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Well characteristics influencing microscopic particulate analysis risk index

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WELL CHARACTERISTICS INFLUENCING
MICROSCOPIC PARTICULATE ANALYSIS
RISK INDEX

by

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ABSTRACT

Cryptosporidium parvum is a common surface water contaminant that can cause illness in human beings. The presence of this etiological agent in groundwater identifies the groundwater as under the direct influence (GWUDI) of surface water. Currently the determination of GWUDI water sources requires an expensive, labor-intensive laboratory procedure called the Microscopic Particulate Analysis (MPA). The results of the MPA provide a risk index that rates the degree of surface water contamination. The objective of this study is to identify other methods of identifying GWUDI of surface waters, such as well characteristics and hydrogeologic factors which may contribute to higher MPA risk indices.

In order to determine which public water systems that are GWUDI, a total of sixty-two wells at water treatment systems suspected of being GWUDI were investigated. The wells sampled were distributed across seven counties in the Central Florida region. Water samples were collected and analyzed at the Department of Health Laboratory in Tampa, Florida using the MPA. The study also investigated the well characteristics and the hydrogeology of the well locations.

The results also showed that 13% of the wells sampled were in the high risk range while 29% and 58% of the wells sampled were within the moderate and low risk ranges, respectively. It was also observed that some well characteristics and the hydrogeology of an area generally influence the MPA risk index. The results also suggested that older wells tend to have higher risk. Karst regions were observed to be susceptible to a higher risk than sandy areas.

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Finally, I would like to dedicate this thesis to the greatest people in the world, my parents, Bob and Fran. Their constant support, encouragement, and love have been truly amazing. My dad's words to me, "Fly like an eagle, see the world, realize all your dreams," truly gave me my wings.

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CHAPTER 1

INTRODUCTION

1.1 Background

In 1993, the largest waterborne disease outbreak in the United States occurred in Milwaukee, Wisconsin causing illness in more than 400,000 people (Fox and Lytle, 1996). During the summer of 1995 in Gainesville, Florida, the local health department notified the Gainesville Regional Utilities regarding an outbreak among children and counselors attending a day camp (Regan et. al., 1998). The etiological agent responsible was *Cryptosporidium parvum*, which has been recognized as a human pathogen since 1976 (Juranek et al, 1995). Prior to 1982, *Cryptosporidiosis* was rarely reported, as it was predominately associated with immunocompromised individuals. With the increased number of those who had acquired immunodeficiency syndrome (AIDS) and the aid of newly developed laboratory diagnostic techniques, the number of reported cases has grown since 1982.

Cryptosporidium parvum is a protozoan parasite ranging from 3 to 7 microns in size found in drinking water sources, which is highly resistant to typical doses of chemical disinfectants used in potable water treatment systems. *Giardia lamblia* is a similar protozoan found in surface waters, but ranges from 7 to 15 microns in size. From 1988 to 1993, the American Water Works Association conducted extensive monitoring of numerous treatment systems across the United States and found the presence of *Cryptosporidium parvum* in 60.2 percent of its surface water sources (LeChevallier and Norton, 1995). The results of the study suggested that any potable water treatment system using a surface water, or a groundwater under the direct influence (GWUDI) of a surface water as a raw source, is at risk of containing *Giardia lamblia* or *Cryptosporidium parvum*. Based on this, it must be assumed that all surface waters are or will become, contaminated with *Giardia* or *Cryptosporidium* (Wilson et. al., 1996).

In 1986, the U.S. Environmental Protection Agency (USEPA) amended the Safe Drinking Water Act (SDWA), often referred to as the Surface Water Treatment Rule (SWTR), which deals with the disinfection of public water systems. The requirements under SWTR apply to all surface water sources and to "groundwaters under the direct influence of surface waters." As part of this rule, all states in the U.S. will need to identify those groundwaters influenced by surface waters since they are consequently at risk to waterborne diseases.

Groundwaters can be under the direct influence by one of two means. A groundwater can be under the direct influence of a surface water if it shows "significant occurrence" of insects, algae or large diameter pathogens such as *Giardia lamblia*, as enough information was not available on the risk of *Cryptosporidium parvum* when the

Rule was passed. Secondly, a groundwater source can be GWUDI if it shows significant and relatively rapid shifts in water characteristics that are closely related to surface water conditions. Typically, water characteristics, such as temperature, conductivity, pH, and turbidity cannot and/or have not been monitored sufficiently to conclude any correlations between ground and surface waters. Therefore, in order to evaluate the subsurface biota for the possibility of *Cryptosporidium parvum* and *Giardia lamblia*, the USEPA has directed water treatment systems to have a pair of microscopic particulate analyses (MPA) conducted during the wet and dry seasons. These MPA samples are to be analyzed in strict accordance with the method outlined in the USEPA Consensus Method for Determining Groundwaters Under the Direct Influence of Surface Water using Microscopic Particulate Analysis (Vasconcelos and Harris, 1992). The Consensus Method is a collaborative effort to standardize an acceptable measure of microscopic particulates in groundwaters as an indication of the presence of *Cryptosporidium, Giardia,* and other waterborne diseases. The method consists of numerous analyses of groundwater sources of drinking water and assigns a Risk Index (RI), which indicates the possibility of the source being a GWUDI. Because of the major water treatment improvements that may be required, the Consensus Method has been criticized for its accuracy. The EPA (Vasconcelos and Harris, 1992) suggested that the MPA consensus protocol should be regarded as a tentative method with limited recovery efficiency data available for review. Also the EPA guidance manual stated that "it should be emphasized that surface water influence on a groundwater source cannot be determined solely on the basis of one or two MPA." Therefore, there is need to develop a technique that will combine the MPA methodology and a hydrogeologic assessment to evaluate the presence or absence of subsurface biota.

1.2 Scope and Objectives

Because of the high cost of the MPA and the questionable accuracy associated with it, other existing indicators need to be identified. Based on this, two major objectives were considered.

1) Evaluate well characteristics and their relationship to the MPA Risk Index (RI_{MPA}).
2) Identify hydrogeologic characteristics influencing the determination of GWUDI sources and their relationship to the RI_{MPA}.

In this study, site-specific well parameters are investigated as factors that may be indicators of GWUDI source waters. Using these parameters as possible indicators of GWUDI, correlations and relationships between these well characteristics and the MPA Risk Index will be determined and evaluated. The well characteristics considered for correlation to the MPA Risk Indices include:

- Total Depth of the well
- Casing depth of the well
- Diameter of the well
- Age of the well

As runoff collects in surface water bodies, it infiltrates into the ground, removing most of the large particulate contaminants. When the water continues to seep through the layers of the subsurface, the percolation removes many of the particulates. The stratigraphy provides a natural filtration for the surface water as it recharges the aquifer system. When this process is bypassed, such as in karst geology, surface contaminants can reach the groundwater source. The site-specific hydrogeologic parameters included in this study are:

- Depth to static water level
- Depth to confining layer
- Thickness of confining layer
- Surficial geologic material
- Karst geology and sinkhole formations
- Areas of aquifer recharge

1.3 Limitations

The limitations of this study include lack of site specific well data and data obtained from the laboratory. The data used for this study were based on the Microscopic Particulate Analysis, as described in the USEPA Consensus Method for determining GWUDI of surface waters. Also, some of the well data were collected from well completion reports, which do not reflect any changes to the well over time. While the data used for the hydrogeological analysis were based on the Saint John's River Water Management District (SJRWMD) wells within the vicinity of the sampled wells.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Two major outbreaks of *Cryptosporidium* have occurred since 1993 and both outbreaks occurred while there were no records of failure in the treatment processes, such as an increase in turbidity or positive bacteria tests (Fox and Lytle, 1996). In addition, both outbreaks occurred in treatment facilities that were using surface water as a raw source. These sources, as well as groundwaters under the direct influence of surface waters (GWUDI), are the facilities that are impacted by the new regulations set forth by the United States Environmental Protection Agency (USEPA). These new regulations, known as the Surface Water Treatment Rule (SWTR), are amendments to the Safe Drinking Water Act (SDWA) set forth in 1986. The Rule provides stricter standards for water treatment systems using surface water or groundwaters under the direct influence of surface waters. Since the State of Florida relies on groundwater for ninety-two percent of its drinking water, it became necessary to evaluate all public water supply sources for the possibility of surface water contamination. Thus, evaluation of the current method is necessary to assess groundwaters under the direct influence of surface waters (GWUDI).

2.2 The Hydrologic Cycle

The hydrologic cycle is a simplified model of the interactions of water movement from surface water to the atmosphere through evaporation, to soil through infiltration, to groundwater through percolation and to vegetation through transpiration. Figure 2.1 illustrates the hydrologic cycle.

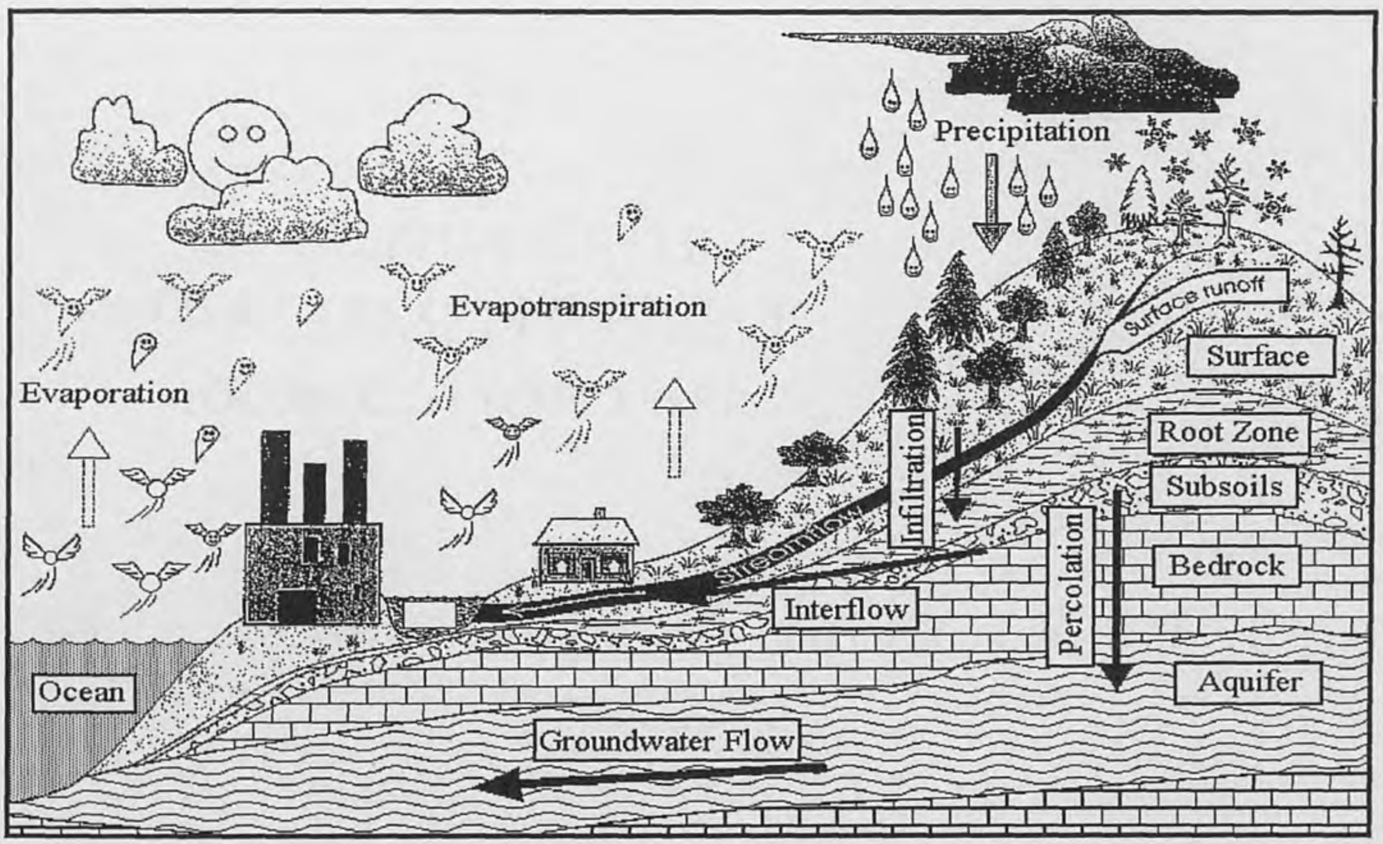


Figure 2.1 The Hydrologic Cycle (Ward and Elliot, 1995)

Because this study involves the interaction between surface water and groundwater, several subsurface characteristics must be identified. Figure 2.2 identifies various subsurface formations.

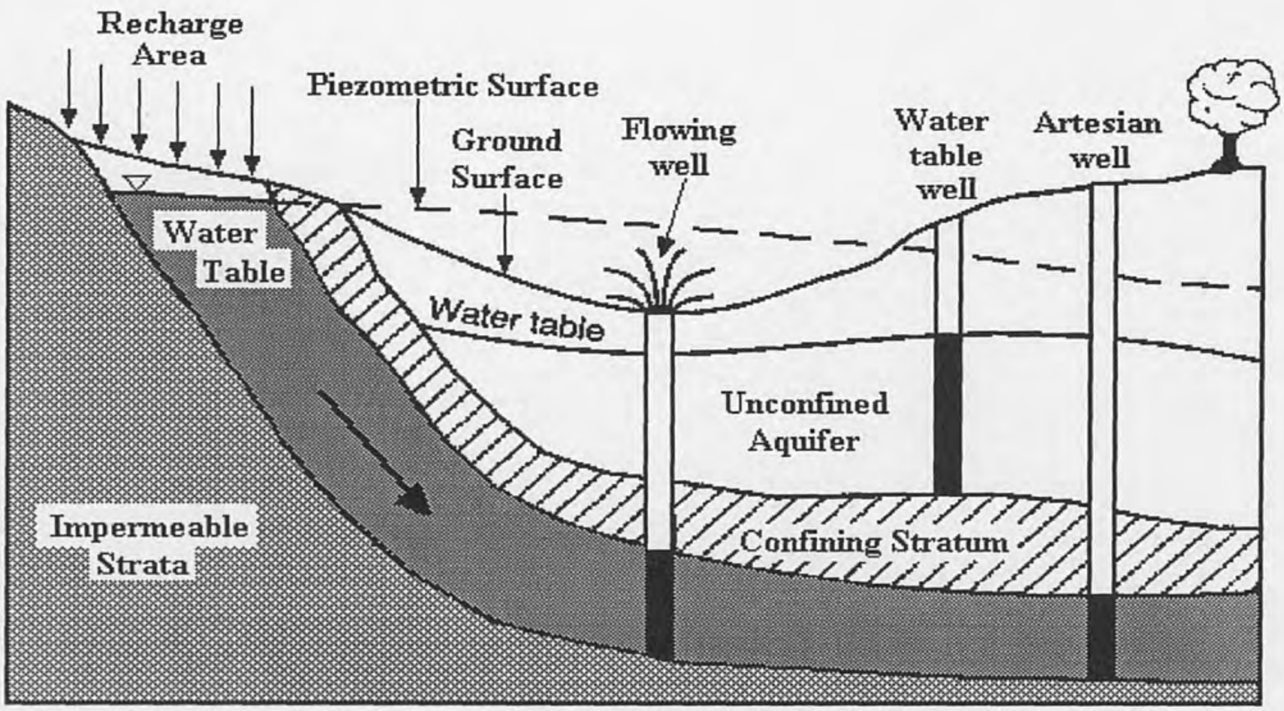


Figure 2.2 Subsurface Hydrogeology (Bedient et al., 1994)

Rock that contains groundwater and allows the water to flow through is termed an aquifer, while the capacity or ability of a rock to transmit the water is called the permeability. Some formations, such as aquitards, restrict percolation and allow only a small portion of the water to travel downwards, while aquicludes consist of impermeable rock that does not permit percolation. Factors that influence the permeability of an aquifer include the type and material of the aquifer, the size of the pores, the frequency of cracks or fractures, driving static head, and heterogeneities within the aquifer. These parameters are very important in assessing the filtration effectiveness of an aquifer system.

Because this study focuses on wells in Central Florida, it is important to describe the typical geology of the area. Figure 2.3 depicts the subsurface hydrogeology in the Central Florida region. On the left side of the figure are the geologic units and on the right are the hydrostratigraphic layers defined by the Southeastern Geological Society on Florida Hydrostratigraphic Unit Definition (1988).

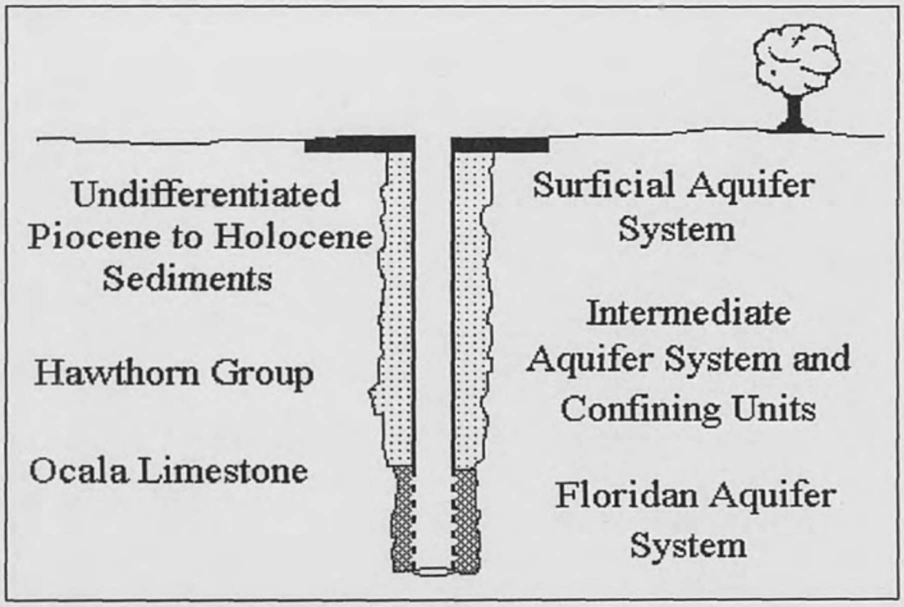


Figure 2.3 Subsurface Hydrogeology in Central Florida

Water can be drawn from different types of aquifers, depending on the depth of the well. An unconfined aquifer, sometimes referred to as a surficial aquifer, are typically used for irrigation purposes; however, if saltwater is present at greater depths, such as on a coastline, this aquifer is sometimes used as a drinking water source (Lehr et al., 1988). Higher quality raw water is typically found at greater depths since the recharging water has filtered through various soil strata. Brassington (1995) suggested that there is a close relationship between groundwater and surface water, since the base flow components of rivers come from local groundwater. In addition, when a river runs at higher elevation than the local water table, the water may percolate down to the water table and add to the groundwater resource. The filtration of surface water contaminants by confining layers is essential for high quality groundwater sources. When this process is bypassed or ineffective, surface water contaminants pose a serious threat to human life.

2.3 Outbreaks of Waterborne Diseases

Four hundred thousand people were affected by an outbreak of *Cryptosporidiosis* in Milwaukee, Wisconsin in 1993 (Juranek et al., 1995). In early 1994, Las Vegas, Nevada experienced another *Cryptosporidiosis* outbreak affecting the immunocompomised, or HIV-infected population of the city (Roefer et al., 1996). Because these treatment facilities met existing state and federal regulations, public health agencies were prompted to detect and prevent further occurrences. In the United States, all outbreaks of waterborne *Cryptosporidiosis* reported from 1984 to 1993 occurred in communities where the treatment facility met state and federal standards for drinking water quality (Fox and Lytle, 1996). Clearly, these outbreaks indicated that compliance with USEPA water treatment standards did not adequately protect against waterborne *Cryptosporidiosis*.

In both of these treatment facilities, the source of drinking water is surface waters, however new regulations may require filtration for all surface waters and GWUDI sources. Therefore, this new legislation poses two major concerns for such epidemics in the State of Florida. Over ninety-two percent of the drinking water sources in the State of Florida is through groundwater. Also, because of the increase in susceptibility and the large number of groundwater wells, the GWUDI in the State of Florida must be identified correctly and conclusively. Secondly, because twenty percent of Florida's population is over the age of sixty-five, the number of immunosuppressed individuals in the state is also very high (Campbell, 1994).

2.4 Pertinent Regulations

The contamination of groundwater sources by surface waters is a problem facing treatment plant operators, microbiologists, engineers and hydrogeologists. Because of this, several pieces of legislation discuss different facets of the problem. In the past, the SDWA of 1986 had two aspects of legislation that required evaluation of the occurrence and movement of microbiologic contaminants in surface water. Recently, amendments to the SDWA known as the Surface Water Treatment Rule (SWTR) included groundwaters that may be under the direct influence of surface waters (Waxman, 1986).

2.4.1 Amendments to the Safe Drinking Water Act (SDWA), 1986

There are two important mandates that were established under the SDWA: the Wellhead Protection (WHP) Program and the Groundwater Disinfection Rule (GWDR). The first requires the state agencies to establish wellhead protection areas for all drinking water supply wells. The emphasis of this amendment was placed on the protection of recharge sources instead of protecting the well head itself since the recharge area may be quite distant from the well head.

Secondly, the GWDR requires state agencies to identify potential sources of viruses or fecal contamination and monitor the movement of such contaminants within the contributing zone of water supply wells. The GWDR also develops criteria for USEPA that analyzes the "natural disinfection" of aquifer systems using hydrogeologic information such as distance from potential sources of contamination, well construction techniques, and minimum travel time of groundwater and contaminants.

2.4.2 Surface Water Treatment Rule (SWTR), 1989

In 1989, the USEPA developed a new legislative mandate in response to the requirements of the 1986 amendments to the Safe Drinking Water Act (Waxman, 1986). The Surface Water Treatment Rule (SWTR) was developed in order to protect the public from pathogenic microorganisms in surface waters, such as *Giardia lamblia* and viruses. When this Rule was instated, there was not enough evidence known regarding the adverse effects of *Cryptosporidium parvum*. From 1988 to 1993, the American Water System conducted extensive monitoring and found the presence of *Giardia lamblia* in 53.9 percent and *Cryptosporidium parvum*, another pathogenic organism, in 60.2 percent of its surface water sources (LeChevallier and Norton, 1995). Therefore based on these rules, the USEPA concluded that all surface waters used as a drinking water source have the potential of becoming contaminated with *Giardia* cysts (Juranek et al, 1995).

Giardia lamblia and *Cryptosporidium parvum* are two protozoan parasites that are usually filtered naturally as the surface water percolates through the soil and confining layers as the aquifer recharges. Whenever these protozoa encounter an environment that is unsuitable for survival, these microorganisms encase themselves in a shell, or cyst. While in this dormant phase, the organism maintains life-sustaining functions until the environment becomes suitable for living. While in the cyst-phase of their life cycle, these parasites are not affected by the currently required disinfection techniques such as chlorination. These microorganisms require additional treatment methods, typically involving some type of mechanical filtration or membrane process, which can be rather expensive for smaller treatment facilities.

The SWTR mandates a 99.9% removal or inactivation of *Giardia lamblia* cysts for all surface waters and groundwater systems under the direct influence of surface waters. The removal is determined for an average concentration of 1 cyst per 100 liters in surface waters. For many water treatment facilities, this may require additional treatment, such as chemical coagulation, membrane filtration or other mechanical filtration techniques. Acceptable filtration techniques include direct filtration, slow sand filtration, diatomaceous earth filtration, or any other filtration method that consistently achieves the 99.9% removal or inactivation of viruses and cysts.

The SWTR defines any groundwater under the direct influence (GWUDI) of a surface water to be "any water beneath the surface of the ground with (i) significant occurrence of insects or other macroorganisms, algae, or large diameter pathogens such as *Giardia lamblia* or (ii) significant and relatively rapid shifts in water characteristics such as turbidity, temperature, conductivity, or pH which closely correlate to climatological or surface water conditions."

The Rule defines a GWUDI as one with a significant number of large microorganisms, the presence of Giardia, or one that exhibits changes in water characteristics similar to nearby surface waters. It has been determined that analyzing water directly for *Giardia* requires numerous samples taken in very large volumes. The analysis for *Giardia* is a time-consuming and a rather expensive laboratory procedure. Similarly, the identification of a GWUDI using groundwater and surface water characteristics is unrealistic, due to the lack of data for every public supply groundwater source and nearby surface waters.

The source evaluation protocol in the SWTR determines when a source is subject to the treatment requirements and this involves four steps. First, if a review of the system's records indicates that the source is a pond, lake, or the like, then it is obviously a surface water source. Alternatively, if the source is a well, the evaluation becomes less clear. Step two involves a complete review of the system's files, including review of the field sanitary surveys. This may provide the pertinent information to gather any evidence of surface water contamination, indications of waterborne disease outbreaks, or complaints regarding water quality or infections. Step three is an on-site inspection noting surface water bodies within two hundred feet, lack of well seals, or other evidence of any obvious surface water contamination routes. Otherwise, the groundwater is evaluated using a particulate analysis and/or other water quality parameters to determine if it is under the direct influence of surface waters. The particulate analysis is defined in the USEPA Consensus Method as the Microscopic Particulate Analysis (MPA) and will be discussed later in this chapter. The procedures for sampling and laboratory analysis are presented in chapter three.

The SWTR includes a section summarizing the evaluation of well construction and simple geologic attributes. It also states that the construction of a true groundwater supply well should include:

- A surface sanitary seal using bentonite clay, concrete or other acceptable material;
- A well casing that penetrates a confining bed;
- A well casing or collector laterals that are only perforated or screened below a confining bed.

In addition, the SWTR recognizes that the importance of evaluating the hydrogeology of wells or collectors cannot be overstated. It also suggests that the porosity and transmissivity of the aquifer matrix, hydraulic gradients, and continuity of confining layers may also need to be considered in detail. This statement seems to have been overlooked in the protocol since the sole evaluation method for determining

GWUDI is the MPA, which does not take into account any of the aforementioned subsurface parameters.

2.4.3 Florida Administrative Code (FAC), Chapter 40C-3: Water Wells

The duties and responsibilities relative to regulating the location, construction, repair, and abandonment of wells were transferred from the Florida Department of Environmental Protection (FDEP) to the Saint John's River Water Management District (SJRWMD) in 1990. Regardless of the permit, a well completion report is required when constructing, repairing, or abandoning any well in the District. These reports are required to be filed at the District office within thirty days of completion. However, during this study, it was observed that the well completion reports are now stored at the FDEP office. Out of the seventy wells studied, less than ten well completion reports were available at the local FDEP office. The well completion reports are vital in assessing the hydrogeology of a site.

In Chapter 40C-3.512 of the FAC, it is suggested that well construction techniques require reasonable caution to be taken to maintain the work site in order to minimize the entrance of contaminants into the water resource. In addition, materials used in well construction should be reasonably free of contamination. The water used to mix the drilling fluids must have a minimum free chlorine residual or be supplied from a potable well or water supply system. The gravel or filter pack materials are to be disinfected also. It also requires that wells, which penetrate multiple aquifers, be completed so as to prevent cross-contamination between water bearing zones. If significantly different water quality exists between these aquifers, leakage of water from one to another aquifer must be prevented. This can be accomplished by grouting above and below the contaminated aquifer and ensuring continuous casing throughout the contaminated zone. Chapter 40C-3.517 also governs the grouting and sealing of water wells. According to this code, wells should be grouted and sealed to protect water resource from degradation caused by movement of waters along the well annulus either from the surface to the aquifer or between aquifers. All wells shall be constructed and sealed using a method that insures that an open or unnaturally permeable annular space does not remain when a well is completed.

This code also regulates the grouting based on the diameter of the casing of the well. If the nominal casing size is greater than or equal to four inches, the well must have two inches of grout sealing the annular space for the entire length of casing. If the diameter of the well is less than four inches, it must have a one-inch thick grout seal that ensures that an open or unnaturally permeable annular space does not remain when the well is completed.

According to the FAC Chapter 40C-3.521, wells should be sealed to prevent the movement of contaminants and surface water into the well. The upper terminus of the well casing should include a watertight seal.

2.5 Water Well Construction and Design

Before any well is drilled, the principles of well design should include an optimum combination of performance and longevity at a reasonable cost (Harlan et al., 1989). In addition, the design should comply with the appropriate laws and legislation governing the construction of water wells as previously discussed.

In comparing the MPA Risk Index to characteristics associated with each well, certain well components must be defined. During the selection for the proper dimensional factors for the well, the components ought to be carefully chosen. In Figure 2.4, the typical components of a water supply well are shown.

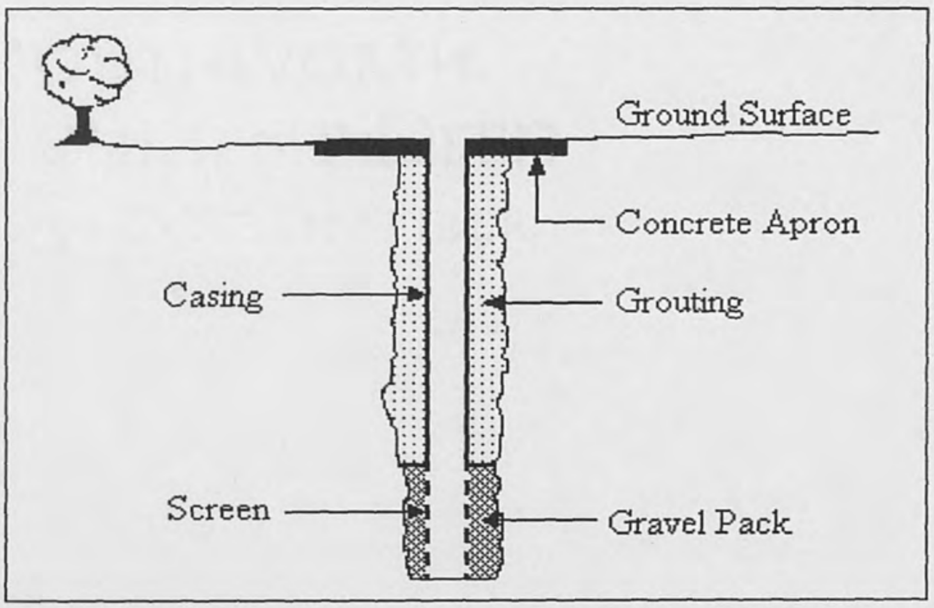


Figure 2.4 Components of a typical water supply well

When the borehole is initially drilled, care must be taken by the driller so that contamination of the now accessible aquifer is prevented. A gravel pack is installed at the intake of the well; and according to Lehr (1988), a gravel pack acts like a miniature aquifer. The same attributes that make up a good gravel pack are the same as those that make up a good aquifer, where a clean, well-rounded, uniform gravel has a high permeability as well as good filtering ability. The diameter of the size of gravel is determined by the sediments found in surrounding geology of the water source.

After the water has passed through the gravel pack, most of the sediments have been removed, but a screen is usually installed at the base of the casing in order to provide further filtration. The slot size of the screen is also a function of the size of particulates found in the raw source and a sieve analysis may be used to analyze the grain-sizes. General rule of thumb for determining the screen length in confined aquifers is summarized in Table 2.1.

Table 2.1 General rules for screen length in confined aquifers (Harlan et al., 1989)

Aquifer Thickness	< 25 ft	25 to 50 ft	> 50
Screening Length	70 %	75 %	80 %

When determining the materials for the casing and the screen, the designer should take into account the water quality, the cost, pertinent government regulations, but most of all, the purpose of the well. If the raw water is corrosive in nature, a thermoplastic pipe made of chemically inert materials is used. This type of casing will not corrode and can extend the life of the well. It is used almost exclusively since it is cheaper and much lighter than steel, thus easily installed (Brassington, 1995). Less reputable drilling contractors have been known to use unsuitable pipes, such as sewer pipe since it is also made from a similar PVC (Brassington, 1995). Consequently, this material has lined some boreholes and small amounts of toxic substances have been found to leach into the water supply (Brassington, 1995). In addition, this casing is half as thick as the thermoplastic made for well casings, and in many situations, resulting in collapse and failure of the borehole.

Altogether, the casing provides the shield between the contaminants in the subsurface and the raw water source. However, if the barrier is crossed or broken in any way, contamination of the raw water source is inevitable. Grouting and sealing the casing in water wells is done for the following reasons:

1) Grouting prevents seepage of polluted surface water down into the well along the outside of the casing.
2) By sealing the entire length of the well, water of unsuitable chemical quality in the strata above is prevented from entering the desirable water-bearing formation, this ensures the guidelines set forth by SJRWMD are met.

In addition to keeping the well free of contamination, grouting the well helps to stabilize and secure the casing to the surrounding borehole. The casing also forms a protective sheath, thus increasing its life by protecting it from exterior corrosion. At the surface, the casing is sealed to the ground surface with a concrete apron that is six feet by six feet in area and at least four inches in thickness (Figure 2.4).

2.6 USEPA Consensus Method for Determining Groundwaters Under the Direct Influence of Surface Water Using Microscopic Particulate Analysis (MPA)

The USEPA Consensus Method was created by a collaborative effort from various hydrogeologists, microbiologists, and engineers throughout the United States. The purpose of the method is to standardize the procedure for evaluating particulates in groundwaters. The method attempts to quantitatively equate the significant occurrence of indicator organisms to a relative risk index for a particular water supply using Microscopic Particulate Analysis (MPA). This USEPA method also emphasized that surface water influence on a groundwater source cannot be determined solely on the analysis of one or two MPA samples. It also suggested that other pertinent information regarding each individual source should be collected according to the USEPA Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems using Surface Water Sources. In conclusion, it finally states that the protocol should be regarded as a tentative method until more reliable methods are available.

The method describes the sampling procedure and the laboratory analysis of MPA. The sampling procedure consists of a two-day event of filtering raw source water for twenty-four hours. The sampling procedure and laboratory analysis will be discussed later in Chapter 3.

2.7 Environmental Indices

Because the result of the MPA is a risk index, a review of environmental indices is deemed necessary. Environmental indices, which are fractions, consisting of a numerator and a denominator, can be used as measures of government and private performances. The numerator represents the measurement of the quantity of interest, while the denominator is the standard of comparison (Inhaber, 1976). The purpose of an index is to simplify the information, present the least amount of possible information and convey the necessary meaning (Ott, 1978). An environmental index attempts to reduce measurements of two or more environmental parameters to a single number that retains meaning.

In general, the calculation of an environmental index consists of two fundamental steps. The first step is to calculate the subindices for the pollutant variables used in the overall index, such that for each pollutant variable, X_i, a subindex I_i is computed using a subindex function $f_i(X_i)$, such that:

$$I_i = f_i(X_i) \qquad (2\text{-}1)$$

Each subindex, I_i, is calculated using a different mathematical function since various pollutants have distinct characteristics. For example, the relationship between the pollutant variable and the subindex may be an increasing or decreasing linear relationship with or without an intercept. On the other hand, the relationship may be non-linear, such as parabolic, exponential or represented by a power equation. Whatever the case may be, it is important to determine this relationship, which depends heavily upon the pollutant. Otherwise, the results may become worthless.

Once all the subindices are determined, the second step to calculate the overall index is to combine all the subindices by using some sort of aggregation function, g, such that:

$$I = g(I_1, I_2, \ldots, I_n) \tag{2-2}$$

Researchers have suggested that the process of combining all the subindices together is another important step in calculating any environmental index. This is where most of the simplification takes place. However, the combination of subindices can be calculated using several different relationships. The aggregation function may be a simple summation, a multiplication, or a weighted sum or product. However, a decision between subindices may be necessary, such as the minimum or maximum operator of the subindices.

CHAPTER 3

DATA COLLECTION

3.1 Introduction

Based on the scope and purpose of this study, various types of data were collected from different sources. The well data consisted of physical characteristics such as total depth, casing depth, diameter, and age of each well. This information was gathered from the Saint John's River Water Management District (SJRWMD) office in Orlando, the SJRWMD headquarters in Palatka, and the Orlando branch office of the Florida Department of Environmental Protection (FDEP). The particle analyses data were collected through a grant from FDEP. Hydrogeologic information for the wells under investigation was obtained from SJRWMD observation wells located closest to the supply wells. For the forty-one sampled wells, the results of the Microscopic Particulate Analyses (MPA) were obtained from the Department of Health's (DOH) laboratory in Tampa, Florida. The other twenty-five wells were sampled previously and the resulting MPA risk indices were obtained from the Tallahassee FDEP office. These wells are distributed within seven counties across Central Florida, Brevard, Lake, Marion, Orange, Osceola, Seminole, and Volusia Counties.

3.2 Microscopic Particulate Analysis (MPA) Sampling Procedure

In order to identify the groundwaters under the direct influence of surface waters (GWUDI) in Florida, suspected groundwater wells were sampled. The sampling program called for the set-up of the sampling apparatus, the pick-up of samples and coordination of courier service to ship the samples to the laboratory in Tampa, Florida. The sampling was to be performed in accordance with the EPA Guidance Manual for the Determination of GWUDI, which was based on the Consensus Method as discussed in Chapter 2. The manual suggests sampling, at a minimum, once during the wet and once during the dry season to encompass the greatest and lowest rates of infiltration. The sampling was performed on public water supply (PWS) wells beginning on August 26, 1997 and completed on October 27, 1997.

3.2.1 Selection of Sampled Wells

The wells selected for sampling of MPA were chosen by the professional geologist at the FDEP Tallahassee office in charge of assessing GWUDI across the entire State of Florida. These wells were selected based on the fact that they had one positive total coliform sample within the last three years. The extrapolated theory is that if the raw water port has total coliform, a probability exists that there could be other surface water contaminants present. In general, most of the wells sampled were in smaller communities using a small local wastewater treatment facility or individual septic tanks. Numerous communities consisted of trailer parks and recreational vehicle facilities.

3.2.2 Organization of Sampling Plan

The selected wells were scattered across the Central Florida region. For an effective sampling program, an organized plan was devised. In this plan, the list of wells was laid out on a map to compare the proximity of the wells to one another. Since the laboratory could only handle a maximum of five samples per week, it was necessary to organize the number of samples per week to be no more than five. Also, since the samples were to reflect the "wet season" samples, it was important to finish sampling as soon as possible so as to obtain a representative sample. Each cluster of five was identified by a letter and was tentatively scheduled for eight consecutive weeks of sampling beginning on August 25, 1997. Due to unavoidable incidences such as weather and equipment failure, the project lasted ten weeks. The sampled wells are summarized in Table 3-1. Figure 3.1 shows all the wells sampled. Detailed descriptions of the sampled well locations for eight counties are shown in Appendix A.

Table 3-1 Grouping and Location of Sampled Wells

Group	Sampling Date	Location	# of Wells
A	August 27, 1997	Sanford, Ocala	3
B	September 2, 1997	Orlando, Osteen	2
C	September 9, 1997	Orange City, Oviedo, Edgewater, Oak Hill	5
D	September 16, 1997	Pierson, Glenwood, Deland, Lake Helen	5
E	September 23, 1997	Fruitland Park, Lady Lake	5
F	September 30, 1997	Clermont, Yalaha, Astatula, Lake Jem	5
G	October 7, 1997	Ormond Beach, Orlando, Winter Park	4
H	October 14, 1997	Poinciana, Apopka, Orlando, Alamonte	5
I	October 21, 1997	Leesburg, Eustis	4
J	October 28, 1997	Sebastian, Micco, Melbourne Beach	3
			41

Figure 3.1 shows the location of the wells sampled in each county.

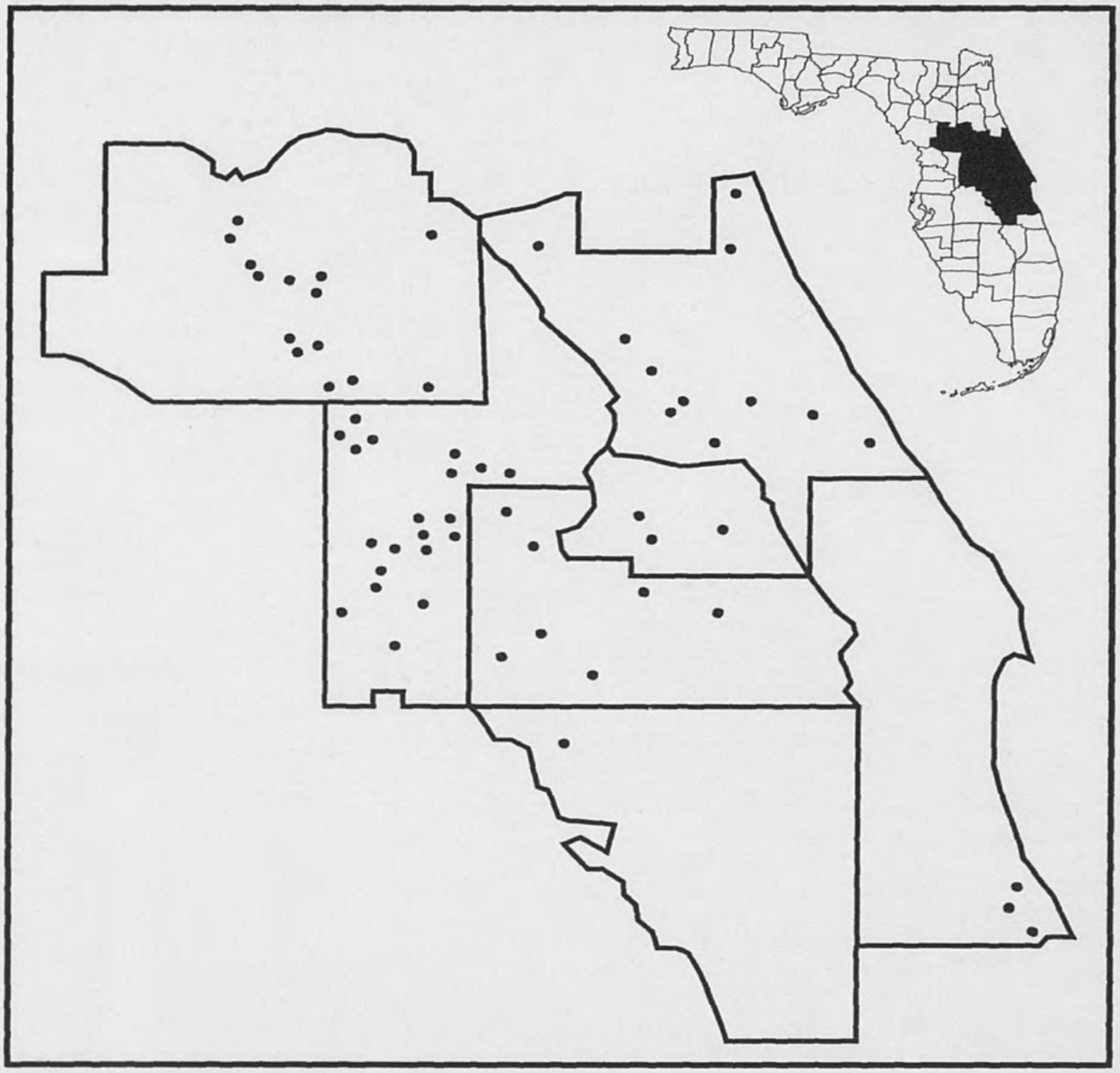


Figure 3.1 Sampled Sites in Central Florida

3.2.3 Equipment

The equipment required to sample a well consisted of the sampling apparatus, proper tools for adjustments, filters, cooler, residual chlorine test kit and dispensables, such as markers, tape, aluminum foil, etc. The apparatus consisted of six parts in series which is illustrated in Figure 3.2.

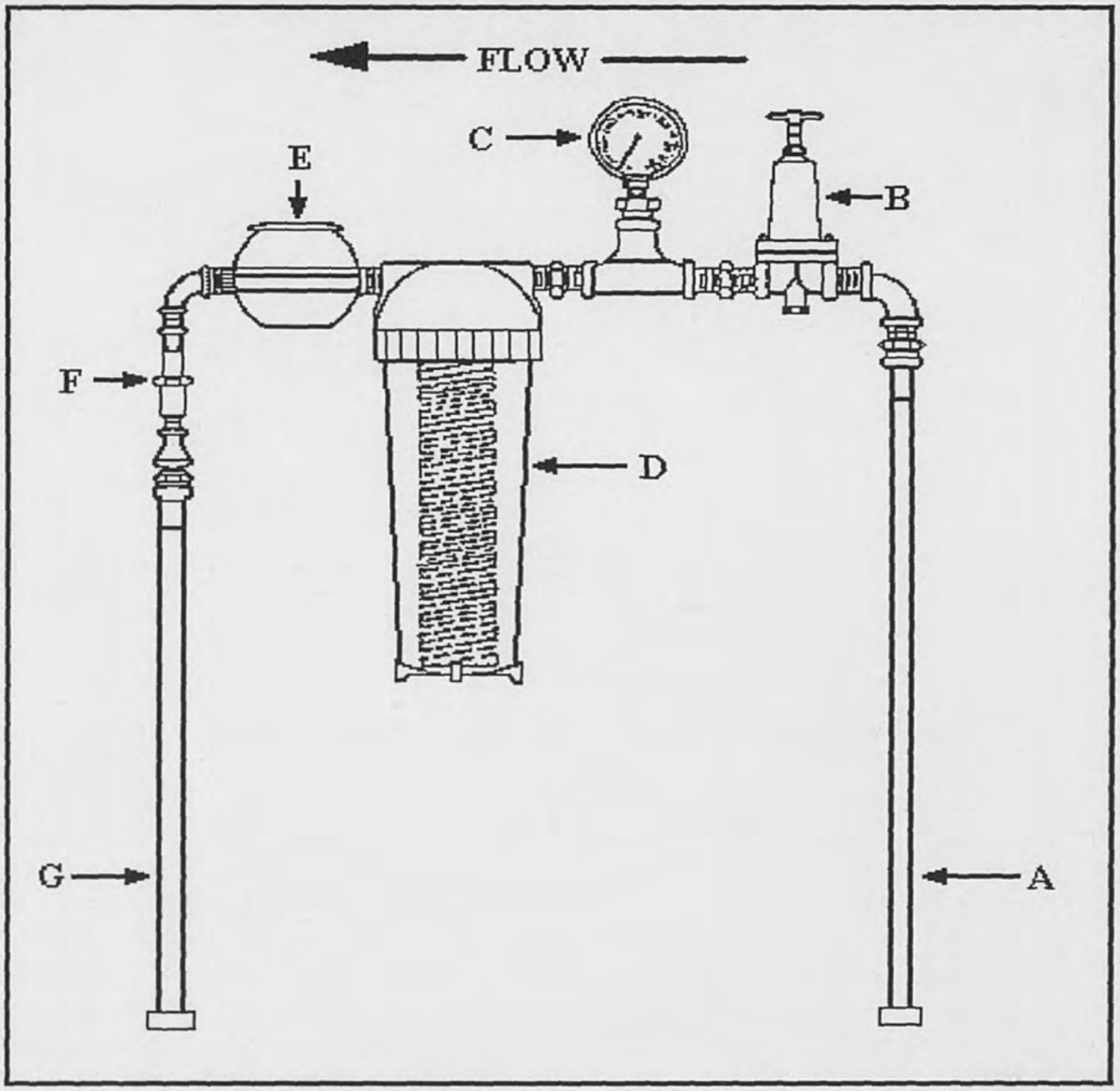


Figure 3.2 Sketch of Water Well Sampling Device

A hose bib at the inlet of the apparatus is attached to the raw water spigot (A). A one-way valve prevented backflow when the pump was off. An adjustable regulator (B) and pressure gauge (C) maintained a pressure of 10 pounds per square inch to prevent high pressure from flushing particles through the filter. The filter housing (D) was a plexi-glass shell that held the filter that collects the sample. In order to calculate the volume of water that passed through the filter, a water meter (E) was included and initial and final readings were taken. A limiting flow orifice (F) maintained a flowrate of approximately one-gallon per minute. Finally, a discharge hose (G) was attached with a backflow prevention device to prevent airflow back through the system when the pump was off.

3.2.4 Set-up of Sampling Apparatus

The sampling procedure involved a two-day event: the first day to set-up the sampling apparatus and the second to pick-up and disassemble it. According to the guidance manual, the recommended sample volume is five hundred gallons, so in order to obtain the necessary volume of groundwater pumped through the filter apparatus at one gallon per minute, the apparatus is attached for up to 24 hours. The samples were required to be transported to the Department of Health's Branch Laboratory in Tampa, Florida within the standard forty-eight hour hold time from the time of collection.

Before the sampling apparatus could be properly affixed to the raw water port, the guidance manual suggests that the well must be purged of three well casings. Typically, the safe assumption was made of twenty minutes of continuous pumping prior to sampling. Using a Hach Color Wheel, residual chlorine readings were measured at the raw water port prior to each sampling to verify a pretreated raw sample. The well was initially purged for twenty minutes to remove any water that may have been sitting in the well casing for quite some time. After the apparatus was installed, the filter housing was flushed with the raw water for an additional ten minutes. Extreme caution was used while inserting the filter into the housing to prevent contamination of the sample by wearing gloves and limiting the exposure of the filter to the air. After the filter was installed, an initial flowmeter reading was taken and recorded. The filter housing was then wrapped with aluminum foil to prevent light penetration that will enhance any photosynthetic growth. A sampling seal was placed across the aluminum foil to verify that the sample had not been tampered with. A photograph of the assembled apparatus is shown in Figure 3.3.

Figure 3.3 Photograph of Water Well Sampling Device

3.2.5 Removal of MPA Samples

During the second site visit, the final meter reading was taken and recorded, so that the total volume sampled could be calculated by simple subtraction. If the final number of gallons that flowed through the filter was less than five hundred, the sample was not collected at that time. Instead, the filter was left to continue sampling and picked up later that morning after other samples were collected. Typically the larger systems, such as municipal plants, did not require additional pumping and could be picked up early on the second day. On the other hand, smaller communities, such as mobile home parks, would sometimes require additional pumping time to achieve a larger sample volume through the filter. These sites were scheduled for later pickups to maximize the sample volume.

When removing the filter from the housing, sanitary rubber gloves were worn. The water in the housing was poured into ziploc bags, along with the filter. The samples were placed into another bag, properly labeled, and preserved with ice in a cooler.

After the five samples were collected, the cooler was closed and sealed with custody tape to guarantee the integrity of the samples. This tape ensured that the samples were relinquished by the sampler and could only be opened by laboratory personnel. The samples were then taken to the Greyhound Bus Station in Orlando, Florida, and sent to Tampa, where a courier service delivered them to the Department of Health Branch laboratory.

3.3 Microscopic Particulate Analysis (MPA) Laboratory Procedure

When the samples arrived at the Department of Health Laboratory in Tampa, Florida, the samples are carefully invoiced, labeled, prepared, and analyzed. The procedure is a very long, tedious analysis that consists of a two-day process. On the first day, the sample was prepared by removing the particulates from the filter and concentrating them into a 'pellet'. On the second day, a microbiologist placed the sample onto microscopic slides and read them using an elaborate microscope. It was suggested that the microscopy procedure could take as long as seventy-two hours (Stark, 1997).

3.3.1 MPA Sample Preparation

Using surgical, powder-free gloves, the filter was carefully removed from the double bags and placed into a metal tray. A sterile scalpel was used to cut the filter fibers lengthwise down the core on each side and was separated into two halves. The fibers were loosened to increase the surface area and each half was placed into clean bags and double-bagged to ensure no sample was lost. This procedure is shown in Figure 3.4.

Figure 3.4 Photograph of MPA filter fibers removed from sample spool

A volume of 1.75 liters of "tween" water is added to the fibers in each bag. The "tween" water contains sodium citrate, which acts as a mild detergent. The bags are placed in a "stomacher," which is a laboratory blender similar to a washing machine. Between each of the three three-minute cycles, for each bag, the bag was removed and each was hand-kneaded to redistribute the fibers. After homogenization, the corners of the double-bags are cut and the liquid is poured out into a beaker. The solution typically appeared as the color of the filter after sampling. The fibers are wrung out to remove as much of the liquid as possible. This is shown in Figure 3.5.

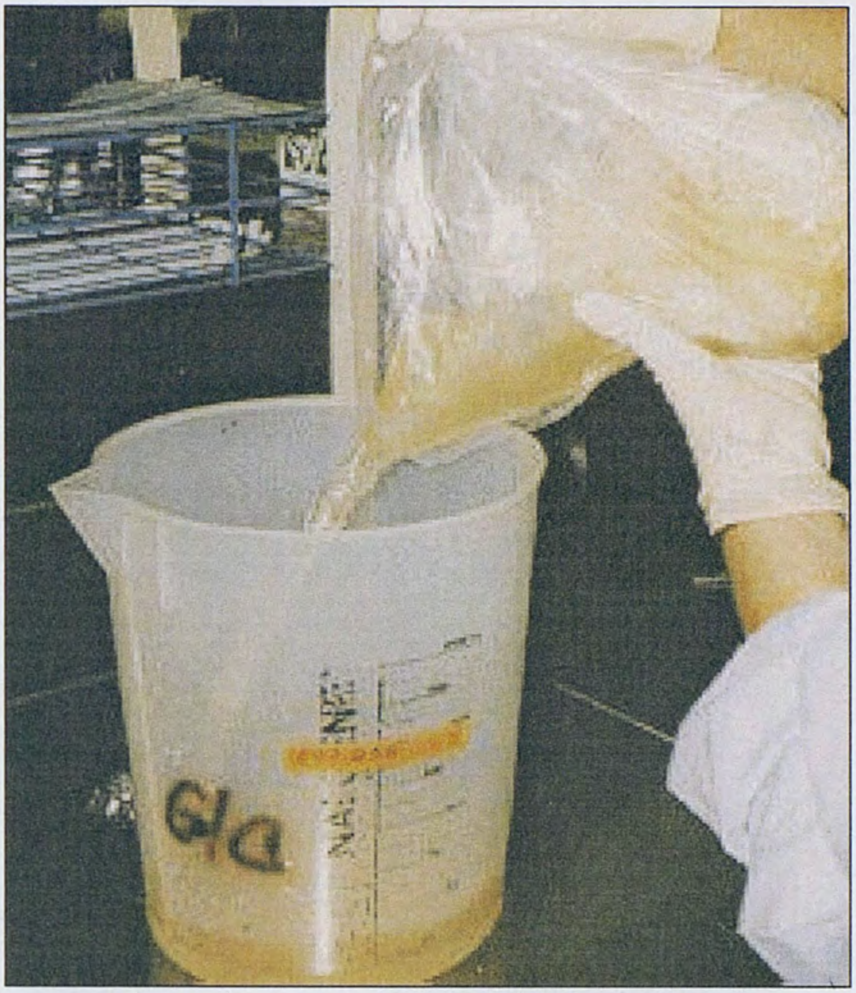


Figure 3.5 Photograph of MPA sample removal from filter fibers

After washing the filter fiber and transposing the particles into a liquid form, the particles were then concentrated into a solid. This was accomplished using several physical separation procedures. The sample was poured equally into four sterile, 250-ml conical beakers and placed in the centrifuge. Here, the sample was physically separated at 2500 revolutions per minute for ten minutes. When the sample is removed from the centrifuge, the supernatant fluid was aspirated using a vacuum and discarded. The contents of the four 250-ml conical beakers were then transferred into one 50-ml conical tube. This tube, which was previously weighed and recorded, was then placed in the centrifuge for another ten minutes at 2500 revolutions per minute and the supernatant was aspirated again. The total packed pellet volume was visually measured using gradations on the tube and calibrated 'dummy' tubes that were labeled with pre-measured increments. The volume of the pellet was converted to microliters (μl) of pellet per 100 gallons of sampled volume.

If the volume of the pooled sediment is greater than 20 µl/100 gallons, according to the USEPA Consensus Method, the sample should go through a process called a 'flotation'. The flotation process removes inorganic sediment, such as clays or silts. A solution of Percoll-sucrose was made with 62 ml of Percoll, which is a chemical that coats the cells and separates them to be more easily identified, 124 ml of 2.5 molar sucrose solution, and 100 ml of distilled water. The sucrose was added in order to increase the density of the solution. The specific gravity was measured using a hydrometer and was set equal to 1.15 by adding sucrose to increase the specific gravity and adding water to lower it. No more than one gram of pellet is added per tube. The Percoll-sucrose solution was placed under the sample solution using a syringe, which then forms a gradient interface. The content of the tube was then allowed to settle by gravity for five minutes. The top cloudy layer was aspirated and the content was diluted with 200 ml of "tween" water. During final centrifugation, the speed was slowly increased as not to disrupt the interface between the pellet and the gradient. After final aspiration, the final pellet volume was measured and recorded.

If the final pellet volume was less than 200 µl, the entire sample was examined at 20 µl per slide. If the final pellet was greater than 200 µl, the slides were prepared until the sediment equivalent of one hundred gallons of sampled water filtered has been examined. This preparation was accomplished using the dilution formula shown in Equation 3.1.

$$\# \text{ of Slides} = \frac{\mu l \text{ of pellet} \times \text{Dilution Factor (2)}}{\# \text{ of 100 Gallons Filtered} \times \frac{20 \mu l \text{ of pellet}}{\text{slide}}} \tag{3.1}$$

3.3.2 MPA Microscopic Evaluation

After the sample had been prepared as a final pellet, 20 ml was placed on a standard glass slide using a micropipet. Since up to thirty slides were required for one sample, each slide is properly labeled with a specimen and slide number. The slide was covered with a 22 mm by 22 mm coverslip, which was placed in such a manner that the particles distribute evenly across the slide and then the slide was sealed with clear nail polish.

The microscopy was performed using a Differential Interference Contrast (DIC) microscope. Each slide was read similar to a book, from left to right and from top to bottom. The left knob on the microscope moved the slide tray horizontally while the right moves it in the vertical direction. The entire slide was visually scanned and all primary and secondary bio-indicators were counted and recorded on an electronic tabulator. Figure 3.6 shows the DIC microscope, electronic tabulator and the particle counting procedure.

Figure 3.6 Differential Interface Contrast (DIC) Microscopy of MPA Sample

3.3.3 Interpretation of the MPA Microscopy Results

The particulate identification consists of two major categories: primary and secondary bio-indicators. According to the authors of the Consensus Method (Vasconcelos and Harris, 1989), the primary particulates are substantial indicators of surface water contamination. Most of the organisms are classified as surface water indicators because of their dependence on sunlight. For instance, blue-green, green, and brown algae require sunlight for their metabolism and sunlight is unavailable in a true groundwater source. Other organisms indirectly rely on sunlight for their food supply, such as most rotifer species. Some species of rotifers consume algae; however, some do not. The microbiologist must be able to correctly identify the species to make this determination.

