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Investigations of Reported Plant and Animal Health Effects in the Three Mile Island Area

U.S. Nuclear Regulatory Commission

U.S. Environmental Protection Agency

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ABSTRACT

The results of investigations into reported problems with plants and animals which may be related to the operation of and accident at the Three Mile Island Nuclear Power Station are presented. The kinds of problems reported are listed, and potential areas of concern (such as the release of radioactive gases and drift from cooling tower plumes) are discussed. Specific case histories are examined, and probable causes attributed. While in some instances not enough data were available for a detailed evaluation to be made, none of the reported problems could be linked to TMI and no general pattern of effects could be seen.

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FOREWORD

Overall responsibility for this report was assigned to Gerald Gears and Dr. Germain LaRoche of the staff of the Nuclear Regulatory Commission (NRC). In conducting the investigations for this report, they began by coordinating their activities with those of the Pennsylvania Department of Agriculture (PDA). Mr. Robert Furrer and Dr. John Cable of the PDA participated in the interview of owners of animals which reportedly had or were having health problems related to TMI. In those few cases where individuals were not interviewed, an attempt was made to inform those individuals of the interest in these problems and to suggest that they contact the authors to arrange an interview. Because only those individuals who reported problems were contacted, this report should in no way be thought of as an epidemiological study showing the incidence and distribution of animal health problems in the TMI area..

After the NRC staff completed the initial interviews and gathering of data, the data were presented to Dr. Bernard Jaroslow, a radiobiologist with Argonne National Laboratory, for analysis and findings concerning possible radiological and pathological causes of these problems. Dr. Jaroslow brought in two persons to aid in his analyses: Dr. Donald Smith, a veterinarian with the U.S. Environmental Protection Agency, Environmental Monitoring Systems Laboratory, Las Vegas, and Dr. John Cable (mentioned above), a veterinarian with the PDA, both of whom have expertise in radiation biology. In addition to reviewing the data supplied to it by the NRC, this team independently interviewed farmers in the TMI region and gave the NRC a report of its findings on the possible relationships between local animal health and the operation of TMI. The team's findings have been incorporated in this report. The conclusions concerning the effects of releases of radioactive materials in gaseous effluents from TMI, as well as postulated causes of livestock problems, are based on these findings.

EXECUTIVE SUMMARY

In the months following the March 1979 accident at the Three Mile Island Nuclear Power Station many questions have been asked and many concerns voiced: did the accident--or even the normal operation of the plant--have any effect on animal and plant life in the vicinity of the plant?

These questions and concerns certainly are understandable. In attempting to provide full and adequate answers, the authors of this paper made every effort to look into reports of unusual problems experienced with animals and plants in the area surrounding TMI. Unfortunately, there were cases that could not be investigated in depth because not enough data were available. In some instances, for example, the bodies of animals which had been deformed or which died under unusual circumstances had been destroyed before any studies could be performed. As a result, the findings are not as detailed as the staff would prefer. Nonetheless, concerned citizens may be assured that in keeping with its mission to safeguard the public health and safety, the staff of the Nuclear Regulatory Commission (NRC) will continue to investigate reports of unusual problems experienced with plants and animals, and any pertinent findings will be made available.

In the report that follows, the authors have addressed the questions raised by the public. Some of these questions, and the authors' responses, are:

1. Did any sickness and disease seen in livestock, pets, and wild animals result from radiation that they received either during operation of the reactors or from the accident at Unit 2?

No reasonable connection could be made between the operation of TMI and the health problems of livestock and pets that were brought to the attention of the staff of the Nuclear Regulatory Commission. The same holds true for the aftermath of the accident. The level of radiation exposure as calculated for the worst case (at Middletown, 100 mrem) was less than 1/1000th of that which might have caused clinically detectable effects in the animal population that was exposed to radiation. Furthermore, there was no apparent relationship between the reported problems and the predominant wind patterns during the accident.

2. If the reported levels of radiation were wrong, couldn't the animals actually have received enough radiation to make them sick?

If the level of radiation exposure after the accident was much greater than reported, say by a thousandfold, complaints about animal health problems would have been different from those made. There would have been many anemic animals, spread throughout the TMI area, and, more frequently, in the path of the radioactive plume (which tended to be north-northwest, east-northeast, and south-southeast of the plant site); this was not the case.

3. Did the salt drift from the cooling towers make the minerals in the soil unavailable to the livestock, thereby producing a mineral deficiency?

The deposition of neutral salts from the drift--primarily sulfates, carbonates, and chlorides--adds only a small increment of salt to what is naturally present in the soil. It would not have acidified the soil or caused the "binding" of selenium to the soil (which could have intensified the problem of dietary insufficiency of selenium); moreover, it would not measurably affect the chemistry of selenium in the soil.

4. If radiation and salt drift were not the cause of the reported sicknesses, what was the cause?

The most likely causes of the reported animal husbandry problems are nutritional deficiencies and infectious diseases, as indicated by disease symptoms as well as by the improved health of livestock that were given feed supplements.

5. Although the radiation dose was small, couldn't it have been enough to cause cancer or mutations?

Some experts believe that any dose of ionizing radiation can potentially cause cancer or mutations, although the possibility of it occurring might be "one in a million." None of the animals brought to the attention of the Pennsylvania Department of Agriculture in connection with TMI were diagnosed as having cancer. The deformed animals that owners called mutants were most likely the victims of infectious disease suffered in the womb.

INVESTIGATIONS OF REPORTED PLANT AND ANIMAL HEALTH EFFECTS IN THE THREE MILE ISLAND AREA

1.0 INTRODUCTION

The Three Mile Island Nuclear Power Plant (known as TMI) is situated in a part of central Pennsylvania that contains productive farmland, as well as several small and medium-sized cities. The TMI region has rich, fertile valleys and rolling hills; agriculture contributes in a major way to the area's economic well-being. As an indication of the importance of farming in this area, it might be noted that in 1974 Lancaster County ranked 18th among all U.S. counties in value of agricultural products sold (Ref. 1). Dairy- and beef-cattle operations are the most common farming enterprises in the area. Dairy-herd size averages about 75 cows per operation, while beef herds are generally smaller, with herds averaging 10 to 20 animals per farm. In the four-county (York, Lebanon, Dauphin, and Lancaster) area surrounding TMI, the number of large domestic farm animals exceeds three-quarters of a million.

After the TMI accident on March 28, 1979, the Pennsylvania Department of Agriculture (PDA) conducted a number of surveys to determine whether there were any unusual agricultural problems which could be related to TMI. The PDA Bureau of Animal Industry inspected farms in the vicinity of TMI, most of them within 5 miles of the site. Bureau officials found that of 96 farms containing between 9,000 to 10,000 head of livestock (horses, cattle, swine, sheep, and goats), only 11 farms reported problems (Ref. 2). An individual residing in the area told of some additional cases, and the Bureau of Animal Industry received a number of complaints from a variety of other sources. The PDA has investigated these problems and, to date, has found no evidence to connect them with TMI. A veterinarian with a long-established practice in the agricultural areas immediately west of TMI testified before the Pennsylvania Public Utilities Commission (PAPUC) (Ref. 3). His testimony outlined abnormal increases in reproductive, bone, and muscle problems among farm animals. Accounts of these animal health problems, as well as of other terrestrial (land-related) problems, have appeared in newspapers (including The Paxton Herald, February 27, 1980; The New York Times, March 27, 1980; and The Baltimore News-American, July 20, 1980). During NRC public meetings at Middletown and Baltimore regarding cleanup of TMI, comments were made about unusual animal health problems in the TMI area. The following report is in response to public concern in this regard, not only in connection with the accident at TMI, but also with the normal operation of the plant. (A similar report on aquatic impacts from the TMI accident was published in November 1979 (Ref. 4).)

2.0 PROBLEMS REPORTED

Sources of information for this document include reports issued by the Commonwealth of Pennsylvania, interviews with the professional staff from the Pennsylvania Department of Agriculture, discussions with experts from state and private universities, testimony given before the Pennsylvania Public Utility Commission concerning animal health effects, and field interviews with

people who have expressed their concern about possible links between TMI and animal health problems. In addition, more than 100 practicing veterinarians were contacted by letter, asking them for any information concerning animal health problems possibly related to TMI.

