	2.3	2.3	2.3	2.3	2.3	2.3	---	---
ENE	1.8	1.8	1.8	1.8	1.8	1.8	---	---
E	1.7	1.8	---	---	2.0	2.0	---	---
ESE	2.6	2.6	4.6	4.7	---	4.3	---	---
SE	2.6	2.6	2.7	2.7	2.6	2.6	---	---
SSE	4.2	4.2	4.2	---	4.2	---	7.0	7.0
S	5.3	5.3	---	---	---	5.3	---	---
SSW	3.8	3.9	3.8	---	---	---	---	---
SW	2.9	2.9	---	2.9	---	---	---	---
WSW	4.5	4.5	4.5	4.5	4.5	4.5	---	---
W	3.0	3.0	3.1	3.1	3.1	3.1	---	---
WNW	2.3	2.3	2.3	2.3	---	---	---	---
NW	2.4	2.4	2.6	2.7	---	---	---	---
NNW	1.6	1.6	2.0	2.0	2.0	2.0	---	---

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Figure 18 For HNP From 1/1/96 To 12/31/96

AIR PARTICULATE for GROSS BETA - Activity (pCi/cubic meter)

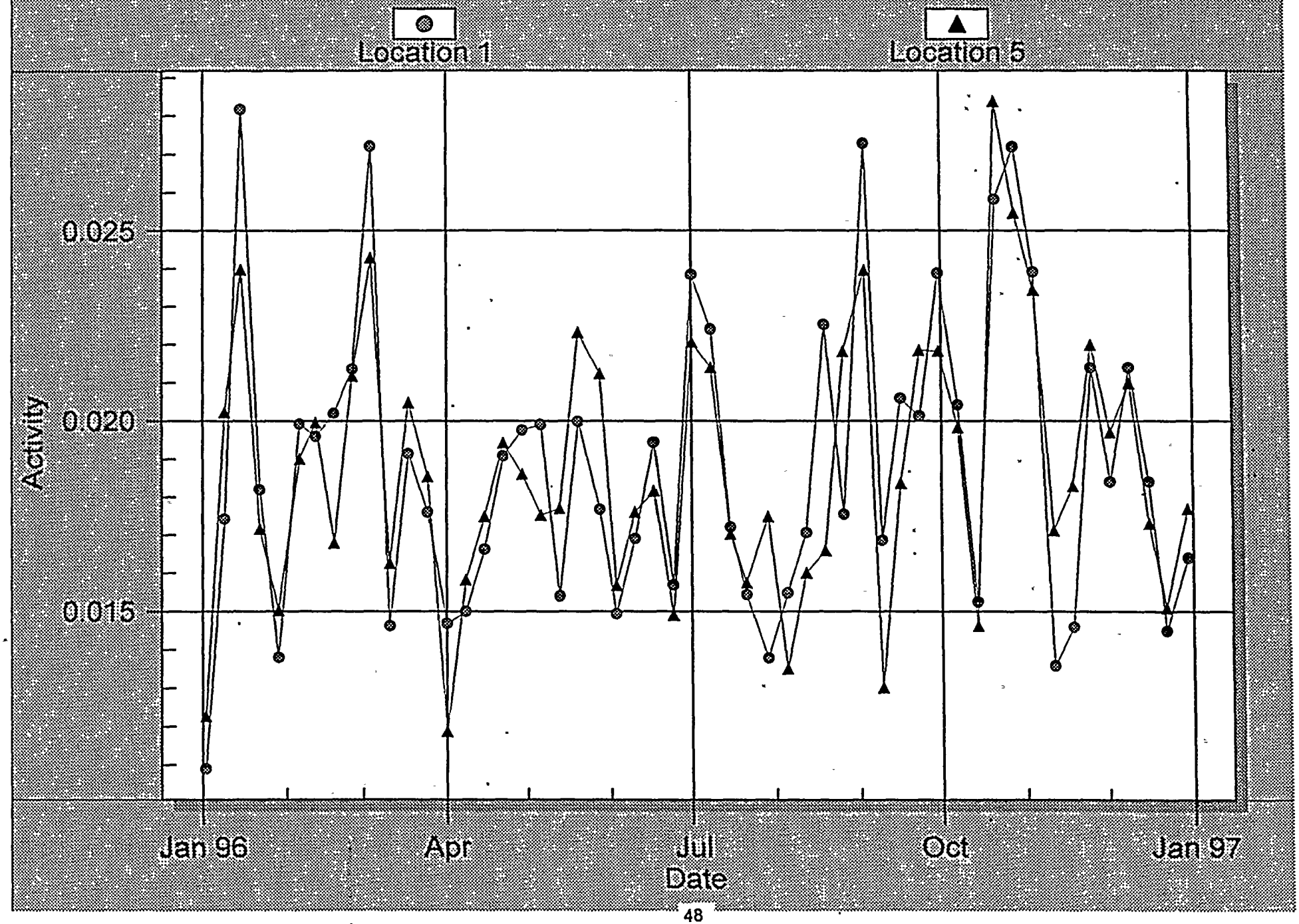


Figure 19 For HNP From 1/1/96 To 12/31/96

AIR PARTICULATE for GROSS BETA - Activity (pCi/cubic meter)

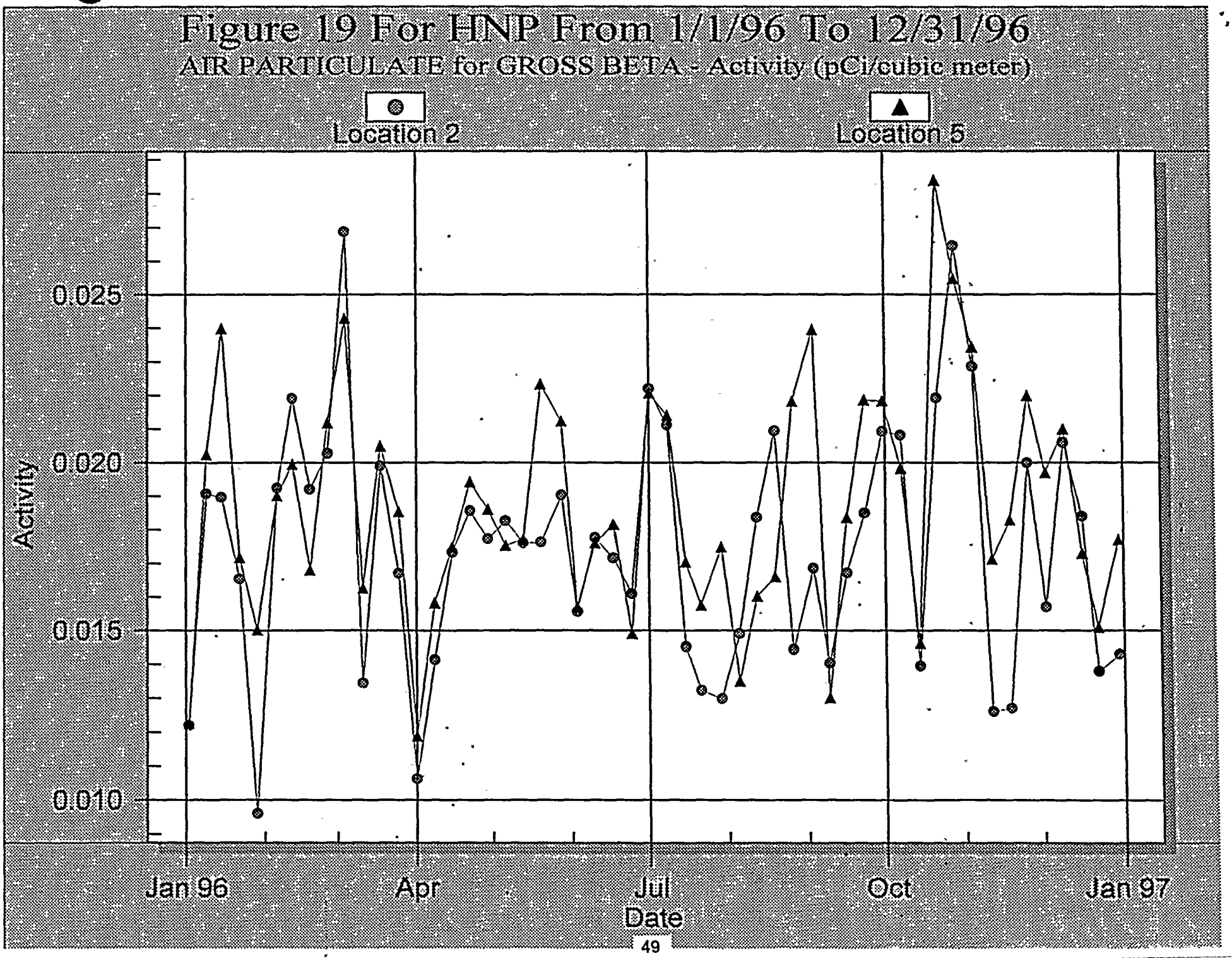


Figure 20 For HNP From 1/1/96 To 12/31/96

AIR PARTICULATE for GROSS BETA - Activity (pCi/cubic meter)

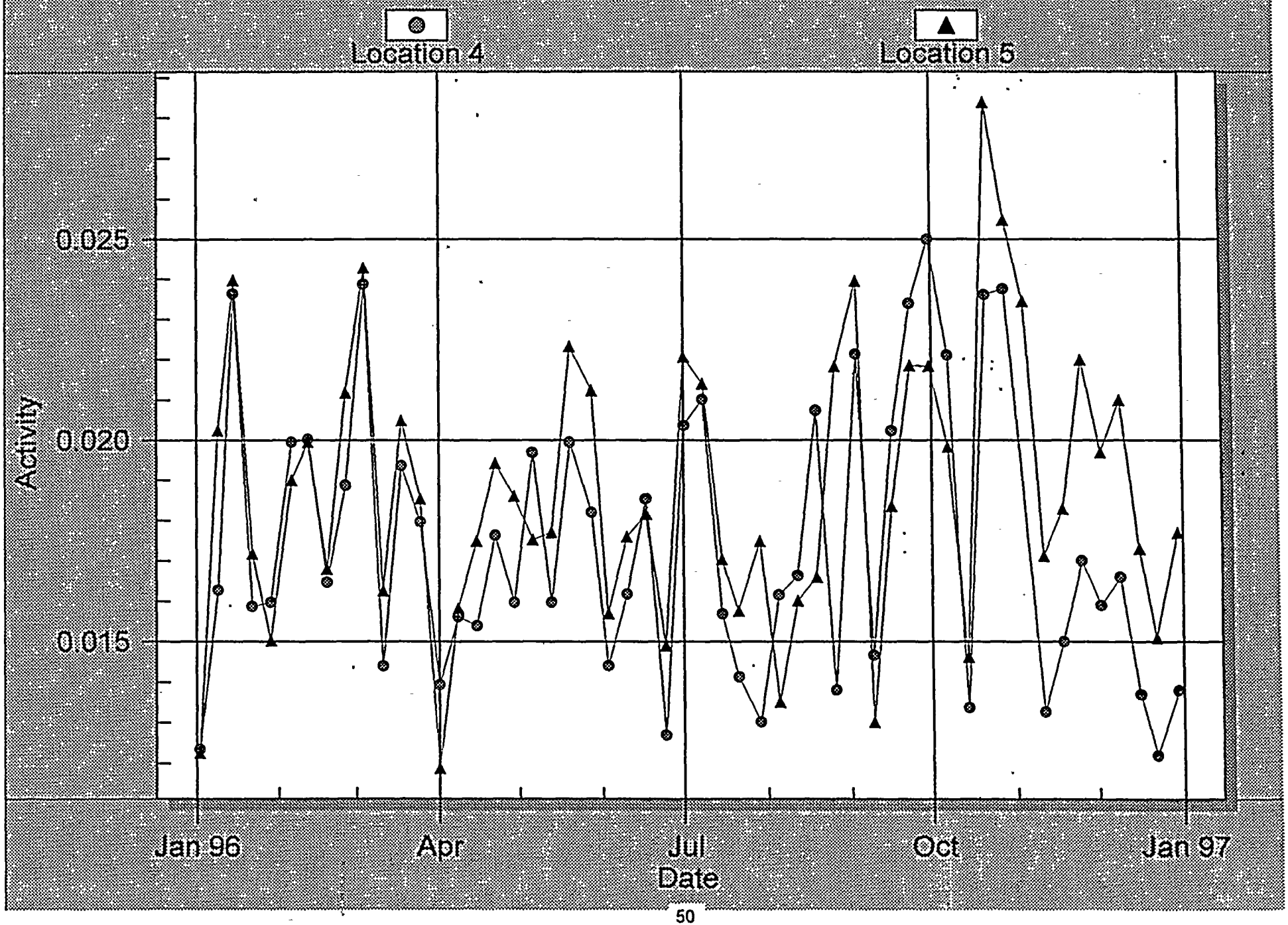


Figure 21 For HNP From 1/1/96 To 12/31/96

AIR PARTICULATEfor GROSS BETA - Activity (pCi/cubic meter)

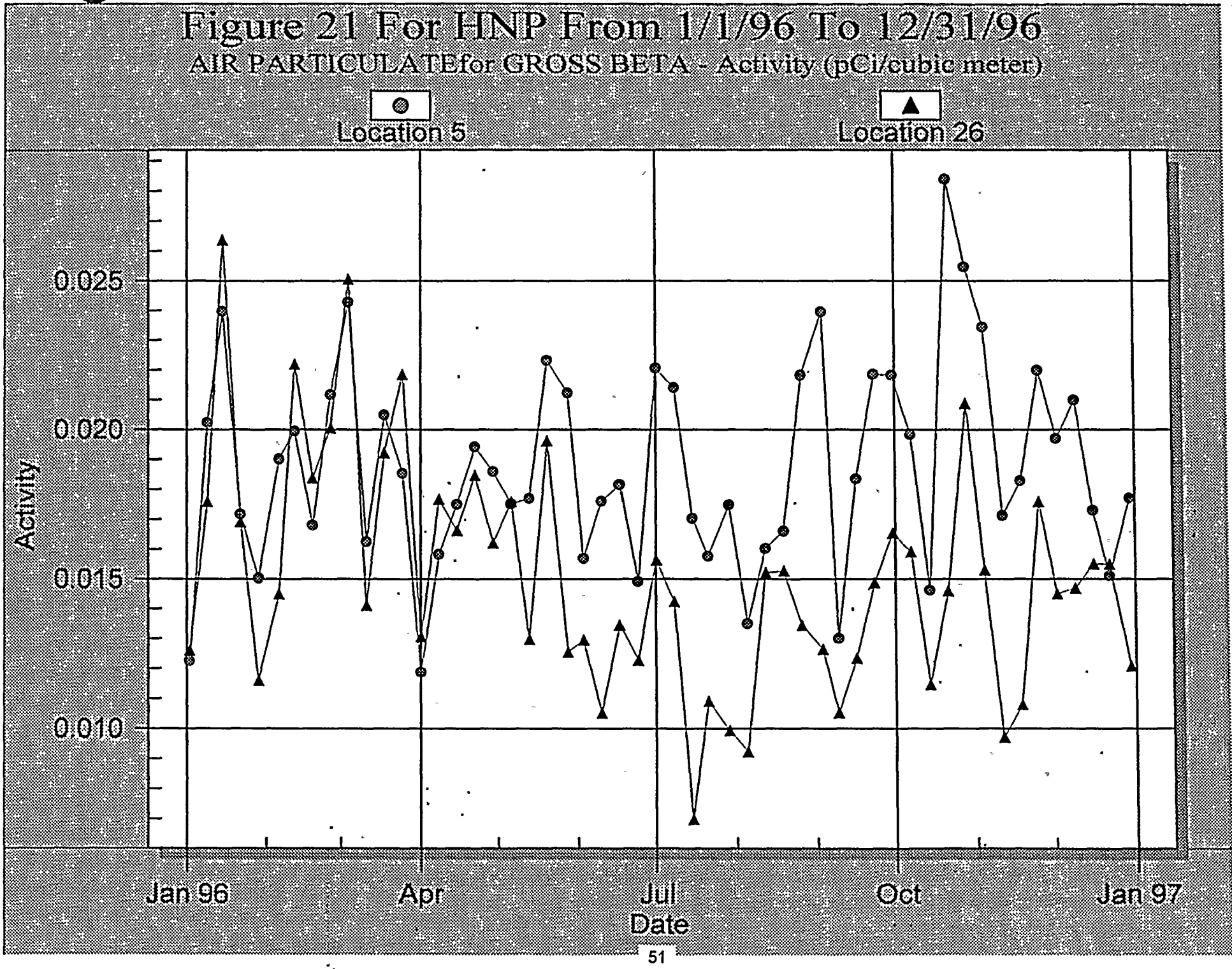


Figure 22 For HNP From 1/1/96 To 12/31/96

AIR PARTICULATE for GROSS BETA - Activity (pCi/cubic meter)

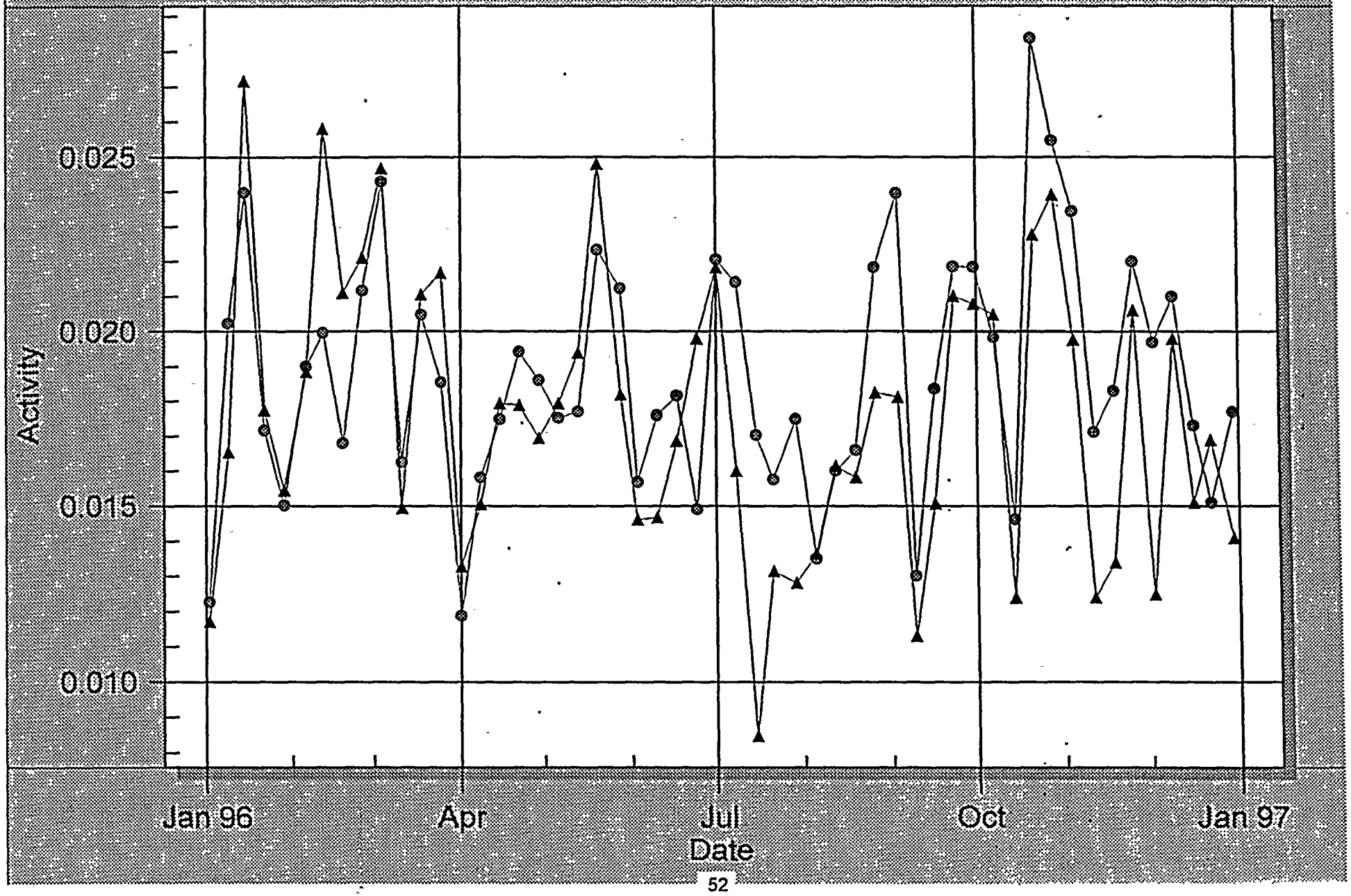


Figure 23 For HNP From 1/1/96 To 12/31/96

DRINKING WATER for GROSS BETA - Activity (pCi/Liter)

