BRAZORIA COUNTY, TEXAS

HURRICANE INLAND FLOODING AND FARM ANIMAL WASTE:

A RISK ASSESSMENT

THESIS

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By

Christy-Ann Archuleta, B.A.

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This work is dedicated to rche

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GLOSSARY

Biochemical oxygen demand. The oxygen used in meeting the metabolic needs of aerobic microorganisms in water rich in organic matter (as water polluted with sewage).

Diel fluctuations. Involving a 24-hour period that usually includes a day and the adjoining night. As in diel fluctuations in temperature.

Digital Ortho Quad (DOQ). US Geological Survey grayscale or color infrared airphotos. Each DOQ is stored in four parts called a DOQQ, digital orthophoto quarter quad. A full DOQ or four DOQQs cover the area of a USGS 7.5-minute topographic map. The resolution of DOQQs is one meter.

Digital Q3 Data. The Federal Emergency Management Agency and the National Flood Insurance Program. The digital data are vector files that are developed by scanning the existing FIRM hardcopy maps, and then vectorizing the scanned images to produce a thematic overlay of flood risks.

Dissolved oxygen. The volume of oxygen that is contained in water.

Ecodisaster. A breakdown or destructuring of the relationship between a community and its environment producing more or less sever reverberations in the psychological, social, and cultural life of the community (Couch and Kroll-Smith 1994)

Effluent. Waste material (as smoke, liquid industrial refuse, or sewage) discharged into the environment especially when serving as a pollutant.

Eutrophication. The process by which a body of water becomes enriched in dissolved nutrients (as phosphates) that stimulate the growth of aquatic plant life usually resulting in the depletion of dissolved oxygen.

Fecal coliform. A bacterium that lives in the lower intestine of animals and are used in public health as indicators of fecal pollution (as of water or food), or produce a toxin causing intestinal illness.

Flood Insurance Rate Map (FIRM). A flood map produced by the Federal Emergency Management Agency and the National Flood Insurance Program. Flood risk information presented on FIRMs is based on historic, meteorological, hydrologic, and hydraulic data, as well as open-space conditions, flood control works, and development.

Geographic Information System (GIS). A set of computer tools for collecting, storing, retrieving at will, transforming, and displaying spatial data from the real for a particular set of purposes (Burrough et. al. 1998).

Grid format. A map in which the information is carried in the form of regular squares. Also called a raster.

Hazard. A source of danger.

Hurricane. A tropical cyclone with winds of 74 miles (118 kilometers) per hour or greater.

Microbial pathogen. An organism of microscopic size that is a specific causative agent (as a bacterium or virus) of disease.

Pathogenic microorganism. An organism of microscopic size that is causing or capable of causing disease.

Preserve. Coastal natural resource areas requiring special management under the Coastal Management Program and defined as any lands owned by the state that are designated and used as parks, recreation areas, scientific areas, wildlife management areas, wildlife refuges, or historic sites and that are designated by the Texas Parks and Wildlife as being coastal in character (GLO 1996).

Raster. A regular grid of cells covering an area.

Risk. Something that creates a hazard.

Saffir-Simpson Hurricane Scale. Is a 1-5 rating based on a hurricane's intensity. This is used to give an estimate of the potential property damage and flooding expected along the coast from a hurricane landfall. Wind speed is the determining factor in the scale (NOAA 2000).

TIGER/Line Files. Topologically Integrated Geographic Encoding and Referencing which is the name for the system and digital database developed at the Census Bureau to support its mapping needs for the Decennial Census and other Bureau programs. The TIGER/Line files are a digital database of geographic features, such as roads, railroads, rivers, lakes, political boundaries, census statistical boundaries, etc. covering the entire United States (US Bureau of the Census 2000).

Tropical Storm. A tropical cyclone with strong winds of less than hurricane intensity.

Turbidity. Water that is thick or opaque with sediment or algae.

United State Geological Survey National Elevation Dataset (NED). Developed by merging the highest-resolution, best-quality elevation data available across the United States into a seamless raster format.

Waste lagoon. A shallow artificial pool or pond for the processing of animal waste.

ABSTRACT

BRAZORIA COUNTY, TEXAS HURRICANE INLAND FLOODING AND FARM ANIMAL WASTE: A RISK ASSESSMENT

by

Christy-Ann Marie Archuleta, B.A.
Southwest Texas State University
May 2001

SUPERVISING PROFESSOR: Pamela S. Showalter, Ph.D.

Large-scale factory farms or contained animal feeding operations (CAFOs) frequently use waste storage lagoons for waste management. Heavy rainfall events and flooding have caused many of these lagoons, which hold millions of gallons of waste, to fail and spill their contents into watersheds. Waste lagoon spills may harm the surrounding environment, human health and safety, and the economy of an area This study focuses on Brazoria County, which is located on the Texas coast and has four CAFOs that use lagoons for waste management within its boundaries.

A risk assessment was performed to evaluate the potential for contamination from a CAFO lagoon spill on the Texas coast in Brazoria County. For the purposes of this research, a risk assessment is defined as an evaluation of the environmental, human

health, human safety, and economic factors that could be at risk in the event of a CAFO waste lagoon spill caused by hurricane inland flooding. This assessment evaluates the risk of lagoons contaminating streams, rivers and other water bodies of Brazoria County. A geographic information system was used to evaluate variables pertaining to the factors that place the area at risk. The goal of this research was to produce a map showing the risk of contamination in Brazoria County if a tropical storm or hurricane generating inland flooding impacted its coast.

CHAPTER I

INTRODUCTION

The population of the world was approximately six billion as of November 2000, and at the current rate of population growth, another 76 million people will be added to that number by November 2001 (World Overpopulation Awareness 2000). The rapidly increasing human population correlates with an increase in consumers, and thereby has spurred a growth of Concentrated Animal Feeding Operations (CAFOs) in the United States, many of which have been located in coastal areas. CAFOs are high production factory farms where large numbers of animals are concentrated into relatively small feedlot facilities. Usually, thousands of animals are housed and processed in a CAFO. There are many alternatives to the farming methods used by large scale CAFOs, however many corporations use this method because more animals can be grown for slaughter at a reduced cost. Currently, there are approximately 57 million head of swine in the United States, producing 102 billion liters (27 billion gallons) of waste a year, and approximately one billion head of poultry in the United States producing 45 billion liters (12 billion gallons) of waste a year. Often, the animal waste from a CAFO is disposed of in large lagoons (Figure 1). Millions of liters of liquid waste and wastewater may be contained in these lagoons, which are essentially deep, earthen, man-made ponds. Modern lagoons are usually lined with clay or other material to lessen the amount of waste that can leak out

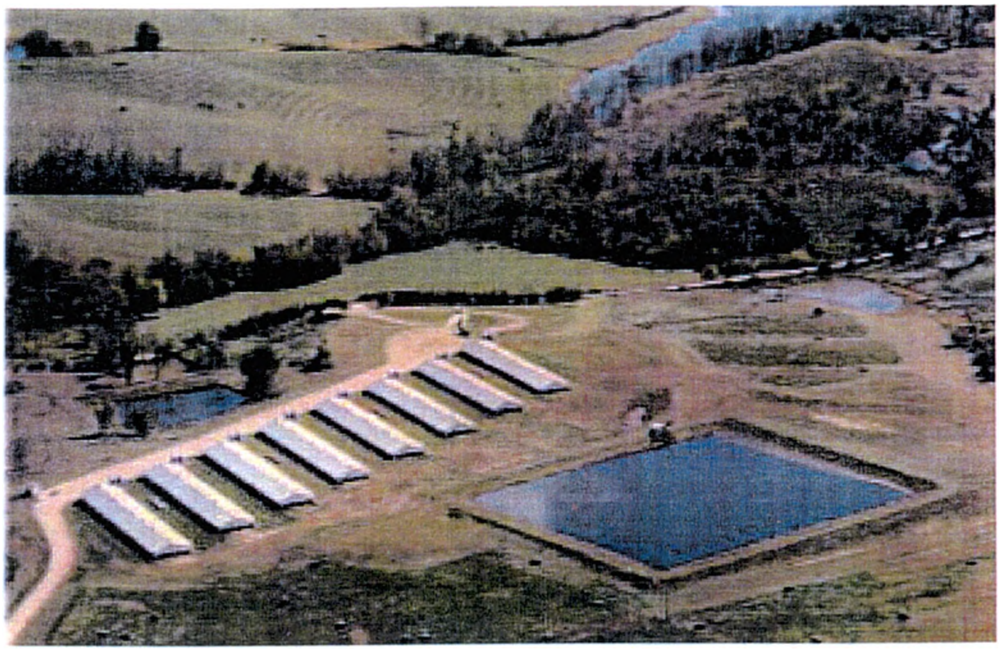


Figure 1. Reprinted from Sierra Club, *Corporate Hogs at the Public Trough*. Photo of Premium Standard Farms Missouri by Ken Midkiff (1999).

into the ground. However, these lagoons are not failsafe constructions and many in the United States have spilled causing detrimental effects to the environment. Manure spills and intentional manure dumping at animal farms in 10 states killed 13 million fish over a four-year period in the late 1990s, according to a report by Natural Resources Defense Council (NRDC), the Clean Water Network, and the Izaak Walton League. The NRDC's report recounts over 1,000 manure spills and 200 fish kills from 1995 through 1998 (Frey et al. 2000). A lagoon may spill because of adverse weather conditions, faulty construction, mismanagement, or human error. Waste may be released from a lagoon structure by breach, overtopping, or inundation from floodwater.

On September 4, 1999, Hurricane Dennis struck the North Carolina coast. While only a category 2 on the Saffir-Simpson Hurricane Scale (Appendix A), Dennis deposited approximately 250 millimeters (10 inches) of rain over eastern North Carolina. Two weeks later, in September 1999, Hurricane Floyd made landfall at North Carolina as a category two hurricane. Floyd produced approximately 500 mm (20 inches) of rain over an unusually large geographic area in the eastern part of the state. Because Hurricane Dennis' earlier landfall had saturated the soil, the precipitation from Hurricane Floyd was unable to soak into the ground and heavy flooding ensued. Inland flooding breached the waste lagoons of numerous CAFOs, pouring hundreds of thousands of poultry and hog carcasses and millions of liters of animal waste into the drainage system of North Carolina. According to Bowie, the consequence of this CAFO flooding was, ". . . an ecological event on the catastrophic scale" (2000, p. 21). The contamination of North Carolina's waterways resulting from the waste lagoon flooding serves as a rationale for examining other hurricane-prone coastal areas that contain CAFOs. The research question this study examines is: Where, and to what extent, are Texas CAFO lagoons hazardous to people and the environment from possible hurricane-induced flooding?

CHAPTER II

LITERATURE REVIEW

Risk Assessment and Geographic Information Systems

Risk assessment may be defined as "… a process in which the probability or frequency of harm for a given hazard (an event or agent which has the potential to cause harm) is estimated" (Harrop and Nixon 1999, 75). In other words, risk assessment evaluates vulnerability, which is the composite measure of the characteristics of risk. Hazards have been divided into two types: technological (acts of people) or natural (acts of God). However, Cutter (1994, xiv) states that hazards, "are no longer viewed as singular events, but as complex interactions between natural, social, and technological systems."

Risk assessment can be a complex task. The components of the risk assessment process are manifold, and a researcher can not address every possible element that may contribute to a population's vulnerability to a potential hazard. According to Lave (1994, 272), "…risk assessment methodological procedures are designed to provide 'reasonable upper-bound estimates' of a given risk." Lave (1994, 272) also notes that, "recognition of this broad range of uncertainty leads to another question: how useful is risk assessment?" There are several reasons why it is a useful process: Despite the uncertainty inherent in risk assessment:

1. Risk assessment helps to focus public debate.

2. Risk assessment guides future research, because it shows very quickly the crucial assumptions and the need for additional data or interpretation.

3. Risk assessment improves science by focusing on what we need to know in the future. Lave (1994, 272)

In 1993, Emani et al. assessed risk to extreme storm events and sea-level rise using Geographic Information Systems (GIS). In their report, the authors defined vulnerability as the differential susceptibility among social groups and locations to suffer losses from hazards (Emani et al. 1993). This definition included the dimensions of exposure, resistance (ability to withstand the impacts of the exposure) and resilience (the ability to recover from impacts) (Emani et al. 1993). The authors suggest that vulnerability is the sum of factors comprising these three dimensions, each of which may be composed of multiple layers, for example,

> The spatial component of exposure has to do with the location of people, the built environment, and different landuses including housing, lifelines, industry and agriculture. Similarly, resistance is determined by socioeconomic factors such as age, ethnicity, income, building codes and practices, and emergency management practices. (Emani et al. 1993, 202-203)

The authors illustrate the types of factors contributing to the dimension of resilience (the ability to rebound from hazards) as: size of the family unit, age, ethnicity, income, social group membership and emergency management practices (Emani et al., 203).

Emani et al. (1993) used a GIS overlay technique to compare the differing factors contributing to risk from sea-level rise and extreme storm events. Landuse was combined with elevation data and residential areas located in areas likely to be flooded by an 8-foot flood. The Census Bureau's Tiger/Line files were combined with socioeconomic data from the summary tape files (STF) to produce maps of vulnerable populations by age or by disability. The data on elevation and topography can also be used with models that simulate flood events and calculate flood damages (Emani et al. 1993).

The United States Environmental Protection Agency has produced a guideline reference for environmental risk assessment of contaminate hazards (United States Environmental Protection Agency 1999). This publication lists many important questions to ask concerning the source, stressor, exposure characteristics, ecosystem characteristics and effects (Appendix B). The questions are designed to help define the particular variables that apply to the system of risk under study, as each situation is unique and will have different source, stressor, exposure characteristics, ecosystem characteristic and effects.

CAFO Lagoons Spills

A number of studies have explored the potential for, and actual damage caused by CAFO lagoon spills. The effects of swine or poultry waste on receiving streams can be quite adverse. Mallin et al. (1997, 1622) found that, "animal waste lagoons are reservoirs of multiple ingredients for water quality problems, including organic and inorganic nutrients, biochemical oxygen demand, heavy metals, and microbial pathogens."

Both swine and poultry wastes are highly concentrated sources of organic and inorganic nutrients, fecal coliform, pathogenic microorganisms and chemical oxygen demand. Bioassays have shown that nitrogen may predominate in poultry litter and its leachate can be more toxic to test organisms than other farm-animal manure (Mallin et al. 1997). CAFO waste lagoons may contribute to high nitrogen (N) or phosphorus (P) loading rates to soils and waters (Hubbard et al. 1999). In the event of a spill, lagoon waste may cause high turbidity and low dissolved oxygen in receiving waters (Mallin et al. 1997, Hubbard et al. 1999). High fecal coliform counts from animal waste spills may be indicative of the presence of microorganisms that are deleterious to human health (Hubbard et al. 1999). Consequently, animal-waste spills may result in contamination of soils, surface waters, and ground waters (Hubbard et al. 1999).

The process of nutrient enrichment in water bodies is called eutrophication. Nutrient enrichment can lead to undesirable changes in ecosystem structure and function, and may cause the death of animals living in the receiving waters due to lack of oxygen (Smith et al. 1999; Hubbard et al. 1999; Burkholder et al.1997). Smith et al. (1999, 182, 185, 186) listed the effects of eutrophication on various receiving waterbodies:

1. Increased biomass and changes in species composition of suspended algae and periphyton.
2. Reduced water clarity.
3. Taste and odor problems.
4. Blockage of intake screens and filters.
5. Fouling of submerged lines and nets.
6. Disruption of flocculation and chlorination processes at water treatment plants.
7. Restriction of swimming and other water-based recreation.
8. Harmful diurnal fluctuations in pH and in dissolved oxygen concentrations.
9. Dense algal mats reduce habitat quality for macroinvertebrates and fish spawning.
10. Increased biomass of marine phytoplankton and epiphytic algae.
11. Shifts in phytoplankton species composition to taxa that may be toxic or inedible (e.g., bloom-forming dinoflagellates).
12. Increases in nuisance blooms of gelatinous zooplankton.
13. Changes in macroalgal production, biomass, and species composition.
14. Changes in vascular plant production, biomass, and species composition.
15. Death and losses of coral reef communities.
16. Decreases in the perceived aesthetic value of the water body.
17. Elevated pH and dissolved oxygen depletion in the water column.
18. Shifts in composition towards less desirable animal species.
19. Increased probability of kills of recreationally and commercially important animal species.

Animal waste lagoon spills may also effect the local economy. A spill may lead to the coating of local marinas with brown, foul-smelling material, discouraging use by potential tourists and fishermen. The estimated economic loss from one such spill for the recreational fishing industry in the area of Jacksonville, North Carolina was four million dollars. The economic loss included businesses that are economically linked to the recreational fishing industry, such as motels, restaurants, and other associated businesses (Burkholder et al. 1997).

Size and Characteristics of Lagoon Spills

In order to estimate the spill risk for a lagoon, it is advisable to examine the relationship between the size of waste lagoons that have spilled and the distance the waste traveled. This comparison will provide a base for considering a potential spill from an intact waste lagoon. For the purpose of this study, seven spills were examined and are summarized in Table 1. On June 21, 1995, a 41.3 million-liter spill came from a swine lagoon in Onslow County, North Carolina. The lagoon almost completely emptied and filled depressions across fields and lawns of adjacent homes and farms about 27 centimeters deep for several days. The effluent flowed overland for about a half of a kilometer and then drained into a small freshwater segment of the New River (Burkholder et al.1997). In June 1995 in Onslow County, North Carolina, 83.3 million liters of hog lagoon wastewater inundated agricultural fields, covered a rural highway, and poured into the headwaters of the New River (Hubbard et al. 1999). Thirty million liters of poultry waste spilled from an egg-farm lagoon in Duplin County, North Carolina June 1995 (Hubbard et al. 1999). On July 3, 1995 in Duplin County, a 1.6-hectare lagoon containing poultry waste spilled 32.6 million liters of chicken manure and other waste into a stream 50 meters from the lagoon. The poultry waste from 75,000 chickens was still detectable 130 kilometers from the spill site in the receiving stream (Mallin et al. 1997). A 3.8 million liter hog-waste spill was discovered in Sampson County, North Carolina in July of 1995, as well (Hubbard et al. 1999). Another spill from a lagoon that held the waste from 6,400 hogs in Brunswich County, North Carolina spilled 7.6 million liters of waste into a nearby system of creeks in August 1995 (Mallin et al. 1997).

The amount of waste released by these spills ranged from 3.8-83.3 million liters, and the waste traveled distances of 0.5 km over land and 130 km in flowing water. While there is a direct correlation between the amount of waste contained within any CAFO lagoon and the number of animals in the CAFO, a variety of environmental factors, including previous weather conditions and topography of the landscape, will effect the capacity of that waste to travel overland in the event of a spill.

Weather and Lagoon Spills

Mallin et al. (1997) found that the extended period of wet weather conditions that occurred before the poultry lagoon spill of July 1995 in Duplin County, North Carolina took place, served to rapidly dilute the poultry waste and prevented what could have been more severe environmental damage in drier conditions. In contrast to the poultry-lagoon spill, the swine-waste spill they examined from August 1995 in Brunswick County, North Carolina occurred during very hot and dry conditions, limiting the downstream transport of the waste. The authors concluded that the sudden onset of rainy conditions after a period without rain would have resulted in the waste effluent being more concentrated causing more severe ecological damage in both cases.

Table 1. Incidence of lagoon spills

	Author	Date	Location	# Animals	Lagoon Size	Amount of Waste	Distance	Type	Dead Fish
1	Burkholder	June, 1995	Onslow County	12000		41.3 million liters	.5 KM	Swine	
2	Hubbard	June, 1995	Onslow County			83.27 million L		Swine	2,600
3	Hubbard	June, 1995	Duplin County			3.8 million L		Swine	
4	Hubbard	June, 1995	Duplin County			30.28 million L		Chicken	
5	Malin et al	July, 1995	Duplin County	75000	1.6 ha surface area	32.6 millin L	50 meters	Chicken	200
6	Hubbard	July, 1995	Sampson County			3.8 million L		Swine	
7	Malin et al.	August, 1995	Brunswick County	6400		7 6 million L		Swine	

Texas Administrative Code and Concentrated Animal Feeding Operations

Burkholder et al. (1997) note state regulation of CAFOs as a contributing factor to the overall problem of lagoon spill pollution of the environment in North Carolina. The authors described a "grandfather-clause" to exempt operations in existence before 1993 from having to alter their lagoon designs to include clay or other suitable liners. In comparing the CAFO situation in Texas to that of North Carolina the Texas regulations were examined.

There are several parts of the Texas Administrative code Rules §321.31 and §321.39 that apply to the problem of CAFOs and heavy rainfall events (appendices C and D). According to these rules, wastewater may be discharged to waters in the state from CAFOs whenever rainfall events, either chronic or catastrophic, cause an overflow of wastewater from a facility designed, constructed, and properly operated to contain wastewater plus the runoff (storm-water) from a 25-year, 24-hour rainfall event. The rules state that there are no limitations on effluent discharges from such retention structures.

The state of Texas also requires that a "Pollution Prevention Plan" (PPP) be developed for each CAFO. The PPPs are supposed to be prepared in accordance with engineering guidance and designed to limit the discharge of pollutants to waters in the state.

CHAPTER III

STUDY AREA

Description of Brazoria County

Brazoria County is located on the Gulf Coast at the mouth of the Brazos River in southeastern Texas, and covers an area of 3,644 square kilometers (Figure 2). Annual rainfall for the county is 1300 millimeters (fifty-two inches) and the mean annual temperature is 20.5°C (69° F) (Kleiner 1999). Brazoria County soils consist mainly of alluvial loams and clays and have very little slope (Crenwelge et al. 1981). According to Crenwelge et al. (1981), nearly all of the soils of Brazoria County are wet during some part of the year, and those in tidal areas are wet continuously. Topography and the abundant rainfall in Brazoria County dictate the moisture content of the soil (Crenwelge et al. 1981).

The principal streams in the county, which flow into the Gulf of Mexico, are the Brazos and San Bernard rivers, Oyster Creek, Bastrop Bayou, and Chocolate Bayou. Hardwood trees cover the area of Brazoria County west of the Brazos River, and the rest is mostly prairie (Kleiner 1999).

According to the 2000 census, the population of Brazoria County is 241,767 people, and is 22.8 percent Hispanic or Latino, 65.4 percent white, 8.3 percent black or African American, 2 percent Asian, and 1.1 percent other races. The median household income of Brazoria County from the 1990 Census was $34,418 (US Bureau of the Census

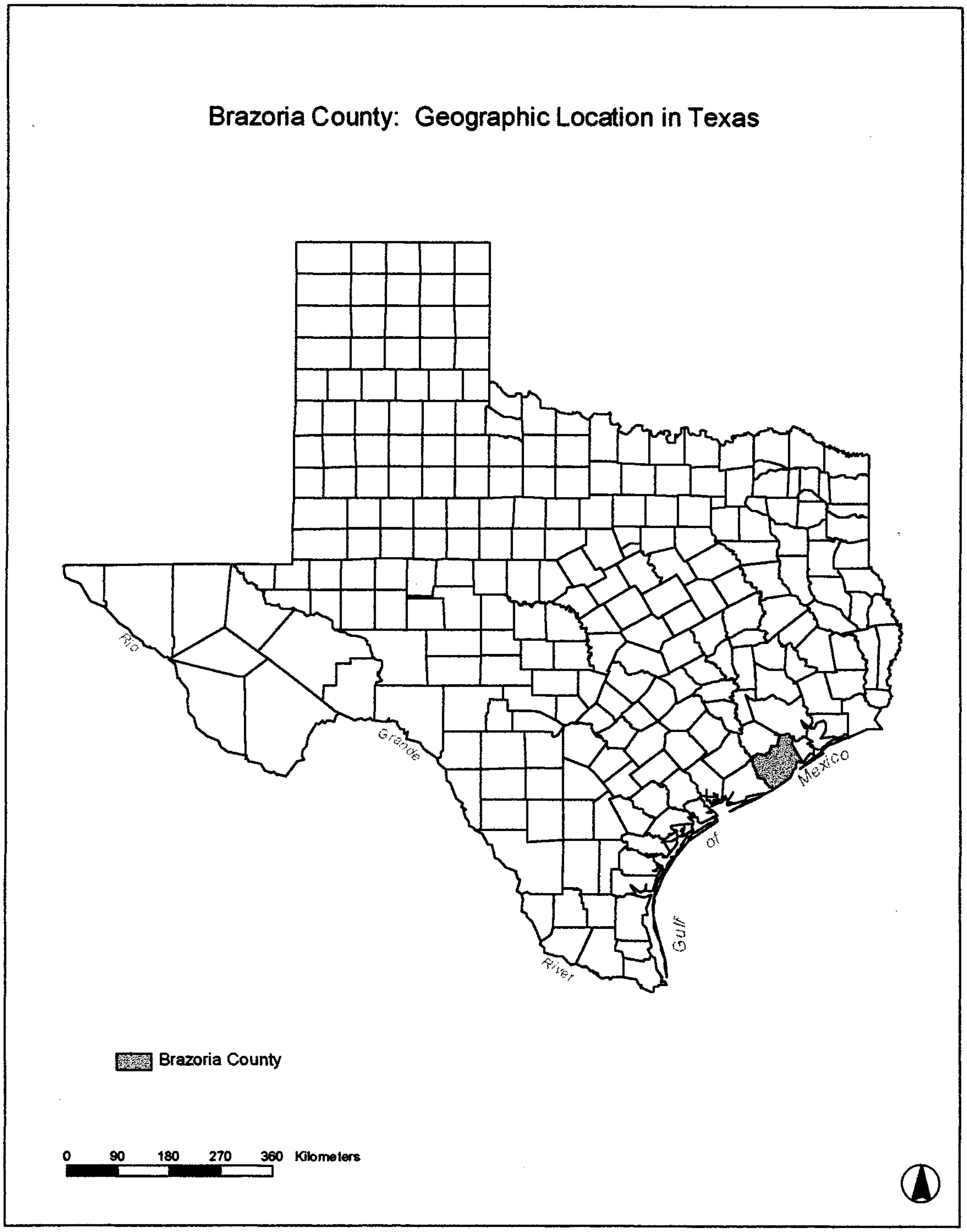


Figure 2. Brazoria County

2001). Much of the income in Brazoria County comes from agriculture, industry, and tourism and recreation, such as water sports, fishing, and hunting (Crenwelge et al. 1981, Kleiner 1999).