A major difficulty encountered in this study was a determination of what constituted unusual animal health problems. There is a lack of background information on the incidence of a large number of animal diseases and other animal health problems. The incidence of dangerous transmissible diseases (such as tuberculosis, rabies, and hog cholera) that can devastate the livestock industry or cause serious human health problems is well known; large sums of money are spent annually to identify and eradicate these diseases. However, other animal diseases and health problems have not generated sufficient concern within the livestock industry to warrant the cost of an indepth animal morbidity and mortality data collection and evaluation program. Information on the incidence of these diseases and health problems is usually available only from the memories of local veterinarians and farmers. Except for those animal diseases that have been designated dangerous transmissible diseases, no long-term documented information is available on animal health problems. Therefore, the use of the terms "unusual" or "abnormal" to describe animal health problems in this report cannot be supported by long-term documented data, but rather reflects the opinions of those interviewed.

All the events described in this report occurred within 20 miles of TMI; most occurred within 5 miles (Figure 2.1). The farms reporting these problems were located in 11 communities in 4 counties, but they were not evenly distributed in the area covered in this report (Table 2.1). Most occurred in York County, generally west of TMI. The number of farms reporting animal health problems, by year, is given in Table 2.2

Table 2.1 Location and number of farms reporting domestic animal problems within a 20-mile radius of TMI

County	Community	Number of farms reporting domestic animal problems
York	Goldsboro (Etters)	11
	York Haven	2
	Manchester	2
	Mount Wolf	1
	Lewisberry	1
	Newberry	1
Lancaster	Marietta	2
	Bainbridge (Conoy)	2
	Elizabethtown	1
Dauphin	Middletown	6
Lebanon	Annville	1
	Total	30

Table 2.2 Number of farms reporting unusual problems with domestic animals, by year

Year	Reports
1977	5
1978	17
1979 pre-accident	14
1979 post-accident	22
1980	1

As a result of the staff investigation, a listing of domestic animal health problems claimed to be related to TMI was compiled. This listing for large domestic animals is shown in Table 2.3 and for small domestic animals in Table 2.4. After an initial review of the reported events, the various domestic animal problems were classified in three broad categories, as outlined in Table 2.5. In addition, other terrestrial problems were reported in the TMI area. These are shown in Table 2.6. A discussion of all of these events is provided in Section 4.

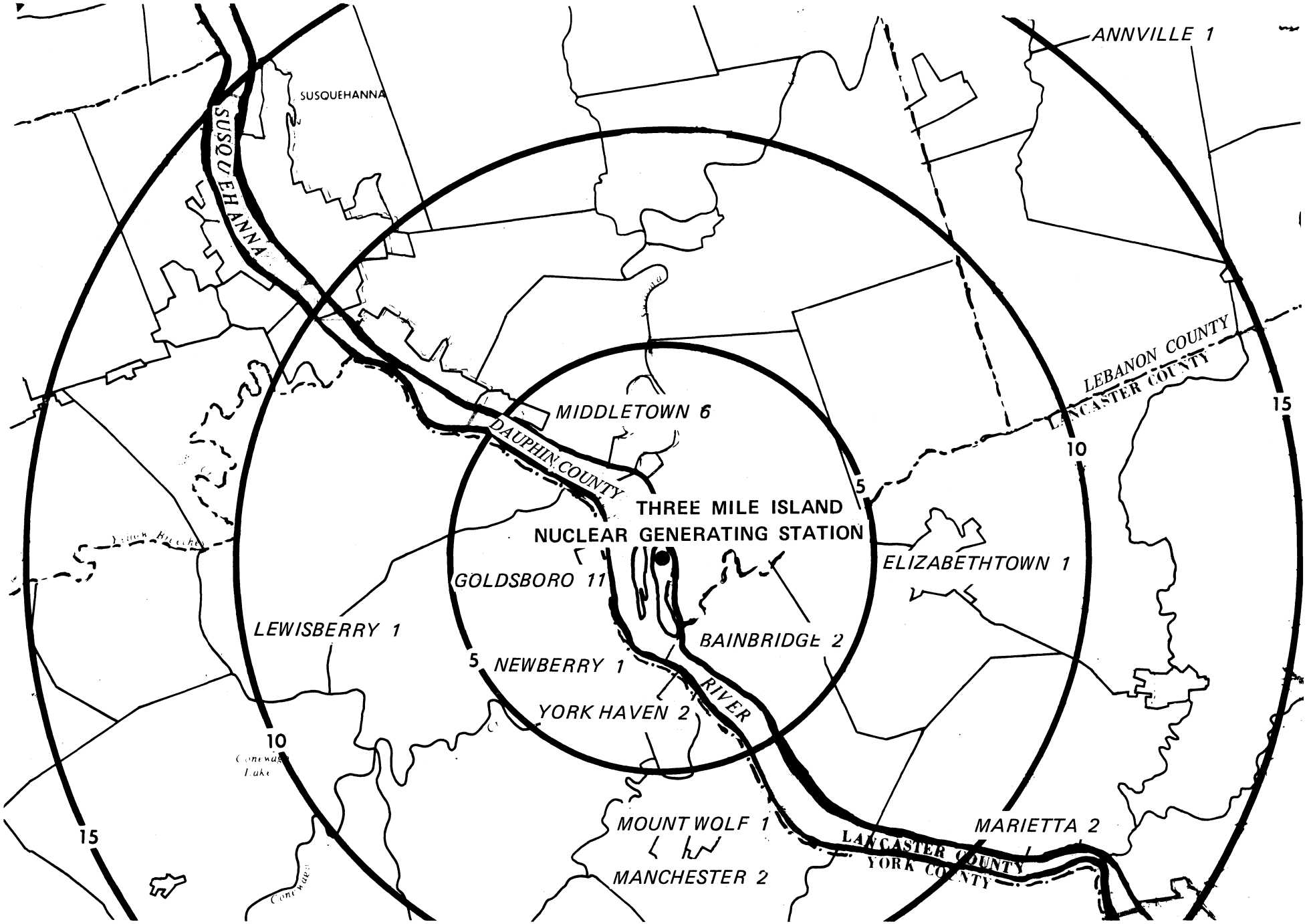

Figure 2.1 Geographic distribution of farms reporting animal health problems within 20 miles of Three Mile Island.

Table 2.3 Health problems of large domestic animals claimed to be related to TMI--location, number, time, and type

Town	Farms* Reporting Problems	Farms Reporting Problems Each Year** 77	78	79 pre-accident	79 post-accident	Milk Cattle	Beef Cattle	Horses	Sheep	Goats	Pigs
Etters (Goldsboro)	10	3				2 calves died, 4 aborted. Stillbirth, cancer reported	Steer broke hip. Calf died.	2 foals died, 2 ok. 7 rebred: 1 delivered, 6 did not.		1 aborted.	
		9				1 calf died. 2 calves died.	2 steers died. 1 steer down, 1 steer ok.	3 aborted. 1 foal stillborn.		1 aborted. Same goat delivered twins 6 months later.	Slow to develop. Breeding problem reported.
							2 steers blind; 1 of these cracked pelvis and died; the other was sent to New Bolton.		Breeding problem reported.		
						1 cow, 1 calf died.	2 steers blind, had soft bones. 1 steer lost control of hindquarters.				
				4		Reproduction problems, weakened livestock, nervous disorders reported.	Steers lost control of hindquarters. 1 broke hips, 1 lost control of hindquarters.	1 foal stillborn. 1 remained in heat longer than usual. 1 had abnormal milk gland. Colt had leg bowed.			
					4	1 cow could not breed. 1 cow aborted. 3 cysts, 2 stillbirths, 1 premature birth, respiratory problems reported.	1 steer lost control of hindquarters.			Hair fell off, raw sores developed. 1 kid stillborn. 1 aborted twins. 2 died when pregnant.	
Mount Wolf	1	1	1	1		Breeding problems reported.					
York Haven	2			2			6 calves died, 1 dwarf born.			Sore feet reported.	
Newberry	1				1						11 died.
Manchester	2				2				2 ewes, 4 newborn lambs died. 3 ewes died.		
Middletown	5	1								No kids produced.	
		1							Lamb born with 1 eye.	14 kids born. Some nannies stopped giving milk 6 months after giving birth.	
		1				4 heifers unable to conceive.					
				1			2 steers died.				
					4	Slight increase in mastitis.	2 steers died.			Kids healthy, except 1 had breathing difficulty. 2 nannies sick.	Breeding problems reported. 1 died.
Marietta	2	2				1 cow died. 4 aborted. 1 had tumor in uterus 2 cows, 3 calves died.					
Bainbridge	2				2	7 cows, 12 calves died.					Stillbirths, breeding problems reported.
Elizabethtown	1	1						4 had stiff joints.			

