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Determination of Properties and the Long Term Acceptance Rate of Effluents from Food Service Establishments that Employ Onsite Sewage Treatment

Prepared By
Brian C. Matejcek
Steve Erlsten
&
Dr. David Bloomquist

Departments of Environmental Engineering Sciences
and Civil & Coastal Engineering
University of Florida
Gainesville, Florida 32611

For the Florida Department of Health

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ABSTRACT

DETERMINATION OF PROPERTIES AND THE LONG TERM ACCEPTANCE RATE OF EFFLUENTS FROM FOOD SERVICE ESTABLISHMENTS THAT EMPLOY ONSITE SEWAGE TREATMENT

Restaurants in Florida have problems in disposing of their high-strength wastes using onsite treatment and disposal systems, with failures occurring regularly. This study is part of the program designed to determine the characteristics of the wastes being generated and to establish possible solutions. This report gives the results of the testing done to characterize the effluents and then develop a synthetic wastewater for use in subsequent tests. Those tests were designed to determine the long-term acceptance rates for typical soils using practical loading protocols. Several recommendations for solving the disposal problems are presented.

The physical and chemical characteristics of the septic tank effluents from fifteen randomly chosen restaurants were determined using a total of 133 samples collected between May 1997 and March 1999. Levels were established for the five-day carbonaceous biochemical oxygen demand ($CBOD_5$), total suspended solids (TSS), and oils and greases (O&G). The effluents were sorted into high-, medium-, and low-strength categories as standards for the long-term acceptance rate (LTAR) study that followed. The low-strength category was comparable in strength to that of effluents from residential septic tank systems. This information was used to prepare non-hazardous artificial wastewater suspensions with physical and chemical characteristics that approximated those of the actual restaurant wastewaters.

The LTAR study used four common Floridian soil types in testing columns (lysimeters) that were designed to simulate drainfield conditions. Artificial wastewater of three strengths was applied under two saturation conditions that simulated those found in restaurants until failure occurred. These failures were due to the physical and biological clogging of the soil infiltration surface and varied widely, depending primarily on the mass loading rates.

Failure occurred primarily in the lysimeters with two feet of unsaturated soil that were dosed with high- and medium-strength wastewater. Twenty-four lysimeters failed during the 112-day study with 20 failures occurring between days 20 and 47. No failures were recorded in lysimeters with low strength wastewater, which received a daily mass loading of 0.0015 $lb/ft^2/day$ or less. In addition, total mass loaded on the low strength soil columns has exceeded the mass loading of the failed columns dosed with medium strength wastewater.

CHAPTER 1

INTRODUCTION

Onsite sewage treatment systems (OSTDS) are the primary means for wastewater treatment and disposal in areas outside of municipality boundaries. The Florida Onsite Wastewater Association (FOWA) reported 36,221 OSTDS installations in the State of Florida in 1996-97 and 35,237 system installations in 1997-98. In addition there were a total of 19,852 and 20,927 repair permits issued in those same respective years by the Florida Department of Health (FDOH). Actual system failures and the potential for system failures have increased concern for surface- and ground-water contamination as well as for other public health issues. Study emphasis has been placed on commercial OSTDS, including food service establishments (FSE) or restaurants, because of high wastewater flows and higher waste strength potentials.

Restaurant OSTDS have significantly higher failure rates than domestic systems. Effluent quality of restaurants may have 2.8 times the concentration of biochemical oxygen demand (BOD) and total suspended solids (TSS) compared to domestic systems (Siegrist et al., 1984). In a Wisconsin study (Siegrist et al., 1984), two restaurants experienced hydraulic failure within months after installation. In comparison, the mean age to failure for residential OSTDS in Florida is approximately 18 years (Sherman et al., 1998). Although higher wastewater strengths induce faster absorption field (drainfield) failures and different establishments vary in strength of waste produced, system designs used for disposal do not vary among establishments. Because restaurant treatment systems are designed based on criteria used for lower strength residential wastes, restaurant owners face economic consequences of drainfield failure along with public health issues. The cost of absorption field replacement can range between $4.00/ft^2 to $12/ft^2 of drainfield (personal correspondence with Florida Septic, Inc., 2000).

The failure of these fields not only represents a serious public health hazard but also may impact ground and surface waters with biological and chemical pollutants (Alhajjar, 1990). Nutrient overloading and BOD in waterways contributes to the degradation of water quality. Nitrogen and phosphorus can lead to eutrophication of water. High BOD concentrations can deplete oxygen levels in receiving waters leading to fish kills and anaerobic conditions. When failure occurs, humans could be exposed to pathogenic microorganisms such as Salmonella, Shigella, Giardia and viruses in the untreated wastewater (Yates, 1989).

Chapter 64E-6 of the Florida Administrative Code (FAC) regulates the design of onsite sewage treatment and disposal systems (OSTDS). There are over 1.6 million residences and commercial establishments in the State of Florida that use OSTDS as the primary means for wastewater disposal. Current design codes are based on estimates of daily flows, but differences between the wastewater strengths and organic loadings for domestic and restaurant effluent are not taken into consideration.

CHAPTER 2

LITERATURE REVIEW

Conventional OSTDS are composed of two primary components: the septic tank and the absorption drainfield. The septic tank allows solids to settle, separates floating debris (scum) from the waste stream and acts as an anaerobic digester (Metcalf and Eddy, 1991). The drainfield provides final aerobic treatment of the wastewater effluent and is the single disposal method of wastewater generated onsite. Restaurant OSTDS include a grease interception tank, where one or more tanks may be placed in series prior to the septic tank. Effluent exits the gravity flow system to the drainfield or into a holding tank (lift station) from which wastewater is pumped to the absorption drainfield.

Grease Interceptors

Grease interceptors (grease traps) are required for all commercial establishments (facilities other than domestic residences) "where grease is produced in quantities that could otherwise cause line stoppage or hinder sewage disposal" (FAC, Chapter 64E-6.013). Additionally, grease traps may be required for restaurants where suspended solids may be produced in excessive quantities (personal correspondence from Paul Myers, FDOH). Grease traps are essentially modified septic tanks and act as heat exchangers (Metcalf and Eddy, 1991). The baffled tank traps oil and grease by cooling the water, solidifying the grease and preventing floating oils from exiting the tank (Metcalf and Eddy, 1991). Grit and suspended solids also settle in the tank. The equation to determine the minimum capacity of the grease interceptor is given (FAC, Chapter 64E-6.013):

Grease interceptor capacity (gallons) = (S) x (GS) x (HR/12) x (LF)

where: S = number of seats in the dining area,
GS = gallons of wastewater per seat (10 gal. for single service restaurant or 25 gal. for all other),
HR = hours of operation,
LF = loading factor (2.0 interstate highways, 1.5 other freeways, 1.25 recreational areas, 1.0 main highways, and 0.75 other).

The minimum and maximum tank volumes of grease interceptors are 750 and 1250 gallons. If the required capacity exceeds 1250 gallons, several grease traps may be placed in series. Failure to capture grease and oil from effluent can cause pump tank malfunction, pipe blockage and drainfield clogging.

Septic Tank

A septic tank is, by definition, "a watertight receptacle constructed to promote separation of solid and liquid components of wastewater, to provide limited digestion of organic matter, to store solids, and to allow clarified liquid to discharge for further treatment and disposal into a drainfield" (FAC, Chapter 64E-6). Oxygen is quickly utilized by microorganisms in the septic tank, leaving settled material to undergo anaerobic decomposition. Baffles in the tank prevent the floating scum layer (oil, grease and solids) from exiting the tank. Septic tank sizing is based upon the estimated daily flow of the establishment. The criteria used to estimate the daily effluent flow of restaurants is located in Table 2-1. The estimated flows are then used to find the effective septic tank capacity. However, as wastewater flows increase, the minimum effective septic tank capacities do not increase linearly (Table 2-2). The resulting detention time of septic tanks therefore decrease as wastewater flow increases (see below example). The capacity information is given in Table 2-2.

Example: A 100-seat, full service restaurant operating for less than 16 hours would have an estimated flow of 4000 gallons/day (Table 2-1). The minimum septic volume required for a flow of 4000 gallons/day is 4800 gallons (Table 2-2), giving a detention time of 1.2 days (volume divided by flow). However, a domestic system with 200 gallons/day of flow requires a 900-gallon septic tank, resulting in a detention time of 4½ days.

Table 2-1. Estimated Sewage Flows for Restaurants (FAC, Chapter 64E-6.008, Table I)

Food Operation	Estimated Gallons Per Day Per Seat
a) Restaurant operating 16 hours or less per day per seat	40
b) Restaurant operating more than 16 hours per day per seat	60
c) Restaurant using single service dishware only and operating 16 hours or less per day per seat	20
d) Restaurant using single service dishware only and operating more than 16 hours per day per seat	35
e) Bar and cocktail lounge per seat; add per pool table or video game	20 15
f) Drive-in restaurant per car space	50
g) Carry out only, including caterers: 1. per 100 square feet of floor space 2. add per employee per 8 hour shift	 50 15
h) Institutions per meal	5
i) Food outlets excluding deli, bakery or meat department 1. per 100 square feet of floor space 2. add for deli per 100 sq. ft. of deli floor space 3. add for bakery per 100 sq. ft. of bakery space 4. add for meat dept. per 100 sq. ft. of meat dept. floor space 5. add per water closet	 10 40 40 75 200

Table 2-2. Septic Tank and Pump Tank Capacity for Restaurants (Adopted from FAC, Chapter 64E-6.008, Table II)

Average Sewage Flow (Gallons/day)	Septic Tank Minimum Effective Capacity (Gallons)	Pump Tank Minimum Effective Capacity (Gallons)
0-200	900	225
201-300	900	375
301-400	1050	450
401-500	1200	600
501-600	1350	600
601-700	1500	750
701-800	1650	900
801-1000	1900	1050
1001-1250	2200	1200
1251-1750	2700	1900
1751-2500	3200	2700
2501-3000	3700	3000
3001-3500	4300	3000
3501-4000	4800	3000
4001-4500	5300	3000
4501-5000	5800	3000

Lift Station

Automatic dosing systems are required for commercial establishments when the flow is greater than 500 gpd or if the area of the drainfield is greater than 1000 square feet (FAC, Chapter 64E-6). Lift stations (also referred to as pump tanks or pumping chambers) are also necessary in situations where wastewater must be elevated to overcome gravity as with mound systems (description later in this chapter). A lift station consists of a storage tank and an automatic dosing device, which discharges effluent to an absorption field. Sizing of lift stations depends on the dose volume, total dynamic head (elevation), desired flow rate and wastewater characteristics (EPA, 1980). Commercial tanks must have at least two alternating pumps with water level controls. The lift station must be sized so the entire drainfield receives effluent during the dosing period. This insures that the entire drainfield is utilized for treatment and disposal instead of individual sections.

Absorption Field

The absorption field, commonly known as a drainfield, provides the final treatment and disposal of the effluent from the OSTDS. Effluent treatment in a drainfield is a combination of physical, chemical and biological treatment. The main components of a drainfield include a series of shallow trenches filled with a porous media or aggregate (gravel), which surrounds a distribution pipe (Viessman and Hammer, 1993). The bottom of the trench is filled with a 6- to 10-inch layer of porous media (aggregate), and a single distribution pipe is laid. Then it is encased in the porous media (porous media has a minimum thickness of 12 inches). The distribution lines (usually a 4-inch minimum inner diameter pipe with two rows of holes or perforations) and porous media distribute the OSTDS effluent over the entirety of the drainfield (FAC, Chapter 64E-6.014). A membrane composed of polyester bonded filament covers each trench and prevents intrusion of the backfilled soil (drainfield soil cover) into the porous media.

Soil below the drainfield must have an effective depth of at least 42 inches of slightly limited or moderately limited soil (suitable soil). Slightly limited soils include sand, loamy sand and fine sand with a rapid percolation (1 to 4 min/inch). Moderately limited soils include sandy loam, fine sand loam and very fine sand with a moderate percolation (5 to 10 min/inch). Clay loam, sandy clay and silt with percolation rates between 15 and 30 min/inch are also considered moderately limited soils. Severely limited soils are unsuitable for drainfield installation and include clay, organic soils or bedrock with percolation rates greater than 30 min/inch. Soils with percolation rates less than one min/inch or coarse sand with a water table less than 48 inches below the soil surface are also considered severely limited soils. In addition to the limitation rating, there must be a minimum of 24 inches of unsaturated soil between the bottom of the drainfield and the seasonally high water table (FAC, Chapter 64E-6.008). Additional soil criteria are given in Table 2-3.

Table 2-3. Soil Criteria for Absorption Fields (U.S. EPA, 1980)

Soil Quality	Criteria
Texture	Desirable - sandy or loamy textures Undesirable - highly porous and slowly permeable clay soils
Color	Desirable - bright uniform colors indicate well-drained & well-aerated soils Undesirable - dull, gray or mottled soils indicate saturation
Structure	Desirable - granular, blocky or prismatic structures Undesirable - platy soils with flat structure
Percolation Rate	Desirable - rate greater than 1 min/inch and less than 30 min/inch Undesirable - rate less than 1 min/inch or greater than 30 min/inch
Unsaturated Depth	Desirable - greater than two feet unsaturated soil between the seasonally high water table and the bottom of the drainfield

The trench system is the most common type of absorption system (Amoozegar et al., 1998), however all of the following systems are found extensively in Florida. The absorption trench has a maximum width of 36 inches, maximum length of 100 feet and minimum depth of 18 inches. This system is installed below the elevation of undisturbed native soil (soil naturally deposited and unaltered by the activities of man). There is a minimum separation of 24 inches of undisturbed native soil between the trenches. The parallel ends of the perforated distribution pipes are perpendicularly connected to form a continuous circuit (FAC, Chapter 64E-6.014). Figure 2-1 displays only one of the multiple trenches that compose a trench system drainfield.

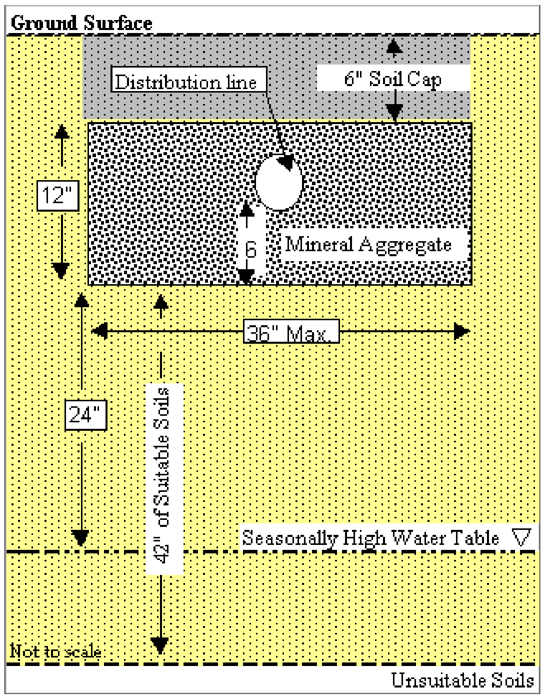


Figure 2-1. Cross-section of a Standard Trench Drainfield System

An absorption bed can be constructed in lieu of an absorption trench, which is essentially a wide trench with multiple effluent distribution lines. The entire soil content of the bed is removed and replaced with a porous media (EPA, 1980). Distribution lines are placed on the porous media with a 36-inch maximum separation between lines and a maximum infiltration area of 1500 ft^2 (FAC, Chapter 64E-6.014). The lack of “sidewalls” (trench minimum depth of 12 inches) between each distribution line can reduce the available soil infiltration surface area by a factor of five when compared to absorption trenches. Thus trench systems are the preferred method of effluent disposal. Absorption beds require less total land area than trench systems (EPA, 1980). However, the maximum allowable sewage loading rate for absorption beds is reduced by 20% to 45% (depending on soil texture) compared to the loading rate of an equivalent trench system (FAC Chapter 64E-6.008).

A second type of absorption field is called a mound system. Mound systems are required for severely limited soils (poorly drained soils) and where the seasonally high water table is too near the ground surface (EPA, 1980). These systems are trench or bed systems that have been raised above the ground surface elevation with the use of fill material. Fill material consisting of moderately limited or slightly limited soil (usually sand or fine sand) is transported and placed above the existing native soil until a predetermined elevation is reached (Metcalf and Eddy, 1991). There must be at least 42 inches of suitable soil below the bottom of the drainfield and a minimum of 24 inches of unsaturated soil above the seasonally high water table (EPA, 1980). The porous media and distribution line network is laid in a similar manner to the trench or bed systems and the mound system is capped with a minimum of 9 inches of fill material. The maximum allowable sewage loading rate for mound systems is reduced by 16% to 27% (depending on soil texture) compared to the loading rate of an equivalent trench or bed system. The side slopes of a 36-inch mound drainfield are two feet horizontal for each vertical foot. Slopes for mounds greater than 36 inches high are 3:1 (FAC, Chapter 64E-6.009).

Mound systems are more costly to install than standard subsurface systems due to the purchase and transportation of fill material. Costs also may include the addition of a lift station, which is often required to pump effluent to mound systems because of the raised elevation of the drainfield. Figure 2-2 illustrates the location of the ground surface with respect to the drainfield, however the actual heights of subsurface suitable and unsuitable soils will vary between sites.

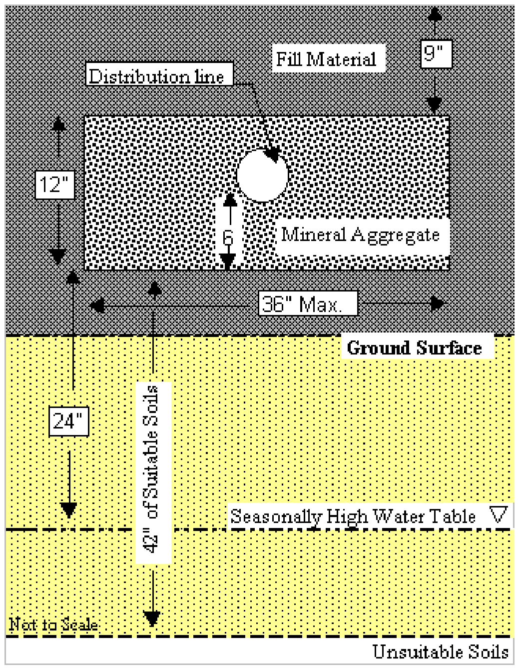


Figure 2-2. Cross-section of a Mound Drainfield System

A filled system is a variation on the mound system. In this case, "a portion, but not all, of the drainfield sidewalls are located at an elevation above the elevations of undisturbed native soil" (FAC, Chapter 64E-6.002). In this case, unsuitable soils in terms of texture or permeability are excavated and replaced with fill material. These systems are designed in accordance with the minimum requirements for mound systems. Filled systems require less land space when compared to mound systems due to the reduced height and reduction of the corresponding side slope. In addition, filled systems can receive the equivalent maximum allowable sewage loading rates as absorption trench and bed systems, which are greater than the allowable sewage loading rates to mound systems (FAC, Chapter 64E-6.009).

Aerobic Treatment Systems

Alternative systems to conventional septic tanks have typically focused on aeration. Generally air is bubbled through the wastewater effluent to maintain aerobic conditions. Aerobic digestion is more efficient than anaerobic with increased uptake of BOD (Bitton, 1994). Statewide there were 1,161 aerobic permits in 1996-97 and 1,222 in 1997-98 issued by FDOH (FOWA, 1999). Several variations of aerobic systems are manufactured, including the Nibbler™ system, which was utilized at two restaurant sites in the study.

The Nibbler™ is an aerobic digester pretreatment system that treats high strength wastewater and is capable of accepting "shock loads" during peak flow times. The system uses aeration to up-flow wastewater through submerged buoyant media in the unit (Sluth, 1989). Waste strength levels are reduced to concentrations found in residential OSTDS.

System Failure

A drainfield system is designed to distribute effluent for filtration, oxidation, reduction and absorption by the soil. System failure is the discharge of untreated (or inadequately treated) wastewater into the environment, including discharge to the ground surface, ground water or surface waters (FAC, Chapter 64E-6.002). Drainfield failure specifically refers to the clogging of the drainfield by either or both physical clogging or biological interference. Characteristic initial indicators include reduced water flow from the restaurant. Later indicators of failure include ponding over the drainfield, sewage overflowing from tanks and wastewater backing up into buildings.

Physical clogging of the drainfield occurs when suspended solids, sludge, oils and grease reach the drain field. These particles collect on the soil infiltration surface and limit water permeability through the soil. The oils and grease not collected in the grease interceptor can pose severe problems in the drainfield because of their persistence.

A biological clogging mat or biomat forms on the porous media and infiltration surface of the drainfield after the system has been in service for some time. The biomat is both a physical and biological filter and treats effluent for BOD and TSS as it passes over the biomat (Metcalf and Eddy, 1991). Biomat thickness ranges from 0.7-cm to 2.5-cm in the soil and attaches to the porous media below the perforated distribution pipe (May, 1996). The biomat thickness will increase as the microorganisms metabolize the depositing organics in the effluent. However, the permeability of the soil at the infiltration layer is greatly decreased by this process. The hydraulic capacity of the drainfield becomes a function of the biomat rather than a result of the hydraulic characteristics of the soil (Metcalf and Eddy, 1991).

Effluent flow to the drainfield can be gravity flow or by periodic doses by a pump. In gravity flow systems wastewater intermittently flows to the drainfield, resulting in locally distributed anaerobic (absence of molecular oxygen) regions due to saturation. A heavy and uniform biomat is formed due to these conditions. The biomat attached to the soil surface and drainfield aggregate supporting the perforated distribution pipe "acts as a submerged anaerobic filter" metabolizing organic materials into methane and carbon dioxide (Metcalf and Eddy, 1991). Effluent is constantly entering the system, leaving the infiltration soil surface saturated. However, the vadose zone (unsaturated zone between the ground surface and water table) remains aerobic due to the slow infiltration of effluent through the biomat.

Periodic dosing is usually aerobic and the biomat attached to the drainfield aggregate "acts as a trickling filter"(Metcalf and Eddy, 1991). Dosing provides better wastewater distribution over the entire drainfield, which allows for more efficient treatment, compared to intermittent gravity flow systems. In addition the biomat is more evenly distributed throughout the drainfield but is thinner than with intermittent flow (Metcalf and Eddy, 1991). Under aerobic conditions, microorganisms digest the organic matter and convert it to carbon dioxide, water and other inert materials. Effluent treatment is more rapid under aerobic conditions when compared to anaerobic biological treatment (Metcalf and Eddy, 1991).

The infiltration surface includes not only the soil below the perforated distribution line but also the sidewalls of the trench system. Wastewater infiltrates the drainfield sidewalls, and the biomat will continue to form on the trench walls and adjacent porous media. System longevity becomes a function of the effluent loading rate, sidewall height (depth of the trench) and clogged soil infiltration rate (Keys et al., 1998). In addition, the formation of the biomat is a function of wastewater loading: increasing the organic loading tends to accelerate the biomat growth (Amoozegar, 1998).

For soils high in clay mineral content, reduction of the soils infiltration capacity can be severely reduced during drainfield installation (Uebler, 1984). Digging with a backhoe can cause "soil smearing" or a reorientation of the soil particles, which reduces the soils absorptive capacity compared to the undisturbed conditions (Uebler, 1984).

Problems observed with sizing OSTDS based primarily on hydraulic loading are that the effluent quality and resulting mass loading is not taken into consideration for drainfield design. This increased waste strength has been shown in previous studies to have significant impact on the performance of an OSTDS and may shorten the life of the system. The purpose of this study is to determine the effects of wastewater strength (constituent concentration) on drainfield absorption systems. Concentrations of biochemical oxygen demand ($CBOD_5$), total suspended solids (TSS), and oils and grease in the effluents of operating restaurants determine effluent strength. The average effluent concentrations for these three parameters are significantly higher for restaurants than they are for residences.

Phase I - An Examination of Restaurant OSTDS

The research presented in this report is the second phase of a two-phase restaurant OSTDS study. The conception and completion of this research was a direct result of recommendations and conclusions derived from the first phase. This research was initiated in January 1997 and was completed in June 2000 and is the main focus of this report. Phase I of the research began in January 1996 and was completed in January 1997 (Waters, 1998) and is summarized below.

Phase I of the study investigated several effluent properties from food service establishments (FSE) that employ onsite sewage treatment and disposal systems (OSTDS). Septic tank effluent from a total of 19 restaurants was sampled in Alachua and surrounding counties in North Central Florida. Each restaurant was sampled twice and analyzed for 5-day biochemical oxygen demand (EPA Method 405.1), total suspended solids (EPA Method 160.2) and n-hexane extractable oils and grease (EPA Method 1664). Additional qualitative analyses using a gas chromatograph and mass spectrometer (GCMS) were run to determine the presence of trace organics from degreasers and cleaning agents (EPA Method 625). Soil borings from each site were examined to determine the suitability of soil to accept septic tank effluent.

The State of Florida Department of Health and Rehabilitative Services provided a list of 161 restaurants operating in North Central Florida. The restaurants were divided into eight categories (Table 2-4). The original hypothesis was that restaurant category might be an indicator of effluent quality.

Table 2-4. Food Service Establishment Categories

Category	Restaurant Type
1	Restaurants operating less than 16 hours per day
2	Single Service restaurants operating less than 16 hours per day
3	Single Service restaurants operating more than 16 hours per day
4	Bars and cocktail lounges
5	Drive in restaurants
6	Food outlets
7	Bakeries
8	Convenience Stores

Restaurants selected for this study were operating an OSTDS and permission had been granted by the owner/manager to participate in the study. Limitations for collection of effluent samples included travel distance, and the time and budget limitations set for Phase I.

Each effluent sample was collected from a location immediately prior to discharge to the septic tank drainfield. A number of restaurants used lift stations, which are holding tanks located after the septic tanks and prior to the drainfields. Floats in a lift station activate pumps when the septic tank effluent reaches a predetermined level, and the effluent is then pumped into the drainfield. Florida Septic Inc., a septic tank installer/contractor for restaurant OSTDS, installed sampling ports between the septic tank and drainfield for restaurants without lift stations. Grab samples (approximately 4 liters each) were taken from each restaurant and analyzed for 5-day biochemical oxygen demand (BOD), total suspended solids (TSS) and oils and grease (O&G). In addition, samples were collected and analyzed for trace organics using EPA Method 625 for both the extraction and analysis (Waters, 1998).

The BOD_5, TSS and O&G analyses were selected to quantify effluent quality of OSTDS-treated wastewater. BOD_5 gives a general indication of the amount of biodegradable matter in the effluent. TSS determines the concentration of suspended solids in solution. O&G determines the amount of n-hexane extractable material (HEM) in the sample. HEM includes non-volatile hydrocarbons, vegetable oils, animal fats, waxes, greases and similar materials.

Results from the laboratory analyses of the 38 samples (two grab samples from each restaurant) varied greatly between sites, restaurant categories and sampling events. BOD_5 values ranged from 103 mg/L to 2820 mg/L, TSS concentrations ranged from 40 mg/L to 4775 mg/L and O&G concentrations ranged from 10 mg/L to 300 mg/L (Waters, 1998). Analyses using the GCMS (EPA Method 625) showed no detectable levels of toxic organics from cleaning products, nor were any compounds detected that might inhibit anaerobic activity or negatively impact effluent characteristics.

The two main statistical evaluations that were completed on the data were the Analysis of Variance (ANOVA) and the Duncan Multiple Range Test. The Duncan analysis is a measurement of the sample size required to detect a statistical difference between two categories that are a given number of standard deviations apart and carried out for various error values (alpha and beta). The results of all the restaurant data collected in the respective categories and statistically analyzed using the ANOVA procedure are listed in Table 2-5.

Table 2-5. Analytical Results For Each Restaurant Category (Waters, 1998)

Category	Mean BOD_5 Value (mg/L)	Standard Deviation (mg/L)	Mean TSS Value (mg/L)	Standard Deviation (mg/L)	Mean O&G Value (mg/L)	Standard Deviation (mg/L)
1	761.0	266	225.7	19	83.1	75
2	601.8	313	123.0	125	32.5	35
3	548.3	290	141.3	158	80.2	94
4	451.0	71	78.5	38	23.6	*
5	1920.0	1273	454.0	269	77.7	67
6	571.3	396	259.5	207	83.0	54
7	571.3	396	259.5	207	83.0	54
8	440.9	237	42.7	20	17.5	18

* - No standard deviation because only one sample analyzed

The resulting conclusions of both the ANOVA and Duncan Multiple Range Tests show that the number of samples collected is insufficient to make a statistical determination of variations between restaurant categories. The Duncan Multiple Range Test further demonstrates that at least 38 samples from each category are necessary to provide accurate results.

The Phase I study concluded that effluents from restaurants treated with OSTDS contain high concentrations of BOD, TSS and O&G when compared to domestic systems. No correlation was determined among the three tests, suggesting that all three analyses are required to characterize effluent. The study also indicated that restaurant type or category was a poor indicator of system performance. Recommendations from Phase I focused on increasing the number of samples per site and changing the sampling procedure from grab samples to composite samples to more accurately characterize effluent (Waters, 1998).

CHAPTER 3

EXPERIMENTAL METHODS

The purpose of the study was to monitor selected effluent properties from food service establishments (FSE) that employ onsite sewage treatment and disposal systems (OSTDS) and to conduct a long-term acceptance rate study (LTAR). A total of 15 restaurants were sampled in Alachua and surrounding counties in North Central Florida. Eight samples were collected from each restaurant and analyzed for CBOD, TSS and O&G. The LTAR laboratory study consisted of triplicate lysimeters packed with four typical soil types commonly found in Florida, two saturation conditions and dosed with one of three categories of wastewater strength determined from the field data. This research (Phase II) was initiated in January 1997 and was completed in June 2000.

The Florida Department of Health entered into a contract (LPC80) with the University of Florida to complete Phase II of the restaurant study. The first eight tasks of the contract refer to collection of effluent samples, the analyses of those samples and the final characterization of the restaurant effluent samples. The specific tasks included: 1) purchase of equipment, 2) determination of 15 food service establishments, 3) formulation of a sampling plan, 4) obtaining or creating site plans, 5) survey of FSE operations, 6) collection of eight effluent samples from 15 restaurants and analyzing for $CBOD_5$, TSS and O&G, 7) collection flow, pH and temperature data, and 8) categorization of food operation wastewater effluent into three strength categories.

Contract tasks 9, 10 and 11 deal specifically with the lysimeter study. Task 9 provides for the determination of the four soil types to be used in the long-term acceptance rate (LTAR) study that are representative of soils commonly used in the state for drainfields. Task 10 specifies the lysimeter design and experimental conditions with three wastewater strength levels, four soil types, two saturation conditions and triplicate columns. Task 11 is the implementation of the LTAR study with the response variable in days to failure.

Restaurant Characterization

Restaurant Selection

Seven of the 19 restaurants sampled in Phase I also participated in Phase II. The Phase I site numbers were 1,4, 6, 9, 11, 13 and 19 and were changed in Phase II to numbers 6, 7, 8, 4, 3, 9 and 10, respectively. The additional eight sites were chosen randomly from a list of restaurants operating in North Central Florida, which was provided by the State of Florida Department of Health.

Restaurant Sampling

Sample collection changed from a single grab sample used in Phase I (Waters, 1998) to a 24-hour composite sample based upon recommendations from the first study. This was accomplished using an ISCO Portable Sampler. This device produces a 300-ml sample suctioned by the sampler's peristaltic pump every hour for a 24-hour period and deposited into a 2.5 gallon Nalgene composite bottle. Prior to setup at the site, the composite bottle was surrounded by ice for sample preservation. A vinyl suction line attached to a weight with a stainless steel strainer was dropped into the lift station and adjusted until the strainer was at mid depth between the tank bottom and water surface. The lift station manhole cover was then returned with one side straddling a wood block to prevent pinching of the sampling hose. The ISCO sampler was activated and then locked securely on-site. All restaurants' OSTDS in this phase of the research had lift stations to allow easy access for sampling.

The sampling crew installed the sampler at a location and returned the following day to retrieve the equipment. The composite container was shaken to thoroughly mix the composite sample and re-suspend any solids that had settled since collection. Using 1-liter amber sample jars, samples were collected and iced for the return trip to the UF Water Chemistry Lab.

Analyses

Samples were collected for the same three analyses as in Phase I with one minor exception. The biochemical oxygen demand (BOD) was modified to carbonaceous biochemical oxygen demand ($CBOD_5$) using a nitrification inhibitor to prevent any oxygen loss during the five-day test due to the nitrification process. The resulting oxygen depletion would be solely the result of microorganisms respiring. The two remaining analyses, total suspended solids (TSS) and oils and grease (O&G), remained unchanged. Standard operating procedures of each for the analyses are detailed in Appendix B from Waters (1998).

$CBOD_5$ and TSS were the first two tests run because of the 48-hour and one-week respective holding times compared to the 28-day preserved sample holding time for O&G. The $CBOD_5$ analysis (EPA Method 405.1) measures the change in dissolved oxygen (DO) over a five-day period. Effluent samples were diluted in a 300-ml BOD bottle containing nitrification inhibitor. Dilution water consisted of distilled-deionized water (DDI) and HACH BOD Nutrient Buffer Pillows. A HACH BOD standard solution of 300 mg/L glucose and 300 mg/L glutamic acid was used for quality control. Samples were seeded with POLYSEED, a BOD seed inoculum manufactured by Polybac Corporation. A YSI Model 5905 dissolved oxygen probe and a YSI Model 57 dissolved oxygen meter measured the initial and final DO of the samples that were incubated in a Labline Incubator at 20.^{o}C. $CBOD_5$ was then calculated as follows:

$$CBOD_5 = \frac{\text{Initial D.O. (mg/L)} - \text{Final D.O. (mg/L)}}{\text{Sample Volume}} \times (300 \text{ ml})$$

Total Suspended Solids analysis (EPA Method 160.2) involves filtering a known volume of sample through a pre-weighed Whatman glass microfiber filter (47-mm diameter) using a 300-ml magnetic filter funnel. After filtering, the Whatman filter was heated at 104^{o}C to remove all moisture and then cooled in a desiccator. The filter was weighed a second time, then the concentration of suspended solids was calculated by dividing the change in mass of the filter by the sample volume.

Oils and grease were measured using the EPA 1664 hexane extraction method. Samples preserved with H_2SO_4 are shaken vigorously with n-hexane for two minutes in a separatory funnel and then given ten minutes for the two fluids to separate. The supernatant is separated from the sample and filtered through sodium sulfate into a pre-weighed round bottom flask. The hexane in the supernatant is volatilized, leaving a residue inside the flask.

The change in mass of the flask, based on sample volume, yields the concentration of O&G. The quality control solution was a product of Spex Certiprep.

Survey of Restaurants

The response from the survey of restaurants was as expected. The majority of restaurant owners and all of the managers of chain stores were unable to provide information on their septic systems. They were, however, able to complete the sections of the survey that dealt with daily operations. Approximately half of the restaurants responded to the survey in 1998. The survey was sent to the other sites a second time. The responses from the eleven restaurants that returned the survey are found in Appendix C. Survey questions not answered were left blank.

Flow Data

The ISCO 4501 Pump Station Flow Monitor was used to determine the flow of effluent to the drainfield. The monitor was connected to the pump station control box of the lift station and then logged the time that each pump was active during a one-week period. The power supply of the unit had to be converted from AC to DC, which caused a number of problems. The monitor was only capable of logging three days of pump events rather than the desired week's worth of data. The recorded data revealed that only one of the two pumps had been active for the entire 72-hour period. Initial problems were traced to the rechargeable batteries, but replacement Nickel-Cadmium batteries continued to give the same results. It was discovered that the flow monitor activated once the power supply was connected and did not respond to the pump station controls. An additional battery connected in parallel provided the pump station with enough voltage to log events for the seven-day period.

Differences in pump station control boxes made it difficult to find pump control wires. Connections made to the wrong wires caused the control box circuit breaker to trip. Two sites (1 & 5) did not have pump control boxes therefore no data was recorded. The owners of Site 12 decided to no longer participate in the study. Site 11 closed permanently before flow data could be collected.

The computer software that accompanied the Model 4501 flow monitor required an input for the volume measurement of water pumped to the drainfield. Overall, detailed system information was limited. Individual restaurants were unable to provide the specific information needed. Because of name changes of restaurants and the many different filing systems, review of the permits for the sites was difficult. Permits at the Department of Health were sometimes filed by restaurant name or by address or by permit number. The limited information discovered did not cover the detailed requirements of the monitor's software. The flow data collection was unsuccessful. The decision to use the monitor as a portable, DC powered flow meter, in retrospect, was not appropriate.

Temperature and pH

An ISCO Parameter Actuator Logger (PAL 1101) was used to collect pH and temperature measurements. The PAL 1101 and the Model 4501 were secured on site for a one-week period. Temperature and pH were not logged at sites incompatible with the Model 4501 or at Site 12, which declined further participation in the study. The PAL 1101 logged hourly measurements of pH and temperature. This information can be found in Appendix D.

Long Term Acceptance Rate Study

The long-term acceptance rate (LTAR) study used soil columns (lysimeters) to simulate drainfield conditions outward from the discharge. Testing conditions required four soil types, two saturation conditions, and three strengths of wastewater. Each of these conditions was done in triplicate to equal 72 individual lysimeters plus four soil control columns. Lysimeters were dosed with a synthetic wastewater with concentrations based on results of laboratory analyses from field sampling. Hydraulic loading rates for each soil type were taken from the FAC, Chapter 64E-6.

It was planned that the lysimeters be either completely saturated or completely unsaturated. This was changed to lysimeters with an imposed one-foot or two-foot variably unsaturated zone. The unsaturated zone thickness was established by the spacing of an imposed water table beneath the bottom of the simulated drainfield. The altered saturation conditions were more representative of existing sites in Florida due to seasonally high water tables and shallow aquifers.

Lysimeter Construction

The interior design height of the lysimeters required six inches of aggregate and forty-two inches of suitable soil below the discharge pipe, which are the minimum requirements for a drainfield installation (FAC, Chapter 64E-6). One way to minimize error and reduce the effects of channeling is by using a large diameter lysimeter, which reduces the ratio of the column surface area to the surface area of the soil. The final lysimeter diameter was chosen to be eight inches.

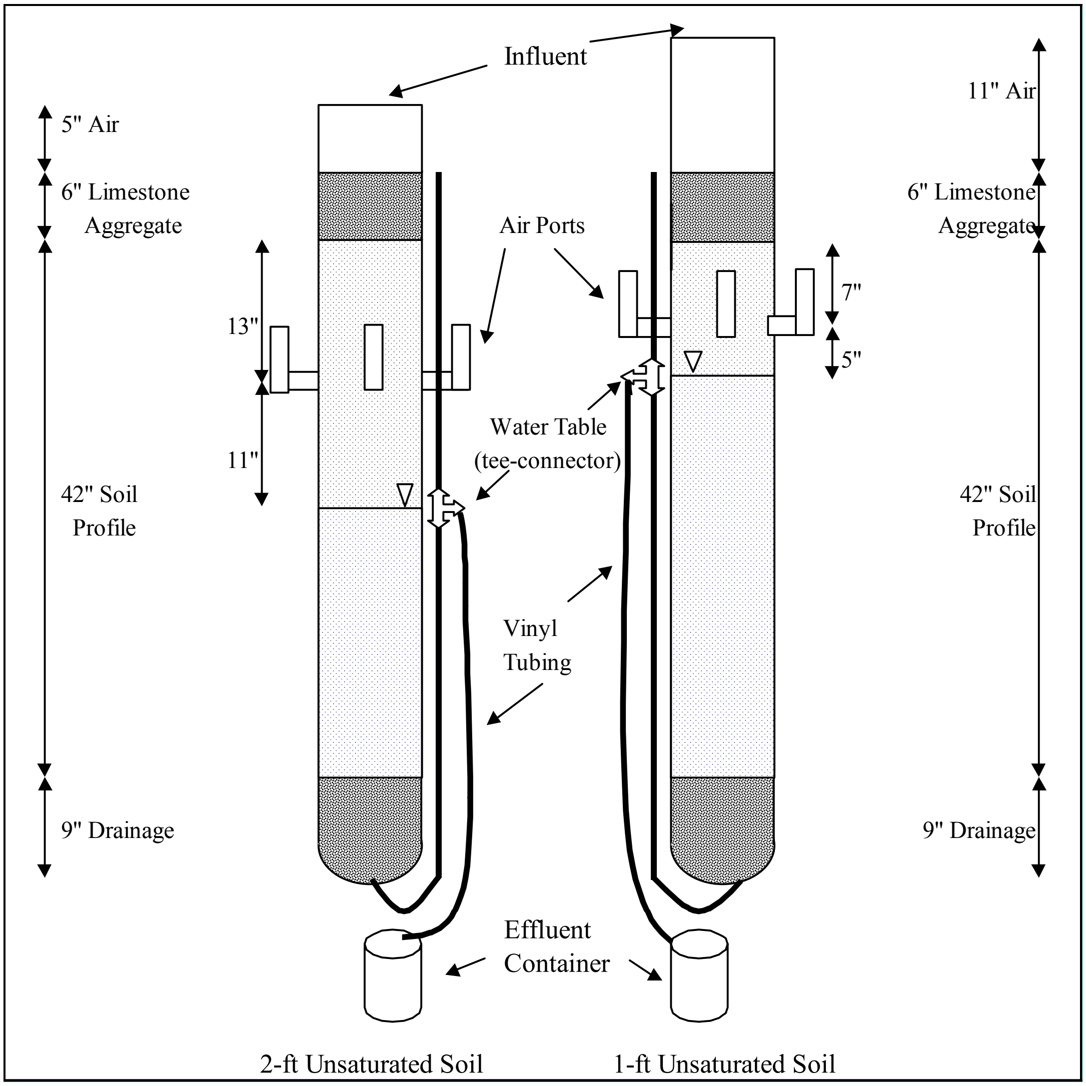


Figure 3-1. Lysimeter Design

The lysimeters were constructed with 8.18-inch I.D. PVC with an 8.625-inch O.D. The PVC pipes (100-psi rating) were supplied in twenty-foot lengths. Seventy-six 5.5-foot lengths were cut. Schedule 40 end-caps sealed the bottoms of the columns. It was necessary to coat the interior walls with an epoxy and sand mixture to reduce the possibility of water channeling.

Clear vinyl tubing was used to set the water table height in the lysimeters and for collection of column effluent (Figure 3-1). The decision to use this material was based upon cost and ease of installation in the limited available space on the column underside. A ½ inch hole was drilled in the bottom of each column for a connector capable of coupling 3/8-inch through ½-inch vinyl tubing. A tee-connector was placed at the required saturation level on the column exterior to determine the water table depth. Clear vinyl tubing (3/8-inch) extended from the lysimeter bottom-drain up to the tee-connector and down to a one-gallon container. A final length of vinyl tubing extended from the tee-connector to the top of the column and prevented the formation of a siphon.

A 9-inch multi-layered drainage system composed of aggregate and sand with decreasing grain size was placed in the bottom of each column. This system retained the soil in the columns but allowed water to flow through the media. Each layer of the aggregate was rinsed thoroughly and packed using a funnel to prevent damage to the epoxy/sand coating on the interior walls of the columns. The bottom layer of the drainage system (4 to 5 inches) was drainfield aggregate (20 to 26 mm diameter) provided by Florida Septic, Inc. The next layer was 1 to 1½ inches of crushed brick (8.5 to 19 mm diameter). The last four layers were ¾ to 1 inch thick and consisted of pea gravel (5.5 to 8.5 mm diameter), fine crushed brick (2.5 to 3.8 mm diameter), course silica sand (1.0 to 1.8 mm diameter) and a medium grit sand (0.5 to 1.25 mm diameter). The particle diameters for each layer were determined using sieves and are the 15 and 85 percent passing for each material (d_{15} and d_{85}).

Air ports were installed to prevent the column walls from creating an anaerobic boundary and to simulate the horizontal flow of oxygen present in actual field conditions. Three symmetrical 1-7/8" holes were drilled into each pipe to receive 1½" PVC elbow joints (air ports) located at mid depth of the unsaturated zone (Figure 3-1). The columns with two feet of unsaturated soil conditions had air ports at approximately 13 inches below the soil infiltration surface. Air ports for the one-foot unsaturated conditions were located at approximately 7 inches below the soil infiltration surface.

The lysimeter stand was constructed using 2”x 4”lumber, requiring 183 eight-foot boards and 45 pounds of nails. The heavy-duty structure was necessary considering the combined 17,000-pound load after soil packing and saturation. The drain system design demanded that 1,100 feet of vinyl tubing and 228 air ports be installed before the lysimeters were completed. The final cost for materials was $56.91 per lysimeter.

Soil Selection

Four soil types were selected to represent soils commonly used for drainfields in Florida, which spanned the majority of texture and hydrologic conditions. The soils selected also had to be amenable to laboratory experiments. The use of finer textured materials, such as clays, had the potential to cause problems. Clay minerals have “elongated shapes with planar geometry” (Myers, 1998), creating difficulty in replicating pore size in experimentation. The shrink/swell potential of clays poses another problem. Shrinking or swelling of clays could change the soil porosity in the lysimeter and either increase or decrease the hydraulic conductivity. Additionally, swelling could potentially crack the experimental lysimeters (Myers, 1998).

Because of these factors, the soils collected for this study were limited to soils with textures no finer than loamy sand and fine sand with low shrink/swell potential. Two sandy soils, Astatula and Millhopper, commonly found on the sand ridges of the state and a poorly drained soil, Myakka, common in Florida's flatwoods were originally chosen for the study. Due to seasonal high water tables, characteristic of flatwood soils, the Myakka soil series would contain two different types of fill material commonly used in the construction of mound systems (loamy sand and fine sand). Hydraulic loading rates differ for these two fill materials because of the different textures and permeabilities. Thus, Myakka soil with a loamy sand fill and Myakka soil with fine sand fill comprised the remaining two soil types.

The Candler soil series replaced the Astatula and the Pomona soil series was used in place of Myakka due to availability and immediate location of these soils. Each replacement had similar soil properties and equivalent loading rates. Astatula and Candler were used as fill material for the flatwoods soil.

Soil Properties

The Pomona series soils are sandy, siliceous, hyperthermic Ultic Haplaquods. Pomona is a poorly drained soil and has a seasonal high water table that can be less than 10 inches below the surface for 1 to 3 months of the year. The water table is at a depth of 10 to 40 inches for about 6 months and at greater than 40 inches during the dry season. The subsurface is dark gray to light gray sand to fine sand in the first 20 inches of depth. The subsoil extends to 69 inches where the upper part of the subsoil is dark brown to dark reddish brown sand to fine sand to a depth of 24 inches. The next layer is a pale brown and the lower subsoil is a very pale brown or grayish brown sandy loam to sandy clay loam. Permeability is rapid in the subsurface (6 to 20 in/hr) and moderate in the subsoil (0.6 to 2.0 in/hr). The available water capacity is low (0.05 to 0.10 inch water/inch soil) in the subsurface and low to high in the subsoil (0.05 to 0.20 inch water/inch soil) (Thomas et al., 1985).

