

# AmerGen

A PECO Energy/British Energy Company

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U. S. Nuclear Regulatory Commission  
Attention: Document Control Desk  
Washington, DC 20555

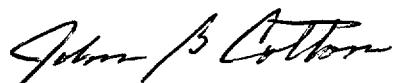
Dear Sir or Madam:

SUBJECT: THREE MILE ISLAND NUCLEAR STATION  
UNITS 1 AND 2 ( TMI-1 & TMI-2 )  
OPERATING LICENSE NO. DPR-50 AND POSSESSION ONLY LICENSE NO. DPR-73  
DOCKET NOS. 50-289 AND 50-320  
1999 RADILOGICAL ENVIRONMENTAL MONITORING REPORT

In accordance with TMI-1 Technical Specification 6.9.3.1 and TMI-2 Technical Specification 6.8.1.1, enclosed is the 1999 Radiological Environmental Monitoring Report for the Three Mile Island Nuclear Station.

Please contact Adam Miller of TMI-1 Regulatory Engineering at (717) 948-8128 if you have any questions regarding this submittal.

Sincerely,

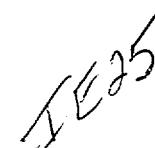


John B. Cotton  
Vice President, TMI Unit 1

JBC/awm

Enclosure

cc: Region I Administrator  
TMI-1 Senior Project Manager  
TMI-2 Project Manager  
TMI Senior Resident Inspector  
GPU Nuclear TMI-2 Cognizant Officer  
File 00011



# Radiological Environmental Monitoring Report

## 1999



Prepared by  
Three Mile Island  
Environmental Affairs

**AmerGen**  
A PECO Energy/British Energy Company

**1999 RADIOLOGICAL ENVIRONMENTAL MONITORING REPORT**

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# LIST OF ABBREVIATIONS, SYMBOLS AND ACRONYMS

**ABBREVIATIONS**

cubic feet per second .....	cfs
cubic meter(s) .....	m <sup>3</sup>
curie(s) .....	Ci
curie(s) per year .....	Ci/yr
east .....	E
east-northeast .....	ENE
east-southeast .....	ESE
gram(s) .....	g
hour(s) .....	h
liter(s) .....	L
meter(s) .....	m
microroentgen(s) per hour .....	µR/h
mile per hour .....	mph
millirem(s) .....	mrem
millirem(s) per hour .....	mrem/h
millirem(s) per standard month .....	mrem/std month
millirem(s) per year .....	mrem/yr
milliroentgen(s) .....	mR
milliroentgen(s) per hour .....	mR/h
milliroentgen(s) per standard month .....	mR/std month
north .....	N
northeast .....	NE
northwest .....	NW
north-northeast .....	NNE
north-northwest .....	NNW
percent .....	%
picocurie(s) .....	pCi
picocurie(s) per cubic meter .....	pCi/m <sup>3</sup>
picocurie(s) per gram .....	pCi/g
picocurie(s) per liter .....	pCi/L
reference(s) .....	Ref. (Refs.)
rem(s) per year .....	rem/yr
Roentgen(s) .....	R
Roentgen(s) equivalent man .....	rem
south .....	S
southeast .....	SE
southwest .....	SW
south-southeast .....	SSE

south-southwest .....	SSW
standard deviation .....	std dev
standard month .....	std month
west .....	W
west-northwest .....	WNW
west-southwest .....	WSW
year(s) .....	yr

**ELEMENT SYMBOLS**

actinium .....	Ac
americium .....	Am
antimony .....	Sb
argon .....	Ar
barium .....	Ba
beryllium .....	Be
carbon .....	C
cesium .....	Cs
chromium .....	Cr
cobalt .....	Co
curium .....	Cm
hydrogen (tritium) .....	H-3
iodine .....	I
iron .....	Fe
krypton .....	Kr
lanthanum .....	La
manganese .....	Mn
niobium .....	Nb
nitrogen .....	N
oxygen .....	O
plutonium .....	Pu
potassium .....	K
radium .....	Ra
radon .....	Rn
silver .....	Ag
strontium .....	Sr
thorium .....	Th
tritiated water vapor .....	HTO
uranium .....	U
xenon .....	Xe
zinc .....	Zn
zirconium .....	Zr

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**ACRONYMS**

Aboveground Tank Monitoring Program .....	ATMP	high efficiency particulate air .....	HEPA
Accident Generated Water.....	AGW	International Committee on Radiation Protection .....	ICRP
AmerGen Energy Company, LLC .....	AmerGen	lower limit of detection .....	LLD
American National Standards Institute .....	ANSI	maximum permissible concentration .....	MPC
Annual Land Use Census .....	ALUC	mean sea level .....	msl
as low as reasonably achievable.....	ALARA	Milton Hershey School .....	MHS
biological effects of atomic radiation .....	BEAR	minimum detectable concentration .....	MDC
biological effects of ionizing radiation .....	BEIR	National Academy of Sciences .....	NAS
borated water storage tank .....	BWST	National Council on Radiation Protection and Measurements .....	NCRP
Building 48 .....	48S	National Institute of Standards and Technology .....	NIST
Department of Energy .....	DOE	National Voluntary Laboratory Accreditation Program .....	NVLAP
East Dike Catch Basin .....	EDCB	Offsite Dose Calculation Manual .....	ODCM
Environmental Measurement Laboratory.....	EML	Operations Support Facility .....	OSF
Environmental Radioactivity Laboratory.....	ERL	Pennsylvania State Bureau of Radiation Protection .....	PaBRP
Federal Radiation Council.....	FRC	Post Defueling Monitored Storage .....	PDMS
Final Safety Analysis Report.....	FSAR	pressurized water reactor .....	PWR
GPU Nuclear, Inc .....	GPU Nuclear	quality assurance .....	QA
Groundwater Monitoring Program.....	GMP	quality control .....	QC

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**ACRONYMS**

radiological environmental monitoring program .....	REMP	United States Nuclear Regulatory Commission .....	USNRC
Red Hill Dam .....	RHD	York Haven Generating Station .....	YHGS
Safe Harbor Dam.....	SHD	York Haven Dam .....	YHD
simplified environmental effluent dosimetry system.....	SEEDS	York Haven Pond.....	YHP
Teledyne Brown Engineering.....	TBE		
thermoluminescent dosimeter.....	TLD		
Three Mile Island.....	TMI		
Three Mile Island Environmental Affairs.....	TMIEA		
Three Mile Island Nuclear Station.....	TMINS		
Three Mile Island - Unit 1 .....	TMI-1		
Three Mile Island - Unit 2 .....	TMI-2		
Title 10 of the Code of Federal Regulations, Part 20 .....	10 CFR 20		
Title 10 of the Code of Federal Regulations, Part 50, Appendix I .....	10 CFR 50 App. I		
Title 40 of the Code of Federal Regulations, Part 190 .....	40 CFR 190		
United Nations Scientific Committee on the Effects of Atomic Radiation.....	UNSCEAR		
United States Environmental Protection Agency.....	USEPA		

## **SUMMARY AND CONCLUSIONS**

The radiological environmental monitoring performed in 1999 by the Environmental Affairs Department at Three Mile Island Nuclear Station (TMINS) is discussed in this report. The environmental sample results and the doses calculated from measured effluents indicated that TMINS operations in 1999 had no adverse effect on the health of the public or the environment.

The operation of a nuclear power station results in the release of small amounts of radioactive materials to the environment. A radiological environmental monitoring program (REMP) has been established to monitor radiation and radioactive materials in the environment around TMINS. The results of environmental measurements are used to assess the impact of TMINS operations, to demonstrate compliance with the TMI-1 and TMI-2 Technical Specifications (Refs. 1 and 2) and applicable Federal and State regulations, and to verify the adequacy of containment and radioactive effluent control systems. The program also evaluates the estimated radiation doses to individuals due to radioactive effluents.

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Summaries and interpretations of the data are published annually in the Radiological Environmental Monitoring Report. Previous reports in this series are referenced at the end of the report (Refs. 3 through 29). Additional information concerning releases of radioactive materials to the environment is contained in the Radiological Effluent Release Reports. These reports are submitted annually to the United States Nuclear Regulatory Commission (USNRC).

Many of the radioactive materials discussed in this report are normally present in the environment, either from natural processes or as a result of non-TMINS activities such as past atmospheric nuclear weapon tests and medical industry activities. To determine the impact of TMINS operations, if any, on the environment and the public, results from samples collected close to TMINS (indicator stations) are compared to results from samples obtained at distant sites (control or background stations). Comparisons with historical data also are performed, as appropriate.

During 1999, samples of air, surface, effluent, drinking and storm water, sediments, fruits, vegetables, grains, fish, groundwater and milk were collected. Direct radiation exposures also were measured in the vicinity of TMINS. Samples were analyzed for gross beta and gross alpha radioactivity, tritium (H-3), strontium-89 (Sr-89) and strontium-90 (Sr-90), iodine-131 (I-131) and/or gamma-emitting radionuclides. The results are discussed in the various sections of this report. Additionally, radiological impacts in terms of radiation dose as a result of TMINS radioactive releases were calculated and are

discussed in this report (**Radiological Impact of TMINS Operations and Appendix I**).

The results provided in this report are summarized in the following highlights:

- In 1999, 1324 samples were collected from the aquatic, atmospheric and terrestrial environments around TMINS. There were 2047 analyses performed on these samples. Also, 2085 radiation exposure measurements were taken using thermoluminescent dosimeters (TLDs). Finally, 420 groundwater samples were collected and 459 analyses were performed on these samples. The monitoring performed in 1999 met or exceeded the sample collection and analysis requirements of the TMI-1 and TMI-2 Technical Specifications.
- In addition to natural radioactivity, low concentrations of radionuclides such as H-3, Sr-90, cesium-137 (Cs-137) and I-131 were detected in some media and were attributed to either fallout from prior nuclear weapon tests, the medical industry or TMINS operations.
- As a result of routine TMINS operations, the raw surface water collected downstream of the TMINS liquid discharge outfall typically had H-3 concentrations greater than those detected in control samples. This was expected because H-3 was released in liquid effluents and the samples were collected at a location where mixing of liquid effluents with Susquehanna River water was incomplete. Although raw water is not consumed by humans, all of the measured concentrations were well below the United

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States Environmental Protection Agency's (USEPA) Primary Drinking Water Standard of 20,000 picocuries per liter (pCi/L).

- Several indicator drinking water samples contained H-3 at concentrations above those detected in control samples. A portion of the H-3 measured in the indicator samples was attributed to routine operations at TMINS. Like surface water, the H-3 concentrations measured in drinking water were well below the standard established by the USEPA.
- Very low concentrations of H-3 were detected in indicator fish samples as a result of routine TMINS operations. Its presence was not unexpected because H-3 was released in liquid effluents and the indicator fish samples were collected in a zone where mixing of effluents and river water was incomplete. The hypothetical whole body dose from consuming fish flesh at the measured concentrations was insignificant and a small fraction of the dose received from natural background radiation.
- Low concentrations of TMINS-related Cs-137 were detected in aquatic sediments collected proximal to or just downstream of the TMINS liquid discharge outfall. During 1999, as well as in previous years, this material was routinely released in TMINS liquid effluents. Additionally, Cs-137 is readily adsorbed by suspended particles in the water column and bottom sediments. Since Cs-137 also was detected in the control samples, a portion of the Cs-137 measured in the indicator
- samples was attributed to fallout from prior nuclear weapon tests.
- Groundwater samples collected from the onsite monitoring wells, the industrial wells and the clearwell contained H-3 above ambient concentrations as a result of routine operations at TMI-1 and past operations at TMI-2. Additionally, two pipe leaks caused elevated levels of H-3 in certain onsite wells. Both pipes were repaired. All H-3 concentrations detected in onsite groundwater were below the effluent concentration specified in USNRC 10 CFR 20 (Appendix B, Table 2).
- Tritium was detected in onsite groundwater used for drinking. The presence of H-3 in these samples was attributed to routine TMI-1 operations and possibly past TMI-2 operations. All of the H-3 concentrations measured in onsite drinking water were a small fraction (< 5 percent) of the USEPA Primary Drinking Water Standard.
- Gamma radiation exposure rates recorded at the offsite indicator TLD stations averaged 58 milliroentgens per year (mR/yr), respectively. Offsite controls were similar, averaging 64 mR/yr. The exposure rates were consistent with those presented by the National Council on Radiation Protection and Measurements (Ref. 30). No significant increase in ambient gamma radiation levels was detected.
- During 1999, small amounts of radioactive materials were released in TMI-1 and TMI-2 liquid and gaseous effluents. Excluding H-3, the amount of radioactive

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material released from TMI-1 was one of the lowest in plant operating history. This achievement was attributed to good fuel integrity, minimal leakage in the steam generators and improved efficiency of the waste processing systems. Tritium, because of its chemical and physical properties, can not be removed practically from water or air.

- The calculated doses to the public from TMINS operations in 1999 were well below all applicable regulatory limits and significantly less than doses received from other common sources of radiation. The hypothetical maximum whole body dose potentially received by an individual from 1999 TMI-1 and TMI-2 liquid and airborne effluents combined was conservatively calculated to be 0.166 mrem. This dose is equivalent to 0.0553 percent of the dose that an individual living in the TMI area receives each year from natural background radiation.
- The hypothetical maximum whole body dose to the surrounding population from all 1999 liquid and airborne effluents was calculated to be 11.8 person-rem. This dose is equivalent to 0.00179 percent of the dose that the total population living within 50 miles of TMI receives each year from natural background radiation.

In conclusion, radioactive materials related to TMINS operations were detected in environmental samples, but the measured concentrations were low and consistent with measured effluents. The environmental sample results verified that the doses received by the public from TMINS effluents in 1999 were well below applicable dose limits and

only a small fraction of the doses received from natural background radiation. Additionally, the results indicated that there was no permanent buildup of radioactive materials in the environment and no significant increase in background radiation levels.

Therefore, based on the results of the radiological environmental monitoring program (REMP) and the doses calculated from measured effluents, TMINS operations in 1999 did not have any adverse effects on the health of the public or on the environment.

## **INTRODUCTION**

### **Characteristics of Radiation**

Instability within the nucleus of radioactive atoms results in the release of energy in the form of radiation. Radiation is classified according to its nature -- particulate and electromagnetic. Particulate radiation consists of energetic subatomic particles such as electrons (beta particles), protons, neutrons, and alpha particles. Because of its limited ability to penetrate the human body, particulate radiation in the environment contributes primarily to internal radiation exposure via inhalation and ingestion.

Electromagnetic radiation in the form of x-rays and gamma rays has characteristics similar to visible light but is more energetic and, hence, more penetrating. Although x-rays and gamma rays are penetrating and can pass through varying thicknesses of materials, once they are absorbed they produce energetic electrons which release their energy in a manner that is identical to beta particles. The principal concern for gamma radiation in the environment is their contribution to external radiation exposure.

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Atoms of radioactive elements disintegrate continually. The rate that atoms undergo disintegration (radioactive decay) varies among radioactive elements, but is uniquely constant for each specific radionuclide (or radioactive isotope). The term "half-life" defines the time it takes for the activity of a radionuclide to decay to one half of its original activity. Half-lives can vary from a fraction of a second for some radionuclides to millions of years for others. In fact, the natural background radiation that all mankind has been exposed to is largely due to the radionuclides of uranium (U), thorium (Th), and potassium (K). These radioactive elements were formed with the creation of the universe and, owing to their very long half-lives, will continue to be present for millions of years to come. For example, potassium-40 (K-40) has a half-life of 1.3 billion years and exists naturally within our bodies. As a result, approximately 4000 atoms of potassium emit radiation internally within each of us every second of our lives.

In assessing the impact of radioactivity on the environment, it is important to know the quantity of radioactivity released and the resultant radiation doses. The common unit of radioactivity is the curie (Ci). It represents the radioactivity in one gram (g) of natural radium (Ra), which is also equal to a decay rate of 37 billion radiation emissions every second. Because extremely small amounts of radioactive material exist in the environment, it is more convenient to use fractions of a curie. Subunits like picocurie, pCi, (one trillionth of a curie) are frequently used to express the radioactivity present in environmental and biological samples.

The biological effects of radiation to the entire human body (whole body equivalent dose) are the same whether the radiation source is external or internal to the body. The important factor is how much radiation energy or dose is deposited. The unit of radiation dose is the Roentgen equivalent man (rem), which also incorporates the variable effectiveness of different forms of radiation to produce biological change. For environmental radiation exposures, it is convenient to use millirem (mrem) to express dose (1000 mrem equals 1 rem). When radiation exposure occurs over periods of time, it is appropriate to refer to the dose rate. Dose rates, therefore, define the total dose for a fixed interval of time. Environmental radiation exposures are usually expressed with reference to one year (mrem/yr).

### **Sources of Radiation**

Life on earth has evolved amid the constant exposure to natural radiation. In fact, the single major source of radiation to which the general population is exposed comes from natural sources. Although everyone on the planet is exposed to natural radiation, some people receive more than others. Radiation exposure from natural background has three components (i.e., cosmic, terrestrial, and internal) and varies with altitude, geographic location and living habits.

For example, cosmic radiation originating from deep interstellar space and the sun increases with altitude, since there is less air which acts as a shield. Similarly, terrestrial radiation resulting from the presence of naturally-occurring radionuclides in the soil and rocks varies and may be significantly

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higher in some areas of the country than in others. Even the use of particular building materials for houses, cooking with natural gas, and home insulation affect exposure to natural radiation.

The presence of radioactivity in the human body results from the inhalation and ingestion of air, food, and water containing naturally-occurring radionuclides. For example, drinking water contains trace amounts of uranium and radium and milk contains radioactive potassium. Table 1 summarizes the common sources of radiation and their average annual doses.

The average person in the United States receives about 300 mrem/yr from natural

background radiation sources (Ref 30). This estimate was revised from about 100 to 300 mrem because of the inclusion of radon gas which was always present but was not previously included in the calculations.

In some regions of the country, the amount of natural radiation is significantly higher. Residents of Colorado, for example, receive an additional 60 mrem/yr due to the increase in cosmic and terrestrial radiation levels. In fact, for every 100 feet above sea level, a person will receive an additional 1 mrem/yr from cosmic radiation. In several regions of the world, naturally high concentrations of uranium and radium deposits result in doses of several thousand mrem/yr to their residents (Ref. 31).

**TABLE 1**

**Sources and Doses of Radiation\***

Natural (82%)		Manmade (18%)	
<u>Source</u>	Radiation Dose (mrem/yr)	<u>Source</u>	Radiation Dose (mrem/yr)
Radon	200 (55%)	Medical X-rays	39 (11%)
Cosmic rays	27 (8%)	Nuclear Medicine	14 (4%)
Terrestrial	28 (8%)	Consumer products	10 (3%)
Internal	40 (11%)	Other	<1 (<1%)
APPROXIMATE		(Releases from nat. gas, phosphate mining, burning of coal, weapons fallout, & nuclear fuel cycle)	
TOTAL	300	APPROXIMATE	
		TOTAL	60

\* Percentage contribution of the total dose is shown in parentheses.

Source: Ref. 30

Recently, public attention has focused on radon (Rn), a naturally-occurring radioactive gas produced from uranium and radium decay. These elements are widely distributed in trace amounts in the earth's crust.

Unusually high concentrations have been found in certain parts of eastern Pennsylvania and northern New Jersey. Radon levels in some homes in these areas are hundreds of times greater than levels found elsewhere in the United States. However, additional surveys are needed to determine the full extent of the problem nationwide.

Radon is the largest component of natural background radiation and may be responsible for a substantial number of lung cancer deaths annually. The National Council on Radiation Protection and Measurements (NCRP) estimates that the average individual in the United States receives an annual dose of about 2,400 mrem to the lung from natural radon gas (Ref. 30). This lung dose is considered to be equivalent to a whole body dose of 200 mrem. The NCRP has recommended actions to control indoor radon sources and reduce exposures.

When radioactive substances are inhaled or swallowed, they are not uniformly distributed within the body. For example, radioactive iodine selectively concentrates in the thyroid gland, radioactive cesium is distributed throughout the body water and muscles, and radioactive strontium concentrates in the bones. The total dose to organs by a given radionuclide also is influenced by the quantity inhaled or ingested, the duration of time that it remains in the body and its physical, biological and chemical characteristics. Depending on their rate of radioactive decay and biological elimination from the body,

some radionuclides stay in the body for very short times while others remain for years.

In addition to natural radiation, we are exposed to radiation from a number of manmade sources. The single largest source comes from diagnostic medical x-rays, and nuclear medicine procedures. Some 180 million Americans receive medical x-rays each year. The annual dose to an individual from such radiation averages about 53 mrem. Much smaller doses come from nuclear weapon fallout and consumer products such as televisions, smoke detectors, and fertilizers. Production of commercial nuclear power and its associated fuel cycle contributes less than 1 mrem to the annual dose of about 360 mrem for the average individual living in the United States.

Fallout commonly refers to the radioactive debris that settles to the surface of the earth following the detonation of a nuclear weapon. It is dispersed throughout the environment either by dry deposition or washed down to the earth's surface by precipitation. There are approximately 200 radionuclides produced in the nuclear weapon detonation process. A number of these are detected in fallout. The fallout radionuclides that produce most of the radiation exposures to humans are I-131, Sr-89, Cs-137, and Sr-90. There has been no atmospheric nuclear weapon testing since 1980 and many of the radionuclides, still present in our environment, have decayed significantly. Consequently, doses to the public from fallout have been decreasing.

As a result of the nuclear accident at Chernobyl, Ukraine, on April 26, 1986, radioactive materials were dispersed

throughout the environment and detected in various environmental media such as air, milk, and soil. Cesium-134, Cs-137, I-131 and other radionuclides were detected in the weeks following the Chernobyl accident.

### **Nuclear Reactor Operations**

Common to the commercial production of electricity is the consumption of fuel to produce heat and steam. The steam drives the turbine which generates electricity. Unlike the burning of coal, oil, or gas in fossil-fuel powered plants to generate heat, the fuel of most nuclear reactors is comprised of the element uranium in the form of uranium oxide. The fuel produces heat by the process called fission.

In fission, the uranium atom absorbs a neutron (an atomic particle found in nature and also produced by the fissioning of uranium in the reactor) and splits to produce smaller atoms termed fission products, along with heat, radiation and free neutrons. The free neutrons travel through the reactor and are similarly absorbed by the uranium, permitting the fission process to continue.

As this process continues, more fission products, radiation, heat and neutrons are produced and a sustained reaction occurs. The heat produced is transferred – via the reactor coolant water - from the fuel to produce steam. The steam drives a turbine generator to produce electricity. Most of the fission products are radioactive. That is, they are unstable atoms that emit radiation as they decay to stable atoms. Neutrons which are not absorbed by the uranium fuel may be absorbed by stable atoms in the materials which make up the components and

structures of the reactor. In such cases, stable atoms often become radioactive. This process is called activation and the radioactive atoms which result are called activation products.

The TMINS reactors (TMI-1 and TMI-2) are pressurized water reactors (PWR). Only TMI-1 is an operating reactor. At the end of 1993, TMI-2 was placed in a condition called Post-Defueling Monitored Storage (PDMS). As the name implies, TMI-2 will continue to be monitored until operations at TMI-1 cease. At that time, both TMI-1 and TMI-2 will be decommissioned.

The nuclear fuel used in an operating reactor such as TMI-1 is contained within sealed fuel rods arranged in arrays called bundles. The bundles are located within a massive steel reactor vessel. Pressurized water reactors utilize steam generators to transfer the heat of the coolant water to the secondary steam loop. Thus, the steam generators serve as a boundary between the radioactive primary loop and the secondary steam loop.

As depicted in Figure 1, heat is added to the water as it is pumped around and through the fuel bundles in the reactor vessel. The hot primary coolant then passes inside thousands of sealed tubes within the steam generator. Heat is transferred through the tube walls into the secondary water which flows around the tubes, thereby creating steam for use in the turbine. After the energy is extracted from the steam in the turbine, it is cooled and condensed back into water by a third loop which circulates water between the condenser and the cooling towers.

Several hundred radionuclides of some 40 different elements are created during the process of generating electricity. And, because of reactor engineering designs, the short half-lives of many radionuclides, and their chemical and physical properties, nearly all radioactivity is contained.

Pressurized water reactors have five independent barriers that confine radioactive materials given off by the reactor fuel as it heats the water. Under normal operating conditions, essentially all radioactivity is contained within the first two barriers.

The ceramic uranium fuel pellets provide the first barrier. Most of the fission products are either trapped or chemically bound in the fuel where they remain. However, a few fission products that are volatile or gaseous at normal operating temperatures may not be contained in the fuel.

The second barrier consists of zirconium (Zr) alloy tubes (cladding) that resist corrosion and high temperatures. The fuel pellets are contained within these tubes. There is a small gap between the fuel and the cladding, in which the noble gases and other volatile radionuclides collect and are contained.

The primary coolant water is the third barrier. Many of the fission products, including radioactive iodine, strontium and cesium are soluble and are retained in water in an ionic (electrically charged) form. These materials can be removed in the primary coolant purification system. However, krypton (Kr) and xenon (Xe) do not readily dissolve in the coolant, particularly at high temperatures. Krypton and xenon collect as a gas above the coolant when the water is depressurized.

The fourth barrier consists of the reactor pressure vessel and the steel piping of the primary coolant system. The reactor pressure vessel is a 36-foot high tank with steel walls about 9 inches thick. It encases the reactor core. The remainder of the primary coolant system includes the pressurizer, steam generators and associated piping. This system provides containment for radioactivity in the primary coolant.

The reactor building (or containment building) provides the fifth barrier. It has steel-lined concrete walls about 4 feet thick that enclose the reactor pressure vessel and the primary coolant system.

#### **Sources of Liquid and Airborne Effluents**

Although the previously described barriers contain radioactivity with high efficiency, small amounts of radioactive fission products diffuse or migrate through minor flaws in the fuel cladding and into the primary coolant. Trace quantities of reactor system component and structure surfaces that have been activated also get into the primary coolant water. Many of the soluble fission and activation products such as iodines, strontiums, cobalts, and cesiums are removed by demineralizers in the purification system of the primary coolant. The physical and chemical properties of noble gas fission products in the primary coolant prevent their removal by the demineralizers.

Because the reactor system has many valves and fittings, an absolute seal cannot be achieved. Small amounts of noble gases and trace quantities of residual fission and activation products have the potential for escape into the reactor building and

associated buildings. A portion of the airborne effluents comes from the atmosphere around the primary coolant system, which receives steam and liquid leakage from valves and pumps on systems carrying primary coolant. Environmental release of airborne radioactivity is reduced by simply holding the radioactivity inside the reactor building for a period of time which allows for the natural radioactive decay of some radionuclides. Radioactive gases from purification systems also contribute to airborne effluents and are collected and stored in tanks for radioactive decay before being released.

Airborne effluents pass through a two-stage filtration system prior to environmental release. High efficiency particulate air (HEPA) filters effectively remove radionuclides such as strontium and cesium with a 99 percent (%) efficiency. Activated charcoal filters remove radioiodines with a 90 to 95 % efficiency. Noble gases and tritium, however, cannot be removed by either of these filtration processes because of their chemical and physical properties.

Ventilation systems throughout the plant are designed to maintain a negative pressure (suction) with respect to the outside atmosphere. This pressure differential assures that all building air and air exhausted from potentially radioactive areas of the buildings is filtered by HEPA and charcoal filters prior to release to the environment.

Liquid wastes are generated from the primary coolant purification system and from small amounts of liquids which escape from valves, piping, and equipment associated with the primary coolant system during normal operations. Liquids are treated using filters,

demineralizers, and evaporators to remove radioactivity from the water prior to release. Purified water is reused or released to the river and the processed wastes are concentrated for offsite burial at approved, licensed facilities. Tritium, because of its chemical behavior, is not removed from liquid wastes.

As a result of minor leakage in the steam generators, small amounts of radioactive materials are present in the secondary (steam loop) water. Although not all of the water is treated, all of the water is monitored and diluted with nonradioactive water prior to being released.

Operations at TMINS are conducted such that releases of liquid and gaseous wastes are a small percentage of the Federal limits. Consequently, the doses associated with these releases are a small fraction of the dose limits established by the Federal Government.

# AmerGen Three Mile Island Nuclear Station

A PECO Energy/British Energy Company

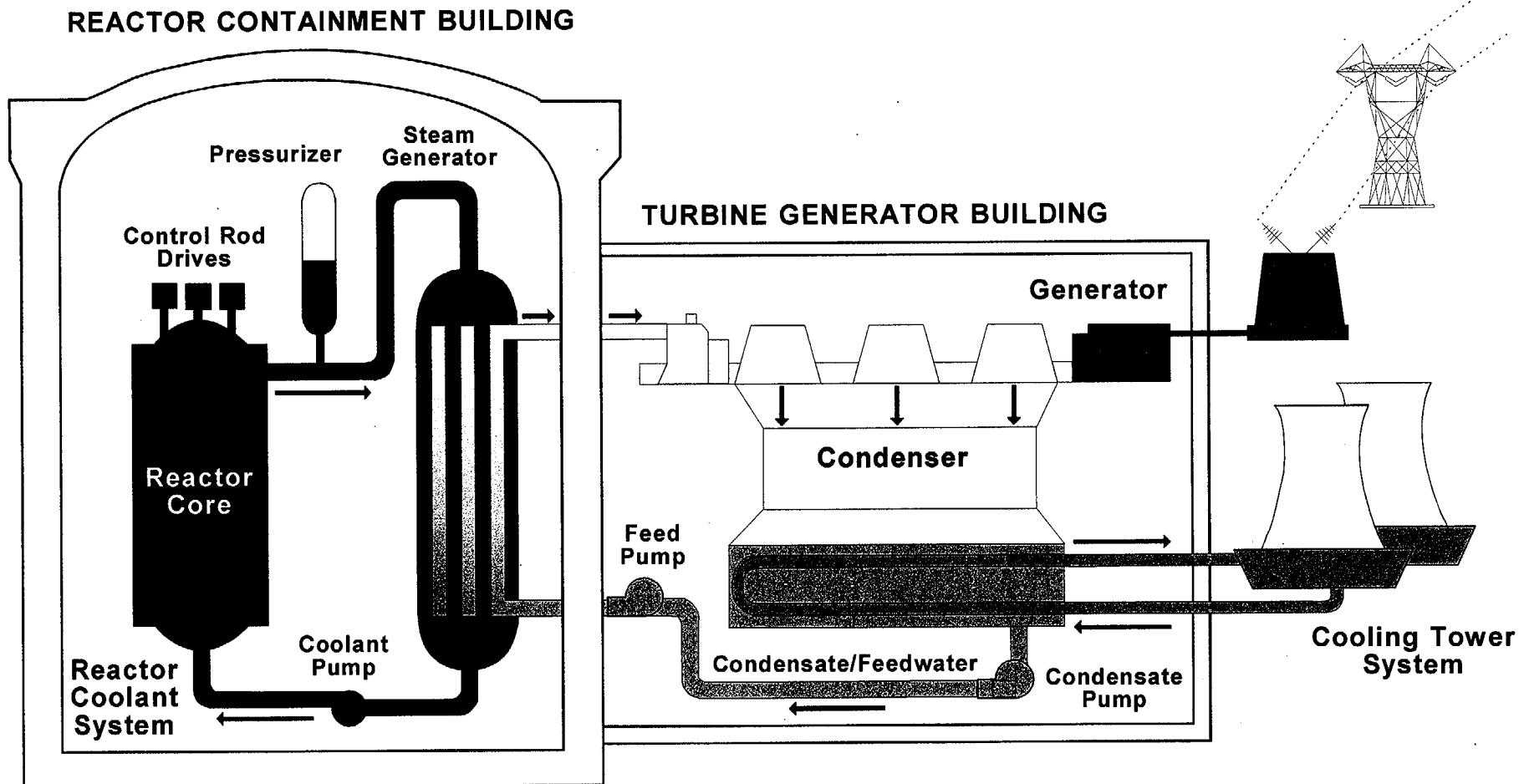


Figure 1

## **DESCRIPTION OF THE TMINS SITE**

### **General Information**

Three Mile Island (TMI) is located in Londonderry Township of Dauphin County, Pennsylvania. It lies approximately 2.5 miles north of the southern tip of the county, where the county borders of Dauphin, Lancaster, and York converge. The Island is part of an 814 acre tract of land which encompasses TMI and several adjacent islands in the Susquehanna River (Refs. 32 and 33). Aligned north to south, TMI is approximately 11,000 feet long and 1700 feet wide. The eastern and western riverbanks are 900 and 6500 feet, respectively, from TMI. Covering about 200 acres of land, Three Mile Island Nuclear Station (TMINS) is situated on the northern one-half of TMI.

The Island is relatively flat with elevations ranging from about 280 feet above mean sea level (msl) at the water's edge to slightly more than 300 feet above msl in the north-central portion. The topography of the area immediately surrounding TMI is characterized by rolling terrain which slopes to the river valley floor. The hills within a two mile radius have a maximum relief of about 200 feet with the highest elevation seldom exceeding 500 feet above msl. The Susquehanna River at the site drains a watershed area of approximately 25,000 square miles.

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With the exception of the southern border of TMI, the Island is bounded by the part of the Susquehanna River known as York Haven Pond or Lake Frederick. The pond, which is 1.5 miles wide at the site, is formed by the York Haven and Red Hill Dams. Three Mile Island and Shelley Island divide the river into three main channels. Several lesser channels also are formed by smaller islands.

The historical average annual flow of the Susquehanna River in the TMI region is 34,000 cubic feet per second (cfs). During 1999, the annual average flow was lower than the historical average. The flow in 1999 averaged about 24,683 for the TMI region with monthly averages ranging from 4,503 cfs in July to 54,134 cfs in April. The maximum flow was recorded in January at 213,333 cfs (Ref. 34). The historical average annual maximum flow is about 300,000 cfs while the minimum daily flow recorded for the region is 1,700 cfs (Ref. 32). A flood protection dike completely surrounds TMINS and was designed based upon a flow of 1,100,000 cfs. For comparison, the maximum flow/flood of record occurred in June 1972 as a result of tropical storm "Agnes". This event produced a flow of 1,020,000 cfs.

Present uses of the Susquehanna River include public and industrial water supply, power generation, and recreation such as boating, swimming and fishing. While there are no commercial fisheries on the Susquehanna River in the TMI region, recreational fisherman catch several different sporting species that inhabit the River. Three of the more prevalent sporting fishes in the vicinity of TMI include Smallmouth bass, Channel catfish and Walleye.

Based on 1990 census data (Ref. 35), approximately 175,000 people reside within a ten-mile radius of TMINS. The nearest

population center is Goldsboro with a population of 458 people. It lies approximately one mile to the west of the site. About 2.5 miles to the north, 9,254 people reside in the town of Middletown. Harrisburg, situated 12 miles to the northwest, is the nearest major city with a population of 52,376. Land within a 10 mile radius of the site is used primarily for farming. Farm products include poultry, meat, fruit, dairy products, vegetables, corn, wheat, alfalfa, tobacco, and other crops of lesser importance.

### **Climatological Summary - 1999\***

The Appalachian Mountains, located about 20 miles to the north of TMI, protect the area somewhat from the cold winter outbreaks of Arctic air that invade central and western Pennsylvania. However, the site is too far inland to derive the full benefits of a coastal climate like that in the more southeastern region of Pennsylvania. Summers tend to be warm and humid and winters are cool, with frequent periods of precipitation. Summer rainfall typically comes from thunderstorm activity, while most of the precipitation in the winter is a result of coastal winter storms. Normal yearly precipitation (water equivalent) for the TMI region is 40.5 inches. Winds primarily are from the northwesterly direction.

During 1999, the winds blew from the west-northwest (WNW), the northwest (NW) and the north-northwest (NNW) approximately 36 percent of the time.

#### **\*Sources:**

- 1) Onsite Meteorological Data.
- 2) National Climatic Data Center, Asheville, NC
- 3) National Weather Service, State College, PA

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The annual average wind speed during 1999 in the TMI region was about 8.9 miles per hour (mph). Monthly averages ranged from 7.1 mph in August to 13.0 mph in March (Ref. 36).

During 1999, the average monthly temperatures ranged from 30.7°F (January) to 81.9°F (July). The maximum monthly deviation occurred in July when the temperatures averaged 6.2°F above the normal monthly temperature. The lowest temperature of the year occurred on January 6 (7°F). The highest temperature was recorded on July 6 (102°F). The overall annual average temperature was about 55.6°F which is about 2.7°F above the normal annual average temperature (normal dry bulb). For the TMI area, 1999 was the third warmest year on record. The only warmer years were 1998 which had an average temperature of 56.5 and 1991 which averaged 55.6.

A total of 43.0 (water equivalent) inches of precipitation was recorded at TMI during 1999. This amount was about 2.5 inches above the normal total. Monthly precipitation totals ranged from a low of about 1.5 inches in November to a high of 10.4 inches in September. The amount of precipitation that fell in September exceeded the normal total for the month by approximately 6.9 inches.

The greatest 24-hour precipitation event in the region occurred on September 15 and 16 when about 3.5 inches of rain fell. The year's greatest snowfall event (8.3 inches) in the region was recorded on March 14. The greatest snowfall month also was March. A total snowfall of 10.6 inches was recorded for the month. The annual snowfall totaled 19.4 inches.

The year was characterized by below normal snowfall, the warmest July on record and the

third warmest November on record. A drought, which was the worst since the early 1960's, dominated much of the summer and early fall. The drought was finally broken by two tropical systems which reversed the dry conditions and caused flooding in September.

A summary of wind and dispersion information (a wind rose and joint frequency tables) for the TMINS site is provided in Appendix K. This information is normally generated from data obtained from the TMINS meteorological tower. When real-time data are not available or invalid, default values are entered into the database. The default values are consistent with actual meteorology for the TMI vicinity. During 1999, a total of 269 hours of real-time data (3.2%) were not available or invalid. This was mainly due to computer interface problems during conversion to a new Y2K compliant system and to several electric storms during the year which rendered some of the equipment inoperable or inaccurate.

## **EFFLUENTS**

### **Historical Background**

Almost from the outset of the discovery of x-rays in 1895 by Wilhelm Roentgen, the potential hazard of ionizing radiation was recognized and efforts were made to establish radiation protection standards. The International Commission on Radiological Protection (ICRP) and the NCRP were established in 1928 and 1929, respectively. These organizations have the longest continuous experience in the review of radiation health effects and with making recommendations on guidelines for radiological protection and radiation exposure limits.

In 1955, the United Nations created a Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) to summarize reports received on radiation levels and the effects on man and his environment. The National Academy of Sciences (NAS) formed a committee in 1956 to review the biological effects of atomic radiation (BEAR). A series of reports have been issued by this and succeeding NAS committees on the biological effects of ionizing radiation (BEIR), the most recent being 1990 (known as BEIR V).

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These committees and commissions of nationally and internationally recognized scientific experts have been dedicated to the understanding of the health effects of radiation by investigating all sources of relevant knowledge and scientific data and by providing guidance for radiological protection. Their members are selected from universities, scientific research centers and other national and international research organizations. The committee reports contain scientific data obtained from physical, biological, and epidemiological studies on radiation health effects and serve as scientific references for information presented in this report.

Since its inception, the USNRC has depended upon the recommendations of the ICRP, the NCRP, and the Federal Radiation Council (FRC), incorporated in the USEPA in 1970, for basic radiation protection standards and guidance in establishing regulations for the nuclear industry (Refs. 37 through 40).

### **Effluent Release Limits**

As part of routine operations at a nuclear power station, limited quantities of radioactive materials are released to the environment in liquid and airborne effluents. At TMINS, an effluent control program is implemented to ensure that the amounts of radioactive materials released to the environment are minimal and do not exceed release limits.

The Federal government establishes limits on radioactive materials released to the environment. Regulated by the USNRC, these limits are set at levels to protect the health and safety of the public. They are specified in the Technical Specifications for

TMI-1 and TMI-2 and the Offsite Dose Calculation Manual, ODCM, (Ref. 41). Operations are conducted such that releases of radioactive effluents are a small percentage of the Federal limits.

A recommendation of the ICRP, NCRP, and FRC is that radiation exposures should be maintained at levels which are "as low as reasonably achievable" (ALARA) and commensurate with the societal benefit derived from the activities resulting in such exposures. For this reason, dose limit guidelines were established by the USNRC for releases of radioactive effluents from nuclear power plants. These guidelines are presented in Title 10 of the Code of Federal Regulations, Part 50, Appendix I (10 CFR 50, App. I). Maintaining doses within these operational guidelines demonstrates that releases of radioactive effluents are being maintained "as low as reasonably achievable". These USNRC ALARA guidelines are a fraction of the dose limits established by the USEPA.

The USNRC 10 CFR 50, App. I guidelines are as follows:

- The dose to a member of the public from radioactive materials released in liquid effluents is limited to  $\leq 3$  mrem/yr to the total body or  $\leq 10$  mrem/yr to any organ.
- The air dose due to noble gases at a location which would be occupied by a member of the public is limited to  $\leq 10$  mrad/yr for gamma radiation or  $\leq 20$  mrad/yr for beta radiation.
- The dose to a member of the public from noble gases released in gaseous effluents is

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limited to  $\leq$  5 mrem/yr to the total body or  $\leq$  15 mrem/yr to the skin.

- The dose to a member of the public from airborne iodines, tritium and particulates is limited to  $\leq$  15 mrem/yr to any organ.

The USEPA dose limits as defined in Title 40 of the Code of Federal Regulations, Part 190 (40 CFR 190), are as follows:

- The dose to a member of the public shall not exceed in a year 25 mrem/yr to the total body, 75 mrem/yr to the thyroid, and 25 mrem/yr to any other organ as a result of uranium fuel cycle operations.

### **Effluent Control Program**

Effluent control includes plant components such as the ventilation system and filters, waste gas holdup tanks, demineralizers and evaporator systems. In addition to minimizing the release of radioactivity, the effluent control program includes all aspects of effluent monitoring. This includes the operation and data analysis associated with a complex radiation monitoring system, collection and analysis of effluent samples, and a comprehensive quality assurance (QA) program. Over the years, the program has evolved in response to changing regulatory requirements and plant conditions. For example, additional instruments and samplers have been installed to ensure that measurements of effluents remain onscale in the event of any accidental release of radioactivity.

**Effluent Instrumentation:** Liquid and airborne effluent measuring instrumentation is designed to monitor the presence and the

amount of radioactivity in effluents. The instruments provide continuous surveillance of radioactivity releases. Calibrations of effluent instruments are performed using reference standards certified by the National Institute of Standards and Technology (NIST). The instruments are calibrated to respond to specific radionuclides and are sensitive enough to measure 100 to 1,000 times below the applicable release limits.

Each instrument is equipped with alarms which are connected to the Control Room. The alarm setpoints are set to ensure that effluent release limits will not be exceeded. If radiation monitor alarm setpoints are reached, liquid and airborne releases are automatically terminated.

**Effluent Sampling and Analysis:** In addition to continuous radiation monitoring instruments, samples of effluents are taken and subjected to laboratory analysis to identify the specific radionuclide quantities being released. Sampling and analysis provide a sensitive and precise method of determining effluent composition. Samples are analyzed using state-of-the-art laboratory counting equipment. Radiation instrument readings and sample results are compared to ensure correct correlation.

### **Effluent Data**

The amount of radioactivity released from TMINS varies and is dependent upon operating conditions, power levels, fuel conditions, efficiency of liquid and gas processing systems, and proper functioning of plant equipment. The largest variations occur in the airborne effluents of fission and activation gases that are particularly sensitive

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to the holdup time capability in the gas processing system and to the integrity of the fuel cladding.

During 1999, small amounts of radioactive materials were released in TMI-1 and TMI-2 liquid and airborne effluents. Excluding tritium (H-3), the total amount of radioactivity released from TMI-1 in 1999 was one of the lowest in its operating history. This notable achievement was due primarily to good fuel integrity, minimal leakage in the steam generators and improved efficiency of the waste processing systems. Tritium, because of its chemical and physical properties, can not be removed practically from air or water. However, the doses from inhaling and ingesting H-3 released in TMINS liquid and airborne effluents are relatively small because this radionuclide is a low energy beta emitter.

As expected, the doses potentially received by individuals from 1999 TMI-1 and TMI-2 liquid and airborne effluents were very low and a small fraction of the Federal limits. Doses to the public are discussed in more detail in **Radiological Impact of TMINS Operations and Appendix I**.

The amounts of radioactive materials released from TMINS as well as the associated doses to the public are summarized and reported annually to the USNRC. The following sections discuss the radioactive constituents of the 1999 TMI-1 and TMI-2 liquid and airborne effluents. They also are summarized in Table 2.

**Noble Gases:** Noble gases such as argon, xenon and krypton are produced and released from operating nuclear power stations. These gases are readily dispersed in the atmosphere

when released and do not react chemically or biologically with other materials.

During 1999, TMI-1 released approximately 225 Ci of noble gases to the atmosphere. Included were approximately 210 Ci of xenon, 16 Ci of krypton and less than 1 Ci of argon. Xenon-133 with a half-life of five days was the predominant noble gas and the predominant radionuclide released in 1999 TMI-1 airborne effluents. A very small amount of xenon (< 0.0001 Ci) also was released in 1999 TMI-1 liquid effluents. Radioactive noble gases were not detected in 1999 TMI-2 liquid or airborne effluents.

**Iodines and Particulates:** The discharge of radioiodines and radioactive particulates to the environment is minimized by factors such as their high chemical reactivity, solubility in water, and the high efficiency of removal in airborne and liquid processing systems.

During 1999, radioiodines were not detected in TMI-2 liquid or gaseous effluents. For TMI-1, radioiodines I-131 and I-133 were detected in gaseous effluents, but not in liquid effluents. The other isotopes of iodine were not released at detectable amounts either because of a very short half-life or a low production rate. For example, I-129 has a 17 million year half-life but its production in the nuclear fission process is so low that it cannot be detected routinely in effluents.

Radioactive particulates were released as a result of 1999 TMI-1 operations. Released were radio cesiums Cs-134 and Cs-137, radio strontiums Sr-89 and Sr-90 and activation products iron-55 (Fe-55), cobalt-58 (Co-58), Co-60 and antimony-125 (Sb-125). Except for Co-58, all of these radionuclides

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were released in TMI-1 liquid effluents. Only Co-58 and Cs-137 were measured in TMI-1 airborne effluents. For TMI-2, small amounts of Sr-90 and Cs-137 were released in liquid effluents; no particulates were detected in TMI-2 airborne effluents.

The total amounts of radioiodines and radioactive particulates released from TMI-1 and TMI-2 in 1999 liquid effluents were < 0.01 Ci and < 0.0001 Ci, respectively. For airborne effluents, < 0.001 Ci of radioiodines and radioactive particulates were released from TMI-1.