*This number represents the total number of different farms reporting reporting problems during this period; some farms reported problems in more than 1 year; some of these farms also are among those reporting problems with small animals (Table 2.4).
**The staff has no reports of TMI-related problems before 1977; the figures for 1979 post-accident include 1 report from early 1980.

Table 2.4 Health problems of small domestic animals claimed to be related to TMI--location, number, time, and type

Town	Farms* Reporting Problems	Farms Reporting Problems Each Year** 77 78	79 pre-accident	79 post-accident	Rabbits	Cats	Dogs	Chicken, Geese, and Ducks	Guinea Pigs
Etters (Goldsboro)	6	4			Died.	10 kittens died. 1 cat died.		Low reproduction rate, mutation in ducks reported. No reproduction in ducks reported.	
			2			4 sick and dying. 1 died, 2 ok.			
				4	1 died. 26 died.	Breeding problems reported. 1 kitten died, 2 ok. 5 kittens died. 2 kittens had muscle problem. 3 kittens died. 2 litters died.		Mutations reported. Ducks had digestive problems.	19 died.
Lewisberry	1	1				3 bred with no results. 1 litter died. Mutation, casper.			
Middletown	3	1				Litter died.		No reproduction in geese reported.	
		2			2 aborted. False pregnancies reported. 1 litter died.	4 litters aborted. 1 litter stillborn.		Goose eggs did not hatch; geese stopped setting.	
				2		2 litters died, 1 cat miscarried. 8 cats, litter of kittens died.	1 had cancerous lymph node. 1 born without eye socket. Poodles bled excessively when in heat.	6 geese died.	
Annville	1			1		3 developed leukemia (viral form).	9 puppies died.		

*This number represents the total number of different farms reporting problems during this period; some farms reported problems in more than 1 year; some of these farms also are among those reporting problems with large animals (Table 2.3).
**The staff has no reports of TMI-related problems before 1977; the figures for 1979 post-accident include 1 report from early 1980.

Table 2.5 Classifications of animal health problems claimed to be related to TMI.

Problem	Milk Cattle	Beef Cattle	Horses	Sheep	Goats	Pigs	Native & Domestic Birds	Ducks	Rabbits	Cats	Dogs	Guinea Pigs
Reproductive problems												
Prolonged heat cycle or no heat periods	X	X	X	X	X	X	X	X		X		
Reproductive rate very low	X		X		X	X	X	X	X	X		
Sterility	X	X	X	X	X	X	X	X		X		
Abortions	X	X	X	X	X	X			X	X		
Stillbirths	X	X	X	X	X	X				X		
Lack of dilation--Caesarean needed				X	X	X						
Mutations				X				X	X		X	
Premature birth	X				X							
Milk glands did not function properly (stopped giving milk)			X		X							
Bone and muscle problems												
Multiple fractures (broken bones)	X	X										
Muscle disorders	X	X			X	X				X		
Enlarged joints--arthritis	X		X									
Soft bones (bow legs)		X	X									
Miscellaneous												
Blindness	X	X										
Hair fell out--raw sores												
Mastitis	X											
Cancer--tumor	X											
Death from unknown causes	X	X		X	X	X			X	X		X

Table 2.6 Additional terrestrial problems reported in the TMI area

Reported effects on wildlife
Fewer starlings and robins were seen during the spring and summer of 1979.
Small game animals (e.g., squirrels, rabbits, and pheasants) were fewer in number.
No "hop toads" were seen in the last 2 years.
Reported effects on vegetation
Individual trees of many species had dead branches and/or leaves.
Two pears trees produced less fruit than they did in previous years, and one of these trees is dying.
Plants beneath a cemetery wire fence are dead.
Plants around a watering trough were dead.
Report of a "glowing fish"
Reports of a "white powder"

3.0 AREAS OF POTENTIAL IMPACT

Three potential impacts on livestock derive from TMI: one is from radioactive gaseous releases from the plant during normal operation (see Section 3.2.1), the second is from radioactive gases released during and after the accident at TMI-2 from March 28, 1979 to April 7, 1979 (see Section 3.2.2), and the third is from fallout of chemical salts in the drift from cooling tower plumes during operation (see Section 3.3). Each of these hazards will be discussed in detail in this section.

It should be noted that many of the reported concerns about effects on animals or vegetation were related to events that occurred before the accident at TMI. Several of the farmers who were interviewed specifically blamed the plume from the cooling towers as contributing to their problems.

To prepare the reader for the discussion of the three potential areas of impacts on livestock, a short explanation of the biological effects of radiation is provided below.

3.1 General Biological Effects of Radiation

3.1.1 Description of Radiation Dose Rates

In the discussion of radiation exposure from the TMI reactor, it might help the reader to recall what doses of radiation are received each year from natural sources. (These doses are called "background radiation.") In the Harrisburg, Pennsylvania area, a short distance from TMI, the natural or background radiation is about 120 millirems per year (mrem/yr); it varies throughout the United States from 70 to 310 mrem/yr (Ref. 5).

To evaluate the potential hazards posed by the radioactivity released during operation and during the 10 days following the accident, it is necessary to consider the amount of radiation that might be received by an animal (dose) during these periods and then to estimate the degree of injury, if any, that might be expected from that dose. The injury that an animal might receive from a given dose is estimated on the basis of carefully controlled laboratory experiments, by scientists throughout the world, in which animals were given predetermined doses of radiation and their injuries then studied.

Dose is a measure of the amount of energy deposited in tissue as radiation passes through it. A radiation dose of 1 rad is equivalent to the deposition of 100 ergs of energy per gram of tissue. A millirad (mrad) is 1/1000th of a rad. Certain types of radiation have either a greater or lesser biological effect for the same dose. For example, the destructive effect to biological tissue from high energy protons can be about 10 times greater than from gamma or beta radiation for the same dose. The concept of "dose equivalent," measured in rems, was created so that doses from different types of radiation could be measured in a universal unit.

The "dose equivalent" is calculated by multiplying the dose times a "quality factor" which is a measure of the relative biological destructiveness of the radiation. The quality factor for gamma and beta radiation is about 1, and for high energy protons is about 10. For example, the cumulative dose equivalent from a dose of 1 rad of gamma radiation and 1 rad of high energy proton radiation would be 11 rem. Since practically all the radiation dose from TMI was due to gamma and beta radiation, both of which have a quality factor of 1, the concepts of dose and dose equivalent are used interchangeably; hence, 1 rad = 1 rem.

3.1.2 Kinds of Radiation

In order to understand the effects of ionizing radiation, it is necessary first to know some of the properties of the different kinds of radiation. For instance, X-rays and gamma rays have much greater penetrating powers than beta or alpha particles. At the high energy level of gamma rays, 70 percent of the radiation passes through a person's body (a 20-centimeter thickness of biological tissue), while 30 percent of the energy will be absorbed and cause injury to the tissue. Beta radiation is almost completely absorbed within a few millimeters to a centimeter of tissue thickness, and alpha radiation can be almost completely absorbed by a thickness of tissue equal to a few sheets of paper. Special radiation-measurement devices, called dosimeters, are used to estimate the dose of each type of radiation.

3.1.3 Kinds of Radiation Effects

Ionizing radiation can damage living cells. While much of the injury can be repaired by the cells themselves, when the radiation dose is large, many cells may be killed. If enough cells in an important tissue or organ are killed, serious damage can result. For example, if enough bone marrow cells are damaged, the animal can become anemic and die. If the dose is less, fewer cells are killed, and the animal may be able to repopulate the blood with red and white cells after a period of anemia. Doses resulting from TMI were not high enough to cause these levels of injury.

At very low doses, few bone marrow cells die, but some may be changed in ways which are not fully understood after they repair the initial radiation damage. Many years later, these cells may change into leukemia cells, and the animal may develop a cancer called leukemia. A similar sequence of events takes place in other tissues and organs, but in vertebrates, bone marrow stem cells are among those most sensitive to external radiation. Because these changes do not involve reproductive cells, this type of injury is not transmitted genetically to further generations.

When the cells affected are reproductive cells (eggs or sperm or their predecessor stem cells), events occur which are somewhat similar to those experienced by bone marrow cells. If the reproductive cells are killed or severely injured with a large dose of radiation, the animal may become sterile or at least less fertile. If the genetic material in a reproductive cell is damaged, the cell will contain an altered genetic structure (mutation), which may or may not result in an effect in a future generation.