A review of the history of hurricanes shows that counties bordering the Gulf of Mexico are at risk from hurricanes. From 1886 to 1999 there were 61 tropical cyclones that were within 120 kilometers (75 miles) of the National Weather Service Houston/ Galveston County warning area (Lichter 1999). According to the National Weather Service Houston/ Galveston County:

> The area has a rich history of tropical cyclone hits, including the infamous 1900 Galveston hurricane, the deadliest natural disaster in the United States history, and Tropical Storm Claudette (1979), which produced the still-standing continental U.S. record 24-hour rainfall total of 43-inches in Alvin. (Lichter 1999)

According to a report produced by Texas A&M University (Appendix E), Brazoria County has in any given year a:

1) 37% chance of tropical storms and hurricanes

2) 23% chance of all hurricanes

3) 7% chance of extreme hurricane

Study Area CAFOs

Brazoria County was selected as the study area because it contains the only State permitted hog or chicken CAFOs located on the coast of Texas. There are four state permitted CAFOs (Figure 3). These CAFOs serve a total of 148,184 chickens and 5,208 swine according to issued by the Texas Natural Resource Conservation Commission (TNRCC) in 1995 (Texas Natural Resources Conservation Commission 1995; Appendix F). All of the CAFOs in Brazoria County are owned and operated by the Texas

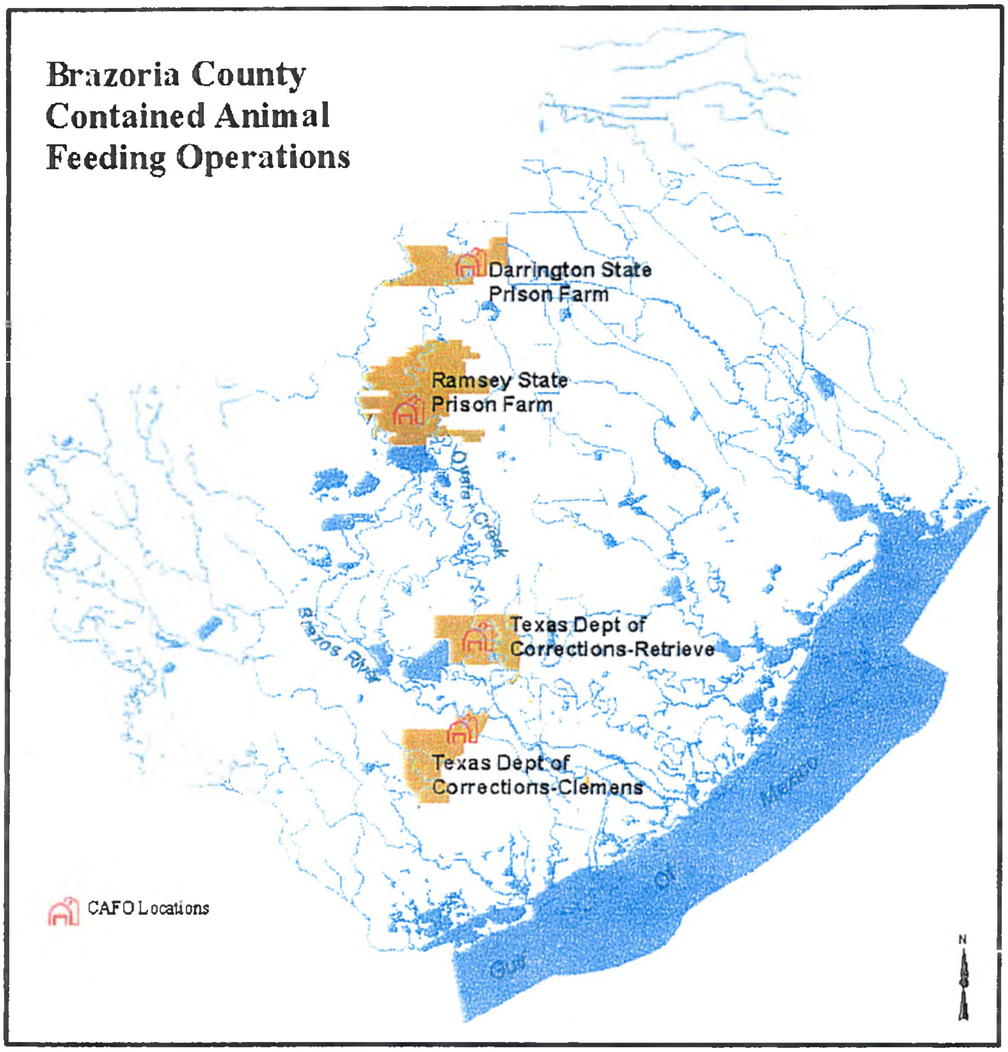


Figure 3. Brazoria County

Department of Criminal Justice, and all are located along Oyster Creek and the Brazos River.

CHAPTER IV

METHODOLOGY

Introduction

CAFO lagoons may cause harm to people and the environment when they spill as a result of contamination from flooding. CAFOs that are located in coastal areas have a unique flood risk, in that they are vulnerable to hurricanes and tropical storms. While a large number of factors may cause a waste lagoon to fail, including floods resulting from rain events, or human construction error, to narrow the scope of the study, only lagoon failures resulting from tropical storm- or hurricane-induced inland flooding are examined. Consequently, the research evaluates the probability of a storm event contaminating Brazoria County with animal waste in a manner similar to the contamination caused by the rainfall-induced flooding from Hurricane Floyd in North Carolina.

The research question this study examines is: Where, and to what extent, are Texas CAFO lagoons hazardous to people and the environment secondary to hurricane-induced flooding? This question was answered by means of a risk assessment, which was performed using Geographic Information Systems (GIS) technology. The research method prepared for this thesis combines the work of Emani et al. (1993) and the EPA's *Guidelines for Ecological Risk Assessment* (United States Environmental Protection Agency 1999).

Burrough and McDonnell (1998) discuss the fact that there are many definitions of GIS, based on the use of GIS as a spatial analysis tool, a database, and a method for organization. For the purpose of this study, the authors' definition of GIS as a spatial analysis tool works best:

> GIS is a powerful set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes. (Burrough and McDonnell 1998, 79)

In this case, spatial data on factors of risk for Brazoria County are collected, stored, transformed and displayed in the form of a "risk map". This entire process can be summed up as a method for risk assessment.

Unit of Analysis

The Environmental Systems Research Institute (ESRI) software package ArcView version 3.2© 1999 in conjunction with the Spatial Analyst© 1999 extension, ESRI's ArcInfo version 8.0© 2000, and ArcMap 8.1© 2000 with the Spatial Analyst© 2000 extension were used to create a map of areas at risk. This technology was used to analyze the relationships between data converted into a grid format, which is where the spatial data is carried in the form of regular squares, also called a raster format. The resolution of the grid was 30 meters, which is the resolution for the National Elevation Dataset (NED), which was created by the USGS by mosaicking digital elevation models (DEMs) for the entire United States. This step was performed so that every 30-meter grid cell for every layer of information could be mathematically manipulated, because every grid cell for every layer would spatially coincide with the other layers.

Variables Used

A list of factors contributing to risk of contamination was arranged according to operational variables for the factors of environmental, human, and economic risk (Table 2). This list was based on the EPA's guidelines for environmental risk assessment, but has been expanded to include human and economic risk. The reasoning behind combining environmental and human risk factors is based on Crouch and Kroll-Smith's (1994, 289) definition of an ecodisaster, "a breakdown or destructuring of the relationship between a community and its environment producing more or less severe reverberations in the psychological, social and cultural life of the community." The relationship between people and their environment necessitates that environmental risk be considered when evaluating human risk.

A primary goal of this research was to define the factors of vulnerability for CAFOs and their surrounding areas. Information specific to the CAFOs was obtained by accessing TNRCC's permit information for each of the four CAFOs in Brazoria County, interviewing the appropriate personnel from the Department of Corrections (Appendix G) and ground-truth data collection.

FEMA's Flood Insurance Rate Maps (FIRMs), and Digital Q3 flood data for the area were obtained to identify 100-year and 500-year flood areas. The United States Geological Survey's National Elevation Dataset (NED) was used to estimate elevation and slope. Point locations for public water supply sources were downloaded from the Texas Natural Resources Conservation Commission (TNRCC) website. Coverages containing locations of migratory bird nests, marinas, preserves, high priority areas and

Table 2. Operational Variables by Risk Type

Human Health and Safety	Environmental	Economic
Location of populated places: TIGER city boundaries	Location of wildlife: GLO Species Locations, Migrating bird nest locations. GLO priority areas and preserves	Location of businesses dependent on water-bodies for income such as: marinas, oyster farms
Water well locations	Distance to flowing water	Distance to flowing water
Distance to flowing water	Number of CAFO animals	Number of CAFO animals
Elevation and slope	Elevation and slope	Elevation and slope
Slope	Slope	Slope
Location of 100-year and 500-year flood-zones	Location of 100-year and 500-year flood-zones	Location of 100-year and 500-year flood-zones

oysters were obtained from the Texas General Land Office's website. Finally, TIGER shapefiles were obtained from the Texas Water Development Board (TWDB) to delineate cities, lakes, and rivers.

To spatially locate the CAFOs, Digital Orthophoto Quarter Quads (DOQQs) were used in conjunction with coordinate data and rough plan maps obtained from TNRCC. The DOQQs were interpreted to delineate what visually appeared to be the CAFO buildings and lagoons and a coverage was created of these locations. Overlaying the new coverage on top of the DOQQs produced a map for each farm location (Figures 4 - 8).

Analysis

Clemens Unit Interview and Survey

Clemens Unit Visit

On March 9th, 2001, the Clemens Unit of Brazoria County was visited. During that time, four Clemens Unit personnel were interviewed and image-maps (Figures 4 - 8) offered to the personnel, who assisted by verifying the locations of the lagoons and buildings on the maps. Arrangements were made with Mr. Steve Ecord from the Texas Department of Criminal Justice (TDCJ) to tour the Clemens Unit, its CAFO facilities, and to view the farrowing-slab (where baby pigs are raised) and feeder-slab as well as their adjoining lagoons. Photographs of these facilities were taken with the permission of the Clemens Unit personnel and the understanding that no pictures were to be taken of inmates or the prison facilities other than the feeder-slab, farrowing-slab and lagoons.

Upon arrival at the hog facilities, an observer would notice that the Clemens Unit type of CAFO is fairly different from the descriptions of a typical commercial large-scale hog farming business. The characteristics of the other three Brazoria County Units are unknown other than the descriptions found in their TNRCC records because those

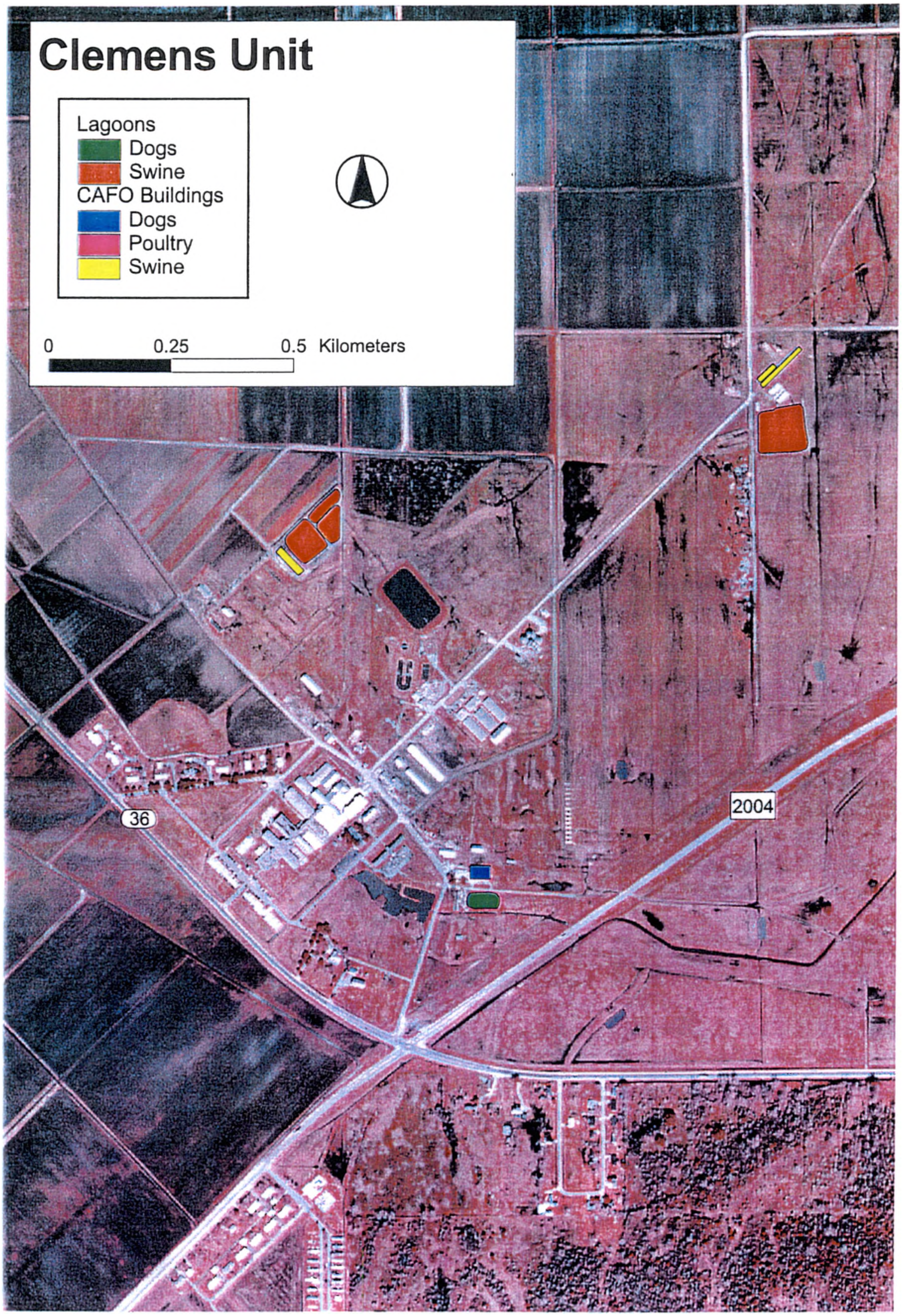


Figure 4. Clemens Unit.

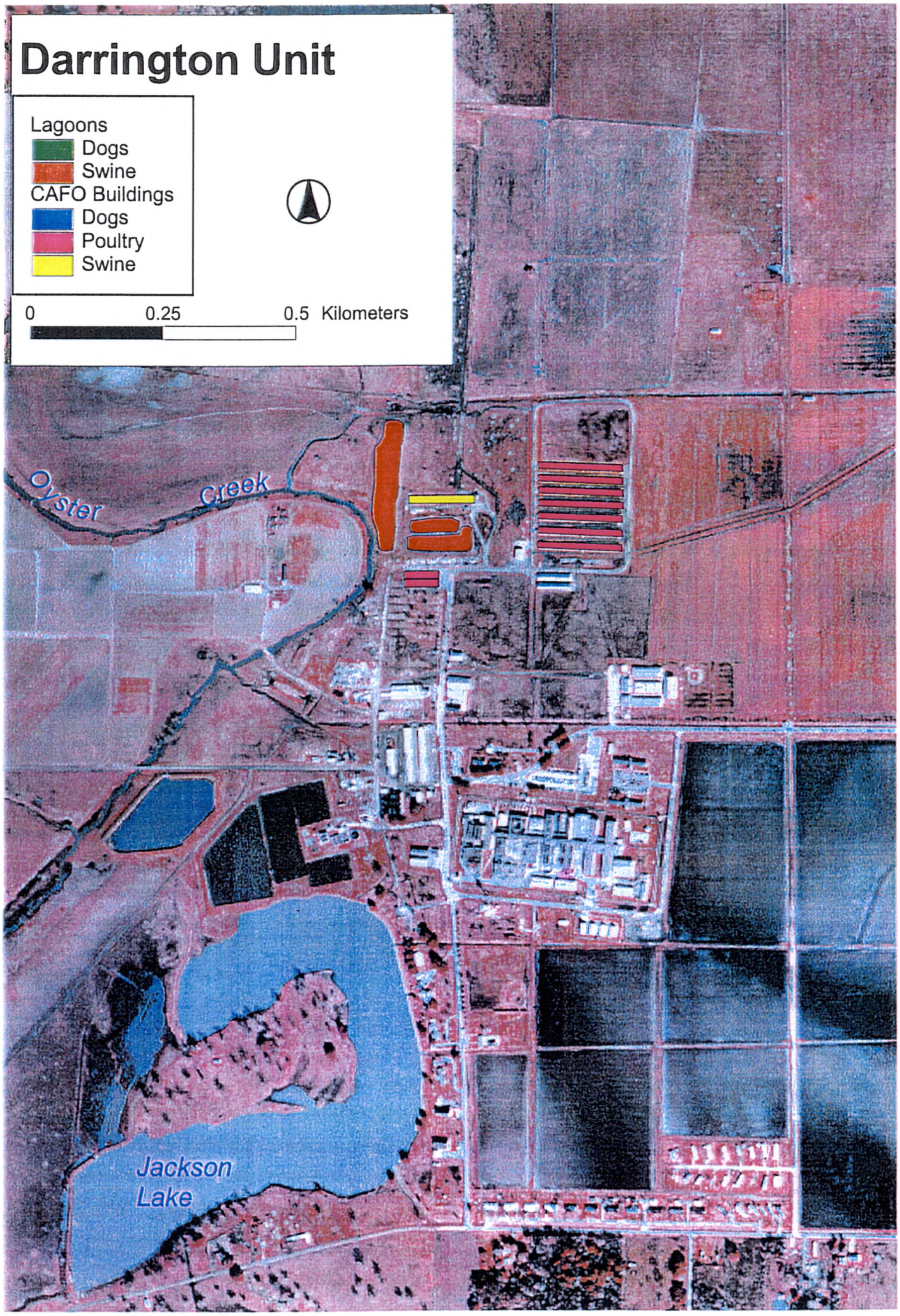


Figure 5. Darrington Unit.

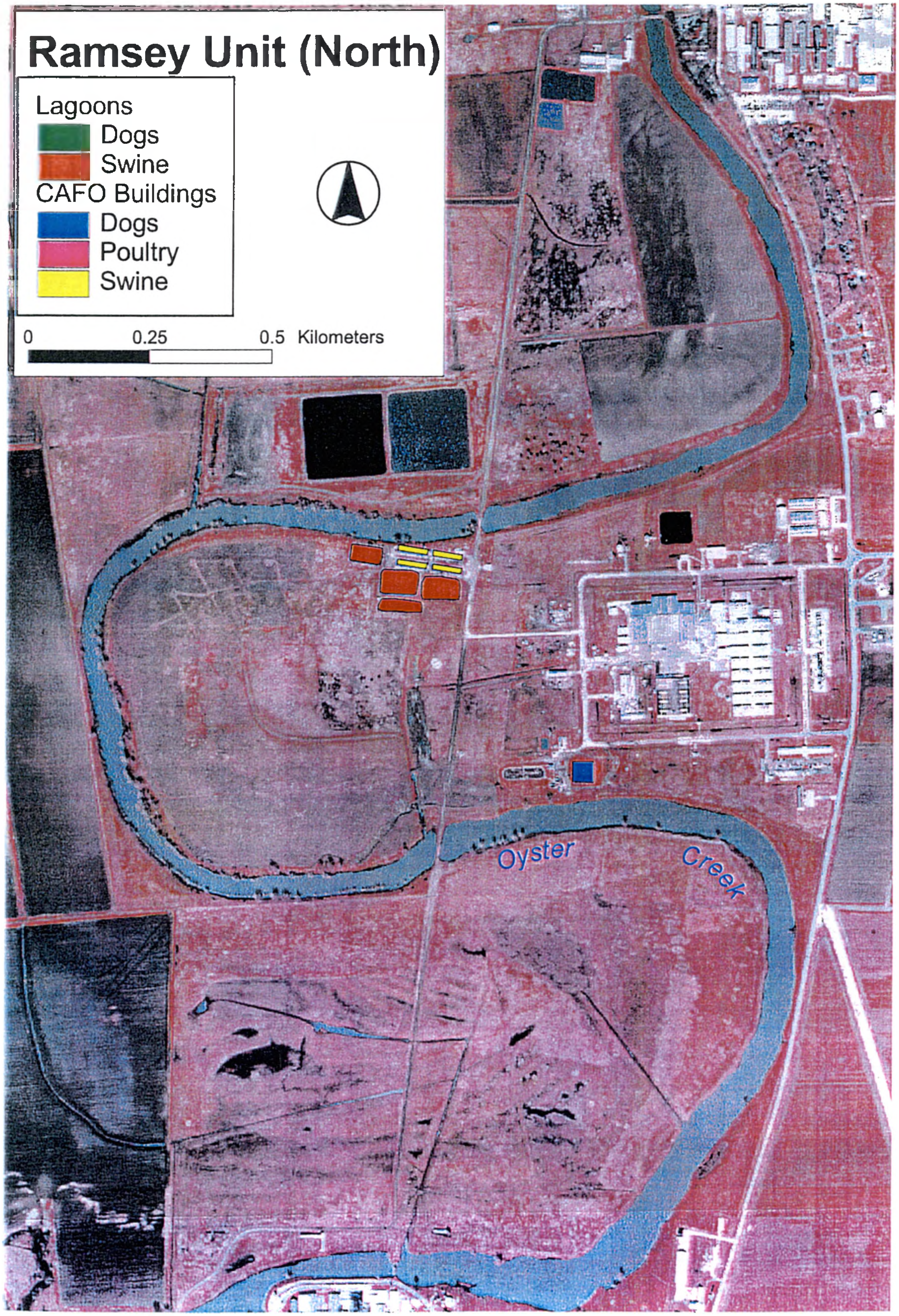


Figure 6. Ramsey Unit (North).

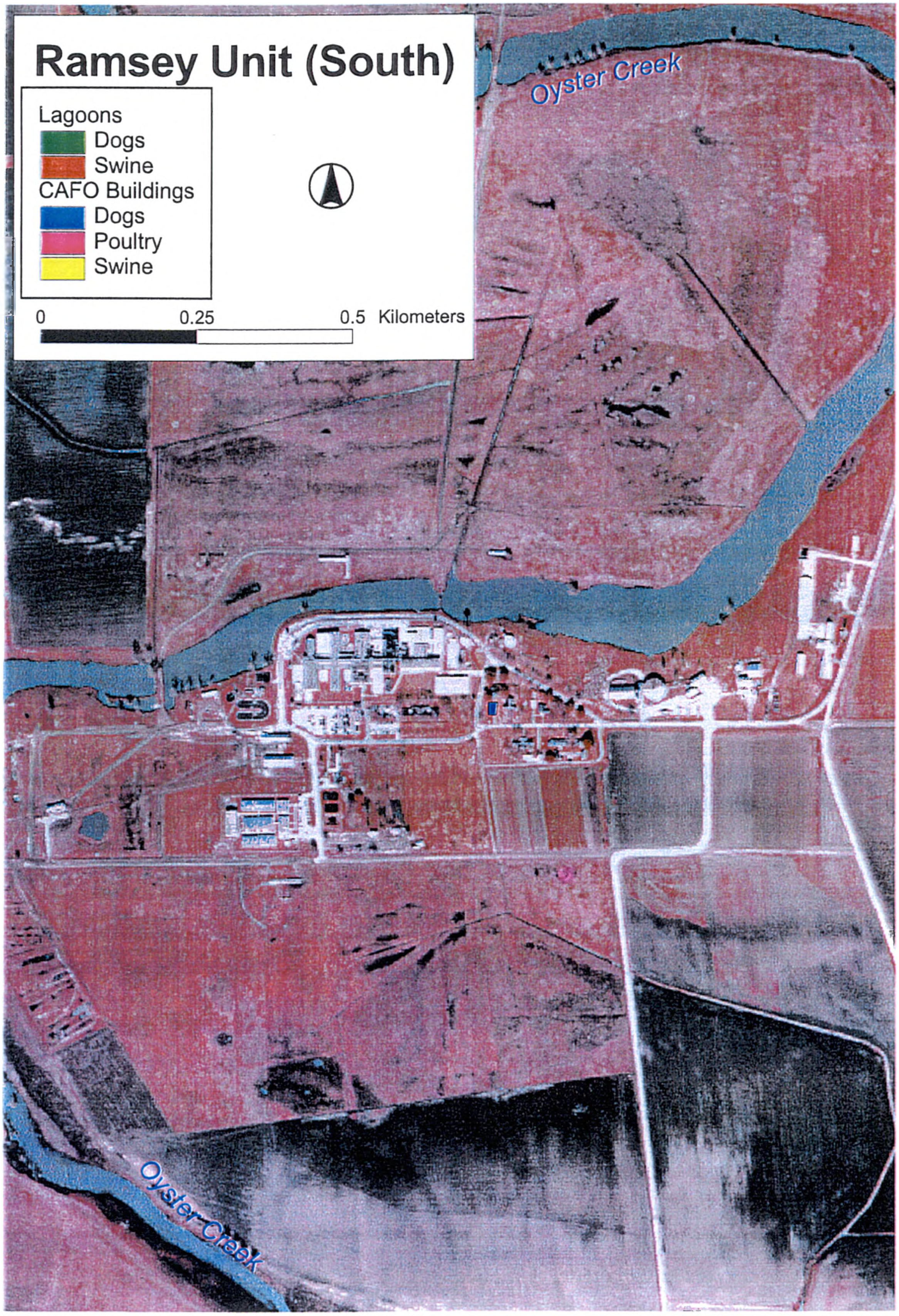


Figure 7. Ramsey Unit (South).