The combined amounts of radioiodines and radioactive particulates released in liquid effluents from TMI-1 for the period of 1986 through 1999 are depicted in Figure 2. As shown in Figure 2, the amounts released in 1996 through 1999 were much lower than those released in previous years. The reduction was due primarily to good fuel integrity, minimal component leakage and improved efficiency of the liquid waste processing systems.

**Tritium:** Tritium was released in 1999 TMI-1 liquid and gaseous effluents. It was the predominant radioactive material released in TMI-1 liquid effluents. Tritium also was released in TMI-2 liquid and gaseous effluents, but at much lower amounts.

Tritium is a radioactive isotope of hydrogen. It is produced in the reactor coolant as a result of neutron interaction with 1) naturally-occurring deuterium (also a hydrogen isotope) present in water, 2) boron used for reactivity control of the reactor and 3) lithium hydroxide used for pH control.

During 1999, the amounts of H-3 released in TMI-1 liquid and gaseous effluents were approximately 550 Ci and 90 Ci, respectively. For comparison, approximately 320 Ci and 120 Ci of H-3 were released in 1998 TMI-1 liquid and gaseous effluents. Figure 3 shows the amounts of H-3 released in TMI-1 liquid effluents for the period 1986-1999. For TMI-2, H-3 releases were < 0.001 Ci and approximately 4 Ci for liquids and gases, respectively. Similar amounts of H-3 were released in 1998 TMI-2 liquid and gaseous effluents.

To put these amounts of H-3 into perspective, the world inventory of natural cosmic ray produced H-3 is 70 million Ci, which corresponds to a production rate of 4 million Ci/yr (Ref. 42). Tritium contributions to the environment from nuclear power production are too small to have any significant effect on the existing global environmental concentrations.

**Transuranics:** Transuranics are produced by neutron capture in the fuel, and typically emit alpha and beta particles as they decay. Important transuranic isotopes produced in reactors are U-239, plutonium-238 (Pu-238), Pu-239, Pu-240, Pu-241, americium-241 (Am-241), Pu-243, plus other isotopes of americium and curium (Cm). They have half-lives ranging from hundreds of days to millions of years. Transuranics are mostly retained within the nuclear fuel. Because they are so insoluble and non-volatile, they are not readily transported from implant pathways to the environment. Gas and liquid processing systems remove greater than 90% of any transuranics outside the reactor coolant. Since greater than 99% of all transuranics are retained within the fuel and transuranic

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removal processes are extremely efficient,  
releases in airborne and liquid effluents are not  
routinely detected.

During 1999, transuranics were not detected  
in TMI-1 or TMI-2 effluents.

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**TABLE 2**

**Radionuclide Composition of TMINS Effluents for 1999 <sup>(1)</sup>**

<u>Radionuclide</u> <sup>(2)</sup>	<u>Half-Life</u> <sup>(3 &amp; 4)</sup>	<u>Liquid Effluents (Ci)</u>		<u>Airborne Effluents (Ci)</u>	
		<u>TMI-1</u>	<u>TMI-2</u>	<u>TMI-1</u>	<u>TMI-2</u>
H-3	1.23E+1 yr	5.51E+2	3.99E-4	9.12E+1	3.89E+0
Ar-41	1.83E+0 h			7.30E-1	
Mn-54	3.13E+2 day				
Fe-55	2.70E+0 yr	2.44E-3			
Co-58	7.08E+1 day			5.90E-7	
Fe-59	4.46E+1 day				
Co-60	5.27E+0 yr	1.51E-5			
Kr-85	1.07E+1 yr			1.57E+1	
Kr-85m	4.48E+0 h			1.18E-2	
Kr-87	7.63E+1 min			1.49E-3	
Kr-88	2.84E+0 day			9.06E-4	
Sr-89	5.05E+1 day	2.94E-5			
Sr-90	2.86E+1 yr	9.49E-5	1.42E-6		
Nb-95	3.51E+1 day				
Ag-110m	2.50E+2 day				
Sb-125	2.77E+0 yr	1.85E-6			
I-131	8.04E+0 day			1.52E-4	
Xe-131m	1.18E+1 day			2.13E+0	
I-133	2.08E+1 h			3.80E-4	
Xe-133	5.25E+0 day	8.85E-5		1.97E+2	
Xe-133m	2.19E+0 day			7.11E+0	
Cs-134	2.06E+0 yr	1.99E-4			
Xe-135	9.11E+0 h			1.60E+0	
Xe-135m	1.54E+1 min			4.15E-2	
Cs-137	3.02E+1 yr	5.58E-3	2.40E-5	2.79E-6	
Xe-138	1.41E+1 min			3.94E-3	

<sup>(1)</sup> The results are expressed in exponential form (i.e., 1.22E-2 = 0.0122).

<sup>(2)</sup> Refer to List of Abbreviations, Symbols and Acronyms (p. v) for nomenclature of the radionuclides/elements.

<sup>(3)</sup> Kocher. "Radioactive Decay Tables." 1981.

<sup>(4)</sup> yr = year, h = hour, min = minute

## Historical Releases of Radioiodines and Radioactive Particulates in TMI-1 Liquid Effluents

mCi by Year

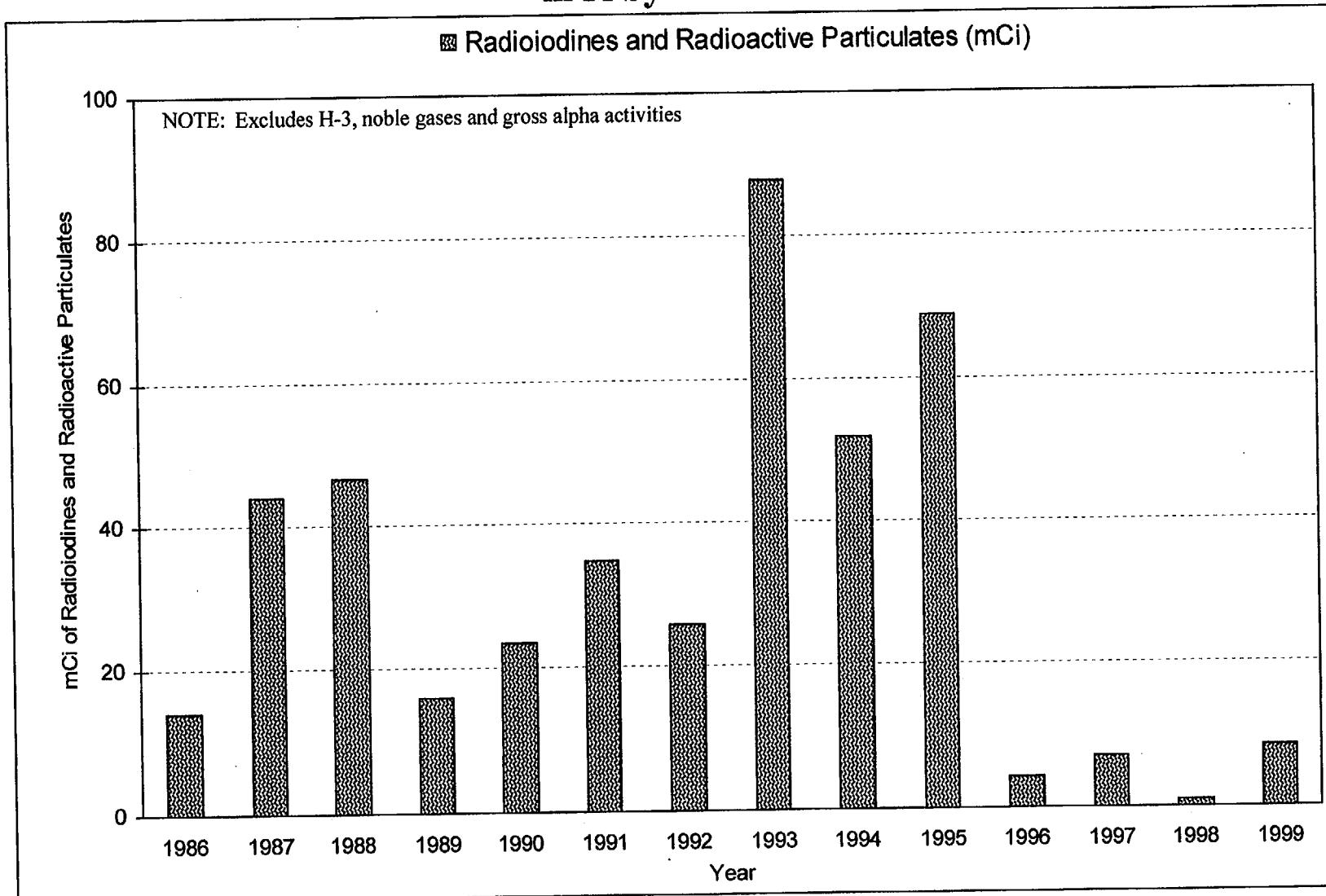
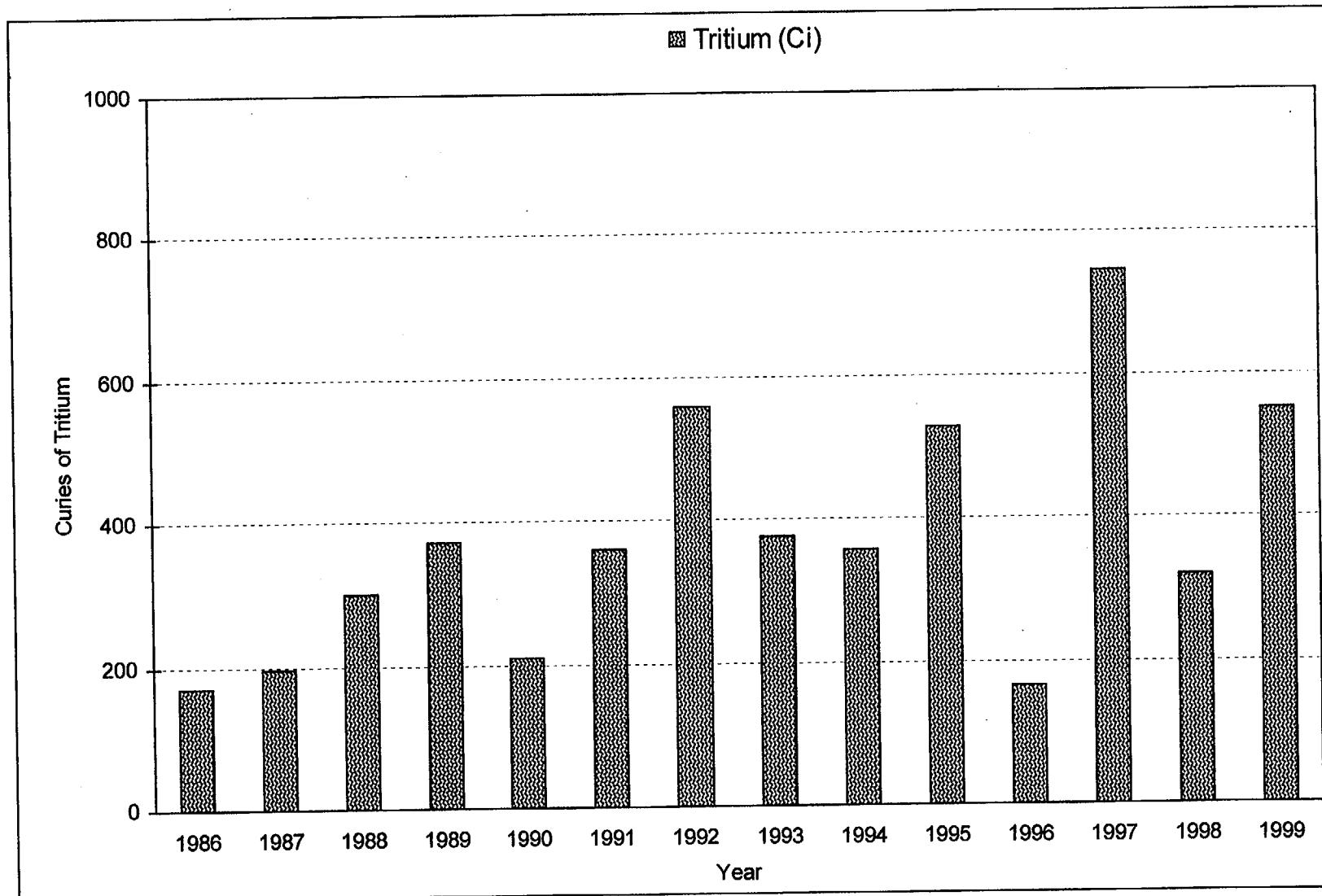


Figure 2

## **Historical Releases of Tritium in TMI-1 Liquid Effluents**

### **Curies by Year**



**Figure 3**

## **RADIOLOGICAL ENVIRONMENTAL MONITORING**

A comprehensive radiological environmental monitoring program (REMP) is in place at TMINS to measure levels of radiation and radioactive materials in the environment. The information obtained from the REMP is then used to determine the effect of TMINS operations, if any, on the environment and the public.

The USNRC has established regulatory guides which contain acceptable monitoring practices. The TMINS REMP was designed on the basis of these regulatory guides along with the guidance provided by the USNRC Radiological Assessment Branch Technical Position for an acceptable radiological environmental monitoring program (Ref. 43). The TMINS REMP meets or exceeds the monitoring requirements set forth by the USNRC.

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The important objectives of the REMP are:

- To assess dose impacts to the public from TMINS operations.
- To verify implant controls for the containment of radioactive materials.
- To determine buildup of long-lived radionuclides in the environment and changes in background radiation levels.
- To provide reassurance to the public that the program is capable of adequately assessing impacts and identifying noteworthy changes in the radiological status of the environment.
- To fulfill the requirements of the TMI-1 and TMI-2 Technical Specifications.

### **Environmental Exposure Pathways to Humans from Airborne and Liquid Effluents**

As previously discussed (**Effluents**), small amounts of radioactive materials are released to the environment as a result of operating a commercial nuclear power station. Once released, these materials move through the environment in a variety of ways and may eventually reach humans via breathing, drinking, eating and direct exposure. These routes of exposure are referred to as environmental exposure pathways. Figure 18 illustrates the important exposure pathways.

As can be seen from this figure, these exposure pathways are both numerous and varied. While some pathways are relatively simple, such as inhalation of airborne radioactive materials, others may be complex. For example, radioactive airborne particulates

may deposit on grass and when eaten by cows may be transferred into milk. The milk may then be consumed by humans. This route of exposure is referred to as the air-grass-cow-milk-human pathway.

Although radionuclides can reach humans by a number of pathways, some are more important than others. The critical pathway for a given radionuclide is the one that produces the greatest dose to a population, or to a specific segment of the population. This segment of the population is called the critical group, and may be defined by age, diet, or other cultural factors. The dose may be delivered to the whole body or confined to a specific organ. The organ receiving the greatest fraction of the dose is called the critical organ. This information was used to develop the TMINS REMP.

### **Sampling**

The TMINS REMP consists of two phases -- the preoperational and the operational. Data gathered in the preoperational phase is used as a basis for evaluating radiation levels and radioactivity in the vicinity of the plant after the plant becomes operational. The operational phase began in 1974 at the time TMI-1 became operational.

The program consists of taking radiation measurements and collecting samples from the environment, analyzing them for radioactivity content, and then interpreting the results. With emphasis on the critical exposure pathways to humans, samples from the aquatic, atmospheric, and terrestrial environments are collected. These samples include, but are not limited to, air, water, sediment, fish, milk, fruits, vegetables and groundwater. Thermoluminescent dosimeters

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(TLDs) are placed in the environment to measure gamma radiation levels.

The Offsite Dose Calculation Manual, ODCM, (Ref. 41) implements the TMI-1 and TMI-2 Technical Specifications and defines the sample types to be collected and the analyses to be performed. As appropriate, changes to the REMP are initiated by recommendations from the scientific staff of the TMINS Environmental Affairs Department (TMIEA). However, the minimum sampling and analysis requirements specified in the ODCM are maintained.

Sampling locations were established by considering topography, meteorology, population distribution, hydrology, areas of public interest and land use characteristics of the local area. The sampling locations are divided into two classes, indicator and control. Indicator locations are those which are expected to show effects from TMINS operations, if any exist. These locations were selected primarily on the basis of where the highest predicted environmental concentrations would occur. The indicator locations are typically downstream or within a few miles of TMINS.

Control stations are located generally upstream or at distances greater than 10 miles from TMINS. The samples collected at these sites are expected to be unaffected by TMINS operations. Data from control locations provide a basis for evaluating indicator data relative to natural background radioactivity and fallout from prior nuclear weapon tests. Figures 4, 5 and 6 show the current sampling locations around TMI. Table A-1 in Appendix A describes the sampling locations by distance and azimuth along with the type(s) of samples collected at each sampling location.

### **Analysis**

In addition to specifying the media to be collected and the number of sampling locations, the ODCM also specifies the frequency of sample collection and the types and frequency of analyses to be performed. Also specified are analytical sensitivities (detection limits) and reporting levels. Table A-2 in Appendix A provides a synopsis of the sample types, number of sampling locations, collection frequencies, number of samples collected, types and frequencies of analyses, and number of samples analyzed. Table A-3 in Appendix A lists samples which were not collected or analyzed per the requirements of the ODCM. Sample analyses which did not meet the required analytical sensitivities are presented in Appendix B. Changes in sample collection and analysis are described in Appendix C.

Measurement of low radionuclide concentrations in environmental media requires special analysis techniques. Analytical laboratories use state-of-the-art laboratory equipment designed to detect all three types of radiation emitted (alpha, beta, and gamma). This equipment must meet the analytical sensitivities required by the ODCM. Examples of the specialized laboratory equipment used are germanium detectors with multichannel analyzers for determining specific gamma-emitting radionuclides, liquid scintillation counters for detecting H-3 and low level proportional counters for detecting gross alpha and beta radioactivity.

Calibrations of the counting equipment are performed by using standards traceable to the National Institute of Standards and Technology (NIST). Computer hardware and software used in conjunction with the

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counting equipment perform calculations and provide data management. Analysis methods are described in Appendix L.

### **Data Review**

The analytical results are routinely reviewed by TMIEA scientists to assure that sensitivities have been achieved and that the proper analyses have been performed. Investigations are conducted when action levels or USNRC reporting levels are reached or when anomalous values are discovered. The action levels were established by TMIEA and are typically 10 percent of the USNRC reporting levels specified in the ODCM. These levels are purposely set low so that corrective action can be initiated before a reporting level is reached. This review process is discussed in more detail in Appendix D.

Table 3 provides a summary of radionuclide concentrations detected in the primary environmental samples. Statistical methods used to derive this table along with other statistical conclusions are detailed in Appendix H. Quality control (QC) sample results were used mainly to verify the primary sample result or the first result in the case of a duplicate analysis. Therefore, the QC results were excluded from Table 3 and the main text of this report to avoid biasing the results.

### **Quality Assurance Program**

A quality assurance (QA) program is conducted in accordance with guidelines provided in Regulatory Guide 4.15, "Quality Assurance for Radiological Monitoring Programs" (Ref. 44) and as required by the Technical Specifications. It is documented by TMIEA written policies, procedures, and records. These documents encompass all

aspects of the REMP including sample collection, equipment calibration, laboratory analysis and data review.

The QA program is designed to identify possible deficiencies so that immediate corrective action can be taken. It also provides a measure of confidence in the results of the monitoring program in order to assure the regulatory agencies and the public that the results are valid. The QA program for the measurement of radioactivity in environmental samples is implemented by:

- Auditing all REMP-related activities including analytical laboratories.
- Requiring analytical laboratories to participate in a cross check program(s).
- Requiring analytical laboratories to split samples for separate analysis (recounts are performed when samples cannot be split).
- Splitting samples, having the samples analyzed by independent laboratories, and then comparing the results for agreement.
- Reviewing QC results of the analytical laboratories including spike and blank sample results and duplicate analysis results.

The QA program and the results of the cross-check programs are outlined in Appendix E and F, respectively.

The TLD readers are calibrated monthly against standard TLDs to within five percent of the standard TLD values. Also, each group of TLDs processed by a reader contains control TLDs that are used to correct for

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minor variations in the reader. The accuracy and variability of the results for the control TLDs are examined for each group of TLDs to assure the reader is functioning properly. In addition, each element (TLD) has an individual correction factor based on its response to a known exposure.

Other cross checks, calibrations, and certifications are in-place to assure the accuracy of the TLD program:

- Semiannually, randomly selected TLDs are sent to an independent laboratory where they are irradiated to set doses not known. TLDs which meet the criteria specified by the National Voluntary Laboratory Accreditation Program (NVLAP) are used for this test. The TMINS dosimetry laboratory processes the TLDs and the results are compared against established limits.
- Every two years, each TLD is checked to ensure an appropriate correction factor is assigned to each element of the TLD.
- Every two years, TMINS dosimetry program is examined and NVLAP recertified by the NIST.
- Ten environmental TLD stations have vendor-supplied quality control badges which are processed by the vendor. The results are compared against TMINS TLD results.

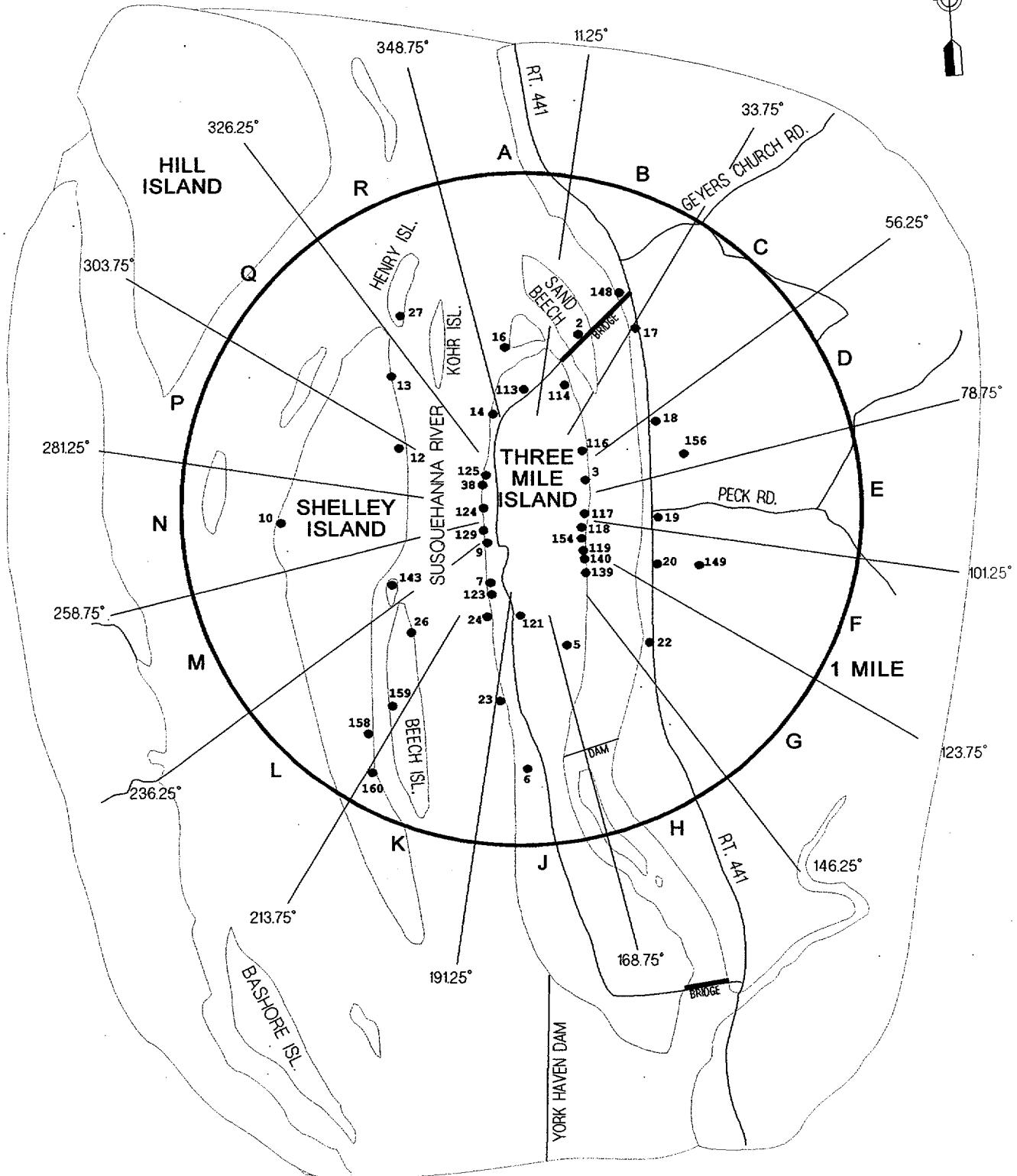
The environmental dosimeters were tested and qualified to the American National Standard Institutes (ANSI) publication N545-1975 and the USNRC Regulatory Guide 4.13 (Refs. 45 and 46). The results for some of these tests

were published in the Health Physics Journal (Ref. 47).

In addition to the TMIEA REMP, the Pennsylvania State Bureau of Radiation Protection (PaBRP) also maintains a surveillance program in the TMI area. This program provides an independent assessment of radioactive releases and the radiological impact on the surrounding environment. The results from this program have compared favorably with those from the TMIEA program.

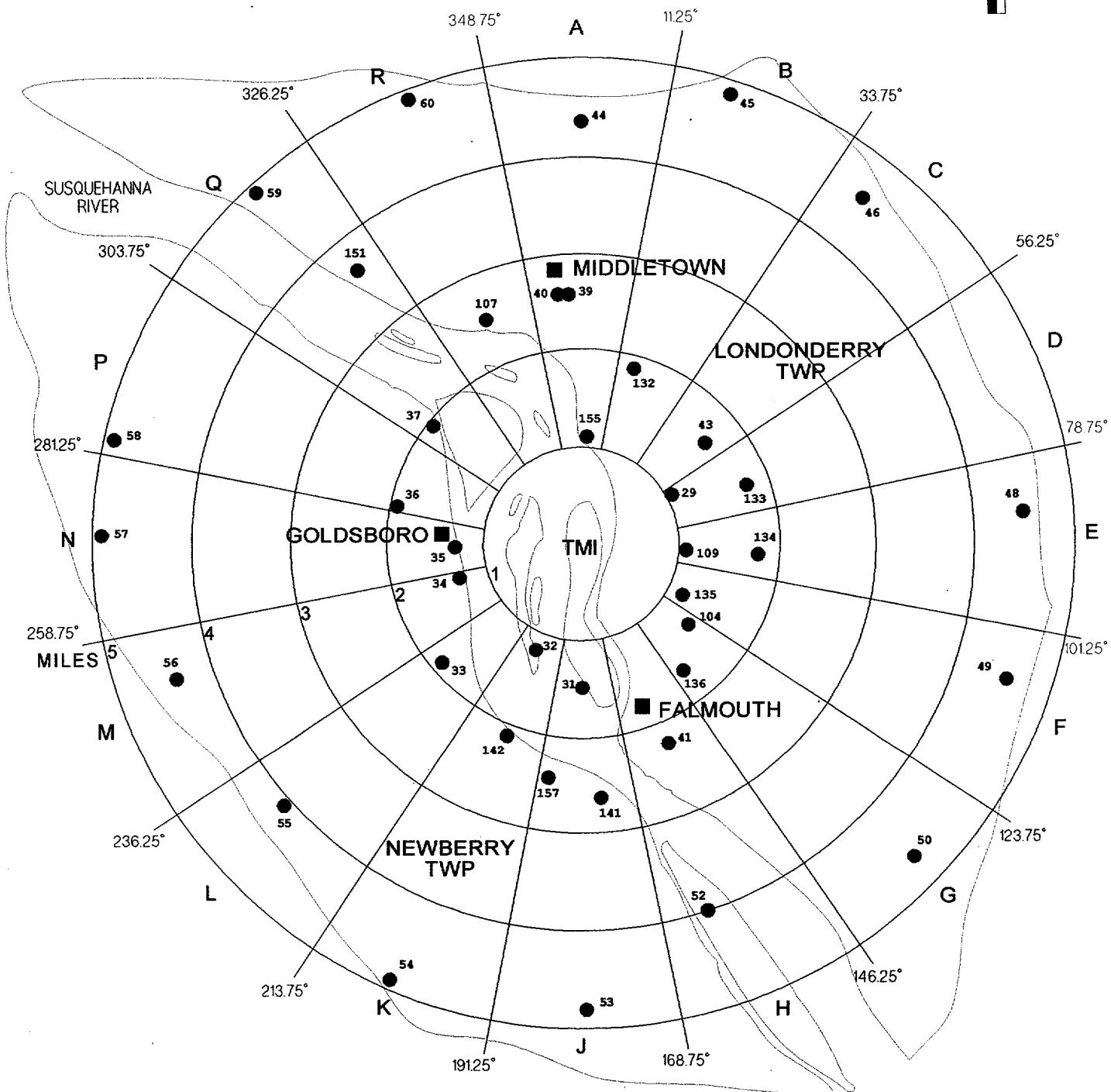
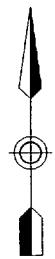
The TMINS Environmental Affairs Department also collects and analyzes samples of the TMINS liquid discharge as a QC check for the implant effluent monitoring program. Results obtained by the REMP were consistent with those reported for the implant effluent monitoring program.

**Figure 4**



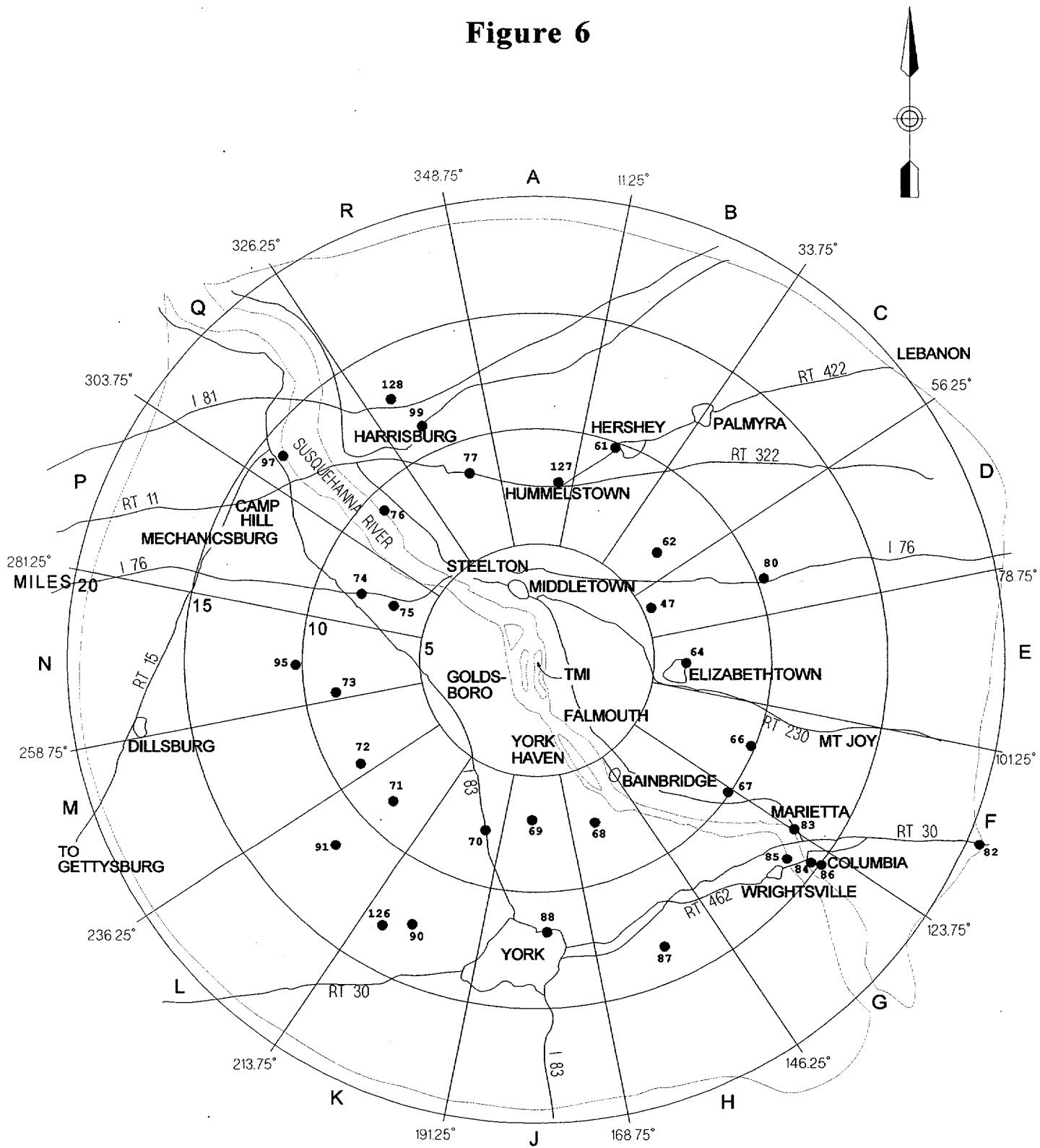
## **Locations of REMP Stations Within 1 Mile of TMINS**

**Figure 5**



**Locations of REMP Stations  
1 to 5 Miles from TMINS**

**Figure 6**



## **Locations of REMP Stations Greater Than 5 Miles From TMINS**

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**TABLE 3**  
**Summary of Radionuclide Concentrations in 1999 Environmental Samples**  
**from Three Mile Island Nuclear Station<sup>(1)</sup>**

Media or Pathway Sampled (Unit of Measurement)	Analyses	Total Number of Analyses Performed(2)	Lower Limit of Detection LLD(3)	Indicator Locations Mean (F)(4) (Range)	Location with Highest Mean(9) Station Name Distance, Direction, and Description(6)	Mean (F)(4) (Range)	Control Locations Mean (F)(4) (Range)	Number of Reportable Results(7)
Air Iodine (pCi/m <sup>3</sup> )	I-131	466	0.07	ND(8)	---	---	ND	0
Air Particulates (pCi/m <sup>3</sup> )	Gr-Alpha	260	0.0015	1.6E-03 (174/208) (6.7E-04 - 3.2E-03)	Q4-1, 3.7 mi NW Hbg Int Airport	1.7E-03 (44/52) (6.7E-04 - 3.2E-03)	1.7E-03 (45/52) (7.2E-04 - 3.5E-03)	0
	Gr-Beta	466	0.01	1.6E-02 (414/414) (5.8E-03 - 3.3E-02)	Q15-1, 13.5 mi NW West Fairview	1.6E-02 (52/52) (7.1E-03 - 3.4E-02)	1.6E-02 (52/52) (7.1E-03 - 3.4E-02)	0
	Sr-89	10	0.001	ND	---	---	ND	0
	Sr-90	10	0.01	ND	---	---	ND	0
	Gamma Spec.	36						
	Be-7		0.05	6.7E-02 (32/32) (4.5E-02 - 8.7E-02)	A3-1, 2.6 mi N Middletown	7.3E-02 (4/4) (6.1E-02 - 8.2E-02)	6.7E-02 (4/4) (5.9E-02 - 7.6E-02)	0
	Cs-134		0.05	ND	---	---	ND	0
	Cs-137		0.06	ND	---	---	ND	0
	K-40		0.02	8.6E-03 (2/32) (7.4E-03 - 9.7E-03)	F1-3, 0.6 mi ESE 500 kV Substation	9.7E-03 (1/4)	ND	0
Fish (pCi/g, wet)	H-3	8	0.2	8.8E-02 (3/4) (6.9E-02 - 1.1E-01)	Indp, Indicator Predator Below Discharge	9.7E-02 (2/2) (8.4E-02 - 1.1E-01)	ND	0
	Sr-89	8	0.025	ND	---	---	ND	0
	Sr-90	8	0.01	ND	---	---	ND	0

Note: See footnotes at end of table.

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Media or Pathway Sampled (Unit of Measurement)	Analyses	Total Number of Analyses Performed(2)	Lower Limit of Detection LLD(3)	Indicator Locations Mean (F)(4) (Range)	Location with Highest Mean(9)		Control Locations Mean (F)(4) (Range)	Number of Reportable Results(7)
					Station Name Distance, Direction, and Description(6)	Mean (F)(4) (Range)		
Fish (pCi/g,wet)	Gamma Spec.	8						
	Co-58		0.13	ND	---	---	ND	0
	Co-60		0.13	ND	---	---	ND	0
	Cs-134		0.13	ND	---	---	ND	0
	Cs-137		0.15	ND	---	---	ND	0
	Fe-59		0.26	ND	---	---	ND	0
	K-40		0.50	3.1E+00 (4/4) (2.8E+00 - 3.4E+00)	Bkgp, Control Predator Above Discharge	3.4E+00 (2/2) (3.3E+00 - 3.4E+00)	3.3E+00 (4/4) (3.0E+00 - 3.4E+00)	0
	Mn-54		0.13	ND	---	---	ND	0
Aquatic Sediment (pCi/g, dry)	Zn-65		0.26	ND	---	---	ND	0
	Gamma Spec.	8						
	Be-7		0.2	2.5E+00 (6/6) (7.5E-01 - 5.0E+00)	J2-1, 1.5 mi S Above York Haven Dam	3.8E+00 (2/2) (2.5E+00 - 5.0E+00)	2.0E+00 (2/2) (1.4E+00 - 2.5E+00)	0
	Cs-134		0.15	ND	---	---	ND	0
	Cs-137		0.18	1.8E-01 (6/6) (1.1E-01 - 2.4E-01)	K1-3, 0.3 mi SSW West Shore of TMI	2.0E-01 (2/2) (1.8E-01 - 2.2E-01)	1.1E-01 (2/2) (9.8E-02 - 1.2E-01)	0
	K-40		0.2	1.4E+01 (6/6) (7.7E+00 - 2.1E+01)	J2-1, 1.5 mi S Above York Haven Dam	1.9E+01 (2/2) (1.6E+01 - 2.1E+01)	1.2E+01 (2/2) (1.1E+01 - 1.2E+01)	0

Note: See footnotes at end of table.

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Media or Pathway Sampled (Unit of Measurement)	Total Number of Analyses Performed(2)	Lower Limit of Detection LLD(3)	Indicator Locations Mean (F)(4) (Range)	Location with Highest Mean(9) Station Name Distance, Direction, and Description(6)	Mean (F)(4) (Range)	Control Locations Mean (F)(4) (Range)	Number of Reportable Results(7)
Aquatic Sediment (pCi/g,dry)	Ra-226	0.2	2.5E+00 (6/6) (1.7E+00 - 3.1E+00)	J1-2, 0.5 mi S West Shore of TMI	2.7E+00 (2/2) (2.6E+00 - 2.8E+00)	1.8E+00 (2/2) (1.2E+00 - 2.4E+00)	0
	Th-232	0.2	1.2E+00 (6/6) (8.0E-01 - 1.6E+00)	J2-1, 1.5 mi S Above York Haven Dam	1.5E+00 (2/2) (1.3E+00 - 1.6E+00)	1.1E+00 (2/2) (9.8E-01 - 1.2E+00)	0
Drinking Water (pCi/L)	Gr-Beta	36	4	2.9E+00 (22/24) (1.3E+00 - 5.5E+00)	G15-2, 13.6 mi SE Wrightsville Water Supply	3.1E+00 (12/12) (1.8E+00 - 5.5E+00)	2.5E+00 (6/12) (1.6E+00 - 3.8E+00)
	H-3	36	2000	2.1E+02 (14/24) (9.8E+01 - 4.9E+02)	G15-3, 14.8 mi SE Lancaster Water Authority	2.7E+02 (7/12) (1.4E+02 - 4.9E+02)	1.1E+02 (4/12) (8.6E+01 - 1.5E+02)
I-131	84	1	ND	---	---	ND	0
Gamma Spec.	36						
Ba-140		60	ND	---	---	ND	0
Co-58		15	ND	---	---	ND	0
Co-60		15	ND	---	---	ND	0
Cs-134		15	ND	---	---	ND	0
Cs-137		18	ND	---	---	ND	0
Fe-59		30	ND	---	---	ND	0
La-140		15	ND	---	---	ND	0

Note: See footnotes at end of table.

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**TABLE 3**  
**Summary of Radionuclide Concentrations in 1999 Environmental Samples**  
**from Three Mile Island Nuclear Station<sup>(1)</sup>**

Media or Pathway Sampled (Unit of Measurement)	Total Number of Analyses Performed(2)	Lower Limit of Detection LLD(3)	Indicator Locations Mean (F)(4) (Range)	Location with Highest Mean(9)		Control Locations Mean (F)(4) (Range)	Number of Reportable Results(7)
Drinking Water (pCi/L)	Mn-54	15	ND	---	---	ND	0
	Nb-95	15	ND	---	---	ND	0
	Zn-65	30	ND	---	---	ND	0
	Zr-95	30	ND	---	---	ND	0
Fruits (pCi/g, wet)	Gamma Spec.	2		---	---	ND	0
	Cs-134	0.06	ND	---	---	ND	0
	Cs-137	0.08	ND	---	---	ND	0
	I-131	0.06	ND	---	---	ND	0
	K-40	0.4	2.5E+00 (1/1)	E1-2, 0.4 mi E TMI Visitors Center	2.5E+00 (1/1)	2.4E+00 (1/1)	0
Grains (pCi/g, wet)	Gamma Spec.	2		---	---	ND	0
	Cs-134	0.06	ND	---	---	ND	0
	Cs-137	0.08	ND	---	---	ND	0
	I-131	0.06	ND	---	---	ND	0
	K-40	0.4	2.6E+00 (1/1)	B10-2, 10.1 mi NNE Milton Hershey School, Hershey	2.7E+00 (1/1)	2.7E+00 (1/1)	0

Note: See footnotes at end of table.

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**TABLE 3**  
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**from Three Mile Island Nuclear Station<sup>(1)</sup>**

Media or Pathway Sampled (Unit of Measurement)	Total Number of Analyses Performed(2)	Lower Limit of Detection LLD(3)	Indicator Locations Mean (F)(4) (Range)	Location with Highest Mean(9)		Control Locations Mean (F)(4) (Range)	Number of Reportable Results(7)	
Broad Leaf Vegetables (pCi/g, wet)	Sr-89	2	0.025	ND	---	---	ND	0
	Sr-90	2	0.01	3.6E-03 (1/1)	E1-2, 0.4 mi E TMI Visitors Center	3.6E-03 (1/1)	2.5E-03 (1/1)	0
	Gamma Spec.	2						
	Cs-134		0.02	ND	---	---	ND	0
	Cs-137		0.02	ND	---	---	ND	0
	I-131		0.025	ND	---	---	ND	0
	K-40		0.4	3.2E+00 (1/1)	E1-2, 0.4 mi E TMI Visitors Center	3.2E+00 (1/1)	2.2E+00 (1/1)	0
	Gamma Spec.	2						
	Cs-134		0.06	ND	---	---	ND	0
	Cs-137		0.08	ND	---	---	ND	0
	I-131		0.06	ND	---	---	ND	0
	K-40		0.4	3.8E+00 (1/1)	B10-2, 10.1 mi NNE Milton Hershey School, Hershey	4.4E+00 (1/1)	4.4E+00 (1/1)	0

Note: See footnotes at end of table.

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**from Three Mile Island Nuclear Station<sup>(1)</sup>**

<u>Media or Pathway Sampled (Unit of Measurement)</u>	<u>Total Number of Analyses Performed(2)</u>	<u>Lower Limit of Detection LLD(3)</u>	<u>Indicator Locations Mean (F)(4) (Range)</u>	<u>Location with Highest Mean(9)</u>			<u>Control Locations Mean (F)(4) (Range)</u>	<u>Number of Reportable Results(7)</u>
Milk (cow) (pCi/L)	I-131	130	1	ND	---	---	ND	0
	Sr-89	20	5	ND	---	---	ND	0
	Sr-90	20	2	9.6E-01 (6/16) (5.9E-01 - 1.3E+00)	E2-2, 1.1 mi E Dairy Farm	1.3E+00 (1/4)	1.0E+00 (1/4)	0
	Gamma Spec.	130						
	Ba-140		60	ND	---	---	ND	0
	Cs-134		15	ND	---	---	ND	0
	Cs-137		18	ND	---	---	ND	0
	K-40		80	1.5E+03(104/104) (1.3E+03 - 1.7E+03)	P7-1, 6.7 mi WNW Dairy Farm	1.5E+03 (26/26) (1.4E+03 - 1.7E+03)	1.5E+03 (26/26) (1.4E+03 - 1.6E+03)	0
	La-140		15	ND	---	---	ND	0
	Ra-226		50	1.3E+02 (2/104)	D2-1, 1.1 mi ENE Dairy Farm	1.3E+02 (1/26)	ND	0
					P7-1, 6.7 mi WNW Dairy Farm	1.3E+02 (1/26)		
Surface Water (10) (pCi/L)	H-3	48	2000	2.3E+03 (10/12) (1.0E+02 - 1.0E+04)	J1-2, 0.5 mi S West Shore of TMI	2.3E+03 (10/12) (1.0E+02 - 1.0E+04)	1.1E+02 (10/36) (9.2E+01 - 1.5E+02)	0
	I-131	84	1	(11)	A3-2, 2.5 mi N Swatara Creek, Middletown	1.0E+00 (10/28) (3.7E-01 - 2.5E+00)	9.1E-01 (14/84) (3.7E-01 - 2.5E+00)	0

Note: See footnotes at end of table.

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<u>Media or Pathway Sampled (Unit of Measurement)</u>	<u>Total Number of Analyses Performed(2)</u>	<u>Lower Limit of Detection LLD(3)</u>	<u>Indicator Locations Mean (F)(4) (Range)</u>	<u>Location with Highest Mean(9)</u>		<u>Control Locations Mean (F)(4) (Range)</u>	<u>Number of Reportable Results(7)</u>
Surface Water (pCi/L)	Gamma Spec.	48					
	Ba-140	60	ND	---	---	ND	0
	Co-58	15	ND	---	---	ND	0
	Co-60	15	ND	---	---	ND	0
	Cs-134	15	ND	---	---	ND	0
	Cs-137	18	ND	---	---	ND	0
	Fe-59	30	ND	---	---	ND	0
	K-40	50	3.4E+01 (1/12)	J1-2, 0.5 mi S West Shore of TMI	3.4E+01 (1/12)	ND	0
	La-140	15	ND	---	---	ND	0
	Mn-54	15	ND	---	---	ND	0
	Nb-95	15	ND	---	---	ND	0
	Ra-226	50	ND	A3-2, 2.5 mi N Swatara Creek, Middletown	4.4E+01 (1/12)	4.4E+01 (1/36)	0
	Zn-65	30	ND	---	---	ND	0
	Zr-95	30	ND	---	---	ND	0

Note: See footnotes at end of table.