If the altered reproductive cell unites with an unaltered counterpart reproductive cell, the offspring will carry the mutation. The fact that the offspring carries a mutation does not necessarily mean that the animal will exhibit a characteristic different from its parents. That is, the characteristic may not be expressed in any observable fashion. Most mutations which occur are not expressed (they are so-called "recessive").

Because animal species have developed over long periods, most species populations have a genetic system which can tolerate some mutation; therefore, most mutations which occur--while they may be harmful to the individual animal or to its offspring--may not be harmful to the species population. Hence, in certain cases, a mutation may be beneficial, or at least neutral, and ultimately become fixed in the population. For example, a mutation which results in a change in eye color and improved vision would be beneficial. If vision were impaired, the chance for survival would be decreased. If the change in eye color did not improve or impair vision, it would be a matter of chance whether or not the change would become fixed in the population.

Sickness or injury that is observed within a few months after exposure to radiation is classified as acute radiation syndrome. There is generally a large variation in sensitivity to radiation injury within a population of a single species because of age variation, as well as health and environmental variations. This makes it difficult to assign an exact dose range that will cause a specific radiation syndrome. In humans, 50 rems (50,000 mrem) or less of whole body

radiation generally produces no obvious signs of injury. At 100 rems (100,000 mrem), a small percentage of people will show mild blood changes; at 200 rems (200,000 mrem), most people will show signs of blood changes, and the most sensitive will die. At 600 rems (600,000 mrem) or more, almost all exposed persons will die, unless they have intensive medical assistance.

The observable characteristics of acute radiation syndrome are about the same for most mammals, but the dose required to produce each set of symptoms varies. While doses resulting from the TMI accident were very small in comparison to the levels needed for these characteristics to appear, it is interesting to compare the relative senstivity of various species. The relative radiation sensitivity of common animals and birds can be broken down into four major groups (Ref. 6):

(1) most sensitive: goats, swine, dogs, cats, man, and burros
(2) less sensitive: guinea pigs, cows, and horses
(3) still less sensitive: rabbits, rats, and mice
(4) least sensitive: birds

For low radiation doses, some cells exposed to radiation may suffer subtle disabilities that, in a long-lived animal, may not be expressed for many years. For reasons not clearly understood, some intracellular event triggers a change in these cells, and the damage becomes apparent as, for example, a cancer. Such a change is classified as a "latent effect."

Radiation injury to embryos and fetuses may appear as birth defects, but, as mentioned above, unless the reproductive cells are affected, these defects are not passed on to successive generations. The type of defect that is observed depends upon the stage of development during irradiation. Generally the earlier the developmental stage, the more sensitive the developing organism is to radiation. For example, effects such as spontaneous abortions, stillbirths, or developmental abnormalities can occur in some animals exposed to doses of radiation in the womb on the order of 5 rems (5000 mrem) or more (Refs. 7, 7a).

The symptoms and diseases that are associated with radiation effects can also be caused by a variety of chemicals, trauma, and infectious organisms. However, no single agent causes the same spectrum of abnormalities as ionizing radiation.

In regard to injury to vegetation, lethal radiation doses for plants are usually hundreds of times larger than those for mammals. An experiment at the Brookhaven National Laboratory on Long Island (Ref. 8) has shown that oak leaves become misshapen only after exposure to 7 rems (7000 mrem) per day over several weeks during the time the leaves are developing. It took some 6 months exposure at 60 rems (60,000 mrem) per day to kill the oak trees in the Long Island experiment.

Those interested in a short, nontechnical explanation of the biological effects of radiation are referred to an article by M. H. Barnett, "The Biological Effects of Ionizing Radiation: An Overview." It may be obtained from the U.S. Department of Health and Human Services, Food and Drug Administration, Bureau of Radiological Health, Rockville, MD 20857.

3.2 Effects of the Release of Radioactive Gases from TMI

3.2.1 Release of Radioactive Gases During Normal Operation

All nuclear power plants produce low levels of radioactive gases during normal operation which must be released. The calculated releases of radioactive materials in gaseous effluents from TMI Unit 2 during normal operation are shown in Table 3.1. The calculated dose to a "maximum exposed individual" at the site boundary would not exceed 6.0 mrem/yr from radioiodine and particulates (including radioactive carbon ^{14}C and tritium ^{3}H) (Ref. 9, Table 5.10). A "maximum exposed individual" is defined as one who is in residence at the site boundary 24 hours a day without shelter or clothing.

Table 3.1 Calculated releases of radioactive materials in gaseous effluents from TMI-2 during normal operation

Material	Release (in Curies/yr/unit)
Krypton	397
Xenon	6322
Tritium	560
Argon	25
Carbon	8
Iodine	0.02
Cobalt, Iron, Manganese, Cesium, and Stronium	0.002

Source: U.S. Nuclear Regulatory Commission, "Final Environmental Statement, Operation of the Three Mile Island Nuclear Station, Unit 2," NUREG-0112, 1976.

Given the emissions shown above, an animal living at the site boundary without shelter would have received, at maximum, a dose calculated to be less than 20 mrem/yr during operation of both TMI-1 and TMI-2 (Ref. 9. p. 5-16).

These figures are for the site boundary. The dose would be greatly decreased with distance and with intermittent exposure. For example, animals living at Goldsboro would have received less than 0.8 mrem/yr when both reactors were in operation (Ref. 10). The reported cases of animal sickness were in areas 1.5 to 20 miles from the site; consequently, their exposures would have been far less than the maximum of 20 mrem/yr indicated above. Many of the cases were from farms in the vicinity of Goldsboro; these animals would have received less than 0.8 mrem/yr, a very small fraction of natural background radiation. In fact, the year-to-year variation in natural background radiation can be 10 or more mrem/yr. In view of these facts, the 0.8 mrem resulting from the operation of TMI could not have caused the sicknesses that are described in Section 7 and Tables 2.4, 2.5, and 2.6.

The monitoring records of radioactive releases during normal operation, sent by the Metropolitan Edison Co. (operator of TMI) to the NRC Office of Inspection and Enforcement, Region I, show two instances when radioactive emissions exceeded the control station values.* These emissions were about 1/1000th of the maximum permissible concentration limit stated in Title 10 of the Code of Federal Regulations, Part 20, for members of the public, and none of the TMI-1 Technical Specification limits were exceeded (according to letters from W. M. Creitz, President of Met-Ed, to J. P. O'Reilly, NRC Office of Inspection and Enforcement, Region I, October 24, 1975 and January 2, 1976). In all respects, emissions were in accord with design objectives. The radiation release data, therefore, suggest that the operational emissions were at levels well below that which could have caused the reported animal sickness.

3.2.2 Release of Radioactive Gases During the Period of the TMI Accident and Possible Consequences

During the period of the accident at TMI (March 28 to April 7, 1979), the principal radioactive materials released were Xenon-133 and Xenon-135, plus traces of Iodine-131. Some short-lived Krypton isotopes may have been released in small amounts (Ref. 5).

The exposure of animals to radiation from the accident at TMI-2 was: 10-25 mrem in the Etters area, 1-5 mrem at Lewisberry, about 100 mrem at Middletown, 10-25 mrem at York Haven, 1-5 mrem at Mount Wolf and Bainbridge, 0.1-1.0 mrem at Marietta, and less than 0.1 mrem at Mt. Joy and in Lebanon County (Ref. 5). The exposure rates at distances beyond 10 miles from the plant were extrapolated from a curve drawn through the plotted exposure measurements as a function of distance within 10 miles of the plant, because exposure rates beyond 10 miles were too low to measure.

As can be seen from the discussion in Section 3.1.3, none of the health problems in animals and wildlife that were reported could have been caused by exposure to radiation released from the TMI accident at the levels reported and calculated.

*A control station is one which is located so that it is not affected by plant releases.

If the measures of radiation exposure after the accident were grossly underestimated (say by more than a thousandfold), reports of animal health problems would have come from many who had no pre-accident complaints, and the symptoms would have been different. The most sensitive response to a large, acute dose of radiation is observed in the bone marrow. Therefore, if radiation had been the cause of the reported problems (in animal reproduction, muscular weakness, and brittle bones), veterinarians would have found many anemic animals. These animals would have been found throughout the TMI area, and more frequently in the path of the radioactive plume, which tended to be either north-northwest, east-northeast, or south-southeast. Such was not the case. Instead, the complaints after the accident at TMI centered, primarily, around husbandry problems and problems with reproduction; the majority of reported cases came from farms west and west-southwest of TMI. These problems are similar to those voiced by some of the same individuals before the accident and are fewer in number.