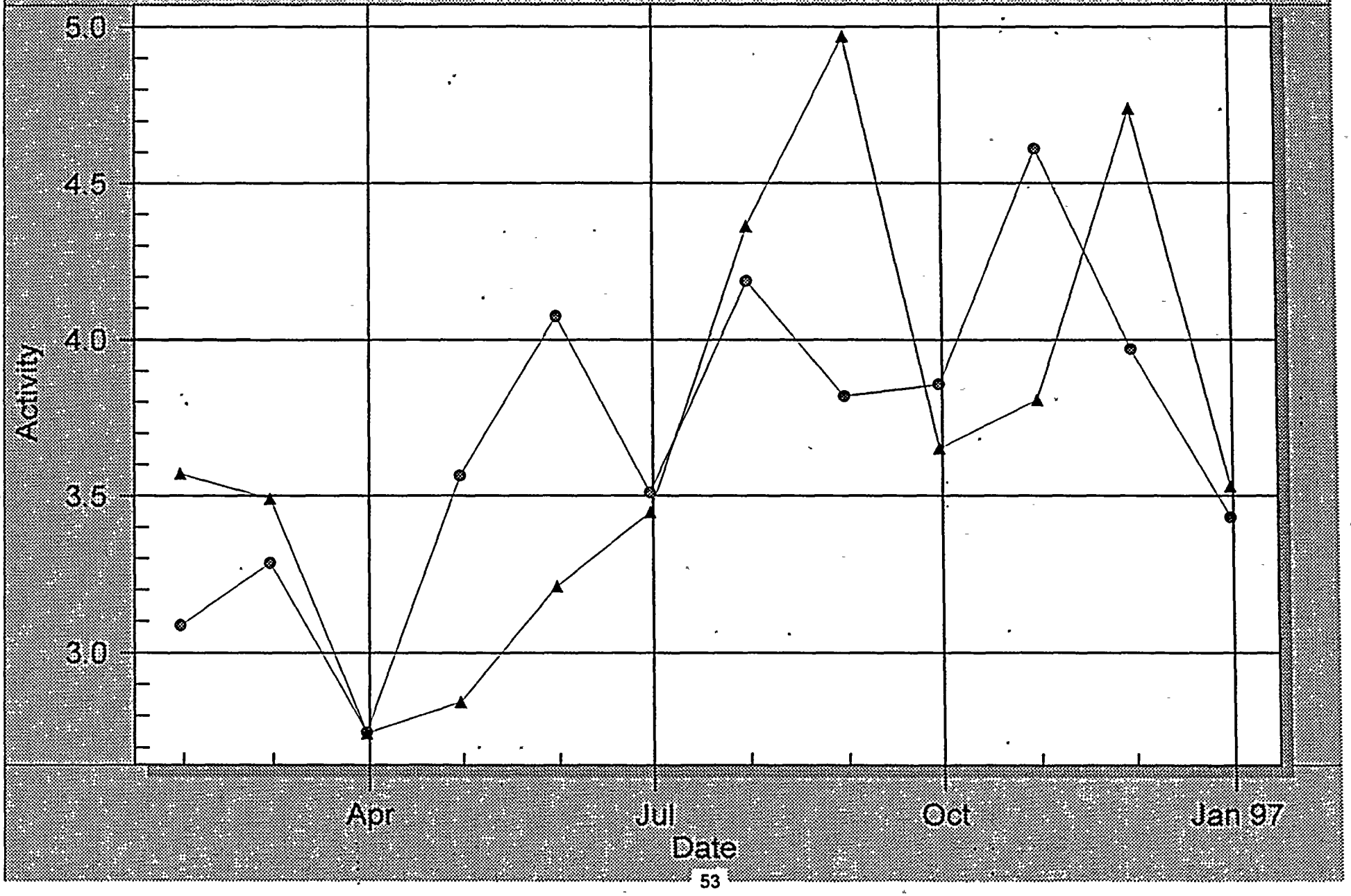


Figure 24 For HNP From 1/1/96 To 12/31/96

SURFACE WATER for GROSS BETA - Activity (pCi/Liter)

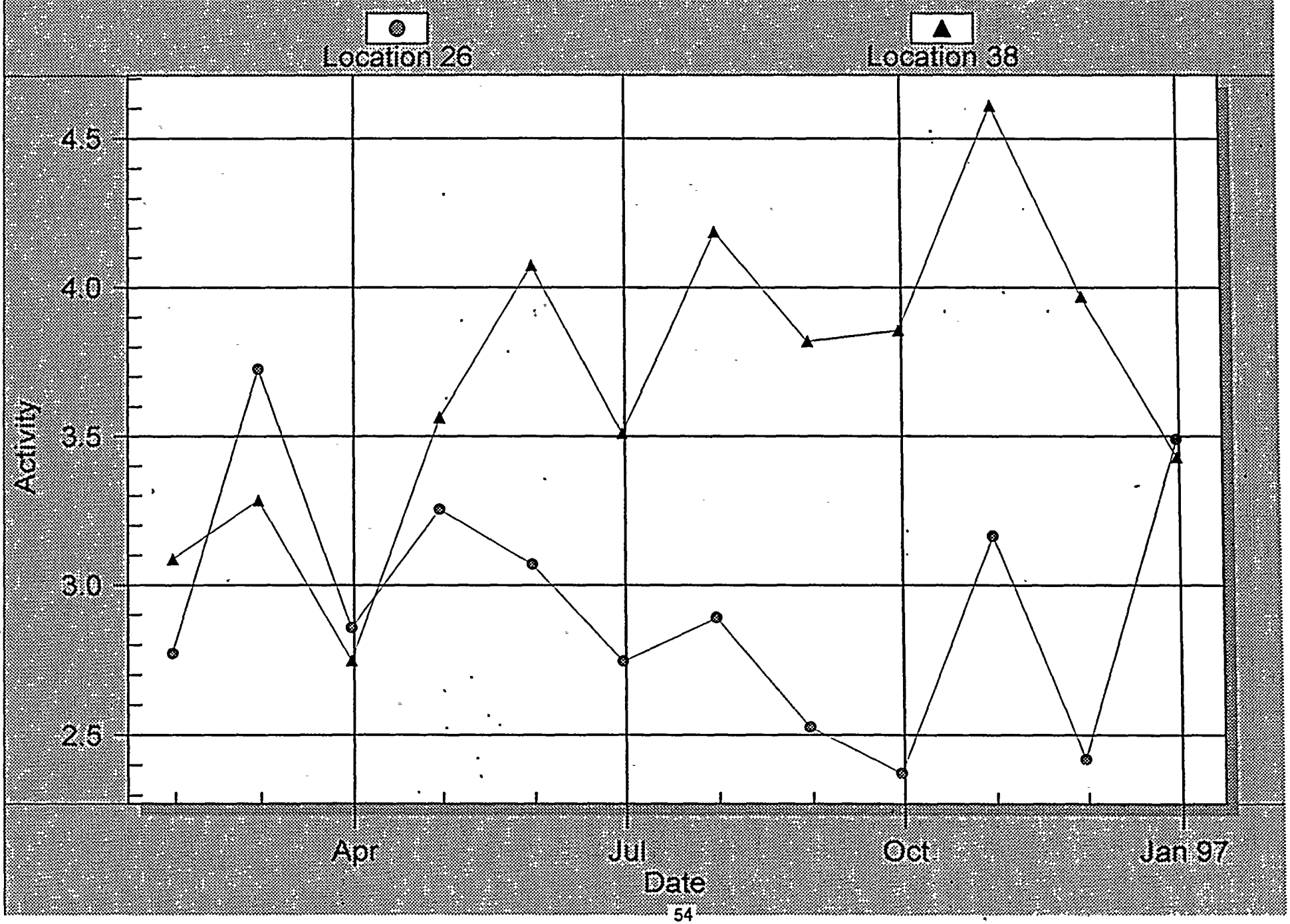


Figure 25 HNP 1996 Surface Water Tritium

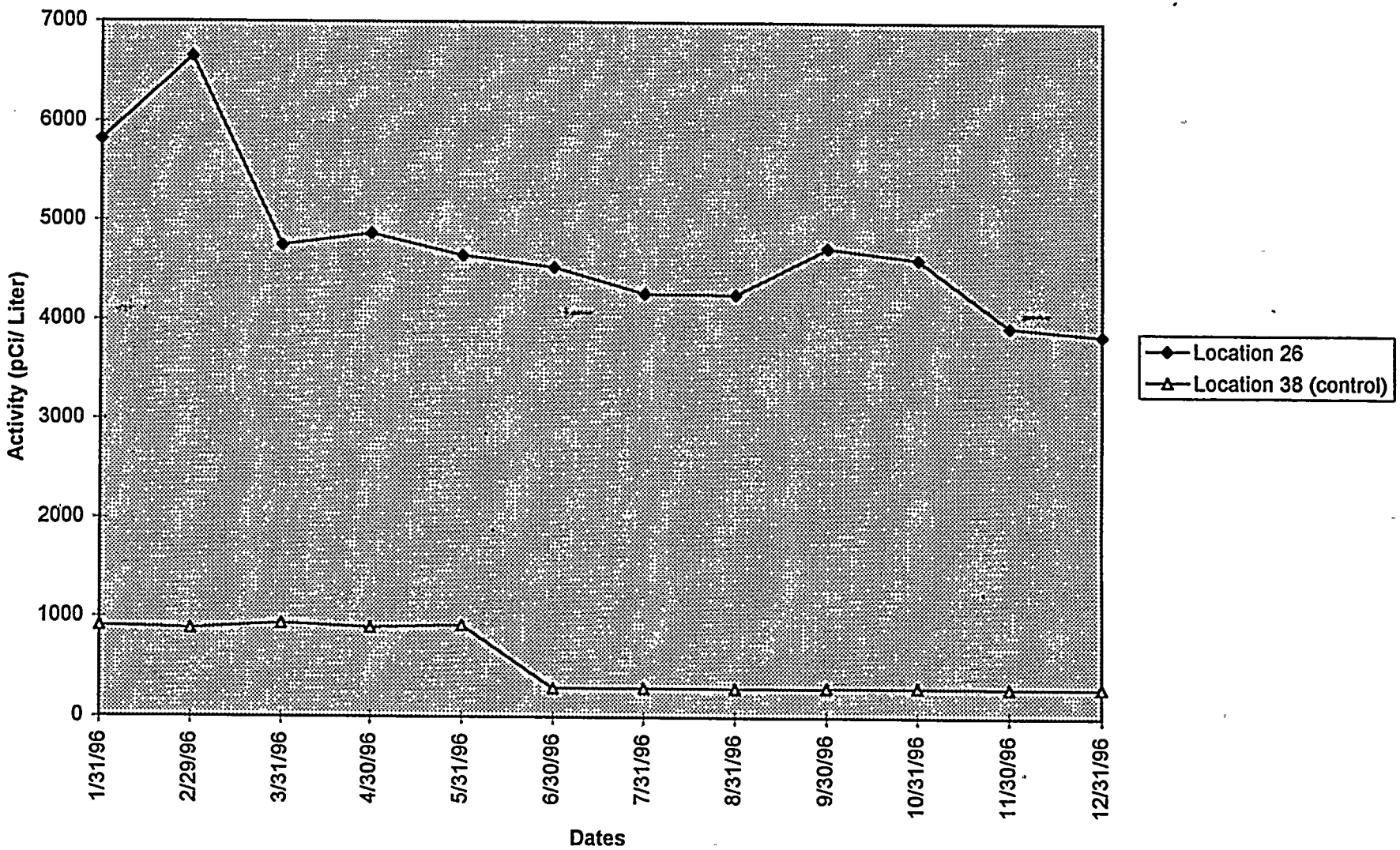
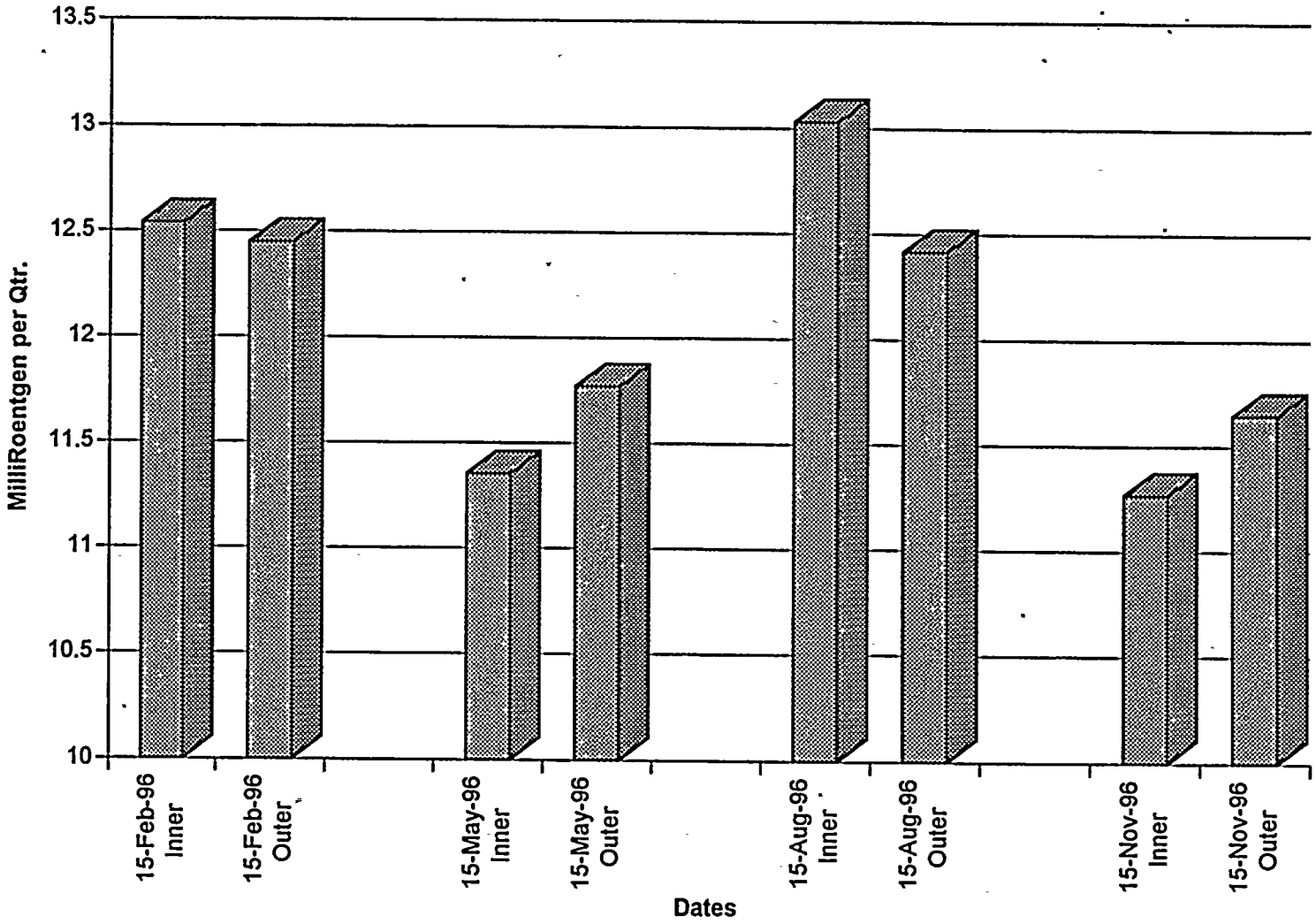
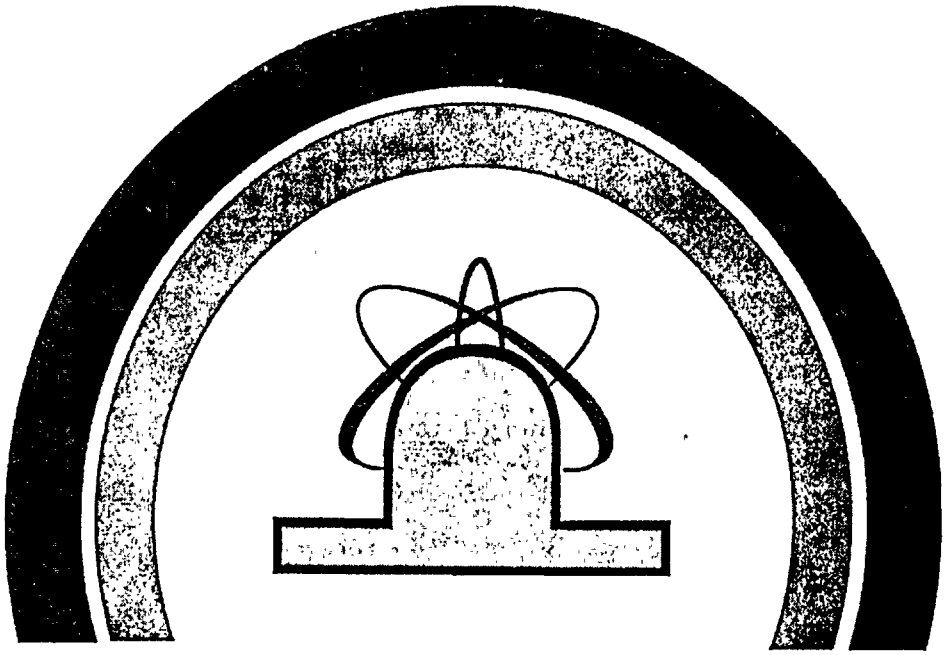


Figure 26 HNP 1996 TLD Averages for Inner and Outer Ring Locations



RADIOLOGICAL ENVIRONMENTAL OPERATING REPORT

1997



HARRIS NUCLEAR PLANT

CAROLINA POWER & LIGHT

Harris Energy & Environmental Center

Carolina Power & Light Company

New Hill, North Carolina

RADIOLOGICAL ENVIRONMENTAL OPERATING REPORT

FOR THE

SHEARON HARRIS NUCLEAR POWER PLANT

JANUARY 1 THROUGH DECEMBER 31, 1997

Prepared by:

Sharon P. Langdon

Reviewed by:

W. M. Poyle, II

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EXECUTIVE SUMMARY

The Harris Nuclear Plant is operated by Carolina Power & Light Company under a license granted by the Nuclear Regulatory Commission. Provisions of the Nuclear Regulatory Commission's Regulatory Guide 4.8, Harris Nuclear Plant Technical Specifications, and the Harris Nuclear Plant Offsite Dose Calculation Manual establish the requirements of the Radiological Environmental Monitoring Program. This report provides the results of the Radiological Environmental Monitoring program from January 1, 1997 through December 31, 1997.

The Radiological Environmental Monitoring program was established in 1982. Radiation and radioactivity in various environmental media have been monitored for more than 14 years, including 5 years prior to commencing operation. Monitoring is also provided for control locations which would not be impacted by operations of the Harris Nuclear Plant. Using these control locations and data collected prior to operation allows comparison of data collected at locations near the Harris Nuclear Plant which could potentially be impacted by its operations.

Radiation levels show no significant change from pre-operational radiation levels. Monitoring results for environmental media are summarized as follows:

- Air- monitoring results are similar or less than the concentrations of radioactivity from pre-operation monitoring. These observations are also consistent with past operational data.
- Milk monitoring results are similar to all the past years where no I-131 concentrations were detected.
- Terrestrial vegetation includes various crops collected during a growing season.
- Aquatic organism monitoring includes fish and benthic organisms.
- Surface (and drinking) water results indicate no detectable gamma-emitting radionuclides or I-131.
- Surface water results from Harris Lake show the presence of tritium, which is attributed to plant operation.
- External radiation dose showed no measurable change from pre-operational data.

The continued operation of the Harris Nuclear Plant has not significantly contributed radiation or the presence of radioactivity in the environmental media monitored. The measured concentrations of radioactivity and radiation are well within applicable regulatory limits.

INTRODUCTION TO NUCLEAR OPERATIONS

Figure 1: CP&L SERVICE AREA

Carolina Power & Light Company (CP&L) operates an integrated electrical system serving more than one million customers in North Carolina and South Carolina. A system map is provided (Figure #1) that illustrates the area served and the location of the nuclear generating units including the Harris (Blue), Brunswick (Green), and Robinson (Brown) Nuclear Plants. The service area is more than 30,000 square miles and has a population of more than 3,500,000 people.

The energy sources for electrical generation include coal, fuel oil, natural gas, hydro-power, and nuclear fuel. No one energy source is best. Each fuel source has merits and disadvantages. Fossil fuels pose issues associated with clean air including emissions of sulfur dioxide and oxides of nitrogen. Both natural gas and hydro-power are in limited supply.