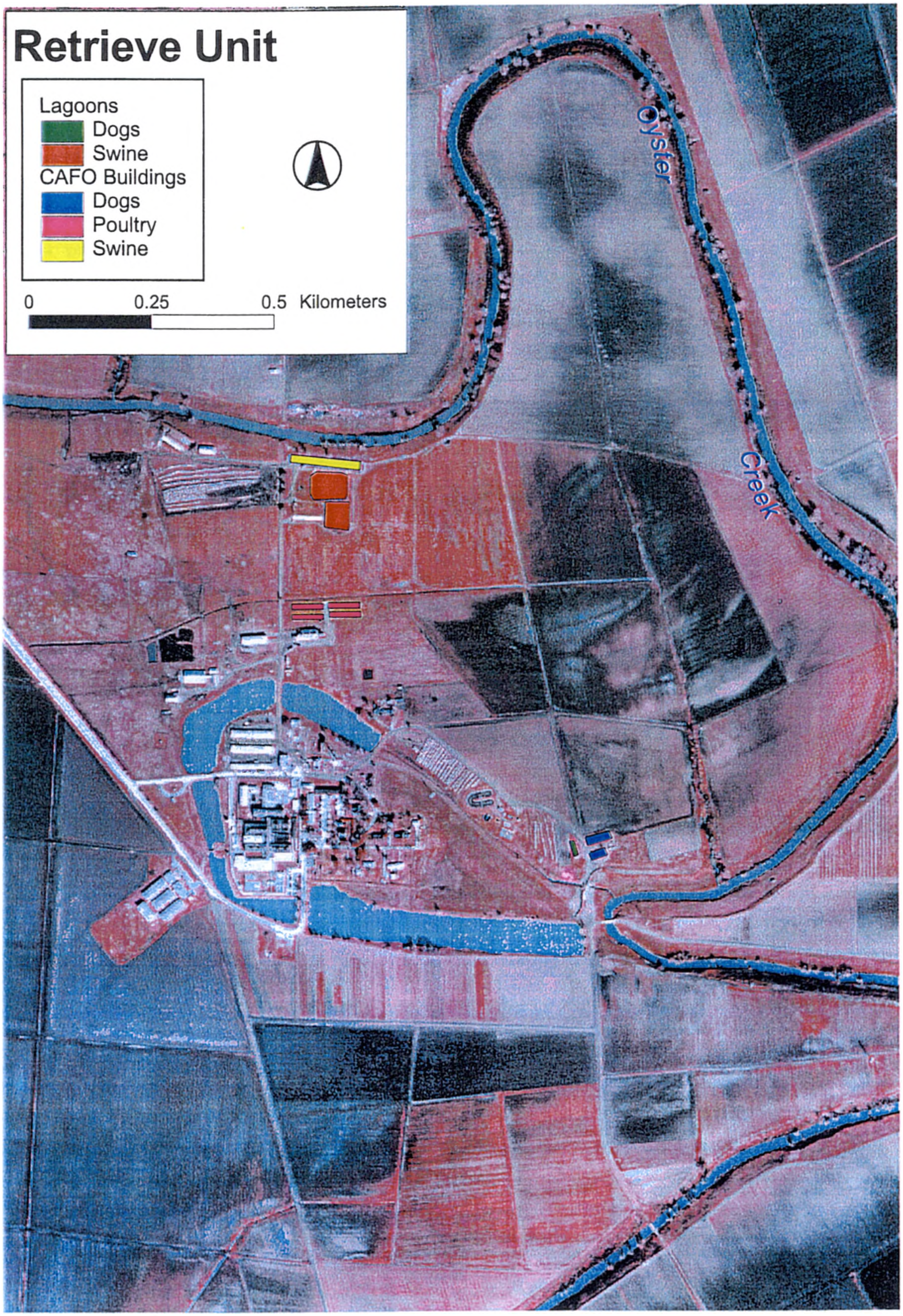


Figure 8. Retrieve Unit.

facilities were not visited. The other facilities may be more similar to a large-scale commercial farm than the Clemens Unit because of the larger number of animals they house relative to the Clemens Unit. Clemens is permitted to have a maximum of 300 head-swine, while the other units are permitted for between 1000 to 2000 head-swine.

One factor that differentiates a state-run facility from the large-scale commercial facilities is the large labor force, which contributes to the upkeep of the CAFOs by means of the inmate population. The entire prison farm system is designed to be extremely labor-intensive, and the result is meticulously kept facilities. The concrete slabs are manually washed daily in order to deliver the waste to the lagoons. Upon visiting the Clemens Unit lagoons, very little odor was detectable, and birds and turtles were found feeding on the leftover scraps of pig-feed, which were floating in the lagoons (Figure 9). Old tires are used as an erosion control device in the lagoons to help prevent spills. When placed against the banks of a lagoon, tires act to deter to the numerous turtles that live in the pond from digging into the lagoon walls, an act that can cause the walls of the lagoon to fail. The prison officials stated that they use the turtles that live in the lagoons as an indicator of the over-all cleanliness of the water. The Clemens Unit employs a three-stage lagoon at the feeder slab. Wastewater is sent from one lagoon to the next to aid in aeration and filtration of the water.

An estimated $1.3 million dollars is saved per year by feeding food scraps to the pigs rather than sending the food waste to the landfill. According to the prison personnel, the pigs prefer the scraps to the dry pellet food they are offered as well (Figure 10).

The largely self-sustaining Texas Prison system produces most of its own food to feed the inmates and prison personnel. They grow their own "garden-crops" such as

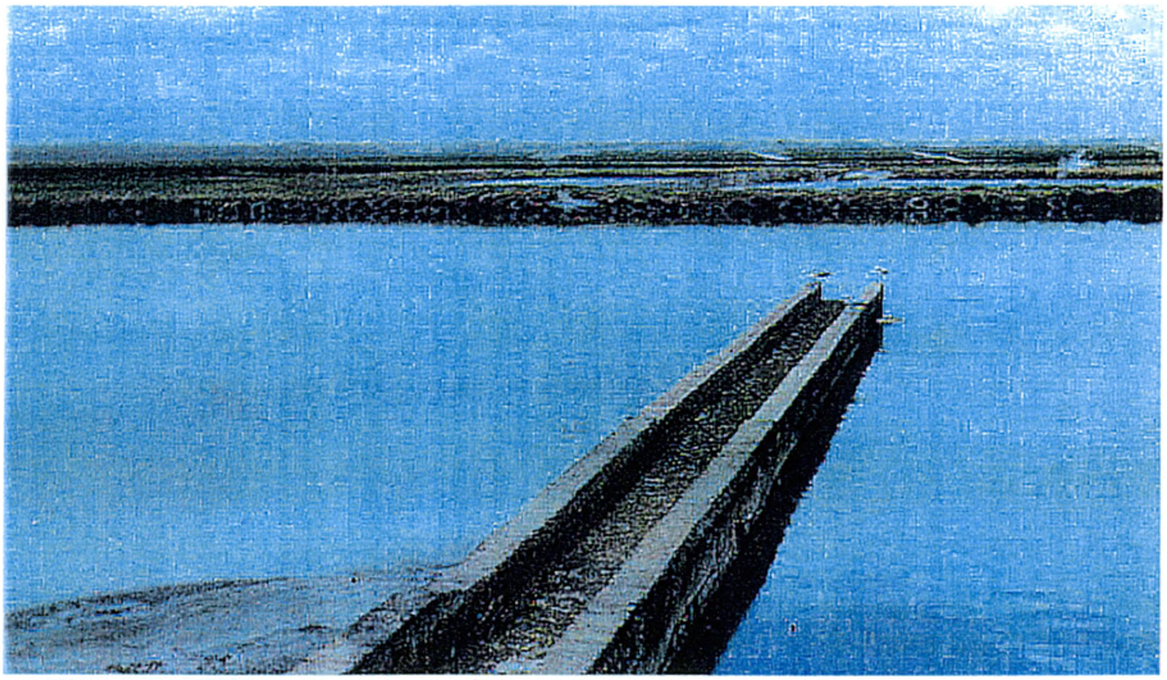


Figure 9. Clemens Unit Lagoon. Seagulls may be seen feeding at the end of the ramp, which delivers food scraps to the lagoon. The second and third stage lagoons may barely be seen in the distance.

Figure 10. Swine eating food scraps from the prison.

lettuce, green beans, and onions, as well as grain crops such as corn. Dry chicken manure is applied to the "garden crops" as fertilizer (Figure 11). No chicken waste is deposited in the Brazoria County waste lagoons – it is all used as fertilizer. Swine waste is not used as fertilizer, because it may contain pathogenic microorganisms. Large-scale commercial factory farms, like the ones found in North Carolina, generally have thousands of animals contributing to the waste in the lagoons, and are reportedly foul smelling and very full of waste (Sierra Club 2000). The conditions of the Ramsey, Retrieve and Darrington Units lagoons' is unknown by the author.

A factor in determining the location of CAFOs, and thereby the proximity to flood zones, mentioned by the prison officials, is that of the long history of prison farming in Brazoria County. According to the officials, these farms have been used for approximately one-hundred years – since the time they were leased from plantation owners. According to Lucko (1999), Texas bought the 2,238 hectare (5,527 acre) Clemens Farm in 1899. Texas then added an adjoining plantation that increased the size of Clemens to 20283 hectare (8,212 acres). In 1908, the State bought the 19172 hectare (7,762) acre Ramsey farm. By 1921, the 16665 hectare (6,747 acre) Darrington Farm and the 18347 hectare (7,428 acre) Retrieve Plantation were added to the Brazoria County prison farms. The actual amount of time the current hog and chicken facilities have been in use was unknown by the prison officials. According to the Clemens Unit personnel, information about the safest and best places to build facilities has been passed down over the many decades these farms have been running.

A third factor influencing the risk of Brazoria County, according to the Clemens Unit personnel, is that a state-run facility is held under higher scrutiny than commercial

Figure 11. Lettuce, one of the prison's garden-crops.

sites. State-run facilities are expected to be examples of properly run CAFOs that uphold state environmental laws and are built according to plans dictated by the state. One difficulty with running the Texas Department of Criminal Justice CAFOs is that they are expected to implement the best pollution prevention technology available while keeping their budgets as low as possible. The prison farms generally try to use the pollution prevention technology that is deemed the most affordable, but the least expensive may not be the best pollution prevention technology available. The Brazoria County prison farms are inspected annually to ensure they are following their TNRCC Pollution Prevention Plans.

Risk Assessment

Past Hurricane and Tropical Storm Investigation

In order to understand the impact of hurricane- or tropical storm-induced flooding on Brazoria County, two past flood events were evaluated – the flooding of October 1994 associated with Hurricane Rosa and the flooding associated with Tropical Storm Frances in 1998. In order to determine if the FEMA Digital Q3 data would be useful for describing these past floods, a determination had to made as to whether these floods ranked as 100-year or 500-year floods. USGS PEAKFQ (public domain MSDOS program) was used to analyze the peak stream flow gage heights for the stream gage on the Brazos River at Rosharon in Brazoria County. This program determined the flood recurrence intervals at a 95 percent confidence limit using Pearson type III regression analysis (Table 3). News reports of events associated with these flood occurrences were evaluated in order to gain an understanding of the impact these flood events had on the area (to be discussed in Chapter V – Results and Analysis).

Table 3. Recurrence Intervals (years) for Estimated Peak Stream Flow (ft^3/sec; m^3/sec)

Year	**Peak (ft^3/sec)**	**Peak (m^3/sec)**
1.25	27409.71	776.04
2	47112.25	1333.87
5	72983.23	2066.34
10	88293.37	2499.81
25	105302.7	2981.39
50	116368.9	3294.70
100	126199.8	3573.04
200	134985.8	3821.80
500	145233.7	4111.94

Possible Future Hurricane and Tropical Storm Risk Assessment

In order to describe the relationship between the risk factors, identified in Table 2, and the amount of impact the CAFO lagoons could have on the landscape, GIS spatial analysis was performed. The type of spatial analysis used is cost-weighted distance analysis, and was performed using ESRI's ArcMap© 2000 with the Spatial Analyst© 2000 extension.

This process involves the combination of data from several input grid themes by converting their cell values to a common scale, and then adding the weighted cell values together to create a "cost theme". In this case, cost was the likelihood of contaminants impacting the variables determined to be risk factors (either contributing to risk or at risk) on the landscape. The coverages that were used as risk factors described the locations of: public water supply sources, migratory bird nests, marinas, oyster farms, the Texas General Land Office (GLO) high priority areas and preserves, and 100-year and 500-year flood zones. Areas of lower elevation and steeper slope were determined to be areas contributing more significantly to risk and were classified to indicate that value. The Spatial Analyst extension was used to create a grid showing the slope characteristics of the area using the NED data. Arc/Info was used to clip the NED Grid to the area covered by the Brazoria County boundaries. Datasets representative of the input factors were translated into a grid format using ArcView Spatial Analyst. Each input shapefile or coverage was projected into UTM coordinates (Zone 15, NAD 83) with map units of meters. This step was done to ensure that the final grid would have a cell size with a unit of meters.

Next, the projected coverages and shapefiles were translated into GRIDs using ArcView Spatial Analyst. These grids were then reclassified so that they would have a common classification scale. According to Zuuring (1999) the human brain is limited in the number of classes that it can cope with. Zuuring (1999) recommends that seven classes plus or minus two per level in the hierarchy is the most "comfortable" number of classes the brain comprehends. Therefore, the elevation was classified into seven values – a value of seven was assigned to the lowest elevation, and a value of one was assigned to the highest elevation. This one to seven scale was applied to each risk factor – but in this case seven represented the geographic location of a risk factor and zero represented areas where no risk factor was found. There were two exceptions to this type of classification. The first exception was the 500 year flood plain, which was assigned a value of five to indicate the smaller probability of risk of flood than that of the 100-year flood plain. Another exception was the city layer, which was also given a value of five because of the fact that the broad delineation of a city does not directly indicate that flood water will come in contact with people or factors influencing human risk. The city boundary was used as a proxy factor for specific data regarding exact locations of human infrastructure. The value of five was subjectively and qualitatively selected for the 500-year flood zone and the city boundaries because there is no actual "value" representing the reduced risk that the 500-year flood zone and the city boundaries pose to the overall risk equation. The logic behind choosing the number five is that the value would still register as having an impact in the risk equation, yet would appear as having somewhat less of an impact. The cost-weighted distance method was selected for the analysis because one of its primary uses is to produce risk maps, and that was the desired output for this project. The cost-weighted method is also well suited for analyzing grids, which was the format selected for representing the data.

CHAPTER V

RESULTS AND ANALYSIS

The analysis concentrated on three areas. The first area of concentration was the determination of the severity of past storm events, and to ascertain the affect of these events on the CAFOs. The second area of concentration was the visual interpretation of the risk assessment maps. The final area of concentration was to evaluate the findings from the interview with the Clemens Unit personnel.

Past Hurricane or Tropical Storm Induced Flood Events

Past Flood Recurrence Interval Ratings

Using the USGS PEAKFQ software program, a determination was made that neither of the past tropical storm or hurricane induced flood events that were evaluated would be considered a 25-year, 100-year or 500-year flood event (Appendix H). The October 1994 flood was almost at the level of a 10-year flood event, and the highest stream-flow rating in recorded history was registered during the time of that flood. Both of these floods had considerable impact on Brazoria County, however the Texas Department of Criminal Justice personnel stated that neither of these events caused the Brazoria County CAFO lagoons to become inundated or to fail. In fact, they stated that the Brazoria County lagoons have never failed because of a flood event.

October 1994 Floods

The remnant of Hurricane Rosa brought heavy rain to the Houston-Galveston area from October 17th to the 21st of 1994 (Duprè 1995). A convection cell fed by the jet-stream of Hurricane Rosa formed and produced large amounts of rain in the Gulf of Mexico (Duprè 1995). These events caused a subsequent "super-cell" to develop, which produced up to thirty 750 millimeters (30 inches) of rain in the Houston-Galveston area over a four day period (Duprè 1995), and caused the Brazos River to remain flooded until October 27th, 1994 (National Weather Service of Houston/Galveston 2001). During this time, a peak stream flow rate was measured at the Rosharon gage on the Brazos of 2389.58 m^3/sec (84,400 ft^3/sec) with a gage height of 15.79 meters (51.82 feet) (United State Geological Survey 1999). A total of seventeen people were killed, $900 million in damage to homes, bridges and agriculture occurred, and over 22,000 homes were flooded throughout the area from this storm (National Weather Service of Houston/Galveston 2001). According to the results of the PEAKFQ analysis, a streamflow rate of 2499.81 m^3/sec (88,293.37 ft^3/sec) would cause a ten-year flood for the Rosharon streamflow gage. Therefore, there is a four-percent chance of this type of flood occurring in any one year.

Tropical Storm Frances

Tropical Storm Frances brought a maximum of 32 millimeters (sixteen inches) of rain to Brazoria County, measured over the period of September 10th through the 13th of 1998 (National Oceanographic and Atmospheric Organization 2001). The high amount of rain combined with tides that were running 1 – 2 meters above normal did not allow the rain to easily run off into the bays, resulting in more widespread flooding of inland creeks and bayous (Del Greco and Hinson 1998). The peak discharge during Tropical Storm Frances, measured at Rosharon, was 520.95 m^3/sec (18,400 ft^3/sec), with a gage-height of twenty-four feet. According to the PEAKFQ computations, this flood does not reach the 1.25-year flood rate of 776.04 m^3/sec (27409.71 ft^3/sec) (Table 3), with a gage-height of approximately thirty feet, which means there is a an eighty-percent chance of a flood like this occurring in any one year. Many small, ungaged watersheds flooded, including Oyster Creek, which flows very near the Ramsey, Retrieve and Darrington prison farms. This storm had a major impact and consequent damage in Galveston, Harris, Brazoria and Matagorda Counties in Texas, which received Presidential Disaster Declarations. The total damage for all counties surpassed $286 million dollars (Del Greco and Hinson 1998).

Risk Assessment Map Interpretation

The cost-weighted distance analysis procedure produced three maps. The first map represents the cost surface of risk factors for Brazoria County (Figure 12). This map indicates the locations of the input risk factors and shows where multiple layers cross each other and their relative values. The second map (Figure 13) shows the final cost-weighted distance surface along with the basic locations of the CAFO lagoons, and gives the observer an indication of the general dispersal of risk throughout the county. The final map shows the cost-weighted distance surface and is superimposed by the 1998 TIGER/LINE themes for roads, railroads, and rivers, and the locations of the risk factors (Figure 14). This final map is suitable for determining the severity of risk for each of the "at risk" factors. For example, using this map, the number of public water supply sources that are in a high-risk area in Brazoria County can be determined. Four additional maps were created from the cost-weighted distance surface map – each showing a close-up of the individual prison farms (Figures 15-18). These maps indicated that the Darrington Unit (Figure 15) has fourteen public water supply sources (PWSS), and one migratory bird nest in the "high-risk" vicinity. The Ramsey unit (Figure 16) has six PWSS and two migratory bird nests in the "high-risk" vicinity. The Retrieve Unit (Figure 17) has 40 PWSS, and the Clemens Unit (Figure 18) 36 PWSS in the "high-risk" vicinity.

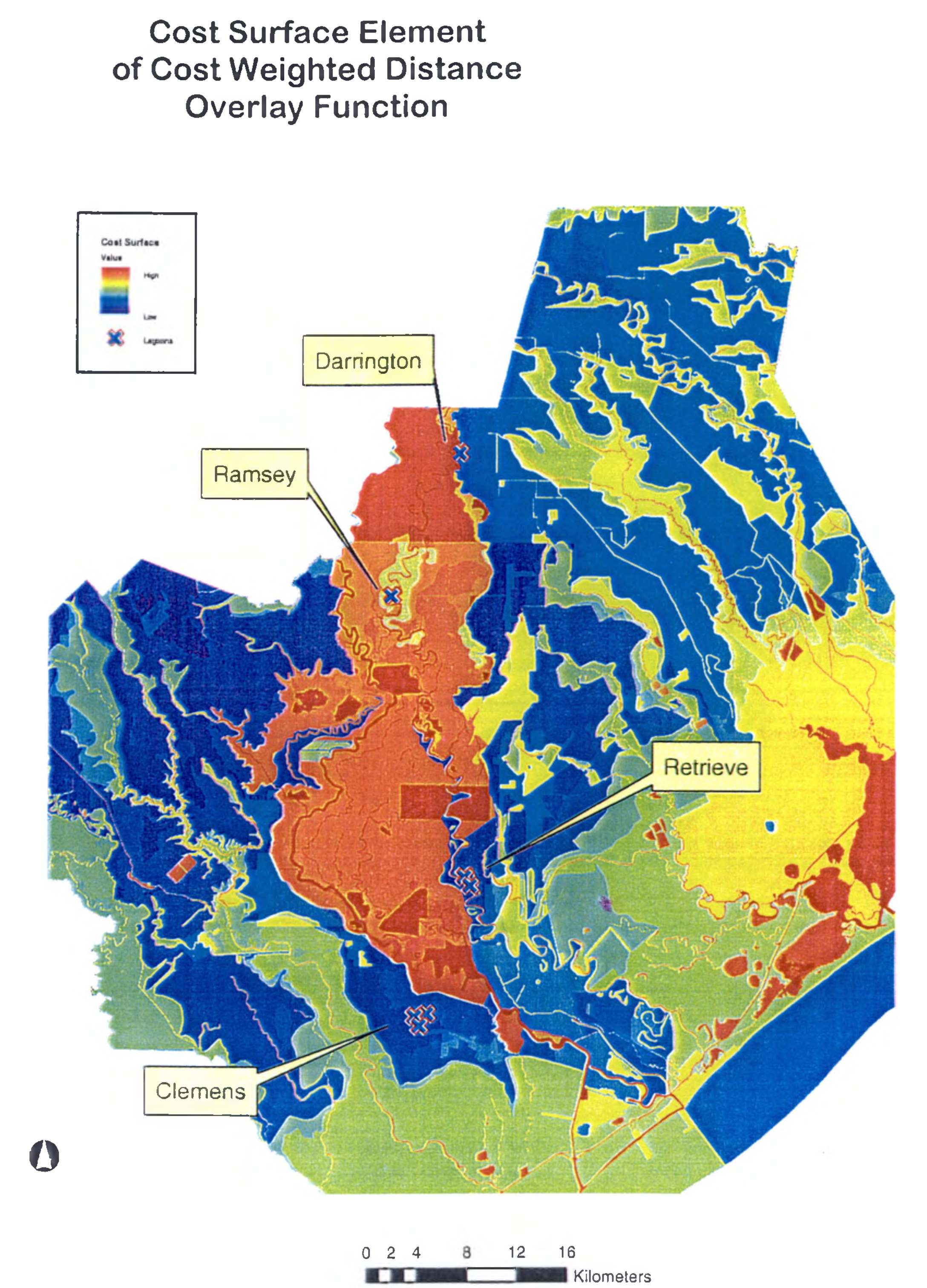


Figure 12. Cost Surface Element of Cost Weighted Distance Overlay Function

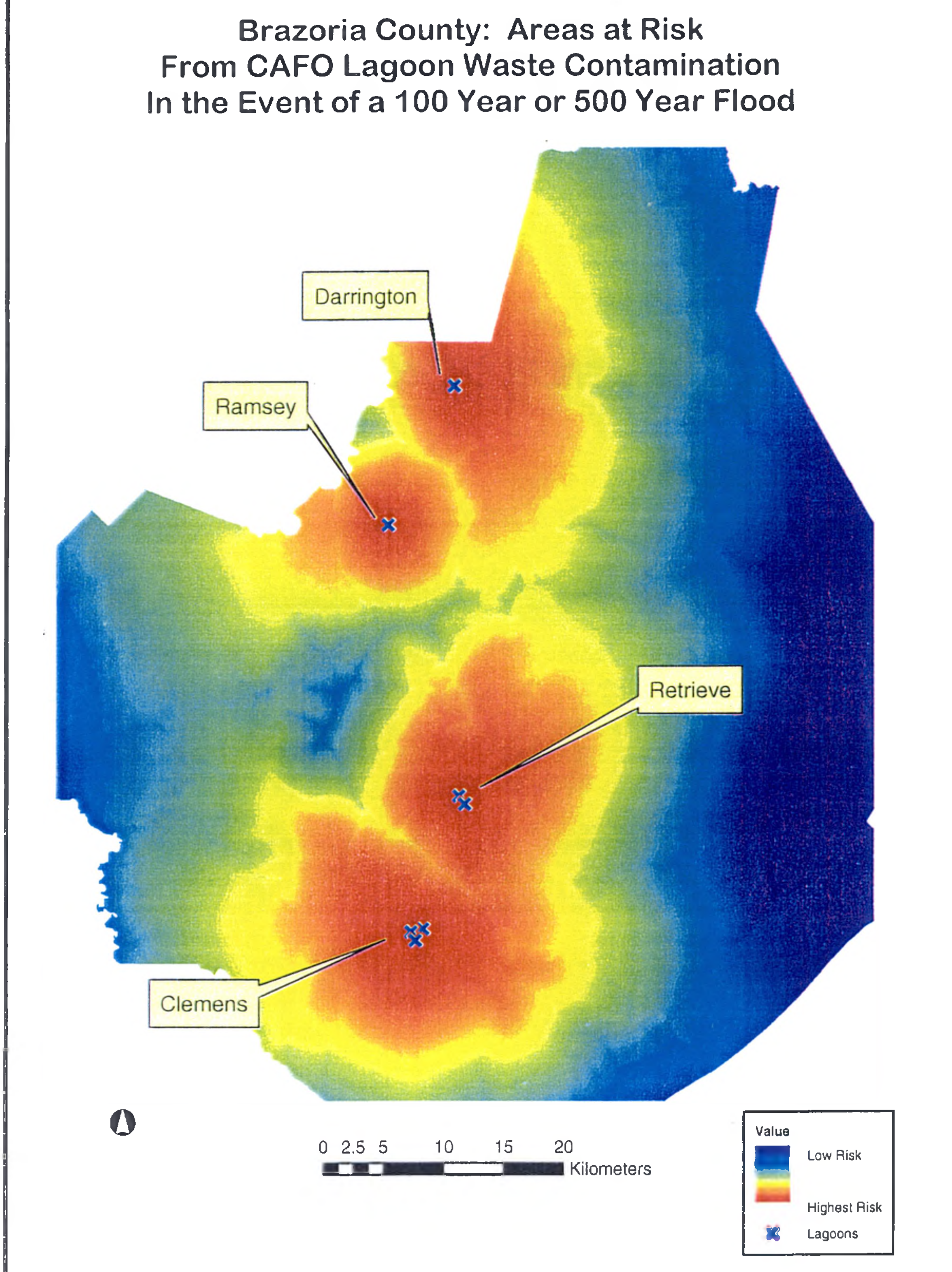


Figure 13. Areas at Risk from CAFO Lagoon Waste Contamination.