3.3 Effects of the Drift from the Cooling Tower Plumes During Plant Operation

Farmers in the Etters-Newberrytown-Reesers Summit triangle have expressed concern that mineral deficiencies observed in farm animals after the startup of TMI were caused by the operation of the cooling towers at TMI. These farmers reported that the emissions of chemicals (especially chlorides) from the TMI cooling towers have accumulated in the soils and are chemically binding the selenium to the soil. Binding of selenium to the soil could restrict plant and crop intake of this limited element and, thus, result in selenium deficiencies in animals which eat these crops.

3.3.1 Composition of Cooling Tower Water and Steam

Cooling towers provide one means of discharging waste heat from nuclear and fossil-fuel power plants. During the combined operation of TMI Units 1 and 2, four natural draft cooling towers were in operation. The steam vapor emitted from the towers contained a variety of chemical elements and compounds, termed drift. Since the Susquehanna River was the source of water used in the cooling towers, the basic chemistry of the water in the cooling towers reflected the Susquehanna River water chemistry. However, because the river water in the towers was recirculated and some was lost by evaporation from the top of the towers, these chemicals became concentrated about 6-fold. In addition, chlorine was added to the cooling tower water to prevent buildup of biological slimes in the cooling circuits, and sulfuric acid was added for pH control.

Therefore, the three sources of chemicals in the cooling tower water were:

(1) dissolved chemicals from river water, concentrated about 6-fold
(2) sulfuric acid (soluble sulfates)
(3) chlorine reaction products

The concentrations of chemicals in the cooling towers are shown in Table 3.2.

Table 3.2 Concentrations of chemicals in TMI cooling towers

Material	Amount
(1) concentrated dissolved solids from river water	1110 parts per million (ppm)*. Contained in this value are 440 ppm sulfates, 70 ppm chlorides, and 30 ppm carbonates (Refs. 9, 10).
(2) added sulfates as sulfuric acid	28 ppm (Ref. 9).
(3) added chlorides to control fouling	1 ppm (Ref. 9).

*Average river water dissolved solids concentration is 195 parts per million (ppm). Concentration factor for cooling towers used was 5.6 (195 x 5.6 = 1109 ppm).

3.3.2 Observations of Similar Cooling Towers

The average chemical salt concentration in the TMI cooling towers is calculated to be 1140 ppm. For purposes of comparison, towers using brackish or salt (sea) water have concentrations ranging from 12,000 to 35,000 ppm. The NRC routinely monitors nuclear plants using fresh water cooling towers (like TMI) to determine if offsite vegetative damage results from the deposition of these chemicals from fallout from cooling tower drift. (These programs were initiated in 1974 for TMI.) A review of the cooling tower monitoring reports for TMI (including aerial infrared and natural color photographs) indicates that there has been no effect on vegetation from the chemical drift deposited by these towers (see Section 4.2.2). This finding coincides with monitoring data gained at a wide variety of other nuclear facilities and from the literature for fossil-fuel plants throughout the world which employ natural draft cooling towers (Ref. 11).

In fact, in all NRC monitoring programs which look at different types of cooling towers under a wide variety of conditions, damage has been detected at only the Palisades Nuclear Plant on the shore of Lake Michigan. The towers at that plant are different from those at TMI in that they are low in profile (65 feet high versus 370 feet for TMI) and are surrounded by sand dunes on which there are trees taller than the towers themselves. These trees are so situated (within several hundred feet of the towers) that the cooling tower plume impacts them directly. Trees within 300 feet of the Palisades towers exhibit damage from ice in the winter and from chemical drift in the summer. This damage can be clearly observed in the aerial infrared photographs (Ref. 12). Analyses of soil collected within 200 feet of the Palisades towers show slight increases in sulfate levels (Ref. 13). Damage to the tree foliage has been attributed to high levels of sulfates from the chemical drift. There have been no biological or soil effects demonstrated beyond 500 feet of these towers (Ref. 13).

3.3.3 Effects of Cooling Tower Plume Drift on Soil

As noted earlier, some residents of the Etters-Newberrytown-Ressers Summit area suspect that chemicals from the towers are restricting selenium uptake by crops and forage plants, thereby causing nutritional deficiencies in the animals which eat them (Ref. 14).

Two specific cooling tower chemicals have been questioned, chlorides and sulfates. NRC calculations for TMI indicate relatively low levels of chlorides as well as of carbonates in the cooling tower water, in comparison to sulfates (71 ppm chlorides and 468 ppm sulfates). Moreover, neither chlorides nor carbonates contribute importantly to selenium chemistry in soils (Ref. 14). Therefore, the discussion that follows will concentrate primarily on possible sulfate-selenium interactions.

Examining the data for Palisades and TMI, it appears that the cooling tower water of both power plants has similar sulfate concentrations (Palisades 435 ppm and TMI 468 ppm). Based also upon the Palisades' soil data mentioned above, any suspected increases in soil-sulfate levels at TMI would be found within 3000 to 5000 feet of the towers. (The distance of 3000 feet is assumed to take into account the increased height of and, therefore, the increased dispersion of chemical drift from the TMI towers.) Model calculations and field measurements also indicate that the largest proportion of drift from natural draft towers falls out within 1 mile of the tower (Ref. 12). Areas bounded within the 1-mile radius of the TMI towers include Shelley Island in the west and a small shore segment on the east which is comprised of farms interspersed with small housing developments. A review of monitoring data and natural color and infrared aerial photographs of these areas shows no signs of vegetation damage similar to that at the Palisades site. Therefore, it appears that the areas within the Etters-Newberrytown-Ressers Summit triangle are beyond the distance where one would find levels of sulfates or chlorides deposited from the TMI cooling towers sufficient to change soil chemical parameters and contribute to selenium deficiency problems. Further, the increased soil-sulfate levels at Palisades were found in predominantly downwind areas. The predominant wind patterns at TMI do not coincide with the location of the Etters-Newberrytown-Ressers Summit triangle. In fact, according to NRC meteorologists, wind direction into this area is westerly, from the towers, less than 20 percent of the time (Table 3.3). The low frequency of wind from the towers into this area, combined with the lack of foliage damage near the towers, leads to the staff's conclusion that significant soil accumulations of drift chemicals which would result in the suspected selenium problem are not reasonable. This conclusion is further reinforced by a study made at Chalk Point, Maryland, where brackish water is used as a coolant. During 4 years of operation there was no increase of salts in the soil or damage to vegetation (Ref. 11).

Table 3.3 Onsite wind direction and frequency measured at the 100-ft level, 1972-1975*

Wind from	Frequency (percent)
ENE	4.6
E	7.2
ESE	6.2

*For complete wind direction and frequency, see "Draft Programmatic Impact Statement related to decontamination and disposal of radioactive wastes resulting from March 28, 1979 accident at Three Mile Island Nuclear Station, Unit 2," NUREG-0683, July 1980.

4.0 CASE HISTORIES AND DETAILED DISCUSSION OF PROBLEM AREAS

This section presents those individual case histories reviewed as part of the preparation of this report. The events included were examined and diagnosed as to etiology as much as possible from available information. They were then analyzed to determine whether the health effects could reasonably be related to the operation of the reactors or the accident at TMI, based on clinical or experimental observations.

4.1 Reported Domestic Animal Health Problems

Descriptions of the reported domestic animal health incidents investigated are based on owner interviews or depositions and available laboratory test results. Most of the information was collected after the fact and is retrospective. Each case was evaluated on the basis of available information.

A major difficulty encountered in evaluating these reported animal health problems is that very few of these animals were available for diagnostic purposes or had been presented to either Pennsylvania's Summerdale Diagnostic Laboratory, the Pennsylvania State University, or the Veterinary Medicine School of the University of Pennsylvania. In the few cases that were presented to the laboratories, there was no evidence of radiation damage, nor was there any evidence that radioactive materials were involved in any health problem.

Reported individual domestic animal case histories are grouped into the three broad categories outlined in Table 2.5. When possible, evaluations have been made for each reported case.

4.1.1 Reproductive Problems

Episodes of farm animals requiring caesarian delivery of young were reported after the accident. According to reports, pigs would deliver part of their litter and then stop. Veterinary assistance would then be required to complete delivery. The frequency of the need for this type of veterinary assistance was said to be higher than usual for the area (Ref. 3). Recurrence of this specific problem was not evident in 1980; however, an increase of stillbirths in pigs was reported during the spring of 1980.