Nuclear energy is a vital component in a diversified energy mix. In 1997 nuclear energy supplied 47.4% of CP&L's total electrical generation. This nuclear component was generated from four units including the Harris Nuclear Plant. The remaining energy sources were primarily from coal-fired generation, and a very small contribution from oil, natural gas and hydro-power.

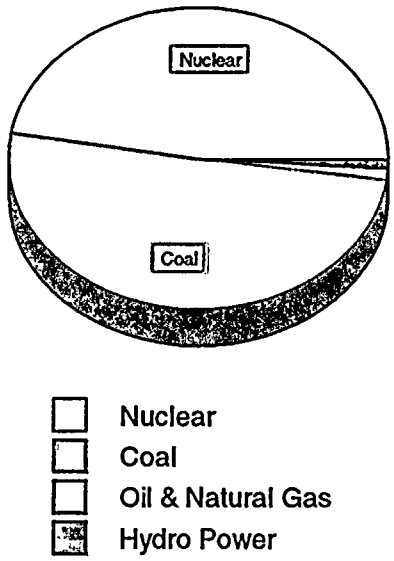

Figure 2: 1997 ENERGY SOURCES

BENEFITS OF NUCLEAR POWER

Nuclear energy is a viable, clean, safe, and readily available source of energy. The operation of the Harris Nuclear Plant results in a very small impact on the environment. Nuclear generation serves a vital role in the operation of the Carolina Power & Light system as well as in the nations electrical needs. Nuclear energy currently supplies more than twenty percent of the nation's electrical energy. It is an important source of electrical energy now and is meeting the growing electrical needs for the future.

Nuclear energy has the following advantages over other fuel sources:

- The fuel is uranium which is relatively inexpensive when compared with the fuels of coal, natural gas, and fuel oil.
- Emissions from nuclear stations do not include sulfur dioxide, oxides of nitrogen, or carbon dioxide. Sulfur dioxide is well known as a significant contributor to acid rain leading to acidification of streams and lakes. Oxides of nitrogen play a key role in the formation of ozone which is a significant pollutant in urbanized air quality. Finally, carbon dioxide is a significant green house gas.
- Nuclear energy is safe. Nuclear power in the United states has an excellent safety record, starting with the first commercial nuclear plant in 1957.

To better understand this source of energy, a basic understanding of radiation, it's effects, risk assessment, and reactor operation follow.

RADIATION AND RADIOACTIVITY

The Atom

All matter consists of **atoms**. An atom is the smallest unit into which an element can be divided and still retain its identity as that element. An atom is made up of a number of different particles. These particles are **protons, neutrons, and electrons**. Each proton is positively charged (+). Each neutron has no charge. And the electron is negatively charged (-). The heavier particles including protons and neutrons are found in the center of the atom in a very small cluster referred to as the **nucleus**. (The term nuclear refers to this nucleus.) Nearly all the mass of the atom is found in the nucleus. Electrons orbit the nucleus. Since the atom is electrically neutral (no charge) the number of protons and electrons in the atom are equal. See Figure 3 a conceptional drawing of an atom. The electrons (red) are shown in orbit around the nucleus. The protons (green), and the neutrons (black) are shown in the nucleus at the center of the atom.

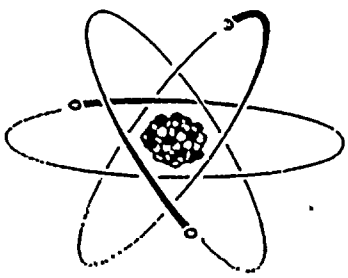

Figure 3: The Atom

Elements, Isotopes, and Radionuclides

Simple substances that can not be decomposed in any chemical reaction are known as **elements**. Hydrogen, oxygen, iron, chlorine, and uranium are examples of elements. The atoms of such

elements differ in the number of protons (also know as the atomic number) in their nucleus. For example the number of protons in each example above is 1 for hydrogen, 8 for oxygen, 26 for iron, 17 for chlorine, and 92 for uranium. The number of neutrons in the nucleus may vary in atoms of the same element. Atoms that contain the same number of protons but a different number of neutrons are referred to as **isotopes** of that element. An example is the element hydrogen which has three isotopes -- one with no neutrons, a second with one neutron, an the third with two neutrons. Isotopes can be unstable (also referred to as **radioactive**), which means they will readily transform to another isotope and are called **radionuclides**. Of more than one thousand known isotopes less than twenty-five percent are considered stable. It is important to remember that a significant number of radioactive isotopes occur naturally.

When referring to isotopes of an element, it is common to refer to the element by the symbol for it's name (or the name) followed by the total number of protons and neutrons; for example H-3 or hydrogen-3 describing an atom with one proton and two neutrons.

Radiation

Radiation is defined as the conveyance of energy through space. This conveyance may occur in the form of particles, waves, or photons. Some common forms of radiation are sunlight, microwaves or radio waves. These are all examples of non-ionizing radiation. **Ionizing radiation** differs in its interaction with matter because its energy is capable of removing an electron from the outer part of an atom resulting in the remaining atom being positively charged and a free electron. There are two types of ionizing radiation -- particulate radiation and electromagnetic radiation. **Particulate radiations** are energetic particles which will travel in a straight line if unhindered. Three types of particulate radiation of interest in nuclear energy, those being beta particles which are high-energy electrons (not part of an atom), neutrons, and alpha particles which consist of two protons and two neutrons. **Electromagnetic Radiations** are high-energy waves (or photons) which have no apparent mass (not a particle). There are two types of electromagnetic radiation of interest which are gamma rays and X-rays. **Gamma rays** have their origin in the nucleus of the atom. **X-rays** have their origin in the stored energy of the electrons orbiting the nucleus. There are many important differences in the behavior of these radiations which will be discussed in the later sections.

Radioactivity

Radionuclides are atoms that are unstable and will eventually reach a stable state through a process know as radioactive decay. This process results in the emission of energy or energetic particles from the nucleus of the unstable atom. The process may occur in a single step or may be composed of a series of steps to various radioisotopes. When this process proceeds through a series of steps it is called a **radioactive decay series.**

There are at least three natural radioactive-decay series which are the thorium, neptunium, and

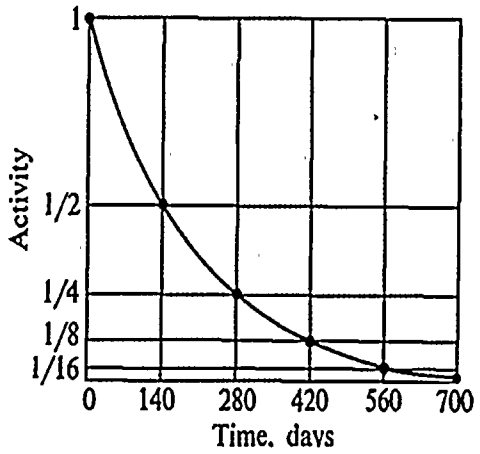

Figure 4: Radioactive Decay

the uranium series. These radioactive decay series as well as naturally occurring K(potassium)-40, C(carbon)-14, H(hydrogen)-3 are significant contributors to background radiation levels, which are addressed in greater detail later.

The rate at which atoms undergo radioactive decay varies greatly. A common expression of the tendency for radioactive decay is the half-life associated with a particular isotope. The half-life is the amount of time required for one-half of the number of atoms for an isotope to experience radioactive decay. The longer the half-life the less likely an atom will experience radioactive decay in a fixed time interval. Half-lives vary from extemely small fractions of a second (billionths) to millions of years. Figure 4 illustrates an isotope with a 140-day half-life. Note that the activity decreases by half in 140 days, and then by half again the next 140 days and thereafter.

RADIATION INTERACTION WITH MATTER

Ionization

As alpha, beta, gamma, and X-ray radiation interact with matter they impart part or all of their energy to the matter in a single interaction. It may require many interactions to absorb the energy of a single particle or photon of radiation. One of the most common ways energy is dissipated is ionization. As we discussed earlier this results in the creation of a positively charged atom and a free electron. The positively charged atom and the free electron are referred to as a charged pair. The creation of the charged pair is one of the primary contributions to damage of biological systems.

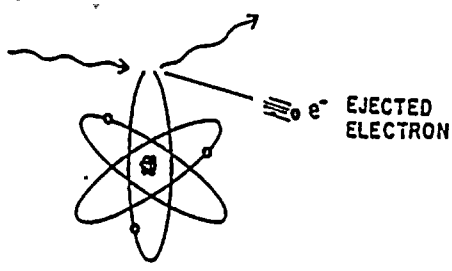

Figure 5: Ionization

Radiation Ranges

Each type of radiation we have discussed interacts with the matter they travel through differently because of the different characteristics of each radiation.

Alpha particles are composed of two protons and two neutrons. This is the heaviest particulate radiation with a positive charge of two (two protons). The alpha particle is the slowest of the radiations we will review with a speed of no more than 20,000 miles per second. As a result of these characteristics the alpha travels only a few centimeters (or inches) in air and is readily stopped by a sheet of paper. The alpha leaves it's energy in a short distance characterized by a great many ionizations.

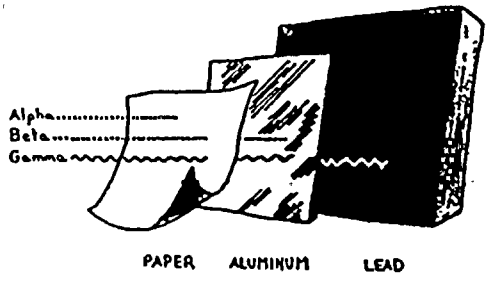

Figure 6: Radiation Ranges & Shielding

Beta particles are basically a very high-energy electron. Beta particles have a negative charge. It is a very light particle, with a mass of about one two-thousandth of a proton (or about one eight-thousandth of an alpha particle). Beta particles are very fast, approaching the speed of light. Due to their speed and lower charge, the beta particles travel several meters (or yards) in air and are readily stopped by a small piece of metal or other dense material. The beta particle leaves its energy in many ionizations but with the ionizations distributed along a much longer path of travel.

Gamma rays are photons (or energy waves, not a charged particle). Like light (also a photon) it travels at a speed of approximately 186,000 miles per second. The gamma ray travels much larger distances without interacting. When the gamma ray interacts with matter it creates very high-energy electrons similar to beta particles which in turn create ionizations as their energy is dissipated. Due to these differences the gamma ray travels much greater distances before its energy is dissipated. To dissipate the energy of a gamma ray several inches of lead are required.

RADIATION QUALITIES AND UNITS OF MEASURE

There are numerous qualities and units used to describe radiation and radioactivity and their effects. Those used in this report relate to activity, absorbed dose, and dose equivalent. It is also common to express numbers in scientific notation or use prefixes with the number denoting the number of zeros (0) before or after the decimal. A few examples are provided below.

Prefix	Number Represented	Number in Scientific Notation
pico	.000000000001	$1x10^{-12}$
nano	.000000001	$1x10^{-9}$
micro	.000001	$1x10^{-6}$
milli	.001	$1x10^{-3}$
centi	.01	$1x10^{-2}$
kilo	1,000.	$1x10^{3}$
mega	1,000,000.	$1x10^{6}$

Activity is the number of radioactive transformations (decays, disintegrations) that occur in a fixed time interval. The unit used to express activity is the **curie.** The curie is defined as 37,000,000,000 disintegrations per second; also expressed as $3.7x10^{10}$ s^{-1}. A curie is a unit of activity, not an amount of material or the number of atoms. The amount of material or number of atoms necessary to produce a curie of activity vary over a very wide range. Atoms with very long half-lives would require many more atoms to produce a curie of activity versus atoms with short half-lives.

Absorbed dose describes the energy absorbed per unit of mass of tissue. The unit used to express absorbed dose is the **rad** (radiation absorbed dose). One rad is an absorbed radiation dose of 100 ergs(a measure of a very small amount of energy) per gram. The rad can be used with all types of radiation including X-rays, gamma-rays, and particulate radiations. The absorbed dose can be measured with various radiation-detection instruments which allows the assessment of damage to biological systems subjected to radiation and radioactive materials.

Dose equivalent is an expression of the biological effect of the radiation on tissue. The unit used to express absorbed dose equivalent is the **rem.** Dose equivalent is obtained by multiplying the absorbed dose (expressed in rad) by a **quality factor** (QF) for the type of radiation being considered.

$$\underline{\text{Dose equivalent}} = \underline{\text{absorbed dose}} \text{ X } \underline{\text{quality factor}}$$

Some types of radiation create more biological damage due to the extent of ionization in small areas. From our discussion of alpha particles, the intense ionizations caused by the alpha particle results in a much higher Quality Factor for this radiation. This relationship for quality factors and

different radiations we have discussed is illustrated below.

Table 1

Quality Factors for Various Radiations

Radiation	Quality Factor
Gamma-rays	1
X-rays	1
Beta Particles	1
Alpha Particles	20

SOURCES OF RADIATION

Background Radiation

Radiation occurs naturally and is an everyday fact of our existence. Mankind has always lived with radiation and radioactive materials and will continue to in the future. The radiation that occurs naturally is referred to as **background radiation.** Mankind experiences two types of radiation dose: first is radiation that originates outside the body and is called **external radiation,** and the second is radiation that originates inside the body and is called **internal radiation.** External radiation comes from the earth, the atmosphere, and every structure(buildings) around us as well as a source referred to as **cosmic radiation** which is generated in the stars throughout the galaxy including our own sun.

Cosmic radiation is composed of gamma-rays (some of very high energy) and many different types of energetic particulate radiation. Some of the particulate forms of radiation include neutrons, alpha particles, and heavy particles (including nuclei). These high-energy cosmic radiations have the capability to interact with other atoms on earth and generate new isotopes. As we have already discussed, some of these may be radioactive. Common examples of radionuclides formed from cosmic radiations are carbon-14 and tritium (H-3). The atmosphere around the earth serves as an effective shield causing much of the energy of cosmic radiations to be dissipated prior to reaching the surface of the earth. However, each of us may receive a dose equivalent, due external cosmic radiation, to 20 to 50 mrem (.020 to .050 rem) annually. The actual dose is influenced by the elevation we live. Higher elevations provide less shielding and therefore the doses are higher. A single plane flight can also contribute to our dose from cosmic radiations. The average passenger could expect to receive a dose of 2.8 mrem (.0028 rem) per flight.

Another important contributor to external absorbed dose is **terrestrial radiation.** This is the

radiation from the earth itself, and the air around each of us. The sources of terrestrial radiation include the thorium, neptunium, and the uranium decay series as well as potassium-40. The absorbed dose varies about 15 to 140 mrem (.015 to .140 rem) annually. However there are a very few areas that these terrestrial absorbed doses exceed 800 mrem each year.

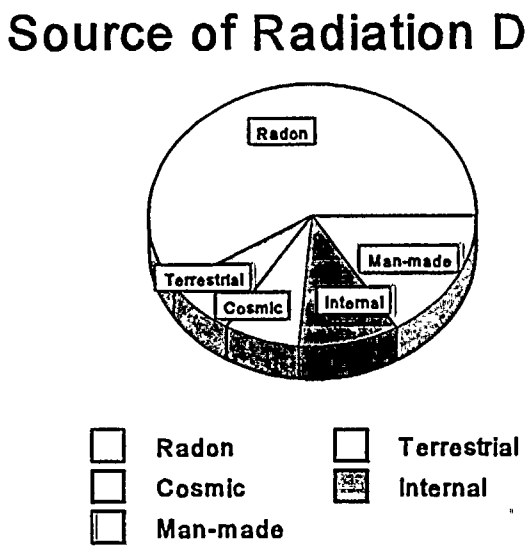

Figure 7: Radiation Sources (BIER V)

One of the most important sources of dose is that contributed by internal radiations. These radionuclides are part of our body, the air we have breathed, or the food we have consumed. One if the most significant contributors is **radon.** Radon is a radioactive gas that is part of the uranium decay series. Radon's concentration varies greatly based upon the geology of each community, but is found in soils and rock everywhere. If it is allowed to concentrate in a building, the dose from radon can be increased significantly. Normally radon does not pose a significant health threat. Since radon is an alpha particle emitter, inhaling radon gas makes the lung our greatest concern (IE the alpha does not travel far but has a high quality factor for the affected tissue). The health effect of breathing radon is an increased risk of lung cancer.

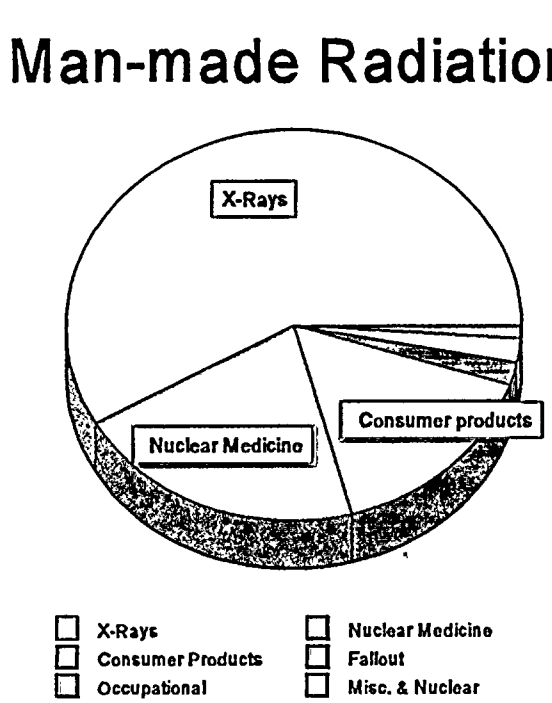

Figure 8: Man-Made Radiation Sources (BIER V)

Man-made radiations are important to completing our understanding of sources of radiation. An important aspect in discussing man-made radiation is the benefit man derives from the use of these. Medical uses of radiation are the major contributor, including diagnostic X-ray, and nuclear medical treatment. Consumer products such as televisions, display screens, smoke detectors, and many other devices are the next most important class of man-made radiations. Fallout from prior weapons testing is now a small contributor to total radiation dose. Occupational exposure is also a factor from the medical, manufacturing, and nuclear industries. Finally, contributions from nuclear plant operations represent less that 1% of the man-made radiations for the average member of the general public. The data presented in figure 8 illustrates the importance of the different sources of man-made radiation for the average member of the public.

HEALTH EFFECTS OF RADIATION

The effects of ionizing radiation has been of concern to the scientific community for several decades. The oldest body established to study radiations biological effects dates from at least 1928 with the establishment of the International Commission on Radiological Protection. Much of our knowledge is based upon very high doses from animal experiments, accidents handling radioactive materials, and war time nuclear weapons use and its survivors. It has been a classical problem of how to relate doses at these levels to much lower medical use (although some treatments are designed to deliver high dose) and occupational radiation levels. Environmental levels of radiation represent even greater challenges because of the extemely low doses compared with medical and occupational levels. Experiments with animals represent additional challenges because they may not accurately represent human biological responses to radiation.

Radiations biological effects are classified as **somatic** and **genetic** (or hereditary). Somatic effects are observed in the individual receiving the radiation dose. Genetic effects are observed in the decedents of the individual receiving the radiation dose.

Somatic effects can be classified as **acute** or **chronic.** Acute effects occur within a short time (days) after the dose is received. Generally acute effects require very high doses. Blood changes have been observed in the range of 25 to 50 rem (or 50,000 mrem). Other acute effects can be expected at even higher doses. Our knowledge of this level of dose are the survivors of nuclear weapons, accidents, and planned medical treatments. These dose levels are more than 500 times normal environmental background radiation. For this reason, these effects are not important to a discussion of environmental radiation.

Chronic effects are generally used to refer to effects that are observed a long period of time and these have also been referred to as **delayed effects.** The effects are also generally associated with radiation dose received over a long period know as **chronic exposure.** However is not necessary for the exposure to occur over a long period. The most important chronic effect is cancer. There are numerous forms of cancer. The rate of cancer in individuals at low doses (at occupational or environmental levels) has not been observed directly. "Cancers induced by radiation are indistinguishable from those occurring naturally; hence, their existence can be inferred only on the basis of statistical excess above the natural incidence." The current practice is to use observations at a much higher dose to establish the rate of cancers at that dose and then assume that the rate of cancers must be proportional to the lower dose. This has created a scientific disagreement, because some scientists believe this method over estimates the cancer risk from low doses of radiation. However this appears to be a conservative assumption. Some risk exists but it is believed to be a small risk of cancer at occupational levels. The Committee of the Biological Effect of Ionizing Radiation further states "It is by no means clear whether dose rates of gamma or X-rays of about 100 mrad per year are in any way detrimental to exposed people....." Environmental radiation levels are in the range of 100 mrad per year or less as we have discussed.