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**from Three Mile Island Nuclear Station<sup>(1)</sup>**

Media or Pathway Sampled (Unit of Measurement)	Analyses	Total Number of Analyses Performed(2)	Lower Limit of Detection LLD(3)	Indicator Locations Mean (F)(4) (Range)	Location with Highest Mean(9) Station Name Distance, Direction, and Description(6)	Mean (F)(4) (Range)	Control Locations Mean (F)(4) (Range)	Number of Reportable Results(7)
Direct Radiation (mR/std month)	Gamma	2085(5)		4.7E+00 (1827/1827) (3.2E+00 - 9.6E+00)	H8-1, 7.4 mi SSE Saginaw Road Starview	7.6E+00 (24/24) (7.4E+00 - 7.9E+00)	5.3E+00 (258/258) (4.2E+00 - 7.3E+00)	0

Notes:

- (1) This table presents primary (base) program results > minimum detectable concentration (MDC). It does not include results from the Quality Control (QC) program, the Rodent Monitoring Program or the Groundwater Monitoring Program. The results listed are expressed in exponential form (i.e., 1.2E-2 = .012). Results from recounts supersede original results; reanalysis results supersede both original and/or recount results.
- (2) The total number of analyses does not include duplicate analyses, recounts, or reanalyses.
- (3) The ODCM LLD (or MDC) is given when applicable. It should be noted that, in some cases, the TMINS REMP achieves LLDs that are lower than those required by the ODCM.
- (4) (F) is the ratio of results > MDC to the number of samples analyzed. Means and ranges are based on results > MDC.
- (5) The total number of samples or elements (TLDs) used for data analysis.
- (6) All distances are measured from a point that is midway between the TMI-1 and TMI-2 reactor buildings.
- (7) USNRC reporting levels as specified in the ODCM.
- (8) ND= Not Detected (i.e. all net sample concentrations were equal to or less than the MDC).
- (9) The location with the highest mean was determined using more than two significant figures.
- (10) Sample results from TMINS liquid discharge point (Station K1-1) were used as a check for the implant effluent sampling program and, therefore, were not included in this table.
- (11) Analysis not performed.

Note: See footnotes at end of table.

## **DIRECT RADIATION MONITORING**

Radiation is a normal component of the environment resulting primarily from natural sources, such as cosmic radiation and naturally-occurring radionuclides, and to a lesser extent from manmade sources, such as fallout from prior nuclear weapon tests. The cessation of atmospheric nuclear weapon tests and the decay of fallout products have resulted in a gradual decrease in environmental radiation levels. Direct radiation monitoring measures ionizing radiation primarily from cosmic and terrestrial sources.

Gamma radiation exposure rates near TMINS were measured using thermoluminescent dosimeters (TLDs). TLD stations were arranged in roughly concentric rings around TMINS, generally with one station in each of the 16 compass sectors, at the site boundary and 1, 2, 5, 8 and 10 or more miles from the site. Those TLD stations approximately 10 or more miles from the site were control (or background) stations while those less than 10 miles from the site were indicator stations. Indicator stations were located to detect any potential effect of TMINS operations on environmental radiation levels. Control stations were located at sites that should be unaffected by TMINS operations.

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The TLDs were processed each calendar quarter. All gamma radiation exposure rates recorded during 1999 were within normal ranges and were consistent with previous results.

No relationship between TMINS operations and offsite exposure rates was detected at any station. The 1999 quarterly exposure rates for the individual TLD stations and a map showing onsite TLD station locations are contained in Appendix M. Offsite TLD stations are depicted on Figures 4, 5 and 6.

### **Sample Collection and Analysis**

A thermoluminescent dosimeter (TLD) is composed of a crystal (phosphor) which absorbs and stores energy in traps when exposed to ionizing radiation. These traps are so stable that they do not decay appreciably over time. When heated, the crystal emits light proportional to the amount of radiation received, and the light is measured to determine the integrated exposure. This process is referred to as thermoluminescence. The reading process 'rezeros' (anneals) the TLD and prepares it for reuse. The TLDs in use for environmental monitoring at TMINS are capable of accurately measuring exposures between 1 mR (well below normal environmental exposures for the quarterly monitoring periods) and 200 R.

Each TLD station consists of 2 primary program TLD badges, each of which has 4 phosphors or elements. Since each TLD responds to radiation independently, this provides 8 independent detectors at each station. In addition, 10 stations have a vendor-supplied quality control TLD badge which has 4 independent detectors, for a total of 12 detectors at each station. The quality control

badges are used as an independent check on the accuracy of the primary program TLD results.

Of the 4 elements in the primary program's TLDs, 3 are composed of calcium sulfate and 1 is composed of lithium borate. The calcium sulfate elements are shielded with a thin layer of lead making the response to different energies of gamma radiation more linear. The lead also shields the elements from beta radiation, making them sensitive to gamma radiation only. The lithium borate element is shielded differently to permit the detection of beta radiation as well as gamma. The combination of different phosphor materials, shielding, and multiple phosphors per badge permit quantification of both gamma and beta radiation. Only the calcium sulfate phosphors are used for environmental monitoring; however, the lithium borate elements can be used to evaluate beta exposures or as a backup to the calcium sulfate elements should more data be required.

Data from the TLDs were evaluated by obtaining the average of the usable element results at each station, and comparing the result to historical averages and ranges for the period of TMINS shutdown between the first quarter of 1980 and the third quarter of 1985. The averages and overall trends of the indicator and control stations were also compared with each other and with averages and trends obtained for the five-year shutdown period.

All TLD exposure rate data presented in this report were normalized to a standard month (std month) to adjust for variable field exposure periods. A std month is 30.4 days. Several badges were used to quantify transit exposure during storage and handling of TLDs. Transit exposures were subtracted from gross field exposures to produce net field exposures.

## **1999 RADIOLOGICAL ENVIRONMENTAL MONITORING REPORT**

### **Results**

In 1999, the average annual exposure rate for offsite indicator stations, which excludes stations located on the TMINS site boundary fence, was  $4.8 \pm 1.5$  mR/std month. Quarterly exposure rates at offsite indicator stations ranged from 3.5 to 7.9 mR/std month. The average annual exposure rate for all control stations, those stations approximately 10 miles or more from TMINS, was  $5.3 \pm 1.4$  mR/std month. Quarterly exposure rates at control stations ranged from 4.2 to 7.3 mR/std month. Similar exposure rates were measured in 1998 when offsite indicators and controls averaged  $4.5 \pm 1.5$  mR/std month and  $4.9 \pm 1.6$  mR/std month, respectively.

Control stations typically have been slightly higher than average exposures at offsite indicator stations. This is a result of variation in the natural radioactive characteristics of rock and soil near the stations. The historical average exposure rate (for the period from 1980 to 1985, when TMINS did not operate) was 5.2 mR/std month for indicator stations and 5.7 mR/std month for control stations. Generally, exposure rates at both indicator and control stations have been decreasing gradually due to the cessation of atmospheric nuclear weapon testing and the decay of fallout products. This trend is depicted in Figure 7.

Some indicator stations located on the site boundary fence can show elevated exposure rates, especially in Sectors E, F, and G. Stations in these sectors are located close enough to radioactive material transit and storage areas to be affected to some degree. In 1999, the average annual exposure rate for all indicator stations, including those stations located on the TMINS site boundary fence, was  $4.7 \pm 1.6$  mR/std month. Quarterly

average exposure rates ranged from 3.2 to 9.6 mR/std month. Similar exposure rates were measured in 1998 when all indicator stations averaged  $4.4 \pm 1.6$  mR/std month and ranged from 3.1 to 8.3 mR/std month.

Some onsite stations in Sections E, F, and G did show slightly elevated exposure rates for some of 1999, but average onsite exposure rates still were lower than is typical for offsite stations. This is consistent with previous results and is a function of the differing characteristics of the land surface and geology in the immediate vicinity of the TLD stations. Many onsite stations are located on or above manmade surfaces or structures, which may shield the TLDs from terrestrial sources of radiation.

Exposure rates at stations on the site boundary fence vary with the movement and storage of onsite radioactive materials, and with the number and placement of stations on the fence. Occasionally, stations on the fence may be moved or added to ensure comprehensive coverage of some areas. For these reasons, year-to-year comparisons between stations on the site boundary fence and other indicator or control stations usually are not appropriate.

In 1999, the highest annual average exposure rate of  $7.6 \pm 0.5$  mR/std month was measured at indicator Station H8-1. This annual average exposure rate is typical for Station H8-1, and is lower than the historical (1980-1985) exposure rate of  $7.9 \pm 1.4$  mR/std month for Station H8-1.

Comparisons of exposure rates by distance ring and radial sector also were performed to test for potential effects of TMINS operations. Any effect of TMINS operations on offsite exposure rates should be evidenced by an

## **1999 RADIOLOGICAL ENVIRONMENTAL MONITORING REPORT**

increase in the ring averages closer to TMINS, or in the sector averages in predominant wind directions. For the 1999 data, ring or sector differences were not evident as compared to historical data.

During 1999, average quarterly exposure rates for offsite indicators and controls were relatively constant. The average exposure rates observed at offsite indicator stations for the first, second, third and fourth quarters of 1999 were 4.8, 4.8, 5.1 and 4.7 mR/std month. With slightly higher quarterly exposure rates, the controls trended similarly. Average exposure rates at control stations for the first, second, third and fourth quarters of 1999 were 5.2, 5.3, 5.6 and 5.3 mR/std month. The fact that both indicators and controls trended similarly suggested that TMINS operation did not change offsite exposure rates.

Figure 7 is a plot of gamma exposure rates (as measured by TLDs) in the vicinity of TMINS from 1974 through 1999. Data from onsite indicator stations are excluded from the graph. Based on Figure 7, the trends in exposure rates at indicator stations were similar to those of control stations with the exception of 1979. As a result of the TMI-2 accident, a transitory increase in exposure rates from the release of noble gases was observed. Increases also were observed in both indicator and control stations in 1976, 1977, and 1978 as a result of nuclear weapon tests.

No elevated exposure rates as a result of TMINS operations were observed at any offsite TLD station in 1999. Thermoluminescent dosimeters are sensitive and accurate mechanisms for measuring the low exposure rates characteristic of environmental levels. Effects of normal TMINS operations, however, are generally too small to be discernible outside

the normal range of background radiation levels.

The annual average gamma radiation exposure rate recorded at all offsite indicator TLD monitoring stations was 4.8 mR/std month. This equates to an annual exposure rate of 58 mR/yr. An exposure of this magnitude is consistent with the annual average radiation dose a person receives from cosmic and terrestrial sources (Table 1, "Sources and Doses of Radiation").

# Historical Gamma Exposure Rates

## mR per Standard Month by Quarter

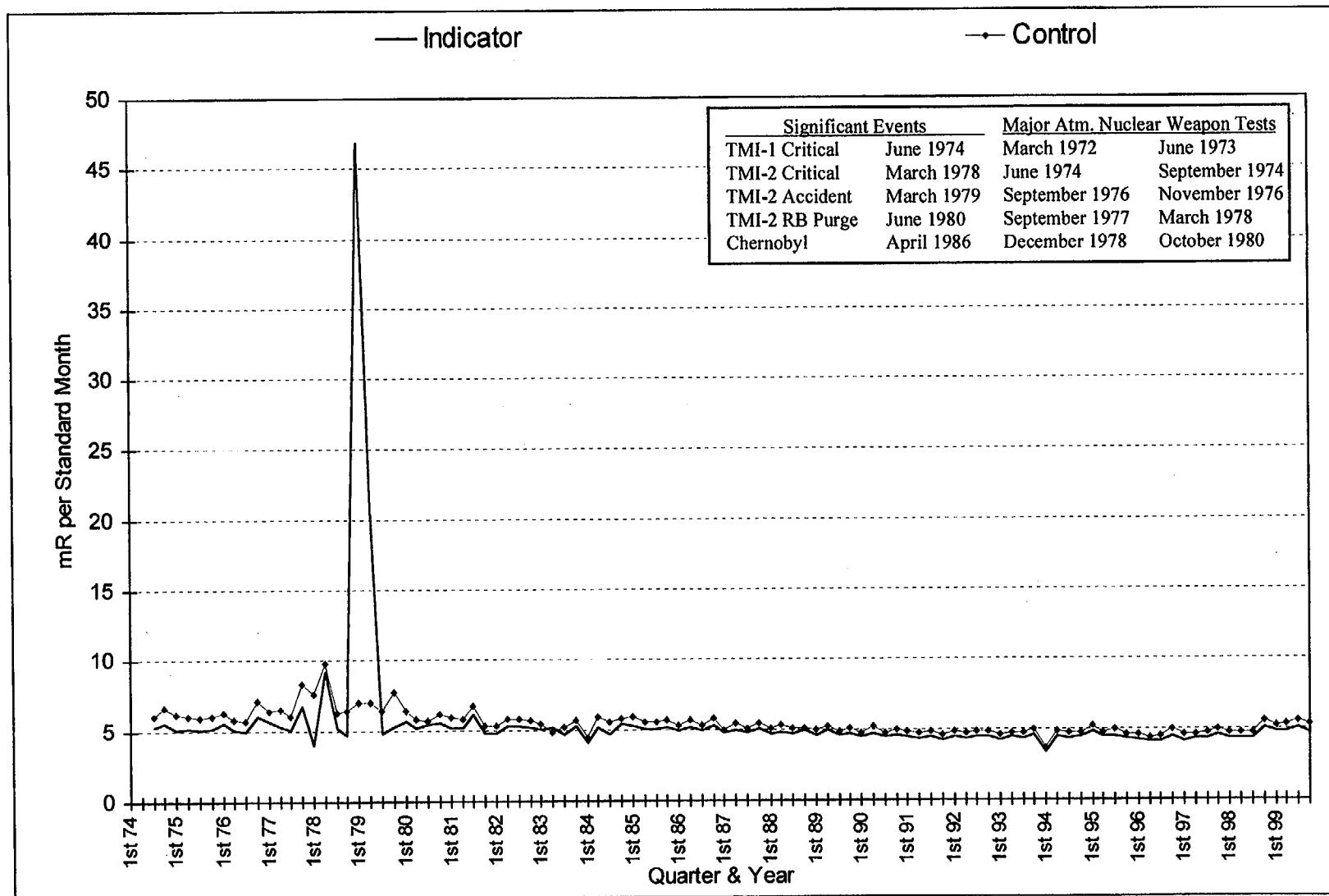


Figure 7

## **ATMOSPHERIC MONITORING**

A potential exposure pathway to humans is inhalation of airborne radioactive materials. To monitor this exposure pathway, ambient air was sampled by a network of continuously operating samplers and then analyzed for radioactivity content. Based on the analytical results, no contribution to the general levels of airborne radioactivity was attributed to TMINS operations during 1999.

### **Sample Collection and Analysis**

The indicator air sampling stations were located primarily in the prevailing downwind directions to the east (TMINS Visitors Center, Station E1-2), the east-southeast (500 kV Substation, Station F1-3), the southeast (dairy farm near Falmouth, Station G2-1), and the south-southeast (Falmouth, Station H3-1) of TMINS and in the nearby communities of Goldsboro (Station M2-1) and Middletown (Station A3-1). There also were indicator air sampling sites to the north-northeast (TMINS North Gate, Station B1-4) and the northwest (Harrisburg International Airport,

## **1999 RADIOLOGICAL ENVIRONMENTAL MONITORING REPORT**

Station Q4-1). The control air sampling station was located in West Fairview (Station Q15-1), a community situated more than 13 miles from TMINS. This station provided background data for comparison.

Mechanical air samplers were used to continuously draw air through glass fiber filters and charcoal cartridges. To maintain a constant flow rate throughout the collection period, each sampler was equipped with an electronic mass flow controller. This device automatically adjusted the flow rate to compensate for dust loading and changes in atmospheric pressure and temperature.

Total air volumes were measured and recorded with dry gas meters. Air volumes were then adjusted based on vacuum readings over the collection period. All air samplers were calibrated semiannually and maintained by instrumentation technicians.

The glass fiber filters were used to collect airborne particulate matter. The filters were collected weekly and analyzed for gross beta radioactivity. Five of these filters also were analyzed weekly for gross alpha radioactivity. The filters were then combined quarterly by individual station locations and analyzed for gamma-emitting radionuclides. Additionally, the weekly filters analyzed for gross alpha radioactivity were prepared as semiannual composites by location and analyzed for Sr-89 and Sr-90.

During the year, two glass fiber filters had sampling periods of less than two days. These filters were not analyzed for gross beta radioactivity because the particulate matter collected was not representative of the weekly sampling period. The filters were, however, included in the quarterly composite samples

that were analyzed for gamma-emitting radionuclides.

Cartridges containing activated charcoal were used for monitoring gaseous radioiodines. These cartridges were placed downstream of the particulate filter at each of the air sampling stations. Charcoal cartridges were collected weekly and analyzed separately from the particulate filters for I-131.

Two of the charcoal cartridges collected during 1999 had sampling periods of two days or less. These samples were not analyzed for gaseous radioiodines because they did not adequately represent the weekly collection period.

### **Air Particulate Results**

During 1999, more than 450 air particulate samples (filters) were collected weekly from nine locations and analyzed for gross beta radioactivity. The particulate matter (dust particles) collected on all indicator and control filters contained gross beta radioactivity above the minimum detectable concentration (MDC).

The gross beta concentrations measured on the filters collected from indicator sites ranged from  $0.0058 \pm 0.0016 \text{ pCi/m}^3$  to  $0.033 \pm 0.003 \text{ pCi/m}^3$  and averaged  $0.016 \pm 0.009 \text{ pCi/m}^3$ . The air particulate samples collected from the control location had gross beta concentrations that ranged from  $0.0071 \pm 0.0021 \text{ pCi/m}^3$  to  $0.034 \pm 0.003 \text{ pCi/m}^3$  and averaged  $0.016 \pm 0.010 \text{ pCi/m}^3$ . The 1999 annual average gross beta concentrations were consistent with the 1998 averages of  $0.015 \pm 0.010 \text{ pCi/m}^3$  and  $0.016 \pm 0.010 \text{ pCi/m}^3$  for indicators and controls, respectively.

## 1999 RADIOLOGICAL ENVIRONMENTAL MONITORING REPORT

The air sampling location with the highest annual average gross beta concentration (based on more than two significant figures) was control Station Q15-1 (West Fairview). The average gross beta concentration for airborne particulates collected at this station was  $0.016 \pm 0.010 \text{ pCi/m}^3$ . This average concentration was well below the preoperational average concentration of  $0.15 \pm 0.16 \text{ pCi/m}^3$  and, as shown on Table 4, was similar to the annual average gross beta concentrations calculated for particulate samples collected at the other air sampling sites.

As depicted in Figure 8, average weekly gross beta concentrations at indicator and control air monitoring locations were somewhat variable, but trended similarly throughout the monitoring period. The weekly gross beta concentrations and trends at individual air sampling sites also were similar.

The 1999 data indicated that gross beta radioactivity levels did not change as a result of TMINS operations. Additionally, the gross beta radioactivity associated with airborne particulates was due primarily to naturally-occurring radionuclides.

Historical trends of average quarterly gross beta concentrations associated with airborne particulates from 1972 to 1999 are depicted in Figure 9. Generally, the gross beta concentrations have decreased with time. The 1999 average gross beta concentration of  $0.016 \text{ pCi/m}^3$ , for indicators and controls combined, is approximately 10% of the 1974 preoperational average concentration ( $0.15 \text{ pCi/m}^3$ ).

The overall diminution in gross beta concentrations is a direct result of the ban on

atmospheric nuclear weapon tests and the radioactive decay of fallout products from previous detonations. Elevated concentrations at both indicator and control air monitoring stations were noted after each major nuclear weapon test, the TMI-2 accident, and the Chernobyl accident. The trends for indicator and control stations were similar for the entire TMINS operational period.

The particulate filters collected weekly from five air sampling sites (Stations B1-4, H3-1, M2-1, Q4-1 and Q15-1) also were analyzed for gross alpha radioactivity. During 1999, the particulate matter on approximately 84% of the filters (219 of 260) contained gross alpha radioactivity above the MDC. Air particulate gross alpha concentrations (detected above the MDC) at indicator stations ranged from  $0.00067 \pm 0.00048 \text{ pCi/m}^3$  to  $0.0032 \pm 0.0008 \text{ pCi/m}^3$  and averaged  $0.0016 \pm 0.0011 \text{ pCi/m}^3$ . Control samples ranged from  $0.00072 \pm 0.00049 \text{ pCi/m}^3$  to  $0.0035 \pm 0.0007 \text{ pCi/m}^3$  and averaged  $0.0017 \pm 0.0013 \text{ pCi/m}^3$ . For comparison, indicators and controls averaged  $0.0019 \pm 0.0016 \text{ pCi/m}^3$  and  $0.0021 \pm 0.0019$ , respectively, in 1998.

The air sampling location with the highest annual average gross alpha concentration (based on more than two significant figures) was indicator Station Q4-1 (Harrisburg International Airport). The 1999 average gross alpha concentration for particulate samples collected at this site was  $0.0017 \pm 0.0012 \text{ pCi/m}^3$ . As shown on Table 5, similar annual average gross alpha concentrations were calculated for the other four air particulate sampling sites.

## **1999 RADIOLOGICAL ENVIRONMENTAL MONITORING REPORT**

Average weekly gross alpha concentrations are depicted in Figure 10. Actual concentrations (whether positive, negative or zero) were used to calculate weekly averages because approximately 16% of the weekly results were below the MDC. Using actual concentrations eliminates biases in the data and missing data points on graphs.

As depicted in Figure 10, average weekly gross alpha concentrations varied throughout the monitoring period. However, the trends for indicator and control concentrations generally were similar.

The data obtained in 1999 indicated that gross alpha radioactivity levels did not change as a result of TMINS operations. Also, the gross alpha radioactivity measured on the particulate filters was due primarily to naturally-occurring radionuclides.

Historical trends of average quarterly gross alpha concentrations from 1972 through 1999 are displayed in Figure 11. Gross alpha concentrations during the preoperational period (1972-1974) averaged 0.001 pCi/m<sup>3</sup> with maximum concentrations up to 0.006 pCi/m<sup>3</sup>. Although some of the operational concentrations were slightly higher than the preoperational average concentration, control sample concentrations were comparable to indicator sample concentrations. The overall trends for gross alpha concentrations in air particulates at indicator and control stations were similar throughout the TMINS operational period.

Gamma-emitting radionuclides related to TMINS operations were not detected on any of the 40 quarterly composites (including QC filters) that were analyzed in 1999. As expected, all of the quarterly composite

samples contained naturally-occurring beryllium-7 (Be-7). Concentrations detected on indicator samples were similar to those detected on control filters. Also, naturally-occurring potassium-40 (K-40) was detected on two primary samples and two quality control samples.

Strontium analyses were performed on a total of 10 air particulate semiannual composite samples during 1999. Neither Sr-89 nor Sr-90 was detected above the MDC.

### **Air Iodine Results**

During 1999, more than 450 charcoal cartridges were collected weekly and analyzed for I-131. None of the weekly samples contained I-131 (or any other isotope of iodine) above the MDC.

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**TABLE 4**

**1999 Average Gross Beta Concentrations  
in Airborne Particulates  
(pCi/m<sup>3</sup>)**

<u>Station</u>	<u>Description</u>	<u>Average +/- 2 std dev*</u>
A3-1(I)	Middletown	0.016 ± 0.010
B1-4(I)	TMINS North Gate	0.016 ± 0.009
E1-2(I)	TMINS Visitors Center	0.016 ± 0.009
F1-3 (I)	500 kV Substation	0.015 ± 0.008
G2-1(I)	Dairy Farm (Near Falmouth)	0.016 ± 0.009
H3-1(I)	Falmouth	0.015 ± 0.009
M2-1(I)	Goldsboro	0.016 ± 0.009
Q4-1(I)	Hbg. International Airport	0.016 ± 0.009
Q15-1(C)	West Fairview	0.016 ± 0.010

\* Averages and standard deviations are based on concentrations > MDC.

(I) = Indicator Station (C) = Control Station

**TABLE 5**

**1999 Average Gross Alpha Concentrations  
in Airborne Particulates  
(pCi/m<sup>3</sup>)**

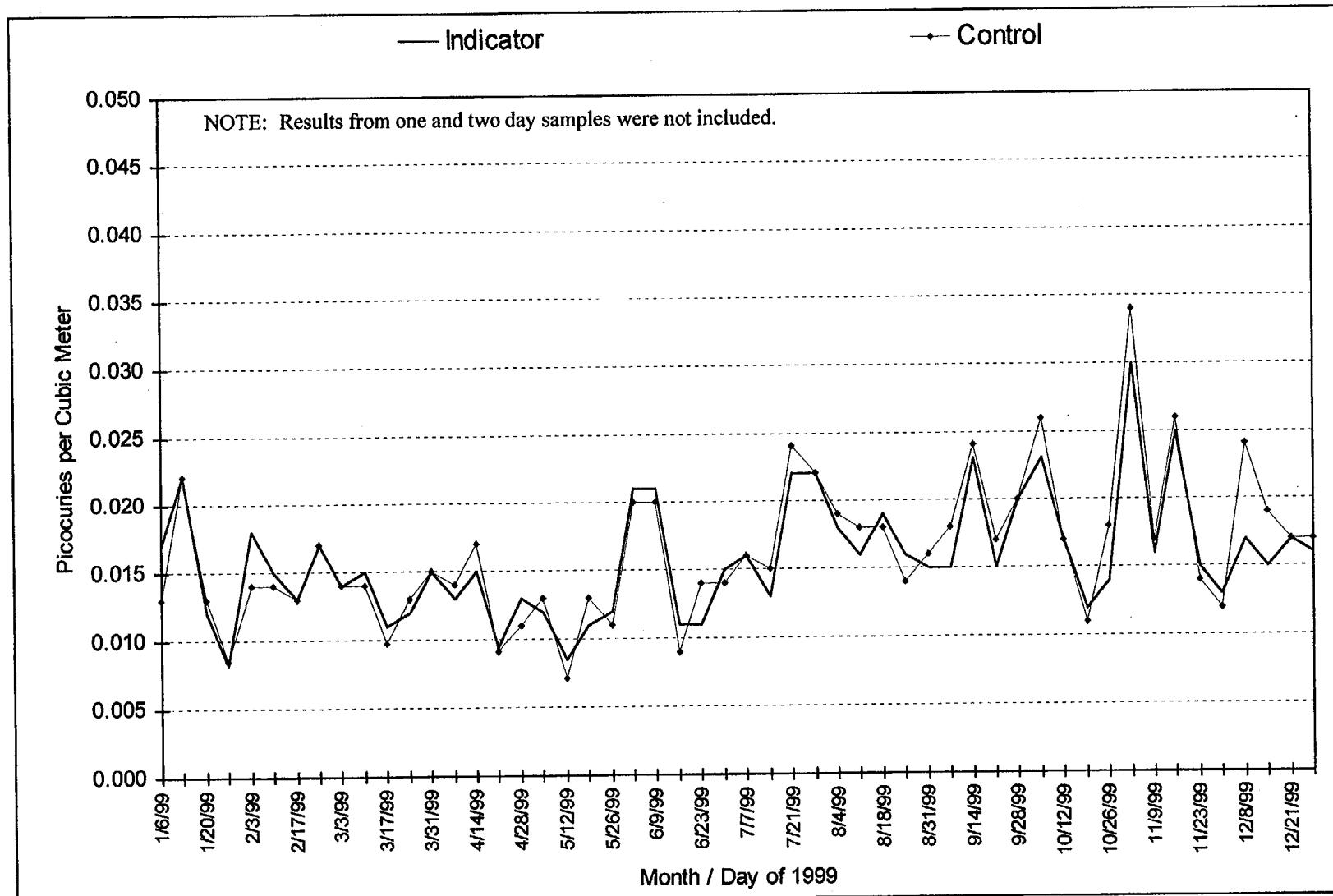
<u>Station</u>	<u>Description</u>	<u>Average +/- 2 std dev*</u>
B1-4(I)	TMINS North Gate	0.0016 ± 0.0009
H3-1(I)	Falmouth	0.0015 ± 0.0010
M2-1(I)	Goldsboro	0.0017 ± 0.0011
Q4-1(I)	Hbg. International Airport	0.0017 ± 0.0012
Q15-1(C)	West Fairview	0.0017 ± 0.0013

\* Averages and standard deviations are based on concentrations > MDC.

(I) = Indicator Station (C) = Control Station

# 1999 Gross Beta Concentrations in Air Particulates

## Picocuries per Cubic Meter by Week



# Historical Gross Beta Concentrations in Air Particulates

## Picocuries per Cubic Meter by Quarter

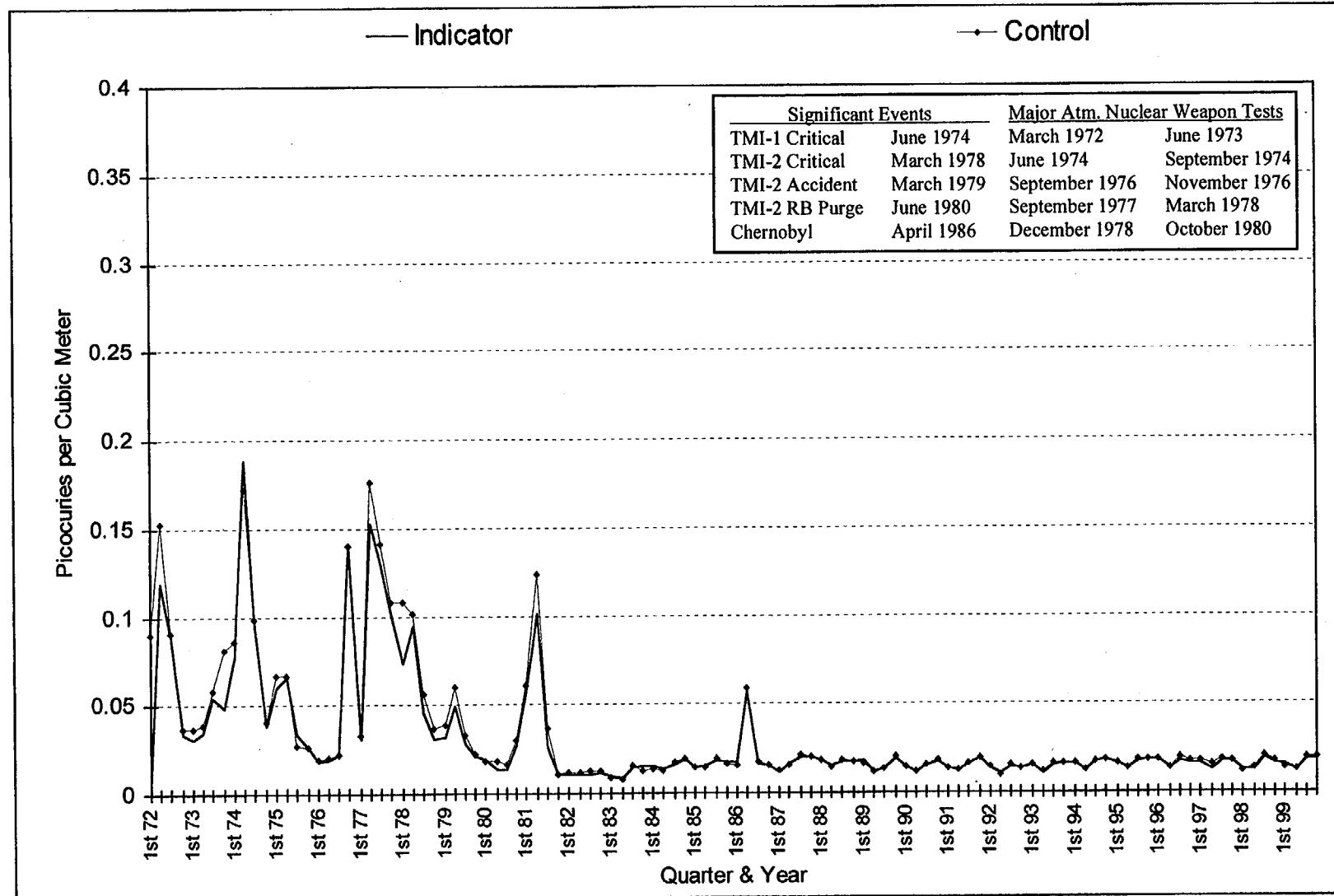


Figure 9

# 1999 Gross Alpha Concentrations in Air Particulates

## Picocuries per Cubic Meter by Week

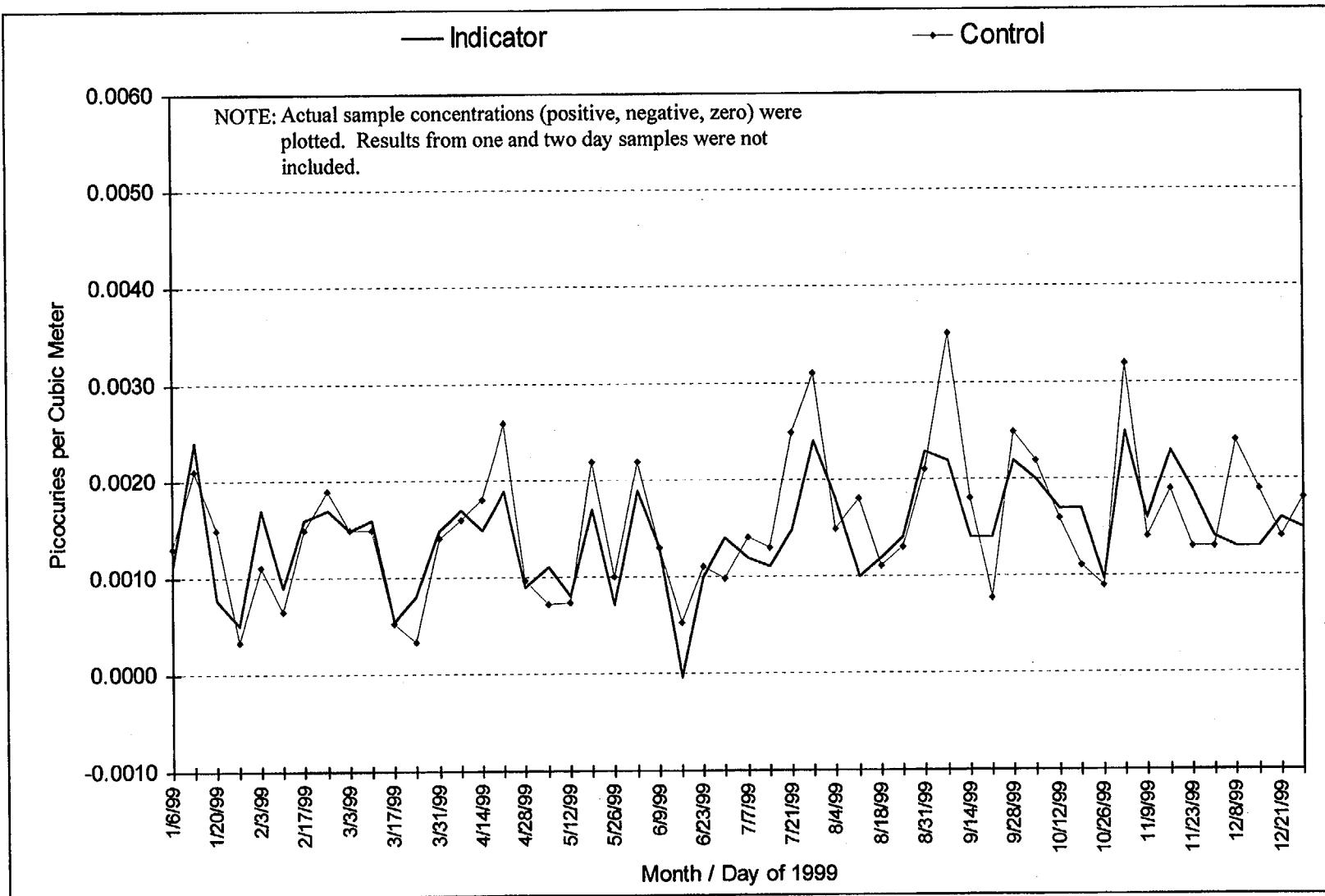
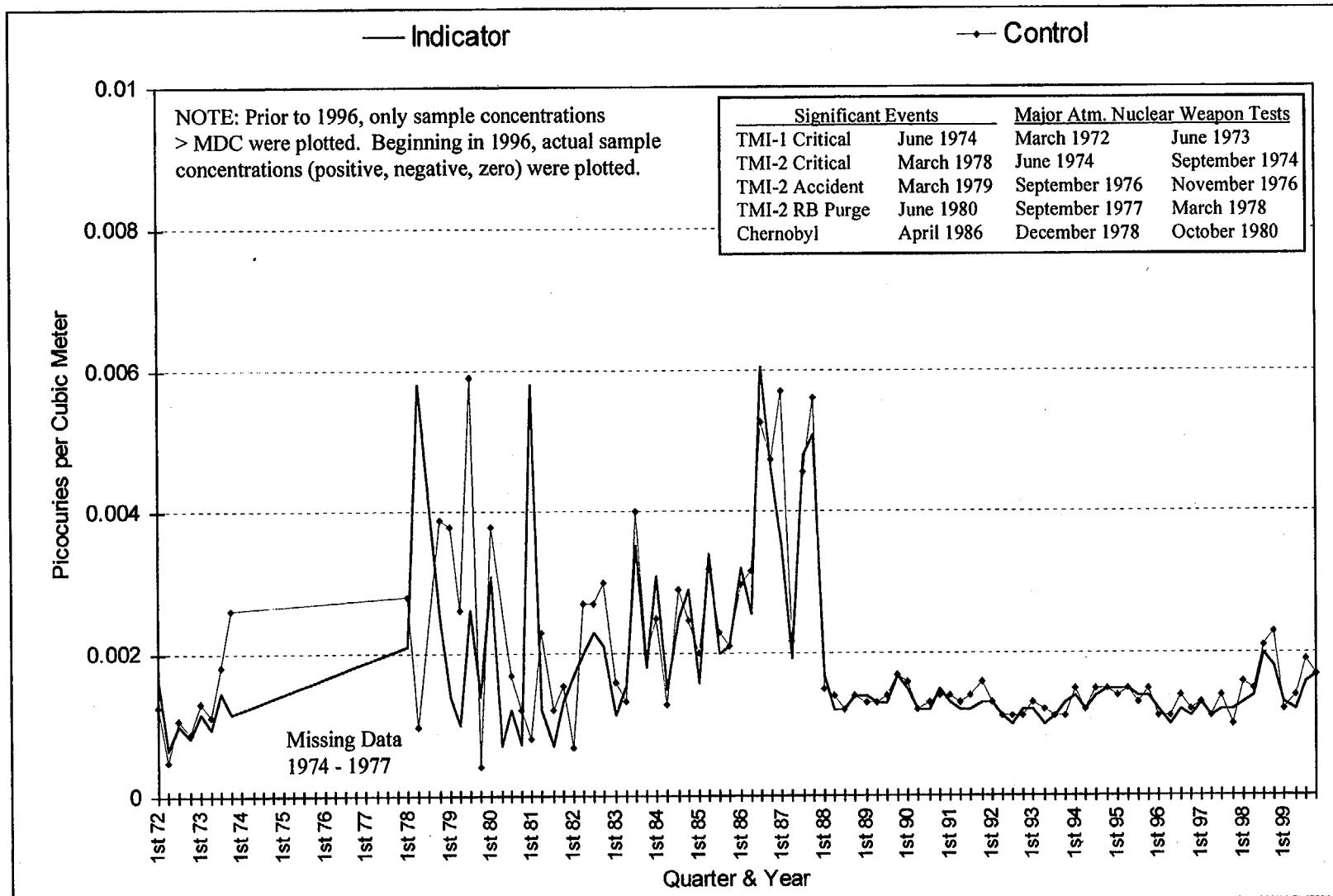


Figure 10

# Historical Gross Alpha Concentrations in Air Particulates

## Picocuries per Cubic Meter by Quarter



**Figure 11**

## AQUATIC MONITORING

Since radioactive materials are released to the Susquehanna River from routine operations at TMINS and this watershed is used as a source for drinking water and recreational activities, the aquatic environment is monitored extensively for radionuclides of potential TMINS origin. Recreational activities in the TMI reach of the Susquehanna River include fishing, boating, swimming and other water sports.

Monitoring of the aquatic environment in the vicinity of TMINS was accomplished by collecting and analyzing samples of surface water, drinking water, fish and river sediments. The indicator (downstream) sampling sites were chosen based on studies of travel time and mixing characteristics for the Susquehanna River. Control samples were collected from locations which were not expected to be affected by TMINS operations. The impact of TMINS operations was assessed by comparing control sample concentrations to those measured in indicator samples. As applicable, comparisons with results from previous years also were performed.

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During 1999, samples from the aquatic environment were found to contain low concentrations of radioactive materials attributable to routine TMINS operations. They included Cs-137 in sediments and H-3 in surface water, drinking water and possibly fish. The concentrations found in these samples, however, were too low to adversely impact humans or the environment. Radionuclides attributable to medical facilities and their patients, natural production in the atmosphere and fallout from prior nuclear weapon tests also were identified in various aquatic media.

### **Sample Collection and Analysis**

Surface (raw/unfinished) and drinking (finished) water samples were collected at seven stations (three indicators and four controls) and analyzed during 1999. Indicator samples were collected from locations along the Susquehanna River which were downstream of the TMINS liquid discharge outfall. Indicator surface water samples were collected at one location, Station J1-2 (west shore of TMI). Indicator drinking water samples were collected at two water treatment facilities -- Station G15-2 (Wrightsville Water Supply, Wrightsville, PA) and Station G15-3 (Lancaster Water Authority, Columbia, PA).

Control samples were collected from the Susquehanna River upstream of the TMINS liquid discharge outfall or from its tributaries. Control surface water samples were collected from three locations -- Station A3-2 (Swatara Creek, Middletown, PA), Station F15-1 (Chickies Creek, Marietta, PA) and Station Q9-1 (Steelton Water Authority, Steelton, PA). Control drinking water samples were obtained at one water treatment facility --

Station Q9-1 (Steelton Water Authority, Steelton, PA).

Samples of the TMINS liquid discharge (Station K1-1) also were collected and analyzed. The liquid discharge samples were collected from a location where the water was not yet mixed with the Susquehanna River. As appropriate, data from the liquid discharge samples were compared with data obtained from samples collected as part of the TMINS Effluent Monitoring Program.

Except for those collected at Station F15-1 (Chickies Creek), all water samples were normally obtained by an automatic water compositor. Samples from Chickies Creek (Station F15-1) were collected as grabs twice per week. Grab samples also were collected when the automatic compositors were not operating (e.g. AC power loss, sampler malfunction or frozen sampling line). The water compositors collected a measured volume of water at a preset interval of time (30 or 60 minutes). These samplers were maintained and calibrated by instrumentation technicians.

The composite samples normally were retrieved biweekly (every two weeks). To verify that the samplers were operating properly, a surveillance was performed weekly. Occasionally, composite samples were retrieved weekly to close out a calendar month or quarter. The grab samples collected from Chickies Creek (Station F15-1) were composited into weekly or biweekly samples.

The weekly and biweekly composite samples from indicator Stations G15-3 and G15-2 along with those collected from control Stations Q9-1, F15-1 and A3-2 were analyzed

## **1999 RADIOLOGICAL ENVIRONMENTAL MONITORING REPORT**

for low-level I-131 using a chemical separation/concentration technique. Samples of the TMINS liquid discharge also were analyzed for low-level I-131 employing the same technique.

All water samples retrieved weekly and biweekly were combined by station into monthly composites and analyzed for H-3 and gamma-emitting radionuclides, including I-131. Monthly gross beta analyses also were performed on all drinking water samples and the samples collected from Station K1-1. Semiannual composite samples were prepared only from monthly samples collected at Station K1-1 and then analyzed for Sr-89 and Sr-90.

Electro-shocking equipment and hook and line were used to collect fish samples in the spring (May and June) and fall (September and October) of 1999. To monitor the progression of radionuclides through the food chain, bottom feeding fish as well as predator species were collected. Indicator samples were collected from zones or areas immediately at or downstream of the TMINS liquid discharge outfall, while control specimens were gathered from locations greater than ten miles upstream of TMI. The edible portions were analyzed for Sr-89, Sr-90, H-3 and gamma-emitting radionuclides.

As part of the routine REMP, river sediments from four locations (three indicators and one control) were collected in the spring (June) and fall (October) of 1999. Indicator sediment samples were collected at a site just downstream of the TMINS liquid discharge outfall (Station K1-3), at the York Haven Dam, YHD, (Station J2-1) and at a site on the west shore of TMI, between the TMINS

liquid discharge outfall and the YHD (Station J1-2). The control samples were obtained from the Susquehanna River just upstream of TMI (Station A1-3).

All sediment samples were collected using a dredge designed for this purpose. They were dried and then analyzed for gamma-emitting radionuclides.

### **Water Results**

Iodine-131 is produced during the fission process and may be a constituent of TMI-1 liquid effluents. This radionuclide also may be discharged to the Susquehanna River and its tributaries by medical facilities and their patients via the municipal sewage system. Institutions such as hospitals utilize this material for diagnostic studies of the thyroid and thyroid therapy. Iodine-131 from medical facilities and their patients is commonly detected in REMP samples because the methods used to treat sewage do not remove this material.

During 1999, low-level I-131 using the chemical separation/concentration technique was detected above the minimum detectable concentration (MDC) in 14 of 84 control surface water samples and 3 of 56 control drinking water samples. All three were quality control samples. Iodine-131 above the MDC also was identified in 11 of 28 samples collected from Station K1-1, the TMINS liquid discharge. None of the indicator drinking water samples collected in 1999 contained I-131 above the MDC. Indicator surface water samples were not analyzed using the chemical separation/concentration technique.

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The I-131 concentrations measured in control surface water samples ranged from  $0.37 \pm 0.26$  pCi/L to  $2.5 \pm 0.5$  pCi/L and averaged  $0.9 \pm 1.2$  pCi/L. For comparison, the average I-131 concentration for 1998 control surface water samples was  $1.2 \pm 2.0$  pCi/L.

As mentioned previously, three quality control drinking water samples collected at control Station Q9-1 (Steelton Water Authority) contained I-131 above the MDC. The concentrations ranged from  $0.26 \pm 0.15$  pCi/L to  $0.34 \pm 0.14$  pCi/L and averaged  $0.30 \pm 0.08$  pCi/L. In 1998, two 1998 quality control samples contained I-131 above the MDC. The 1998 concentrations were similar to those detected in 1999. The medical industry was responsible for the presence of I-131 in all 1999 control surface and drinking water samples.

Eleven of twenty-eight TMINS liquid discharge samples collected in 1999 contained I-131 above the MDC. The I-131 concentrations ranged from  $0.40 \pm 0.29$  pCi/L to  $2.1 \pm 0.4$  pCi/L and averaged  $1.0 \pm 0.9$  pCi/L. The 1998 results were similar, ranging from  $0.35 \pm 0.22$  pCi/L to  $2.6 \pm 0.4$  pCi/L and averaging  $1.3 \pm 1.1$  pCi/L.