The Candler series soils are hyperthermic, uncoated Typic Quartzipsamments. Candler has a rapid permeability (6 to 20 in/hr), low water capacity (0.05 to 0.10 inch water/inch soil), very low organic content and a water table exceeding 72 inches below the surface. This soil has low natural fertility and contains sparse vegetation including scrub oaks or pine. The surface is dark gray brown fine sand, 5 inches thick, and the subsurface is fine sand to 85 inches. The subsurface soil is yellow in the upper region and pale brown in the lower region. Textures for soil exceeding 109 inches are loamy sand (Thomas et al., 1985). Candler is locally referred to as “Archer Gold”.

The Millhopper series soils are loamy, siliceous, hyperthermic Grossarenic Paleudults. Millhopper soils are moderately well drained and found in areas of uplands and flatwoods. The surface layer is dark grayish brown sand and 7 inches thick; the subsurface layer extends to 48 inches and is yellowish brown sand in the upper region to pale brown sand in the lower. The subsoil extends to 80 inches and is very pale brown to yellowish brown loamy sand to loamy fine sand. The water table is 60 to 70 inches but may be at a depth of 40 to 60 inches for 1 to 4 months. Millhopper has rapid permeability in the subsurface (6 to 20 in/hr) and moderate permeability in the subsoil (0.6 to 2.0 in/hr). The available water capacity is low in the subsurface (0.05 to 0.10 inch water/inch soil) and moderate in the subsoil (0.10 to 0.15 inch water/inch soil). The soil has low natural fertility and low to moderately low organic matter content (Thomas et al., 1985).

<u>Soil Location</u>

The physical location of each soil was determined from the Soil Survey of Alachua County, Florida (Thomas et al, 1985). Permission to excavate on individual sites was obtained, and each soil series was verified using a four-inch soil borer.

The Pomona soil series (fine sand) was excavated from the Austin Cary Memorial Forest located north of Gainesville. The Candler soil series (fine sand) was collected from a farm located 10 miles north of the Town of Archer and 15 miles east of Gainesville. Millhopper (sand to loamy sand) was excavated from the University of Florida Natural Area Testing Laboratory (NATL) located on the southwest corner of campus. The Candler fill was excavated from a sandpit used by Florida Septic Inc., which is near the Town of Interlachen and 35 miles east of Gainesville. The soil texture of the Candler fill was loamy sand due the depth of the sandpit, which was greater than 109 inches deep. Astatula Fill (fine sand to very fine sand) was obtained in Clearwater at a residential drainfield replacement by AA Cut Rate Septic Service, who was excavating 34 inches of Myakka to replace with fill material.

Soil Collection

At each collection site a small vertical trench approximately six feet long, two feet wide and three feet deep was excavated and that soil was discarded. The trench revealed the soil profile and determined the number of horizons to be collected. Digging then proceeded in a horizontal direction rather than vertical. The top 16 inches of soil, including the dark-colored organic rich soil, was scraped and discarded from the previously undisturbed land adjacent to the trench. The second soil horizon was scraped horizontally and placed in sandbags. The original trench depth was then increased and that soil discarded. The next horizon of soil adjacent to the trench was then scraped and bagged. This process continued until 24.3 cubic feet (60 sandbags) of soil had been collected with a 42-inch profile depth or until the "grave" was 58 inches deep. The discarded soil was then replaced in the hole and the filled sandbags were taken to the University of Florida. The total soil volume collected for the 76 lysimeters was 3.60 yd^3.

Packing of Soil Columns

The 1985 Alachua County Soil Survey provided dry bulk density ranges for each soil series. The field density test for each site was taken using a sand cone (ASTM Standard D 1556) with results within ranges listed by the survey. A target dry bulk density of 1.55 g/cm^3 was chosen for packed columns of both the Pomona and Millhopper soil series (personal correspondence with Dr. Mansell), which had field test densities of 1.54 and 1.57 g/cm^3 respectively. The same target density value was chosen for both soil series to eliminate packing density as an issue for column failure. This value fell in the range of both soil series for all relevant soil layers.

The Candler dry bulk field density was determined to be 1.6 g/cm^3, which exceeded the Soil Survey range of 1.35 to 1.55 g/cm^3 but was within the range typically found in sandy soils, 1.50 to 1.60 g/cm^3 (personal correspondence from Dr. Mansell). A dry bulk target density of 1.50 g/cm^3 was chosen.

Because of the large volume of soil required for the study, guaranteeing uniform soil properties for each column set was an issue. Noticeable differences in initial moisture contents were evident in the excavated soil stored and stacked in sandbags. Moisture content of the soil increased in sandbags near the bottom of the stack. The decision was made to air dry all soils until the moisture content was less than 0.5 % by mass. Oven drying was unfeasible because of the large volume of soil required for the study. Sandbags for each soil layer were dumped, spread on a large tarp and mixed twice a day. Daily moisture content was taken in five different soil locations on the tarp. The initial soil moisture contents were 8.6, 3.7, 2.8 and 1.9 percent by weight for Pomona, Millhopper, Candler and Astatula fill, respectively. The drying process reduced the moisture content by approximately one-half of a percentage point per day.

All soil was sifted using a screen equivalent to #15 sieve to remove roots and similar debris. Soils were dried, sifted, mixed by hand shovels, weighed and poured into each column through a large funnel. The depth of each increment was measured with the column top as a datum. There were a total of 18 columns packed with each soil series.

Packing took place in increments not to exceed six inches of column depth but varied between four and six inches depending on the actual depth of each soil horizon as measured in the field (Figure 3-2). Once the volume and the target densities were established, the dry mass of soil needed for each packing increment was determined and weighed using an OHAUS Heavy Duty Solution Balance with a 20 kg (45 lb.) capacity. The soil was then gravity poured into each column using a large funnel. The funnel spout was shaken during the pouring process to ensure an even distribution of soil in the column and prevent mounding.

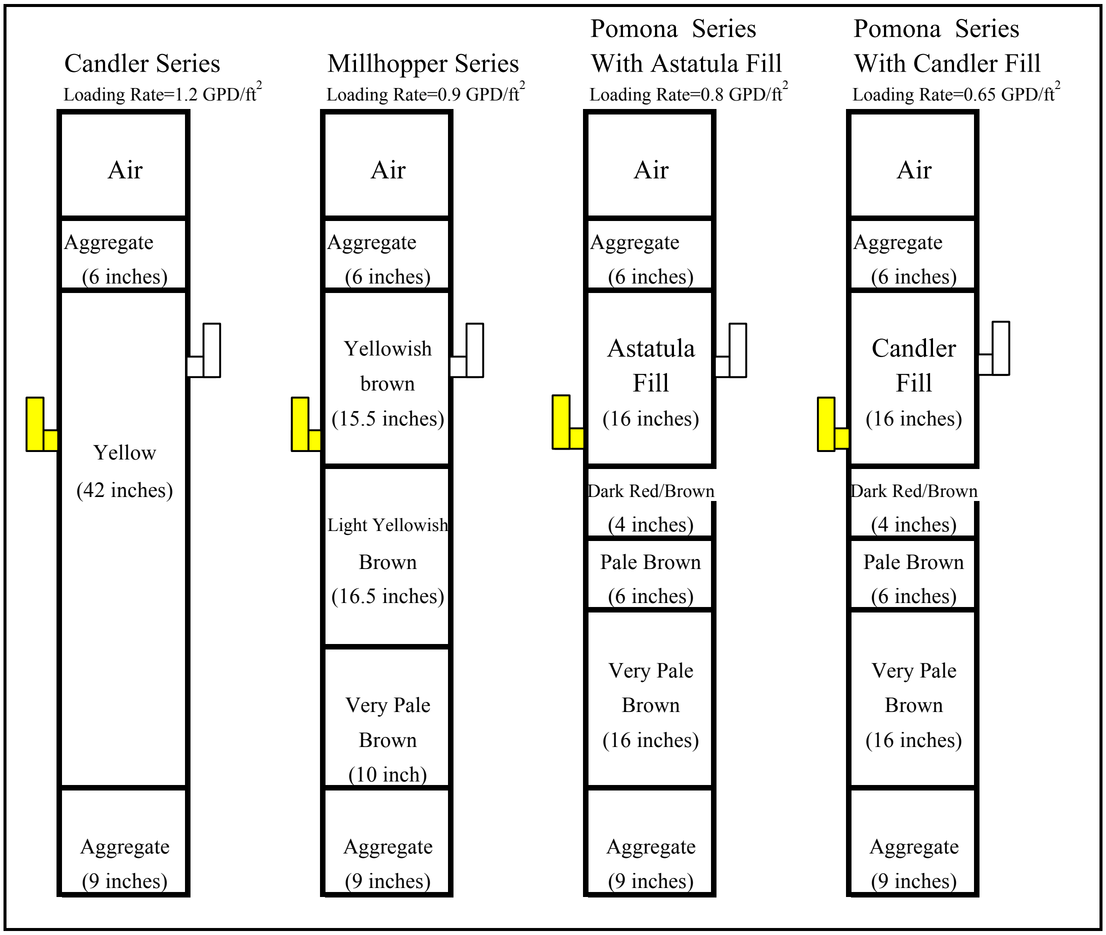


Figure 3-2. Soil Profiles for Lysimeter Study

Using a rubber mallet, the outside of the column was tapped lightly around the circumference at the equivalent location of the soil increment until the correct soil height was achieved and thus the target density was insured. This process was repeated for the remaining soil increments with each soil increment depth recorded (Appendix A). The lysimeters were topped off with six inches of #5 limestone representing the aggregate located below the drainfield discharge pipe.

The Candler and Millhopper lysimeters were packed with a 42-inch profile of each soil series (Figure 3-2) collected in the field. Both soil series have low water tables, rapid to moderate percolation and sandy soils, which are ideal for trench system installation. Therefore these lysimeters modeled absorption trench systems with loading rates of 1.2 gal/ft^2 for the Candler lysimeters and 0.9 gal/ft^2 for Millhopper lysimeters (FAC, Chapter 64E-6.008).

The mound system was simulated by the Pomona soil series (Figure 3-2), which was packed with a 26-inch soil profile and 16 inches of fill material. This flatwood soil has a high water table and therefore requires the use of fill material to raise the elevation of the soil infiltration surface (drainfield). A fine sand (Astatula fill) and a loamy sand (Candler fill excavated from depths greater than 109 inches) were packed above the Pomona Soil series. The lysimeter loading rates of the Pomona with loamy sand fill was 0.65 gal/ft^2 and Pomona with fine sand fill was 0.80 gal/ft^2 (FAC, Chapter 64E-6.009).

Experimental Control Lysimeters

One additional lysimeter was packed for each of the four soil types. These four columns were the experimental control columns and were dosed only with tap water. The saturation level was two feet of unsaturated soil below the drainfield. Each column received the same loading rate of approximately 1.2 gal/ft^2.

Hydraulic Conductivity

Constant head permeability tests (ASTD 2434-68, 1994) were conducted to determine the hydraulic conductivity of the packed soil (Riveria, 1999). The hydraulic conductivity was calculated using Darcy's constant head equation (Domenico and Schwartz, 1998).

$$K = QL / Ah$$

Where, K = hydraulic conductivity
Q = volumetric flow rate
L = length of soil in soil column
A = cross sectional area
h = constant elevation head

The columns were initially saturated through upward flow by attaching a 5-gallon bucket of water to the underside of the columns. The air ports were plugged with a rubber seal and the columns were left to slowly saturate overnight. The purpose of the slow saturation was to prevent changes in soil density and to push out/up as much air as possible. Once the columns were saturated, a bucket half filled with water was attached to the column. The water level was kept constant throughout testing. Two constant head tests were performed on each column with 10-minute and 20-minute time duration. Water flowed from the bottom of the columns to a hole 3 inches above the soil surface and was collected to determine flow (Q). The constant elevation head (h) was 13 inches, length of soil (L) was 42 inches and cross-sectional area (A) was 52.55 inches in all columns. The hydraulic conductivity for the lysimeter temperature was calculated and then converted to a corresponding value at 68^{o}F (20^{o}C) using a temperature conversion factor (Riveria, 1999). The mean hydraulic conductivity and standard deviation for the Candler, Millhopper, Pomona with Candler Fill and Pomona with Astatula Fill were 29.31, 15.43, 13.83 and 12.49 in/hr and 2.11, 1.05, 1.33 and 1.13 in/hr, respectively. The hydraulic conductivity for each lysimeter with respect to soil type appears in Appendix A (Riveria, 1999).

Synthetic Wastewater.

The daily dosing requirement of wastewater was 7.8 gallons per day for each of the three wastewater strengths or per 24-column set. It was deemed infeasible to collect three different wastewater strengths from three different field sites on a daily basis for the entirety of the LTAR study. In addition, concerns over the variability of wastewater strength at each site over time led to the final decision to use a synthetic wastewater for the lysimeter study.

The synthetic wastewater needed to have components that would contribute to O&G, TSS and BOD and have similar wastewater concentrations found in restaurants. The three strengths of the synthetic wastewater were determined by statistical analysis of the restaurant field sampling data. The O&G component had a further stipulation to include both animal fat and vegetable oil. The final synthetic wastewater mix was composed of Armour SPAM™, Crisco Vegetable Oil, Purina Brand Dog Food and dextrose. Originally, the animal fat portion of the O&G component was chosen to be Armour Lard, but keeping lard suspended in water proved impossible. Therefore, SPAM™ became the next obvious replacement. Dog food was the major contributor to TSS in the synthetic mix and dextrose was added to adjust for BOD. Return activated sludge (RAS) from the UF Wastewater Treatment Plant was added to provide a microorganism population to the synthetic wastewater and simulate microbes present in septic tank effluent of OSTDS.

Each component was individually tested four times for BOD, TSS and O&G. After the results were analyzed and the moisture content of each constituent determined, the four components were mixed in 3.78-liter (1-gallon) batches, continuously stirred with a magnetic stirrer and tested. Table 3-1 shows the percent moisture content for each component and percent recovery for each analysis. For example, mixing 100 mg of SPAM into 1 liter of water and analyzing for TSS, O&G and $CBOD_5$ would result in concentrations of 20, 17 and 19 mg/L, respectively. Low mass recovery from each analysis is attributed to the moisture content of SPAM. Factoring in the 53% moisture content will almost double the percent recovery for each parameter.

Table 3-1. Moisture Content and Analysis Percent Recovery

	% Recovery of Total Mass			Moisture Content
	TSS	O&G	$CBOD_5$	% Total Mass
Spam	20%	17%	19%	53%
Dog food	41%	9%	17%	10%
Dextrose	0%	0%	50%	1%
Crisco	31%	69%	43%	0%

Twelve small-scale batches and three full-scale batches were mixed. The mass requirements for each component were determined by solving the four simultaneous equations using MS Excel Solver. Table 3-2 details the actual mass input compared to expected concentrations of $CBOD_5$, TSS and O&G of each component based upon the percent recoveries from Table 3-1.

Table 3-2 Synthetic Wastewater Concentrations

Component	Low Strength				Medium Strength				High Strength			
	Actual (mg/L)	Recovery (mg/L) TSS	O&G	CBOD	Actual (mg/L)	Recovery (mg/L) TSS	O&G	CBOD	Actual (mg/L)	Recovery (mg/L) TSS	O&G	CBOD
Spam	21.9	4.4	3.6	4.2	73.6	14.8	12.3	14.1	268.1	53.7	44.7	51.3
Dog food	80.9	33.5	7.6	14.1	164.6	68.1	15.5	28.8	279.4	115.6	26.3	48.9
Dextrose	183.4	0.3	0.0	91.5	546.8	0.9	0.0	273.0	1199.9	2.1	0.0	599.1
Crisco	4.0	1.2	2.8	1.7	20.0	6.2	13.8	8.6	30.0	9.3	20.6	12.9
Total	290	39	14	112	805	90	42	325	1777	181	92	712

Synthetic Wastewater Batching Process

The full-scale synthetic wastewater setup includes a Scienceware Large-Volume Magnetic Stirrer capable of mixing 55 gallons using a Bel Art 6-inch Giant Polygon magnetic stir bar in a Nalgene Cylindrical HDPE 30-gallon tank (batch container). The batching procedure began with filling the container with 61 liters of tap water and starting the magnetic stirrer. The tap water had been left standing for four days to dechlorinate. The total chlorine concentration (HACH Chlorine Test Kit Model CN-66) reduced from approximately 0.6 mg/L to 0.3 mg/L over the four days. Each synthetic wastewater batch lasted two days or four dosing periods. The dextrose was weighed and dumped into the 30-gallon batch container, which then dissolved in stirred water. The dog food, SPAM™ and Crisco were each weighed, recorded and dumped into a 14-speed Osterizer blender. Hot water (½ liter) was added and the mixture was blended for one minute at high speed and then poured into the batch container. An additional five and one-half liters of hot water were mixed in the blender to completely remove any O&G/TSS residue from the sides the blender. The blender's contents were then poured into the filled batch container. Sludge from the UF Wastewater Treatment Plant was added to each batch at a concentration of one-quarter of the respective TSS concentration. This process was then repeated for the remaining two wastewater strengths. Batches were mixed from low strength to high strength. The recipe ingredients and mass requirements for the three synthetic wastewater strengths are located in Table 3-3).

Table 3-3 Synthetic Wastewater Mass Requirements

Synthetic Wastewater Component	Low Strength Mass (grams)	Medium Strength Mass (grams)	High Strength Mass (grams)
Spam	1.45	4.88	17.76
Dog Food	4.82	9.81	16.65
Dextrose	9.11	27.16	59.61
Crisco	0.26	1.32	1.99

Dosing

The lysimeters were dosed twice a day with synthetic wastewater effluent, once in the morning and again in the evening. Columns were dosed in numerical order and daily doses each began at different ends of each waste strength category. The purpose of dosing in ascending and descending numerical order is to prevent any column from constantly receiving either a diluted or concentrated dose.

The columns were dosed using three 40-oz transfer cups with handles and a pre-measured color-coded bottle (one colored bottle per soil type). Single doses for the triplicate soil columns were measured, poured into the transfer cups and then dumped onto the limestone aggregate in the lysimeters. The same four color-coded bottles were used for all three strengths to ensure consistent loading. Dosing began with the low waste strength columns and ended with the high strength.

Measurements

Column effluent flowed into 1-gallon jugs (effluent containers). This volume was measured every two days as an estimate of the influent. Monitoring these volumes provided initial failure detection. Column effluent for 12 lysimeters per week was analyzed for BOD and TSS. Clean 1-gallon containers replaced the effluent containers for the 24-hour sample collection period. The pH reading of the column effluent of each soil type was recorded weekly using a pocket pH probe manufactured by pHep.

The daily minimum, maximum and current temperatures were recorded using a Fisherbrand Traceable Sentry Memory Thermometer located on the low strength column set on one side of the lab. A Fisherbrand Traceable Relative Humidity/Temperature Meter was located on the medium strength column set and recorded the minimum, maximum and current values for humidity and temperature on the opposite side of the room.

CHAPTER 4

RESULTS AND DISCUSSION

Restaurant Effluent Characterization

Effluent samples were collected from 15 restaurants and analyzed for $CBOD_5$, TSS and O&G between June 1997 and February 1999. The data were then analyzed to characterize restaurant effluent into three categories of wastewater strength: high, medium and low.

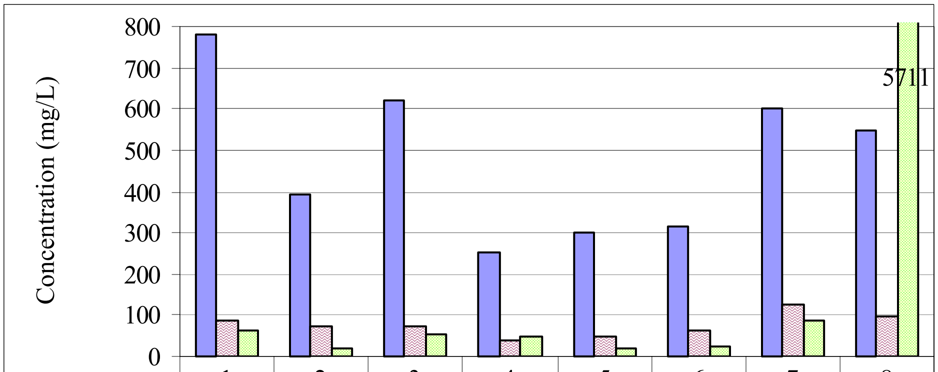
The original sampling plan dictated the collection of 120 samples with eight samples collected from each of the 15 sites. The required number of sample collections for this research was based upon recommendations from Waters (1999). The actual number of samples collected and analyzed was 133 (Table 4-1). Wastewater strength varied between sites by as much as two orders of magnitude, and because of fluctuations at particular sites, there was a problem in determining the appropriate range of dilutions for the $CBOD_5$ test. Therefore, thirteen additional samples were required to compensate for unpredictable $CBOD_5$ results.

Table 4-1. Restaurant Sample Collection

	Run I			Run II			Run III			Run IV			Run V			Run VI			Run VII			Run VIII			Run IX			Run X		
Site #	Date	sample#	Day	Date	sample#	Day	Date	sample#	Day	Date	sample#	Day	Date	sample#	Day	Date	sample#	Day	Date	sample#	Day	Date	sample#	Day	Date	sample#	Day	Date	sample#	Day
1	05/23/97	1	R	06/29/97	7	S	9/6	16	S	11/15/97	29	S	1/15	40	R	2/21	52	S	4/8	62	W	6/8	76	M	---	---	--	---	---	--
2	05/30/97	2	F	07/12/97	9	S	9/16	17	S	11/15/97	30	S	1/15	41	R	2/21	53	S	4/8	63	W	6/8	77	M	---	---	--	---	---	--
3	06/04/97	3	W	08/01/97	14	F	9/12	18	F	12/6	31	S	1/17	42	S	2/26	55	R	4/16	65	R	6/24	79	W	---	---	--	---	---	--
4	06/13/97	4	F	07/22/97	11	T	10/10	23	F	12/29/98	36	M	1/21	46	W	2/27	58	F	4/17	69	F	5/6	73	W	12/5	116	S	---	---	--
5	06/20/97	5	F	09/12/97	19	F	10/10	24	F	12/12/97	33	F	1/17	44	S	2/26	56	R	4/16	66	R	12/5	115	S	1/14	122	R	---	---	--
6	06/26/97	6	R	07/30/97	13	W	9/19	21	F	01/28/98	48	W	4/24	70	F	9/16	91	W	10/21	99	W	11/10	106	T	12/1	114	T	12/21	117	M
7	07/03/97	8	W	09/12/97	20	F	10/17/97	25	F	12/6	32	S	1/17	43	S	2/26	54	R	4/16	64	R	6/24	78	W	---	---	--	---	---	--
8	07/16/97	10	W	08/21/97	15	R	10/1	22	W	01/21/98	45	W	2/27	59	F	4/17	68	F	5/6	71	W	9/3	87	R	---	---	--	---	---	--
9	07/26/97	12	S	01/05/98	37	M	08/29/98	84	S	09/12/98	90	S	10/4	95	N	10/25	101	N	11/8	105	N	11/22	110	N	1/10	120	N	2/7	129	N
10	10/18/97	26	S	12/12/97	34	F	12/29/98	35	M	01/21/98	47	W	2/27	57	F	4/17	67	F	5/6	72	W	9/3	86	R	---	---	--	---	---	--
11	01/10/98	38	S	02/05/98	50	R	03/25/98	60	W	5/19	74	T	7/13	81	M	8/24	82	M	9/5	88	S	10/1	93	R	11/4	104	W	1/19	124	T
12	10/25/97	27	S	01/10/98	39	S	02/05/98	51	R	03/25/98	61	W	5/19	75	T	7/13	80	M	8/24	83	M	10/1	94	R	---	---	--	---	---	--
13	11/07/97	28	F	01/30/98	49	F	08/29/98	85	S	10/04/98	96	N	10/25	100	N	11/12	109	R	11/24	111	T	1/10	121	N	1/19	127	T	2/7	130	N
14	09/05/98	89	S	09/26/98	92	N	10/11/98	97	N	10/31/98	103	S	11/10	108	T	12/1	112	T	1/7	119	R	1/19	125	T	---	---	--	---	---	--
15	10/12/98	98	M	10/31/98	102	S	11/10/98	107	T	12/01/99	113	T	1/7	118	R	1/22	126	F	2/4	128	R	2/12	131	F	2/22	132	M	---	---	--
	1997									1998									1999											

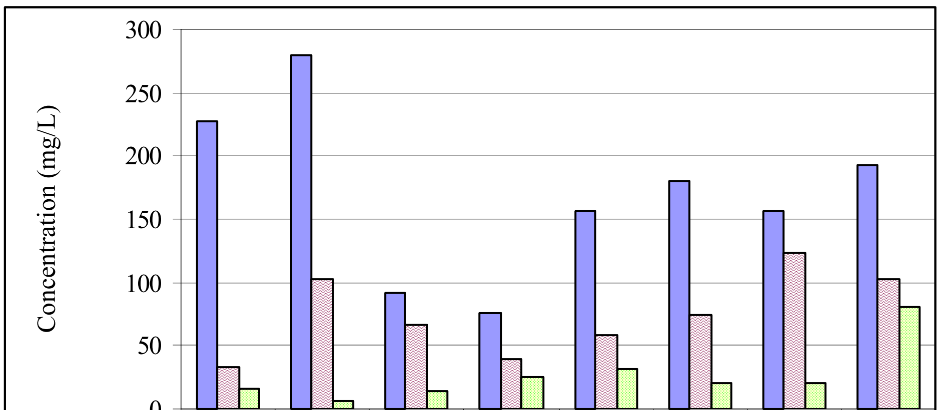
Figures 4-1 through 4-15 show all the results of $CBOD_5$, TSS and O&G for each restaurant site. A table attached to each figure details the actual concentrations for each sample. $CBOD_5$ results not represented graphically are generally due to sample dilutions, which did not deplete at least 2 mg/L dissolved oxygen over the 5-day test period. This means there was not enough depletion (NED) in the sample for a calculated concentration value and an estimate based upon the maximum possible $CBOD_5$ was determined. The corresponding table values have been listed with a *less than* symbol (<) and a computed value based on the dilution of the sample.

$CBOD_5$ samples from Site #4 and Site #5 in October 1997 failed due to excessive holding times and the corresponding values are undetermined. O&G values listed in the concentration table as (<5) represent samples with concentrations less than the minimum detectable limit of 5 mg/L for this analysis and blank table values represent samples not analyzed (Sites 3, 13 and 15).



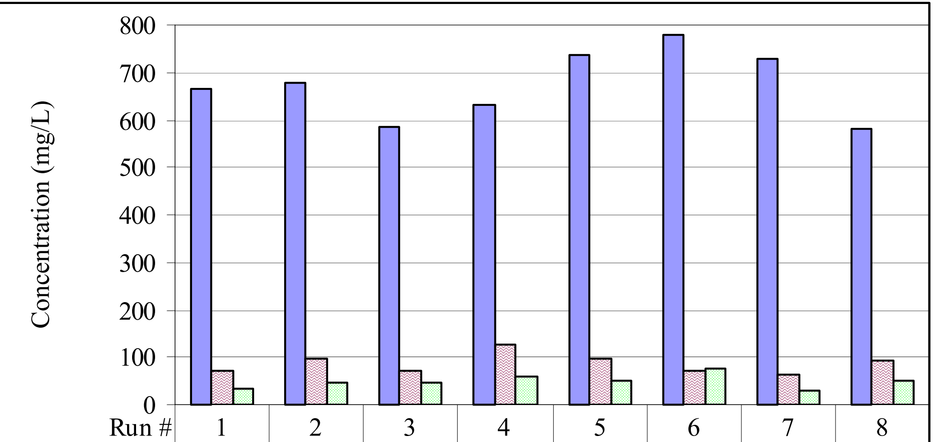
Run #	1	2	3	4	5	6	7	8
CBOD	780	395	623	252	302	315	600	548
TSS	88	72	73	37	50	63	125	97
O&G	65	21	51	47	17	26	85	5711

Figure 4-1. Effluent Concentrations from Site 1



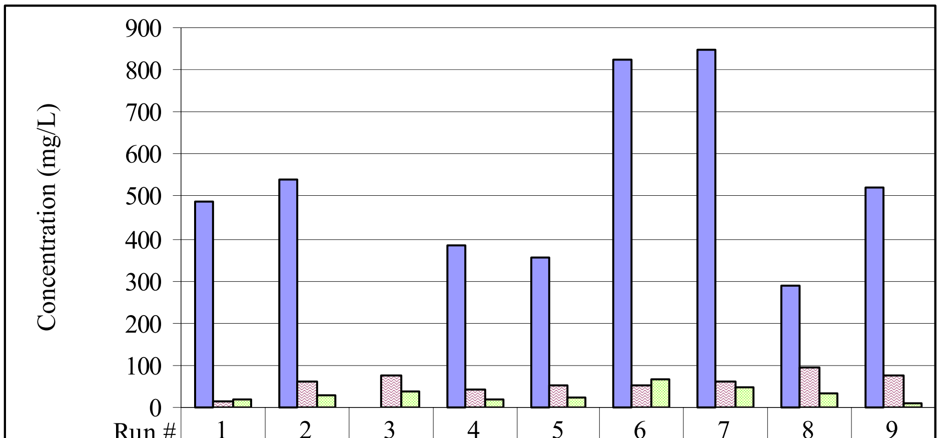
Run #	1	2	3	4	5	6	7	8
CBOD	228	279	91	76	156	180	156	192
TSS	33	103	67	40	58	75	124	103
O&G	15	6	14	26	32	20	20	80

Figure 4-2. Effluent Concentrations from Site 2



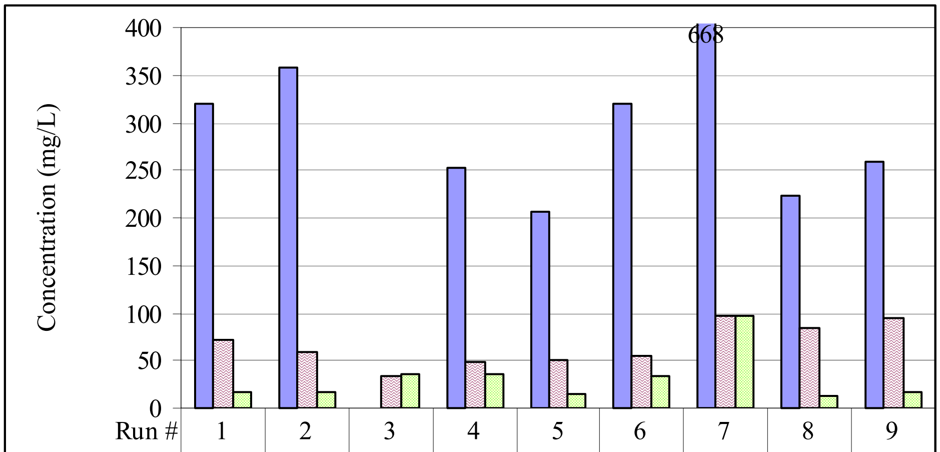
Run #	1	2	3	4	5	6	7	8
CBOD	667	680	585	630	735	780	728	580
TSS	73	98	70	126	99	73	64	94
O&G	34	48	47	59	52	76	30	52

Figure 4-3. Effluent Concentrations from Site 3



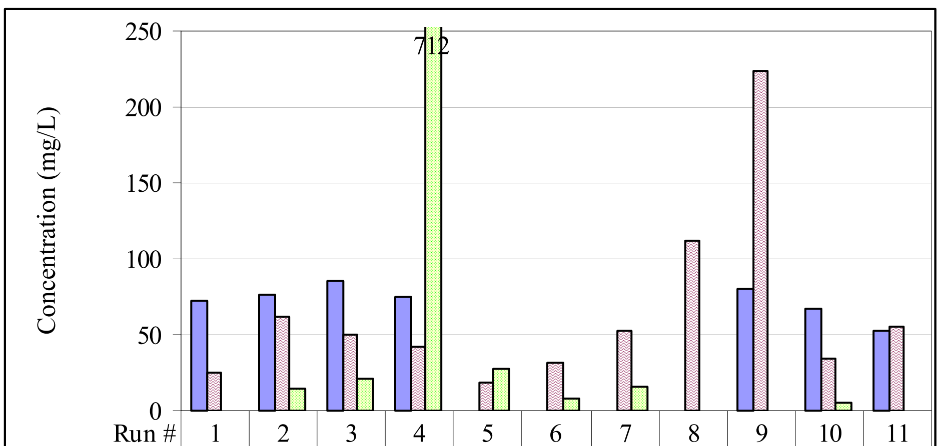
Run #	1	2	3	4	5	6	7	8	9
CBOD	487	540		386	356	825	848	288	520
TSS	16	64	75	43	54	52	64	93	77
O&G	18	28	36	18	24	65	48	32	9

Figure 4-4. Effluent Concentrations from Site 4



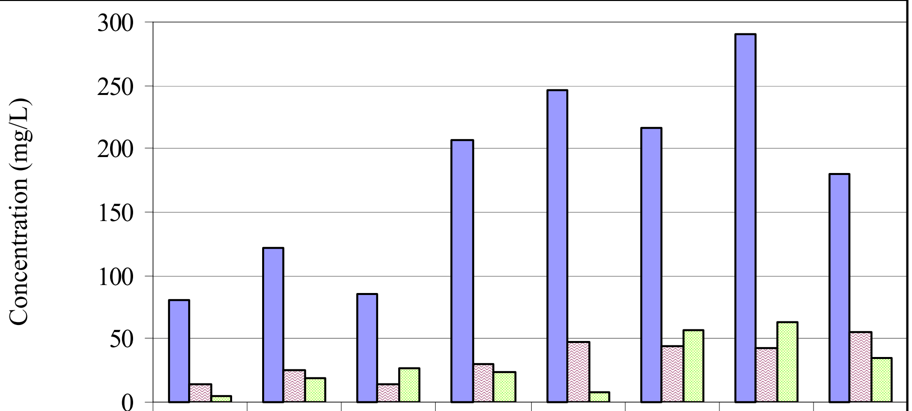
Run #	1	2	3	4	5	6	7	8	9
CBOD	319	357		252	207	321	668	223	258
TSS	72	58	33	49	50	55	97	85	96
O&G	18	16	35	37	16	33	97	13	16

Figure 4-5. Effluent Concentrations from Site 5



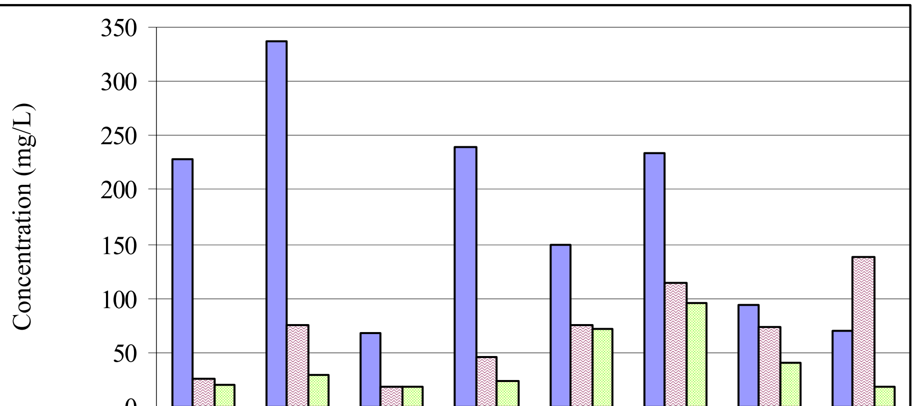
Run #	1	2	3	4	5	6	7	8	9	10	11
CBOD	72	76	86	75	<40	<40	<40	<20	80	67	53
TSS	25	62	50	42	19	32	53	112	223	35	55
O&G	<5	14	21	712	27	8	16	<5	<5	5	

Figure 4-6. Effluent Concentrations from Site 6



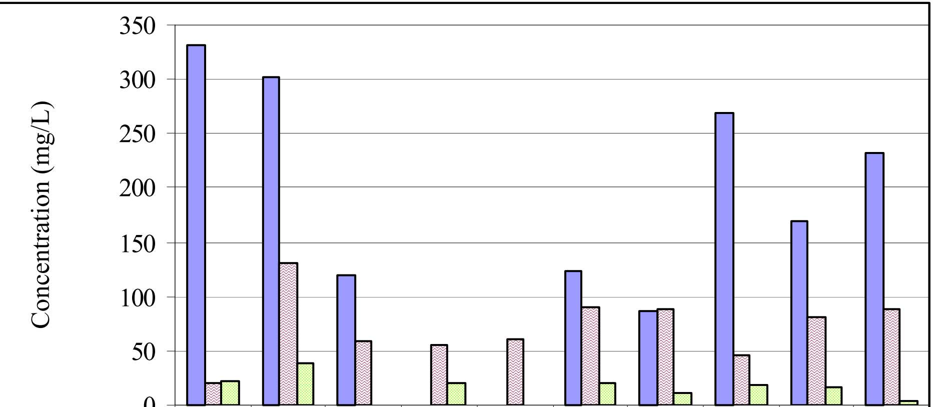
Run #	1	2	3	4	5	6	7	8
CBOD	81	121	86	207	246	216	291	180
TSS	14	25	14	30	48	44	43	56
O&G	5	20	27	23	8	56	63	35

Figure 4-7. Effluent Concentrations from Site 7



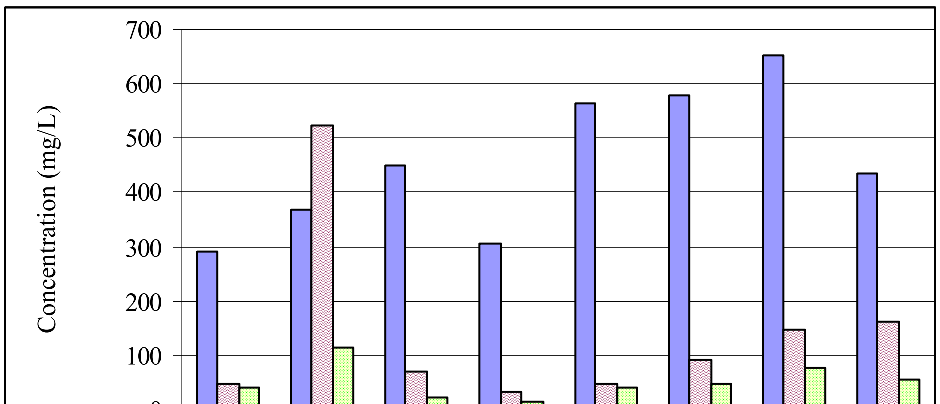
Run #	1	2	3	4	5	6	7	8
CBOD	228	337	69	240	150	234	94	70
TSS	26	75	19	46	75	115	75	139
O&G	20	29	18	24	72	96	40	18

Figure 4-8. Effluent Concentrations from Site 8



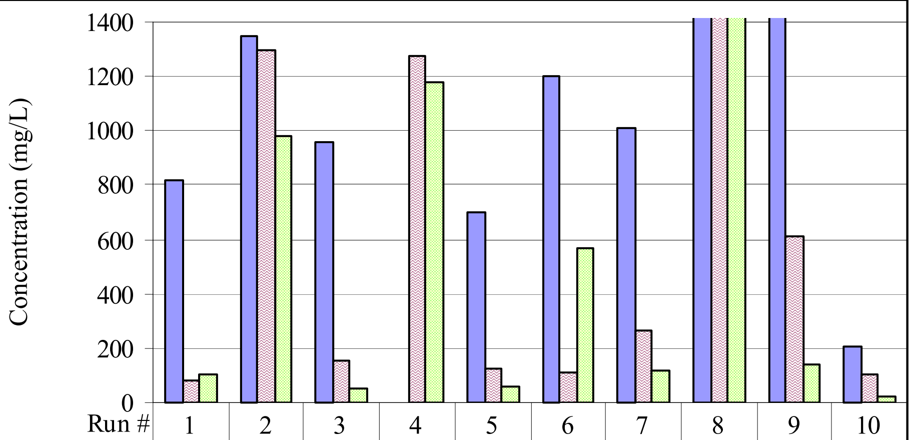
Run #	1	2	3	4	5	6	7	8	9	10
CBOD	332	303	120	<120	<120	123	87	269	169	233
TSS	20	131	59	55	62	90	88	47	81	88
O&G	22	38	<5	20	<5	20	10	19	17	5

Figure 4-9. Effluent Concentrations from Site 9



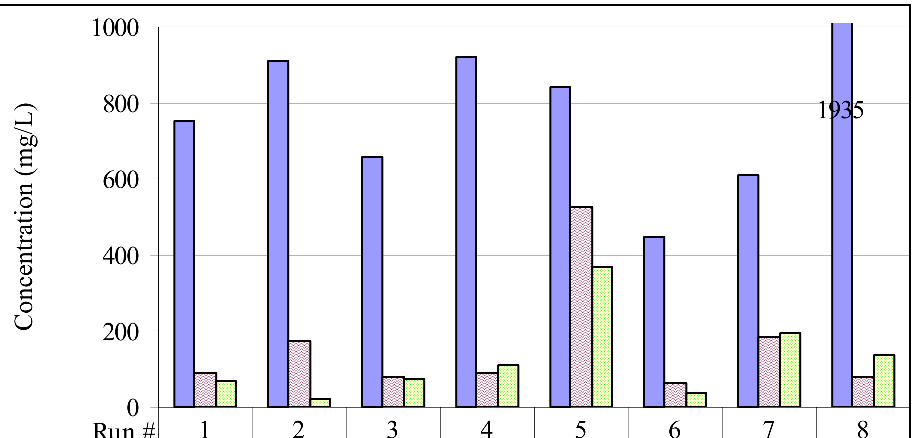
Run #	1	2	3	4	5	6	7	8
CBOD	291	367	450	305	563	578	653	435
TSS	47	524	71	34	47	90	148	164
O&G	42	113	23	14	40	49	78	56

Figure 4-10. Effluent Concentrations from Site 10



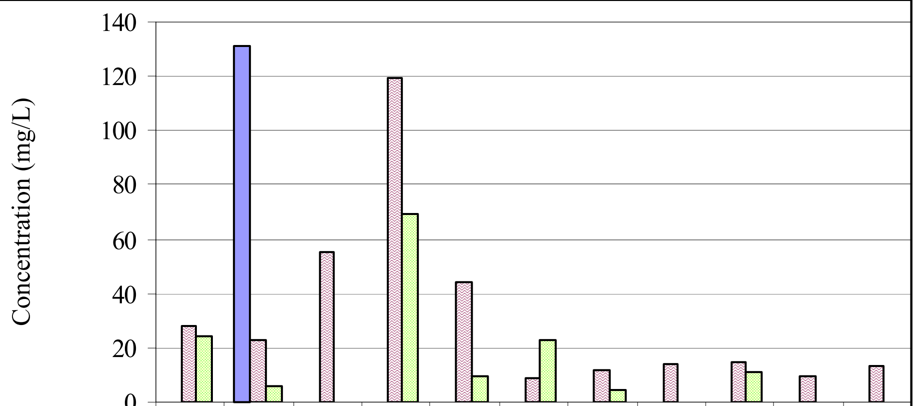
Run #	1	2	3	4	5	6	7	8	9	10
CBOD	818	1350	960	>2100	698	1200	1009	4080	1853	207
TSS	79	1293	154	1277	126	108	268	1774	608	105
O&G	100	983	51	1182	56	569	115	7160	138	23

Figure 4-11. Effluent Concentrations from Site 11



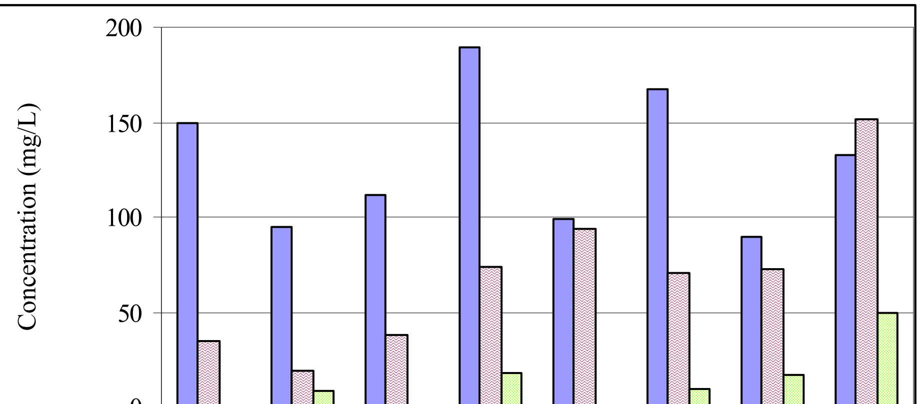
Run #	1	2	3	4	5	6	7	8
CBOD	755	910	660	920	840	450	608	1935
TSS	88	172	80	92	528	64	182	81
O&G	68	22	74	112	367	38	196	137

Figure 4-12. Effluent Concentrations from Site 12



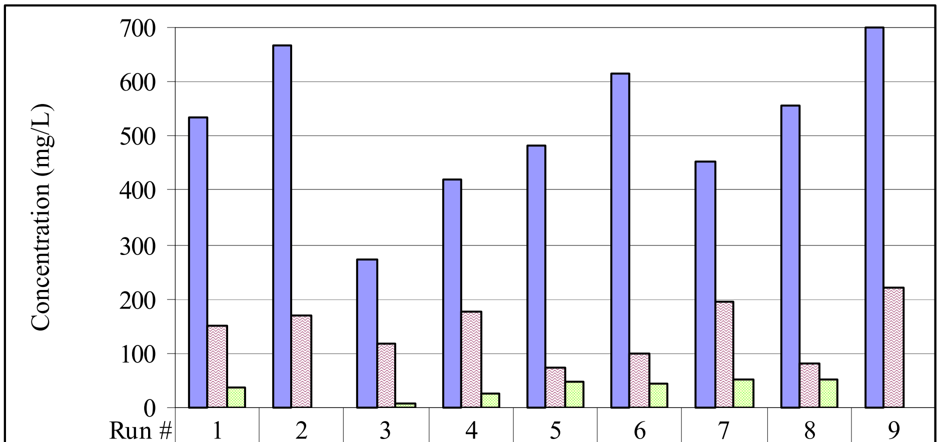
Run #	1	2	3	4	5	6	7	8	9	10	11
CBOD	<40	131	<40	<40	NED	NED	NED	NED	NED	NED	NED
TSS	28	23	56	119	44	9	12	14	15	10	13
O&G	24	6	<5	69	10	23	5	<5	11	<5	

Figure 4-13. Effluent Concentrations from Site 13



Run #	1	2	3	4	5	6	7	8
CBOD	150	95	112	189	99	167	89	133
TSS	34	19	38	74	93	70	73	152
O&G	<5	8	<5	18	<5	9	17	49

Figure 4-14. Effluent Concentrations from Site 14



Run #	1	2	3	4	5	6	7	8	9
CBOD	533	668	271	421	482	616	454	558	699
TSS	151	169	118	177	75	100	195	80	222
O&G	38		9	25	49	43	53	50	

Figure 4-15. Effluent Concentrations from Site 15

Statistical analysis of the data consisted of Analysis of Variance (ANOVA) using the Statistical Analysis System software (SAS). The data were grouped into three categories of strength of wastewater: high, medium and low. Grouping iterations were repeated until the most significant difference in the means between the three groups was found while keeping the variation and p-value within the groups at a minimum. Sample concentrations over 1200 mg/L BOD, 1000 mg/L TSS and 200 mg/L O&G were considered outliers and not a statistically representative sample. The outliers were therefore not included in the analysis to determine the three waste strength categories or the characterization of each restaurant site. The results of the statistical analysis are presented in Table 4-2 through Table 4-4.