A calibrated vertical ocular micrometer was used to measure the size of various bio-indicators and other particulates. The microbiota were identified to at least the class or phyta level and a picture was taken of each identified species.

The primary bio-indicators of a GWUDI are the presence of *giardia*, coccidia (*cryptosporidium*), diatoms and algae containing chlorophyll, insects and larvae, rotifers and plant debris. Examples of some primary surface water indicating microbiota are shown in Figure 3.7.

Diatom 1000x

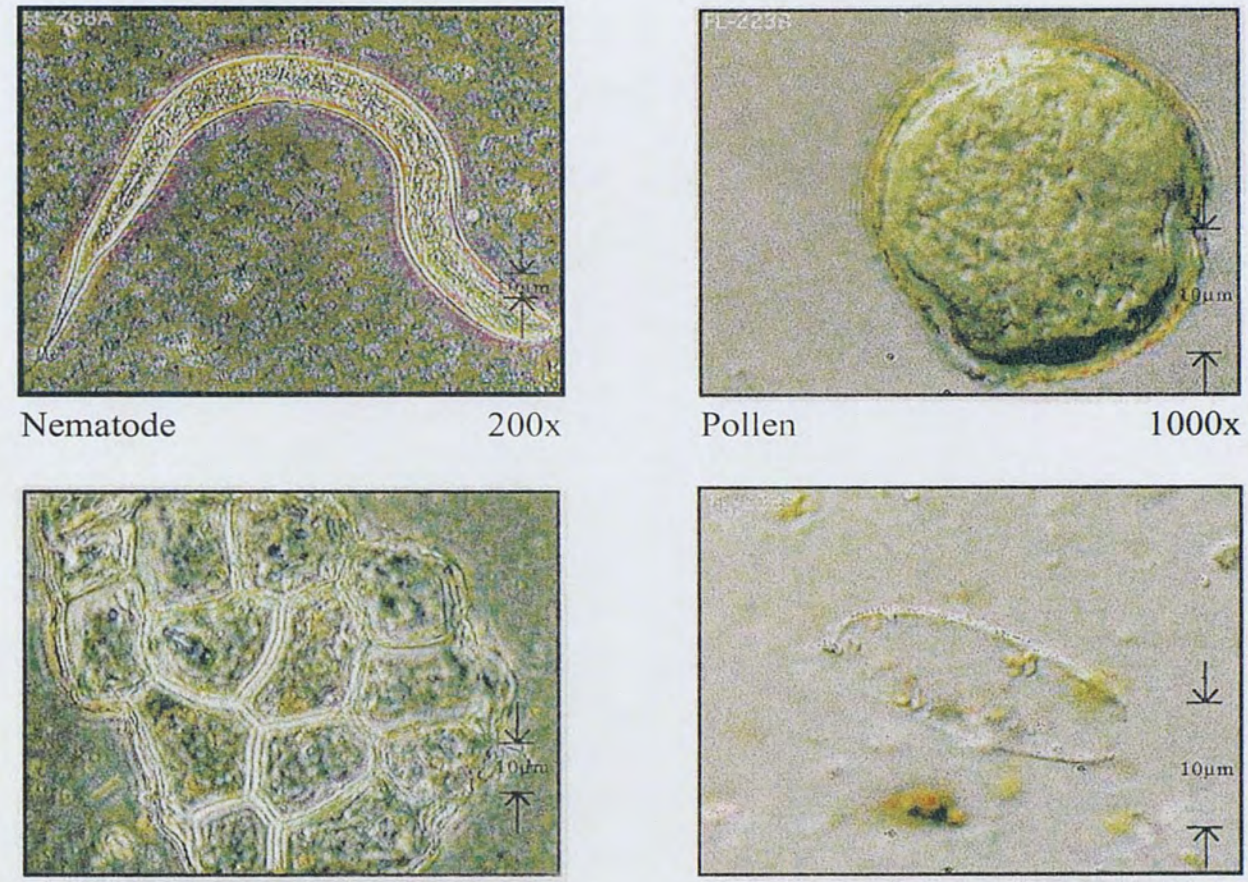
Blue-green Algae 1000x

Rotifer 400x

Green Algae 1000x

Figure 3.7 Photographs of Primary Bio-indicators Identified in the MPA

Other particulates are counted as secondary indicators, but their relative concentration has little significance according to the Consensus Method. These secondary particulates include large and fine amorphous debris, minerals, plant pollen, nematodes, crustacia, amoeba, eggs, bacteria, fungi and spores. Examples of these microbiota are shown in Figure 3.8.



Nematode 200x

Pollen 1000x

Plant Debris w/o Chlorophyll 400x

Protozoa - Amoeba 1000x

Figure 3.8 Photographs of Secondary Bio-indicators Identified in the MPA

All bio-indicators identified and used in the determination of the risk index for the 62 sampled wells are summarized in Appendix B.

3.3.4 MPA Classification and Quantification of Particulates

After counting the number of bio-indicators, the Consensus Method uses a pair of tables to evaluate the concentration, frequency and associated risk of each indicator. The number of each type of primary bio-indicators identified within each sample was added and the sum was compared to a range shown in Table 3.2. Depending on the frequency range, each indicator was ranked as being extremely heavy (EH), heavy (H), moderate (M), rare (R), or absent or no score (NS).

Table 3.2 Numeric Range of Bio-Indicators Counted per 100 Gallons Sampled

Indicators of Surface Water	EH	H	M	R	NS
Giardia	> 30	16 – 30	6 – 15	1 – 5	< 1
Coccidia	> 300	16 – 30	6 – 15	1 – 5	< 1
Diatoms	> 150	41 – 149	11 – 40	1 – 10	< 1
Other Algae	> 100	96 – 299	21 – 95	1 – 20	< 1
Insects/Larvae	> 100	31 – 99	16 – 30	1 – 15	< 1
Rotifers	> 150	61 – 149	21 – 60	1 – 20	< 1
Plant Debris	> 200	71 - 200	26 – 70	1 - 25	< 1

Using the frequency from Table 3.2, a risk factor is now assigned to the sample as shown in Table 3.3. These tables are included in the USEPA Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems

Using Surface Water Sources. This guidance manual was based on the Consensus Method discussed in Chapter 2.

Table 3.3 Relative Risk Indices associated with Particulate Frequencies

Indicators of	Relative Risk Index				
Surface Water	EH	H	M	R	NS
Giardia	40	30	25	20	0
Coccidia	35	30	25	20	0
Diatoms	16	13	11	6	0
Other Algae	14	12	9	4	0
Insects/Larvae	9	7	5	3	0
Rotifers	4	3	2	1	0
Plant Debris	3	2	1	0	0

These relative risk factors, or risk indices (RI), have been determined by a consensus of scientists across the United States. Typical MPA result for this study is shown in Table 3.4, while the summary of MPA results for the sixty-three wells in this study are summarized in Appendix B. The risk index (RI) determined herein using the MPA results will be denoted as RI_{MPA} throughout this thesis.

Table 3.4 Typical MPA results

County	PWS#	Site I.D.	Well I.D.	MPA Result	Risk Index
Marion	3420074	City of Belleview	Well 4	10	Moderate

3.4 Well Characteristics

The desired parameters included the total depth of the well, the casing depth, the diameter of each well and year the well was drilled, to determine the age of each well. These parameters were included in the questionnaire sent to the owner of all the wells sampled for MPA prior to arrival on site. However, these parameters were frequently unknown to the operator and owner of the wells. After installation of any well, the driller is required to submit a well completion report to the local regulatory agency – the Water Management District.

However, the data collection for the well characteristics was accomplished by visiting the Florida Department of Environmental Protection (FDEP) branch office in Orlando. At FDEP, all permits were filed by their respective Public Water Supply (PWS) identification number. Records for all counties where samples were collected were found at this facility except for Volusia County, which had its own Department of Health (DOH) office that served the county.

For the counties of Brevard, Indian River, Orange, Osceola, Marion, Lake and Seminole the pertinant data were collected from the PWS permit files at the FDEP-

Orlando office. The latitude and longitude of the location of each well were also collected. An example of the collected data is shown in Table 3.5 and the complete set of data of well characteristics for the sixty-two wells is included in Appendix C.

Table 3.5 Construction Characteristics Collected for a Marion County Well

PWS I.D. #	Year	Total Depth (ft)	Casing Depth (ft)	Diam. (in)	Latitude (° ′ ″)	Longitude (° ′ ″)
3420074	1982	250	105	16	29 03 00	82 03 10

Where a parameter was unavailable, the entire site was not used in the data analysis. The latitude and longitude proved to be very helpful in determining the hydrogeology of each site.

3.5 Hydrogeologic Data

Hydrogeologic data was stored in an ArcInfo, GIS database system called GeoSys/4G. The database system accessed is located at the Saint John's River Water Management District (SJRWMD) Office in Palatka, Florida. Using the latitude and longitude coordinates for each sampled well, a corresponding nearby SJRWMD monitoring well could be identified, since these monitoring wells had well logs associated with them. The hydrogeology of the sampled site was assumed to be similar to the hydrogeology of the monitoring well, if the distance between the two wells was relatively small. Using the latitude and longitude for the pairs of wells, the distance between the wells was calculated. This distance was less than three miles for most of the wells, however several exceeded five miles. Table 3.6 presents the distance between the wells and the complete set of sixty-two wells is in Appendix D.

Table 3.6 Distance Between Sampled Wells and SJRWMD Monitoring Wells

PWS ID #	Latitude (° ′ ″)	Longitude (° ′ ″)	SJRWMD ID	Latitude (° ′ ″)	Longitude (° ′ ″)	Distance (mi)
3420074	29 03 00	82 03 10	M-0082	29 03 37	82 04 33	2.18

Also, the gamma log plots for the monitored wells were collected electronically. After obtaining the file from the SJRWMD database in the form of a plot file, it was then transformed into a text file and finally imported to Microsoft Excel. This type of data collection was the least time-consuming and most efficient. The gamma log plots show the radioactivity of the subsurface versus the depth. Different types of subsurface soils emit distinct radioactivity. The stratigraphy, or layering of soils, can be determined by interpreting these plots. Figure 3.9 illustrates the gamma log plot from a Marion County well and all sixty-three wells are summarized in Appendix E.

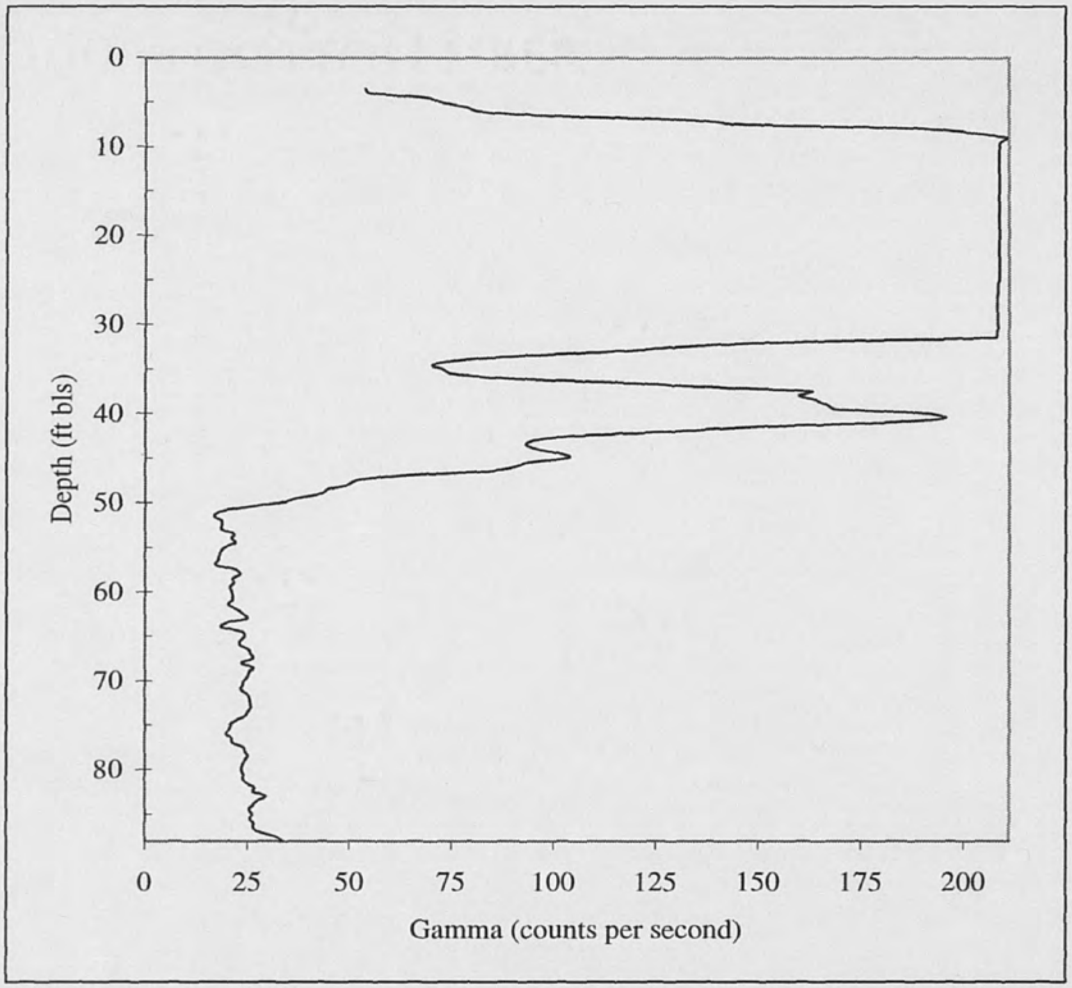


Figure 3.9 Gamma Log Plot from a SJRWMD Monitor Well in Marion County

3.6 Summary of Data Collection

Initially, the data collection for this study involved the sampling of raw water groundwater wells and shipment to the laboratory for analysis. After obtaining the results of the MPA from the DOH laboratory, the well characteristics and hydrogeologic parameters were calculated. These data were necessary for the investigation of the sampled wells. All data collected were to be used for comparison with the RI_{MPA} to identify factors that may be used as complimentary indicators of GWUDI.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

Well characteristics and well hydrogeology were investigated to identify parameters that may serve as complimentary or preliminary indicators of GWUDI. Each parameter was compared with the score of the Microscopic Particulate Analysis Risk Index (RI_{MPA}) to determine if any one factor played an indicating role in assessing groundwaters under the direct influence of surface waters. The results were also analyzed to determine if there was correlation between the RI_{MPA} and the parameters investigated, thus to identify factors that may be used as indicators of GWUDI before the use of the expensive and time-consuming Microscopic Particulate Analysis.

For a general understanding of the location and number of wells used in this study, the Microscopic Particulate Analysis Risk Indices and the location of wells were compiled and are summarized in Table 4.1 and displayed in Figure 4.1.

Table 4.1 Summary of Microscopic Particulate Analysis Well Risk Indices (RI_{MPA})

County	Low (< 10)	Moderate (10 - 20)	High (> 20)	Total
Lake	13	4	3	20
Marion	0	10	4	14
Orange	3	4	1	8
Volusia	12	1	0	13
Brevard	3	0	0	3
Seminole	3	0	0	3
Osceola	1	0	0	1
Total	36	18	8	62

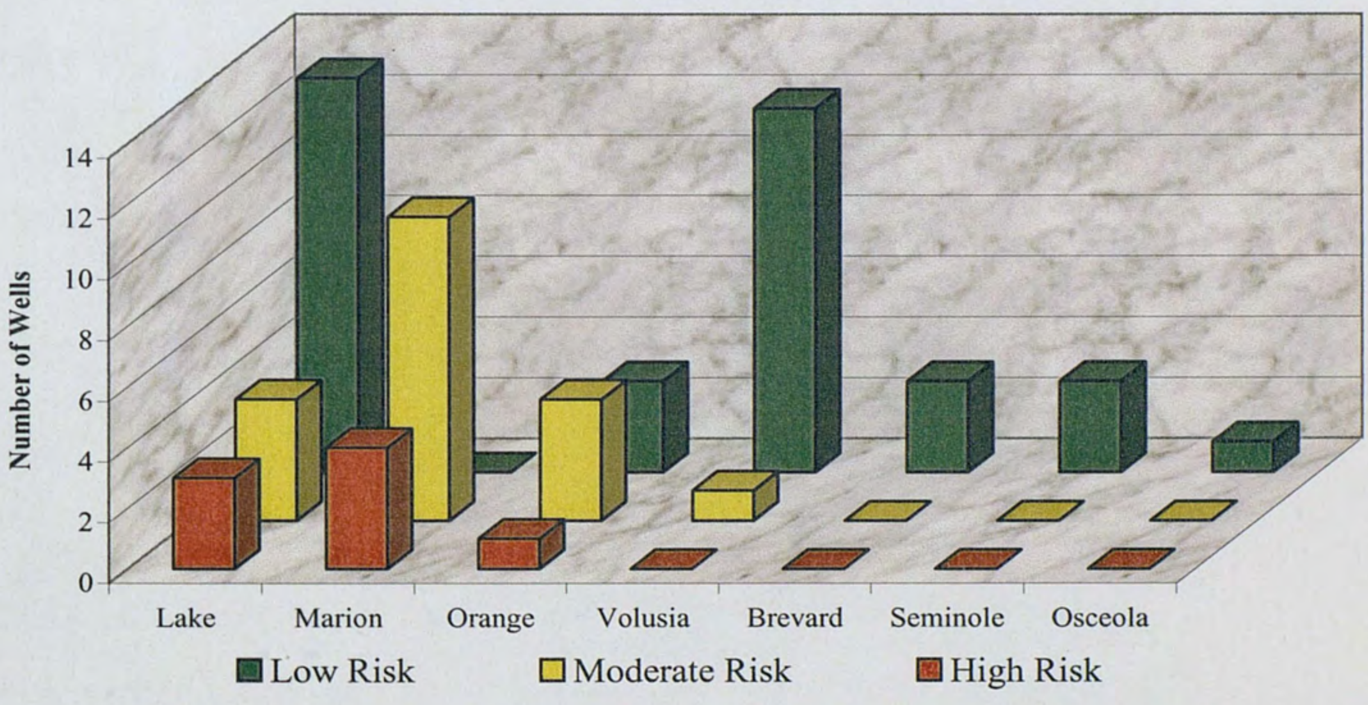


Figure 4.1 Summary of Microscopic Particulate Analysis Well Risk Indices (RI_{MPA})

Based on the sixty-two wells investigated in this study, eight raw water sources were categorized as being high risk ($RI_{MPA} > 20$) and these wells are all located in Lake, Marion, and Orange Counties. None of these counties is adjacent to large water bodies such as oceans, gulfs, or inter-coastals. However, there are large lakes and rivers in the immediate area. In addition, all of these counties are located in the central region of the State of Florida at the highest elevations.

4.2 Well Characteristics and the RI_{MPA}

The well characteristics used for the analyses were collected at the FDEP office in Orlando, Florida and the branch offices for the Volusia County Department of Health in Deland and Daytona Beach. The parameters include the year the well was drilled, hence, the age of the well, total depth of the well, the casing depth, and the diameter of the well. In addition, the total volume of raw water sampled at each well for MPA was also related to the RI_{MPA}.

4.2.1 The Age of the Well versus RI_{MPA}

The period the wells were drilled was reviewed in order to evaluate the influence of different construction materials during well installation. As discussed in Chapter 2, various materials were used for the casing of drinking water wells. As the technology for more improved materials became available, the standards were also changed. While reviewing the period the wells were drilled, it was expected that older wells may have slightly higher risk indices associated with them. The age of the well may reflect older pipes that may have deteriorated and left the well vulnerable to higher risk. The plot of age versus RI_{MPA} for all 62 wells is shown in Figure 4.2.

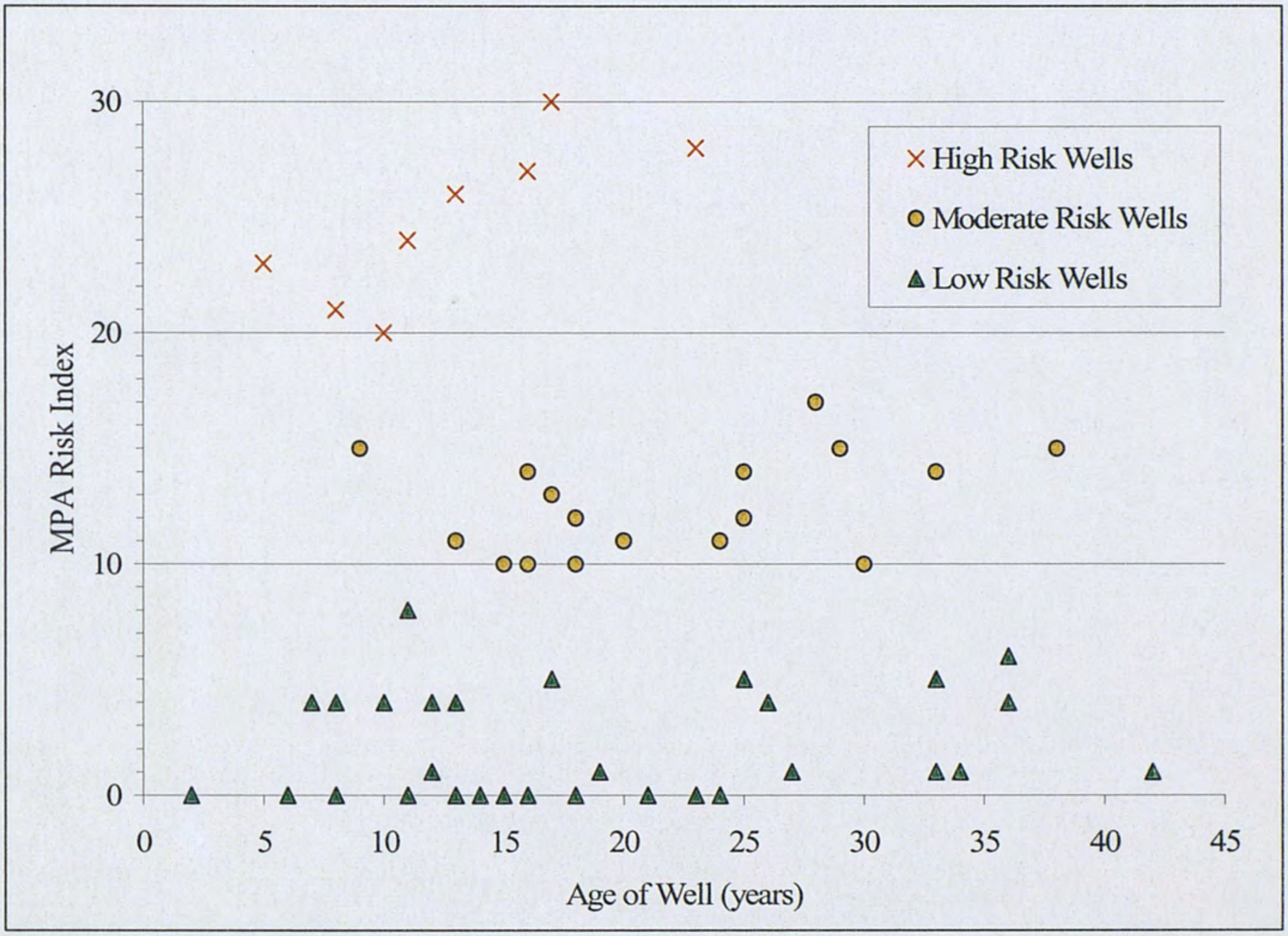


Figure 4.2 Age of Wells versus RI_{MPA}

Figure 4.2 shows three distinct groups of data. The data in the high risk sources ($RI_{MPA} > 20$), the moderate risk sources ($10 < RI_{MPA} < 20$) and the low risk ($RI_{MPA} < 10$) appear to have individual trends. In general, the rate of increase of the RI_{MPA} with age increases from low to high risk values. The results of this comparison did not appear to show the impact of pipe construction materials with respect to time. Wells that are fairly new, less than five years, were found to have high risk index.

4.2.2 Total Depth of the Well

The depth of each well, measured in feet below land surface (ft bls), was correlated to the RI_{MPA} to determine if it may be an indicator of GWUDI. As discussed in Chapter 2, the total depth of the well is the casing depth plus the screening length as shown in Figure 2.3. Since GWUDI is surface water dependent, it is expected that as the total depth of the well increased, the risk index is expected to decrease due to additional filtration stratigraphy between the surface and the groundwater resource. The RI_{MPA} is compared with the total depth of the wells under study in Figure 4.3.

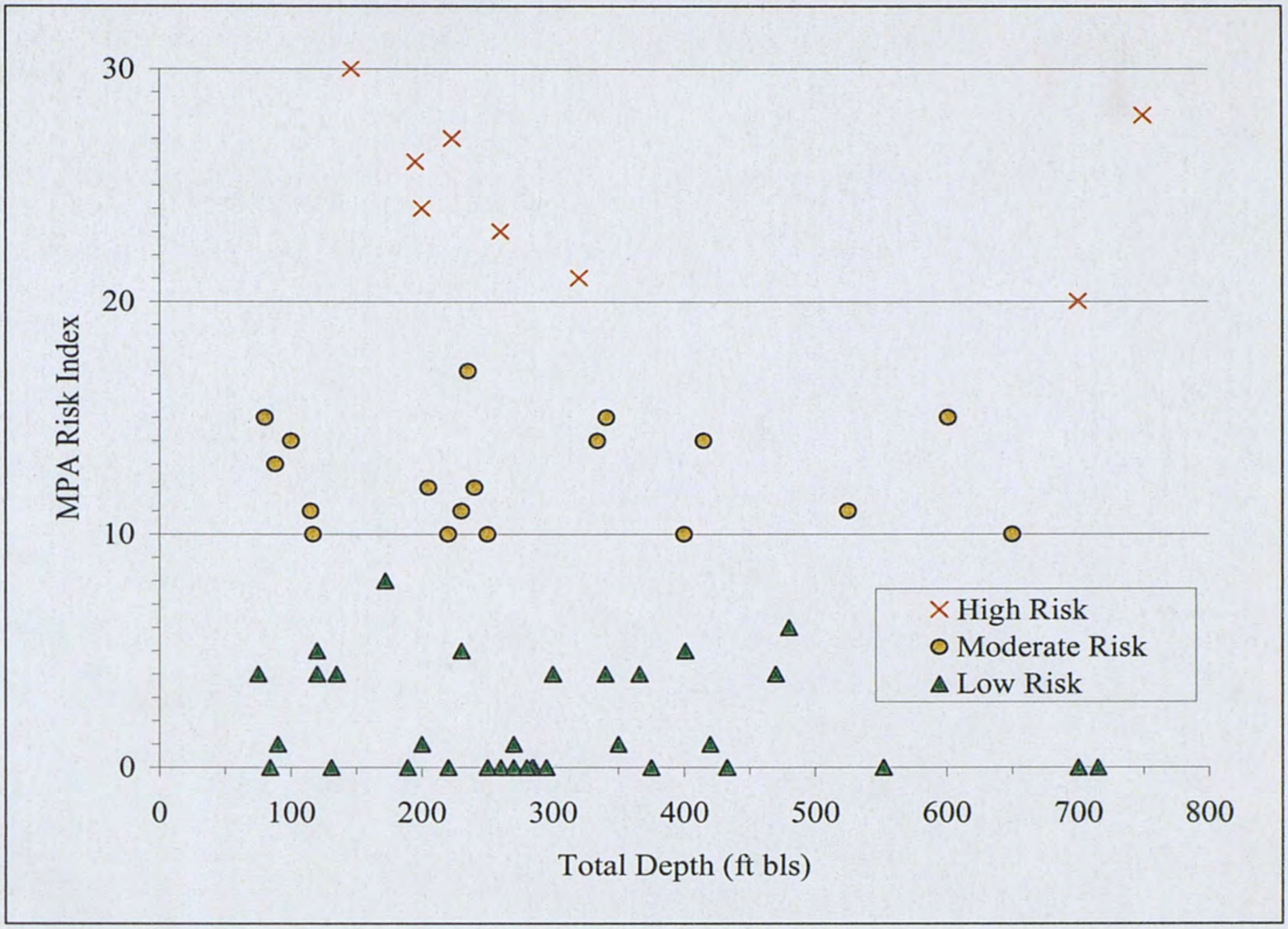


Figure 4.3 Total Depth of Wells versus RI_{MPA}

From this figure, it is evident that there appears to be no relationship relating the total depth of the sampled wells with the RI_{MPA}. Within each risk range, there is no obvious relationship between these parameters. Because there is noise in the data, the casing depth was compared with the RI_{MPA} to investigate if any correlation exists between the results and the MPA.

4.2.3 Casing Depth of the Well

The casing depth, measured in feet below land surface (ft bls), depicts the minimum distance that surface waters must travel to contaminate the raw source. This parameter is always less than the total depth. For obvious reasons, this parameter could be of importance in evaluating the structural integrity of the well and possibility of leaky joints. The deeper the casing, the more joints, thus increasing the opportunity for a direct route to the raw water source. However, if the casing remains in tact, the deeper the casing the less likely for surface water intrusion to the groundwater systems. Therefore, less chances of well water contamination. Figure 4.4 shows the casing depth compared with the RI_{MPA}.

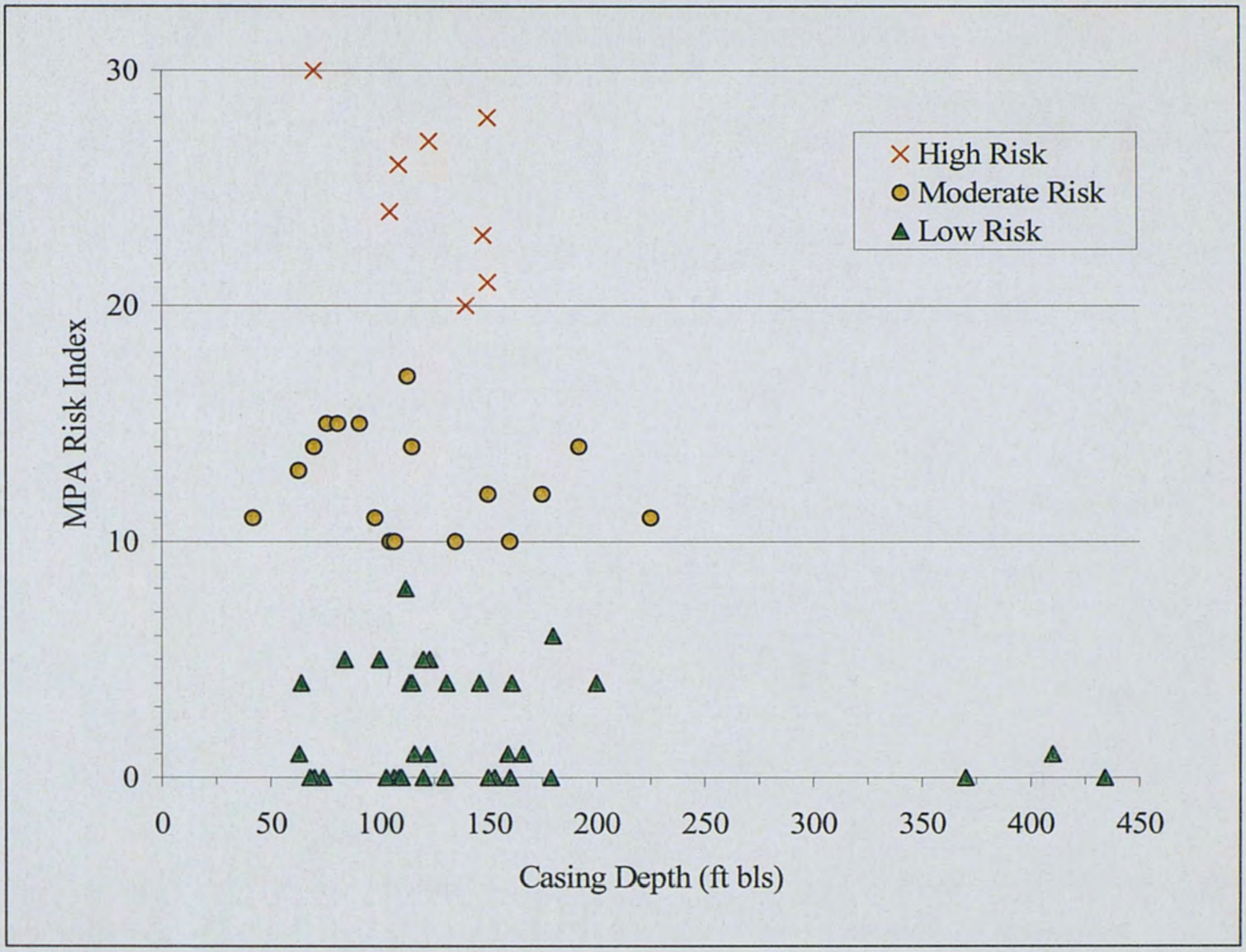


Figure 4.4 Casing Depth of the Wells versus the RI_{MPA}

Similar to Figure 4.2, Figure 4.4 shows three distinct groups of data. In general, it was observed that the RI_{MPA} appears to decrease with increase in casing depth for the high risk index ranges. The results also show that casing depths greater than 250 feet below land surface are associated with lower risk indices.

4.2.4 Diameter of the Well

The diameter of each well was investigated because of its direct correlation to the capacity pumped from the well. Similarly, the diameter of the well was expected to have direct relationship to the RI_{MPA}. Figure 4.5 illustrates the diameter for each of the sixty-two wells plotted versus the risk index based on the MPA.

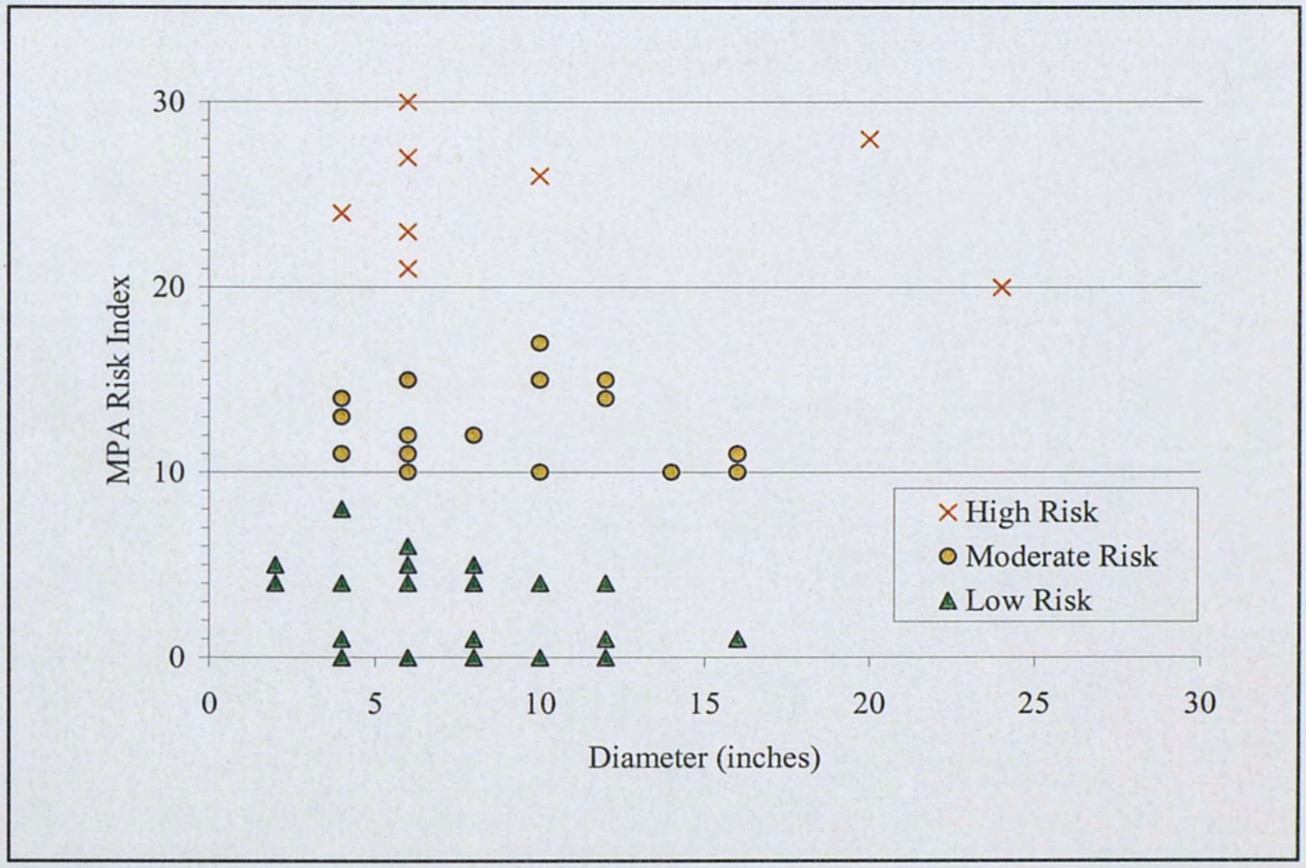


Figure 4.5 Diameter of the Wells versus RI_{MPA}

The data also show three distinct groups of low to high risks. The observation of the behavior of the relationship between the RI_{MPA} and the well diameter within each risk category show some noise in the data. However, it appears that the larger the diameter, the more susceptible to the bio-indicators.

4.3 Site Specific Hydrogeologic Results and the RI_{MPA}

Because of the poor correlation between some of the well characteristics and the RI_{MPA} there was need to further investigate other parameters, such as the hydrogeologic characteristics and their relationship with the risk index score. From the review of hydrogeologic characteristics that may influence the susceptibility of a groundwater supply to surface water contaminants, additional parameters were identified. The data was obtained using nearby SJRWMD monitoring wells and by interpretation of the gamma ray log plots. The site-specific factors included in this study are the depth to the confining layer, the thickness of the confining layer, and the volume of sediment in each sample.

4.3.1 Depth to Confining Layer

According to Wilson et al. (1996), the depth to the confining layer and the thickness of this confining layer may play the most important role in filtering the percolating recharge water. The confining layer throughout Florida consists of a formation called the Hawthorne group, which has more clay than any other found in the State of Florida. According to the Bureau of Geology, in general, the Hawthorn is marked by gamma-ray activities that are significantly higher than the overlying and underlying sediments (Hoenstine, 1984). In addition, the Hawthorne-Ocala interface is always marked by a large decrease in gamma activity near the upper extents of the Ocala formation (Hoenstine, 1984). The depth to the top of the Hawthorne formation is the depth to the confining layer. The illustration of these depths is shown on the gamma-ray plot in Figure 4.6.

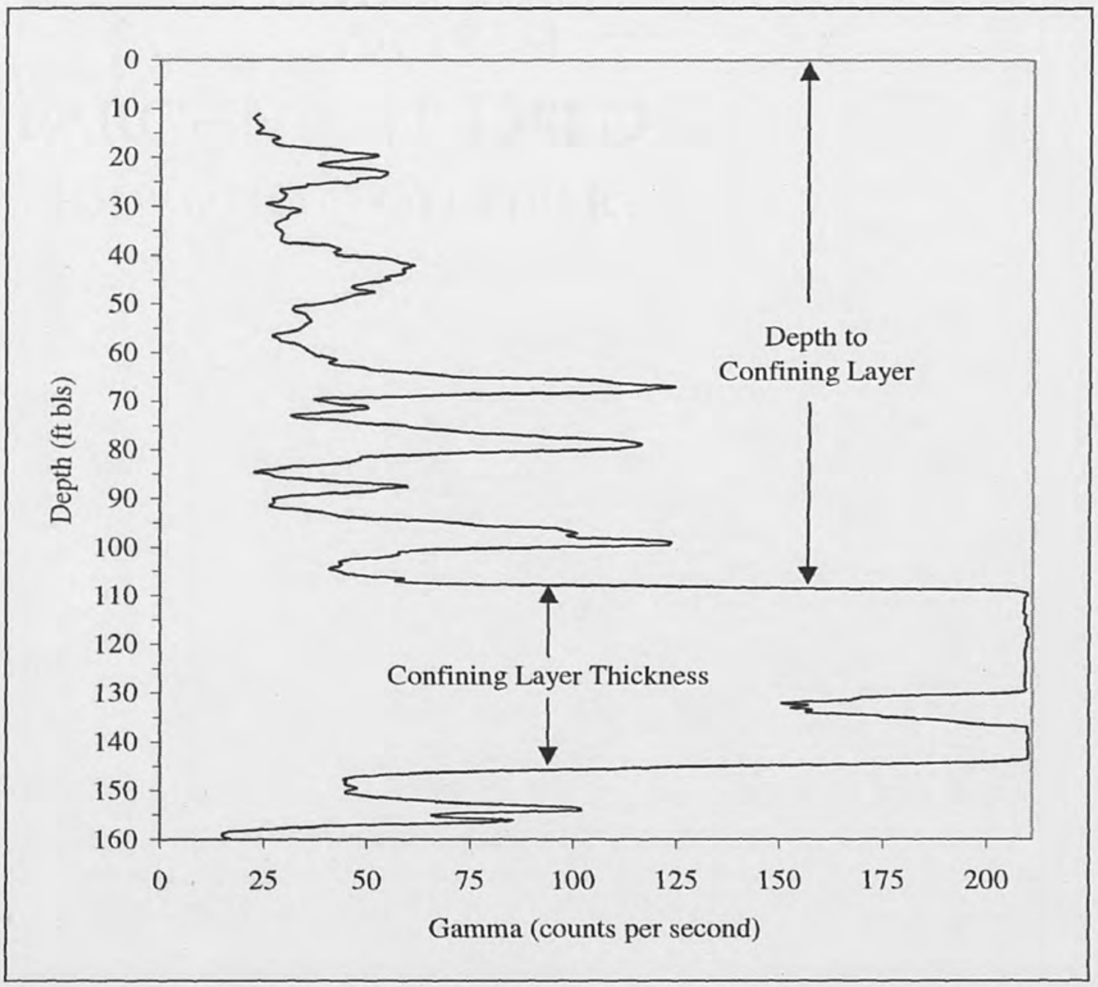


Figure 4.6 Gamma Log Plot Depicting Confining Layer Depth and Thickness.

For every well sampled for MPA, a nearby SJRWMD well was identified. The gamma log plot for the SJRWMD well was assumed to be similar to the stratigraphy for the nearby sampled well. As shown in Appendix D, ninety-two percent of the monitoring wells are within three miles of the sampled wells. The correlation of depth to the confining layer and the RI_{MPA} is shown in Figure 4.7.

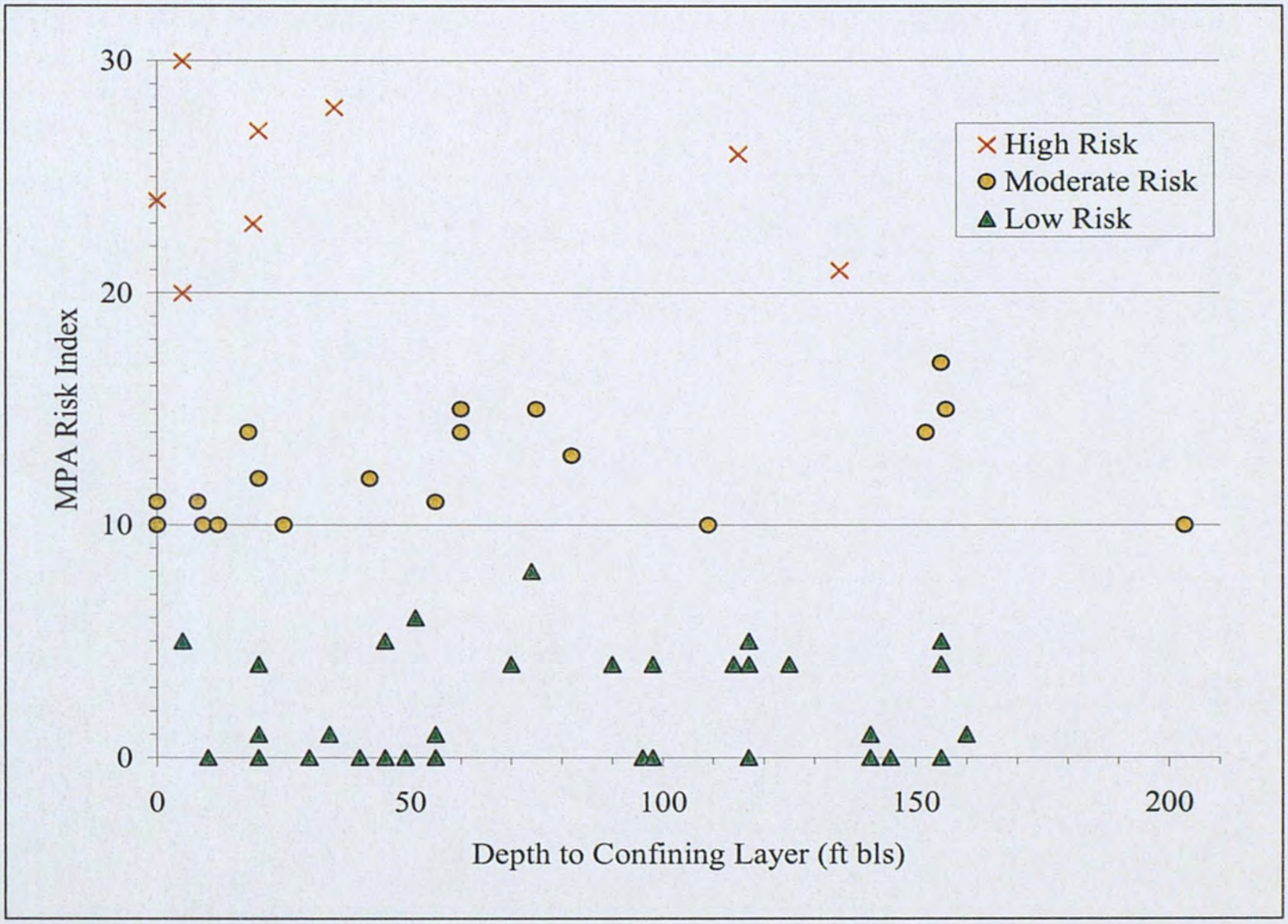


Figure 4.7 Depth to Confining Layer versus RI_{MPA}

It appears from Figure 4.7, that no apparent relationship exists between the depth to the confining layer and the RI_{MPA} for these sixty-two samples. Within each risk range, there is also no obvious trend or grouping of data that might indicate a correlation of any kind.

4.3.2 Thickness of Confining Layer

The thickness of the Hawthorne formation can contribute to the effective filtration of particulate matter as it percolates and recharges the aquifer. This thickness was measured as the difference between the depth to the underlying aquifer and the depth to the confining layer, as depicted in Figure 4.6. The thickness of the Hawthorne formation is compared to the RI_{MPA} in Figure 4.8.

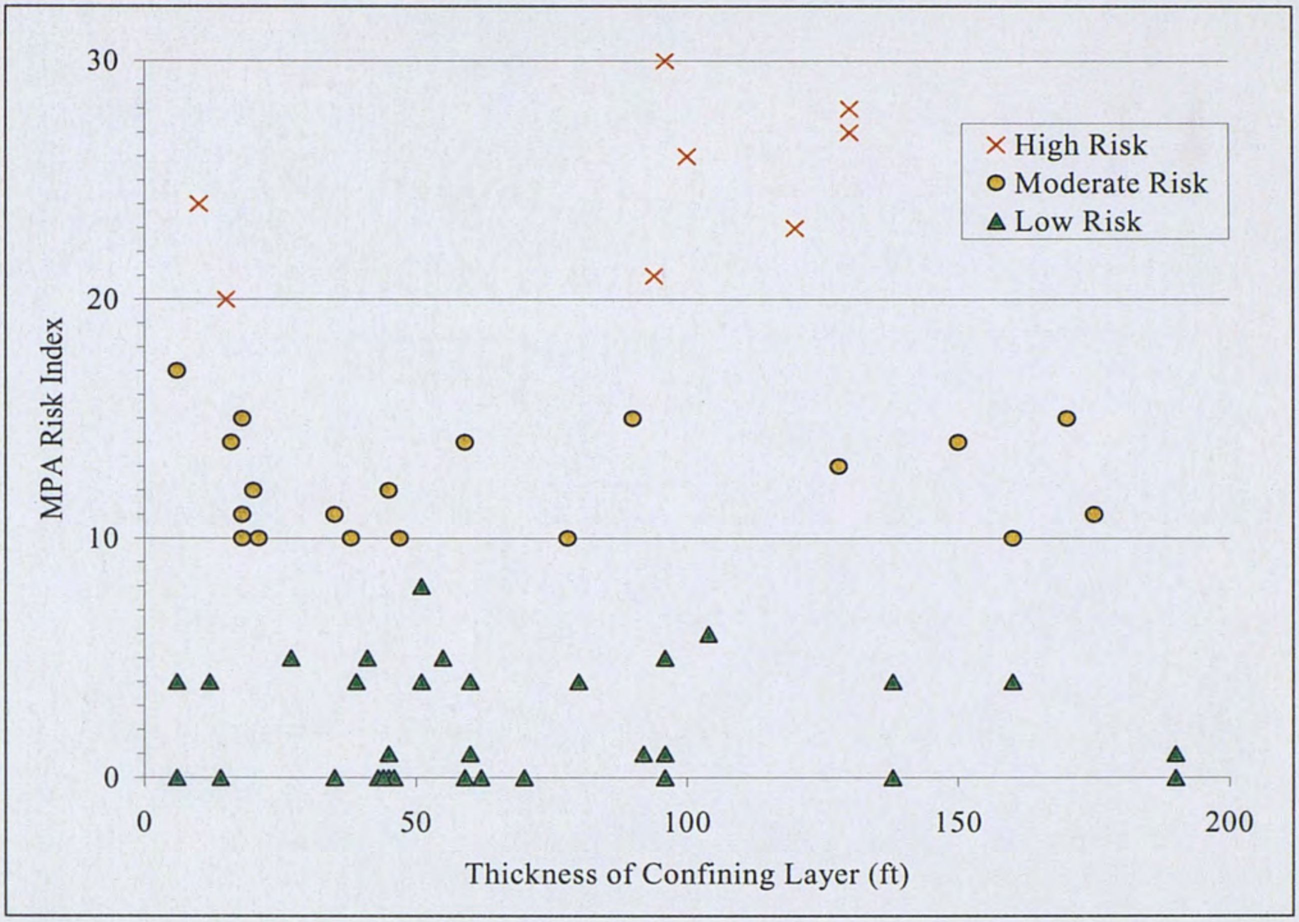


Figure 4.8 Thickness of the Confining Layer versus the RI_{MPA}

The results were found to be very similar to the results obtained for the total depth and thickness to the confining layer. The overall graph and each risk index range, does not appear to show any correlation.

4.4 General Hydrogeologic Assessment in Central Florida

Based on the previous analyses comparing the RI_{MPA} with well characteristics and hydrogeology, there were no obvious relationships existing for some of the parameters investigated in this study. However, the geographic locations for these sixty-two wells show various groupings of data throughout the Central Florida region. Figure 4.9 shows the distribution of the wells sampled in various counties and the associated risk score.

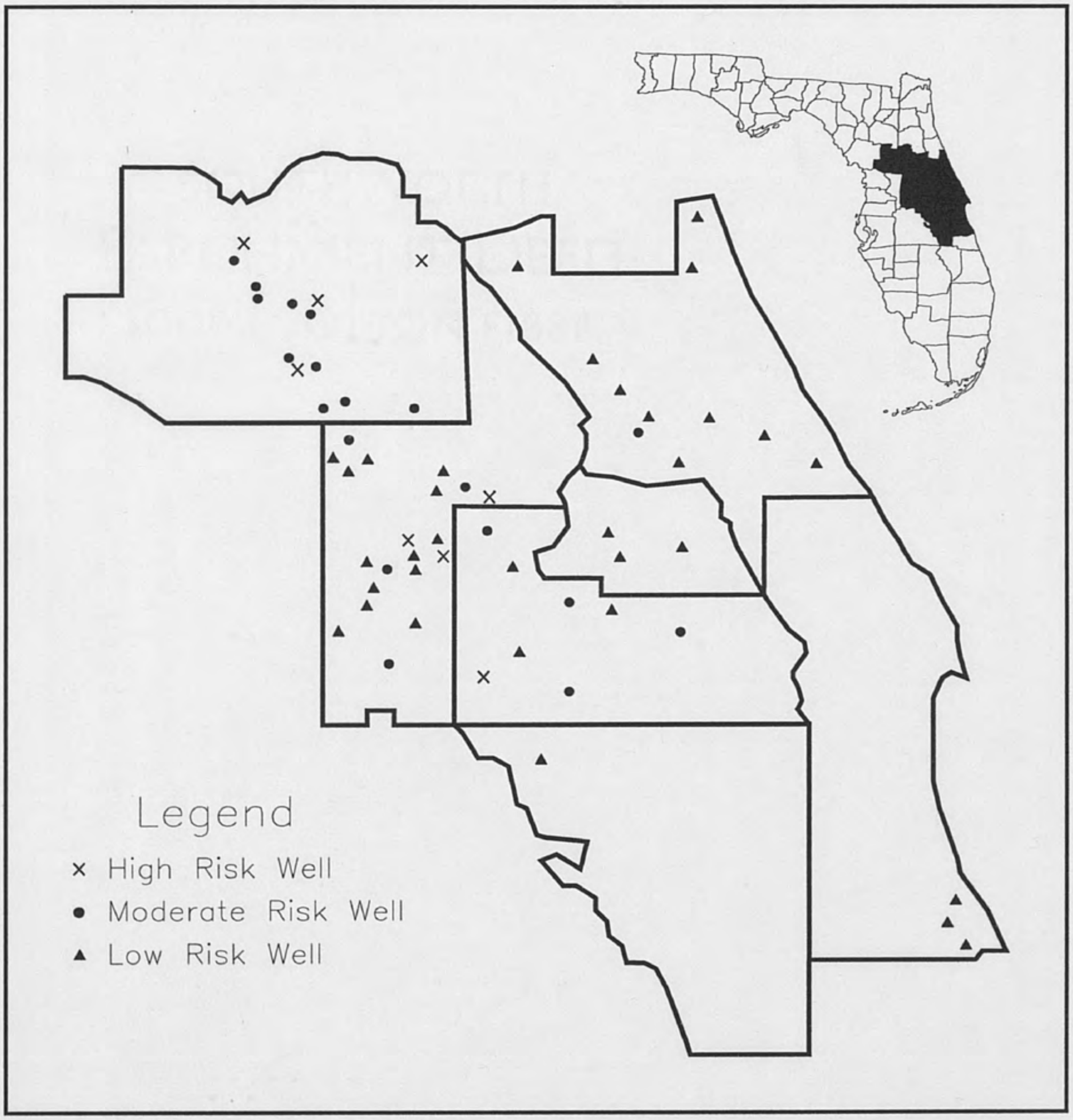


Figure 4.9 Map of Central Florida Showing High, Moderate, and Low RI_{MPA}.

From Figure 4.9, the high risk raw water sources are located along the center of the state. In addition, it can be identified from this figure that the wells at moderate risk are also located toward the center of the state, but tend to spread toward the coast. Because of the tendency of the data to cluster together, additional investigation of the general geology of the areas was necessary. Figure 4.10 shows the karst development in the State of Florida and adapted from Wright (1974). Karst regions occur when limestone or dolostone come in contact with slightly acidic waters. This causes the soluble limestone to dissolve and as the water continues to pass through the void spaces, which gradually enlarge and can become sinkholes. Virtually the entire State of Florida is subject to the development of sinkholes, but the distribution is not uniform as seen in Figure 4.10.

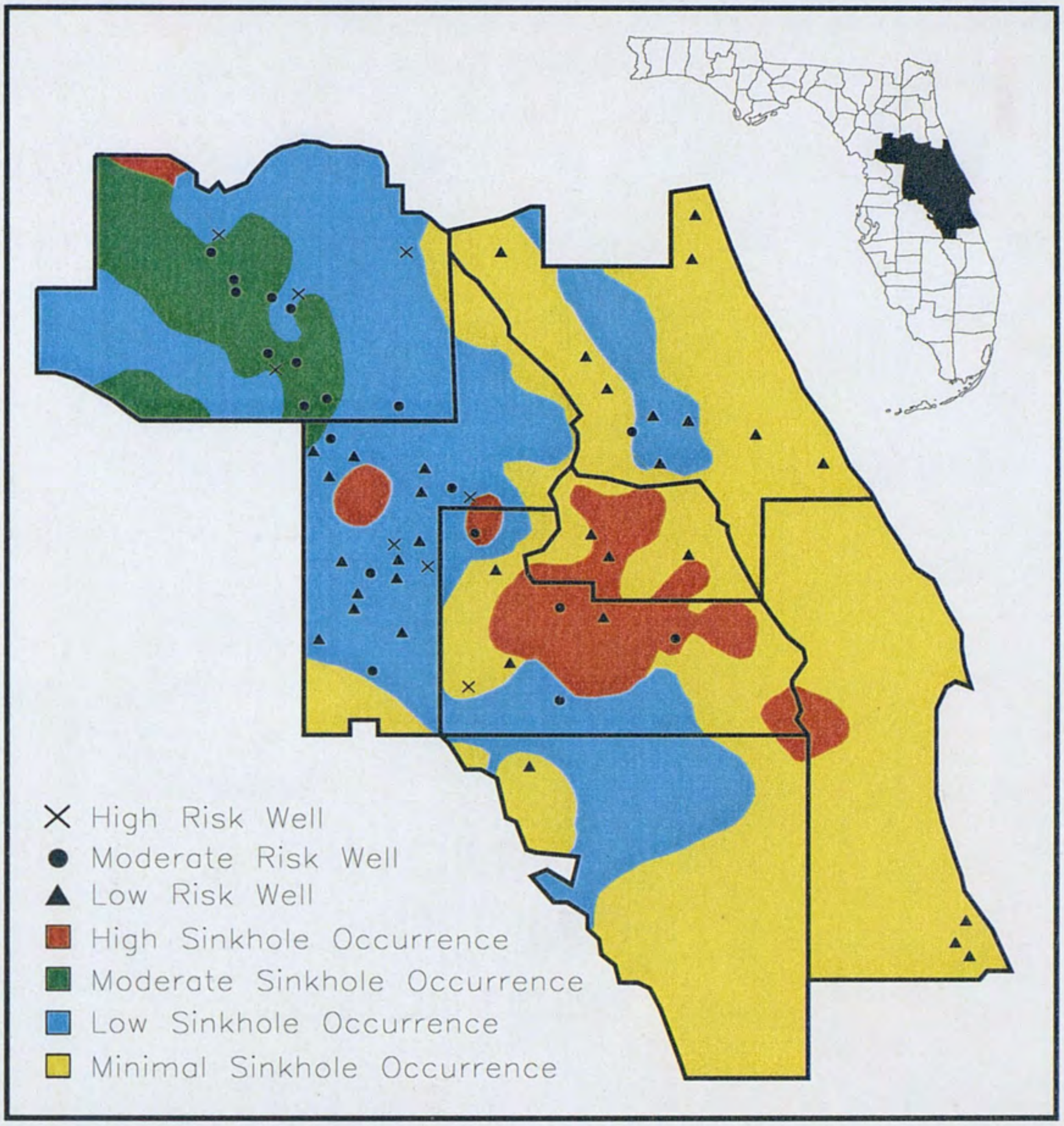


Figure 4.10 Karst Geology in the Central Florida region

As shown in Figure 4.10, the regions of sinkhole occurrence are related to the RI_{MPA}. It was observed that the karst regions throughout Central Florida are associated with high sinkhole occurrence. Most of the high and moderate risk sources were observed in the high to moderate sinkhole occurrence regions.