Similar problems in goats and sheep were also reported, but increases in the number of stillbirths in these animals were not observed. Again, these problems do not appear to be recurring events. Sterility and lower reproductive rates, especially in ducks and goats, have been reported, but not confirmed.

Case 1
Description: Horse breeding was unsuccessful: poor conception rates, 3 spontaneous abortions, 1 stillbirth, 2 foals died.

Evaluation: The veterinarian for the farm attributed the problems to chronic reproductive system infections and other problems commonly found in mares of the same age, type, and condition.

Case 2
Description: A series of breeding problems with dairy cows and goats for the years 1975-1979 and a poor hatch from duck eggs in 1978 were reported.

Evaluation: An analysis of the breeding problems by the local breeders' cooperative showed that the record was about average. The cooperative offered to evaluate the herd further to determine how the conception rate could be improved. At the time of the interview for this report (May 29, 1980), contact between the owner of the herd and the cooperative had not yet been established. No data regarding the duck egg hatch were available.

Case 3
Description: Reproductive problems, muscular weaknesses, and nervous disorders in milk cows (early 1979, before the accident at TMI) were reported.

Evaluation: These reports were similar to others in the area in which the symptoms were associated with mineral deficiencies. In this case there have been no problems since the farmer added mineral supplements to the feed.

Case 4
Description: Seven litters of kittens died or were aborted between 1978 and May 1979.
Of 100 goose eggs incubated in 1978, there was only 1 hatchling and it died.
Of an unknown number of eggs laid in January 1979, none hatched.

Evaluation: The specific cause of the loss of these kittens is unknown, but common viral diseases of cats, such as feline panleukopenia (cat distemper) and respiratory diseases, cause high mortality in young cats.
Available information was insufficient for a diagnosis of why the goose eggs did not hatch, but the problem could be infertile eggs or heating or chilling of eggs during incubation.

Case 5
Description: Goats had low reproductive success from 1976 to 1978.

Evaluation: Dr. Samuel Guss, former extension veterinarian for the Pennsylvania State University, diagnosed the low reproductive rate as a genetic trait that is associated with infertility. A new buck, without the specific genetic trait associated with infertility, was obtained in 1979. Reproduction is now satisfactory. One goat died from toxemia of pregnancy, according to records at the New Bolton Center of the University of Pennsylvania School of Veterinary Medicine.

Case 6
Description: Seven cows died and 12 calves were either aborted or stillborn in the spring of 1979 (beginning April 3, 1979).

Evaluation: A thorough evaluation of the farm's animals, plants, and management practices was made by the Pennsylvania Department of Agriculture, the Pennsylvania State University, and the School of Veterinary Medicine of the University of Pennsylvania. Feed, water, soil, blood, milk, and animals were examined and analyzed. Radioactive materials were not the cause of any of the farm's problems. The major cattle herd problem, including the abortions and stillbirths, was a virus disease (infectious bovine rhinotracheitis), according to a memo from J. M. Dick, D. V. M., Cattle Health Division, PDA, to J. A. Nikoloff, PDA, April 7, 1979 (Ref. 2).

Case 7
Description: Two litters of kittens died in 1978.

Evaluation: Insufficient information to diagnose the cause of loss of kittens, but cat distemper and respiratory diseases commonly kill whole litters of kittens.

Case 8
Description: Ducks laid 290 eggs without a hatch in 1978. Since April 1979, 1 goat has aborted, and 26 rabbits and 19 guinea pigs died.

Evaluation: No clinical data have been obtained. Reportedly, the duck eggs had been kept in an incubator. Dr. Samuel Guss, former extension veterinarian for the Pennsylvania State University, suggests two reasons why eggs do not hatch: eggs are not fertilized or electric power fluctuations to the incubator can cause a slight heating or cooling of eggs.

Case 9
Description: Breeding problems with 6 rabbits experienced since 1976; some litters died, and some congenital malformations were seen.

Evaluation: No clinical data were available. The breeding histories of the 6 rabbits showed some success and some failures. The data were inadequate to show any unusual lack of success. Litter deaths and malformations are not uncommon in rabbits.

Case 10
Description: Breeding problems in a herd of 48 dairy cows appeared to be more severe during the last 3 years.

Evaluation: Representatives of the PDA Bureau of Animal Industry visited the farm. While there was not sufficient information available for them to make an evaluation at that time, the farmer was informed of the capability of Pennsylvania's Summerdale Diagnostic Laboratory's to help him with his herd problems.

Case 11
Description: Breeding problems with sows were reported; pigs were stillborn (Ref. 2).

Evaluation: Representatives of the PDA Bureau of Animal Industry visited the farm. While there was not sufficient information available for them to make an evaluation at that time, the farmer was informed of the Summerdale Laboratory's capability to help him with his pigs.

Case 12
Description: Breeding problems with swine were reported.

Evaluation: No evaluation was made; insufficient data were available.

Case 13
Description: 1 cow died, 3 aborted (Ref. 2).

Evaluation: No evaluation was made; insufficient data were available.

Case 14
Description: A poodle was born without one eye socket (oral report by a private citizen).

Evaluation: This was probably a developmental malformation, cause unknown.

4.1.2 Bone and Muscle Problems

Bone and muscle disorders in animals, especially cattle, were also frequently reported. A number of calves weighing between 200 and 500 pounds were cited as having broken bones or muscle-control problems. These animals were often described as "downers" because they were not able to stand up or walk without staggering. They were said to exhibit poor weight gains and poor development. Reportedly, many of these animals died or had to be slaughtered. There were also occasional reports of animals which experienced respiratory problems shortly before they died.

As the case histories in this section indicate, several animals were diagnosed as having mineral deficiency problems. Some of the farmers who started to feed their livestock mineral and vitamin supplements have not seen a reappearance of these problems. A farmer who recently reported the loss of a calf with broken pelvic bones was not feeding his livestock a vitamin/mineral supplement. Farmers who had been regularly feeding supplements did not report any unusual

health problems associated with nutritional deficiencies. Descriptions of muscular weakness, in some cases, resembled symptoms associated with selenium deficiencies (Ref. 15). Because soils and associated forage crops in the regior around TMI are considered to be low in selenium, it is possible that selenium deficiencies would appear in livestock not given proper feed supplementation (Ref. 16).

Case 15
Description: Three young steers had difficulty in walking. One suffered a broken leg in the winter of 1977 and one had a broken pelvis in the winter of 1978.

Evaluation: One of the animals was diagnosed by the School of Veterinary Medicine of the University of Pennsylvania as having osteoporosis (rickets). It is likely that the others had the same problem. Mineral supplements were recommended by local veterinarians, but the animals continued to receive only home-grown feed without mineral supplements.

Case 16
Description: Steers with weak hindquarters, lameness, and enlarged joints were reported in 1979.

Evaluation: No clinical, laboratory, or autopsy data were available. The extension veterinarian of the Pennsylvania State University recommended that a selenium-calcium supplement be used. Since feeding the supplement, there have been no problems. This strongly suggests that the problem was a mineral deficiency.

Case 17
Description: Two steers which died in 1978 suffered from muscular weakness. Some kittens died.

Evaluation: The veterinarian suggested that there was a mineral deficiency in the diet of the steers. No clinical information is available on the dead kittens.

Case 18
Description: Two steers and a colt had hindquarter weakness and broken bones in 1978 and 1979.

Evaluation: The School of Veterinary Medicine of the University of Pennsylvania diagnosed the problem as rickets, which indicates a nutritional deficiency. The hay crop the summer before the problem began was not good. There have been no problems since the feed has been improved and mineral supplements used.

Case 19
Description: Two steers suffered from loss of control of hindquarters; one died in December 1978 and the other in January 1979. Four cats had symptoms of acute dehydration, ending in death.

Evaluation: The steers' case histories resemble those for instances of mineral deficiency that were reported and diagnosed. No clinical data were available on the cats, but the verbal description of the symptoms, given by the owner, suggests that the cause was highly infectious, acute feline distemper.

4.1.3 Miscellaneous Reported Domestic Animal Health Problems

4.1.3.1 Deaths for Which the Precise Cause Is Unknown.

Case 20

Description: Almost all of a large commercial collection of 500 birds (parakeets, canaries, cockatiels, etc.) died within a 2-hour period on May 2, 1979. They were housed in an enclosed space, ventilated by a fan.