Table 4-2. Analytical Results for Carbonaceous Biochemical Oxygen Demand (mg/L)

Sites	N	Mean	St Dev	Range	Median
1	8	477	188	(252-780)	472
2	8	170	67	(76-279)	168
3	8	673	72	(580-780)	674
4	8	531	207	(288-848)	504
5	8	326	148	(207-668)	289
6	7	73	11	(53-86)	75
7	8	178	76	(81-291)	194
8	8	178	97	(89-337)	189
9	8	204	92	(87-332)	201
10	9	428	149	(207-653)	435
11	4	871	141	(698-1009)	889
12	7	735	173	(450-920)	755
13	1	131	*	131	131
14	9	129	37	(89-189)	133
15	8	500	124	(271-668)	508
All Data	109	374	255	(53-1009)	302
Low	33	111	39	(53-189)	95
Medium	44	324	99	(192-540)	307
High	32	712	125	(548-1009)	674

* - Only one sample included in analysis due to NED of remaining samples

Table 4-3. Analytical Results for Total Suspend Solids (mg/L)

Sites	N	Mean	St Dev	Range	Median
1	8	76	28	(37-125)	72
2	8	75	32	(33-124)	71
3	8	87	21	(64-126)	84
4	9	60	22	(16-93)	64
5	9	66	22	(33-97)	58
6	11	64	58	(19-223)	50
7	8	34	16	(14-56)	36
8	8	71	41	(19-139)	75
9	10	72	31	(20-131)	71
10	7	86	52	(34-164)	71
11	6	140	68	(79-268)	117
12	7	109	48	(64-182)	88
13	11	31	33	(9-119)	15
14	8	69	42	(19-152)	71
15	10	148	54	(75-223)	159
All Data	128	77	49	(9-268)	72
Low	60	39	17	(9-64)	43
Medium	53	90	17	(67-126)	88
High	15	181	37	(139-268)	169

Table 4-4. Analytical Results for Oil and Grease (mg/L)

Sites	N	Mean	St Dev	Range	Median
1	7	44	25	(17-85)	47
2	8	27	23	(6-80)	20
3	8	50	14	(30-76)	50
4	9	31	17	(9-65)	28
5	9	31	26	(13-97)	18
6	9	11	10	(5-27)	8
7	8	30	21	(5-63)	25
8	8	40	29	(18-96)	27
9	10	15	11	(5-38)	18
10	8	52	32	(14-113)	45
11	6	81	44	(23-138)	78
12	7	93	60	(22-196)	74
13	10	15	21	(5-69)	8
14	8	14	16	(5-49)	9
15	7	38	16	(9-53)	43
All Data	122	36	33	(5-196)	24
Low	65	14	14	(5-26)	16
Medium	35	41	9	(27-56)	40
High	22	92	33	(56-196)	79

A Wisconsin study (Siegrist et al., 1984) compared the concentrations of restaurant and domestic effluent quality. Ranges for domestic effluent concentrations for BOD (118 to189 mg/L), TSS (41 to55 mg/L) and O&G (6.4 to 8.4 mg/L) were reported. Ranges for restaurant effluent concentrations for BOD (101 to 880 mg/L), TSS (44 to 372 mg/L) and O&G (24-144 mg/L) were reported as averages for three small communities. The results of an individual household effluent, which were used for their lysimeter study, listed BOD as 132 mg/L and TSS as 87 mg/L (Siegrist et al., 1984). The concentration of CBOD, TSS and O&G for the low strength categorization of wastewater in this study is 111, 39 and 14 mg/L, respectively. The concentrations for CBOD and TSS are slightly less than the concentration ranges given for domestic effluent in the Siegrist study. The O&G concentration was 5.6 mg/L greater than domestic concentrations but 10 mg/L less than the concentration of restaurant effluent.

Figures 4-16 through 4-18 show a graphical representation of the statistical analyses of field data for $CBOD_5$, TSS and O&G. The ranges of the wastewater strength categories are color-coded: high strength has dark shading, medium strength has light shading and the low strength is not shaded. The horizontal lines indicate the parameter range of concentrations or variance for each site. The data points on the site lines of Figures 4-16 through 4-18 represent the four-quartile ranges with each range between points representing 25% of the data. This equates to the data points representing the minimum value, first quartile, second quartile (median value), third quartile, and maximum concentration values of the restaurant samples. For example, using the Categorization of $CBOD_5$ per Site, Figure 4-16 shows that over 75% of the samples collected from Site #5 fall into the medium strength waste category while less than 25% of the samples for Site #12 can be considered medium strength.

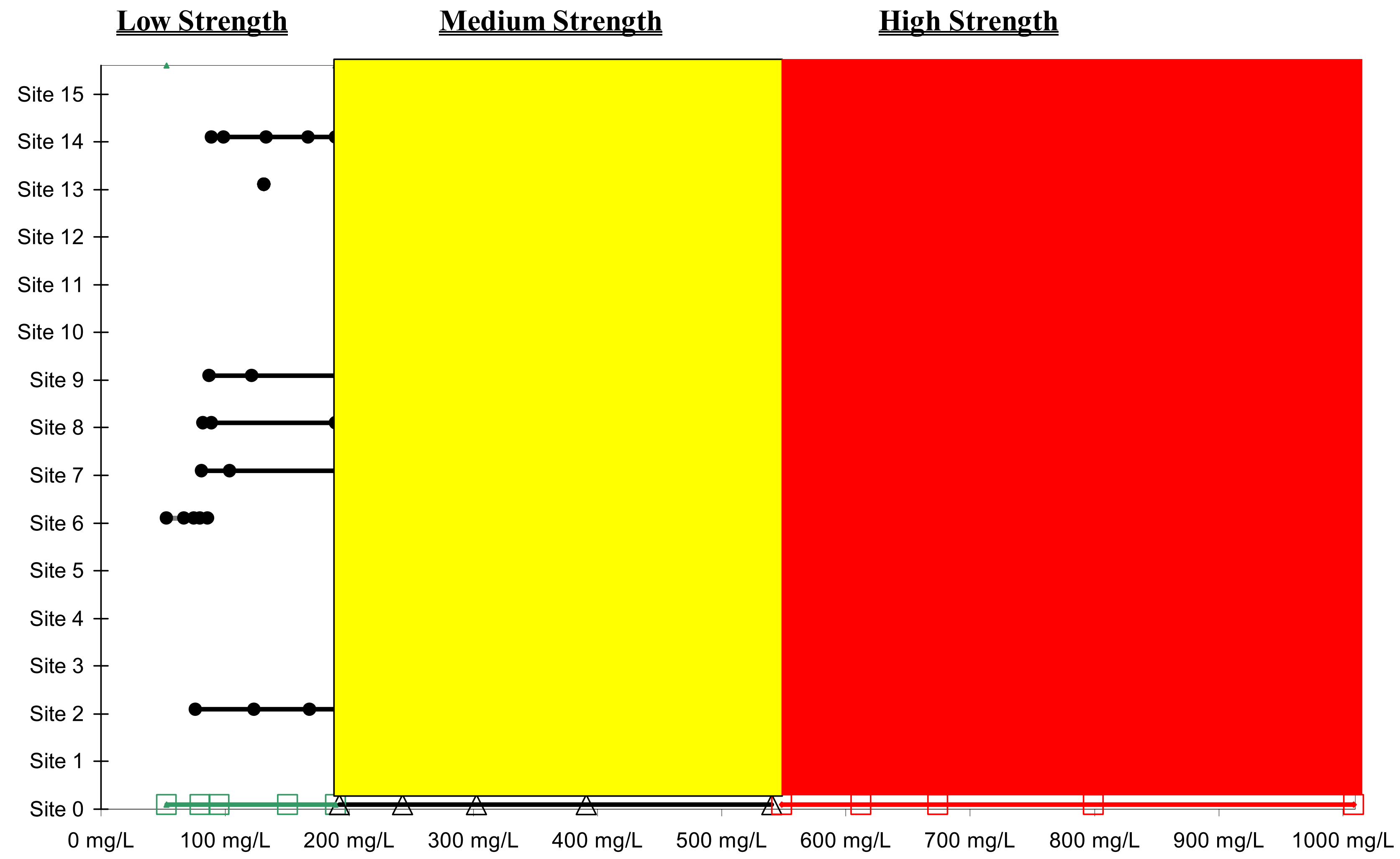


Figure 4-16 Categorization of CBOD per Site

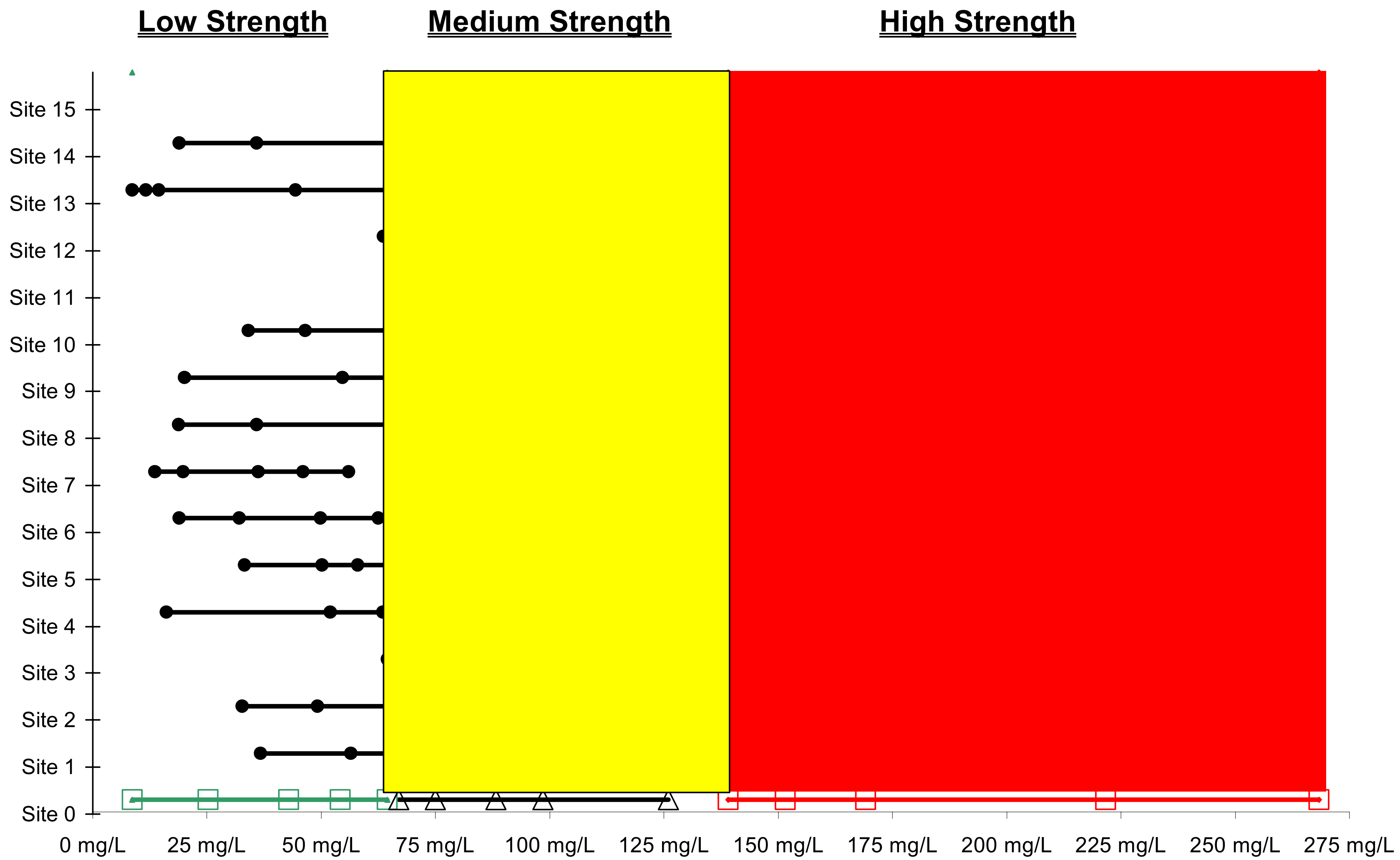


Figure 4-17 Categorization of TSS per Site

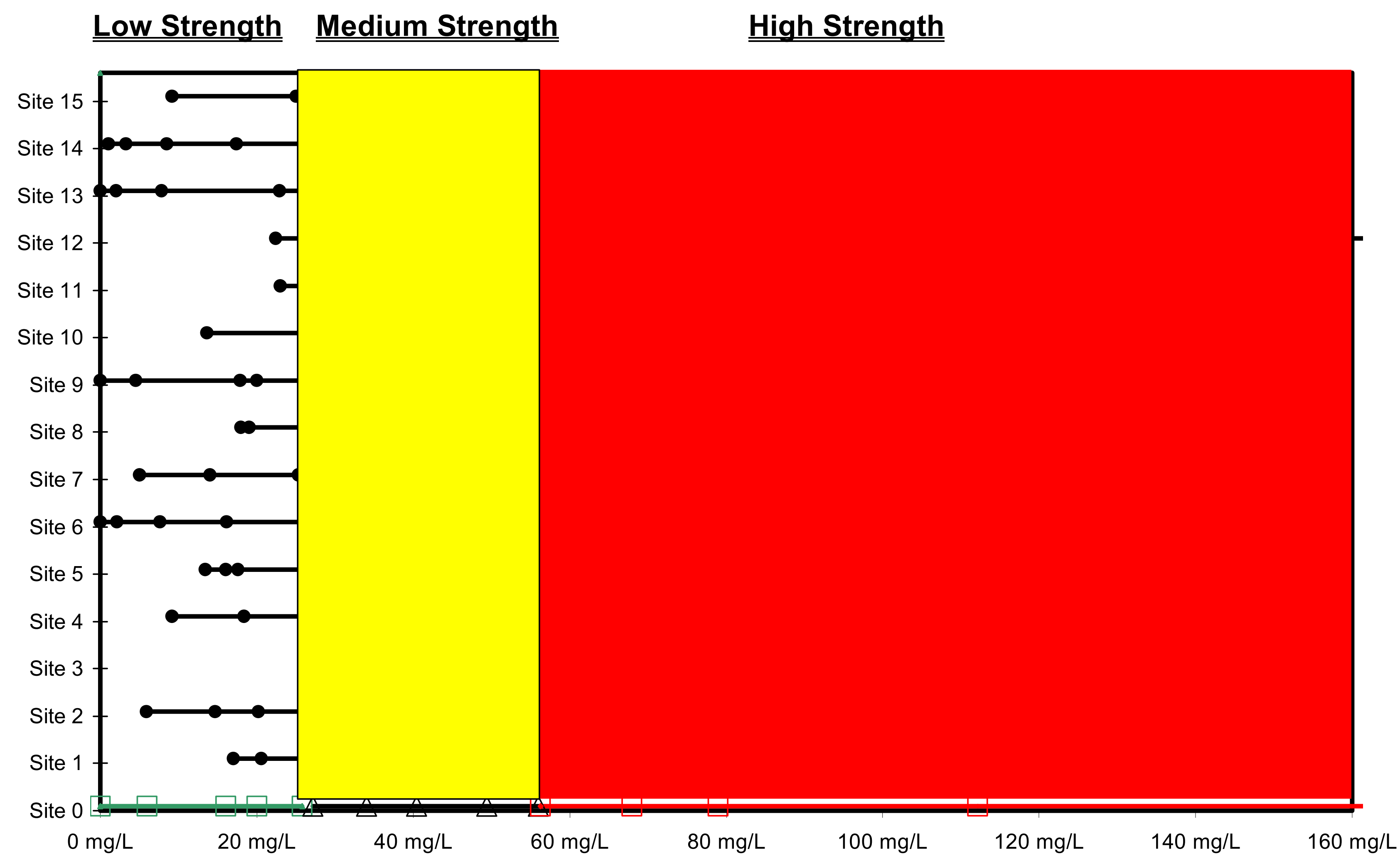


Figure 4-18 Categorization of O&G per Site

Sites #11 and #12, both described in the high strength category, had the most variability in their respective results (Figures 4-11 and 4-12). A twelve-year-old drainfield at Site #11 was replaced in June 1998, falling between sampling events 4 and 5 (Figure 4-11). Figure 4-11 then shows that sample 8, taken six months after installing the new drainfield, was loaded with extremely high concentrations of $CBOD_5$, TSS and O&G with 4080 mg/L, 1774 mg/L and 7160 mg/L, respectively. Site #12 (Figure 4-12) had peak values of TSS and O&G during sampling event 5. The owner remarked that "spring cleaning" coincided with that time period.

Site #3 (Figure 4-3) had remarkably consistent results throughout the study when compared to the other sites. This is an indication of a well-maintained system. This system is operating at capacity with both TSS and O&G falling in the medium strength ranges and $CBOD_5$ in the high range (Figures 4-16 through 4-18).

The results from Site #14 (Figure 4-14) imply that the OSTDS has effective wastewater treatment, but site observations during sampling proved this is not the case. The lift station did not have a permanent lid covering the access hole; rather, a piece of wood paneling was used as a cover. On two separate sampling events wastewater was observed to have previously overflowed the tank and collected in a depression near the lift station access hole. Mosquitoes had capitalized on the constant access to standing water in the tank and had reproduced to such an extent that they swarmed. Due to a missing tank lid, the low values for BOD (Figure 4-16) and O&G (Figure 4-18) could be attributed to the ponded conditions of the lift station.

Sites #6 and #13 use Nibbler aerobic treatment systems that reduced waste strengths to the low strength category (Figures 4-16 through 4-18). This level of effluent quality is expected for systems with aerobic treatment units, but the sites did have some exceptions. Site #6 had an extremely high value of 712 mg/L for O&G on sample run four and a TSS value of 223 mg/L on run nine. Both events are unusual for this site based on the analysis of the remaining ten samples. Site #13 had one sampling event with high concentrations for TSS and O&G during run four. $CBOD_5$ for Site #13 was difficult to analyze. The presence of chlorine was detected using HACH Free and Total Chlorine Reagent Powder Pillows. Analysis with a HACH DR 2000 Spectrophotometer (Method 80) reported values of 41 mg/L total chlorine and 32 mg/L free chlorine for sample six. Chlorine was detected in three subsequent samples. $CBOD_5$ results in Figure 4-13 were reported as NED; because of interference caused by the presence of chlorine, estimation of $CBOD_5$ based on sample dilution was deemed unreliable. These two sites overall had the lowest concentrations of constituents in the wastewater effluent when compared to the standard septic tank systems of the remaining sites.

Long Term Acceptance Rate Study

A total of 76 lysimeters were built and packed with four soil types under two saturation conditions with triplicate columns and dosed with a synthetic wastewater derived from values of each of the three categories of wastewater determined from the restaurant characterization. The lysimeters were dosed twice a day for 112 days with synthetic wastewater comprised of dextrose, vegetable oil, SPAM and dog food. Dosing began March 10, 2000, and continued through June 30, 2000.

The aforementioned Wisconsin study (Siegrist et al., 1984) conducted a similar LTAR experiment with 4-inch lysimeters dosed with effluent from a domestic OSTDS (concentrations correspond to the low strength wastewater category) and a restaurant OSTDS (concentrations correspond to the high strength waste category). It was presumed that wastewater strength would determine the order of column failure with the high strength lysimeters failing or clogging before the medium strength. Failure in the high strength columns was predicted to be 29 days or less (Siegrist et al., 1984). Lysimeters dosed with medium strength wastewater were expected to clog within 60 days from the first loading. The medium strength wastewater target concentration was approximately half that of the high strength wastewater, thus complete failure was expected to take twice as long. The columns dosed with low strength wastewater were not expected to fail during the course of the experiment. Lysimeters loaded with domestic strength wastewater in the Wisconsin study had no ponding on the soil infiltration surface during the 67 days of dosing (Siegrist et al., 1984).

Failure would be attributed to a combination of both physical and biological clogging. However, it was assumed that physical clogging would be the dominant factor for failure of the high strength wastewater columns since biomat formation is not an immediate (Amoozegar, 1998).

Synthetic Wastewater

A total of sixty-four samples of the synthetic wastewater were analyzed for $CBOD_5$ and TSS and thirty-five samples were analyzed for O&G (Table 4-5). There was a considerable difference between the target values (Table 4-6) and actual influent concentrations of O&G for the medium and high strength synthetic wastewater. Particles in the wastewater adhered to the sides of the batch container, the magnetic stir bar and the marble tile (spinning surface for stir bar). The high strength waste had the greatest loss of components, which was evident when the container was cleaned before each new batch. The surface of the stir bar, marble tile and batch container had a "greasy" coating after each batch was complete. In addition, scum lines formed on the interior walls of the batch container marking the water line after each dose. The medium strength container had less distinct water lines and particle loss than the high strength. Low strength was relatively clean in comparison with no visible deposition of particles. However, the stir bar had a slightly "greasy" feel when cleaned.

The high strength waste had more particle deposition on the aggregate above the soil surface compared to the medium and low strength synthetic wastewater. The adhesion of O&G and TSS in the batch container formed "sheets" of particles that did not entirely break up into solution as with the medium strength and low strength wastewater. Particulate was visible on

Table 4-5. Target Concentrations for Synthetic Wastewater

Waste Strength	CBOD mg/L Mean	CBOD mg/L StDev	TSS mg/L Mean	TSS mg/L StDev	O&G mg/L Mean	O&G mg/L StDev
High	712	125	181	37	92	33
Med	325	99	90	17	41	9
Low	112	39	39	17	14	8

Table 4-6. Synthetic Wastewater Concentrations

Batch Number	CBOD (mg/L) High	CBOD (mg/L) Med	CBOD (mg/L) Low	TSS (mg/L) High	TSS (mg/L) Med	TSS (mg/L) Low	O&G (mg/L) High	O&G (mg/L) Med	O&G (mg/L) Low
1	967	508	161	136	129	30	47	33	19
3	822	379	134	282	123	59	59	35	12
4	845	602	185	237	145	75	69	42	14
6	654	247	84	254	134	48	-[b]	-[b]	-[b]
7	710	340	100	185	119	50	61	52	12
9	757	208	40	168	109	41	-[b]	21	-[b]
10	759	233	87	196	124	53	49	28	9
12	652	213	116	109	107	33	-[b]	-[b]	-[b]
13	618	165	30	200	183	38	63	58	11
14	494	293	108	152	70	33	-[a]	28	10
17	610	126	64	112	101	54	-[a]	33	18
18	679	419	135	102	86	36	32	31	-[b]
21	607	342	117	100	73	39	-[b]	-[b]	-[b]
24	-[a]	393	53	-[a]	91	70	47	23	-[b]
25	498	304	76	69	87	57	21	15	6
28	577	282	70	176	150	54	72	20	16
32	556	259	87	46	126	51	-[b]	-[b]	-[b]
35	628	355	79	245	123	54	-[b]	-[b]	-[b]
38	345	131	-[a]	201	116	-[a]	25	13	-[b]
42	402	268	91	141	102	57	-[b]	-[b]	-[b]
45	632	376	133	134	99	40	-[b]	-[b]	-[b]
48	621	335	127	194	72	45	-[b]	-[b]	-[b]
n	21	22	21	21	22	21	11	14	10
Mean	640	308	99	164	112	48	50	31	13
Stnd Dev	144	115	39	62	28	12	17	13	4
Median	628	299	91	168	113	50	49	30	12

a – Sample jar broken
b – Sample not collected

top of the aggregate rock after dosing, suggesting that the entire high strength wastewater concentration may not have contacted the soil surface.

Column Failure

Column failure or clogging occurs when the permeability of the soil interface below the simulated drainfield becomes limiting so as to prevent the percolation of wastewater through the media. Clogging prevents rapid flow through the sequence of the larger pores and does not require plugging of all the pores. Specifically for this study, failures were recorded before the morning dose based on the water level of wastewater being above the drainfield aggregate. The aggregate line represents the location of the simulated discharge pipe. If this condition were to occur in a restaurant situation, it could cause sewage backup into the facility. Indications of clogging showed approximately one two weeks before actual column failure. During this period prior to clogging, water at or near the aggregate line was observed after the evening dose but would percolate through the soil overnight. Water was not noticeable in columns operating without failure. Another indicator of failure is in the measurement of column effluent, which shows a sudden decrease of volume flowing through the column immediately prior to failure. Failure is recorded in Figure 4-20 by the number of days the lysimeters were dosed, and is shown with a dark box around the lysimeter circle.

The plan view of the twenty-four low strength columns is shown on Figure 4-19. There were no column failures during the 112 days of testing. In addition, there were no indications of failure such as ponding or decrease in the effluent volume measurement.

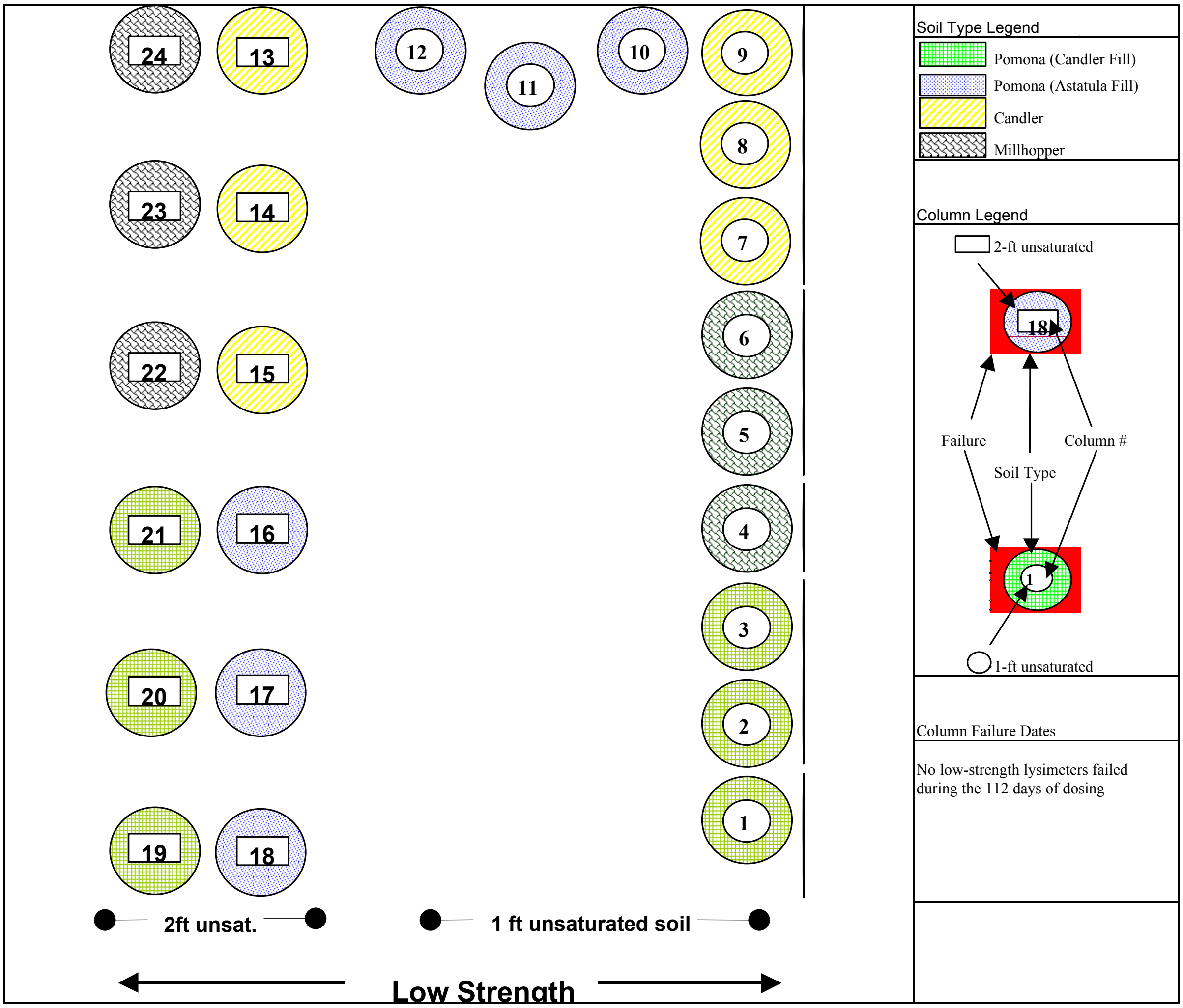


Figure 4-19. Column Failure for Low Strength Wastewater

The plan views of the forty-eight lysimeters dosed with medium strength wastewater and high strength wastewater are illustrated in Figure 4-20. The forty-eight experimental lysimeters are divided into two sets of twenty-four columns based on dosing strength of the synthetic wastewater loaded during experimentation. Columns #25 through #36 are packed with the specified four soil types, dosed with medium strength wastewater and have two-feet of variably unsaturated soil below the simulated drainfield. Columns #37 through #48 are identical to the first twelve lysimeters except that the saturation condition has only one-foot of variably unsaturated soil. Each condition has triplicate columns and each soil type has a texture coding (Figure 4-20). The experimental setup of the high strength (columns #49 through #72) and low strength categories (columns #1 through #24) are mirror images of the medium strength set. Column failure is indicated by a shaded square block around the column and the corresponding date of failure reported in days. Columns not shaded did not fail in the 112 days of testing.

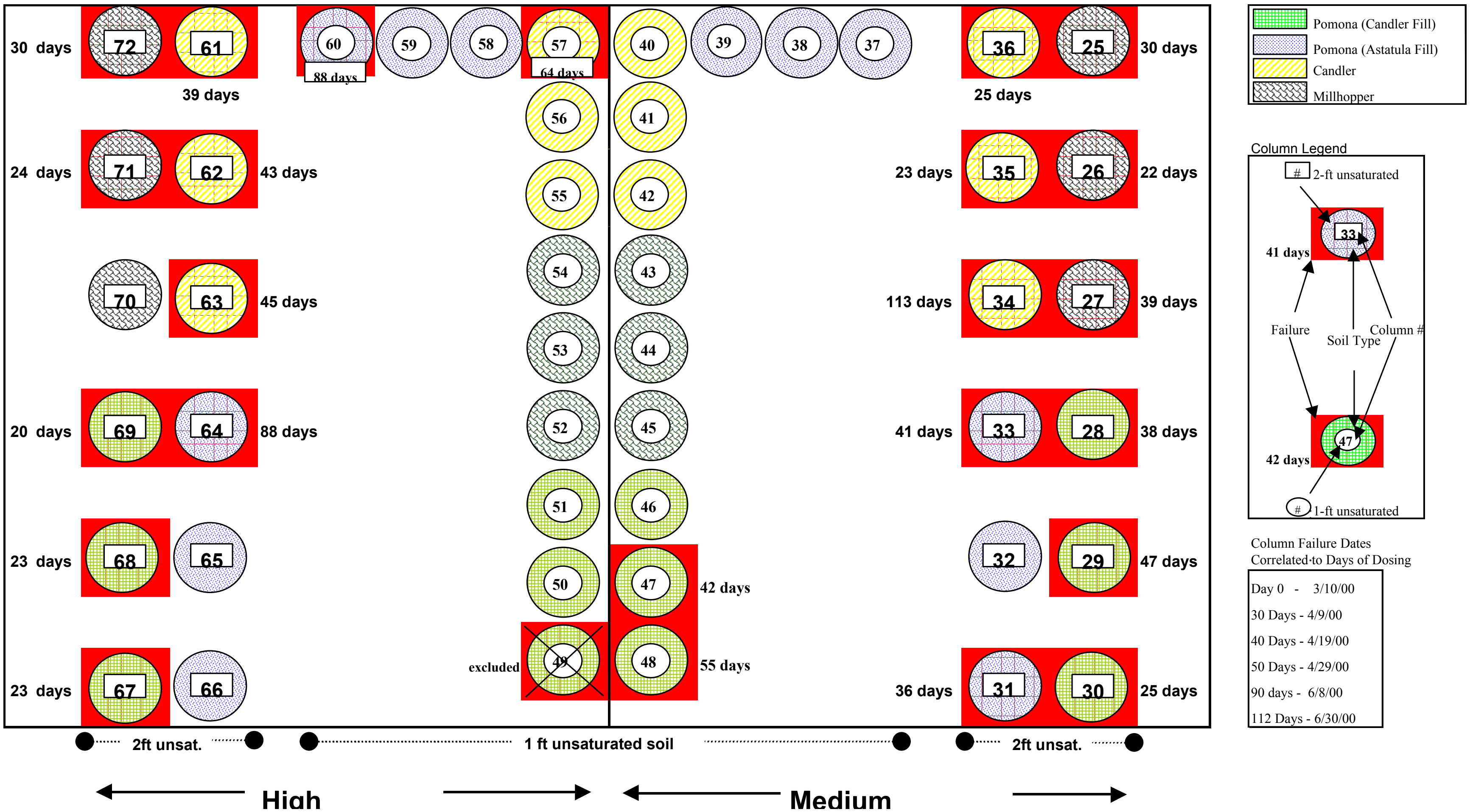


Figure 4-20. Column Failure for Medium and High Strength Wastewater Columns

One foot unsaturated columns

Only four columns with one foot of unsaturated soil (two medium and two high) failed. Failure for column #60 (Pomona with Astatula fill) was declared on day 88 prior to the morning dose due to the presence of aqueous solution above the aggregate line from the previous day's dosage. However, indications of failure were present on day 57 including both visible ponding and a decrease in the volume measurement of the column effluent. A Candler column (#57) clogged in the high strength category and columns #47 and #48 (Pomona with Candler Fill) failed in the medium strength category. Column #49 was excluded from the study due to soil breakthrough of the column drainage filter. Soil poured into the vinyl tubing and impeded water flow.

Within 15 minutes after every dose, all of the columns with one foot of unsaturated soil had water collection in the air ports. The water level in the air ports rose approximately three inches before seeping back into the column. There were approximately four inches of unsaturated soil between the imposed water table and the bottom of the air ports in the columns with a one-foot unsaturated zone. Water storage in the air ports suggests that the four inches of soil above the water table did not have sufficient pore space to retain the solution. This effect did not occur in columns with a two-foot zone (approximately ten inches of unsaturated soil between the imposed water table and air port).

Moisture content in the vadose zone (unsaturated soil between the water table and soil surface) differed between the one- and two-foot unsaturated columns. The soil in the imposed vadose zone is variably unsaturated. Water remains in small voids in the soil due to increasing capillary pressure, thus soils are not completely dry. The lowest limit of water retention in soils is known as the "residual volumetric water content" (Domenico and

Schwartz, 1998) or field capacity. Soil inches above the water table may be essentially saturated although the soil water is under suction.

Water content in unsaturated soil is dependent on soil texture and pore size distribution. In this study, the soil texture in the vadose zone included sand, fine sand and loamy sand. The Candler soil is a fine sand with a high hydraulic conductivity. Millhopper is classified as a loamy sand, however the texture in the first 48 inches is sand. The texture of soils in columns packed with Pomona and Astatula Fill are fine sands. The Pomona with Candler Fill columns have textures of fine sand and loamy sand, respectively. The Candler Fill was excavated from a sandpit at a depth greater than 109 inches where the texture of Candler becomes loamy (Thomas et al., 1985).

Figure 4-21 gives the general volumetric water content curves for sand, fine sand and silty sand. These general relationships between soil texture and the pressure head versus volumetric water content can be applied to the saturation conditions found in this study. Sands have lower water retention than fine sand and reach field capacity at a higher pressure head. In addition, sands and fine sands require at least 24 inches of soil above the water table to reach the residual volumetric water content (Figure 4-21).

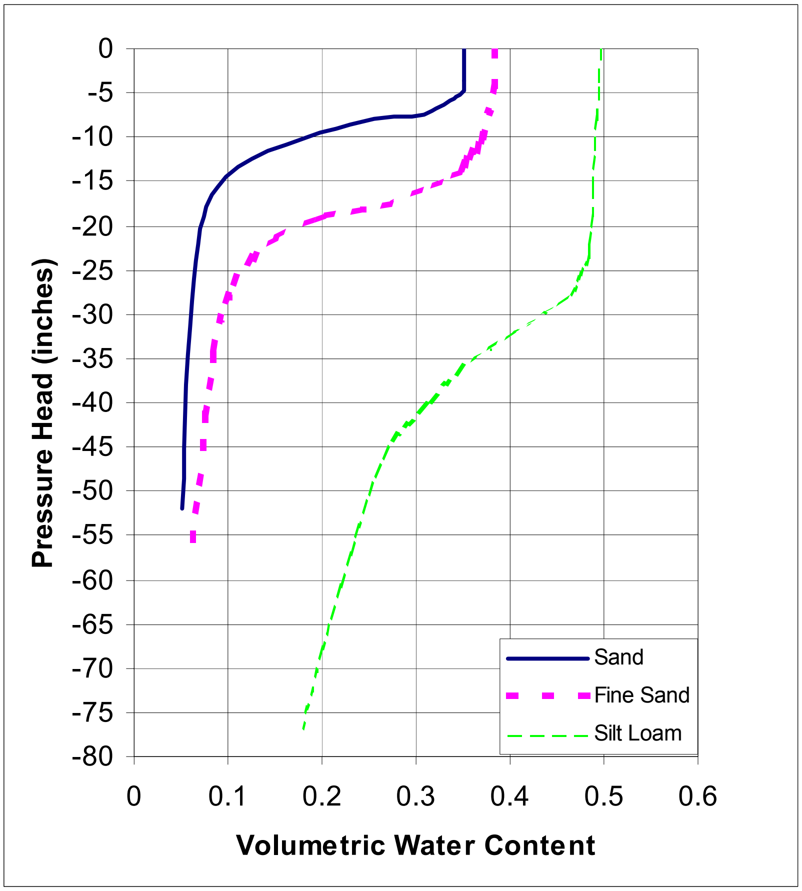


Figure 4-21. Volumetric Water Content of Soils (Adopted from Domenico and Schwartz, 1998)

Columns with 12 inches of unsaturated soil are partially saturated throughout the vadose zone and soil immediately below the air ports is saturated. Thus, the temporary storage of wastewater in the airports on the one-foot unsaturated columns is a result of pressure head. Saturation conditions immediately change during the dosing periods where water content increases.

Hydraulic conductivity is a function of the moisture content or pressure head. Soils at or near saturation have a maximum hydraulic conductivity (Domenico and Schwartz, 1998). Thus, flow in columns with one foot of unsaturated soil is greater than flow in columns with two feet of unsaturated soil due to increased water retention in the soil.

Two-foot unsaturated columns

Failure occurred primarily in columns with two feet of unsaturated soil. Additionally, columns dosed with the medium and high strength wastewater failed during the same time period with no lag period between the two strengths. Twenty of the two-foot unsaturated columns (eleven medium strength and nine high strength) and four of the one-foot unsaturated columns (two medium strength and two high strength) failed in the 112 days of experimentation. Eighteen of the two-foot unsaturated lysimeters failed between 20 days and 47 days from the start of dosing. The last two-foot unsaturated columns to fail were column #34 and column #64, which failed on day 113 and 88, respectively. Column #34 was declared failed on day 113 before the morning dosage of synthetic wastewater. It has been included in the resulting presentation because column failure was a result of the 112th dosage day. The four failures for the one-foot unsaturated columns occurred between day 42 and day 88.

Some inconsistencies are apparent in the two-foot unsaturated columns for both medium and high strength waste categories. The medium strength category had two columns (#32 and #34) that did not fail with the corresponding replicates. Both columns had a higher hydraulic conductivity prior to wastewater loading compared to their replicates. Column #34 (Candler) failed 89 days after the replicate columns #35 and #36. The hydraulic conductivity for column #34 was 32.53 in/hr, which was 3.04 and 6.94 in/hr greater than the Candler replicates with no significant difference in average packing density (93.31 lb/ft^3). However, the density of the top most layer of Candler soil for column #34 had a density of 89.90 lb/ft^3. Column #32 (Pomona with Astatula Fill) did not fail in the 112-day LTAR study compared to replicate columns #31 and #33, which failed in 36 and 41 days, respectively. Column #32 had a hydraulic conductivity of 0.83 and 1.91 in/hr higher than the Pomona with Astatula Fill replicates with no significant difference in density.

The two-foot unsaturated high strength columns had four columns (#64, #65, and #66) that did not fail in the time period of 20 to 47 days. Column #70 (Millhopper) did not fail during the 112-day study and was receiving wastewater 80 days beyond replicate columns #71 and #72. Hydraulic conductivity was 17.15 in/min and 1.72 in/min higher than failed Millhopper column #72 but 0.46 in/min less than column #71. Column #64 failed after 88 days and columns #65 and #66 did not fail during the study. All three columns had hydraulic conductivity between 13.03 and 14.25 in/min and density between 96.96 and 95.91 lb/ft^3.

There are side notes concerning columns #34, #64 and #65. Column #34 had visible aqueous solution below the top of the aggregate line on day 21. Aqueous solution was visible in the evening but had percolated through the soil by morning. Signs of failure for column #34 were noted during the time period when the replicate columns were declared failed (day 23 and 25), however failure for #34 took an additional 89 days. Column #64 had visible ponding above the aggregate line on day 57. Based on the previous column failures, it should not have taken more than 14 days for failure (declared prior to the morning dose) once water is first observed on previous day. However, this column required 30 days. Column #65 had ponding near the aggregate line at the same date. Six days later, no ponding was visible and the column did not fail during experimentation. There is a possibility that the pressure head on the column was sufficient to “blow” out the biofilm at the soil interface and create a hydraulic channel.

A general linear model (GLM) was performed using the SAS system with the model including main effects and two factor interactions. Any interaction with a statistical p-value greater than 0.25 was removed from the model. With a significance level of 0.05, the interaction between mass loading and soil type was found to be significant. Interactions between soil type and waste strength were also found to be significant. The GLM R^2 fit was 0.9998. The mean and standard deviation for medium and high strength wastewater are found in Table 4-7.

Table 4-7. Mean Days to Failure for Two-Foot Unsaturated Columns

	Candler	Millhopper	Pomona with Candler	Pomona with Astatula	Synthetic Wastewater
N	3	3	3	2	Medium Strength
Mean	53.7	30.3	36.7	38.5	Medium Strength
St.Dev.	51.4	8.5	11.1	3.5	Medium Strength
N	3	2	3	1	High Strength
Mean	42.3	27.0	22.0	88 *	High Strength
St.Dev.	3.1	4.2	1.7	*	High Strength
N	6.0	5	6	3	All Data
Mean	48.0	29.0	29.3	55.0	All Data
St.Dev.	33.1	6.6	10.7	28.7	All Data
Median	41.0	30.0	24.0	41.0	All Data

*-One column of three failed.

Days to failure versus wastewater loading rate with respect to wastewater strength are presented in Figure 4-22. Failure in the Candler columns (1.2 gpd/ft^2) was more rapid with the medium strength wastewater (with the exception of column #34) than with the high strength. Day to failure for the high strength wastewater was almost double that of the medium strength columns packed with Candler. Failure in the Pomona with Candler Fill columns (0.65 gpd/ft^2) was more rapid with the high strength wastewater (days 22 and 23) than with the medium strength (days 25 through 47). Days to failure in the Millhopper (0.9 gpd/ft^2) for both wastewater strengths overlapped during the same relative time period (days 22 to 39).

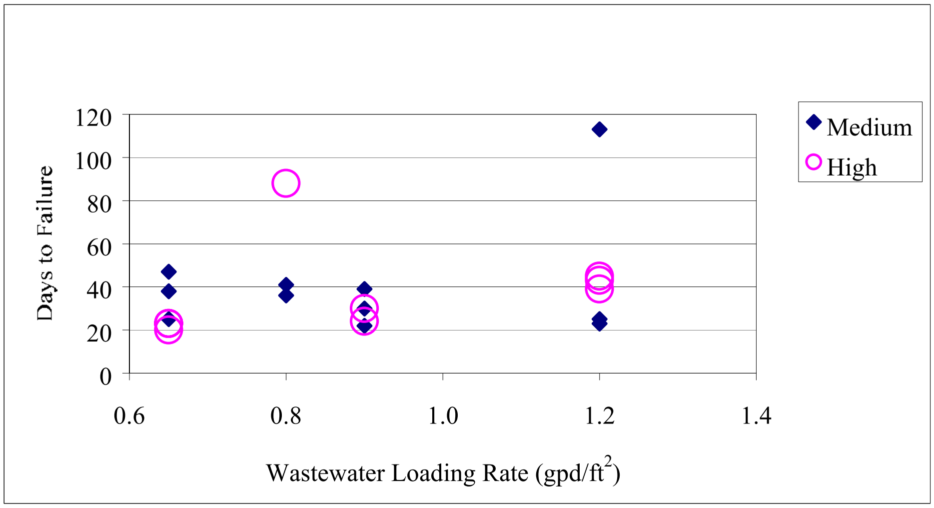


Figure 4-22. Days to Failure versus Wastewater Loading Rate

The same inverse relationship between the high strength and medium strength wastewater with respect to loading rates and soil type can be seen in Figure 4-23 and Figure 4-24. The figures present day to failure verses the mass loading for the high and medium wastewater strengths for the two-foot unsaturated columns with respect to soil type. The Millhopper, Pomona with Astatula Fill and Pomona with Candler Fill have slopes of 2.8 and a R^2 fit of 0.97 or greater for the medium strength wastewater (Figure 4-23). The third failed Candler column (#34), which failed on day 113 with a mass loading of 77 grams of TSS and $CBOD_5$, is not shown on the figure but was included in the regression analysis. The slope of the linear regression line for the Candler series is 1.51 with a R^2 equal to 1.

The Candler, Millhopper and Pomona with Candler Fill columns dosed with high strength wastewater (Figure 4-24) had slopes of 0.69, 3.99 and 0.79 with R^2 fits greater than 0.95. Separate figures for days to failure versus $CBOD_5$, TSS and volume are not shown. Those plots would look *identical* to Figures 4-23 and 4-24 because the mass loading depends on failure date and influent concentrations of the wastewater strength.