The map of recharge areas to the Floridan Aquifer identifying areas of high, moderate, low and minimal or no recharge was adapted from Stewart (1980) and is shown in Figure 4.11. The areas of high recharge are typically well-drained uplands with poorly developed stream drainage systems and numerous sinkhole formations. Moderate areas of recharge occur where confining layers are locally thin or breached. Also, moderate recharge can occur where the water table is significantly higher than the potentiometric surface of the Floridan aquifer system. Low recharge areas have a relatively thick and extensive confining layer, which restricts the movement of water to the Floridan aquifer. Areas of minimal or no recharge include springs and areas where artesian flow occurs.

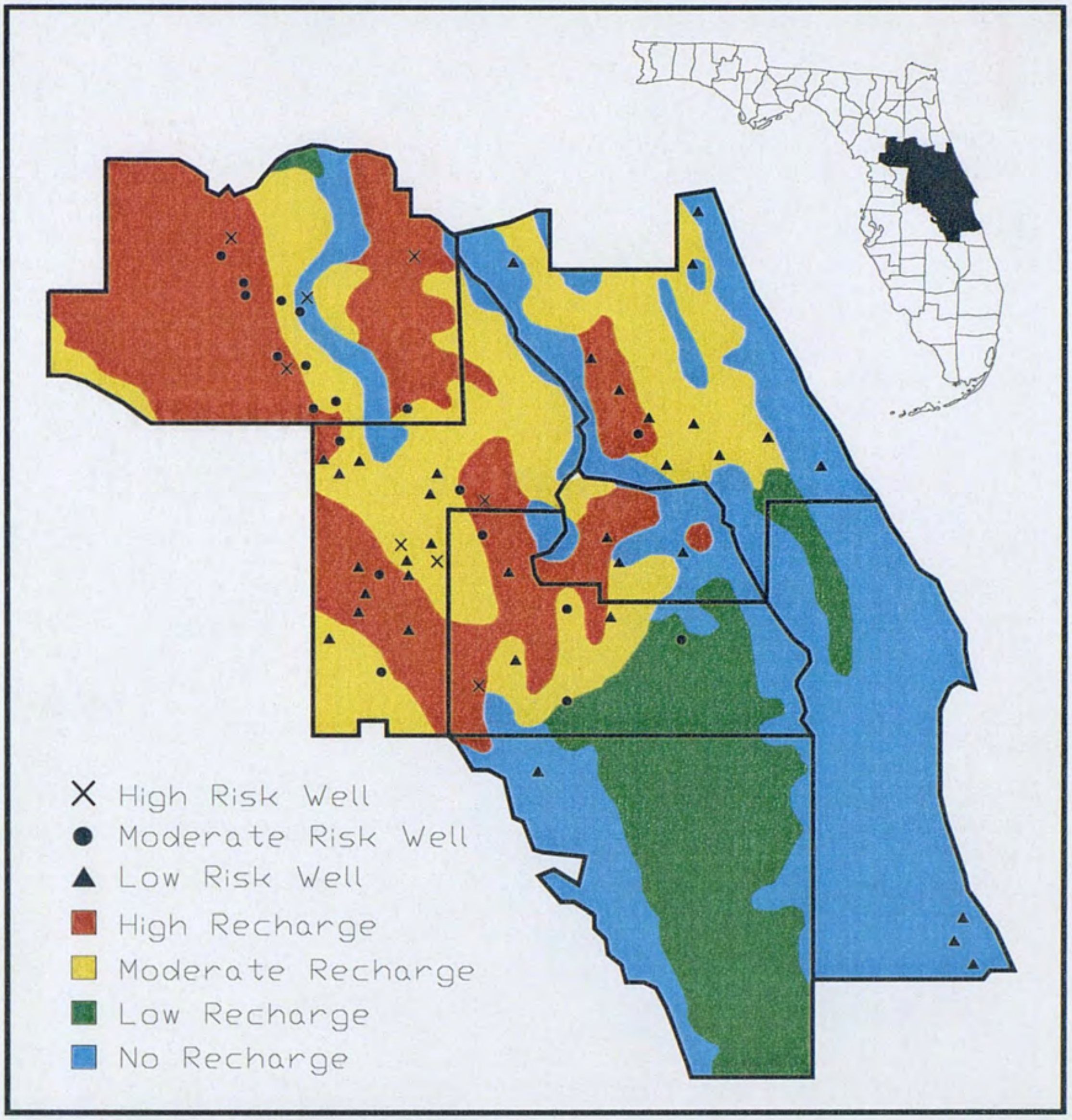


Figure 4.11 Recharge Intensities into the Floridan aquifer system

As shown in Figure 4.11, recharge intensities are related to the high, moderate, and low risk wells. Based on this recharge delineation map, the high and moderate risk wells are generally associated with high and moderate recharge areas. In addition, these high recharge areas are typically related to karst subsurface geology.

Another factor that was considered in this study that may contribute to the determining factors of GWUDI sources was the surficial geology. Figure 4.12 depicts the five basic surface materials in the Central Florida Region: limestone and dolomite, medium to fine sand, clayey sand, sand and shell beds, and peat.

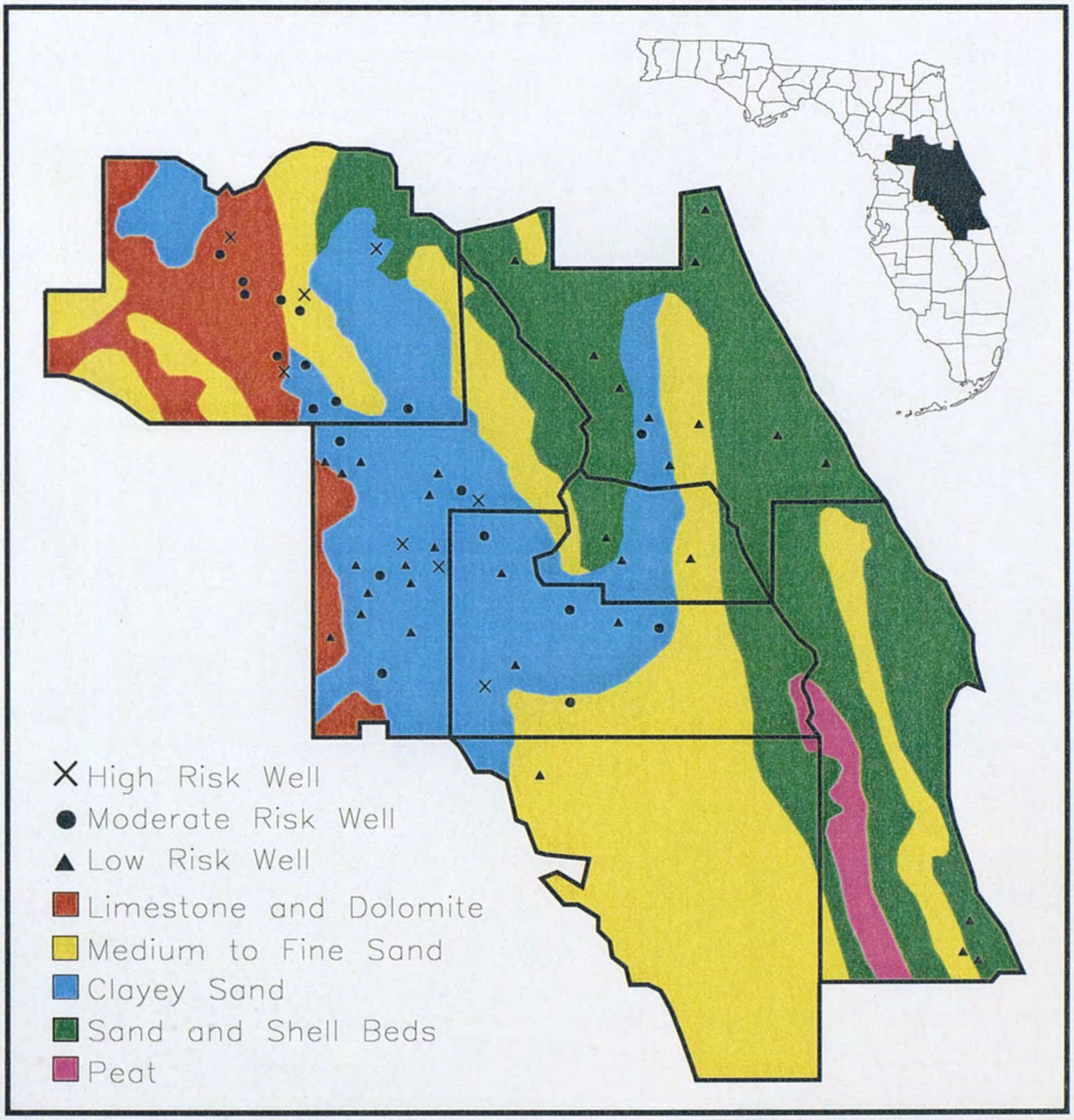


Figure 4.12 Surficial Geology in Central Florida

This figure shows most of the high risk and moderate risk wells are in the limestone, dolomite, clayey sand surface material category. Also, only low risk wells are located in areas of sand and shell beds.

4.5 Summary of Results

These maps show that the wells along the center of the state have a higher RI_{MPA} and are generally associated with karst subsurface formations and higher recharge areas. Also, the general geology, which consists of vast amounts of limestone and thin confining layers, was observed as a contributing factor to the susceptibility of the wells to bio-indicators.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Based on the data collected in this study, well and hydrogeologic characteristics were compared with risk indices generated from the microscopic particulate analysis (RI_{MPA}). From these analyses, factors were assessed that may influence the determination of groundwaters under the direct influence of surface waters.

The analyses of the well characteristics included the total depth, casing depth, diameter, and age of the wells. Based on the data presented in Chapter 4, section 2, the age, casing depth and the diameter of the well appear to have some sort of relationship when compared to the RI_{MPA}. The figures show three distinct groups of data for high, moderate and low risk sources. In general, Figure 4.2 shows that the rate of increase of the RI_{MPA} with age increases from low to high risk indices, while the reverse is the case for the casing depth and the diameter of the wells.

The site specific hydrogeologic characteristics were compared to the RI_{MPA} as summarized in Chapter 4, section 3. This was investigated to assess the filtration effectiveness of the confining layer, as well as the distance surface water must travel to contaminate the groundwater. From the results it can be concluded that there was no apparent relationship between the site-specific hydrogeologic components and the RI_{MPA}.

After assessing the hydrogeology locally, general geology maps of the Central Florida region were compared with the RI_{MPA}. Karst regions, recharge intensities, and surficial material maps were compared with the location of the high, moderate, and low risk sources based on the MPA. From these comparisons, the following conclusions can be drawn:

- All the high risk wells were located toward the center of the state.
- High risk wells are generally associated with karst subsurface formations and higher recharge areas.
- The general geology of high and moderate risk wells consists of vast amounts of limestone and have thin confining layers.

Since groundwater provides fifty-two percent of the United States with drinking water, proper identification of suspected groundwaters under the direct influence of surface waters is very important.

5.2 Recommendations

The results of this study suggest a review of the methodology and accuracy of the Consensus Method protocol involving the Microscopic Particulate Analysis (MPA). Measurements of accuracy, using matrix spikes or certified knowns, and precision, such as duplicates and replicates, may further verify the analytic procedure. For additional quality control purposes, verification of the procedure may include the analysis of a "blank" sample filter that has been prepared with deionized water. Also, the exploration of relationships between laboratory parameters and the RI_{MPA} is suggested.

In order to identify the factors that cause surface water to contaminate the groundwater resources, additional information beyond those factors considered in this study, such as stratigraphic and lithologic formations surrounding sampled wells, need to be investigated. This effort will help protect the groundwater free from surface water contaminants for future generations.

APPENDIX A

LOCATION MAPS OF WELLS

A-1 Brevard County

A-2 Lake County

A-3 Marion County

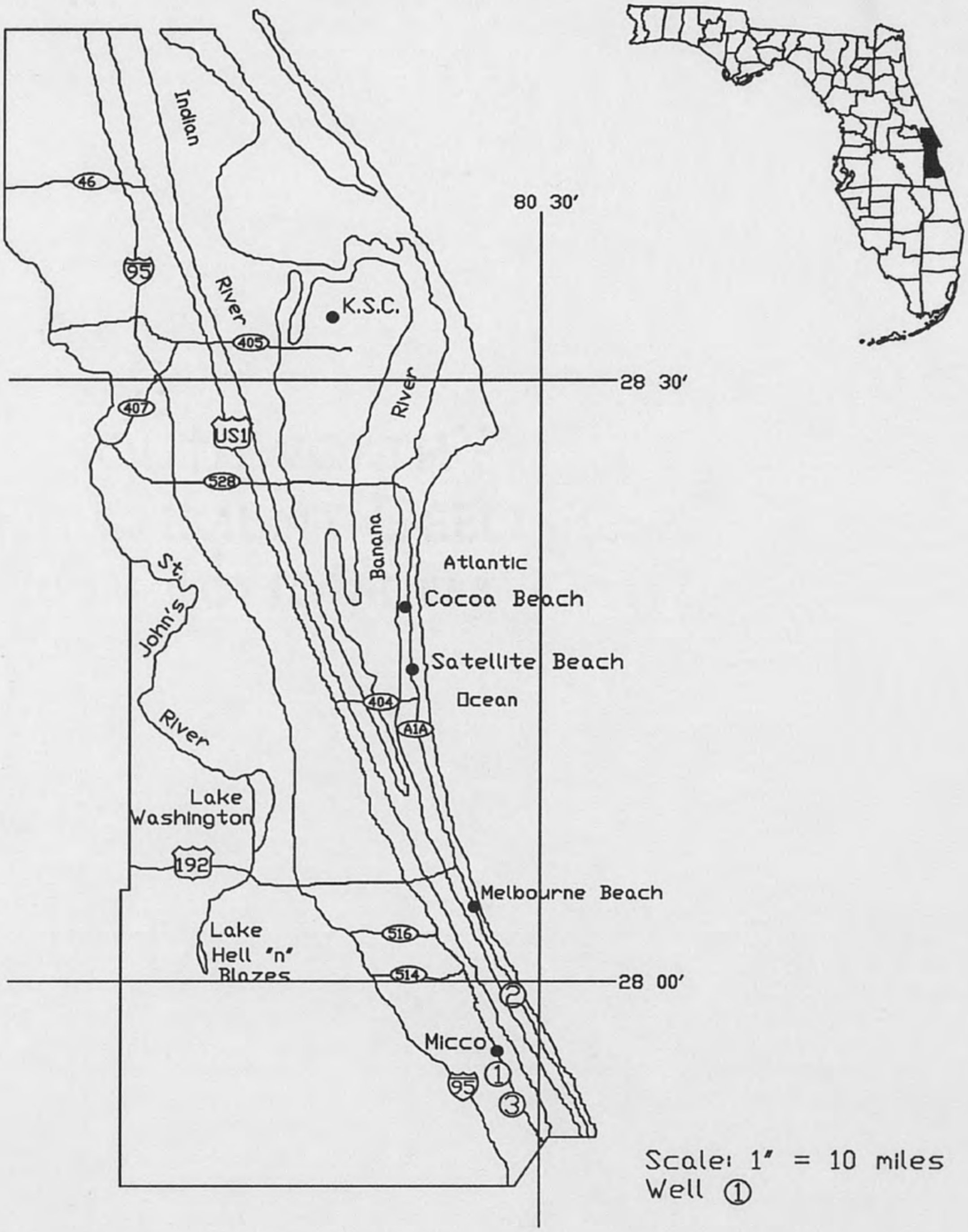
A-4 Orange County

A-5 Osceola County

A-6 Seminole County

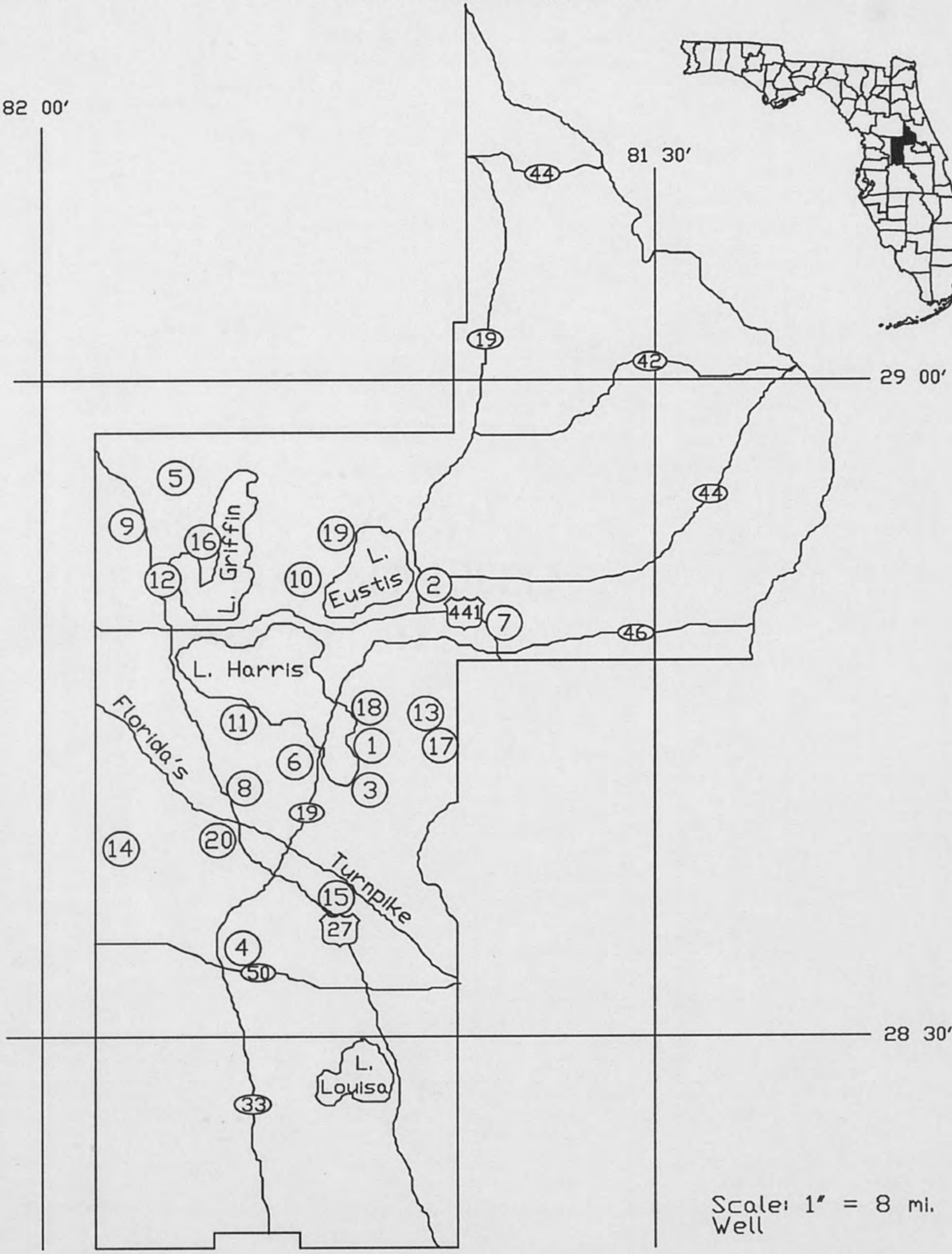
A-7 Volusia County

Appendix A-1
Wells in Brevard County, Florida



Well #	PWS #	Site	Latitude (° ′ ″)	Longitude (° ′ ″)
1	3054056	Snug Harbor Village	27 53 19	80 30 32
2	3054062	South Shores Utilities	27 58 20	80 30 40
3	3050596	Indian River Shores	27 53 45	80 30 30

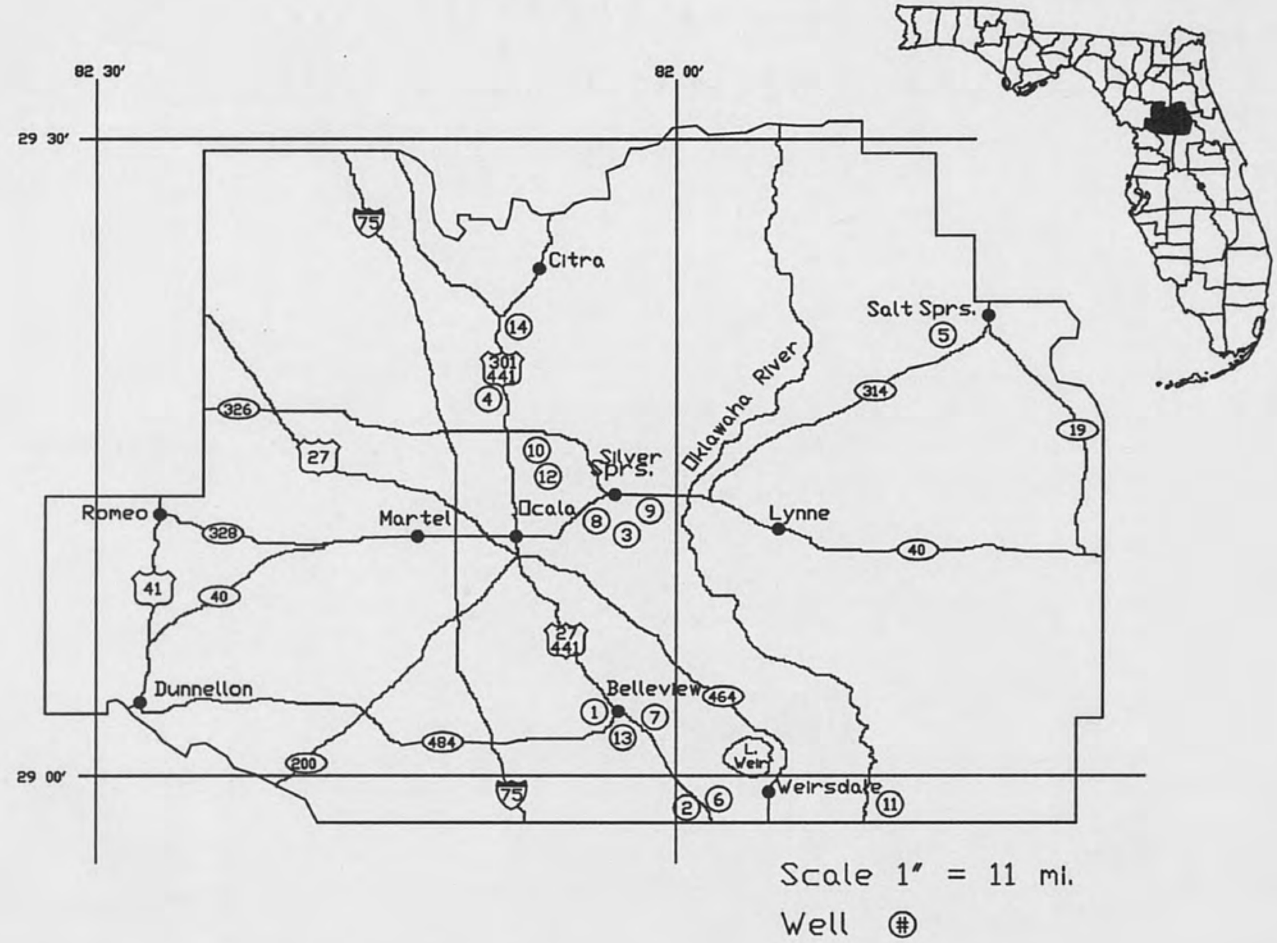
Appendix A-2
Wells in Lake County, Florida



Appendix A-2
Wells in Lake County, Florida

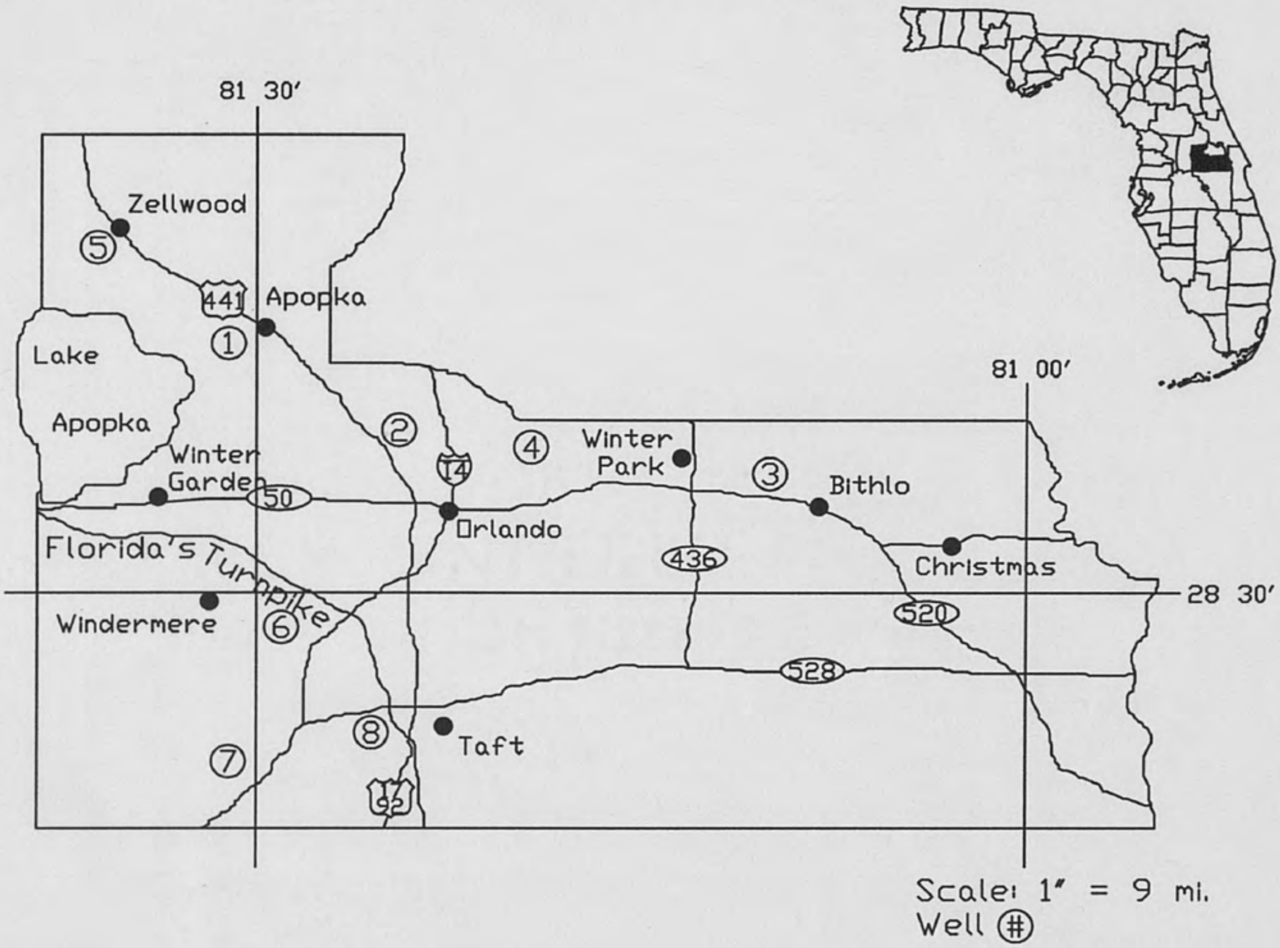
Well #	PWS #	Site	Latitude (° ′ ″)	Longitude (° ′ ″)
1	3350322	E. Lake Harris	28 43 30	81 44 12
2	3350346	City of Eustis	28 50 50	81 40 14
3	3350426	Friendly Center	28 43 25	81 44 12
4	3350476	Groveland Water Dept	28 34 07	81 50 37
5	3350544	Hobby Hill	28 53 30	81 54 30
6	3350573	Howey in the Hills	28 42 35	81 46 15
7	3350858	City of Mount Dora	28 49 00	81 38 30
8	3350981	Palm Mobile Home	28 41 49	81 51 30
9	3351021	Piney Woods	28 52 30	81 55 12
10	3351182	Silver Lake Estates	28 50 17	81 47 22
11	3351282	Stone Mountain	28 45 11	81 50 27
12	3351421	Valencia Terrace	28 50 58	81 53 28
13	3351426	Venetian Village	28 45 25	81 41 09
14	3354010	Water Oak Ctry Club	28 55 40	81 55 15
15	3354104	Clerbrook RV	28 36 30	81 45 30
16	3354661	Picciola Landing	28 51 30	81 53 20
17	3354662	Lake Beauclaire S/D	28 45 82	81 40 70
18	3354836	Bella Vista Golf Course/Marina	28 45 00	81 45 00
19	3354867	Quail Ridge Estates	28 53 00	81 46 02
20	3354929	Royal Highlands	28 39 50	81 52 00

Appendix A-3
Wells in Marion County, Florida



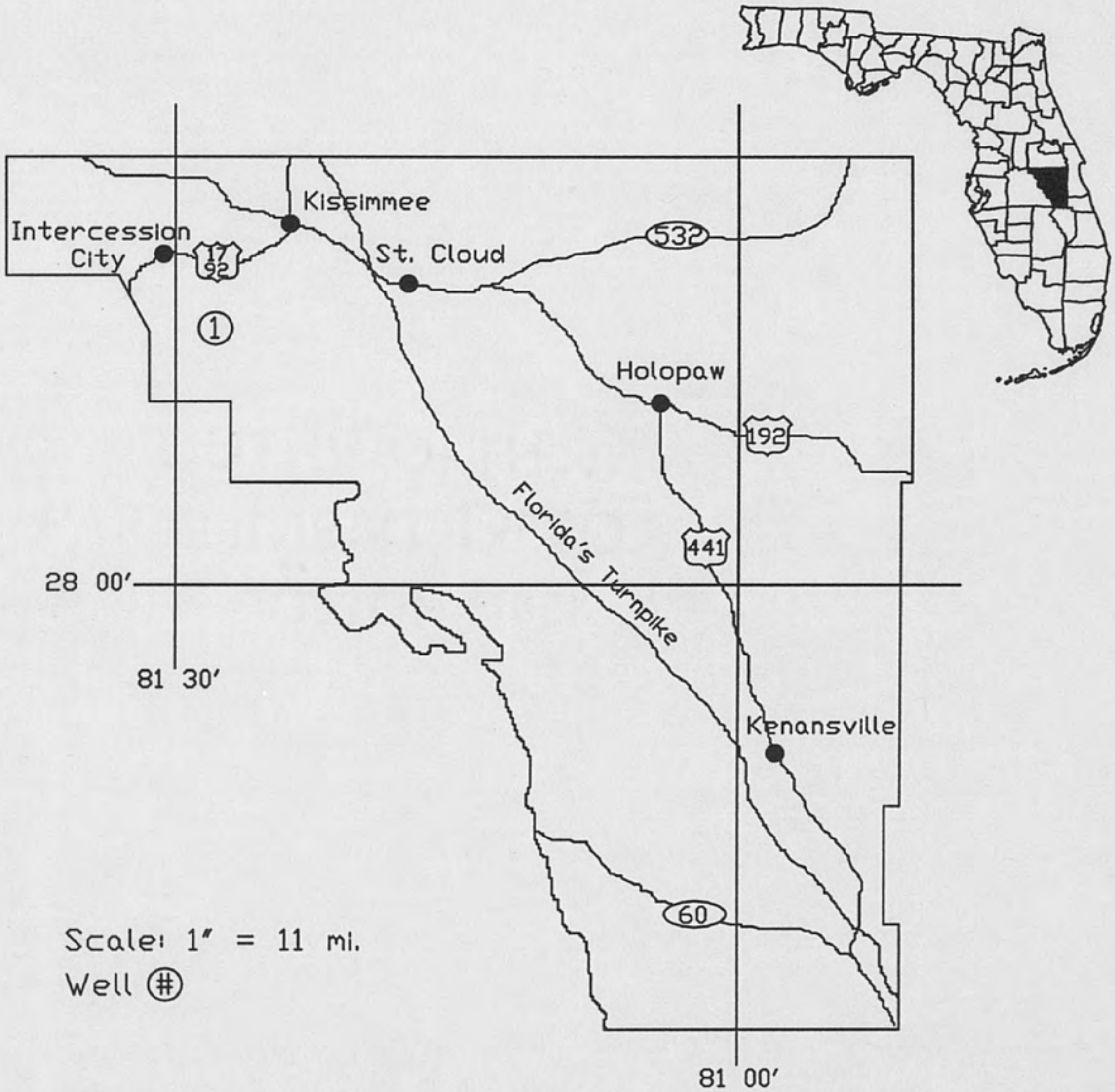
Well #	PWS #	Site	Latitude (° ' ")	Longitude (° ' ")
1	3420074	City of Belleview	29 03 00	82 03 10
2	3420085	Big Lake Village MHP	28 57 30	81 57 03
3	3420199	Citrus Park	29 07 10	82 05 20
4	3420386	Florida Correctional Inst.	29 18 36	82 12 09
5	3420924	Ocala East Villas	29 21 35	81 44 10
6	3421269	Stanton-Weirsdale Elem.	28 58 10	81 55 50
7	3421467	Whispering Oaks RV Park	29 03 05	82 02 05
8	3421554	Ocala Garden Apartments	29 10 00	82 08 30
9	3424031	Florida Heights	29 08 40	82 03 10
10	3424034	Oakmuir	29 15 57	82 07 50
11	3424229	Child's Haven	28 56 47	81 38 07
12	3424645	Windstream and Carriage Hill	29 09 00	82 08 00
13	3424671	Soul's Harbor Academy	29 02 30	82 03 30
14	3424968	Marion City Elem. School	29 22 10	82 11 50

Appendix A-4
Wells in Orange County, Florida



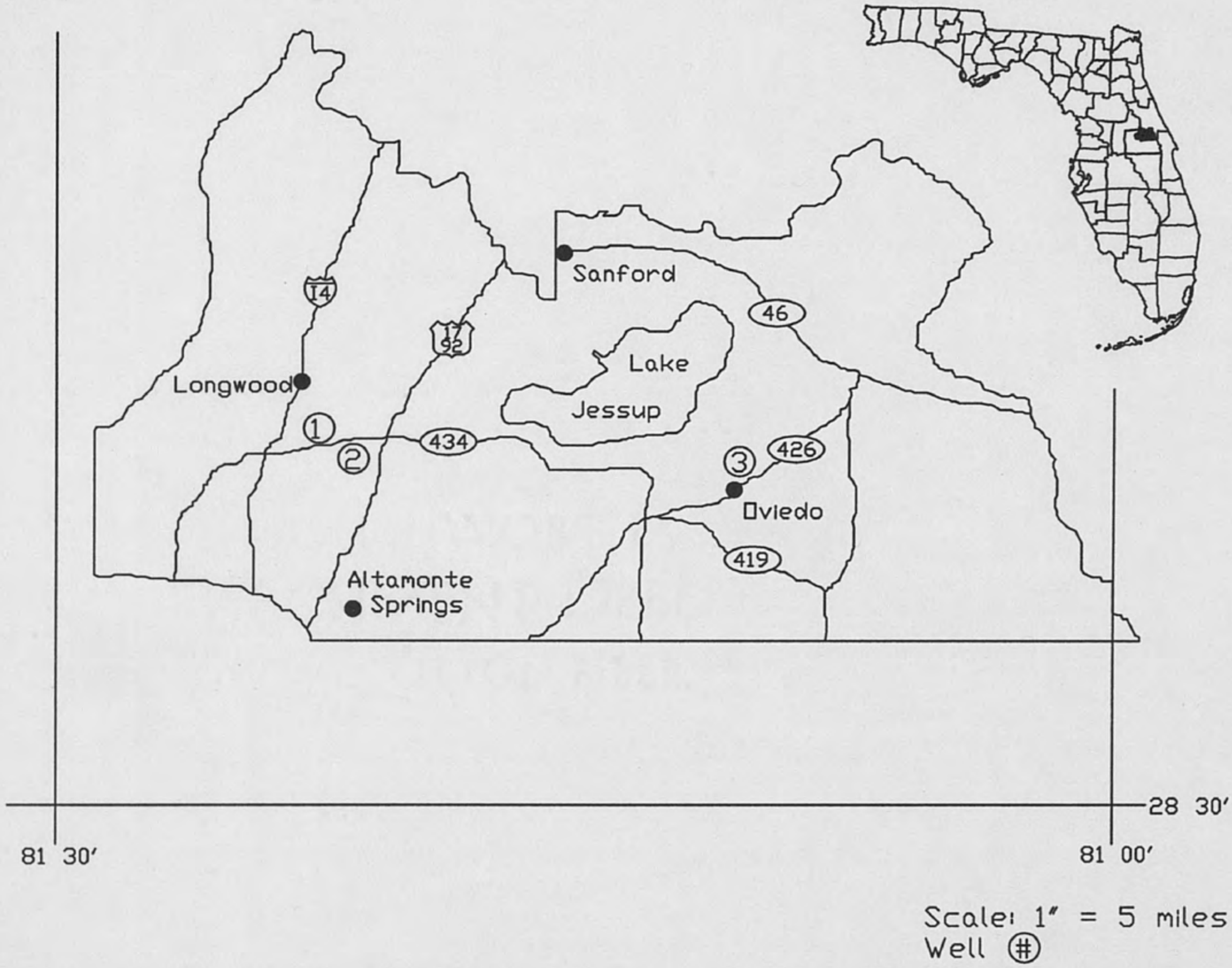
Well #	PWS #	Site	Latitude (° ′ ″)	Longitude (° ′ ″)
1	3480114	Brightwood Manor	28 45 22	81 31 58
2	3480327	Town of Eatonville	28 36 48	81 23 30
3	3480409	Univ. of Central Fl	28 35 50	81 12 10
4	3481482	City of Winter Park, Plant 5	28 35 48	81 18 12
5	3481506	Zellwood Station	28 44 02	81 36 23
6	3481546	OCUD/Western Regional	28 29 25	81 29 00
7	3484093	WDW Central	28 22 55	81 31 05
8	3484119	OCPU/South Regional Water	28 23 10	81 26 10

Appendix A-5
Well in Osceola County, Florida



Well #	PWS #	Site	Latitude (° ′ ″)	Longitude (° ′ ″)
1	3494315	Poinciana WTP #2	28 10 46	81 29 46

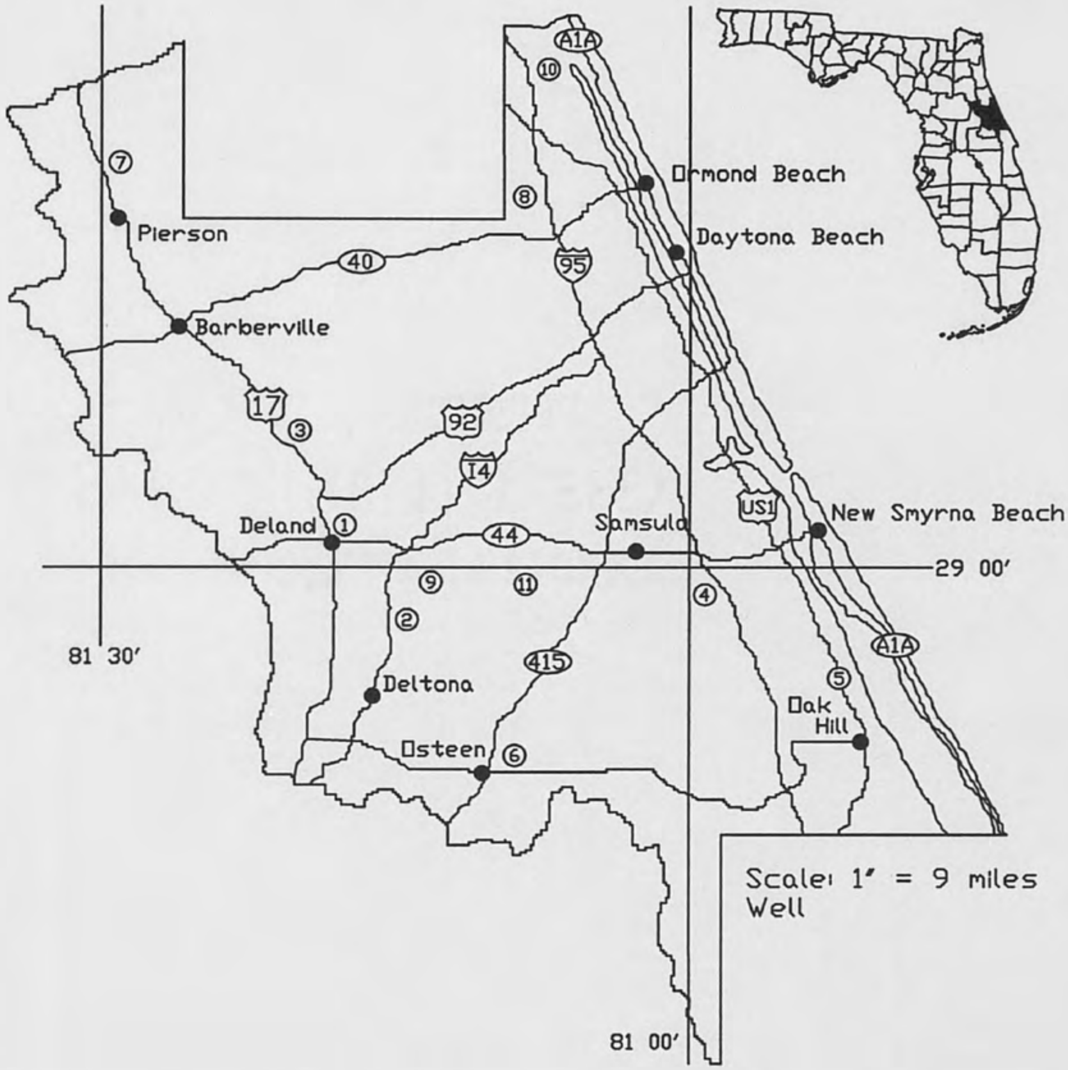
Appendix A-6
Wells in Seminole County, Florida



Well #	PWS #	Site	Latitude (° ′ ″)	Longitude (° ′ ″)
1	3590039	Apple Valley-Sanlando	28 40 24	81 23 44
2	3590111	Bretton Woods	28 38 36	81 22 57
3	3590970	City of Oviedo	28 38 30	81 11 30

Appendix A-7

Wells in Volusia County, Florida



Well #	PWS #	Site	Latitude (° ′ ″)	Longitude (° ′ ″)
1	3640286	City of Deland	29 02 00	81 17 00
2	3640287	Deltona Well # 12	28 55 48	81 14 10
2	3640287	Deltona Well # 20	28 55 48	81 14 10
2	3640287	Deltona Well # 32	28 55 48	81 14 10
3	3640317	Duvall Home for Retarded	29 05 32	81 21 19
4	3640331	City of Edgewater	28 57 02	80 57 49
5	3640587	Indian Harbor Estates	28 54 04	80 51 42
6	3640643	Kove Estates Association	28 50 23	81 10 19
7	3641308	Sunny Sands Resort	29 14 22	81 27 20
8	3641373	Tomoka View Estates	29 15 47	81 07 45
9	3641550	Lake Helen Water	28 58 45	81 13 45
10	3644123	Halifax Plantation	29 24 16	81 08 44
11	3644125	The Magnolias	28 57 46	80 56 21

APPENDIX B

MICROSCOPIC PARTICULATE ANALYSES RESULTS

B-1 Determination of MPA Risk Indices

B-2 Summary of MPA Results

Appendix B-1

Determination of Microscopic Particulate Analysis Risk Index

County:	Brevard	Total volume of water filtered (gal):	287
PWS I.D.:	3050596	Total volume filter sediment (μl):	60
Utility:	Indian River Shores	μl sediment/100 gallons sampled:	20.9
Lab Sample I.D.:	E97-662	Number of slides examined:	1

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	1	R	4
Insects/Larvae	0	NS	0
Rotifers	0	NS	0
Plant Debris (with chlorophyll)	3.4	R	0
	EPA Relative Risk Index:		**4**

County:	Brevard	Total volume of water filtered (gal):	658
PWS I.D.:	3054056	Total volume filter sediment (μl):	50
Utility:	Snug Harbor	μl sediment/100 gallons sampled:	7.6
Lab Sample I.D.:	E97-664	Number of slides examined:	5

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	0	NS	0
Insects/Larvae	0	NS	0
Rotifers	0	NS	0
Plant Debris (with chlorophyll)	4.5	R	0
	EPA Relative Risk Index:		**0**

Appendix B-1

Determination of Microscopic Particulate Analysis Risk Index

County:	Brevard	Total volume of water filtered (gal):	1835
PWS I.D.:	3054062	Total volume filter sediment (μ l):	130
Utility:	South Shores	μ l sediment/100 gallons sampled:	7.1
Lab Sample I.D.:	E97-663	Number of slides examined:	1

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	0	NS	0
Insects/Larvae	0	NS	0
Rotifers	0	NS	0
Plant Debris (with chlorophyll)	10.7	R	0
	EPA Relative Risk Index:		**0**

County:	Lake	Total volume of water filtered (gal):	163
PWS I.D.:	3350322	Total volume filter sediment (μ l):	20
Utility:	East Lake Harris	μ l sediment/100 gallons sampled:	12.3
Lab Sample I.D.:	E97-549	Number of slides examined:	2

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	0	NS	0
Insects/Larvae	0	NS	0
Rotifers	0	NS	0
Plant Debris (with chlorophyll)	29.4	M	1
	EPA Relative Risk Index:		**1**

Appendix B-1
Determination of Microscopic Particulate Analysis Risk Index

County:	Lake	Total volume of water filtered (gal):	295
PWS I.D.:	3350346	Total volume filter sediment (μ l):	500
Utility:	City of Eustis	μ l sediment/100 gallons sampled:	170
Lab Sample I.D.:	FL-403	Number of slides examined:	10

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	27	M	9
Insects/Larvae	0	NS	0
Rotifers	27	M	2
Plant Debris (with chlorophyll)	0	NS	0
	EPA Relative Risk Index:		**11**

County:	Lake	Total volume of water filtered (gal):	433
PWS I.D.:	3350426	Total volume filter sediment (μ l):	50
Utility:	Friendly Center	μ l sediment/100 gallons sampled:	11.5
Lab Sample I.D.:	E97-548	Number of slides examined:	5

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	0	NS	0
Insects/Larvae	0	NS	0
Rotifers	0	NS	0
Plant Debris	24.4	R	0
	EPA Relative Risk Index:		**0**

Appendix B-1

Determination of Microscopic Particulate Analysis Risk Index

County: Lake
PWS I.D.: 3350476
Utility: Groveland
Lab Sample I.D.: FL-236

Total volume of water filtered (gal): 119
Total volume filter sediment (μ l): 10
μ l sediment/100 gallons sampled: 8.4
Number of slides examined: 9

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	2	R	6
Other Algae (with chloroplasts)	40	M	9
Insects/Larvae	0	NS	0
Rotifers	0	NS	0
Plant Debris	0	NS	0
	EPA Relative Risk Index:		**15**

County: Lake
PWS I.D.: 3350544
Utility: Hobby Hill
Lab Sample I.D.: E97-533

Total volume of water filtered (gal): 152
Total volume filter sediment (μ l): 10
μ l sediment/100 gallons sampled: 6.6
Number of slides examined: 1

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	21.4	M	9
Insects/Larvae	1.3	R	3
Rotifers	7.2	R	1
Plant Debris	88.8	H	2
	EPA Relative Risk Index:		**15**

Appendix B-1
Determination of Microscopic Particulate Analysis Risk Index

County:	Lake	Total volume of water filtered (gal):	191
PWS I.D.:	3350573	Total volume filter sediment (μ l):	250
Utility:	Howey in the Hills	μ l sediment/100 gallons sampled:	131
Lab Sample I.D.:	FL-440	Number of slides examined:	10

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	395	EH	14
Insects/Larvae	0	NS	0
Rotifers	0	NS	0
Plant Debris	0	NS	0
	EPA Relative Risk Index:		**14**

County:	Lake	Total volume of water filtered (gal):	635
PWS I.D.:	3350858	Total volume filter sediment (μ l):	200
Utility:	City of Mt. Dora	μ l sediment/100 gallons sampled:	31
Lab Sample I.D.:	FL-032	Number of slides examined:	1

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	31	M	11
Other Algae (with chloroplasts)	2866	EH	14
Insects/Larvae	0	NS	0
Rotifers	142	H	3
Plant Debris	0	NS	0
	EPA Relative Risk Index:		**28**

Appendix B-1
Determination of Microscopic Particulate Analysis Risk Index

County:	Lake	Total volume of water filtered (gal):	119
PWS I.D.:	3350981	Total volume filter sediment (μl):	120
Utility:	Palm M.H. Park	μl sediment/100 gallons sampled:	101
Lab Sample I.D.:	E97-632	Number of slides examined:	8

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	1.6	R	4
Insects/Larvae	0	NS	0
Rotifers	0	NS	0
Plant Debris	0	NS	0
	EPA Relative Risk Index:		**4**

County:	Lake	Total volume of water filtered (gal):	556
PWS I.D.:	3351021	Total volume filter sediment (μl):	100
Utility:	Piney Woods	μl sediment/100 gallons sampled:	18
Lab Sample I.D.:	E97-534	Number of slides examined:	3

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	1.4	R	4
Insects/Larvae	0	NS	0
Rotifers	36.6	M	2
Plant Debris	0	NS	0
	EPA Relative Risk Index:		**6**

Appendix B-1
Determination of Microscopic Particulate Analysis Risk Index

County:	Lake	Total volume of water filtered (gal):	422
PWS I.D.:	3351182	Total volume filter sediment (μ l):	40
Utility:	Silver Lake Estates	μ l sediment/100 gallons sampled:	9.5
Lab Sample I.D.:	E97-633	Number of slides examined:	4

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	1	R	4
Insects/Larvae	0	NS	0
Rotifers	0	NS	0
Plant Debris	8.1	R	0
	EPA Relative Risk Index:		**4**

County:	Lake	Total volume of water filtered (gal):	320
PWS I.D.:	3351282	Total volume filter sediment (μ l):	10
Utility:	Stone Mountain	μ l sediment/100 gallons sampled:	3.1
Lab Sample I.D.:	E97-547	Number of slides examined:	1

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	0	NS	0
Insects/Larvae	0	NS	0
Rotifers	0	NS	0
Plant Debris	3.8	R	0
	EPA Relative Risk Index:		**0**

Appendix B-1
Determination of Microscopic Particulate Analysis Risk Index

County:	Lake	Total volume of water filtered (gal):	450
PWS I.D.:	3351421	Total volume filter sediment (μl):	160
Utility:	Valencia Terrace	μl sediment/100 gallons sampled:	35.6
Lab Sample I.D.:	E97-532	Number of slides examined:	3

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	0	NS	0
Insects/Larvae	0	NS	0
Rotifers	0	NS	0
Plant Debris	0	NS	0
	EPA Relative Risk Index:		**0**

County:	Lake	Total volume of water filtered (gal):	124
PWS I.D.:	3351426	Total volume filter sediment (μl):	20
Utility:	Venetian Village	μl sediment/100 gallons sampled:	16.1
Lab Sample I.D.:	E97-550	Number of slides examined:	2

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	0.5	NS	0
Insects/Larvae	0	NS	0
Rotifers	0.9	R	1
Plant Debris	4.2	R	0
	EPA Relative Risk Index:		**1**

Appendix B-1

Determination of Microscopic Particulate Analysis Risk Index

County:	Lake	Total volume of water filtered (gal):	NA
PWS I.D.:	3354010	Total volume filter sediment (μ l):	NA
Utility:	Water Oak C.C.	μ l sediment/100 gallons sampled:	NA
Lab Sample I.D.:	NA	Number of slides examined:	NA

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	NA	NA	NA
Other Algae (with chloroplasts)	NA	NA	NA
Insects/Larvae	NA	NA	NA
Rotifers	NA	NA	NA
Plant Debris	NA	NA	NA
	EPA Relative Risk Index:		**1**

County:	Lake	Total volume of water filtered (gal):	505
PWS I.D.:	3354104	Total volume filter sediment (μ l):	900
Utility:	Clerbrook R.V.	μ l sediment/100 gallons sampled:	178
Lab Sample I.D.:	E97-546	Number of slides examined:	2

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	0	NS	0
Insects/Larvae	0	NS	0
Rotifers	0	NS	0
Plant Debris	1	R	0
	EPA Relative Risk Index:		**0**

Appendix B-1
Determination of Microscopic Particulate Analysis Risk Index

County:	Lake	Total volume of water filtered (gal):	332
PWS I.D.:	3354661	Total volume filter sediment (μ l):	10
Utility:	Picciola Landing	μ l sediment/100 gallons sampled:	3
Lab Sample I.D.:	E97-531	Number of slides examined:	1

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	2.1	R	4
Insects/Larvae	2.1	R	3
Rotifers	0.6	R	1
Plant Debris	17.1	R	0
	EPA Relative Risk Index:		**8**

County:	Lake	Total volume of water filtered (gal):	101
PWS I.D.:	3354662	Total volume filter sediment (μ l):	20
Utility:	Lake Beauclaire S/D	μ l sediment/100 gallons sampled:	20
Lab Sample I.D.:	FL-366	Number of slides examined:	3

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	17	M	11
Other Algae (with chloroplasts)	815	EH	14
Insects/Larvae	0	NS	0
Rotifers	6	R	1
Plant Debris	0	NS	0
	EPA Relative Risk Index:		**26**

Appendix B-1
Determination of Microscopic Particulate Analysis Risk Index

County:	Lake	Total volume of water filtered (gal):	190
PWS I.D.:	3354836	Total volume filter sediment (μ l):	40
Utility:	Bella Vista Golf Course	μ l sediment/100 gallons sampled:	21
Lab Sample I.D.:	FL-371	Number of slides examined:	6

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	4	R	6
Other Algae (with chloroplasts)	316	EH	14
Insects/Larvae	0	NS	0
Rotifers	4	R	1
Plant Debris	0	NS	0
	EPA Relative Risk Index:		**21**

County:	Lake	Total volume of water filtered (gal):	344
PWS I.D.:	3354867	Total volume filter sediment (μ l):	80
Utility:	Quail Ridge Estates	μ l sediment/100 gallons sampled:	23
Lab Sample I.D.:	E97-634	Number of slides examined:	2

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	0.6	R	4
Insects/Larvae	0	NS	0
Rotifers	0	NS	0
Plant Debris	11	R	0
	EPA Relative Risk Index:		**4**

Appendix B-1
Determination of Microscopic Particulate Analysis Risk Index

County: Lake	Total volume of water filtered (gal): 263
PWS I.D.: 3354929	Total volume filter sediment (μl): 1500
Utility: Royal Highlands	μl sediment/100 gallons sampled: 570
Lab Sample I.D.: E97-635	Number of slides examined: 10

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	0	NS	0
Insects/Larvae	0	NS	0
Rotifers	0	NS	0
Plant Debris	0	NS	0
		EPA Relative Risk Index:	**0**

County: Marion	Total volume of water filtered (gal): 699
PWS I.D.: 3420074	Total volume filter sediment (μl): 50
Utility: City of Belleview	μl sediment/100 gallons sampled: 7
Lab Sample I.D.: FL-005	Number of slides examined: 3

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	1	R	6
Other Algae (with chloroplasts)	1	R	4
Insects/Larvae	0	NS	0
Rotifers	0	NS	0
Plant Debris	0	NS	0
		EPA Relative Risk Index:	**10**

Appendix B-1
Determination of Microscopic Particulate Analysis Risk Index

County:	Marion	Total volume of water filtered (gal):	272
PWS I.D.:	3420085	Total volume filter sediment (μ l):	80
Utility:	Big Lake Village	μ l sediment/100 gallons sampled:	18
Lab Sample I.D.:	FL-30	Number of slides examined:	8

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	272	H	12
Insects/Larvae	0	NS	0
Rotifers	0	NS	0
Plant Debris	0	NS	0
	EPA Relative Risk Index:		**12**

County:	Marion	Total volume of water filtered (gal):	314
PWS I.D.:	3420199	Total volume filter sediment (μ l):	50
Utility:	Citrus Park	μ l sediment/100 gallons sampled:	16
Lab Sample I.D.:	FL-27	Number of slides examined:	4

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	1	R	6
Other Algae (with chloroplasts)	7	R	4
Insects/Larvae	0	NS	0
Rotifers	0	NS	0
Plant Debris	0	NS	0
	EPA Relative Risk Index:		**10**

Appendix B-1
Determination of Microscopic Particulate Analysis Risk Index

County:	Marion	Total volume of water filtered (gal):	255
PWS I.D.:	3420386	Total volume filter sediment (μ l):	30
Utility:	Florida Correctional	μ l sediment/100 gallons sampled:	12
Lab Sample I.D.:	E97-127	Number of slides examined:	3