Genetic radiation effect occur when radiation changes the genetic material in cells. As we have discussed the process of ionization removes electrons from the atom. These electrons are

sometimes necessary in the creation of chemical bonds. If the bonds are part of the genetic material of the cell, it could result in changed genetic material (mutations). Radiation is just one of several agents that contribute to genetic change. Chemicals including those that occur naturally are a significant contributor to genetic mutations. Background radiation levels only provide a minor contribution to total mutations. To double the general mutation (from all sources) rate would require a dose of 50 to 250 rem (or 50,000 to 250,000 mrem). This is approximately 500 to 2,500 times the normal environmental background of about 100 mrem.

GENERAL HEALTH RISK

Every human activity has risk associated with it. The air we breath, the food we eat, where we live or work all have different risks. Many times our perception of these risks is quite different than the real risk of an activity. There was widespread fear and misunderstanding regarding the fire and safety hazard from electricity early this century. Now electricity is accepted as part of our daily existence. Radiation is unique in that it can not be seen, felt, smelled, or detected by any of the human senses. It is detected by instruments or laboratory analysis specially designed to detect radiation. Thus it is understandable to be wary of something we can not readily sense and may not have a personal knowledge about. There are other similar hazards we tend to accept such as micro-wave radiations, carbon monoxide in the operation of some furnaces and our vehicles due to our familiarity with these.

A common was of expressing risk is a reduction of life expectancy from a particular activity. Below you will find a table of common activities and the associated reduction in life expectancy.

Table 2

REDUCTION IN AVERAGE LIFE EXPECTANCY

ACTIVITY	REDUCTION IN LIFE EXPECTANCY
CIGARETTE SMOKING 2 PACKS/DAY	10 YEARS
CIGARETTE SMOKING 1 PACK/DAY	7 YEARS
HEART DISEASE	5.8 YEARS
LIVING IN CITY VERSUS RURAL	5 YEARS
OVERWEIGHT 30 %	3.6 YEARS
CANCER	2.7 YEARS
COMMERCIAL NUCLEAR POWER	12 MINUTES

NUCLEAR POWER PLANT OPERATIONS

The primary difference between a nuclear generating station and fossil generating station is the source of heat or thermal energy. The steam turbine, condenser, condensate and feed water systems are much the same. The uranium fuel within the nuclear reactor is the source of heat or energy in the nuclear generating station.

Nuclear Fission

Certain heavy radionuclides are known to naturally undergo a special form of radioactive decay, called spontaneous fission. Spontaneous **fission** means the nuclei of these radioisotopes literally split into two or three new nuclei (also known as fission fragments) and a few free neutrons(not in a nucleus). The protons and neutrons are shared between these new nuclei. One isotope of Uranium known a U-235 is known to undergo fission. The other more common isotope of Uranium known as U-238 does not fission so easily.

Fission can also be stimulated by neutrons interacting with the nucleus of these atoms. Simply stated a neutron reaches the nucleus and produces fission fragments, free neutrons, and heat. Fission of Uranium produces more than one neutron per fission. Therefore; if there is enough uranium (especially U-235) present it is possible to produce more fissions and keep the process going or cause more and more fissions to occur. When the rate of fission initiated is self sustaining or increasing a **chain reaction** has been established. It is this sustained chain reaction and the energy produced that produces the heat needed to generate steam for electrical generation.

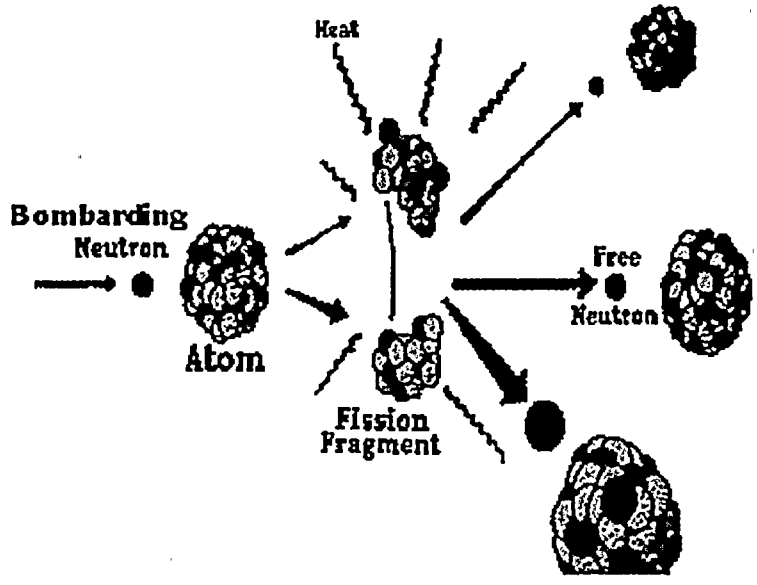

Figure 9: Nuclear Fission

Uranium Fuel

Uranium is mined from the earth the same as many minerals are as an ore. This uranium ore is then taken to a mill to concentrate the uranium. The extraction process for uranium uses acids to dissolve the uranium and separate it from the ore. This uranium is then **converted** chemically to a gas uranium hexafloride (in chemical notation UF_6) While in this form it is possible to separate the lighter U-235 from the heavier U-238. This process of separation is called **gaseous diffusion.** The reason for separation is to allow more of the U-235 to be included in the fuels used in commercial reactors. We have already discussed that U-235 fissions more readily that U-238. This process that increases the amount of U-235 is also referred to as **enrichment.** After enrichment this gas is chemically converted to uranium dioxide (in chemical notation UO_2). At this point the uranium dioxide is a gray powder. The next process takes this powder and under high pressure, and temperature creates a ceramic pellet of uranium dioxide. This process is part of the **fuel fabrication.** The fuel fabricator also ensures that each fuel pellet also has the proper amount of U-235 and U-238. The additional U-235 added is referred to as the percent enrichment which for commercial reactors is about 6% of the total uranium in the fuel. These fuel pellets are placed into long tubes of zirconium alloy or **fuel rods.** These rods of uranium fuel are then placed with other such fuel rods into a **fuel assembly.** This fuel assembly is the basic unit that is shipped to the nuclear power plant. It is important to note that the entire process of making nuclear fuel is carefully controlled to ensure the quality of the nuclear fuel.

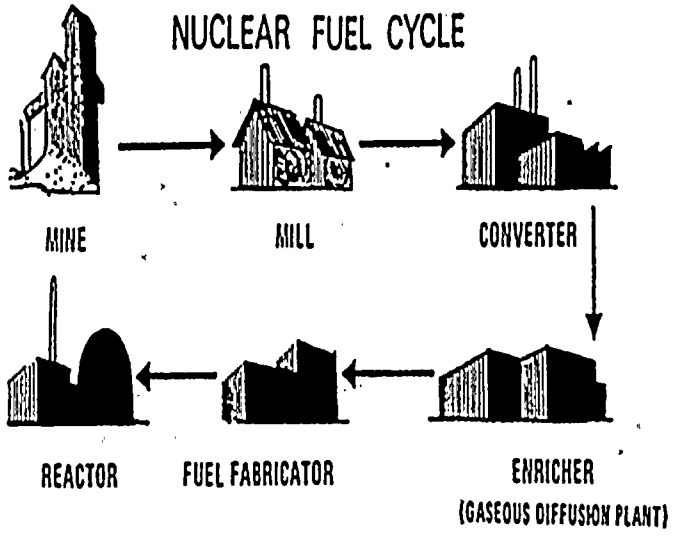

Figure 10: The Nuclear Fuel Cycle

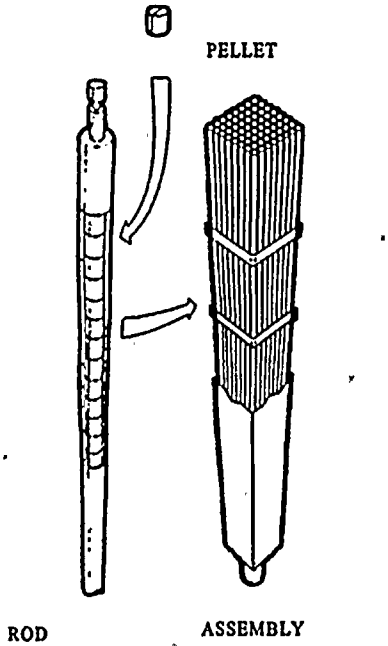

Figure 11: Fuel Pellets, Rods & Assemblies

PLANT SYSTEMS

System Summary

There are four (4) grouping of major plant systems and these are the reactor, the turbine generator, the condensate and feed water systems, and various support systems including various emergency systems. The reactor and its nuclear fuel is the source of heat to generate high pressure steam. The turbine is a large rotating fan like machine that the steam causes to rotate. The turbine is connected to an electrical generator which produces a rotating magnetic field. Electricity is generated in winding of metallic conductors around this magnetic field and then transmitted to the electrical transmission system and from there to the customers in the service area and sold to neighboring utilities.

After the steam has spent most all of its energy in the turbine, water vapor remains and must be recovered for reuse. The water vapor is recovered as water in a condenser. The condenser is a large system of tubes that are water cooled. The water used to cool the condenser is one of the most visible features at any power plant. Either large quantities of water are used or a cooling tower is used. After the steam has been recovered as water it is returned through a system of pumps, piping and heaters to the steam generator. The process of reusing this water and steam in a continuing cycle is referred to as the **steam cycle.**

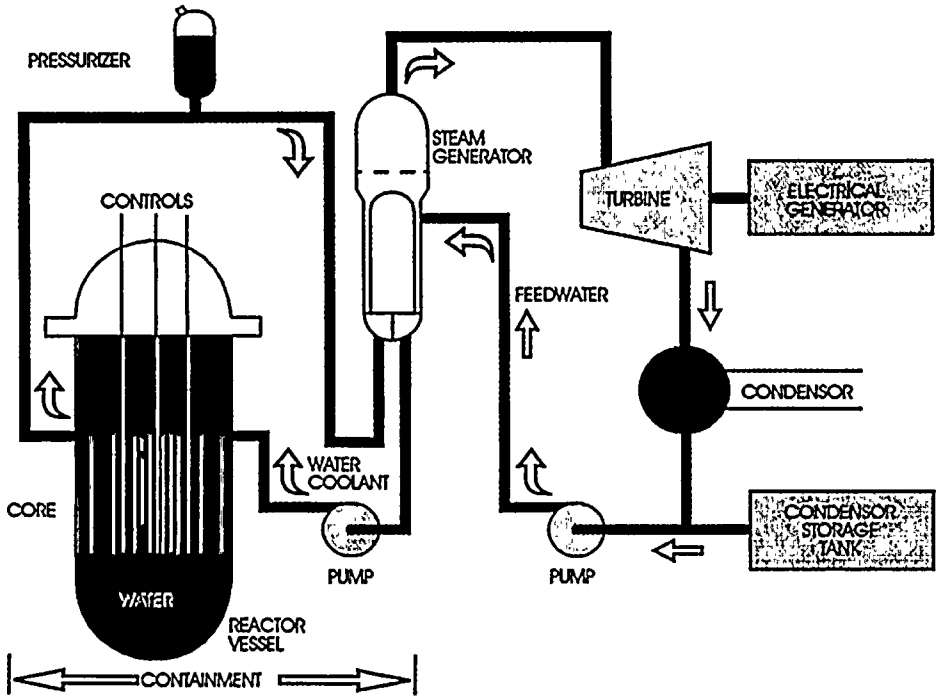

Figure 12: Major Plant Systems for The Pressurized Water Reactor

Reactor Types and the Reactor Vessel

There are approximately 180 commercial nuclear reactors being used to generate electricity in the United States today. Of these, there are two basic types of reactor in use today, the **Pressurized Water Reactor** (PWR) and the **Boiling Water Reactor** (BWR). The basic difference is the point where steam is formed. The boiling water reactor forms steam in the reactor while the pressurized water reactor forms steam through a separate heat exchanger called a steam generator. The Harris Plant is a Pressurized Water Reactor (PWR). There are other types of reactors used for research and military purposes.

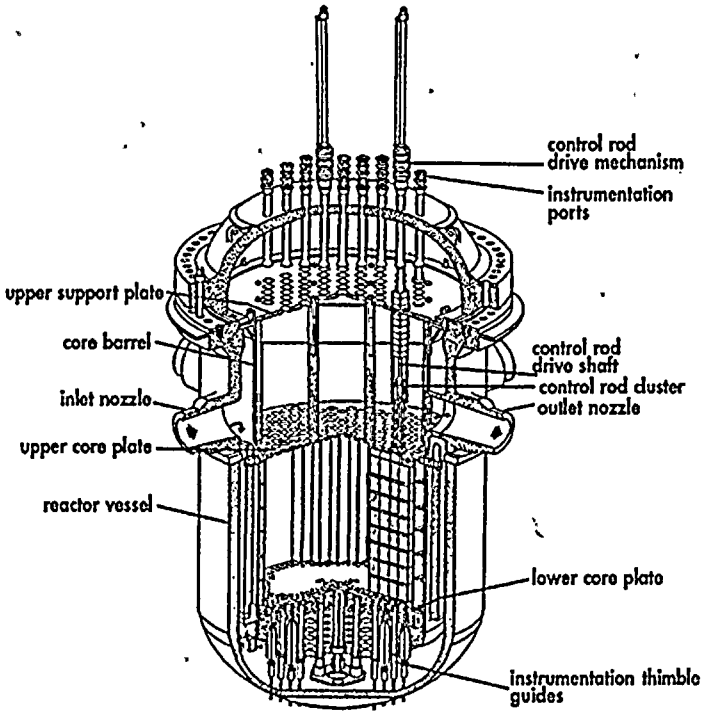

Figure 13: Reactor Vessel

The collection of fuel assemblies is referred to as the **reactor core.** The Harris Plant has 157 fuel assemblies in the reactor core. The reactor core, the controls, instrumentation as well as other components are located in the reactor vessel. The components vary greatly by reactor type. The reactor vessel is a specially designed container which supports all of the components. The reactor vessel varies in wall thickness from 4.87 inches of steel on the lower head to 7.75 inches of steel at the core elevation with a stainless steel lining.

The rate of nuclear fission is controlled by neutron absorbing materials. One of the most common materials used is an isotope of boron known as boron-10 (B-10). Also control rods are used that are made of other materials including indium and cadmium. By controlling how much of the control rods are inserted in the reactor core the rate of nuclear fission is controlled. The Harris Plant has 52 control rods.

The boiling water reactor generates steam with a significant water fraction and this steam must have this water removed. The reactor vessel for the boiling water reactor contains a steam separator which removes most of the water fraction. After treatment by the steam separator the steam passes through a steam dryer to remove additional water. The water removed by the steam separator and dryer is returned to the water in the reactor vessel. The boiling water reactor also has a special pair of recirculating pumps that provide additional control of steam generation and reactor power.

The pressurized water reactor does not generate steam in the reactor. The reactor vessel is pressurized to prevent boiling from occurring in the reactor or the reactor vessel. Steam is generated in a heat exchanger called the steam generator. The steam and the water from which

steam is generated is a separate water system from reactor water or reactor coolant. This separate water system is referred to as **secondary system** while the reactor's water system is referred to as the **primary system.** In the pressurized water reactor it is this secondary water that steam is made from and recycled through the condenser and feedwater system. This water is returned to the steam generator.

The PWR steam generators serve as the point of steam production. The reactor water of primary system is not allowed to boil or produce steam. This primary system water (or coolant) is circulated to the steam generators and back to the reactor in a continuous cycle. While in the steam generator the primary coolant(or water) transfers some of it's heat or energy to the secondary coolant(water) by heating the secondary coolant and making steam with the secondary coolant. It is important to note that there is no exchange of water between the primary coolant and the secondary coolant. This process is made possible because the pressure in the primary(reactor) systems are maintained at a point which prevents boiling in the reactor.

The pressurizer is the system that supports regulation of reactor pressure. The pressurizer is a vessel partly filled with water and is in free exchange with the water in the reactor and primary systems. The pressurizer also allows for the volumetric expansion of the primary coolant(water) as the reactor starts up, while maintaining the pressure of the reactor.

Sources of Radioactive Materials In Reactor Operation

There are two primary means that radioactive materials are produced in reactor operation which are:

- Fission produces two or more fission fragments in each fission. These fission fragments become the nuclei of new atoms as **fission products.** As we have already discussed many atoms are radioactive as is the case with these fission fragments. Example of these isotopes are iodine-131 (I-131), strontium-90 (Sr-90), cesium-137 (Cs-137), as well as others.
- Activation of normally stable nuclei occurs in the neutron field in the reactor. This occurs because neutrons are absorbed by the nucleus of an atom and a new isotope of that atom is created. The new isotopes may be radioactive. Examples of these isotopes include tritium (H-3) and cobalt-60 (Co-60). These radionuclei are referred to as **activation products.**

The sources of radioactive emissions from nuclear power operations are the treatment of water from the reactor systems, and the treatment of air in the buildings that house plant systems. Each of these emissions is managed to reduce the emissions to levels that are considered as low as reasonably achievable. The radiological monitoring program is designed to assess the impacts of these emissions even though they are acknowledged to be small contributors to background radiation.

Barriers to Release of Radioactive Materials

There are several barriers to release of radioactive materials. In order these are:

- the ceramic fuel pellet itself
- the zirconium cladding of the fuel rod
- the reactor vessel and it's associated piping
- the containment building

The fuel, fuel rods, and the reactor vessel have already been discussed. The **containment** building is illustrated in figure 14. The containment houses the reactor core, the reactor vessel and it's associated piping, reactor coolant pumps and the pressurizer.

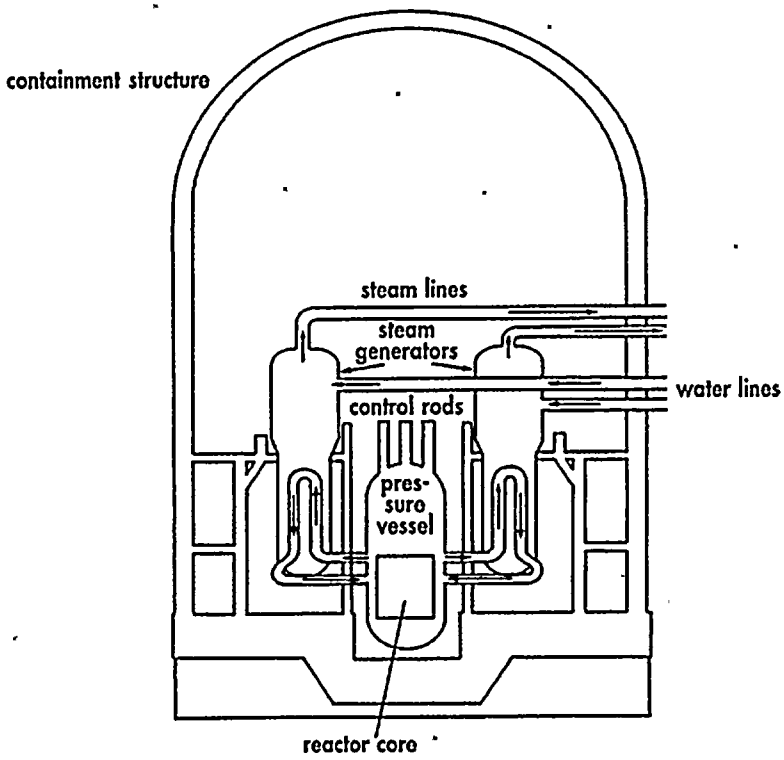

Figure 14: Primary Containment Structure

This containment is maintained at a pressure lower than the pressure outside the building. This is accomplished by a system of fans and filter systems the treat the air inside the secondary containment; thus, any air leakage would be into the secondary containment from the outside. The air coming from secondary containment is all filtered and treated prior to discharge.

REACTOR SAFETY

There are several points regarding nuclear safety that are important to understand and these are:

- Commercial nuclear generating station can not explode as a nuclear weapon. The uranium for weapons is highly enriched and must be carefully timed and configured to create an explosion. The uranium in commercial generating stations is low enrichment and can not be configured to create a nuclear explosion.
- The **reactor control system** regulates the power output of the reactor by controlling the rate of nuclear fission. This is accomplished by inserting or withdrawing control rods or by the addition of neutron absorbing materials. A special safety system is part of the reactor control system call the **reactor protection system** which will cause the control rods to be quickly inserted. This insertion causes to nuclear chain reaction to stop. There are numerous sensors that measure different plant conditions that would cause the reactor protection system to activate.
- There are several emergency systems that provide adequate cooling and water to the reactor in the event these are required. Should there be breakage of piping carrying water to the reactor this is referred to as a Loss of Coolant. These systems are activated upon a drop in reactor pressure or a low level of water in the reactor. The exact activation varies by reactor type. These systems that delivery this supplemental source of water are referred to as the **Emergency Core Cooling System.** There are even backup systems to the individual Emergency Core Cooling Systems. This practice is referred to as defense in depth. Safety is not dependent on any one device but is a system of several backups.