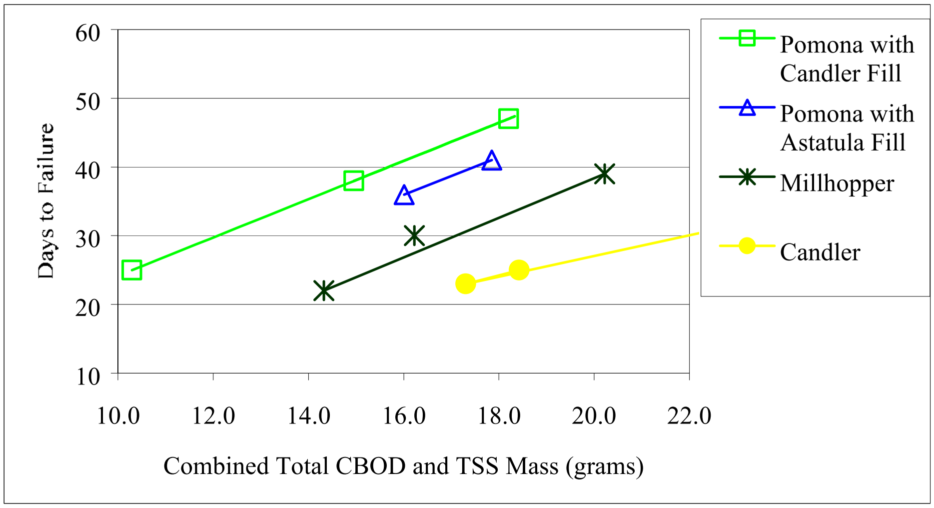


Figure 4-23. Days to Failure versus Mass Loading of Medium Strength Wastewater

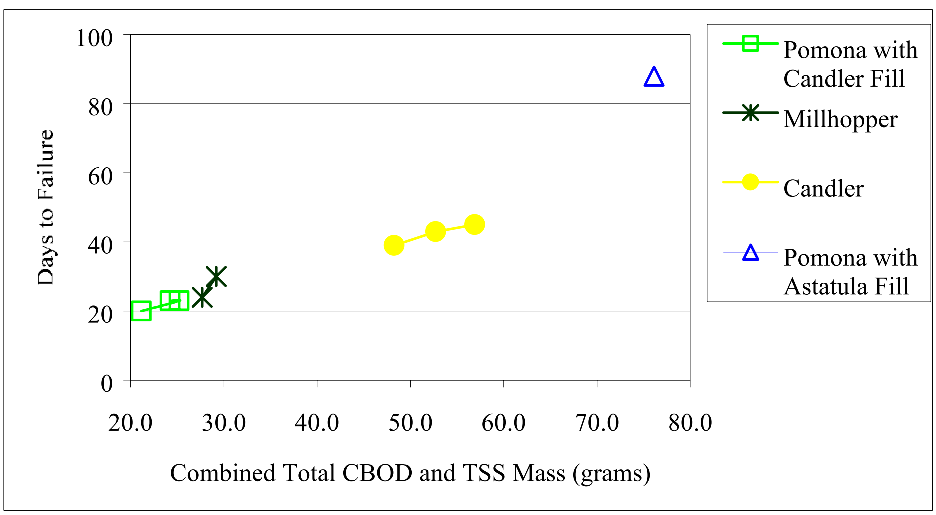


Figure 4-24. Days to Failure versus Mass Loading of High Strength Wastewater

Figure 4-25 presents days to failure versus total combined mass of $CBOD_5$ and TSS with respect to wastewater strength. The high strength wastewater has more variability in terms of days of failure and thus an increased total mass loading when compared to the medium wastewater plot for columns with two feet of unsaturated soil. The two wastewater strengths (neglecting soil type) have similar trend line slopes and R^2 values.

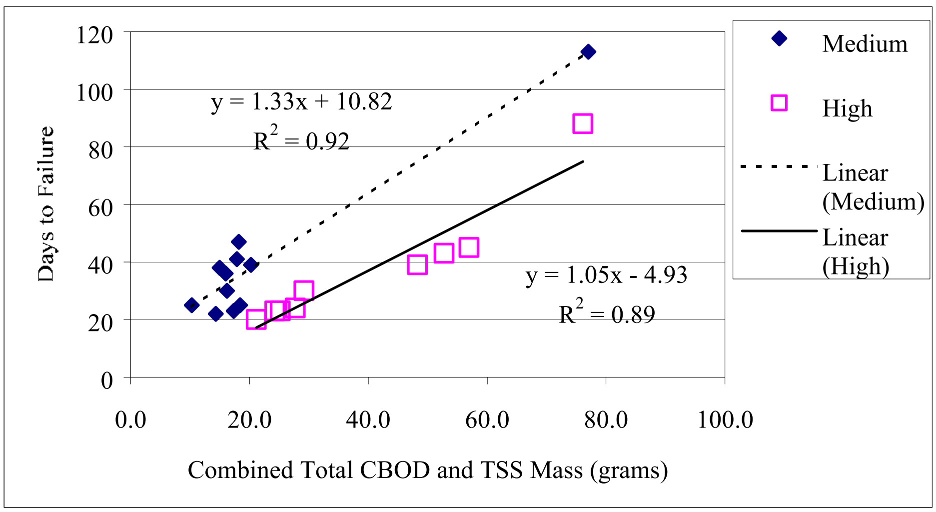


Figure 4-25. Days to failure versus Mass Loaded

Table 4-8 through Table 4-15 show the total mass of synthetic waste loaded on the soil columns for each wastewater strength and soil type. The tables include total volume dosed, days to failure, total mass loading and mass loaded per day. A table in Appendix A shows the mass loading for all 72 columns for the 112-day study.

Table 4-8. Total Mass Loading of Candler Soil Series for Two Feet of Unsaturated Soil (lb/ft^2)

Column #	$CBOD_5$ lb/ft^2	TSS lb/ft^2	O&G lb/ft^2	Sum of $CBOD_5$&TSS lb/ft^2	Total Mass $CBOD_5$,TSS,O&G lb/ft^2	Days of Dosing	Total Volume Liters	Synthetic Wastewater Strength
13	0.104	0.051	0.013	0.155	0.169	112	174.7	Low
14	0.107	0.053	0.014	0.160	0.174	112	179.6	Low
15	0.090	0.044	0.012	0.134	0.146	112	151.0	Low
34 (fail)	0.341	0.124	0.034	0.465	0.499	113*	183.2	Medium
35 (fail)	0.077	0.028	0.008	0.105	0.112	23	41.2	Medium
36 (fail)	0.082	0.030	0.008	0.111	0.120	25	43.8	Medium
61 (fail)	0.232	0.059	0.018	0.292	0.309	39	60.1	High
62 (fail)	0.254	0.065	0.020	0.319	0.338	43	65.6	High
63 (fail)	0.274	0.070	0.021	0.344	0.365	45	70.8	High

Table 4-9. Daily Mass Loading of Candler Soil Series for Two Feet of Unsaturated Soil ($lb/ft^2/day$)

Column #	$CBOD_5$ $lb/ft^2/day$	TSS $lb/ft^2/day$	O&G $lb/ft^2/day$	Sum of $CBOD_5$&TSS $lb/ft^2/day$	Total Mass $CBOD_5$,TSS,O&G $lb/ft^2/day$	Days of Dosing	Volume Loaded L/day	Synthetic Wastewater Strength
13	0.00093	0.00046	0.00012	0.00139	0.00151	112	1.560	Low
14	0.00096	0.00047	0.00012	0.00143	0.00155	112	1.603	Low
15	0.00081	0.00039	0.00010	0.00120	0.00130	112	1.349	Low
34 (fail)	0.00302	0.00110	0.00030	0.00412	0.00442	113*	1.621	Medium
35 (fail)	0.00333	0.00121	0.00033	0.00455	0.00488	23	1.790	Medium
36 (fail)	0.00326	0.00119	0.00033	0.00445	0.00478	25	1.754	Medium
61 (fail)	0.00595	0.00152	0.00046	0.00747	0.00794	39	1.540	High
62 (fail)	0.00590	0.00151	0.00046	0.00741	0.00786	43	1.526	High
63 (fail)	0.00608	0.00156	0.00047	0.00764	0.00811	45	1.574	High

Table 4-10. Total Mass Loading of Millhopper Soil Series for Two Feet of Unsaturated Soil (lb/ft^2)

Column #	$CBOD_5$ lb/ft^2	TSS lb/ft^2	O&G lb/ft^2	Sum of $CBOD_5$&TSS lb/ft^2	Total Mass $CBOD_5$,TSS,O&G lb/ft^2	Days of Dosing	Total Volume Liters	Synthetic Wastewater Strength
22	0.082	0.040	0.010	0.121	0.132	112	136.4	Low
23	0.081	0.040	0.010	0.121	0.132	112	136.2	Low
24	0.072	0.035	0.009	0.108	0.117	112	121.2	Low
25 (fail)	0.072	0.026	0.007	0.098	0.105	30	38.6	Medium
26 (fail)	0.063	0.023	0.006	0.087	0.093	22	34.1	Medium
27 (fail)	0.090	0.033	0.009	0.122	0.131	39	48.1	Medium
70	0.561	0.144	0.043	0.705	0.748	112	145.2	High
71 (fail)	0.133	0.034	0.010	0.167	0.178	24	34.5	High
72 (fail)	0.140	0.036	0.011	0.176	0.187	30	36.3	High

Table 4-11. Daily Mass Loading of Millhopper Soil Series for Two Feet of Unsaturated Soil ($lb/ft^2/day$)

Column #	$CBOD_5$ $lb/ft^2/day$	TSS $lb/ft^2/day$	O&G $lb/ft^2/day$	Sum of $CBOD_5$&TSS $lb/ft^2/day$	Total Mass $CBOD_5$,TSS,O&G $lb/ft^2/day$	Days of Dosing	Volume Loaded L/day	Synthetic Wastewater Strength
22	0.00073	0.00036	0.00009	0.00108	0.00118	112	1.218	Low
23	0.00073	0.00036	0.00009	0.00108	0.00118	112	1.216	Low
24	0.00065	0.00032	0.00008	0.00096	0.00105	112	1.083	Low
25 (fail)	0.00239	0.00087	0.00024	0.00327	0.00351	30	1.287	Medium
26 (fail)	0.00288	0.00105	0.00029	0.00393	0.00422	22	1.549	Medium
27 (fail)	0.00230	0.00084	0.00023	0.00313	0.00336	39	1.234	Medium
70	0.00501	0.00128	0.00039	0.00629	0.00668	112	1.296	High
71 (fail)	0.00555	0.00142	0.00043	0.00697	0.00740	24	1.436	High
72 (fail)	0.00468	0.00120	0.00036	0.00588	0.00624	30	1.211	High

Table 4-12. Total Mass Loading of Pomona with Astatula Fill Soil Series for Two Feet of Unsaturated Soil (lb/ft^2)

Column #	$CBOD_5$ lb/ft^2	TSS lb/ft^2	O&G lb/ft^2	Sum of $CBOD_5$&TSS lb/ft^2	Total Mass $CBOD_5$,TSS,O&G lb/ft^2	Days of Dosing	Total Volume Liters	Synthetic Wastewater Strength
16	0.074	0.036	0.009	0.110	0.119	112	123.5	Low
17	0.073	0.036	0.009	0.109	0.118	112	122.1	Low
18	0.074	0.036	0.009	0.110	0.119	112	123.6	Low
31 (fail)	0.071	0.026	0.007	0.097	0.104	36	38.1	Medium
32	0.240	0.087	0.024	0.327	0.351	112	128.8	Medium
33 (fail)	0.079	0.029	0.008	0.108	0.116	41	42.5	Medium
64 (fail)	0.366	0.094	0.028	0.460	0.488	88	94.7	High
65	0.501	0.128	0.039	0.630	0.669	112	129.8	High
66	0.495	0.127	0.038	0.622	0.661	112	128.2	High

Table 4-13. Daily Mass Loading of Pomona with Astatula Fill Soil Series for Two Feet of Unsaturated Soil ($lb/ft^2/day$)

Column #	$CBOD_5$ $lb/ft^2/day$	TSS $lb/ft^2/day$	O&G $lb/ft^2/day$	Sum of $CBOD_5$&TSS $lb/ft^2/day$	Total Mass $CBOD_5$,TSS,O&G $lb/ft^2/day$	Days of Dosing	Volume Loaded L/day	Synthetic Wastewater Strength
16	0.00066	0.00032	0.00008	0.00098	0.00107	112	1.103	Low
17	0.00065	0.00032	0.00008	0.00097	0.00105	112	1.091	Low
18	0.00066	0.00032	0.00008	0.00098	0.00107	112	1.104	Low
31 (fail)	0.00197	0.00072	0.00020	0.00269	0.00288	36	1.058	Medium
32	0.00214	0.00078	0.00021	0.00292	0.00313	112	1.150	Medium
33 (fail)	0.00193	0.00070	0.00019	0.00263	0.00282	41	1.036	Medium
64 (fail)	0.00416	0.00107	0.00032	0.00523	0.00555	88	1.077	High
65	0.00448	0.00115	0.00035	0.00562	0.00597	112	1.159	High
66	0.00442	0.00113	0.00034	0.00556	0.00590	112	1.145	High

Table 4-14. Total Mass Loading of Pomona with Candler Fill Soil Series for Two Feet of Unsaturated Soil (lb/ft^2)

Column #	$CBOD_5$ lb/ft^2	TSS lb/ft^2	O&G lb/ft^2	Sum of $CBOD_5$&TSS lb/ft^2	Total Mass $CBOD_5$,TSS,O&G lb/ft^2	Days of Dosing	Total Volume Liters	Synthetic Wastewater Strength
19	0.060	0.029	0.008	0.089	0.097	112	100.6	Low
20	0.060	0.029	0.008	0.089	0.096	112	99.7	Low
21	0.060	0.029	0.008	0.090	0.097	112	100.7	Low
28 (fail)	0.066	0.024	0.007	0.090	0.097	38	35.6	Medium
29 (fail)	0.081	0.029	0.008	0.110	0.118	47	43.3	Medium
30 (fail)	0.046	0.017	0.005	0.062	0.067	25	24.5	Medium
67 (fail)	0.117	0.030	0.009	0.147	0.156	23	30.2	High
68 (fail)	0.121	0.031	0.009	0.152	0.162	23	31.4	High
69 (fail)	0.102	0.026	0.008	0.128	0.136	20	26.3	High

Table 4-15. Daily Mass Loading of Pomona with Candler Fill Soil Series for Two Feet of Unsaturated Soil ($lb/ft^2/day$)

Column #	$CBOD_5$ $lb/ft^2/day$	TSS $lb/ft^2/day$	O&G $lb/ft^2/day$	Sum of $CBOD_5$&TSS $lb/ft^2/day$	Total Mass $CBOD_5$,TSS,O&G $lb/ft^2/day$	Days of Dosing	Volume Loaded L/day	Synthetic Wastewater Strength
19	0.00054	0.00026	0.00007	0.00080	0.00087	112	0.898	Low
20	0.00053	0.00026	0.00007	0.00079	0.00086	112	0.890	Low
21	0.00054	0.00026	0.00007	0.00080	0.00087	112	0.899	Low
28 (fail)	0.00174	0.00063	0.00017	0.00238	0.00255	38	0.936	Medium
29 (fail)	0.00172	0.00062	0.00017	0.00234	0.00251	47	0.922	Medium
30 (fail)	0.00182	0.00066	0.00018	0.00249	0.00267	25	0.980	Medium
67 (fail)	0.00507	0.00130	0.00039	0.00637	0.00677	23	1.313	High
68 (fail)	0.00527	0.00135	0.00041	0.00662	0.00703	23	1.364	High
69 (fail)	0.00509	0.00130	0.00039	0.00639	0.00679	20	1.317	High

The low strength columns received mass loading rates of less than 0.0015 $lb/ft^2/day$. In terms of total mass received they have surpassed the failed medium strength columns.

Column effluent sampling

Column effluent was sampled for $CBOD_5$ and TSS. One hundred fifty-two samples were collected and analyzed for $CBOD_5$ and TSS between April 2000 and June 2000 for the 72 lysimeters. $CBOD_5$ for the low, medium and high strength categories of waste is listed in Tables 4-16, 4-17 and 4-18. TSS values for the column sets are found in Tables 4-19, 4-20 and 4-21 (see pages 86-91). Because of the number of columns, only a few samples were collected from each lysimeter. Time durations vary between sampling, thus preventing a data plot. However, general trends concerning the treatment efficiency of columns with one foot and two feet of unsaturated soil can be observed from the data in the tables.

Columns with two-foot unsaturated conditions (medium wastewater columns #25 through #36 and high strength wastewater columns #61 through #72) had "not enough depletion" (NED) values for $CBOD_5$, which means the $CBOD_5$ of the diluted sample was below 2 mg/L. The majority of these values are reported as <3, which corresponds to a dilution of 200 mL of sample with 100 mL dilution water. The estimated $CBOD_5$ based on the dilutions are listed in each table for the columns tested. There were two exceptions: column #70, which had a $CBOD_5$ effluent concentration of 10 mg/L on day 23, and column #66 with concentrations of 41 mg/L and 7 mg/L on day 34 and 49. Neither column failed during the study.

Columns with one foot of unsaturated soil for both the medium category (columns #37 - #48) and the high category (columns #50 - #60) had detectable CBOD concentrations in the effluent. Concentrations ranged from 53 mg/L to 230 mg/L on day 23 for the high strength category (Table 4-18) with values decreasing to NED on day 84 for the columns tested. There were fewer samples collected for the medium strength category (Table 4-17), but columns tested on day 63 had column effluent concentrations ranging from 24 mg/L to 44 mg/L. Concentrations dropped to <3 mg/L by day 84.

Effluent samples were also analyzed for TSS (Tables 4-19, 4-20 and 4-21). The data provided similar results with respect to the comparison of the two saturation conditions and supported the trends suggested for $CBOD_5$. Lysimeters with two feet of unsaturated soil for the columns dosed with high and medium strength wastewater produce a higher quality of effluent than wastewater treated in columns with only one foot of unsaturated soil (Tables 4-20 and 4-21). However, the TSS concentrations seem to remain constant throughout the study rather than approach zero as with the $CBOD_5$.

There were no column failures for low strength waste during the 112 days of testing. $CBOD_5$ levels (Table 4-16) of the effluent of twenty-six samples were below 5 mg/L. TSS concentrations of column effluent (Table 4-19) appear to follow the predicted trend with respect to the two saturation conditions; one-foot unsaturated columns had higher values of TSS than two-foot unsaturated columns.

There may have been some interference with the $CBOD_5$ and TSS analyses of the column effluents. The column effluent color changed from a light yellow tint to a darker tint, and the vinyl tubing changed from clear to yellowish to gray and finally to a dark black coating during the first 20 days of dosing for the high category. The tubing on the medium columns was a slightly lighter shade but darkened up within 5 days of the high. Low strength columns took additional time. A red to pinkish color was noted on day 60 in the tubing just below the tee connector for the high strength columns with one foot of unsaturated soil (Columns #50 through #60). The changes in color may correspond to changes in microbial populations. These organisms (algae, fungi and bacteria) may have contributed suspended solids to the TSS analyses of the column effluents. Additionally, the organisms may have metabolized organic carbon from the synthetic wastewater, thus reducing concentrations of $CBOD_5$.

Temperature may have affected the column failure rates. Temperatures ranged from 68°F to 88°F over the duration of the study (Figure 4-26). There was an increase in temperature at day 55 from a high of 78°F degrees to day 64 with a high temperature of 86°F during the initial failure indications of column #64. It was noted in a published wastewater infiltration study that, "Cold and wet conditions apparently induced clogging of mound system sand filters, but that dry hot conditions rejuvenated the infiltration surfaces by allowing aerobic decomposition of slime and effluent solids in sand pore spaces" (Ronner et al., 1998). Typical restaurant effluent temperatures measured at the sites ranged between 68°F and 84°F. The range of relative percent humidity is illustrated on Figure 4-27. Ranges varied on a daily basis with no observed effects due to percent relative humidity.

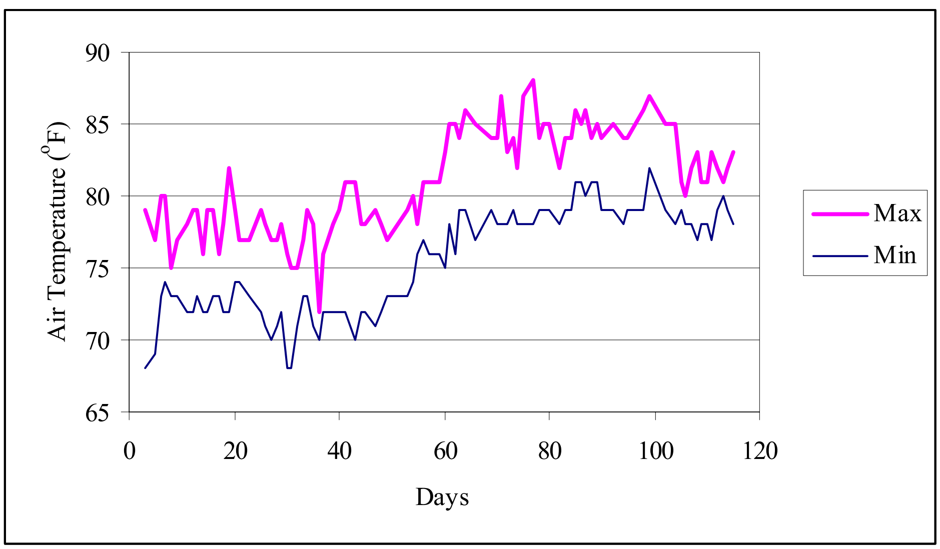


Figure 4-26. Air Temperature During LTAR Study

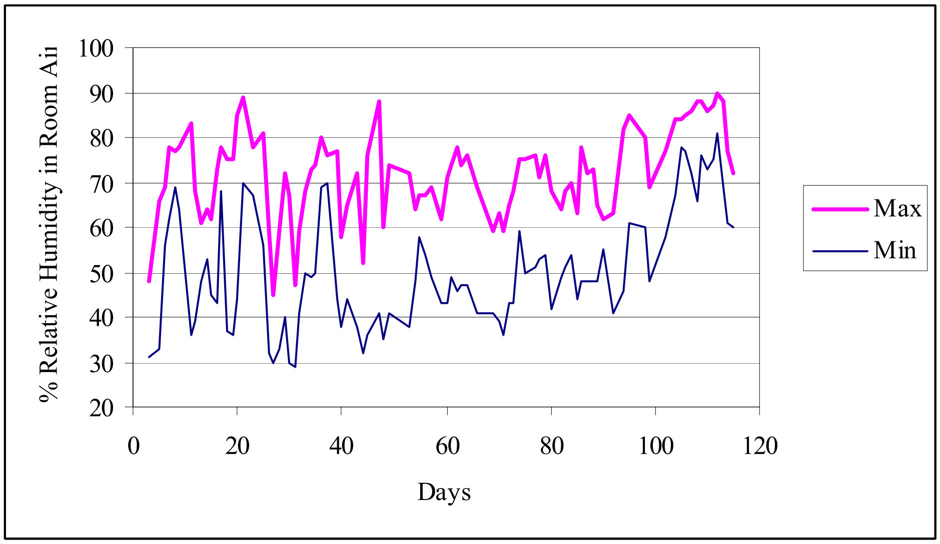


Figure 4-27. Percent Relative Humidity in Room Air

The soil columns' large diameter (8.1 inches) was chosen to reduce the possibility of error caused by water channeling along the interior walls of the column. Water tends to flow through the path of least resistance (largest pores or openings). In this case, the interior walls of the PVC columns, even though coated with sand, may have channeled the flow of water and thus circumvented percolation through the soil. This is theorized because the synthetic wastewater immediately began to percolate through the soil after dosing. Under the conditions imposed by the lysimeters, percolation of unsaturated soil in comparison with saturated soil is reduced due to pressure heads (suction head) and capillary forces (Domenico and Schwartz, 1998). However, ponding on the soil surface (0.5 to 1.0 inch) should occur until the entire dose has been absorbed by the soil. During the ponding phase, the synthetic wastewater had the potential to flow along the interior walls of the column rather than percolate through the soil. Channeling may have allowed the synthetic wastewater to circumvent the biomat at the infiltration surface, preventing initial filtration and degradation of the wastewater.

The effluent quality seemed to have distinct differences with respect to the two saturation conditions for the lysimeters sampled. Columns with two feet of unsaturated soil were able to effectively treat $CBOD_5$ in the synthetic wastewater by day 34. The columns with one foot of unsaturated soil took up to 84 days to adequately treat the wastewater.

The soil columns with one foot of unsaturated soil eventually treated the synthetic wastewater effectively for $CBOD_5$, however it took 2.5 times longer than columns with two feet of unsaturated soil. Actual field conditions would not guarantee constant aerobic conditions in soils with only one foot of unsaturated soil. Thus, onsite sewage treatment of restaurant wastewater appears to be a problem under field conditions. The effects of seasonally high water tables, shallow aquifers and rainfall were not taken into account during this study.

Aerobic degradation may convert 60 to 70 percent of available carbon to carbon dioxide. Anaerobic decomposition may only degrade 20% of $CBOD_5$ to carbon dioxide (Bicki et al., 1984). The remaining carbon is converted to organic intermediates or biomass that may further hinder water infiltration capacity. Aerobic degradation of $CBOD_5$ is more rapid than under anaerobic conditions (Metcalf and Eddy, 1991). Thus anaerobic conditions hinder wastewater stabilization in comparison with aerobic degradation, allowing the potential for groundwater contamination. The same effect can be observed during the lag time required to effectively treat the waste upon system startup.

The direct relationship between waste strength and drainfield failure has been proven in previous studies, including the Wisconsin Study (Siegrist et al., 1984). Data analyzed for this project have resulted in similar conclusions. In this study failure occurred between 20 days and 47 days for both the high and medium strength wastewater with the exceptions of column #34 (113 days) and #64 (88 days). Failure for both high and medium strength columns occurred sporadically throughout that time period and both strengths exhibit similar failure trend lines (Figure 4-25 on page 77), suggesting that both the medium and high strength wastewater exceeded the ability of the soil to stabilize the wastewater. In comparison, none of the columns dosed with low strength wastewater (domestic strength) failed during the LTAR Study, and the total mass loading of the low strength columns exceeded the total mass loaded on the failed columns dosed with medium strength wastewater. In addition, none of the aforementioned control columns for each soil type dosed with tap water failed. This suggests that high daily mass loading rate is a direct cause of drainfield failures.

A proposed alternative to the current prescriptive code approach for OSTDS serving food service establishments is to have the design specifications based on defined performance standards. Limits could be established based on parameters including BOD, TSS, O&G, ammonia-nitrogen, orthophosphate or fecal coliform (Hoover, 1998). These parameters are simple to analyze, cost effective and routinely analyzed by most wastewater laboratories. Because of the cost incurred in monitoring well installation and sample collection systems, it appears that *end of pipe sampling* for the OSTDS system would be the most cost effective (Hoover, 1998). Performance standards used in combination with current hydraulic loading rates will result in drainfield designs capable of final treatment of restaurant effluent.

Table 4-16. $CBOD_5$ Column Effluent Low Strength

Dose	12	17	19	21	25	28	32	35	38	42	45	48	Unsat.	Soil type
Date	04/02/00	04/13/00	04/16/00	04/20/00	04/28/00	05/05/00	05/12/00	05/18/00	05/25/00	06/02/00	06/07/00	06/12/00	Condition	
1											NED <3		1	Pomona with Candler Fill
2											NED <3		1	Pomona with Candler Fill
3								5			3		1	Pomona with Candler Fill
4											NED <3		1	Millhopper
5											NED <3		1	Millhopper
6								4			3		1	Millhopper
7											NED <3		1	Candler
8													1	Candler
9								NED <3					1	Candler
10													1	Pomona with Astatula Fill
11											NED <3		1	Pomona with Astatula Fill
12											3		1	Pomona with Astatula Fill
13													2	Candler
14	NED <17			NED <2									2	Candler
15			3					NED <3					2	Candler
16											NED <3		2	Pomona with Astatula Fill
17												NED <3	2	Pomona with Astatula Fill
18											NED <3		2	Pomona with Astatula Fill
19												NED <3	2	Pomona with Candler Fill
20				NED <3								NED <3	2	Pomona with Candler Fill
21												NED <3	2	Pomona with Candler Fill
22								NED <3				NED <3	2	Millhopper
23												NED <3	2	Millhopper
24			NED <3									NED <3	2	Millhopper

Table 4-17. $CBOD_5$ Column Effluent Medium Strength

Dose	12	17	19	21	25	28	32	35	38	42	45	48	Unsat.	Soil type
Date	04/02/00	04/13/00	04/16/00	04/20/00	04/28/00	05/05/00	05/12/00	05/18/00	05/25/00	06/02/00	06/07/00	06/12/00	Condition	
25	NED <24	NED <4	*	*	*	*	*	*	*	*	*	*	2	Millhopper
26	*	*	*	*	*	*	*	*	*	*	*	*	2	Millhopper
27			NED <5	*	*	*	*	*	*	*	*	*	2	Millhopper
28		NED <6	NED <6	*	*	*	*	*	*	*	*	*	2	Pomona with Candler Fill
29			NED <5	NED <3	*	*	*	*	*	*	*	*	2	Pomona with Candler Fill
30		*	*	*	*	*	*	*	*	*	*	*	2	Pomona with Candler Fill
31			*	*	*	*	*	*	*	*	*	*	2	Pomona with Astatula Fill
32			NED <5	NED <3	TMD >9	NED <3						NED <3	2	Pomona with Astatula Fill
33		NED <5	NED <3	*	*	*	*	*	*	*	*	*	2	Pomona with Astatula Fill
34			NED <6	NED <3	NED <3	NED <3						NED <3	2	Candler
35	NED <40	*	*	*	*	*	*	*	*	*	*	*	2	Candler
36		NED <8	*	*	*	*	*	*	*	*	*	*	2	Candler
37						9	31		18				1	Pomona with Astatula Fill
38						TMD >14	43		12				1	Pomona with Astatula Fill
39						TMD >14	24		NED <8	NED <8			1	Pomona with Astatula Fill
40	53												1	Candler
41						TMD >14	36		NED <10	NED <7			1	Candler
42				TMD >11		51	40			NED <7			1	Candler
43						TMD >45	31		NED <12	NED <7			1	Millhopper
44	NED <40				TMD >9		37			NED <8			1	Millhopper
45						31	37						1	Millhopper
46				NED <3			NED <4		NED <12			NED <3	1	Pomona with Candler Fill
47					*	*	*	*	*	*	*	*	1	Pomona with Candler Fill
48					NED <3	*	*	*	*	*	*	*	1	Pomona with Candler Fill

*- Failed Column

Table 4-18. $CBOD_5$ Column Effluent High Strength

Dose	12	17	19	21	25	28	32	35	38	42	45	48	Unsat.	Soil type
Date	04/02/00	04/13/00	04/16/00	04/20/00	04/28/00	05/05/00	05/12/00	05/18/00	05/25/00	06/02/00	06/07/00	06/12/00	Condition	
50	54					45	24					NED <3	1	Pomona with Candler Fill
51			31		TMD >45		96	65	NED <15	NED <12			1	Pomona with Candler Fill
52			144		138				NED <24	NED <15			1	Millhopper
53	53		354	84	41								1	Millhopper
54					75			NED <40	NED <20	NED <12			1	Millhopper
55				TMD >164	NED <60			24		NED <15			1	Candler
56	TMD >114				TMD >56			NED <30		NED <18			1	Candler
57								*	*	*	*	*	1	Candler
58					90			28		NED <12			1	Pomona with Astatula Fill
59	230		164		168			52		NED <12			1	Pomona with Astatula Fill
60						TMD >44	75	47		NED <15	*	*	1	Pomona with Astatula Fill
61		NED <8		*	*	*	*	*	*	*	*	*	2	Candler
62	NED <24	NED <8		NED <3	*	*	*	*	*	*	*	*	2	Candler
63		NED <7			*	*	*	*	*	*	*	*	2	Candler
64		NED <9		NED <3					NED <3	NED <3	*	*	2	Pomona with Astatula Fill
65	NED <40	NED <8				NED <3	NED <3				NED <3	NED <3	2	Pomona with Astatula Fill
66		41			7			NED <3	NED <3		NED <3	NED <3	2	Pomona with Astatula Fill
67	NED <24	*	*	*	*	*	*	*	*	*	*	*	2	Pomona with Candler Fill
68	*	*	*	*	*	*	*	*	*	*	*	*	2	Pomona with Candler Fill
69	*	*	*	*	*	*	*	*	*	*	*	*	2	Pomona with Candler Fill
70	10	NED <6		NED <3								NED <3	2	Millhopper
71			*	*	*	*	*	*	*	*	*	*	2	Millhopper
72		NED <5	*	*	*	*	*	*	*	*	*	*	2	Millhopper

*- Failed Column

Table 4-19. TSS Column Effluent Low Strength

Dose	12	17	19	21	25	28	32	35	38	42	45	48	Unsat.	Soil type
Date	04/02/00	04/13/00	04/16/00	04/20/00	04/28/00	05/05/00	05/11/00	05/18/00	05/25/00	06/02/00	06/07/00	06/14/00	Condition	
1											0		1	Pomona with Candler Fill
2											1		1	Pomona with Candler Fill
3								1			1		1	Pomona with Candler Fill
4											15		1	Millhopper
5											12		1	Millhopper
6								8			11		1	Millhopper
7											1		1	Candler
8													1	Candler
9								1					1	Candler
10													1	Pomona with Astatula Fill
11											1		1	Pomona with Astatula Fill
12											1		1	Pomona with Astatula Fill
13													2	Candler
14	2			0									2	Candler
15			4					1					2	Candler
16											1		2	Pomona with Astatula Fill
17												0	2	Pomona with Astatula Fill
18											0		2	Pomona with Astatula Fill
19												0	2	Pomona with Candler Fill
20				0								1	2	Pomona with Candler Fill
21												1	2	Pomona with Candler Fill
22								0				0	2	Millhopper
23												0	2	Millhopper
24			4									0	2	Millhopper

Table 4-20. TSS Column Effluent Medium Strength

Dose Date	12 04/02/00	17 04/13/00	19 04/16/00	21 04/20/00	25 04/28/00	28 05/05/00	32 05/11/00	35 05/18/00	38 05/25/00	42 06/02/00	45 06/07/00	48 06/14/00	Unsat. Condition	Soil type
25	35	22	*	*	*	*	*	*	*	*	*	*	2	Millhopper
26	*	*	*	*	*	*	*	*	*	*	*	*	2	Millhopper
27			4	*	*	*	*	*	*	*	*	*	2	Millhopper
28		23	4	*	*	*	*	*	*	*	*	*	2	Pomona with Candler Fill
29			2	1	*	*	*	*	*	*	*	*	2	Pomona with Candler Fill
30		*	*	*	*	*	*	*	*	*	*	*	2	Pomona with Candler Fill
31			*	*	*	*	*	*	*	*	*	*	2	Pomona with Astatula Fill
32			5	2	4	3						2	2	Pomona with Astatula Fill
33		15	3	*	*	*	*	*	*	*	*	*	2	Pomona with Astatula Fill
34			4	4	3	5						1	2	Candler
35	108	*	*	*	*	*	*	*	*	*	*	*	2	Candler
36		36	*	*	*	*	*	*	*	*	*	*	2	Candler
37						6	8		11				1	Pomona with Astatula Fill
38						11	7		8				1	Pomona with Astatula Fill
39						12	5		6	2			1	Pomona with Astatula Fill
40	27												1	Candler
41						23	24		7	10			1	Candler
42				7		30	35			9			1	Candler
43						29	22		18	15			1	Millhopper
44	86				34		30		27	14			1	Millhopper
45						47	49						1	Millhopper
46				1			3		1			2	1	Pomona with Candler Fill
47					*	*	*	*	*	*	*	*	1	Pomona with Candler Fill
48					0		*	*	*	*	*	*	1	Pomona with Candler Fill

*- Failed Column

Table 4-21. TSS Column Effluent High Strength

Dose Date	12 04/02/00	17 04/13/00	19 04/16/00	21 04/20/00	25 04/28/00	28 05/05/00	32 05/11/00	35 05/18/00	38 05/25/00	42 06/02/00	45 06/07/00	48 06/14/00	Unsat. Condition	Soil type
50	41					30	31					8	1	Pomona with Candler Fill
51			5		29		13	13	8	4			1	Pomona with Candler Fill
52			76		53				37	37			1	Millhopper
53	59		99	64	43								1	Millhopper
54					53			36	34	28			1	Millhopper
55				19	17			30		50			1	Candler
56	87				54			68		34			1	Candler
57								*	*	*	*	*	1	Candler
58					18			14		7			1	Pomona with Astatula Fill
59	36		13		12			14		8			1	Pomona with Astatula Fill
60						14	19	21		12	*	*	1	Pomona with Astatula Fill
61		5	*	*	*	*	*	*	*	*	*	*	2	Candler
62	43	5		1	*	*	*	*	*	*	*	*	2	Candler
63		5			*	*	*	*	*	*	*	*	2	Candler
64		5		1					3	2	*	*	2	Pomona with Astatula Fill
65	32	2				1	3				1	1	2	Pomona with Astatula Fill
66		17			6			2	2		9	5	2	Pomona with Astatula Fill
67	18	*	*	*	*	*	*	*	*	*	*	*	2	Pomona with Candler Fill
68	*	*	*	*	*	*	*	*	*	*	*	*	2	Pomona with Candler Fill
69	*	*	*	*	*	*	*	*	*	*	*	*	2	Pomona with Candler Fill
70	74	33		20								3	2	Millhopper
71	*	*	*	*	*	*	*	*	*	*	*	*	2	Millhopper
72		68	*	*	*	*	*	*	*	*	*	*	2	Millhopper

*- Failed Column

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

An investigation to determine the properties of effluents from food service establishments that employ onsite sewage treatment and disposal and the long-term acceptance rate (LTAR) of typical soils found in Florida drainfields was conducted. One hundred thirty-three samples from fifteen restaurants in North Central Florida were collected and analyzed for 5-day carbonaceous biochemical oxygen ($CBOD_5$), total suspended solids (TSS), and Oil and Grease (O&G). The food operation wastewater effluents were categorized into three relative waste strength categories: high, medium, and low.

The LTAR study was conducted with triplicate columns using four soil types representative of soils commonly used for drainfields in Florida. Each soil type was subjected to two saturation conditions and dosed with three strength categories of wastewater as determined from a sampling of restaurant effluents. It was necessary to construct a total of 76 lysimeters, including four controls. The response variable for this study was days until column failure.

Conclusions

1. Restaurant wastewaters that have been treated with conventional onsite sewage treatment systems (septic tanks and grease traps) can have significantly higher concentrations of $CBOD_5$, TSS and O&G in the effluent when compared to domestic systems.

2. Restaurant wastewaters that have been treated with Aerobic Treatment Units (Nibbler™) produce effluent with significantly lower concentrations of $CBOD_5$, TSS and O&G when

compared to restaurants using conventional treatment methods. Effluent quality of the Nibbler™ system is similar to domestic OSTDS wastewater strengths.

3. Hydraulic loading alone does not cause drainfields to fail. Effluent concentration and hydraulic loading both contribute to clogging and formation of biomat, resulting in failure.

4. There is a possible threshold at which drainfields will fail due to mass loading. Candler soil columns receiving less than 0.0015 lb/ft^2/day of contaminant mass did not fail. Candler soil columns receiving 0.0043 lb/ft^2/day did fail. Therefore, there is a possible threshold at which drainfields fail due to daily mass loading. In this case it appears to be between 0.0015 and 0.0043 lb/ft^2/day for Candler soil. A similar case can be made for all four soil types. Below the thresholds, drainfields appear to be able to adequately treat the daily load and are poised for the next application with no apparent permanent failure.

Recommendations

1. Performance-based criteria for OSTDS need to be developed that include limits for BOD, TSS and O&G. Additionally, modification of the current prescriptive code is needed. Conventional OSTDS sizing criteria are not providing sufficient treatment. Limits should be established for restaurant effluent concentrations to be in the low wastewater strength category (similar concentrations to that of waste from domestic systems).

2. Restaurant systems must be able to handle high strength wastes and high flows. Research should be conducted to determine the proper tank sizing and to obtain the optimal retention

time for the various ranges of wastewater strength. This is particularly necessary for systems that do not receive additional treatment between the primary septic tank and the drainfield.

3. Eventual phasing out of conventional OSTDS for food service establishments is recommended. Pretreatment of restaurant effluent utilizing currently available aerobic treatment units, sequencing batch reactors and other commercially available treatment systems would reduce $CBOD_5$ and TSS in the effluent to concentrations similar to domestic waste strength. This would result in drainfield sizes of approximately one-third that of the size required to treat high strength wastewater (see conclusion 4).

4. Drainfield sizing should include mass loading rates and hydraulic loading rates based upon soil properties. Mass loading rates should not exceed 0.0015 lb/ft^2/day but this value may need to be reduced based on soil properties.

5. The LTAR study should be continued. All high and medium strength wastewater columns should be dosed until failure. The low strength columns should be modified to determine the apparent failure threshold discovered in Phase II. One low strength column from each soil type and saturation condition (eight columns total) should have the wastewater strength increased to a concentration between the medium and low wastewater strengths. The purpose is to better identify the mass loading per day threshold at which the soil columns are able to accept and treat the wastewater with no apparent detrimental effects. Such a study could further investigate the link between mass loading rates and failure.

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APPENDIX A
SOIL DENSITY DATA

SOIL PROPERTIES AND CHARACTERISTICS FOR THE ONSITE SEWAGE TREATMENT AND DISPOSAL SYSTEMS COLUMN STUDY

By
Jose J. Rivera

Excerpts of Jose Rivera's Masters Report presented to the Geotechnical Department in partial fulfillment of the requirements for the Masters of Engineering Degree. University of Florida 1999

SOILS COLLECTED AND TESTING PERFORMED

Selected Soils

The type of soils selected for this project had to be representative of the soils commonly found in most parts of the State of Florida. During an earlier stage of this project, it was decided to find two types of sand, one with well drained characteristics of the type common on the sand ridges of the State, and one with poorly drained characteristics like those of the Florida flatwoods. A loamy sand was selected as the third soil. Soils with finer materials like clay were not selected because it would be hard to run large-scale permeability tests on these types of soils. Another factor in deciding which soils to use was their availability. They had to be accessible to us so that we could collect them and bring them to the laboratory. The soils selected were Archer Gold, also known as Candler, Millhopper, and Pomona.

Archer Gold (Candler)

As described by the Alachua County Soil Survey, this soil was formed in thick marine beds of sandy marine deposits. Typically a dark grayish brown surface layer composed of a fine sand is found up to a depth of 6 inches. Then a subsurface layer of 82 inches or more of a fine sand with different tones of brown can be found. Colors vary from pale brown, light yellowish brown, yellow, pale brown to a very pale brown. This soil has a low availability of water because of its high permeability. It also has a low natural fertility. The organic matter content of the surface layer is low to very low. For these reasons this soil has very severe limitations for cultivated crops (Alachua County Soil Survey). It has also been determined to have slight limitations for dwellings, small commercial buildings, roads and streets, and septic tank absorption fields (Alachua County Soil Survey). This soil has poor filtration and groundwater contamination can be a hazard in areas where homes with septic tanks are concentrated. The typical groundwater level is at a depth of more than 72 inches.

This soil was collected from a farm located between Gainesville and the town of Archer. The collected soil is of a bright yellow color, and it is comprised of only one layer. Several tests had to be performed in order to determine its properties. A sand cone density test, following ASTM standard D 1556, was done in the field in order to determine its insitu wet density. Water content was also determined in the field by putting a sample in a sealed plastic bag and then following ASTM method D 2216 once the sample reached the laboratory. Once in the laboratory, several grain size analyses were done to obtain the gradation curve corresponding to this soil. This was performed as soon as the soil was collected, after drying, and before placement into the columns. For the determination of the grain size distribution, ASTM standard D 421 was followed. Rigid wall constant head permeability tests were also conducted on the soil following ASTM standard D2434.

Sieve Analysis

Several grain size analyses were performed on samples collected right before they were placed into the columns. The purpose was to for classification and variance of our soil sampled. All results were plotted in the same graph, which can be found in Figure 1 (at the end of the Chapter). The uniformity coefficient (Cu) for the samples tested ranged between 1.42 and 1.88. Small uniformity coefficients like the ones obtained, indicate that a small range of particle sizes is present. The coefficient of curvature (Cc) ranged between 0.96 and 1.17. These values indicate that the soil is poorly graded. The Unified Soil Classification System (USCS) suggests that for sands to be well graded the Cu should be greater than 6 and the Cc between 1 and 3 for a soil to be well graded. Since both criteria are not met, it shows that the samples of Archer Gold tested are poorly graded. Also, because the entire soil passed the number 4 sieve and less than 5 percent passed the number 200 sieve, according to the Unified Soil Classification System (USCS) this sand classifies as poorly graded sand (SP).

Density (field and in columns)

The results obtained from the field sand cone density test, 102.6 pcf, were used to determine soil column densities. Typical maximum dry density and natural density were also obtained from the Alachua County Soil Survey. Higher densities create more critical situations because the permeability is lower. A lower density, like the natural density presented in the soil survey, was used instead because the soils in drainage fields are not heavily compacted. This is also done to achieve better drainage conditions. Since the results of this study will be used to evaluate the existing conditions in the field, it was decided to use the natural density instead of using the maximum densities obtained with compaction. The target dry density for this soil type was between 90 and 94 lb/ft^3. The density was measured by knowing the weight of the soil placed to achieve a five-inch elevation increment from the bottom. *The densities and measurements for each column are at the end of the chapter (Appendix Table 3-1A through 3-1C).*

<u>Millhopper</u>

This is considered a moderately well drained soil. It is typically composed of a dark grayish brown sand surface layer of up to 9 inches in thickness. Then a layer of fine sand of about 49 inches thick follows, which is what was used for the columns. The upper 17 inches of this layer is of a yellowish brown color, the middle 22 inch layer is a light yellowish brown, and the bottom 10 inches are a very pale brown. The subsoil, the B horizon or the part below the upper profile found under plow depth, extends to a depth of 89 inches. The available water capacity, or the capacity of soils to hold water available for use by most plants, is low in the surface and the subsurface layers and is low to medium in the subsoil (Alachua County Soil Survey). The permeability of the surface and subsurface layers are considered to be rapid (20 in/hr). It then starts to slow down in the subsoil from moderately rapid to slow. The natural fertility of this soil is considered to be low and its organic matter content is low to moderately low. The water table in this soil ranges from 40 to 60 inches in the wet season, and from 60 to 72 inches in the dry season.

This soil has been determined to have only slight limitations in sites of homes without basements, small commercial buildings, and for local roads and streets. Moderate limitations have been found in the use of septic tank absorption fields. This is mainly because of the depth of the water table during wet seasons.

This soil was collected from a location inside the University of Florida's entomology forest, near SW 34th street. The soil collected is composed of three layers, and is of a pale brown and yellow color. The sand cone density test done in the field shows a density of 102 pcf (depth of 12 inches). Once a sample of the soil had been dried, a sieve analysis was performed. Several more samples were analyzed before placing the soils into the columns. In this case gradation curves were individually found for all three layers. A constant head rigid wall permeability test for all layers was also conducted in individual samples. The same type of test was done for the columns.