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	5.8	R	6
Other Algae (with chloroplasts)	7.1	R	4
Insects/Larvae	0	NS	0
Rotifers	0	NS	0
Plant Debris	101	H	2
	EPA Relative Risk Index:		**12**

County:	Marion	Total volume of water filtered (gal):	313
PWS I.D.:	3420924	Total volume filter sediment (μ l):	10
Utility:	Ocala East Villas	μ l sediment/100 gallons sampled:	3
Lab Sample I.D.:	FL-277	Number of slides examined:	1

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	51	H	13
Other Algae (with chloroplasts)	6639	EH	14
Insects/Larvae	0	NS	0
Rotifers	0	NS	0
Plant Debris	0	NS	0
	EPA Relative Risk Index:		**27**

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Determination of Microscopic Particulate Analysis Risk Index

County:	Marion	Total volume of water filtered (gal):	635
PWS I.D.:	3421269	Total volume filter sediment (μl):	20
Utility:	Stanton-Weirsdale Elem.	μl sediment/100 gallons sampled:	3
Lab Sample I.D.:	FL-268	Number of slides examined:	2

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	87	M	9
Insects/Larvae	0	NS	0
Rotifers	2	R	1
Plant Debris	0	NS	0
	EPA Relative Risk Index:		**10**

County:	Marion	Total volume of water filtered (gal):	499
PWS I.D.:	3421467	Total volume filter sediment (μl):	20
Utility:	Whispering Oaks MHP	μl sediment/100 gallons sampled:	4
Lab Sample I.D.:	FL-223	Number of slides examined:	2

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	1	R	6
Other Algae (with chloroplasts)	7	R	4
Insects/Larvae	0	NS	0
Rotifers	8	R	1
Plant Debris	0	NS	0
	EPA Relative Risk Index:		**11**

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Determination of Microscopic Particulate Analysis Risk Index

County:	Marion	Total volume of water filtered (gal):	1111
PWS I.D.:	3421554	Total volume filter sediment (μl):	75
Utility:	Ocala Garden Apart.	μl sediment/100 gallons sampled:	9
Lab Sample I.D.:	FL-04	Number of slides examined:	4

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	49	M	9
Insects/Larvae	0	NS	0
Rotifers	2	R	1
Plant Debris	0	NS	0
	EPA Relative Risk Index:		**10**

County:	Marion	Total volume of water filtered (gal):	874
PWS I.D.:	3424031	Total volume filter sediment (μl):	130
Utility:	Florida Heights	μl sediment/100 gallons sampled:	10
Lab Sample I.D.:	FL-01	Number of slides examined:	1

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	275	EH	16
Other Algae (with chloroplasts)	1105	EH	14
Insects/Larvae	0	NS	0
Rotifers	0	NS	0
Plant Debris	7	R	0
	EPA Relative Risk Index:		**30**

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Determination of Microscopic Particulate Analysis Risk Index

County: Marion
PWS I.D.: 3424034
Utility: Oakmuir West
Lab Sample I.D.: FL-10

Total volume of water filtered (gal): 447
Total volume filter sediment (μ l): 50
μ l sediment/100 gallons sampled: 11
Number of slides examined: 5

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	78	M	9
Insects/Larvae	1	R	3
Rotifers	34	M	2
Plant Debris	4	R	0
		EPA Relative Risk Index:	**14**

County: Marion
PWS I.D.: 3424229
Utility: Child's Haven
Lab Sample I.D.: FL-034

Total volume of water filtered (gal): 109
Total volume filter sediment (μ l): 50
μ l sediment/100 gallons sampled: 46
Number of slides examined: 10

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	132	H	12
Insects/Larvae	0	NS	0
Rotifers	1	R	1
Plant Debris	0	NS	0
		EPA Relative Risk Index:	**13**

Appendix B-1
Determination of Microscopic Particulate Analysis Risk Index

County: Marion
PWS I.D.: 3424645
Utility: Windstream & Carriage
Lab Sample I.D.: E97-126

Total volume of water filtered (gal): 316
Total volume filter sediment (μ l): 30
μ l sediment/100 gallons sampled: 9
Number of slides examined: 3

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	37.6	M	9
Insects/Larvae	0	NS	0
Rotifers	0.3	NS	0
Plant Debris	113.2	H	2
	EPA Relative Risk Index:		**11**

County: Marion
PWS I.D.: 3424671
Utility: Soul's Harbor Academy
Lab Sample I.D.: FL-12

Total volume of water filtered (gal): 224
Total volume filter sediment (μ l): 50
μ l sediment/100 gallons sampled: 22
Number of slides examined: 3

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	14	M	11
Other Algae (with chloroplasts)	164	H	12
Insects/Larvae	0	NS	0
Rotifers	14	R	1
Plant Debris	0	NS	0
	EPA Relative Risk Index:		**24**

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Determination of Microscopic Particulate Analysis Risk Index

County:	Marion	Total volume of water filtered (gal):	206
PWS I.D.:	3424968	Total volume filter sediment (μ l):	150
Utility:	Marion County Elem.	μ l sediment/100 gallons sampled:	73
Lab Sample I.D.:	FL-235	Number of slides examined:	10

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	24	M	11
Other Algae (with chloroplasts)	249	H	12
Insects/Larvae	0	NS	0
Rotifers	0	NS	0
Plant Debris	0	NS	0
	EPA Relative Risk Index:		**23**

County:	Orange	Total volume of water filtered (gal):	436
PWS I.D.:	3480114	Total volume filter sediment (μ l):	100
Utility:	Brightwood Manor	μ l sediment/100 gallons sampled:	22.9
Lab Sample I.D.:	E-97-611	Number of slides examined:	2

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	0	NS	0
Insects/Larvae	0	NS	0
Rotifers	0	NS	0
Plant Debris	0.4	NS	0
	EPA Relative Risk Index:		**0**

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Determination of Microscopic Particulate Analysis Risk Index

County:	Orange	Total volume of water filtered (gal):	556
PWS I.D.:	3480327	Total volume filter sediment (μ l):	50
Utility:	Town of Eatonville	μ l sediment/100 gallons sampled:	9
Lab Sample I.D.:	FL040	Number of slides examined:	2

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	10785	EH	14
Insects/Larvae	0	NS	0
Rotifers	2	R	1
Plant Debris	0	NS	0
	EPA Relative Risk Index:		**15**

County:	Orange	Total volume of water filtered (gal):	500
PWS I.D.:	3480409	Total volume filter sediment (μ l):	720
Utility:	University of Central FL	μ l sediment/100 gallons sampled:	144
Lab Sample I.D.:	E97-457	Number of slides examined:	10

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	4.1	R	4
Insects/Larvae	0	NS	0
Rotifers	295	EH	4
Plant Debris	73	H	2
	EPA Relative Risk Index:		**10**

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Determination of Microscopic Particulate Analysis Risk Index

County: Orange	Total volume of water filtered (gal): 901
PWS I.D.: 3481482	Total volume filter sediment (μl): 130
Utility: City of Winter Park	μl sediment/100 gallons sampled: 14.4
Lab Sample I.D.: E97-572	Number of slides examined: 2

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	0	NS	0
Insects/Larvae	0	NS	0
Rotifers	2.1	R	1
Plant Debris	15.2	R	0
	EPA Relative Risk Index:		**1**

County: Orange	Total volume of water filtered (gal): 1035
PWS I.D.: 3481506	Total volume filter sediment (μl): 700
Utility: Zellwood Station	μl sediment/100 gallons sampled: 68
Lab Sample I.D.: FL-303	Number of slides examined: 4

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	6005	EH	14
Insects/Larvae	0	NS	0
Rotifers	0	NS	0
Plant Debris	0	NS	0
	EPA Relative Risk Index:		**14**

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Determination of Microscopic Particulate Analysis Risk Index

County: Orange
PWS I.D.: 3481546
Utility: Water Meadows WTP
Lab Sample I.D.: E97-575

Total volume of water filtered (gal): 1149
Total volume filter sediment (μl): 930
μl sediment/100 gallons sampled: 81
Number of slides examined: 6

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	0	NS	0
Insects/Larvae	0	NS	0
Rotifers	0	NS	0
Plant Debris	0	NS	0
	EPA Relative Risk Index:		**0**

County: Orange
PWS I.D.: 3484093
Utility: Walt Disney World
Lab Sample I.D.: FL-365

Total volume of water filtered (gal): 332
Total volume filter sediment (μl): 10
μl sediment/100 gallons sampled: 3
Number of slides examined: 4

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	1	R	6
Other Algae (with chloroplasts)	4539	EH	14
Insects/Larvae	0	NS	0
Rotifers	0	NS	0
Plant Debris	0	NS	0
	EPA Relative Risk Index:		**20**

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Determination of Microscopic Particulate Analysis Risk Index

County: Orange
PWS I.D.: 3484119
Utility: OCPU/South Regional
Lab Sample I.D.: FL-364

Total volume of water filtered (gal): 1461
Total volume filter sediment (μ l): 50
μ l sediment/100 gallons sampled: 3.4
Number of slides examined: 2

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	63	M	9
Insects/Larvae	0	NS	0
Rotifers	5	R	1
Plant Debris	0	NS	0
	EPA Relative Risk Index:		**10**

County: Osceola
PWS I.D.: 3494315
Utility: Poinciana Utility
Lab Sample I.D.: E97-607

Total volume of water filtered (gal): 294
Total volume filter sediment (μ l): 10
μ l sediment/100 gallons sampled: 3.4
Number of slides examined: 1

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	3.1	R	4
Insects/Larvae	0	NS	0
Rotifers	0.3	NS	0
Plant Debris	12.2	R	0
	EPA Relative Risk Index:		**4**

Appendix B-1
Determination of Microscopic Particulate Analysis Risk Index

County: Seminole
PWS I.D.: 3590039
Utility: Apple Valley
Lab Sample I.D.: E97-609

Total volume of water filtered (gal): 1673
Total volume filter sediment (μ l): 1600
μ l sediment/100 gallons sampled: 95.6
Number of slides examined: 2

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	0	NS	0
Insects/Larvae	0	NS	0
Rotifers	10.4	R	1
Plant Debris	0	NS	0
	EPA Relative Risk Index:		**1**

County: Seminole
PWS I.D.: 3590111
Utility: Bretton Woods
Lab Sample I.D.: E97-610

Total volume of water filtered (gal): 704
Total volume filter sediment (μ l): 40
μ l sediment/100 gallons sampled: 5.7
Number of slides examined: 4

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	1.3	R	4
Insects/Larvae	0	NS	0
Rotifers	0	NS	0
Plant Debris	32.5	M	1
	EPA Relative Risk Index:		**5**

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Determination of Microscopic Particulate Analysis Risk Index

County:	Seminole	Total volume of water filtered (gal):	1198
PWS I.D.:	3590970	Total volume filter sediment (μ l):	50
Utility:	City of Oviedo	μ l sediment/100 gallons sampled:	4.2
Lab Sample I.D.:	E97-470	Number of slides examined:	5

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0.1	NS	0
Other Algae (with chloroplasts)	4.8	R	4
Insects/Larvae	0	NS	0
Rotifers	0	NS	0
Plant Debris	7.2	R	0
	EPA Relative Risk Index:		**4**

County:	Volusia	Total volume of water filtered (gal):	878
PWS I.D.:	3640286	Total volume filter sediment (μ l):	950
Utility:	City of Deland	μ l sediment/100 gallons sampled:	108
Lab Sample I.D.:	E97-486	Number of slides examined:	6

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	0	NS	0
Insects/Larvae	0	NS	0
Rotifers	19.1	R	1
Plant Debris	5	R	0
	EPA Relative Risk Index:		**1**

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Determination of Microscopic Particulate Analysis Risk Index

County:	Volusia	Total volume of water filtered (gal):	748
PWS I.D.:	3640287	Total volume filter sediment (μ l):	134
Utility:	Deltona Well # 12	μ l sediment/100 gallons sampled:	180
Lab Sample I.D.:	E96-160	Number of slides examined:	5

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	425	EH	14
Insects/Larvae	1	R	3
Rotifers	0	NS	0
Plant Debris	0	NS	0
	EPA Relative Risk Index:		**17**

County:	Volusia	Total volume of water filtered (gal):	1253
PWS I.D.:	3640287	Total volume filter sediment (μ l):	2000
Utility:	Deltona Well # 20	μ l sediment/100 gallons sampled:	160
Lab Sample I.D.:	E96-161	Number of slides examined:	5

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	0	NS	0
Insects/Larvae	0	NS	0
Rotifers	0	NS	0
Plant Debris	0	NS	0
	EPA Relative Risk Index:		**0**

Appendix B-1
Determination of Microscopic Particulate Analysis Risk Index

County:	Volusia	Total volume of water filtered (gal):	1334
PWS I.D.:	3640287	Total volume filter sediment (μ l):	440
Utility:	Deltona Well # 32	μ l sediment/100 gallons sampled:	33
Lab Sample I.D.:	E96-162	Number of slides examined:	2

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	0	NS	0
Insects/Larvae	0	NS	0
Rotifers	0	NS	0
Plant Debris	0	NS	0
	EPA Relative Risk Index:		**0**

County:	Volusia	Total volume of water filtered (gal):	409
PWS I.D.:	3640317	Total volume filter sediment (μ l):	400
Utility:	Duvall Home	μ l sediment/100 gallons sampled:	97.8
Lab Sample I.D.:	E97-484	Number of slides examined:	4

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	0	NS	0
Insects/Larvae	0	NS	0
Rotifers	0	NS	0
Plant Debris	0	NS	0
	EPA Relative Risk Index:		**0**

Appendix B-1
Determination of Microscopic Particulate Analysis Risk Index

County: Volusia	Total volume of water filtered (gal): 1263
PWS I.D.: 3640331	Total volume filter sediment (μl): 20
Utility: Edgewater	μl sediment/100 gallons sampled: 1.6
Lab Sample I.D.: E97-467	Number of slides examined: 2

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	0	NS	0
Insects/Larvae	0	NS	0
Rotifers	0	NS	0
Plant Debris	2.6	R	0
	EPA Relative Risk Index:		**0**

County: Volusia	Total volume of water filtered (gal): 233
PWS I.D.: 3640587	Total volume filter sediment (μl): 400
Utility: Indian Harbor Estates	μl sediment/100 gallons sampled: 172
Lab Sample I.D.: E97-469	Number of slides examined: 6

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	0	NS	0
Insects/Larvae	0	NS	0
Rotifers	0.4	NS	0
Plant Debris	0.4	NS	0
	EPA Relative Risk Index:		**0**

Appendix B-1
Determination of Microscopic Particulate Analysis Risk Index

County: Volusia
PWS I.D.: 3640643
Utility: Kove Estates
Lab Sample I.D.: E97-458

Total volume of water filtered (gal): 501
Total volume filter sediment (μl): 415
μl sediment/100 gallons sampled: 82.8
Number of slides examined: 3

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	0.9	R	4
Insects/Larvae	0	NS	0
Rotifers	0.9	R	1
Plant Debris	0	NS	0
	EPA Relative Risk Index:		**5**

County: Volusia
PWS I.D.: 3641308
Utility: Sunny Sands
Lab Sample I.D.: E97-487

Total volume of water filtered (gal): 430
Total volume filter sediment (μl): 290
μl sediment/100 gallons sampled: 67.4
Number of slides examined: 3

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	0	NS	0
Insects/Larvae	0	NS	0
Rotifers	0	NS	0
Plant Debris	0	NS	0
	EPA Relative Risk Index:		**0**

Appendix B-1
Determination of Microscopic Particulate Analysis Risk Index

County:	Volusia	Total volume of water filtered (gal):	562
PWS I.D.:	3641373	Total volume filter sediment (μ l):	30
Utility:	Tomoka View Estates	μ l sediment/100 gallons sampled:	4.34
Lab Sample I.D.:	E97-573	Number of slides examined:	3

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	6.5	NS	4
Insects/Larvae	0	NS	0
Rotifers	3.5	NS	1
Plant Debris	20.1	NS	0
	EPA Relative Risk Index:		**5**

County:	Volusia	Total volume of water filtered (gal):	352
PWS I.D.:	3641550	Total volume filter sediment (μ l):	130
Utility:	Lake Helen Water	μ l sediment/100 gallons sampled:	36.9
Lab Sample I.D.:	E97-485	Number of slides examined:	5

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	0	NS	0
Insects/Larvae	0	NS	0
Rotifers	0	NS	0
Plant Debris	0	NS	0
	EPA Relative Risk Index:		**0**

Appendix B-1
Determination of Microscopic Particulate Analysis Risk Index

County:	Volusia	Total volume of water filtered (gal):	800
PWS I.D.:	3644123	Total volume filter sediment (μ l):	20
Utility:	Halifax Plantation	μ l sediment/100 gallons sampled:	2.5
Lab Sample I.D.:	E97-574	Number of slides examined:	2

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	0.6	R	4
Insects/Larvae	0	NS	0
Rotifers	0	NS	0
Plant Debris	5.2	R	0
	EPA Relative Risk Index:		**4**

County:	Volusia	Total volume of water filtered (gal):	132
PWS I.D.:	3644125	Total volume filter sediment (μ l):	60
Utility:	The Magnolias	μ l sediment/100 gallons sampled:	45.5
Lab Sample I.D.:	E97-468	Number of slides examined:	2

Primary Particulates	#/100 Gal	Relative Frequency	Relative Risk Factor
Giardia	NA		
Coccidia	NA		
Diatoms (with chloroplasts)	0	NS	0
Other Algae (with chloroplasts)	0	NS	0
Insects/Larvae	0.8	NS	3
Rotifers	0.8	NS	1
Plant Debris	0	NS	0
	EPA Relative Risk Index:		**4**

Appendix B-2
Summary of Microscopic Particulate Analyses Results

County	PWS#	Site I.D.	Well I.D.	MPA Result	Risk Index
Brevard	3050596	Indian River Shores	Primary	4	Low
	3054056	Snug Harbor Village	1	0	Low
	3054062	South Shores Utilities	2	0	Low
Lake	3350322	E. Lake Harris	Primary	1	Low
	3350346	City of Eustis, Mt. Homer	Primary	11	Moderate
	3350426	Friendly Center	Primary	0	Low
	3350476	Groveland Water Dept	Well # 5	15	Moderate
	3350544	Hobby Hill	2	15	Moderate
	3350573	Howey in the Hills	Primary	14	Moderate
	3350858	City of Mount Dora	Well # 4	28	High
	3350981	Palm Mobile Home	1	4	Low
	3351021	Piney Woods	1	6	Low
	3351182	Silver Lake Estates	1	4	Low
	3351282	Stone Mountain	Primary	0	Low
	3351421	Valencia Terrace	1	0	Low
	3351426	Venetian Village	2	5	Low
	3354010	Water Oak Ctry Club	3	1	Low
	3354104	Clerbrook RV	2	0	Low
	3354661	Picciola Landing	Primary	8	Low
	3354662	Lake Beauclaire S/D	Well # 1	26	High
	3354836	Bella Vista Golf Course/Marina	Primary	21	High
	3354867	Quail Ridge Estates		4	Low
	3354929	Royal Highlands	1	0	Low
Marion	3420074	City of Belleview, Plant 2	Well 4	10	Moderate
	3420085	Big Lake Village MHP	# 1	12	Moderate
	3420199	Citrus Park	West Well # 1	10	Moderate
	3420386	Florida Correctional Inst.	Primary Well	12	Moderate
	3420924	Ocala East Villas	One Well	27	High
	3421269	Stanton-Weirsdale Elem.	East	10	Moderate
	3421467	Whispering Oaks RV Park	Well # 1	11	Moderate
	3421554	Ocala Garden Apartments	Well # 1	10	Moderate
	3424031	Florida Heights	Primary	30	High
	3424034	Oakmuir	West Well	14	Moderate
	3424229	Child's Haven	N Well # 1	13	Moderate
	3424645	Windstream and Carriage Hill	6" Well	11	Moderate
	3424671	Soul's Harbor Academy	Soul's Harbor	24	High
	3424968	Marion City Elem. School	East	23	High

Appendix B-2
Summary of Microscopic Particulate Analyses Results

County	PWS#	Site I.D.	Well I.D.	MPA Result	Risk Index
Orange	3480114	Brightwood Manor	B/U	0	Low
	3480327	Town of Eatonville	Well # 2	15	Moderate
	3480409	Univ. of Central Fl	1	10	Moderate
	3481482	City of Winter Park, Plant 5	Well # 7	1	Low
	3481506	Zellwood Station	Well # 2	14	Moderate
	3481546	OCUD/Western Regional	2/OM	0	Low
	3484093	WDW Central	Primary 17	20	High
	3484119	OCPU/South Regional Water	Primary # 1	10	Moderate
Osceola	3494315	Poinciana WTP #2	Village #2	4	Low
Seminole	3590039	Apple Valley-Sanlando	1	1	Low
	3590111	Bretton Woods	2	5	Low
	3590970	City of Oviedo	203	4	Low
Volusia	3640286	City of Deland	#5	1	Low
	3640287	Deltona	Well # 12	17	Moderate
	3640287	Deltona	Well # 20	0	Low
	3640287	Deltona	Well # 32	0	Low
	3640317	Duvall Home for Retarded	2	0	Low
	3640331	City of Edgewater	6	0	Low
	3640587	Indian Harbor Estates	2	0	Low
	3640643	Kove Estates Association	1	5	Low
	3641308	Sunny Sands Resort	Primary	0	Low
	3641373	Tomoka View Estates	small	5	Low
	3641550	Lake Helen Water	3	0	Low
	3644123	Halifax Plantation	1	4	Low
	3644125	The Magnolias	West	4	Low

APPENDIX C

WELL CHARACTERISTICS

Appendix C
Well Characteristics

County	PWS#	Year Drilled	Age of Well (years)	Total Depth (ft bls)	Casing Depth (ft bls)	Diameter (in)
Brevard	3050596	1987	10	75	64	2
	3054056	1981	16	84	74	6
	3054062	1983	14	552	370	6
Lake	3350322	1964	33	200	116	8
	3350346	1977	20	525	225	16
	3350426	1973	24	260	160	4
	3350476	1988	9	601	91	10
	3350544	1959	38	80	76	6
	3350573	1964	33	334	192	12
	3350858	1974	23	750	150	20
	3350981	1961	36	340	146	8
	3351021	1961	36	480	180	6
	3351182	1971	26	366	200	10
	3351282	1976	21	270	106.5	8
	3351421	1973	24	285	130	8
	3351426	1972	25	230	123	6
	3354010	1985	12	270	159	8
	3354104	1982	15	295	120	8
	3354661	1986	11	172	112	4
	3354662	1984	13	195	109	10
	3354836	1989	8	320	150	6
	3354867	1989	8	340	131	10
	3354929	1995	2	375	153	12
Marion	3420074	1982	15	250	105	16
	3420085	1972	25	205	175	6
	3420199	1979	18	220	107	6
	3420386	1979	18	240	150	8
	3420924	1981	16	223	123	6
	3421269	1981	16	117	107	6
	3421467	1973	24	115	42	4
	3421554	1978	19	90	63	4
	3424031	1980	17	146	70	6
	3424034	1972	25	100	70	4
	3424229	1980	17	88	63	4
	3424645	1984	13	230	98	6
	3424671	1986	11	200	105	4
	3424968	1992	5	260	148	6

Appendix C
Well Characteristics

County	PWS#	Year Drilled	Age of Well (years)	Total Depth (ft bls)	Casing Depth (ft bls)	Diameter (in)
Orange	3480114	1974	23	433	70	10
	3480327	1968	29	341	81	12
	3480409	1967	30	400	135	10
	3481482	1963	34	1324	1037	16
	3481506	1981	16	415	115	12
	3481546	1979	18	715	434	12
	3484093	1987	10	700	140	24
	3484119	1982	15	650	160	14
Osceola	3494315	1990	7	470	146	12
Seminole	3590039	1970	27	420	166	8
	3590111			401	120	8
	3590970	1987	10	300	161	12
Volusia	3640286	1955	42	350	122	12
	3640287	1969	28	235	113	10
	3640287	1984	13	284	68	10
	3640287	1989	8	131	120	12
	3640317	1979	18	280	150	6
	3640331	1986	11	250	103	10
	3640587	1979	18	220	179	6
	3640643	1980	17	230	84	6
	3641308	1974	23	189	109	4
	3641373	1964	33	120	100	2
	3641550	1991	6	700	110	12
	3644123	1985	12	135	114	6
	3644125	1984	13	120	115	4

APPENDIX D

DISTANCE BETWEEN SJRWMD WELLS AND SUSPECTED GWUDI SAMPLED WELLS

Appendix D
Well Proximity

		Sampled Well							SJRWMD Well						
	PWS	Latitude			Longitude			SJRWMD	Latitude			Longitude			Dist.
County	ID	°	′	″	°	′	″	ID	°	′	″	°	′	″	(mi.)
Brevard	3050596	27	53	45	80	30	30	BR-1218	27	59	9	80	31	7	8.73
	3054056	27	53	19	80	30	32	BR-1218	27	59	9	80	31	7	9.42
	3054062	27	58	20	80	30	40	BR-1218	27	59	9	80	31	7	1.46
Lake	3350322	28	43	30	81	44	12	L-0684	28	42	55	81	44	15	0.94
	3350346	28	50	50	81	40	14	L-0109	28	51	2	81	39	52	0.61
	3350426	28	43	25	81	44	12	L-0684	28	42	55	81	44	15	0.81
	3350476	28	34	7	81	50	37	L-0269	28	35	27	81	51	3	2.23
	3350544	28	53	30	81	54	30	L-0114	28	52	12	81	54	28	2.09
	3350573	28	42	35	81	46	15	L-0105	28	42	45	81	46	35	0.54
	3350858	28	49	0	81	38	30	L-0467	28	49	35	81	38	51	1.06
	3350981	28	41	49	81	51	30	L-0011	28	41	36	81	52	14	1.09
	3351021	28	52	30	81	55	12	L-0114	28	52	12	81	54	28	1.14
	3351182	28	50	17	81	47	22	L-0107A	28	49	38	81	47	58	1.34
	3351282	28	45	11	81	50	27	L-0182	28	43	38	81	51	43	3.07
	3351421	28	50	58	81	53	28	L-0009	28	50	13	81	53	32	1.21
	3351426	28	45	25	81	41	3	L-0035	28	45	35	81	42	12	1.64
	3354010	28	55	40	81	55	15	L-0118	28	55	48	81	55	10	0.24
	3354104	28	36	30	81	45	30	L-0456	28	34	43	81	45	5	2.93
	3354661	28	51	30	81	53	20	L-0274	28	51	4	81	53	24	0.70
	3354662	28	45	82	81	40	30	L-0035	28	45	35	81	42	12	2.71
	3354836	28	45	0	81	45	0	L-0189	28	45	36	81	44	29	1.21
	3354867	28	53	0	81	46	2	L-0116A	28	52	32	81	46	57	1.49
	3354929	28	39	50	81	52	0	L-0639	28	40	49	81	52	14	1.62
Marion	3420074	29	3	0	82	3	10	M-0082	29	3	37	82	4	33	2.18
	3420085	28	57	30	81	57	3	M-0310	28	58	21	81	57	42	1.64
	3420199	29	7	10	82	5	20	M-0096	29	7	37	82	5	48	0.98
	3420386	29	18	36	82	12	9	M-0139	29	18	20	82	11	2	1.62
	3420924	29	21	35	81	44	10	M-0149	29	21	43	81	44	19	0.30
	3421269	28	58	10	81	55	50	L-0282	28	57	32	81	55	27	1.15
	3421467	29	3	5	82	2	5	M-0064	29	3	16	82	0	9	2.73
	3421554	29	10	0	82	8	30	M-0019	29	10	18	82	7	52	1.01
	3424031	29	8	40	82	3	10	M-0102	29	9	35	82	4	0	1.88
	3424034	29	15	57	82	7	50	M-0135	29	17	25	82	7	35	2.38
	3424229	28	56	47	81	38	7	L-0119	28	55	55	81	38	1	1.40
	3424645	29	9	0	82	8	0	M-0019	29	10	18	82	7	52	2.10
	3424671	29	2	30	82	3	30	M-0076	29	1	56	82	4	55	2.19
	3424968	29	22	10	82	11	50	M-0148	29	21	28	82	11	43	1.14

Appendix D
Well Proximity

County	PWS ID	Sampled Well Latitude °	′	″	Longitude °	′	″	SJRWMD ID	SJRWMD Well Latitude °	′	″	Longitude °	′	″	Dist. (mi.)
Orange	3480114	28	45	22	81	31	58	OR0340	28	45	18	81	30	43	1.77
	3480327	28	36	48	81	23	30	OR0620	28	36	30	81	22	45	1.16
	3480409	28	35	50	81	12	10	OR0316	28	34	24	81	13	28	2.95
	3481482	28	35	47	81	18	12	OR0078	28	35	47	81	18	14	0.05
	3481506	28	44	2	81	36	23	OR0071	28	43	37	81	35	52	0.99
	3481546	28	29	25	81	29	0	OR0257	28	30	8	81	30	32	2.45
	3484093	28	22	55	81	31	5	OR00007	28	22	51	81	31	9	0.14
	3484119	28	23	10	81	26	10	OR00002	28	21	41	81	24	70	2.77
Osceola	3494315	28	10	46	81	29	46	OS00012A	28	9	56	81	26	54	4.28
Seminole	3590039	28	40	24	81	23	44	S-0068	28	40	33	81	23	36	0.31
	3590111	28	38	36	81	22	57	S-1217	28	38	48	81	22	12	1.11
	3590970	28	38	30	81	11	30	S-1215	28	38	0	81	11	55	1.00
Volusia	3640286	29	2	0	81	17	0	V-0267	29	3	23	81	17	21	2.28
	3640287	28	55	48	81	14	10	V-0353	28	56	45	81	14	45	1.73
	3640287	28	55	48	81	14	10	V-0353	28	56	45	81	14	45	1.73
	3640287	28	55	48	81	14	10	V-0353	28	56	45	81	14	45	1.73
	3640317	29	5	32	81	21	19	V-0275	29	5	48	81	21	26	0.46
	3640331	28	57	2	80	57	49	V-0570	28	57	3	80	56	50	1.38
	3640587	28	54	4	80	51	42	V-0242	28	54	11	80	51	48	0.23
	3640643	28	50	23	81	10	19	V-0368	28	50	45	81	9	48	0.94
	3641308	29	14	22	81	27	20	V-0333	29	14	40	81	27	15	0.50
	3641373	29	15	47	81	7	45	V-0440	29	15	30	81	6	38	1.63
	3641550	28	58	45	81	13	45	V-0350	28	56	45	81	14	45	3.51
	3644123	29	4	16	81	18	44	V-0353	28	56	45	81	14	45	13.32
	3644125	28	57	46	80	56	21	V-0571	28	57	36	80	57	2	1.00

APPENDIX E

GAMMA LOG PLOTS

E-1 Brevard County

E-2 Lake County

E-3 Marion County

E-4 Orange County

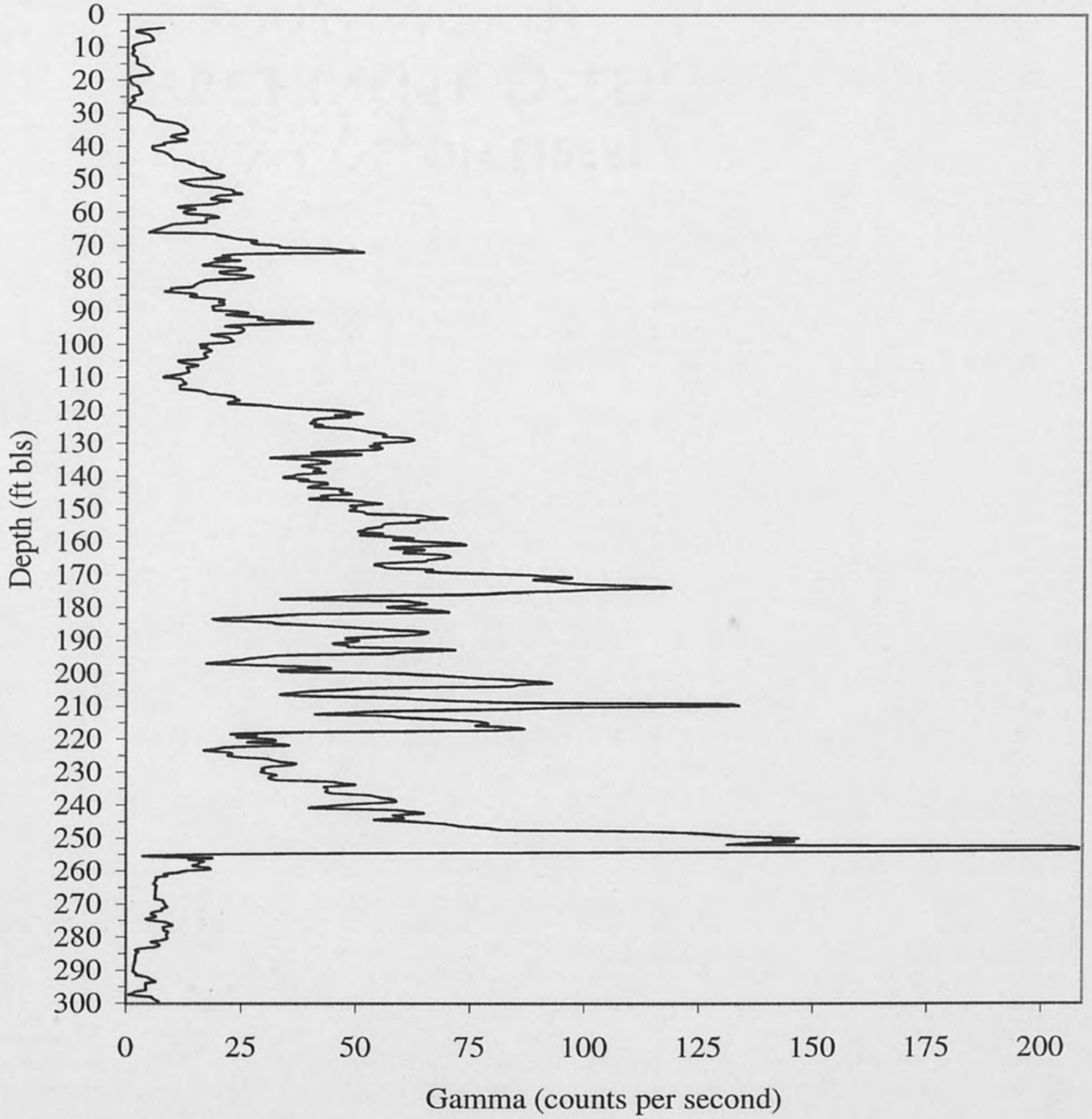
E-5 Osceola County

E-6 Seminole County

E-7 Volusia County

Appendix E-1
Gamma Log Plots for Brevard County Wells

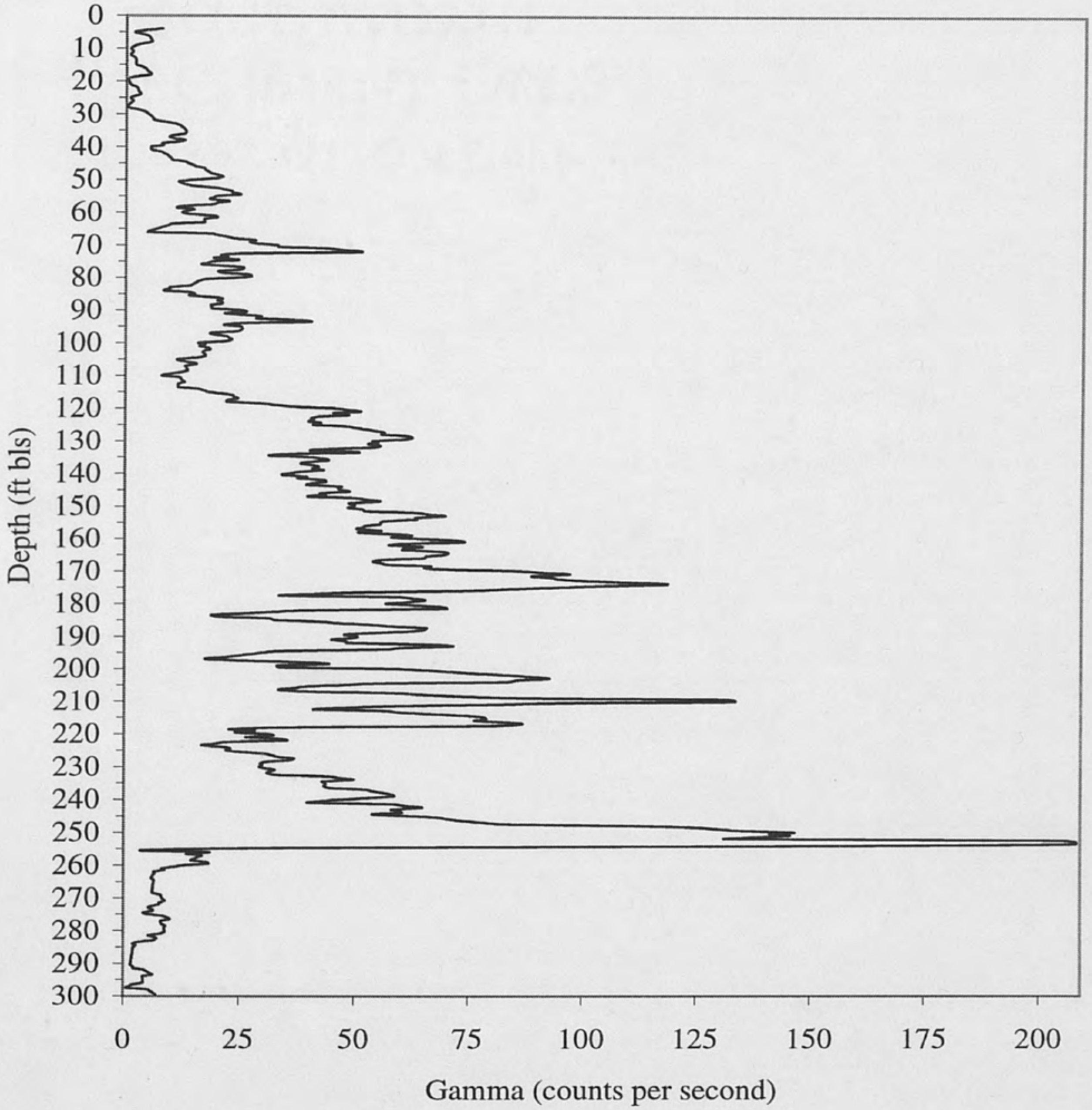
SJRWMD I.D.:	BR1218	PWS I.D.:	3050596
Latitude:	27 59 09	Latitude:	27 53 19
Longitude:	80 31 07	Longitude:	80 30 30
Depth to Confining Layer:	117 ft	Distance:	8.73 mi
Depth to Aquifer:	255 ft		



Appendix E-1

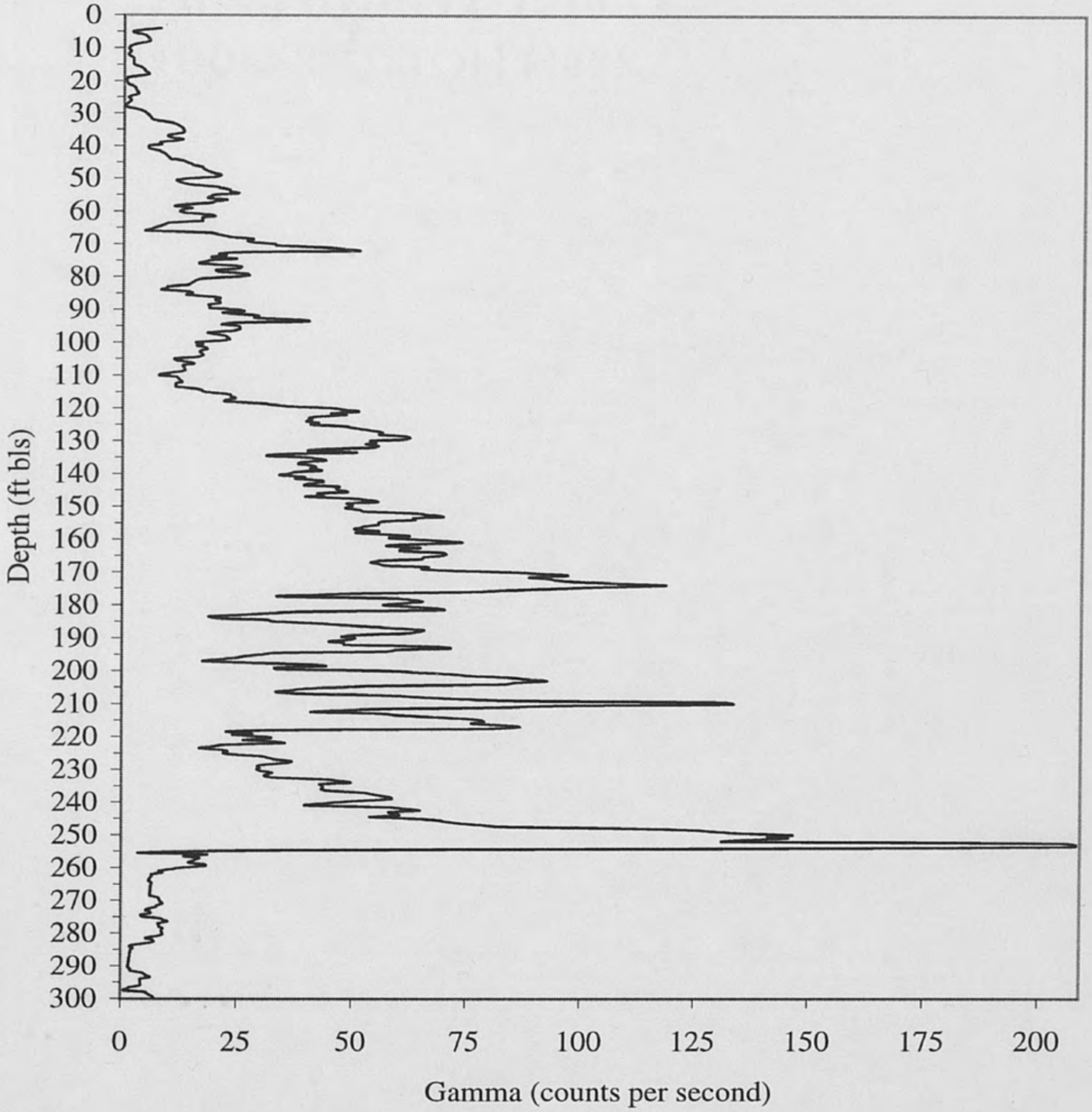
Gamma Log Plots for Brevard County Wells

SJRWMD I.D.:	BR1218	PWS I.D.:	3054056
Latitude:	27 59 09	Latitude:	27 53 19
Longitude:	80 31 07	Longitude:	80 30 32
Depth to Confining Layer:	117 ft	Distance:	9.42 mi
Depth to Aquifer:	255 ft		



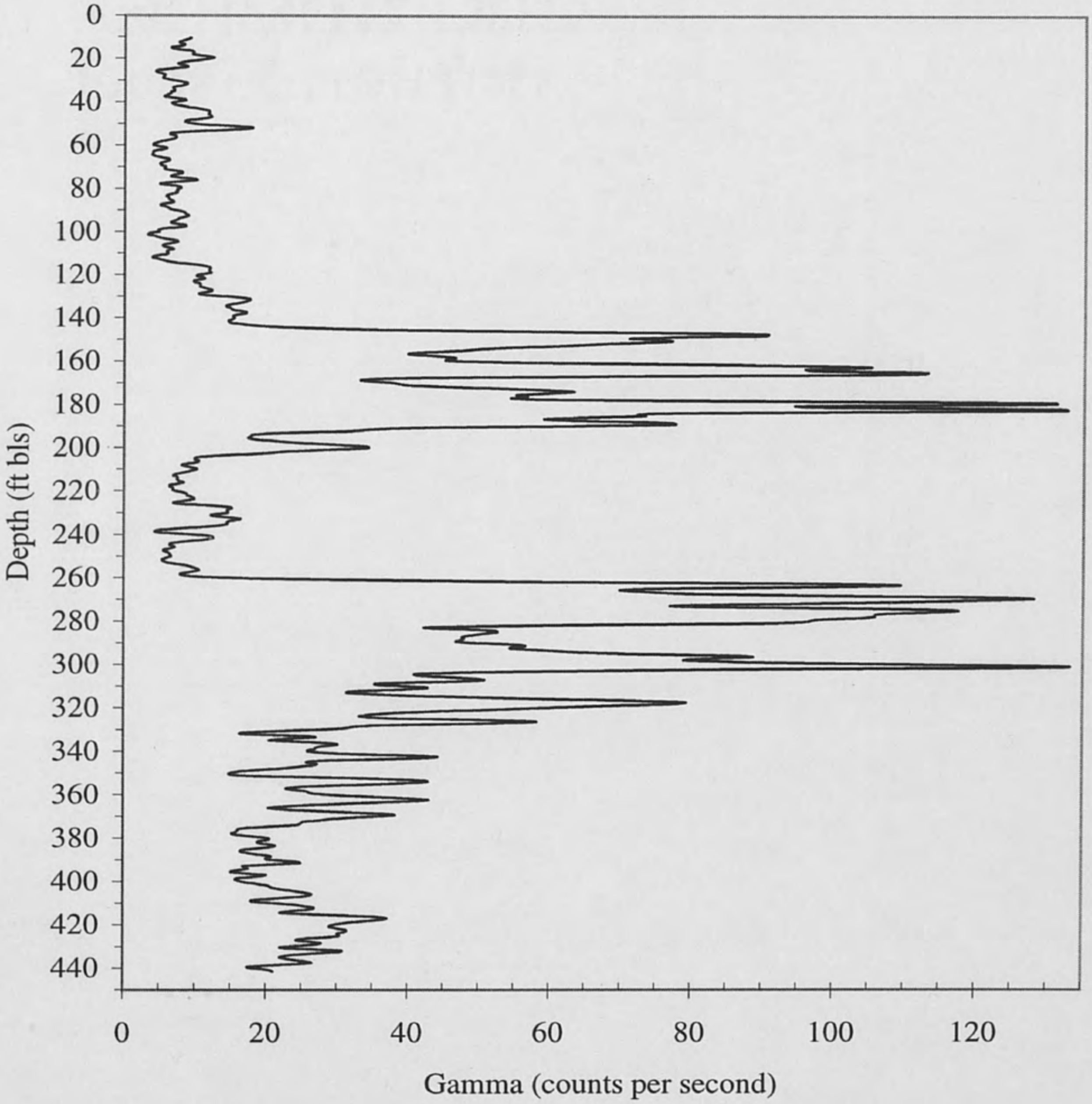
Appendix E-1
Gamma Log Plots for Brevard County Wells

SJRWMD I.D.:	BR1218	PWS I.D.:	3054062
Latitude:	27 59 09	Latitude:	27 58 20
Longitude:	80 31 07	Longitude:	80 30 40
Depth to Confining Layer:	117 ft	Distance:	1.46 mi
Depth to Aquifer:	255 ft		



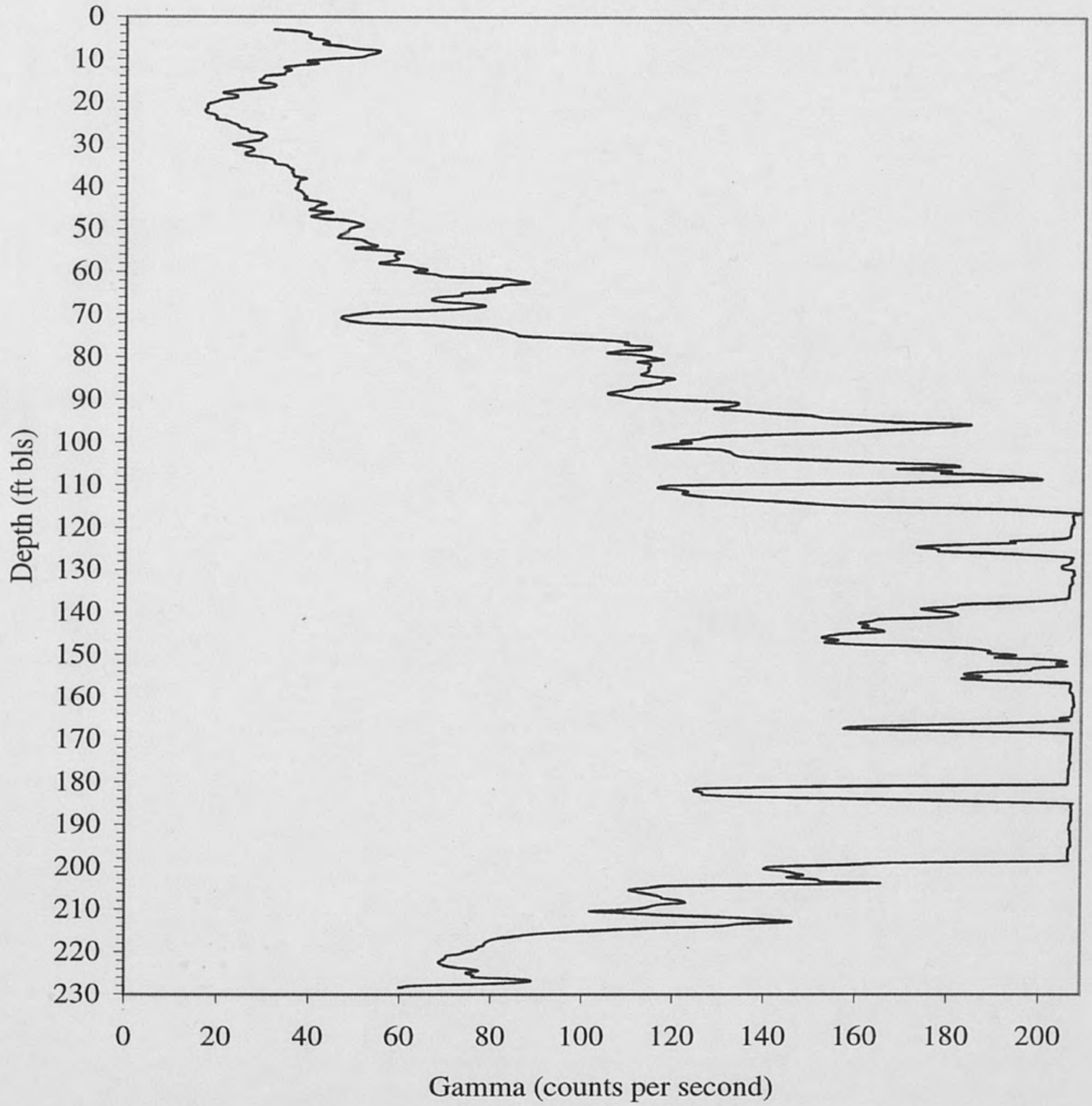
Appendix E-2
Gamma Log Plots for Lake County Wells

SJRWMD I.D.:	L-0684	PWS I.D.:	3350322
Latitude:	28 42 55	Latitude:	28 43 30
Longitude:	81 44 15	Longitude:	81 44 12
Depth to Confining Layer:	141 ft	Distance:	0.94 mi
Depth to Aquifer:	331 ft		



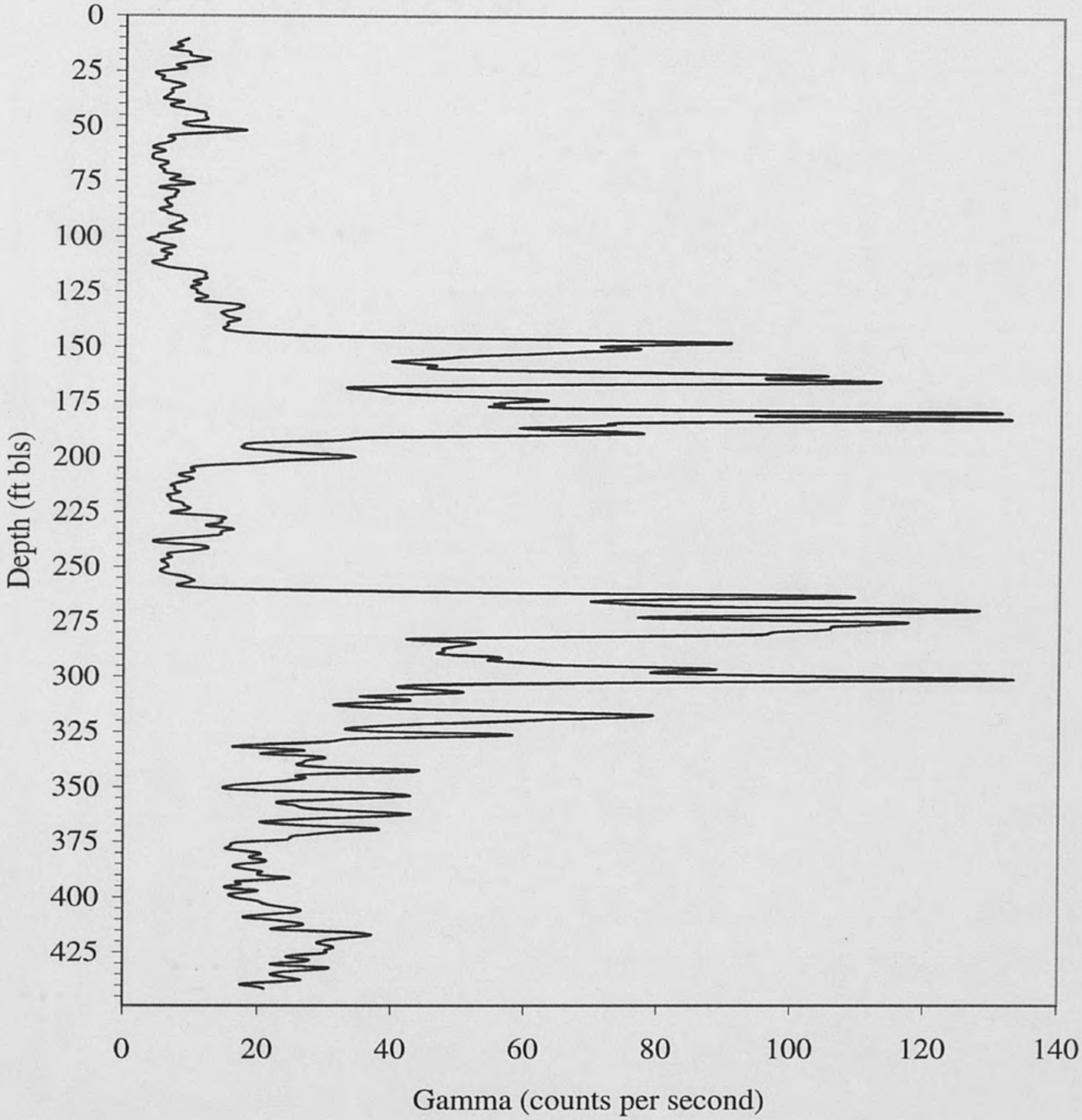
Appendix E-2
Gamma Log Plots for Lake County Wells

SJRWMD I.D.:	L-0109	PWS I.D.:	3350346
Latitude:	28 51 02	Latitude:	28 50 50
Longitude:	81 39 52	Longitude:	81 40 14
Depth to Confining Layer:	55 ft	Distance:	0.61 mi
Depth to Aquifer:	230 ft		



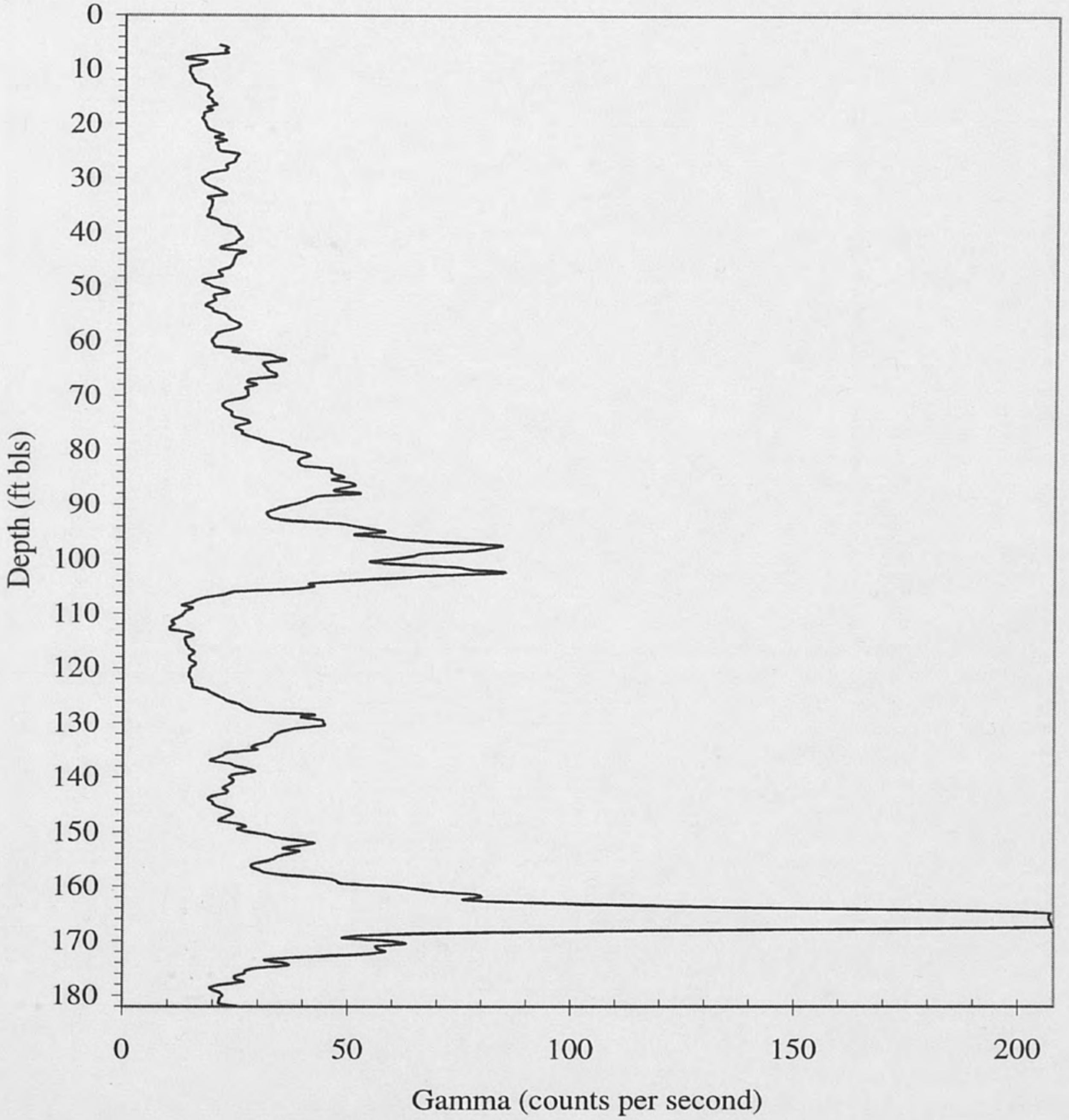
Appendix E-2
Gamma Log Plots for Lake County Wells