The Harris Nuclear Plant is designed to be a safe means of generating electrical power. This level of safety is further enhanced through the discipline of operation provided by a well qualified and trained staff. Ongoing training is provided to the staff to ensure a high quality performance from each member of the plant staff. Although the requirements are high for the staff, reactor operators and senior reactor operators must also pass a rigorous license examination by the Nuclear Regulatory Commission on a regular basis. These examinations test knowledge of plant systems, design, procedures, problem solving, regulatory requirements, and the ability to function as a team responding to plant conditions.

RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM

PURPOSE AND REQUIREMENTS FOR THE RADIOLOGICAL MONITORING PROGRAM

Although the operation of a nuclear generating station may result in the raising of background radiation only a small amount, it is important to measure these emissions of radioactivity and radiation to access their impact on the surrounding populations. The purpose of the radiological monitoring program is to measure accumulation of radioactivity in the environments, to determine whether this radioactivity is the result of operations of the Harris Plant, and to assess the potential dose to the off-site population based on the cumulative measurements of radioactivity of plant origin. Radiological monitoring programs provide an additional verification of the radiological controls of nuclear generating stations.

The radiological monitoring program was established in 1982 and continues to collect samples and evaluate them for 14 years.

Requirements are established for the radiological monitoring program as follows:

- Technical Specifications
- Off-Site Dose Calculation Manual(ODCM)
- various procedures

Additional guidance regarding the radiological monitoring program may be found in the following:

- NRC Regulatory Guide 1.109
- NRC Regulatory Guide 4.13
- NRC Regulatory Guide 4.15

General Site Description

The Harris Nuclear Plant consists of a pressurized water reactor with a design rating of 860 MWe (Mega Watts electric). Commercial production was initiated on January 3, 1987. The Harris Nuclear Plant is located in southwest Wake County, North Carolina. The site is along U.S. route 1 approximately sixteen (16) miles southwest of Raleigh, North Carolina and is displayed on the map of central North Carolina (Figure 15). The site is also approximately fifteen (15) miles northeast of Sanford, North Carolina.The nearest community is New Hill which is north of the site.

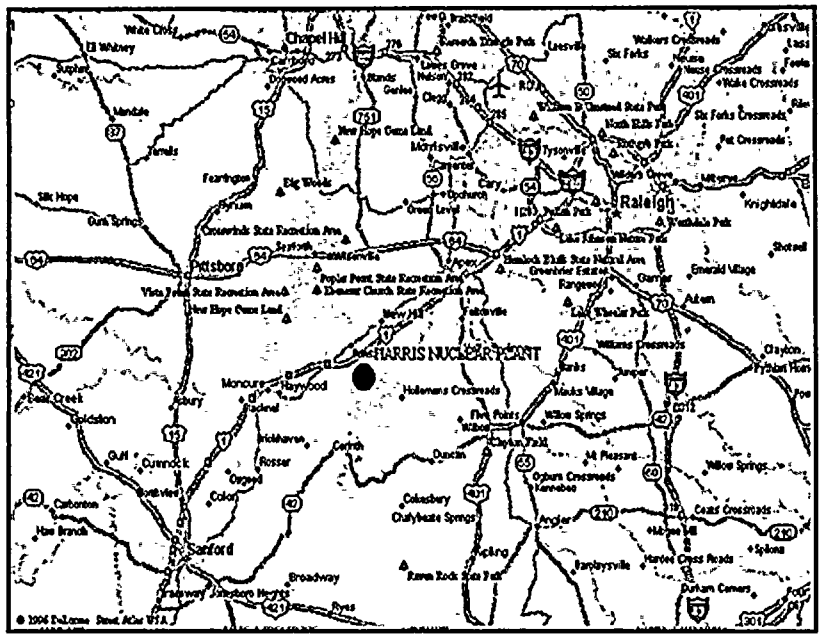

Figure 15 Location of Harris Nuclear Plant

Harris Lake is adjacent to the plant itself and is the source of cooling tower makeup water. The lake was impounded in the construction of Harris Plant. The lake is fed by Buckhorn Creek and is approximately 4,000 acres in area. The main dam is approximately 4.7 miles south of the site. The primary discharges to Harris Lake from the plant are surface runoff, cooling tower blow down, and radiological waste process systems.

Fishing, boating, and swimming are popular activities on Harris Lake and other nearby lakes. Carolina Power & Light encourages the recreational use of the lake and adjoining lands through a variety of agreements with state and local goverment. One of these agreements is the gamelands agreement encouraging hunting.

Within a five mile radius most of the land is wooded with only a few residences and limited agricultural activity. There are no non company industrial structures or residences on the plant site. The chief use of the land is for production of timber and pulp fiber.

Within a ten mile radius the area would be considered rural with significant populations in Apex, Holly Springs, and Fuquay-Varina. Currently these communities are experiencing significant growth.

Within a fifty mile radius much of the land is used in agricultural production. Significant crops include corn, soybeans, and tobacco. Livestock is also an important component with significant production in cattle, hogs, poultry, and dairy products.

Consumption of drinking water, food crops, and fish are sample media that are examples of ingestion pathways for exposure.

RADIOLOGICAL MONITORING PROGRAM QUALITY ASSURANCE

A required component of the environmental radiological monitoring program is the Quality Assurance Program. The standards for the quality assurance program are established in the NRC Regulatory Guide 4.15, "Quality Assurance for Radiological Monitoring Programs. The purpose of the quality assurance program is to "(1) to identify deficiencies in the sampling and measurement processes to those responsible for these operations so that corrective action can be taken, and (2) to obtain some measure of confidence in the results of the monitoring programs in order to assure the regulatory agencies and the public that the results are valid."(NRC Regulatory Guide 4.15 B Pg. 4.15-2) This provides the opportunity to implement corrective actions that address possible deficiencies. Examples of the activities of the quality assurance program include:

- regular review of sample collection and records
- regular review of laboratory procedures and methods
- participation in the Analytics, Inc. Environmental Cross-Check Program, which provides an independent assessment of the quality of laboratory results.
- the use of known concentrations of radioactivity in test samples by the laboratory to ensure consistent quality results on an ongoing basis.

RADIOLOGICAL MONITORING PROGRAM GENERAL DESCRIPTION

Although the contribution to background radiation is small, we have established this program to measure the exposure pathways to man. An exposure pathway describes the source of the radiological exposure. The primary forms of radiological emissions from the plant are airborne and liquid discharge. The following pathways are monitored; external dose, ingestion of radioactive materials, and the inhalation of radioactive material. Specific methods and different environmental media are required to assess each pathway. Below in Table 3 is a list of the media used to assess each of these pathways.

Table 3

Media Used to Assess Exposure Pathways to Man

Pathway of Exposure to Man	Media Sampled
External Dose	Thermoluminescent Dosimetry(TLD) Shoreline Sediment
Ingestion	Aquatic Vegetation Drinking Water Food Crops Fish Ground Water Milk Broadleaf Vegetation Surface Water
Inhalation	Air Samples (Particulate & Radioiodine)

Sampling Locations

Sampling locations are chosen based upon meteorological factors, preoperation monitoring, and results of the land use surveys. A number of locations are selected as controls. Control stations are selected because they are unaffected by the operation of the plant. Sample locations may be seen in figures 16 and 17. A description of each sample location may be found in Table 4.

Radiological Sampling Locations

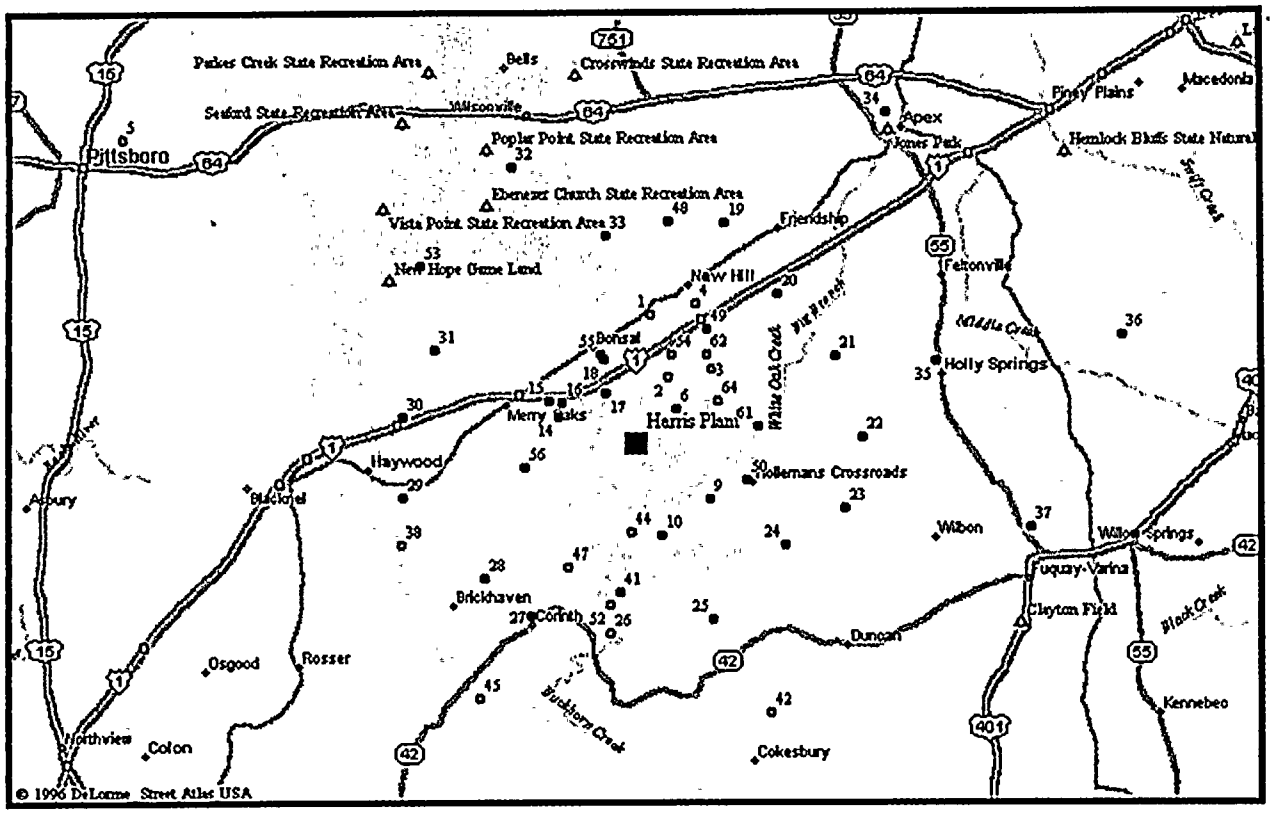

Figure 16: Radiological Sampling Locations (Distant from Plant) (Scale 1 inch=3.9 miles)

Thermoluminescent dosimeter and shoreline sediment locations(only) are displayed in black, ingestion and waterborne pathways in blue, and inhalation or air sampling stations in red.

Stations 1 through 5, and 26 include air sampling and thermoluminescent dosimeters.

Sample Types	Sample Locations
Air Cartridge & Particulate	1-5, 26,47(RED)
Shoreline Sediment	26,41
Ground Water	39,57-60(BLUE)
Drinking Water	38, 40(BLUE)
Surface Water	26, 38, 40 (BLUE)
Thermoluminescent Dosimeter	1-37, 48-50, 53, 56, 63 (BLACK EXCEPT AT SHARED LOCATIONS)
Milk	5, 42 (BLUE)
Fish	44, 45(BLUE)
Food Products & Broadleaf Vegetation	5, 54, 55, 62, 64, 65,66 (BLUE)
Aquatic Vegetation & Bottom Sediment	41, 45, 46, 52, 61

Radiological Sampling Locations

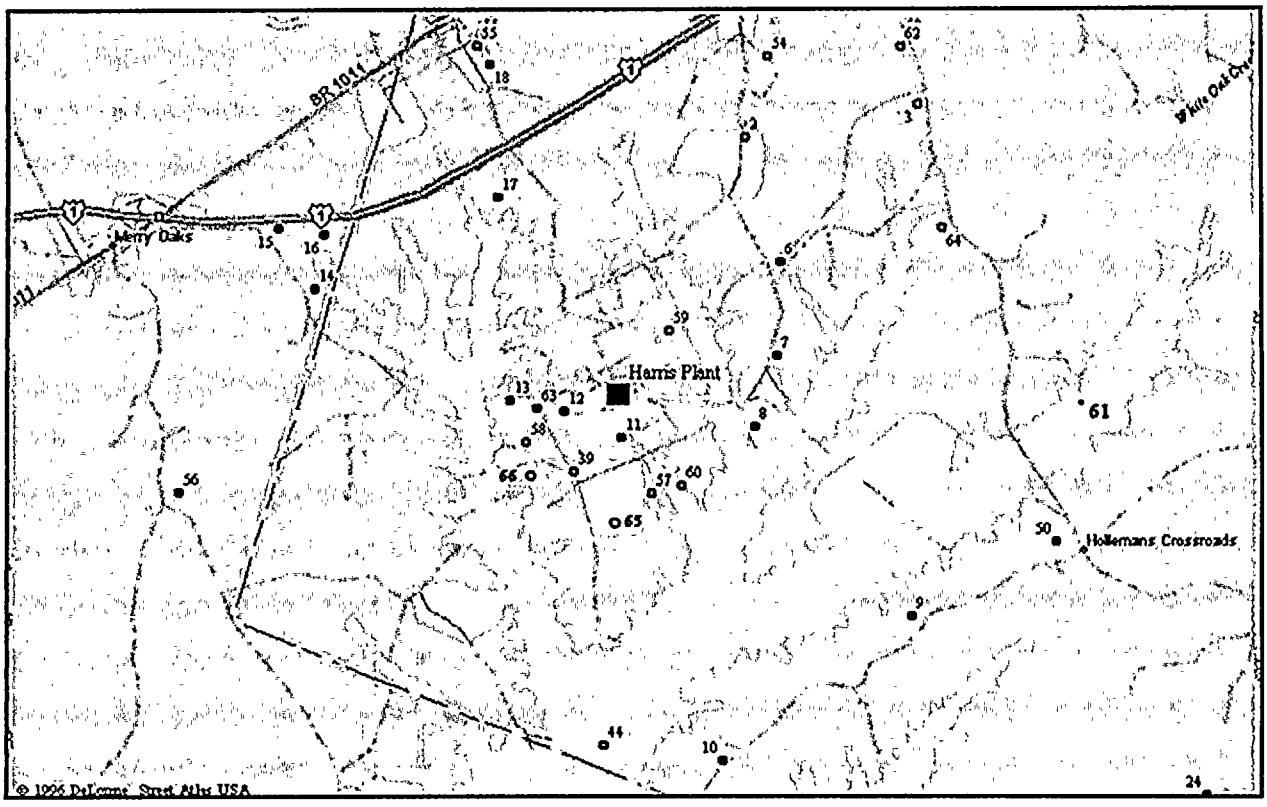

Figure 17 Radiological Sampling Locations (Nearest Plant) (Scale 1 inch = 1 miles)

Thermoluminescent dosimeter and shoreline sediment locations(only) are displayed in black, ingestion and waterborne pathways in blue, and inhalation or air sampling stations in red.

Stations 1 through 5, and 26 include air sampling and thermoluminescent dosimeters.

Sample Types	Sample Locations
Air Cartridge & Particulate	1-5, 26,47(RED)
Shoreline Sediment	26,41
Ground Water	39,57-60(BLUE)
Drinking Water	38, 40(BLUE)
Surface Water	26, 38, 40 (BLUE)
Thermoluminescent Dosimeter	1-37, 48-50, 53, 56, 63 (BLACK EXCEPT SHARED LOCATION)
Milk	5, 42 (BLUE)
Fish	44, 45(BLUE)
Food Products & Broadleaf Vegetation	5, 54, 55, 62, 64, 65, 66 (BLUE)
Aquatic Vegetation & Bottom Sediment	41, 45, 46, 52, 61

Table 4

Harris Nuclear Plant
Radiological Monitoring Sampling Locations

Sample Type	Location & Description	Frequency	Sample Size	Analysis
Air Cartridge (AC)	1--2.6 miles N 2--1.4 miles NNE 4--3.1 miles NNE 5--13.4 miles WNW--Pittsboro* 26--4.7 miles S 47--3.4 miles SSW	Weekly or as required by dust loading	30,000 ft^3 (900 m^3)	Iodine
Air Particulate (AP)	1--2.6 miles N 2--1.4 miles NNE 4--3.1 miles NNE 5--13.4 miles WNW--Pittsboro* 26--4.7 miles S 47--3.4 miles SSW	Weekly or as required by dust loading	30,000 ft^3 (900 m^3)	Gross Beta (Weekly) Composite Gamma (Quarterly)
Fish (FI)	44--Site varies in Harris Lake 45--Site varies in Cape Fear River*	Semiannual (In Season)	1 kg (wet) Free Swimmers & Bottom Feeders	Gamma
Drinking Water (DW)	38--6.2 miles WSW* 40--17.2 miles SSE Lillington 51--Water Treatment Plant (On Site)	Weekly Monthly Composite	8 liters	I-131, Gamma Tritium Gross Beta
Groundwater (GW)	39--.07 miles SSW 57--.04 miles SSW 58--.5 miles WSW 59--.5 miles NNE 60--.5 miles ESE	Quarterly	8 liters	Gamma Tritium
Milk(MK)	5— 18.2 miles WNW Manco Dairy* 42--7.0 miles SSE Maple Knoll Dairy	Semimonthly	8 liters	I-131 Gamma
Shoreline Sediment (SS)	26--4.6 miles S 41--3.8 miles S	Semiannual	500 grams	Gamma
Surface Water (SW)	26--4.7 miles S 38--6.2 miles WSW * 40--17.2 miles SSE Lillington	Weekly Monthly Composite	8 liters	I-131, Gamma Tritium Gross Beta
Aquatic Vegetation	26--4.7 miles S 41--3.8 miles S 61--2.5 miles E	Annually	500 grams	Gamma
Botton Sediment (SD)	52--3.8 miles S	Semiannual	500 grams	Gamma
Food Products (FP)	5--18.0 miles NNW--Pittsboro* 54--1.7 miles NNE--Wilkins or Morris 55--2.0 miles NNW--L. L. Goodwin 62--2.3 miles NE--Lee 64--1.8 miles ENE-Michael	Monthly during growing season when milk samples not performed	500 grams	Gamma
Broadleaf Vegetation (BL)	65--1.36 miles S 66--1.33 miles SSW	Monthly when available	500 grams	Gamma

* Control Stations

Table 4 (Continued)

Harris Nuclear Plant

Radiological Monitoring Sampling Locations

Sample Type	Location & Description	Frequency	Sample Size	Analysis
Thermoluminescent Dosimetry (TLD)	1--2.6 miles N 2-1.4 miles NNE 3--2.6 miles ENE 4--3.1 miles NNE 5--13.4 miles WNW--Pittsboro* 6--0.8 mile NE 7-0.7 mile E 8--0.6 mile ESE 9--2.2 miles SE 10--2.2 miles SSE 11-0.6 mile S 12--0.9 mile SSW 13--0.7 mile WSW 14--1.5 miles W 15--2.0 miles W 16--1.9 miles WNW 17--1.5 miles NW 18--1.4 miles NNW 19--5.0 miles NNE 20--4.5 miles NE 21--4.8 miles ENE 22 --4.3 miles E 23 --4.8 miles ESE 24--4.0 miles SE 25--4.7 miles SSE 26--4.7 miles S 27--4.8 miles SW 28--4.8 miles SSW 29--5.7 miles WSW 30--5.6 miles W 31--4.7 miles WNW 32--6.4 miles NNW 33--4.5 miles NNW 34--8.7 miles NE--Apex 35--6.9 miles E--Holly Springs 36--10.9 miles E 37--9.2 miles ESE--Fuquay-Varina 48--4.5 miles N 49--2.5 miles NNE 50--2.6 miles ESE 53--5.8 miles NW 56--3.0 miles WSW 63--0.6 mile S'W	Quarterly	Not Applicable	TLD Reading

* Control Stations

SUMMARY OF RADIOLOGICAL MONITORING PROGRAM

This report presents the results of the Radiological Environmental Monitoring Program conducted during 1997 for the Shearon Harris Nuclear Power Plant (SHNPP) and fulfills the reporting requirements of Technical Specifications 6.9.1.3. The program was conducted in accordance with Operational Requirement 3.12.1 in the Off-Site Dose Calculation Manual (ODCM), and applicable procedures.