Sieve Analysis

A sample collected at the time the soil was being retrieved was sieved soon after it was brought into the laboratory for filter selection purposes. Then before placing the soil into the columns, several samples were sieved from each individual layer. It was determined that the bottom layer has a uniformity coefficient (C_u) between 1.89 and 2.12. The coefficient of curvature (Cc) was between 1.14 and 1.2. All samples had the entire material pass the number 4 sieve, and less than 2 percent of the material pass the number 200 sieve. This classifies the bottom layer as poorly graded sand (SP). Figure 2 shows the grain size distribution for all tests performed for this layer.

The same procedure was followed for the middle layer of the Millhopper and its samples. In this case the uniformity coefficient (C_u) was between 1.9 and 2.05. The coefficient of curvature (Cc) ranged between 1.01 and 1.08. The entire sample passed the number four sieve while less than two percent passed the number 200 sieve. This layer would also classify as poorly graded sand (SP) according to the Unified Soil Classification System. The grain size distribution for the middle layer is found in Figure 3.

The same was done for the top layer of the Millhopper. The uniformity coefficient (C_u) was between 1.89 and 2.06. The coefficient of curvature (Cc) was found to range between 1.16 and 1.18. Once again, the entire material passed the #4 sieve, while less than two percent passed the #200 sieve. This layer also classifies as poorly graded sand (SP). The grain size distribution for this layer can be found in Figure 4.

It is clear from the grain size distributions that there is hardly any difference between any of the three layer collected. This could be because of soil disturbance previous to its collection for this study. It is possible that some of the soil was removed in the past and when it was put back in its place all of the layers got mixed up. At the same time, the only difference outlined in the soil description found in the Alachua County Soil Survey only points out color differences and no other differences are outlined.

Density (field and in columns)

A sand cone density test was done in the field in order to obtain the soil's natural density, 102 pcf (at a depth of 12 inches). Using the field water content, the insitu dry density of this soil was 98.05 lb/ft^3. According to the Alachua County Soil Survey, the maximum dry density of Millhopper is 112 lb/ft^3. The natural density of this type of soil according to the Soil Survey ranges between 93 and 104 lb/ft^3. The density aimed at in the columns was 96.76 lb/ft^3, which can be obtained by simply pouring the sand into the columns. The amount of soil placed for every six inches of pipe was weighed before putting it in the columns. Then the change in elevation would be measured from the bottom to determine the actual density that was obtained. *The densities for each column are at the end of the chapter (Table 3-2A through 3-2C).*

Pomona

This sand is considered to be a poorly drained soil, and it is found mainly in the flatwoods (the broad, nearly level, low ridges of dominantly poorly drained soils). The surface layer is typically a 5-inch thick very dark gray sand. The subsurface is also a sand up to 16 inches in thickness. The top 4 inches is a very dark gray color and is coated with some organic material. Then another 4-inch layer of dark reddish brown sand follows. The final 8-inch layer is a pale to very pale brown sand. A loamy subsoil follows and extends to a depth of about 69 inches. The water table in Pomona soils can be found at a depth of 10 inches during the wet season, which can be from one to three months. The rest of the time it can be at a depth of more than 40 inches from the surface. Surface water runoff is usually slow for this soil. Permeability can be rapid at the surface layer but decreases with increasing depth. Pomona soils have several limitations for urban uses, including absorption fields for septic tanks (Alachua County Soil Survey). A good drainage system is needed to remove the excess water that will come during wet periods. A potential hazard of groundwater contamination may occur due to the high level of the water table during the wet season.

The Pomona soil was collected at the University of Florida's Cary Forest. The soil collected was composed of three different layers. The top layer collected was four inches thick dark brown sand, followed by a lighter brown six-inch layer. The bottom 16-inch layer was light gray to white sand. By the time the bottom of the final layer was reached, the water table was found. Two sand cone density tests were done in the field, following ASTM procedures: one at the top layer and one at the bottom layer. Two grain-size distribution analyses were done on two different samples in the laboratory. Then before placing the soil into the columns, more grain size analyses were done to each layer of soil (as collected from the field).

Sieve Analysis

Several grain size analyses were performed for the three layers of the Pomona collected right before it was placed into the columns. The top layer had a uniformity coefficient (C_u) that ranged between 2.08 and 2.45. The coefficient of curvature (Cc) was between 0.92 and 1.09. The entire soil passed the number 4 sieve and a little over 3 percent of the sample passed the number 200 sieve. This layer can be classified as a poorly graded sand (SP). In Figure 5 the grain size distribution of this layer can be seen.

Following the same procedure for the middle layer, a uniformity coefficient (C_u) between 2.08 and 2.31 was obtained. The coefficient of curvature (Cc) was between 0.95 and 1.03. The entire sample passed the number 4 sieve and about 3 percent passed the number 200 sieve. This means that this layer also classifies as a poorly graded sand (SP). The grain size distribution curves are included in Figure 6.

Similar results were obtained for the bottom layer of Pomona. Here the uniformity coefficient (C_u) is between 2.17 and 2.5, while the coefficient of curvature is between 1.04 and 1.30. The entire sample passed the number 4 sieve and almost 4 percent passed the number 200 sieve. This layer also classifies as a poorly graded sand (SP). Refer to the Figure 7 for the grain size distribution curves.

Density (field and in columns)

The field density obtained in the field using the sand cone method was 96.31 lb/ft^3 (at a depth of 12 inches). The maximum dry density found according to the Alachua County Soil Survey is 112 lb/ft^3. The range for the natural density is 87.4 to 112.7 lb/ft^3. The target density for the columns was 96.76 lb/ft^3. Known weights of soil were poured into the columns and the differences in elevations were recorded. This way the density for every lift of soil was obtained. Then the overall density for the column was calculated. Two sets of Pomona columns were built. Each set contains a five-inch layer of fill used for the top of the column. For the first set Candler was used as the fill and for the second set Astatula was used. The Candler used as fill was not the same used for the all Candler columns. *Tables (Appendix tables 3-3A through 3-4C) show the different increments, their respective densities, and the density for each column.*

<u>Geotextile and Filter Design</u>

In order to prevent the sand from coming out through the bottom of the columns, it was necessary to install a filter system capable of retaining all the material in the column while allowing the water to flow out. Two options were considered as possible solutions to this situation. The first was installing a geotextile between the coarse gravel placed at the bottom of the column and the sand layer. A second option considered was to install a filter composed of natural materials. This would be done by gradually decreasing the size of the particles (from the bottom up) until the material added is able to hold the sand in place and still allow the water to flow adequately.

To evaluate the performance of the first option, a geotextile was placed on top of the coarse gravel, where the bottom of the sand layer will be located. Before selecting the type of geotextile to be used several conditions had to be examined. A retention criterion was first evaluated. The National Highway Institute (NHI) uses empirical correlations based on the grain size distribution of the soil and the apparent opening size (O_{95}) of the fabric. They recommend that for retention of the soil the apparent opening size of the fabric be the particle diameter corresponding to 85% of the passing material multiplied by a factor B.

$O_{95} = B*d_{85}$

To find B, the uniformity coefficient for the soil has to be determined first. The uniformity coefficient, C_u, of a soil is the particle diameter corresponding to the 60% passing material divided by the diameter of the particles corresponding to the 10% passing material.

$C_u = d_{60}/d_{10}$

The values for the diameters of the particles and the percents passing are obtained from the sieve analyses that were performed for every soil, and are described under the Selected Soils section. There were two samples of Pomona tested right after collecting the sand from the field. Each corresponded to a different layer of the Pomona formation. One sample of Archer Gold and one sample of Millhopper were tested as well. Only one sample was selected for these last two soil types. Additional grain size analyses were performed before packing of the columns took place. A total of five more sieve analyses were performed for each layer of soil. The Archer Gold has only one layer. The Millhopper has three different layers and the Pomona has three layers as well. The field samples were compared to the samples tested later on in order to determine more precise values.

Table 3-5. Soil Properties

Soil Type	**d_{85} (mm)**	**d_{60} (mm)**	**d_{15} (mm)**	**d_{10} (mm)**	**$C_u = d_{60}/d_{10}$**
Pomona, bottom	0.35 – 0.38	0.24 – 0.26	0.13 – 0.15	0.10 – 0.12	2.00 – 2.60
Archer Gold	0.37 – 0.38	0.32 – 0.34	0.18 – 0.25	0.17 – 0.24	1.33 – 2.00
Millhopper, bottom	0.43 – 0.55	0.33 – 0.36	0.18 – 0.22	0.17 – 0.18	1.83 – 2.12

The criteria evaluated by the NHI establish the following values of B based on the uniformity coefficient.

$C_u < 2, C_u > 8$ $B = 1$

$2 \leq C_u \leq 4$ $B = 0.5\ C_u$

$4 < C_u \leq 8$ $B = 8/C_u$

The first condition is the one that controls all of the soils that we are dealing with. Therefore in order to meet the retention criteria, the O_{95} of the geotextile fabric has to be less than one half C_u to one time the diameter of the particles corresponding to 85% of the passing material.

The next criterion examined is the clogging resistance of the geotextile. Clogging resistance is the ability of the geotextile to prevent the soil particles from getting into its openings and reducing its hydraulic conductivity. In this case the recommendations from the NHI are as follows.

$O_{95} \geq 3*d_{15}$ $C_u > 3$

The second recommendation establishes that if the uniformity coefficient is less than three, then the O_{95} used for the retention criteria is good enough to meet the clogging resistance. So in this case the O_{95} obtained still has to be less than the d_{85} of each soil, which is the same condition that has to be met for the retention criteria.

The permeability of the geotextile compared to that of the soil also plays an important role. It must be greater than that of the soil so that it does not become a limiting factor. This is very important because when the soil is tested, it should be allowed to drain as fast as it can, and not be impeded by the geotextile drain. When the conditions are severe, it is simply recommended that the geotextile be more permeable than the soil. If the conditions are severe the NHI recommends that the permeability of the geotextile should be more than ten times that of the soil. Our conditions are considered to be severe, simply because we must make sure that the soil can drain under its own terms and not be restricted by the geotextile.

The type of geotextile selected was Amoco 4510. Amoco Fabrics and Fibers Company in Atlanta, Georgia donated a sample of this geotextile to the project. This geotextile is a polypropylene non-woven, needle-punched fabric. It is designed to resist commonly encountered soil chemicals, mildew and insects, and is non-biodegradable. The polypropylene is a polymer, which is stable within a pH range of 2 to 13. Therefore this geotextile will pose no problems to our study. The properties of the selected fabric are included in the following table.

Table 3-6. Geotextile Properties (from Amoco Fabrics and Fibers Company)

Property	Test Method	Minimum Average Roll Value (English)	Minimum Average Roll Value (Metric)
Unit Weight	ASTM-D-5261	10 oz/yd^2	339 g/m^2
Grab Tensile	ASTM-D-4632	250 lb	1.11 kN
Grab Elongation	ASTM-D-4632	50 %	50 %
Mullen Burst	ASTM-D-3786	550 psi	3790 kPa
Puncture	ASTM-D-4833	165 lb	0.730 kN
Trapezoidal Tear	ASTM-D-4533	100 lb	0.445 kN
UV Resistance	ASTM-D-4355	70 % at 500 hrs	70 % at 500 hrs
AOS	ASTM-D-4751	100 sieve	.15 mm
Permittivity	ASTM-D-4491	1.2 sec^{-1}	1.2 sec^{-1}
Flow Rate	ASTM-D-4491	85 gal/min/ft^2	3460 L/min/m^2
Coefficient of Permeability	ASTM-D-4491	0.30 cm/sec	0.30 cm/sec
Thickness	ASTM-D-5199	85 mils	2.15 mm

The O_{95} for this geotextile is 0.15 mm, which is about one and a half times the d_{85} of all the selected soils. Its permeability is 0.30 cm/sec, which is many times larger than the typical permeability of sandy soils.

The second option that was considered was to use aggregates of decreasing grain sizes between the coarse gravel and the sand. To do this it is important to verify that a coarser material will not let the finer material placed above it penetrate its layer. The main idea behind this is to prevent smaller particles from having direct contact with passageways large enough to allow appreciable loss of the erodible materials (Cedergren). Several relationships have been established by using the grain size distribution of the working materials. Bertram developed the first in 1940. He established the following criterion:

$$\frac{D_{15}(filter)}{D_{85}(soil)} < 4$$

This ratio between the two soils is called the piping ratio. The U.S. Army Corps of Engineers (1955) and the U.S. Army (1971) also developed their own criterion. In this case the same condition was used, but they established that it should be less than or equal to 5. If this piping ratio is met, then our filter system will be safe from clogging and erosion.

A second criterion was developed in order to determine if the filter would have sufficient discharge capacity. It is important that the filter has the capacity to remove seepage quickly so that high seepage forces and hydrostatic pressures are avoided. Good discharge capacity is also important because the sand layer must be the one to clog, and the filter must not play a role in determining when the columns fail (clog).

Bertram's criterion for discharge capacity is as follows:

$$\frac{D_{15}(filter)}{D_{15}(soil)} > 5$$

The U.S. Corps of Engineers developed an additional ratio.

$$\frac{D_{50}(filter)}{D_{50}(soil)} \leq 25$$

The U.S. Corps of Engineers recommends the use of multi-layered filters to be used in order to prevent fine material from entering a pipe hole and clogging it. For this study this is very important because the outlet at the bottom of the column must not be clogged. Otherwise, the column would fail due to the closing of the only outlet instead of the failure of the soil, which is what we are interested in.

Originally it was decided to put a geotextile between the gravel and the sand. This was changed later because it was preferred to have all natural materials. So the multi-layered filter was used instead. Several types of aggregates would have to be used because the grain size difference between the sand and the coarse gravel is extremely large. On top of the coarse gravel a layer of coarse brick (brick nuggets) was placed. This was followed by pea gravel. Then fine brick nuggets were placed. Then thin layers of coarse and medium sand were placed. All of these materials, except for the sands, were washed thoroughly before placing them inside the columns to clean them from any dust they may have. To determine the piping ratio for all of the materials to be used, it was necessary to do a sieve analysis for each one. The results would then be graphed in order to get the required grain sizes. Figure 8 shows how each material compares to each other in terms of grain size distribution. In this figure the soil to the left of the curve being analyzed is considered the filter material. The curve located at the right of the curve analyzed is then the soil being retained. Knowing this, and finding the corresponding values for the particle diameters corresponding to the 15, 50, and 85 percent passing for each material, the different filter criteria can be examined. The following table presents a summary of the results.

Table 3-7. Granular Filter Properties

Material	**d_{15} (mm)**	**d_{50} (mm)**	**d_{85} (mm)**	**Piping Ratio < 4**	**Bertram's Discharge > 5**	**COE's Retention ≤ 25**
Gravel	20	23	25.4	-	-	-
Coarse Brick	8.5	14	19	1.05	2.35	1.64
Pea Gravel	5.5	6.7	8.5	1	1.55	2.09
Fine Brick	2.45	3.8	4.75	1.16	2.24	1.76
Silica Sand	1.0	1.5	1.8	1.36	2.45	2.53
Medium Sand	0.5	0.75	1.25	0.8	2.0	2.0
Collected Sands	0.18-0.60	0.22-0.34	0.35-0.55	0.91-1.43	0.83-2.78	2.2-3.4

The piping ratio for the fine brick is determined by dividing the d_{15} of the material above by its d_{85} (5.5/4.75 = 1.16). To find the discharge ratio of the fine brick, the d_{15} of the material above is divided by the fine brick's d_{15} (5.5/2.45 = 2.24). For the ratio used, the d_{50} of the material above the fine brick is divided by the fine brick's d_{50} (6.7/3.8 = 1.76). To determine the ratios between the medium sand and the collected sands, the smaller possible value for the numerator was used, along with the largest possible denominator (Piping ratio = 0.5/0.55 = 0.91).

The layer thickness for the gravel was between four and five inches. The following layer of brick nuggets ranged from one to one and a half inches in thickness. The pea gravel was from ¾ to one inch thick. This same layer thickness was used for the fine brick and the coarse silica sand. Only ½ to ¾ inches were used for the medium grain sized sand. The piping ratio is met for all of the aggregate layers. This is very important because the sand that is placed in the column must remain inside the column throughout the entire testing time. The discharge capacity is not met for any of the aggregate layers. This is not a major concern in this case because it is only necessary that the filter have a higher permeability than the sand. There was also a concern that since each layer of aggregate was fairly thin, the integrity of the filter would be compromised if any layer were not retained in its place. The main objective with discharge capacity for these columns is to have a higher permeability so that the water is not collected in the sand layer. The relatively small thickness of each filter layer and the constant increase in particle sizes of the filter material will allow the water to pass through the filter without being retained. In order to prove that the permeability of the filter would not be a problem, constant head permeability tests had to be done for every material used, as well as variable head tests on smaller samples.

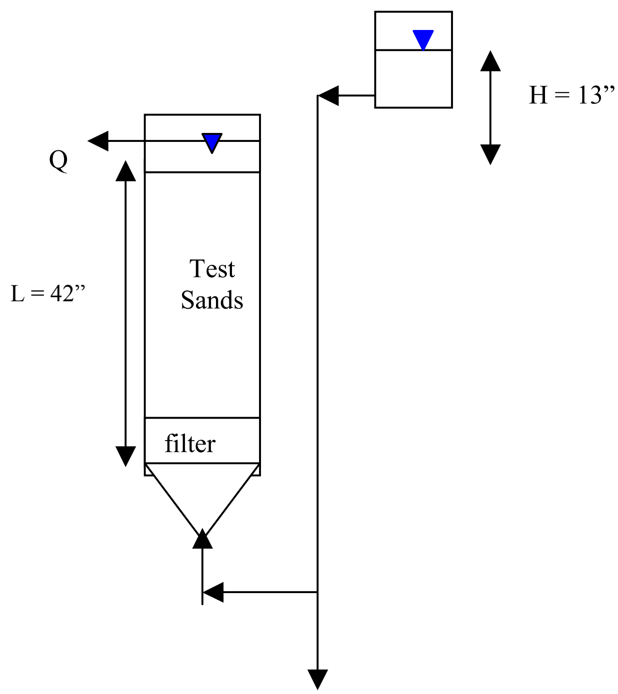
Permeability

Archer Gold (Candler)

The Alachua County Soil Survey presents a range of values for the permeability of Candler as it is found in the field. The ranges were determined to be between 6 and 20 inches per hour (0.004 and 0.014 cm/sec). Constant head permeability tests were done in order to test the hydraulic conductivity of each of the packed columns. The columns were saturated at such a slow pace to try to prevent any major changes in the density and to push as much air out of the soil as possible.

Once the columns were saturated, a bucket half filled with water was connected to the each. The level of the water in the bucket was held constant throughout the testing time by using a piezometer to verify water level. The water forced through the column came out from a hole that was drilled in the column approximately three inches above the top level of the soil. The elevation head in all the tested columns was 13 inches. The length of the soil tested was 42 inches for all columns. Therefore, the hydraulic gradient was kept constant for all columns and the results obtained can be compared.

Testing started once a constant flow of water was observed to come out the nozzle. The water that flowed through the columns was collected in a bucket and weighed after the test was completed. Two tests were performed on each column.



The data collected was then used to solve Darcy’s equation for the permeability, which is our only unknown. This test was done by following the ASTM test procedures outlined for smaller-scale laboratory constant-head tests.

Darcy’s equation for a constant head permeability test is as follows:

Q (volume/time) $= k*i*A = k*(\Delta h/L)*\pi*r^2$

The volume of water is the quantity collected during the test. The time is either 10 or 20 minutes; Δh is the head difference, which for all columns was 13 inches; L is the length of the sample, which for all columns is 42 inches; and d is the inside diameter of the columns, which is eight inches.

The quantity of water collected during the test was weighed and converted to a volume by dividing the weight of the water by the density of water. Solving for the permeability, k gives the columns permeability at the test temperature. Then, using a temperature conversion factor that permeability to the value corresponding to 20^{o}C gives us a permeability, which can be used to compare all columns.

Table 3-8. Candler Permeability

Column	*7*	*8*	*9*	*13*	*14*	*15*
Permeability (cm/sec)	2.23E-02	2.23E-02	2.21E-02	2.03E-02	2.15E-02	2.03E-02
Column	*34*	*35*	*36*	*40*	*41*	*42*
Permeability (cm/sec)	2.30E-02	1.81E-02	2.08E-02	1.94E-02	1.94E-02	1.94E-02
Column	*55*	*56*	*57*	*61*	*62*	*63*
Permeability (cm/sec)	2.13E-02	2.23E-02	2.18E-02	1.92E-02	1.84E-02	2.01E-02

The average permeability of this set of columns is 0.0207 cm/sec (+/- 0.0016), which is higher than the field permeability presented in the Alachua County Soil Survey. Piping occurring between the column walls and the soil is one reason for the higher values. Although the interiors of the columns are covered with coarse particles, this does not cover the totality of the contact surface and water will always find the path of least resistance. This can be a significant source of error during any column study.

To verify the results obtained for the column tests, constant head tests were performed using an ASTM permeameter. This device is designed to determine a soil's permeability using ASTM method D 2434. Knowing the volume of the permeameter cylinder, the quantity of soil needed for each test was determined by using the density of the soil in the columns. The test is performed by following the procedure outlined in the ASTM description. The permeability of the soil sample is found by using Darcy's Law. The result had to be modified to compensate for temperature. Permeability of this soil was 0.0194 cm/sec, which is fairly close to what was found in the columns. A second run of permeameter tests was conducted with wastewater to get an idea of what will happen when testing starts.

Viscosity of the wastewater influences test results because the permeability not only depends on the media, but also on the properties of the liquid. The permeability here was reduced to 0.0104 cm/sec. Although this gives an indication of what will happen, it is difficult to make any exact predictions based on these results because the relative diameter of the suspended solids in the wastewater is much larger in the permeameter than they are in the columns. The pore openings in the stone diffuser used in the permeameter are much smaller than the voids of the gravel located on the surface of the drain field. Therefore, the clogging of the surface of the stone has a significant impact on the results, and does not allow any certain conclusions to be drawn.

Millhopper

The Alachua County Soil Survey presents three ranges of permeability for Millhopper. The surface layer has a range of 6 to 20 inches per hour, which translates to 0.004 to 0.014 cm per second. The middle layer, starting at a depth of 58 down to 64 inches from the surface, has a permeability range between 2 and 6 inches per hour, or 0.0014 to 0.004 cm per second. The bottom layer has permeability values ranging between 0.06 to 2 inches per hour, or 4.23×10^{-5} to 0.004 cm per second.

The same constant head test done before was also used for these columns. In this case everything (hydraulic gradient and area) remained the same.

The results obtained in this case are found in the following table. The average permeability of these columns is 0.0109 cm/sec (+/- 7.8×10^{-4} cm/sec). This value fits in the range for the soil in the top layer. The effects of channeling have to be considered in this case as well.

The permeameter test was also done for this soil. In this case a sample of each layer was used to run individual tests. The permeability's found for the top, medium, and bottom layer is 0.0094 cm/sec, 0.0087 cm/sec, and 0.0085 cm/sec respectively. These values are slightly lower than the column average, but still fall in the ranges presented in the Soil Survey. A test with wastewater was done for the sample of the middle layer. In this case the permeability was reduced to 0.0053 cm/sec.

Table 3-9. Millhopper Permeability

Column	*4*	*5*	*6*	*22*	*23*	*24*
Permeability (cm/sec)	0.97E-02	1.04E-02	1.09E-02	1.03E-02	1.15E-02	1.16E-02
Column	*25*	*26*	*27*	*43*	*44*	*45*
Permeability (cm/sec)	1.04E-02	1.13E-02	1.15E-02	1.04E-02	0.994E-02	1.05E-02
Column	*52*	*53*	*54*	*70*	*71*	*72*
Permeability (cm/sec)	1.02E-02	1.07E-02	1.12E-02	1.21E-02	1.24E-02	1.09E-02

Pomona

The range of values presented in the Alachua County Soil Survey varies depending on the soil layers. The top layer has values ranging from 6 to 20 inches per hour or 0.004 to 0.014 cm per second. The second layer, which extends from a depth of 25 inches to 32 inches, has values between 0.6 to 20 inches per hour, or 4.23×10^{-4} to 0.014 cm per second. A third layer, which was the last layer excavated, has values ranging from 2 to 20 inches per hour or 0.0014 to 0.014 cm per second.

The same constant head permeability test outlined previously was followed for these columns. The results obtained for the columns with the Candler fill are as follows.

Table 3-10. Pomona Permeability (with Candler Fill)

Column	*1*	*2*	*3*	*19*	*20*	*21*
Permeability (cm/sec)	8.56E-03	8.91E-03	7.96E-03	7.90E-03	8.86E-03	8.26E-03
Column	*28*	*29*	*30*	*46*	*47*	*48*
Permeability (cm/sec)	8.56E-03	8.97E-03	8.94E-03	9.43E-03	10.43E-03	9.73E-03
Column	*49*	*50*	*51*	*67*	*68*	*69*
Permeability (cm/sec)	9.73E-03	9.73E-03	7.71E-03	7.86E-03	8.21E-03	9.66E-03

For this set of columns the average permeability was 0.0089 cm/sec (+/- 8.4×10^{-4}cm/sec). Unfortunately this average falls in all of the ranges established for the different layers. The results for the tests done for the columns with the Astatula as the top fill are as follows.

Table 3-11. Pomona Permeability (with Astatula Fill)

Column	*10*	*11*	*12*	*16*	*17*	*18*
Permeability (cm/sec)	10.04E-03	10.10E-03	9.96E-03	12.34E-03	9.94E-03	8.76E-03
Column	*31*	*32*	*33*	*37*	*38*	*39*
Permeability (cm/sec)	9.01E-03	10.36E-03	9.77E-03	9.68E-03	8.31E-03	11.00E-03
Column	*58*	*59*	*60*	*64*	*65*	*66*
Permeability (cm/sec)	9.13E-03	9.87E-03	8.46E-03	9.20E-03	9.72E-03	10.05E-03

In this case the average was 0.0098 cm/sec (+/- 9.7×10^{-4} cm/sec). This value also falls in the range of any of the three layers described for the Pomona soils.

Permeability tests were done for all three layers of Pomona and for each layer of fill with the ASTM permeameter method. The bottom, middle, and top layers had permeability of 0.0071 cm/sec, 0.0078 cm/sec, and

0.0088 cm/sec respectively. Using wastewater for the bottom layer, a permeability of 0.0050 cm/sec was found. The permeability found for the Astatula and Candler fills were 0.0125 cm/sec and 0.0119 cm/sec respectively.

SUMMARY AND CONCLUSIONS

The main goal of this report is to find the properties of the soils used for the column study, and it was completed successfully. It was determined that grain size distributions of the materials collected coincide with the values found in the soils survey used as a reference point. The densities placed in the columns were modeled after what is commonly found in the field, or where drainage fields are normally constructed. The permeability of the columns was compared to the permeability of each soil type in them and it was found that they were all similar. The results obtained for the permeability also fell in the range established in soil survey used as a reference. The results of these tests serve to prove the validity of the columns when compared to real conditions. A secondary goal was to demonstrate that the permeability of the columns were among a reasonable range of values for each soil type, which was demonstrated as well. By making sure that there is a similarity in the permeability of each column within each soil type, it is assured that the results obtained when they are tested can be compared to each other. The last goal of this report was to make any possible predictions about the results from the dosing of the columns with the wastewater. Even though the conditions are not the same for the columns and the test used, it was determined that soils have a much smaller permeability when tested with the same wastewater that will be used for the columns. This comes as a result of the permeability not being dependent on the soil only, but on the properties of the fluid as well. Based on this, Pomona should fail first, followed by Millhopper and finally Candler.

Table A-1. Candler Drainage Measurements

Column #	Agg	Nugget	P gravel	Fine Bri	Coarse	Cadjust	Med grit
42	4.75	6.25	7	7.75	8.5	8.75	9.25
41	4.25	5.75	6.75	7.25	8.25	8.75	9.25
40	4.5	5.5	7	7.75	8.5	8.75	9.25
36	5	6	7	7.75	8.5	8.75	9.25
35	5	6	7	8	8.75	8.75	9.25
34	4.75	5.75	6.5	7.25	8	8.75	9.25
63	5.25	6.75	7.5	8.25	8.75	8.75	9.25
62	5.25	6.25	7.25	8	9	8.75	9.25
61	4.5	5.75	6.5	7.5	8.25	8.75	9.25
57	4.5	6	6.75	7.5	8.25	8.75	9.25
56	4.75	5.75	6.5	7.5	8.25	8.75	9.25
55	4.25	6	7	7.75	8.5	8.75	9.25
13	6	7.25	8.25	9	9.5	9.5	10
14	5.25	7	7.75	8.5	9.5	9.5	10
15	5	7	7.75	8.25	9	9	9.75
9	5.25	6.5	7.25	8	9	9	9.5
8	4.75	6	6.75	7.5	8.25	8.75	9.5
7	5.5	6.75	7.5	8.25	9	9	9.75

Table A-2. Candler Soil Measurements

#	Datum	0"-6"*	0"-12"	0"-18"	0"-24"	0"-30"	0"-36"	0"-42"	42-end
42	9.25	14.5	20.5	26.25	32	38.25	44.25	51.25	51.25
41	9.25	14.75	20.75	26.75	32.5	38.75	44.75	50.75	51.25
40	9.25	15	20.75	26.875	32.75	38.75	44.75	50.75	51.25
36	9.25	14.75	20.75	26.75	32.75	38.75	44.75	50.75	51.25
35	9.25	14.75	20.75	26.75	32.75	38.75	44.875	51	51.25
34	9.25	14.75	20.75	26.75	32.75	38.75	44.75	51	51.25
63	9.25	15.25	21.25	27.25	33.25	39.25	45.25	51.25	51.25
62	9.25	14.75	20.75	26.75	32.75	38.75	44.875	51	51.25
61	9.25	14.75	20.75	26.75	32.75	38.875	45	51.125	51.25
57	9.25	15	20.875	26.75	32.75	38.875	44.75	50.625	51.25
56	9.25	14.75	20.875	26.75	32.75	38.75	44.75	50.75	51.25
55	9.25	15.25	20.75	26.25	32	38.25	44.25	50.25	51.25
13	10	15.875	21.875	27.875	34	40	45.75	51.75	52
14	10	15.75	21.5	27.75	33.25	39.5	45.5	51.5	52
15	9.75	15.5	21.125	27.25	33.25	39.5	45.5	51.5	51.75
9	9.5	15.25	21	27	33.25	39.5	45.5	51.25	51.5
8	9.5	15.25	21	27	33.25	39.25	45.25	51.25	51.5
7	9.75	15.5	21.75	27.5	33.25	39.5	45.5	51.75	51.75

Table A-3. Candler Soil Density of Increment Depth

#	0"-6"	7"-12"	13"-18"	19"-24"	25"-30"	31"-36"	37"-42"	Average
42	103.5	90.5	97.7	97.7	89.9	93.6	80.3	93.31
41	98.7	90.5	93.6	97.7	89.9	93.6	93.6	93.97
40	94.5	94.5	91.7	95.6	93.6	93.6	93.6	93.89
36	98.7	90.5	93.6	93.6	93.6	93.6	93.6	93.93
35	98.7	90.5	93.6	93.6	93.6	91.7	91.7	93.38
34	98.7	90.5	93.6	93.6	93.6	93.6	89.9	93.39
63	90.5	90.5	93.6	93.6	93.6	93.6	93.6	92.75
62	98.7	90.5	93.6	93.6	93.6	91.7	91.7	93.38
61	98.7	90.5	93.6	93.6	91.7	91.7	91.7	93.11
57	94.5	92.4	95.6	93.6	91.7	95.6	95.6	94.17
56	98.7	88.7	95.6	93.6	93.6	93.6	93.6	93.95
55	90.5	98.7	102.2	97.7	89.9	93.6	93.6	95.19
13	92.4	90.5	93.6	91.7	93.6	97.7	93.6	93.33
14	94.5	94.5	89.9	102.2	89.9	93.6	93.6	94.02
15	94.5	96.6	91.7	93.6	89.9	93.6	93.6	93.37
9	94.5	94.5	93.6	89.9	89.9	93.6	97.7	93.39
8	94.5	94.5	93.6	89.9	93.6	93.6	93.6	93.34
7	94.5	86.9	97.7	97.7	89.9	93.6	89.9	92.89
Avg/Depth	96.1	92.0	94.4	94.6	92.0	93.7	92.5	

Table A-4. Candler Soil Density of Total Depth

#	0"-6"	0"-12"	0"-18"	0"-24"	0"-30"	0"-36"	0"-42"
42	103.5	96.6	96.9	97.1	95.6	95.2	92.8
41	98.7	94.5	94.2	95.1	94.0	93.9	93.9
40	94.5	94.5	93.5	94.0	94.0	93.9	93.9
36	98.7	94.5	94.2	94.0	94.0	93.9	93.9
35	98.7	94.5	94.2	94.0	94.0	93.6	93.3
34	98.7	94.5	94.2	94.0	94.0	93.9	93.3
63	90.5	90.5	91.6	92.1	92.4	92.6	92.8
62	98.7	94.5	94.2	94.0	94.0	93.6	93.3
61	98.7	94.5	94.2	94.0	93.6	93.2	93.0
57	94.5	93.4	94.2	94.0	93.6	93.9	94.2
56	98.7	93.4	94.2	94.0	94.0	93.9	93.9
55	90.5	94.5	96.9	97.1	95.6	95.2	95.0
13	92.4	91.5	92.2	92.1	92.4	93.2	93.3
14	94.5	94.5	92.9	95.1	94.0	93.9	93.9
15	94.5	95.5	94.2	94.0	93.2	93.2	93.3
9	94.5	94.5	94.2	93.1	92.4	92.6	93.3
8	94.5	94.5	94.2	93.1	93.2	93.2	93.3
7	94.5	90.5	92.9	94.0	93.2	93.2	92.8
Avg/Depth	96.1	93.9	94.0	94.2	93.7	93.7	93.5

Table A-5. Millhopper Drainage Measurements

Column #	Agg	Nugget	P gravel	Fine Bric	Coarse	Med grit
25	5.75	7	8	8.75	9.25	9.5
26	5	6	7.25	8	8.5	8.75
27	5.75	6.75	8	9	9.375	9.625
43	5	6.75	7.5	8	8.5	8.875
44	5	6.25	7.25	8	8.5	8.75
45	5	6.5	7.5	8.25	8.625	9
70	3.75	4.75	5.75	6.25	6.5	6.875
71	3.75	4.5	5.5	6.25	6.5	6.75
72	4	5	5.75	6.25	6.75	6.875
54	5	6.75	7.375	8	8.5	8.875
53	4.75	6.5	6.75	7.5	7.875	8.25
52	5	6.5	7.75	8.25	8.5	8.875
24	5.5	7.75	7.75	8.25	8.875	9
23	5	6.5	7.5	8.25	8.75	9
22	5.5	6.75	7.5	8.25	8.75	9
6	5.75	7.25	8	9	9.125	9.625
5	4	5.25	6.25	7	7.5	7.625
4	5.5	6.75	7.75	8.5	8.875	9

Table A-6. Millhopper Soil Measurements

	Depth	5	5	5.5	5.5	5.5	5.5	5.5	4.5	42
	Weight	6.674	6.674	7.342	7.342	7.342	7.342	7.342	6.007	kg
#	Datum	0"-5"	0"-10"	0"-15.5"	0"-21"	0"-26.5"	0"-32"	0"-37.5"	0"-42"	42-end
25	9.5	14.5	19.625	25	30.375	35.875	41.375	46.875	51.375	51.5
26	8.75	14	18.75	24.5	29.75	35.5	41	46.5	50.75	50.75
27	9.625	14.75	19.75	25.125	30.375	36	41.5	47	51.5	51.625
43	8.875	14.875	19.25	24.5	30	35.375	40.75	46.375	50.5	50.875
44	8.75	13.75	18.75	24.125	29.5	35	40.375	45.875	50.375	50.75
45	9	14.125	18.875	24.375	29.875	35.375	40.5	46	50.625	51
70	6.875	12.125	17.125	22.75	28.125	33.75	39.375	44.875	49.25	49.25
71	6.75	12	17	22.25	27.75	33.375	38.875	44.5	48.875	48.875
72	6.875	12	17	22.25	27.625	33.375	38.875	44.375	48.875	48.875
54	8.875	14	19.125	24.5	30.125	35.875	41.125	46.5	50.875	50.875
53	8.25	13.5	18.5	24.125	29.625	35.125	40.625	46	50.375	50.375
52	8.875	14.125	19.25	24.75	30.375	35.875	41.375	46.875	51.25	51.25
24	9	14.125	19.25	24.5	30.125	35.625	41.125	46.75	51	51
23	9	14.125	19.25	24.75	30.25	35.75	41.25	46.75	51	51
22	9	14.125	19.25	25.75	30.125	35.75	41.25	46.75	51	51
6	9.625	14.625	19.875	25.375	30.25	35.875	41.25	46.75	51.125	51.625
5	7.625	12.75	17.75	23.25	28.75	34.25	39.75	45.375	49.625	49.625
4	9	14.125	19.25	24.75	30.125	35.625	41.125	46.625	51	51

Table A-7. Millhopper Soil Density of Increment Depth

Depth	5	5	5.5	5.5	5.5	5.5	5.5	4.5	
Weight	6.6742	6.6742	7.34162	7.34162	7.34162	7.34162	7.34162	6.00678	
#	0"-5"	6"-10"	11"-15.5"	16.5"-21"	22"-26.5"	27.5"-32"	33"-37.5"	38.5"-42"	
25	96.7633	94.4033	99.0136	99.0136	96.7633	96.7633	96.7633	96.7633	97.0309
26	92.1556	101.856	92.5562	101.371	92.5562	96.7633	96.7633	102.455	97.0597
27	94.4033	96.7633	99.0136	101.371	94.613	96.7633	96.7633	96.7633	97.0568
43	80.6361	110.587	101.371	96.7633	99.0136	99.0136	94.613	105.56	98.4447
44	96.7633	96.7633	99.0136	99.0136	96.7633	99.0136	96.7633	96.7633	97.6072
45	94.4033	101.856	96.7633	96.7633	96.7633	103.844	96.7633	94.1481	97.6631
70	92.1556	96.7633	94.613	99.0136	94.613	94.613	96.7633	99.528	96.0079
71	92.1556	96.7633	101.371	96.7633	94.613	96.7633	94.613	99.528	96.5713
72	94.4033	96.7633	101.371	99.0136	92.5562	96.7633	96.7633	96.7633	96.7997
54	94.4033	94.4033	99.0136	94.613	92.5562	101.371	99.0136	99.528	96.8628
53	92.1556	96.7633	94.613	96.7633	96.7633	96.7633	99.0136	99.528	96.5455
52	92.1556	94.4033	96.7633	94.613	96.7633	96.7633	96.7633	99.528	95.9692
24	94.4033	94.4033	101.371	94.613	96.7633	96.7633	94.613	102.455	96.9232
23	94.4033	94.4033	96.7633	96.7633	96.7633	96.7633	96.7633	102.455	96.8848
22	94.4033	94.4033	81.8767	121.645	94.613	96.7633	96.7633	102.455	97.8654
6	96.7633	92.1556	96.7633	109.169	94.613	99.0136	96.7633	99.528	98.0961
5	94.4033	96.7633	96.7633	96.7633	96.7633	96.7633	94.613	102.455	96.911
4	94.4033	94.4033	96.7633	99.0136	96.7633	96.7633	96.7633	99.528	96.8002
Average	93.4	96.9	97.0	99.6	95.6	97.7	96.5	99.8	

Table A-8. Millhopper Soil Density of Total Depth

Depth	5	5	5.5	5.5	5.5	5.5	5.5	4.5	
Weight	6.6742	6.6742	7.34162	7.34162	7.34162	7.34162	7.34162	6.00678	
#	0"-5"	0"-10"	0"-15.5"	0"-21"	0"-26.5"	0"-32"	0"-37.5"	0"-42"	42-end
25	96.7633	95.5687	96.7633	97.3428	97.2219	97.1428	97.087	97.0522	96.76
26	92.1556	96.7633	95.2274	96.7633	95.859	96.0132	96.1225	96.7633	96.76
27	94.4033	95.5687	96.7633	97.9292	97.2219	97.1428	97.087	97.0522	96.76
43	80.6361	93.2659	95.9892	96.1908	96.7633	97.1428	96.7633	97.6351	96.76
44	96.7633	96.7633	97.55	97.9292	97.6849	97.9107	97.7407	97.6351	96.76
45	94.4033	97.9882	97.55	97.3428	97.2219	98.2993	98.071	97.6351	96.76
70	92.1556	94.4033	94.4776	95.6249	95.4132	95.2747	95.4901	95.907	95.91
71	92.1556	94.4033	96.7633	96.7633	96.3091	96.3868	96.1225	96.4762	96.48
72	94.4033	95.5687	97.55	97.9292	96.7633	96.7633	96.7633	96.7633	96.76
54	94.4033	94.4033	95.9892	95.6249	94.9714	96.0132	96.4419	96.7633	96.76
53	92.1556	94.4033	94.4776	95.0657	95.4132	95.6425	96.1225	96.4762	96.48
52	92.1556	93.2659	94.4776	94.513	94.9714	95.2747	95.4901	95.907	95.91
24	94.4033	94.4033	96.7633	96.1908	96.3091	96.3868	96.1225	96.7633	96.76
23	94.4033	94.4033	95.2274	95.6249	95.859	96.0132	96.1225	96.7633	96.76
22	94.4033	94.4033	89.5422	96.1908	95.859	96.0132	96.1225	96.7633	96.76
6	96.7633	94.4033	95.2274	98.5227	97.6849	97.9107	97.7407	97.9292	96.76
5	94.4033	95.5687	95.9892	96.1908	96.3091	96.3868	96.1225	96.7633	96.76
4	94.4033	94.4033	95.2274	96.1908	96.3091	96.3868	96.4419	96.7633	96.76
Average	93.4	95.0	95.6	96.6	96.3	96.6	96.6	96.9	

Table A-9. Pomona with Candler Fill Drainage Measurements

Column #	Agg	Nugget	P gravel	Fine Bric	Coarse	Med grit
28	4.75	5.75	6.5	7	7.5	8
29	4.5	5.5	6.25	6.75	7.25	7.875
30	4.75	5.75	6.5	7.25	7.75	8.25
46	5	6	6.375	6.875	7.75	8.25
47	4.75	6	6.5	7.125	8	8.5
48	5	6.25	7	7.375	8.25	8.75
67	3.75	5	5.75	6.25	6.75	7.25
68	3.5	4.5	5.25	5.75	6.25	6.75
69	3.75	5.25	5.875	6.25	7	7.5
49	4.75	6	6.5	7.25	8	8.5
50	5	6	6.75	7.5	8	8.375
51	4.5	5.75	6.5	7.25	7.75	8.125
19	4.25	5.5	6.25	6.75	7.5	8
20	5	6.25	6.75	7.25	8	8.5
21	5	6.25	7	7.5	8.25	8.75
1	6	7.25	8.125	8.625	9.375	10
2	5.75	7	8.25	8.625	9.375	10
3	6	7.25	8	8.625	9.25	9.75

Table A-10. Pomona with Candler Fill Soil Measurements

	Pomona					Candler		
	Depth	5.5	5.5	5	6	4	6	5	5.25
#	Datum	0"-5.5"	0"-11"	0"-16"	0"-22"	0"-26"	0"-32"	0"-37"	0"-42"
28	8	13.375	18.75	23.5	29.75	33.875	39.875	44.875	50.125
29	7.875	13.125	18.625	23.25	29.625	33.625	39.625	44.625	50
30	8.25	13.625	18.875		28.25	29.375	40	45.125	50.375
46	8.25	13.625	18.875	24.25	30.25	34.25	40.25	45.375	50.625
47	8.5	13.75	19	23.75	30	34.125	40.125	45.25	50.5
48	8.75	14.25	19.625	24.5	30.75	34.75	40.75	45.75	51
67	7.25	12.5	17.875	22.75	28.875	33	39	44	49.5
68	6.75	11.875	17.125	22.125	28.5	32.5	38.5	43.5	49
69	7.5	12.75	18.125	22.875	29.125	33.25	39.25	44.25	49.875
49	8.5	13.875	19.125	24.125	30.375	34.25	40.25	45.25	50.625
50	8.375	13.625	19	23.825	30.125	34.125	40.25	45.25	50.5
51	8.125	13.5	18.75	23.625	29.875	34	39.875	44.875	50.375
19	8	13.375	18.875	23.75	30	34.125	40.125	45.25	50.375
20	8.5	14.125	19.5	24.5	30.875	34.875	40.125	46	51.5
21	8.75	14.25	19.5	24.5	30.875	34.875	40.875	46	51.375
1	10	15.375	20.875	25.625	31.875	35.875	41.875	47.25	52.5
2	10	15.25	20.625	25.5	31.75	35.75	41.875	47	52.75
3	9.75	15.125	20.5	25.375	31.75	35.75	41.75	46.875	52.125

Table A-11. Pomona with Candler Fill Soil Density of Increment Depth

	Pomona					Candler				
Depth	5.5	5.5	5	6	4	6	5	5.25		
Weight	7.34162	7.34162	6.6742	8.00904	5.33936	7.75053	6.45877	6.78171	Pomona	Candler
#	0"-5.5"	5.5"-11"	11"-16"	16"-22"	22"-26"	26"-32"	32"-37"	37"-42"	Avg	Avg
28	99.0136	99.0136	101.856	92.8928	93.8311	93.64	93.64	93.64	**97.3215**	**93.64**
29	101.371	96.7633	104.609	91.0714	96.7633	93.64	93.64	91.4623	**98.1156**	**92.9141**
30	99.0136	101.371		96.7633			91.3561	93.64	**99.0494**	**92.498**
46	99.0136	101.371	90.0124	96.7633	96.7633	93.64	91.3561	93.64	**96.7848**	**92.8787**
47	101.371	101.371	101.856	92.8928	93.8311	93.64	91.3561	93.64	**98.2645**	**92.8787**
48	96.7633	99.0136	99.2445	92.8928	96.7633	93.64	93.64	93.64	**96.9355**	**93.64**
67	101.371	99.0136	99.2445	94.7886	93.8311	93.64	93.64	89.3836	**97.6498**	**92.2212**
68	103.844	101.371	96.7633	91.0714	96.7633	93.64	93.64	89.3836	**97.9626**	**92.2212**
69	101.371	99.0136	101.856	92.8928	93.8311	93.64	93.64	87.3973	**97.793**	**91.5591**
49	99.0136	101.371	96.7633	92.8928	99.8847	93.64	93.64	91.4623	**97.9851**	**92.9141**
50	101.371	99.0136	100.273	92.1556	96.7633	91.729	93.64	93.64	**97.9153**	**93.00**
51	99.0136	101.371	99.2445	92.8928	93.8311	95.6323	93.64	89.3836	**97.2706**	**92.8853**
19	99.0136	96.7633	99.2445	92.8928	93.8311	93.64	91.3561	95.9239	**96.3491**	**93.64**
20	94.613	99.0136	96.7633	91.0714	96.7633	107.017	79.6936	89.3836	**95.6449**	**92.0315**
21	96.7633	101.371	96.7633	91.0714	96.7633	93.64	91.3561	91.4623	**96.5465**	**92.1528**
1	99.0136	96.7633	101.856	92.8928	96.7633	93.64	87.107	93.64	**97.4579**	**91.4623**
2	101.371	99.0136	99.2445	92.8928	96.7633	91.729	91.3561	85.4974	**97.8571**	**89.5275**
3	99.0136	99.0136	99.2445	91.0714	96.7633	93.64	91.3561	93.64	**97.0213**	**92.8787**
Average	99.6	99.6	99.1	92.9	95.9	94.3	91.6	91.7		