Evaluation: The PDA diagnosed the deaths of the 500 birds in a 2-hour period as most probably resulting from toxic fumes or overheating; there was no indication of any specific disease, nor does there appear to be any possible scenario in which the radiation released during the accident could have been responsible. In an experimental study, 30 parakeets were exposed to a lethal dose of whole-body ^{60}Co irradiation (3400 R), and their deaths occurred between 4 to 8 days after exposure (Ref. 17). If the parakeets in that experiment had been exposed to a dose of radiation that would cause deaths around 30 days after exposure (the approximate time between the accident at TMI and the death of the birds), then the deaths would have been spread over days instead of 2 hours. In the same experiment, the dying birds showed signs of weakness, diarrhea, and anemia for days before death, and, at autopsy, necrosis of the liver and kidney were seen. The pathologist's report on 4 parakeets of the 500 birds that died on May 2 stated that no specific disease was found; bacteriological, virological, serological, toxicological, and histopathological tests did not produce significant results (according to the results of examinations by C. D. Clark, D. V. M., Chief, Division of Laboratories, Pennsylvania State Veterinary Diagnostic Laboratory, Case H-49461, May 30, 1979). Radiation from TMI must be excluded as a cause of death because lethal doses would not kill all birds in 2 hours, and the birds showed no signs typical of radiation injury.

Case 21

Description: From April 9, 1979 to March 5, 1980, 15 individuals brought into the Bureau of Animal Industry about 84 dead birds of many species (parrots, parakeets, starlings, robins, finches, etc.) from a 20-mile radius around TMI.

Evaluation Dead birds inspected by the Bureau of Animal Industry were found to have died from a variety of causes, including traumatic injury, poisoning, and hepatitis (according to a memo from D. S. Ingraham, D. V. M., of the PDA, to J. A. Nikoloff of the PDA Press Office, July 5, 1979). Radiation scans conducted on three samples showed nothing unusual.

Case 2
Description: Dead cats and a dead rabbit were reported in 1978. A neurologic problem in a cat and malformation in a duck were also reported.

Evaluation: Veterinarian examined one cat, but no diagnosis was given. Insufficient data were available for the other cats or for the rabbit.
The kitten and ducks suffered developmental malformation. The description of the kitten's problem resembles feline cerebellar ataxia seen in kittens infected in the womb with feline distemper virus (Ref. 15).

Case 25
Description: Two cows died in January 1979, one calf in February, and two calves in April of the same year.

Evaluation: This mortality is considered within the normal range for a herd this size (105 head).

4.1.3.2 Cancers and Tumors in Milk Cows and Loss of Hair in Goats

Case 2
Description: A goat lost hair in spots on its back in 1979. A cow was diagnosed as having cancer.

Evaluation: No diagnosis was given regarding the goat, because sufficient data were not available for an evaluation.

Case 13
Description: Uterine tumors were found in milk cows.

Evaluation: Available data were insufficient to make an evaluation.

4.1.3.3 Mastitis

Case 26
Description: Slight increase in mastitis reported.

Evaluation: No evaluation made; insufficient data available.

4.1.3.4 Shipping Fever

Case 22
Description: Four steers died between February and April 1979.

Evaluation: The owner stated that the animals died from shipping fever. When a representative of PDA visited the farm, he was told that there was no problem (according to a memo from J. M. Dick, D.V.M., to J. A. Nikoloff, PDA Press Office, April 7, 1979).

Case 24
Description: Recently purchased cows became sick.

Evaluation: Shipping fever (bovine pneumonia pasteurellosis) or virus infection was diagnosed by the Bureau of Animal Industry.

4.1.3.5 Foot Rot in Sheep

Case 23
Description: Sore feet in sheep were reported.

Evaluation: A veterinarian treated sheep and goats for foot rot, and the animals recovered.

4.2 Additional Reported Terrestrial Problems in the TMI Area

4.2.1 Reported Effects on Wildlife

Description: Observations reported were: (1) fewer starlings and robins were seen during the spring and summer of 1979; (2) small game animals (e.g., squirrels, rabbits and pheasants) were fewer in number, and (3) no hop toads have been seen in the last 2 years.

Evaluation: Mr. Dale E. Sheffer, Chief of the Division of Game Management of the Pennsylvania Game Commission, and Dr. C. J. McCoy, who specializes in the study of amphibians and reptiles at the Carnegie Museum of Natural History, Pittsburgh, Pennsylvania, were contacted. In addition, bird watchers (hobbyists) from both sides of the Susquehanna River were contacted, and copies of their society newsletters were obtained.

In his letter of May 20, 1980, Mr. Sheffer confirms the low numbers of small and medium-sized game seen. However, he attributes these smaller populations to reduced habitats which are the result of increased human population, changes in farming methods, and the prolonged severe winters of 1976-77 and 1977-78. Mr. Sheffer also said that the white-tail deer population has been maintained at about the same level since 1957.

In his letter of May 30, 1980, Dr. McCoy states that he is not surprised that residents of York County have noticed a decline in abundance of toads. He says that a general decline has been reported by a great many observers, over many parts of Pennsylvania and the eastern United States, over the past 20 to 30 years. Dr. McCoy attributes this decline primarily to the tremendous increase in the use of chemical pesticides in both agricultural and household applications since about 1945. He adds, "Unfortunately we lack the prepesticide-era baseline data on toad populations that would permit us to assess the impact of chemical pesticides on the toads."

Bird hobbyists keep very close watch on bird populations. Besides their well-publicized Christmas bird counts, they pay special attention to spring and fall migrations, conduct breeding bird surveys, and maintain lists of all birds species seen and confirmed by bird watcher society members for each year.

They have not reported any reduction in the starling or robin populations for 1979. They also have not reported any unusual events or variation in the bird populations that could be attributed to TMI.

4.2.2 Reported Effects on Vegetation

Description: Observations reported were: (1) individual trees of many species had dead branches and/or leaves; (2) two pear trees produced less fruit than they did in previous years, and one is dying; (3) plants beneath a cemetery wire fence are dead; and (4) plants around a watering trough were dead.

Evaluation: Both color and black-and-white photographs of individual trees and groups of trees were studied. The two pear trees were examined, and the cemetery visited. The farm with dead plants around the watering trough was not visited because the farmer reported that the area was revegetated. The Plant Disease Clinic at the Pennsylvania State University was contacted. The reports and aerial photographs of the monitoring of the effects of cooling tower operation on vegetation which had been submitted by Metropolitan Edison Company since 1974 were reviewed.

The Penn State Plant Disease Clinic provided computer printouts of all plant specimens submitted there from Dauphin, Lancaster, and York Counties for 1978 and 1979. These printouts show that 93 plant specimens were submitted to the Plant Clinic in 1978, and 94 specimens in 1979. In 1978, 4 of the samples were inadequate, and for 3 samples the causal agent of the problem could not be specifically identified. In 1979 there were 2 inadequate samples and 10 that could not be identified as to cause of injury. The damage to all other specimens was identified by the Clinic as attributable to normal biological or environmental factors.

The Plant Clinic reported that there was heavy infestation of fire blight (a bacterial disease) in pear trees throughout the state in 1979. In the spring of 1980, specimen leaves were collected from the two pear trees (mentioned above) and were submitted to the Plant Clinic. The Clinic analysis of the dark spots on the leaves indicates that they were caused by either red spider or pear-slug feeding.

As part of the conditions for operating cooling towers at TMI, the NRC has required annual surveys of the vegetation since 1974. These surveys consist of aerial infrared and natural color photographs of a 25-square-mile area, as well as on-the-ground reconnaissance by road along 8 transects on the east side of the Susquehanna River and 14 transects on the west side of the river. The photographs and reports show that locust leaf miner was the predominant source of vegetation stress, followed by antracnose disease, caused by marssonina juglandis, a leaf spot disease of nut trees. All vegetation stress was attributable to natural causes.

The cemetery was visited, and the vegetation under the whole length of the fence examined. There was no indication of plants dying under the south or west fences. Under the whole length of the north and east fences, an area some four inches wide lacked plants. This denuded area ran along one side of the fence, then suddenly crossed under the fence and ran along the other side of the fence for the remainder of its length. It appears that this denuded area represents "animal runways" or "passageways for animals."

4.2.3 Report of a "Glowing Fish"

Description: In a May 2, 1979 report on TMI emergency extension activities, the Dauphin County Agricultural Extension Agent related the following: A housewife bought a shad at the supermarket. She cut it in pieces, and her husband took it to the basement to put it in the freezer. There was no light in the basement, and the man noticed that the fish glowed in the dark. The housewife asked if this could be radioactivity. The agent said he did not think so, but suggested that she contact the Pennsylvania Bureau of Foods and Chemistry.