Generally, each time I-131 was detected in a liquid discharge sample, a similar concentration of this material was measured in a control sample(s). Sometimes, however, I-131 was not detected concurrently in a control sample or the concentration detected in the discharge sample was slightly higher than the concentration measured in the control sample(s). This may have been caused by the process used to cool water at TMINS.

Water is continually withdrawn from the Susquehanna River for cooling. During one of the cooling processes, a large amount of water is evaporated. The suspended and dissolved materials remain in the water and, therefore, are concentrated. One of these materials may be medically-related I-131 (i.e. I-131 released by upstream medical facilities and/or their patients). To prevent a buildup of these concentrated materials, some of the water is diluted and then returned or discharged to the Susquehanna River. It is possible that the dilution water also contains medically-related I-131.

The similarity of the control and discharge results along with the possibility that I-131 may be concentrated during the cooling process suggested that medical facilities and their patients, and not TMINS, was the source of the I-131 detected in the liquid discharge samples. The absence of I-131 in 1999 liquid effluent samples supported this conclusion.

In 1999, H-3 above the MDC was measured in 10 of 36 monthly control surface water samples and 10 of 12 monthly indicator surface water samples. Table 6 lists the annual average H-3 concentrations and the ranges for the samples collected at each surface water station. Also included in the table are the annual average concentrations and ranges based on actual sample concentrations, whether positive, negative or zero.

The H-3 measured in the control surface water samples ranged from  $92 \pm 59$  pCi/L to  $150 \pm 50$  pCi/L and averaged  $110 \pm 30$  pCi/L. These concentrations were consistent with those measured previously in control surface and drinking water samples. The presence of

## 1999 RADIOLOGICAL ENVIRONMENTAL MONITORING REPORT

H-3 in the control samples was attributed to fallout from prior nuclear weapon tests and natural production of this material in the atmosphere.

As expected, H-3, a major component of 1999 TMINS liquid effluents, was detected above the MDC in 83% of the monthly surface water samples collected at indicator Station J1-2. This station is located just downstream of the TMINS liquid discharge outfall where mixing of liquid effluents with river water is incomplete. More complete mixing is not achieved until liquid effluents pass over the York Haven Dam (YHD).

The annual average H-3 concentration for the samples collected at Station J1-2 was  $2300 \pm 6300$  pCi/L. The results ranged from  $100 \pm 60$  pCi/L to  $10000 \pm 1000$  pCi/L. Sampler malfunctions during the year caused biases in the monthly concentrations as well as the annual average concentration.

Some results were biased low because the automatic water compositor was not collecting samples during periods of high activity H-3 releases. Conversely, at least one monthly result was biased high as a result of collecting grab samples during periods when high activity H-3 was released.

For comparison, H-3 was detected in 6 of 12 1998 monthly samples collected at Station J1-2. The concentrations ranged from  $91 \pm 51$  pCi/L to  $7800 \pm 800$  pCi/L and averaged  $2400 \pm 6000$  pCi/L. A higher average concentration was expected in 1999 because a larger amount of H-3 was released in 1999 liquid effluents. Approximately 550 Ci of H-3 were released in liquid effluents in 1999, whereas, about 320 Ci were released in 1998.

Figure 12 depicts the 1999 monthly trends of H-3 concentrations in surface water samples collected at Station J1-2. Actual concentrations (whether positive, negative or zero) were plotted. For comparison, the actual monthly H-3 concentrations measured in the TMINS liquid discharge samples also are depicted in Figure 12. Except for the biased results, this figure shows that the H-3 concentrations measured in the samples obtained from Station J1-2 were directly related to those detected in the TMINS liquid discharge samples (Station K1-1). Historical trends of H-3 concentrations in surface water are shown in Figure 13.

A dose estimate was not performed for H-3 in surface water because this medium normally is not consumed by humans. All of the H-3 concentrations measured in surface water during 1999 were, however, below the USEPA Primary Drinking Water Standard of 20,000 pCi/L.

In 1999, H-3 above the MDC was measured in 14 indicator drinking water samples and 4 controls. Table 6 lists the annual average H-3 concentrations for the samples collected at each drinking water station. Also included are the annual average concentrations based on actual sample concentrations, whether positive, negative or zero.

The control drinking water samples collected in February, July, August and September at Station Q9-1 (Steelton Water Authority, Steelton, PA) contained H-3 ranging from  $86 \pm 54$  pCi/L to  $150 \pm 50$  pCi/L and averaging  $110 \pm 60$  pCi/L. The concentrations measured in the 1999 control samples were consistent with those measured in the 1999 control surface water samples as well as those

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measured in control surface and drinking water samples from previous years. For example, the 1998 control surface and drinking water results averaged  $120 \pm 50$  pCi/L and  $110 \pm 40$  pCi/L, respectively. The presence of H-3 in the control drinking water, like control surface water, was attributed to fallout from prior weapon tests and natural production of this material in the atmosphere.

Seven monthly drinking water samples from indicator Station G15-2 (Wrightsville Water Supply, Wrightsville, PA) and seven monthly drinking water samples from indicator Station G15-3 (Lancaster Water Authority, Columbia, PA) contained H-3 above the MDC. The H-3 concentrations averaged  $210 \pm 220$  pCi/L and ranged from  $98 \pm 57$  pCi/L to  $490 \pm 70$  pCi/L.

The H-3 concentrations measured in the 1999 indicator drinking water samples were similar to those measured in 1998, when six samples contained H-3 above the MDC. The measured concentrations averaged  $220 \pm 380$  pCi/L and ranged from  $89 \pm 52$  pCi/L to  $590 \pm 90$  pCi/L. The 1999 results also were consistent with those measured in other years.

Figure 14 (upper) displays the average monthly H-3 concentrations measured in the 1999 indicator and control drinking water samples. Instead of only using concentrations above the MDC, actual concentrations (whether positive, negative or zero) were used for the graph. This method eliminated biases in the data and missing data points. For comparison, the actual H-3 concentrations obtained from samples collected at Station K1-1 also were included in Figure 14 (lower).

Generally, Figure 14 shows that the highest average indicator concentrations occurred when the highest amounts of H-3 were released in TMINS liquid effluents. The concentrations measured in the indicator samples were consistent with data gathered from travel time and mixing studies. There were a number of months when the indicator average was similar to or less than the control sample concentration. This indicated that the H-3 measured in both indicator and control drinking water samples was most likely due to fallout or natural production.

To put the 1999 H-3 results into perspective, the highest monthly indicator concentration of  $490 \pm 70$  pCi/L represented less than 3.0% of the USEPA Primary Drinking Water Standard (20,000 pCi/L). Furthermore, if an individual drank water at this concentration for an entire year, the maximum hypothetical whole body dose would be 0.051 mrem. This calculated dose is equivalent to 0.017% of the whole body dose that an individual living in the TMI area receives each year from natural background radiation (300 mrem).

Generally, the H-3 concentrations detected in samples collected at Station K1-1 (TMINS liquid discharge) agreed well with those obtained from the TMINS Effluent Monitoring Program.

The monthly composites of all drinking water samples were analyzed for gross beta activity. Table 7 lists, by station, the annual averages and ranges for gross beta concentrations above the MDC. Averages and ranges based on actual concentrations are included for comparison. The monthly (composite) TMINS liquid discharge samples from Station K1-1 also were analyzed for gross beta.

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Most of the drinking water samples collected in 1999 contained gross beta radioactivity concentrations above the MDC. Indicator results ranged from  $1.3 \pm 0.8$  pCi/L to  $5.5 \pm 1.3$  pCi/L and averaged  $2.9 \pm 2.3$  pCi/L. Similarly, the controls ranged from  $1.6 \pm 0.8$  pCi/L to  $3.8 \pm 1.0$  pCi/L and averaged  $2.5 \pm 1.5$  pCi/L. The 1999 averages were consistent with the 1998 averages of  $2.7 \pm 1.9$  pCi/L and  $2.6 \pm 1.4$  pCi/L for indicators and controls, respectively.

The monthly gross beta averages for indicator and control drinking water are plotted in Figure 15. Actual concentrations were used for this graph. Generally, indicator and control sample concentrations trended similarly throughout the year. Minor differences were evident, but expected.

The variability in the gross beta concentrations was directly related to the type of treatment and the overall contaminant removal efficiency of each water treatment facility. For example, suspended solids with adsorbed man-made or naturally-occurring radioactive materials are removed from raw river water by common treatment processes such as filtration and sedimentation. The amount removed by these processes will vary as a function of the individual system design and operation.

All of the drinking water results for 1999 were well below the Federal and State Primary Drinking Water Standard of 50 pCi/L for gross beta radioactivity. The results indicated that gross beta radioactivity detected in all drinking water samples was attributed to naturally-occurring radioactive materials.

In 1999, all but one of the monthly composite samples from Station K1-1 (TMINS liquid discharge) had gross beta radioactivity concentrations above the MDC. The gross beta concentrations ranged from  $2.2 \pm 0.9$  pCi/L to  $10 \pm 2$  pCi/L and averaged  $5.7 \pm 5.9$  pCi/L. The 1999 results were consistent with those reported in previous years for Station K1-1 samples. All TMINS liquid discharge samples, like drinking water samples, had gross beta concentrations well below the Federal and State Primary Drinking Water Standard of 50 pCi/L.

Monthly composite samples of surface and drinking water were analyzed for the presence of gamma-emitting radionuclides. None of the samples collected in 1999 contained detectable levels of reactor-produced, gamma-emitting radionuclides. Naturally-occurring K-40 and Ra-226 were detected in a few samples.

Semiannual composite samples were prepared from the monthly TMINS liquid discharge samples and then analyzed for the presence of Sr-89 and Sr-90. None of the 1999 semiannual composites contained Sr-89 or Sr-90 above the MDC.

### **Fish Results**

During 1999, fish samples were collected at one indicator and one control location in the spring (May and June) and fall (September and October). They included recreationally important predators (Smallmouth bass, Largemouth bass and Striped bass) and bottom feeders (Yellow bullhead and Channel catfish). All samples were analyzed for gamma-emitting radionuclides, Sr-89, Sr-90, and H-3.

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None of the fish samples collected in 1999 contained detectable levels of reactor-produced, gamma-emitting radionuclides. As expected, naturally-occurring K-40 was detected in all fish samples. Indicator concentrations were similar to those measured in the controls.

All fish samples were analyzed for Sr-89 and Sr-90. Neither of these radioactive materials was detected above the MDC in any of the 1999 fish samples.

Tritium above the MDC was detected in 3 of 4 indicator fish samples. None of the controls contained H-3 above the MDC. Indicator H-3 concentrations ranged from  $0.069 \pm 0.039$  pCi/g (wet) to  $0.11 \pm 0.05$  pCi/g (wet) and averaged  $0.088 \pm 0.41$  pCi/g (wet).

Like previous years, 1999 indicator fish samples contained somewhat higher H-3 concentrations than controls. This was expected for a number of reasons. First, H-3 was released routinely in 1999 TMINS liquid effluents. Second, indicator fish samples were collected in the York Haven Pond (YHP) between the TMINS liquid discharge outfall and the York Haven Dam (YHD). In this region of the YHP, mixing of TMINS liquid effluents and river water is incomplete. More complete mixing is not achieved until liquid effluents pass over the YHD.

Since H-3 was measured at slightly higher concentrations in the indicator samples, it is possible that a portion of the H-3 measured in these samples was due to routine TMINS operations. Since H-3 was detected in previous control fish samples, a portion of this material also was due to fallout and natural production in the atmosphere.

A conservative dose estimate was performed assuming that an individual consumed fish flesh with the highest H-3 concentration for one year. The maximum hypothetical whole body dose would be 0.00024 mrem. This calculated dose is equivalent to 0.000080% of the whole body dose that an individual living in the TMI area receives each year from natural background radiation (300 mrem).

### **Sediment Results**

In June and October of 1999, routine REMP sediment samples were collected from four sites in the Susquehanna River. Control samples were collected from a location upstream of the TMINS liquid discharge outfall. Indicators were collected from three sites in the York Haven Pond (YHP) between TMINS liquid discharge outfall and the York Haven Dam (YHD). All samples were analyzed for gamma-emitting radionuclides.

Naturally-occurring Be-7, K-40, Ra-226 and thorium-232 (Th-232) as well as fallout and/or reactor-produced Cs-137 were identified in all indicator and control samples. No other reactor-produced, gamma-emitting radionuclides were detected above the MDC.

Indicator Cs-137 concentrations ranged from  $0.11 \pm 0.03$  pCi/g (dry) to  $0.24 \pm 0.03$  pCi/g (dry) and averaged  $0.18 \pm 0.11$  pCi/g (dry). Control sample concentrations were slightly lower, ranging from  $0.098 \pm 0.037$  pCi/g (dry) to  $0.12 \pm 0.04$  pCi/g (dry) and averaging  $0.11 \pm 0.03$  pCi/g (dry). For comparison, 1998 average Cs-137 concentrations were  $0.18 \pm 0.06$  pCi/g (dry) and  $0.13 \pm 0.16$  pCi/g (dry), for indicators and controls, respectively.

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The sediment samples collected from Indicator Station K1-3, a location just downstream of the TMINS liquid discharge outfall, had the highest annual average Cs-137 concentration. The concentrations ranged from  $0.18 \pm 0.02$  pCi/g (dry) to  $0.22 \pm 0.05$  pCi/g (dry) and averaged  $0.20 \pm 0.06$  pCi/g (dry). This was expected because Cs-137 is typically released in TMINS liquid effluents and less mixing of effluents and river water occurs at this location. Also, radioactive materials such as Cs-137 are readily adsorbed by suspended particles in the water and bottom sediments.

As mentioned previously, Cs-137 is a fallout product of weapons testing as well as a constituent of TMINS liquid effluents. Since 4 of 6 (67%) indicator sample concentrations were slightly higher than those measured in 1999 control samples it is reasonable to conclude that an increment of the Cs-137 detected in the indicator samples was due to TMINS operations. The presence of this material in the control samples indicated that a portion of the Cs-137 detected in the indicator samples also was due to fallout from prior atmospheric nuclear weapon tests.

Figure 16 depicts Cs-137 concentrations in river sediments from 1984 through 1999. As shown in this figure, no discernible buildup of Cs-137 occurred at indicator locations prior to and after 1995. This was primarily due to periodic scouring or removal of bottom sediments during high river flows (Ref. 48).

A temporary buildup of Cs-137 in sediments was noted in 1995. This was caused by lower than normal river flows during the year and especially in the spring months when most scouring occurs. In 1996, the average Cs-137

concentrations in indicator samples trended downward. The reduction was due to releasing lower amounts of Cs-137 and having higher than average river flows which increase dilution of liquid effluents and promote scouring.

Based on the annual average concentration of Cs-137 in samples collected from Station K1-3, an estimate of the shoreline whole body dose to the maximally exposed individual was calculated. For this calculation, the annual average Cs-137 control concentration was subtracted to account for fallout Cs-137. The calculated whole body dose (0.00020 mrem/yr) was insignificant and a small percentage (0.000067%) of the whole body dose received by an individual from natural background radiation (300 mrem/yr).

In previous years, sediment samples were collected at Safe Harbor Dam (SHD), the first major sediment trap downstream of TMINS. The purpose of this sampling was to determine if radionuclides released in TMINS liquid effluents were present and accumulating at SHD.

The results indicated that a portion of the Cs-137 detected in the SHD sediments may be due to TMINS operations since the concentrations were higher than those collected at control locations. However, the absence of other reactor-related radionuclides, such as Cs-134, indicated that recent TMINS discharges were not present at significant levels and most of the Cs-137 was attributable to fallout from prior nuclear weapon tests and/or the Chernobyl Accident of 1986. The results also indicated that a buildup of TMINS-related materials was not occurring at SHD.

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**TABLE 6**

**1999 Average Tritium Concentrations in Surface and Drinking Water  
(pCi/L)**

<u>Station</u>	<u>Description</u>	Sample Concentrations > MDC <sup>(1)</sup>		Actual Sample Concentrations <sup>(2)</sup>	
		<u>Average +/- 2 std dev</u>	<u>Range</u>	<u>Average +/- 2 std dev</u>	<u>Range</u>
<b>Surface Water</b>					
A3-2 (C)	Swatara Creek (Middletown, PA)	110 ± 0	110	54 ± 73	(-12) - 110
F15-1 (C)	Chickies Creek (Marietta, PA)	110 ± 20	100 - 120	57 ± 87	4.4 - 120
Q9-1 (C)	Steelton Water Authority (Steelton, PA)	110 ± 50	92 - 150	60 ± 100	(-19) - 150
J1-2 (I)	West Shore of TMI	2300 ± 6300	100 - 10000	2000 ± 6000	20 - 10000
<b>Drinking Water</b>					
Q9-1 (C)	Steelton Water Authority (Steelton, PA)	110 ± 60	86 - 150	50 ± 110	(-52) - 150
G15-2 (I)	Wrightsville Water Supply (Wrightsville, PA)	150 ± 80	98 - 200	110 ± 120	12 - 200
G15-3 (I)	Lancaster Water Authority (Columbia, PA)	270 ± 260	140 - 490	180 ± 300	10 - 490

<sup>(1)</sup> Averages and ranges are based on sample results above the minimum detectable concentration (MDC). Duplicate analysis results and quality control sample results are not included.

<sup>(2)</sup> Averages and ranges are based on actual sample concentrations (whether positive, negative or zero). Negative sample concentrations are enclosed in parentheses. Using actual sample concentrations (sample count rate minus background or blank count rate) to calculate annual averages eliminates biases such as those caused by averaging only sample concentrations above the MDC. Negative sample concentrations are important to the overall average, but have no physical significance. Duplicate analysis results and quality control sample results are not included.

(I) = Indicator Station (C) = Control Station

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**TABLE 7**

**1999 Average Gross Beta Concentrations in Drinking Water  
(pCi/L)**

<b><u>Station</u></b>	<b><u>Description</u></b>	<b>Sample Concentrations &gt; MDC <sup>(1)</sup></b>		<b>Actual Sample Concentrations <sup>(2)</sup></b>	
		<b>Average +/- 2 std dev</b>	<b>Range</b>	<b>Average +/- 2 std dev</b>	<b>Range</b>
Q9-1 (C)	Steelton Water Authority (Steelton, PA)	2.5 ± 1.5	1.6 - 3.8	1.5 ± 2.4	(-0.38) - 3.8
G15-2 (I)	Wrightsville Water Supply (Wrightsville, PA)	3.1 ± 2.5	1.8 - 5.5	3.1 ± 2.5	1.8 - 5.5
G15-3 (I)	Lancaster Water Authority (Columbia, PA)	2.7 ± 2.2	1.3 - 4.3	2.4 ± 2.4	0.62 - 4.3

<sup>(1)</sup> Averages and ranges are based on sample results above the minimum detectable concentration (MDC). Duplicate analysis results and quality control sample results are not included.

<sup>(2)</sup> Averages and ranges are based on actual sample concentrations (whether positive, negative or zero). Negative sample concentrations are enclosed in parentheses. Using actual sample concentrations (sample count rate minus background or blank count rate) to calculate annual averages eliminates biases such as those caused by averaging only sample concentrations above the MDC. Negative sample concentrations are important to the overall average, but have no physical significance. Duplicate analysis results and quality control sample results are not included.

(I) = Indicator Station (C) = Control Station

# 1999 Tritium Concentrations in Surface Water

## Picocuries per Liter by Month

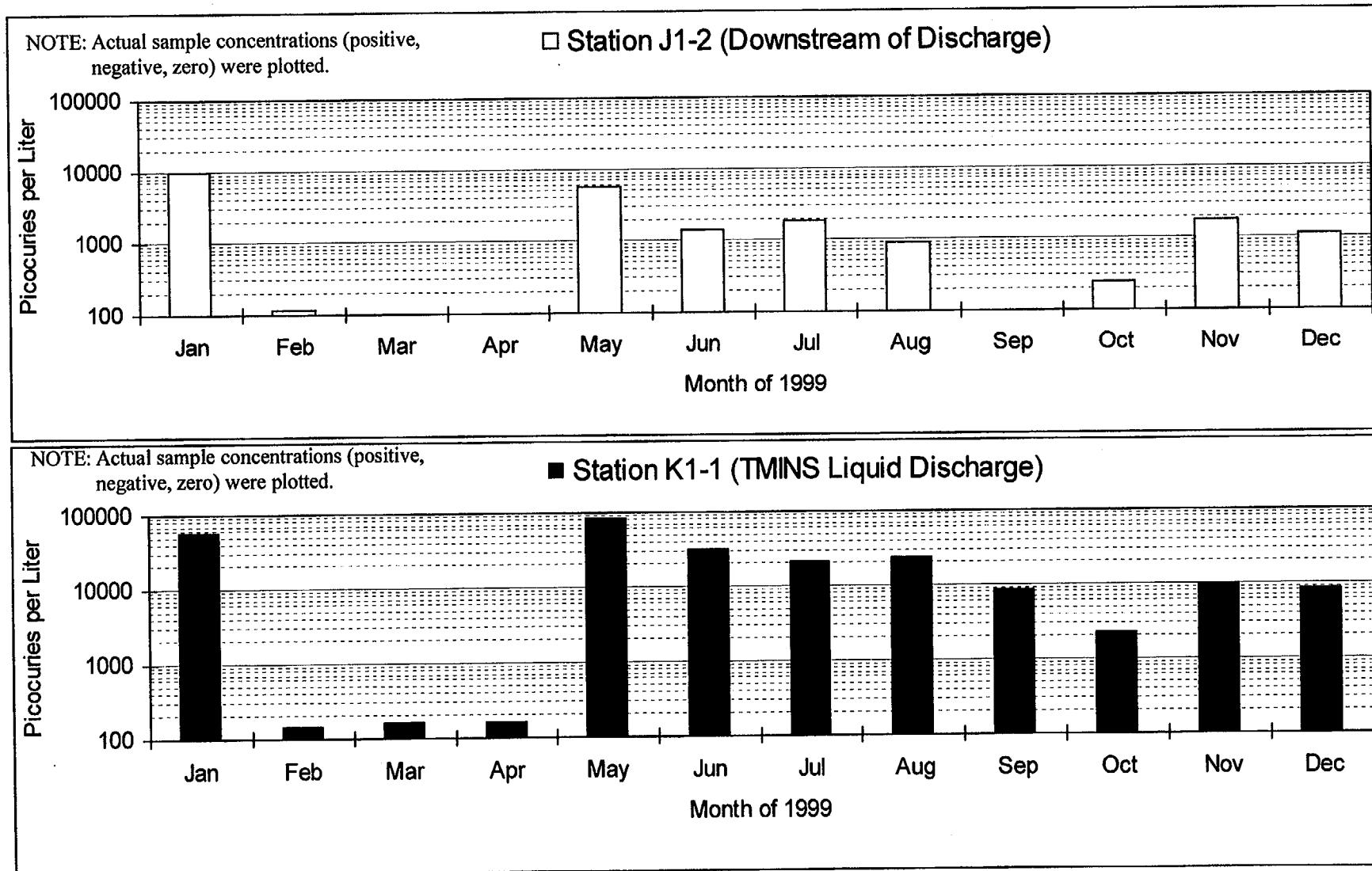


Figure 12

# Historical Tritium Concentrations in Surface Water

## Picocuries per Liter by Quarter

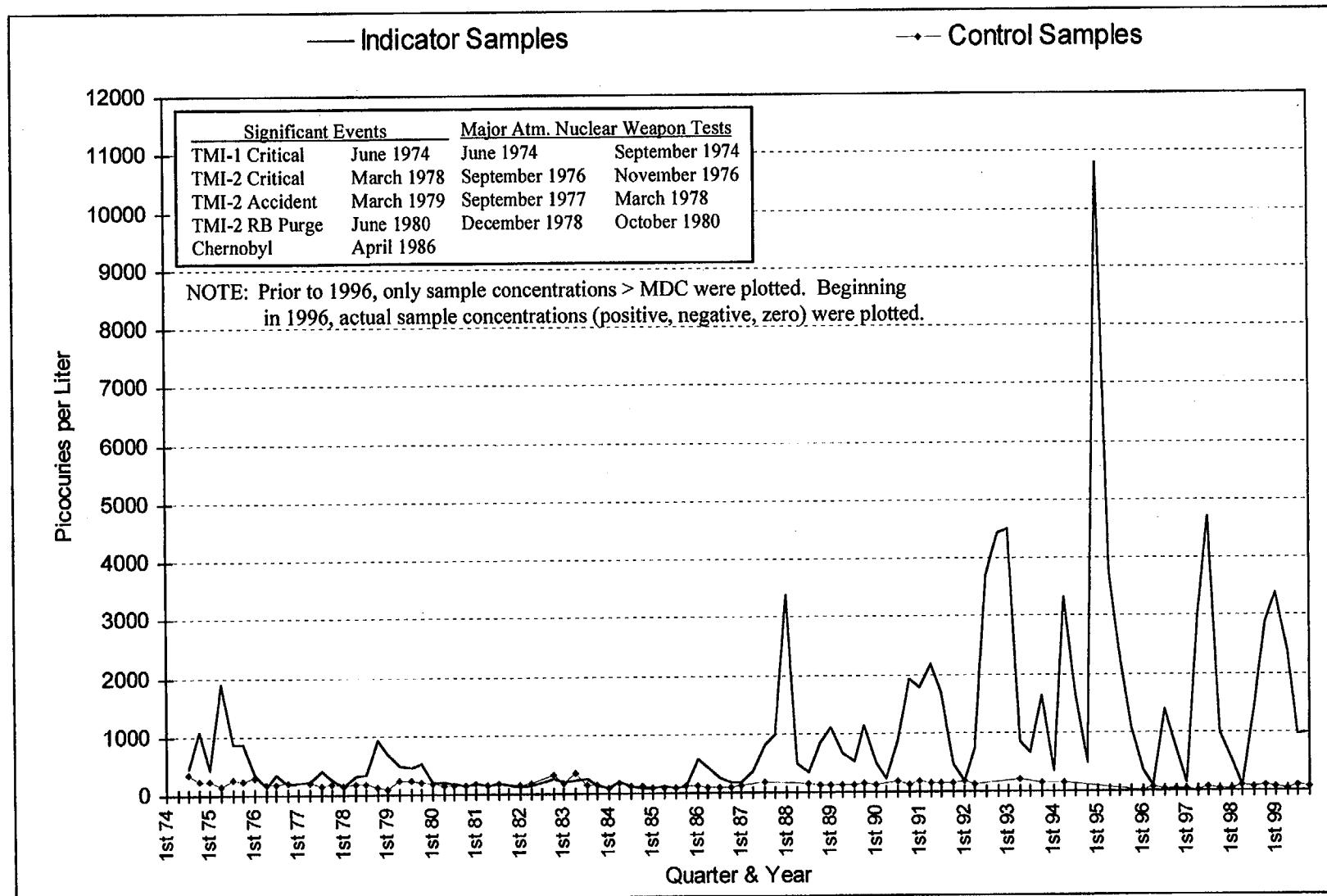


Figure 13

# 1999 Tritium Concentrations in Drinking Water

## Picocuries per Liter by Month

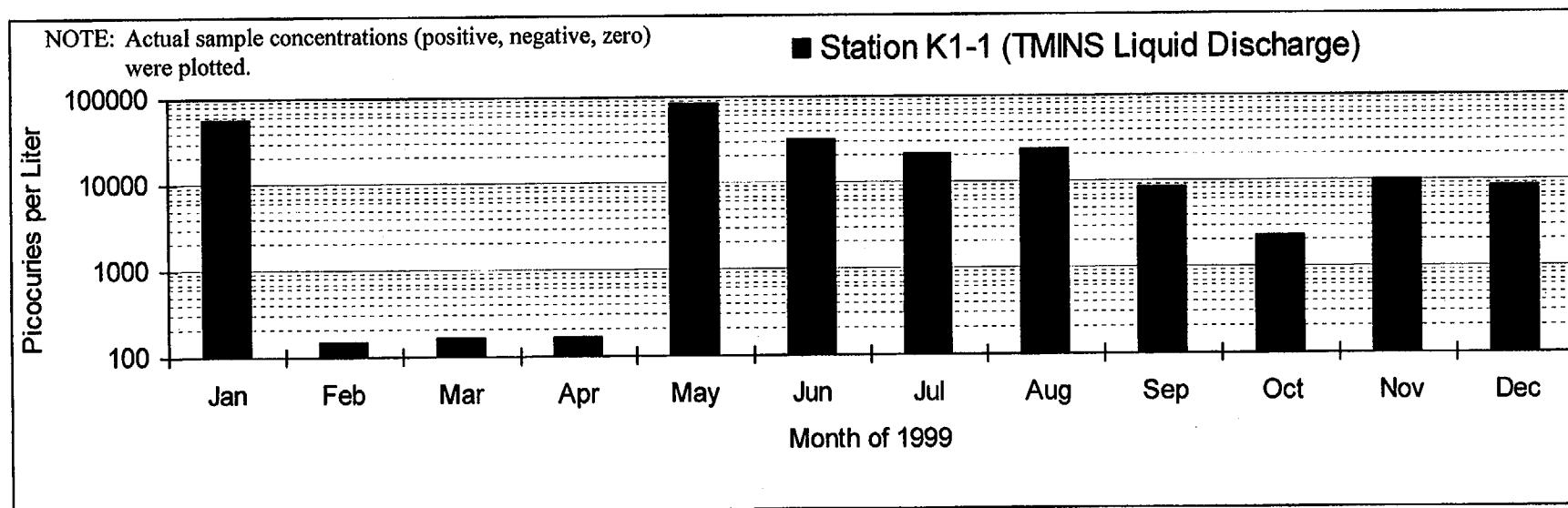
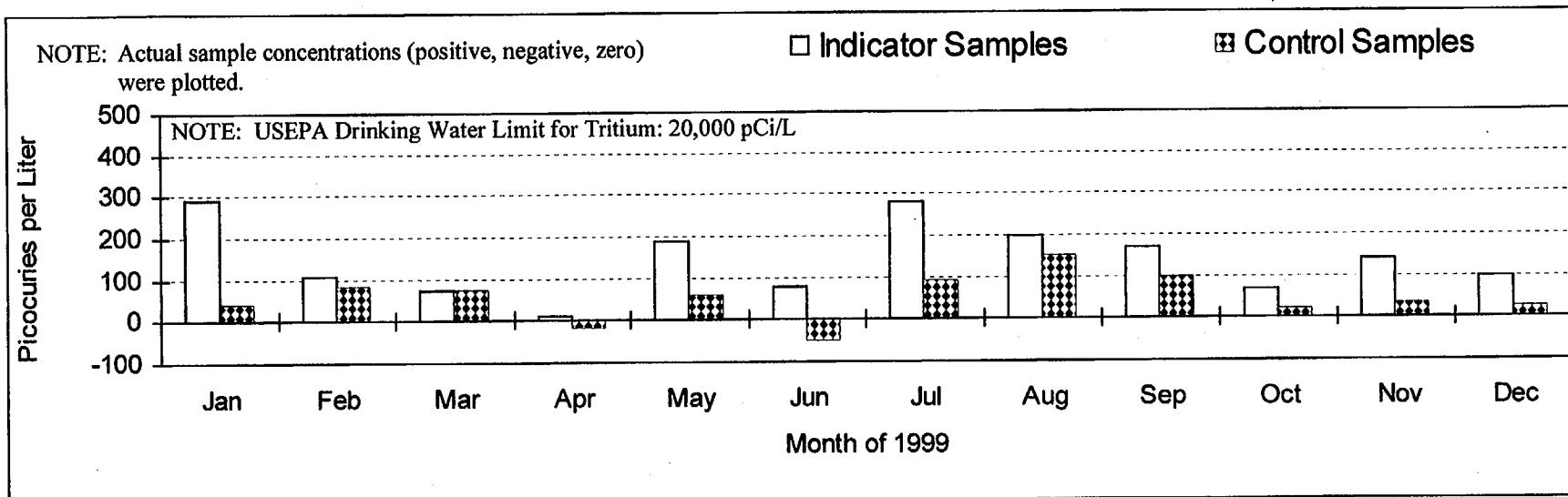


Figure 14

# 1999 Gross Beta Concentrations in Drinking Water

## Picocuries per Liter by Month

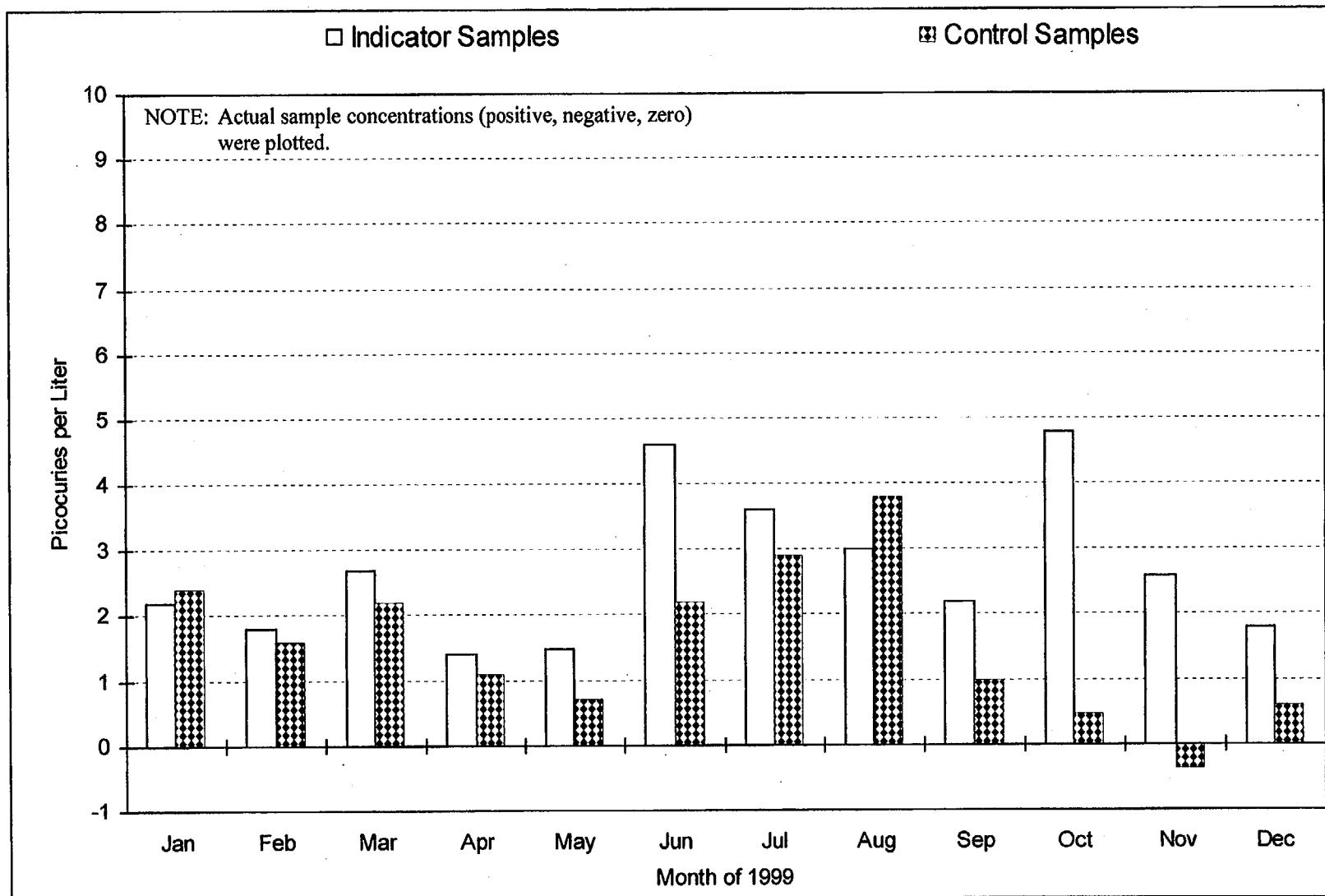


Figure 15

# Historical Cesium-137 Concentrations in Aquatic Sediments

## Picocuries per Gram (dry)

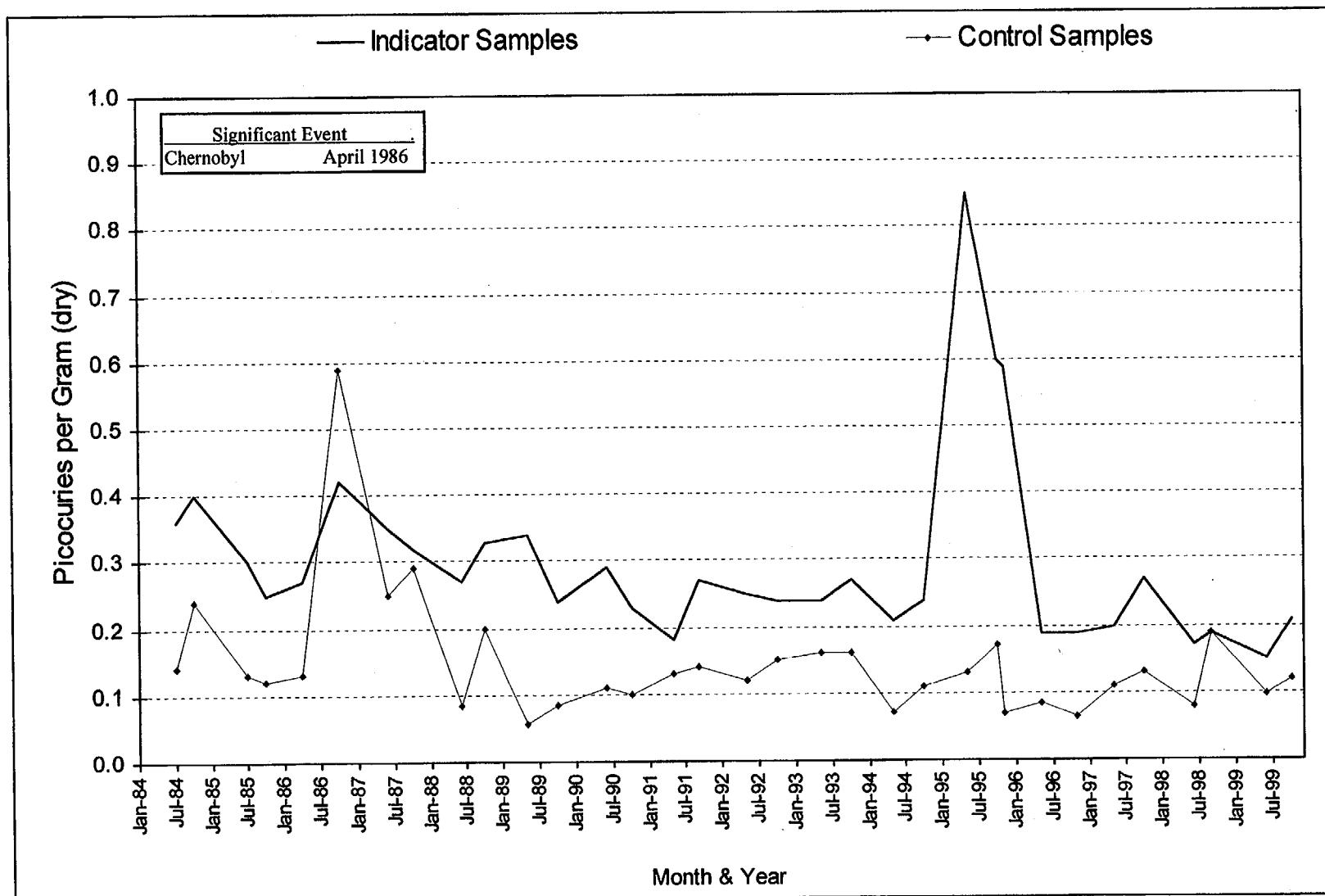


Figure 16

## **TERRESTRIAL MONITORING**

Radionuclides released to the atmosphere may deposit on soil and vegetation. They may eventually be incorporated into milk, meat, fruits, vegetables, or other food products. To assess the impact of TMINS operations to humans from the ingestion pathway, primary food product samples such as green leafy vegetables, root vegetables, fruits, grains and milk were collected and analyzed during 1999. The ingestion pathway also is normally assessed by collecting and analyzing deer meat samples. No deer meat samples were analyzed in 1999 because indicator samples were not available.

In addition to edible products, rodent carcasses are normally analyzed as part of the TMI-2 Post-Defueling Monitored Storage (PDMS) Rodent Collection and Analysis Program. The purpose of this program is to determine if radioactive materials have been transported by the movement of animals from radiologically-controlled areas to unrestricted areas. No rodent carcasses were available for analysis in 1999.

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The radiological contribution of TMINS operations was determined by comparing the results of samples collected in prevalent downwind locations, primarily to the south and east of the site, with control samples collected from distant or generally upwind directions. Comparisons with results from previous years also were performed, as applicable.

The analytical results of samples collected during 1999 indicated that there was no discernible TMINS contribution to radioactivity levels in locally-produced food products. As expected, Sr-90 was found in milk and broad leaf vegetable samples. The concentrations observed in samples collected near TMINS (indicators) were similar to levels observed in samples collected from the distant sites (controls) and consistent with data from prior years. The presence of Sr-90 in both indicator and control samples was attributed to fallout from prior atmospheric nuclear weapon tests.

As part of the REMP, a surveillance was performed to identify relevant changes in the use of land (unrestricted areas) around TMI. This land use surveillance consisted of a dairy census, a garden census and a residence census.

The dairy census was performed to determine the location of the nearest milk animal within five miles of TMINS in each of the sixteen meteorological sectors. Prior to 1997, all milk animals within five miles of TMINS were included in the dairy census. The results of the 1999 dairy census are listed in Table G-1 of Appendix G.

The purpose of the residence and garden censuses was to locate the nearest residence and garden in each of the meteorological sectors, respectively. Only gardens of greater than 500 square feet producing broad leaf vegetation were included in the garden census. The results of the residence and garden censuses are listed in Tables G-2 and G-3 of Appendix G, respectively.

The results of these censuses provide a basis for modifying the radiological environmental monitoring program and the model used for calculating offsite doses. Based on the 1999 land use surveillance, only minor changes to the dose model were required.

### **Sample Collection and Analysis**

During 1999, samples of raw cow milk were collected biweekly from local farmers at one control and four indicator locations. Indicator samples were collected at locations that have a high potential for impact by TMINS operations. These locations generally were proximate to TMINS and in dominant wind directions. Conversely, the control station was located greater than 10 miles from TMINS in a non-prevalent wind direction. The samples collected at this site should be unaffected by operations at TMINS.

A gamma isotopic analysis and a low-level I-131 analysis were performed on each biweekly milk sample. The biweekly milk samples were then composited quarterly by station and analyzed for Sr-89 and Sr-90.

Terrestrial vegetation - fruits, grains, root vegetables and leafy vegetables - were collected when ripe from one indicator and

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one control garden. Maintained by TMIEA, the indicator garden was located at the TMINS Visitors Center (Station E1-2). The control garden was located at Milton Hershey School (MHS). This garden was maintained by MHS students in cooperation with TMIEA.

Like indicator milk samples, indicator terrestrial vegetation samples were collected at a location having a high potential for impact by operations at TMINS. Controls samples were obtained from a distant site where they should be unaffected by TMINS operations.

Tomatoes, cabbages, red beets and sweet corn were collected in 1999. All samples were analyzed for gamma-emitting radionuclides, including I-131. Cabbage samples also were analyzed for Sr-89 and Sr-90.

Deer meat samples are normally obtained and analyzed as part of the routine REMP. Deer meat samples were not analyzed in 1999 because indicator samples were not available.

When available, a limited number of rodent carcasses are analyzed as part of the non-routine REMP. During 1999, no carcasses were available for analysis.

### **Milk Results**

During 1999, 130 biweekly milk samples were collected and analyzed. Iodine-131 was not detected above the minimum detectable concentration (MDC) in any of the milk samples. Gamma isotopic analyses yielded only naturally-occurring potassium-40 (K-40) and radium-226 (Ra-226). Potassium-40 was detected in all 1999 milk samples. The K-40

concentrations measured in the indicator samples were similar to those measured in the controls. Radium-226, a naturally-occurring radionuclide commonly measured in soil, was detected in two milk samples. Its presence in the milk was probably due to ingestion of soil by the cows.

Strontium analyses were performed on 20 quarterly composite samples. None of the samples contained Sr-89 above the MDC. As expected, Sr-90 was measured in a number of milk samples. Six of sixteen indicator samples (37%) and one of four control samples (25%) contained Sr-90 above the MDC.

Strontium-90 concentrations in the indicator samples ranged from  $0.59 \pm 0.38$  pCi/L to  $1.3 \pm 0.5$  pCi/L and averaged  $0.96 \pm 0.48$  pCi/L. The concentration measured in the control sample was  $1.0 \pm 0.6$  pCi/L. The Sr-90 concentrations measured in 1999 milk samples were consistent with those measured in 1998 when indicator and control sample concentrations averaged  $1.1 \pm 0.7$  pCi/L and  $1.1 \pm 0.9$  pCi/L, respectively.

The milk collected from Indicator Station E2-2, the dairy farm located 1.1 miles east of TMINS, contained the highest annual average Sr-90 concentration. Strontium-90 above the MDC was detected in one of the four quarterly composite samples. The concentration was  $1.3 \pm 0.5$  pCi/L. Milk samples collected in 1999 from the other farms had similar Sr-90 concentrations. Additionally, the milk samples collected in previous years from this and other dairy farms contained similar Sr-90 concentrations.

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The results indicated that the Sr-90 measured in the 1999 milk samples was unrelated to operations at TMINS. Its presence in this medium was primarily due to the transfer of this long-lived fallout product from soil to animal feed (fresh or stored) to cow to milk.

Figure 17 depicts the trends of Sr-90 concentrations in indicator and control cow milk samples since 1979. The data plotted for 1996 through 1999 were based on actual sample concentrations because many of the results were below the MDC. Using actual concentrations eliminates biases in the data and missing data points on graphs.

As shown on Figure 17, the Sr-90 concentrations have trended downward. This decrease is directly related to the cessation of atmospheric nuclear weapon testing and the radioactive decay and depletion of both atmospheric and terrestrial Sr-90 associated with prior weapon testing.

### **Terrestrial Vegetation Results**

A total of eight terrestrial vegetation samples - leafy vegetables (cabbages), root vegetables (red beets), fruits (tomatoes) and grains (sweet corn) - were collected and analyzed in 1999. Naturally-occurring K-40 was measured in all terrestrial vegetation samples. Indicator concentrations were similar to controls. No gamma-emitting radionuclides (including I-131) attributable to TMINS operations were detected above the MDC.