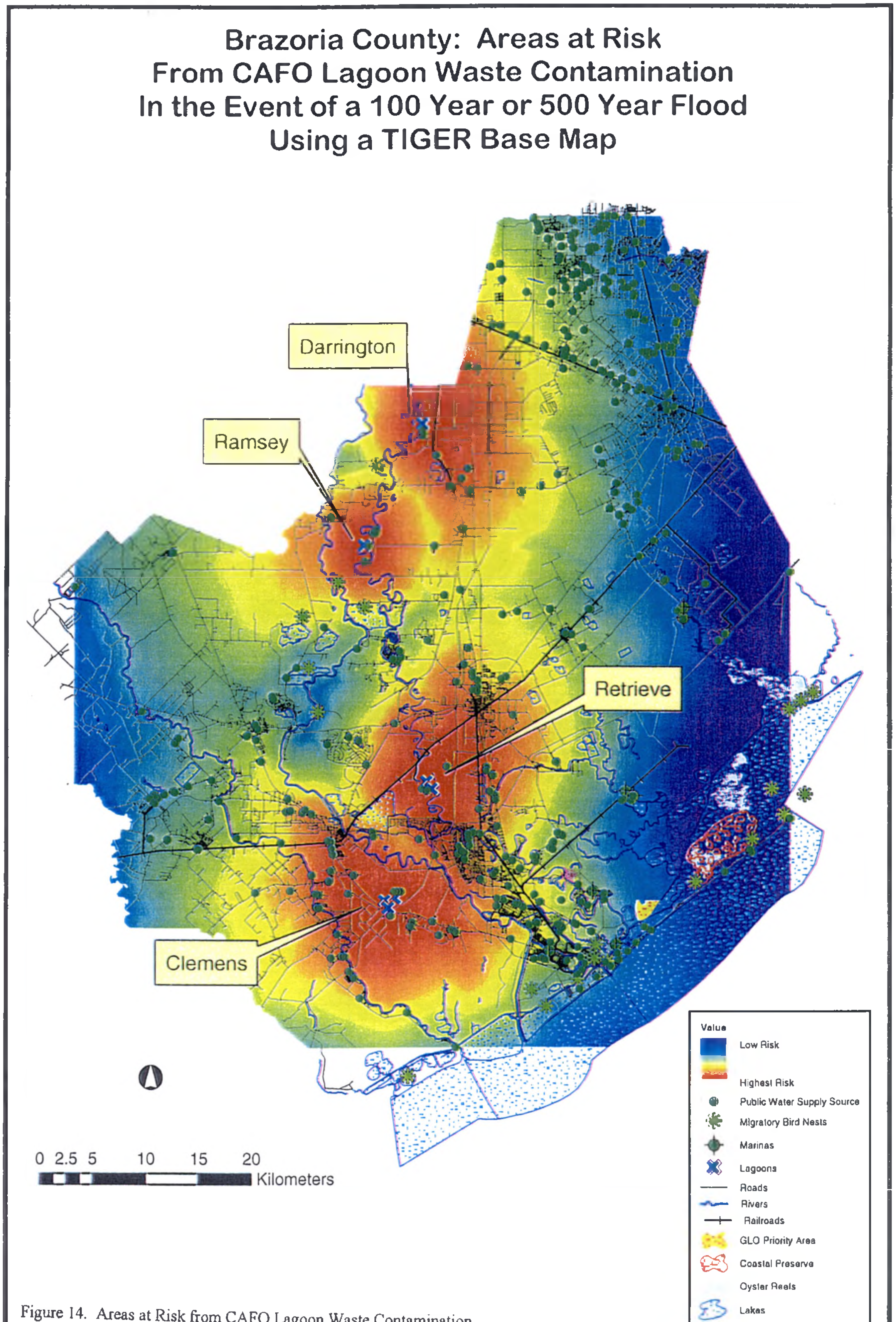


Figure 14. Areas at Risk from CAFO Lagoon Waste Contamination.

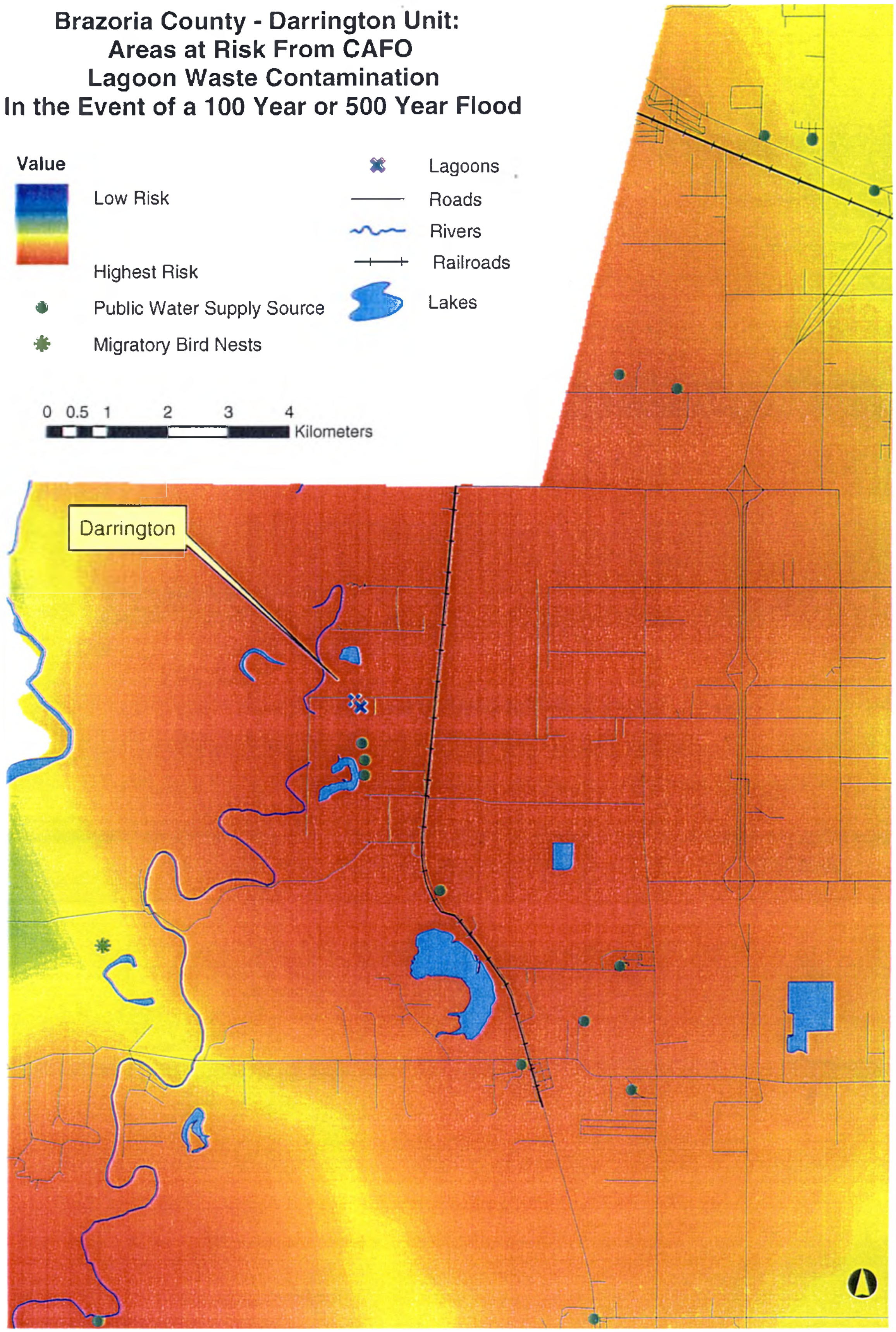


Figure 15. Darrington Unit.

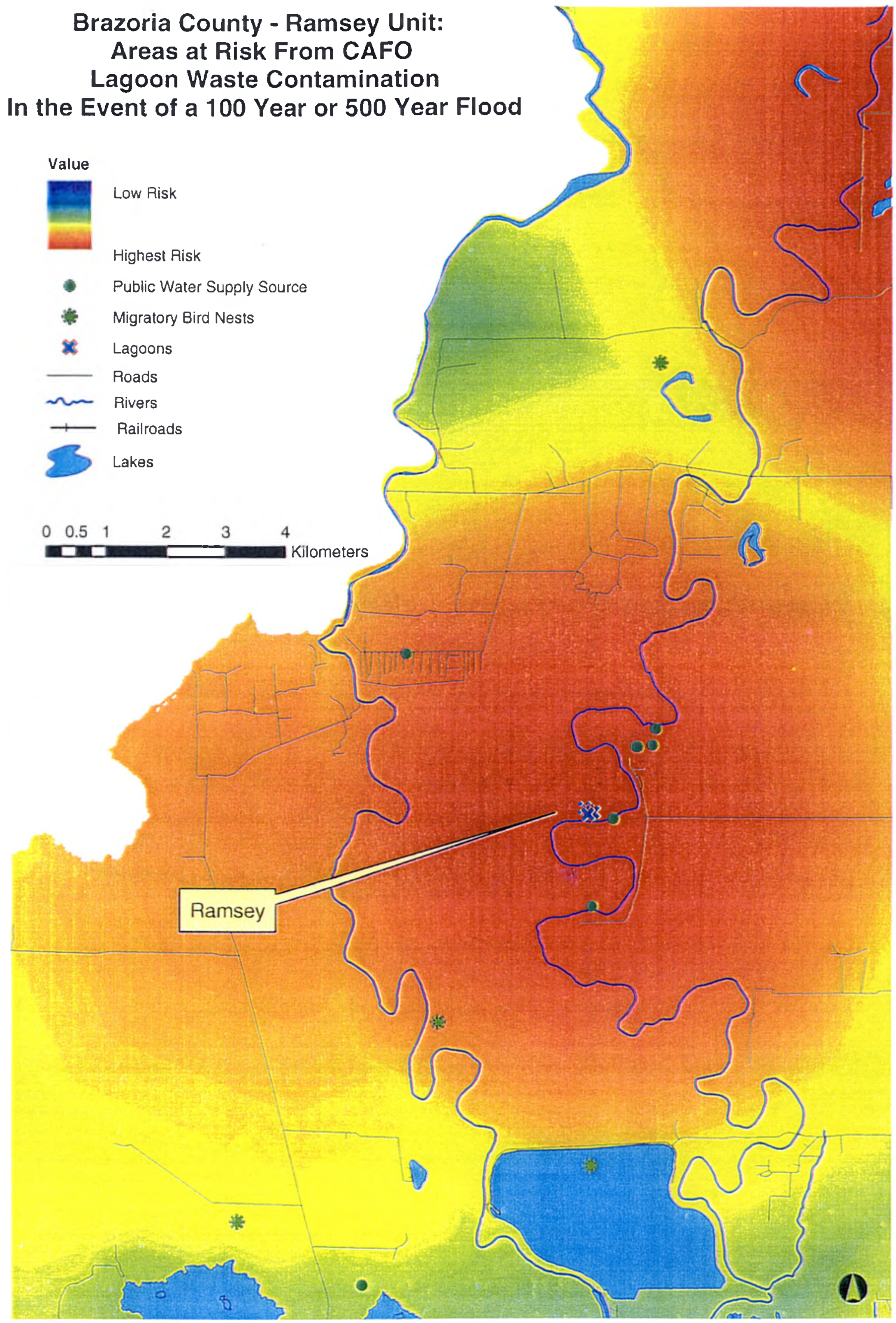


Figure 16. Ramsey Unit.

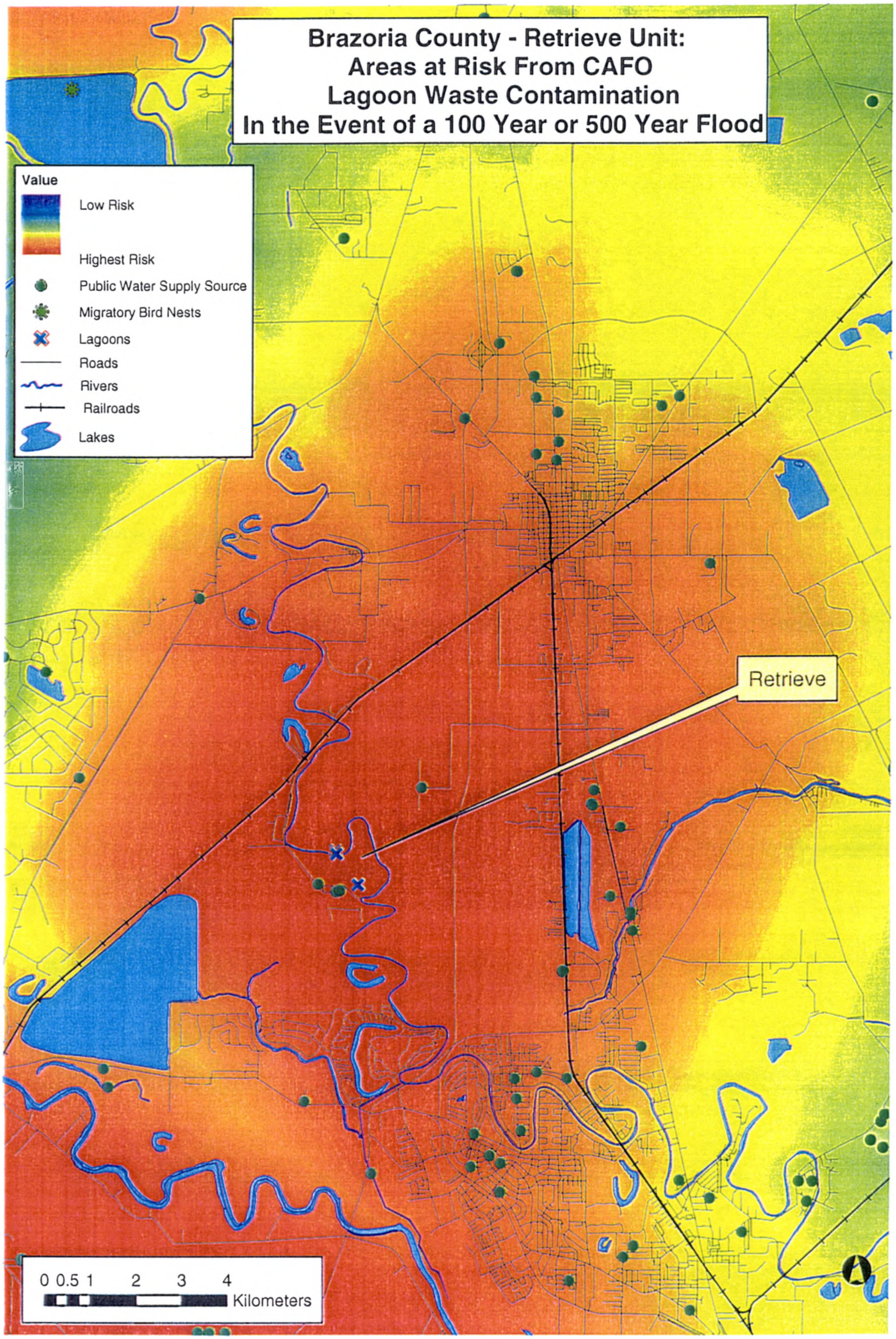


Figure 17. Retrieve Unit.

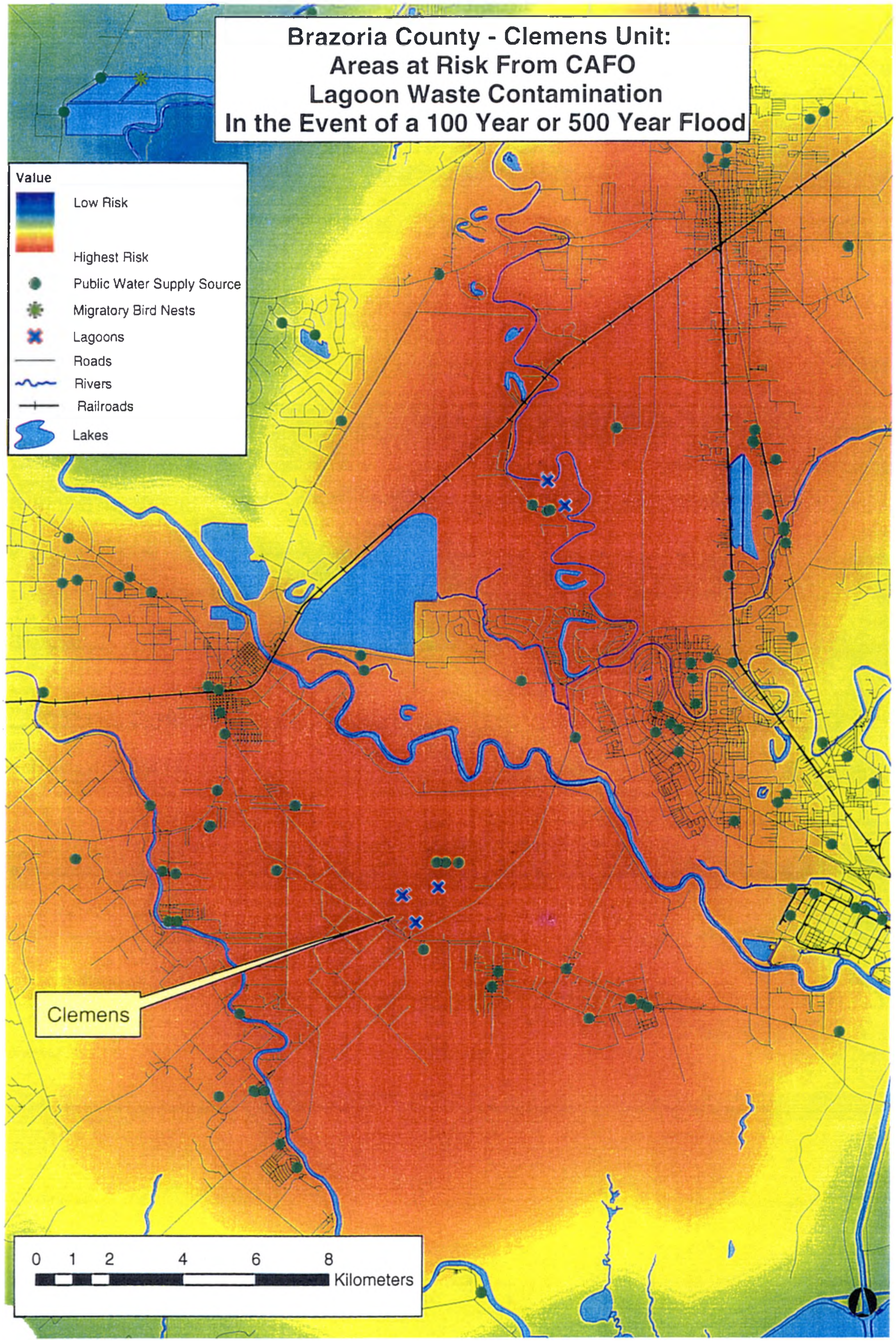


Figure 18. Clemens Unit.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

A CAFO waste lagoon spill may harm the local environment, human health and safety, and the local economy of an area. Hurricane Floyd caused tremendous harm and contamination when inland flooding inundated North Carolina's CAFOs built in the floodplains. Because of the potential damage that can be inflicted on hurricane-prone coasts, a risk assessment should be performed in such areas. The focus of this research was to evaluate the potential risk of hurricane-induced CAFO flooding in Brazoria County, Texas. An overlay technique based on the research of Emani et al. (1993) using ESRI's ArcView GIS, Arc/INFO and ArcMap with the Spatial Analyst extension was used to determine the risk of contamination and to determine what factors are most at risk secondary to distance, elevation and slope relative to the sources of contamination.

The risk assessment maps that resulted from the cost-weighted distance technique indicate a large number of factors located in "high-risk" areas in Brazoria County. There are 96 public water supply sources found to be at "high-risk" from flooding and three migratory bird nesting areas. According to the literature, waste lagoon effluent has been reported to travel approximately 50 meters over dry land and 130 kilometers in streams. If waste can travel 130 kilometers in a running stream, and Brazoria County is only about fifty kilometers long and seventy kilometers wide, this fact suggests that most of Oyster Creek faces some risk of lagoon contamination. The cost-weighted distance tool offers the ability to divide the risk into gradations – and offers a qualitative result such as high-risk areas, moderate-risk areas, and comparatively low-risk areas. This assessment is relative, in that all risks are estimated according to their topography in relation to the location of other risk factors. The findings of this risk assessment should be used to gain knowledge of approximate locations of risk. Risk areas could be further assessed on a larger scale and "ground-truthed" to subsequently evaluate the characteristics of vulnerable populations.

This research is based on available data products, and therefore is limited by the quality and accessibility of these products. To improve the findings discussed here, additional data products could be obtained and included in the analysis. The October 1994 and September 1998 floods could have been delineated if satellite imagery were available. Using satellite imagery of Brazoria County, taken just after the floods and at another later date, change detection analysis could have been performed. Change detection would entail taking the two images and subtracting the grayscale reflectance values for each grid cell from each date from each other. This subtraction would leave values that would indicate the difference in reflectance values from each date, or where change had occurred over time. In the case of flooding, the changes that would be revealed might be water level differences and vegetation modification from flood damage. Change detection could have provided a delineation of the flood extent in Brazoria County, and knowing the location of the flood water would have offered a better understanding of the impacts of these severe floods. If the flood events of differing levels were compared, this comparison would have put the magnitude of the100-year and 500-year flood events into better perspective.

A basic knowledge of soil patterns in Brazoria County shows that the types of soils found near Oyster Creek may contribute to the chance of flooding in this area. The two main types of soils that are found around Oyster Creek are Pledger-Brazoria soils, and Asa-Norwood soils (Figure 19). Pledger-Brazoria soils are clayey and rather poorly drained. Asa-Norwood soils are loamy, well-drained, moderately permeable, and found on bottom lands. Both of these soils have a susceptibility to flooding (Crenwelge et al. 1981). More detailed soil information, combined with results of the change detection analysis could provide a useful understanding of the flood potential of the area near the CAFOs in Brazoria County.

The results of this study provide a baseline determination of areas at risk from contamination should inland flooding cause a lagoon-waste spill. This information may be useful in many aspects of hazards research. The "risk-map" produced from this research could be used in planning, mitigation, preparation, and response to hazards. An example of to which these four aspects of hazards readiness could be applied is the siting and safety of groundwater wells. According to the University of Missouri-Columbia (1999), improperly constructed or poorly maintained wells can allow bacteria, pesticides, fertilizer or oil products to contaminate groundwater, and these contaminants can put human and livestock health at risk. This map could be used in planning where to dig future water wells or decide on the type of well equipment that is needed, in order to avoid the risk of possible contamination. Measures could be taken to prevent contamination to the wells that exist in "high-risk" areas, thereby providing mitigation to possible flooding events. This map might be used in preparation for a possible future flood event by identifying people whose drinking water may become contaminated by flood water and may need potable water brought to them. Finally, the map could be used in response to hazards if it were distributed to emergency management personnel during a flood crisis, so that they may analyze this aspect of the situation – adding to the information that determines where their resources may be most needed.