Table A-12. Pomona with Candler Fill Soil Density of Total Depth

	Pomona					Candler				
Depth	5.5	5.5	5	6	4	6	5	5.25	Pomona	Candler
Weight	7.34162	7.34162	6.6742	8.00904	5.33936	7.75053	6.45877	6.78171	Total	Total
#	0"-5.5"	0"-11"	0"-16"	0"-22"	0"-26"	26"-32"	26"-37"	26"-42"	0"-26"	26"-42"
28	99.0136	99.0136	99.8847	97.8756	97.2308	93.64	93.64	93.64	**97.23**	**93.64**
29	101.371	99.0136	100.697	97.8756	97.7028	93.64	93.64	92.9252	**97.70**	**92.92519**
30	99.0136	100.179								
46	99.0136	100.179	96.7633	96.7633	96.7633	93.64	92.5879	92.9252	**96.76**	**92.92519**
47	101.371	101.371	101.522	99.0136	98.1794	93.64	92.5879	92.9252	**98.18**	**92.92519**
48	96.7633	97.8756	98.2993	96.7633	96.7633	93.64	93.64	93.64	**96.76**	**93.64**
67	101.371	100.179	99.8847	98.4413	97.7028	93.64	93.64	92.2212	**97.70**	**92.22121**
68	103.844	102.592	100.697	97.8756	97.7028	93.64	93.64	92.2212	**97.70**	**92.22121**
69	101.371	100.179	100.697	98.4413	97.7028	93.64	93.64	91.5278	**97.70**	**91.52782**
49	99.0136	100.179	99.0857	97.3163	97.7028	93.64	93.64	92.9252	**97.70**	**92.92519**
50	101.371	100.179	100.208	97.8756	97.7028	91.729	92.5879	92.9252	**97.70**	**92.92519**
51	99.0136	100.179	99.8847	97.8756	97.2308	95.6323	94.7163	92.9252	**97.23**	**92.92519**
19	99.0136	97.8756	98.2993	96.7633	96.3004	93.64	92.5879	93.64	**96.30**	**93.64**
20	94.613	96.7633	96.7633	95.1416	95.3876	107.017	92.5879	91.5278	**95.39**	**91.52782**
21	96.7633	99.0136	98.2993	96.2167	96.3004	93.64	92.5879	92.2212	**96.30**	**92.22121**
1	99.0136	97.8756	99.0857	97.3163	97.2308	93.64	90.553	91.5278	**97.23**	**91.52782**
2	101.371	100.179	99.8847	97.8756	97.7028	91.729	91.5591	89.5088	**97.70**	**89.50882**
3	99.0136	99.0136	99.0857	96.7633	96.7633	93.64	92.5879	92.9252	**96.76**	**92.92519**
Average	99.6	99.5	99.4	97.9	98.4				**98.40**	

Table A-13. Pomona with Astatula Fill Drainage Measurements

Column #	Agg	Nugget	P gravel	Fine Bric	Coarse	Med grit
31	4.75	5.75	6.5	7	7.75	8.25
32	5	6	6.5	7	7.75	8.25
33	4.5	5.75	6.5	7	7.75	8.25
37	4.75	6	6.5	7.25	8	8.5
38	4.75	6	6.5	7.125	8	8.5
39	4.5	5.75	6.5	7.125	7.75	8.25
58	4	5	5.5	6.125	7	7.5
59	3.75	5	5.625	6.125	7	7.625
60	4	5.25	5.75	6.125	7	7.5
64	3.75	5	5.5	6.25	7	7.5
65	3.75	5.25	5.75	6.5	7.25	7.75
66		6.75	7.5	8	8.75	9.25
10	4	5.5	6.5	7.125	8	8.25
11	3.25	4.25	5.25	6.375	6.875	7.25
12	4.75	5.25	6.125	6.625	7.125	7.875
16				7.75	8.5	9
17				8	8.75	9.25
18				8.25	9	9.5

Table A-14. Pomona with Astatula Fill Soil Measurements

		Pomona					Astatula		
	Depth	5.5	5.5	5	6	4	5.5	5.5	5 / 5.5
#	Datum	0"-5.5"	0"-11"	0"-16"	0"-22"	0"-26"	0"-31.5"	0"-37"	0"-42"
31	8.25	13.5	19.25	24.25	30.375	34.375	39.875	45.25	50.25
32	8.25	13.75	19.25	24.25	30.375	34.375	39.75	45.25	50.25
33	8.25	13.75	19.25	24.25	30.375	34.375	39.875	45.375	50.375
37	8.5	14	19.5	24.5	30.5	34.5	39.875	45.25	50.625
38	8.5	13.875	19.375	24.5	30.375	34.375	39.75	45.125	50.625
39	8.25	13.75	19.125	24.25	30.25	34.375	39.625	45	50.5
58	7.5	13.875	18.5	23.375	29.375	33.375	38.875	44.375	49.875
59	7.625	13	18.625	23.5	29.5	33.5	38.875	44.375	49.875
60	7.5	12.75	18.25	23.25	29.25	33.25	38.75	44.25	49.625
64	7.5	12.5	18.75	23.375	29.5	33.625	39.125	44.625	49.625
65	7.75	13.25	18.5	23.5	29.625	33.625	39.125	44.625	49.75
66	9.25	14.75	20.25	25.25	31.375	35.75	41.25	46.625	51.625
10	8.25	13.75	19.375	24.375	30.5	34.5	39.875	45.25	50.75
11	7.25	12.75	18.125	23.25	29.375	33.5	39	44.5	49.875
12	7.875	13.125	18.625	23.5	29.625	33.5	39	44.375	49.875
16	9	14.25	19.75	24.75	31	35.375	40.5	46	51
17	9.25	14.5	20.25	25.125	31.25	35.625	41.125	46.325	51.25
18	9.5	14.75	20.5	25.375	31.5	35.625	41.125	46.5	51.5

Table A-15. Pomona with Astatula Fill Soil Density of Increment Depth

	Pomona					Astatula				
Depth	5.5	5.5	5	6	4	5.5	5.5	5 / 5.5		
Weight	7.34162	7.34162	6.6742	8.00904	5.33936	7.34162	7.34162	6.8-7.3	Average	Average
#	0"-5.5"	5.5"-11"	11"-16"	16"-22"	22"-26"	26"-31.5"	31.5"-37"	37"-42"	lbs/ft^3	g/cm^3
31	101.371	92.5562	96.7633	94.7886	96.7633	96.7633	99.0136	96.7633	96.8479	1.55
32	96.7633	96.7633	96.7633	94.7886	96.7633	99.0136	96.7633	96.7633	96.80	1.55
33	96.7633	96.7633	96.7633	94.7886	96.7633	96.7633	96.7633	96.7633	96.5165	1.55
37	96.7633	96.7633	96.7633	96.7633	96.7633	99.0136	99.0136	99.0136	97.6072	1.56
38	99.0136	96.7633	94.4033	98.8221	96.7633	99.0136	99.0136	96.7633	97.5695	1.56
39	96.7633	99.0136	94.4033	96.7633	93.8311	101.371	99.0136	96.7633	97.2404	1.56
58	83.4821	115.07	99.2445	96.7633	96.7633	96.7633	96.7633	96.7633	97.7016	1.57
59	99.0136	94.613	99.2445	96.7633	96.7633	99.0136	96.7633	96.7633	97.3673	1.56
60	101.371	96.7633	96.7633	96.7633	96.7633	96.7633	96.7633	99.0136	97.6206	1.56
64	106.44	85.1517	104.609	94.7886	93.8311	96.7633	96.7633	96.7633	96.8888	1.55
65	96.7633	101.371	96.7633	94.7886	96.7633	96.7633	96.7633	94.4033	96.80	1.55
66	96.7633	96.7633	96.7633	94.7886	88.4693	96.7633	99.0136	96.7633	95.761	1.53
10	96.7633	94.613	96.7633	94.7886	96.7633	99.0136	99.0136	96.7633	96.8103	1.55
11	96.7633	99.0136	94.4033	94.7886	93.8311	96.7633	96.7633	99.0136	96.4175	1.54
12	101.371	96.7633	99.2445	94.7886	99.8847	96.7633	99.0136	96.7633	98.0741	1.57
16	101.371	96.7633	96.7633	92.8928	88.4693	103.844	96.7633	96.7633	96.70	1.55
17	101.371	92.5562	99.2445	94.7886	88.4693	96.7633	102.346	98.2369	96.722	1.55
18	101.371	92.5562	99.2445	94.7886	93.8311	96.7633	99.0136	96.7633	96.7915	1.55
Average	98.3	96.7	97.5	95.5	94.9	98.0	98.1	97.1	97.0	

Table A-16. Pomona with Astatula Fill Soil Density of Total Depth

	Pomona					Astatula			
Depth	5.5	5.5	5	6	4	5.5	5.5	5 / 5.5	
Weight	7.34162	7.34162	6.6742	8.00904	5.33936	7.34162	7.34162	6.8-7.3	
#	0"-5.5"	0"-11"	0"-16"	0"-22"	0"-26"	0"-31.5"	0"-37"	0"-42"	g/cm^3
31	101.371	96.7633	96.7633	96.2167	96.3004	96.3809	96.7633	96.7633	1.55
32	96.7633	96.7633	96.7633	96.2167	96.3004	96.7633	96.7633	96.7633	1.55
33	96.7633	96.7633	96.7633	96.2167	96.3004	96.3809	96.4375	96.4762	1.55
37	96.7633	96.7633	96.7633	96.7633	96.7633	97.1489	97.4216	97.6247	1.56
38	99.0136	97.8756	96.7633	97.3163	97.2308	97.5374	97.7541	97.6247	1.56
39	96.7633	97.8756	96.7633	96.7633	96.3004	97.1489	97.4216	97.3359	1.56
58	83.4821	96.7633	97.5253	97.3163	97.2308	97.1489	97.0914	97.0488	1.55
59	99.0136	96.7633	97.5253	97.3163	97.2308	97.5374	97.4216	97.3359	1.56
60	101.371	99.0136	98.2993	97.8756	97.7028	97.5374	97.4216	97.6247	1.56
64	106.44	94.613	97.5253	96.7633	96.3004	96.3809	96.4375	96.4762	1.55
65	96.7633	99.0136	98.2993	97.3163	97.2308	97.1489	97.0914	96.7633	1.55
66	96.7633	96.7633	96.7633	96.2167	94.9376	95.2514	95.7925	95.907	1.54
10	96.7633	95.6761	96.0132	95.6761	95.8418	96.3809	96.7633	96.7633	1.55
11	96.7633	97.8756	96.7633	96.2167	95.8418	96.0014	96.1139	96.4796	1.55
12	101.371	99.0136	99.0857	97.8756	98.1794	97.9292	98.0889	97.9153	1.57
16	101.371	99.0136	98.2993	96.7633	95.3876	96.7633	96.7633	96.7633	1.55
17	101.371	96.7633	97.5253	96.7633	95.3876	95.6249	96.5676	96.7633	1.55
18	101.371	96.7633	97.5253	96.7633	96.3004	96.3809	96.7633	96.7633	1.55
Average	98.3	97.3	97.3	96.8	96.5	96.7	96.9	97.0	

Table A-17. Candler Soil with 1.2 GPD/ft^2

Column #	Total Mass $CBOD_5$,TSS,O&G grams	Days of dosing	Unsat. Condition feet	Waste Strength Category	K in/hr	Permeability min/inch	Density lb/ft^3
7	26.9	112	1	Low	31.67	1.89	92.75
8	26.6	112	1	Low	31.62	1.90	93.31
9	26.4	112	1	Low	31.39	1.91	93.31
13	26.7	112	2	Low	28.82	2.08	93.31
14	27.5	112	2	Low	30.47	1.97	93.87
15	23.1	112	2	Low	28.83	2.08	93.31
34 (fail)	80.7	113	2	Medium	32.53	1.84	93.31
35 (fail)	18.1	23	2	Medium	25.59	2.34	93.31
36 (fail)	19.3	25	2	Medium	29.49	2.03	93.87
40	82.5	112	1	Medium	27.50	2.18	93.87
41	80.3	112	1	Medium	27.50	2.18	93.87
42	79.6	112	1	Medium	27.49	2.18	92.75
55	150.4	112	1	High	30.22	1.99	95.01
56	153.6	112	1	High	31.67	1.89	93.87
57 (fail)	78.3	64	1	High	30.95	1.94	94.15
61 (fail)	50.8	39	2	High	27.27	2.20	93.03
62 (fail)	55.5	43	2	High	26.02	2.31	93.31
63 (fail)	59.9	45	2	High	28.52	2.10	92.75

Table A-18. Millhopper with 0.9 GPD/ft^2

Column #	Total Mass $CBOD_5$,TSS,O&G grams	Days of dosing	Unsat. Condition feet	Waste Strength Category	K in/hr	Permeability min/inch	Density lb/ft^3
4	21.0	112	1	Low	13.75	4.36	96.76
5	21.1	112	1	Low	14.75	4.07	96.76
6	20.6	112	1	Low	15.42	3.89	97.93
22	20.9	112	2	Low	14.53	4.13	96.76
23	20.8	112	2	Low	16.32	3.68	96.76
24	18.6	112	2	Low	16.49	3.64	96.76
25 (fail)	17.0	30	2	Medium	14.73	4.07	97.05
26 (fail)	15.0	22	2	Medium	15.98	3.76	96.76
27 (fail)	21.2	39	2	Medium	16.25	3.69	97.05
43	62.7	112	1	Medium	14.81	4.05	97.64
44	63.1	112	1	Medium	14.09	4.26	97.64
45	63.2	112	1	Medium	14.90	4.03	97.64
52	122.3	112	1	High	14.45	4.15	95.91
53	123.9	112	1	High	15.19	3.95	96.48
54	120.4	112	1	High	15.83	3.79	96.76
70	122.7	112	2	High	17.15	3.50	95.91
71 (fail)	29.1	24	2	High	17.61	3.41	96.48
72 (fail)	30.7	30	2	High	15.43	3.89	96.76

Table A-19. Pomona with Astatula Fill with 0.8 GPD/ft^2

Column #	Total Mass $CBOD_5$,TSS,O&G grams	Days of dosing	Unsat. Condition feet	Waste Strength Category	K in/hr	Permeability min/inch	Density lb/ft^3
10	18.7	112	1	Low	14.24	4.21	96.76
11	18.9	112	1	Low	14.31	4.19	96.48
12	18.6	112	1	Low	14.12	4.25	97.92
16	18.9	112	2	Low	17.50	3.43	96.76
17	18.7	112	2	Low	14.09	4.26	96.76
18	18.9	112	2	Low	12.42	4.83	96.76
31 (fail)	16.8	36	2	Medium	12.77	4.70	96.76
32	56.7	112	2	Medium	14.68	4.09	96.76
33 (fail)	18.7	41	2	Medium	13.85	4.33	96.48
37	56.6	112	1	Medium	13.71	4.38	97.62
38	56.6	112	1	Medium	11.77	5.10	97.62
39	55.1	112	1	Medium	15.59	3.85	97.34
58	108.6	112	1	High	12.94	4.64	97.05
59	108.0	112	1	High	13.99	4.29	97.34
60 (fail)	80.5	88	1	High	11.99	5.01	97.62
64 (fail)	80.1	88	2	High	13.03	4.60	96.48
65	109.6	112	2	High	13.78	4.35	96.76
66	108.3	112	2	High	14.25	4.21	95.91

Table A-20. Pomona with Candler Fill with 0.65 GPD/ft^2

Column #	Total Mass $CBOD_5$,TSS,O&G grams	Days of dosing	Unsat. Condition feet	Waste Strength Category	K in/hr	Permeability min/inch	Density lb/ft^3
1	15.3	112	1	Low	12.13	4.95	95.00
2	15.5	112	1	Low	12.63	4.75	94.44
3	14.9	112	1	Low	11.28	5.32	95.28
19	15.4	112	2	Low	11.19	5.36	95.28
20	15.3	112	2	Low	12.56	4.78	93.90
21	15.4	112	2	Low	11.70	5.13	94.72
28 (fail)	15.7	38	2	Medium	12.14	4.94	95.85
29 (fail)	19.1	47	2	Medium	12.71	4.72	95.85
30 (fail)	10.8	25	2	Medium	12.67	4.74	95.85
46	46.4	112	1	Medium	13.37	4.49	95.28
47 (fail)	18.0	42	1	Medium	14.79	4.06	96.13
48 (fail)	22.5	55	1	Medium	13.79	4.35	95.56
50	97.7	112	1	High	13.93	4.31	95.85
51	91.3	112	1	High	10.93	5.49	95.56
67 (fail)	25.5	23	2	High	11.15	5.38	95.56
68 (fail)	26.5	23	2	High	11.63	5.16	95.56
69 (fail)	22.3	20	2	High	13.69	4.38	95.28

Table A-21. Mass Loading of Lysimeters

Column #	Total Volume Liters	Loading gal/ft^2	CBOD Mass grams	TSS Mass grams	O&G Mass grams	CBOD Mass lb/ft^2	TSS Mass lb/ft^2	O&G Mass lb/ft^2	Sum of CBOD&TSS lb/ft^2	Total Mass CBOD,TSS,O&G lb/ft^2	Days of dosing	CBOD Mass lb/ft^2/day	TSS Mass lb/ft^2/day	O&G Mass lb/ft^2/day	Sum of CBOD&TSS lb/ft^2/day	Total Mass CBOD,TSS,O&G lb/ft^2/day	Volume Loaded L/day	Unsat. Condition	Strength	Soil type
1	100.3	0.65	9.9	4.9	1.3	0.060	0.029	0.008	0.089	0.097	112	0.00054	0.00026	0.00007	0.00080	0.00087	0.896	1	Low	Pomona with Candler Fill
2	101.1	0.65	10.0	4.9	1.3	0.060	0.030	0.008	0.090	0.098	112	0.00054	0.00026	0.00007	0.00080	0.00087	0.903	1	Low	Pomona with Candler Fill
3	97.5	0.65	9.6	4.7	1.2	0.058	0.029	0.007	0.087	0.094	112	0.00052	0.00025	0.00007	0.00077	0.00084	0.870	1	Low	Pomona with Candler Fill
4	137.3	0.9	13.6	6.6	1.7	0.082	0.040	0.011	0.122	0.133	112	0.00073	0.00036	0.00009	0.00109	0.00118	1.226	1	Low	Millhopper
5	137.9	0.9	13.6	6.7	1.8	0.082	0.040	0.011	0.123	0.133	112	0.00074	0.00036	0.00009	0.00110	0.00119	1.231	1	Low	Millhopper
6	134.4	0.9	13.3	6.5	1.7	0.080	0.039	0.010	0.120	0.130	112	0.00072	0.00035	0.00009	0.00107	0.00116	1.200	1	Low	Millhopper
7	175.6	1.2	17.4	8.5	2.2	0.105	0.051	0.013	0.156	0.170	112	0.00094	0.00046	0.00012	0.00140	0.00152	1.568	1	Low	Candler
8	173.9	1.2	17.2	8.4	2.2	0.104	0.051	0.013	0.155	0.168	112	0.00093	0.00045	0.00012	0.00138	0.00150	1.553	1	Low	Candler
9	172.6	1.2	17.1	8.4	2.2	0.103	0.050	0.013	0.154	0.167	112	0.00092	0.00045	0.00012	0.00137	0.00149	1.541	1	Low	Candler
10	122.5	0.8	12.1	5.9	1.6	0.073	0.036	0.009	0.109	0.118	112	0.00065	0.00032	0.00008	0.00097	0.00106	1.094	1	Low	Pomona with Astatula Fill
11	123.2	0.8	12.2	6.0	1.6	0.074	0.036	0.009	0.110	0.119	112	0.00066	0.00032	0.00008	0.00098	0.00106	1.100	1	Low	Pomona with Astatula Fill
12	121.3	0.8	12.0	5.9	1.5	0.072	0.035	0.009	0.108	0.117	112	0.00065	0.00032	0.00008	0.00096	0.00105	1.083	1	Low	Pomona with Astatula Fill
13	174.7	1.2	17.3	8.5	2.2	0.104	0.051	0.013	0.155	0.169	112	0.00093	0.00046	0.00012	0.00139	0.00151	1.560	2	Low	Candler
14	179.6	1.2	17.8	8.7	2.3	0.107	0.053	0.014	0.160	0.174	112	0.00096	0.00047	0.00012	0.00143	0.00155	1.603	2	Low	Candler
15	151.0	1.2	14.9	7.3	1.9	0.090	0.044	0.012	0.134	0.146	112	0.00081	0.00039	0.00010	0.00120	0.00130	1.349	2	Low	Candler
16	123.5	0.8	12.2	6.0	1.6	0.074	0.036	0.009	0.110	0.119	112	0.00066	0.00032	0.00008	0.00098	0.00107	1.103	2	Low	Pomona with Astatula Fill
17	122.1	0.8	12.1	5.9	1.6	0.073	0.036	0.009	0.109	0.118	112	0.00065	0.00032	0.00008	0.00097	0.00105	1.091	2	Low	Pomona with Astatula Fill
18	123.6	0.8	12.2	6.0	1.6	0.074	0.036	0.009	0.110	0.119	112	0.00066	0.00032	0.00008	0.00098	0.00107	1.104	2	Low	Pomona with Astatula Fill
19	100.6	0.65	9.9	4.9	1.3	0.060	0.029	0.008	0.089	0.097	112	0.00054	0.00026	0.00007	0.00080	0.00087	0.898	2	Low	Pomona with Candler Fill
20	99.7	0.65	9.9	4.8	1.3	0.060	0.029	0.008	0.089	0.096	112	0.00053	0.00026	0.00007	0.00079	0.00086	0.890	2	Low	Pomona with Candler Fill
21	100.7	0.65	10.0	4.9	1.3	0.060	0.029	0.008	0.090	0.097	112	0.00054	0.00026	0.00007	0.00080	0.00087	0.899	2	Low	Pomona with Candler Fill
22	136.4	0.9	13.5	6.6	1.7	0.082	0.040	0.010	0.121	0.132	112	0.00073	0.00036	0.00009	0.00108	0.00118	1.218	2	Low	Millhopper
23	136.2	0.9	13.5	6.6	1.7	0.081	0.040	0.010	0.121	0.132	112	0.00073	0.00036	0.00009	0.00108	0.00118	1.216	2	Low	Millhopper
24	121.2	0.9	12.0	5.9	1.5	0.072	0.035	0.009	0.108	0.117	112	0.00065	0.00032	0.00008	0.00096	0.00105	1.083	2	Low	Millhopper
25 (fail)	38.6	0.9	11.9	4.3	1.2	0.072	0.026	0.007	0.098	0.105	30	0.00239	0.00087	0.00024	0.00327	0.00351	1.287	2	Medium	Millhopper
26 (fail)	34.1	0.9	10.5	3.8	1.1	0.063	0.023	0.006	0.087	0.093	22	0.00288	0.00105	0.00029	0.00393	0.00422	1.549	2	Medium	Millhopper
27 (fail)	48.1	0.9	14.8	5.4	1.5	0.090	0.033	0.009	0.122	0.131	39	0.00230	0.00084	0.00023	0.00313	0.00336	1.234	2	Medium	Millhopper
28 (fail)	35.6	0.65	11.0	4.0	1.1	0.066	0.024	0.007	0.090	0.097	38	0.00174	0.00063	0.00017	0.00238	0.00255	0.936	2	Medium	Pomona with Candler Fill
29 (fail)	43.3	0.65	13.3	4.9	1.3	0.081	0.029	0.008	0.110	0.118	47	0.00172	0.00062	0.00017	0.00234	0.00251	0.922	2	Medium	Pomona with Candler Fill
30 (fail)	24.5	0.65	7.5	2.7	0.8	0.046	0.017	0.005	0.062	0.067	25	0.00182	0.00066	0.00018	0.00249	0.00267	0.980	2	Medium	Pomona with Candler Fill
31 (fail)	38.1	0.8	11.7	4.3	1.2	0.071	0.026	0.007	0.097	0.104	36	0.00197	0.00072	0.00020	0.00269	0.00288	1.058	2	Medium	Pomona with Astatula Fill
32	128.8	0.8	39.7	14.5	4.0	0.240	0.087	0.024	0.327	0.351	112	0.00214	0.00078	0.00021	0.00292	0.00313	1.150	2	Medium	Pomona with Astatula Fill
33 (fail)	42.5	0.8	13.1	4.8	1.3	0.079	0.029	0.008	0.108	0.116	41	0.00193	0.00070	0.00019	0.00263	0.00282	1.036	2	Medium	Pomona with Astatula Fill
34 (fail)	183.2	1.2	56.4	20.6	5.7	0.341	0.124	0.034	0.465	0.499	113	0.00302	0.00110	0.00030	0.00412	0.00442	1.621	2	Medium	Candler
35 (fail)	41.2	1.2	12.7	4.6	1.3	0.077	0.028	0.008	0.105	0.112	23	0.00333	0.00121	0.00033	0.00455	0.00488	1.790	2	Medium	Candler
36 (fail)	43.8	1.2	13.5	4.9	1.4	0.082	0.030	0.008	0.111	0.120	25	0.00326	0.00119	0.00033	0.00445	0.00478	1.754	2	Medium	Candler

Table A-21. Cont.

Column #	Total Volume Liters	Loading gal/ft^2	CBOD Mass grams	TSS Mass grams	O&G Mass grams	CBOD Mass lb/ft^2	TSS Mass lb/ft^2	O&G Mass lb/ft^2	Sum of CBOD&TSS lb/ft^2	Total Mass CBOD,TSS,O&G lb/ft^2	Days of dosing	CBOD Mass lb/ft^2/day	TSS Mass lb/ft^2/day	O&G Mass lb/ft^2/day	Sum of CBOD&TSS lb/ft^2/day	Total Mass CBOD,TSS,O&G lb/ft^2/day	Volume Loaded L/day	Unsat. Condition	Strength	Soil type
37	128.5	0.8	39.6	14.4	4.0	0.239	0.087	0.024	0.326	0.350	112	0.00214	0.00078	0.00021	0.00291	0.00313	1.148	1	Medium	Pomona with Astatula Fill
38	128.5	0.8	39.6	14.4	4.0	0.239	0.087	0.024	0.326	0.350	112	0.00213	0.00078	0.00021	0.00291	0.00313	1.147	1	Medium	Pomona with Astatula Fill
39	125.1	0.8	38.5	14.0	3.9	0.233	0.085	0.023	0.318	0.341	112	0.00208	0.00076	0.00021	0.00284	0.00304	1.117	1	Medium	Pomona with Astatula Fill
40	187.3	1.2	57.7	21.0	5.8	0.349	0.127	0.035	0.476	0.510	112	0.00311	0.00113	0.00031	0.00425	0.00456	1.672	1	Medium	Candler
41	182.3	1.2	56.2	20.5	5.6	0.339	0.124	0.034	0.463	0.497	112	0.00303	0.00110	0.00030	0.00413	0.00444	1.628	1	Medium	Candler
42	180.6	1.2	55.6	20.3	5.6	0.336	0.122	0.034	0.459	0.492	112	0.00300	0.00109	0.00030	0.00409	0.00440	1.613	1	Medium	Candler
43	142.3	0.9	43.8	16.0	4.4	0.265	0.096	0.027	0.361	0.388	112	0.00236	0.00086	0.00024	0.00322	0.00346	1.270	1	Medium	Millhopper
44	143.2	0.9	44.1	16.1	4.4	0.267	0.097	0.027	0.364	0.390	112	0.00238	0.00087	0.00024	0.00325	0.00349	1.279	1	Medium	Millhopper
45	143.5	0.9	44.2	16.1	4.4	0.267	0.097	0.027	0.364	0.391	112	0.00238	0.00087	0.00024	0.00325	0.00349	1.281	1	Medium	Millhopper
46	105.3	0.65	32.4	11.8	3.2	0.196	0.071	0.020	0.267	0.287	112	0.00175	0.00064	0.00018	0.00239	0.00256	0.940	1	Medium	Pomona with Candler Fill
47 (fail)	40.8	0.65	12.6	4.6	1.3	0.076	0.028	0.008	0.103	0.111	42	0.00181	0.00066	0.00018	0.00246	0.00264	0.970	1	Medium	Pomona with Candler Fill
48 (fail)	51.2	0.65	15.8	5.7	1.6	0.095	0.035	0.010	0.130	0.139	55	0.00173	0.00063	0.00017	0.00236	0.00254	0.930	1	Medium	Pomona with Candler Fill
50	115.6	0.65	74.0	18.9	5.7	0.447	0.114	0.035	0.561	0.596	112	0.00399	0.00102	0.00031	0.00501	0.00532	1.032	1	High	Pomona with Candler Fill
51	108.0	0.65	69.1	17.7	5.4	0.417	0.107	0.032	0.524	0.556	112	0.00373	0.00095	0.00029	0.00468	0.00497	0.964	1	High	Pomona with Candler Fill
52	144.7	0.9	92.6	23.7	7.2	0.559	0.143	0.043	0.702	0.746	112	0.00499	0.00128	0.00039	0.00627	0.00666	1.292	1	High	Millhopper
53	146.6	0.9	93.8	24.0	7.3	0.566	0.145	0.044	0.711	0.755	112	0.00506	0.00129	0.00039	0.00635	0.00674	1.309	1	High	Millhopper
54	142.5	0.9	91.2	23.3	7.1	0.551	0.141	0.043	0.692	0.734	112	0.00492	0.00126	0.00038	0.00618	0.00656	1.273	1	High	Millhopper
55	178.0	1.2	113.9	29.2	8.8	0.688	0.176	0.053	0.864	0.917	112	0.00614	0.00157	0.00048	0.00771	0.00819	1.589	1	High	Candler
56	181.8	1.2	116.3	29.8	9.0	0.703	0.180	0.054	0.882	0.937	112	0.00627	0.00161	0.00049	0.00788	0.00836	1.623	1	High	Candler
57 (fail)	92.6	1.2	59.3	15.2	4.6	0.358	0.092	0.028	0.450	0.477	64	0.00559	0.00143	0.00043	0.00703	0.00746	1.448	1	High	Candler
58	128.6	0.8	82.2	21.1	6.4	0.497	0.127	0.038	0.624	0.662	112	0.00444	0.00114	0.00034	0.00557	0.00591	1.148	1	High	Pomona with Astatula Fill
59	127.8	0.8	81.7	20.9	6.3	0.494	0.126	0.038	0.620	0.658	112	0.00441	0.00113	0.00034	0.00554	0.00588	1.141	1	High	Pomona with Astatula Fill
60 (fail)	95.2	0.8	60.9	15.6	4.7	0.368	0.094	0.028	0.462	0.491	88	0.00418	0.00107	0.00032	0.00525	0.00558	1.082	1	High	Pomona with Astatula Fill
61 (fail)	60.1	1.2	38.4	9.8	3.0	0.232	0.059	0.018	0.292	0.309	39	0.00595	0.00152	0.00046	0.00747	0.00794	1.540	2	High	Candler
62 (fail)	65.6	1.2	42.0	10.7	3.3	0.254	0.065	0.020	0.319	0.338	43	0.00590	0.00151	0.00046	0.00741	0.00786	1.526	2	High	Candler
63 (fail)	70.8	1.2	45.3	11.6	3.5	0.274	0.070	0.021	0.344	0.365	45	0.00608	0.00156	0.00047	0.00764	0.00811	1.574	2	High	Candler
64 (fail)	94.7	0.8	60.6	15.5	4.7	0.366	0.094	0.028	0.460	0.488	88	0.00416	0.00107	0.00032	0.00523	0.00555	1.077	2	High	Pomona with Astatula Fill
65	129.8	0.8	83.0	21.2	6.4	0.501	0.128	0.039	0.630	0.669	112	0.00448	0.00115	0.00035	0.00562	0.00597	1.159	2	High	Pomona with Astatula Fill
66	128.2	0.8	82.0	21.0	6.4	0.495	0.127	0.038	0.622	0.661	112	0.00442	0.00113	0.00034	0.00556	0.00590	1.145	2	High	Pomona with Astatula Fill
67 (fail)	30.2	0.65	19.3	4.9	1.5	0.117	0.030	0.009	0.147	0.156	23	0.00507	0.00130	0.00039	0.00637	0.00677	1.313	2	High	Pomona with Candler Fill
68 (fail)	31.4	0.65	20.1	5.1	1.6	0.121	0.031	0.009	0.152	0.162	23	0.00527	0.00135	0.00041	0.00662	0.00703	1.364	2	High	Pomona with Candler Fill
69 (fail)	26.3	0.65	16.8	4.3	1.3	0.102	0.026	0.008	0.128	0.136	20	0.00509	0.00130	0.00039	0.00639	0.00679	1.317	2	High	Pomona with Candler Fill
70	145.2	0.9	92.9	23.8	7.2	0.561	0.144	0.043	0.705	0.748	112	0.00501	0.00128	0.00039	0.00629	0.00668	1.296	2	High	Millhopper
71 (fail)	34.5	0.9	22.0	5.6	1.7	0.133	0.034	0.010	0.167	0.178	24	0.00555	0.00142	0.00043	0.00697	0.00740	1.436	2	High	Millhopper
72 (fail)	36.3	0.9	23.2	6.0	1.8	0.140	0.036	0.011	0.176	0.187	30	0.00468	0.00120	0.00036	0.00588	0.00624	1.211	2	High	Millhopper

Figure A-1: Sieve Analysis for Candler

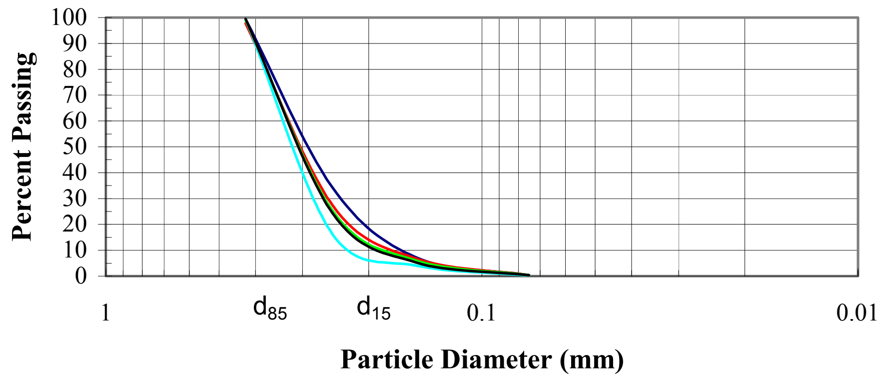


Figure A-2: Sieve Analysis for Millhopper (bottom layer)

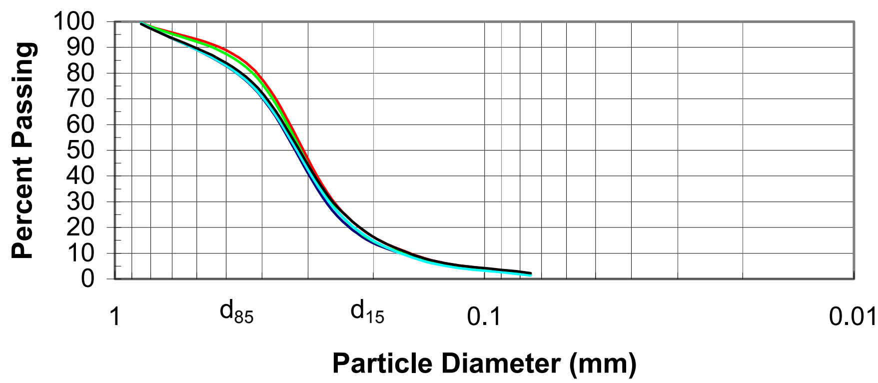


Figure A-3: Sieve Analysis for Millhopper (middle layer)

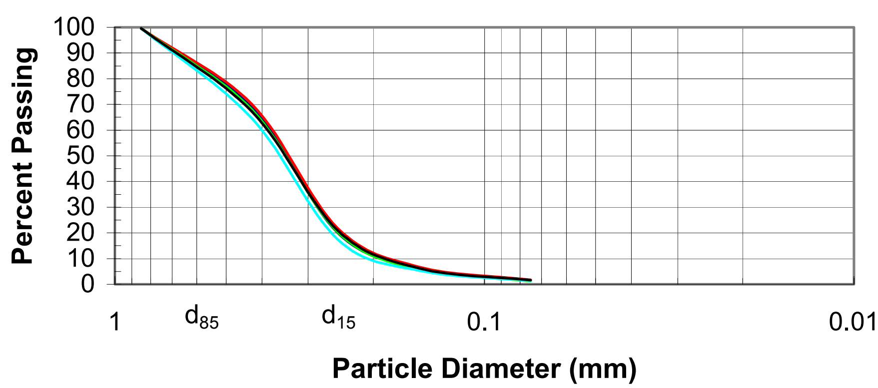


Figure A-4: Sieve Analysis for Millhopper (top layer)

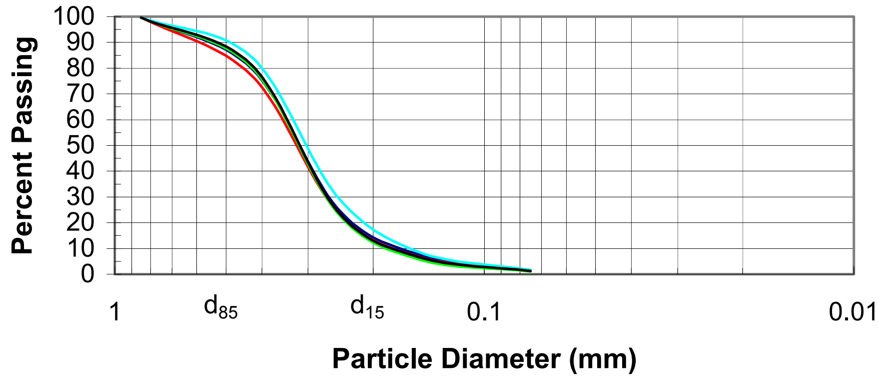


Figure A-5: Sieve Analysis for Pomona (top layer)

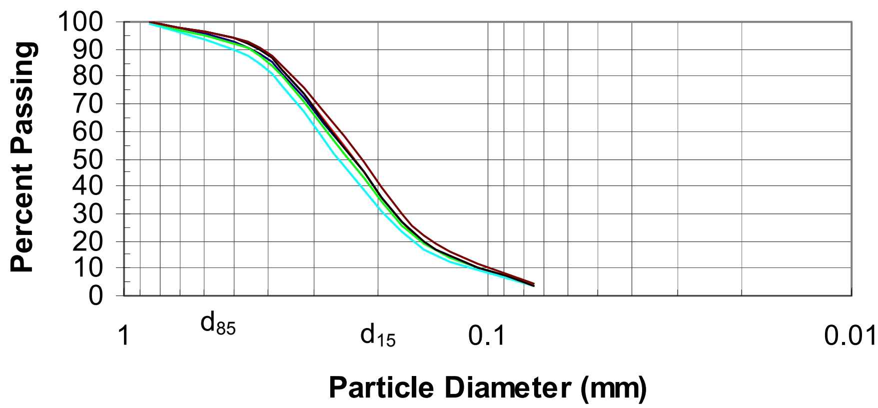


Figure A-5: Sieve Analysis for Pomona (top layer)

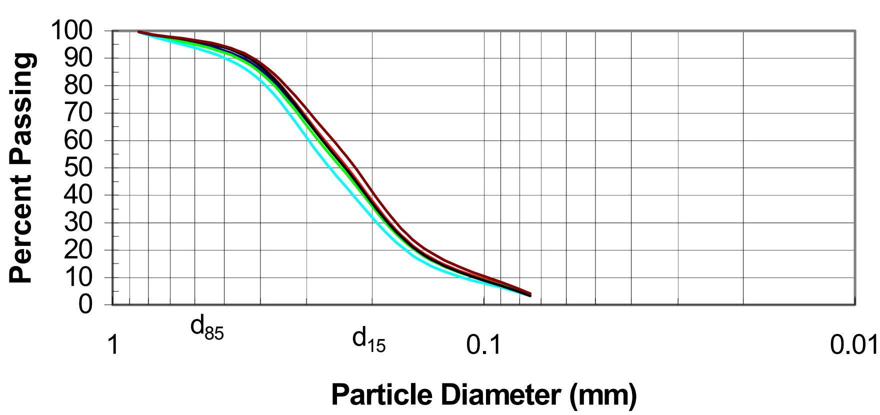


Figure A-7: Sieve Analysis for Pomona (bottom layer)

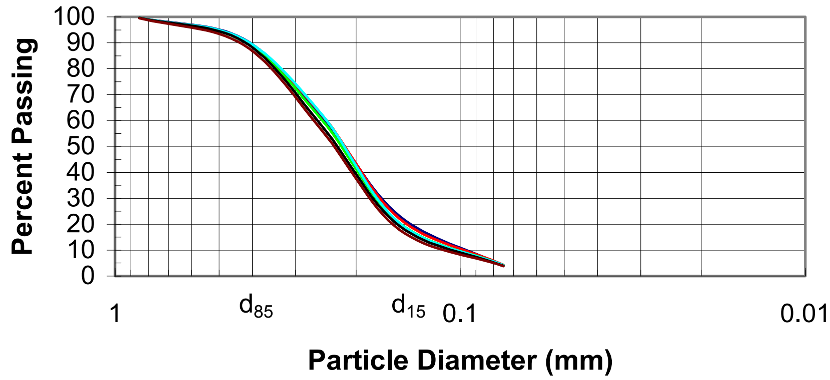


Figure A-10: Sieve Analysis for Astatula

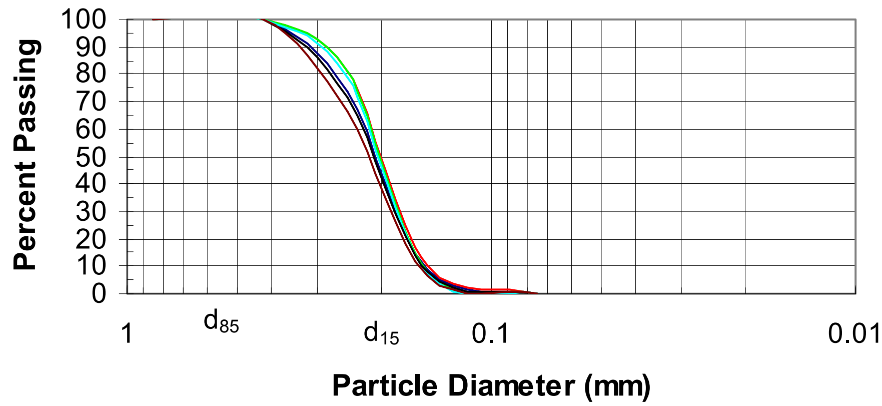
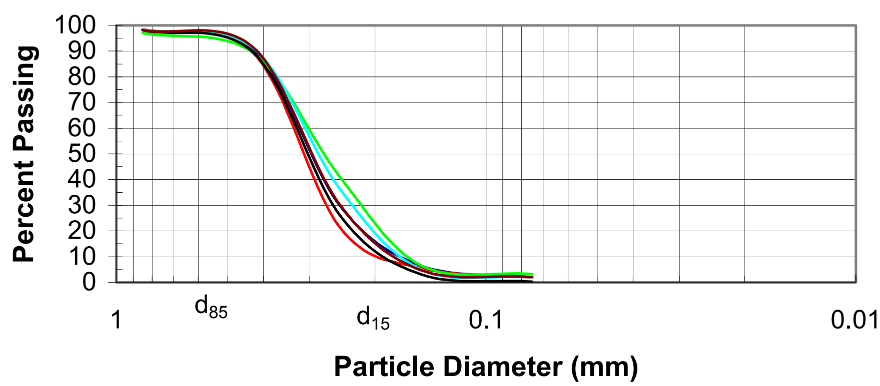


Figure A-9: Sieve Analysis for Candler (Fill)



APPENDIX B
STANDARD OPERATING PROCEDURES

BIOCHEMICAL OXYGEN DEMAND
EPA Method 405.1

General Discussion:
This test measures the oxygen utilized during a 5-day incubation period for the degradation of organic material (carbonaceous demand) and the oxygen used to oxidize inorganic material such as sulfides or ferrous iron. The test may also measure the oxygen used to oxidize reduced forms of nitrogen (nitrogenous demand) unless an inhibitor prevents their oxidation.

Report results as $CBOD_5$ when inhibiting the nitrogenous oxygen demand; when nitrification is not inhibited, report results as BOD_5.

This method consists of filling an airtight 300 mL BOD bottle with sample and incubating it at 20±1 °C for 5 days. Dissolved oxygen (DO) is measured initially and after incubation, and the BOD is computed from the difference of the initial and final DO. Because the initial DO is determined immediately after the dilution is made, all oxygen uptake, including that occurring in the first 15 minutes is included in the BOD.

Samples should by analyzed within 48 hours of the time of collection. The sample should be kept at or below 4 °C. Do not freeze or preserve samples. Use a chilled fraction.

Equipment:
1. DO meter
2. BOD bottles
3. Stir plate
4. 500 mL flask
5. Pipettes
6. Plastic caps for BOD bottles

Reagents:
1. Distilled Deionized Water
2. Hach Buffer Nutrient Pillow: one pillow per 6 L DI water
3. BOD Polyseed: one capsule per 250 mL DI water
4. Nitrification Inhibitor: 2 shots per BOD bottle (for $CBOD_5$ only)
5. Hach Glucose-Glutamic Acid Standard Solution (300 mg/L)

Procedure:
1. In a 500 mL Erlenmeyer flask, dissolve polyseed in 250 mL of distilled deionized water. Mix thoroughly for one hour using a magnetic stir bar/plate.
2. Prepare dilution water by adding 1 buffer pillow to 6 liters of deionized water. Shake container vigorously 100 times, until DO is between 7 and 9 mg/L. Alternately, the solution in the container can be aerated for approximately 20 minutes instead of shaking.