Strontium may be incorporated into plants by either uptake from soil or direct deposition on foliar surfaces. In 1999, none of the leafy vegetables (cabbages) contained Sr-89 above

the MDC. Low-level Sr-90 was detected above the MDC in both the indicator and the control sample. The measured concentrations were  $0.0036 \pm 0.0017$  pCi/g (wet) and  $0.0025 \pm 0.0015$  pCi/g (wet), respectively.

In previous years, similar Sr-90 concentrations were detected in both indicator and control samples. For example, the 1998 indicator cabbage sample contained Sr-90 at a concentration of  $0.0074 \pm 0.0021$  pCi/g (wet). This radionuclide also was measured in the 1998 control sample at a concentration of  $0.0047 \pm 0.0020$  pCi/g (wet).

As in previous years, the data indicated that the Sr-90 measured in the 1999 cabbage samples was attributed to fallout from prior nuclear weapon tests and, therefore, was unrelated to operations at TMINS. The detection of Sr-90 was not unexpected because measurable amounts of this long-lived fallout product are still present in the terrestrial environment. Additionally, cabbages have a tendency to absorb Sr-90 residing in the soil.

### **Deer Meat Results**

Deer meat samples are normally obtained via local hunters and/or road-kills and analyzed as part of the routine REMP. During 1999, no deer meat samples were analyzed because indicator samples were not available.

### **Rodent Results**

No rodent carcasses were available for analysis in 1999. Previous data suggest that

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rodents are not transporting radioactive materials to unrestricted areas.

A pest control program is in place at TMINS. This program minimizes the potential for rodents to transport radioactive materials to unrestricted areas.

# Historical Strontium-90 Concentrations in Cow Milk

## Picocuries per Liter by Quarter

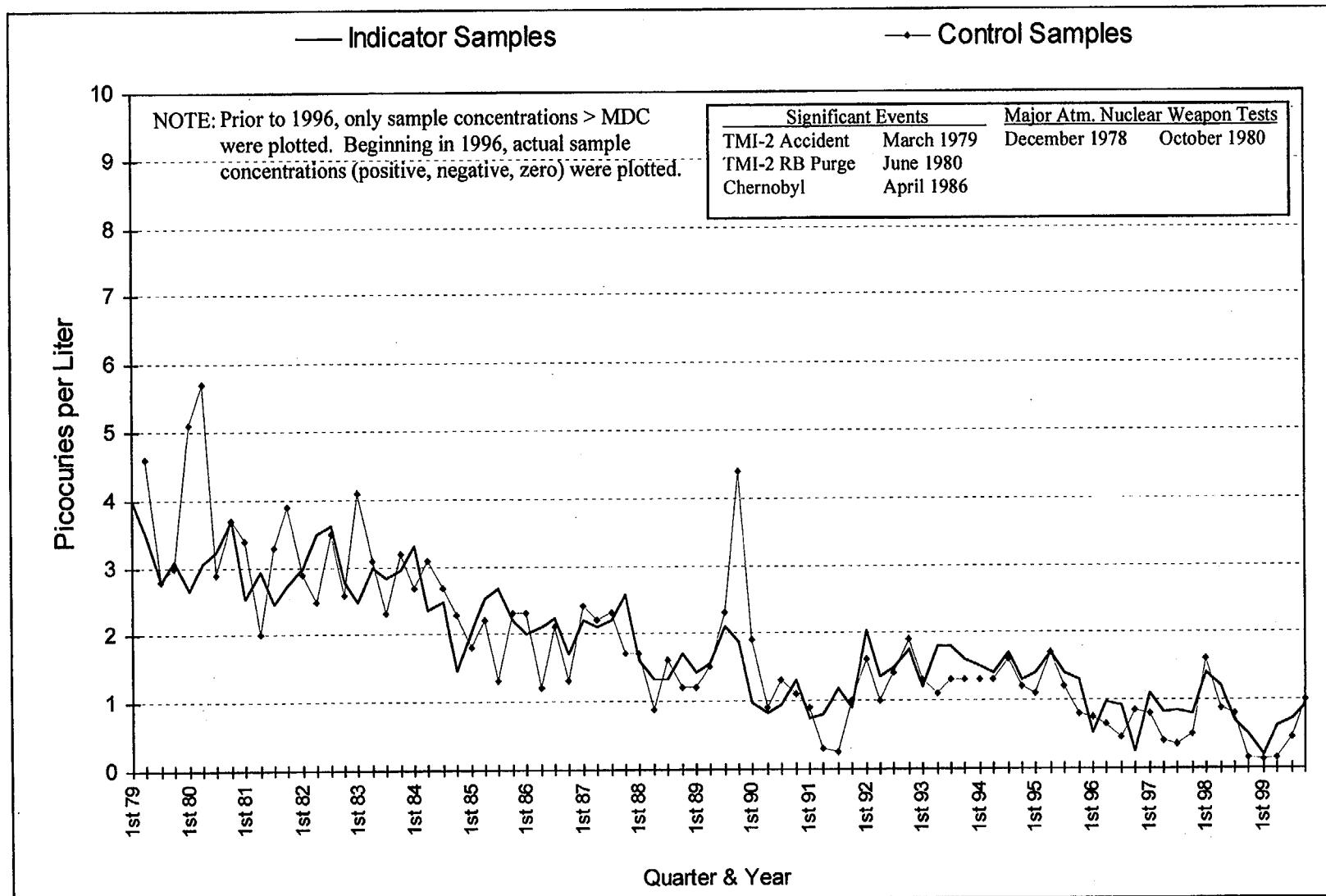


Figure 17

## **GROUNDWATER MONITORING**

Three Mile Island (TMI) is located in the Triassic lowland of Pennsylvania, a region often referred to as the Gettysburg Basin. The Island was formed as a result of fluvial deposition by the Susquehanna River. It is composed of sub-rounded to rounded sand and gravel, containing varying amounts of silt and clay. Soil depths on TMI vary from approximately six feet at the south end to about 30 feet at the center. The site is underlain by Gettysburg shale that lies at an elevation of approximately 277 feet (Refs. 32 and 33).

The Island has two different water-bearing zones. One is composed of the soils overlying the Gettysburg shale (bedrock). The other is the bedrock. Relative to the natural soils, the movement of groundwater is much quicker in the bedrock. Groundwater from TMI migrates to the Susquehanna River, but does not impact onshore groundwater supplies. The migration of TMI groundwater to onshore supplies is prevented by the higher levels and the opposing flows of groundwater that exist beneath the surrounding terrain on the opposite sides of the Susquehanna River. The estimated travel time for groundwater to reach the river from the central portion of TMI is approximately 12 years (Ref. 49).

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A groundwater monitoring program (GMP) was initiated in 1980 to detect leakage of water, if any, from the TMI-2 Reactor and Auxiliary Buildings and outside storage tanks. Since 1980, the TMINS GMP has been expanded and now monitors activities associated with both TMI-1 and TMI-2.

During 1999, most of the onsite groundwater samples contained H-3 above the minimum detectable concentration (MDC). The presence of H-3 in these samples was attributed primarily to routine TMI-1 operations and previous TMI-2 operations. Additionally, two pipe leaks contributed to elevated levels of H-3 in certain onsite wells. Projects to repair or replace the pipes were completed. Both pipes continue to be monitored.

Tritium above the MDC was detected in all offsite groundwater samples (8 of 8) and onsite storm water samples (3 of 3). Its presence was due to a combination of routine TMI-1 operations, natural production in the atmosphere and fallout from prior nuclear weapon tests.

All H-3 concentrations measured in the groundwater collected from the onsite stations were below the USNRC 10 CFR 20 effluent concentration limit. Additionally, the onsite and offsite groundwater used for drinking contained H-3 at concentrations that were well below the USEPA Primary Drinking Water Standard of 20,000 pCi/L.

None of the groundwater samples collected in 1999 contained Sr-90 or gamma-emitting radionuclides related to TMINS operations. The same can be said for storm water and sediment collected from Station EDCB.

The 1999 TMINS GMP results indicated that the concentrations of radioactive materials measured in onsite and offsite groundwater were too low to have a significant adverse impact on humans or the environment.

As part of the TMINS Groundwater Protection Plan, an aboveground tank monitoring program (ATMP) was established in 1997. The purpose of the program is to detect tank or component leakage at an early stage so that impacts to the local environment, such as soil and groundwater, can be minimized.

In 1999, three aboveground tanks were monitored. Monitoring was performed by collecting and analyzing either sponge samples or groundwater samples along with precipitation samples. Periodic inspections also were performed at one of the tanks. No discernible tank or component leakage was identified in 1999.

### **Sample Collection and Analysis**

Several changes were made to the TMINS GMP in 1999. Groundwater sampling replaced sponge sampling to monitor aboveground tanks. The collection and analysis of OSF samples was reduced from monthly to quarterly. Additionally, special or non-routine groundwater samples were collected from various stations. Finally, onsite Stations MS-8 and AIT were not monitored. The changes are discussed further in Appendix C.

Groundwater from 20 onsite and 8 offsite stations were sampled in 1999. Of the 20 onsite, groundwater stations, 14 were monitoring wells (MS-1, MS-2, MS-4, MS-5,

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MS-7, MS-19, MS-20, MS-21, MS-22, OS-14, OS-18 and RW-1, RW-2 and TRANS), 2 were drinking water wells (OSF and 48S), 3 were industrial wells (NW-A, NW-B and NW-C). The other onsite, groundwater station was the TMINS Pretreatment Building clearwell (NW-CW). Added in 1997, the clearwell is a holding tank for the water pumped from the industrial wells. All offsite stations (A2-2, D1-4, E1-2, J3-3, K1-6, L1-3, L1-4 and N2-1) were drinking water wells. Storm water and sediment were sampled in 1999 from one onsite station (EDCB).

The locations of the onsite groundwater stations sampled in 1999 are shown on Figures J-1 and J-2 (Appendix J). Figure J-2 also shows the location of Station EDCB. The offsite groundwater stations are depicted on Figures 4 and 5 (**Radiological Environmental Monitoring**).

All groundwater samples were collected using standard plumbing, a dedicated, in-well pumping system or a bailing device. Most groundwater stations were sampled either weekly, monthly, quarterly or annually. A few were sampled on an as needed basis. Storm water and sediment from Station EDCB were collected monthly and annually, respectively.

All groundwater samples collected in 1999 were analyzed for H-3. Some of these samples were analyzed individually for gamma-emitting radionuclides and some were combined into annual composites and analyzed for Sr-90.

The monthly storm water samples collected from Station EDCB were combined into quarterly samples and analyzed for H-3 and gamma-emitting radionuclides. The annual

sediment sample collected from this station was analyzed for gamma-emitting radionuclides.

Sponge and precipitation samples were collected monthly after the first significant precipitation event. The precipitation and water extracted from the sponges were analyzed for H-3.

### **Groundwater Results**

During 1999, H-3 was the only radionuclide consistently detected in samples collected from the onsite monitoring wells, the industrial wells and the clearwell. The results are summarized in Table J-1 of Appendix J. For comparison, Table J-1 also includes 1998 station averages. The presence of H-3 in the samples was attributed primarily to routine operations at TMI-1 and past operations at TMI-2. Additionally, leaks in two pipes were the source of H-3 in a few of the onsite groundwater samples. Projects to repair or replace the pipes were completed. Both pipes continue to be monitored.

Generally, the H-3 concentrations measured in most onsite monitoring well samples remained the same or trended downward in 1999. Additionally, the annual average concentrations generally were similar to or below those calculated for the period just prior to the operations of the TMI-2 Evaporator (January 1991 through August 1993).

The highest H-3 concentrations were measured in the onsite groundwater samples collected from Stations MS-4, MS-19, RW-1, RW-2, MS-22, OS-18, NW-A, NW-B, NW-C and NW-CW.

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The RW-1 well was originally drilled to recover oil from a past pipe leak. After the oil recovery process was completed, the well was included in the TMINS GMP to provide additional monitoring coverage for TMI-1 activities and systems (e.g. tanks, components and pipes).

The 1999 RW-1 H-3 concentrations averaged  $7,200 \pm 5,300$  pCi/L and ranged from 1,800 to 11,000 pCi/L. For comparison, the 1998 RW-1 H-3 concentrations averaged  $1,100 \pm 2,200$  pCi/L and ranged from 160 to 3,400 pCi/L.

In the past, the groundwater collected from RW-1 was impacted by leakage of system components that migrated to the ground near the well. A decrease was noted for the last six months of 1997 through most of 1998 as a result of repairing the components at the end of 1996. At the end of 1998, the H-3 concentrations in RW-1 began to increase. An investigation was initiated. A leak in a nearby pipe was discovered and repaired. Groundwater at three other stations - MS-4, MS-19 and RW-2 - also were affected by this leak. Since the pipe was repaired, the H-3 concentrations in the groundwater at all four stations have trended downward.

Although most of the H-3 detected in these samples was due to the pipe leak, some also was due to normal atmospheric releases of this material from TMI-1.

Station MS-22 was installed in November of 1996 to monitor the TMI-1 Borated Water Storage Tank (BWST). The station is located near the TMI-1 Station Vent, a release point where the largest amount of airborne H-3 is vented to the environment. The 1999 MS-22

H-3 concentrations averaged  $960 \pm 640$  pCi/L and ranged from 520 to 1,700 pCi/L. For comparison, the 1998 MS-22 H-3 concentrations averaged  $3,600 \pm 9,300$  pCi/L and ranged from 1,200 to 18,000 pCi/L.

The concentrations measured in the 1999 MS-22 samples were within the expected range based on the location of this station. The presence of H-3 in these samples was attributed to routine airborne releases of H-3 from the TMI-1 Station Vent. A similar conclusion can be made based on the results of the aboveground tank monitoring program which indicated no leakage and, therefore, no contribution from the TMI-1 BWST or its components.

In August of 1998, Station OS-18 was added to the TMINS GMP. The well was originally installed to investigate alleged past spills of photographic waste. It was not sampled for several years and was never sampled for radioactive materials. The well was added to the TMINS GMP because of its proximity to pipes that transport water containing radioactive materials, including H-3. These pipes were the last significant potential sources of H-3 to the groundwater.

The 1999 OS-18 H-3 concentrations averaged  $26,000 \pm 54,000$  pCi/L and ranged from 320 to 130,000 pCi/L. For comparison, the 1998 OS-18 H-3 concentrations averaged  $11,000 \pm 13,000$  pCi/L and ranged from 3,800 to 31,000 pCi/L.

The highest concentrations occurred shortly after water was transported in one of the pipes. This indicated that there may be a leak in at least one of the lines. A test to determine

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the integrity of the lines began in March of 1999. One of the pipes was found to be leaking and was repaired. Monitoring is ongoing to determine if the pipe was successfully repaired or if there is another unidentified leak in the same pipe or a different pipe.

Industrial Wells NW-A, NW-B and NW-C were installed in the latter part of 1995. Sampling of these wells was initiated in 1996. Beginning in June of 1997, water from the industrial wells was used to supply water to various TMI-1 systems. Prior to this period, the water used in these systems was obtained from the Susquehanna River.

Industrial Wells NW-A and NW-B supplied all service water to the plant during 1998. Industrial Well NW-C was turned off in the latter part of 1997 because of increasing H-3 concentrations. Pumping and sampling of NW-C resumed in August of 1998 to 1) determine current H-3 concentrations in NW-C well water, 2) determine, if possible, peak H-3 concentrations in deep aquifers, 3) reduce, if possible, H-3 concentrations in deep aquifers and 4) determine the effect on NW-A and NW-B well water.

The water pumped from NW-C in 1998 was not used in the plant. Rather, it was sent via hose to a location where it was monitored, diluted and then discharged to the Susquehanna River. Pumping and sampling of NW-C was discontinued in October because of the onset of winter. The colder temperatures could lead to a frozen hose. All three industrial wells supplied service water to the plant in 1999. Generally, the H-3 concentrations were similar (NW-A) or decreased (NW-B and NW-C) throughout the

year. Additionally, the concentrations measured in 1999 were lower than those measured in 1998.

The 1999 H-3 concentrations in water collected from NW-A averaged  $1,800 \pm 500$  pCi/L and ranged from 740 to 2,400 pCi/L. Similar, the 1998 concentrations averaged  $2,300 \pm 1,200$  pCi/L and ranged from 620 to 3,400 pCi/L.

During 1999, the H-3 concentrations for NW-B were somewhat higher averaging  $3,800 \pm 4,400$  pCi/L and ranging from 2,100 to 9,800 pCi/L. For comparison, the 1998 NW-B concentrations averaged  $9,400 \pm 5,400$  pCi/L and ranged from 3,300 to 16,000 pCi/L.

The 1999 NW-C H-3 concentrations averaged  $50,000 \pm 52,000$  pCi/L and ranged from 23,000 to 160,000 pCi/L. For comparison, the 1998 H-3 concentrations averaged  $56,000 \pm 76,000$  pCi/L and ranged from 32,000 to 230,000 pCi/L

The 1999 NW-C H-3 concentrations decreased with time, starting generally at 60,000 pCi/L in February and ending at approximately 20,000 pCi/L in December. The data collected in 1999 (like 1998) suggested that pumping NW-C on a continuous basis shielded or protected NW-A and NW-B from higher levels of H-3.

The presence of H-3 in the water collected from the industrial wells was expected because the wells are located in an area that can be impacted by past TMI-2 operations. A portion of the H-3 detected in the samples also was due to routine TMI-1 operations.

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The magnitude of the H-3 concentrations measured in NW-C water, however, was higher than expected. The higher than expected results in NW-C along with somewhat steady concentrations in NW-A and NW-B suggested that another source of H-3 may exist. It is likely that the pipe leak that affected OS-18 (discussed above) may have affected the H-3 concentrations found in the industrial well water.

All of the H-3 concentrations found in water collected from the onsite monitoring wells, the industrial wells and the clearwell were well below the USNRC 10 CFR 20 (Appendix B, Table 2) effluent concentration of 1,000,000 pCi/L.

Tritium also was measured in the water collected from the two onsite drinking water wells, Stations 48S and OSF. In 1997, the well at Station 48S was established as the primary source for drinking water on TMINS. To a lesser extent, water from the OSF well also was used for drinking. Occasionally, water from this well also was used to supply water for various TMI-1 systems.

In 1999, 4 of 5 samples collected from Station 48S contained H-3 above the minimum detectable concentration (MDC). The concentrations averaged  $250 \pm 50$  pCi/L and ranged from 220 to 280 pCi/L. The 1999 concentrations were consistent with those measured in 1998 (Table J-1). The 1998 48S H-3 concentrations averaged  $280 \pm 170$  pCi/L and ranged from 200 to 380 pCi/L.

The 1999 OSF H-3 concentrations averaged  $490 \pm 140$  pCi/L and ranged from 380 to 590 pCi/L. As shown on Table J-1, the 1999 OSF concentrations were similar to those reported

in 1998. The 1998 OSF H-3 concentrations averaged  $520 \pm 160$  pCi/L and ranged from 410 to 670 pCi/L.

The H-3 detected in the 1999 onsite drinking water samples was attributed primarily to routine operations at TMI-1 (e.g. routine airborne releases) and possibly past operations at TMI-2 (e.g. prior airborne releases from the TMI-2 Evaporator). A portion of the H-3 detected in the onsite well water also was attributed to natural production in the atmosphere and fallout from prior nuclear weapon tests. All of the H-3 concentrations detected in the onsite drinking water were a small fraction of the USEPA Primary Drinking Water Standard of 20,000 pCi/L.

A conservative dose estimate was performed assuming that a TMINS employee drank OSF water at the 1999 average H-3 concentration for one working year. The maximum hypothetical whole body dose would be 0.0089 mrem. This calculated dose is equivalent to 0.0030% of the whole body dose that an individual living in the TMI area receives each year from natural background radiation (300 mrem).

Offsite groundwater samples were collected annually from eight locations. Six of these locations were added to the TMINS GMP in 1998. Tritium above the MDC was detected in all eight samples. Presented in Table J-2, the H-3 concentrations ranged from 120 to 200 pCi/L and averaged  $140 \pm 50$  pCi/L. The 1998 concentrations were similar ranging from 140 to 180 pCi/L and averaging  $160 \pm 40$  pCi/L.

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The 1999 concentrations also were similar to those detected in 1999 control surface water samples. Therefore, the H-3 detected in the 1999 offsite groundwater samples was attributed primarily to natural production in the atmosphere and fallout from prior nuclear weapon tests. It also is possible that a small portion of H-3 was due to routine operations at TMI-1 (e.g. routine airborne releases). Like the onsite groundwater used for drinking, all of the H-3 concentrations detected in the offsite groundwater were a small fraction of the USEPA Primary Drinking Water Standard of 20,000 pCi/L.

Some of the 1999 groundwater samples (individual or composite) were analyzed for Sr-90 and/or gamma-emitting radionuclides. None were found to contain detectable Sr-90 or gamma-emitting radionuclides related to TMINS operations. Naturally-occurring potassium-40 (K-40) was found in one onsite sample.

**Storm Water and EDCB Sediment Results**

Storm water from Station EDCB, an onsite collection basin, was normally collected monthly. The monthly samples were then combined into quarterly samples and analyzed for H-3 and gamma-emitting radionuclides.

Gamma-emitting radionuclides above the MDC were not detected. Three samples contained H-3 above the MDC. The concentrations averaged  $300 \pm 50$  pCi/L and ranged from 270 to 310 pCi/L. Similar H-3 concentrations were measured in 1998.

Since these concentrations were higher than those typically measured control surface water, a portion of H-3 detected in the 1999

storm water was attributed to routine operations at TMI-1 (e.g. routine airborne releases). A portion of the H-3 also was due to natural production in the atmosphere and fallout from prior nuclear weapon tests.

A sediment sample from Station EDCB was collected in the fall and analyzed for gamma-emitting radionuclides. Naturally-occurring Be-7, K-40, Ra-226 and thorium-232 (Th-232) as well as fallout and/or reactor-produced Cs-137 were identified. No other reactor-produced, gamma-emitting radionuclides were detected above the MDC. The Cs-137 concentration was  $0.24 \pm 0.04$  pCi/g (dry). Since control sediment samples have contained similar concentrations, the Cs-137 measured in the sample collected from Station EDCB was most likely due to fallout from previous weapon tests and not TMINS operations.

## **RADIOLOGICAL IMPACT OF TMINS OPERATIONS**

An assessment of potential radiological impact indicated that radiation doses to the public from 1999 operations at TMINS were well below all applicable regulatory limits and were significantly less than doses received from natural sources of radiation. The 1999 whole body dose potentially received by an assumed maximum exposed individual from TMI-1 and TMI-2 liquid and airborne effluents was conservatively calculated to be about 0.166 mrem. This dose is equivalent to 0.0553% of the dose that an individual living in the TMI area receives each year from natural background radiation.

The 1999 whole body dose to the surrounding population from TMI-1 and TMI-2 liquid and airborne effluents was calculated to be 11.8 person-rem. This is equivalent to 0.00179% of the dose that the total population living within 50 miles of TMI receives each year from natural background radiation.

### **Determination of Radiation Doses to the Public**

Dose assessments can be performed by using either effluent data and an environmental transport model or environmental sample data. To the extent possible, doses to the public are based on the direct measurement of dose rates from external sources and the measurement of radionuclide concentrations in environmental media which may contribute to an internal dose of radiation. Thermoluminescent dosimeters (TLDs) positioned in the environment around TMINS provide measurements to determine external radiation doses to humans. Samples of air, water and food products are used to determine internal doses.

The quantity of radioactive materials released during normal operations are typically too small to be measured once distributed in the offsite environment. Therefore, the potential offsite doses are more effectively calculated for TMINS operations using a computerized model that predicts concentrations of radioactive materials in the environment and subsequent radiation doses based on measured effluents. Another reason for using effluent data and a transport model is that environmental sampling data cannot provide enough information to calculate population doses.

Doses are calculated using an advanced "class A" dispersion model. This model incorporates the guidelines and methodology set forth by the USNRC in Regulatory Guide 1.109. Due to the conservative assumptions that are used in the model, the calculated doses are generally higher than the doses based on actual environmental sample concentrations. Therefore, the model predicts doses that are higher than actual doses received by people.

The type and amount of radioactivity released from TMINS is calculated using measurements from effluent radiation instruments and effluent sample analyses. Once released, the dispersion of radionuclides in the environment is readily determined by computer modeling. Airborne releases are diluted and carried away from the site by atmospheric diffusion which continuously acts to disperse radioactivity. Variables which affect atmospheric dispersion include wind speed, temperature at different elevations, terrain, and shift in wind direction. A weather station on the north end of TMI is linked to a computer terminal that permanently records the meteorological data. Computer models also are used to predict the downstream dilution and travel times for liquid releases into the Susquehanna River. Actual monthly Susquehanna River flows are obtained from GPU Generation, Inc. at the York Haven Hydroelectric Station.

The human exposure pathways also are included in the model and are depicted in Figure 18. The exposure pathways considered for the discharge of TMINS liquid effluents are consumption of drinking water and fish, and shoreline exposure. The exposure pathways considered for the discharge of TMINS airborne effluents are plume exposure, inhalation, cow milk consumption, goat milk consumption, fruit and vegetable consumption, meat consumption and land deposition.

Numerous data files are used in the calculations that describe the area around TMI in terms of population distribution and foodstuffs production. Data files include such information as the distance from the plant stack to the site boundary in each sector, the population groupings, milk cows, milk goats, gardens of more than 500 square feet, meat animals,

downstream drinking water users, and crop yields.

When determining the dose to humans, it is necessary to consider all applicable pathways and all exposed tissues, summing the dose from each to provide the total dose for each organ as well as the whole body from a given radionuclide. Dose calculations involve determining the energy absorbed per unit mass in the various tissues. Thus, for radionuclides taken into the body, the metabolism of the radionuclide in the body must be known along with the physical characteristics of the nuclide such as energies, types of radiations emitted and half-life. The dose assessment model also contains dose conversion factors for the radionuclides for each of four age groups (adults, teenagers, children and infants) and eight organs (total body, thyroid, liver, skin, kidney, lung, bone and GI tract).

Doses are calculated for what is termed the "maximum hypothetical individual". This individual is assumed to be affected by the combined maximum environmental concentrations wherever they occur. For liquid releases, the maximum hypothetical individual would consume 193 gallons of Susquehanna River water per year from the first downstream drinking water supplier, eat 46 pounds of fish each year that reside in the plant discharge area and stand 67 hours per year on the shoreline influenced by the plant discharge. For airborne releases, the maximum hypothetical individual would live at the location of highest radionuclide concentration for inhalation and direct plume exposure. Additionally, this individual each year would consume 106 gallons of cow milk, 141 pounds of leafy vegetables, 1389 pounds of non-leafy vegetables and fruits and 243 pounds of meat produced at the locations with the highest

predicted radionuclide concentrations. Consumption of goat milk is not included, since this exposure pathway does not currently exist. Doses to the population within 50 miles of TMI for airborne effluents and the entire population using Susquehanna River water downstream of the plant also are calculated.

#### **Results of Dose Calculations**

The maximum hypothetical doses due to 1999 TMI-1 and TMI-2 liquid and airborne effluents are summarized in Tables 8 and 9. Table 8 compares the calculated maximum hypothetical individual doses to the USNRC 10 CFR 50 App. I guidelines. This table also compares the calculated doses (to an individual of the public) from effluents and direct radiation to USEPA 40 CFR 190 dose limits.

Table 9 presents the maximum hypothetical whole body doses to an individual and the total population from 1999 TMINS effluents (i.e. TMI-1 and TMI-2 liquid and airborne effluents combined). For airborne releases, population doses are calculated for all people living within 50 miles of TMINS. For liquid releases, population doses are calculated for all people using Susquehanna River water downstream of TMINS. The maximum individual and population whole body doses presented in Table 10 are compared to the doses received from natural background radiation.

As shown in Table 8, the doses calculated for 1999 operations at TMINS were well below the Federal dose limits (USEPA 40 CFR 190) and the guidelines of USNRC 10 CFR 50 App. I. This conclusion was supported by radionuclide concentrations detected in actual environmental samples.

Doses from natural background radiation provide a baseline for assessing the potential public health significance of radioactive effluents. Natural background radiation from cosmic, terrestrial and natural radionuclides in the human body (not including radon), averages about 100 mrem/yr. Additionally, the average individual living in the United States receives an annual dose of about 2,400 mrem to the lung from natural radon gas. This lung dose is considered to be equivalent to a whole (or total) body dose of 200 mrem (Ref. 30). Therefore, the average person in the United States receives a whole body dose of about 300 mrem/yr from natural background radiation sources.

As shown on Table 9, the hypothetical maximum whole body dose potentially received by an individual from 1999 TMI-1 and TMI-2 liquid and airborne effluents combined was conservatively calculated to be 1.66E-1 mrem. This dose is equivalent to 5.53E-2 percent of the dose that an individual living in the TMI area receives each year from natural background radiation (300 mrem).

The hypothetical maximum whole body dose to the surrounding population from all 1999 TMI-1 and TMI-2 liquid and airborne effluents was calculated to be 1.18E+1 person-rem. This dose is equivalent to 1.79E-3 percent of the whole body dose that the total population in the TMI area receives each year from natural background radiation.

The low doses calculated for 1999 TMINS operations were the result of efforts to maintain releases "as low as reasonably achievable" (ALARA). Appendix I of this report contains a more detailed discussion of these dose calculations.

In conclusion, radioactive materials related to TMINS operations were detected in environmental samples, but the measured concentrations were low and consistent with measured effluents. The environmental sample results verified that the doses received by the public from TMINS effluents in 1999 were well below applicable dose limits and only a small fraction of the doses received from natural background radiation. Additionally, the results indicated that there was no permanent buildup of radioactive materials in the environment and no increase in background radiation levels.

Therefore, based on the results of the radiological environmental monitoring program (REMP) and the doses calculated from measured effluents, TMINS operations in 1999 did not have any adverse effects on the health of the public or on the environment.

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**TABLE 8**

**Calculated Maximum Hypothetical Doses to an Individual  
from 1999 TMI-1 and TMI-2 Liquid and Airborne Effluents**

<b><u>Maximum Hypothetical Doses To An Individual</u></b>			
	<b>USNRC 10 CFR 50 APP. I Guidelines (mrem/yr)</b>	<b>Calculated Dose (mrem/yr)</b>	
		<b>TMI-1</b>	<b>TMI-2</b>
From Radionuclides In Liquid Releases	3 total body, or 10 any organ	1.56E-1	6.13E-4
From Radionuclides In Airborne Releases (Noble Gases)	5 total body, or 15 skin	2.14E-3	0
From Radionuclides In Airborne Releases (Iodines, Tritium and Particulates)	15 any organ	1.44E-2	1.05E-4
	<b>USEPA 40 CFR 190 Limits (mrem/yr)</b>	<b>Calculated Dose (mrem/yr)</b>	
		<b>TMI-1 and TMI-2</b>	<b>Combined*</b>
Total from Site	75 thyroid	6.16E-1	
	25 total body or other organs	8.29E-1	

\* This sums together TMI-1 and TMI-2 maximum doses regardless of age group for different pathways. The combined doses also include a calculated dose due to direct radiation from TMINS. The direct radiation dose is calculated from environmental TLD data. For 1999, the direct radiation dose from TMINS operations was 5.86E-1 mrem. This was based on a maximum net fenceline dose rate of 6.39E+0 mrem/std month and a shoreline/fenceline occupancy factor of 67 hours (Regulatory Guide 1.109). Therefore, the maximum potential dose (to any organ or the total body) from TMI-1 and TMI-2 effluents and direct radiation combined was 8.29E-1 mrem.

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**TABLE 9**

**Calculated Whole Body Doses to the Maximum Individual and the Population from 1999 TMI-1 and TMI-2 Liquid and Airborne Effluents**

	Calculated Maximum Individual Whole Body Dose (mrem/yr)	
	<u>TMI-1</u>	<u>TMI-2</u>
From Radionuclides In Liquid Releases	1.56E-1	6.13E-4
From Radionuclides In Airborne Releases (Noble Gases)	2.14E-3	0
From Radionuclides In Airborne Releases (Iodines, Tritium and Particulates)	7.35E-3	1.05E-4

**Individual Whole Body Dose Due to TMI-1 and TMI-2 Operations:** 1.66E-1 mrem/yr

**Individual Whole Body Dose Due to Natural Background Radiation:** 3.00E+2 mrem/yr

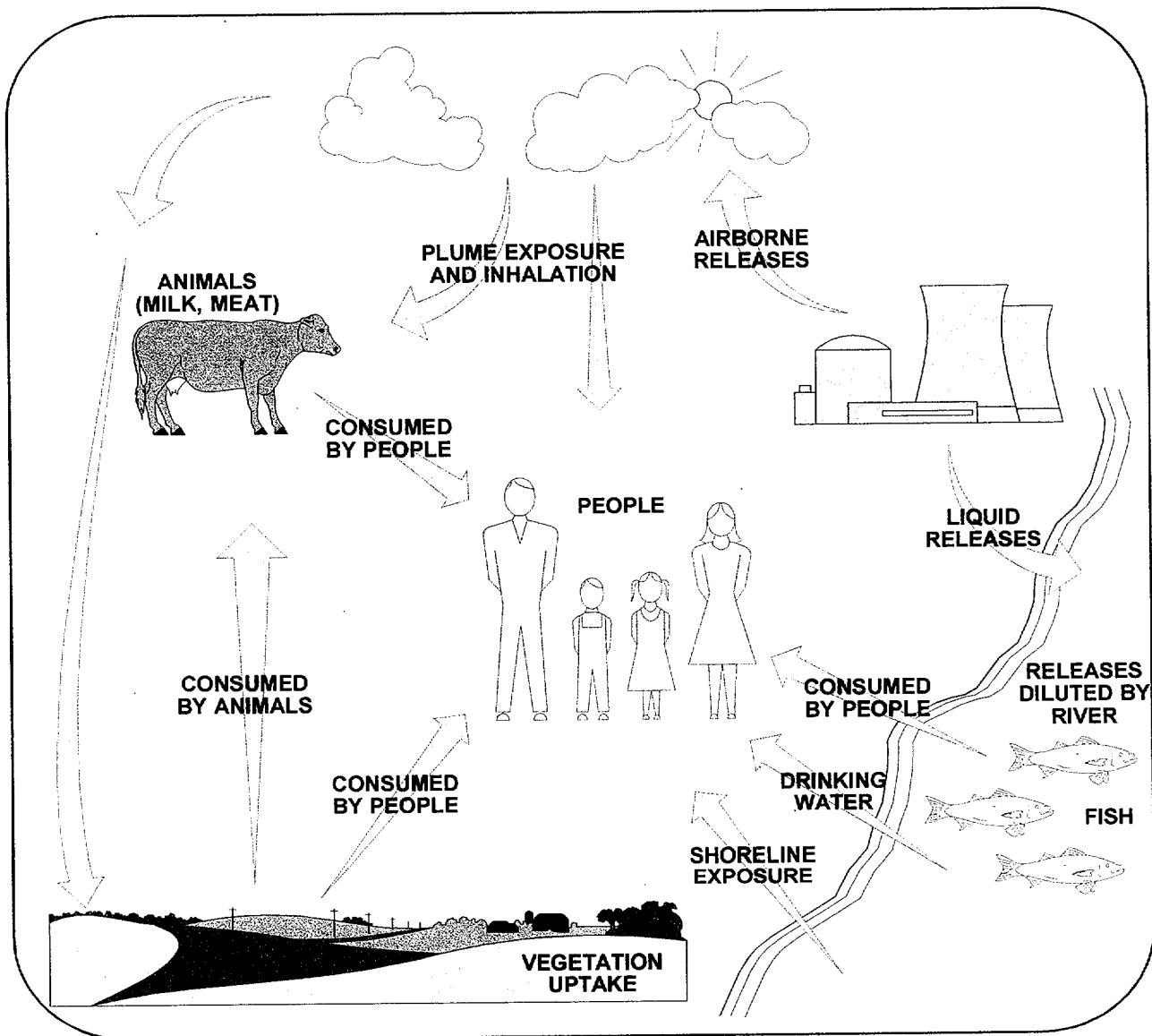
	Calculated Population Whole Body Dose (person-rem/yr)	
	<u>TMI-1</u>	<u>TMI-2</u>
From Radionuclides In Liquid Releases (Downstream Susquehanna River Water Users)	1.14E+1	8.18E-4
From Radionuclides In Airborne Releases (Population within 50 Mile Radius of TMNS)	3.72E-1	9.87E-3

**Population Whole Body Dose Due to TMI-1 and TMI-2 Operations:** 1.18E+1 person-rem/yr

**Population Whole Body Dose Due to Natural Background Radiation:** 6.60E+5 person-rem/yr

**Figure 18**

**Exposure Pathways For Radionuclides  
Routinely Released From TMINS**



**PREDOMINANT RADIONUCLIDES**

**NOBLE GASES (Xe,Kr)**  
Plume exposure

**ACTIVATION PRODUCTS (Co-60, Mn-54)**  
Shoreline exposure

**RADIOIODINES (I-131, I-133)**  
Inhalation and consumption of milk, water, fruits, and vegetables

**RADIOCESIUMS (Cs-134, Cs-137)**  
Shoreline exposure and consumption of milk, meat, fish, water, fruits, and vegetables

**RADIOSTRONTIUMS (Sr-89, Sr-90)**  
Consumption of milk, meat, fruits, and vegetables

**TRITIUM (H-3)**  
Inhalation and consumption of water, milk, fruits, and vegetables

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## **APPENDIX A**

### **1999 REMP Sampling Locations and Descriptions, Synopsis of REMP, and Sampling and Analysis Exceptions**

**1999 RADIOLOGICAL ENVIRONMENTAL MONITORING REPORT**

**TABLE A-1**

**TMINS Radiological Environmental Monitoring Program Sample Locations - 1999**

<u>Sample Medium</u>	<u>Station Code</u>	<u>Map Number</u>	<u>Distance*</u>	<u>Azimuth</u>	<u>Description</u>
AQS	A1-3	16	0.5 mi	0°	N of site off north tip of TMI in Susquehanna River
ID	A1-4	113	0.3	5	N of Reactor Building on W fence adjacent to North Weather Station, TMI
GW	A2-2	155	1.2	4	N of site at Tri-County Marina
AP, AI, ID	A3-1	39	2.6	358	N of site at Mill Street Substation
SW	A3-2	40	2.5	355	N of site at Swatara Creek, Middletown
ID	A5-1	44	4.3	3	N of site on Vine Street Exit off Route 283
ID	A9-3	127	8.1	3	N of site at Duke Street Pumping Station, Hummelstown
ID	B1-1	2	0.6	25	NNE of site on light pole in middle of North Bridge, TMI
ID	B1-2	114	0.4	26	NNE of Reactor Building on top of dike, TMI
AP, AI	B1-4	148	0.8	28	NNE of site at North Gate, TMI
ID	B2-1	132	1.9	16	NNE of site on Sunset Dr. (off Hillsdale Rd.)
ID	B5-1	45	4.8	18	NNE of site at intersection of School House and Miller Roads
ID	B10-1	61	9.4	21	NNE of site at intersection of West Areba Avenue and Mill Street, Hershey
FP	B10-2	1	10.1	28	NNE of site at Milton Hershey School, Hershey
ID	C1-1	17	0.7	35	NE of site along Route 441 N
ID	C1-2	116	0.3	54	NE of Reactor Building on top of dike, TMI
ID	C2-1	43	1.6	48	NE of site at Middletown Junction
ID	C5-1	46	4.5	42	NE of site on Kennedy Lane
ID	C8-1	62	7.2	48	NE of site at Schenk's Church on School House Road
AQF	Control	-	-	-	All locations where finfish are collected upstream of the TMINS liquid discharge outfall (above Dock St. Dam, Harrisburg) are grouped together and referred to as "control"
GAD	Control	-	-	-	All locations greater than 10 miles from TMINS
ID	D1-1	3	0.2	74	ENE of Reactor Building on top of dike, TMI
ID	D1-2	18	0.6	60	ENE of site on Laurel Road
GW	D1-4	156	0.6	73	ENE of site at residence on Orchard Lane, Middletown
M	D2-1	29	1.1	65	ENE of site at farm on Gingrich Road
ID	D2-2	133	1.7	73	ENE of site along Hillsdale Rd. (S of Zion Rd.)
ID	D6-1	47	5.2	65	ENE of site off Beagle Road
ID	D15-1	80	10.9	63	ENE of site along Route 241, Lawn, PA
AP, AI, ID, GW, FP	E1-2	19	0.4	95	E of site at TMI Visitor's Center
ID	E1-4	117	0.2	98	E of Reactor Building on top of dike, TMI
M	E2-2	109	1.1	93	E of site at farm on Pecks Road
ID	E2-3	134	1.9	96	E of site along Hillsdale Rd. (N of Creek Rd.)
ID	E5-1	48	4.6	81	E of site at intersection of North Market Street (Route 230) and Zeager Road
ID	E7-1	64	6.8	86	E of site along Hummelstown Street, Elizabethtown
ID	F1-1	20	0.5	117	ESE of site near entrance to 500 kV Substation

**1999 RADILOGICAL ENVIRONMENTAL MONITORING REPORT**

**TABLE A-1 (Continued)**

**TMINS Radiological Environmental Monitoring Program Sample Locations - 1999**

<u>Sample Medium</u>	<u>Station Code</u>	<u>Map Number</u>	<u>Distance*</u>	<u>Azimuth</u>	<u>Description</u>
ID	F1-2	118	0.2 mi	109°	ESE of Reactor Building on top of dike midway within Interim Solid Waste Staging Facility, TMI
AP,AI	F1-3	149	0.6	105	ESE of site in 500 kV Substation
ID	F1-4	154	0.3	115	ESE of Reactor Building on top of dike, TMI
ID	F2-1	135	1.2	120	ESE of site along Engle Road
ID	F5-1	49	4.7	107	ESE of site along Amosite Road
ID	F10-1	66	9.4	112	ESE of site along Donegal Springs Road, Donegal Springs
SW	F15-1	83	12.6	122	ESE of site at Chickies Creek, Marietta
ID	F25-1	82	21.1	113	ESE of site at intersection of Steel Way and Loop Roads, Lancaster
ID	G1-2	22	0.6	143	SE of site along Route 441 S
ID	G1-3	119	0.3	129	SE of Reactor Building on top of dike, TMI
ID	G1-5	139	0.3	144	SE of Reactor Building on top of dike, TMI
ID	G1-6	140	0.3	141	SE of Reactor Building on top of dike, TMI
AI,AP,M	G2-1	104	1.4	125	SE of site at farm on Becker Road
ID	G2-4	136	1.7	135	SE of site on Becker Road
ID	G5-1	50	4.8	131	SE of site at intersection of Bainbridge and Risser Roads
ID	G10-1	67	9.8	127	SE of site at farm along Engles Tollgate Road, Marietta
ID	G15-1	84	14.4	124	SE of site at Columbia Water Treatment Plant
SW	G15-2	85	13.6	128	SE of site at Wrightsville Water Treatment Plant
SW	G15-3	86	14.8	124	SE of site at Lancaster Water Treatment Plant
ID	H1-1	5	0.5	167	SSE of site, TMI
AP,AL,ID	H3-1	41	2.3	159	SSE of site in Falmouth-Collins Substation
ID	H5-1	52	4.1	157	SSE of site by Guard Shack at Brunner Island Steam Electric Station
ID	H8-1	68	7.4	163	SSE of site along Saginaw Road, Starview
ID	H15-1	87	13.2	157	SSE of site at intersection of Orchard and Stonewood Roads, Wilshire Hills
AQF	Indicator	-	-	-	All locations where finfish are collected downstream of the TMINS liquid discharge outfall are grouped together and referred to as "indicator"
GAD	Indicator	-	-	-	All locations within ten miles of TMINS
ROD	Indicator	-	-	-	All locations where rodents are collected within the owner controlled area, TMI
ID	J1-1	6	0.8	184	S of site, TMI
SW, AQS	J1-2	23	0.5	188	S of site downstream of the TMINS liquid discharge outfall in Susquehanna River
ID	J1-3	121	0.3	189	S of Reactor Building on wooden post of Building 221, just S of Unit 2 Admin. Building, TMI
AQS	J2-1	31	1.5	182	S of site in Susquehanna River just upstream of the York Haven Dam
ID	J3-1	141	2.7	178	S of site at York Haven/Cly
GW	J3-3	157	2.3	189	S of site at residence on River Road, York Haven
ID	J5-1	53	4.9	182	S of site along Canal Road, Conewago Heights

**1999 RADIOLOGICAL ENVIRONMENTAL MONITORING REPORT**

**TABLE A-1 (Continued)**

**TMINS Radiological Environmental Monitoring Program Sample Locations - 1999**

<u>Sample Medium</u>	<u>Station Code</u>	<u>Map Number</u>	<u>Distance*</u>	<u>Azimuth</u>	<u>Description</u>
ID	J7-1	69	6.5 mi	177°	S of site off of Maple Street, Manchester
ID	J15-1	88	12.6	180	S of site in Met-Ed York Load Dispatch Station
EW	K1-1	7	0.2	209	On site at RML-7 Main Station Discharge Building
AQS	K1-3	24	0.3	202	SSW of site in Susquehanna River
ID	K1-4	123	0.2	208	SSW of Reactor Building on top of dike behind Warehouse 2, TMI
GW	K1-6	160	0.8	213	SSW of site at summer residence on Shelley Island in Susquehanna River
ID	K2-1	32	1.1	200	SSW of site on S Shelley Island
ID	K3-1	142	2.1	202	SSW of site along Rt. 262, N of Cly
ID	K5-1	54	5.0	200	SSW of site along Conewago Creek Road, Strinestown
ID	K8-1	70	7.4	196	SSW of site at intersection of Coppenhaffer Road and Route 295, Zions View
ID	K15-1	90	12.7	204	SSW of site on the Bird's Nest Child Care Center Building, Weiglestown
M	K15-2	126	12.8	208	SSW of site at farm along Route 74 N
ID	L1-1	9	0.1	235	SW of site on top of dike W of Mech. Draft Cooling Tower, TMI
ID	L1-2	26	0.5	221	SW of site on Beech Island
GW	L1-3	158	0.8	326	SW of site at summer residence on Shelley Island in Susquehanna River
GW	L1-4	159	0.7	324	SW of site at summer residence on Beech Island in Susquehanna River
ID	L2-1	33	1.9	227	SW of site along Route 262
ID	L5-1	55	4.1	228	SW of site at intersection of Stevens and Wilson Roads
ID	L8-1	71	8.0	225	SW of site along Rohlers Church Rd., Andersontown
ID	L15-1	91	11.7	225	SW of site on W side of Route 74, rear of church, Mt. Royal
ID	M1-1	129	0.1	249	WSW of Reactor Building on SE corner of U-2 Screenhouse fence, TMI
ID	M1-2	143	0.5	241	WSW of site on W side of unnamed island between N tip of Beech Island and Shelley Island
AP, AL, ID	M2-1	34	1.3	253	WSW of site adjacent to Fishing Creek, Goldsboro
ID	M5-1	56	4.3	249	WSW of site at intersection of Lewisberry and Roxberry Roads, Newberrytown
ID	M9-1	72	8.6	242	WSW of site along Alpine Road, Maytown
ID	N1-1	10	0.7	270	W of site on Shelley Island
ID	N1-3	124	0.1	270	W of Reactor Building on fence adjacent to Screenhouse entrance gate, TMI
ID, GW	N2-1	35	1.2	262	W of site at Goldsboro Marina
ID	N5-1	57	4.9	268	W of site off of Old York Road along Robin Hood Drive
ID	N8-1	73	7.8	260	W of site along Route 382, 1/2 mile north of Lewisberry
ID	N15-2	95	10.4	274	W of site at intersection of Lisburn Road and Main Street, Lisburn
ID	P1-1	12	0.4	293	WNW of site on Shelley Island
ID	P1-2	38	0.2	290	WNW of Reactor Building on fence N of Unit 1 Screenhouse, TMI
ID	P2-1	36	1.9	283	WNW of site along Route 262
ID	P5-1	58	4.9	285	WNW of site at intersection of Valley Road (Route 262) and Beinhower Road

**1999 RADIOLOGICAL ENVIRONMENTAL MONITORING REPORT**

**TABLE A-1 (Continued)**

**TMINS Radiological Environmental Monitoring Program Sample Locations - 1999**

<u>Sample Medium</u>	<u>Station Code</u>	<u>Map Number</u>	<u>Distance*</u>	<u>Azimuth</u>	<u>Description</u>
M	P7-1	75	6.7 mi	293°	WNW of site at farm along Old York Road, New Cumberland
ID	P8-1	74	8.0	292	WNW of site along Evergreen Road, Reesers Summit
ID	Q1-1	13	0.5	317	NW of site on Shelley Island
ID	Q1-2	125	0.2	318	NW of Reactor Building on fence W of Warehouse 1, TMI
ID	Q2-1	37	1.8	310	NW of site along access road along river
AP,AI	Q4-1	151	3.7	325	NW of site at airport near control tower
ID	Q5-1	59	5.0	318	NW of site along Lumber Street, Highspire
SW, ID	Q9-1	76	8.5	308	NW of site at the Steelton Water Company
AP, AI, ID	Q15-1	97	13.5	305	NW of site behind West Fairview Fire Dept. Social Hall
ID	R1-1	14	0.2	335	NNW of Reactor Building along W fence, TMI
ID	R1-2	27	0.7	332	NNW of site on Henry Island
ID	R3-1	107	2.6	338	NNW of site at Crawford Station, Middletown
ID	R5-1	60	4.9	339	NNW of site at intersection of Spring Garden Drive and Route 441
ID	R9-1	77	8.1	340	NNW of site at intersection of Derry and 66th Streets, Rutherford Heights
ID	R15-1	99	11.2	330	NNW of site at intersection of Route 22 and Colonial Road, Colonial Park

**IDENTIFICATION KEY**

ID = Immersion Dose (TLD)  
 SW = Surface Water  
 M = Milk (Cow)  
 AP = Air Particulate

GW = Ground Water (offsite)  
 AQS = Aquatic Sediment  
 EW = Effluent Water  
 GAD = Meat (Game)

AQF = Finfish  
 AI = Air Iodine  
 FP = Food Products (Green Leafy Vegetation, Fruits, Vegetables)  
 ROD = Rodents

\* All distances are measured from a point that is midway between the reactor buildings of TMI-1 and TMI-2.