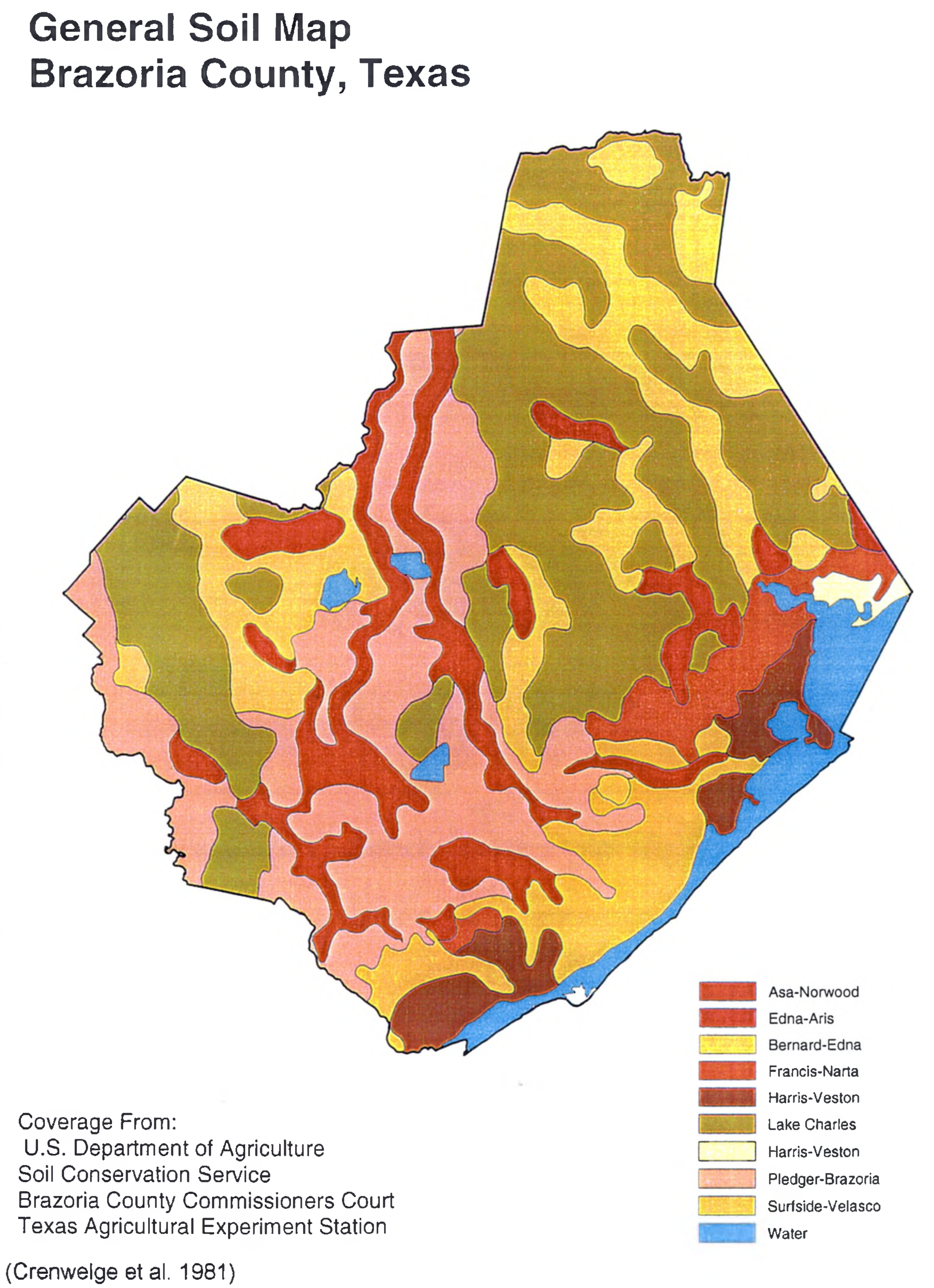


Figure 19. Soil Map

APPENDIX A

SAFFIR SIMPSON HURRICANE SCALE

The Saffir-Simpson Hurricane Scale

(Source: Todd Spindler and Jack Beven 1999 - National Hurricane Center of the National Oceanographic and Atmospheric Organization)

The Saffir-Simpson Hurricane Scale is a 1-5 rating based on the hurricane's present intensity. This is used to give an estimate of the potential property damage and flooding expected along the coast from a hurricane landfall. Wind speed is the determining factor in the scale, as storm surge values are highly dependent on the slope of the continental shelf in the landfall region. Note that all winds are using the U.S. 1-minute average.

Category One Hurricane:

Winds 119-153 km/hr (64-82 kt or 74-95 mph). Storm surge generally 4-5 ft above normal. No real damage to building structures. Damage primarily to unanchored mobile homes, shrubbery, and trees. Some damage to poorly constructed signs. Also, some coastal road flooding and minor pier damage. Hurricanes Allison of 1995 and Danny of 1997 were Category One hurricanes at peak intensity.

Category Two Hurricane:

Winds 154-177 km/hr (83-95 kt or 96-110 mph). Storm surge generally 2 – 3 meters above normal. Some roofing material, door, and window damage of buildings. Considerable damage to shrubbery and trees with some trees blown down. Considerable damage to mobile homes, poorly constructed signs, and piers. Coastal and low-lying escape routes flood 2-4 hours before arrival of the hurricane center. Small craft in unprotected anchorage break moorings. Hurricane Bonnie of 1998 was a Category Two hurricane when it hit the North Carolina coast, while Hurricane Georges of 1998 was a Category Two Hurricane when it hit the Florida Keys and the Mississippi Gulf Coast.

Category Three Hurricane:

Winds 178-209 km/hr (96-113 kt or 111-130 mph). Storm surge generally 9-12 ft above normal. Some structural damage to small residences and utility buildings with a minor amount of curtainwall failures. Damage to shrubbery and trees with foliage blown off trees and large tress blown down. Mobile homes and poorly constructed signs are destroyed. Low-lying escape routes are cut by rising water 3-5 hours before arrival of the hurricane center. Flooding near the coast destroys smaller structures with larger structures damaged by battering of floating debris. Terrain continuously lower than 5 ft above mean sea level may be flooded inland 13 km (8 miles) or more. Evacuation of low-lying residences with several blocks of the shoreline may be required. Hurricanes Roxanne of 1995 and Fran of 1996 were Category Three hurricanes at landfall on the Yucatan Peninsula of Mexico and in North Carolina, respectively.

Category Four Hurricane:

Winds 210-249 km/hr (114-135 kt or 131-155 mph). Storm surge generally 13-18 ft above normal. More extensive curtainwall failures with some complete roof structure failures on small residences. Shrubs, trees, and all signs are blown down. Complete destruction of mobile homes. Extensive damage to doors and windows. Low-lying escape routes may be cut by rising water 3-5 hours before arrival of the hurricane center. Major damage to lower floors of structures near the shore. Terrain lower than 10 ft above sea level may be flooded requiring massive evacuation of residential areas as far inland as 10 km (6 miles). Hurricane Luis of 1995 was a Category Four hurricane while moving over the Leeward Islands. Hurricanes Felix and Opal of 1995 also reached Category Four status at peak intensity.

Category Five Hurricane:
Winds greater than 249 km/hr (135 kt or 155 mph). Storm surge generally greater than 18 ft above normal. Complete roof failure on many residences and industrial buildings. Some complete building failures with small utility buildings blown over or away. All shrubs, trees, and signs blown down. Complete destruction of mobile homes. Severe and extensive window and door damage. Low-lying escape routes are cut by rising water 3-5 hours before arrival of the hurricane center. Major damage to lower floors of all structures located less than 15 ft above sea level and within 500 yards of the shoreline. Massive evacuation of residential areas on low ground within 8-16 km (5-10 miles) of the shoreline may be required. Hurricane Mitch of 1998 was a Category Five hurricane at peak intensity over the western Caribbean. Hurricane Gilbert of 1988 was a Category Five hurricane at peak intensity and is the strongest Atlantic tropical cyclone of record.

APPENDIX B

EXCERPT FROM (1998) U.S. ENVIRONMENTAL PROTECTION AGENCY "RISK ASSESSMENT GUIDELINES"

Risk Assessment Guidelines

(Source: United States Environmental Protection Agency 1998)

Source and Stressor Characteristics

- What is the source? Is it anthropogenic, natural, point source, or diffuse nonpoint?
- What type of stressor is it: chemical, physical, or biological?
- What is the intensity of the stressor (e.g., the dose or concentration of a chemical, the magnitude or extent of physical disruption, the density or population size of biological stressor)?
- What is the mode of action? How does the stressor act on organisms or ecosystem functions?

Exposure Characteristics

- With what frequency does a stressor event occur (e.g., is it isolated, episodic, or continuous; is it subject of natural daily, seasonal, or annual periodicity)?
- What is its duration? How long does it persist in the environment (e.g., for chemical, what is its half-life, does it bioaccumulate; for physical, is habitat alteration sufficient to prevent recover; for biological, will it reproduce and proliferate);
- What is the timing of exposure? When does it occur in relation to critical organism life cycles or ecosystem events (e.g., reproduction, lake overturn)?
- What is the spatial scale of exposure? Is the extent or influence of the stressor local, regional, global, habitat-specific, or ecosystem-wide?
- What is the distribution? How does the stressor move through the environment (e.g., for chemical, fate and transport; for physical, movement of physical structures; for biological, life-history dispersal characteristics)?

Ecosystems Potentially at Risk

- What are the geographic boundaries? How do they relate to functional characteristics of the ecosystem?

- What are the key abiotic factors influencing the ecosystem (e.g., climatic factors, geology, hydrology, soil type, water quality)?
- Where and how are functional characteristics driving the ecosystem (e.g., energy source and processing, nutrient cycling)?
- What are the structural characteristics of the ecosystem (e.g., species number and abundance, trophic relationships)?
- What habitat types are present?
- How do these characteristics influence the susceptibility (sensitivity and likelihood of exposure) of the ecosystem to the stressor(s)?
- Are there unique features that are particularly valued (e.g., the last representative of an ecosystem type)?
- What is the landscape context within which the ecosystem occurs?
- Ecological Effects
- What are the type and extent of available ecological effects information (e.g., field surveys, laboratory tests, or structure-activity relationships)?
- Given the nature of the stressor (if known), which effects are expected to be elicited by the stressor?
- Under what circumstances will effects occur?

APPENDIX C

TEXAS ADMINISTRATIVE CODE
TITLE 30 ENVIRONMENTAL QUALITY
PART 1 TEXAS NATURAL RESOURCE CONSERVATION COMMISSION
CHAPTER 321 CONTROL OF CERTAIN ACTIVITIES BY RULE
SUBCHAPTER B CONCENTRATED ANIMAL FEEDING OPERATIONS
RULE §321.31 Waste and Wastewater Discharge and Air Emission Limitations

(a) Pursuant to §305.1 of this title (relating to Scope and Applicability), it is the policy of the Texas Natural Resource Conservation Commission that there shall be no discharge or disposal of waste or wastewater from animal feeding operations into or adjacent to waters in the state, except in accordance with subsection (b) of this section, any individual permits issued by the commission prior to the effective date of these rules, or a CAFO general permit issued or adopted by the commission. Waste and wastewater generated by a CAFO under this subchapter shall be retained and utilized in an appropriate and beneficial manner as provided by commission rules, orders, registrations, authorizations, CAFO general permits, or individual permits.

(b) Wastewater may be discharged to waters in the state from CAFOs authorized to operate under this subchapter whenever rainfall events, either chronic or catastrophic, cause an overflow of process wastewater from a facility designed, constructed, and properly operated to contain process generated wastewaters plus the runoff (storm water) from a 25-year, 24-hour rainfall event for the location of the facility authorized under this subchapter. There shall be no effluent limitations on discharges from retention structures constructed, operated, and maintained to contain the 25-year, 24-hour storm event if the discharge is the result of a rainfall event which exceeds the design capacity, and the retention structure has been properly operated and maintained. Retention structures shall be designed in accordance with §321.39 of this title (relating to Pollution Prevention Plans). Facilities authorized under this rule shall comply with §305.125 of this title (relating to Standard Permit Conditions) and all applicable permit conditions contained in TNRCC rules.

(c) Facilities shall be operated in such a manner as to prevent the creation of a nuisance or a condition of air pollution as mandated by Texas Health and Safety Code, Chapters 341 and 382.

Source Note: The provisions of this §321.31 adopted to be effective April 1, 1987, 12 TexReg 904; amended to be effective September 18, 1998, 23 TexReg 9354; amended to be effective July 27, 1999, 24 TexReg 5721

APPENDIX D

TEXAS ADMINISTRATIVE CODE
TITLE 30 ENVIRONMENTAL QUALITY
PART 1 TEXAS NATURAL RESOURCE CONSERVATION COMMISSION
CHAPTER 321 CONTROL OF CERTAIN ACTIVITIES BY RULE
SUBCHAPTER B CONCENTRATED ANIMAL FEEDING OPERATIONS
RULE §321.39 Pollution Prevention Plans

(a) A pollution prevention plan shall be developed for each CAFO covered under this subchapter. Pollution prevention plans shall be prepared in accordance with good engineering practices and shall include measures necessary to limit the discharge of pollutants to waters in the state. The plan shall describe and ensure the implementation of practices which are to be used to assure compliance with the limitations and conditions of this subchapter. The plan shall identify a specific individual(s) at the facility who is responsible for development, implementation, maintenance, and revision of the pollution prevention plan. The activities and responsibilities of the pollution prevention personnel shall address all aspects of the facility's pollution prevention plan.

(b) Where a NRCS plan has been prepared for the facility, the pollution prevention plan may refer to the NRCS plan when the NRCS plan documentation contains equivalent requirements for the facility. When the operator uses a NRCS plan as partial completion of the pollution plan, the NRCS plan must be kept on site. Design and construction criteria developed by the NRCS can be substituted for the documentation of design capacity and construction requirements (see subsection (f) of this section) of the pollution prevention plan provided the required inspection logs and water level logs in subsection (f)(3) and (11) of this section are kept with the NRCS Plan. Waste management plans developed by the NRCS can be substituted for the documentation of application rate calculations in subsection (f)(19) and (24) of this section. NRCS Waste Management Plans which have been prepared since January 1, 1989 are considered by the Natural Resources Conservation Service to contain adequate management practices. To insure the protection of water quality, the Natural Resources Conservation Service has determined that NRCS plans prepared prior to 1989 must be submitted for renewal with the Natural Resources Conservation Service or a waste management professional before December

1995. NRCS has determined that all plans should be reviewed every five (5) years to insure proper management of wastes.

(c) The plan shall be signed by the operator or other signatory authority in accordance with §305.44 of this title (relating to Signatories to Applications), and be retained on site. The plan shall be updated as appropriate.

(d) Upon completion of a plan review, the executive director may notify the operator at any time that the plan does not meet one or more of the minimum requirements of this subchapter. After such notification from the executive director, the operator shall make changes to the plan within 90 days after such notification unless otherwise provided by the executive director.

(e) The operator shall amend the plan prior to any change in design, construction, operation, or maintenance, which has a significant effect on the potential for the discharge of pollutants to waters in the state or if the pollution prevention plan proves to be ineffective in achieving the general objectives of controlling pollutants in discharges from concentrated animal feeding operations.

(f) The plan shall include, at a minimum, the following items.

> (1) Each plan shall provide a description of potential pollutant sources. Potential pollutant sources include any activity or material that may reasonably be expected to add pollutants to waters in the state from the facility. An evaluation of potential pollutant sources shall identify the types of pollutant sources, provide a description of the pollutant sources, and indicate all measures that will be used to prevent contamination from the pollutant sources. The type of pollutant sources found at any particular site varies depending upon a number of factors, including, but not limited to: site location, historical land use, proposed facility type, and land application practices. The evaluation shall encompass all land that will be used as part of the CAFO as indicated in the site plan. Each potential pollutant

source must be identified in the plan. A thorough site inspection of the facility is recommended to ensure that all sources have been identified. Potential pollutant sources found at CAFO facilities include, but are not limited to, the following: manure; sludge; wastewater; dust; silage stockpiles; fuel storage tanks; pesticide storage and applications; lubricants; disposal of any dead animals associated with production at the CAFO; land application of waste and wastewater; manure stockpiling; pond clean-out; vehicle traffic; and pen clean-out. Each plan shall include:

(A) A site plan/map, or topographic map indicating, an outline of the property that will be used in the waste generation and utilization activities of the concentrated animal feeding area; each existing structural control measure to reduce pollutants in wastewater and precipitation runoff; and surface water bodies.

(B) The plan shall identify the specific location of any recharge features identified on any tracts of land planned to be utilized under the provisions of this subchapter. In addition, the plan should also locate and describe the function of all measures installed to prevent impacts to identified recharge features.

(C) A list of any significant spills of these materials at the facility after September 18, 1998, or for new facilities, since date of operation.

(D) All existing sampling data.

(2) The pollution prevention plan for each facility shall include a description of management controls appropriate for the facility, and the operator must implement such controls. The appropriateness and priorities of any controls shall reflect the identified sources of pollutants at the facility.

(3) The plan shall include the location and a description of structural controls. Structural controls shall be inspected, by those individuals identified in the PPP as responsible for development, implementation, maintenance and revision of the plan, at least four times per year for structural integrity and maintenance. The plan shall include dates for inspection of the retention facility, and a log of the findings of such inspections. The appropriateness of any controls shall reflect the identified sources of pollutants at the facility.

(4) The plan must include documentation of the assumptions and calculations used in determining the appropriate volume capacity of the retention facilities. In addition to the 25-year, 24-hour rainfall, the volume capacity of the retention facility shall be designed to meet the demands of a hydrologic needs analysis (water balance) which demonstrates the irrigation water requirements for the cropping system maintained on the wastewater application site(s). Precipitation inputs to the hydrologic needs analysis (water balance) shall be the average monthly precipitation taken from an official source such as the "Climatic Atlas of Texas," LP-192, published by the Texas Department of Water Resources, dated December, 1983, or the most recent edition, or successor publication. The consumptive use requirements of the cropping system shall be developed on a monthly basis, and shall be calculated as a part of the hydrologic needs analysis (water balance). The following volumes shall be considered in determining the analysis:

(A) the runoff volume from all open lot surfaces;

(B) the runoff volume from all areas between open lot surfaces that is directed into the retention facilities;

(C) the rainfall multiplied by the area of the retention and waste basin;

(D) the volume of rainfall from any roofed area that is directed into the retention facilities;

(E) all waste and process generated wastewater produced during a 21 day, or greater, period;

(F) the estimated storage volume for a minimum one year of sludge accumulation;

(G) the storage volume required to contain all wastewater and runoff during periods of low crop demand;

(H) the evaporation volume from retention facility surfaces;

(I) the volume applied to crops in response to crop demand;

(J) the minimum treatment volume required for waste treatment, if treatment lagoon; and/or

(K) any additional storage volume required as a safety measure as determined by the system designer.

(5) The maximum required storage value calculated by the hydrologic analysis requirements shall not encroach on the storage volume required for the 25-year, 24-hour rainfall event. Wastewater application rates utilized in the hydrologic needs analysis (water balance) shall not induce runoff or create tailwater.

(6) In addition, the retention facility shall include a top freeboard of not less than two feet. Freeboard shall account for settlement and slope stability of the materials used at the time of design and construction.

(7) (Air quality only) A lagoon in a single lagoon system and a primary lagoon in a multi-stage lagoon system shall be designed to maintain the necessary treatment volume or surface area as calculated using the manure production data (mean plus one standard deviation) published by American Society of Agricultural Engineers (ASAE) standards D384.1, dated June, 1988, and applicable updates to comply with anaerobic lagoon design criteria as established by ASAE standards EP-403.2, dated December, 1992, and applicable updates, or other site-specific data documented in the PPP.

(8) Evaporation systems shall be designed to withstand a ten-year (consecutive) period of maximum recorded monthly rainfall (other than catastrophic), as determined by a hydrologic needs analysis (water balance), and sufficient freeboard (not less than one foot) shall be maintained to dispose of rainfall and rainfall runoff from the 25-year, 24-hour rainfall event without overflow. In the hydrologic needs analysis determination, in any month in which a catastrophic event occurs, the analysis shall replace such an event with not less than the long-term average rainfall for that month.

(9) Site specific information should be used to determine retention capacity and land application rates. All site specific information used must be documented in the pollution prevention plan.

(10) The plan shall include a description of the design standards for the retention facility embankments. The following minimum design standards are required for construction and/or modification of a retention facility:

(A) Soils used in the embankment shall be free of foreign material such as trash, brush, and fallen trees;

(B) The embankment shall be constructed in lifts or layers no more than six inches thick and compacted at optimum moisture content;

(C) Embankment construction must be accompanied by compaction testing and certified to be in accordance with NRCS, Corps of Engineers, Bureau of Reclamation or ASCE design standards. Compaction tests must be certified by a licensed professional engineer; and

(D) All embankment walls shall be stabilized to prevent erosion or deterioration.

(11) The plan must include a schedule for liquid waste removal. A date log indicating weekly inspection of wastewater level in the retention facility, including specific measurement of wastewater level will be kept with the plan. Retention facilities shall be equipped with either irrigation or evaporation or liquid removal systems capable of dewatering the retention facilities. Operators using pits, ponds, tanks or lagoons for storage and treatment of storm water, manure and process generated wastewater, including flush water waste handling systems, shall maintain in their wastewater retention facility sufficient available capacity to contain rainfall and rainfall runoff from a 25-year, 24-hour rainfall event. The operator shall restore such capacity to store all runoff from a 25-year, 24-hour rainfall event after any rainfall event or accumulation of wastes or process generated wastewater which reduces such capacity, weather permitting. Equipment capable of dewatering the wastewater retention structures of waste and/or wastewater shall be available whenever needed to restore the capacity required to accommodate the rainfall and runoff resulting from the 25-year, 24-hour rainfall event.

(12) A permanent marker (measuring device) shall be maintained in the wastewater retention facilities to show the following: the volume required for a 25-year, 24-hour rainfall event; and the predetermined minimum treatment volume within any treatment pond. The marker shall be visible from the top of the levee. At no time shall a treatment lagoon at a CAFO that is operated under an air

quality authorization be dewatered to a level below the predetermined treatment volume, except for cleanout periods or periods where the net effect of evaporation and rainfall would require the addition of fresh water to maintain the treatment volume without pumping fresh groundwater from an aquifer.

(13) (Air quality only) The primary lagoon in a multi-stage lagoon system shall be designed and operated so that the lagoon maintains a constant level at all times unless prohibited by climatic conditions. Where practical, any contaminated runoff should be routed around the primary lagoon into the secondary lagoon.

(14) A rain gauge shall be kept on site and properly maintained. A log of all measurable rainfall events shall be kept with the pollution prevention plan.

(15) Concentrated animal feeding operations constructing a new or modifying an existing wastewater retention facility shall insure that all construction and design is in accordance with good engineering practices. Where site specific variations are warranted, the operator must document these variations and their appropriateness to the plan. Existing facilities which have been properly maintained and show no signs of structural breakage or leakage will be considered to be properly constructed. Structures built in accordance with site specific Natural Resources Conservation Service plans and specifications will be considered to be in compliance with the design and capacity requirements of this subchapter if the site specific conditions are the same as those used by the NRCS to develop the plan (numbers of animals, runoff area, wastes generated, etc.) All retention structure design and construction shall, at a minimum, be in accordance with the technical standards developed by the NRCS. The operator must use those standards that are current at the time of construction.

(16) The operator shall include in the plan, site specific documentation that no significant hydrologic connection exists between the contained wastewater and waters in the state. Where the operator cannot document that no significant

hydrologic connection exists, the ponds, lagoons and basins of the retention facilities must have a liner which will prevent the potential contamination of surface waters and groundwaters.

(A) The operator can document lack of hydrologic connection by either: documenting that there will be no significant leakage from the retention structure; or documenting that any leakage from the retention structure would not migrate to waters in the state. This documentation shall be certified by a NRCS engineer, licensed professional engineer or qualified groundwater scientist and must include information on the hydraulic conductivity and thickness of the natural materials underlying and forming the walls of the containment structure up to the wetted perimeter.

(B) For documentation of no significant leakage, in-situ materials must, at a minimum, meet the minimum criteria for hydraulic conductivity and thickness described below. Documentation that leakage will not migrate to waters in the state must include maps showing groundwater flow paths, or that the leakage enters a confined environment. A written determination by a NRCS engineer, or a licensed professional engineer that a liner is not needed to prevent a significant hydrologic connection between the contained wastewater and waters in the state will be considered documentation that no significant hydrologic connection exists.

(17) Site-specific conditions shall be considered in the design and construction of liners. NRCS liner requirements or liners constructed and maintained in accordance with NRCS design specifications in Appendix 10d of the Agricultural Waste Management Handbook (or its current equivalent) shall be considered to prevent hydrologic connections which could result in the contamination of waters in the state. Liners for retention structures shall be constructed in accordance with good engineering practices. Where no site specific assessment has been done by a NRCS engineer, licensed professional engineer, or qualified groundwater scientist

the liner shall be constructed to have hydraulic conductivities no greater than 1 x 10[sup]-7[/sup] cm/sec, with a thickness of 1.5 feet or greater or its equivalency in other materials.