Approximately 1060 samples of 13 different media types from indicator stations were compared to approximately 330 control samples. Control stations are locations that are unaffected by plant operations. In approximately 99 percent of the indicator samples there was no difference from the activities observed in the corresponding control samples.

Radioactivity in environmental samples attributed to plant operations in 1997 are as follows:

Environmental Media	Radionuclide	Location of w/Highest Annual Mean	Activity and Occurrence	Maximum Individual Dose (mrem/yr)
Surface Water	H-3	Harris Lake	4,060 pCi/L (12/12)	No ingestion pathway. No dose calculated.
Fish	H-3	Harris Lake	See above. Assumes H-3 equilibrium between lake water and fish tissue.	0.006 Total Body

The radiological environmental data indicates that SHNPP operations in 1997 had no significant impact on the environment or public health and safety.

A statistical summary of all the data for 1997 has been compiled and summarized in Table 5.

The plant-derived activity detected within the scope of the Radiological Environmental Monitoring Program (see Data Summary Table 5) has been tritium activity in Harris Lake water at an average concentration of 4.06 E+3 pCi/L and Harris Lake Bottom Sediment (see Data Summary Table 5) for 1997. No tritium activity was observed at Lillington, N.C., located 17 miles downstream on the Cape Fear River, which is the first public drinking water location below the Harris Lake discharge spillway. No plant-related gamma activity has been detected in fish collected from Harris Lake or in the water samples from Lillington, N.C.

TABLE 5
RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM DATA SUMMARY

Shearon Harris Nuclear Power Plant — **Docket Number: STN 50-400**

Wake County, North Carolina — **Calendar Year: 1997**

Medium or Pathway Sampled or Measured (Unit of Measurement)	Type and Total No. of Measurements Performed	Typical Lower Limit of Detection (LLD) [1]	All Indicator Locations Mean [2] Range	Location w/Highest Annual Mean Name, Distance, and Direction	Mean [2] Range	Control Locations Mean [2] Range
Air Cartridge (pCi/m³)	I-131 308[3]	2.2E-2	All less than LLD		All less than LLD	All less than LLD
Air Particulate (pCi/m³)	Gross Beta 308[3]	1.0E-3	1.94E-2 (256/260) 6.07E-3 - 5.20E-2	Barricade 1.4 miles NNE	2.10E-2 (51/52) 9.37E-3 - 5.20E-2	2.11E-2 (52/52) 9.64E-3 - 4.96E-2
	Gamma 24	Refer to Table 6	All less than LLD		All less than LLD	All less than LLD
Drinking Water[4] (pCi/l)	I-131 104	1.0E+0	All less than LLD		All less than LLD	All less than LLD
	Gross Beta 24	1.0E+0	3.75E+0 (12/12) 2.66E+0 - 6.44E+0	Lillington Cape Fear River 17.2 miles SSE	3.75E+0 (12/12) 2.66E+0 - 6.44E+0	3.84E+0 (12/12) 2.17E+0 - 5.83 E+0
	Gamma 24	Refer to Table 6	All less than LLD		All less than LLD	All less than LLD
	Tritium 24	3.25E+2	All less than LLD		All less than LLD	All less than LLD
Fish Bottom-Feeders (pCi/g, wet)	Gamma 4	Refer to Table 6	All less than LLD		All less than LLD	All less than LLD
Free-Swimmers (pCi/g, wet)	Gamma 8	Refer to Table 6	All less than LLD		All less than LLD	All less than LLD
Broadleaf Vegetation (pCi/g, wet)	Gamma 32 Cs-137	2.9E -2	6.59E-2 (1/32) Single value	Location 66 1.33 miles SSW	6.59E-2 (1/1) Single value	No Control
Food Crop (pCi/g, wet)	Gamma 23	Refer to Table 6	All less than LLD		All less than LLD	All less than LLD

TABLE 5 (cont.)
RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM DATA SUMMARY

Shearon Harris Nuclear Power Plant — **Docket Number: STN 50-400**

Wake County, North Carolina — **Calendar Year: 1997**

Medium or Pathway Sampled or Measured (Unit of Measurement)	Type and Total No. of Measurements Performed	Typical Lower Limit of Detection (LLD) [1]	All Indicator Locations Mean [2] Range	Location w/Highest Annual Mean Name, Distance, and Direction	Location w/Highest Annual Mean Mean [2] Range	Control Locations Mean [2] Range
Aquatic Vegetation (pCi/g, wet)	Gamma 3	Refer to Table 6	All less than LLD		All less than LLD	No control
Groundwater (pCi/l)	Gamma 20	Refer to Table 6	All less than LLD		All less than LLD	No control
	Tritium 20	3.25E+2 (16/20) [4] 1.00E+3 (4/20) [5]	All less than LLD 7.56E+2 (4/20) 6.28E+2 - 9.71E+2	North Bank ESW Intake 0.5 mile WSW	All less than LLD 7.56E+2 (4/4) 6.28E+2 - 9.71E+2	No control
Milk (pCi/l)	I-131 33 [3]	1.0E+0	All less than LLD		All less than LLD	All less than LLD
	Gamma 33 [3]	Refer to Table 6	All less than LLD		All less than LLD	All less than LLD
Shoreline Sediments (pCi/g, dry)	Gamma 8	Refer to Table 6	All less than LLD		All less than LLD	No control
Bottom Sediment (pCi/g, dry)	Gamma 4 Co-60	6.5E-2	4.75E +0 (4/4) 4.59E -1 - 8.75E +0	Harris Lake Cooling Tower Mixing Zone 3.8 miles S	4.75E +0 (4/4) 4.59E -1 - 8.75E +0	No control
	Sb-125	1.59E -1	9.50E-1 (3/4) 3.50E-1 - 1.39E+0	Harris Lake Cooling Tower Mixing Zone 3.8 miles S	9.50E-1 (3/4) 3.50E-1 - 1.39E+0	No control
	Cs-137	5.2E -2	3.99E -1 (4/4) 1.24E -1 - 6.82E -1	Harris Lake Cooling Tower Mixing Zone 3.8 miles S	3.99E -1 (4/4) 1.24E -1 - 6.82E -1	No control

TABLE 5 (cont.)
RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM DATA SUMMARY

Shearon Harris Nuclear Power Plant
Wake County, North Carolina

Docket Number: STN 50-400
Calendar Year: 1997

Medium or Pathway Sampled or Measured (Unit of Measurement)	Type and Total No. of Measurements Performed	Typical Lower Limit of Detection (LLD) [1]	All Indicator Locations Mean [2] Range	Location w/Highest Annual Mean Name, Distance, and Direction	Mean [2] Range	Control Locations Mean [2] Range
Surface Water[4] (pCi/l)	I-131 104	1.0E+0	All less than LLD		All less than LLD	All less than LLD
	Gross Beta 36	1.0E+0	3.43E+0 (24/24) 1.88E+0 - 6.44E+0	Lillington Cape Fear River 17.2 miles SSE	3.75E+0 (12/12) 2.66E+0 - 6.44E+0	3.84E+0 (12/12) 2.17E+0 - 5.83E+0
	Gamma 36	Refer to Table 6	All less than LLD		All less than LLD	All less than LLD
	Tritium 36	3.25E+2 (24/36)[6] 1.00E+3(12/36)[6]	All less than LLD 4.06E+3 (12/24) 3.27E+3 - 6.00E+3	Harris Lake 4.7 miles S	All less than LLD 4.06E+3 (12/12) 3.27E+3 - 6.00E+3	All less than LLD
Direct Radiation (mR/qtr)[5]	TLD 164[5]		1.25E+1 (160/160) 1.16E+1 - 1.35E+1	Apex at Jones Park 8.7 miles NE-Apex	1.82E+1 (3/3) 1.38E+1 - 2.66E+1	1.64E+1 (4/4) 1.53E+1 - 1.76E+1

FOOTNOTES TO TABLE 5

1. The Lower Limit of Detection (LLD) is the smallest concentration of radioactive material in a sample that will yield a net count above system background which will be detected with 95 percent probability and with only 5 percent probability of falsely concluding that a blank observation represents a "real" signal. Due to counting statistics and varying volumes, occasionally lower LLDs are achieved.

2. Mean and range are based on detectable measurements only. The fractions of all samples with detectable activities at specific locations are indicated in parentheses.

3. Missing samples are discussed in Missed Samples and Analyses.

4. Although quarterly composite samples are required, monthly composite samples are used to provide more frequent and sensitive analyses.

5. TLD exposure is reported in milliroentgen (mR) per 90-day period (quarter) beginning in 1995. This is the exposure standard used to compare data to the Nuclear Regulatory Commission (NRC).

6. Tritium Lower Limit of Detection (LLD) was lowered to 3.25 E+2 pCi/L in June 1996 for samples that typically demonstrate activity less than the LLD. The LLD was lowered at the request of the plants in order to maintain comparable LLD and result values with the state (N.C. and S.C.) Agencies' laboratories. Other samples that typically exhibit activity greater than the LLD have a tritium Lower Limit of Detection (LLD) of 1.0 E+3 pCi/L.

INTERPRETATIONS AND CONCLUSIONS

Air Monitoring

All 308 air cartridge samples from indicator and control stations had I-131 activities which were less than the LLD of 1.5 E-2 pCi/m^3. I-131 was detected in air samples for a six-week period following the Chernobyl incident in April 1986. With this exception, no I-131 has been detected in air samples collected from 1987 through 1997, which is the entire operating history of the plant.

Gross beta activity was detectable in all airborne particulate samples from the five indicator locations. The 256 samples had an average concentration of 1.94E-2 pCi/m^3, a value similar to preoperational data of 2.0 E-2 pCi/m^3. Similar gross beta activities were observed at the control location in Pittsboro which had an average concentration of 2.11E-2 pCi/m^3 in 52 samples. These concentrations are typical of the natural environment and are not attributed to plant operations. Figures 18 through 22 provide a graphic representation of the gross beta activity at the indicator locations compared to the control location for the period January through December 1997.

No plant-related gamma activity was detected in quarterly composite filter samples from either the indicator or control locations. Typical LLDs for air particulates are contained in Table 6.

Drinking Water

None of the 52 drinking water samples collected at the Lillington Municipal water supply nor the 52 control samples collected from the Cape Fear River above the Buckhorn Dam contained detectable I-131 activity (< 1.0 E+0 pCi/L) during 1997. This has been the experience for the preoperational and operational period with the exception of 1986 when the fallout from Chernobyl was detected.

The average annual gross beta concentrations at the indicator and control locations were similar with activities of 3.72 E+0 pCi/L and 3.84 E+0 pCi/L, respectively, similar to the preoperational average of 4.00 E+0 pCi/L. These activities are attributed to the natural environment and are not attributed to plant operations. Figure 23 provides graphic representation of the gross beta activity during 1997 for Location 40 (Lillington).
Analyses for gamma-emitting radionuclides indicated all concentrations were less than the

lower limit of detection for drinking water. Table 6 contains typical LLD values for gamma-emitting radionuclides in drinking water.

Tritium concentrations in all of the Lillington Municipal Water Supply samples were less than the lower limit of detection (3.25 E+2 pCi/L) (see Footnotes to Table 5, Footnote 6).

Fish

Analyses for gamma-emitting radionuclides in two samples of bottom-feeding fish and in four samples of free-swimming species (sunfish and largemouth bass) from the indicator location, Harris Lake, revealed no detectable activity for 1997 consistent with the data for 1989-1996. During the Chernobyl period, Cs-134, 137 were detected in both control and indicator samples.

Fish are considered to be in equilibrium with the tritium activity in the lake and the most exposed individual (a child) would have to consume approximately 15 pounds (lbs.) of fish a year (6.9 kg fish/yr.). The total body dose to the maximum exposed child individual due to tritium was calculated by Regulatory Guide 1.109, Rev.1, October 1977, Equation A-1, to be 0.006 mrem/year.

Equation A-1

$$R_{aipj} = C_{ip}\, U_{ap}\, D_{aipj}$$

where as:

R_{aipj}	=	total body dose in mrem/yr of H-3
C_{ip}	=	concentration of nuclide (H-3) in pCi/kg = pCi/L
U_{ap}	=	maximum exposed individual's consumption (Reg. Guide 1.109 Table E-5) (approx. 15 lbs. of fish/yr. = 6.9 kg of fish/yr.)
D_{aipj}	=	ingestion dose factor for total body of individual in U_{ap} in mrem/pCi (Reg. Guide 1.109 Table E-13)

The dose due to tritium in the fish was also calculated using the child as the maximum exposed individual with the exposure to the liver, the result was the same. The total body dose and dose to the liver (ingestion dose factor - Reg. Guide 1.109 Table E-11) for the exposed individual being an adult consuming approximately 46 lbs. of fish a year (21 kg fish/yr.) Reg.

Guide 1.109 Table E-5) calculates to be 0.009 mrem/year.

Broadleaf Vegetation

Broadleaf vegetation sampling is accomplished by collecting monthly three different species of samples, when available, at two off site locations (two indicator locations of the highest predicted annual average ground level D/Q). The highest predicted annual average ground level D/Q (ODCM Table A-1 through A-4) was at the site boundary in both the South sector at 1.36 miles (BL-65) and the SSW sector at 1.33 miles (BL-66). Broadleaf sampling is conducted since no milk animals are located within a radius of approximately five miles of the plant and is used to simulate dose to an individual via the milk pathway for compliance purposes.

During 1997, one of 32 samples taken from the indicator sites demonstrated detectable concentrations of Cs-137 for a single value of 6.59 E-2 pCi/g (wet). It is concluded that the indicator value reflects natural fallout Cs-137 contamination, not contamination attributed to plant operations.

Surface Water

Surface water samples were collected and analyzed weekly for I-131. Water samples collected during 1997 contained no detectable I-131 (LLD < 1.0E+0 pCi/L) as they have been since plant operations began in 1987.

Average gross beta concentrations at the indicator and control locations were 3.43 E+0 pCi/L and 3.84 E+0 pCi/L, respectively in 1997, indicating no adverse influence from plant operations (See Figure 24).

Surface water samples were analyzed for gamma-emitting radionuclides and tritium. All concentrations of man-made gamma-emitters were less than their respective lower limits of detection (see Table 6).

The annual average tritium concentration in Harris Lake was 4.06 E+3 pCi/L with minimum and maximum values of 3.27 E+3 pCi/L and 6.00 E+3 pCi/L, respectively. The Harris Lake tritium activity showed a slight decline in tritium concentration compared to 4.75 E+3 pCi/L in 1996 (see Figure 25).

Groundwater

Groundwater samples are collected on site at SHNPP and analyzed for gamma-emitting radionuclides and tritium. Concentrations of the gamma radionuclides were all less than their respective lower limits of detection during 1997. Therefore, there appears to be no downwelling of activity. No tritium or gamma-emitter activity has been observed greater than the required LLD over the period from 1985-1995. Tritium activity (greater than the LLD of 3.25 E+2 pCi/L) was detected in groundwater 58 (0.5 mile WSW Sector N Bank ESW Intake) three out of four quarters in 1996 and all of 1997. No activity was observed in first quarter 1996, which had an LLD of 1.0 E+3 pCi/L. The tritium LLD activity for pre-operational samples through first quarter 1996 was 1.0 E+3 pCi/L and from second quarter (June) 1996 through present the LLD activity has been decreased to 3.25 E+2 pCi/L (see Footnotes to Table 5, footnote 6). The groundwater wells are all abandoned wells and are not a water supply for drinking or irrigation; therefore, there is no radiological dose via this pathway.

Milk

During 1997 as in all past years with the exception of the Chernobyl period, no I-131 concentrations were detected in milk samples throughout the entire year. There were also no other gamma-emitting radionuclides from plant operations detected in the milk. The only detectable gamma-emitting nuclide identified in each milk sample was potassium-40 (K-40). This is a naturally occuring nuclide in any living organism or product there of. The K-40 concentrations in milk range from 1.11E+3 pCi/L - 1.92E+3 pCi/L for the control location and 1.20E+3 pCi/L - 1.98E+3 pCi/L for the indicator sample location.

In May of 1997, the Maple Knoll Dairy (indicator Mk-42 – located in the SSE sector) ceased operations. In lieu of the semimonthly milk samples, per Harris Nuclear Plant Off-Site Dose Calculation Manual (ODCM) Table 3.12-1, broadleaf vegetation samples were collected in both the South (S) and SSW sectors.

Shoreline Sediment

Shoreline sediment samples were collected (1) opposite the discharge structure and (2) near the main dam in 1997. No plant-related radioactivity has been observed in either sample 1994-1997. No long-term trends are readily identifiable.

Bottom Sediment

The 1997 data shows Cobalt-60 (4.59 E-1 to 8.75 E+0 pCi/g dry) and Cesium-137 (1.24 E-1 to 6.82 E-1 pCi/g dry) activity in the indicator sample, which is sampled quarterly. Also, Antimony(Sb)-125 was observed three out of four quarters for a range in activity of 3.50 E-1 to 1.39 E+0 pCi/g dry. The bottom sediment sample from Harris Lake poses no radiological dose to the general public via this pathway due to the fact that it is not easily assessable (i.e. bottom sediment is approximately forty to sixty plus feet under water).

Food Crops

In addition to milk sampling (or broadleaf vegetation sampling), a food product sampling program was maintained. Various crops were collected during a growing season which basically continued year round. The species selected were primarily broad-leaf vegetables most sensitive to direct fallout of airborne radioactive particulates. Crops sampled in 1997 included turnip greens, cabbage, collards, tomatoes, mustard greens, cucumbers, lettuce, and radishes. Gamma spectrometry analyses of the food crops detected no plant-related activity in 15 samples from indicator locations and 8 samples from control locations collected in 1997.

Aquatic Vegetation

No gamma activity was detected in the three annual aquatic vegetation samples collected from the Harris Lake in 1997.

External Radiation Exposure

Thermoluminescent dosimeters (TLDs) were used to monitor ambient radiation exposures in the plant environs. The average quarterly exposure from the indicator locations was 12.5 mR and 16.4 mR from the control station. The highest indicator location was 8.7 miles NE of the plant (Apex at Jones Park) and averaged 18.2 mR/qtr. The differences among these locations is attributed to variations in soils and local geology and are not the result of plant operations.

Comparison of the quarterly TLD exposure within approximately 2 miles (inner ring) of the plant with that at approximately 5 miles (outer ring) is presented in Figure 26; these data illustrate that the inner and outer rings are approximately equal.

MISSED SAMPLES AND ANALYSES

Air Cartridge and Air Particulates

No samples were available for:

- AC/AP-2, August 11, due to a tripped breaker.
- AC/AP-47, September 15, due to a tripped breaker.
- AC/AP-47, October 13, due to a tripped breaker.
- AC/AP-1, December 22, due to a pump motor malfunction.

Low AC/AP Volumes for:

- AC/AP-2, July 21, due to a tripped breaker.
- AC/AP-2, September 2, due to a tripped breaker.
- AC/AP-4, November 17, due to a malfunction of the flow meter.

Food Crops

Food crops were not available for sampling during February, March, and September.

Milks

On May 19, 1997, the Maple Knoll Dairy (Mk-42 - located in the SSE sector), ceased operations. In lieu of the semimonthly milk samples, per Harris Nuclear Plant Off-Site Dose Calculation Manual (ODCM) Table 3.12-1, broadleaf vegetation samples were collected in both the South (S) and SSW sectors. The broadleaf vegetation samples collected were three different kinds representative of the area. The vegetation site location will be designated BL-65 (S sector) and BL-66 (SSW sector).

Broadleaf Vegetation

Broadleaf vegetation samples were not available for sampling during November and December.

TLDs

Eight of a possible 172 TLD samples were missing during 1997 due to vandalism. They were:

First Quarter	-	TLDs 9, 10, 14, and 50 were missing in the field. (The State of North Carolina's TLDs for location numbers 9, 10, and 50 were also missing.)
Second Quarter	-	TLD 18 was missing in the field.
Third Quarter	-	TLDs 34 and 63 were missing in the field.
Fourth Quarter	-	TLD 9 was missing in the field.

ANALYTICAL PROCEDURES

Gross Beta

Gross beta radioactivity measurements are made utilizing a Tennelec Low-Background Alpha/Beta Counting System. The LLD for air particulates is approximately 1.0E-3 pCi/m^3 for SHNPP samples. Air particulate samples are mounted in 2-inch stainless steel planchets and counted directly.

Gross beta activity in drinking and surface waters is determined by evaporating 1 liter of the sample and counting a planchet on a Tennelec Low-Background Alpha/Beta Counting System for 50 minutes. Typical LLD for gross beta is 1.0E+0 pCi/L.