**1999 RADIOLOGICAL ENVIRONMENTAL MONITORING REPORT**

**TABLE A-2**

**Synopsis of the 1999 TMINS REMP<sup>(1)</sup>**

<u>Sample Type</u>	<u>Number of Sampling Locations</u>	<u>Collection Frequency<sup>(6)</sup></u>	<u>Number of Samples Collected</u>	<u>Type of Analysis</u>	<u>Analysis Frequency</u>	<u>Number of Samples Analyzed<sup>(2)</sup></u>
Air Iodine	9	Weekly	468	I-131	Weekly	466
Air Particulate	9	Weekly	468	Gr-Beta Gr-Alpha Gamma Sr-89 Sr-90	Weekly Weekly Quarterly Semiannually Semiannually	466 260 36 10 10
Fish	2	Semiannually	8	Gamma H-3 Sr-89 Sr-90	Semiannually Semiannually Semiannually Semiannually	8 8 8 8
Aquatic Sediment	4 <sup>1<sup>(8)</sup></sup>	Semiannually Annually	8 1	Gamma Gamma	Semiannually Annually	8 1
Discharge Water	1	Weekly Biweekly	4 24	I-131 I-131 Gamma Gr-Beta H-3 Sr-89 Sr-90	Weekly Biweekly Monthly Monthly Monthly Semiannually Semiannually	4 24 12 12 12 2 2
Fruits	2	Annually	2	Gamma	Annually	2
Grains	2	Annually	2	Gamma	Annually	2
Broad Leaf Vegetables	2	Annually	2	Gamma Sr-89 Sr-90	Annually Annually Annually	2 2 2
Vegetables	2	Annually	2	Gamma	Annually	2
Groundwater	5 2 7 13 <sup>1<sup>(9)</sup></sup>	Weekly Monthly Quarterly Annually As Needed	219 16 24 13 148	H-3 H-3 H-3 H-3 H-3 Gamma Gamma Gamma Sr-90	Weekly Monthly Quarterly Annually As Needed Quarterly Annually As Needed Annually	219 16 24 13 148 28 2 2 7
Dosimeters (TLD) <sup>(3)</sup>	90	Quarterly	2085	Immersion Dose	Quarterly	2085 <sup>(4)</sup>

NOTE: See Notes at end of table.

**1999 RADIOLOGICAL ENVIRONMENTAL MONITORING REPORT**

**TABLE A-2**

**Synopsis of the 1999 TMINS REMP<sup>(1)</sup>**

<u>Sample Type</u>	<u>Number of Sampling Locations</u>	<u>Collection Frequency<sup>(6)</sup></u>	<u>Number of Samples Collected</u>	<u>Type of Analysis</u>	<u>Analysis Frequency</u>	<u>Number of Samples Analyzed<sup>(2)</sup></u>
Milk	5	Biweekly	130	Gamma I-131 Sr-89 Sr-90	Biweekly Biweekly Quarterly Quarterly	130 130 20 20
Storm Water	1	Monthly	9	Gamma H-3	Quarterly Quarterly	3 3
Surface/Drinking Water	7	Weekly Biweekly	28 168	I-131 I-131 Gamma Gr-Beta H-3	Weekly Biweekly Monthly Monthly Monthly	24 <sup>(5)</sup> 144 <sup>(5)</sup> 84 36 84
Deer Meat	2	When Available	0	Gamma	When Available	0
Rodent	1	When Available	0	Radiological Frisk or Gamma	When Available	0

**NOTES:**

- (1) This table is a synopsis of the primary (base) program only. It does not include the quality control (QC) program.
- (2) The total number of analyses does not include duplicate analyses, recounts, or reanalyses.
- (3) A dosimeter is considered to be a phosphor (element).
- (4) This is the total number of samples or elements (TLDs) used for data analysis.
- (5) Water samples collected from Station J1-2 were not analyzed for low level I-131.
- (6) Weekly means once per week, biweekly means once every two weeks, monthly means once per month, quarterly means once per three months, semiannually means once every six months and annually means once per year.
- (7) Groundwater samples were collected on an as needed basis from Stations TRANS, MS-4, MS-7, MS-19, OS-18, NW-C, NW-CW, RW-1, RW-2, OSF and 48S.
- (8) This reflects the sample collected from Station EDCB.

**1999 RADIOLOGICAL ENVIRONMENTAL MONITORING REPORT**

**TABLE A-3**

**Sampling and Analysis Exceptions 1999\***

<b><u>Period of Deviation</u></b>	<b><u>Description of Deviation and Corrective Action</u></b>
December 28, 1998 to January 12, 1999	During the first week of this period, intermittent automatic water compositing occurred at the indicator surface water station (J1-2R) because of frozen river conditions. During the second week of this period no automatic compositing occurred for the same reason. Two grab samples were collected during the second week and were combined with the first week's composite sample.
January 12, 1999 to January 26, 1999	Automatic water compositing did not occur for the first five days of this sampling period at the indicator surface water station (J1-2R) because of frozen river conditions. The sampler resumed sampling on January 17, 1999. Therefore, five days of sampling were missed at this station.
	During this period there were four days when the automatic water compositor at the control drinking water station (Q9-1F) did not collect samples. This was due to an electrical malfunction. When the problem was discovered, the unit was reset and proper compositing resumed.
January 26, 1999 to February 9, 1999	During the first week of this period, there were 43 samples intermittently missed because of a frozen inlet line at the indicator surface station (J1-2R). No corrective action was warranted because there was sufficient compositored water available and the unit was sampling upon arrival at the station.
February 9, 1999 to February 23, 1999	During this two week period a total of 43 intermittent hourly samples were missed because of frozen conditions at the indicator surface water station (J1-2R). Adequate sample volume was available for collection so grab sampling was not necessary.

**1999 RADIOLOGICAL ENVIRONMENTAL MONITORING REPORT**

**TABLE A-3 (Continued)**

**Sampling and Analysis Exceptions 1999\***

<b><u>Period of Deviation</u></b>	<b><u>Description of Deviation and Corrective Action</u></b>
February 23, 1999 to March 9, 1999	Intermittent samples were missed during this period because of freezing conditions and pump problems at the indicator surface water station (J1-2R). Radiological Instruments personnel were notified of the malfunction and the pump problem was fixed.
April 13, 1999 to April 27, 1999	At the end of this sampling period 59 hourly samples were missed because of a power loss at the indicator surface water station (J1-2R). The unit was reset so proper compositing could again continue.
May 25, 1999 to June 8, 1999	Half way into this collection period the compositor was found to be locked up, most likely due to a power outage, at the indicator surface water station (J1-2R). Approximately six days of sampling were missed before the unit was placed back into proper operation.
August 23, 1999 to August 30, 1999	Due to a loss of power, 209 out of approximately 336 samples were missed at the indicator surface water station (J1-2R). The unit was reset and the problem was investigated by Radiological Instruments personnel.
August 30, 1999 to September 13, 1999	In an attempt to correct prior problems at the indicator surface water station (J1-2R), too much water was being collected during each hourly period. This, in turn, caused the collection tub to fill up after only 30 hours and the magnetic float switch cut off the sampler. Later in the sampling period, half the water was dumped out to allow for continued sampling and the sampler was finally replaced at the end of the period due to continuous malfunctions.

**1999 RADIOLOGICAL ENVIRONMENTAL MONITORING REPORT**

**TABLE A-3 (Continued)**

**Sampling and Analysis Exceptions 1999\***

<b><u>Period of Deviation</u></b>	<b><u>Description of Deviation and Corrective Action</u></b>
September 13, 1999 to September 27, 1999	During the second week of this sampling period, the water composito at the indicator drinking water station (G15-3F) stopped sampling because of mechanical difficulties. The unit was put back into operation at the end of the sampling period. About six days of sampling were missed.

- \* The exceptions described in this table are those which are considered deviations from radiological environmental monitoring as required by the Technical Specifications and the ODCM. Other sampling and analysis deviations occurred during the year. They were not included in this table because the minimum number of samples were collected and analyzed. Reports describing all sampling and analysis exceptions are on file at Three Mile Island Environmental Affairs.

## **APPENDIX B**

### **1999 Lower Limit of Detection (LLD) Exceptions**

**1999 RADIOLOGICAL ENVIRONMENTAL MONITORING REPORT**

**TABLE B**

**Analytical Results Which Failed to Meet  
the USNRC Required LLD During 1999**

<b><u>Sample Media</u></b>	<b><u>Analysis</u></b>	<b><u>Required LLD</u></b>	<b><u>No. of Samples Which Failed to Meet the LLD</u></b>	<b><u>Comments</u></b>
Surface Water (SW)	La-140	15 pCi/L	1	The quality control (QC) laboratory inadvertently failed to analyze the January drinking water (composite) sample from Station Q9-1F (Steelton Water Authority) in a timely fashion. The primary sample, however, was analyzed to the required LLD.
Air Particulate (AP)	I-131	0.07 pCi/m <sup>3</sup>	1	The quality control (QC) laboratory inadvertently failed to analyze the first quarter air particulate (composite) sample from Station E1-2 (TMINS Visitors Center) in a timely fashion. The primary sample, however, was analyzed to the required LLD.
Surface Water (SW)	Ba-140 La-140	60 pCi/L 15 pCi/L	1 1	The quality control (QC) laboratory inadvertently failed to analyze the June drinking water (composite) sample from Station Q9-1F (Steelton Water Authority) in a timely fashion. The primary sample, however, was analyzed to the required LLDs.

## **APPENDIX C**

### **1999 REMP Changes**

**1999 RADIOLOGICAL ENVIRONMENTAL MONITORING REPORT**

**TABLE C**

**1999 TMINS REMP Changes**

- January, 1999      The collection of groundwater from Station OSF was reduced from monthly to quarterly. The quarterly samples were analyzed for H-3 and gamma-emitting radionuclides. Additionally, a composite of the quarterly samples was analyzed for Sr-90. Decreasing H-3 concentrations prompted this change.
- Monitoring at groundwater Stations MS-8 and AIT was discontinued in 1999. Station AIT is a pipe/tunnel where groundwater occasionally infiltrates. The low H-3 concentrations measured in the 1998 samples justified this change.
- May, 1999      The collection and analysis of sponge samples was discontinued. Sponge sampling was replaced with the collection and analysis of quarterly groundwater samples from Stations MS-20 and RW-2 and monthly samples from Station MS-22. Prior to May 1999, Stations MS-20 was monitored annually, MS-22 was monitored monthly and RW-2 was monitored only when needed. The quarterly samples collected from Stations MS-20 and RW-2 were analyzed for H-3 only. The monthly samples collected from Station MS-22 were analyzed for H-3. The samples collected in March, June, September and December were analyzed for gamma-emitting radionuclides. Additionally, a composite of the latter four samples was analyzed for Sr-90. This change was implemented because groundwater monitoring is as (or possibly more) effective for monitoring the aboveground tanks for leakage as collecting and analyzing sponge samples.
- Various, 1999      To gather additional information, special (i.e. not normally sampled) or non-routine (i.e. outside the normal schedule) groundwater samples were collected at various stations throughout the year. They included Stations MS-4, MS-7, MS-19, RW-1, RW-2, OS-18, OSF, 48S, NW-C, NW-CW and TRANS. Station TRANS is a well located in the central part of TMI near the Transportation Building. All but Stations RW-2 and TRANS were monitored in 1998.

## **APPENDIX D**

### **1999 Action Levels**

## **1999 RADIOLOGICAL ENVIRONMENTAL MONITORING REPORT**

Analytical results of environmental samples were routinely reviewed and evaluated by the staff of Three Mile Island Environmental Affairs (TMIEA). The results were checked for LLD violations, anomalous values, USNRC reporting levels, main sample and quality control (QC) sample agreement (Appendix E), and action levels.

Established by TMIEA, the action level is defined as that level of reactor-related radioactivity which when detected in environmental samples initiates an investigation and subsequent actions, as necessary. An action level is reached if either of the following two criteria is met:

- The radioactivity concentration at an indicator station reaches or exceeds those concentrations listed in Table D-1. (With the exception of I-131 in food products and water and Sr-90 in milk, water, fish, food products and airborne particulates, all concentrations listed correspond to 10% of the USNRC reporting levels.)
- The radioactivity concentration at the indicator station reaches or exceeds 10 times the mean concentration for the control locations. (This criterion applies only to those media and analyses which are not listed in Table D-1.)

Action levels for gamma exposure rates measured by TLDs have also been established. For TLDs, an action level is reached if any of the following three criteria is met:

- The exposure rate at an indicator station not on the owner controlled area fence exceeds three times the mean of the control stations.
- The exposure rate at an indicator station on the owner controlled area fence exceeds 135 mR/std month (50% of the 40 CFR 190 limit of 25 mR/yr adjusted by a 67 hour recreational factor).
- The exposure rate at an indicator station not on the owner controlled area fence exceeds either two times the previous quarterly result or two times the historical average for the station.

If an action level is reached, an investigation is initiated which consists of some or all of the following actions:

- Examine the collection or surveillance sheets for an indication of any equipment malfunctions, collection or delivery errors.
- Examine the running tables (prior data) for trends.
- Review control station data.
- Review QC or duplicate sample data (if available).
- Review TMI-1 and TMI-2 effluent data.
- Recount and/or reanalyze the sample.
- Collect and analyze an additional sample.

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The results of the investigation are then documented on the form provided in the TMIEA procedure 6510-SUR-4523.05. As appropriate, site personnel are apprised of plant-related radioactivity that exceeds the TMIEA action level. If it is concluded that the detected activity is related to TMINS operations and also exceeds the USNRC reporting limits as defined in the ODCM, a detailed report will be issued to the USNRC.

During 1999, 2 indicator sample concentrations equaled or exceeded an action level. They are summarized in Table D-2. For each investigation conducted in 1999, it was concluded that the action level concentration was caused by normal TMINS operations. However, none of the 1999 action level concentrations were reportable to the USNRC.

Two monthly surface water samples collected at Station J1-2 contained H-3 at concentrations equal to or greater than 2000 pCi/L, the TMIEA action level concentration for H-3 in surface water. The presence of H-3 in these samples was attributed to TMINS operations.

Tritium at concentrations greater than background levels is expected in surface water collected at Station J1-2 because 1) H-3 is normally present in TMINS liquid effluents and 2) the samples are collected just downstream of the TMINS liquid discharge outfall where mixing of liquid effluents with river water is incomplete. Complete mixing is not usually achieved until the water passes over York Haven Dam (YHD), a structure downstream of the sampling site. Dose estimates for ingesting water were not performed because these samples were non-potable water. The H-3 concentrations that equaled or exceeded the GPU Nuclear TMIEA action level were not reportable to the USNRC.

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**TABLE D-1**

**TMINS REMP Action Levels for Positive Radioactivity  
Concentrations in Environmental Samples**

<u>Analysis</u>	<u>Water<sup>(a)</sup> (pCi/L)</u>	<u>Airborne Particulates or Gases (pCi/m<sup>3</sup>)</u>	<u>Fish (pCi/g, wet)</u>	<u>Milk (pCi/L)</u>	<u>Food Products (pCi/g, wet)</u>
H-3	2000				
Mn-54	100		3		
Fe-59	40		1		
Co-58	100		3		
Co-60	30		1		
Zn-65	30		2		
Sr-90	4 <sup>(b)</sup>	.05 <sup>(b)</sup>	.05 <sup>(b)</sup>	4 <sup>(b)</sup>	.05 <sup>(b)</sup>
Zr-Nb-95	40				
I-131	1 <sup>(b)</sup>	.09		.3	.05 <sup>(b)</sup>
Cs-134	3	1	.1	6	.1
Cs-137	5	2	.2	7	.2
Ba-La-40	20			30	

(a) Includes surface and drinking water.

(b) 50% of USNRC reporting level.

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**TABLE D-2**

**Investigations Conducted During 1999**

<b>Collection Date</b>	<b>Reason for Investigation</b>	<b># of Indicator Samples Exceeding the Action Level</b>	<b>Conclusion of Investigation</b>
1. December 28, 1998 to January 26, 1999	The composite surface water sample collected at indicator Station J1-2, located just downstream of the TMINS liquid discharge outfall, contained an H-3 concentration ( $10,000 \pm 1,000$ pCi/L) which equaled or exceeded the GPUN action level of 2000 pCi/L.	1	The H-3 identified in the water sample was due to the discharge of approximately 133 Ci of this material from TMINS into the Susquehanna River. Concentrations of H-3 above background levels are expected in this sample because the collection site is located proximate to the TMINS liquid discharge outfall where mixing of effluents and river water is incomplete. Since the sample is raw (non-potable) river water, a dose due to ingestion was not calculated. The result was not reportable to the USNRC.
2. April 27, 1999 to May 25, 1999	The composite surface water sample collected at indicator Station J1-2, located just downstream of the TMINS liquid discharge outfall, contained an H-3 concentration ( $5,800 \pm 600$ pCi/L) which equaled or exceeded the GPUN action level of 2000 pCi/L.	1	The H-3 identified in the water sample was due to the discharge of approximately 168 Ci of this material from TMINS into the Susquehanna River. Concentrations of H-3 above background levels are expected in this sample because the collection site is located proximate to the TMINS liquid discharge outfall where mixing of effluents and river water is incomplete. Since the sample is raw (non-potable) river water, a dose due to ingestion was not calculated. The result was not reportable to the USNRC.

## **APPENDIX E**

### **1999 Quality Control Results**

## ***1999 RADIOLOGICAL ENVIRONMENTAL MONITORING REPORT***

A quality assurance (QA) program is an essential part of any radiological environmental monitoring program (REMP). It provides reasonable assurance that the results of radiation measurements are valid. To be effective, elements of quality assurance must be evident in all phases of the monitoring program. These include, but are not limited to, sample collection, preservation and shipment, receipt of samples by the analysis laboratory, preparation and analysis of samples and data review and reporting. An effective QA program will allow for the identification of deficiencies in all monitoring processes so that appropriate investigative and corrective actions can be implemented.

The United States Nuclear Regulatory Commission (USNRC) published Regulatory Guide 4.15, "Quality Assurance for Radiological Monitoring Programs (Normal Operations) - Effluent Streams and the Environment", which defines an acceptable QA program (Ref. 44). The guidance contained in Regulatory Guide 4.15 has been adopted by AmerGen and GPU Nuclear. To meet the objectives of this position document, procedures and plans have been written and implemented.

In the laboratory, samples are typically analyzed one time. Therefore, laboratory personnel must be reasonably confident with the analytical results which are generated. One means of achieving confidence in the results is through the analysis of quality control (QC) samples.

During 1999, two independent laboratories analyzed the TMINS REMP samples. The primary (or base) program samples were analyzed by AmerGen (previously GPU Nuclear) Environmental Radioactivity Laboratory (ERL). Separate or split samples were analyzed by Teledyne Brown Engineering (TBE) Environmental Services. Three types of QC samples were analyzed routinely by the laboratories. They included intra-laboratory split samples, cross check program samples, and inter-laboratory split samples. A discussion of each QC sample type is provided below.

### **Intra-laboratory Split Samples**

Each laboratory is required to split at a minimum every twentieth sample and perform an analysis (or analyses) on each portion. The samples which can not be split (e.g., air particulate filters) are counted twice. Staff scientists check the results of the two analyses for agreement. Agreement is determined using the criteria listed in USNRC Inspection Procedure 84750, "Radioactive Waste Treatment, and Effluent and Environmental Monitoring" (Ref. 50). Prior to 1998, agreement was considered to be acceptable if the coefficient of variation for the two results was eighty-five percent or less. Non-agreement of the sample concentrations may result in recounting or reanalyzing the sample(s) in question. During 1999, all of the paired intra-laboratory split sample results were found to agree.

### **Cross Check Program Samples**

The laboratories analyzing environmental samples participate in at least two separate cross check programs. Both laboratories participate in the cross check program conducted by Analytics, Inc. The ERL also participates in the cross check program conducted by the Environmental

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Measurement Laboratory (EML) of the United States Department of Energy (DOE) while TBE Environmental Services also participates in a program conducted by Environmental Resource Associates (ERA).

All samples are sent to the laboratories as unknowns. Participation in these programs provides an independent check on the ability of each laboratory to perform analyses on various kinds of samples containing detectable concentrations of radioactivity. The results submitted by the laboratories are compared to 1) control limits established by ERA, 2) control limits established by the DOE EML or 3) agreement criteria used by the USNRC in their Inspection Procedure 84750. If the results are outside the established limits or agreement criteria, the laboratories are requested to perform an investigation and take corrective action, as necessary.

The 1999 cross check program results from each laboratory are listed in Appendix F. Explanations are provided for those results which were not submitted and/or which were not within the established limits.

### **Inter-laboratory Split Samples**

The third type of QC sample is the inter-laboratory split sample. These samples are the ones that are collected routinely for the REMP. After or during the collection process, the sample is thoroughly mixed (as necessary) to ensure that, as much as possible, the distribution of radioactivity in the sample is homogeneous. The sample is then split into two portions. One portion is sent to the ERL and the other portion is sent to TBE Environmental Services.

Since it is impractical to split airborne materials (filters, charcoal cartridges, etc.) separate samples from independent, but co-located, samplers are collected and then sent to the analysis laboratories. Unfortunately, this practice of using distinctly different samples may result in higher than normal concentration differences for the two samples.

Analysis results from the ERL are then compared to those reported by TBE Environmental Services. The agreement criteria are the same as that used for the intra-laboratory split samples. Corrective action for disagreements may include recounting or reanalyzing the sample(s).

Table E-1 outlines the 1999 inter-laboratory split sample program. During 1999, all but 11 of the paired inter-laboratory split sample results were found to agree per the established agreement criteria. An explanation for each non-agreement can be found in Table E-2.

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**TABLE E-1**

**1999 Inter-laboratory Split Sample Program**

Sample Medium	No. of Primary Stations	No. of QC Stations	Percentage of Primary Samples Submitted for QC Analysis
Air Particulate (AP)	9	1	11 percent
Air Iodine (AI)	9	1	11 percent
Surface/Drinking Water (SW)	7	1	14 percent
Milk (M)	5	1	20 percent
TLDs (ID)	90	10	11 percent
Groundwater (GW)	9(1)	1	11 percent
Aquatic Sediment (AQS)	8(2)	1(2)	13 percent
Fish (AQF)	8(2)	1(2)	13 percent
Food Products (FPF,FPG,FPL,FPV)	8(2)	2(2)	25 percent
Meat (GAD)	0(3)	0(3)	Not Applicable
Rodent (ROD)	0(4)	0(4)	Not Applicable

- (1) This refers to the total number of groundwater stations sampled quarterly in 1999.
- (2) This refers to the total number of samples collected and analyzed in 1999.
- (3) Deer meat samples were not available in 1999.
- (4) Rodent samples were not available in 1999; rodent samples are not split with the QC laboratory.

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**TABLE E-2**

**1999 Inter-laboratory Split Sample Non-agreements**

<b>Sample Medium</b>	<b>Collection Date</b>	<b>Station</b>	<b>Analysis</b>	<b>Action and/or Resolution</b>
1. GW	03/05/99	MS-2	H-3	The primary and QC sample results were $490 \pm 100$ pCi/L and $290 \pm 110$ pCi/L, respectively. No follow-up actions were requested because the results were not statistically different (i.e. the results with their counting uncertainties overlapped).
2. SW	05/25/99 - 06/29/99	Q9-1F	Gr-B	The primary and QC sample results were $2.2 \pm 1.0$ pCi/L and $4.8 \pm 2.1$ pCi/L, respectively. No follow-up actions were requested because the results were not statistically different (i.e. the results with their counting uncertainties overlapped).
3. SW	06/29/99 - 07/27/99	Q9-1F	Gr-B	The primary and QC sample results were $2.9 \pm 1.1$ pCi/L and $5.9 \pm 2.1$ pCi/L, respectively. No follow-up actions were requested because the results were not statistically different (i.e. the results with their counting uncertainties overlapped).
4. AP	06/30/99 - 09/28/99	E1-2	K-40	The primary and QC sample results were $< 0.03$ pCi/m <sup>3</sup> and $0.00525 \pm 0.00202$ pCi/m <sup>3</sup> , respectively. The non-agreement was due to counting the QC sample longer than the primary sample. No further action was taken because the QC sample concentration was below the estimated minimum detectable concentration (MDC) reported for the primary sample. Potassium-40 is a naturally-occurring radionuclide. Its presence in the QC sample was unrelated to TMINS operations.
5. GW	09/03/99	MS-2	K-40	The primary and QC sample results were $< 40$ pCi/L and $159 \pm 28$ pCi/L, respectively. The QC sample was reanalyzed with filtration because it yielded the higher of the two sample concentrations. The reanalysis result ( $< 50$ pCi/L) agreed with the original primary sample result. No further actions were requested.
6. M	07/14/99 - 09/22/99	G2-1	Sr-90	The primary and QC sample results were $< 0.7$ pCi/L (with a net or actual concentration of $0.68 \pm 0.47$ pCi/L) and $1.5 \pm 0.6$ pCi/L, respectively. No follow-up actions were requested because the net or actual concentrations were not statistically different (i.e. the results with their counting uncertainties overlapped).

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**TABLE E-2**

**1999 Inter-laboratory Split Sample Non-agreements**

Sample Medium	Collection Date	Station	Analysis	Action and/or Resolution
7. SW	08/30/99 - 09/27/99	Q9-1F	Gr-B	The primary and QC sample results were < 1.4 pCi/L and 3.9 ± 1.0 pCi/L, respectively. The QC sample was reanalyzed because it yielded the higher of the two sample concentrations. The reanalysis result (< 2 pCi/L) agreed with the original primary sample result. No further actions were requested.
8. SW	08/30/99 - 09/27/99	Q9-1F	H-3	The primary and QC sample results were 100 ± 60 pCi/L and < 300 pCi/L, respectively. The QC sample was reanalyzed because it yielded the higher of the two sample concentrations and the administrative LLD for H-3 was not achieved. The reanalysis result (< 200 pCi/L) agreed with the original primary sample result and achieved the administrative LLD. No further actions were requested.
9. M	10/20/99	G2-1	K-40	The primary and QC sample results were and 1200 ± 100 pCi/L and 1760 ± 180 pCi/L, respectively. Both samples were recounted. The recounts results (1300 ± 100 pCi/L and 1160 ± 120 pCi/L) agreed per the established agreement criteria.
10. AP	09/28/99 - 12/28/99	E1-2	K-40	The primary and QC sample results were < 0.019 pCi/m³ and 0.00580 ± 0.00233 pCi/m³, respectively. The non-agreement was due to counting the QC sample longer than the primary sample. No further action was taken because the QC sample concentration was below the estimated minimum detectable concentration (MDC) reported for the primary sample. Potassium-40 is a naturally-occurring radionuclide. Its presence in the QC sample was unrelated to TMINS operations.
11. SW	11/30/99 - 12/27/99	Q9-1F	H-3	The primary and QC sample results were < 90 pCi/L and 440 ± 120 pCi/L, respectively. The QC sample was reanalyzed because it yielded a result that was inconsistent with historical data. The reanalysis result (< 200 pCi/L) agreed with the original primary sample result. No further actions were requested.

## **APPENDIX F**

### **1999 Cross Check Program Results**

**1999 RADIOLOGICAL ENVIRONMENTAL MONITORING REPORT**

**TABLE F-1**  
**1999 DOE EML Cross Check Program Results**

Collection Date	Media	Nuclide	ERL VALUE (A & D)	UNCERTAINTY (A)	DOE EML VALUE (B & D)	UNCERTAINTY (C)	RATIO	Min. RATIO	Max. RATIO	AGREEMENT
3/1/1999	Air Filter	AM-241	0.13	0.01	0.134	0.001	0.970	0.73	2.58	YES
		CO-57	3.1	0.4	3.01	0.14	1.030	0.65	1.39	YES
		CO-60	5	0.8	4.96	0.28	1.008	0.75	1.32	YES
		CS-137	6.3	0.8	6.05	0.3	1.041	0.73	1.37	YES
		PU-238	0.26	0.03	0.272	0.001	0.956	0.74	1.4	YES
		PU-239	0.12	0.01	0.124	0.003	0.968	0.76	1.44	YES
		SB-125	3.7	1	3.59	0.31	1.031	0.61	1.43	YES
		SR-90	0.31	0.1	0.644	0.015	0.481	0.61	1.93	NO (E)
		U-234	0.064	0.007	0.06	0.002	1.067	0.83	1.92	YES
		U-238	0.063	0.007	0.061	0.003	1.033	0.84	2.61	YES
		U-NAT	0.13		0.123	0.004	1.057	0.8	3.35	YES
3/1/1999	Air Filter	ALPHA	1.7	0.2	1.61	0.16	1.056	0.5	1.55	YES
		BETA	1.5	0.1	1.56	0.16	0.962	0.72	1.67	YES
3/1/1999	Soil	AM-241	7.2	2.1	4.894	0.969	1.471	0.63	2.31	YES
		CS-137	665	65	659.5	24.95	1.008	0.83	1.32	YES
		K-40	370	35	362.75	20.156	1.020	0.78	1.53	YES
		PU-239	7.8	3.1	8.112	1.068	0.962	0.69	1.74	YES
		SR-90	17	5	32.4	0.529	0.525	0.6	3.66	NO (F)
		U-234	140	28	140.667	1.155	0.995	0.47	1.3	YES
		U-238	145	28	145	1.732	1.000	0.44	1.42	YES
		U-NAT	285		291	3	0.979	0.46	1.39	YES
3/1/1999	Vegetation	AM-241	3.5	1	3.522	0.59	0.994	0.68	2.7	YES
		CM-244	1.9	0.6	1.671	0.542	1.137	0.47	1.65	YES
		CO-60	24	3	21.45	1	1.119	0.69	1.46	YES
		CS-137	505	50	467	20	1.081	0.8	1.39	YES
		K-40	730	70	656.5	20	1.112	0.79	1.42	YES
		PU-239	5.1	1.1	5.204	0.428	0.980	0.68	6.95	YES
		SR-90	700	70	736.1	7.7	0.951	0.5	1.33	YES

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**TABLE F-1  
1999 DOE EML Cross Check Program Results**

Collection Date	Media	Nuclide	ERL VALUE (A & D)	UNCERTAINTY (A)	DOE EML VALUE (B & D)	UNCERTAINTY (C)	RATIO	Min. RATIO	Max. RATIO	AGREEMENT
3/1/1999	Water	AM-241	1.2	0.2	1.146	0.051	1.047	0.75	1.49	YES
		CO-60	55	5	51.1	3	1.076	0.8	1.2	YES
		CS-137	42	4	39.375	2.405	1.067	0.8	1.26	YES
		FE-55	96	10	97.4	1.65	0.986	0.44	1.53	YES
		H-3	130	30	121.08	6.78	1.074	0.71	1.79	YES
		PU-238	0.78	0.14	0.772	0.037	1.010	0.78	1.25	YES
		PU-239	1	0.2	1.009	0.058	0.991	0.8	1.39	YES
		SR-90	2.6	0.6	4.104	0.045	0.634	0.75	1.5	NO (G)
		U-234	0.29	0.07	0.269	0.016	1.078	0.8	1.4	YES
		U-238	0.27	0.06	0.262	0.016	1.031	0.8	1.26	YES
		U-Nat	0.57		0.541	0.025	1.054	0.67	1.42	YES
3/1/1999	Water	ALPHA	1100	100	1090	20	1.009	0.61	1.32	YES
		BETA	1400	100	1100	40	1.273	0.55	1.54	YES
9/1/1999	Air Filter	Am-241	0.12	0.01	0.127	0.0099	0.945	0.73	2.58	YES
		Co-57	7.2	0.7	7.73	0.033	0.931	0.65	1.39	YES
		Co-60	6.3	0.6	6.35	0.41	0.992	0.75	1.32	YES
		Cs-137	6.2	0.6	6.43	0.42	0.964	0.73	1.37	YES
		Mn-54	7.5	0.8	7.91	0.45	0.948	0.74	1.4	YES
		Pu-238	0.077	0.012	0.0968	0.0065	0.795	0.76	1.44	YES
		Pu-239	0.12	0.01	0.136	0.011	0.882	0.61	1.43	YES
		Ru-106	5	2.2	5.5	1.76	0.909	0.61	1.93	YES
		Sr-90	12	1	0.336	0.0141	35.714	0.83	1.92	NO (H)
		U-234	0.066	0.013	0.0658	0.0034	1.003	0.83	1.92	YES
		U-238	0.062	0.013	0.0646	0.0048	0.960	0.84	2.61	YES
		U-NAT	0.13		0.133	0.0081	0.977	0.8	3.35	YES
9/1/1999	Air Filter	ALPHA	2.9	0.3	2.77	0.26	1.047	0.5	1.55	YES
		BETA	2.7	0.3	2.66	0.26	1.015	0.72	1.67	YES
9/1/1999	Soil	Am-241	1.8	0.7	1.44	0.19	1.250	0.63	2.31	YES
		Cs-137	210	20	204	5	1.029	0.63	2.31	YES
		K-40	845	85	780	27	1.083	0.78	1.53	YES
		Pu-239	3	0.8	3.2	0.5	0.938	0.69	1.74	YES
		Sr-90	19	2	13	.47	1.46	.6	1.66	YES
		U-234	197	20	190	5.2	1.037	0.6	3.66	YES
		U-238	203	20	202	7.2	1.005	0.47	1.3	YES
		U-NAT	407		401	8.7	1.015	0.46	1.39	YES

**1999 RADIOLOGICAL ENVIRONMENTAL MONITORING REPORT**

**TABLE F-1**  
**1999 DOE EML Cross Check Program Results**

Collection Date	Media	Nuclide	ERL VALUE (A & D)	UNCERTAINTY (A)	DOE EML VALUE (B & D)	UNCERTAINTY (C)	RATIO	Min. RATIO	Max. RATIO	AGREEMENT
9/1/1999	Vegetation	Am-214	3	0.4	2.88	0.22	1.042	0.68	2.7	YES
		Cm-244	1.9	0.2	1.61	0.36	1.180	0.47	1.65	YES
		Co-60	17	2	17.6	1	0.966	0.69	1.46	YES
		Cs-137	440	40	440	20	1.000	0.8	1.39	YES
		K-40	515	50	513	20	1.004	0.79	1.42	YES
		Pu-238	0.39	0.08	0.5	0.1	0.780	0.66	7.94	YES
		Pu-239	4.4	0.5	4.3	0.46	1.023	0.68	6.95	YES
		Sr-90	650	70	595	29	1.092	0.5	1.33	YES
9/1/1999	Water	Am-241	0.87	0.1	0.85	0.1	1.024	0.75	1.49	YES
		Co-60	.54	5	52.4	2.2	1.031	0.8	1.2	YES
		Cs-137	215	20	76	3.4	2.829	0.8	1.26	NO (I)
		Fe-55	44	4	53	2	0.830	0.44	1.53	YES
		H-3	150	10	80.7	3.7	1.859	0.71	1.79	NO (I)
		Pu-238	0.8	0.08	0.79	0.08	1.013	0.78	1.25	YES
		Pu-239	0.89	0.09	0.87	0.1	1.023	0.8	1.39	YES
		Sr-90	1.5	0.6	1.72	0.1	0.872	0.75	1.5	YES
		U-234	0.4	0.05	0.37	0.02	1.081	0.8	1.4	YES
		U-238	0.41	0.06	0.36	0.02	1.139	0.8	1.26	YES
9/1/1999	Water	U-NAT	0.82		0.76	0.04	1.079	0.67	1.42	YES
		ALPHA	1400	100	1580	20	0.886	0.61	1.32	YES
		BETA	910	90	740	40	1.230	0.55	1.54	YES

- A. The ERL Value is an average of 1 to 4 determinations.
- B. The DOE EML value is the mean of replicate determinations for each nuclide.
- C. The DOE EML uncertainty is the standard error of the mean.
- D. The units are Bq/L for water, Bq/kg (dry) for soil, Bq/kg (wet) for vegetation and total Bq for air filters.
- E. The Sr-90 in EML air particulate result (0.31 Bq/UN) is not acceptable with the EML value (0.644 Bq/UN). Three aliquots were analyzed using different size volumes, 0.05, 0.1, and 0.15 unit. The digestion of the filter was adequate because all other analyses performed, such as gamma isotopic and Alpha Spec., were acceptable. The Sr-90 results did yield a high uncertainty and in retrospect larger aliquots should have been analyzed. Future analysis of cross-check samples will process larger aliquots, especially if the activity is low, as was the case with this survey.
- F. The EML soil Sr-90 result (17 Bq/Kg) is not within acceptable agreement with the EML value (32.4 Bq/Kg). Three aliquots (3g, 5g, and 7g) were processed and yielded results of 15.6, <15, and 18.5 Bq/Kg. The two positive results were averaged and reported. Upon review of these results it shows that the larger aliquot used for the analysis yielded the highest result. Future analysis of EML soil samples will process larger aliquots, similarly to the sample size used for environmental samples, that is, ~25 grams.
- G. The Sr-90 in EML water (known value 4.104 Bq/L) failed to achieve acceptable results. Two aliquots were analyzed and yielded results of  $3.1 \pm 0.8$  and  $2.1 \pm 0.4$  Bq/L. These results overlap and were averaged before submitting the final result of 2.6 Bq/L to EML. A subsequent reanalysis was performed yielding 2.4 and 2.8 Bq/L. All these samples were counted on the same detector, Detector 46. Reanalysis samples were then counted on Detector 42. Surprisingly, Detector 42 results averaged 3.6 Bq/L, an acceptable 0.88 ratio to the known. This would lead one to think that perhaps detector 46's efficiency is incorrect. However, the Sr-90 check standard was acceptable for all reports. Further testing by counting additional samples on different

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- detectors showed no discrepancies. Two things will be done for future samples. First, different volume aliquots will be taken for analysis. This will show if there are problems with lower activity results. Secondly, samples will be counted on different detectors to determine whether detector efficiency is a problem.
- H. The ERL Sr-90 value ( $12 \pm 1$  Bq/filter) submitted does not agree with the EML value ( $0.336 \pm 0.014$  Bq/filter). The ratio was 35.7 and the acceptance range is for ratios between 0.83 and 1.92. A reanalysis was performed and the result ( $0.37 \pm 0.11$  Bq/filter) has a ratio of 1.09 and is Acceptable. An investigation was conducted to determine why the original result exceeded the acceptable range. The sample was analyzed in duplicate using 0.1 and 0.2 UNIT of digested sample. After reviewing the first count (total strontium), the data looked normal, 280 and 354 counts respectfully. After an ingrowth period of one week, the total strontium samples were dissolved and passed through the original columns in order to separate out the ingrown yttrium. The yttrium portion was evaporated onto a planchet and counted. These counts also looked normal, i.e., one sample had twice as many counts as the other (1761 and 3119 counts). In retrospect, looking at both the total strontium counts and the purified yttrium counts together, it can be seen that there is no way the yttrium counts could be higher then the total strontium counts. There must have been something that contaminated the yttrium portion. There are two possibilities for what could have occurred. The samples were analyzed with five other crosscheck samples, all with much higher activities. There could have been cross contamination however, none of the other crosschecks came up low in their known activity. Another possibility is that during the ingrowth period, besides yttrium ingrowing from the strontium, there was also bismuth ingrowing from the lead that had a stronger affinity to adhere onto the Sr resin. This bismuth is normally removed by passing a 0.05M HNO<sub>3</sub> rinse through the column, which is what the procedure instructs you to do. This rinse may have been omitted causing the bismuth to be counted with the yttrium and resulting in a much higher count rate and activity. In order to prevent this omission from occurring again, the calculation program now has a step built in to alert the analyst if the total strontium counts are lower than the yttrium counts. This warning will prevent false positives from being reported.
- I. The water sample received from the EML consisted of a spiked, 455 mL aliquot (approximate) of acidified water. The Lab ID number was 109360 so it was duplicated as 109361. When the first 100 ml aliquot was measured out into a gamma counting container its result was significantly higher than the duplicate result. The analyst then poured the aliquots back into the original container. Before reporting the duplicate results, fresh aliquots were gamma scanned and were found to agree with each other. Upon investigation it was discovered that the graduated cylinder used was contaminated with Cs-137. The sample that contaminated the graduated cylinder may also have resulted in the H-3 contamination. ERL staff have been instructed to use disposable labware for high activity samples or to gamma scan glassware and dispose of it if it is contaminated.

The control limit concept was established from percentiles of historic data distributions (1982 - 1992). The evaluation of this historic data and the development of the control limits are presented in DOE report EML-564. The control limits for QAP-XLVII were developed from percentiles of data distributions for the years 1991 - 1999.