(18) Where a liner is installed to prevent hydrologic connection the operator must maintain the liner to inhibit infiltration of wastewaters. Liners shall be protected from animals by fences or other protective devices. No trees shall be allowed to grow within the potential distance of the root zone. Any mechanical or structural damage to the liner shall be evaluated by a NRCS engineer or a licensed professional engineer within 30 days of the damage. Documentation of liner maintenance shall be kept with the pollution prevention plan. The operator shall have a NRCS engineer, licensed professional engineer, or qualified groundwater scientist review the documentation and do a site evaluation every five years. If notified by the executive director that significant potential exists for the contamination of waters in the state or drinking water, the operator shall install a leak detection system or monitoring well(s) in accordance with that notice. Documentation of compliance with the notification must be kept with the pollution prevention plan, as well as all sampling data. In the event monitoring well(s) are required, the operator must sample each monitor well annually for nitrate as nitrogen, chloride, and total dissolved solids using the methods outlined in the PPP, and compare the analytical results to the baseline data. If a ten percent deviation in concentration of any of the sampled constituents is found, the operator must notify the executive director within 30 days of receiving the analytical results. Data from any monitoring wells must be kept on site for three years with the pollution prevention plan. The first year's sampling shall be considered the baseline data and must be retained on site for the life of the facility unless otherwise provided by the executive director.

(19) The pollution prevention plan shall describe measures that will be used to minimize entry of non-process wastewater into retention facilities. Such measures may include the construction of berms, embankments, or similar structures.

Retention facilities shall be equipped with either irrigation or evaporation systems capable of dewatering the retention facilities, or a regular schedule of wastewater removal by contract hauler. The pollution prevention plan must include all calculations, as well as, all factors used in determining land application rates, acreage, and crops. Land application rates must take into account the nutrient contribution of any land applied manures. If land application is utilized, the following requirements shall apply.

(A) The discharge or drainage of irrigated wastewater is prohibited where it will result in a discharge of pollutants into or adjacent to waters in the state.

(B) When wastewater is used to irrigate land application areas, the plan shall include: a description of waste handling procedures and equipment availability; the calculations and assumptions used for determining land application rates; and all nutrient analysis data. Application rates shall not exceed the nutrient uptake of the crop coverage or planned crop planting with any land application of wastewater and/or manure. Land application rates of wastewaters shall be based on the available nitrogen content, however, where annual soil sampling analysis for extractable phosphorus as described in paragraph (28)(F) of this subsection indicates a level greater than 200 ppm of extractable phosphorus (reported as P) in Zone 1 for a particular waste or wastewater land application field, the operator may apply wastewater to the affected application area only in accordance with the conditions established in paragraph (28)(G) of this subsection.

(C) Wastewater shall not be irrigated when the ground is frozen or saturated or during rainfall events (unless in accordance with subparagraph (E) of this paragraph).

(D) Irrigation practices shall be managed so as to reduce or minimize ponding or puddling of wastewater on the site, pollution of waters in the state, and prevents the occurrence of nuisance conditions.

(E) It shall be considered proper operation and maintenance for a facility which has been properly operated in accordance with this subchapter, and that is in danger of imminent overflow due to chronic or catastrophic rainfall, to discharge wastewaters to land application sites for filtering prior to discharging to waters in the state. Only that portion of the total retention facility wastewater volume necessary to prevent overflow due to chronic or catastrophic rainfall shall be land applied for filtering prior to discharging to waters in the state. Monitoring and reporting requirements for such discharges shall be consistent with §321.42 of this title (relating to Monitoring and Reporting Requirements).

(F) Facilities including ponds, pipes, ditches, pumps, diversion and irrigation equipment shall be maintained to insure ability to fully comply with the terms of this subchapter and the pollution prevention plan.

(G) Adequate equipment or land application area shall be available for removal of such waste and wastewater as required to maintain the retention capacity of the facility for compliance with this subchapter.

(H) Where land application sites are isolated from surface waters and groundwaters and no potential exists for runoff to reach any waters in the state, application rates may exceed nutrient crop uptake rates only upon written approval of the executive director. No land application under this subsection shall cause or contribute to a violation of water quality standards or create a nuisance.

(I) The pollution prevention plan shall include the following information:

(i) a site map showing the location of any land application areas, either on-site or off-site which are owned, operated, or under the control of the facility owner or operator which will be utilized for land application of waste or wastewater;

(ii) the location and description of the major soil types within the identified land application areas;

(iii) crop types and rotations to be implemented on an annual basis;

(iv) predicted yield goals based on the major soil types within the identified land application areas;

(v) procedures for calculating nutrient budgets to be used to determine application rates;

(vi) a detailed description of the type of equipment and method of application to be used in applying the waste or wastewater; (vii) projected rates and timing of application of the manure and wastewater as well as other sources of nutrients that will be applied to the land application areas.

(J) The owner or operator shall maintain on-site and update records of all waste and wastewater either utilized at the facility or removed from the facility.

(i) For facilities where waste or wastewater is applied on property owned, operated, or controlled by the owner or operator, such records shall include the following information: date of waste or wastewater application; location of the specific application site and the number of acres utilized during each application event; acreage of each individual crop on which waste or wastewater is applied; number of dry tons, percent nitrogen based on a dry basis, and the percent moisture content of the manure; and actual annual yield of each harvested crop.

(ii) Where waste or wastewater is removed from the facility, records must be maintained in accordance with paragraph (23) of this subsection.

(20) Solids shall be removed in accordance with a pre-determined schedule for cleanout of all treatment lagoons to prevent the accumulation of solids from exceeding 50% of the original treatment volume. Removal of solids shall be conducted during favorable wind conditions that carry odors away from nearby receptors and the operator shall notify the regional office of the commission as soon as the lagoon cleaning is scheduled, but not less than 10 days prior to cleaning, and verification shall be reported to the same regional office within five days after the cleaning has been completed. At no time shall emissions from any activity create a nuisance. Any increase in odors associated with a properly managed cleanout under this subsection will be taken into consideration by the executive director when determining compliance with the provisions of this subchapter.

(21) Manure and Pond Solids Handling and Land Application. Storage and land application of manure shall not cause a discharge of pollutants to waters in the state, cause a water quality violation in waters in the state or cause a nuisance condition. At all times, sufficient volume shall be maintained within the control facility to accommodate manure, other solids, wastewaters and contaminated storm water (rainwater runoff) from the concentrated animal feeding areas.

(22) Where the operator decides to land apply manures or pond solids, the plan shall include: a description of waste handling procedures and equipment

availability; the calculations and assumptions used for determining land application rates; and all nutrient analysis data. Land application rates of wastes shall be based on the available nitrogen content of the solid waste, except however, where annual soil sampling analysis for extractable phosphorus as described in paragraph (28)(F) of this subsection indicates a level greater than 200 ppm of extractable phosphorus (reported as P) in Zone 1 for a particular waste or wastewater land application field, the operator may apply manure or pond solids to the affected application area only in accordance with the conditions established in paragraph (28)(G) of this subsection.

(23) If manure is sold or given to other persons for off-site land application or disposal, the operator must maintain a log of: date of removal from the CAFO; name of hauler; and amount, in wet tons, dry tons, or cubic yards, of waste removed from the CAFO. (Incidental amounts, given away by the pick- up truck load, need not be recorded.) Where the wastes are to be land applied by the hauler, the operator must make available to the hauler any nutrient sample analysis of the manure from that year.

(24) The procedures documented in the pollution prevention plan must ensure that the handling and land application of wastes as defined in §321.32 of this title (relating to Definitions) comply with the following requirements.

(A) Manure storage capacity based upon manure and waste production and land availability shall be provided. Storage and/or surface disposal of manure in the 100-year flood plain, near water courses or recharge feature is prohibited unless protected by berms or other structures. The land application of wastes at agronomic rates shall not be considered surface disposal in this case and is not prohibited.

(B) When manure is stockpiled, it shall be stored in a well drained area with no ponding of water, and the top and sides of stockpiles shall be adequately sloped to ensure proper drainage. Runoff from manure storage piles must be retained on site.

(C) Waste shall not be applied to land when the ground is frozen or saturated or during rainfall events.

(D) Manure shall be uniformly applied to suitable land at appropriate times and at agronomic rates. Discharge (run-off) of waste from the application site is prohibited. Timing and rate of applications shall be in response to crop needs, assuming usual nutrient losses, expected precipitation, and soil conditions.

(E) All necessary practices to minimize waste manure transport to waters in the state shall be utilized and documented to the plan.

(F) Edge-of-field, grassed strips shall be used to separate water courses from runoff carrying eroded soil and manure particles. Land subject to excessive erosion shall be avoided.

(G) Where land application sites are isolated from surface waters and no potential exists for runoff to reach waters in the state, application rates may exceed nutrient crop uptake rates only upon written approval by the executive director. No land application under this subchapter shall cause or contribute to a violation of surface water quality standards, contaminate groundwater or create an nuisance condition.

(H) Nighttime application of liquid or solid waste shall be allowed only in areas with no occupied residence(s) within 0.25 mile from the outer boundary of the actual area receiving waste application. In areas with an occupied residence within 0.25 mile from the outer boundary of the actual area receiving waste application, application shall only be allowed from one hour after sunrise until one hour before sunset, unless the current occupants of such residences have in writing agreed to such nighttime applications.

(I) Accumulations of solids on concrete cow lanes at dairies and concrete swine pens, without slotted floors, shall be scraped or flushed at least once per week or in accordance with proper design and maintenance of the facility. Farrowing pens at swine facilities which are not scraped or flushed once per week shall be scraped/flushed after each group of sows have been removed from the facility.

(J) Buildings designed with mechanical flush/scrape systems shall be flushed/scraped at least once per week or as often as necessary to maintain the design efficiency. This provision would include, but would not be limited to swine and caged poultry operations.

(K) Earthen pens shall be designed and maintained to ensure good drainage and to prevent ponding.

(L) Facilities that utilize a solid settling basin(s) shall remove solids from the basin as often as necessary to maintain the design efficiency.

(25) The plan shall include an appropriate schedule for preventative maintenance. Operators will provide routine maintenance to their control facilities in accordance with a schedule and plan of operation to ensure compliance with this subchapter. The operator shall keep a maintenance log documenting that preventative maintenance was done. A preventive maintenance program shall involve inspection and maintenance of all runoff management devices (mechanical separators, catch basins) as well as inspecting and testing facility equipment and containment structures to uncover conditions that could cause

breakdowns or failures resulting in discharge of pollutants to waters in the state or the creation of a nuisance condition.

(26) The plan shall identify areas which, due to topography, activities, or other factors, have a high potential for significant soil erosion. Where these areas have the potential to contribute pollutants to waters in the state the pollution prevention plan shall identify measures used to limit erosion and pollutant runoff.

(27) The operator shall document to the pollution prevention plan as soon as possible, any planned physical alterations or additions to the permitted facility. The operator must insure that any change or facility expansion will not result in a discharge in violation of the provisions of this subchapter or will require an amendment to an existing authorization in force at the time of modification.

(28) Prior to commencing wastewater irrigation or waste application on land owned or operated by the operator, and annually thereafter, the operator shall collect and analyze representative soil samples of the wastewater and waste application sites according to the following procedures.

(A) Sampling procedures shall employ accepted techniques of soil science for obtaining representative and analytical results.

(B) Samples should be taken within the same 45 day timeframe each year.

(C) Obtain one composite sample for each soil depth zone per land management unit and per uniform (soils with the same characteristics and texture) soil type within the land management unit. For the purposes of this subchapter, a land management unit shall be considered to be an area associated with a single center pivot system or a tract of land on which similar soil characteristics exist and similar management practices are being used.

(D) Composite samples shall be comprised of 10-15 randomly sampled cores obtained from each of the following soil depth zones:

(i) Zone 1: 0-6 inches for land application areas where the waste is incorporated directly into the soil or 0-2 inches for land application areas where the waste is not incorporated into the soil; if a 0-2 inch sample is required under this subsection, then an additional sample from the 2-6 inch soil depth zone shall be obtained in accordance with the provisions of this section; and

(ii) Zone 2: 6-24 inches.

(E) Soil samples shall be submitted to a soil testing laboratory along with a previous crop history of the site, intended crop use, and yield goal. Soil test reports shall include nutrient recommendations for the crop yield goal.

(F) Chemical/nutrient parameters and analytical procedures for laboratory analysis of soil samples from wastewater and waste application sites shall include the following:

(i) Nitrate reported as nitrogen in parts per million (ppm);

(ii) Phosphorus (extractable, ppm)--Texas Agricultural Extension Service Soil Testing Laboratory--TAMU extractant or Mehlich III;

(iii) Potassium (extractable, ppm);

(iv) Sodium (extractable, ppm);

(v) Magnesium (extractable, ppm);

(vi) Calcium (extractable, ppm);

(vii) Soluble salts/electrical conductivity (dS/m)--determined from extract of 2:1 (v/v) water/soil mixture;

(viii) Soil water pH.

(G) When results of the annual soil analysis for extractable phosphorus in subparagraph (F) of this paragraph indicates a level greater than 200 ppm of extractable phosphorus (reported as P) in Zone 1 for a particular waste or wastewater land application field or if ordered by the commission to do so in order to protect the quality of waters in the state, then the operator shall not apply any waste or wastewater to the affected area unless the waste or wastewater application is implemented in accordance with a detailed nutrient utilization plan developed by NRCS, the Texas State Soil and Water Conservation Board, Texas Agricultural Extension Service, an agronomist or soil scientist on full-time staff at an accredited university located in the State of Texas, or any professional agronomist or soil scientist certified by the American Society of Agronomy (ASA) The executive director will issue technical guidance to assist in the development of complete and effective nutrient utilization plans. No land application under an approved nutrient utilization plan shall cause or contribute to a violation of water quality standards or create a nuisance. Land application under the terms of the Nutrient Utilization Plan may commence 30 days after the plan is filed with the executive director, unless prior to that time the executive director has returned the plan for failure to comply with all the requirements of this subsection. The nutrient utilization plan shall, at a minimum, evaluate and address the following factors to assure that the beneficial use of manure is conducted in a manner that prevents phosphorus impacts to water quality:

(i) slope of application fields (as a percentage) and distance of the land application area from waters in the state;

(ii) average rainfall for the area for each month;

(iii) soil series, soil type, soil family classification, and pH values of all soils in application fields;

(iv) chemical characteristics of the waste, including total nitrogen and phosphorus;

(v) recommended rates, methods, and schedules of application of manure and wastewater for all fields;

(vi) crop types, maximum crop uptake rate, and expected yield for each crop; and

(vii) best management practices to be utilized to prevent phosphorus impacts to water quality, including any physical structures and vegetative filterstrips.

(29) The operator shall annually analyze at least one representative sample of irrigation wastewater and one representative sample of solid waste for total nitrogen, total phosphorus and total potassium.

(30) Results of initial and annual soils, wastewater and solid waste analyses shall be maintained on-site as part of the pollution prevention plan.

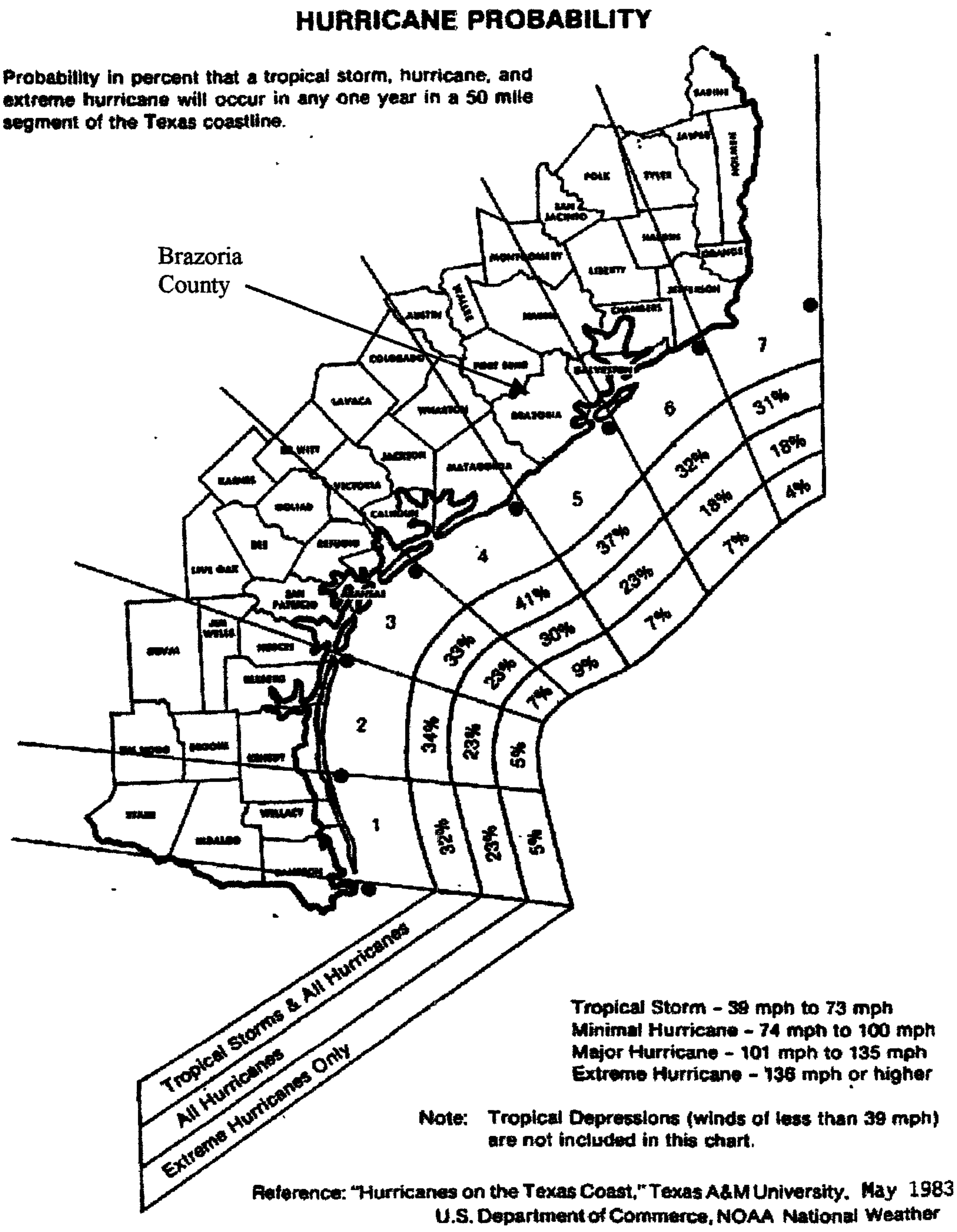
(31) Operators submitting applications for renewal or expansion of existing facilities authorized under this subchapter to utilize a playa lake as a wastewater

retention structure shall within 90 days of the effective date of the renewal, submit a groundwater monitoring plan to the Agriculture Section, Water Quality Division of the Texas Natural Resource Conservation Commission. At a minimum, the ground water monitoring plan shall specify procedures to annually collect a ground water sample from each well providing water for the facility, have each sample analyzed for chlorides and nitrates and compare those values to background values for each well.

Source Note: The provisions of this §321.39 adopted to be effective April 1, 1987, 12 TexReg 904; amended to be effective September 18, 1998, 23 TexReg 9354; amended to be effective July 27, 1999, 24 TexReg 5721

APPENDIX E

Hurricane Probability



Source: Texas A&M University. 1983. Hurricanes on the Texas Coast.
U.S. Department of Commerce, NOAA National Weather.

APPENDIX F

TEXAS NATURAL RESOURCES CONSERVATION COMMISSION: BRAZORIA COUNTY, TEXAS CAFO PERMITS TO DISPOSE OF WASTE

PERMIT NO. 03004

TEXAS NATURAL RESOURCE CONSERVATION COMMISSION
P.O. Box 13087
Austin, Texas 78711-3087

This permit supercedes and replaces Permit No. 03004 approved June 21, 1990.

PERMIT TO DISPOSE OF WASTE
under provisions of Chapter 26
of the Texas Water Code

I. Name of Permittee:
   A. Name Texas Department of Criminal Justice
   Ramsey Units

   B. Address P.O. Box 99
   Huntsville, TX 77342-0099

II. Type of Permit: Regular ________ Amended ________ Renewal __xx__

III. Nature of Business Producing Waste:

Agriculture; Swine and Dog; SIC No. 0213 and 0279.

IV. General Description and Location of Waste Disposal System:

General Description: The feeder slab and dog kennel have a maximum of 2,000 feeder hogs and 110 dogs, respectively, on an average daily basis. The facilities generate stormwater, washdown water and flushwater retained in eight (8) waste storage ponds and related appurtenances. The waste storage ponds have a cumulative surface area of approximately 3.02 acres and a cumulative volume of approximately 15.2 acre-feet. A detailed description can be found in Special Provision 5.0. Wastewater is disposed by irrigation on 76 acres of agricultural land. Manure is disposed by application as fertilizer on agricultural land (See Attachment "A").

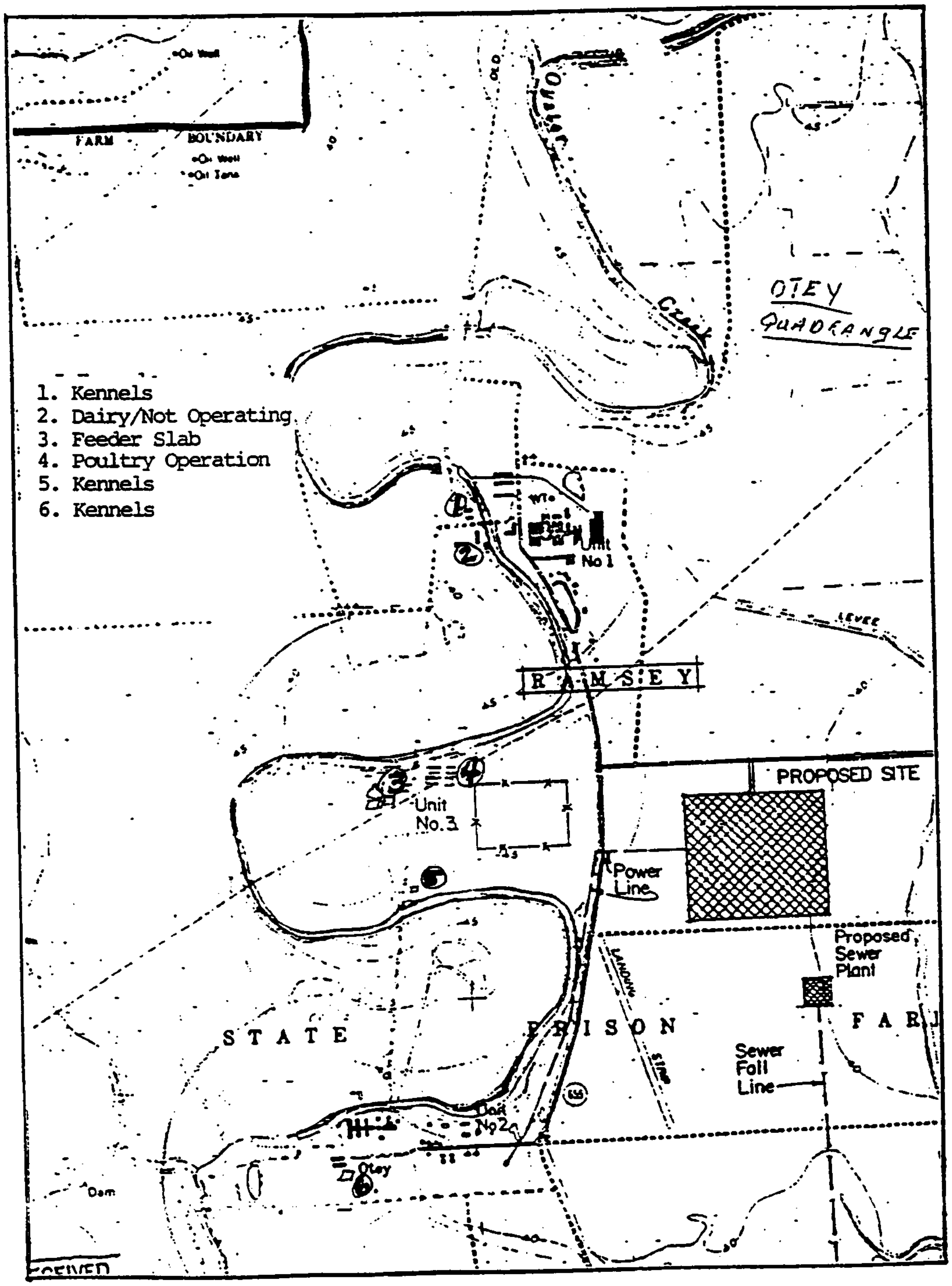
Location: The facilities are located at the Texas Department of Criminal Justice Ramsey I, II, amd III units. The units are located on Farm-to-Market Road 655, approximately five (5) miles west of the intersection of Farm-to-Market Road 521 and Farm-to-Market Road 655. The site is approximately eight (8) miles north of Angleton in Brazoria County, Texas (See Attachment "B").

This permit and the authorization contained herein shall expire at midnight, five years after the date of Commission approval.