SJRWMD I.D.:	L-0684	PWS I.D.:	3350426
Latitude:	28 42 55	Latitude:	28 43 25
Longitude:	81 44 15	Longitude:	81 44 12
Depth to Confining Layer:	141 ft	Distance:	0.81 mi
Depth to Aquifer:	331 ft		



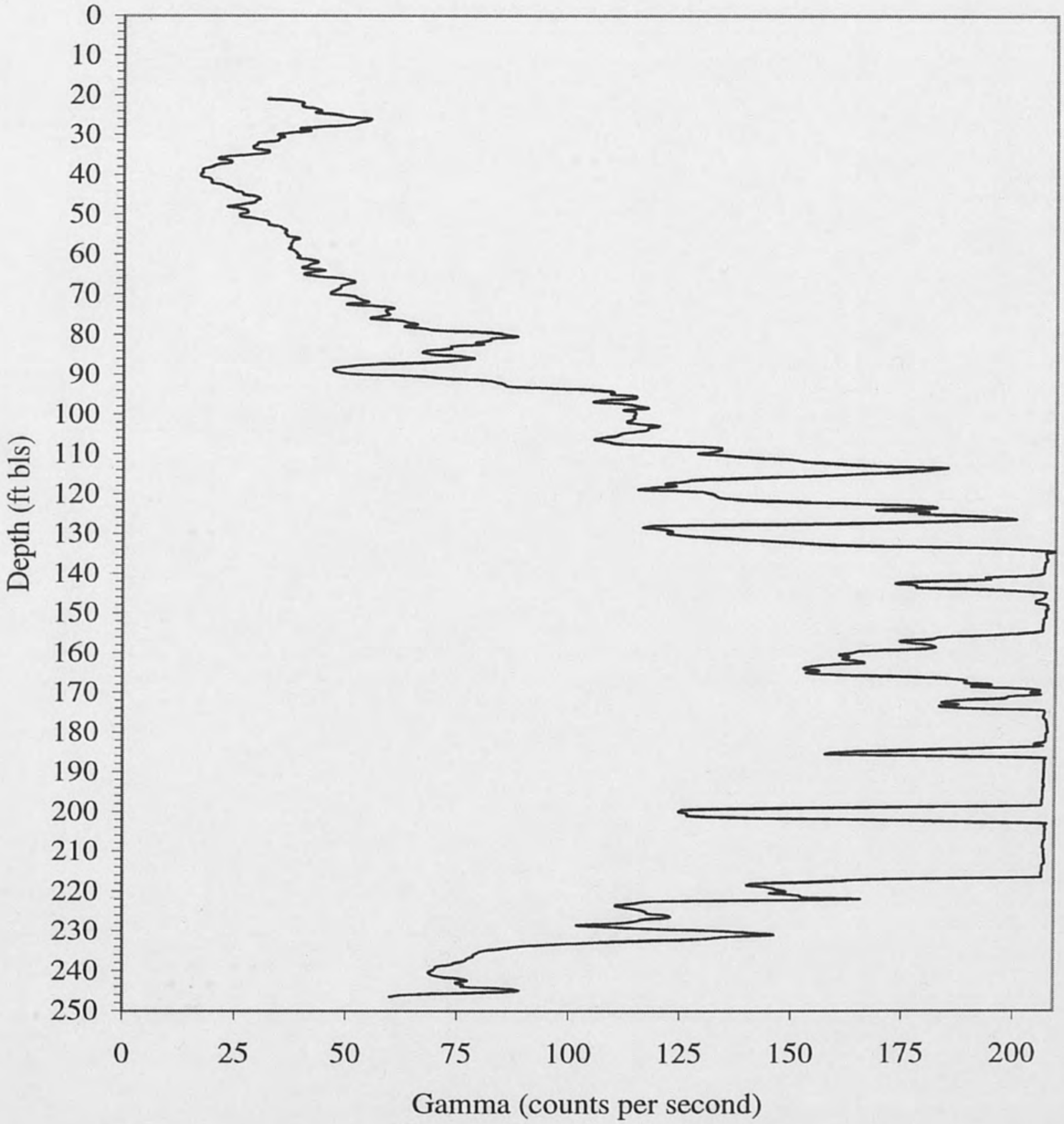
Appendix E-2
Gamma Log Plots for Lake County Wells

SJRWMD I.D.:	L-0269	PWS I.D.:	3350476
Latitude:	28 35 27	Latitude:	28 34 07
Longitude:	81 51 03	Longitude:	81 50 37
Depth to Confining Layer:	156 ft	Distance:	2.23 mi
Depth to Aquifer:	174 ft		



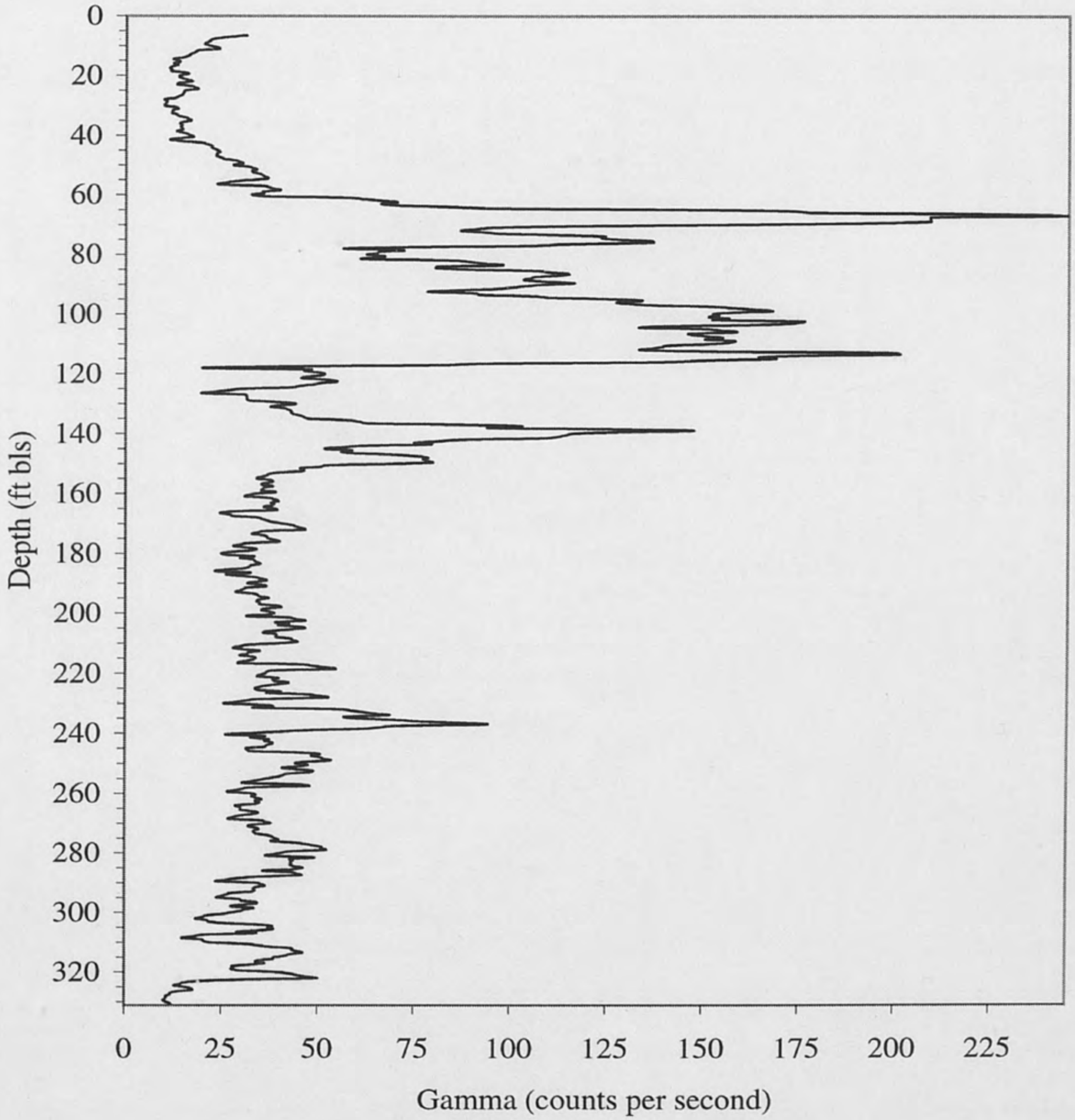
Appendix E-2
Gamma Log Plots for Lake County Wells

SJRWMD I.D.:	L-0114	PWS I.D.:	3350544
Latitude:	28 52 12	Latitude:	28 53 30
Longitude:	81 54 28	Longitude:	81 54 30
Depth to Confining Layer:	75 ft	Distance:	2.09 mi
Depth to Aquifer:	245 ft		



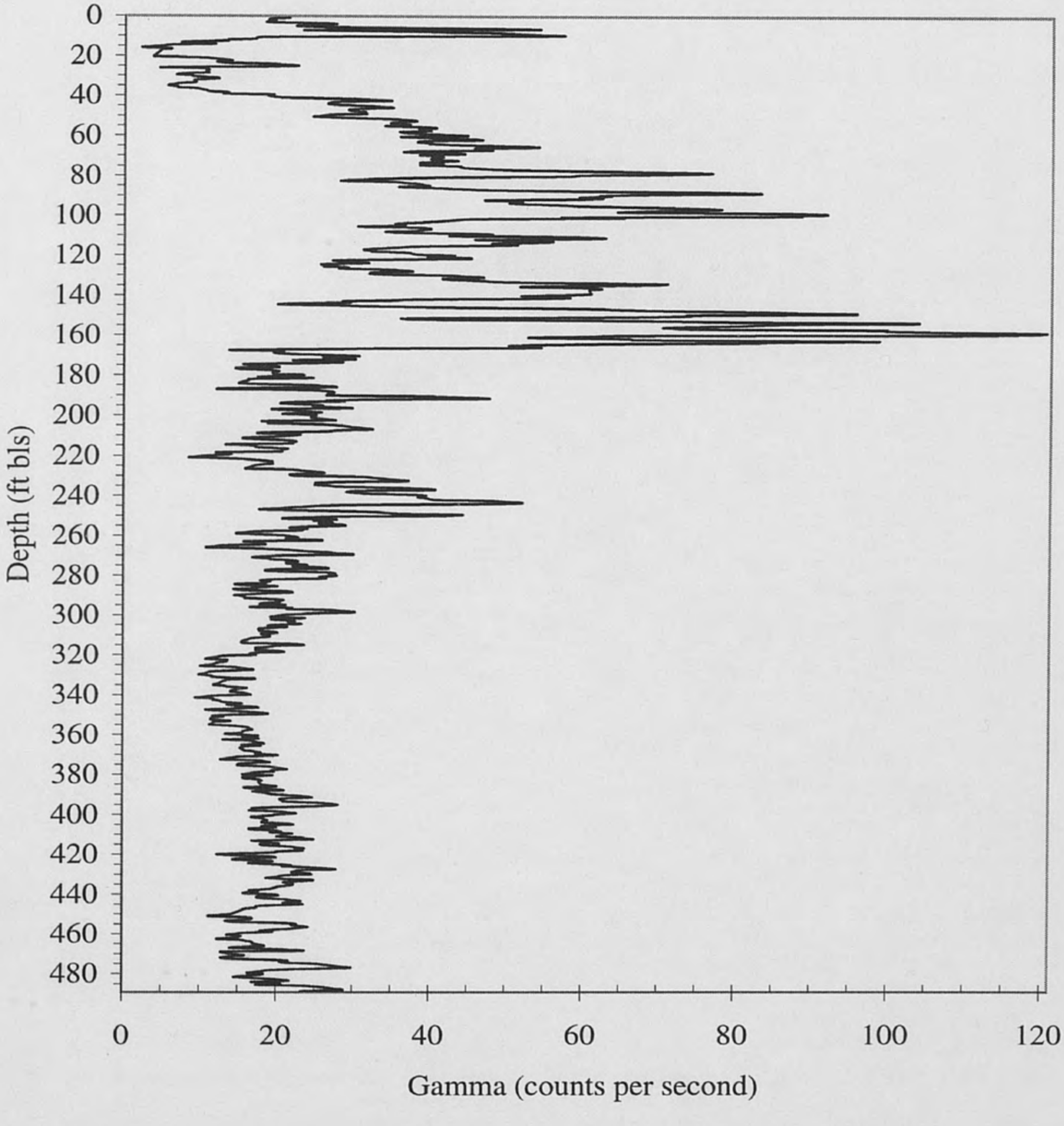
Appendix E-2
Gamma Log Plots for Lake County Wells

SJRWMD I.D.:	L-0105	PWS I.D.:	3350573
Latitude:	28 42 45	Latitude:	28 42 35
Longitude:	81 46 35	Longitude:	81 46 15
Depth to Confining Layer:	60 ft	Distance:	0.54 mi
Depth to Aquifer:	119 ft		



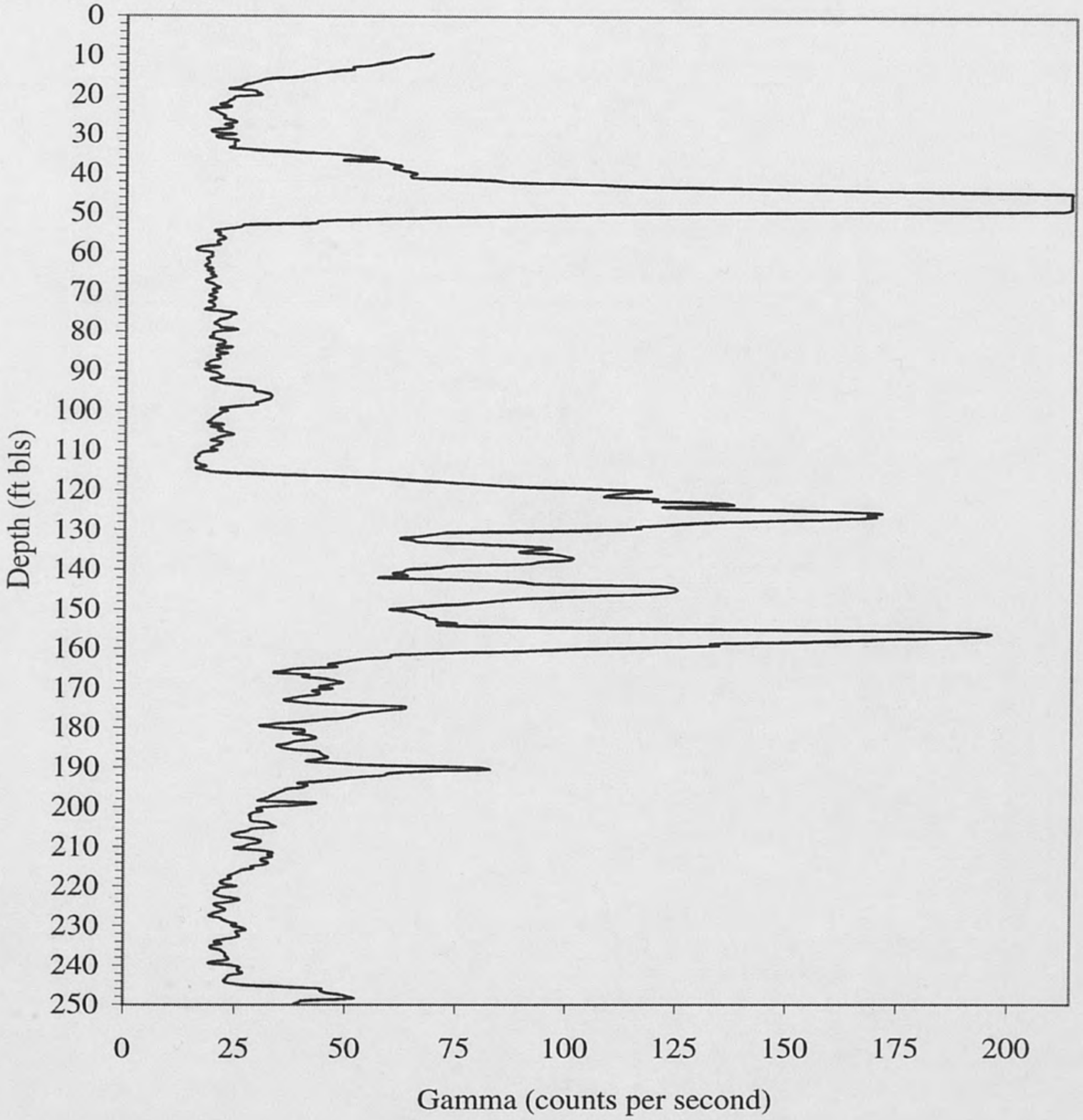
Appendix E-2
Gamma Log Plots for Lake County Wells

SJRWMD I.D.:	L-0467	PWS I.D.:	3350858
Latitude:	28 49 35	Latitude:	28 49 00
Longitude:	81 38 51	Longitude:	81 38 30
Depth to Confining Layer:	35 ft	Distance:	1.06 mi
Depth to Aquifer:	165 ft		



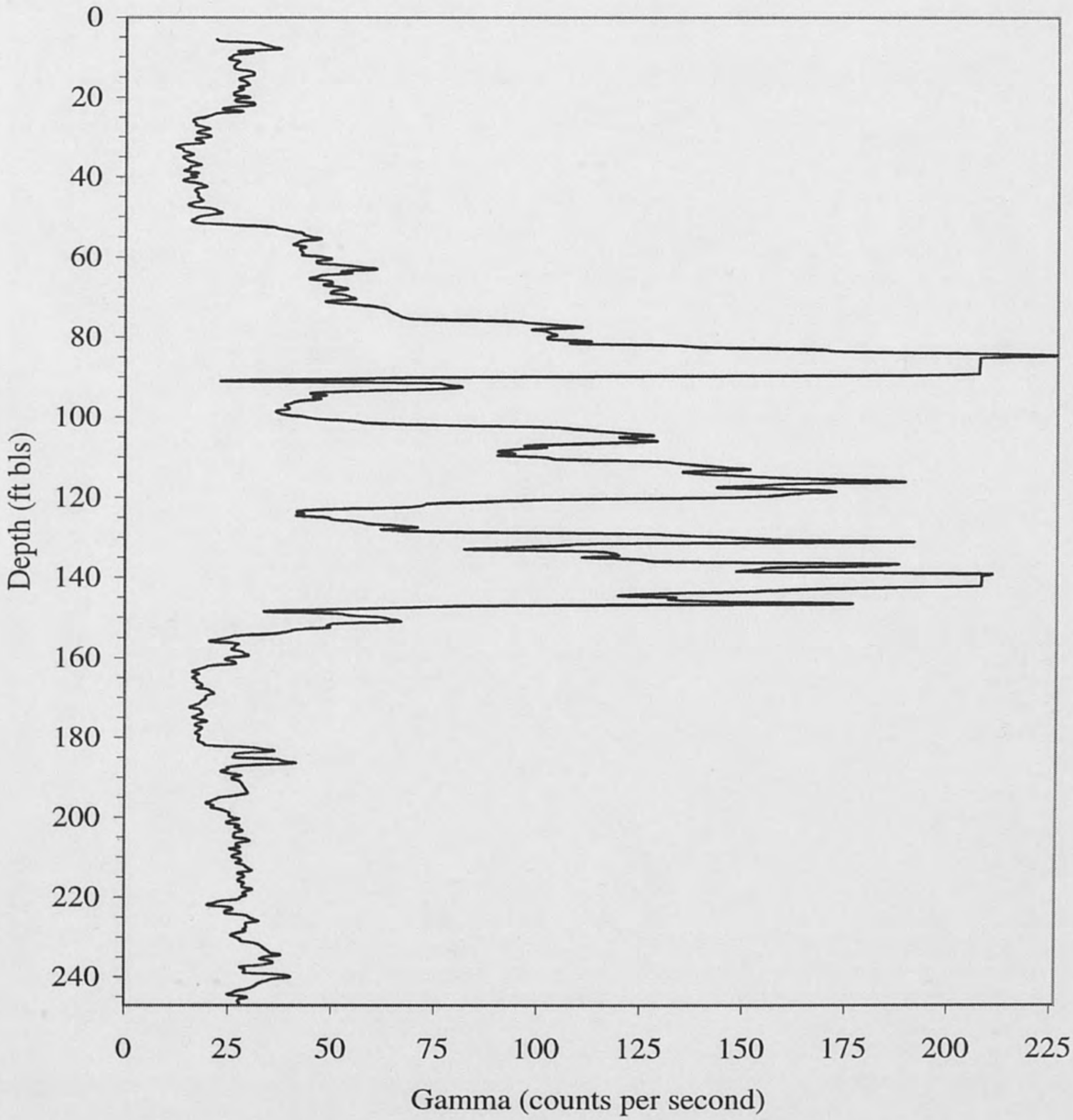
Appendix E-2
Gamma Log Plots for Lake County Wells

SJRWMD I.D.:	L-0011	PWS I.D.:	3350981
Latitude:	28 41 36	Latitude:	28 41 49
Longitude:	81 52 14	Longitude:	81 51 30
Depth to Confining Layer:	114 ft	Distance:	1.09 mi
Depth to Aquifer:	165 ft		



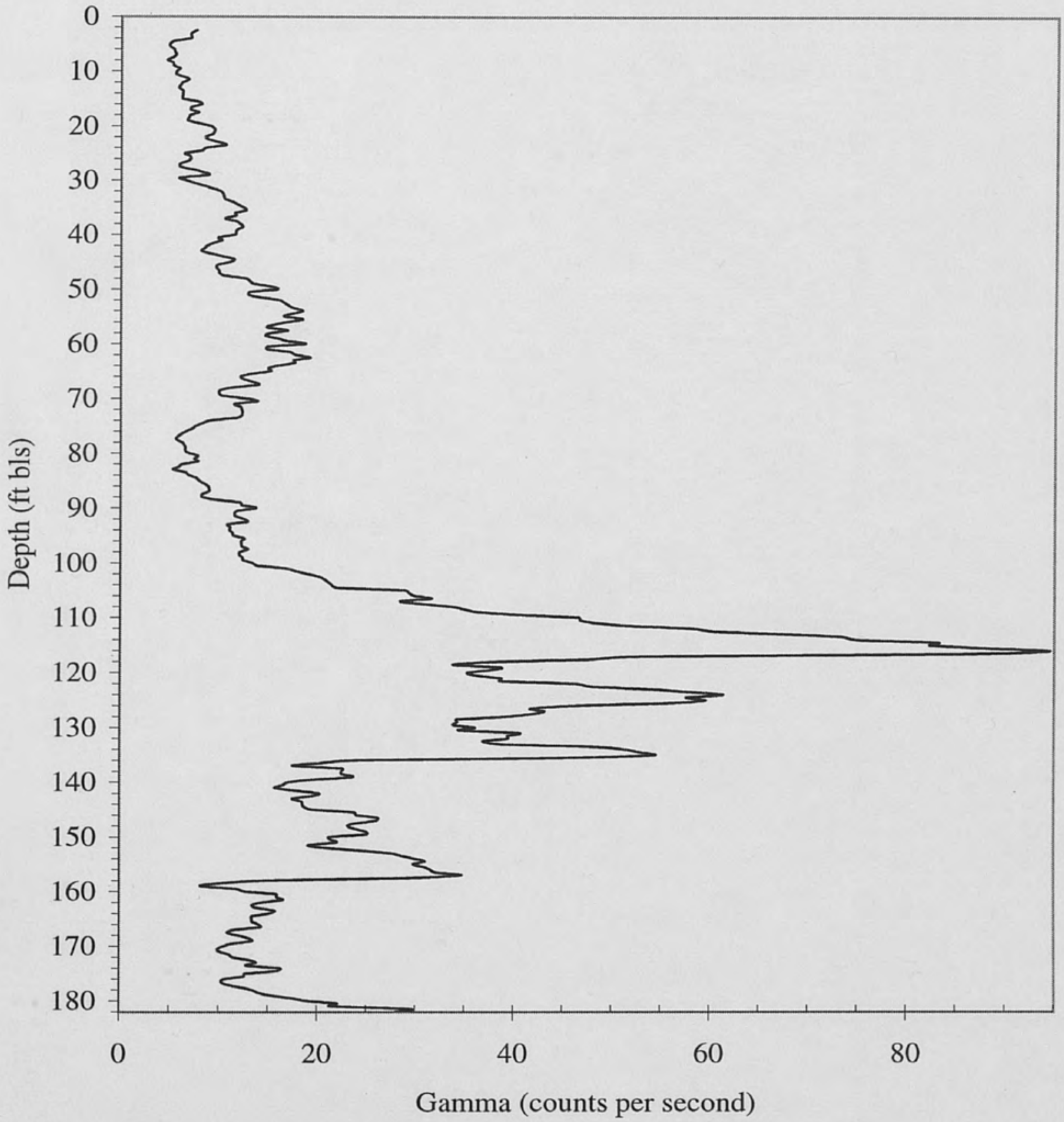
Appendix E-2
Gamma Log Plots for Lake County Wells

SJRWMD I.D.:	L-0114	PWS I.D.:	3351021
Latitude:	28 52 12	Latitude:	28 52 30
Longitude:	81 54 28	Longitude:	81 55 12
Depth to Confining Layer:	51 ft	Distance:	1.14 mi
Depth to Aquifer:	155 ft		



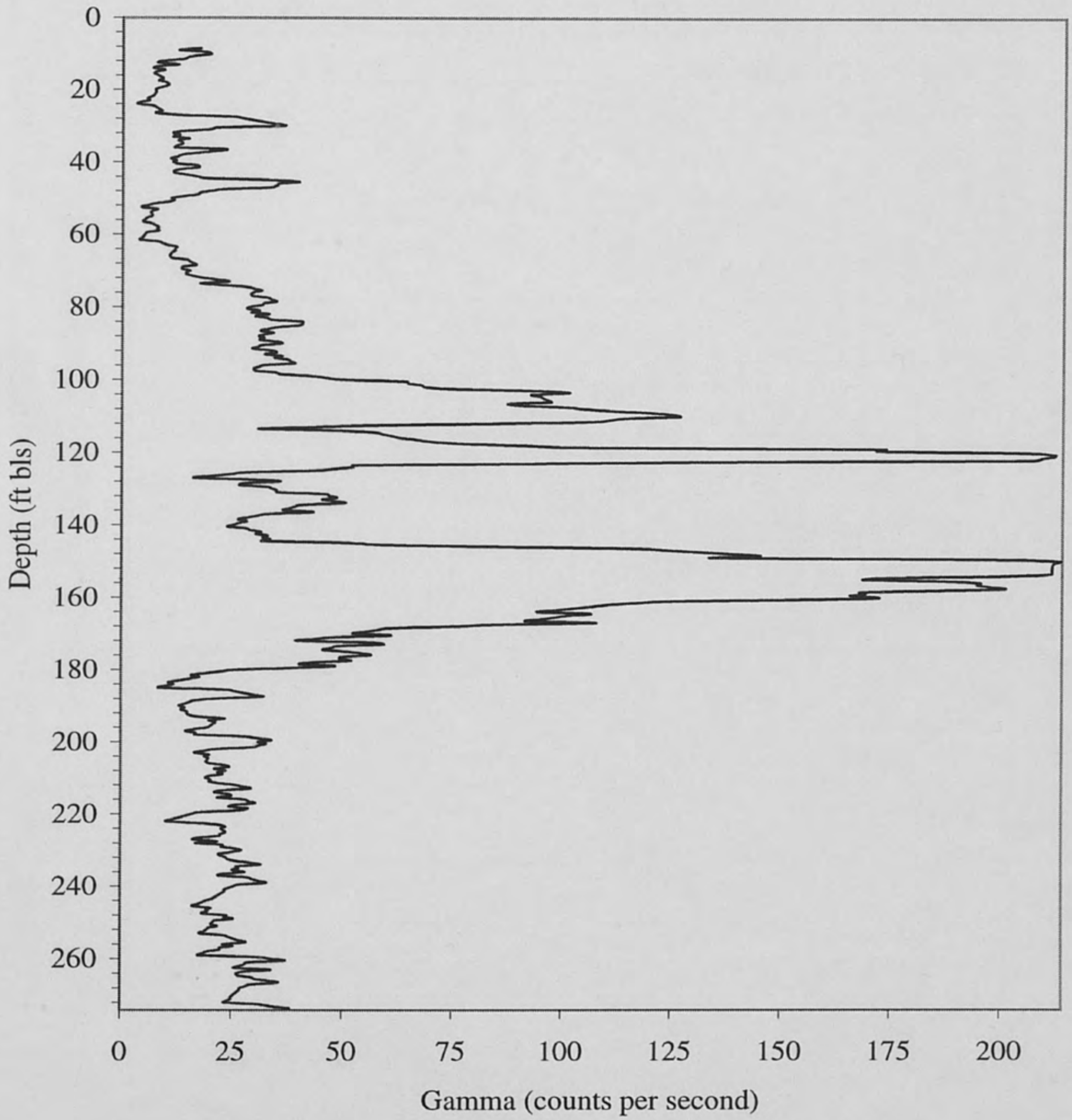
Appendix E-2
Gamma Log Plots for Lake County Wells

SJRWMD I.D.:	L-0107A	PWS I.D.:	3351182
Latitude:	28 49 38	Latitude:	28 50 17
Longitude:	81 47 58	Longitude:	81 47 22
Depth to Confining Layer:	98 ft	Distance:	1.34 mi
Depth to Aquifer:	137 ft		



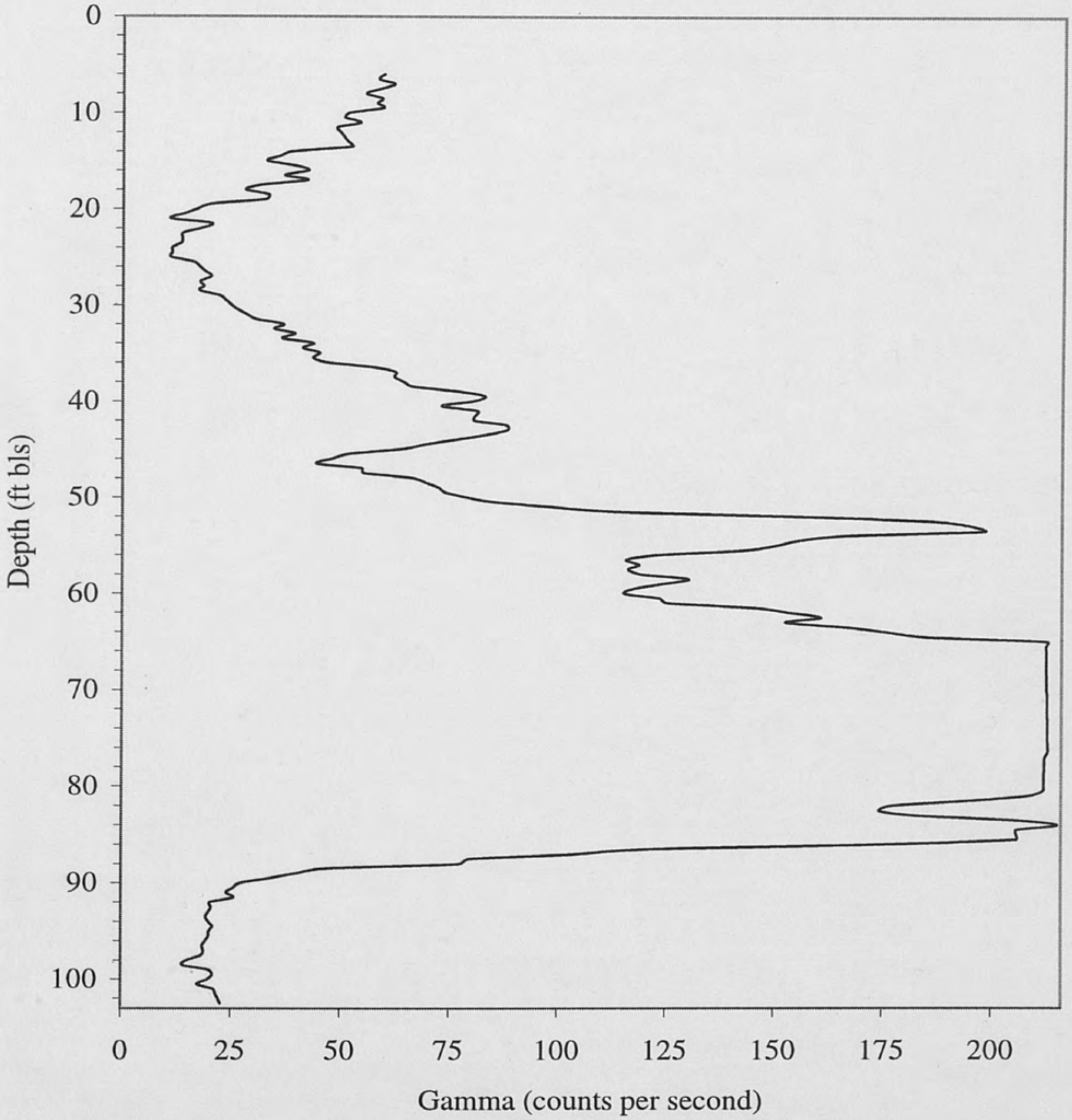
Appendix E-2
Gamma Log Plots for Lake County Wells

SJRWMD I.D.:	L-0182	PWS I.D.:	3351282
Latitude:	28 43 38	Latitude:	28 45 11
Longitude:	81 51 43	Longitude:	81 50 27
Depth to Confining Layer:	145 ft	Distance:	3.07 mi
Depth to Aquifer:	180 ft		



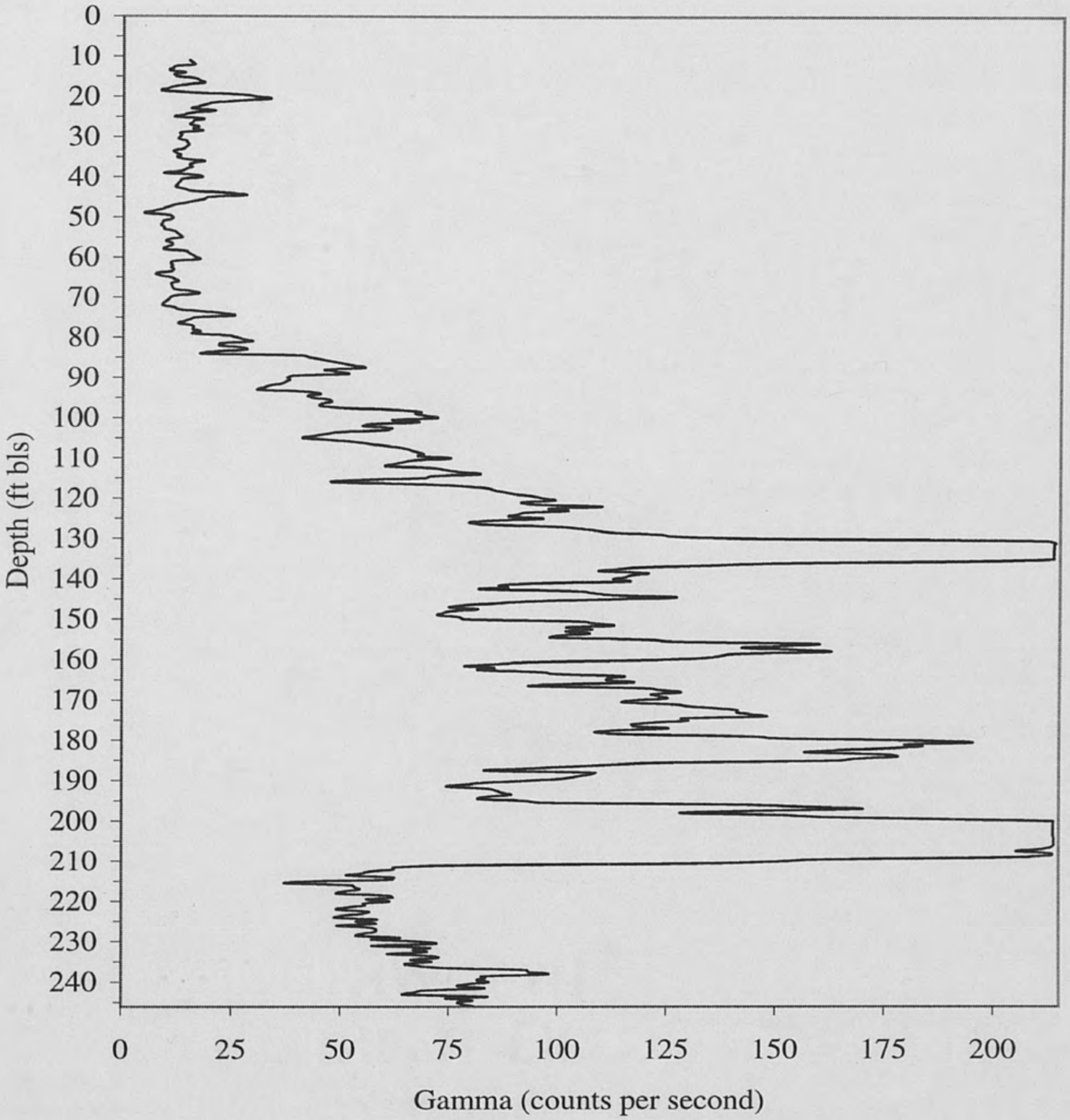
Appendix E-2
Gamma Log Plots for Lake County Wells

SJRWMD I.D.:	L-0009	PWS I.D.:	3351421
Latitude:	28 50 13	Latitude:	28 50 58
Longitude:	81 53 32	Longitude:	81 53 28
Depth to Confining Layer:	45 ft	Distance:	1.21 mi
Depth to Aquifer:	90 ft		



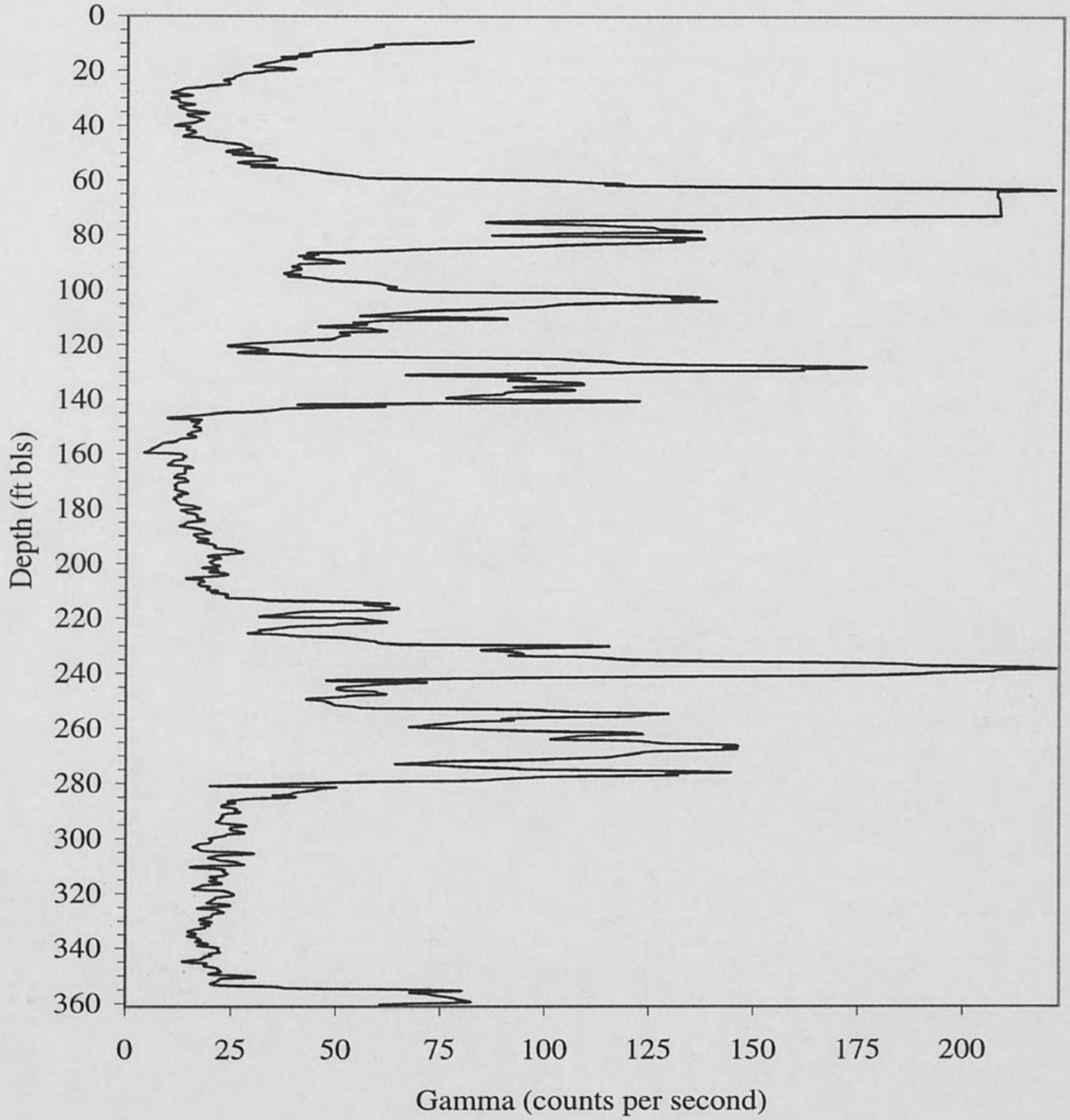
Appendix E-2
Gamma Log Plots for Lake County Wells

SJRWMD I.D.:	L-0035	PWS I.D.:	3351426
Latitude:	28 45 35	Latitude:	28 45 25
Longitude:	81 42 12	Longitude:	81 41 03
Depth to Confining Layer:	117 ft	Distance:	1.64 mi
Depth to Aquifer:	213 ft		



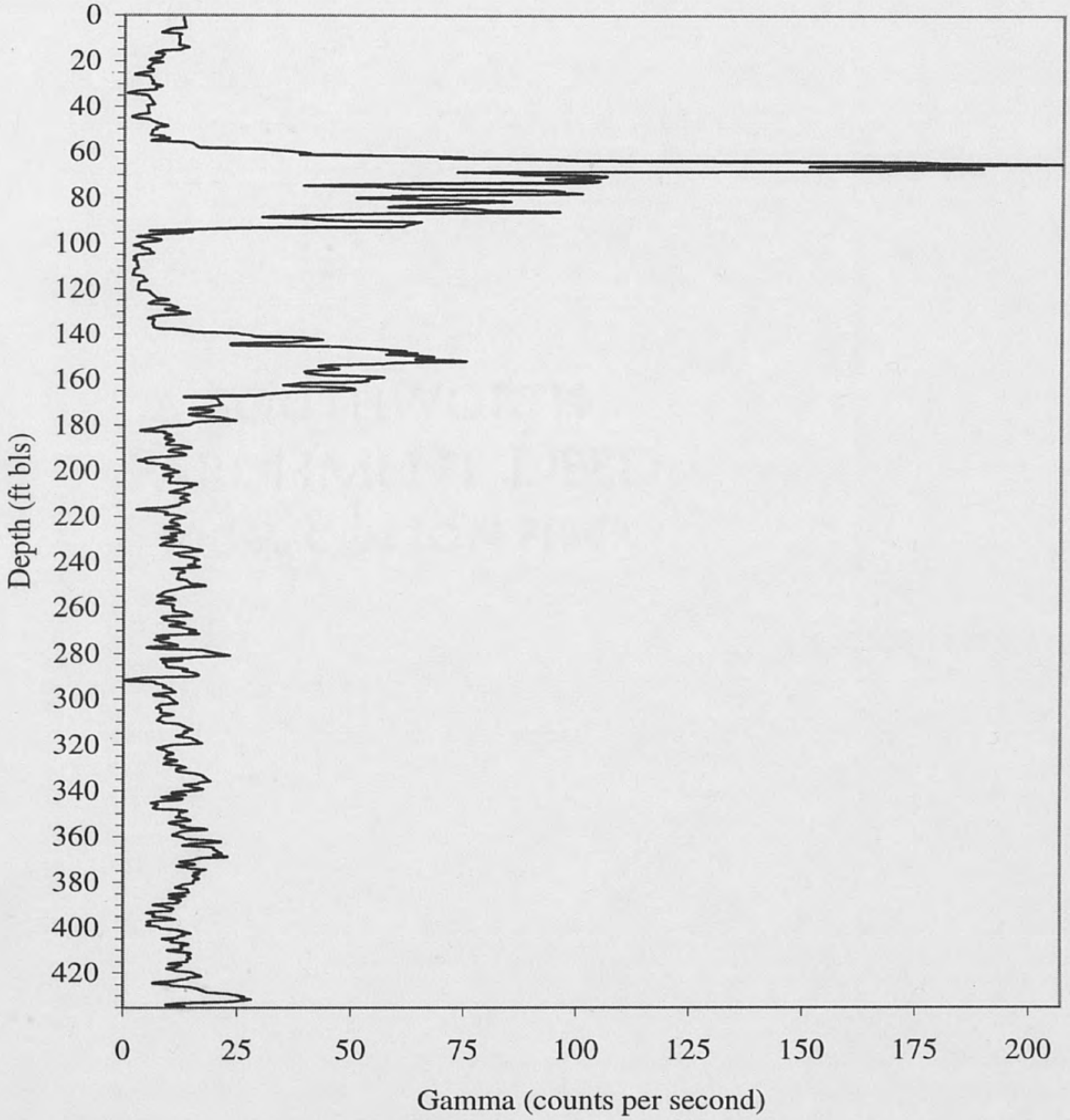
Appendix E-2
Gamma Log Plots for Lake County Wells

SJRWMD I.D.:	L-0118	PWS I.D.:	3354010
Latitude:	28 55 48	Latitude:	28 55 40
Longitude:	81 55 10	Longitude:	81 55 15
Depth to Confining Layer:	55 ft	Distance:	0.24 mi
Depth to Aquifer:	147 ft		



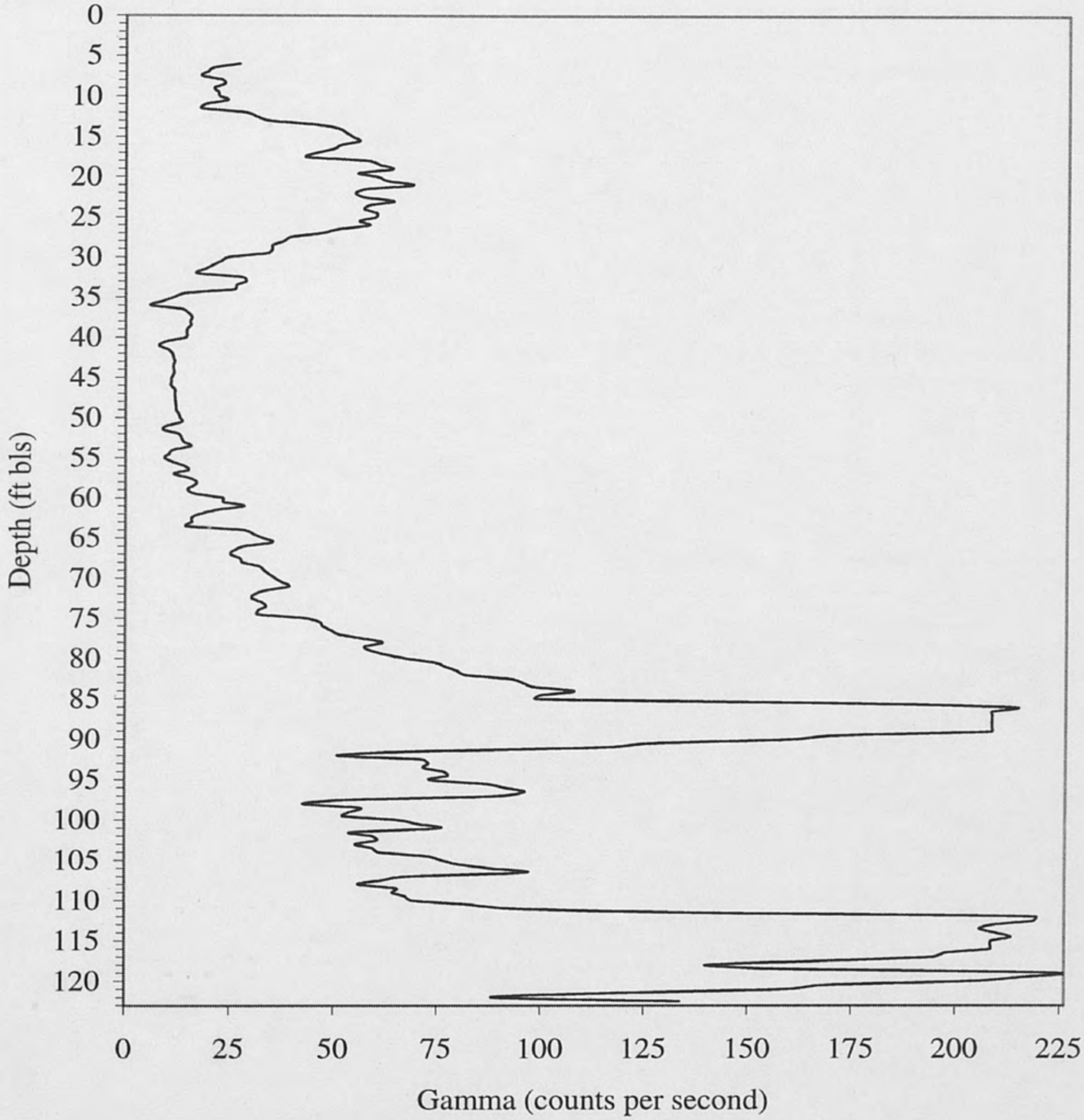
Appendix E-2
Gamma Log Plots for Lake County Wells

SJRWMD I.D.:	L-0466	PWS I.D.:	3354104
Latitude:	28 34 43	Latitude:	28 36 30
Longitude:	81 45 05	Longitude:	81 45 30
Depth to Confining Layer:	55 ft	Distance:	2.93 mi
Depth to Aquifer:	98 ft		



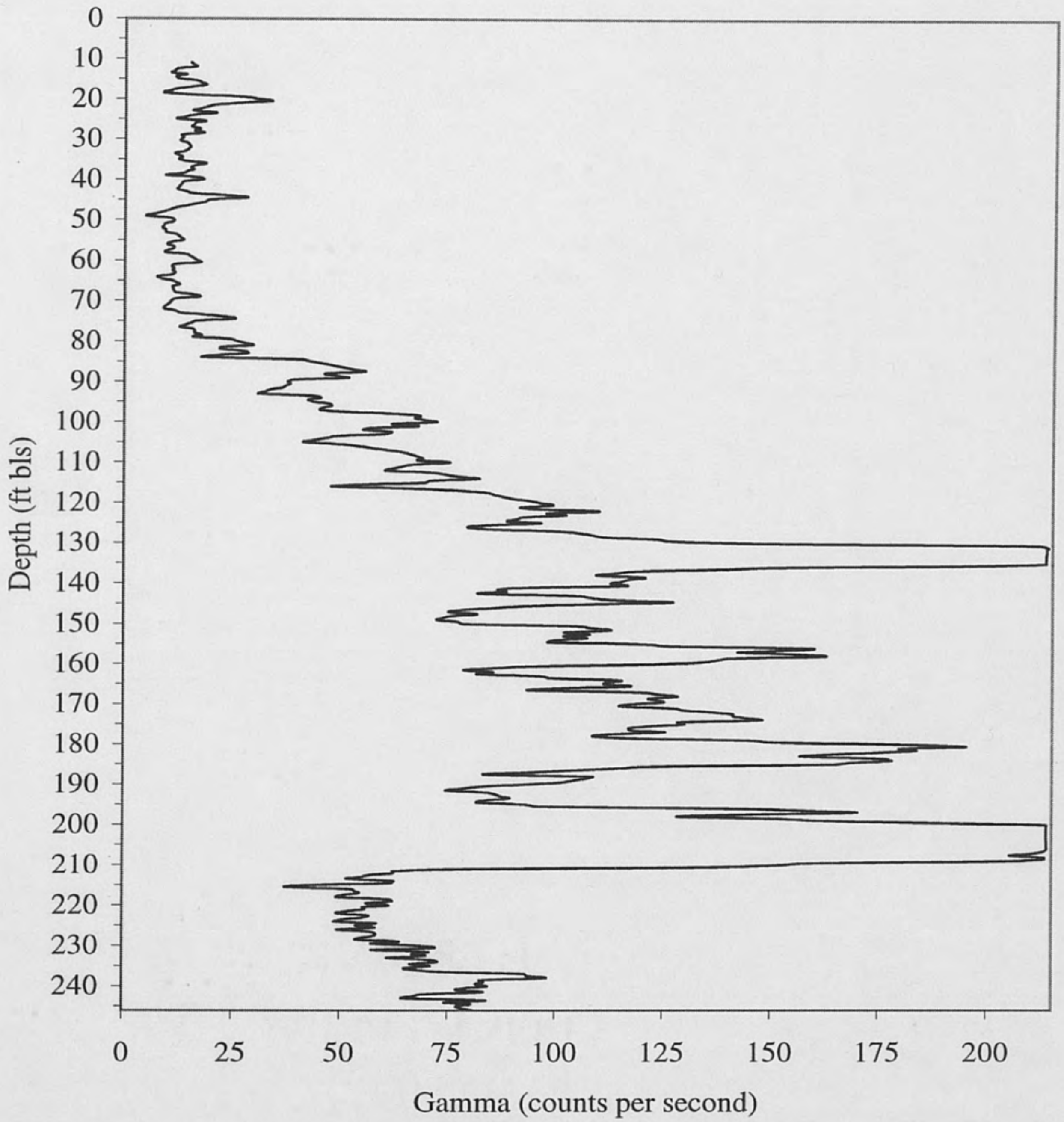
Appendix E-2
Gamma Log Plots for Lake County Wells

SJRWMD I.D.:	L-0274	PWS I.D.:	3354661
Latitude:	28 51 04	Latitude:	28 51 30
Longitude:	81 53 24	Longitude:	81 53 20
Depth to Confining Layer:	74 ft	Distance:	0.70 mi
Depth to Aquifer:	125 ft		



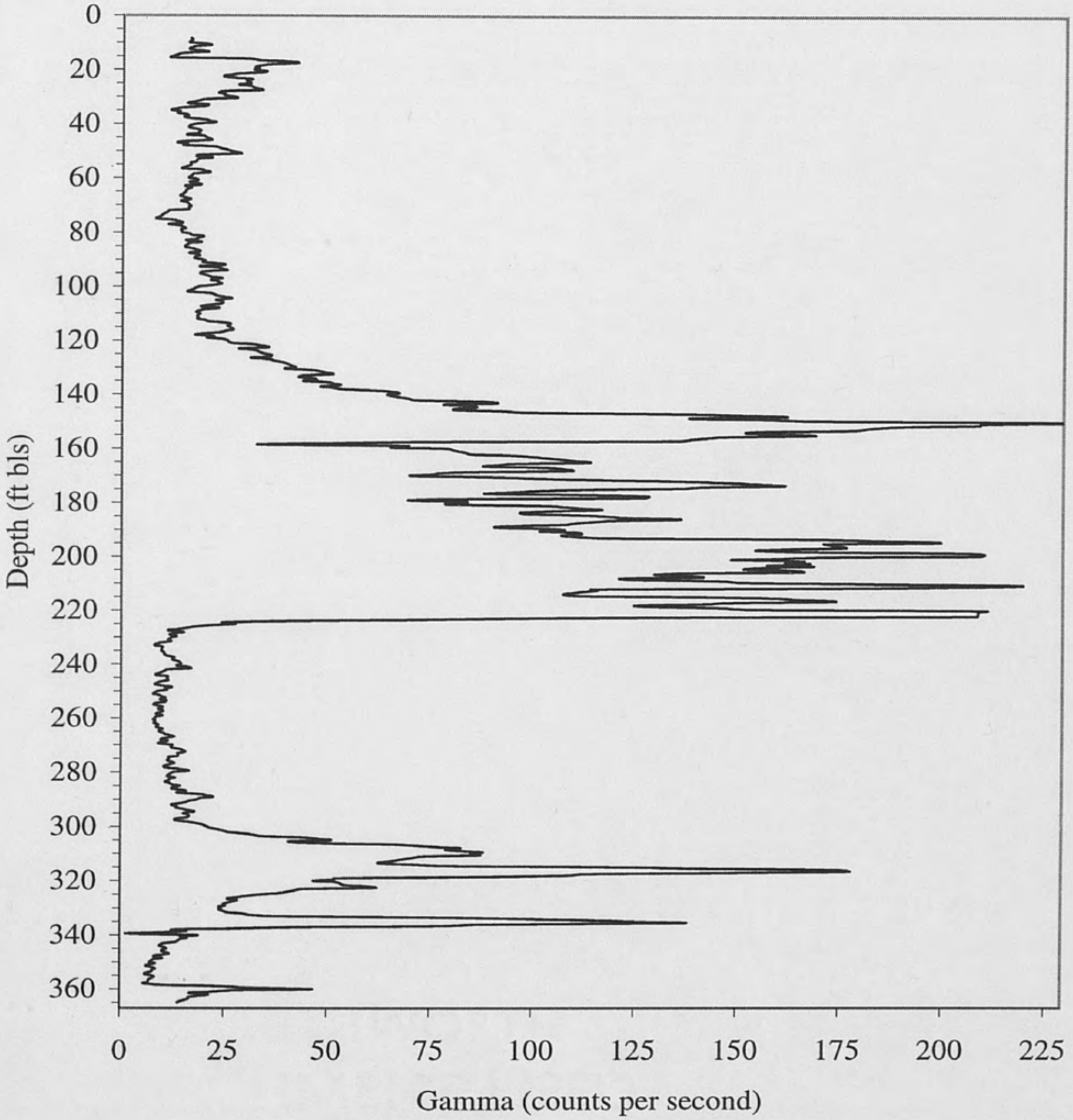
Appendix E-2
Gamma Log Plots for Lake County Wells