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**TABLE F-2**  
**ERL 1999 ANALYTICS Environmental Cross Check Program Results**

Collection Date	Media	Nuclide	ERL VALUE (B)	ANALYTICS			RESOLUTION	RATIO	Min. RATIO	Max. RATIO	AGREEMENT
				VALUE (A)	UNCERTAINTY (3 SIGMA)	(1 SIGMA)					
6/24/1999	Air Filter	Ce-141	180	169	8	2.7	63.4	1.07	0.8	1.25	YES
		Cr-51	250	217	11	3.7	59.2	1.15	0.8	1.25	YES
		Cs-134	110	116	6	2.0	58.0	0.95	0.8	1.25	YES
		Cs-137	200	190	10	3.3	57.0	1.05	0.8	1.25	YES
		Mn-54	98	85	4	1.3	63.8	1.15	0.8	1.25	YES
		Fe-59	69	48	2	0.7	72.0	1.44	0.8	1.25	NO (C)
		Zn-65	150	123	6	2.0	61.5	1.22	0.8	1.25	YES
		Co-60	220	215	11	3.7	58.6	1.02	0.8	1.25	YES
6/24/1999	Cartridge	I-131	89	76	4	1.3	57.0	1.17	0.8	1.25	YES
6/24/1999	Milk	I-131	75	72	4	1.3	54.0	1.04	0.8	1.25	YES
6/24/1999	Milk	Sr-89	66	70	4	1.3	52.5	0.94	0.8	1.25	YES
		Sr-90	41	42	2	0.7	63.0	0.98	0.8	1.25	YES
6/24/1999	Water	Sr-89	86	69	3	1.0	69.0	1.25	0.8	1.25	YES
		Sr-90	42	46	2	0.7	69.0	0.91	0.8	1.25	YES
6/24/1999	Water	I-131	68	68	3	1.0	68.0	1.00	0.8	1.25	YES
		Ce-141	140	134	7	2.3	57.4	1.04	0.8	1.25	YES
		Cr-51	160	172	9	3.0	57.3	0.93	0.8	1.25	YES
		Cs-134	84	92	5	1.7	55.2	0.91	0.8	1.25	YES
		Cs-137	160	151	8	2.7	56.6	1.06	0.8	1.25	YES
		Mn-54	66	68	3	1.0	68.0	0.97	0.8	1.25	YES
		Fe-59	48	38	2	0.7	57.0	1.26	0.8	1.25	NO (C)
		Zn-65	110	98	5	1.7	58.8	1.12	0.8	1.25	YES
		Co-60	190	171	9	3.0	57.0	1.11	0.8	1.25	YES
6/24/1999	Water	I-131	68	68	3	1.0	68.0	1.00	0.8	1.25	YES
6/24/1999	Water	Alpha	91	98	5	1.7	58.8	0.93	0.8	1.25	YES
		Beta	250	290	15	5.0	58.0	0.86	0.8	1.25	YES
		Alpha	46	51	3	1.0	51.0	0.90	0.8	1.25	YES
		Beta	240	271	14	4.7	58.1	0.89	0.8	1.25	YES
9/23/1999	Water	Sr-89	81	77	4	1.3	57.8	1.05	0.8	1.25	YES
		Sr-90	41	38	2	0.7	57.0	1.08	0.8	1.25	YES

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**TABLE F-2**  
**ERL 1999 ANALYTICS Environmental Cross Check Program Results**

Collection Date	Media	Nuclide	ERL	ANALYTICS			RESOLUTION	RATIO	Min. RATIO	Max. RATIO	AGREEMENT
			VALUE (B)	VALUE (A)	UNCERTAINTY (3 SIGMA)	(1 SIGMA)					
9/23/1999	Milk	I-131	100	91	5	1.7	54.6	1.10	0.8	1.25	YES
		Ce-141	200	197	10	3.3	59.1	1.02	0.8	1.25	YES
		Cr-51	160	149	7	2.3	63.9	1.07	0.8	1.25	YES
		Cs-134	89	96	5	1.7	57.6	0.93	0.8	1.25	YES
		Cs-137	230	217	11	3.7	59.2	1.06	0.8	1.25	YES
		Mn-54	180	170	9	3.0	56.7	1.06	0.8	1.25	YES
		Fe-59	96	76	4	1.3	57.0	1.26	0.8	1.25	NO (C)
		Zn-65	160	164	8	2.7	61.5	0.98	0.8	1.25	YES
		Co-60	140	129	6	2.0	64.5	1.09	0.8	1.25	YES
9/23/1999	Water	I-131	91	77	4	1.3	57.8	1.18	0.8	1.25	YES
		Ce-141	240	244	12	4.0	61.0	0.98	0.8	1.25	YES
		Cr-51	180	184	9	3.0	61.3	0.98	0.8	1.25	YES
		Cs-134	100	119	6	2.0	59.5	0.84	0.8	1.25	YES
		Cs-137	280	268	13	4.3	61.8	1.04	0.8	1.25	YES
		Mn-54	220	210	11	3.7	57.3	1.05	0.8	1.25	YES
		Fe-59	100	94	5	1.7	56.4	1.06	0.8	1.25	YES
		Zn-65	220	202	10	3.3	60.6	1.09	0.8	1.25	YES
		Co-60	160	159	8	2.7	59.6	1.01	0.8	1.25	YES
9/23/1999	Water	I-131	80	77	4	1.3	57.8	1.04	0.8	1.25	YES
		Ce-141	240	244	12	4.0	61.0	0.98	0.8	1.25	YES
		Cr-51	180	184	9	3.0	61.3	0.98	0.8	1.25	YES
		Cs-134	110	119	6	2.0	59.5	0.92	0.8	1.25	YES
		Cs-137	280	268	13	4.3	61.8	1.04	0.8	1.25	YES
		Mn-54	230	210	11	3.7	57.3	1.10	0.8	1.25	YES
		Fe-59	110	94	5	1.7	56.4	1.17	0.8	1.25	YES
		Zn-65	220	202	10	3.3	60.6	1.09	0.8	1.25	YES
		Co-60	170	159	8	2.7	59.6	1.07	0.8	1.25	YES
9/23/1999	Water	I-131	79	77	4	1.3	57.8	1.03	0.8	1.25	YES
9/23/1999	Soil	Ce-141	0.32	0.399	0.020	0.007	59.9	0.80	0.8	1.25	YES
		Cr-51	0.38	0.301	0.015	0.005	60.2	1.26	0.8	1.25	NO (D)
		Cs-134	0.15	0.195	0.010	0.003	58.5	0.77	0.8	1.25	NO (D)
		Cs-137	0.37	0.439	0.022	0.007	59.9	0.84	0.8	1.25	YES
		Mn-54	0.30	0.343	0.017	0.006	60.5	0.87	0.8	1.25	YES
		Fe-59	0.13	0.154	0.008	0.003	57.8	0.84	0.8	1.25	YES
		Zn-65	0.32	0.331	0.017	0.006	58.4	0.97	0.8	1.25	YES
		Co-60	0.21	0.260	0.013	0.004	60.0	0.81	0.8	1.25	YES

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Notes:

- A. The Analytics Value is the known concentration. Units are pCi/L for Milk, pCi/g (dry) for Soil and total pCi for Filter and Cartridge.
- B. The ERL Value is an average of three or more determinations. Units are pCi/L for Milk, pCi/g (dry) for Soil and total pCi for Filter and Cartridge.
- C. A new calibration source with Fe-59 has been ordered.
- D. This sample was analyzed three times. The results are

Nuclide	Result 1	Result 2	Result 3	Analytics	Ratio
Cr-51	0.38 ± 0.24	0.37 ± 0.17	L.T. 0.2	0.301	1.26
Cs-134	0.16 ± 0.02	0.14 ± 0.01	0.14 ± 0.01	0.195	0.77

The acceptance range for the ratio is between 0.8 and 1.25. Because the other nuclides in the sample had Acceptable agreement and because of the non-homogeneous nature of soil samples, the small deviation from the acceptance range is acceptable.

To determine agreement or possible agreement:

1. Divide each Analytics value by its associated one sigma uncertainty to obtain the resolution.
2. Divide each ERL value by the corresponding Analytics value to obtain the ratio.
3. The ERL measurement is in agreement if the value of the ratio falls within the limits shown in the following table for the corresponding resolution.

Resolution	Agreement
< 4	0.4 - 2.5
≥ 4 - < 8	0.5 - 2.0
≥ 8 - < 16	0.6 - 1.66
≥ 16 - < 51	0.75 - 1.33
≥ 51 - < 200	0.80 - 1.25
≥ 200	0.85 - 1.18

Criteria are similar to those listed in USNRC Inspection Procedure 84750 "Radioactive Waste Treatment, and Effluent and Environmental Monitoring" with minor adjustments to account for activity concentrations with large uncertainties.

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**TABLE F-3**  
**Teledyne Brown Engineering 1999 ANALYTICS Cross Check Program Results**

Collection Date	Media	Nuclide	TBE VALUE	ANALYTICS		RESOLUTION	RATIO (B)	Min. RATIO	Max. RATIO	AGREEMENT
				VALUE (A)	UNCERTAINTY (3 SIGMA)					
6/24/1999	Water	Sr-89	60	69	3.0	1.0	69.0	0.87	0.8	1.25 YES
		Sr-90	35	46	2.0	0.7	69.0	0.76	0.8	1.25 NO (C)
6/24/1999	Water	Alpha	160	98	5.0	1.7	58.8	1.63	0.8	1.25 NO (D)
		Beta	300	290	15.0	5.0	58.0	1.03	0.8	1.25 YES
6/24/1999	Water	I-131	77	68	3.0	1.0	68.0	1.13	0.8	1.25 YES
		Ce-141	139	134	7.0	2.3	57.4	1.04	0.8	1.25 YES
		Cr-51	162	172	9.0	3.0	57.3	0.94	0.8	1.25 YES
		Cs-134	86	92	5.0	1.7	55.2	0.93	0.8	1.25 YES
		Cs-137	167	151	8.0	2.7	56.6	1.11	0.8	1.25 YES
		Mn-54	77	68	3.0	1.0	68.0	1.13	0.8	1.25 YES
		Fe-59	40	38	2.0	0.7	57.0	1.05	0.8	1.25 YES
		Zn-65	113	98	5.0	1.7	58.8	1.15	0.8	1.25 YES
		Co-60	179	171	9.0	3.0	57.0	1.05	0.8	1.25 YES
		Ce-141	169	162	8.0	2.7	60.8	1.04	0.8	1.25 YES
6/24/1999	Air Filter	Cr-51	241	208	10.0	3.3	62.4	1.16	0.8	1.25 YES
		Cs-134	105	111	6.0	2.0	55.5	0.95	0.8	1.25 YES
		Cs-137	211	182	9.0	3.0	60.7	1.16	0.8	1.25 YES
		Mn-54	96	82	4.0	1.3	61.5	1.17	0.8	1.25 YES
		Fe-59	55	46	2.0	0.7	69.0	1.20	0.8	1.25 YES
		Zn-65	144	118	6.0	2.0	59.0	1.22	0.8	1.25 YES
		Co-60	214	206	10.0	3.3	61.8	1.04	0.8	1.25 YES
		Ce-141	0.274	0.269	0.0	0.0	62.1	1.02	0.8	1.25 YES
6/24/1999	Soil	Cr-51	0.374	0.345	0.0	0.0	60.9	1.08	0.8	1.25 YES
		Cs-134	0.2	0.184	0.0	0.0	61.3	1.09	0.8	1.25 YES
		Cs-137	0.45	0.429	0.0	0.0	61.3	1.05	0.8	1.25 YES
		Mn-54	0.153	0.136	0.0	0.0	58.3	1.13	0.8	1.25 YES
		Fe-59	0.118	0.077	0.0	0.0	57.8	1.53	0.8	1.25 NO (E)
		Zn-65	0.206	0.196	0.0	0.0	58.8	1.05	0.8	1.25 YES
		Co-60	0.351	0.343	0.0	0.0	60.5	1.02	0.8	1.25 YES

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- A. The Analytics Value is the known concentration. Units are pCi/L for Milk, pCi/g (dry) for Soil and total pCi for Filter and Cartridge.
- B. Ratio of Teledyne Brown Engineering to Analytics results.
- C. Under investigation.
- D. A high Gross Alpha result was obtained because the calculation was mistakenly performed using Th-230 counting efficiency. If the normal Am-241 calibration were used, TBE would have reported  $110 + 10 \text{ pCi/L}$ , which is an acceptable value.
- E. Random or coincidental summing caused the problem. Two other energy lines can sum a peak on the same energy band causing more counts to be thrown in. The key line was changed and the resulting value was 0.079, which is in agreement with Analytics.

**To determine agreement or possible agreement:**

1. Divide each Analytics value by its associated one sigma uncertainty to obtain the resolution.
2. Divide each TBE value by the corresponding Analytics value to obtain the ratio.
3. The measurement is in agreement if the value of the ratio falls within the limits shown in the following table for the corresponding resolution.

<u>Resolution</u>	<u>Agreement</u>
< 4	0.4 - 2.5
$\geq 4 - < 8$	0.5 - 2.0
$\geq 8 - < 16$	0.6 - 1.66
$\geq 16 - < 51$	0.75 - 1.33
$\geq 51 - < 200$	0.80 - 1.25
$\geq 200$	0.85 - 1.18

Criteria are similar to those listed in USNRC Inspection Procedure 84750 "Radioactive Waste Treatment, and Effluent and Environmental Monitoring" with minor adjustments to account for activity concentrations with large uncertainties.

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**TABLE F-4**  
**Teledyne Brown Engineering**  
**ERA STATISTICAL SUMMARY**  
**PROFICIENCY TESTING (PT) PROGRAM - 1999**

DATE	MEDIA	NUCLIDE	ERA Known Value (pCi/l) (a)	TBE Result (pCi/l) (b)	Expected Dev. Known (pCi/l) (c)	Control Limits (pCi/l) (d)	Performance Evaluation (e)
8/23/99	Water	U(NAT)	12.4	13.0	3.00	7.20-17.6	A
8/20/99	Water	Ra-226	7.21	7.37	1.08	5.34-9.08	A
8/23/99	Water	Ra-228	4.51	7.17	1.13	2.57-6.45	NA (f)
8/24/99	Water	Sr-89	26.6	25.0	5.00	17.9-35.3	A
8/24/99	Water	Sr-90	40.2	39.7	5.00	31.5-48.9	A
9/15/99	Water	Gr-A	48.6	30.3	12.2	27.7-69.5	CE
9/14/99	Water	Gr-B	20.0	22.0	5.00	11.3-28.7	A
9/01/99	Water	H-3	6130	5530	613	5090-7170	A

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**Footnotes:**

- (a) The ERA Known Value is equal to 100% of the parameter present in the standard as determined by gravimetric and/or volumetric measurements made during standard preparation.
- (b) Average  $\pm$  1 sigma.
- (c) Established per the guidelines contained in the EPA's National Standards for Water Proficiency Testing Criteria Document, December 1998, as applicable.
- (d) Established per the guidelines contained in the EPA's National Standards for Water Proficiency Testing Criteria Document, December 1998, as applicable.
- (e) A= Acceptable. Reported Result falls within the Warning Limits.  
NA = Not Acceptable. Reported Result falls outside of the Control Limits.  
CE = Check for Error. Reported Result falls within the Control Limits and outside of the Warning Limits.
- (f) A calculation error was made by not correcting for Ra-226 content. If this correction is made, an average result of 5.7 pCi/l is obtained which is in the acceptance region.

## **APPENDIX G**

### **1999 Land Use Census**

**1999 RADIOLOGICAL ENVIRONMENTAL MONITORING REPORT**

**TABLE G-1  
1999 ANNUAL DAIRY CENSUS\***

<b>Distance &amp; Direction</b>	<b>Azimuth &amp; Sector Code</b>	<b>**Name, Address &amp; Phone Number</b>	<b>Breed</b>	<b>No. Cows</b>	<b>No. Cows Milked</b>	<b>No. Goats</b>	<b>No. Goats Milked</b>	<b>Dairy Used</b>	<b>Grazing Period</b>
3.3km (2.1mi) N	3° A		Cows, goats, sheep and horses are periodically kept here for quarantine from a few days to a few weeks. Animals are then shipped interstate or to foreign countries. If milked, milk is used as animal feed.						Animals graze for short periods prior to exportation. They also receive prepared feed.
6.6km (4.1mi) NE	35° C		Holstein	120 Cows 100 Heifers	120	--	--	Land O Lakes & Own Use	Milk cows are on home grown feed. Heifers graze June to October.
1.7km (1.1mi) ENE	65° D	***	Holstein	110 Cows 75 Heifers	95-100	--	--	Mt. Joy Co-op & Own Use	May 1 to November 1 plus hay & corn
1.8km (1.1mi) E	93° E	***	Holstein	150 Cows 100 Heifers & Calves	150	--	--	Mt.Joy Co-op	April to November plus home-grown feed for dry cows. Milking cows don't graze & are on home-grown feed.
5.2km (3.2mi) ESE	104° F		Holstein	90 Cows 60 Heifers	80	--	--	Mt.Joy Co-op	May to November (during winter on stored silage & hay)
2.3km (1.4mi) SE	130° G	***	Holstein Ayrshire	65 Cows 30 Heifers	50	--	--	National Farmers Organization & Own Use	April to November (during winter on silage, hay & high moisture corn if available).
7.8km (4.9 mi) SSW	200° K		Holstein	70 Cows 30 Heifers	65	--	--	Land O Lakes & Own Use	April 15 to October 15 (otherwise on silage & baled hay)
20.6km (12.8mi) SSW	208° K	***	Jersey Holstein Ayrshire Brown Swiss Guernsey Milking Shorthorn	150 Cows 120 Heifers & Calves	104	--	--	Land O Lakes & Own Use	No grazing (homegrown corn & alfalfa plus small portion of store-bought feed)
6.0km (3.7mi) WNW	295° P		Holstein Jersey	90 Cows	55	12 Nannies	0	Land O Lakes	May to October (otherwise on home-grown feed)
10.8km (6.7mi) WNW	293° P	***	Holstein	43 Cows 41 Calves & Heifers	42	--	--	Rutters Dairy & Own Use	May to October plus stored feed (hay & silage)

\* Includes the closest dairy farm in each of the 16 meteorological sectors within a distance of five miles of TMINS (if one exists) plus the regularly sampled milk farms.

\*\* Names and addresses are on file at Three Mile Island Environmental Affairs.

\*\*\* Regularly sampled milk farms.

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**TABLE G-2**

**1999 Annual Residence Census\***

<b>Distance and Direction</b>	<b>Azimuth and Sector Code</b>	<b>Name, Address** &amp; Telephone No.</b>	<b>Distance and Direction</b>	<b>Azimuth and Sector Code</b>	<b>Name, Address** &amp; Telephone No.</b>
6,000 ft. (1,839m) N	5° A		12,000 ft. (3,658 m) S	186° J	
3,800 ft. (1,158m) NNE	28° B		3,400 ft. (1,036 m) SSW	213.7° K	
2,800 ft. (853 m) NE	48° C		2,850 ft. (869 m) SW	226° L	
2,450 ft. (747 m) ENE	67.5° D		2,500 ft. (777 m) WSW	250° M	
2,300 ft. (700 m) E	80° E		1,850 ft. (564 m) W	272° N	
5,800 ft. (1,770 m) ESE	123° F		1,900 ft. (579 m) WNW	293° P	
3,750 ft. (1,143 m) SE	145° G		2,150 ft. (655 m) NW	306° Q	
3,750 ft. (1,143 m) SSE	152° H		3,500 ft. (1,067m) NNW	337.5° R	

\* Census identifies nearest residence in each of the sixteen meteorological sectors.

\*\* Names and addresses are on file at Three Mile Island Environmental Affairs.

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**TABLE G-3**

**Annual Garden Census 1999\***

Meteorological Sector Designation	Distance and Direction	Azimuth	**Name, Address & Phone Number	Type of Vegetation	How Used and Distribution of Consumers
A (1)	2.4km (1.5mi) N	4°		Pumpkins, Tomatoes, Squash, Garlic, Beans, Zucchini, Corn, Potatoes, Cabbage, Peppers, Okra, Eggplant, Watermelon, Cauliflower, Broccoli, Red Beets, Celery, Strawberries, Carrots, Asparagus, Grapes, Cucumbers	Own Use 9 Adults 1 Child Also given away to other family members, friends & neighbors. Beans, cucumbers & tomatoes were sold.
B (2)	1.4km (0.9mi) NNE	24°		Cauliflower, Peppers, Cabbage, Tomatoes, Asparagus, Horse Radish, Onions, Beans, Blueberries, Rhubarb, Broccoli, Potatoes, Watermelon, Cantaloupes, Cucumbers, Peas,	Own Use 3 Adults Also given away to family, friends & neighbors.
C (3)	1.3km (0.8mi) NE	34°		Lettuce, Radishes, Tomatoes, Peppers, Apples, Strawberries, Asparagus, Peas, Cantaloupes, Horseradish, Cucumbers, Beans,	Own Use 2 Adults Also given away to family, friends & neighbors.
D (4)	1.0km (0.6mi) ENE	57°		Lettuce, Tomatoes, Peppers, Corn, Carrots, Cucumbers, Beets, Watermelon	Own Use 2 Adults 1 Child 1 Teen
E (5)	0.7km (0.5mi) E	94°		Cabbage, Tomatoes, Corn, Red Beets	Grown primarily for AmerGen REMP. Excess consumed by AmerGen personnel and their families.
F (6)	2.0km (1.3mi) ESE	107°		Cabbage, Spinach, Strawberries, Tomatoes, Peppers, Potatoes, Green Beans, Peas, Lima Beans, Carrots, Watermelon, Cucumbers, Soy Beans, Cantaloupe, Sweet Corn, Sweet Potatoes	Own Use 2 Adults 5 Children Also shared with family & friends.
G (7)	1.0km (0.6mi) SE	135°		Wide assortment of food products including broad-leaf vegetables (cabbage)	Own Use 3 Adults. Also given away to relatives & sold along Rt. 441 at the Red Hill Farm Produce Stand, at the Farm Show Building Farmers Market and at the Hometown Market in Hazelton. Excess goes to Leola Produce Auction.
H (8)	1.3km (0.8mi) SSE	152°		Oregano, Basil, Chives, Corn, Strawberries, Spinach, Tomatoes, Lettuce, Peppers, Egg Plant, Parsley, Pumpkins, Onions, Carrots, Cilantro, Sunflowers, Kohlrabi, Radishes, Catnip	Own Use 2 Adults 2 Teens Also given away to friends & relatives.
J (9)	3.7km (2.3mi) S	186°		Tomatoes, Peppers, Cabbage, Strawberries, Potatoes, Zucchini, Beans, Onions, Cucumbers, Peas, Peaches, Pears, Raspberries	Own Use 2 Adults 2 Teens Also given away to friends and relatives.
K (10)	1.4km (0.9mi) SSW	208°		Peas, Tomatoes, Strawberries, Peppers, Cucumbers, Spinach, Lettuce, Carrots, Onions, Corn, Squash, Watermelon, Dill, Cantaloupes, Beans, Sunflowers, Radishes, Parsley, Cilantro, Oregano, Zucchini, Mint Honeydew, Basil, Borage, Fennel, Catnip,	Own Use 2 Adults Vegetables also canned & frozen for future use.
L (11)	2.5km (1.6mi) SW	232°		Lettuce, Tomatoes, Egg Plant, Squash, Zucchini, Corn, Cabbage, Broccoli, Grapes, Onions, Raspberries, Cucumbers, Beans	Own Use 2 Adults 2 Children Also shared with neighbors, friends & family.
M (12)	2.1km (1.3mi) WSW	253°		Potatoes, Beans, Cabbage, Turnips, Peas, Zucchini, Onions, Lettuce, Tomatoes, Red Beets, Peppers, Egg Plant, Corn, Neck Pumpkins	Own Use 2 Adults Also some given away to friends & family. A small amount is sold.

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**TABLE G-3**

**Annual Garden Census 1999\***

Meteorological Sector Designation	Distance and Direction	Azimuth	**Name, Address & Phone Number	Type of Vegetation	How Used and Distribution of Consumers
N (13)	2.1km (1.3mi) W	265°		Tomatoes, Red Beets, Peppers, Potatoes, Cabbage, Green Beans,	<u>Own Use</u> 2 Adults 2 Children Also given away to friends & family.
P (14)	2.7km (1.7mi) WNW	286°		Cucumbers, Strawberries, Peppers, Pears, Tomatoes, Asparagus, Lettuce, Apples, Corn, Peaches, Squash, Musk Melons, Sugar Snap Peas	<u>Own Use</u> 2 Adults Also given away to family & neighbors.
Q (15)	2.9km (1.8mi) NW	317°		Raspberries, Tomatoes, Peppers, Cabbage, Cucumbers, Cherries, Plums	<u>Own Use</u> 2 Adults
R (16)	3.9km (2.4mi) NNW	343°		Tomatoes, Peppers, Beans, Peas, Cucumbers, Grapes, Onions, Potatoes, Brussel Sprouts, Zucchini, Basil, Dill, Asparagus, Raspberries, Cabbage	<u>Own Use</u> 3 Adults Also given away to family, neighbors & friends.

\* Census identifies nearest garden (greater than 500 ft<sup>2</sup> and having a portion of broad-leaf vegetation) in each of the sixteen meteorological sectors.

\*\* Names and addresses are on file at Three Mile Island Environmental Affairs.

## **APPENDIX H**

### **1999 Data Reporting and Analysis**

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Environmental samples frequently contain very little, if any, radioactivity. Even when very sensitive, state-of-the-art counting equipment is used, many of the sample count rates can not be differentiated from the background count rate or the count rate of the blank sample. When this occurs, the sample is said to have a radioactivity level or concentration at or below the sensitivity of the analysis method. In this case, the analysis result is reported as less than a numerical value that corresponds to the sensitivity of the analysis method. Sensitivities are influenced by parameters such as sample volume, background or blank sample count rate and efficiency of the counting device.

The terms used to describe the sensitivity are the lower limit of detection (LLD) and minimum detectable concentration (MDC). For this report, these two terms are considered to be synonymous. They are defined as:

$$\text{LLD (MDC)} = \frac{4.66 \text{ Sb}}{E * V * 2.22 * Y * \exp(-\lambda \Delta t)}$$

where:

- |            |   |  |
|------------|---|--|
| Sb         | = | the standard deviation of the background counting rate or the counting rate of a blank sample, as counts per minute, |
| E          | = | the counting efficiency of the equipment, as counts per disintegration,  |
| V          | = | the volume or mass of the sample, such as L, g or m <sup>3</sup> ,   |
| 2.22       | = | the number of disintegrations per minute per picocurie,  |
| Y          | = | the chemical yield, if applicable,   |
| $\lambda$  | = | the radioactive decay constant for the particular radionuclide and   |
| $\Delta t$ | = | the elapsed time between sample collection (or end of sample collection period) and counting.                        |

The applicable LLD or MDC for each radionuclide and analysis is listed in Table 3. A large percentage of the 1999 sample results were reported as less than the LLD or MDC. Unless noted otherwise, the results that were reported as less than the LLD or MDC were not included in the calculations of averages, standard deviations and ranges (by station or group) in the text and tables of this report.

The data from samples that contained concentrations above the LLD or MDC were used in the calculations (averages, standard deviations and ranges) contained in this report. The individual sample results were generally reported to two significant figures. Each result also included a two-sigma counting uncertainty (95% confidence interval) to the same decimal place. At a minimum, a counting uncertainty equal to 10 percent of the measured concentration was reported. The counting uncertainties were not used in any statistical calculations in this report.

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The data used in a few tables and all annual graphs were actual sample concentrations. For historical graphs, actual sample concentrations were used for 1996 - 1998 data points only. The actual concentration is calculated by subtracting the background count rate or the count rate of a blank sample from the count rate of the sample. The net count rate is then converted to a net sample concentration which is either positive, negative or zero.

There are several advantages of using actual sample concentrations. Biases in the data (averages, ranges, etc.), such as those caused by averaging only sample concentrations above the MDC, are eliminated. Missing data points on graphs also are eliminated. It should be noted that negative sample concentrations are important to the overall averages and trends in the data, but they have no physical significance. A negative sample concentration simply means that the background or blank sample count rate is greater than the sample.

All sample data were analyzed using SAS, a statistical analysis package developed by SAS Institute, Inc. The data were grouped by station, time period and by control and indicator status. Minimum, maximum and average values were calculated for each of these groups as well as standard deviations ( $2\sigma$ , 95% confidence interval).

Quality control results (inter-laboratory and intra-laboratory) were not statistically analyzed with other data. Including quality control data would introduce a bias at selected stations while providing little additional interpretive information.

## **APPENDIX I**

### **1999 Dose Calculation Methodology and Results**

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To the extent possible, radiological impacts were evaluated based on the measurement of exposure rates or radionuclide concentrations in environmental samples. However, the radioactive materials released from TMINS during 1999 were often too small to be measured once dispersed in the offsite environment. As a result, the potential offsite doses were estimated by using computerized models that predict concentrations of radioactive materials in the environment and subsequent radiation doses on the basis of radionuclides released to the environment. Doses are calculated using an advanced class "A" dispersion model called SEEDS (simplified environmental effluent dosimetry system).

This model incorporates the guidelines and methodology set forth in USNRC Regulatory Guide 1.109, and uses actual monthly Susquehanna River flow data and hourly meteorological information matched to the time of releases to assess the dispersion of effluents in the river and the atmosphere. Combining this assessment of dispersion and dilution with TMINS effluent data for each unit, postulated maximum hypothetical doses to the public are calculated. The maximum individual dose is calculated as well as the population dose to the total population within 50 miles of TMINS for gaseous effluents and the entire population using Susquehanna River water downstream of the station for liquid effluents. Values of environmental parameters and radionuclide concentration factors were chosen to provide conservative results. As a result, the doses calculated using this model are conservative estimates (i.e., overestimated).

The dose summary tables, Table I-1 and I-2, present the maximum hypothetical doses to an individual resulting from TMI-1 and TMI-2 effluents, respectively, during the 1999 reporting period. Population doses for both units also are presented in Table I-1 and Table I-2.

**Liquid (Individual)**

The first two lines of Table I-1 (TMI-1) and Table I-2 (TMI-2) present the maximum hypothetical doses to an individual from liquids. Presented are the total body and critical organ doses for the age groups most affected. As recommended in USNRC Regulatory Guide 1.109, calculations are performed on the four age groups and eight organs. The pathways considered were water ingestion, shoreline exposure, and fresh water sportfish ingestion. The latter two pathways are considered to be the primary recreational activities associated with the Susquehanna River in the vicinity of TMINS. The "critical receptor" would be that individual who drinks water from the Susquehanna River, eats fish that reside in the plant discharge, and stands on the shoreline influenced by the plant discharge. Actual monthly Susquehanna River flows were used in dose calculations for liquid effluents.

For the 1999 reporting period, the calculated maximum hypothetical total body dose received by anyone from TMINS liquid effluents would have been 0.156 mrem (TMI-1) and 0.000613 mrem (TMI-2) to an adult. These represent 5.20 percent and 0.0204 percent, respectively, of the USNRC 10 CFR 50 App. I annual guidelines. The maximum hypothetical organ dose from TMI-1 and TMI-2 liquid effluents would have been 0.232 mrem to the liver of a teen and 0.000954

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mrem, to the liver of a teen, respectively. These represent 2.32 percent and 0.00954 percent, respectively of the USNRC 10 CFR 50 App. I annual guidelines.

**Gaseous (Individual)**

There were six major pathways considered in the dose calculation for gaseous effluents. These are (1) plume exposure, (2) inhalation, consumption of (3) cow milk, (4) fruits and vegetables, (5) meat, and (6) standing on contaminated ground. Ingestion of goat milk was not considered because this pathway did not exist in 1999. Real-time meteorology (the actual conditions that existed at the time of releases) was used in dose calculations for gaseous effluents. Default values were used if data were missing or invalid.

Lines 3 and 4 of Table I-1 (TMI-1) and Table I-2 (TMI-2) present the maximum plume exposures from noble gases at the site boundary. The notation of "air dose" is interpreted to mean that these doses are not to an individual but are considered to be the maximum dose at a location. The location is not necessarily a receptor (individual). The tables present the distance in meters and the affected sector (compass point). With respect to the noble gas releases for the 1999 reporting period, the maximum plume exposure (air dose) would have been 0.00474 and 0.0159 millirads (mrad) for TMI-1, gamma and beta, respectively. The TMI-1 exposures represent 0.0474 and 0.0795 percent of the USNRC 10 CFR 50 App. I annual guidelines, respectively. Since TMI-2 did not release any noble gases during 1999, the gamma and beta air doses listed on Table I-2 are zero.

Lines 5 and 6 present the calculated dose from noble gases to the closest receptor (individual) in the maximally affected sector(s). The location of the receptor is described by both distance (meters) and direction from the site. Plume doses to an individual, regardless of age, from gaseous effluents (noble gases only) during the 1999 reporting period were 0.00214 mrem and 0.00674 mrem for TMI-1 total body and skin dose, respectively. These represent 0.0428 percent and 0.0449 percent of the USNRC 10 CFR 50 App. I annual guidelines for the total body and skin, respectively. As mentioned previously, TMI-2 did not release any noble gases during 1999. Therefore, the total body and skin doses listed on Table I-2 are zero.

Line 7 of Table I-1 and Table I-2 represents the dose to the maximally exposed organ due to airborne releases of iodines, tritium and particulates. This does not include the whole body plume dose that was separated out on line 5. The doses presented in this section again reflect the maximum exposed organ for the appropriate age group.

During 1999, iodines, tritium and particulates released into the atmosphere from TMI-1 would have resulted in a maximum dose of 0.0144 mrem to the thyroid of an infant. The corresponding dose from TMI-2 was 0.000105 mrem to the liver, total body, thyroid, kidney, lung and GI tract of a child. No other organ of any age group would have received a dose greater than this from

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either TMI-1 or TMI-2. These doses are 0.0960 percent and 0.000700 percent of the USNRC 10 CFR 50 App. I annual guidelines.

**Liquid and Gaseous (Population)**

Lines 8-11 of Tables I-1 (TMI-1) and Table I-2 (TMI-2) present the population doses (in person-rem) resulting from the liquid and gaseous effluents. These doses, total body and maximum organ, are summed over all pathways and the affected population. The population doses from liquid effluents are based upon the population encompassed within the region from the TMINS outfall extending down to the Chesapeake Bay (approximately 5,000,000 people). The population doses due to gaseous effluents include the population out to a distance of 50 miles around TMINS (approximately 2,200,000) as well as the much larger total population that can be fed by foodstuffs grown in the 50 mile radius (up to approximately 13,000,000). The population doses are summed over all distances and sectors to give an aggregate dose.

Based upon the calculations performed for the 1999 reporting period, TMI-1 and TMI-2 liquid and gaseous effluents resulted in a combined population dose of 11.8 person-rem to the total body. This is more than 50,000 times lower than the dose that the population living within 50 miles of TMINS receives each year from natural background radiation (660,000 person-rem).

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**TABLE I-1**

**Summary of Maximum Individual and Population Doses  
from TMI-1 Effluents for 1999**

Individual Doses						
Effluent	Organ	Estimated Dose/year (mrem)	Age Group	Location Dist (m) Dir (Toward)	Percent of 10 CFR 50 App. I Annual Guideline	10 CFR 50 App I Annual Guideline (mrem/yr)
1 Liquid	Total Body	1.56E-1	Adult	Receptor 1	5.20E+0	3
2 Liquid	Liver	2.32E-1	Teen	Receptor 1	2.32E+0	10
3 Noble Gas	Gamma Air Dose (mrad)	4.74E-3	--	2000 SSE	4.74E-2	10
4 Noble Gas	Beta Air Dose (mrad)	1.59E-2	--	2000 SSE	7.95E-2	20
5 Noble Gas	Total Body	2.14E-3	All	2450 SSE	4.28E-2	5
6 Noble Gas	Skin	6.74E-3	All	2450 SSE	4.49E-2	15
7 Iodines, Tritium & Particulates	Thyroid	1.44E-2	Infant	580 WNW	9.60E-2	15

**Population Doses**

Effluent	Applicable Organ	Estimated Population Dose (Person-rem)
8 Liquid	Total Body	1.14E+1
9 Liquid	Liver	1.14E+1
10 Gaseous	Total Body	3.72E-1
11 Gaseous	Thyroid	4.25E-1

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**TABLE I-2**

**Summary of Maximum Individual and Population Doses  
from TMI-2 Effluents for 1999**

Individual Doses						
Effluent	Organ	Estimated Dose/year (mrem)	Age Group	Location Dist (m) Dir (Toward)	Percent of 10 CFR 50 App. I Annual Guideline	10 CFR 50 App. I Annual Guideline (mrem/yr)
1 Liquid	Total Body	6.13E-4	Adult	Receptor 1	2.04E-2	3
2 Liquid	Liver	9.54E-4	Teen	Receptor 1	9.54E-3	10
3 Noble Gas	Air Dose (Gamma-mrad)	0	—	—	0	10
4 Noble Gas	Air Dose (Beta-mrad)	0	—	—	0	20
5 Noble Gas	Total Body	0	—	—	0	5
6 Noble Gas	Skin	0	—	—	0	15
7 Iodines, Tritium & Particulates	Liver, Total Body, Thyroid, Kidney, Lung and GI	1.05E-4	Child	2150 NNE	7.00E-4	15

Population Doses		
Effluent	Applicable Organ	Estimated Population Dose (Person-rem)
8 Liquid	Total Body	8.18E-4
9 Liquid	Bone	2.92E-3
10 Gaseous	Total Body	9.87E-3
11 Gaseous	Liver, Thyroid, Kidney, Lung and GI	9.87E-3

## **APPENDIX J**

### **1999 Groundwater Monitoring Results**

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**TABLE J-1**  
**1999 Tritium Concentrations in Onsite Groundwater and Storm water**  
**(pCi/L)**

Station (Well Type)	1998 Average ± 2 std dev*	1999 Average ± 2 std dev*	1999 Range*
MS-1 (Monitoring)	170	350	**
MS-2 (Monitoring)	310 ± 90	460 ± 110	380 - 500
MS-4 (Monitoring)	1,000	1,600 ± 1,800	960 - 2,200
MS-5 (Monitoring)	340 ± 210	360 ± 200	280 - 500
MS-7 (Monitoring)	320 ± 70	270 ± 70	250 - 300
RW-2 (Monitoring)	NS	7,500 ± 3,300	2,200 - 9,800
OS-14 (Monitoring)	300 ± 170	270 ± 170	180 - 380
OS-18 (Monitoring)	11,000 ± 13,000	26,000 ± 54,000	320 - 130,000
MS-19 (Monitoring)	210	5,500 ± 6,100	3,400 - 7,700
MS-20 (Monitoring)	380	700 ± 530	450 - 980
MS-21 (Monitoring)	150	200	**
MS-22 (Monitoring)	3,600 ± 9,300	930 ± 640	520 - 1,700
RW-1 (Monitoring)	1,100 ± 2,200	7,200 ± 5,300	1,800 - 11,000
NW-A (Service Water)	2,300 ± 1,200	1,800 ± 500	740 - 2,400
NW-B (Service Water)	9,400 ± 5,400	3,800 ± 4,400	2,100 - 9,800
NW-C (Service Water)	56,000 ± 76,000	50,000 ± 52,000	23,000 - 160,000
NW-CW (Clearwell)	4,500 ± 2,000	9,200 ± 4,200	3,500 - 12,000
OSF (Drinking Water)	520 ± 160	490 ± 140	380 - 590
48S (Drinking Water)	280 ± 170	250 ± 50	220 - 280
TRANS (Monitoring)	NS	180	**
EDCB (Storm water)	280 ± 250	300 ± 50	270 - 310

\* = Averages, standard deviations and ranges were based on concentrations > the minimum detectable concentration (MDC).

\*\* = Only one concentration in 1999 was > MDC or only one sample was collected in 1999.

< MDC = Measured concentration(s) was equal to or below the MDC.

NS = Station was not sampled and, therefore, no data were available.

(Refer to Figures J-1 and J-2 for locations of onsite groundwater and storm water stations. Refer to Table A-1 and Figures 4 and 5 for locations of the offsite stations).

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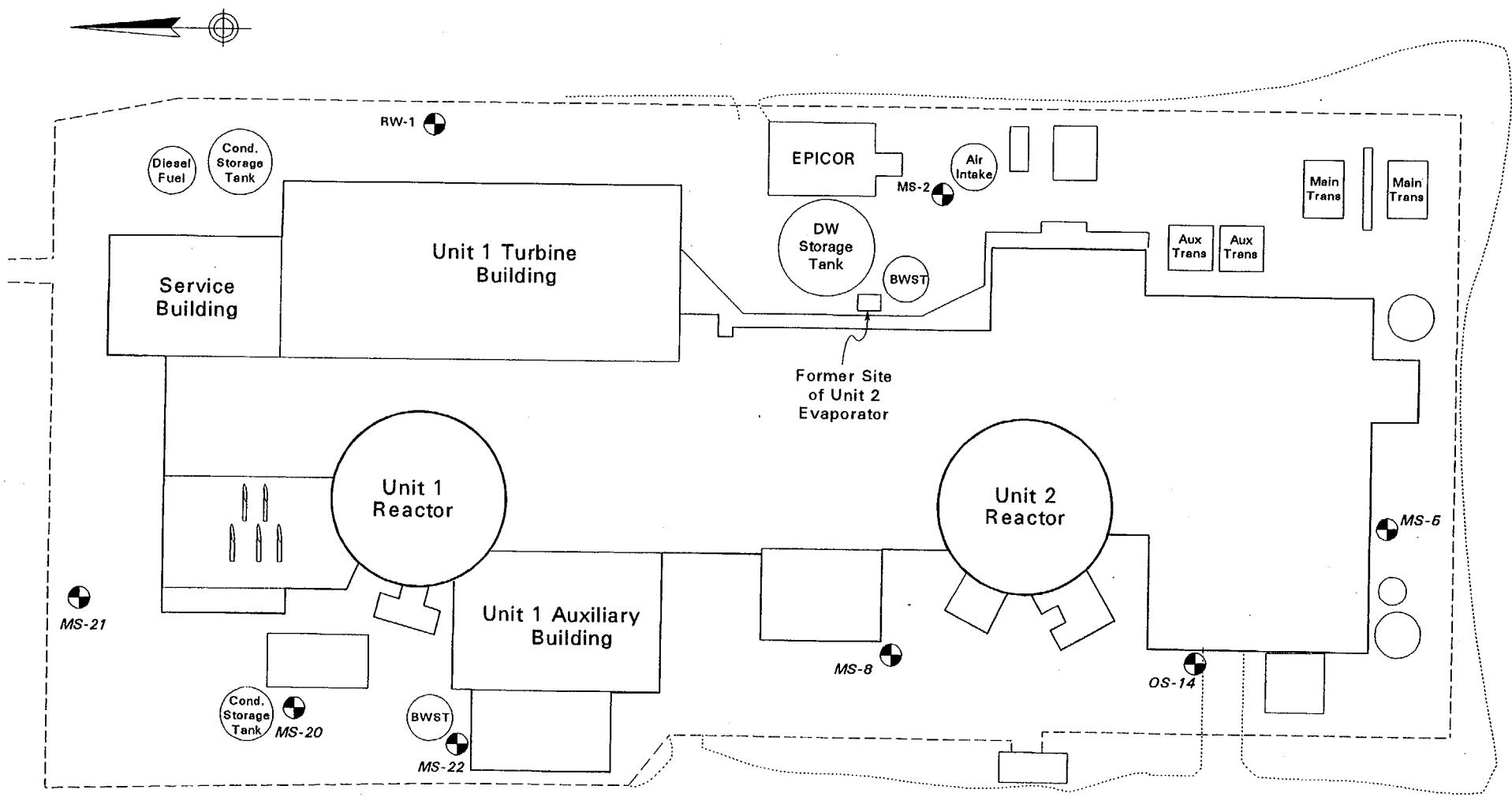
**TABLE J-2**  
**1999 Tritium Concentrations in Offsite Groundwater**  
**(pCi/L)**

<b>Station (Location)</b>	<b>1998 Concentration</b>	<b>1999 Concentration</b>
A2-2 (Tri County Marina)	< MDC	150 ± 70
D1-4 (Residence, East Shore)	180 ± 80	130 ± 80
E1-2 (TMINS Visitors Center)	< MDC	130 ± 70
J3-3 (Residence, West Shore)	< MDC	200 ± 70
K1-6 (Summer Residence, Shelley Is)	140 ± 60	130 ± 70
L1-3 (Summer Residence, Shelley Is)	170 ± 60	120 ± 70
L1-4 (Summer Residence, Beech Is)	< MDC	160 ± 70
N2-1 (Goldsboro Marina)	< MDC	120 ± 70

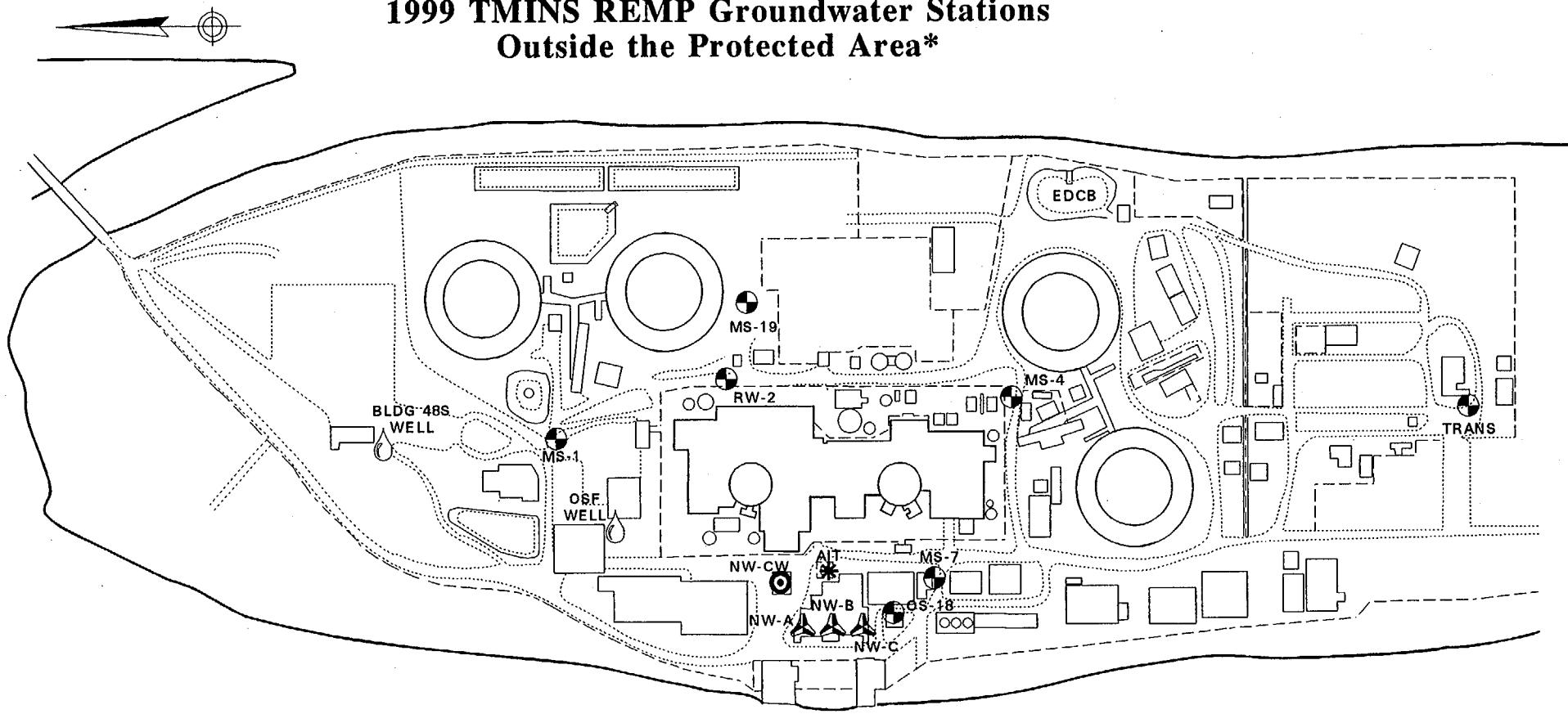
< MDC = Measured concentration was equal to or below the minimum detectable concentration (MDC).

(Refer to Figures J-1 and J-2 for locations of onsite groundwater and storm water stations. Refer to Table A-1 and Figures 4 and 5 for locations of the offsite stations).

**Figure J-1**  
**1999 TMINS REMP Groundwater Stations**  
**Inside the Protected Area**



**Figure J-2**  
**1999 TMINS REMP Groundwater Stations**  
**Outside the Protected Area\***



**LEGEND**

- Monitoring Well
- Drinking Water Well
- Clearwell
- ▲ Industrial Well
- \* Air Intake Tunnel - Groundwater Infiltration

\*The offsite groundwater wells are located at the TMI Visitors Center, two marinas, three summer homes, and two residences. The locations of these wells are shown on Figures 4 and 5.

## **APPENDIX K**

### **1999 Meteorological Data Summary**

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**TABLE K-1  
TMIINS Meteorological Data  
1999 Joint Frequency Tables**

Hours at Each Wind Speed and Direction

Period of Record: 99010100 - 99123123

Stability Class: A

Sensor Height: 100 ft.