3. Turn on the meter and allow to warm up for at least 30 minutes.
4. Check pH of samples using pH strips (should be between 6.5 and 7.5). Record pH in lab book. Neutralize sample if necessary before making dilutions using 1N sulfuric acid or 1N sodium hydroxide. Sample should not be diluted by more than 0.5%. Use more concentrated solutions for neutralizing if necessary.
5. Label the BOD bottles with the sample number and the volume of sample. Set up at least three dilutions for each sample. Suggested volumes are 1 mL, 2 mL, 5 mL, and 15 mL for septic tank effluents.
6. Set up replicate samples using 2 mL, 5 mL, and 15 mL of each sample.
7. Set up one spike for every 10 samples. The spikes are analyzed by adding 1 mL of the glucose-glutamic acid reference to 2 mL of the sample.
8. In addition to the effluent samples, the following quality control should be set up at the beginning of every run:
   1 blank – 300 mL of dilution water
   3 Polyseeds – 4 mL, 6 mL, 8 mL (QS to 300 mL)
   3 Glucose-Glutamic acid references – 3 mL of the glucose-glutamic acid plus 2 mL of seed (QS to 300 mL)
9. Set up a blank and glucose-glutamic acid reference at the end of the run and for every ten samples.
10. For CBOD5 only, add two shots of the nitrification inhibitor to every bottle.
11. Add 2 mL of seed to each sample bottle, except the blanks and Polyseed bottles.
12. Fill the BOD bottles to the neck with the dilution water that has been cooled to 20 °C.
13. Calibrate the DO meter in saturated air. Turn the knob to "red line" and make sure the needle lines up with the red line on the scale. Turn the knob to "zero" and make sure the needle lines up with 0 mg/L on the scale. Turn the knob to "temp" to find the calibration temperature. Turn the knob to "cal 1 – 10" and adjust the needle if necessary so that it reads the DO that corresponds to that temperature (there is a chart on the back of the meter).
14. Place the probe in the first blank, turn on the stirrer and allow to stabilize for one minute. Measure and record the initial DO of the blank. Rinse the probe into the BOD bottle. Tap on the sides of the bottle with a glass stopper to dislodge any air bubbles clinging to the sides. Place the glass stopper in the bottle, making sure there is a water seal in the neck of the bottle. Place a plastic cap over the stopper to prevent the evaporation of the water seal.
15. When reading the samples, if the DO is less than 7.0 mg/L pour half of the sample into a beaker, stopper the remaining portion and shake vigorously. Return the portion in the beaker to the bottle and read DO. If the initial DO is greater than 9.5 mg/L, slowly pour the sample back and forth between two beakers to drive off some of the DO. Pour the sample back into the bottle and read DO.
16. Continue to measure and record the DO of each seed, reference, and sample in the manner described in step 14.
17. Place all bottles in an incubator that remains dark and can achieve a constant temperature of 20 ± 1 °C. The temperature in the incubator should be checked daily.
18. After five days of incubation, remove samples from incubator and calibrate DO meter as described in step 13. Remove plastic caps from each bottle and measure and record the final DO of each sample.

Calculations

1. Calculate the Seed value:

$$\frac{\text{DO diff}_1 + \text{DO diff}_2 + \text{DO diff}_3}{9 \text{ mL}} = \text{SEED DO per 2 mL}$$

2. Determine the BOD/CBOD5 of each sample:

$$\frac{\text{Initial DO} - \text{Final DO} - \text{SEED DO (if any)} \times 300}{\text{Volume of sample (mL)}}$$

3. Calculate the Glucose-Glutamic acid recovery:

$$\frac{\text{Initial DO} - \text{Final DO} - \text{SEED DO (if any)} \times 300}{6 \text{ mL}}$$

4. Calculate the spike target:

Target = 198 (168)

SUSPENDED SOLIDS BY C-FRACTION
From EPA Method 160.2

Reagents:
1. Deionized water

Equipment:
1. Two sidearm flasks
2. Magnetic vacuum membrane filter holder
3. Graduated cylinder
4. Whatman (47 mm diameter) glass microfiber filters
5. Aluminum weighing boats
6. Tweezers
7. Oven
8. Desiccator
9. Mettler AE260 Analytical Balance

Preparation of Filters:
1. Connect two sidearm flasks in series to the vacuum system and place a magnetic vacuum membrane filter holder on top of the second, connecting it by a doughnut.
2. Center a Whatman (47 mm diameter) glass microfiber filter in the filter holder and turn on the vacuum.
3. Pour 30 mL of deionized water into the filter holder and allow it to filter through, leaving the filter fairly dry. Repeat this three times.
4. Turn the vacuum off and remove the filter paper using a pair of tweezers. Place the filter in an aluminum boat.
5. Repeat steps 2 through 4 until enough filters are prepared so as to have one per sample, two for blanks, and one extra for every ten samples.
6. Using a sharpie, number the aluminum boats with 1, 2, 3, etc.
7. Place the aluminum boats in which the filters are sitting into the oven set at 105°C. Leave in the oven for approximately thirty minutes.
8. Remove aluminum boats from the oven and place in a desiccator for approximately one hour.
9. Weigh each aluminum boat with the filter on a Mettler analytical balance and record weight (in mg) into notebook in column labeled "Filter Weight", next to the filter number.

Procedure for Samples:
1. Place filter #1 in the filter holder and turn the vacuum on.
2. Measure 100 mL of deionized water in a graduated cylinder and pour it through the filter.
3. In notebook, record filter number and "Blank #1" in the column labeled Sample ID, and "100 mL" in the column labeled Sample Volume.
4. Turn the vacuum off and remove the filter paper using tweezers. Return the filter to its corresponding aluminum boat.

5. Rinse the graduated cylinder and filter holder with a few ml of deionized water, and let the rinse go through the filter.
6. Place filter #2 in the filter holder and turn the vacuum on.
7. Measure out 100 mL of sample in a graduated cylinder and pour it through the filter.
8. In notebook, record the sample number in the column labeled Sample ID, and “100 mL” in the column labeled Sample Volume, next to the appropriate filter number.
9. Turn the vacuum off and remove the filter paper using tweezers. Return the filter to its corresponding aluminum boat.
10. If the sample is extremely high in suspended solids or of an oily nature, a smaller volume of sample may be used and recorded in the notebook.
11. If the sample is extremely clean and an abundant amount is available, more than 100 mL may be used and recorded in the notebook.
12. Repeat steps 7 through 11 using the remaining filters, remembering to record the sample number and volume next to the appropriate filter number.
13. Be sure to rinse the graduated cylinder and filter holder between samples and to run one duplicate for every 10 samples for quality control.
14. The last filter should be used to run a second blank.
15. When all the samples, duplicates, and blanks have been run, place the aluminum boats with filters into a 105°C oven for approximately thirty minutes.
16. Remove the filters from the oven and place in a desiccator for approximately one hour.
17. Weigh each aluminum boat with filter on the Mettler analytical balance. Record the final weight (in mg) under the column labeled Filter + Residue Weight.

Calculations:

1. Calculate the concentration of total suspended solids by using the following equation:

$$\frac{\text{(Filter + Residue Weight)} - \text{Filter Weight}}{\text{Sample Volume (mL)}} \ast 1000$$

2. If duplicate samples were run, calculate an average value for the sample.

OIL AND GREASE
EPA Method 1664

Introduction and Overview
This method is for the determination of n-hexane extractable material (HEM) in surface and saline waters and industrial and domestic aqueous wastes. Extractable materials that may be determined are relatively non-volatile hydrocarbons, vegetable oils, animal fats, waxes, soaps, greases, and related materials.

This method is capable of measuring HEM in the range of 5 to 1000 mg/L and may be extended to higher levels by analysis of a smaller sample volume collected separately. The Method Detection Limit (MDL) has been determined as 1.4 mg/L. The Minimum Level (ML) has been set at 5.0 mg/L.

Approximately 500 mL of sample is acidified to pH < 2 and serially extracted three times with n-hexane in a separatory funnel. The extract is dried over sodium sulfate. The solvent is evaporated from the extract and the HEM is weighed.

Samples should be analyzed within 28 days of the time of collection. The samples should be kept at or below 4 °C, but do not freeze samples. Preserve samples with H_2SO_4.

Equipment

1. Oven – temperature at 105 ± 5 °C
2. Desiccator
3. Analytical balance
4. Separatory funnel – glass, 1000 mL, with PFTE stopcock
5. Funnel – large, glass, for pouring sample into separatory funnel
6. Funnel – analytical, glass, for removal of water through sodium sulfate
7. Filter paper – Whatman 150 mm (or equivalent), to fit analytical funnel
8. Flask – round-bottom, 250 mL, for collection of hexane extraction
9. Rotovap with cool water circulation and vacuum
10. Graduated cylinders – 50 mL, 500 mL, and 1L
11. Flask – volumetric, 100 mL
12. Tongs – for handling the round-bottom flask

Reagents

1. Distilled deionized water
2. Hydrochloric or sulfuric acid
3. n-hexane – 85% purity
4. Sodium sulfate – ACS, granular anhydrous
5. Hexadecane – 98% minimum purity
6. Stearic acid – 98% minimum purity
7. Acetone – ACS, residue less than 1 mg/L

Procedure

Preparation

1. All glassware must be washed with detergent, rinsed with tap water, rinsed with distilled water, dried in an oven, and then cooled to room temperature in a desiccator.
2. Rinse thoroughly the separatory funnel with 30 mL of n-hexane to remove any remaining interferences. Collect hexane in proper waste container.
3. Bring the analytical batch of samples to room temperature.
4. Shake the sample bottles to mix thoroughly, and decant some of the sample so that the sample bottle is approximately half full. Mark the sample bottle at the water meniscus for later determination of the sample volume.

pH verification

1. Verify that the pH of the sample is less than 2 by dipping a glass-stirring rod into the well-mixed sample. Withdraw the stirring rod and allow a drop of the sample to fall on the pH paper.
2. If the sample is at a neutral pH, add 2-3 mL of HCl or H_2SO_4 to the sample. If the sample is at a high pH, use a proportionately larger amount of acid.
3. Replace the cap and shake the bottle to mix thoroughly. Recheck the pH of the sample using the procedure in step 1. If necessary, add more acid to the sample and retest.

Extraction

1. Tare a clean round-bottom flask, by removing it from the desiccator with tongs and weighing immediately on a calibrated analytical balance.
2. Pour the sample into the separatory funnel.
3. Add 30 mL of n-hexane to the sample bottle and seal the bottle with the original bottle cap. Shake the bottle to rinse all interior surfaces of the bottle, including the lid of the bottle cap. Pour the solvent into the separatory funnel.
4. Extract the sample by shaking the separatory funnel vigorously for 2 minutes with periodic venting into a hood to release excess pressure. Most importantly, vent immediately after the first inversion of the separatory funnel.
5. Allow the organic phase to separate from the aqueous phase for a minimum of 10 minutes. If an emulsion forms between the phases and the emulsion is greater than one-third the volume of the solvent layer, the analyst must employ mechanical techniques to complete the phase separation. The optimum technique depends upon the sample, but may include stirring, filtration through glass wool, use of solvent phase separation paper, centrifugation, use of an ultrasonic bath with ice, addition of NaCl, or other physical methods.
6. In the case of centrifugation, drain the emulsion and solvent layers into a glass centrifuge tube and centrifuge for 5 minutes at approximately 2400 rpm. Transfer centrifuged material to an appropriate separatory funnel and drain solvent layer

through a funnel with filter paper and 10 g Na_2SO_4, both of which have been pre-rinsed, into a clean tared round-bottom flask. Recombine aqueous layers and any remaining emulsion or solids in separatory funnel. Repeat centrifugation step if emulsion persists in subsequent extraction steps.

7. Drain the aqueous layer (lower layer) into the original sample container. Drain a small amount of the organic layer into the sample container to minimize the amount of water remaining in the separatory funnel. The amount of water remaining with the n-hexane must be minimized to prevent dissolution or clumping of the sodium sulfate in the solution drying process.
8. Place approximately 10 g anhydrous Na_2SO_4 in a filter funnel and rinse with a small portion of n-hexane. Discard the rinsate. The specific properties of the sample may necessitate the use of larger amounts of Na_2SO_4.
9. Drain the n-hexane layer (upper layer) from the separatory funnel through the Na_2SO_4 into the pre-weighed round-bottom flask.
10. A milky extract indicates the presence of water. If the extract is milky, allow the solution to stand for up to one hour to allow the water to settle. Decant the solvent layer (upper layer) through sodium sulfate to remove any excess water as in steps 7 and 8.
11. Repeat the extraction twice more with fresh 30 mL portions of n-hexane for 1.5 minutes and 1 minute, respectively. Combine the extracts in the round-bottom flask.
12. Rinse the tip of the separatory funnel, the filter paper, and the funnel with 2-3 small (3-5 mL) portions of n-hexane. Collect the rinsings in the flask.
13. Sodium sulfate has the potential to inflate results for HEM by passing through the filter paper. If the filter paper specified in this method is inadequate for removal of these fines, use of a 0.45-micron filter is recommended.
14. Attach the round-bottom flask to the rotovap and warm the flask by immersing the lower half in a water bath. Allow the n-hexane to slowly evaporate from the flask, leaving behind the HEM.
15. Remove the flask from the heat source and rotovap using tongs. Wipe the outside surface dry to remove moisture and fingerprints.
16. Inspect the residue in the round-bottom flask for crystals. Crystal formation is an indication that sodium sulfate may have dissolved and passed into the round-bottom flask. This may happen if the drying capacity of the sodium sulfate is exceeded or if the sample is not adjusted to a low pH. If crystals are observed, redissolve the extract in 30 mL n-hexane, drain the solvent through a funnel containing a solvent-rinsed filter paper into a clean, tared round-bottom flask. Rinse the first flask twice more, combining all solvent in the new flask, and treat as an extracted sample, using the rotovap to evaporate off the solvent.
17. Place flask into desiccator for 30 minutes minimum. Remove with tongs and weigh immediately to determine the final weight of the flask. Determine the HEM by subtracting the tare weight from the final weight of the flask.
18. Determine the original sample volume in liters by filling the sample bottle to the mark with water and measuring the volume of water in a 1 L graduated cylinder.

Quality Control

For acceptable quality control, the minimum requirements for each analytical batch of 10 or fewer samples consist of a laboratory blank, an ongoing precision and recovery (OPR) sample, matrix spike (MS), and matrix spike duplicate (MSD). The laboratory blank demonstrates freedom from contamination. The OPR, in addition to calibration and calibration verification, demonstrates that the analysis system is in control. The analyses of matrix spike and matrix spike duplicate samples are required to demonstrate method accuracy and precision.

It is suggested that the laboratory obtain a quality control sample (CQS) from a source different from the source for the hexadecane and stearic acid used routinely in the method.

Laboratory Blanks

All materials used in the analysis shall be demonstrated to be free from interferences under the conditions of analysis by running laboratory blanks. Distilled deionized water, used as the laboratory blank, is analyzed to demonstrate freedom from contamination.

1. Extract and concentrate a laboratory water blank with each analytical batch. The blank must be subjected to the same procedural steps as a sample.
2. If material is detected in the blank at a concentration greater than the ML (5.0 mg/L), analysis of samples is halted until the source of contamination is eliminated and a blank shows no evidence of contamination. All samples must be associated with an uncontaminated blank before the results may be reported for regulatory compliance purposes.

Ongoing Precision and Recovery

A hexadecane/stearic acid (1:1) spiking solution prepared in acetone at a concentration of 4 mg/mL each is used as the precision and recovery (PAR) standard.

1. Place 400 ± 4 mg stearic acid and 400 ± 4 mg hexadecane in a 100 mL volumetric flask and fill to the mark with acetone.
2. The solution may require warming for complete dissolution of stearic acid.
3. After the hexadecane and stearic acid have dissolved, transfer the solution to a 100-150 mL vial with a fluoropolymer-lined cap. Mark the solution level on the vial and store in the dark at room temperature.
4. Immediately prior to use, verify the level on the vial and bring to volume with acetone, if required. Warm to redissolve all visible precipitate.
5. If there is doubt of the concentration, remove 5.00 ± 0.05 mL with a volumetric pipet, place in a tared weighing pan, and evaporate to dryness in a fume hood. The weight must be 40 ± 1 mg.

6. Spike 5.00 ± 0.05 mL of the hexadecane/stearic acid spiking solution into 950 – 1050 mL of distilled deionized water to produce concentrations of approximately 20 mg/L each of hexadecane and stearic acid. Half of this volume is used for the extraction. This solution is used as the ongoing precision and recovery standard.
7. One ongoing precision and recovery sample should be run for every ten samples to ensure good quality control. The acceptance criteria for the OPR is 70 – 114%. If the concentration is not in the specified range, the analytical process is out of control, and the analytical batch needs to be re-extracted.
8. The spiking solutions should be checked frequently for signs of degradation or evaporation using the test noted in 5. The solutions must be replaced after six months or as soon as degredation is detected.

Matrix Spikes

The laboratory must spike, in duplicate, a minimum of 10 percent of all samples (one sample in each batch of ten samples). The two sample aliquots shall be spiked with the hexadecane/stearic acid spiking solution.

Calibration and Standardization

1. Calibrate the analytical balance at 2 mg and 1000 mg using class "S" weights.
2. Calibration shall be within ±10% (i.e. ±0.2 mg) at 2 mg and ±0.5% (i.e. ±5 mg) at 1000 mg. If values are not within these limits, recalibrate the balance.
3. Calibrate the balance again after weighing the flasks.

Calculations

1. Calculate the concentration of the HEM ("oil and grease") in the sample per the following equation:

$$\text{HEM (mg/L)} = \frac{\text{final flask weight (mg)} - \text{tared flask weight (mg)}}{\text{sample volume (L)}}$$

2. Report results to three significant figures for HEM found above the ML in all samples. Report results below the ML as < 5 mg/L.
3. Report results to three significant figures for HEM found above the MDL in all blanks. Do not report results below the MDL unless required.

APPENDIX C
RESTAURANT TEMPERATURE AND pH DATA

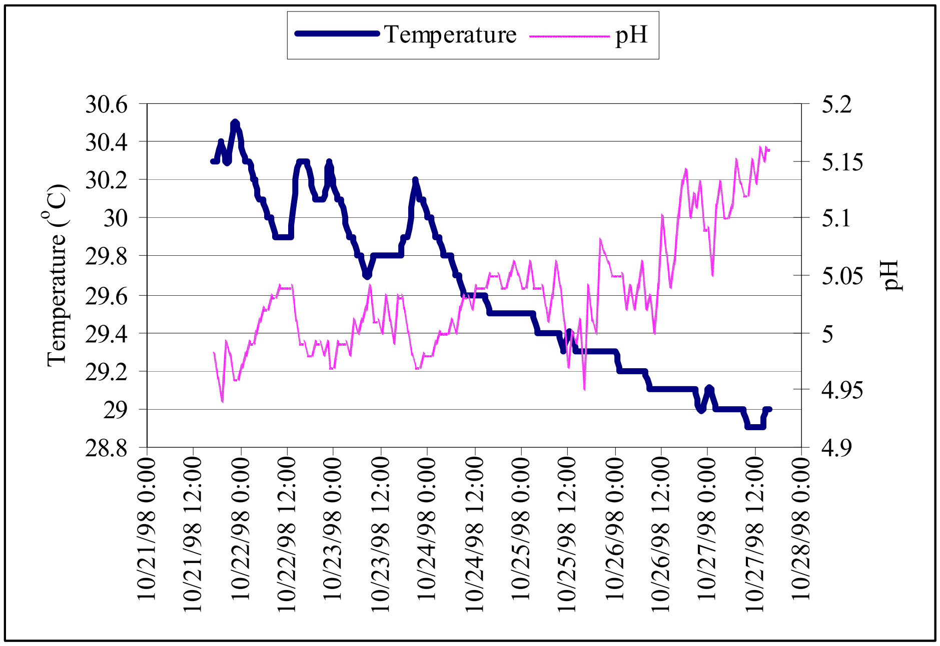


Figure C-1. Temperature and pH for Site 1 (Pump Station Inoperable)

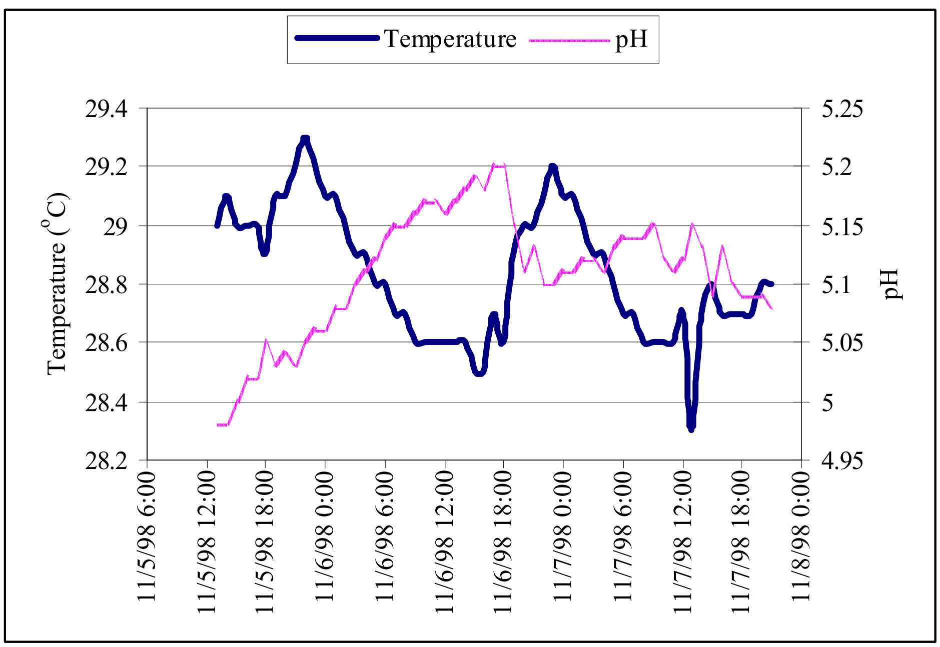


Figure C-2. Temperature and pH for Site 1

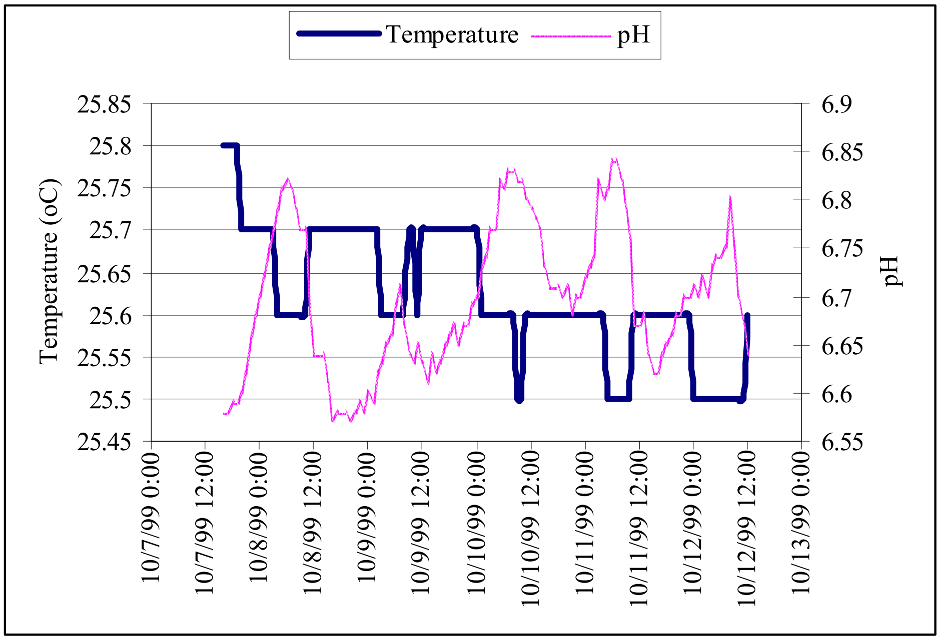


Figure C-3. Temperature and pH for Site 2

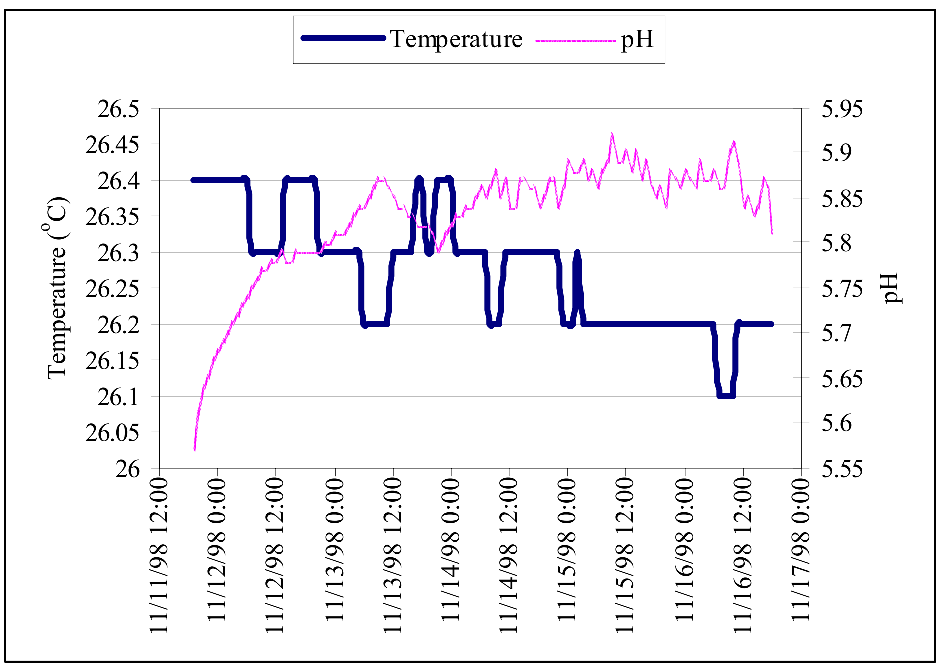


Figure C-4. Temperature and pH for Site 3

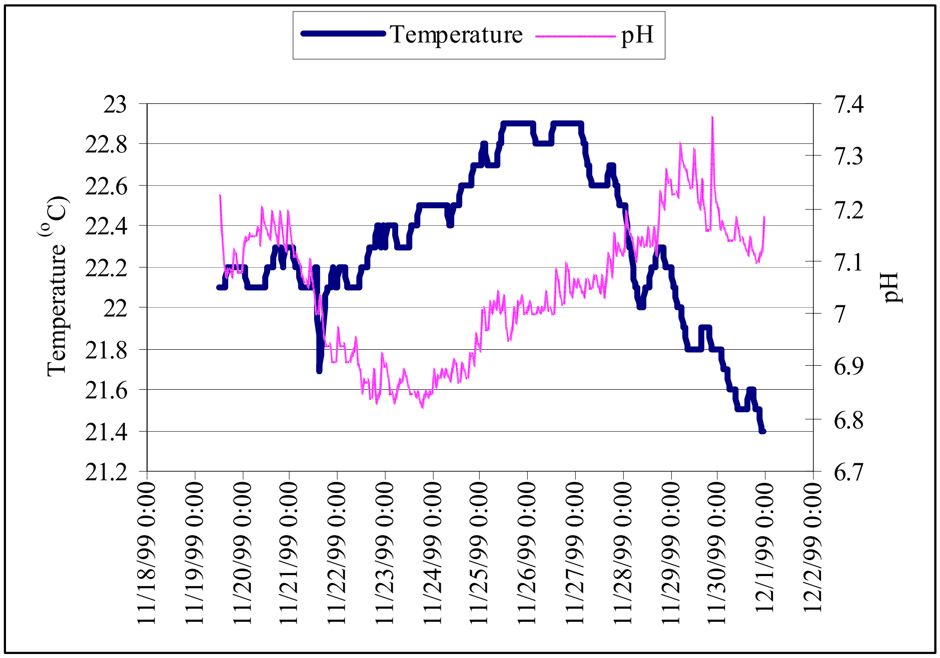


Figure C-5. Temperature and pH for Site 4

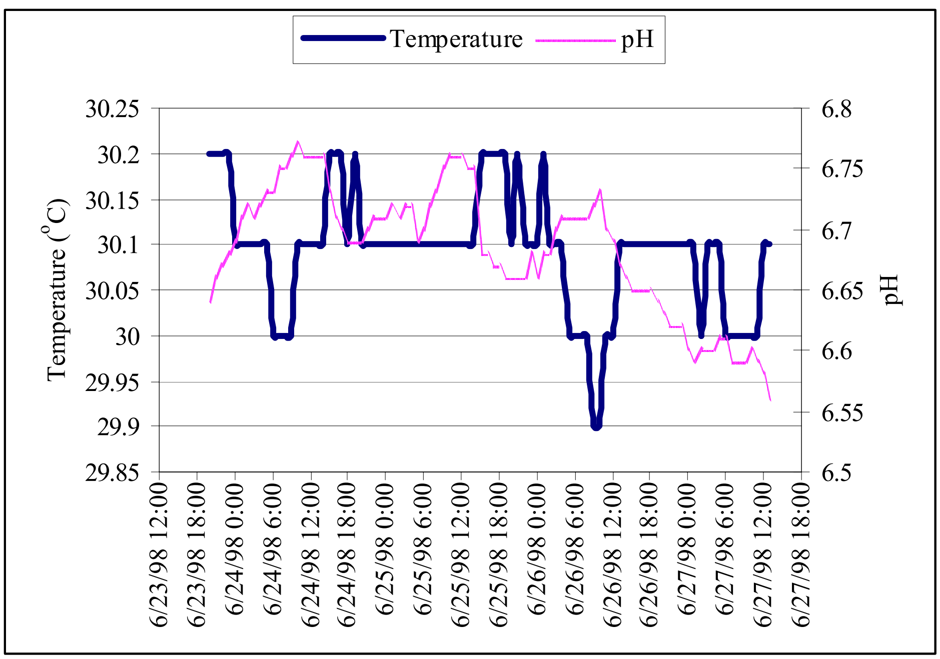


Figure C-6. Temperature and pH for Site 7 (1998)

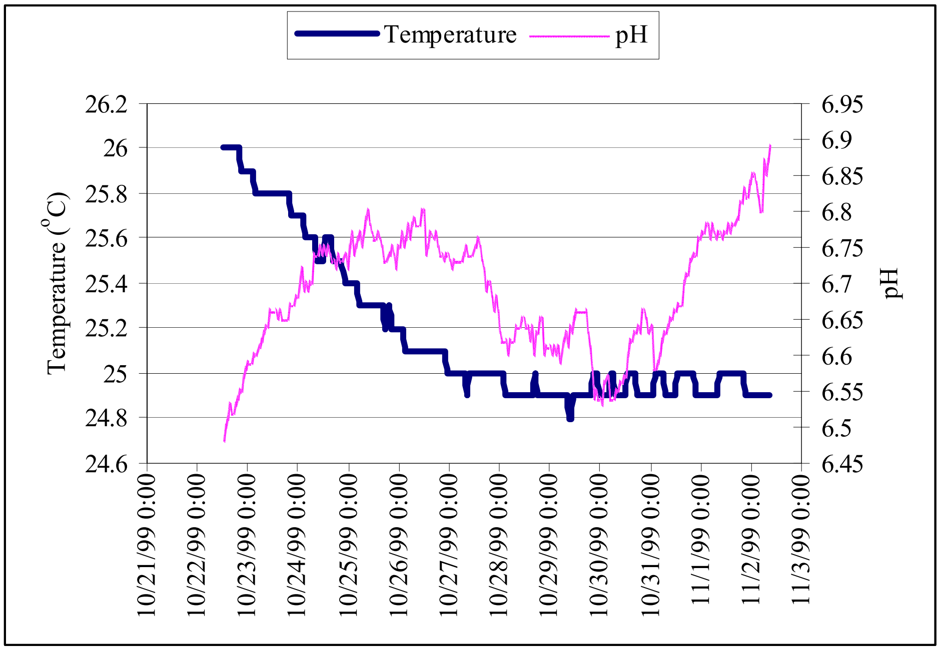


Figure C-7. Temperature and pH for Site 7 (1999)

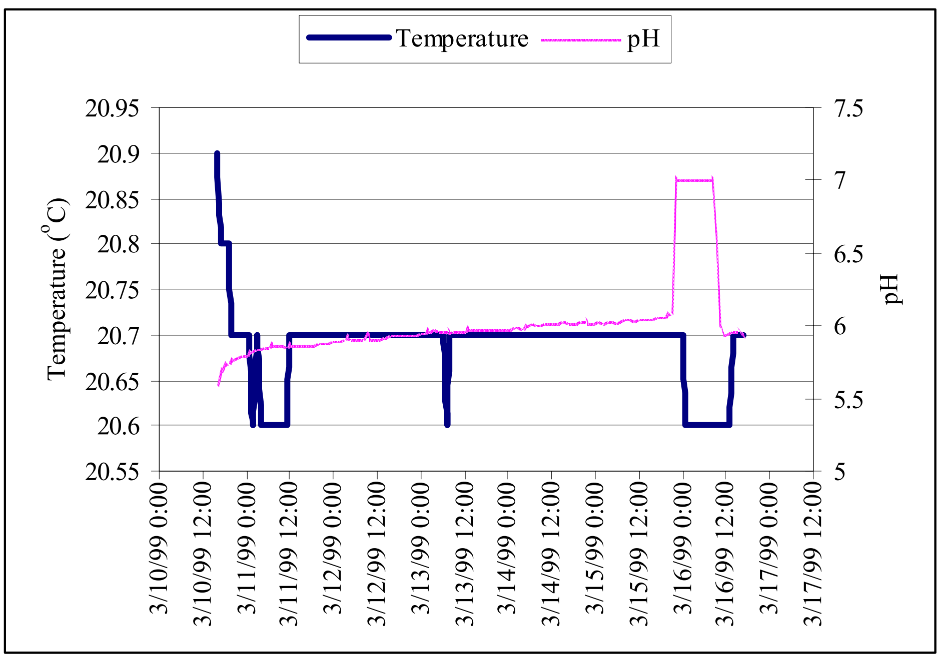


Figure C-8. Temperature and pH for Site 10

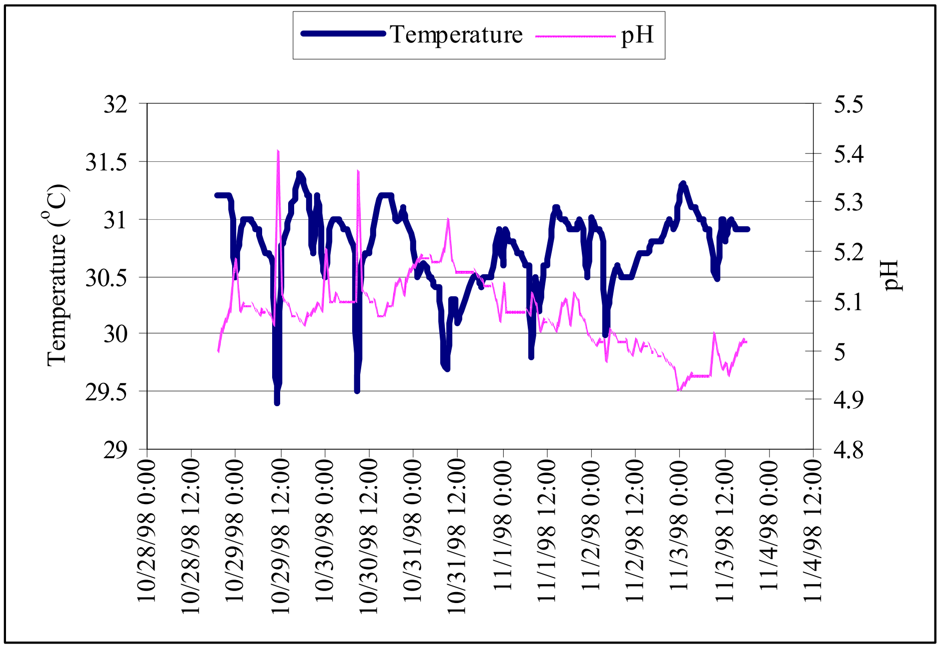


Figure C-9. Temperature and pH for Site 11 (1998)

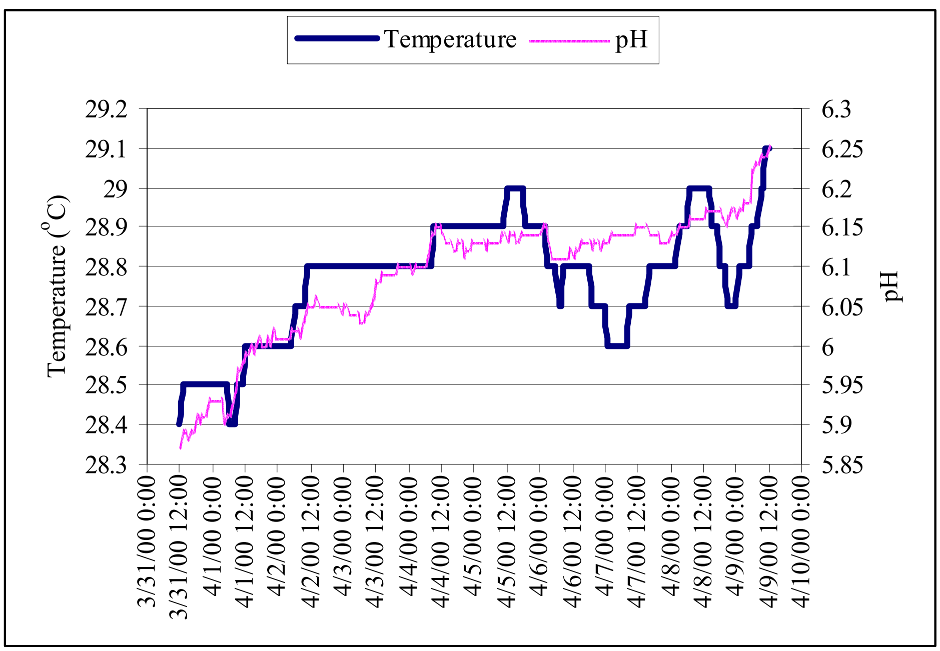


Figure C-10. Temperature and pH for Site 11 (2000)

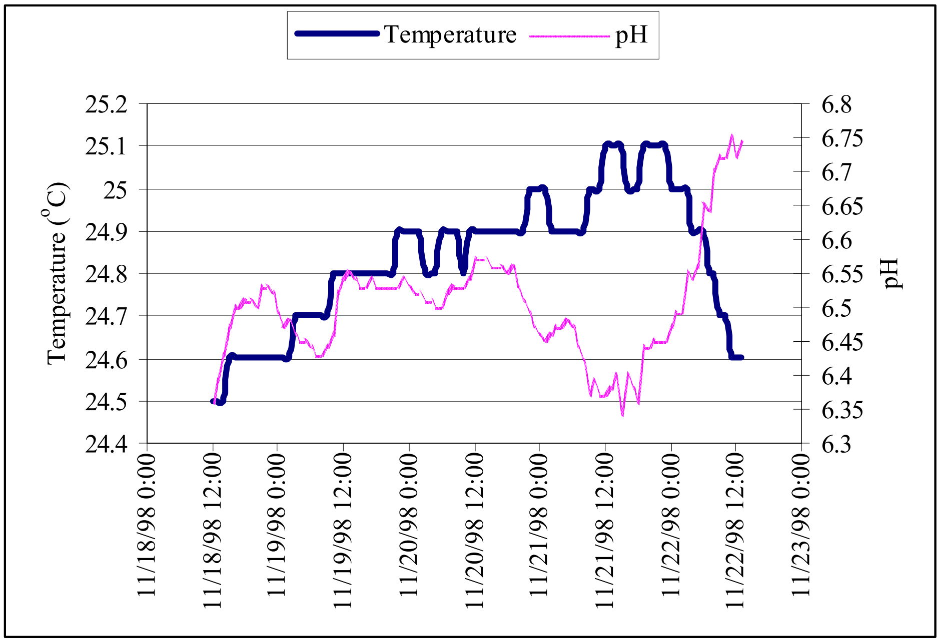


Figure C-11. Temperature and pH for Site 14 (1998)

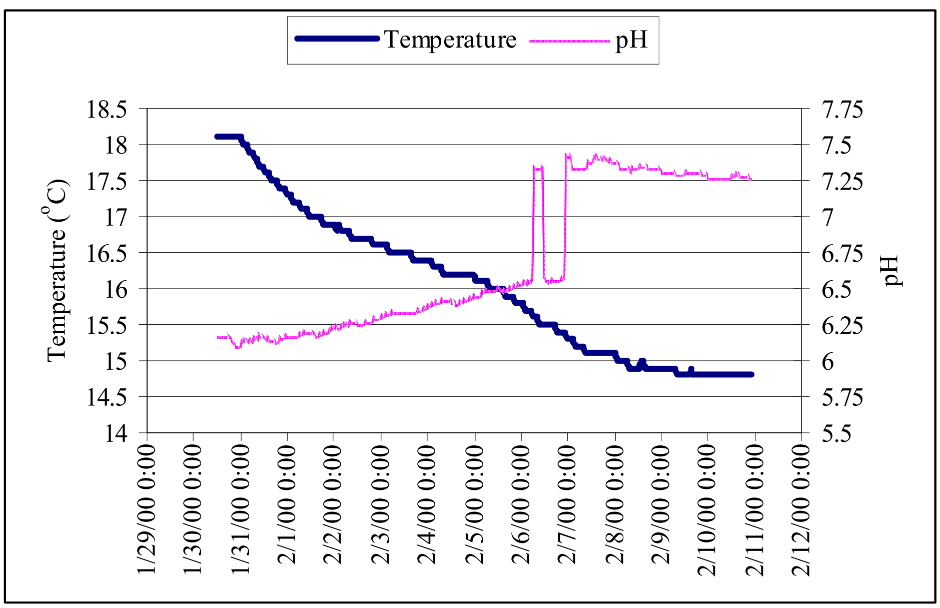


Figure C-12. Temperature and pH for Site 14 (2000)

APPENDIX D
RESTAURANT SURVEYS

Onsite Sewage Treatment Questionnaire
University of Florida

Facility SITE 1

Special Considerations
___ Lounge ___ Banquet Room
Public Restrooms YES (4)
Does facility get extra traffic from people just using the restrooms? NO

Operation Hours
TUE-FRI Weekdays Hours 11:00 AM to 10:00 PM
SAT-SUN Weekends Hours 11:00 AM to 10:00 PM
Hours ___ to ___

Meals Served
___ Breakfast X Lunch X Dinner

Average number of meals served per day
60 Weekdays 100 Saturday
75 Friday 100 Sunday

Seating (capacity) 150 # total Seats

X Dining ___ Lounge ___ Banquet

Type of Service
___ Deli ___ Cafeteria
X Full Service ___ Take Out / Delivery
___ Self Service ___ Other ___

Type of Menu
X American ___ Oriental
___ Mexican ___ Other ___
Does this facility have a salad bar? NO
Does this facility have a deep fat fryer? YES
If yes, # of deep fat fryers. 2
Does this facility have an ice cream or frozen yogurt machine? NO

Type of Tableware
X Standard ___ Disposable
___ Other ___

Kitchen
Does this facility use a garbage disposal? NO
Does this facility have an in-kitchen grease separator? NO
If yes, please provide details. ___

Dishwasher
___ Hot Water Rinse (180^{o}) ___ Chemical Rinse (140^{o})
X Single Automatic dishwasher ___ Conveyer
___ Manual Wash

How do you clean the facility?
___ Hose & Squeegee X mop
___ Other ___

Is the dumpster drain integrated to the sewage system? NO

Are there any kitchen practices which you feel may raise or lower your water use or the strength of waste going to your system?
NO ANSWER

Misc. Comments? NO ANSWER

Drainfield size ___ ft^2
Grease Trap Volume ___ gal
Septic Tank Volume ___ gal
Pump Station Volume ___ gal

Onsite Sewage Treatment Questionnaire
University of Florida

Facility ______SITE 2______

Special Considerations
______ Lounge ______ Banquet Room
Public Restrooms YES
Does facility get extra traffic from people just using the restrooms? NO

Operation Hours
__X__ Weekdays Hours 6:30 AM to 2:30 PM
______ Weekends Hours ______ to ______
Hours ______ to ______

Meals Served
__X__ Breakfast __X__ Lunch ______ Dinner

Average number of meals served per day
__40__ Weekdays __NA__ Saturday
__60__ Friday __NA__ Sunday

Seating (capacity) __20__ # total Seats

__X__ Dining ______ Lounge ______ Banquet

Type of Service
__X__ Deli ______ Cafeteria
__X__ Full Service __X__ Take Out / Delivery
______ Self Service ______ Other ______

Type of Menu
__X__ American ______ Oriental
______ Mexican ______ Other ______
Does this facility have a salad bar? NO
Does this facility have a deep fat fryer? YES
If yes, # of deep fat fryers. ______
Does this facility have an ice cream or frozen yogurt machine? NO

Type of Tableware
______ Standard __X__ Disposable
______ Other ______

Kitchen
Does this facility use a garbage disposal? NO
Does this facility have an in-kitchen grease separator? NO
If yes, please provide details. ______

Dishwasher
______ Hot Water Rinse (180^{o}) ______ Chemical Rinse (140^{o})
______ Single Automatic dishwasher ______ Conveyer
______ Manual Wash

How do you clean the facility?
______ Hose & Squeegee ______ mop
______ Other ______

Is the dumpster drain integrated to the sewage system? yes / no

Are there any kitchen practices which you feel may raise or lower your water use or the strength of waste going to your system?
NO ANSWER

Misc. Comments? NO ANSWER

Drainfield size ______ ft^2
Grease Trap Volume ______ gal
Septic Tank Volume ______ gal
Pump Station Volume ______ gal

Onsite Sewage Treatment Questionnaire
University of Florida

Facility SITE 3

Special Considerations

___ Lounge ___ Banquet Room

Public Restrooms YES

Does facility get extra traffic from people just using the restrooms? YES

Operation Hours

M,T,W,TH,SU Weekdays Hours 6:00 AM to 11:00 PM

F,SA Weekends Hours 6:00 AM to 12:00 AM

Hours ___ to ___

Meals Served

X Breakfast X Lunch X Dinner

Average number of meals served per day

300 Weekdays 400 Saturday

400 Friday 250 Sunday

Seating (capacity) 62 # total Seats

X Dining ___ Lounge ___ Banquet

Type of Service

___ Deli ___ Cafeteria

X Full Service X Take Out / Delivery

___ Self Service ___ Other ___

Type of Menu

X American ___ Oriental

___ Mexican ___ Other ___

Does this facility have a salad bar? NO

Does this facility have a deep fat fryer? YES

If yes, # of deep fat fryers. 3

Does this facility have an ice cream or frozen yogurt machine? YES

Type of Tableware

___ Standard X Disposable

___ Other ___

Kitchen

Does this facility use a garbage disposal? NO

Does this facility have an in-kitchen grease separator? YES

If yes, please provide details. THIS FACILITY HAS A SERVICE THAT PICKS UP THE GREASE MONTHLY

Dishwasher

___ Hot Water Rinse (180°) ___ Chemical Rinse (140°)

___ Single Automatic dishwasher ___ Conveyer

X Manual Wash

How do you clean the facility?

___ Hose & Squeegee X mop

___ Other ___

Is the dumpster drain integrated to the sewage system? YES

Are there any kitchen practices which you feel may raise or lower your water use or the strength of waste going to your system?