SJRWMD I.D.:	L-0035	PWS I.D.:	3354662
Latitude:	28 45 35	Latitude:	28 45 82
Longitude:	81 42 12	Longitude:	81 40 30
Depth to Confining Layer:	115 ft	Distance:	2.71 mi
Depth to Aquifer:	215 ft		



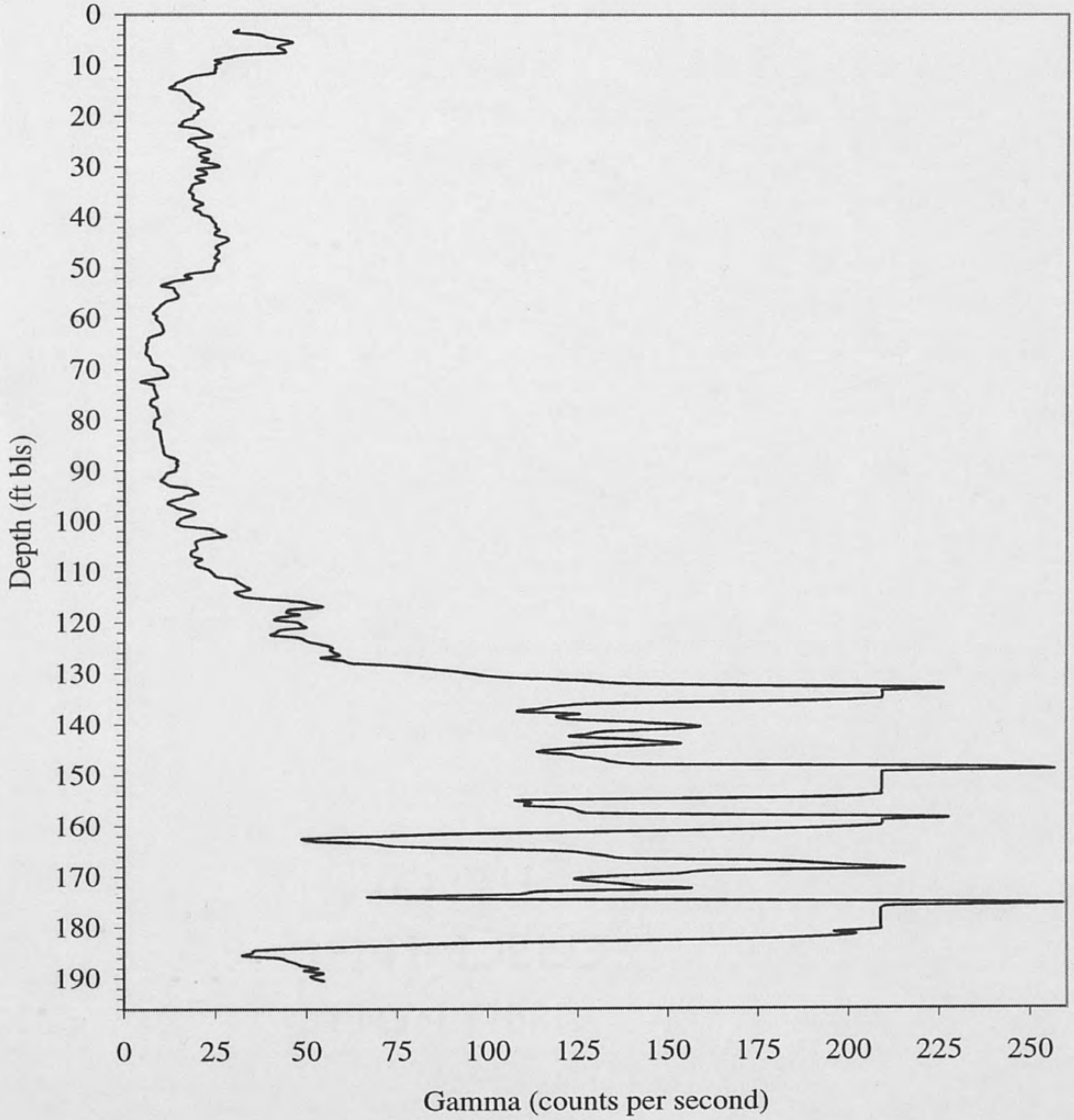
Appendix E-2
Gamma Log Plots for Lake County Wells

SJRWMD I.D.:	L-0189	PWS I.D.:	3354836
Latitude:	28 45 36	Latitude:	28 45 00
Longitude:	81 44 29	Longitude:	81 45 00
Depth to Confining Layer:	135 ft	Distance:	1.21 mi
Depth to Aquifer:	229 ft		



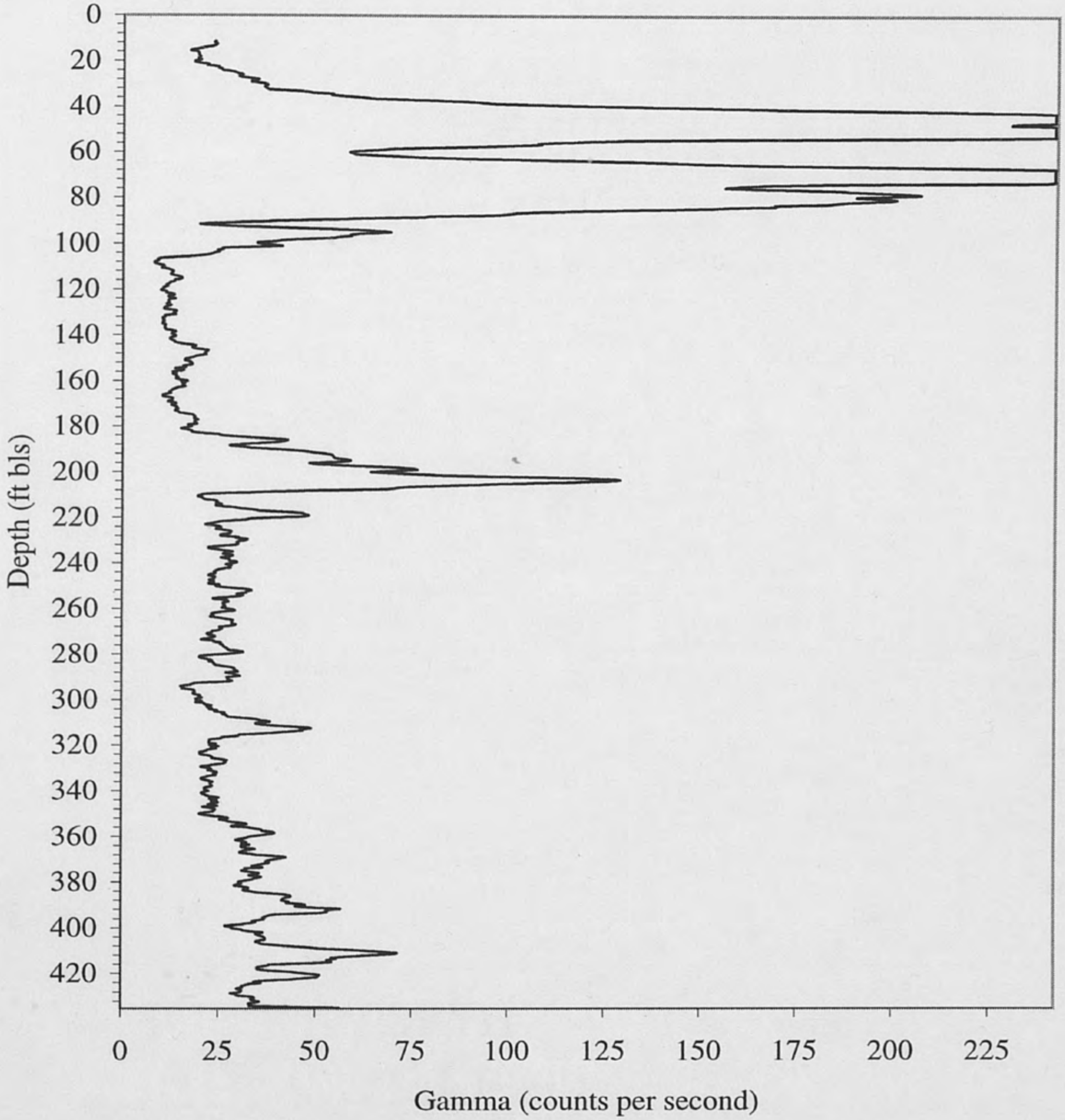
Appendix E-2
Gamma Log Plots for Lake County Wells

SJRWMD I.D.:	L-0116A	PWS I.D.:	3354867
Latitude:	28 52 32	Latitude:	28 53 00
Longitude:	81 46 57	Longitude:	81 46 02
Depth to Confining Layer:	125 ft	Distance:	1.49 mi
Depth to Aquifer:	185 ft		



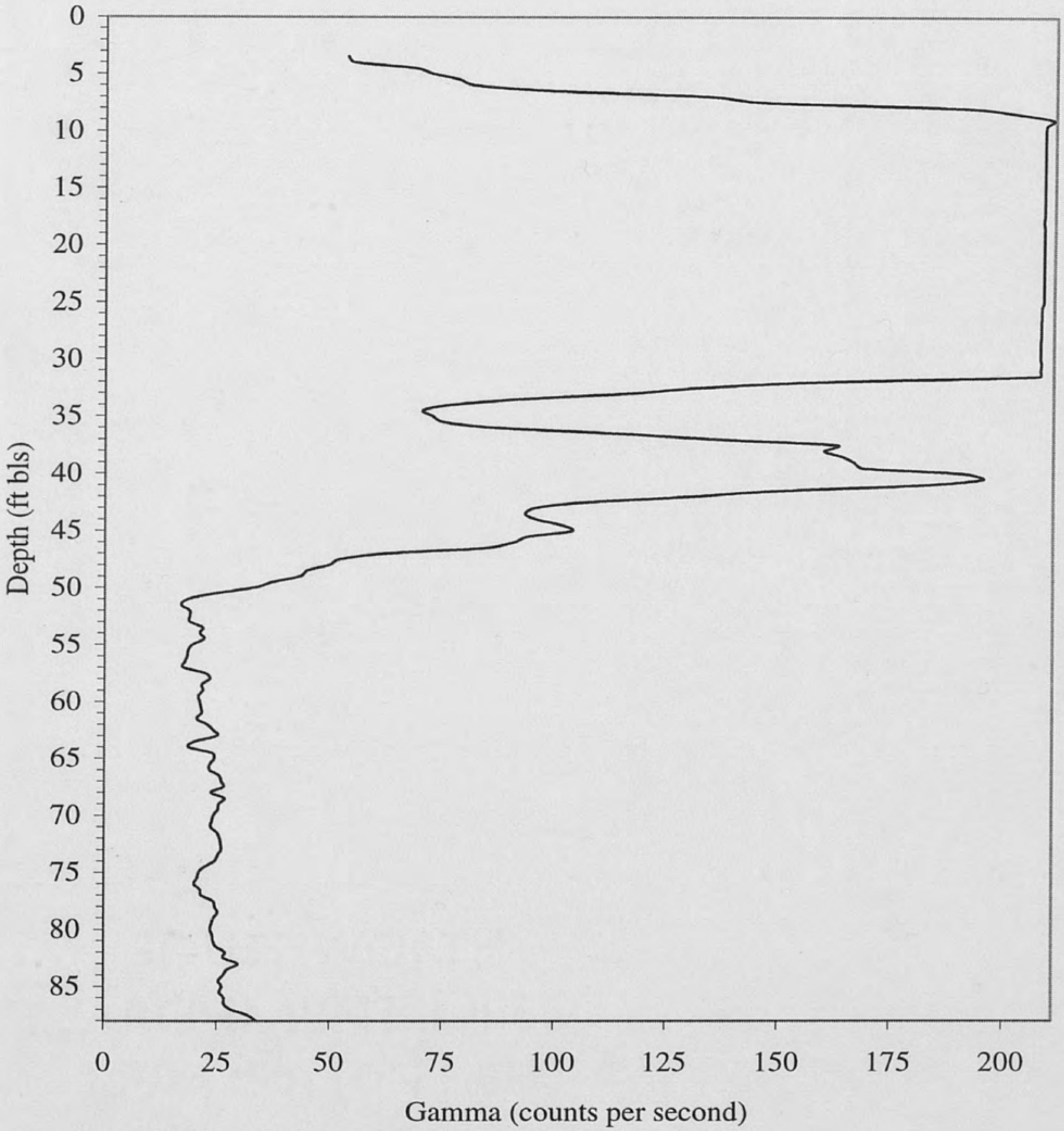
Appendix E-2
Gamma Log Plots for Lake County Wells

SJRWMD I.D.:	L-0639	PWS I.D.:	3354929
Latitude:	28 40 49	Latitude:	28 39 50
Longitude:	81 52 14	Longitude:	81 52 00
Depth to Confining Layer:	30 ft	Distance:	1.62 mi
Depth to Aquifer:	92 ft	I love you, Christy!	



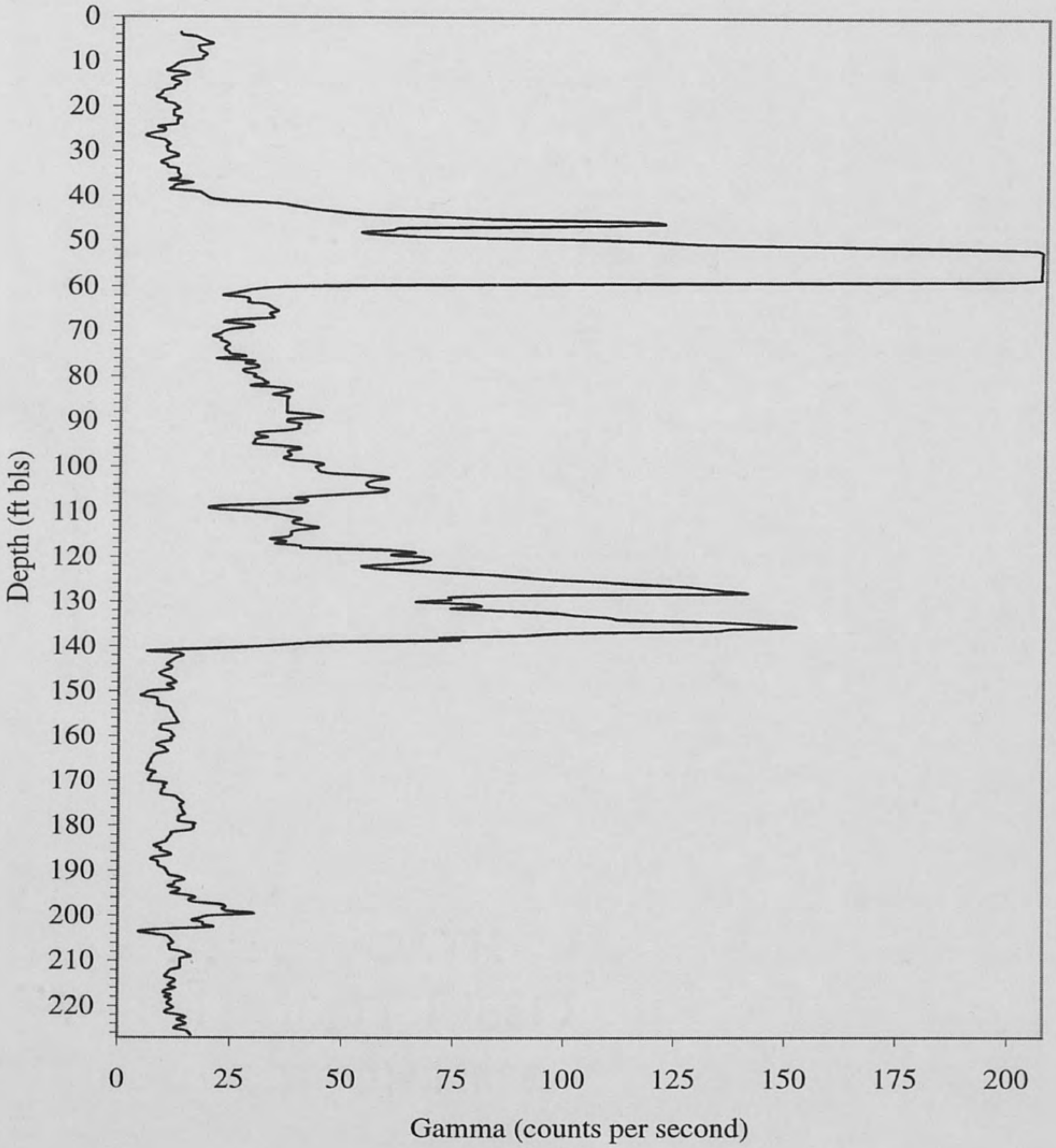
Appendix E-3
Gamma Log Plots for Marion County Wells

SJRWMD I.D.:	M-0082	PWS I.D.:	3420074
Latitude:	29 03 37	Latitude:	29 03 00
Longitude:	82 04 33	Longitude:	82 03 10
Depth to Confining Layer:	9 ft	Distance:	2.18 miles
Depth to Aquifer	47 ft		



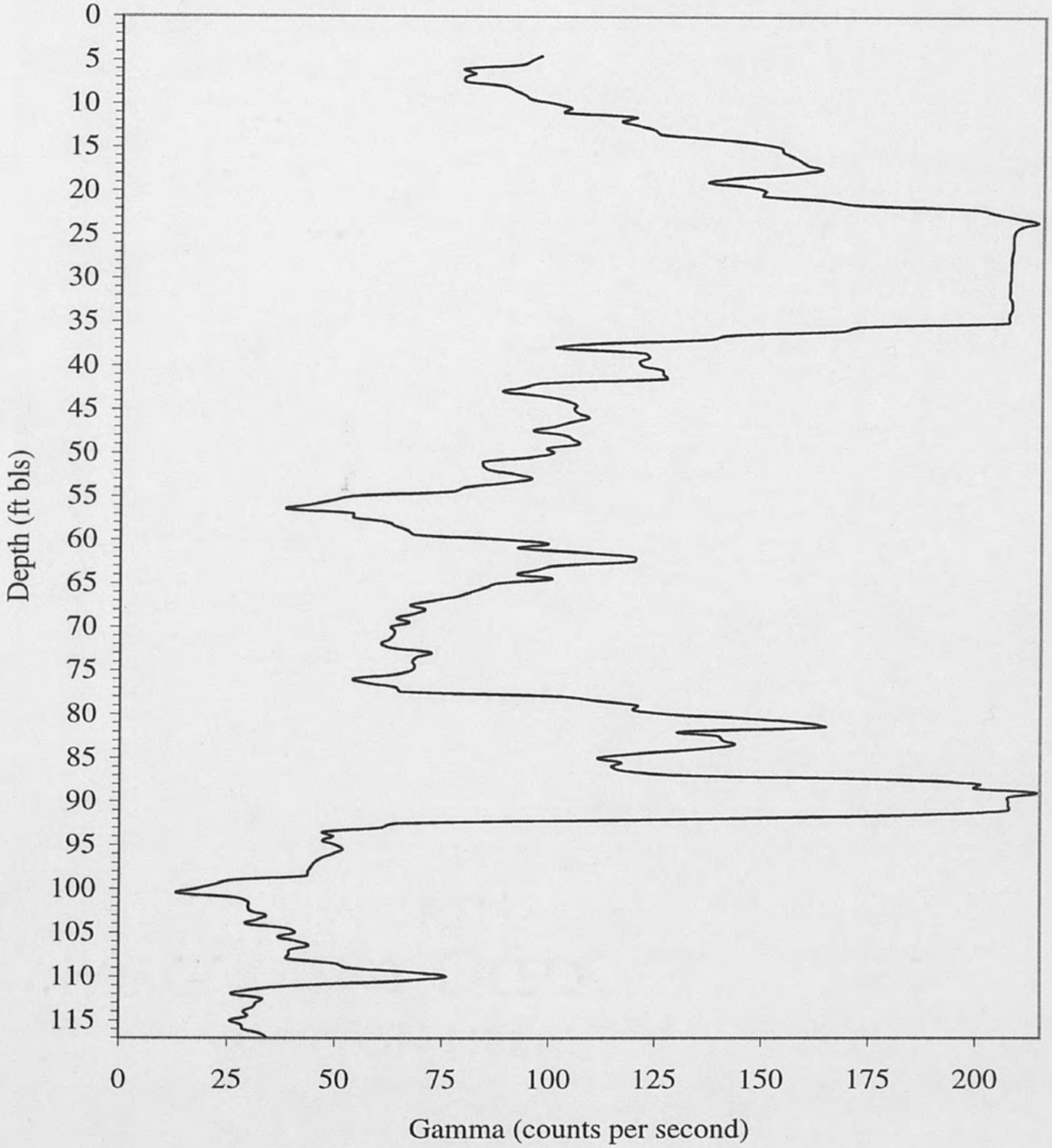
Appendix E-3
Gamma Log Plots for Marion County Wells

SJRWMD I.D.:	M-0310	PWS I.D.:	3420085
Latitude:	28 58 21	Latitude:	28 57 30
Longitude:	81 57 42	Longitude:	81 57 03
Depth to Confining Layer:	42 ft.	Distance:	1.64 mi.
Depth to Aquifer	62 ft		



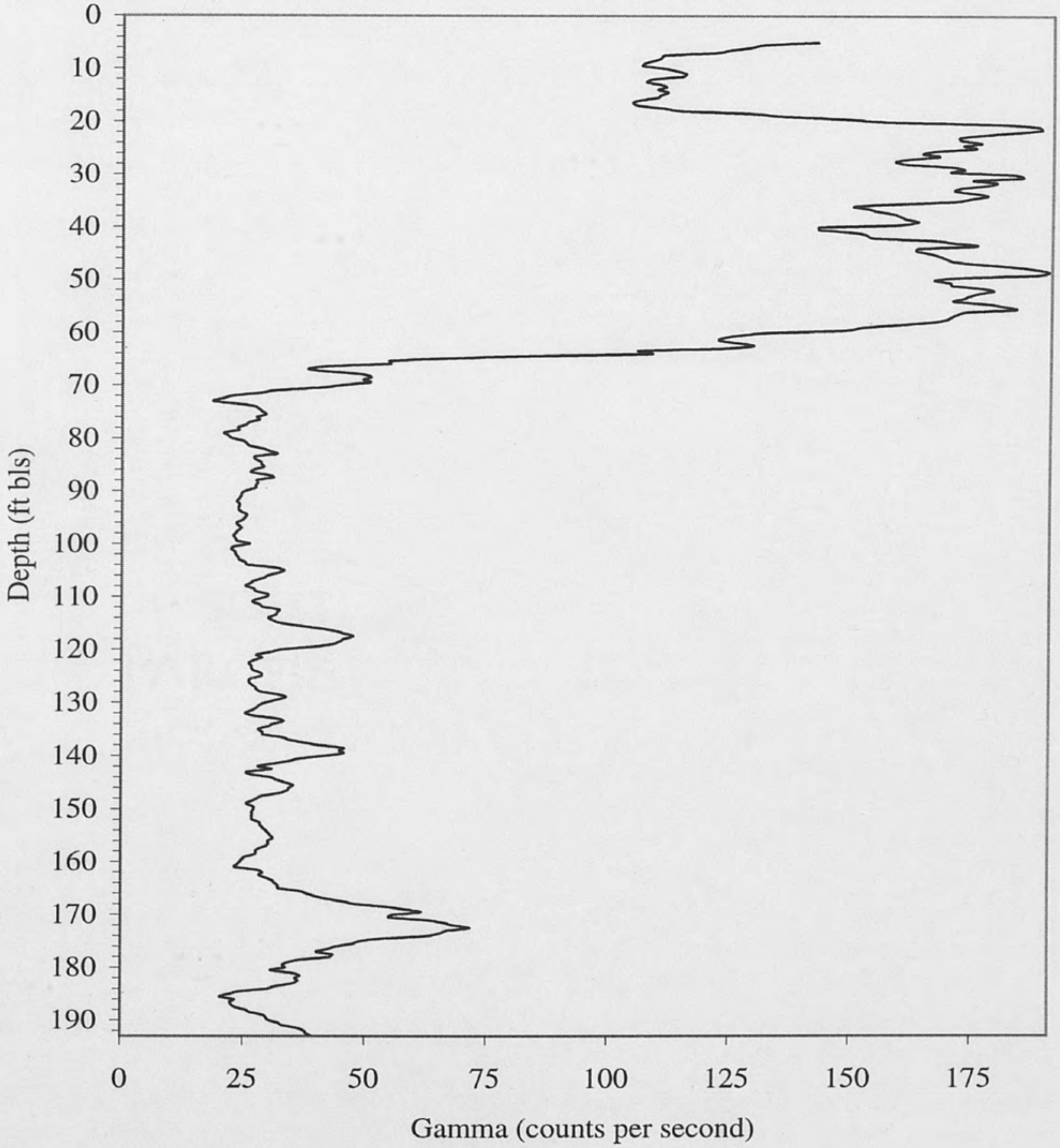
Appendix E-3
Gamma Log Plots for Marion County Wells

SJRWMD I.D.:	M-0095	PWS I.D.:	3420199
Latitude:	29 07 37	Latitude:	29 07 10
Longitude:	82 05 48	Longitude:	82 05 20
Depth to Confining Layer:	12 ft.	Distance:	0.98 mi.
Depth to Aquifer	90 ft.		



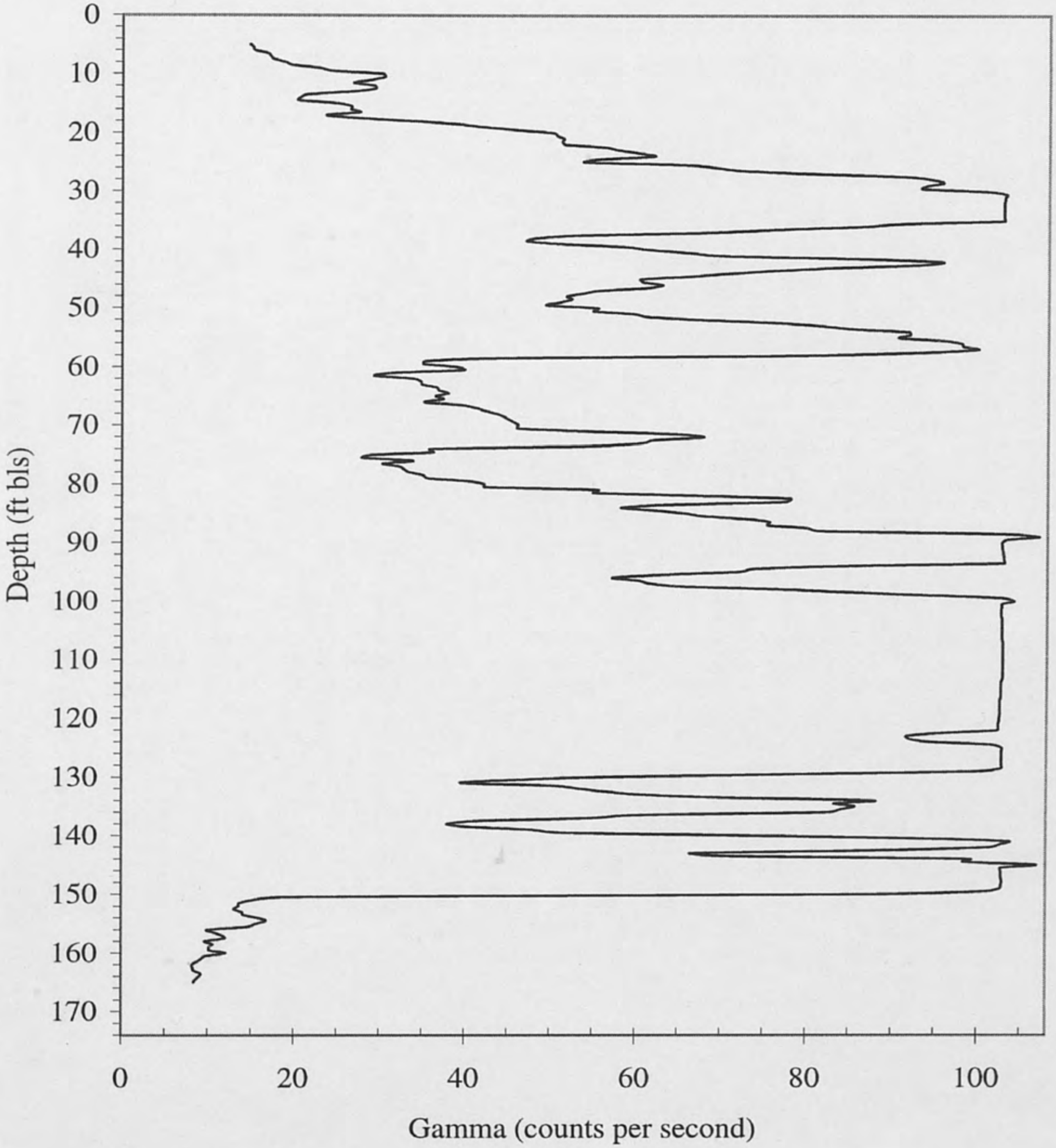
Appendix E-3
Gamma Log Plots for Marion County Wells

SJRWMD I.D.:	M-0139	PWS I.D.:	3420386
Latitude:	29 18 20	Latitude:	29 18 36
Longitude:	82 11 02	Longitude:	82 12 09
Depth to Confining Layer:	20 ft.	Distance:	1.62
Depth to Aquifer	65 ft.		



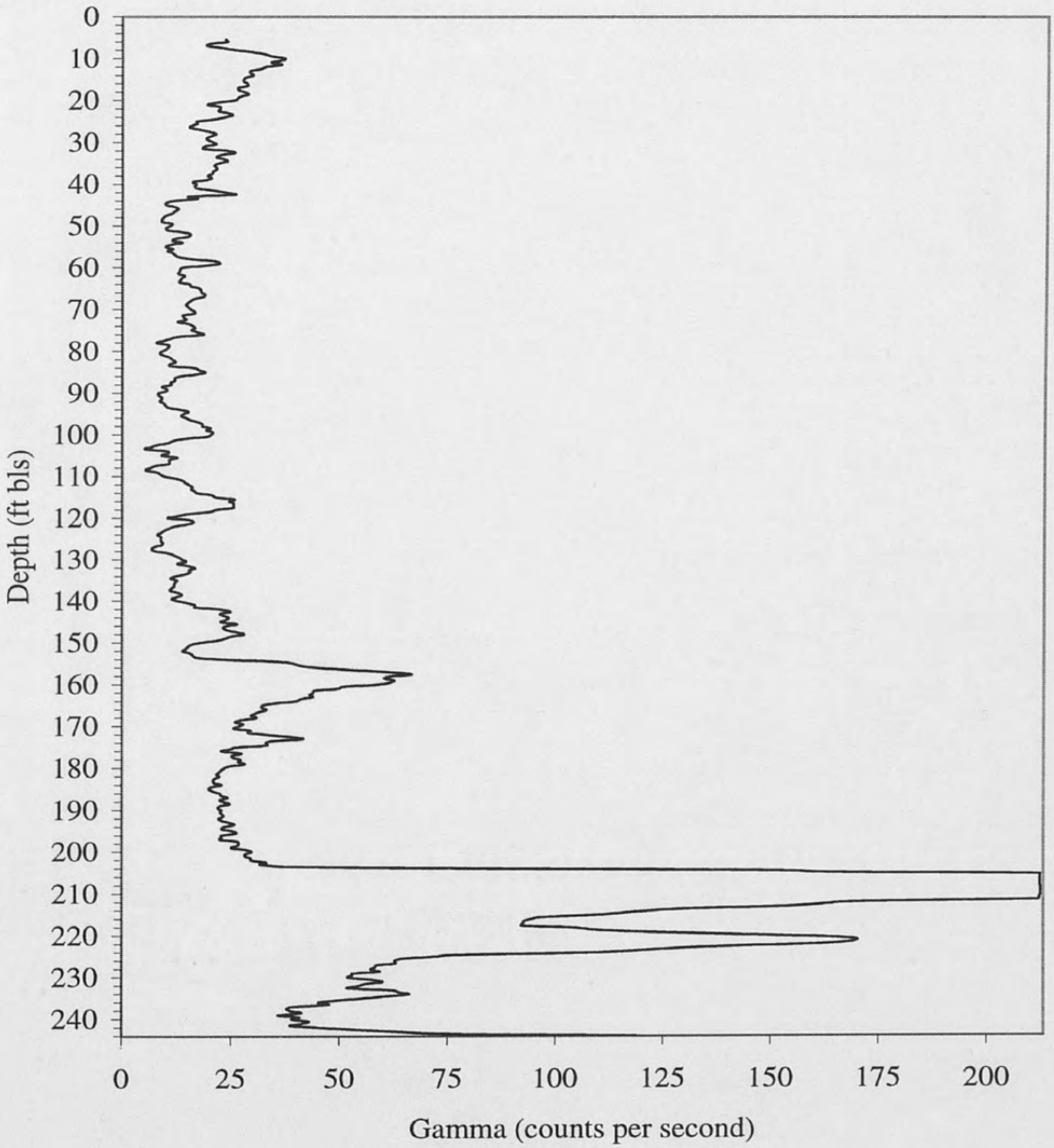
Appendix E-3
Gamma Log Plots for Marion County Wells

SJRWMD I.D.:	M-0149	PWS I.D.:	3420924
Latitude:	29 21 43	Latitude:	29 21 35
Longitude:	81 44 19	Longitude:	81 44 10
Depth to Confining Layer:	20 ft	Distance:	0.30 mi.
Depth to Aquifer	150 ft.		



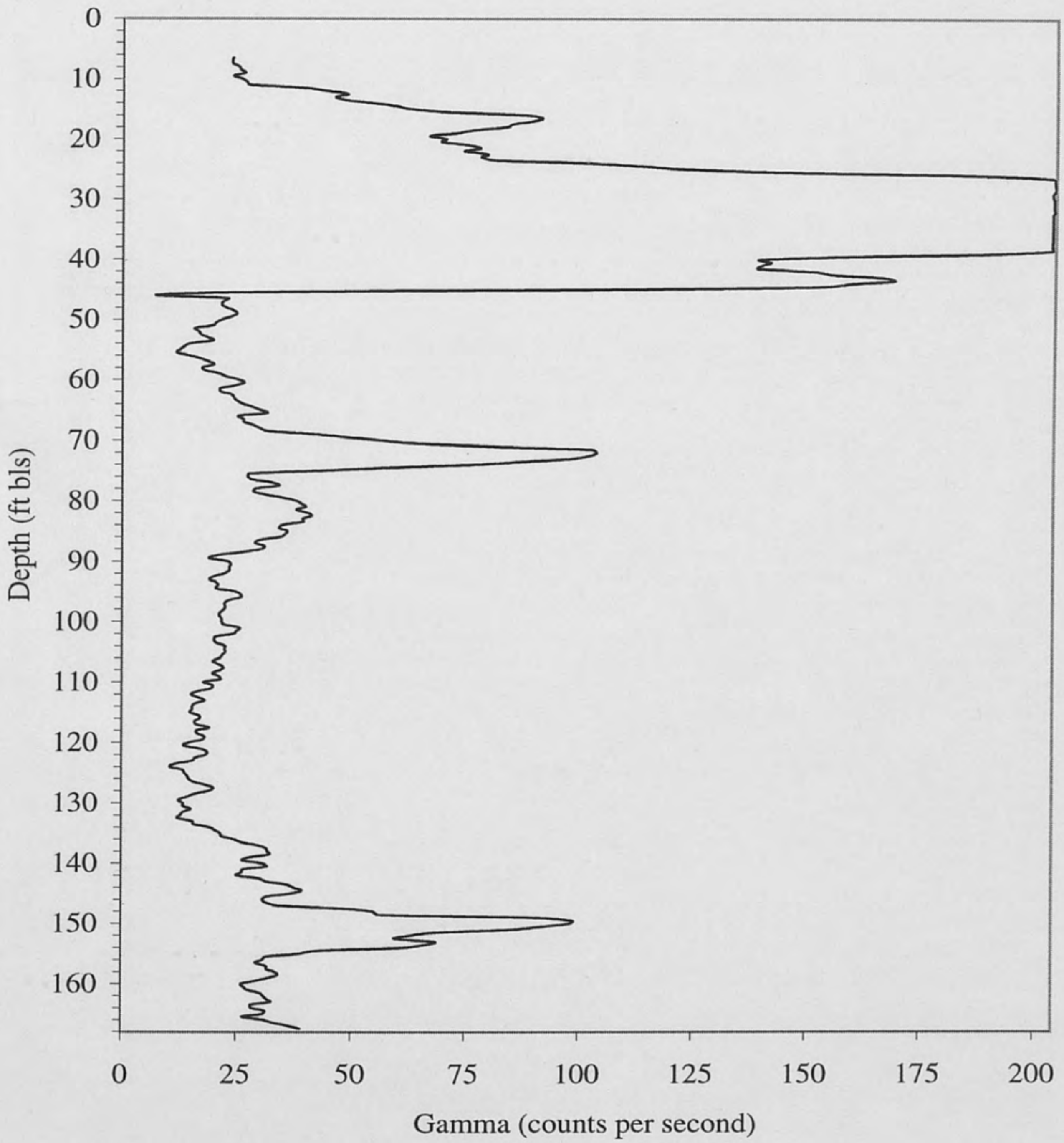
Appendix E-3
Gamma Log Plots for Marion County Wells

SJRWMD I.D.:	L-0282	PWS I.D.:	3421269
Latitude:	28 57 32	Latitude:	28 58 10
Longitude:	81 55 27	Longitude:	81 55 50
Depth to Confining Layer:	203 ft.	Distance:	1.15 mi.
Depth to Aquifer	224 ft.		



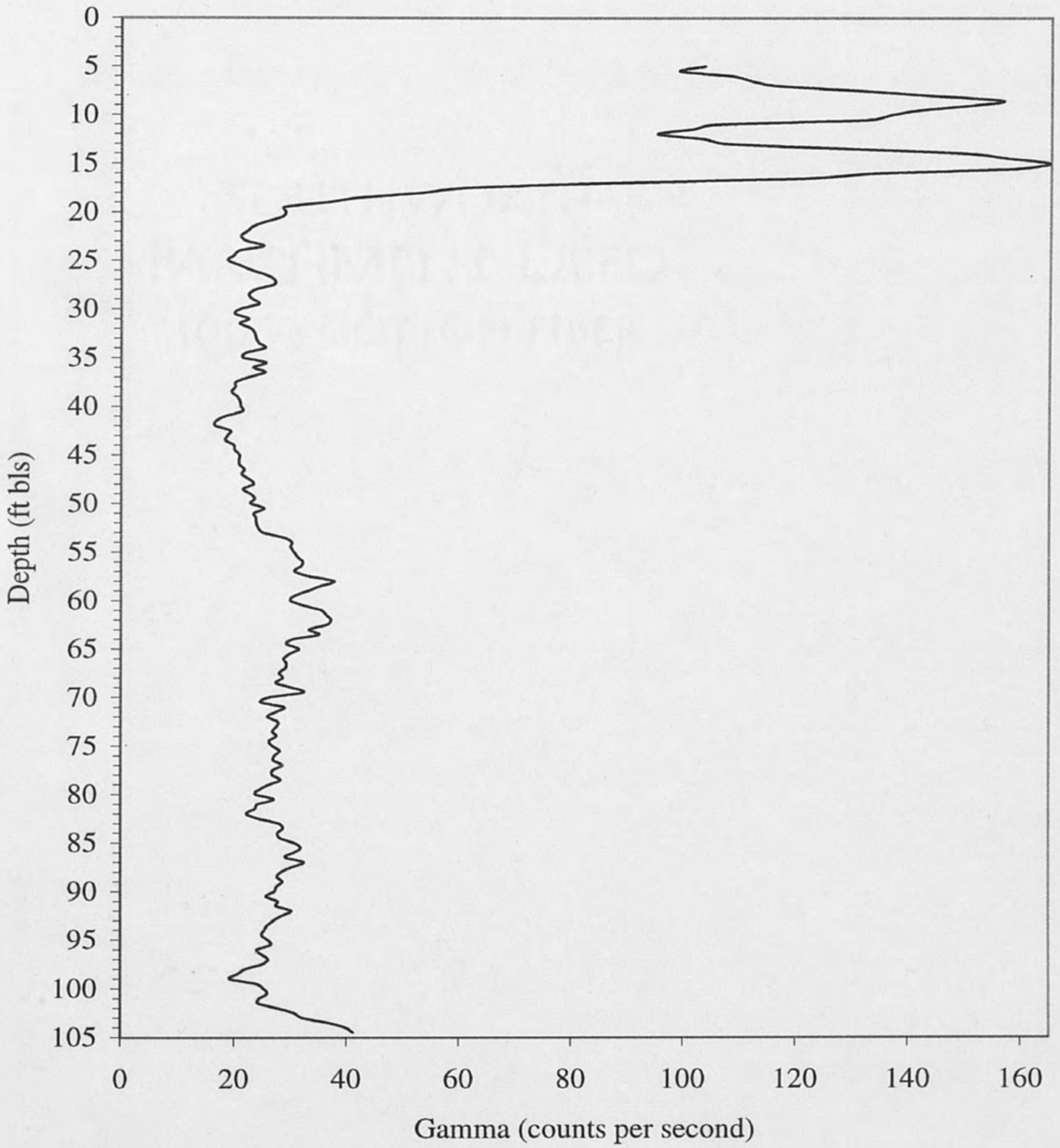
Appendix E-3
Gamma Log Plots for Marion County Wells

SJRWMD I.D.:	M-0064	PWS I.D.:	3421467
Latitude:	29 03 16	Latitude:	29 03 05
Longitude:	82 00 09	Longitude:	82 02 05
Depth to Confining Layer:	8 ft.	Distance:	2.73 mi.
Depth to Aquifer	43 ft.		



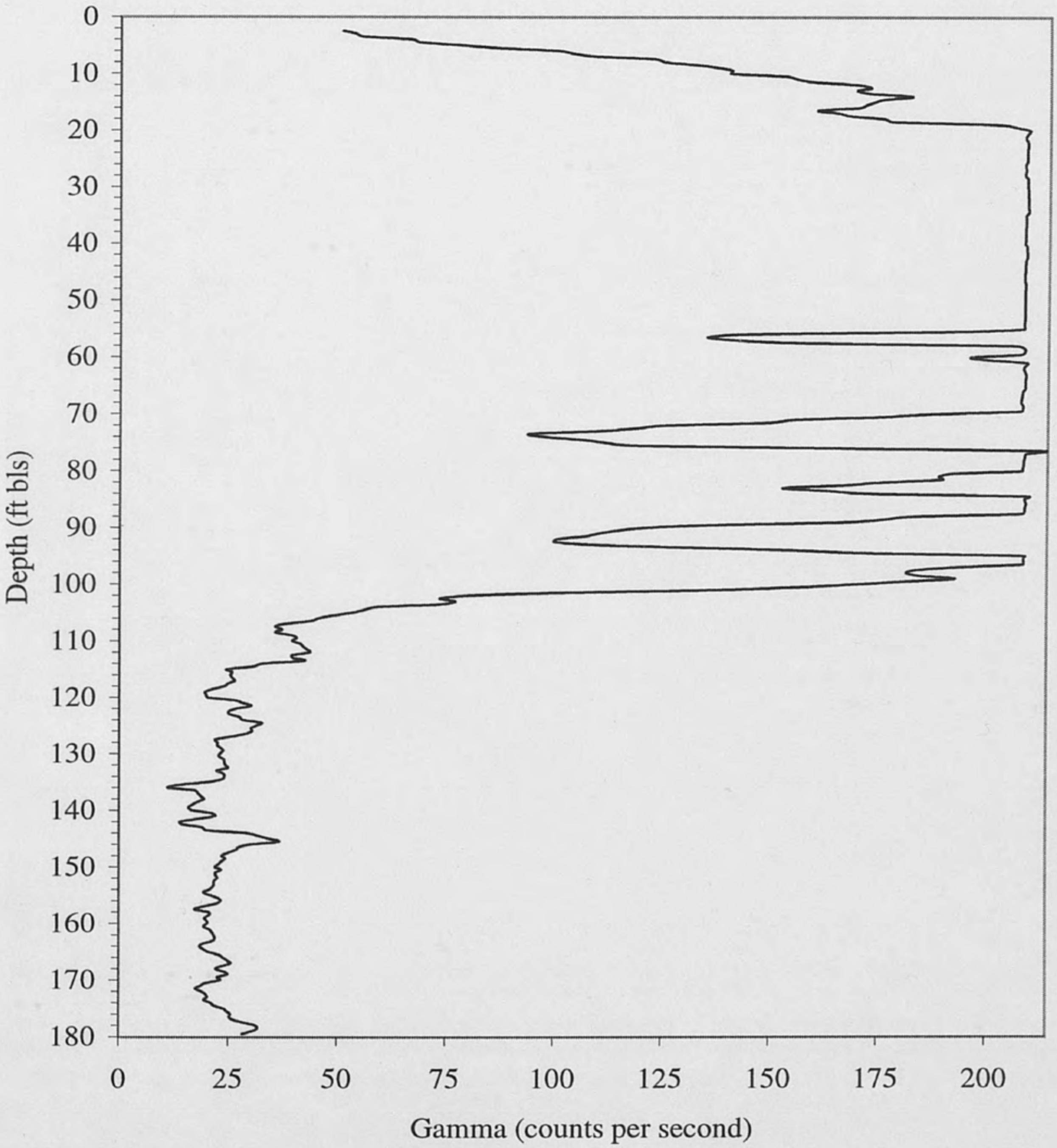
Appendix E-3
Gamma Log Plots for Marion County Wells

SJRWMD I.D.:	M-0019	PWS I.D.:	3421554
Latitude:	29 10 18	Latitude:	29 10 00
Longitude:	82 07 52	Longitude:	82 08 30
Depth to Confining Layer:	0 ft.	Distance:	1.01 mi.
Depth to Aquifer	18 ft.		



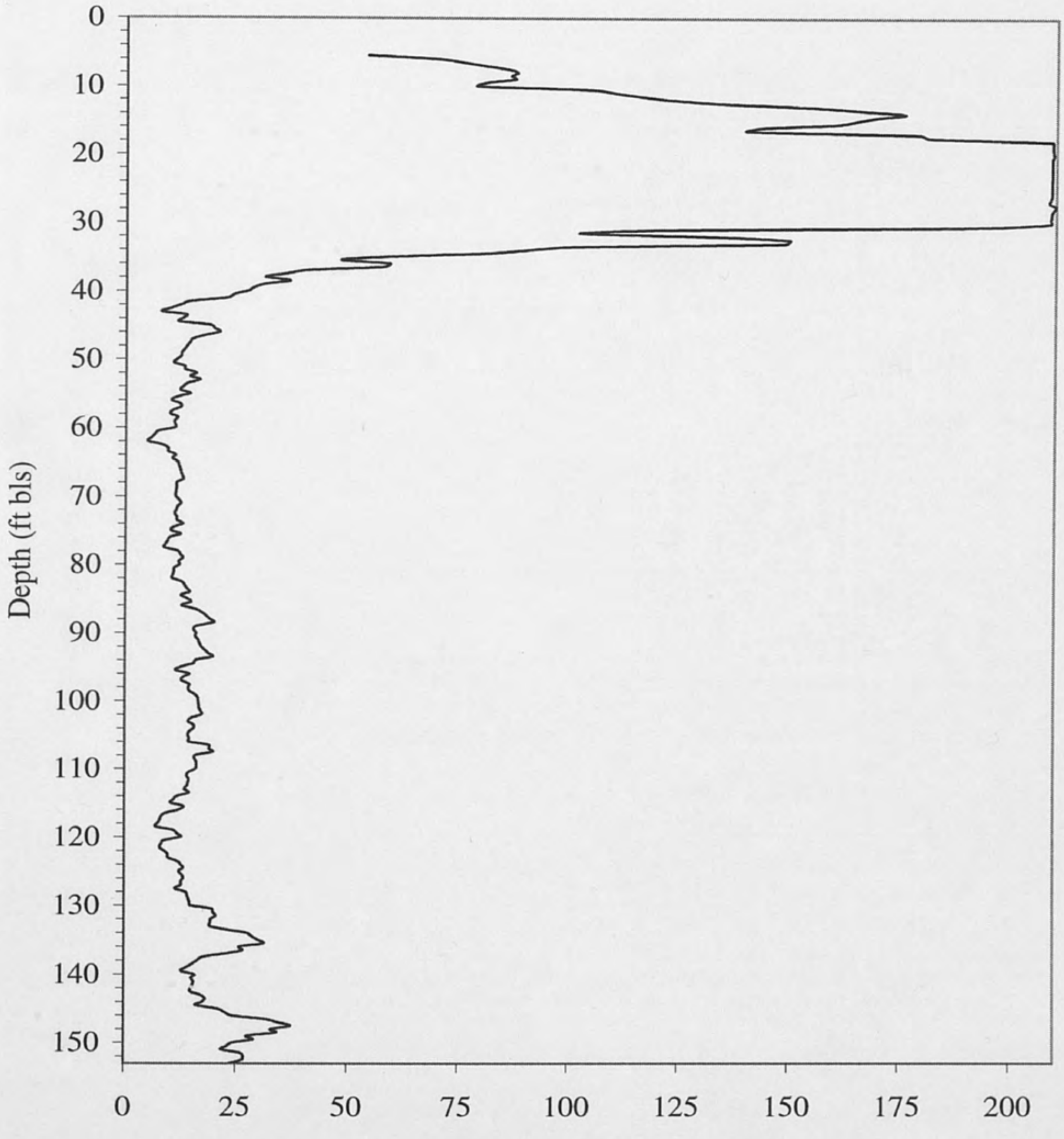
Appendix E-3
Gamma Log Plots for Marion County Wells

SJRWMD I.D.:	M-0102	PWS I.D.:	3424031
Latitude:	29 09 35	Latitude:	29 08 40
Longitude:	82 04 00	Longitude:	82 03 10
Depth to Confining Layer:	5 ft.	Distance:	1.88 mi.
Depth to Aquifer	101 ft.		



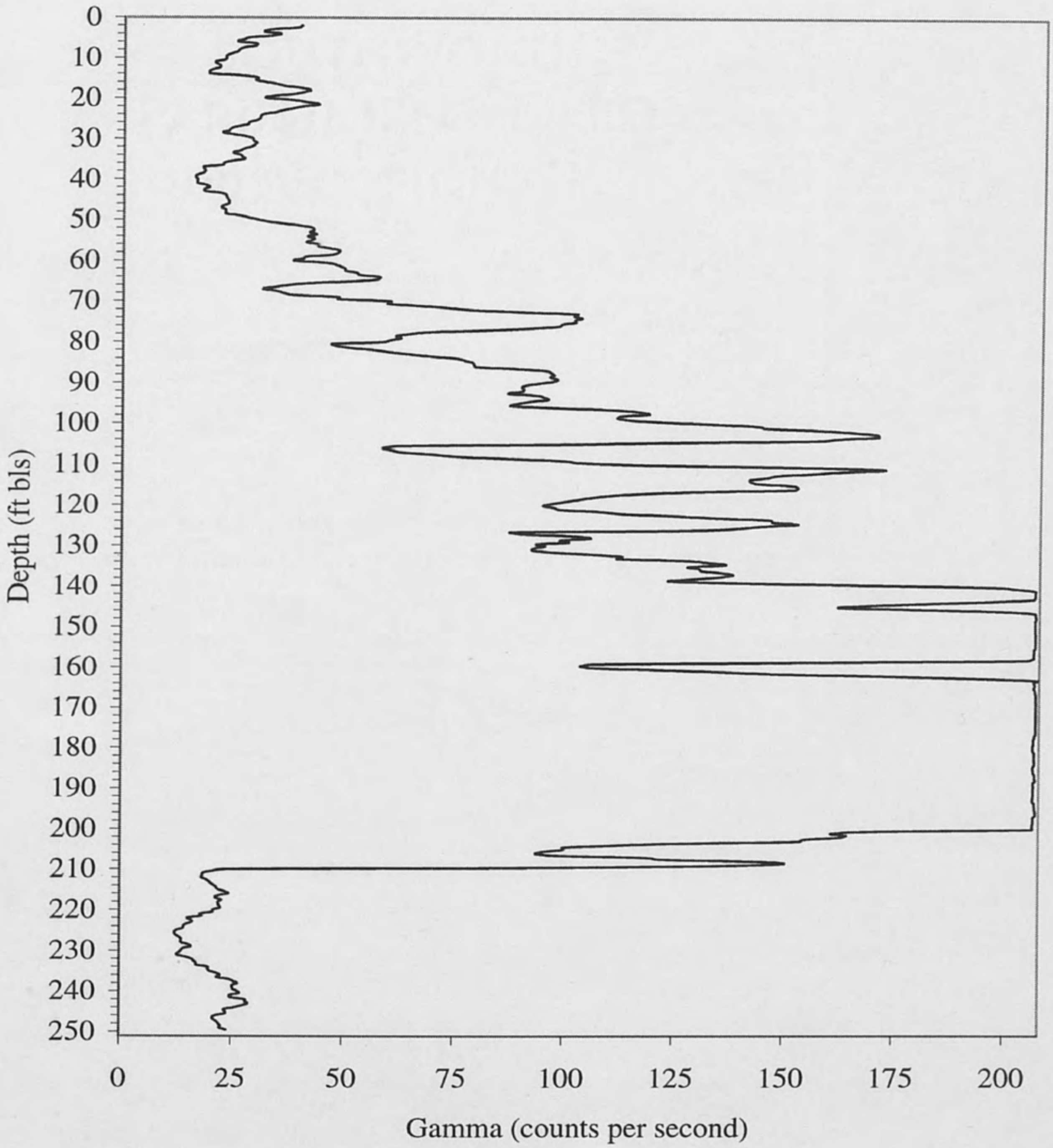
Appendix E-3
Gamma Log Plots for Marion County Wells

SJRWMD I.D.:	M-0135	PWS I.D.:	3424034
Latitude:	29 17 25	Latitude:	29 15 57
Longitude:	82 07 35	Longitude:	82 07 50
Depth to Confining Layer:	18 ft.	Distance:	2.38 mi.
Depth to Aquifer	34 ft.		



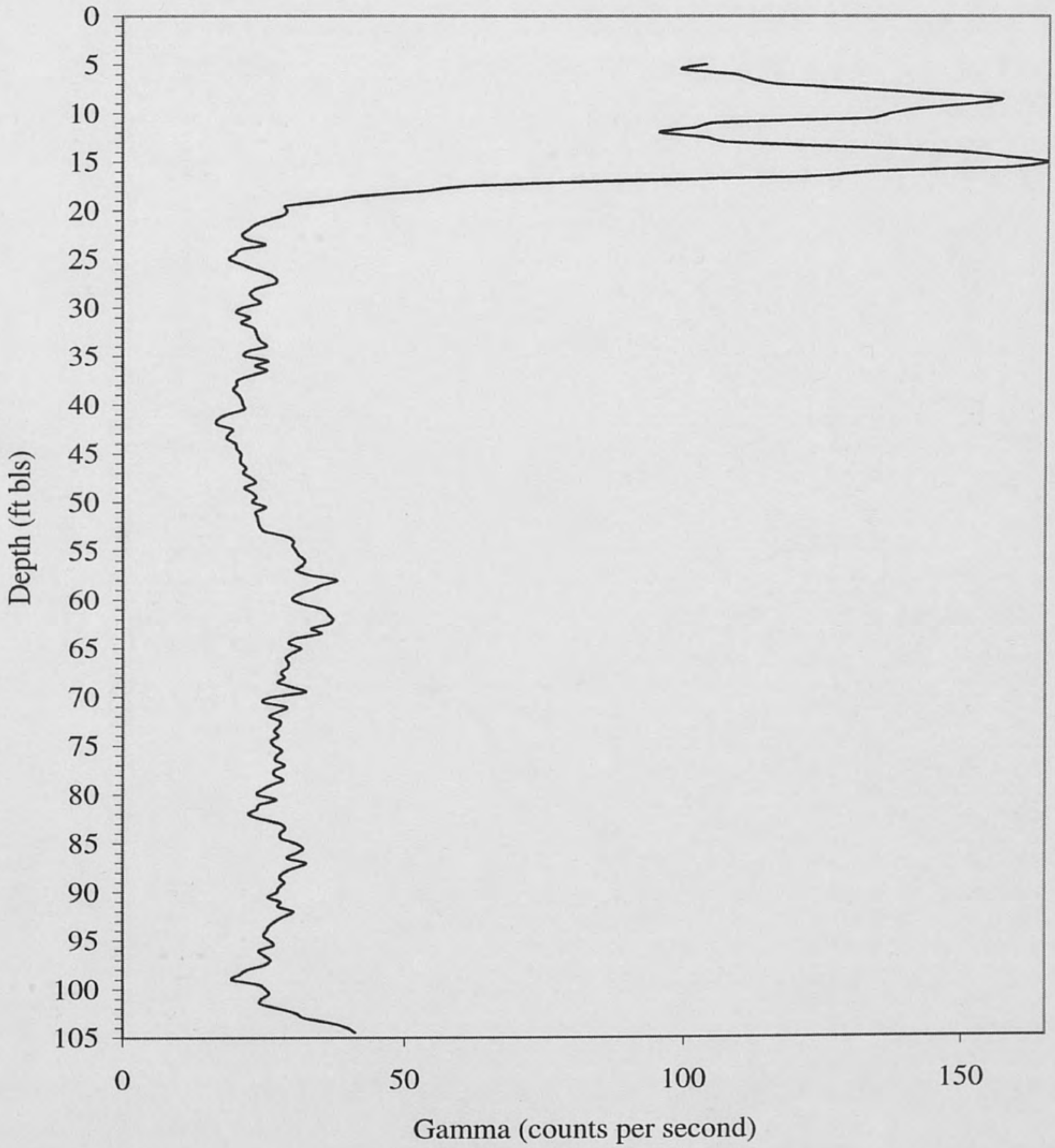
Appendix E-3
Gamma Log Plots for Marion County Wells

SJRWMD I.D.:	L-0119	PWS I.D.:	3424229
Latitude:	28 55 55	Latitude:	28 56 47
Longitude:	81 38 01	Longitude:	81 38 07
Depth to Confining Layer:	82 ft	Distance:	1.40 mi.
Depth to Aquifer	210 ft.		