		Wind Speed (mph)						TOTAL
Sector To	Winds From	1-3	4-7	8-12	13-18	19-24	>24	
N	S	9	19	34	3	0	0	65
NNE	SSW	15	51	38	7	0	0	111
NE	SW	17	41	20	7	0	0	85
ENE	WSW	16	15	10	4	0	0	45
E	W	27	18	19	9	0	0	73
ESE	WNW	36	56	33	6	2	0	133
SE	NW	54	118	88	22	5	6	293
SSE	NNW	58	127	60	43	13	4	305
S	N	12	21	13	1	0	0	47
SSW	NNE	5	11	7	0	0	0	23
SW	NE	4	20	7	0	0	0	31
WSW	ENE	3	17	10	1	0	0	31
W	E	4	35	17	4	0	0	60
WNW	ESE	15	39	21	2	0	0	77
NW	SE	10	27	17	2	0	0	56
NNW	SSE	11	33	10	2	0	0	56
TOTAL		296	648	404	113	20	10	1491

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**TABLE K-1 (Continued)**  
**TMINS Meteorological Data**  
**1999 Joint Frequency Tables**

Hours at Each Wind Speed and Direction

Period of Record: 99010100 - 99123123

Stability Class: **B**

Sensor Height: 100 ft

		Wind Speed (mph)						TOTAL
Sector	Winds	1-3	4-7	8-12	13-18	19-24	>24	
To	From							
N	S	3	8	9	0	0	0	20
NNE	SSW	3	10	8	1	0	0	22
NE	SW	7	8	6	3	0	0	24
ENE	WSW	7	2	8	0	0	0	17
E	W	4	5	19	11	2	0	41
ESE	WNW	5	3	11	13	2	1	35
SE	NW	6	12	28	34	7	0	87
SSE	NNW	10	20	13	21	4	0	68
S	N	4	3	1	4	0	0	12
SSW	NNE	4	3	0	0	0	0	7
SW	NE	1	3	1	0	0	0	5
WSW	ENE	4	9	0	0	0	0	13
W	E	5	11	2	2	0	0	20
WNW	ESE	1	9	9	0	0	0	19
NW	SE	6	6	4	2	0	0	18
NNW	SSE	1	6	5	0	0	0	12
<b>TOTAL</b>		71	118	124	91	15	1	420

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**TABLE K-1 (Continued)**  
**TMINS Meteorological Data**  
**1999 Joint Frequency Tables**

Hours at Each Wind Speed and Direction

Period of Record: 99010100 - 99123123

Stability Class: C

Sensor Height: 100 ft

Sector To	Sector From	Wind Speed (mph)						TOTAL
		1-3	4-7	8-12	13-18	19-24	>24	
N	S	1	3	7	0	0	0	11
NNE	SSW	1	7	8	0	0	0	16
NE	SW	5	0	2	0	0	0	7
ENE	WSW	2	2	1	0	0	0	5
E	W	1	3	3	8	2	0	17
ESE	WNW	1	6	8	9	2	1	27
SE	NW	4	6	19	14	3	0	46
SSE	NNW	3	6	10	13	1	0	33
S	N	4	3	0	1	0	0	8
SSW	NNE	3	3	0	0	0	0	6
SW	NE	1	5	1	0	0	0	7
WSW	ENE	2	4	1	1	0	0	8
W	E	1	4	7	1	0	0	13
WNW	ESE	2	9	14	2	0	0	27
NW	SE	1	3	2	0	0	0	6
NNW	SSE	3	3	1	0	0	0	7
<b>TOTAL</b>		<b>35</b>	<b>67</b>	<b>84</b>	<b>49</b>	<b>8</b>	<b>1</b>	<b>244</b>

**1999 RADIOLOGICAL ENVIRONMENTAL MONITORING REPORT**

**TABLE K-1 (Continued)**  
**TMINS Meteorological Data**  
**1999 Joint Frequency Tables**

Hours at Each Wind Speed and Direction

Period of Record: 99010100 - 99123123

Stability Class: **D**

Sensor Height: 100 ft

		Wind Speed (mph)						TOTAL
Sector To	Winds From	1-3	4-7	8-12	13-18	19-24	>24	
N	S	9	61	43	4	0	0	117
NNE	SSW	19	65	49	7	2	1	143
NE	SW	20	23	19	1	0	0	63
ENE	WSW	20	33	23	4	0	0	80
E	W	17	60	108	36	2	0	223
ESE	WNW	21	84	164	97	16	1	383
SE	NW	19	79	134	119	40	2	393
SSE	NNW	36	87	64	44	4	0	235
S	N	35	58	29	8	0	0	130
SSW	NNE	24	44	9	0	0	0	77
SW	NE	36	42	14	0	0	0	92
WSW	ENE	26	44	22	3	0	0	95
W	E	27	82	63	7	0	0	179
WNW	ESE	23	89	82	10	2	0	206
NW	SE	28	45	22	3	2	0	100
NNW	SSE	10	62	10	3	0	0	85
<b>TOTAL</b>		<b>370</b>	<b>958</b>	<b>855</b>	<b>346</b>	<b>68</b>	<b>4</b>	<b>2601</b>

**1999 RADIOLOGICAL ENVIRONMENTAL MONITORING REPORT**

**TABLE K-1 (Continued)**  
**TMINS Meteorological Data**  
**1999 Joint Frequency Tables**

Hours at Each Wind Speed and Direction

Period of Record: 99010100 - 99123123

Stability Class: E

Sensor Height: 100 ft.

Sector Winds To      From		Wind Speed (mph)						TOTAL
		1-3	4-7	8-12	13-18	19-24	>24	
N	S	32	57	26	2	0	0	117
NNE	SSW	42	76	35	2	0	0	155
NE	SW	40	64	16	2	0	0	122
ENE	WSW	49	46	15	1	0	0	111
E	W	61	75	24	3	0	0	163
ESE	WNW	69	64	46	12	2	0	193
SE	NW	55	57	42	25	7	0	186
SSE	NNW	76	98	19	9	0	0	202
S	N	45	97	33	3	0	0	178
SSW	NNE	36	68	3	0	0	0	107
SW	NE	35	37	0	0	0	0	72
WSW	ENE	37	56	9	0	0	0	102
W	E	46	65	26	0	0	0	137
WNW	ESE	47	44	25	4	0	0	120
NW	SE	44	40	12	1	0	0	97
NNW	SSE	24	44	8	1	0	0	77
TOTAL		738	988	339	65	9	0	2139

**1999 RADIOLOGICAL ENVIRONMENTAL MONITORING REPORT**

**TABLE K-1 (Continued)**  
**TMINS Meteorological Data**  
**1999 Joint Frequency Tables**

Hours at Each Wind Speed and Direction

Period of Record: 99010100 - 99123123

Stability Class: **F**

Sensor Height: 100 ft

		Wind Speed (mph)						TOTAL
Sector To	Winds From	1-3	4-7	8-12	13-18	19-24	>24	
N	S	27	9	1	0	0	0	37
NNE	SSW	38	20	2	0	0	0	60
NE	SW	54	25	2	0	0	0	81
ENE	WSW	52	15	1	1	0	0	69
E	W	66	18	1	0	0	0	85
ESE	WNW	60	13	1	0	0	0	74
SE	NW	55	23	3	0	0	0	81
SSE	NNW	65	51	2	0	0	0	118
S	N	16	29	2	1	0	0	48
SSW	NNE	22	11	0	0	0	0	33
SW	NE	28	2	0	0	0	0	30
WSW	ENE	29	11	0	0	0	0	40
W	E	45	25	1	0	0	0	71
WNW	ESE	56	8	4	0	0	0	68
NW	SE	56	7	1	0	0	0	64
NNW	SSE	42	2	0	0	0	0	44
<b>TOTAL</b>		711	269	21	2	0	0	1003

**1999 RADIOLOGICAL ENVIRONMENTAL MONITORING REPORT**

**TABLE K-1 (Continued)**  
**TMINS Meteorological Data**  
**1999 Joint Frequency Tables**

Hours at Each Wind Speed and Direction

Period of Record: 99010100 - 99123123

Stability Class: **G**

Sensor Height: 100 ft

Sector Winds		Wind Speed (mph)						TOTAL
To	From	1-3	4-7	8-12	13-18	19-24	>24	
N	S	26	8	1	0	0	0	35
NNE	SSW	35	13	3	0	0	0	51
NE	SW	33	10	1	0	0	0	44
ENE	WSW	30	12	0	0	0	0	42
E	W	24	13	0	0	0	0	37
ESE	WNW	27	6	1	0	0	0	34
SE	NW	26	9	0	1	0	0	36
SSE	NNW	31	20	0	0	0	0	51
S	N	26	16	2	0	0	0	44
SSW	NNE	14	5	0	0	0	0	19
SW	NE	12	3	0	0	0	0	15
WSW	ENE	20	8	0	0	0	0	28
W	E	28	9	1	0	0	0	38
WNW	ESE	41	9	1	0	0	0	51
NW	SE	35	1	1	0	0	0	37
NNW	SSE	29	2	0	0	0	0	31
<b>TOTAL</b>		437	144	11	1	0	0	593

**1999 RADIOLOGICAL ENVIRONMENTAL MONITORING REPORT**

**TABLE K-1 (Continued)**  
**TMINS Meteorological Data**  
**1999 Joint Frequency Tables**

Hours at Each Wind Speed and Direction

Period of Record: 99010100 - 99123123

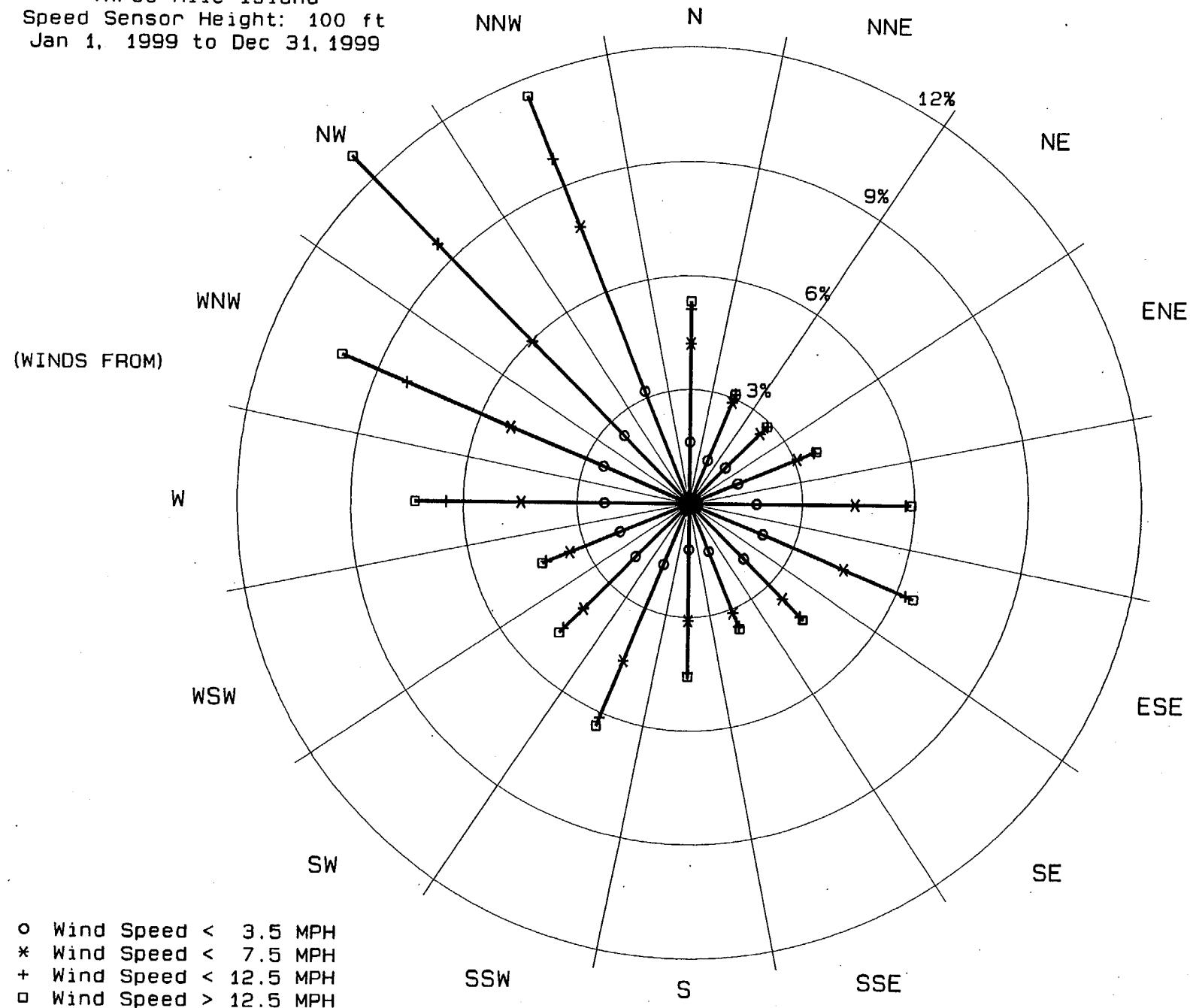
Stability Class: **ALL**

Sensor Height: 100 ft

Sector To	Winds From	Wind Speed (mph)						TOTAL
		1-3	4-7	8-12	13-18	19-24	>24	
N	S	107	165	121	9	0	0	402
NNE	SSW	153	242	143	17	2	1	558
NE	SW	176	171	66	13	0	0	426
ENE	WSW	176	125	58	10	0	0	369
E	W	200	192	174	67	6	0	639
ESE	WNW	219	232	264	137	24	3	879
SE	NW	219	304	314	215	62	8	1122
SSE	NNW	279	409	168	130	22	4	1012
S	N	142	227	80	18	0	0	467
SSW	NNE	108	145	19	0	0	0	272
SW	NE	117	112	23	0	0	0	252
WSW	ENE	121	149	42	5	0	0	317
W	E	156	231	117	14	0	0	518
WNW	ESE	185	207	156	18	2	0	568
NW	SE	180	129	59	8	2	0	378
NNW	SSE	120	152	34	6	0	0	312
<b>TOTAL</b>		2658	3192	1838	667	120	16	8491
(Hours of Missing/Invalid Data: 269)								

Three Mile Island  
Speed Sensor Height: 100 ft  
Jan 1, 1999 to Dec 31, 1999

Figure K-1  
1999 Wind Rose



## **APPENDIX L**

### **1999 REMP Sample Collection and Analysis Methods**

**1999 RADIOLOGICAL ENVIRONMENTAL MONITORING REPORT**

**TABLE L**

**TMINS Radiological Environmental Monitoring Program  
Summary of Sample Collection and Analysis Methods 1999**

<b>Analysis</b>	<b>Sample* Medium</b>	<b>Sampling Method</b>	<b>Approximate Sample Size Analyzed</b>	<b>Analysis Procedure Number</b>	<b>Procedure Abstract</b>
Gr-Alpha	AP	Continuous weekly air sampling through filter paper	1 filter (570 Cubic Meters)	TMI-EA 6510-IMP-4592.05	Low background gas flow proportional counting
			1 filter (570 Cubic Meters)	TBE-Westwood PRO-032-10	Same as above
Gr-Beta	AP	Continuous weekly air sampling through filter paper	1 filter (570 Cubic Meters)	TMI-EA 6510-IMP-4592.05	Low background gas flow proportional counting
			1 filter (570 Cubic Meters)	TBE-Westwood PRO-032-10	Same as above
	DW, EW	Monthly composite of either grabs or biweekly or weekly samples which are automatically composited on a timed frequency	500 mL	TMI-EA 6510-IMP-4592.01	Sample evaporated on stainless steel planchet for low background gas flow proportional counting
			1 liter	TBE-Westwood PRO-032-1	Same as above
Gamma Spectroscopy	AP	Quarterly composite of filter paper collected weekly	12 to 15 filters (6,900 - 9,300 Cubic Meters)	TMI-EA 6510-IMP-4592.05 6510-OPS-4591.04	Sample placed in counting container for gamma isotopic analysis
			12 to 15 filters (6,900 - 9,300 Cubic Meters)	TBE- Westwood PRO-042-5	Same as above
	AI	Continuous weekly air sampling through charcoal cartridges	1 cartridge (570 Cubic Meters)	TMI-EA 6510-OPS-4591.04	Sample counted for gamma isotopic analysis
			1 cartridge (570 Cubic Meters)	TBE- Westwood PRO-042-5	Same as above

**1999 RADIOLOGICAL ENVIRONMENTAL MONITORING REPORT**

**TABLE L**

**TMINS Radiological Environmental Monitoring Program  
Summary of Sample Collection and Analysis Methods 1999**

<b>Analysis</b>	<b>Sample* Medium</b>	<b>Sampling Method</b>	<b>Approximate Sample Size Analyzed</b>	<b>Analysis Procedure Number</b>	<b>Procedure Abstract</b>
Gamma Spectroscopy (Cont'd)	M	Biweekly grab sample of one or more milkings	3.5 liters	TMI-EA 6510-IMP-4592.06 6510-OPS-4591.04	Sample placed in counting container for gamma isotopic analysis
	SW, EW, DW	Monthly composite of either grabs or biweekly or weekly samples which are automatically composited on a timed frequency	1 liter	TBE-Westwood PRO-042-5	Same as above
	AQF	Composite sample of fillets semiannually by feeding types (bottom feeder and predator) collected by either electrofishing or hook and line	3.5 liters	TMI-EA 6510-IMP-4592.06 6510-OPS-4591.04	Sample placed in counting container for gamma isotopic analysis
		Same as above except annual frequency and for predators only	1 liter	TBE-Westwood PRO-042-5	Same as above
			1 kg (if possible)	TMI-EA 6510-IMP-4592.03 6510-OPS-4591.04	Edible portion homogenized and placed in counting container for gamma isotopic analysis
			1 kg (if possible)	TBE-Westwood PRO-042-5	Same as above

**1999 RADIOLOGICAL ENVIRONMENTAL MONITORING REPORT**

**TABLE L**

**TMINS Radiological Environmental Monitoring Program  
Summary of Sample Collection and Analysis Methods 1999**

<b>Analysis</b>	<b>Sample* Medium</b>	<b>Sampling Method</b>	<b>Approximate Sample Size Analyzed</b>	<b>Analysis Procedure Number</b>	<b>Procedure Abstract</b>
Gamma Spectroscopy (Cont'd)	GW	Quarterly or annual grab sample or annual composite of quarterly grab samples which are collected with a hand bailer, from a faucet or using a submersible pump	3.5 liters (if possible)	TMI-EA 6510-IMP-4592.06 6510-OPS-4591.04	Sample decanted and liquid portion placed in counting container for gamma isotopic analysis. Potable samples are mixed (not decanted) prior to analysis
	AQS	Semiannual composite of three or more grab samples collected with a dredge sampler	1 liter (if possible)	TBE-Westwood PRO-042-5	Same as above
	FP, GAD	Grab sample annually or more frequently	1 kg (if possible)	TMI-EA 6510-IMP-4592.04 6510-OPS-4591.04	Dried and sieved sample placed in counting container for gamma isotopic analysis
	FP, GAD	Grab sample annually or more frequently	1 kg (if possible)	TBE-Westwood PRO-042-5	Same as above
	ROD	Trapped or found dead	1 kg (if possible)  As received	TMI-EA 6510-IMP-4592.03 6510-OPS-4591.04	Edible portion homogenized and placed in counting container for gamma isotopic analysis. Only root vegetables and fruits washed prior to analysis
Tritium	SW, EW, DW	Monthly composite of either grabs or biweekly or weekly samples which are automatically composited on a timed frequency	7-10 mL	TMI-EA 6510-IMP-4592.02 6510-OPS-4591.05 6510-OPS-4591.08	Sample filtered, mixed with scintillation fluid for scintillation counting. Distillation may be performed if impurities are found to be present
			2 mL	TBE-Westwood PRO-052-35	Same as above

**1999 RADIOLOGICAL ENVIRONMENTAL MONITORING REPORT**

**TABLE L**

**TMINS Radiological Environmental Monitoring Program  
Summary of Sample Collection and Analysis Methods 1999**

<b>Analysis</b>	<b>Sample* Medium</b>	<b>Sampling Method</b>	<b>Approximate Sample Size Analyzed</b>	<b>Analysis Procedure Number</b>	<b>Procedure Abstract</b>
Tritium (Cont'd)	AQF	Composite sample of fillets semiannually by feeding types (bottom feeder and predator) collected by either electrofishing or hook and line	7-10 mL	TMI-EA 6510-IMP-4592.02 6510-IMP-4592.03 6510-OPS-4591.05 6510-OPS-4591.08	Edible portion is homogenized and freeze-dried in order to extract liquid for counting by liquid scintillation
		Same as above except annual frequency and for predators only	2 mL	TBE-Westwood PRO-052-2 PRO-052-57	Same as above
	GW	Quarterly or annual grab or more frequent sample according to sampling site using a hand bailer, a faucet or a submersible pump	7-10 mL  2 mL or 10 mL	TMI-EA 6510-IMP-4592.02 6510-IMP-4591.05 6510-IMP-4591.08  TBE-Westwood PRO-052-2 PRO-052-35	Same as Tritium in SW, EW, DW  Same as above

**1999 RADIOLOGICAL ENVIRONMENTAL MONITORING REPORT**

**TABLE L**

**TMINS Radiological Environmental Monitoring Program  
Summary of Sample Collection and Analysis Methods 1999**

Analysis	Sample* Medium	Sampling Method	Approximate Sample Size Analyzed	Analysis Procedure Number	Procedure Abstract
I-131	SW, EW, DW	Biweekly or weekly composite using an automatic compositor set for sampling on a preset timed frequency. One SW station is a biweekly or weekly composite of grab samples collected twice per week	3.5 liters  1 liter	TMI-EA 6510-IMP-4592.06  TBE-Westwood PRO-032-11	Sample is concentrated on anion exchange resin, the resin is analyzed by gamma spectroscopy  Anion-exchange, chemical reduction, $\text{CCl}_4$ extraction, palladium precipitation, low-level beta counting
	FP	Grab sample annually at harvest time for each vegetation type	1 kg (if possible)	TMI-EA 6510-IMP-4592.03 6510-OPS-4591.04  TBE-Westwood PRO-032-12	Edible portion homogenized and placed in counting container for gamma isotopic analysis  Carrier added, leached, evaporated and fused, residue dissolved, filtered and reduced with hydroxylamine hydrochloride, precipitated as palladium iodide for counting on low-level beta counter
	M	Biweekly grab sample of one or more milkings	3.5 liters  1 liter	TMI-EA 6510-IMP-4592.06 6510-OPS-4591.04  TBE-Westwood PRO-032-11	Same as I-131 in SW, EW, DW  Same as I-131 in SW, EW, DW

**1999 RADIOLOGICAL ENVIRONMENTAL MONITORING REPORT**

**TABLE L**

**TMINS Radiological Environmental Monitoring Program  
Summary of Sample Collection and Analysis Methods 1999**

<b>Analysis</b>	<b>Sample* Medium</b>	<b>Sampling Method</b>	<b>Approximate Sample Size Analyzed</b>	<b>Analysis Procedure Number</b>	<b>Procedure Abstract</b>
Sr-89, Sr-90	AP	Semiannual composite of filter paper collected weekly	26 weeks of filters per sampling site (14,800 Cubic Meters)	TMI-EA 6510-IMP-4592.12 6510-OPS-4591.01	Sample is leached and strontium in sample is separated through a series of precipitations and then purified using an extraction material in a chromatographic column. The total strontium is dried on a planchet and counted in a low background beta counter. After a period of time, the yttrium-90, which has ingrown from the Sr-90, is separated from the sample and counted to determine the Sr-90 activity. The total strontium minus the Sr-90 will determine Sr-89 activity.
	AQF	Composite sample of fillets semiannually by feeding types (bottom feeders and predators) collected by either electrofishing or hook and line  Same as above except annual frequency and for predators only	26 weeks of filters per sampling site (14,800 cubic meters)  250 g  200 g	TBE-Westwood PRO-032-24  TMI-EA 6510-IMP-4592.12 6510-OPS-4591.01  TBE-Westwood PRO-032-85	Sample is leached and strontium in sample is separated through a series of precipitations, Sr-90 inferred Y-90 on yttrium oxalate precipitate after 5 days or more ingrowth, low-level beta counting follows. After yttrium separation sample is precipitated with SrCO <sub>3</sub> mounted on nylon planchet for counting on low background beta counter for Sr-89 activity.  Similar to TMI-EA Sr-89, Sr-90 in AP except sample (edible portion) is dried and ashed prior to separation.  Similar to TBE-Westwood Sr-89, Sr-90 in AP except sample (edible portion) is dried and ashed prior to separation.

**1999 RADIOLOGICAL ENVIRONMENTAL MONITORING REPORT**

**TABLE L**

**TMINS Radiological Environmental Monitoring Program  
Summary of Sample Collection and Analysis Methods 1999**

<b>Analysis</b>	<b>Sample* Medium</b>	<b>Sampling Method</b>	<b>Approximate Sample Size Analyzed</b>	<b>Analysis Procedure Number</b>	<b>Procedure Abstract</b>
Sr-89, Sr-90 (Cont'd)	EW	Semiannual composite of biweekly or weekly samples which are automatically composited on a timed frequency	1 liter	TMI-EA 6510-IMP-4592.12 6510-OPS-4591.01	Similar to TMI-EA Sr-89, Sr-90 in AP.
	FP (Broad Leaf Veg. only)	Grab sample annually at harvest time	250g	TMI-EA 6510-IMP-4592.12 6510-OPS-4591.01	Similar to TMI-EA Sr-89, Sr-90 in AP except sample (edible portion) is dried and ashed prior to separation.
	GW	Annual composite of quarterly grab samples which are collected with a hand bailer , a submersible pump or by a faucet.	200 g	TBE-Westwood PRO-032-23	Similar to TBE-Westwood Sr-89, Sr-90 in AP except sample (edible portion) is dried and ashed prior to separation .
	M	Quarterly composite of biweekly grab samples	1 liter (if possible)	TMI-EA 6510-IMP-4592.12 6510-OPS-4591.01	Similar to TMI-EA Sr-89, Sr-90 but sample analyzed for Sr-90 only.
			1 liter	TBE-Westwood PRO-032-16	Similar to TBE-Westwood Sr-89, Sr-90 but sample analyzed for Sr-90 only.
			1 liter	TMI-EA 6510-IMP-4592.12 6510-OPS-4591.01	Similar to TMI-EA Sr-89, Sr-90 in AP except sample is dried and ashed prior to separation.
			1 liter	TBE-Westwood PRO-032-105	The method adds a stable strontium carrier, ashes the sample in a muffle furnace and precipitates the phosphates. Strontium then is purified using an extraction material in a chromatographic column. Sample mounting and counting are similar to TBE-Westwood Sr-89, Sr-90 in AP.

**1999 RADIOLOGICAL ENVIRONMENTAL MONITORING REPORT**

**TABLE L**

**TMINS Radiological Environmental Monitoring Program  
Summary of Sample Collection and Analysis Methods 1999**

<b>Analysis</b>	<b>Sample* Medium</b>	<b>Sampling Method</b>	<b>Approximate Sample Size Analyzed</b>	<b>Analysis Procedure Number</b>	<b>Procedure Abstract</b>
Gamma (Direct Radiation)	ID	Dosimeters exchanged quarterly	2 TLDs/8 Elements  1 TLD/4 Elements	TMI-Dosimetry 6610-OPS-4243.01  TBE-Westwood PRO-342-17	Thermoluminescent dosimetry using optical heating of crystals and PM tube for light measurement.  Same as above

\* **Identificaton Key** ..... **Approximate Sample Size Collected per Station \*\***

AI = Air Iodine	.....1 Cartridge (570 Cubic Meters) per week
AP = Air Particulate	.....1 Filter (570 Cubic Meters) per week
AQF = Finfish	.....1 kg semiannually
AQS = Aquatic Sediment	.....1 kg semiannually
DW = Drinking Water	.....4 liters biweekly or weekly
EW = Effluent Water	.....4 liters biweekly or weekly
FP = Food Products (Fruits & Vegetables)	.....1 kg annually
GAD = Game (Deer)	.....1 kg annually or more frequently (if possible)
GW = Ground Water	.....4 liters (if available) quarterly or annually. 250 mL as needed for tritium analysis only
ID = Immersion Dose (TLD)	.....4 TLDs/8 Elements quarterly
M = Milk	.....4 liters biweekly
ROD = Rodents	.....Whole carcass (when available).
SW = Surface Water	.....4 liters biweekly or weekly

\*\* Sample size is for the main laboratory samples. An additional sample of the same size (except for TLDs) is collected at those stations which also are analyzed for quality control (QC) purposes. The QC TLD stations only have one additional dosimeter (4 elements) for QC purposes.

## **APPENDIX M**

### **1999 TLD Quarterly Data**

**1999 RADIOLOGICAL ENVIRONMENTAL MONITORING REPORT**

**TABLE M-1**  
**1999 TLD Quarterly Data**  
**mR Per Std Month  $\pm 2\sigma$**

Station	Historical	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
A1-4	4.3 $\pm$ 0.3	3.9 $\pm$ 0.5	3.8 $\pm$ 0.4	4.1 $\pm$ 0.5	3.9 $\pm$ 0.4
A3-1	4.3 $\pm$ 1.6	3.9 $\pm$ 0.4	3.6 $\pm$ 0.1	4.0 $\pm$ 0.4	3.8 $\pm$ 0.4
A5-1	5.5 $\pm$ 0.9	5.5 $\pm$ 0.9	5.3 $\pm$ 0.3	5.6 $\pm$ 0.4	5.0 $\pm$ 0.5
A9-3	0.0 $\pm$ 0.0	4.2 $\pm$ 0.3	3.9 $\pm$ 0.4	4.3 $\pm$ 0.3	4.1 $\pm$ 0.6
B1-1	4.4 $\pm$ 1.4	4.0 $\pm$ 0.5	4.1 $\pm$ 0.3	4.2 $\pm$ 0.3	4.0 $\pm$ 0.3
B1-2	4.3 $\pm$ 0.7	4.0 $\pm$ 0.4	4.0 $\pm$ 0.3	4.2 $\pm$ 0.3	3.9 $\pm$ 0.5
B2-1	0.0 $\pm$ 0.0	4.0 $\pm$ 0.4	4.1 $\pm$ 0.4	4.3 $\pm$ 0.4	4.0 $\pm$ 0.9
B5-1	5.3 $\pm$ 1.0	5.0 $\pm$ 0.2	5.1 $\pm$ 0.4	5.4 $\pm$ 0.6	4.9 $\pm$ 0.5
B10-1	5.1 $\pm$ 0.8	4.6 $\pm$ 0.5	4.5 $\pm$ 0.4	5.0 $\pm$ 0.2	4.4 $\pm$ 0.5
C1-1	5.2 $\pm$ 0.9	4.6 $\pm$ 0.1	5.0 $\pm$ 0.4	5.0 $\pm$ 0.2	4.7 $\pm$ 0.5
C1-2	4.3 $\pm$ 0.9	4.0 $\pm$ 0.1	3.7 $\pm$ 0.3	4.3 $\pm$ 0.4	3.9 $\pm$ 0.6
C2-1	0.0 $\pm$ 0.0	4.6 $\pm$ 0.3	4.6 $\pm$ 0.6	4.8 $\pm$ 0.2	4.4 $\pm$ 0.4
C5-1	5.1 $\pm$ 0.9	4.9 $\pm$ 0.4	4.8 $\pm$ 0.4	5.4 $\pm$ 0.4	4.8 $\pm$ 0.8
C8-1	5.9 $\pm$ 0.9	5.1 $\pm$ 0.4	5.4 $\pm$ 0.6	5.5 $\pm$ 0.4	5.1 $\pm$ 0.3
D1-1	4.6 $\pm$ 0.8	4.2 $\pm$ 0.3	3.9 $\pm$ 0.4	4.3 $\pm$ 0.2	3.9 $\pm$ 0.5
D1-2	5.4 $\pm$ 2.1	4.5 $\pm$ 0.3	4.7 $\pm$ 0.4	5.2 $\pm$ 0.7	4.6 $\pm$ 0.5
D2-2	0.0 $\pm$ 0.0	5.6 $\pm$ 0.6	5.8 $\pm$ 1.0	6.1 $\pm$ 0.3	5.7 $\pm$ 0.4
D6-1	6.4 $\pm$ 1.3	5.7 $\pm$ 0.4	6.0 $\pm$ 1.0	6.4 $\pm$ 0.7	5.7 $\pm$ 1.0
D15-1	5.7 $\pm$ 1.3	4.9 $\pm$ 0.3	5.1 $\pm$ 0.6	5.3 $\pm$ 0.4	5.0 $\pm$ 0.4
E1-2	4.9 $\pm$ 1.7	4.3 $\pm$ 0.1	4.2 $\pm$ 0.6	4.6 $\pm$ 0.2	4.7 $\pm$ 0.4
E1-4	5.7 $\pm$ 1.3	4.0 $\pm$ 0.2	3.9 $\pm$ 0.4	4.0 $\pm$ 0.3	4.2 $\pm$ 0.6
E2-3	0.0 $\pm$ 0.0	5.2 $\pm$ 0.5	5.2 $\pm$ 0.4	5.7 $\pm$ 0.4	5.2 $\pm$ 0.5
E5-1	5.3 $\pm$ 0.8	5.0 $\pm$ 0.3	4.9 $\pm$ 0.3	5.1 $\pm$ 0.3	4.8 $\pm$ 0.4
E7-1	5.2 $\pm$ 1.0	4.9 $\pm$ 0.3	0.0 $\pm$ 0.0	5.3 $\pm$ 0.5	4.9 $\pm$ 0.5
F1-1	5.0 $\pm$ 1.1	4.6 $\pm$ 0.5	4.5 $\pm$ 0.4	4.8 $\pm$ 0.3	4.4 $\pm$ 0.3
F1-2	0.0 $\pm$ 0.0	4.8 $\pm$ 0.5	5.7 $\pm$ 0.4	5.5 $\pm$ 0.5	9.6 $\pm$ 1.1
F1-4	0.0 $\pm$ 0.0	4.4 $\pm$ 0.7	5.2 $\pm$ 0.7	5.0 $\pm$ 0.5	8.1 $\pm$ 1.0
F2-1	0.0 $\pm$ 0.0	5.3 $\pm$ 0.5	5.6 $\pm$ 0.8	5.7 $\pm$ 0.4	5.2 $\pm$ 0.4
F5-1	6.0 $\pm$ 1.1	5.4 $\pm$ 0.3	5.3 $\pm$ 0.5	5.9 $\pm$ 0.1	5.2 $\pm$ 0.4
F10-1	6.3 $\pm$ 1.1	6.0 $\pm$ 0.4	6.2 $\pm$ 0.7	6.3 $\pm$ 0.3	6.0 $\pm$ 0.7
F25-1	5.6 $\pm$ 1.0	4.9 $\pm$ 0.4	5.0 $\pm$ 0.5	5.4 $\pm$ 0.2	5.2 $\pm$ 0.4
G1-2	4.9 $\pm$ 1.0	4.9 $\pm$ 0.4	4.9 $\pm$ 0.5	5.3 $\pm$ 0.5	4.8 $\pm$ 0.4
G1-3	6.9 $\pm$ 3.6	4.1 $\pm$ 0.5	3.8 $\pm$ 0.2	4.2 $\pm$ 0.4	4.4 $\pm$ 0.6
G1-5	0.0 $\pm$ 0.0	4.0 $\pm$ 0.3	3.8 $\pm$ 0.3	4.0 $\pm$ 0.4	4.0 $\pm$ 0.6
G1-6	0.0 $\pm$ 0.0	5.4 $\pm$ 0.4	4.1 $\pm$ 0.4	4.5 $\pm$ 0.3	4.2 $\pm$ 0.6
G2-4	0.0 $\pm$ 0.0	5.7 $\pm$ 0.2	5.8 $\pm$ 0.6	6.2 $\pm$ 0.6	5.7 $\pm$ 0.5
G5-1	5.1 $\pm$ 2.0	4.5 $\pm$ 0.4	4.6 $\pm$ 0.6	4.7 $\pm$ 0.6	4.2 $\pm$ 0.7
G10-1	7.6 $\pm$ 1.6	7.0 $\pm$ 0.5	7.3 $\pm$ 0.5	7.3 $\pm$ 0.5	6.8 $\pm$ 1.0
G15-1	6.4 $\pm$ 2.3	5.0 $\pm$ 0.3	5.0 $\pm$ 0.4	5.4 $\pm$ 0.3	5.1 $\pm$ 0.6
H1-1	5.3 $\pm$ 2.0	4.5 $\pm$ 0.4	4.5 $\pm$ 0.5	4.8 $\pm$ 0.2	4.5 $\pm$ 0.5
H3-1	4.1 $\pm$ 1.1	3.7 $\pm$ 0.4	3.7 $\pm$ 0.4	3.8 $\pm$ 0.1	3.5 $\pm$ 0.5
H5-1	4.1 $\pm$ 0.9	3.7 $\pm$ 0.3	3.5 $\pm$ 0.2	4.0 $\pm$ 0.4	3.6 $\pm$ 0.4
H8-1	7.9 $\pm$ 1.4	7.4 $\pm$ 0.5	7.6 $\pm$ 0.5	7.9 $\pm$ 0.5	7.4 $\pm$ 0.4
H15-1	5.8 $\pm$ 1.1	5.7 $\pm$ 0.4	5.6 $\pm$ 0.4	6.0 $\pm$ 0.3	5.5 $\pm$ 0.7
J1-1	5.3 $\pm$ 1.4	3.9 $\pm$ 0.4	4.0 $\pm$ 0.2	4.3 $\pm$ 0.3	4.0 $\pm$ 0.3
J1-3	3.7 $\pm$ 0.4	3.4 $\pm$ 0.3	3.3 $\pm$ 0.3	3.5 $\pm$ 0.3	3.2 $\pm$ 0.3
J3-1	0.0 $\pm$ 0.0	4.5 $\pm$ 0.3	0.0 $\pm$ 0.0	4.4 $\pm$ 0.4	4.5 $\pm$ 0.3

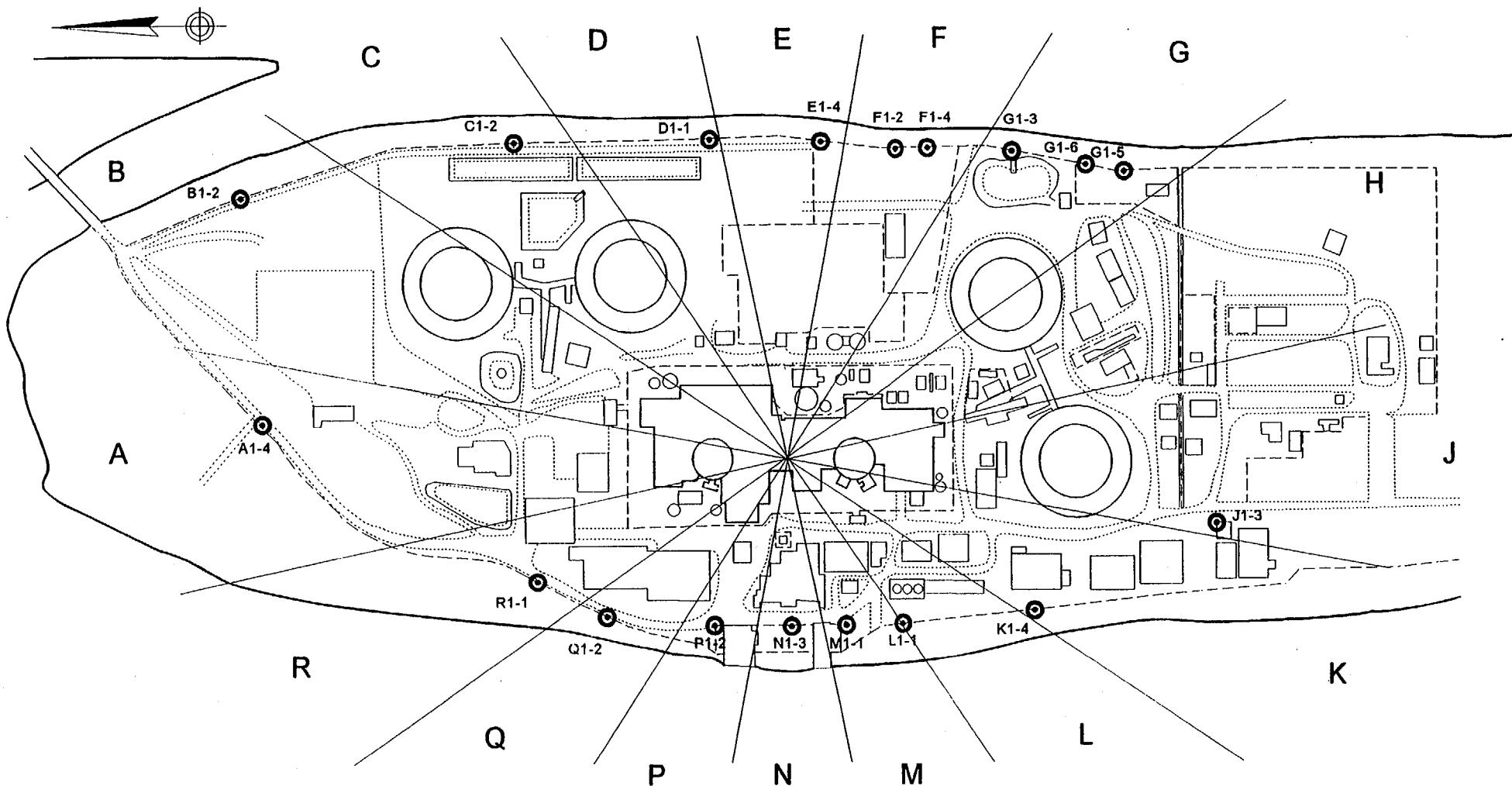
**1999 RADIOLOGICAL ENVIRONMENTAL MONITORING REPORT**

**TABLE M-1**  
**1999 TLD Quarterly Data**  
**mR Per Std Month  $\pm 2\sigma$**

Station	Historical	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
JS-1	5.7±1.3	5.4±0.6	5.5±0.5	5.6±0.2	5.4±0.7
J7-1	4.7±1.1	5.3±0.4	5.7±0.8	5.7±0.3	5.4±0.7
J15-1	6.1±1.7	5.5±0.3	5.4±0.4	5.9±0.3	5.3±0.4
K1-4	4.7±1.5	3.9±0.3	3.9±0.2	4.3±0.2	4.0±0.5
K2-1	5.8±1.2	0.0±0.0	5.2±0.4	5.7±0.7	5.3±0.5
K3-1	0.0±0.0	3.8±0.2	4.0±0.1	4.3±0.5	4.0±0.4
K5-1	6.9±1.2	5.2±0.3	5.4±0.4	5.6±0.4	5.4±0.8
K8-1	5.4±1.3	5.0±0.5	5.0±0.4	5.1±0.3	5.1±0.5
K15-1	4.8±1.3	4.7±0.4	4.6±0.4	4.8±0.2	0.0±0.0
L1-1	5.1±1.9	4.4±0.3	3.9±0.3	4.4±0.3	4.4±0.6
L1-2	4.3±1.1	0.0±0.0	4.2±0.2	4.3±0.1	4.2±0.5
L2-1	5.5±1.3	4.8±0.2	4.7±0.3	5.0±0.5	4.7±0.5
L5-1	4.5±1.0	4.4±0.2	4.3±0.4	4.7±0.4	4.0±0.4
L8-1	5.0±0.9	4.7±0.4	4.7±0.1	4.9±0.2	4.7±0.4
L15-1	5.2±1.4	4.9±0.4	4.9±0.4	5.1±0.2	4.7±0.5
M1-1	0.0±0.0	4.0±0.2	3.7±0.5	4.2±0.3	4.2±0.5
M1-2	0.0±0.0	0.0±0.0	4.2±0.3	4.6±0.3	4.3±0.6
M2-1	4.3±1.5	3.8±0.2	3.7±0.2	4.0±0.2	3.7±0.6
M5-1	5.2±1.1	4.4±0.5	4.5±0.4	4.6±0.3	4.4±0.7
M9-1	6.5±1.2	5.5±0.4	6.2±0.9	6.2±0.4	5.8±0.5
N1-1	4.8±1.4	0.0±0.0	4.4±0.7	4.5±0.3	4.4±0.2
N1-3	4.6±1.2	3.7±0.4	3.6±0.2	4.3±0.3	4.3±0.7
N2-1	5.3±1.0	4.1±0.3	4.0±0.4	4.2±0.3	3.9±0.4
N5-1	5.3±1.3	3.9±0.4	3.8±0.4	4.1±0.5	3.8±0.5
N8-1	5.4±1.2	5.1±0.5	5.0±0.4	5.3±0.3	5.0±0.6
N15-2	5.9±0.9	5.6±0.5	5.6±0.4	5.9±0.3	5.5±0.3
P1-1	4.7±1.3	0.0±0.0	4.3±0.4	4.6±0.3	4.3±0.5
P1-2	0.0±0.0	3.8±0.2	3.9±0.6	5.0±0.5	4.5±0.4
P2-1	5.4±1.2	5.1±0.4	5.5±0.3	5.7±0.4	5.2±0.5
P5-1	4.8±1.0	4.5±0.4	4.9±0.4	4.9±0.3	4.4±0.6
P8-1	4.7±1.0	4.0±0.2	3.9±0.4	0.0±0.0	3.9±0.3
Q1-1	4.6±1.0	0.0±0.0	4.3±0.3	4.8±1.0	4.3±0.4
Q1-2	4.4±0.8	3.6±0.5	3.4±0.3	4.0±0.2	3.7±0.3
Q2-1	5.4±1.1	4.4±0.4	4.3±0.4	4.7±0.3	4.1±0.4
Q5-1	4.9±1.2	4.4±0.3	4.2±0.5	4.7±0.3	4.3±0.2
Q9-1	5.3±1.2	4.6±0.4	4.5±0.5	4.8±0.3	4.3±0.6
Q15-1	5.9±1.1	5.1±0.6	5.4±0.3	5.6±0.4	5.2±0.6
R1-1	4.8±1.2	3.9±0.3	3.9±0.4	4.4±0.5	4.0±0.3
R1-2	4.2±1.2	0.0±0.0	3.9±0.3	4.2±0.2	3.9±0.5
R3-1	0.0±0.0	5.3±0.5	5.5±0.3	5.9±0.4	5.5±0.3
R5-1	5.1±0.9	4.8±0.3	5.1±0.6	5.3±0.4	4.7±0.3
R9-1	5.2±0.9	0.0±0.0	5.3±0.4	5.5±0.5	5.3±0.5
R15-1	4.4±1.0	4.2±0.2	4.4±0.3	4.6±0.2	4.5±0.6

NOTES: 1) A Value of Zero Indicates No Data  
 2) Some Newer Stations Have No Historical Data

**Figure M-1**  
**Onsite TLD Station Locations at TMINS**



Stations H1-1 and J1-1 are located off the map to the south.

*NO SCALE*

TMI-EA (3/95)