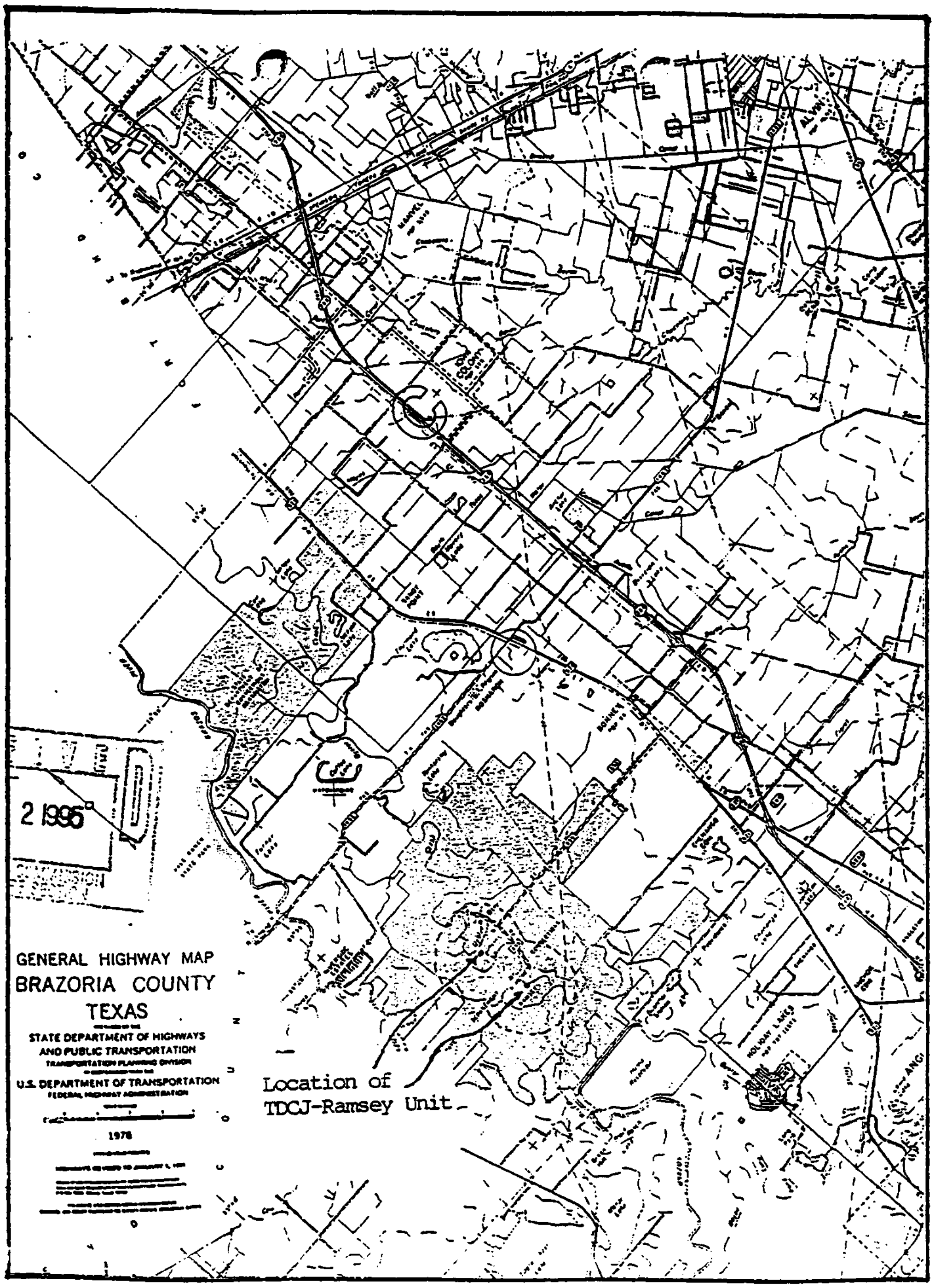
ISSUED DATE: NOV 10 1995

ATTEST: Gloria A. Vasquez

For the Commission



Texas Department of Criminal Justice
Ramsey Unit
Permit No. 03004
Attachment A



Texas Department of Criminal Justice
Ramsey Unit
Permit No. 03004
Attachment B
Location Map

PERMIT NO.03005

TEXAS NATURAL RESOURCE CONSERVATION COMMISSION
P.O. Box 13087
Austin, Texas 78711-3087

This permit supercedes and replaces Permit No. 03005 approved April 25, 1990.

PERMIT TO DISPOSE OF WASTE
under provisions of Chapter 26
of the Texas Water Code

I. Name of Permittee:
   A. Name Texas Department of Criminal Justice
      Darrington Unit
   B. Address P.O. Box 99
      Huntsville, TX 77342-0099

II. Type of Permit: Regular ________ Amended ________ Renewal __xx__

III. Nature of Business Producing Waste:

Agriculture; Swine, Poultry, and Dog; SIC No. 0213, 0252, 0279.

IV. General Description and Location of Waste Disposal System:

General Description: The feeder slab, egg laying facility, and dog kennel operations have a maximum of 1000 swine, 132,184 hens, and 48 dogs, respectively, on an average daily basis. The swine facility generates stormwater, washdown water and flushwater retained in three (3) waste storage ponds (WSP) with a volume of 2.27, 0.79, and 11.89 acre-feet for WSP-A, WSP-B and WSP-C, respectively, for a total of 14.95 acre-feet. The ponds have a surface area of approximately 0.53, 0.22, and 2.29 acres for WSP-A, WSP-B, and WSP-C, respectively, for a total of 3.04 acres. The dog facility generates stormwater, washdown water and flushwater retained in one (1) waste storage pond and three (3) settlement tanks. The dog waste storage pond has a volume of 0.08 acre-feet and a surface area of 0.037 acres. Wastewater is disposed by irrigation on 27 acres of agricultural land. Manure and solids are disposed by application as fertilizer on agricultural land (See Attachment "A").

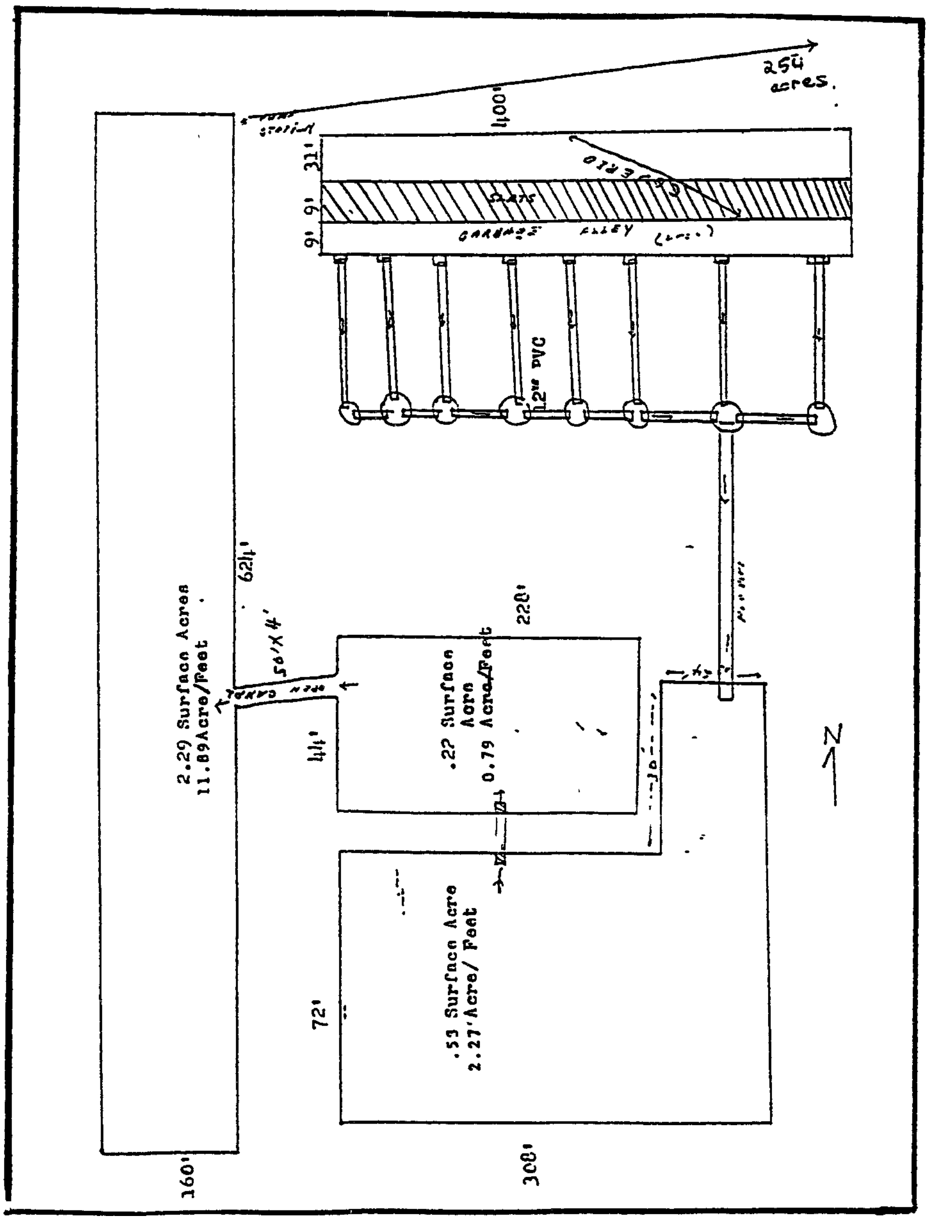
Location: The feeder slab, egg laying facility, and dog kennel operation is located in the Texas Department of Criminal Justice Darrington unit. The unit is located near Rosharon, three (3) miles north of the intersection of Farm-to-Market Road 521 and Farm-to-Market Road 1462 in Brazoria County, Texas (See Attachment "B").

This permit and the authorization contained herein shall expire at midnight, five years after the date of Commission approval.

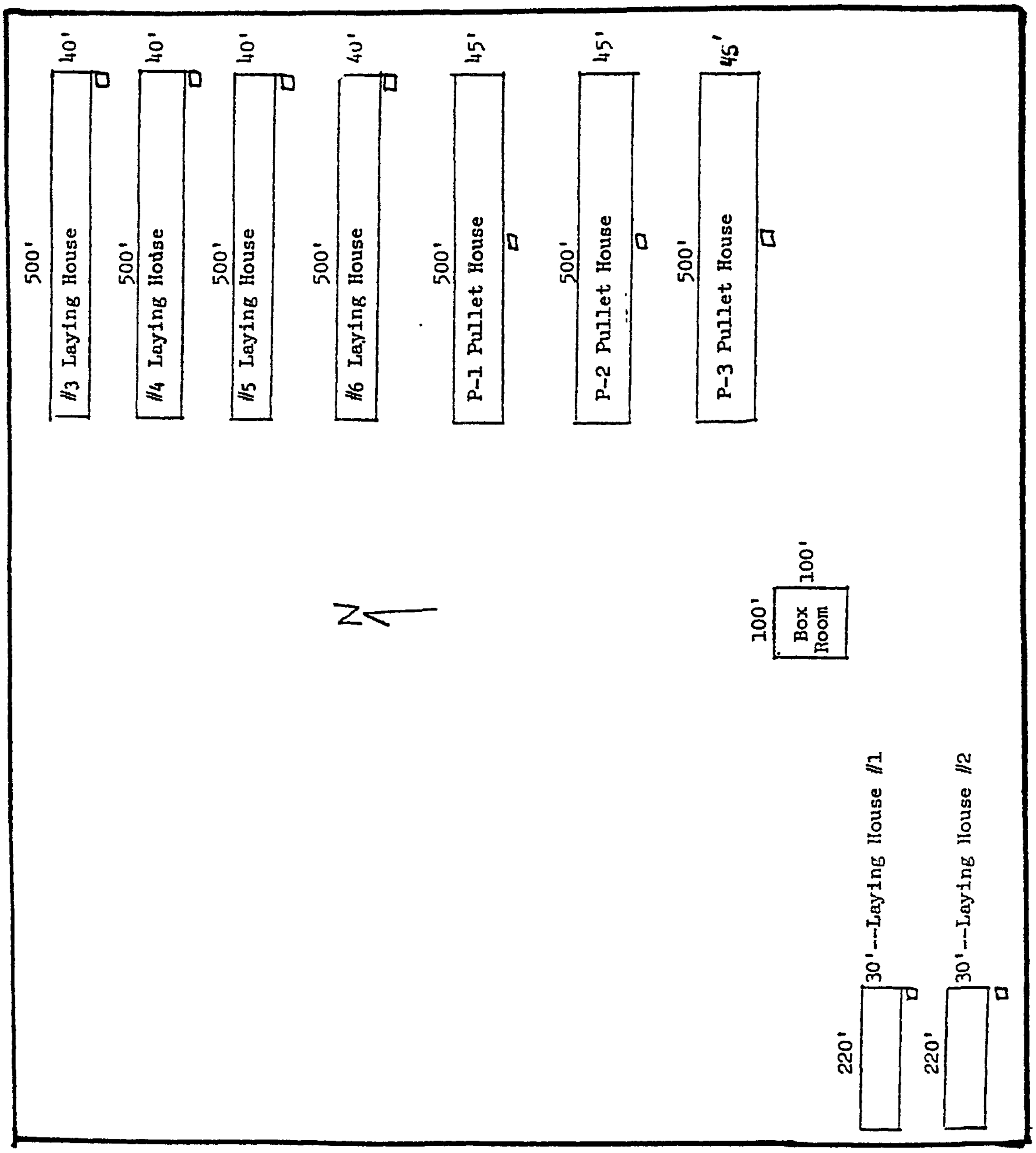
ISSUED DATE: NOV 10 1995

ATTEST: Gloria A. Vasquez

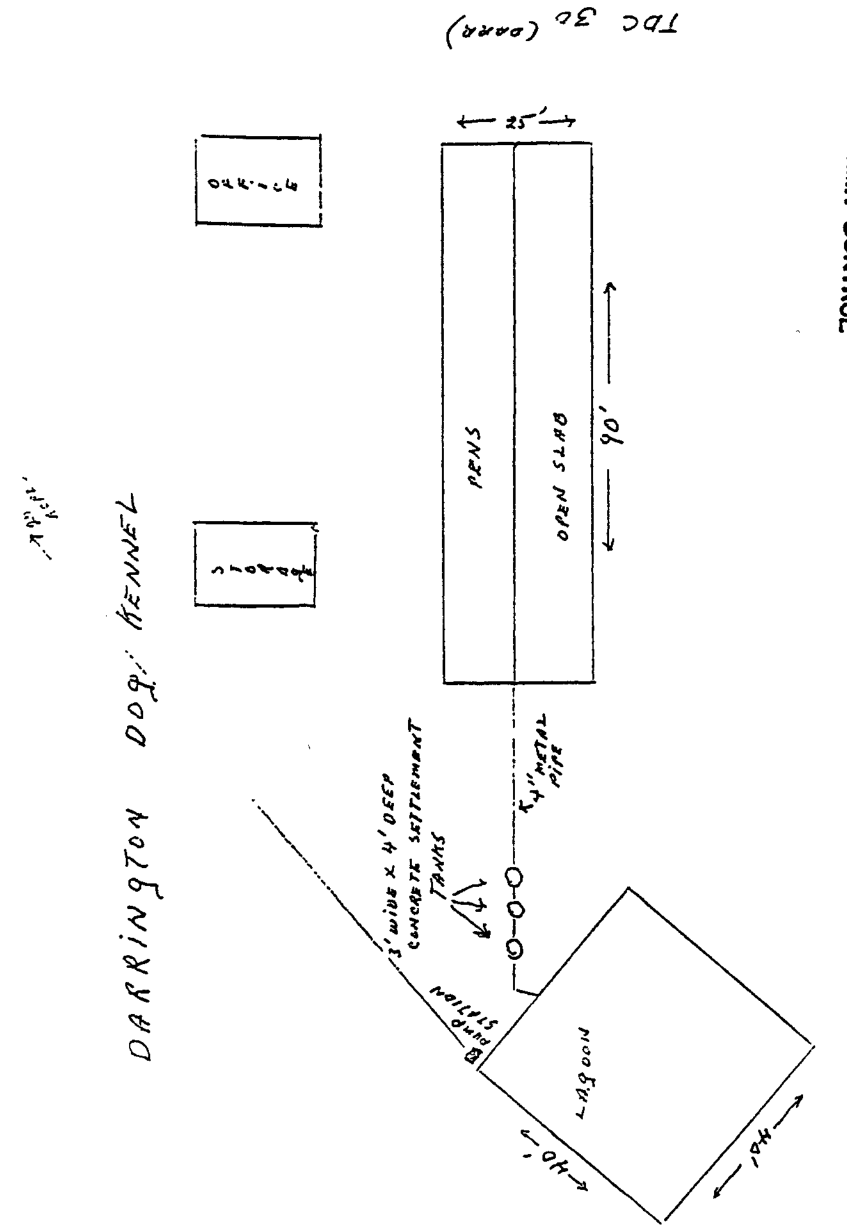
For the Commission



Texas Department of Crimainal Justice
Darrington Unit
Permit No. 03005
Attachment A
Schematic Diagram (of Feeder Slab)

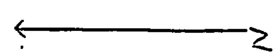


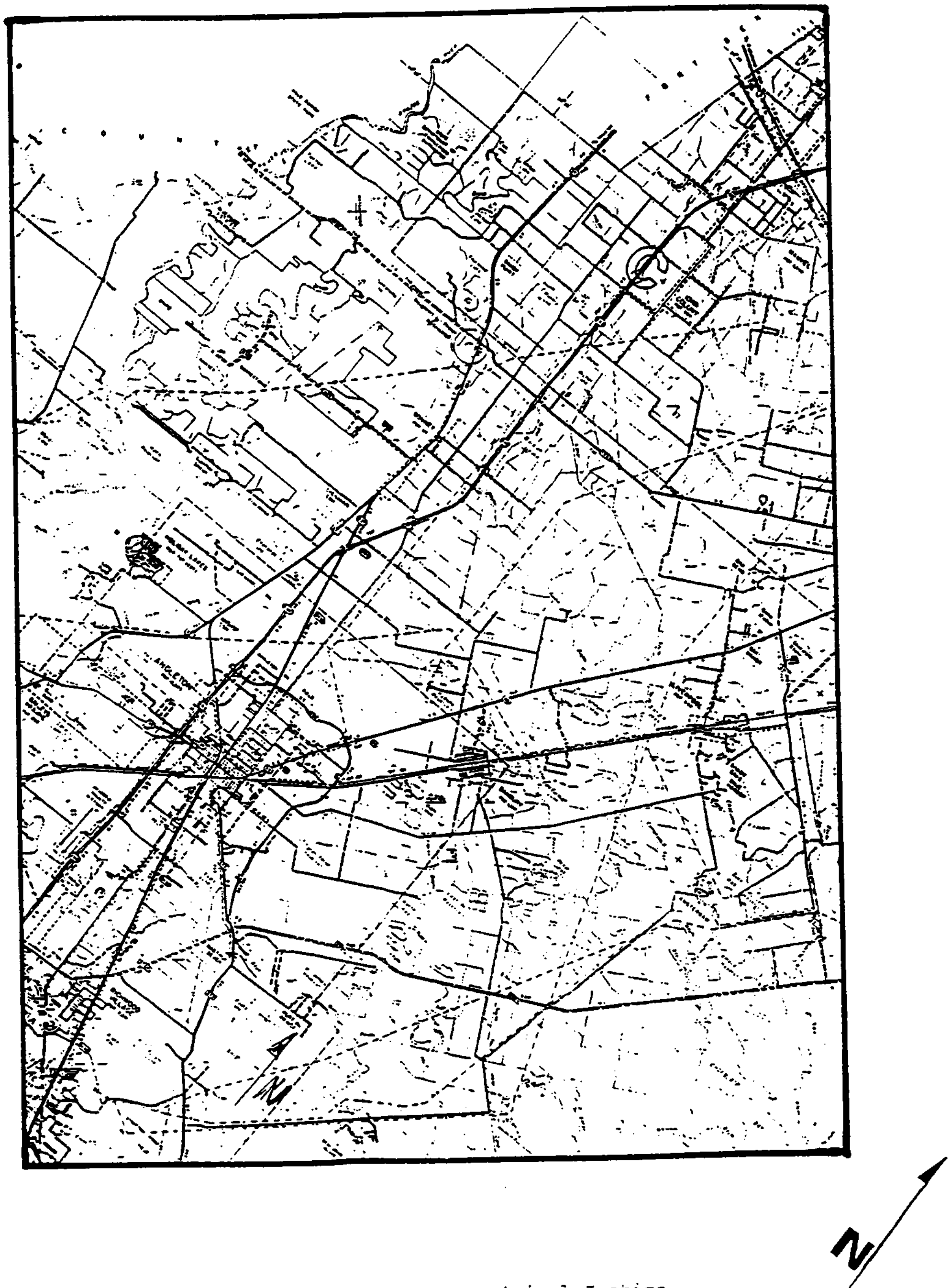
Texas Department of Crimainal Justice
Darrington Unit
Permit No. 03005
Attachment A (Continued)
Schematic Diagram (of Poultry Facility)



RECEIVED
MAR 08 1988
PERMIT CONTROL

Texas Department of Criminal Justice
Darrington Unit
Permit No. 03005
Attachment A (continued)
Schematic Diagram (of Dog Facility)





Texas Department of Criminal Justice
Darrington Unit
Permit No. 03005
Attachment B
Location Map

PERMIT NO. 02993

TEXAS NATURAL RESOURCE CONSERVATION COMMISSION
P.O. Box 13087
Austin, Texas 78711-3087

This permit supercedes and replaces Permit No. 02993 approved April 25, 1990.

PERMIT TO DISPOSE OF WASTE
under provisions of Chapter 26
of the Texas Water Code

I. Name of Permittee:
   A. Name Texas Department of Criminal Justice
      Clemens Unit

   B. Address P.O. Box 99
      Huntsville, TX 77342-0099

II. Type of Permit: Regular ________ Amended ________ Renewal __xx__

III. Nature of Business Producing Waste:

Agriculture: Swine and Dog; SIC No. 0213, 0279.

IV. General Description and Location of Waste Disposal System:

General Description: The feeder slab, farrowing unit, and dog kennel have a maximum of 300 head-swine feeder slab; farrowing unit consisting of a 300 head swine feeder slab, 76 sows and 532 piglets; and a 40 head dog kennel on an average daily basis. The facilities generate stormwater, washdown water and flushwater retained in five (5) storage ponds with a volume of 10.12 acre-feet - swine feeder slab (3 stage system), 8.79 acre-feet - farrowing facilities, and for the dog kennel - 3.35 acre-feet capacity. The ponds have a surface area of approximately 1.5 acres - swine feeder slab (3 stage system), 1.67 acres - farrowing facilities, and for the dog kennel - 0.69 acres. Wastewater is disposed of by irrigation on five (5) acres of agricultural land. Manure and solids are disposed of by application as fertilizer on agricultural land (See Attachment "A").

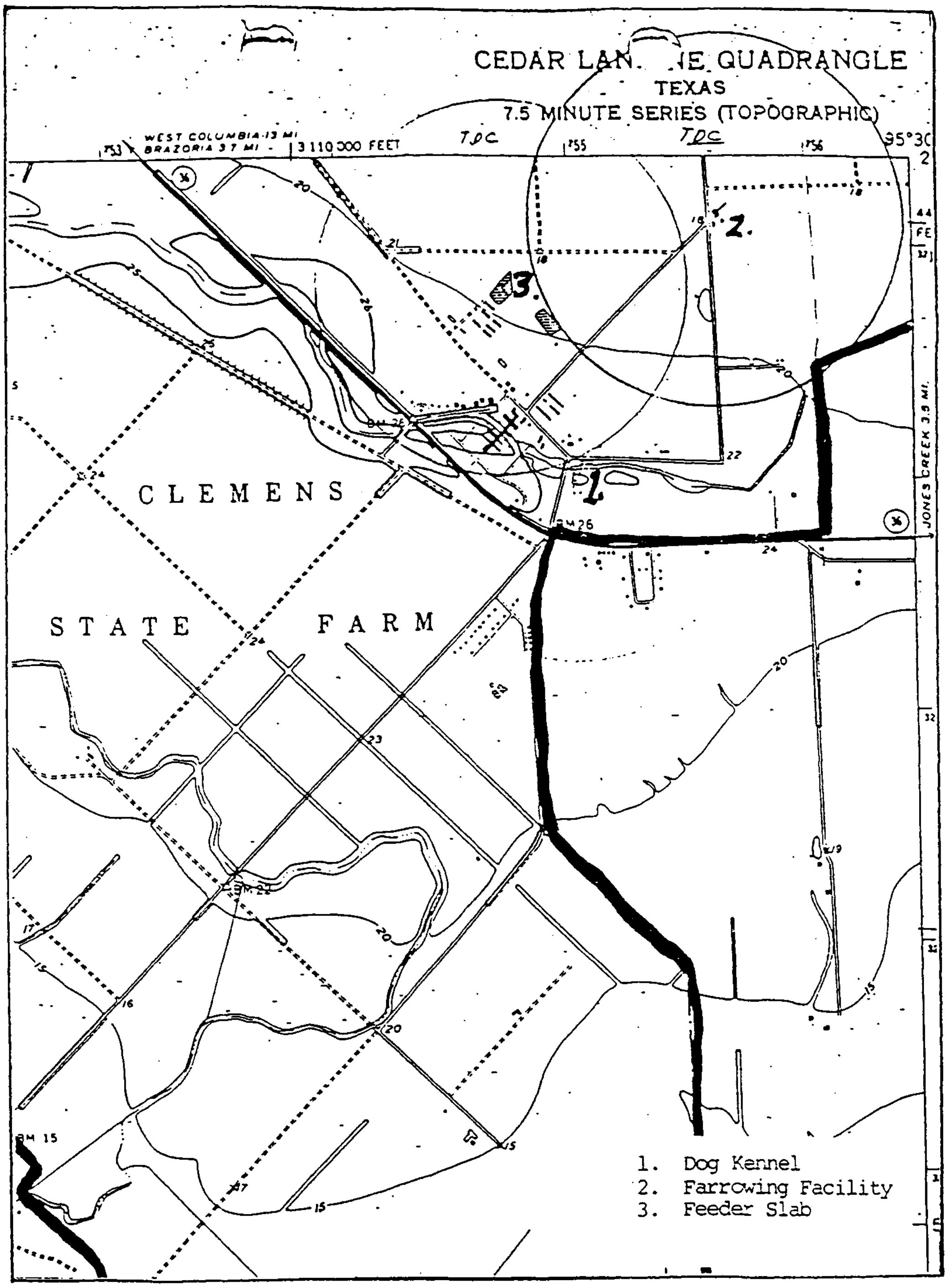
Location: The Clemens unit is located on the northeast side of State Highway 36 approximately four (4) miles southeast of the intersection of State Highway 36 and Farm-to-Market Road 521 at Brazoria in Brazoria County, Texas (See Attachment "B").