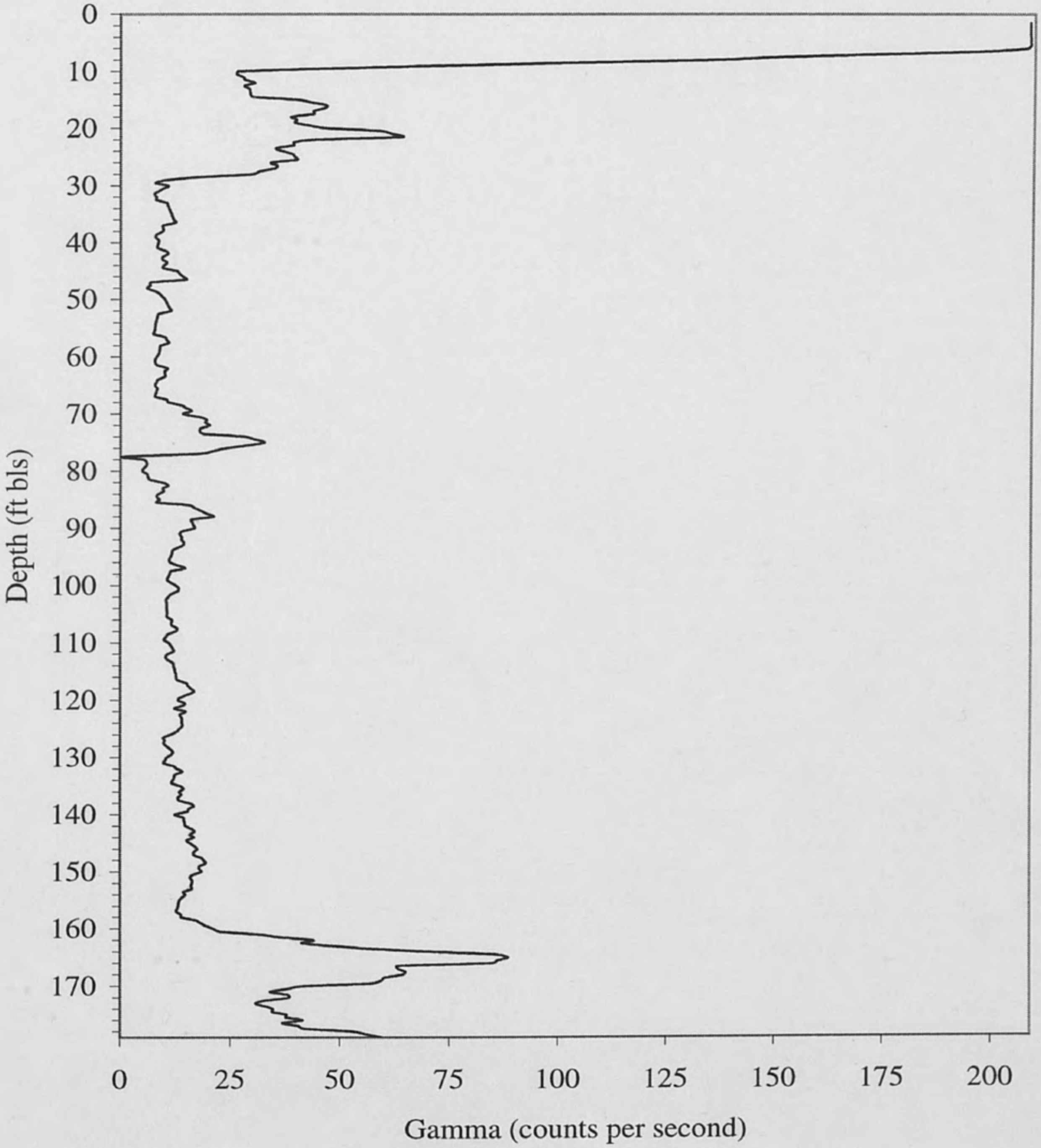
Appendix E-3
Gamma Log Plots for Marion County Wells

SJRWMD I.D.:	M-0019	PWS I.D.:	3424645
Latitude:	29 10 18	Latitude:	29 09 00
Longitude:	82 07 52	Longitude:	82 08 00
Depth to Confining Layer:	0 ft.	Distance:	2.10 mi.
Depth to Aquifer	18 ft.		



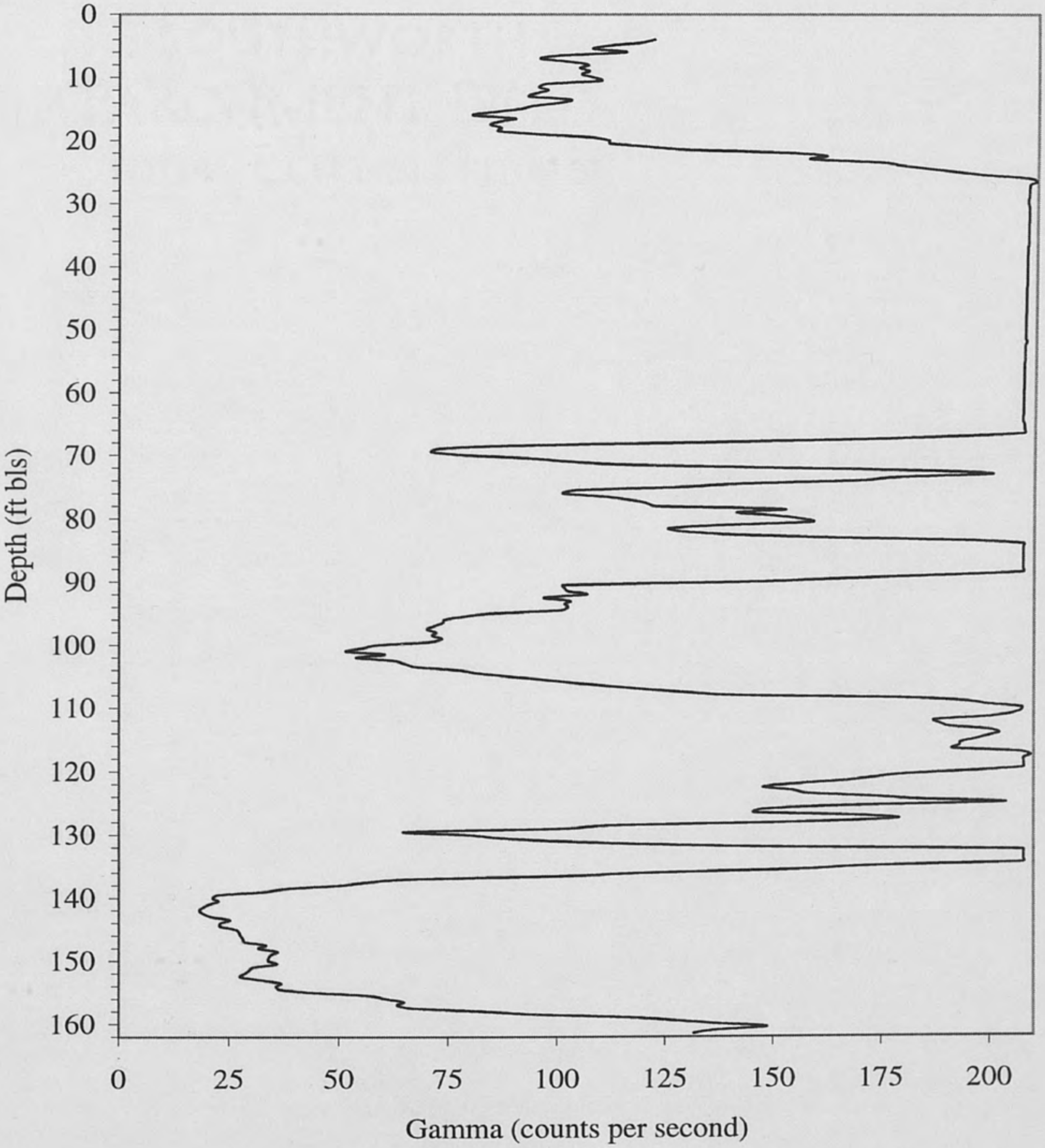
Appendix E-3
Gamma Log Plots for Marion County Wells

SJRWMD I.D.:	M-0076	PWS I.D.:	3424671
Latitude:	29 01 56	Latitude:	29 02 30
Longitude:	82 04 55	Longitude:	82 03 30
Depth to Confining Layer:	0 ft.	Distance:	2.19 mi.
Depth to Aquifer	10 ft.		



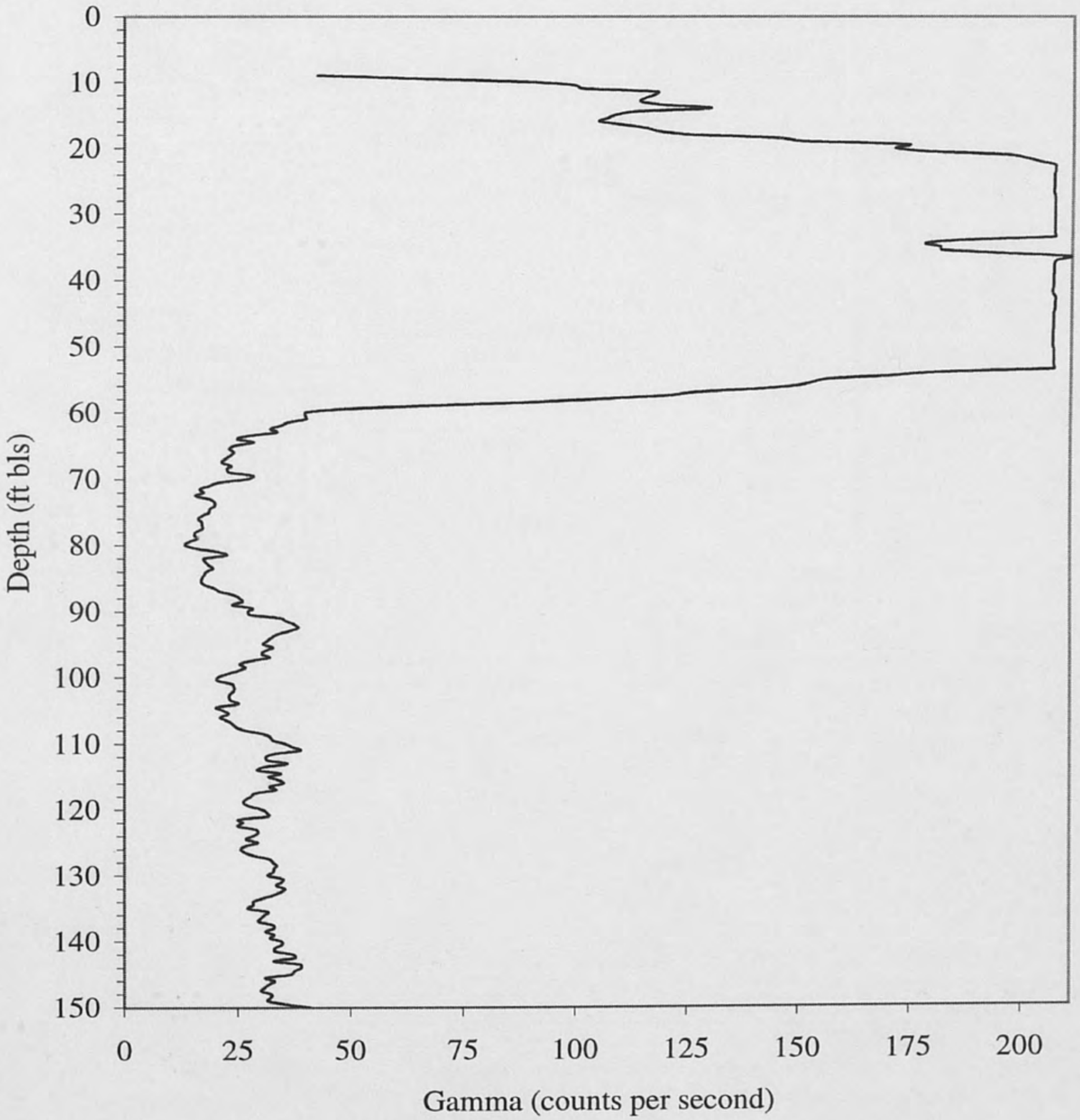
Appendix E-3
Gamma Log Plots for Marion County Wells

SJRWMD I.D.:	M-0148	PWS I.D.:	3424968
Latitude:	29 21 28	Latitude:	29 22 10
Longitude:	82 11 43	Longitude:	82 11 50
Depth to Confining Layer:	19 ft	Distance:	1.14 mi.
Depth to Aquifer	139 ft		



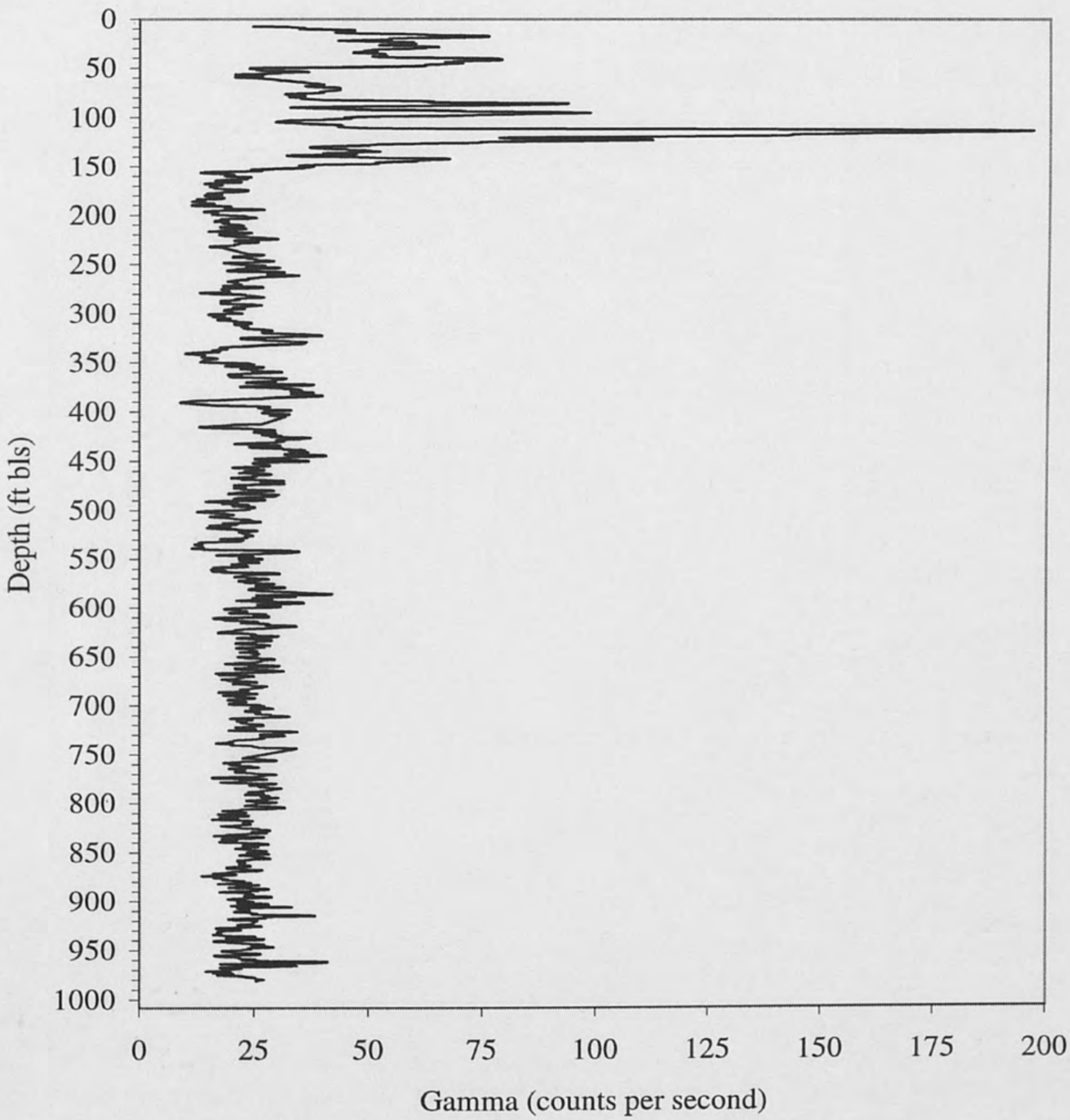
Appendix E-4
Gamma Log Plots for Orange County Wells

SJRWMD I.D.:	OR0340	PWS I.D.:	3480114
Latitude:	28 45 18	Latitude:	28 45 22
Longitude:	81 30 43	Longitude:	81 31 58
Depth to Confining Layer:	10 ft	Distance:	1.77 mi
Depth to Aquifer:	56 ft		



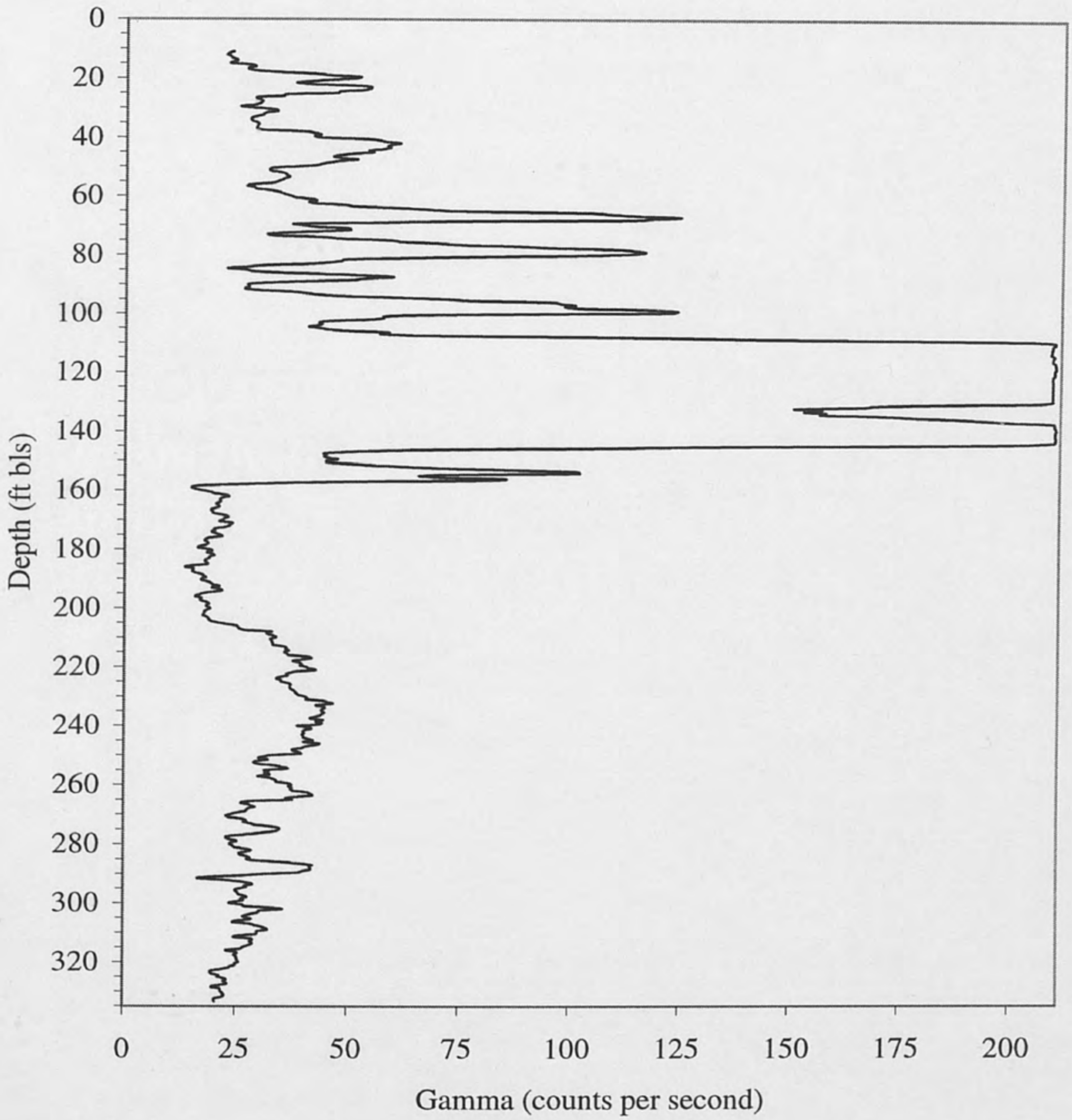
Appendix E-4
Gamma Log Plots for Orange County Wells

SJRWMD I.D.:	OR0620	PWS I.D.:	3480327
Latitude:	28 36 30	Latitude:	28 36 48
Longitude:	81 22 45	Longitude:	81 23 30
Depth to Confining Layer:	60 ft	Distance:	1.16 mi
Depth to Aquifer:	150 ft		



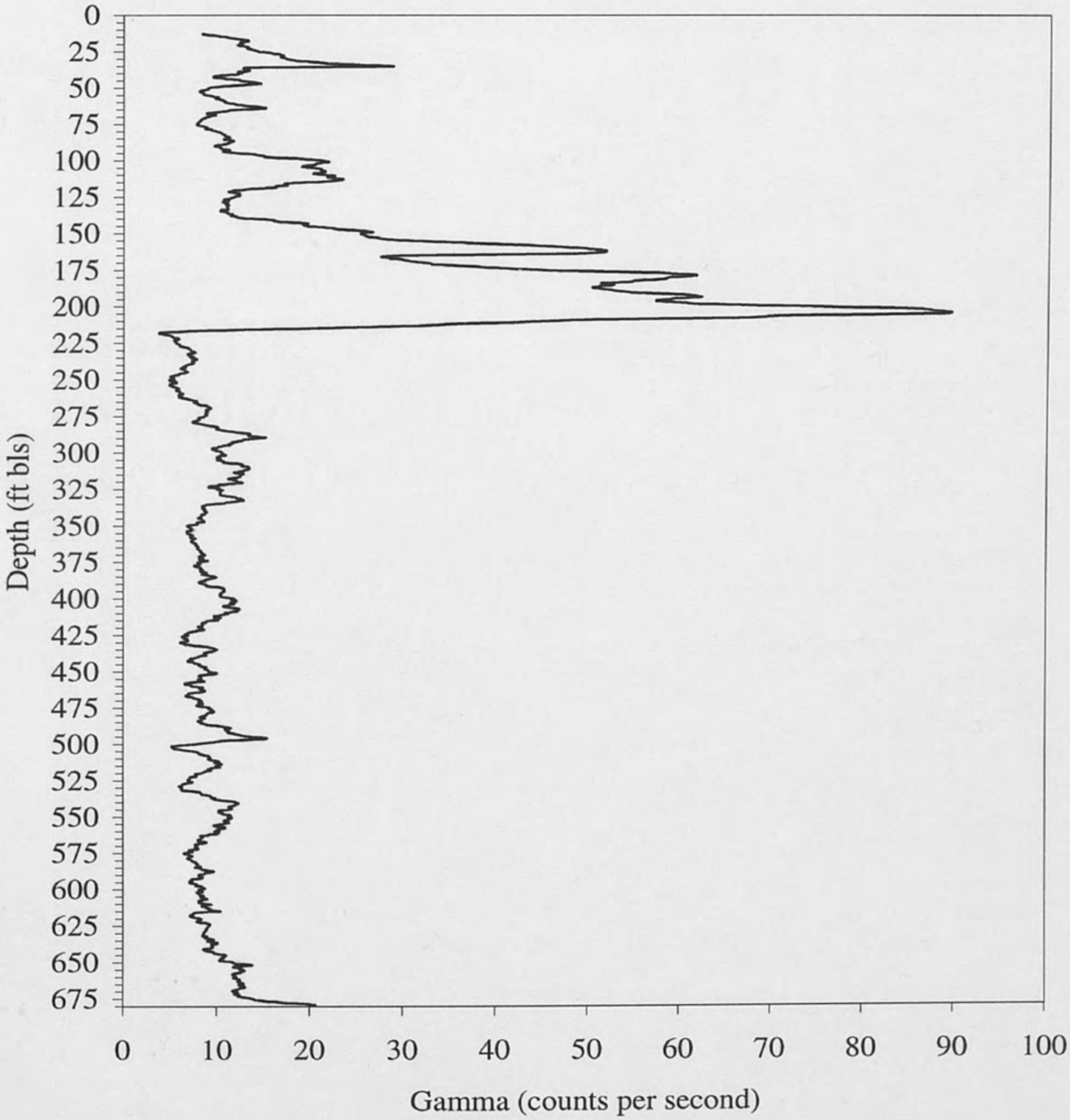
Appendix E-4
Gamma Log Plots for Orange County Wells

SJRWMD I.D.:	OR0316	PWS I.D.:	3480409
Latitude:	28 34 24	Latitude:	28 35 50
Longitude:	81 13 28	Longitude:	81 12 10
Depth to Confining Layer:	109 ft	Distance:	2.95 mi
Depth to Aquifer:	156 ft		



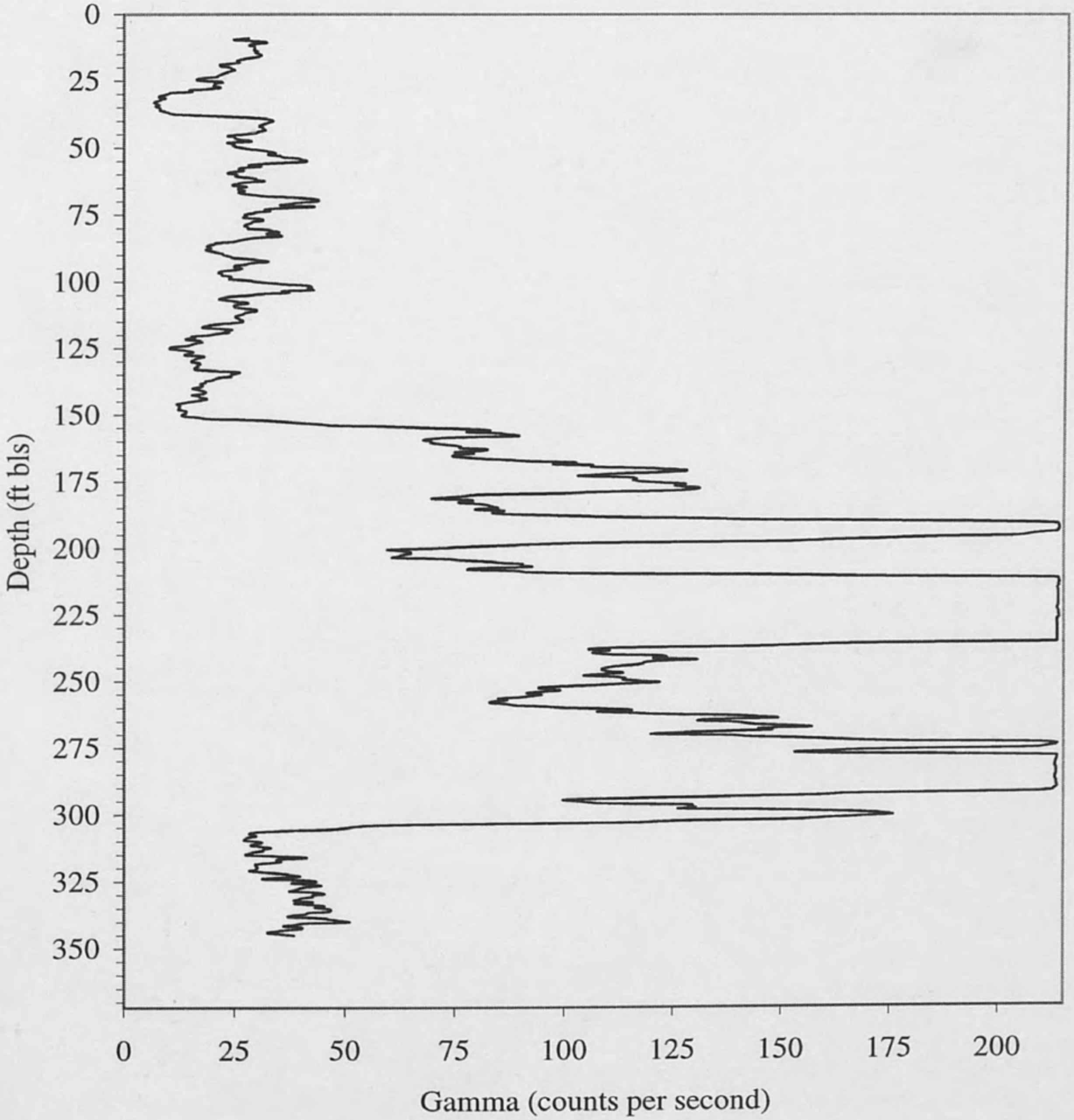
Appendix E-4
Gamma Log Plots for Orange County Wells

SJRWMD I.D.:	OR0078	PWS I.D.:	3481482
Latitude:	28 35 47	Latitude:	28 35 47
Longitude:	81 18 14	Longitude:	81 18 12
Depth to Confining Layer:	160 ft	Distance:	0.05 mi
Depth to Aquifer:	220 ft		



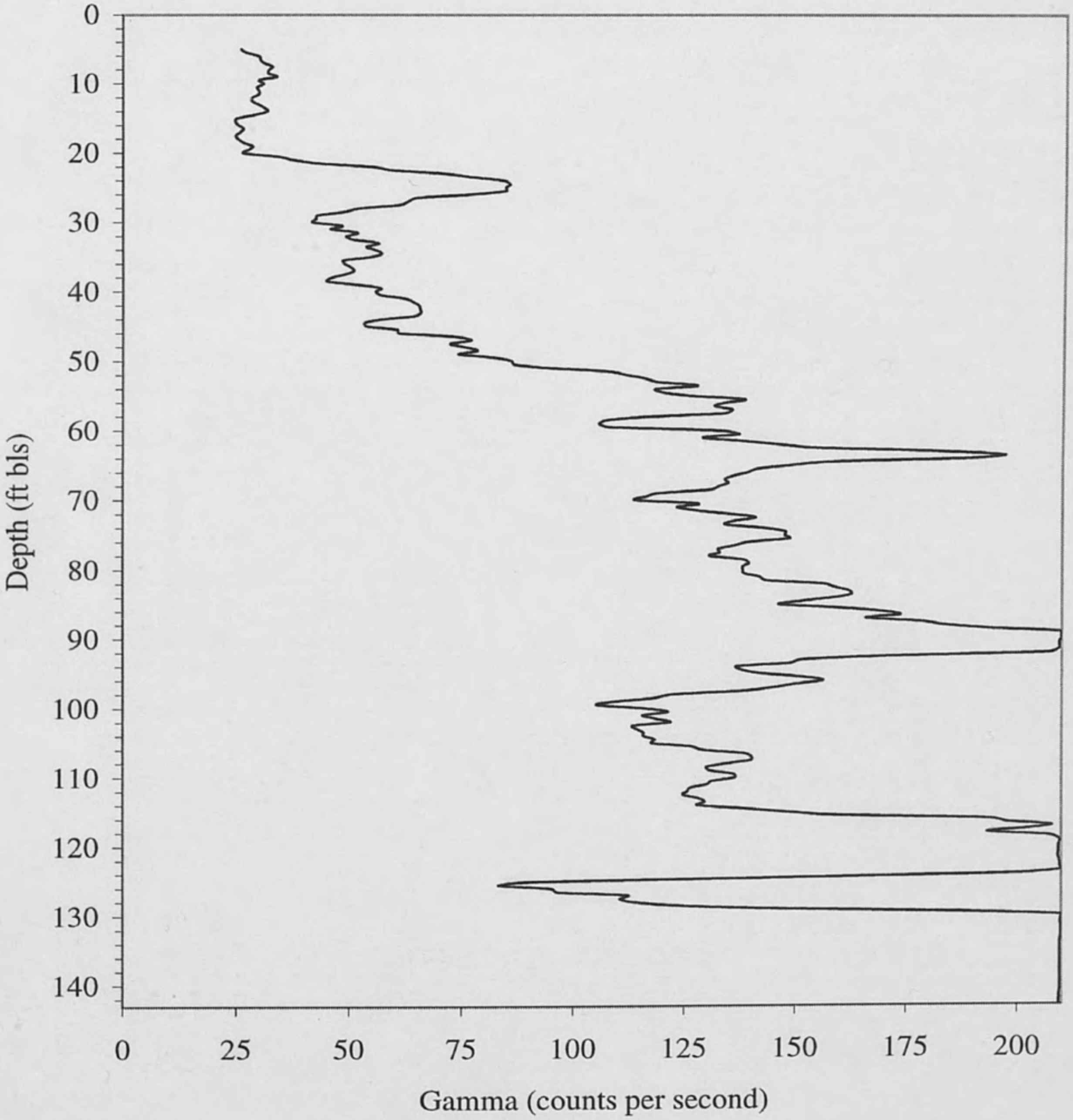
Appendix E-4
Gamma Log Plots for Orange County Wells

SJRWMD I.D.:	OR0071	PWS I.D.:	3481506
Latitude:	28 43 37	Latitude:	28 44 02
Longitude:	81 35 52	Longitude:	81 36 23
Depth to Confining Layer:	152 ft	Distance:	0.99 mi
Depth to Aquifer:	302 ft		



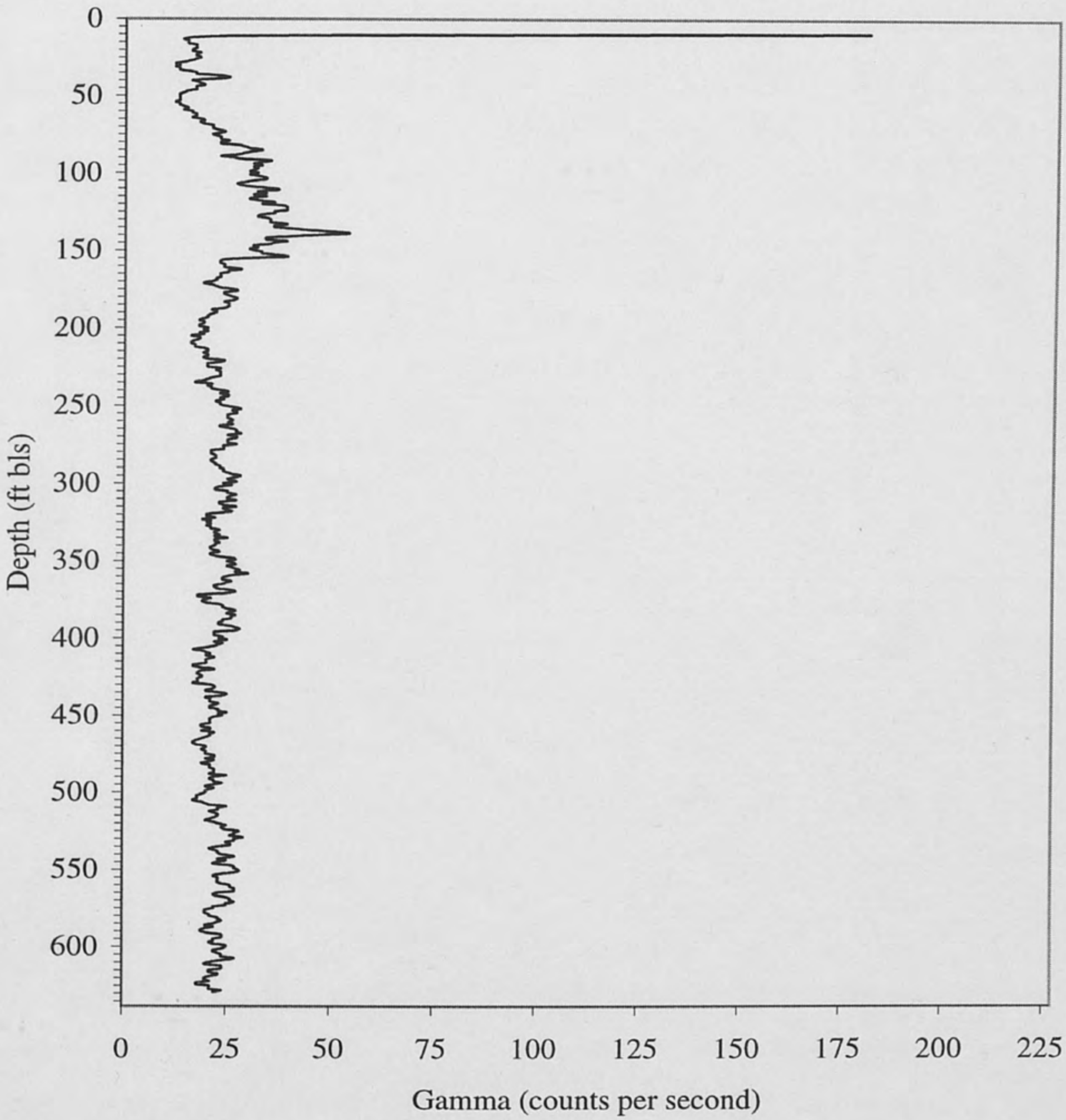
Appendix E-4
Gamma Log Plots for Orange County Wells

SJRWMD I.D.:	OR0257	PWS I.D.:	3481546
Latitude:	28 30 08	Latitude:	28 29 25
Longitude:	81 30 32	Longitude:	81 29 00
Depth to Confining Layer:	49 ft	Distance:	2.45 mi
Depth to Aquifer:	145 ft		



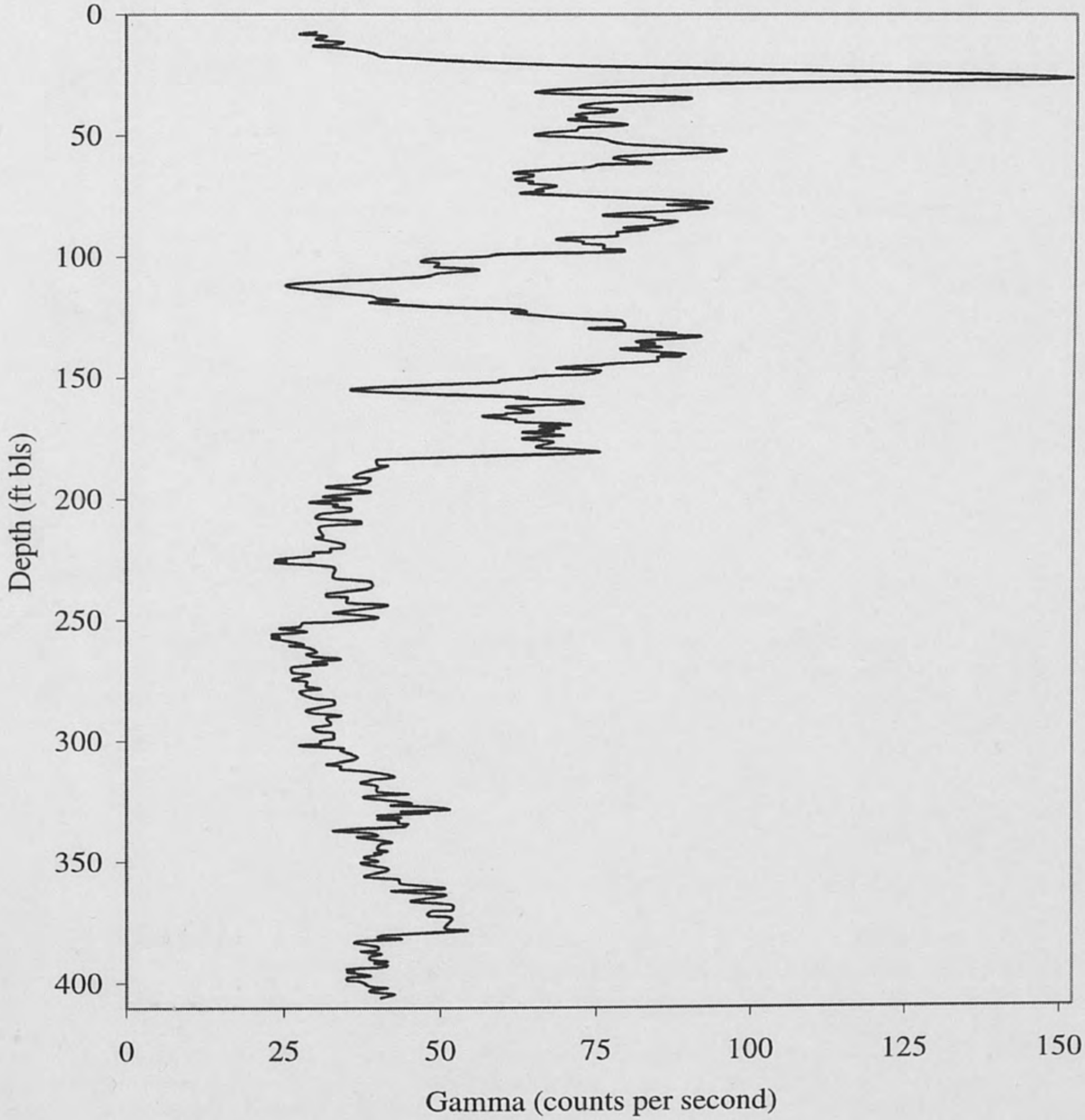
Appendix E-4
Gamma Log Plots for Orange County Wells

SJRWMD I.D.:	OR0007	PWS I.D.:	3484093
Latitude:	28 22 51	Latitude:	28 22 55
Longitude:	81 31 09	Longitude:	81 31 05
Depth to Confining Layer:	5 ft	Distance:	0.14 mi
Depth to Aquifer:	20 ft		



Appendix E-4
Gamma Log Plots for Orange County Wells

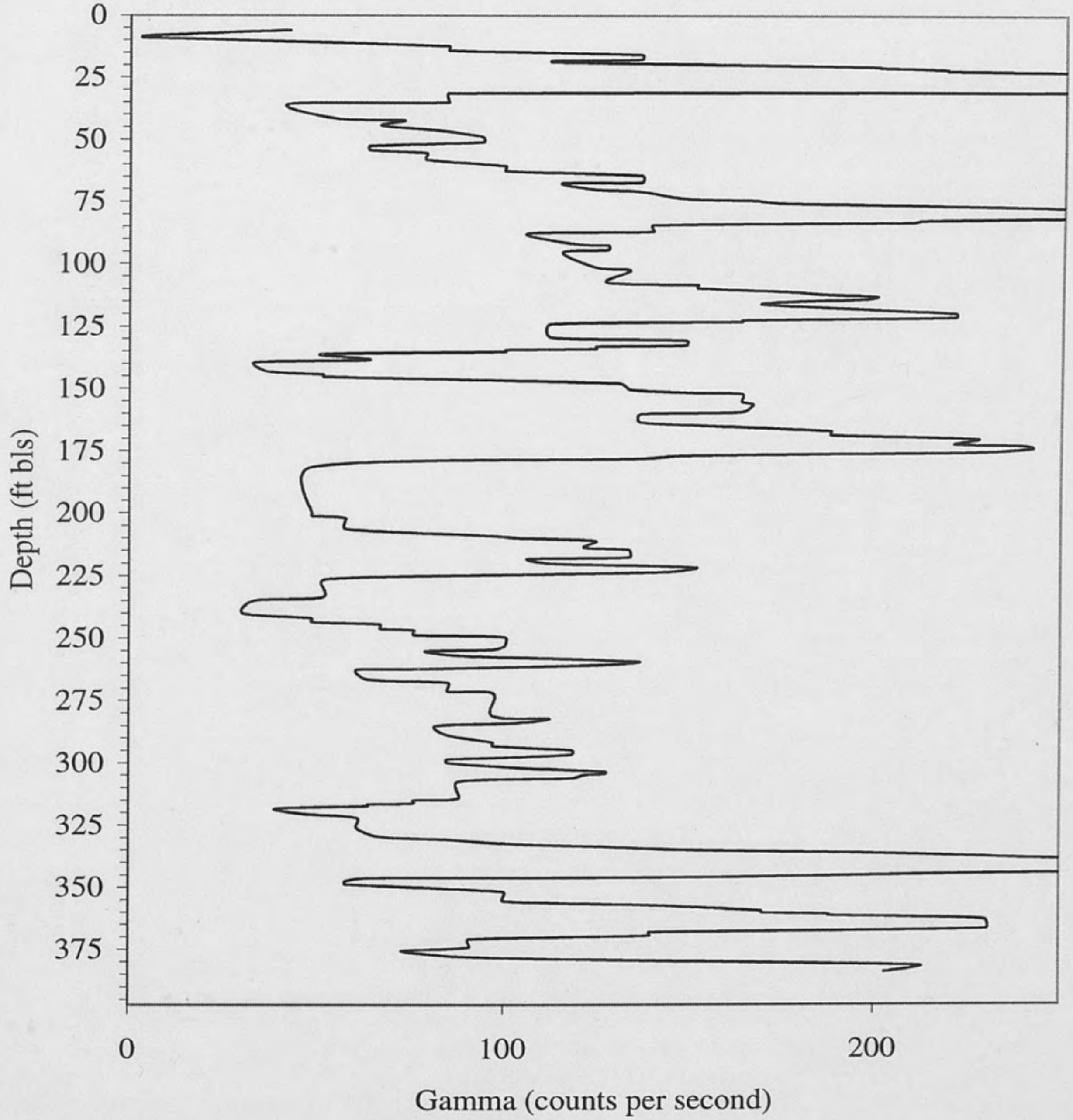
SJRWMD I.D.:	OR0002	PWS I.D.:	3484119
Latitude:	28 21 41	Latitude:	28 23 10
Longitude:	81 24 70	Longitude:	84 26 10
Depth to Confining Layer:	25 ft	Distance:	2.77 mi
Depth to Aquifer:	185 ft		



Appendix E-5

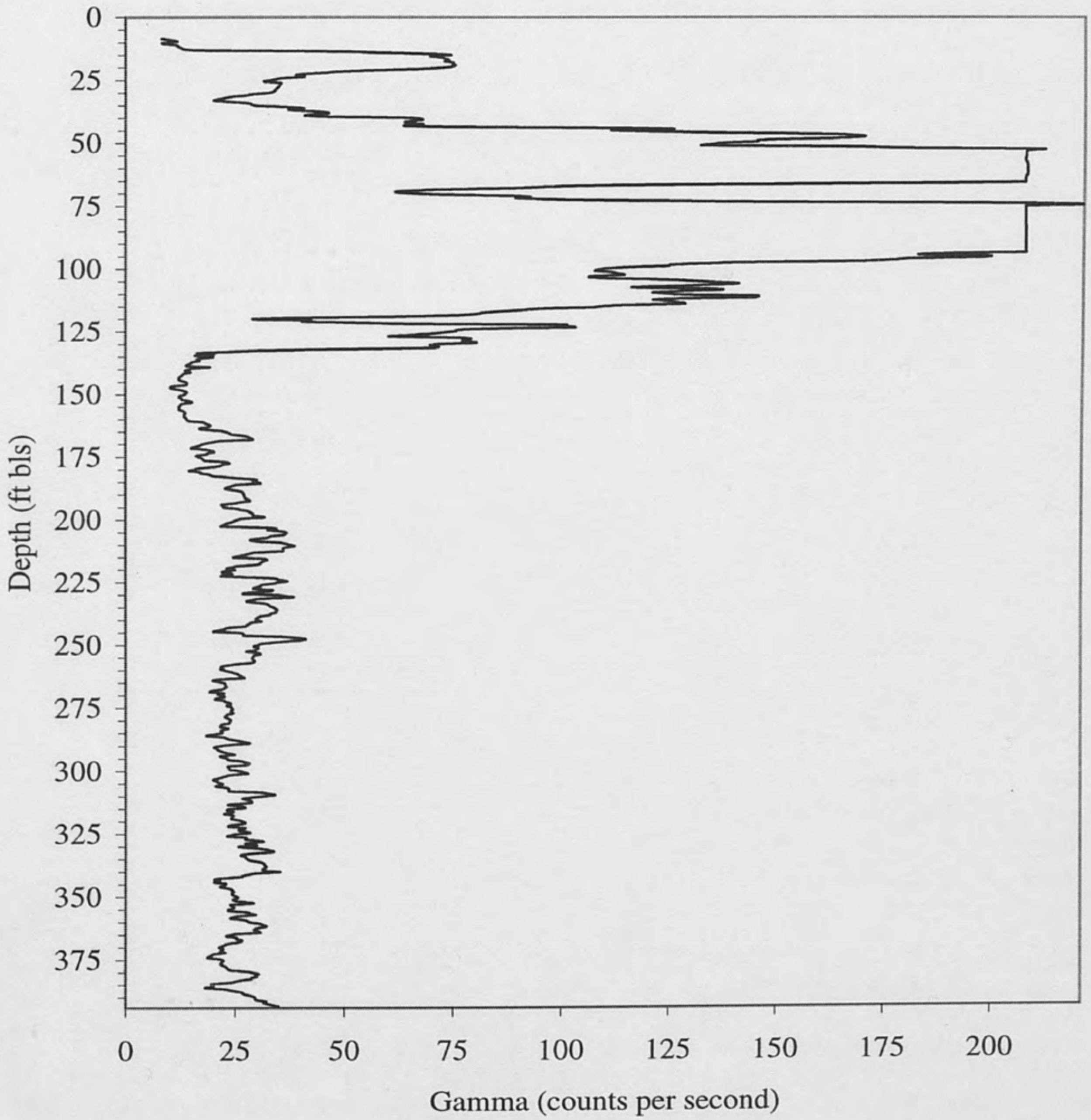
Gamma Log Plot for Osceola County Well

SJRWMD I.D.:	OS00012A	PWS I.D.:	3494315
Latitude:	28 09 56	Latitude:	28 10 46
Longitude:	81 26 54	Longitude:	81 29 46
Depth to Confining Layer:	20 ft	Distance:	4.28 mi
Depth to Aquifer:	180 ft		



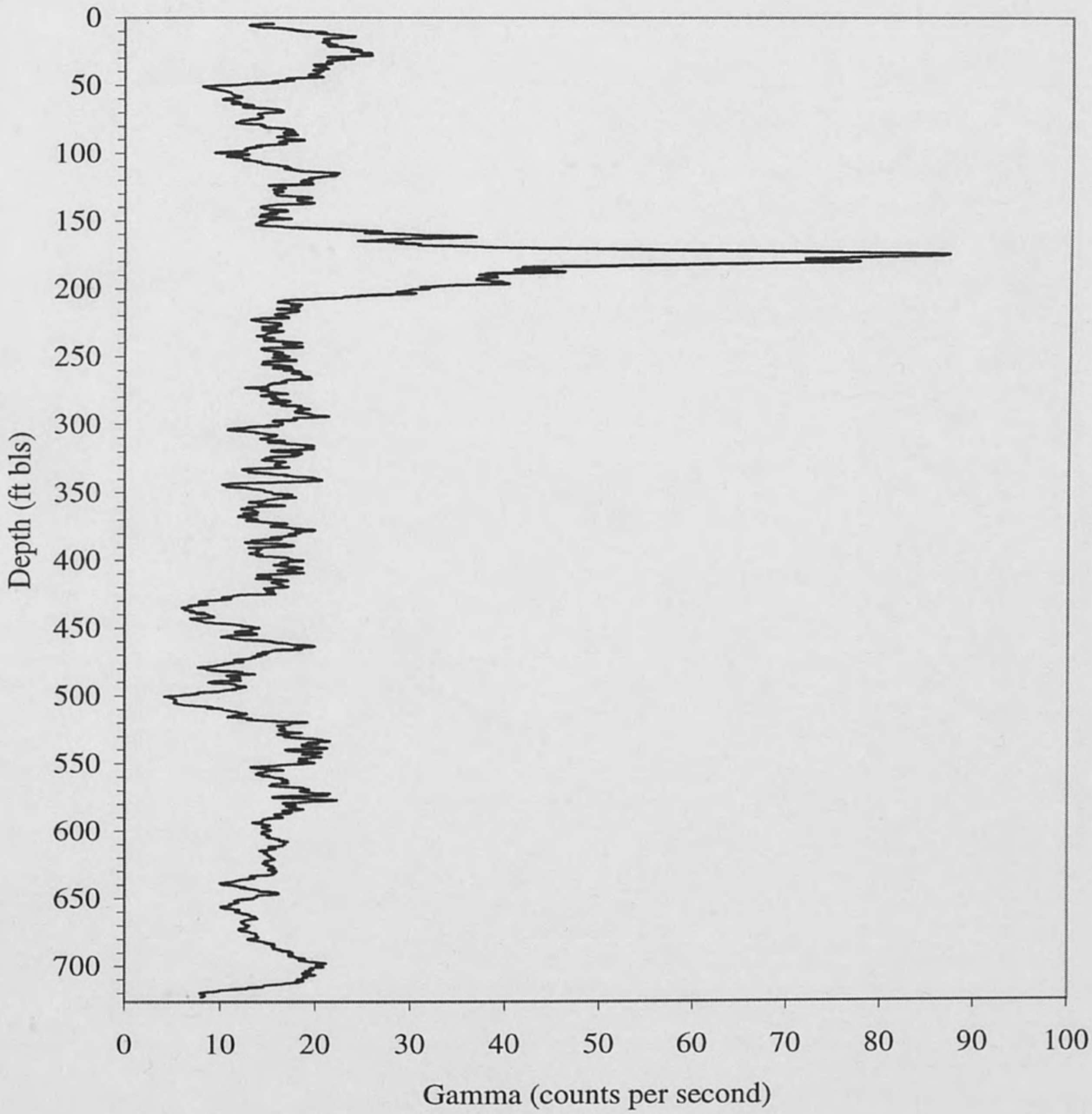
Appendix E-6
Gamma Log Plots for Seminole County Wells

SJRWMD I.D.:	S-0068	PWS I.D.:	3590039
Latitude:	28 40 33	Latitude:	28 40 24
Longitude:	81 23 36	Longitude:	81 23 44
Depth to Confining Layer:	34 ft	Distance:	0.31 mi
Depth to Aquifer:	130 ft		



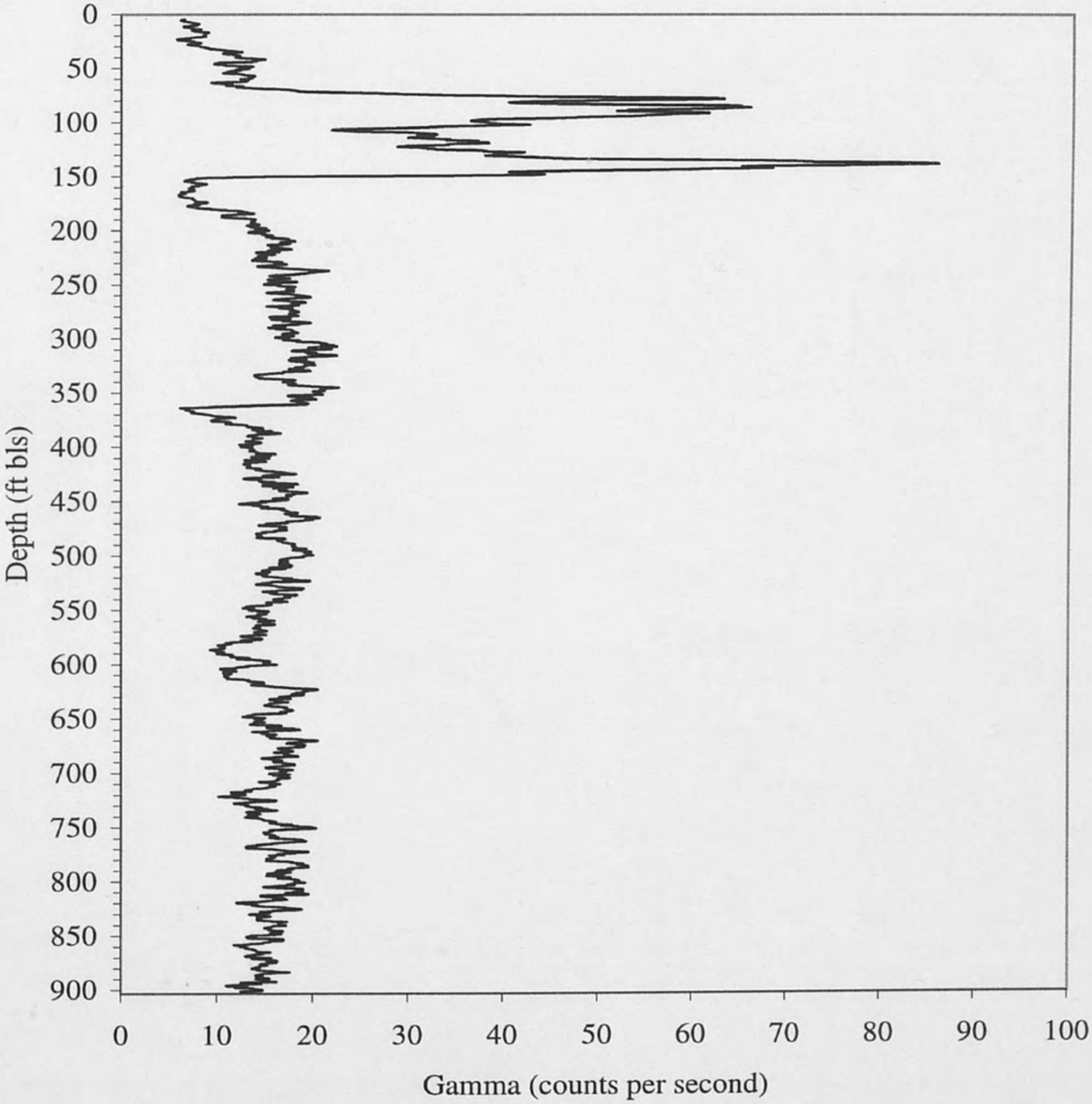
Appendix E-6
Gamma Log Plots for Seminole County Wells