Evaluation: During the course of the investigation for this report, it was not possible to find anyone at the Pennsylvania Bureau of Foods and Chemistry or at the Department of Environmental Resources who was familiar with this case. It should be noted that typically fish purchased in supermarkets in the TMI area would not come from the Susquehanna River in the vicinity of TMI. However, even if the fish had been exposed to ionizing radiation, it would not glow. The glow or luminescence could have been caused by marine (salt water) bacteria.

4.2.4 Reports of "White Powder"

Description: Residents on both sides of the Susquehanna River report seeing a "white powder." Some report seeing it after rains, some see it during the growing season, and some see it year round. Others in the area have never seen it, and no samples were available.

Evaluation: In an attempt to identify the white powder, a number of individuals living in the vicinity of TMI were interviewed, and meteorologists from the following organizations were consulted:

(1) Bureau of Air Quality Control
Pennsylvania Department of Environmental Resources
Harrisburg, Pennsylvania

(2) Argonne National Laboratory
Argonne, Illinois

(3) Emission Measurement and
Characterization Division
Environmental Protection Agency
Research Triangle Park, North Carolina

(4) Pennsylvania Power and Light Company
Allentown, Pennsylvania

(5) Arizona Public Service Company
Phoenix, Arizona

(6) Hydrology-Meteorology Branch
U.S. Nuclear Regulatory Commission
Washington, DC

Because no one interviewed had collected a sample of this white powder, a definitive identification is impossible. The three most likely possibilities are pollen, fly ash, and cooling tower drift. Some individuals claim to have seen the white powder throughout the year; therefore, this would seem to rule out pollen. It has been reported that when this powder is stirred into water (as in an animal's watering trough), the water turns milky white. While pollen will produce this effect, small quantities of fly ash will not; it precipitates out. However, large quantities of fly ash will turn water a milky color, as commonly seen in ash ponds.

According to the Pennsylvania Bureau of Air Quality Control, the only likely local source of fly ash is the Brunner Island coal-fired power plant. This plant is located 4 miles south-southeast of TMI. While it has precipitators that collect fly ash, some is still released. The fly ash that does manage to pass through the precipitators is primarily microscopic, so that a quantity would appear as a fine dust and not a powder. Because of its small size, fly ash is readily dispersed by the wind. The further the fly ash travels, the more dilution occurs, so that after traveling 4 to 5 miles, quantities capable of being seen or of turning water milky are very unlikely.

The Pennsylvania Bureau of Air Quality Control monitoring program has not identified any possible source for the white powder. Moreover, NRC monitoring of fresh water cooling towers throughout the country has not shown any evidence of white powder.

5.0 CONCLUSIONS

Based on the available data, it appears that none of the reported plant and animal health effects discussed above can be directly attributed to the operation of or the accident at the Three Mile Island Nuclear Power Station.

5.1 Effects of Radiological Releases

Radiological releases from TMI would not result in the types of problems reported; the level of radiation exposure from TMI was less than 1/1000th of that which might cause clinically detectable effects in the animal population which was exposed (see Sections 3.2.1 and 3.2.2). The complaints are related to reproductive problems, bone problems, and a series of miscellaneous problems. Although some of these symptoms can be produced by radiation doses exceeding 50,000 mrem,

there are no substantiated experimental data that show that any of these symptoms would have been caused in animals exposed to the levels of radiation received by the animals in question. According to the report of an advisory committee to the National Academy of Sciences on the biological effects of ionizing radiations, "The effects of very low levels - millirads per day - of continuous radiation on early development have been little explored experimentally, but evidence at hand has shown no harmful effects" (Ref. 7). (See also Section 3.1.)

The isolated reports of developmental malformations that were labeled as mutants are most likely to have resulted from nongenetic factors which are known to cause them (e.g., infection, malnutrition, etc.) (Ref. 15). The probability that they could have been caused by radiation from the reactors in normal operation is extremely low because of the extremely small additional annual exposure rate. (See also Section 3.2.)

None of the vegetation problems discussed above could have been caused by TMI. As noted in Section 3.1, plants are usually much less sensitive to radiation damage than animals, and so are even less likely to have experienced any effects from releases from TMI.

5.2 Effects of the Drift from Cooling Tower Plumes

According to NRC staff meteorologists, winds from the easterly quarter would blow drift to the west less than 20 percent of the time. This would decrease the amount of salt deposition in the area west of TMI where most of the complaints were reported. There is little possibility that there would have been a buildup of salt from cooling tower drift in the soil during operation.

Because there was no damage to vegetation from deposition from the Chalk Point plant (which uses brackish water), it is highly unlikely that vegetation damage would result when the coolant is fresh water, and, in fact, none has been observed at TMI.

The suggestion has been made by one of the farmers that the salts from cooling tower drifts have decreased the availability of selenium in the soil, which is marginal for selenium content. The argument that the salts are significantly binding selenium to the soil is highly unlikely. Sulfates which are known to bind selenium are present in the cooling tower drift. However, the addition of sulfate from drift is extremely small and not detectable beyond a very short distance from the towers (see Section 3.3.3). Chlorides and carbonates do not contribute importantly to selenium chemistry in soils (Ref. 14).

5.3 Postulated Causes of Reported Sicknesses and Deaths

Many of the reported livestock problems were probably the result of nutritional deficiences. Several animals were diagnosed by laboratory tests as having rickets. After several of the farmers started giving their livestock mineral and vitamin feed supplements, there was no reappearance of the problems of bone and muscular weakness (see Cases 16 and 18, Section 4.2). Farmers who have been feeding the proper supplements all along did not report any problems associated with nutritional deficiency. The U.S. Food and Drug Administration has recently approved the addition of 0.1 ppm selenium to the diets of beef

and dairy cattle. Selenium supplementation of the feeds for poultry and swine were approved in 1974 and for sheep in 1978 (Ref. 18).

The descriptions of muscular weakness in some cases resembled the symptoms seen with selenium deficiency. This deficiency is associated with skeletal and muscular weakness, reduced fertility, and reduced resistance to disease (Refs. 15, 19). Because the soils around TMI are known to be deficient in selenium, it is possible that selenium deficiency disease would appear in livestock not given feed supplementation.

According a veterinarian consulted in many of the cases discussed in this report, in the last year there has been an increase of problems with reproduction in sheep, goats, and cows (Ref. 4). These problems suggest a nutritional deficiency; however, further research and epidemiological investigation are needed to explain and support these observations.

The symptoms described in the many cases of cat and kitten deaths suggest that infectious diseases were the cause. The cyclic rise and fall of the population of farm cats is well known to veterinarians, and feline distemper virus is one of the common causes. Moreover, the ataxia (lack of coordination) described in some kittens is characteristic of in-the-womb (or neonatal) infection with feline distemper virus.

The lack of hatching of duck and goose eggs could have come about because of fluctuation in incubator temperatures where incubators were used. It is impossible to make a diagnosis from the information available.

5.4 Summary of the TMI Situation

To summarize, while many of the symptoms reported are characteristic of radiation sickness as well as many other common diseases, the necessary spectrum of symptoms which would establish a causal link between the reported problems and TMI was not in evidence. Taken in conjunction with the lack of any systematic geographic pattern of reported problems and the power plant, as well as with the fact that many of the problems were diagnosed as common occurrences in domestic and wild animals, the staff has concluded that no relationship can be established between the operation of TMI or the accidental releases of radioactivity and the reported health effects.

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The documents marked with an asterisk (*) are available for inspection and copying for a fee in the NRC Public Document Room, 1717 H Street, NW, Washington, DC 20555. Documents marked with two asterisks (**) also are available for purchase from the NRC/GPO Sales Program, U.S. Nuclear Regulatory Commission, Washington, DC 20555, and the National Technical Information Service, Springfield, Va. 22161.

All other documents cited may be found in public technical laboratories.

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The results of investigations into reported problems with plants and animals which may be related to the operation of and accident at the Three Mile Island Nuclear Power Station are presented. The kinds of problems reported are listed, and potential areas of concern (such as the release of radioactive gases and drift from cooling tower plumes) are discussed. Specific case histories are examined, and probable causes attributed. While in some instances not enough data were available for a detailed evaluation to be made, none of the reported problems could be linked to TMI and no general pattern of effects could be seen.

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IN THE THREE MILE ISLAND AREA

OCTOBER 1980