Tritium

Liquid samples requiring tritium analysis are treated with a small amount of sodium hydroxide and potassium permanganate crystals and then distilled. Five milliliters of the distillate are mixed with thirteen milliliters of liquid scintillation cocktail and counted in a liquid scintillation counter. Samples which routinely demonstrate activity less than the lower limit of detection count for 500 minutes with an approximate LLD of 3.25 E+2 pCi/L and samples that typically exhibit activity count for 60 minutes with an approximate LLD of 1.0 E+3 pCi/L. The tritium LLD was lowered in 1996 at the request of the plants (see Footnotes to Table 5, Number 6).

Iodine-131

Iodine-131 airborne concentrations are analyzed by the intrinsic germanium (Ge) spectrometry systems. The cartridges are placed on the detector, and each charcoal cartridge is counted individually with an LLD 2.2 E-2 pCi/m^3.

Iodine-131 in milk and drinking water is determined by an instrumental method. Analysis involves passing 4 liters over an anion exchange resin and direct gamma analysis of the resin with an intrinsic Ge detector. The LLD using the Ge detector is less than or equal to 1.0 E+0 pCi/L using a 25,000-second count time.

Gamma Spectrometry

Gamma spectrum analysis utilizes intrinsic germanium detectors with thin aluminum windows housed in steel and lead shields. The analyzer system is the Canberra Nuclear 9900 Gamma Spectroscopy System. Table 6 summarizes LLD values derived from instrument sensitivity based upon a blank sample background.

Air particulate filter quarterly composites are placed in a Petri dish and analyzed directly for 1,500 seconds.

Liquid samples, except milk, are boiled down to a small volume, transferred to a PB-50 beaker and analyzed for 7,000 seconds. One-liter milk samples are analyzed in a Marinelli beaker for 11,000 seconds.

Shoreline and bottom sediments are dried, weighed, and then analyzed in a Marinelli beaker for 1,500 seconds.

Food crop, aquatic vegetation, and broadleaf vegetation samples are weighed as sampled and analyzed in a Marinelli beaker for 7,500 seconds.

Fish samples are cleaned, dressed, and placed in a Marinelli beaker for analysis for 1,500 seconds.

Thermoluminescent Dosimetry

Each area monitoring station includes a TLD packet which is a polyethylene bag containing three calcium sulfate phosphors contained in a Panasonic UD-814 badge. The TLD is lighttight and the bag is weather-resistant.

Dosimeters are machine annealed before field placement. Following exposure in the field, each dosimeter is read utilizing a Panasonic TLD reader. This instrument integrates the light photons emitted from traps as the dosimeter is heated above 150°C. The photons from the lower-energy traps are automatically eliminated through a preheat cycle. Calibration is checked regularly using dosimeters irradiated to known doses. Prior to the measurement of each dosimeter, the instrument is checked through use of an internal constant light source as a secondary standard.

The exposure reported is corrected for exposure received in transit and during storage through the use of control dosimeters.

Interlaboratory Comparison Program

The Radiochemistry Laboratory at the Harris Energy & Environmental Center in New Hill, North Carolina, provides radioanalytical services for CP&L's nuclear plant radiological environmental surveillance programs. In fulfillment of ODCM Operational Requirements, the laboratory is a participant in the Analytics, Inc., Environmental Cross-Check Program and uses its performance in this program as a major determinant of the accuracy and precision of its analytical results. The change in vendors for the Interlaboratory Program was due to the EPA Environmental Cross-Check Program's termination for utility participation as of December 31, 1995.

During 1997, 86 analyses were completed on 15 samples representing five major environmental media (i.e., water, milk, air filters, soil, and air cartridges). Data on the known activities and the standard deviations for the 86 analyses have been received from Analytics, Inc. A comparison of the average of our reported values with the Analytics, Inc., known activity and its standard deviation is provided below:

Standard Deviation From Known Activity	Percent of Analyses
≤ 1 Standard Deviation	42
≤ 2 Standard Deviation	74
≤ 3 Standard Deviation	99

One of 86 analyses exceeded the 3 sigma action level. This was a single isotope, (Mn-54, among ten gamma isotopes identified) in the sample provided in the Gamma in Water from Fourth Quarter 1997 Gamma + I-131 in Water (E1249-72).

The gamma results (Mn-54 isotope) were checked by the following means: (1) rechecked counts submitted, entered, and typed: (2) sample had been consumed in order to perform the chemical separation for I-131, so a recount was unobtainable, (3) this Mn-54 nuclide value is within twenty percent (20%) to the known value. The Radiochemistry laboratory was within Analytics, Inc.'s acceptable criteria for Mn-54 in previous unknown samples. A recommendation is to evaluate the results of the Environmental Interlaboratory Comparison Program based on the isotopes identified by the EPA Environmental Cross-Check Program.

The EPA Program focuses on key isotopes (Co-60, Zn-65, I-131, Ba-133, Cs-134, and Cs-137); where as Analytics Inc. evaluates a sample of ten (10) or more mixed gamma isotopes. This should redirect our program's focus back to specific environmental sensitive isotopes and not a large array of isotopes.

Lower Limits of Detection

All samples analyzed met the LLD required by the ODCM.

TABLE 6

TYPICAL LOWER LIMITS OF DETECTION (A PRIORI)
GAMMA SPECTROMETRY

Drinking Water/Surface Water/Groundwater Samples	
Isotope	**LLD (pCi/L)**
Mn-54	6
Co-58	6
Fe-59	13
Co-60	7
Zn-65	14
Zr-Nb-95	6
I-131	1.0*
Cs-134	7
Cs-137	6
Ba-La-140	8
Other Expected Gamma Emitters	4 to 174
Air Particulates (Quarterly Composite)	
Isotope	**LLD (pCi/m^3)**
I-131	0.045
Cs-134	0.001
Cs-137	0.001
Other Expected Gamma Emitters	0.001 to 0.045
Milk	
Isotope	**LLD (pCi/L)**
I-131	1.0*
Cs-134	10
Cs-137	10
Other Expected Gamma Emitters	6 to 571

*Instrumental analysis of resin concentrates of samples.

TABLE 6 (continued)
TYPICAL LOWER LIMITS OF DETECTION (A PRIORI)
GAMMA SPECTROMETRY

Sediment	
Isotope	**LLD (pCi/kg dry)**
Cs-134	95
Cs-137	52
Other Expected Gamma Emitters	48 to 1764
Fish	
Isotope	**LLD (pCi/kg wet)**
Mn-54	61
Co-58	53
Fe-59	115
Co-60	83
Zn-65	135
Cs-134	68
Cs-137	60
Other Expected Gamma Emitters	16 to 1015
Food Products and Vegetation	
Isotope	**LLD (pCi/kg wet)**
I-131	36 pCi/kg (wet)
Cs-134	33
Cs-137	29
Other Expected Gamma Emitters	21 to 812

LAND-USE CENSUS
PURPOSE OF THE LAND-USE CENSUS

The land-use census identifies the pathways (or routes) that radioactive material may reach the general populations near commercial nuclear generating stations. This is accomplished by completing studies each year that identify how the surrounding lands are used by the population. A comprehensive census of the use of the land within a five mile distance of the plant is completed during the growing season each year. This information is used for dose assessment and to identify changes to the stations sampled and the type of samples. These results ensure that the Radiological Environmental Monitoring Program (REMP) is based upon current data regarding human activity in the vicinity of the plant. Therefore the purpose of the land-use census is both to ensure the monitoring program is current as well as provide data for the calculation of estimated radiation exposure.

The pathways that are evaluated are:

- Ingestion Pathway - Results from eating food crops that may have radioactive materials deposited on them, incorporated radioactive materials from the soil or atmosphere. Another pathway is through drinking milk from local cows or goats if these are present. The grass used to feed these animals may have incorporated or had deposited on it radioactive materials that can be transferred to the milk.
- Direct Radiation Exposure Pathway- Results from deposition of radioactive materials on the ground or from passage of these radioactive materials in the air.
- Inhalation Pathway- Results from breathing radioactive materials transported in the air.

Methodology

The following must be identified within the five (5) mile radius of the plant for each of the sixteen meteorological sectors (compass direction the winds may blow, for example NNE [North North East]):

- The nearest resident
- The nearest garden of greater that 500 square feet, producing broadleaf vegetables
- The nearest milk animal

The primary method is visual inspection from roadside within the five (5) mile radius. This information is supplemented with data from aerial photographs, information from county extension agents, and farm supply businesses.

1997 Land-Use Census Results

The 1997 and 1996 results of the survey for the nearest resident, garden, milk and meat animals in each sector are compared in Table 7.

The nearest resident in each sector remained the same from 1996 to 1997. No gardens were located within 5 miles of the plant for the E, S, and SW sectors. The only change in meat animals was the addition of chickens in the SW sector. The dairy in the SSE sector 7.0 miles from the plant ceased operation in 1997.

TABLE 7

LAND-USE CENSUS COMPARISON (1996-1997)
NEAREST PATHWAY (MILES)

SECTOR	RESIDENT		GARDEN		MEAT ANIMAL		MILK ANIMAL	
	1997	1996	1997	1996	1997	1996	1997	1996
N	2.2	2.2	2.2	2.2	2.2	2.2	---	---
NNE	1.9	1.9	1.9	1.9	2.2	2.2	---	---
NE	2.3	2.3	2.3	2.3	2.3	2.3	---	---
ENE	1.8	1.8	1.8	1.8	1.8	1.8	---	---
E	1.7	1.7	---	---	2.0	2.0	---	---
ESE	2.6	2.6	4.6	4.6	---	---	---	---
SE	2.6	2.6	4.1	2.7	2.6	2.6	---	---
SSE	4.2	4.2	4.2	4.2	4.2	4.2	---	7.0
S	5.3	5.3	5.3	---	---	---	---	---
SSW	3.8	3.8	3.8	3.8	---	---	---	---
SW	2.9	2.9	---	---	2.9	---	---	---
WSW	4.5	4.5	4.5	4.5	4.5	4.5	---	---
W	3.0	3.0	3.1	3.1	3.1	3.1	---	---
WNW	2.3	2.3	2.3	2.3	---	---	---	---
NW	2.4	2.4	2.6	2.6	---	---	---	---
NNW	1.6	1.6	2.0	2.0	2.0	2.0	---	---

Sector and distance determined by Global Positioning System.

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Figure 18 For HNP From 1/1/97 To 12/31/97

AIR PARTICULATE for GROSS BETA - Activity (pCi/cubic meter)

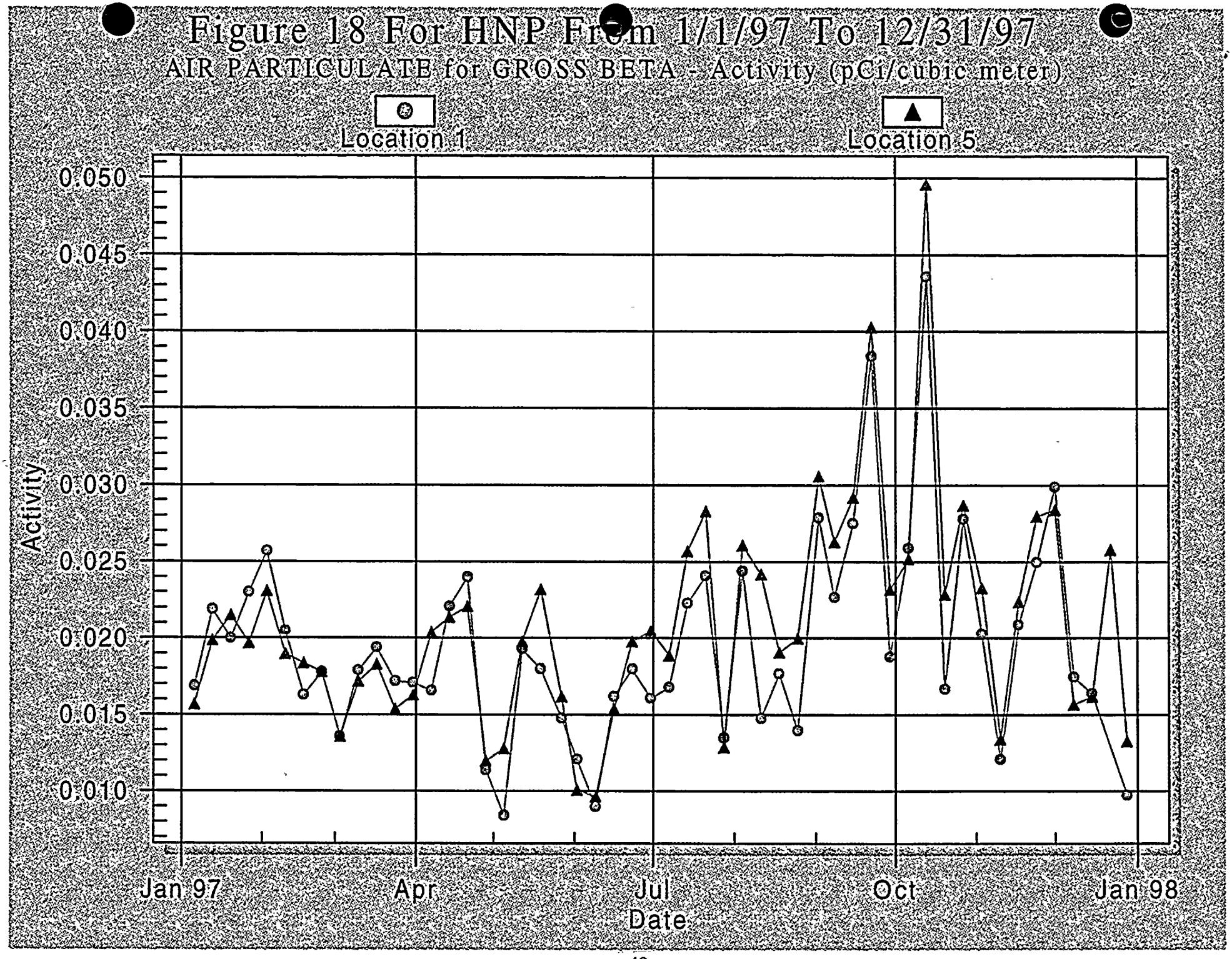

Figure 19 For HNP From 1/1/97 To 12/31/97

AIR PARTICULATE for GROSS BETA - Activity (pCi/cubic meter)

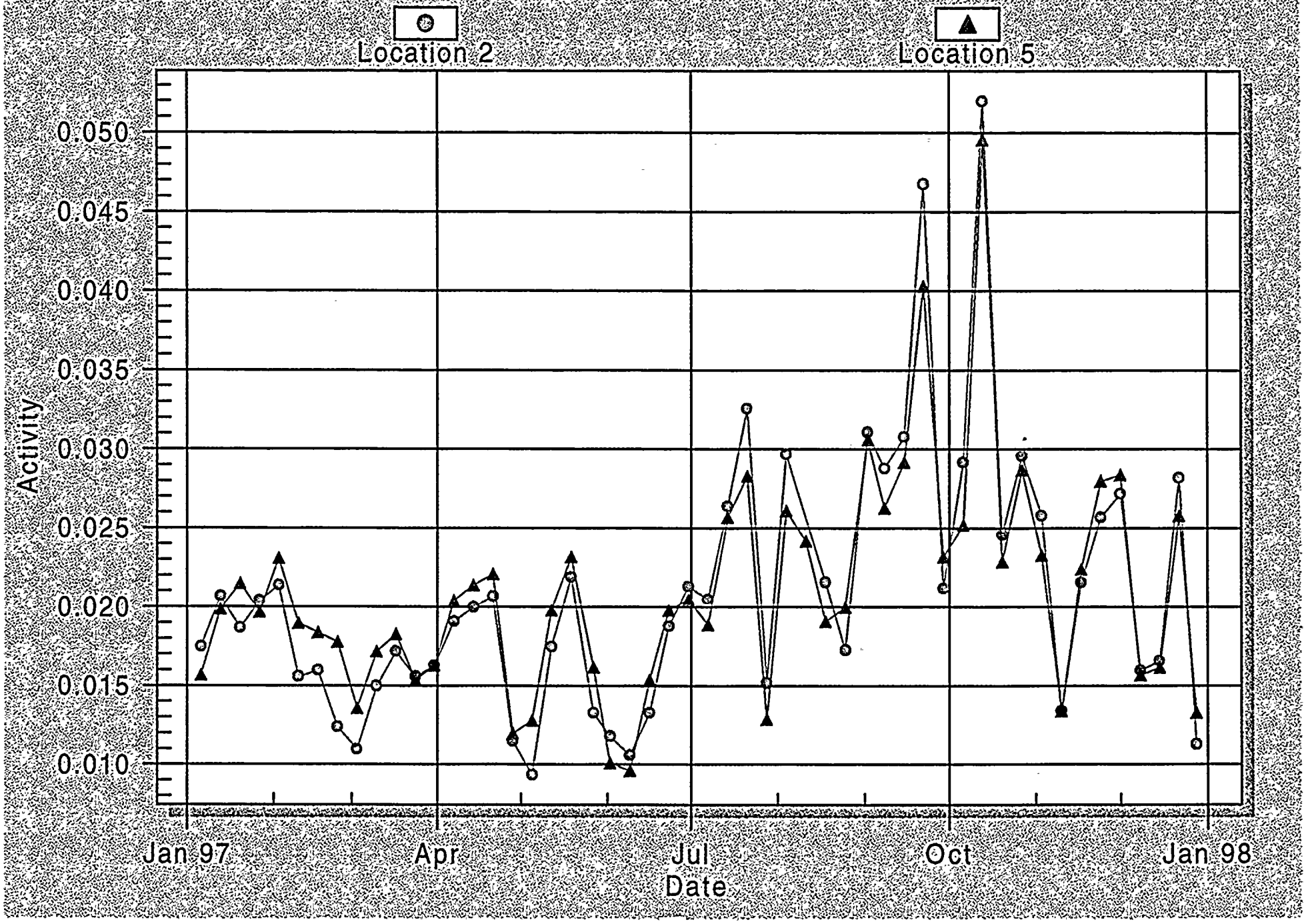

Figure 20 For HNP From 1/1/97 To 12/31/97

AIR PARTICULATE for GROSS BETA - Activity (pCi/cubic meter)

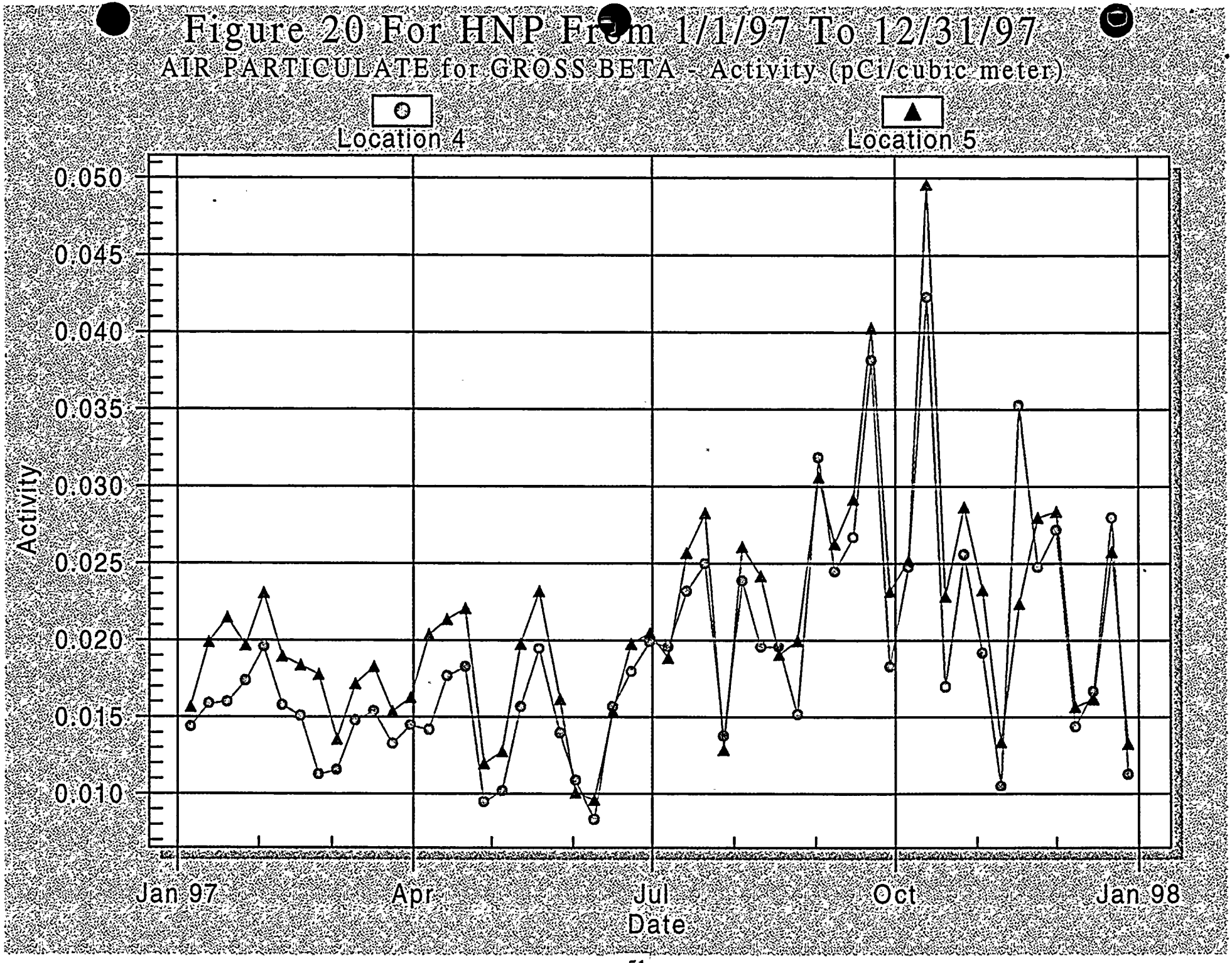

Figure 21 For HNP From 1/1/97 To 12/31/97

AIR PARTICULATE for GROSS BETA - Activity (pCi/cubic meter)