SJRWMD I.D.:	S-1217	PWS I.D.:	3590111
Latitude:	28 38 48	Latitude:	28 38 36
Longitude:	81 22 12	Longitude:	81 22 57
Depth to Confining Layer:	155 ft	Distance:	1.11 mi
Depth to Aquifer:	210 ft		



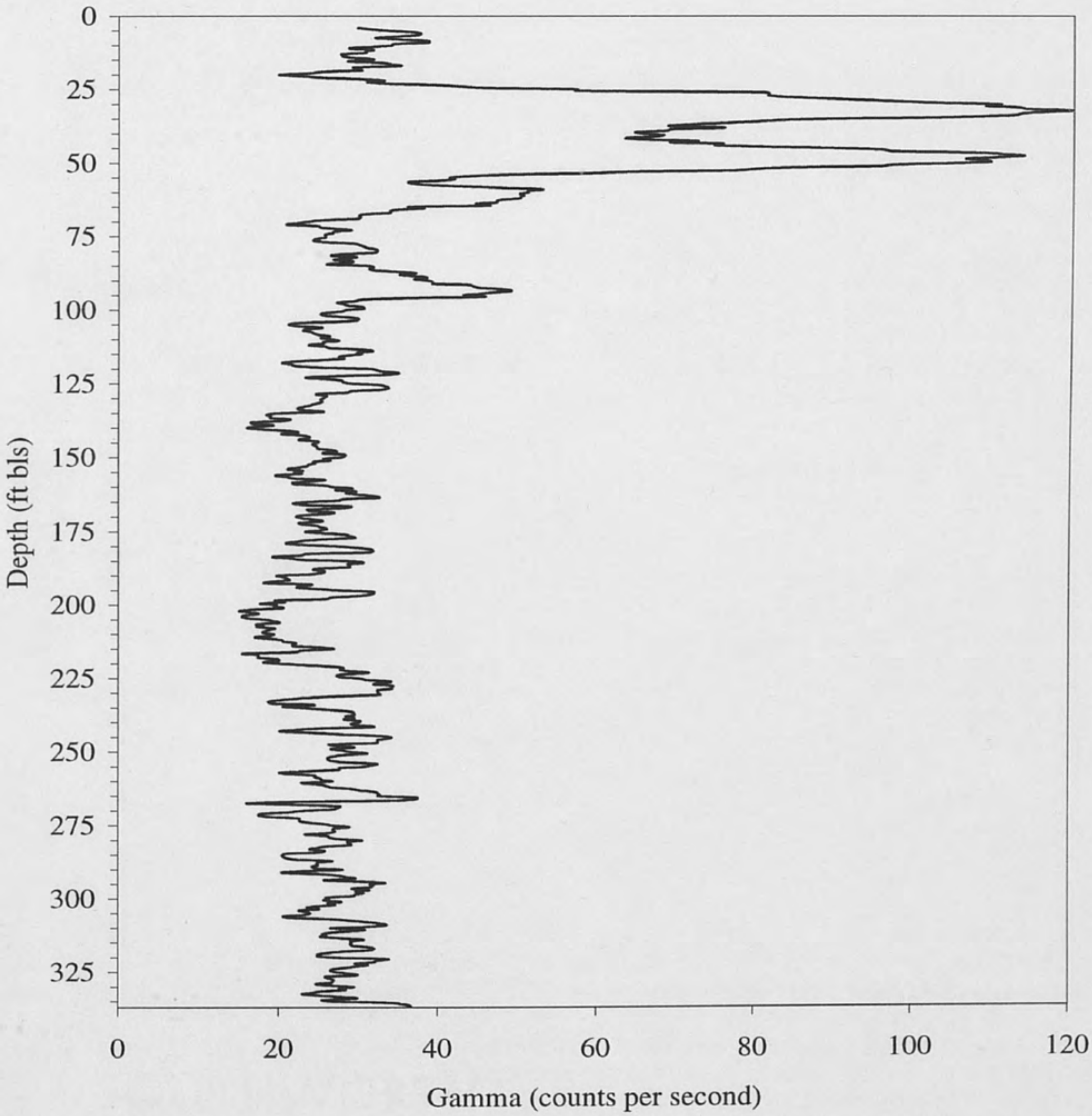
Appendix E-6
Gamma Log Plots for Seminole County Wells

SJRWMD I.D.:	S-1215	PWS I.D.:	3590970
Latitude:	28 38 00	Latitude:	28 38 30
Longitude:	81 11 55	Longitude:	81 11 30
Depth to Confining Layer:	70 ft	Distance:	1.00 mi
Depth to Aquifer:	150 ft		



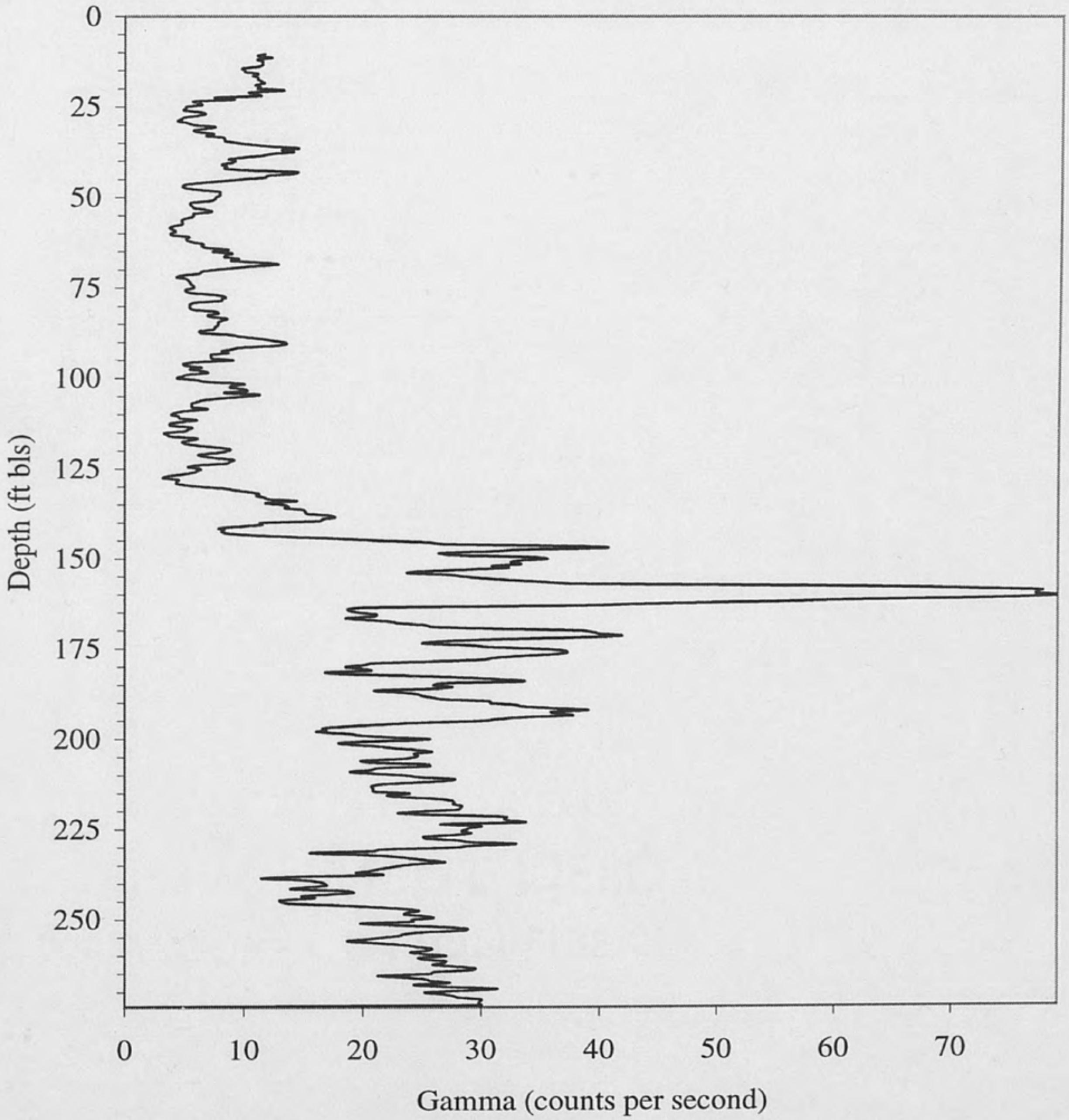
Appendix E-7
Gamma Log Plots for Volusia County Wells

SJRWMD I.D.:	V-0267	PWS I.D.:	3640286
Latitude:	29 03 23	Latitude:	29 02 00
Longitude:	81 17 21	Longitude:	81 17 00
Depth to Confining Layer:	20 ft	Distance:	2.28 mi
Depth to Aquifer:	65 ft		



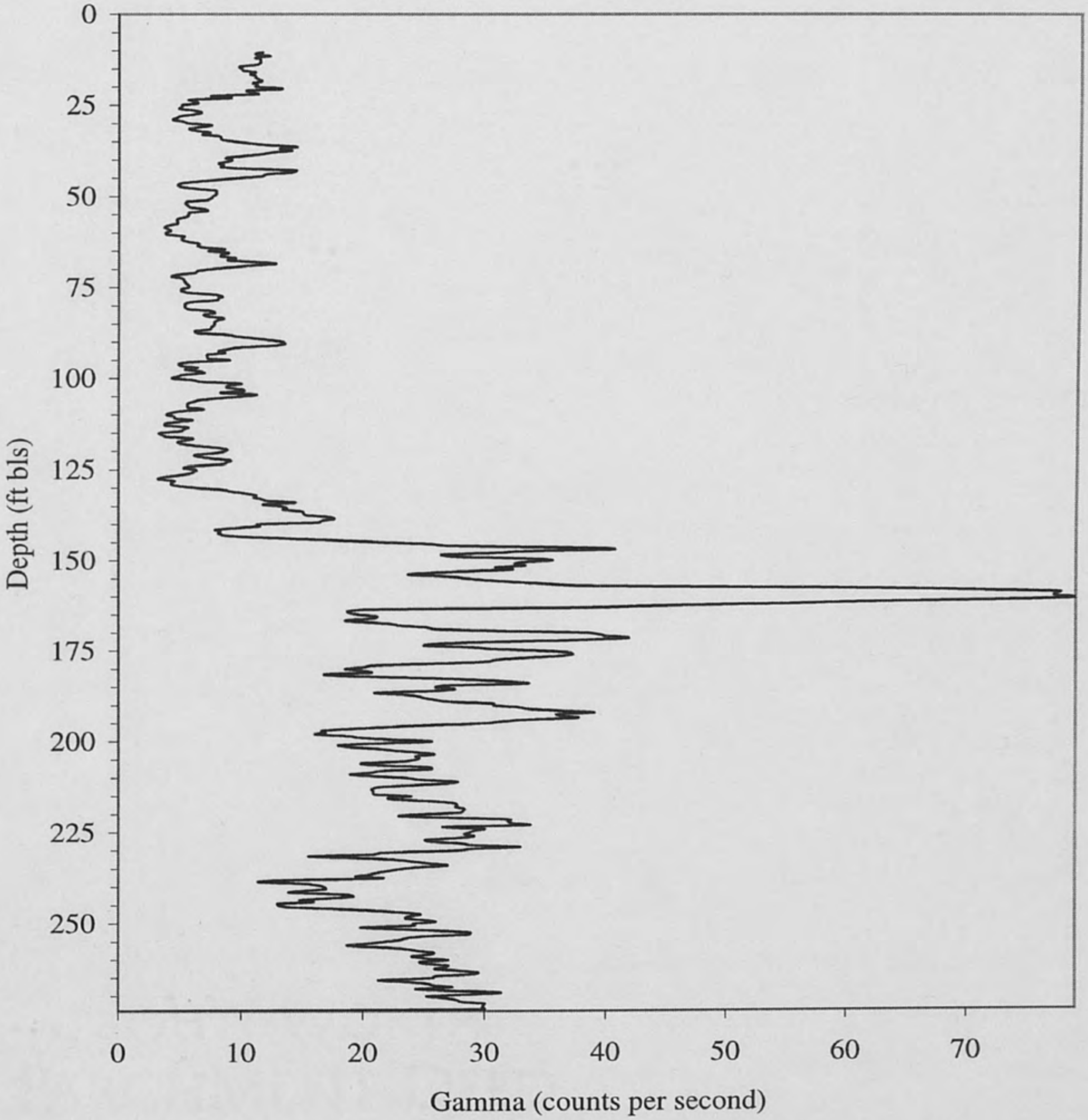
Appendix E-7
Gamma Log Plots for Volusia County Wells

SJRWMD I.D.:	V-353	PWS I.D.:	3640287
Latitude:	28 56 45	Latitude:	28 55 48
Longitude:	81 14 45	Longitude:	81 14 10
Depth to Confining Layer:	155 ft	Distance:	1.73 mi
Depth to Aquifer:	161 ft		



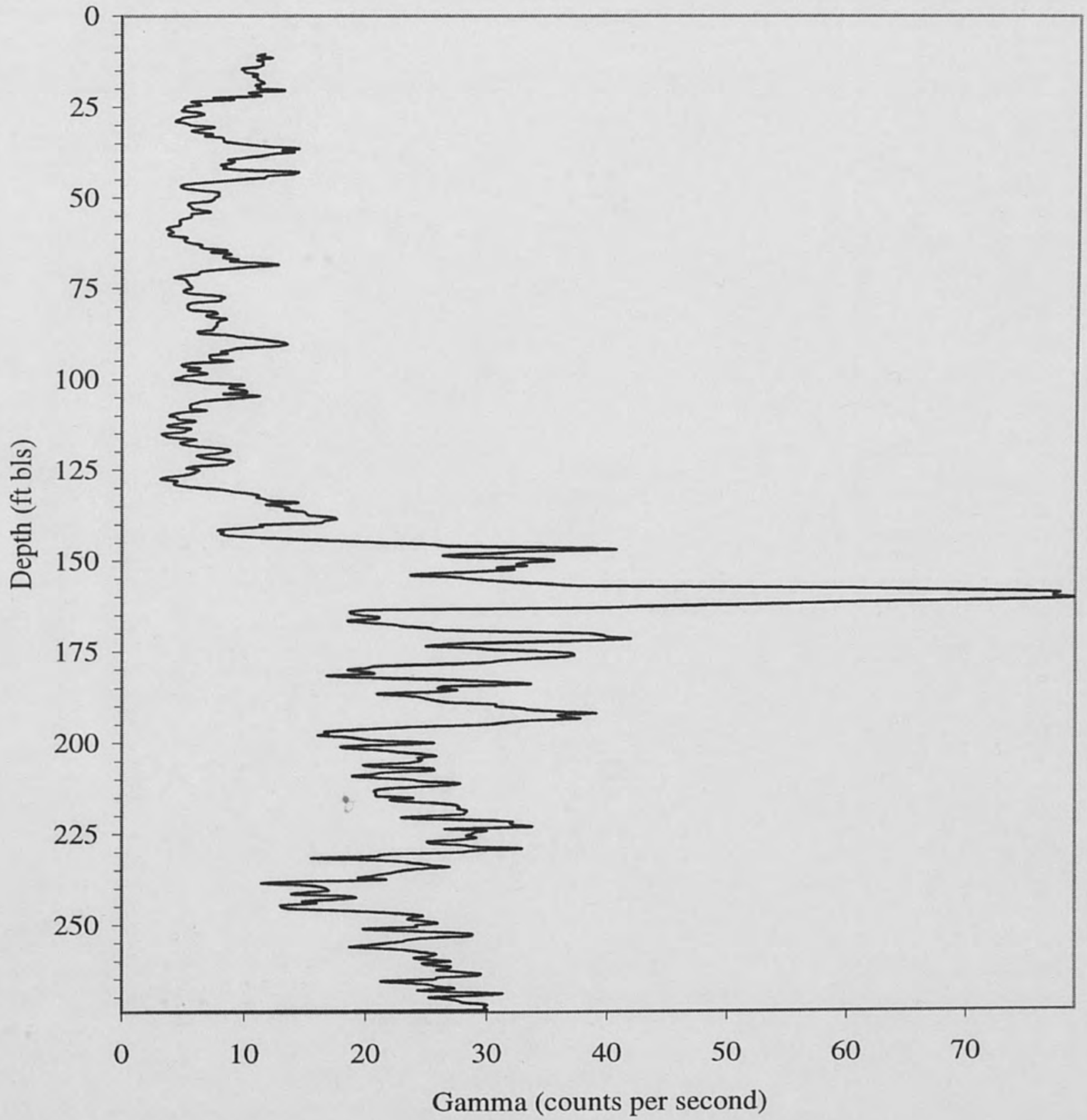
Appendix E-7
Gamma Log Plots for Volusia County Wells

SJRWMD I.D.:	V-353	PWS I.D.:	3640287
Latitude:	28 56 45	Latitude:	28 55 48
Longitude:	81 14 45	Longitude:	81 14 10
Depth to Confining Layer:	155 ft	Distance:	1.73 mi
Depth to Aquifer:	161 ft		



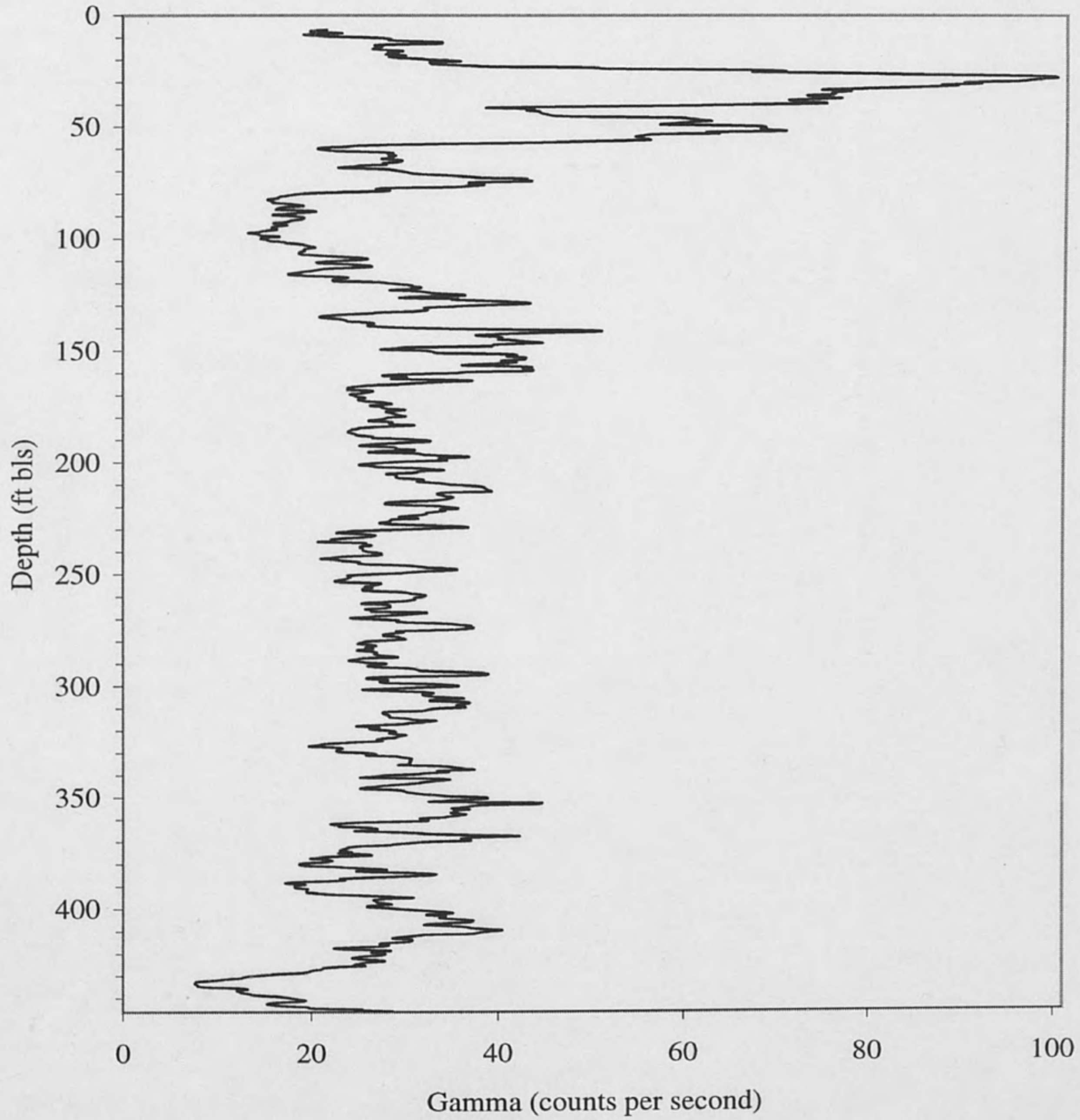
Appendix E-7
Gamma Log Plots for Volusia County Wells

SJRWMD I.D.:	V-353	PWS I.D.:	3640287
Latitude:	28 56 45	Latitude:	28 55 48
Longitude:	81 14 45	Longitude:	81 14 10
Depth to Confining Layer:	155 ft	Distance:	1.73 mi
Depth to Aquifer:	161 ft		



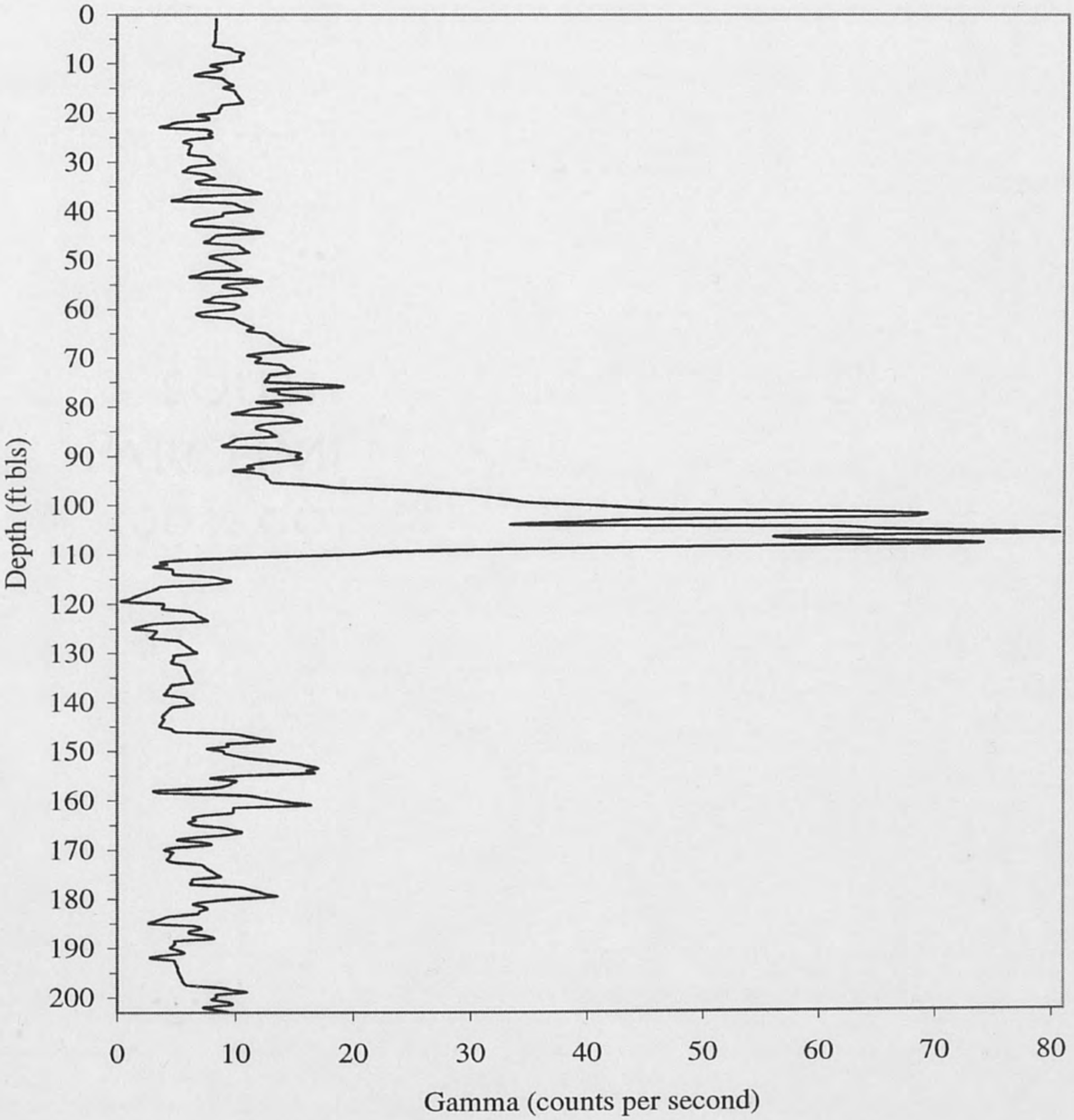
Appendix E-7
Gamma Log Plots for Volusia County Wells

SJRWMD I.D.:	V-0275	PWS I.D.:	3640317
Latitude:	29 05 48	Latitude:	29 05 32
Longitude:	81 21 26	Longitude:	81 21 19
Depth to Confining Layer:	20 ft	Distance:	0.46 mi
Depth to Aquifer:	79 ft		



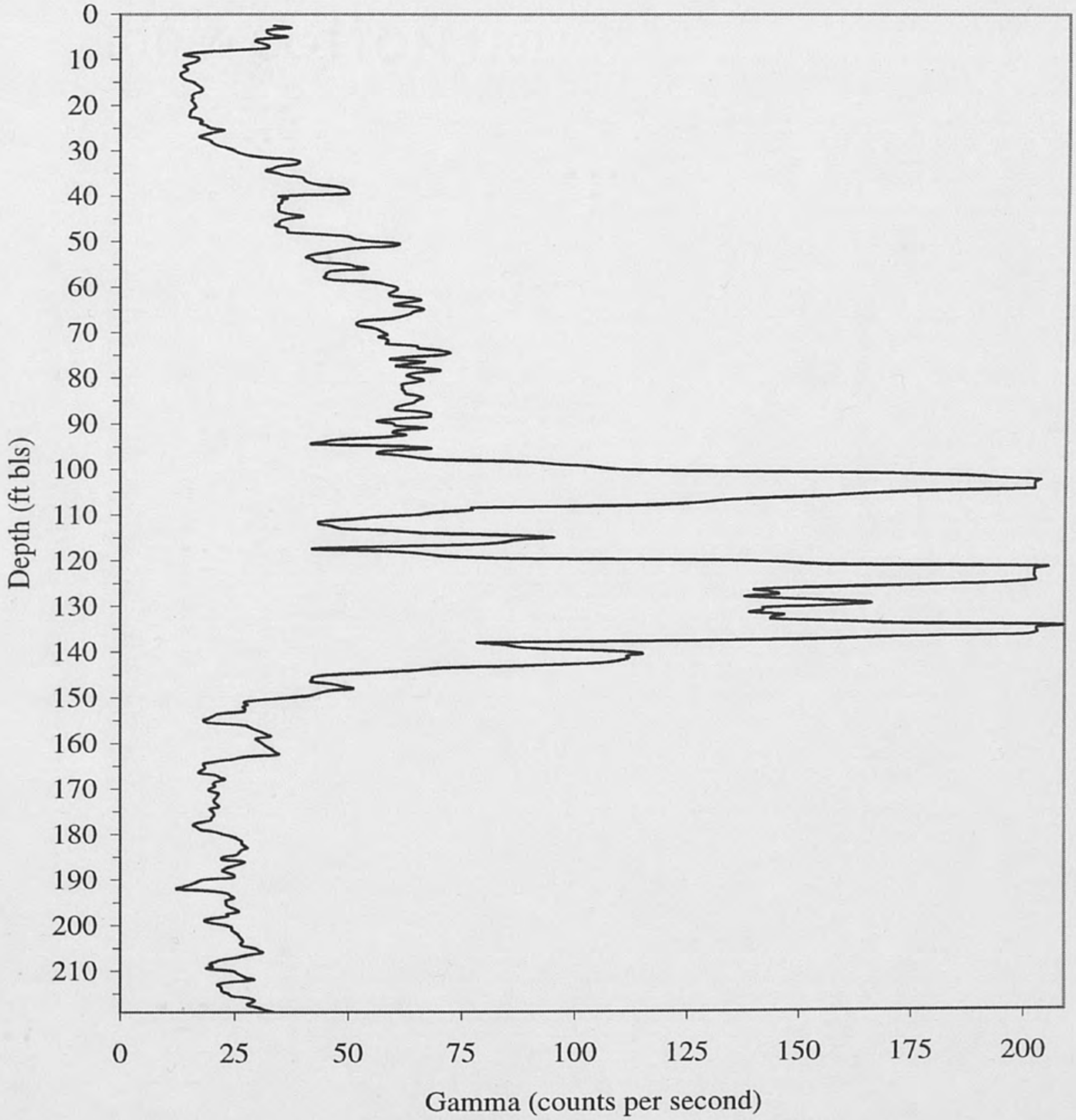
Appendix E-7
Gamma Log Plots for Volusia County Wells

SJRWMD I.D.:	V-0570	PWS I.D.:	3640331
Latitude:	28 57 03	Latitude:	28 57 02
Longitude:	80 56 50	Longitude:	81 57 49
Depth to Confining Layer:	96 ft	Distance:	1.38 mi
Depth to Aquifer:	110 ft		



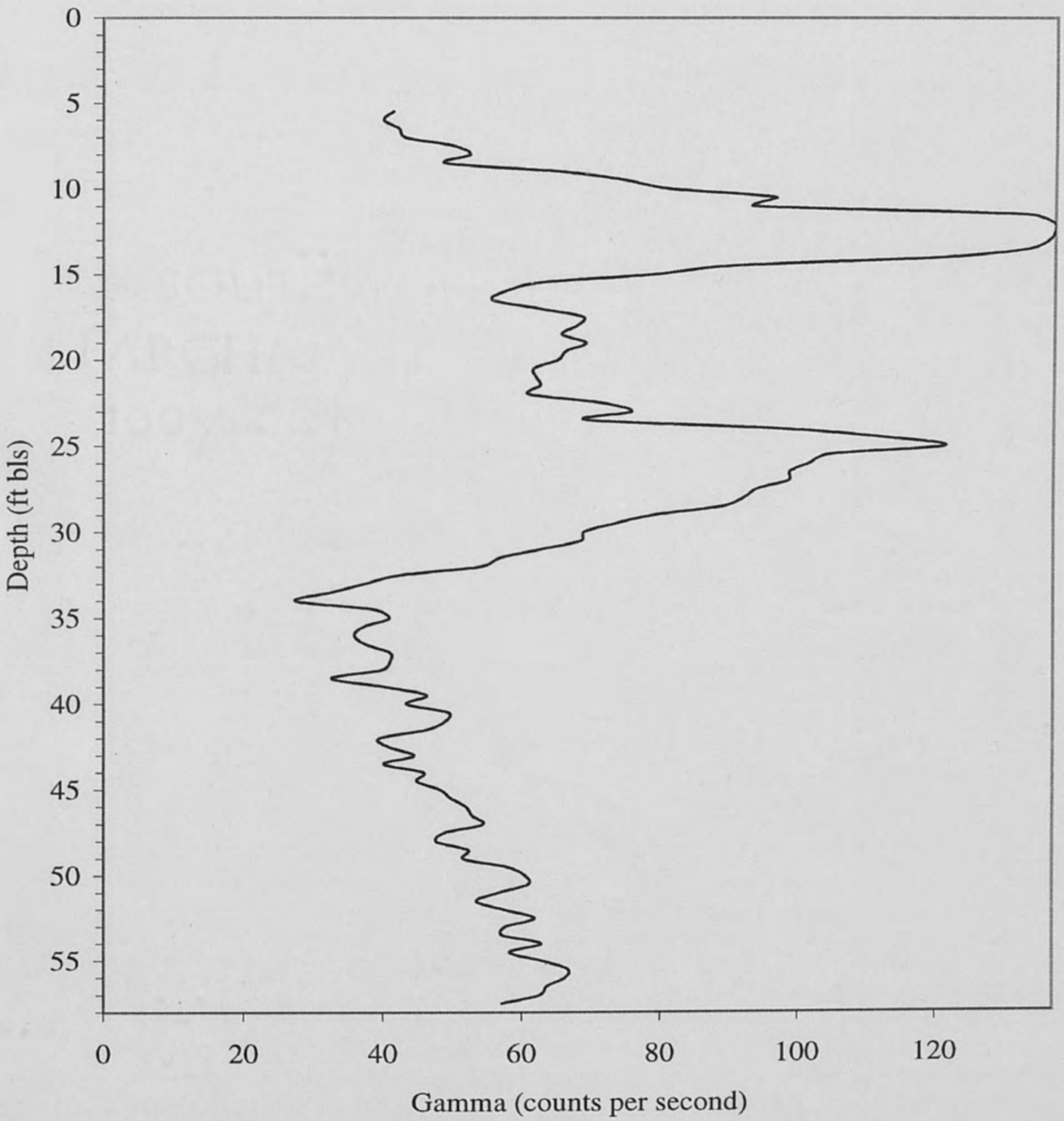
Appendix E-7
Gamma Log Plots for Volusia County Wells

SJRWMD I.D.:	V-0242	PWS I.D.:	3640587
Latitude:	28 54 11	Latitude:	28 54 04
Longitude:	80 51 48	Longitude:	80 51 42
Depth to Confining Layer:	98 ft	Distance:	0.23 mi
Depth to Aquifer:	142 ft		



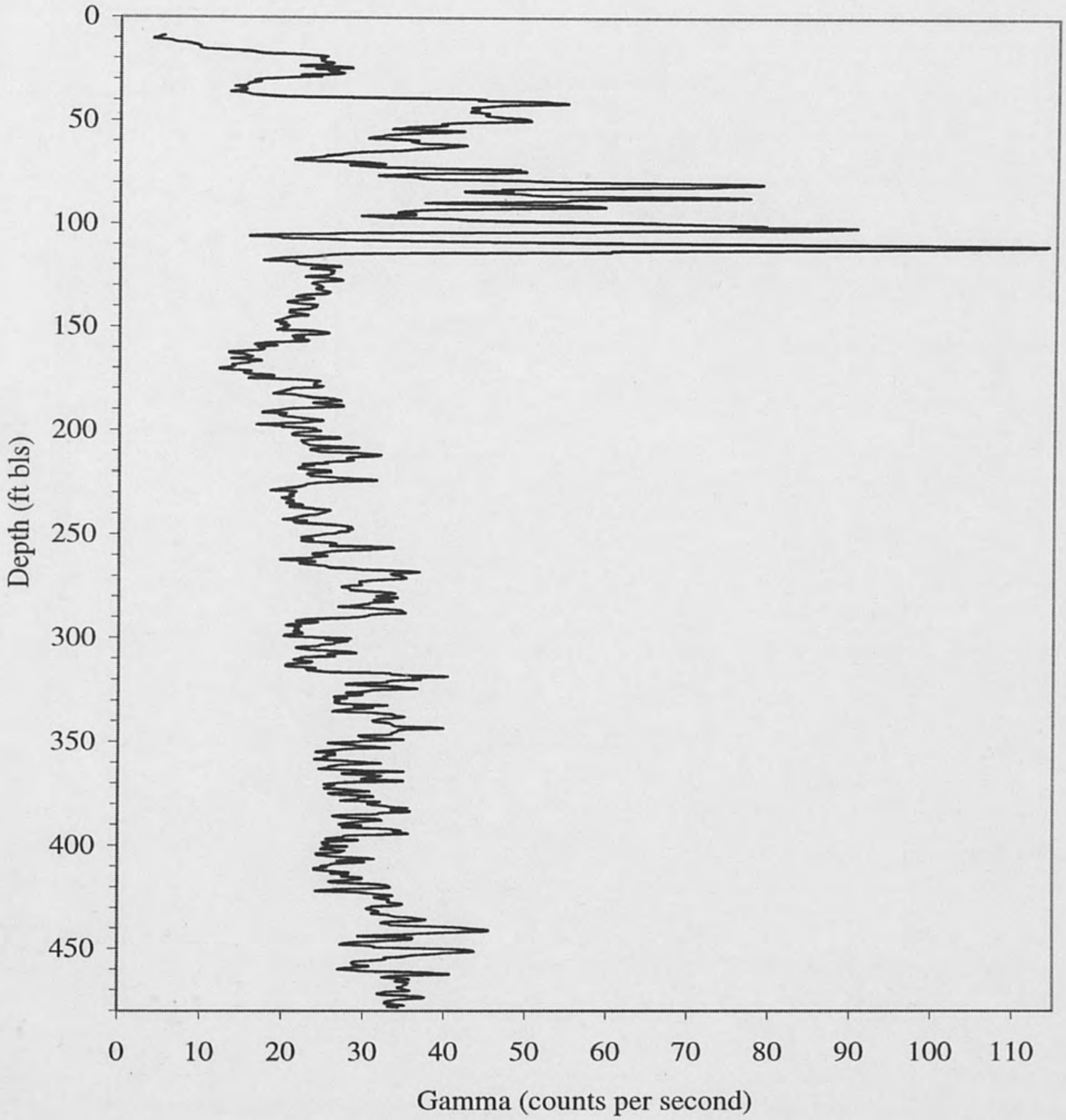
Appendix E-7
Gamma Log Plots for Volusia County Wells

SJRWMD I.D.:	V-0368	PWS I.D.:	3640643
Latitude:	28 50 45	Latitude:	28 50 23
Longitude:	81 09 48	Longitude:	81 10 19
Depth to Confining Layer:	5 ft	Distance:	0.94 mi
Depth to Aquifer:	32 ft		



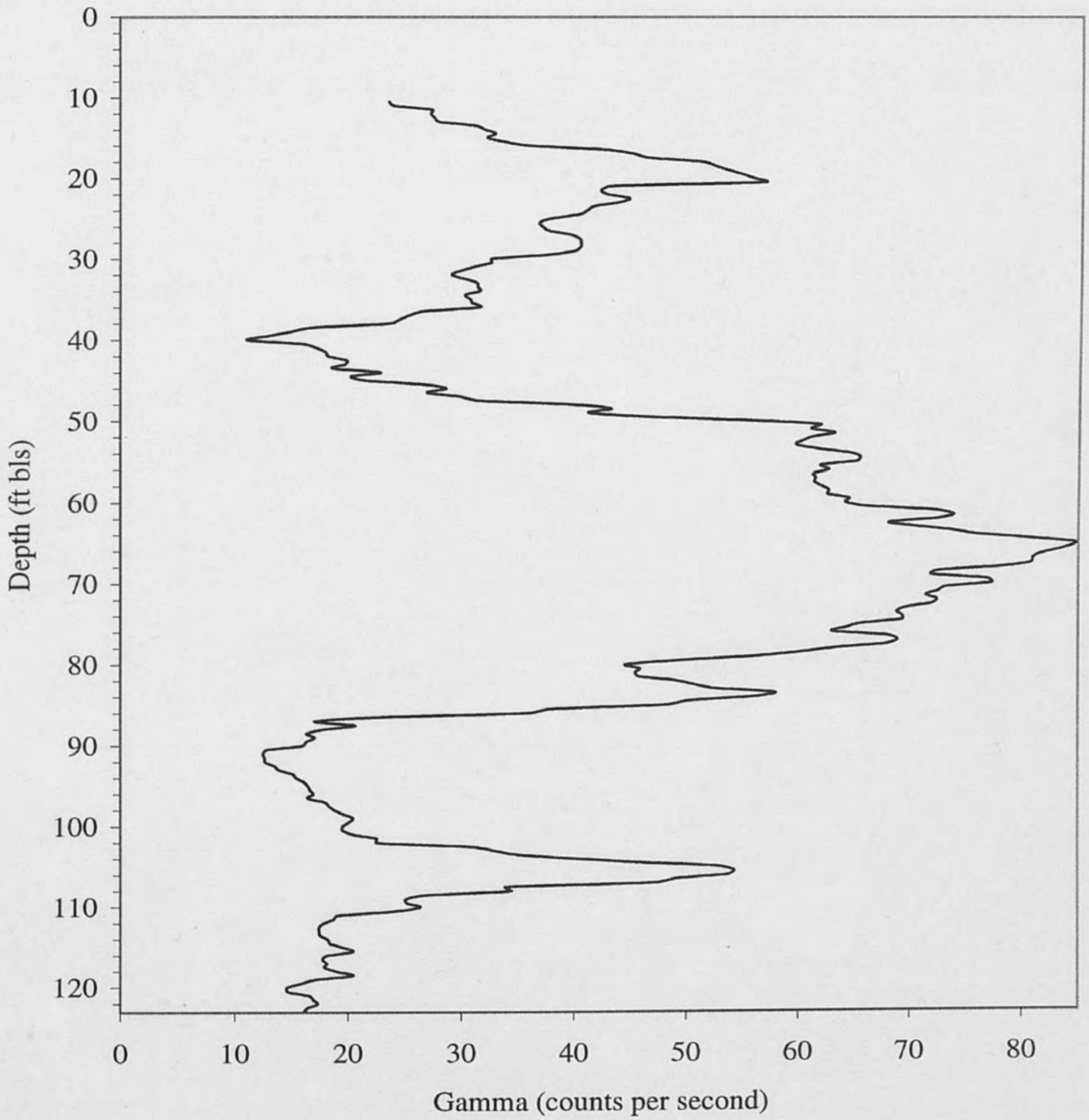
Appendix E-7
Gamma Log Plots for Volusia County Wells

SJRWMD I.D.:	V-0333	PWS I.D.:	3641308
Latitude:	29 14 40	Latitude:	29 14 22
Longitude:	81 27 15	Longitude:	81 27 20
Depth to Confining Layer:	40 ft	Distance:	0.50 mi
Depth to Aquifer:	110 ft		



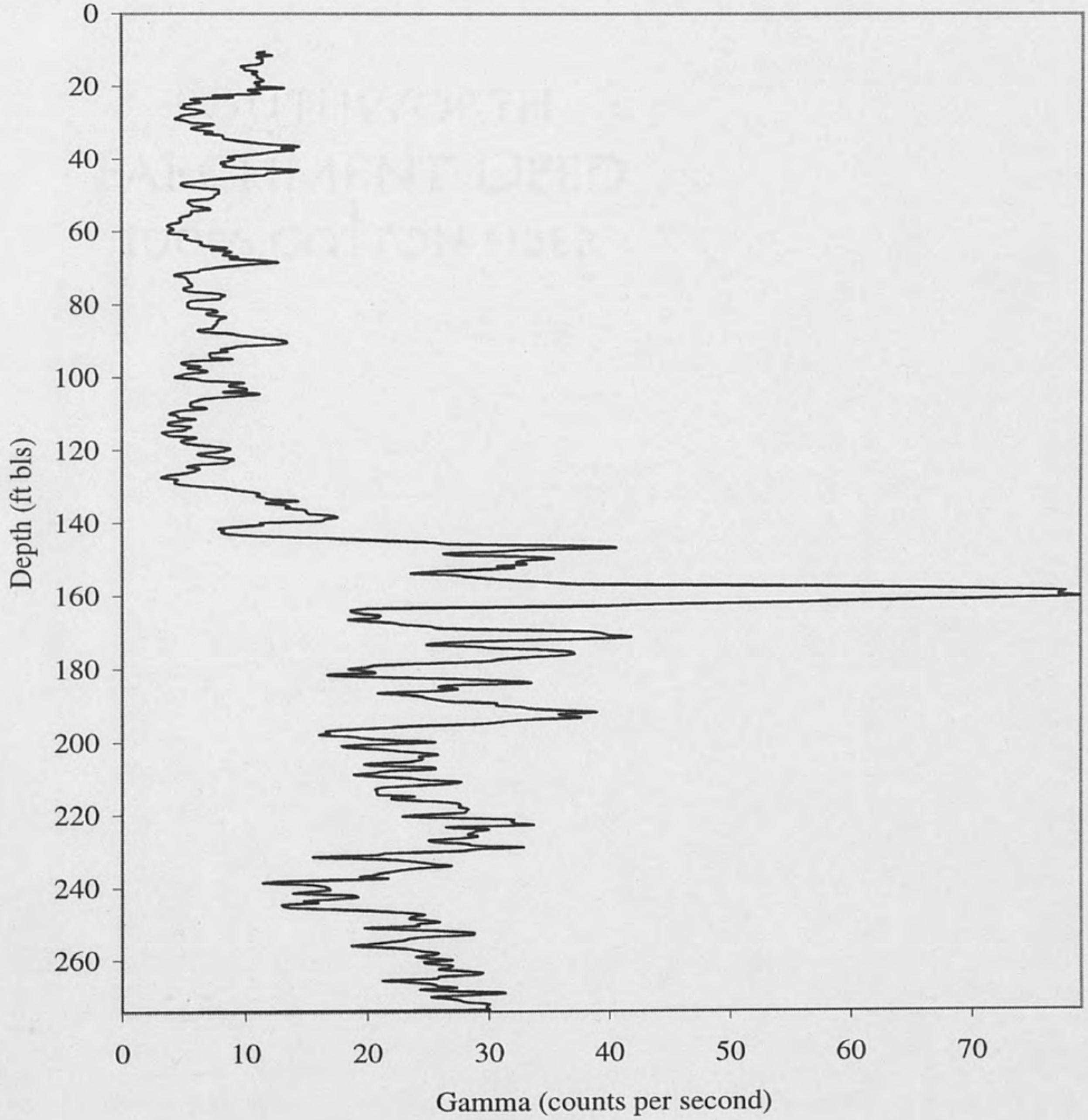
Appendix E-7
Gamma Log Plots for Volusia County Wells

SJRWMD I.D.:	V-0440	PWS I.D.:	3641373
Latitude:	29 15 30	Latitude:	29 15 47
Longitude:	81 06 38	Longitude:	81 07 45
Depth to Confining Layer:	45 ft	Distance:	1.63 mi
Depth to Aquifer:	86 ft		



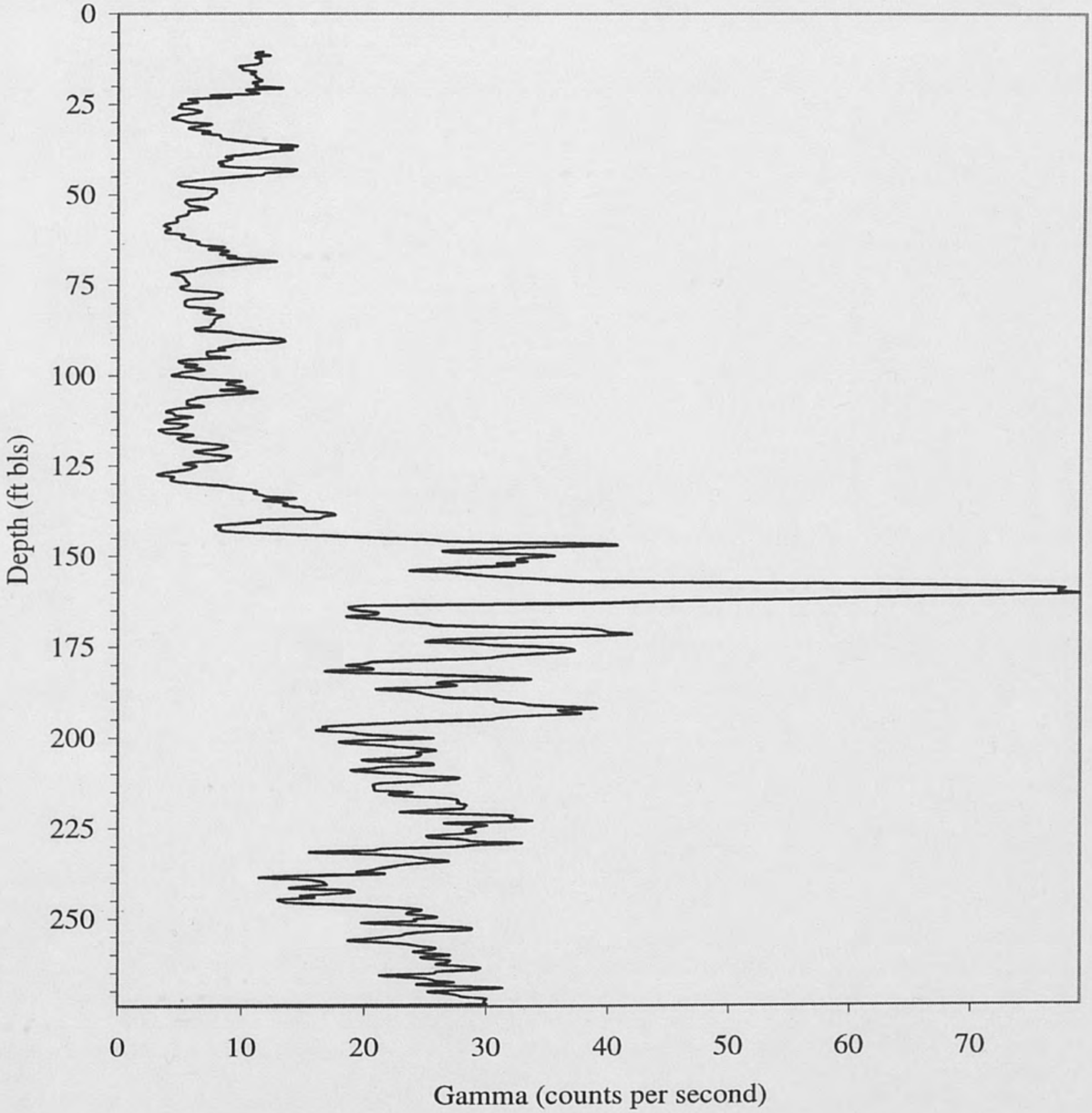
Appendix E-7
Gamma Log Plots for Volusia County Wells

SJRWMD I.D.:	V-0353	PWS I.D.:	3641550
Latitude:	28 56 45	Latitude:	28 58 45
Longitude:	81 14 45	Longitude:	81 13 45
Depth to Confining Layer:	155 ft	Distance:	3.51 mi
Depth to Aquifer:	161 ft		



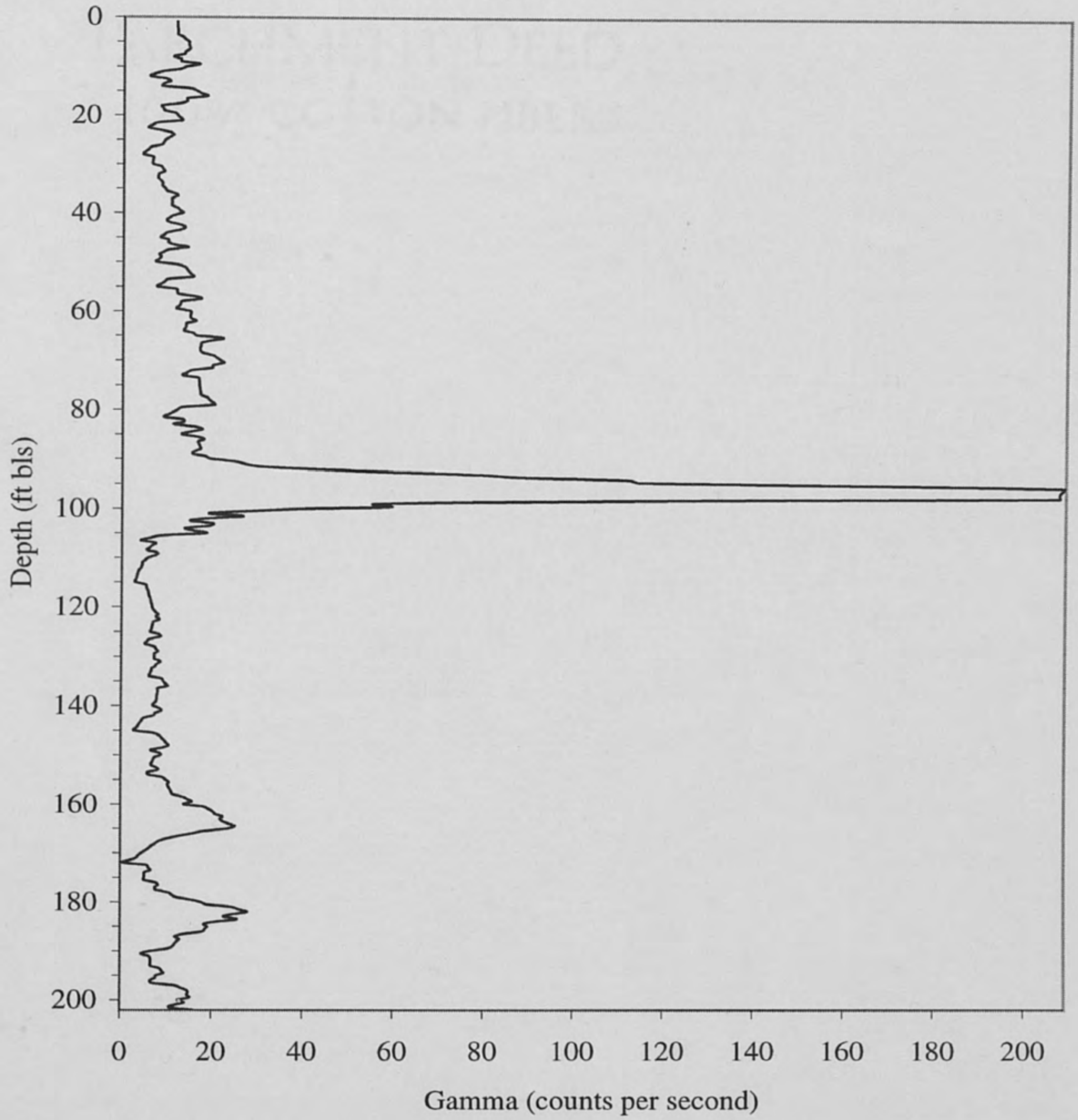
Appendix E-7
Gamma Log Plots for Volusia County Wells

SJRWMD I.D.:	V-0353	PWS I.D.:	3644123
Latitude:	28 56 45	Latitude:	29 04 16
Longitude:	81 14 45	Longitude:	81 18 44
Depth to Confining Layer:	155 ft	Distance:	13.3 mi
Depth to Aquifer:	161 ft		



Appendix E-7
Gamma Log Plots for Volusia County Wells

SJRWMD I.D.:	V-0571	PWS I.D.:	3644125
Latitude:	28 57 36	Latitude:	28 57 46
Longitude:	80 57 02	Longitude:	80 56 21
Depth to Confining Layer:	90 ft	Distance:	1.00 mi
Depth to Aquifer:	102 ft		



LIST OF REFERENCES

Bedient, P.B., Rifai, H.S., and C.J. Newell. Groundwater Contamination: Transport and Remediation. Englewood Cliffs, New Jersey: Prentice Hall, Inc., 1994.

Brassington, R. Finding Water: A Guide to the Construction and Maintenance of Private Water Supplies. 2nd Edition. Chichester, England: John Wiley & Sons, Inc., 1995.

Campbell, P.R., Population Projections for States, by Age, Race, and Hispanic Origin: 1993 to 2020. U.S. Bureau of the Census Current Population Reports. Washington D.C.: U.S. Government Printing Office, 1994.

Florida Administrative Code, Chapter 40C, Water Wells.

Fox, K.R. and D.A. Lytle. "Milwaukee's Crypto Outbreak: Investigations and Recommendations." Journal of American Water Works Association. September 1996: 87-94.

Harlan, R., Kolm, K., and E. Gutentag. Water-Well Design and Construction. New York, New York: Elsevier Science Publishing Company, Inc., 1989.

Hoenstine, R. W. Biostratigraphy of Selected Cores of the Hawthorn Formation in Northeast and East-Central Florida. Report of Investigation No. 93. Tallahassee, Florida: Bureau of Geology, Department of Natural Resources, 1984.

Inhaber, Herbert. Environmental Indices. Ottowa, Canada: John Wiley & Sons, Inc., 1976.

Juranek, D.D., Addiss, D.G., Bartlett, M.E., Arrowood, M.J., Colley, D.G., Kaplan, J.E., Perciasepe, R., Elder, J.R., Regli, S.E. and P.S. Berger. "Cryptosporidiosis and Public Health: Workshop Report." Journal of American Water Works Association. September 1995: 69-81.

LeChevallier, M.W. and W.D. Norton. "Giardia and Cryptosporidium in Raw and Finished Water." Journal of American Water Works Association. September 1995: 54-68.

Lehr, J., Hurlburt, S., Gallagher, B. and J. Voytek. Design and Construction of Water Wells: A Guide for Engineers. New York, New York: Van Nostrand Reinhold Company, 1988.

Ott, W.R. Environmental Indices: Theory and Practices. Ann Arbor, Michigan: Ann Arbor Science Publishers, Inc., 1978.

Regan, J., Roush, S. and R. McVay. "Cryto Happens – Report of a Florida Cryptosporidium Outbreak." Florida Water Resources Journal. February 1998: 29-30.

Roefer, P.A., Monscvitz, J.T., and D.J. Rexing. "The Las Vegas Cryptosporidiosis Outbreak." Journal of American Water Works Association. September 1996: 95-106.

Southeastern Geologic Society. Florida Hydrostratigraphic Unit Definition. 1988.

Stark, L. Personal Interview. Laboratory Director. Florida Department of Health, Tampa Branch Laboratory. October 23, 1996.

Stewart, J.W. Areas of Natural Recharge to the Floridan Aquifer in Florida. Florida Department of Natural Resources, Bureau of Geology. Map Series 98, 1980.

Vasconcelos, J. and S. Harris. Consensus Method for Determining Groundwaters Under the Direct Influence of Surface Water using Microscopic Particulate Analysis (MPA). USEPA Document 9109-92-029. October 1992.

Ward, A. and W. Elliot. Environmental Hydrology. Boca Raton, Florida: Lewis Publishers, 1995.

Waxman. Safe Drinking Water Act Amendments of 1986, Conference Report. House of Representatives. 99th Congress, Session 2d, Report 99-575, May 5, 1986.

Wilson, M.P., Gollnitz, W.D., Boutros, S.N. and W.T. Boria. Determining Groundwater Under the Direct Influence of Surface Waters. Research Report for American Water Works Association Research Foundation: Denver, Colorado, 1996.

Wright, A.P. Environmental Geology and Hydrology, Department of Natural Resources, Bureau of Geology. Special Publication No. 19, pg 94, 1974.