This permit and the authorization contained herein shall expire at midnight, five years after the date of Commission approval.

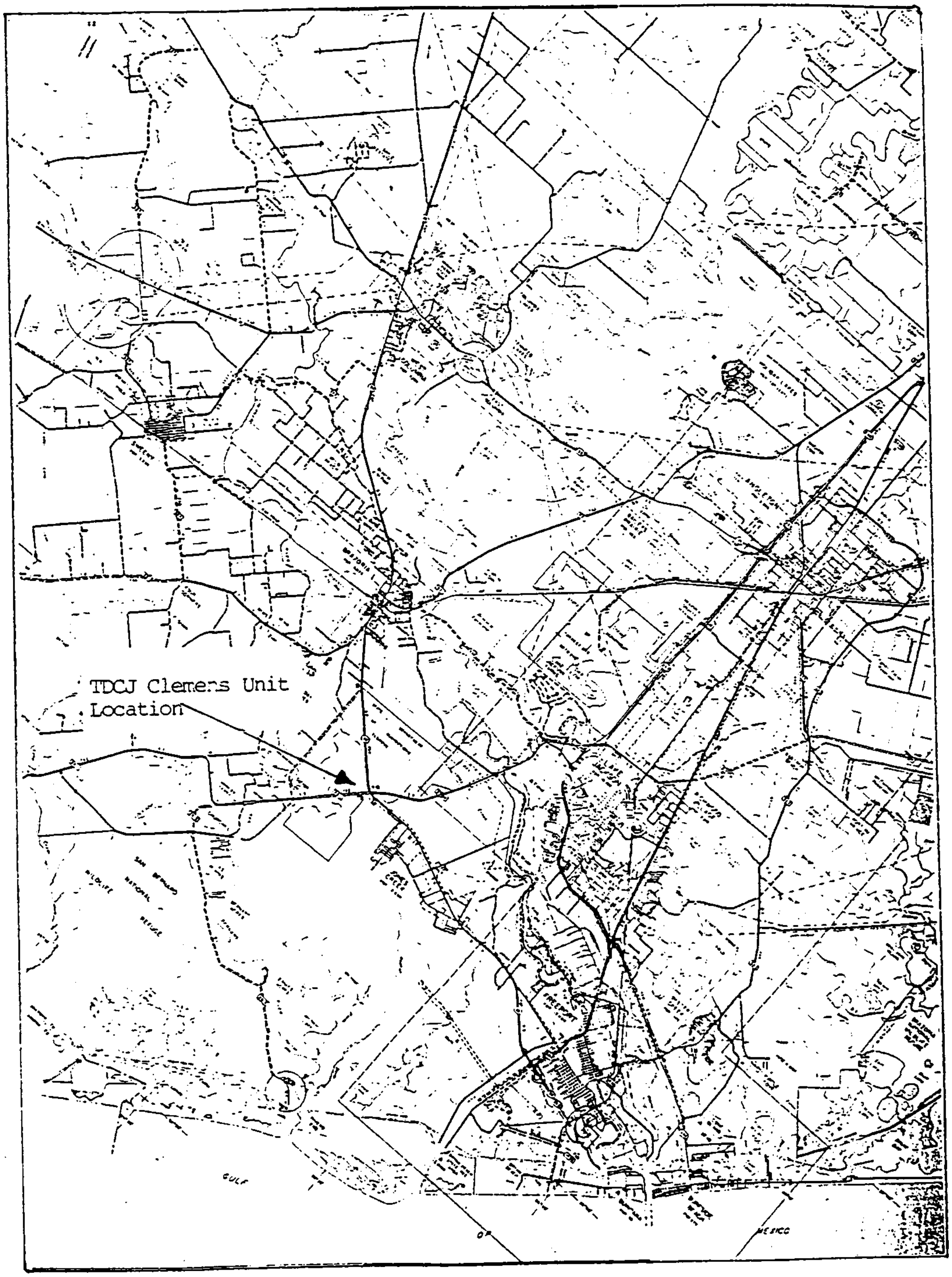
ISSUED DATE: AUG 18 1995

ATTEST: Gloria A. Vasquez

For the Commission



Texas Department of Criminal Justice
Permit No. 02993
Attachment A
Facility Diagram



Texas Department of Criminal Justice
Permit No. 02993
Attachment B
Location Map

PERMIT NO. 02991

TEXAS NATURAL RESOURCE CONSERVATION COMMISSION
P.O. Box 13087
Austin, Texas 78711-3087

This permit supercedes and replaces Permit No. 02991 approved April 25, 1990.

PERMIT TO DISPOSE OF WASTE
under provisions of Chapter 26
of the Texas Water Code

I. Name of Permittee:
   A. Name Texas Department of Criminal Justice
      Retrieve Unit

   B. Address P.O. Box 99
      Huntsville, TX 77342-0099

II. Type of Permit: Regular ________ Amended ________ Renewal xx

III. Nature of Business Producing Waste:

Agriculture; Swine, Dog, and Poultry; SIC No. 0213, 0252, 0279.

IV. General Description and Location of Waste Disposal System:

General Description: The swine, dog, and poultry operation, which has a maximum of 1,000 swine, 28 dogs, and 16,000 chickens on an average daily basis, generates stormwater, washdown water and flushwater retained in four (4) waste storage ponds with a volume of 7.81 acre-feet for the swine 3-stage system and 0.49 acre-feet capacity for the dog facility. The ponds have a surface area of approximately 1.35 acres for the swine 3-stage system and 0.11 acres for the dog facility. Wastewater is disposed of by irrigation on 30 acres of agricultural land. Manure and solids are disposed of by application as fertilizer on agricultural land (See Attachment "A").

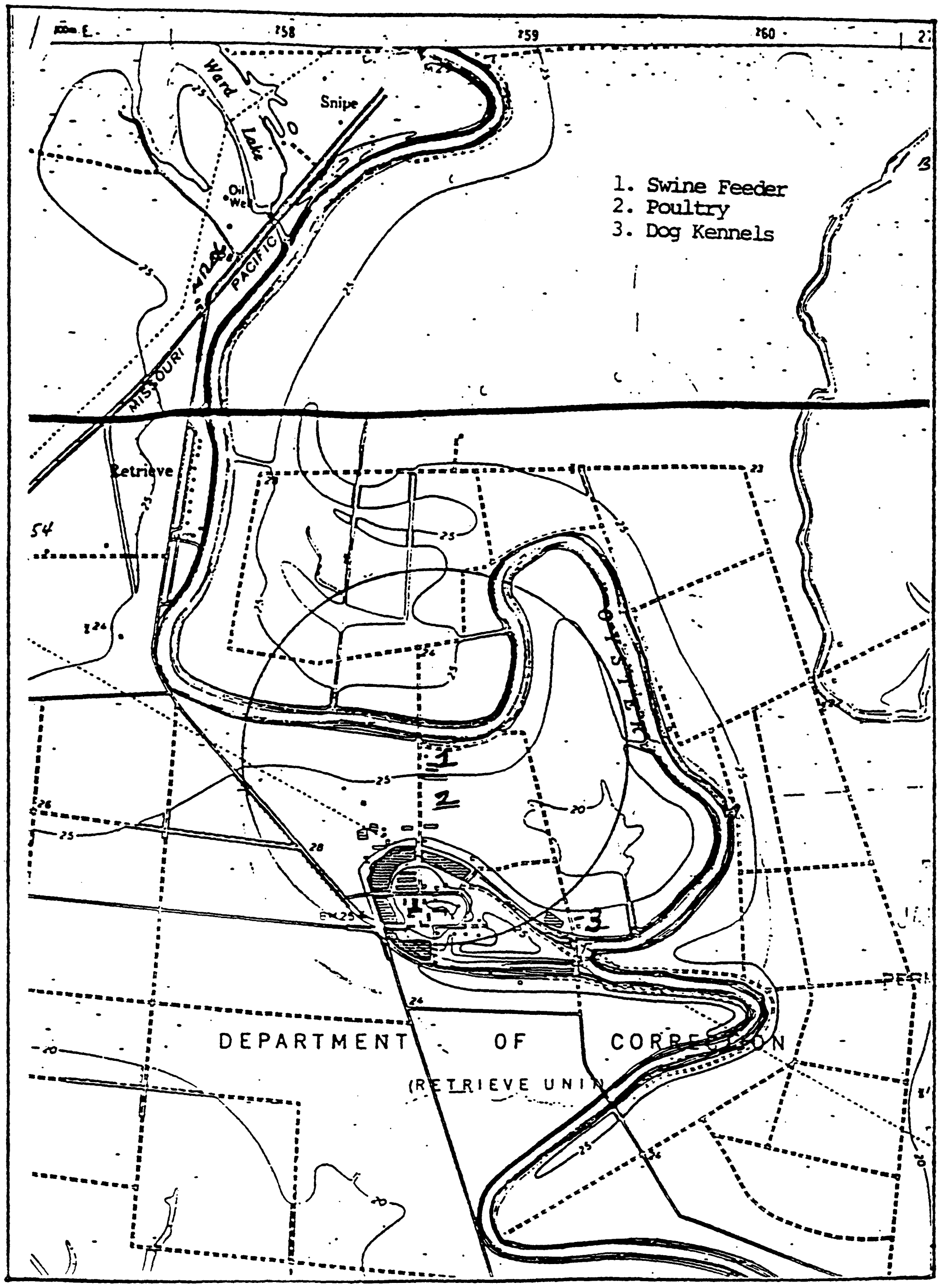
Location: The swine, dog, and poultry operation is located at the Texas Department of Criminal Justice Retrieve Unit. The unit is located on the west side of State Highway 288 approximately two (2) miles north of the intersection of State Highway 288 and Farm-to-Market Road 2004 at Lake Jackson in Brazoria County, Texas (See Attachment "B").

This permit and the authorization contained herein shall expire at midnight, five years after the date of Commission approval.

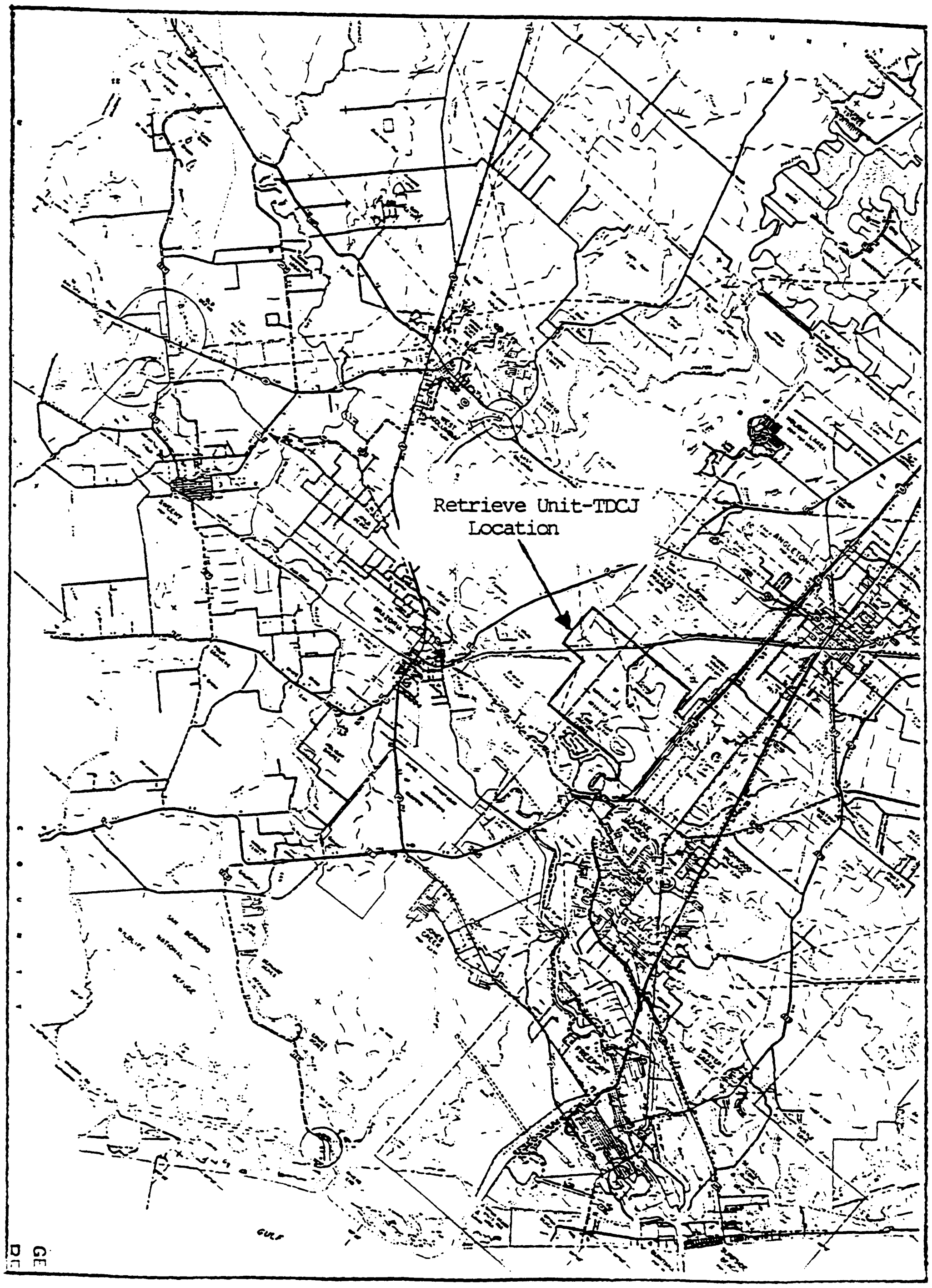
ISSUED DATE: NOV 10 1995

ATTEST: [signature]

[signature]
For the Commission



Texas Department of Criminal Justice
Retrieve Unit
Permit No. 02991
Attachment A
Facility Diagram



Texas Department of Criminal Justice
Retrieve Unit
Permit No. 02991
Attachment B
Location Map

APPENDIX G

TEXAS DEPARTMENT OF CRIMINAL JUSTICE
INTERVIEW RESULTS

These statements, questions and answers are the result of having transcribed the interview with TDCJ personnel from tape, and then sending the results to Michael Corley for verification. Some of the items are questions that remained unanswered from the initial interview, and Michael Corley provided the answers by email.

1. Clemens is the oldest CAFO owned by the state in Brazoria County.

Answer: Yes.

2. None of the poultry waste found at the Brazoria County facilities is emptied into lagoons. It is used as dry fertilizer
on the fields.

Answer: Yes, that is correct.

3. There has never been a lagoon spill at any of the Brazoria County facilities caused by a flood event.

Answer: Not in the last 50 years.

4. Over time, the people who have run the Brazoria County facilities have passed down good information about where the best land is for building CAFO type facilities.

Answer: Yes, that and good engineering and luck.

5. All food grown on the prison farms is for consumption by inmates, unless there is a surplus.

Answer: Yes, and the surplus goes to various food banks.

6. Some of the water from the hog lagoons is pumped onto hay and pasture land. This is a method for ensuring the proper level of the lagoons. This also acts as a safety buffer in the event of heavy rainfall.

Answer: Yes, there is always 2 feet of freeboard
maintained on the terminal lagoon.

7. The lagoons were built according to the state recommendations for withstanding flood events (of what magnitude?)

Answer: 25 year 24 hour rainfall event.

8. The state prison farms are inspected once a year for safety.

Answer: The CAFOs are inspected by TNRCC once per year, but they are inspected by TDCJ Administrators at least monthly, and TDCJ farm personnel daily.

9. The prison farms are expected to meet the environmental legislation of TNRCC and the EPA and also meet the budget guidelines of the Sunset Commission. This makes it difficult for prison to follow all of the recommendations of the TNRCC. (What are the things the prisons would do to improve the environmental safety of the facilities if they had the budget to do them?

Answer: TDCJ CAFOs do meet all of the TNRCC requirements within our budget limits. If we had more money in the budget we would increase the equipment used to manage the lagoons.

10. The prison farms are used as a method to help teach a good work ethic as well as a trade to inmates.

True, but the mission of the Texas Department of Criminal Justice's Swine Program is to produce quality and cost-efficient market hogs to meet the agency's pork consumption needs. Secondary goals are to provide an outlet for recycling kitchen wastes, provide a source of cash revenue, and provide inmate work ethic training. This mission will be accomplished in the most cost effective means possible, thereby reducing the tax burdens of the citizens of the State of Texas.

11. The large numbers of inmates creates a strong workforce to maintain the CAFO facilities.

Answer: Even though there is a large number of total inmates, those that work in the agriculture department have to meet a certain level of security clearance. With the higher level of clearance the inmates options for work and education increase, therefore reducing their numbers of availability, but the crews are staffed and the work gets done every day.

12. The pigs are rotated from one building to another – allowing the lagoon to rest as well as to maintain the health of the pigs.

Answer: Only at the Clemens Unit, the other units rotate pens by groups of pigs thus keeping the average pig inventory constant.

13. The lagoons are run at 50% capacity – meaning they are only half full?

Answer: No, the lagoons are run at 100% capacity with the enzymatic water treating the effluent that enters the lagoon. The water level of the terminal lagoons is always kept at 2 feet of free board.

14. The leftovers from the prisons are fed to the hogs. This saves the state from having to landfill the waste as well as saving the state 1.3 million dollars.

Answer: True.

15. The pigs are given a lot of room inside the pens, because this keeps the pigs from becoming aggressive and helps them to grow bigger.

Answer: True.

16. The turtles in the pond are a good indicator of how clean the water is in the pond.

Answer: True.

17. How many pigs are located at:

Answer:

Inventory	Permit	Avg.
Darrington:	1,000	727
Ramsey:	2,000	1,000
Retrieve:	1,000	850
Clemens:	1,208	360

18. How many chickens are located at:

Answer:

	Permit
Darrington:	132,184
Ramsey:	0
Retrieve:	16,000
Clemens:	0

19. How old are the pig and/or chicken facilities at:

Answer:

CURRENT FACILITIES:

Darrington:	Hogs: 1984	Chickens: 1983
Ramsey:	Hogs: 1955	
Retrieve:	Hogs: 1959	Chickens: 1965
Clemens:	Hogs: 1954	

APPENDIX H

U. S. GEOLOGICAL SURVEY
ANNUAL PEAK FLOW FREQUENCY ANALYSIS
FOLLOWING BULLETIN 17-B GUIDELINES
PROGRAM PEAKFQ
(VERSION 4.0, DECEMBER, 2000)

(Source: Excerpt from processing results from PEAQFQ analysis, March 26, 2001)

U. S. GEOLOGICAL SURVEY
ANNUAL PEAK FLOW FREQUENCY ANALYSIS
Following Bulletin 17-B Guidelines
Program peakfq
(Version 4.0, December, 2000)

Station - 08116650 BRAZOS RIVER NR ROSHARON, TX
2001 MAR 26 22:56:50

INPUT DATA SUMMARY

Number of peaks in record	=	29
Peaks not used in analysis	=	0
Systematic peaks in analysis	=	29
Historic peaks in analysis	=	0
Years of historic record	=	0
Generalized skew	=	-0.287
Standard error of generalized skew	=	0.550
Skew option	=	WEIGHTED
Gage base discharge	=	0.0
User supplied high outlier threshold	=	--
User supplied low outlier criterion	=	--
Plotting position parameter	=	0.00

NO SYSTEMATIC PEAKS WERE BELOW GAGE BASE. 0.0
LOW OUTLIERS BELOW FLOOD BASE WERE DROPPED. 1
NO HIGH OUTLIERS OR HISTORIC PEAKS EXCEEDED HHBASE.

Station - 08116650 BRAZOS RIVER NR ROSHARON, TX
2001 MAR 26 22:56:50

ANNUAL FREQUENCY CURVE PARAMETERS -- LOG-PEARSON TYPE III

	FLOOD BASE		LOGARITHMIC		
	DISCHARGE	EXCEEDANCE PROBABILITY	MEAN	STANDARD DEVIATION	SKEW
SYSTEMATIC RECORD	0.0	1.0000	4.6289	0.2804	-1.373
BULL.17B ESTIMATE	8205.4	0.9655	4.6414	0.2589	-0.742

ANNUAL FREQUENCY CURVE -- DISCHARGES AT SELECTED EXCEEDANCE PROBABILITIES

ANNUAL EXCEEDANCE PROBABILITY	BULL.17B ESTIMATE	SYSTEMATIC RECORD	'EXPECTED PROBABILITY' ESTIMATE	95-PCT CONFIDENCE LIMITS FOR BULL. 17B ESTIMATES LOWER	UPPER
0.9950	--	3645.0	--	--	--
0.9900	--	5201.0	--	--	--
0.9500	14730.0	12200.0	13690.0	10190.0	19070.0
0.9000	19760.0	17940.0	18920.0	14600.0	24660.0
0.8000	27410.0	26920.0	26860.0	21570.0	33210.0
0.5000	47110.0	49090.0	47110.0	39200.0	57040.0
0.2000	72980.0	72910.0	73850.0	60060.0	93420.0
0.1000	88290.0	83690.0	90130.0	71460.0	117200.0
0.0400	105300.0	92920.0	108800.0	83580.0	145000.0
0.0200	116400.0	97520.0	121200.0	91230.0	163900.0
0.0100	126200.0	100800.0	132600.0	97900.0	181100.0
0.0050	135000.0	103100.0	142900.0	103800.0	196900.0
0.0020	145200.0	105200.0	155200.0	110500.0	215600.0
0.6667	36156.3	(1.50-year flood)			
0.4292	52362.3	(2.33-year flood)			

1

Station - 08116650 BRAZOS RIVER NR ROSHARON, TX
2001 MAR 26 22:56:50

INPUT DATA LISTING

WATER YEAR	DISCHARGE	CODES	WATER YEAR	DISCHARGE	CODES
1967	10100.0		1985	45200.0	
1968	79900.0		1986	46700.0	
1969	56900.0		1987	63300.0	
1970	52800.0		1988	14600.0	
1971	25600.0		1989	44000.0	
1972	32400.0		1990	51600.0	
1973	79300.0		1991	53400.0	
1974	54100.0		1992	82700.0	
1975	61900.0		1993	65200.0	

1976	37200.0	1994	37300.0
1977	73000.0	1995	84400.0
1978	12700.0	1996	25000.0
1979	76500.0	1997	63600.0
1980	44500.0	1998	57300.0
1984	7540.0		

Station - 08116650 BRAZOS RIVER NR ROSHARON, TX
2001 MAR 26 22:56:50

EMPIRICAL FREQUENCY CURVES -- WEIBULL PLOTTING POSITIONS

WATER YEAR	RANKED DISCHARGE	SYSTEMATIC RECORD	BULL.17B ESTIMATE
1995	84400.0	0.0333	0.0333
1992	82700.0	0.0667	0.0667
1968	79900.0	0.1000	0.1000
1973	79300.0	0.1333	0.1333
1979	76500.0	0.1667	0.1667
1977	73000.0	0.2000	0.2000
1993	65200.0	0.2333	0.2333
1997	63600.0	0.2667	0.2667
1987	63300.0	0.3000	0.3000
1975	61900.0	0.3333	0.3333
1998	57300.0	0.3667	0.3667
1969	56900.0	0.4000	0.4000
1974	54100.0	0.4333	0.4333
1991	53400.0	0.4667	0.4667
1970	52800.0	0.5000	0.5000
1990	51600.0	0.5333	0.5333
1986	46700.0	0.5667	0.5667
1985	45200.0	0.6000	0.6000
1980	44500.0	0.6333	0.6333
1989	44000.0	0.6667	0.6667
1994	37300.0	0.7000	0.7000
1976	37200.0	0.7333	0.7333
1972	32400.0	0.7667	0.7667
1971	25600.0	0.8000	0.8000
1996	25000.0	0.8333	0.8333
1988	14600.0	0.8667	0.8667
1978	12700.0	0.9000	0.9000
1967	10100.0	0.9333	0.9333

1984	7540.0	0.9667	0.9667

Estimated Peak Stream Discharge (cfs) for Recurrence Intervals

Year	Peak	Gage Height
1.25	27409.71	29.7
2	47112.25	39.2
5	72983.23	48.3
10	88293.37	
25	105302.7	
50	116368.9	
100	126199.8	
200	134985.8	
500	145233.7	

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