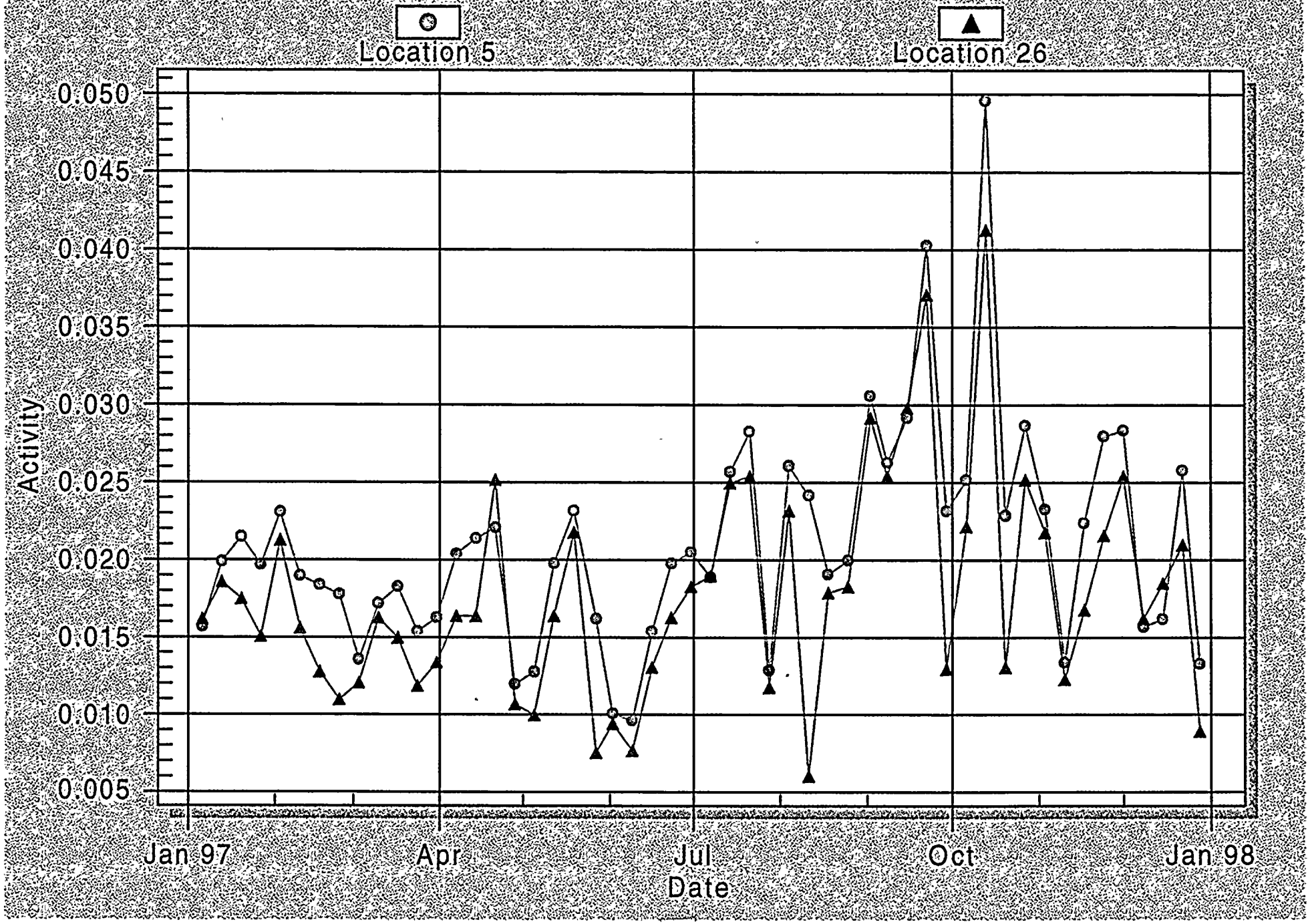

Figure 22 For HNP From 1/1/97 To 12/31/97

AIR PARTICULATE for GROSS BETA - Activity (pCi/cubic meter)

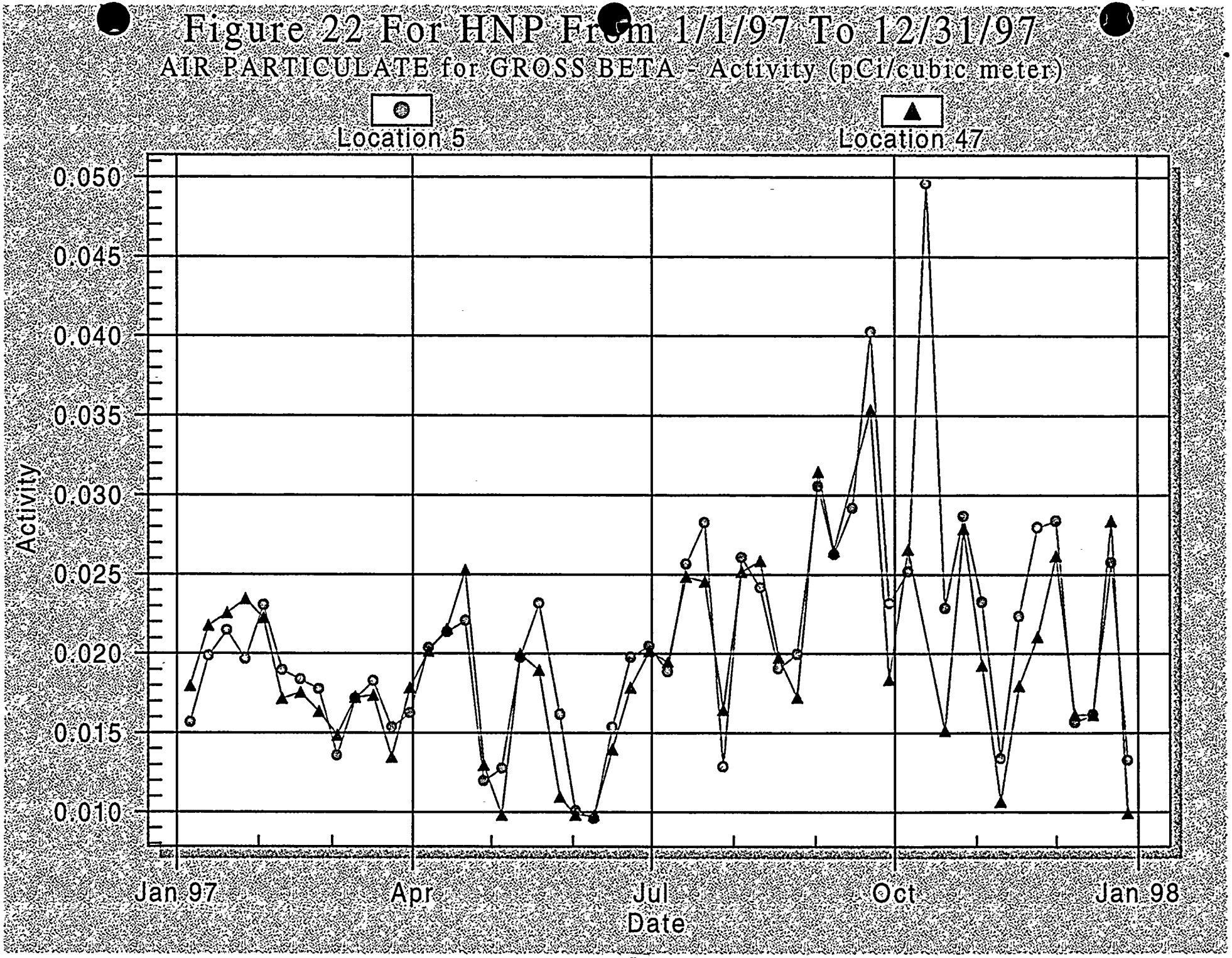

Figure 23 For HNP From 1/1/97 To 12/31/97

DRINKING WATER for GROSS BETA - Activity (pCi/Liter)

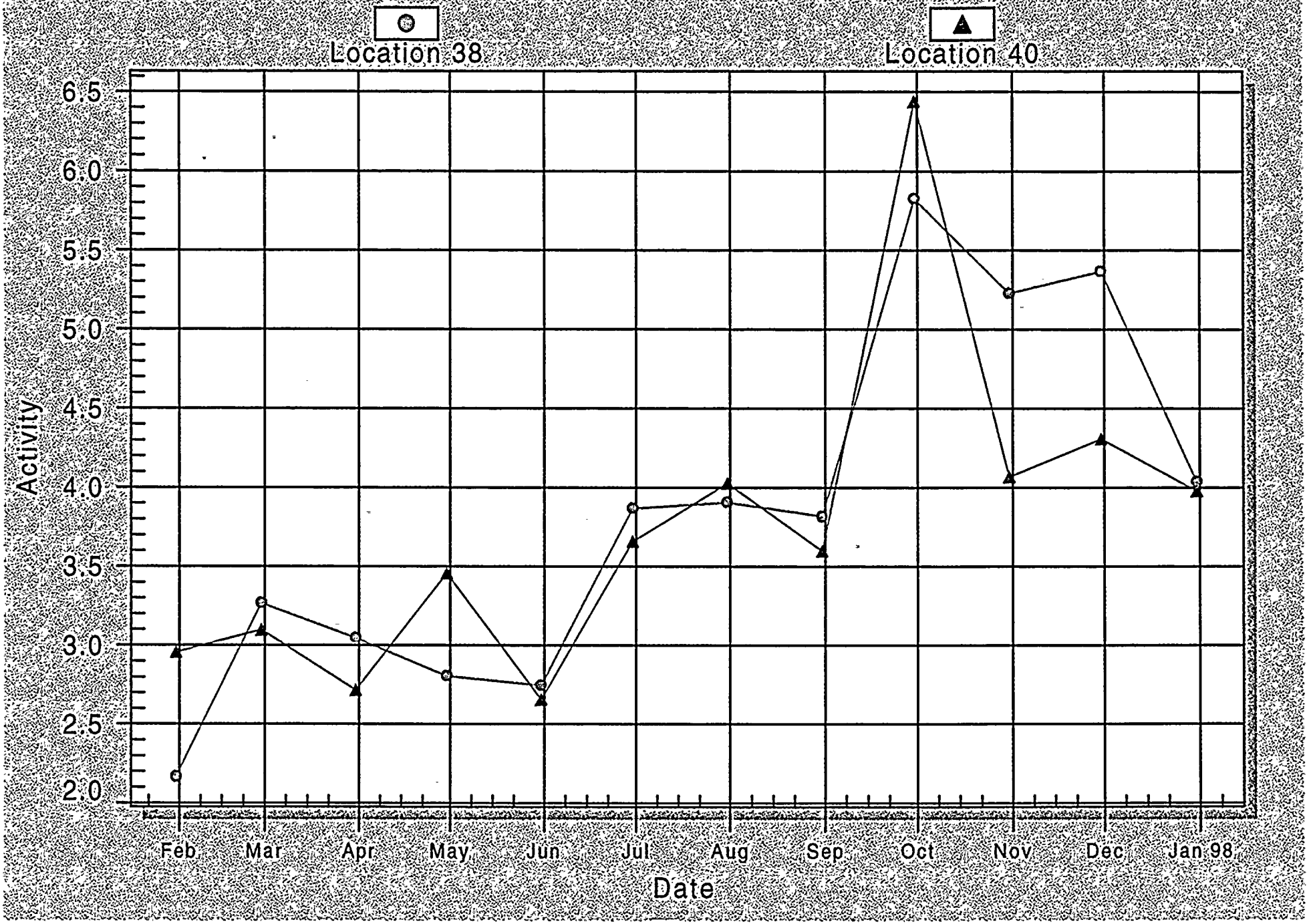

Figure 24 For HNP From 1/1/97 To 12/31/97

SURFACE WATER for GROSS BETA - Activity (pCi/Liter)

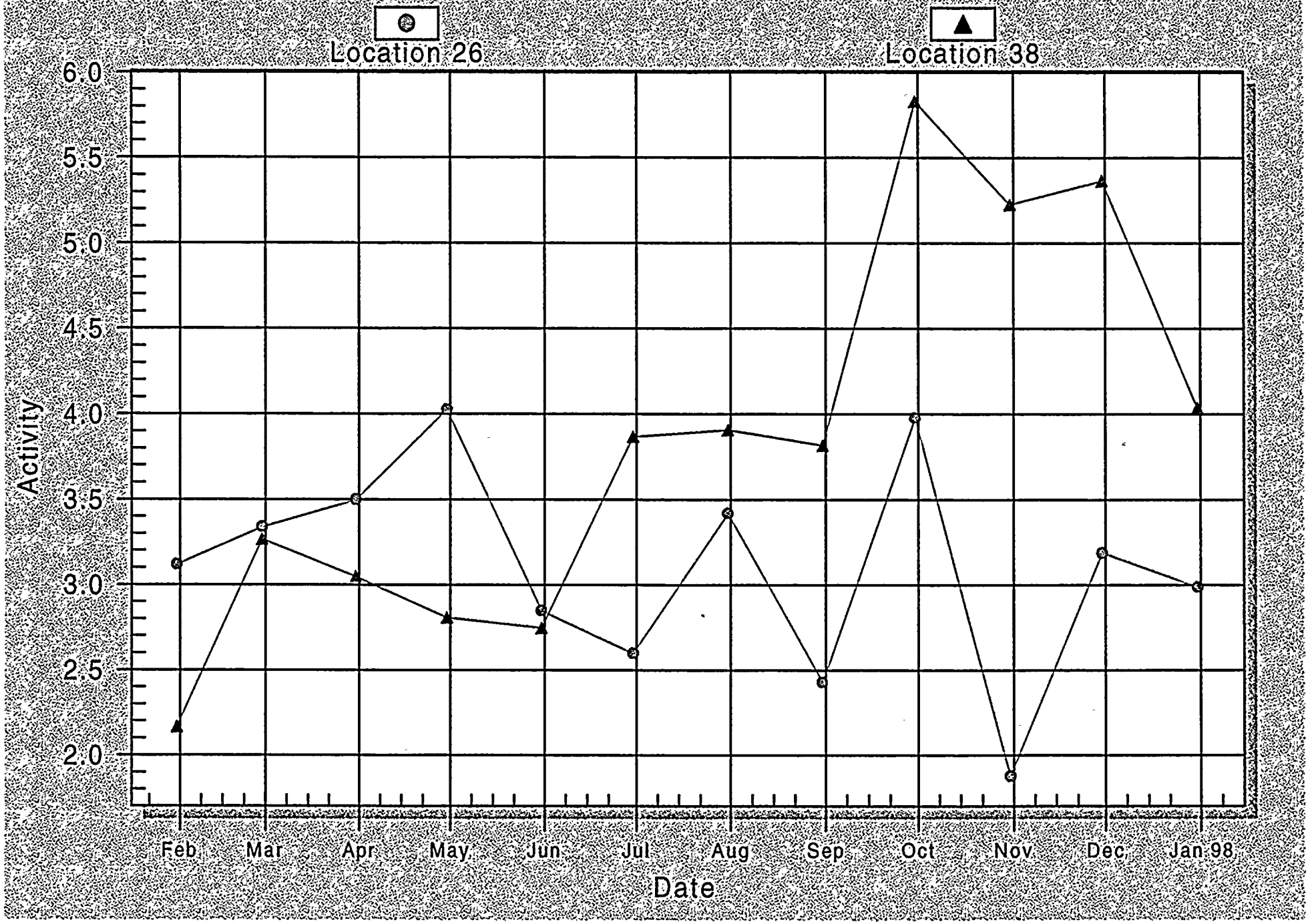

Figure 25 HNP 1997 Surface Water Tritium

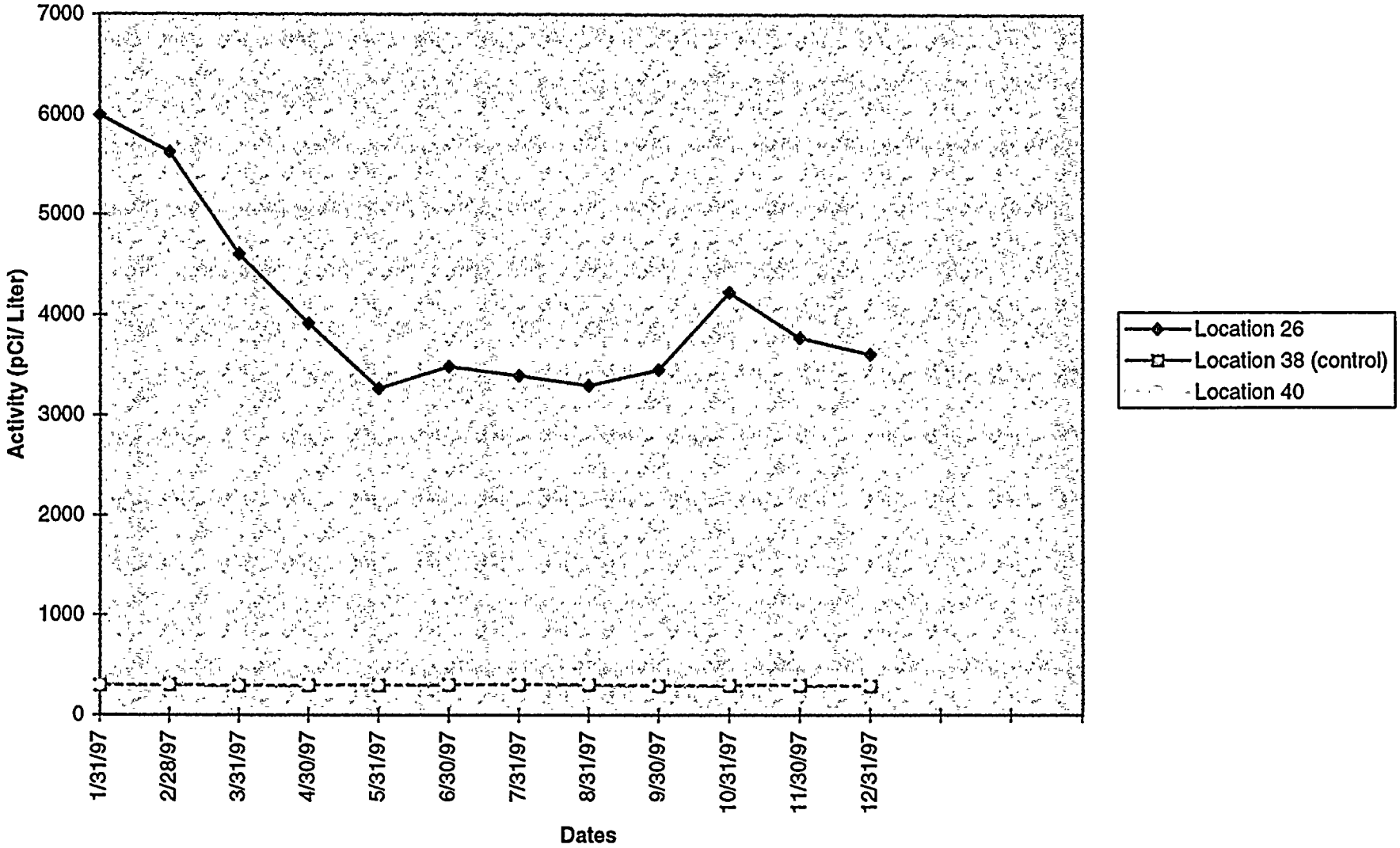

Figure 26 HNP 1997 TLD Averages for Inner and Outer Ring Locations