THE CLEANING PRODUCTS USED, ARE FROM CORPORATE OFFICE AND BASED ON THE REGULATIONS OF STATE/COUNTY.

Misc. Comments? NO ANSWER

Drainfield size ___ ft^2

Grease Trap Volume ___ gal

Septic Tank Volume ___ gal

Pump Station Volume ___ gal

Onsite Sewage Treatment Questionnaire
University of Florida

Facility ______SITE 4______

Special Considerations
______ Lounge ______ Banquet Room
Public Restrooms YES
Does facility get extra traffic from people just using the restrooms? NO

Operation Hours
__X__ Weekdays Hours 5:00 AM to 12:00 AM
__X__ Weekends Hours 5:00 AM to 12:00 AM
Hours ______ to ______

Meals Served
__X__ Breakfast __X__ Lunch __X__ Dinner

Average number of meals served per day EXPRESS RESTAURANT
__80__ Weekdays __170__ Saturday
__160__ Friday __160__ Sunday

Seating (capacity) __2__ # total Seats

______ Dining __X__ Lounge ______ Banquet

Type of Service
______ Deli ______ Cafeteria
______ Full Service __X__ Take Out / Delivery
__X__ Self Service ______ Other ______

Type of Menu
______ American ______ Oriental
__X__ Mexican ______ Other ______
Does this facility have a salad bar? NO
Does this facility have a deep fat fryer? NO
If yes, # of deep fat fryers. ______
Does this facility have an ice cream or frozen yogurt machine? NO

Type of Tableware
______ Standard __X__ Disposable
______ Other ______

Kitchen
Does this facility use a garbage disposal? NO
Does this facility have an in-kitchen grease separator? NO
If yes, please provide details. ______

Dishwasher
______ Hot Water Rinse (180°) ______ Chemical Rinse (140°)
______ Single Automatic dishwasher ______ Conveyer
__X__ Manual Wash

How do you clean the facility?
______ Hose & Squeegee __X__ mop
______ Other ______

Is the dumpster drain integrated to the sewage system? NO

Are there any kitchen practices which you feel may raise or lower your water use
or the strength of waste going to your system?
NO ANSWER

Misc. Comments? NO ANSWER

Drainfield size ______ ft^2
Grease Trap Volume ______ gal
Septic Tank Volume ______ gal
Pump Station Volume ______ gal

Onsite Sewage Treatment Questionnaire
University of Florida

Facility ______ SITE 5 ______

Special Considerations

______ Lounge ______ Banquet Room

Public Restrooms YES (2)

Does facility get extra traffic from people just using the restrooms? NO

Operation Hours

__X__ Weekdays Hours 5:00 AM to 12:00 AM

__X__ Weekends Hours 5:00 AM to 12:00 AM

Hours ______ to ______

Meals Served

______ Breakfast __X__ Lunch __X__ Dinner

Average number of meals served per day EXPRESS RESTAURANT

__100__ Weekdays ______ Saturday

______ Friday ______ Sunday

Seating (capacity) __0__ # total Seats

______ Dining ______ Lounge ______ Banquet

Type of Service

______ Deli ______ Cafeteria

______ Full Service __X__ Take Out / Delivery

__X__ Self Service ______ Other ______

Type of Menu

______ American ______ Oriental

__X__ Mexican ______ Other ______

Does this facility have a salad bar? NO

Does this facility have a deep fat fryer? NO

If yes, # of deep fat fryers. ______

Does this facility have an ice cream or frozen yogurt machine? NO

Type of Tableware

______ Standard __X__ Disposable

______ Other ______

Kitchen

Does this facility use a garbage disposal? NO

Does this facility have an in-kitchen grease separator? NO

If yes, please provide details. ______

Dishwasher

______ Hot Water Rinse (180^o) ______ Chemical Rinse (140^o)

______ Single Automatic dishwasher ______ Conveyer

__X__ Manual Wash 3 COMPARTMENT SINK

How do you clean the facility?

______ Hose & Squeegee __X__ mop

______ Other ______

Is the dumpster drain integrated to the sewage system? NO

Are there any kitchen practices which you feel may raise or lower your water use or the strength of waste going to your system?

NO ANSWER

Misc. Comments? NO ANSWER

Drainfield size ______ ft^2

Grease Trap Volume ______ gal

Septic Tank Volume ______ gal

Pump Station Volume ______ gal

Onsite Sewage Treatment Questionnaire
University of Florida

Facility SITE 6

Special Considerations
___ Lounge ___ Banquet Room
Public Restrooms YES
Does facility get extra traffic from people just using the restrooms? YES

Operation Hours
X Weekdays Hours 5:30 AM to 11:00 PM
X Weekends Hours ___ to ___
Hours ___ to ___

Meals Served
X Breakfast X Lunch X Dinner

Average number of meals served per day
728 Weekdays 972 Saturday
888 Friday 714 Sunday

Seating (capacity) 94 # total Seats

X Dining ___ Lounge ___ Banquet

Type of Service
___ Deli ___ Cafeteria
X Full Service X e Out / Delivery
X Self Service ___ Other ___

Type of Menu
X American ___ Oriental
___ Mexican ___ Other ___
Does this facility have a salad bar? NO
Does this facility have a deep fat fryer? YES
If yes, # of deep fat fryers. 5
Does this facility have an ice cream or frozen yogurt machine? YES

Type of Tableware
___ Standard X Disposable
___ Other ___

Kitchen
Does this facility use a garbage disposal? NO
Does this facility have an in-kitchen grease separator? NO
If yes, please provide details. ___

Dishwasher
___ Hot Water Rinse (180°) X Chemical Rinse (140°)
___ Single Automatic dishwasher ___ Conveyer
___ Manual Wash

How do you clean the facility?
___ Hose & Squeegee X mop
___ Other ___

Is the dumpster drain integrated to the sewage system? NO

Are there any kitchen practices which you feel may raise or lower your water use or the strength of waste going to your system?
NO ANSWER

Misc. Comments? NO ANSWER

Drainfield size ___ ft^2
Grease Trap Volume ___ gal
Septic Tank Volume ___ gal
Pump Station Volume ___ gal

Onsite Sewage Treatment Questionnaire
University of Florida

Facility ______SITE 7______

Special Considerations
______ Lounge ______ Banquet Room
Public Restrooms YES
Does facility get extra traffic from people just using the restrooms? YES

Operation Hours
__X__ Weekdays Hours 24 HRS to ______
__X__ Weekends Hours 24 HRS to ______
Hours ______ to ______

Meals Served
__X__ Breakfast __X__ Lunch __X__ Dinner

Average number of meals served per day
______ Weekdays ______ Saturday
______ Friday ______ Sunday

Seating (capacity) __20__ # total Seats

__X__ Dining ______ Lounge ______ Banquet

Type of Service
______ Deli ______ Cafeteria
__X__ Full Service __X__ Take Out / Delivery
______ Self Service ______ Other ______

Type of Menu
__X__ American ______ Oriental
__X__ Mexican ______ Other ______
Does this facility have a salad bar? NO
Does this facility have a deep fat fryer? NO
If yes, # of deep fat fryers. ______
Does this facility have an ice cream or frozen yogurt machine? NO

Type of Tableware
______ Standard __X__ Disposable
______ Other ______

Kitchen
Does this facility use a garbage disposal? NO
Does this facility have an in-kitchen grease separator? NO
If yes, please provide details. ______

Dishwasher
______ Hot Water Rinse (180°) ______ Chemical Rinse (140°)
______ Single Automatic dishwasher ______ Conveyer
______ Manual Wash

How do you clean the facility?
______ Hose & Squeegee __X__ mop
______ Other ______

Is the dumpster drain integrated to the sewage system?

Are there any kitchen practices which you feel may raise or lower your water use or the strength of waste going to your system?
NO ANSWER

Misc. Comments? NO ANSWER

Drainfield size ______ ft^2
Grease Trap Volume ______ gal
Septic Tank Volume ______ gal
Pump Station Volume ______ gal

Onsite Sewage Treatment Questionnaire
University of Florida

Facility ___SITE 11___

Special Considerations

_____ Lounge _____ Banquet Room

Public Restrooms YES

Does facility get extra traffic from people just using the restrooms? NO

Operation Hours

__X__ Weekdays Hours 11:00 AM to 10:00 PM

__X__ Weekends Hours 6:00 AM to 10:00 PM

Hours _____ to _____

Meals Served

__X__ Breakfast __X__ Lunch __X__ Dinner

Average number of meals served per day

__125__ Weekdays __200__ Saturday

__200__ Friday __200__ Sunday

Seating (capacity) __60__ # total Seats

__X__ Dining _____ Lounge _____ Banquet

Type of Service

_____ Deli _____ Cafeteria

__X__ Full Service _____ Take Out / Delivery

_____ Self Service _____ Other _____

Type of Menu

__X__ American _____ Oriental

_____ Mexican _____ Other _____

Does this facility have a salad bar? YES

Does this facility have a deep fat fryer? YES

If yes, # of deep fat fryers. _____

Does this facility have an ice cream or frozen yogurt machine? NO

Type of Tableware

__X__ Standard _____ Disposable

_____ Other _____

Kitchen

Does this facility use a garbage disposal? NO

Does this facility have an in-kitchen grease separator? NO

If yes, please provide details. _____

Dishwasher

__X__ Hot Water Rinse (180°) _____ Chemical Rinse (140°)

_____ Single Automatic dishwasher _____ Conveyer

_____ Manual Wash

How do you clean the facility?

_____ Hose & Squeegee _____ mop

_____ Other _____

Is the dumpster drain integrated to the sewage system?

Are there any kitchen practices which you feel may raise or lower your water use or the strength of waste going to your system?

NO ANSWER

Misc. Comments? GALLONS PER SEAT ARE NOT A RELIABLE SOURCE. ONSITE SYSTEMS SHOULD BE REVIEWED AS TO SEVERAL TOPICS - SEATING SHOULD BE CONSIDERED BUT IT SHOULD BO BE THE SOLE SOURCE FOR DETERMINATION OF SYSTEM SIZE. ACCORDING TO OUR SEATING WE SHOULD HAVE A SYSTEM THAT HANDLES 17,000 GAL. OF SEWAGE A DAY, WE ONLY CONSUME 2,000-3,000 GAL OF WATER PER DAY - TOTAL! MY ESTIMATES OF SEWAGE FLOW WOULD BE ABOUT 50% OF THAT FIGURE. USING THAT, WE SHOULD BE ABLE TO INCREASE OUR SEATING TO 10 TIMES WHAT WE ARE ALLOWED.

Drainfield size _____ ft^2

Grease Trap Volume _____ gal

Septic Tank Volume _____ gal

Pump Station Volume _____ gal

Onsite Sewage Treatment Questionnaire
University of Florida

Facility SITE 12

Special Considerations
___ Lounge ___ Banquet Room
Public Restrooms YES
Does facility get extra traffic from people just using the restrooms? YES

Operation Hours
X Weekdays Hours 6:00 AM to 9:00 PM
X Weekends Hours 6:00 AM to 10:00 PM
Hours ___ to ___

Meals Served
X Breakfast X Lunch X Dinner

Average number of meals served per day
200 Weekdays 500 Saturday
500 Friday 430 Sunday

Seating (capacity) 85 # total Seats

X Dining ___ Lounge ___ Banquet

Type of Service
___ Deli ___ Cafeteria
X Full Service X Take Out / Delivery
___ Self Service ___ Other ___

Type of Menu
X American ___ Oriental
___ Mexican ___ Other ___
Does this facility have a salad bar? NO
Does this facility have a deep fat fryer? YES
If yes, # of deep fat fryers. ___
Does this facility have an ice cream or frozen yogurt machine? NO

Type of Tableware
X Standard ___ Disposable
___ Other ___

Kitchen
Does this facility use a garbage disposal? NO
Does this facility have an in-kitchen grease separator? YES
If yes, please provide details. ___

Dishwasher
X Hot Water Rinse (180^{o}) ___ Chemical Rinse (140^{o})
___ Single Automatic dishwasher ___ Conveyer
___ Manual Wash

How do you clean the facility?
___ Hose & Squeegee ___ mop
___ Other ___

Is the dumpster drain integrated to the sewage system?

Are there any kitchen practices which you feel may raise or lower your water use or the strength of waste going to your system?
NO ANSWER

Misc. Comments? NO ANSWER

Drainfield size ___ ft^2
Grease Trap Volume ___ gal
Septic Tank Volume ___ gal
Pump Station Volume ___ gal

Onsite Sewage Treatment Questionnaire
University of Florida

Facility SITE 13

Special Considerations
___ Lounge ___ Banquet Room
Public Restrooms YES
Does facility get extra traffic from people just using the restrooms? YES

Operation Hours
X Weekdays Hours 24 HRS to ___
X Weekends Hours 24 HRS to ___
Hours ___ to ___

Meals Served
X Breakfast X Lunch X Dinner

Average number of meals served per day
500 Weekdays 1,000 Saturday
1,000 Friday 700 Sunday

Seating (capacity) 60 # total Seats

X Dining ___ Lounge ___ Banquet

Type of Service
___ Deli ___ Cafeteria
X Full Service X Take Out / Delivery
___ Self Service ___ Other ___

Type of Menu
X American ___ Oriental
___ Mexican ___ Other ___
Does this facility have a salad bar? NO
Does this facility have a deep fat fryer? YES
If yes, # of deep fat fryers. 4
Does this facility have an ice cream or frozen yogurt machine? YES

Type of Tableware
___ Standard X Disposable
___ Other ___

Kitchen
Does this facility use a garbage disposal? NO
Does this facility have an in-kitchen grease separator? NO
If yes, please provide details. ___

Dishwasher
___ Hot Water Rinse (180^o) ___ Chemical Rinse (140^o)
X Single Automatic dishwasher ___ Conveyer
___ Manual Wash

How do you clean the facility?
___ Hose & Squeegee X mop
___ Other ___

Is the dumpster drain integrated to the sewage system?

Are there any kitchen practices which you feel may raise or lower your water use or the strength of waste going to your system?
NO ANSWER

Misc. Comments? NO ANSWER

Drainfield size ___ ft^2
Grease Trap Volume ___ gal
Septic Tank Volume ___ gal
Pump Station Volume ___ gal

Onsite Sewage Treatment Questionnaire
University of Florida

Facility SITE 14

Special Considerations
___ Lounge ___ Banquet Room
Public Restrooms YES (2)
Does facility get extra traffic from people just using the restrooms? YES

Operation Hours
X Weekdays Hours 6:00 AM to 10:00 PM
X Weekends SAT Hours 6:00 AM to 2:00 PM
SUN Hours 6:00 AM to 4:00 PM

Meals Served
X Breakfast X Lunch X Dinner

Average number of meals served per day
200 Weekdays 350 Saturday
300 Friday 300 Sunday

Seating (capacity) 50 # total Seats

X Dining ___ Lounge ___ Banquet

Type of Service
___ Deli ___ Cafeteria
X Full Service ___ Take Out / Delivery
___ Self Service ___ Other ___

Type of Menu
X American ___ Oriental
___ Mexican ___ Other ___
Does this facility have a salad bar? YES
Does this facility have a deep fat fryer? YES
If yes, # of deep fat fryers. 1
Does this facility have an ice cream or frozen yogurt machine? NO

Type of Tableware
X Standard ___ Disposable
___ Other ___

Kitchen
Does this facility use a garbage disposal? NO
Does this facility have an in-kitchen grease separator? NO
If yes, please provide details. THIS FACILITY HAS A COMPANY THAT PICKS UP THE GREASE MONTHLY

Dishwasher
X Hot Water Rinse (180°) ___ Chemical Rinse (140°)
___ Single Automatic dishwasher ___ Conveyer
___ Manual Wash

How do you clean the facility?
___ Hose & Squeegee X mop
___ Other ___

Is the dumpster drain integrated to the sewage system? NO

Are there any kitchen practices which you feel may raise or lower your water use or the strength of waste going to your system?
NO ANSWER

Misc. Comments? NO ANSWER

Drainfield size ___ ft^2
Grease Trap Volume ___ gal
Septic Tank Volume ___ gal
Pump Station Volume ___ gal

Onsite Sewage Treatment Questionnaire
University of Florida

Facility SITE 15

Special Considerations
Lounge; X Banquet Room
Public Restrooms YES (2)
Does facility get extra traffic from people just using the restrooms? NO

Operation Hours

M,T,W	Hours	6:30 AM	to	3:00 PM
TH,F,S	Hours	6:00 AM	to	10:00 PM
SUN	Hours	6:30 AM	to	9:00 PM

Meals Served
X Breakfast; X Lunch; X Dinner

Average number of meals served per day
275 Weekdays; 450 Saturday
400 Friday; 450 Sunday

Seating (capacity) 125 # total Seats

X Dining; Lounge; Banquet

Type of Service
Deli; Cafeteria
X Full Service; X Take Out / Delivery
Self Service; Other

Type of Menu
American; Oriental
Mexican; X Other SEAFOOD
Does this facility have a salad bar? YES
Does this facility have a deep fat fryer? YES
If yes, # of deep fat fryers. 3
Does this facility have an ice cream or frozen yogurt machine? NO

Type of Tableware
X Standard; Disposable
Other

Kitchen
Does this facility use a garbage disposal? NO
Does this facility have an in-kitchen grease separator? NO
If yes, please provide details.

Dishwasher
X Hot Water Rinse (180°); Chemical Rinse (140°)
Single Automatic dishwasher; Conveyer
Manual Wash

How do you clean the facility?
X Hose & Squeegee; X mop
Other

Is the dumpster drain integrated to the sewage system? NO

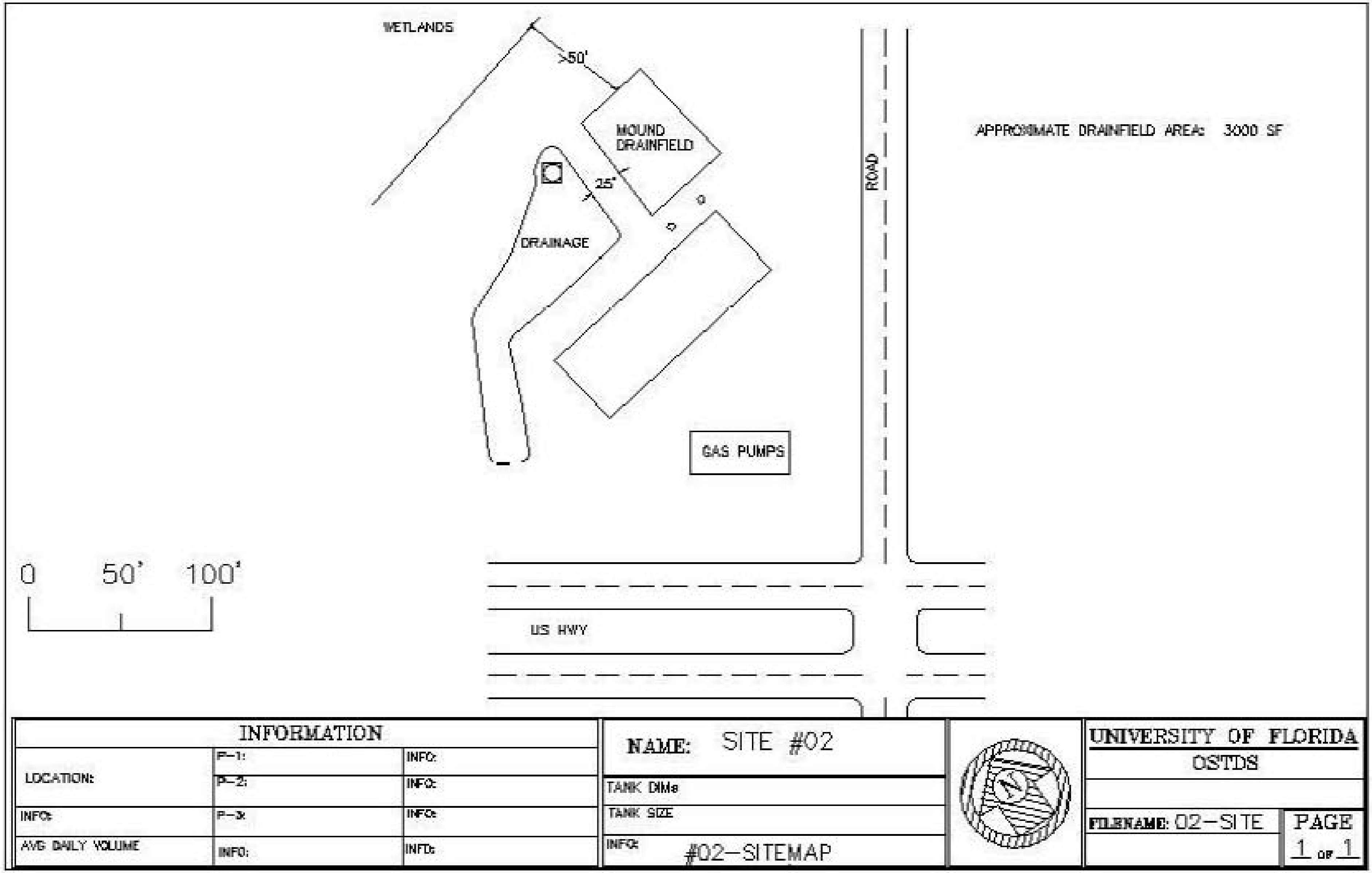
Are there any kitchen practices which you feel may raise or lower your water use or the strength of waste going to your system?
NO ANSWER

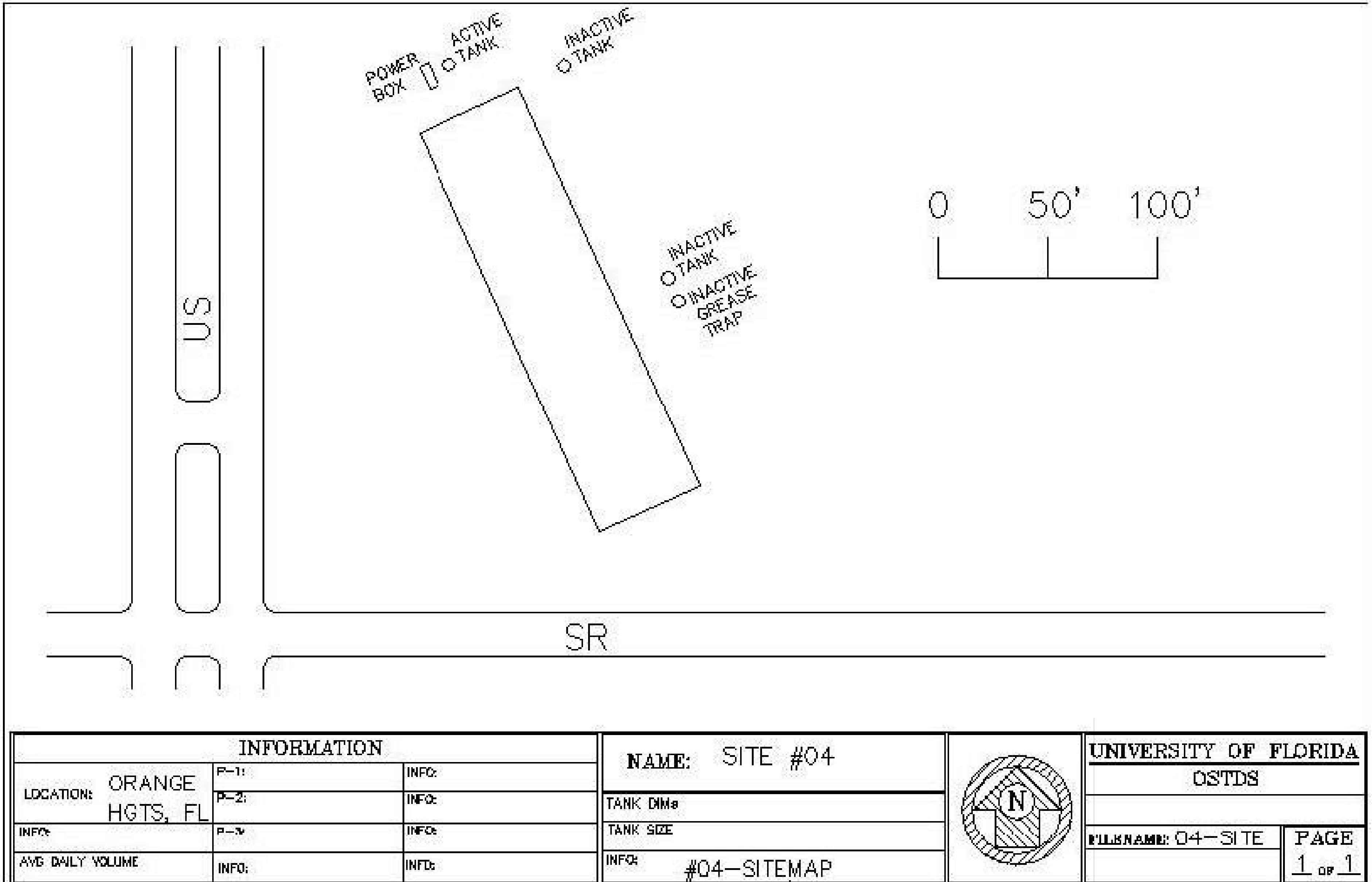
Misc. Comments? NO ANSWER

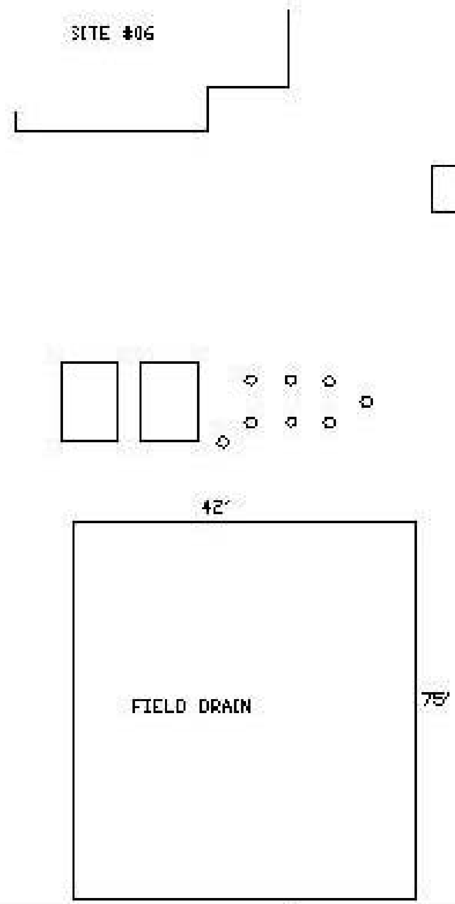
Drainfield size ______ ft^2
Grease Trap Volume ______ gal
Septic Tank Volume ______ gal
Pump Station Volume ______ gal

2 GREASE TRAPS
3 DRAINFIELDS EACH 2000 SQ FT
LIFT STATATION (1,800 OR 2,500 ?) GAL

APPENDIX E
RESTAURANT SITE PLANS


WETLANDS
>50'
MOUND DRAINFIELD
25'
DRAINAGE
ROAD
APPROXIMATE DRAINFIELD AREA: 3000 SF
GAS PUMPS
0 50' 100'
US HWY
INFORMATION
LOCATION:
P-1:
P-2:
P-3:
INFO:
AVG DAILY VOLUME
NAME: SITE #02
TANK DIMs
TANK SIZE
INFO: #02-SITEMAP
UNIVERSITY OF FLORIDA
OSTDS
FILENAME: 02-SITE
PAGE 1 OF 1

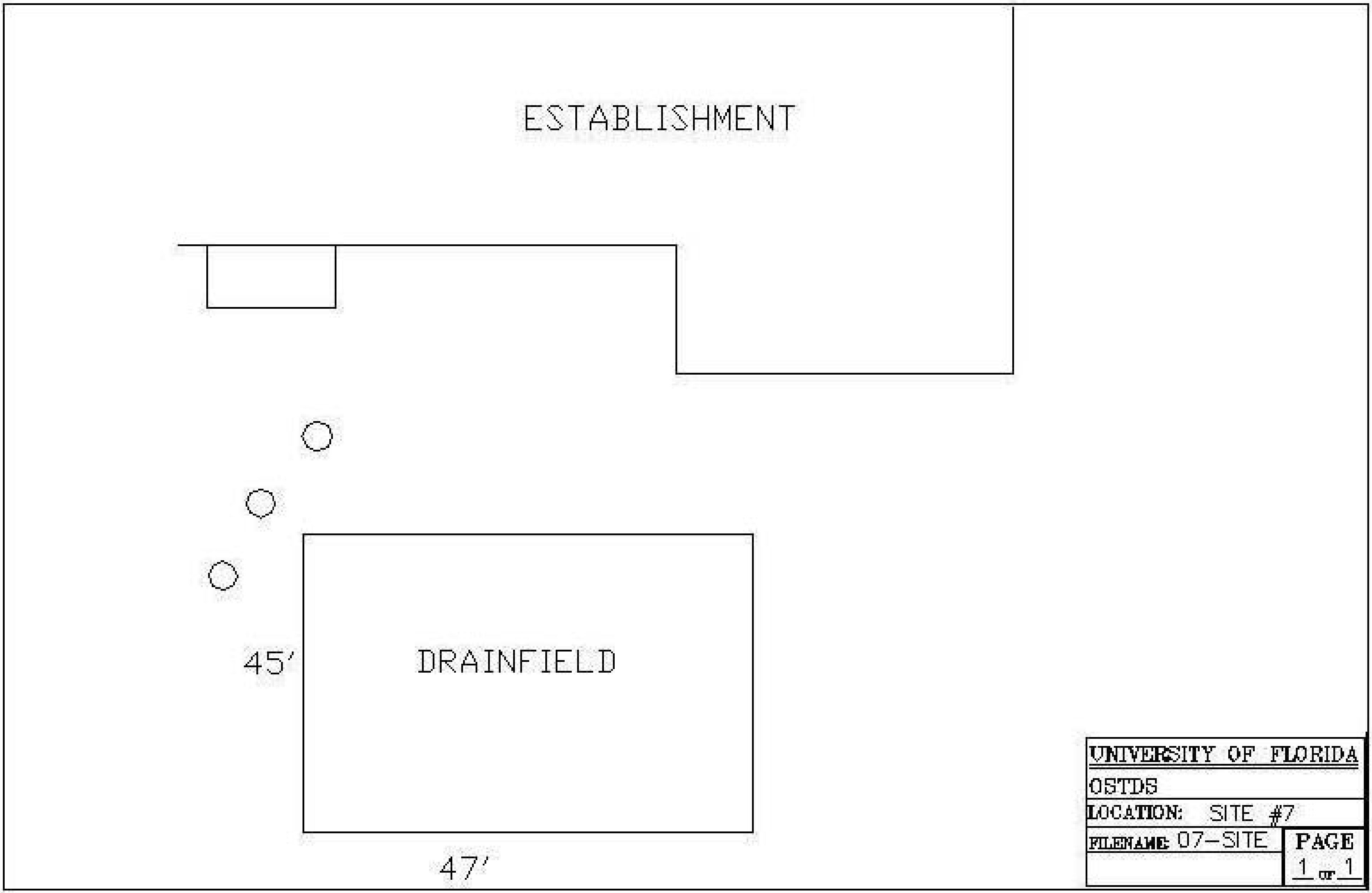

POWER BOX
ACTIVE TANK
INACTIVE TANK
INACTIVE TANK
INACTIVE GREASE TRAP
0
50'
100'
US
SR
INFORMATION
LOCATION: ORANGE HGTS, FL
P-1:
P-2:
P-3:
INFO:
INFO:
INFO:
INFO:
INFO:
INFO:
AVG DAILY VOLUME
NAME: SITE #04
TANK DIMs
TANK SIZE
INFO: #04-SITEMAP
N
UNIVERSITY OF FLORIDA
OSTDS
FILENAME: 04-SITE
PAGE 1 OF 1

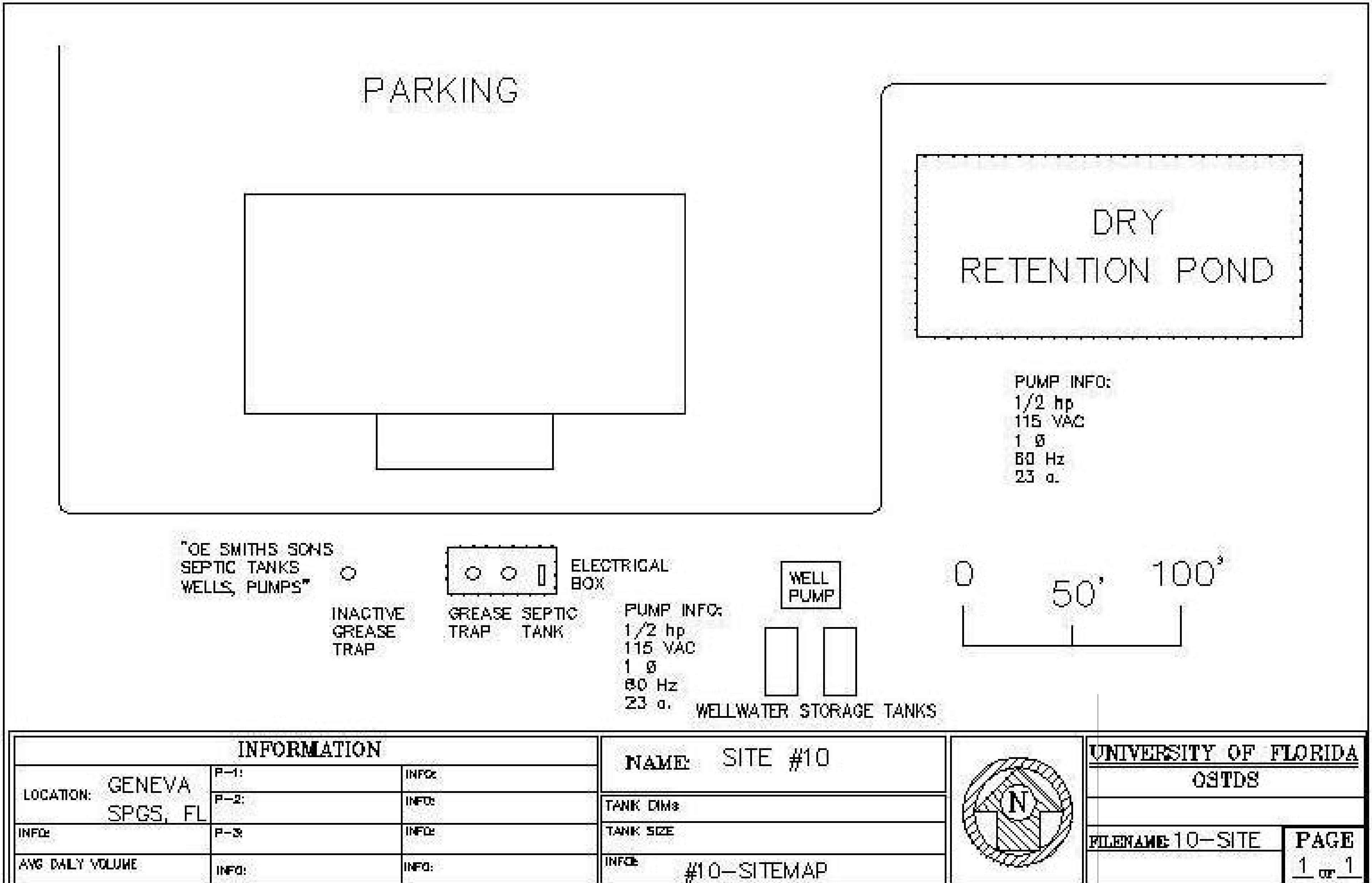


INFORMATION		
LOCATION: HIGH SPRINGS	P-1:	INFO:
	P-2:	INFO:
INFO:	P-3:	INFO:
	INFO:	INFO:

NAME: SITE #06
TANK DIMs
TANK SIZE
INFO: #06-SITEMAP

UNIVERSITY OF FLORIDA OSTDS	
FILENAME: 06-SITE	PAGE 1 OF 1


ESTABLISHMENT
DRAINFIELD
45'
47'
UNIVERSITY OF FLORIDA
OSTDS
LOCATION: SITE #7
FILENAME: 07-SITE
PAGE 1 OF 1


PARKING
DRY RETENTION POND
PUMP INFO:
1/2 hp
115 VAC
1 Ø
60 Hz
23 a.
"OE SMITHS SONS SEPTIC TANKS WELLS, PUMPS"
INACTIVE GREASE TRAP
GREASE TRAP
SEPTIC TANK
ELECTRICAL BOX
PUMP INFO:
1/2 hp
115 VAC
1 Ø
60 Hz
23 a.
WELL PUMP
WELLWATER STORAGE TANKS
0
50'
100'
INFORMATION
LOCATION: GENEVA SPGS, FL
P-1:
INFO:
P-2:
INFO:
INFO:
P-3:
INFO:
AVG DAILY VOLUME
INFO:
INFO:
NAME: SITE #10
TANK DIMS
TANK SIZE
INFO: #10-SITEMAP
N
UNIVERSITY OF FLORIDA
OSTDS
FILENAME: 10-SITE
PAGE 1 OF 1

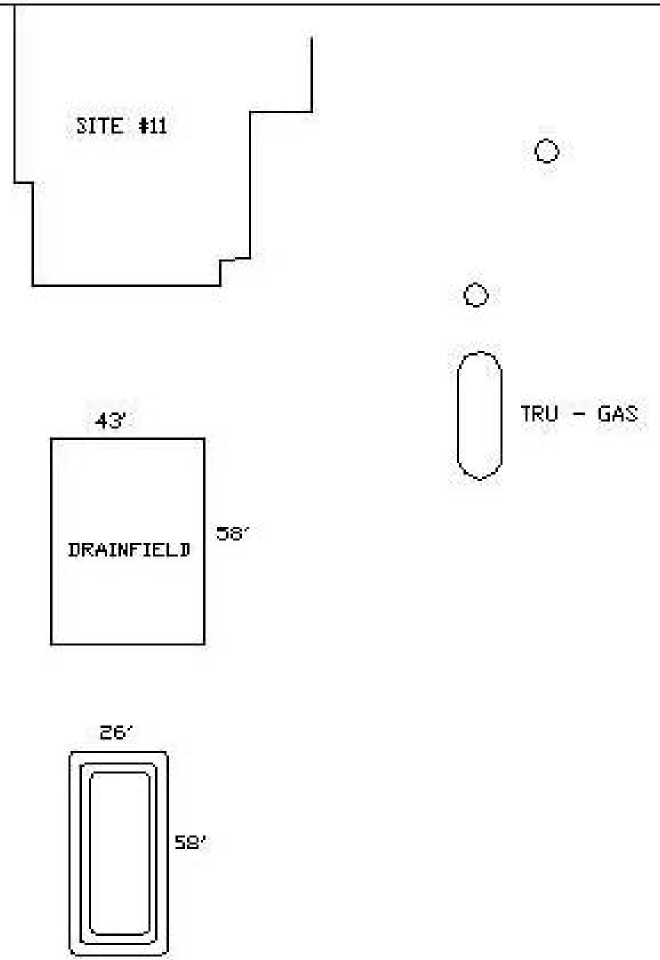
SYSTEM INFORMATION

1050 gal GREASE TRAP

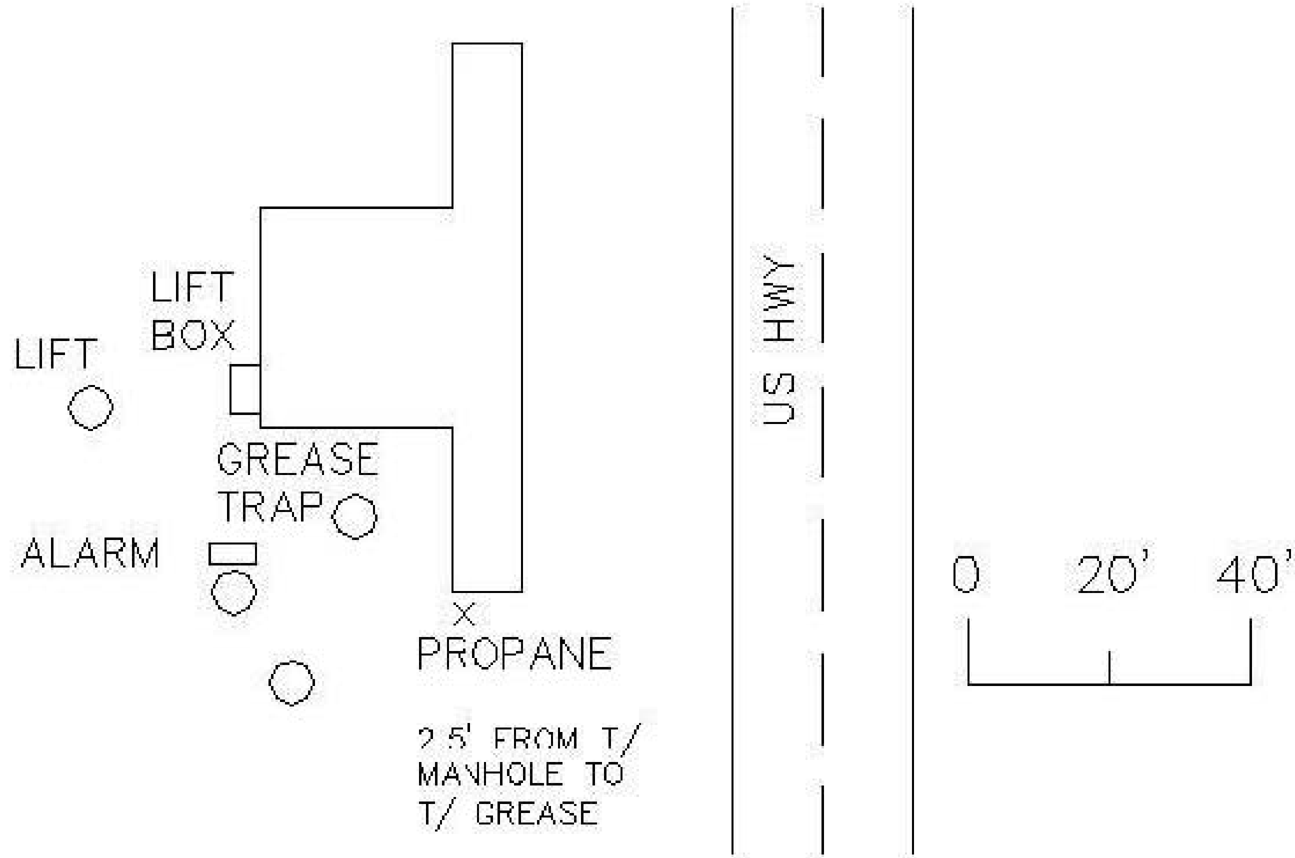
2800 gal SEPTIC TANK

1050 gal LIFT STATION

DRAINFIELD: BED-SYSTEM



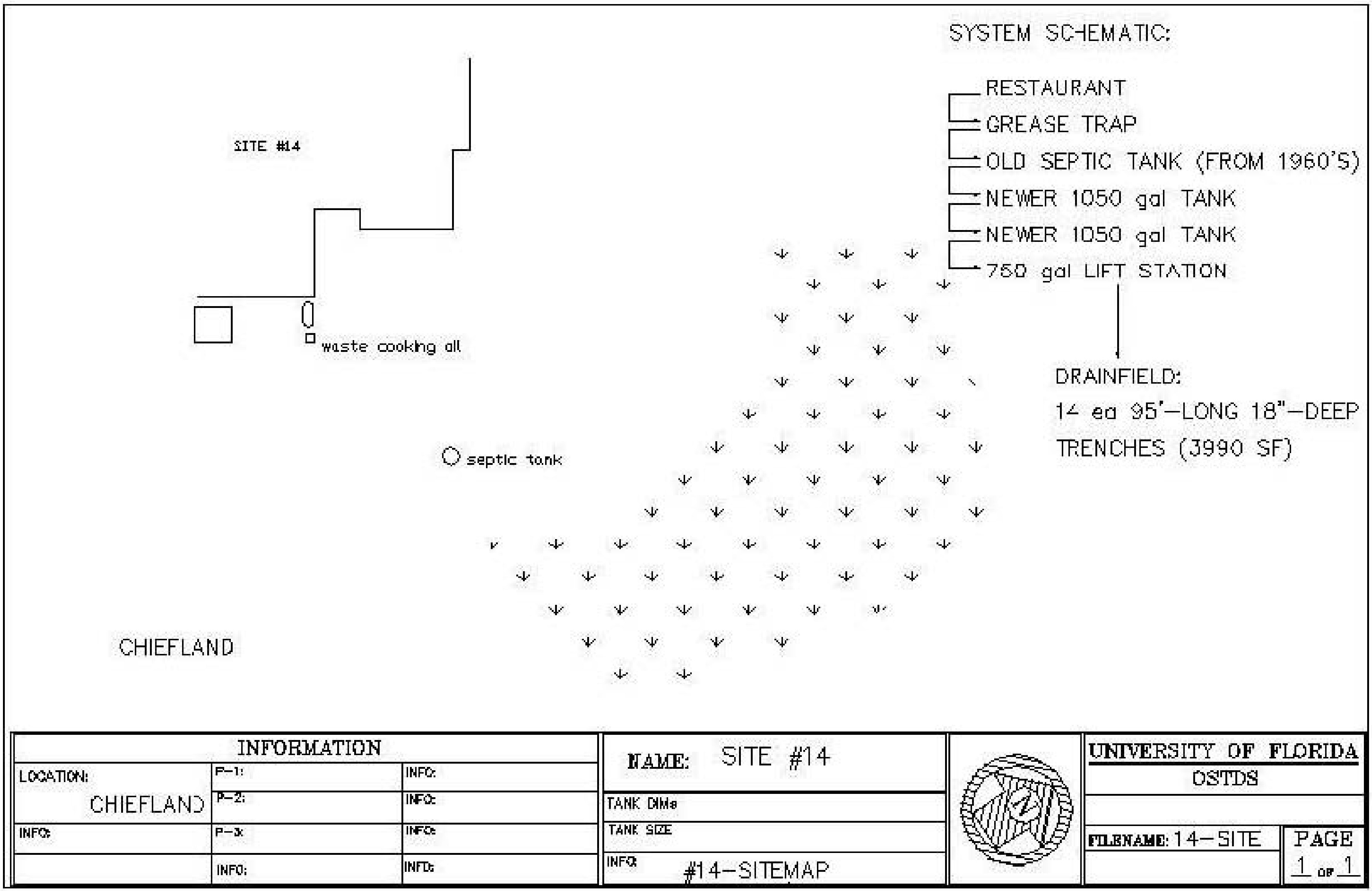
INFORMATION				NAME: SITE #11		UNIVERSITY OF FLORIDA OSTDS
LOCATION: CHIEFLAND	P-1:	115 VAC	INFO:			
		60 Hz	INFO:	TANK DIMs		
INFO:		1 Phase	INFO:	TANK SIZE		FILENAME: 11-SITE — PAGE 1 OF 1
		1 Hp	INFO:	INFO: #11-SITEMAP		

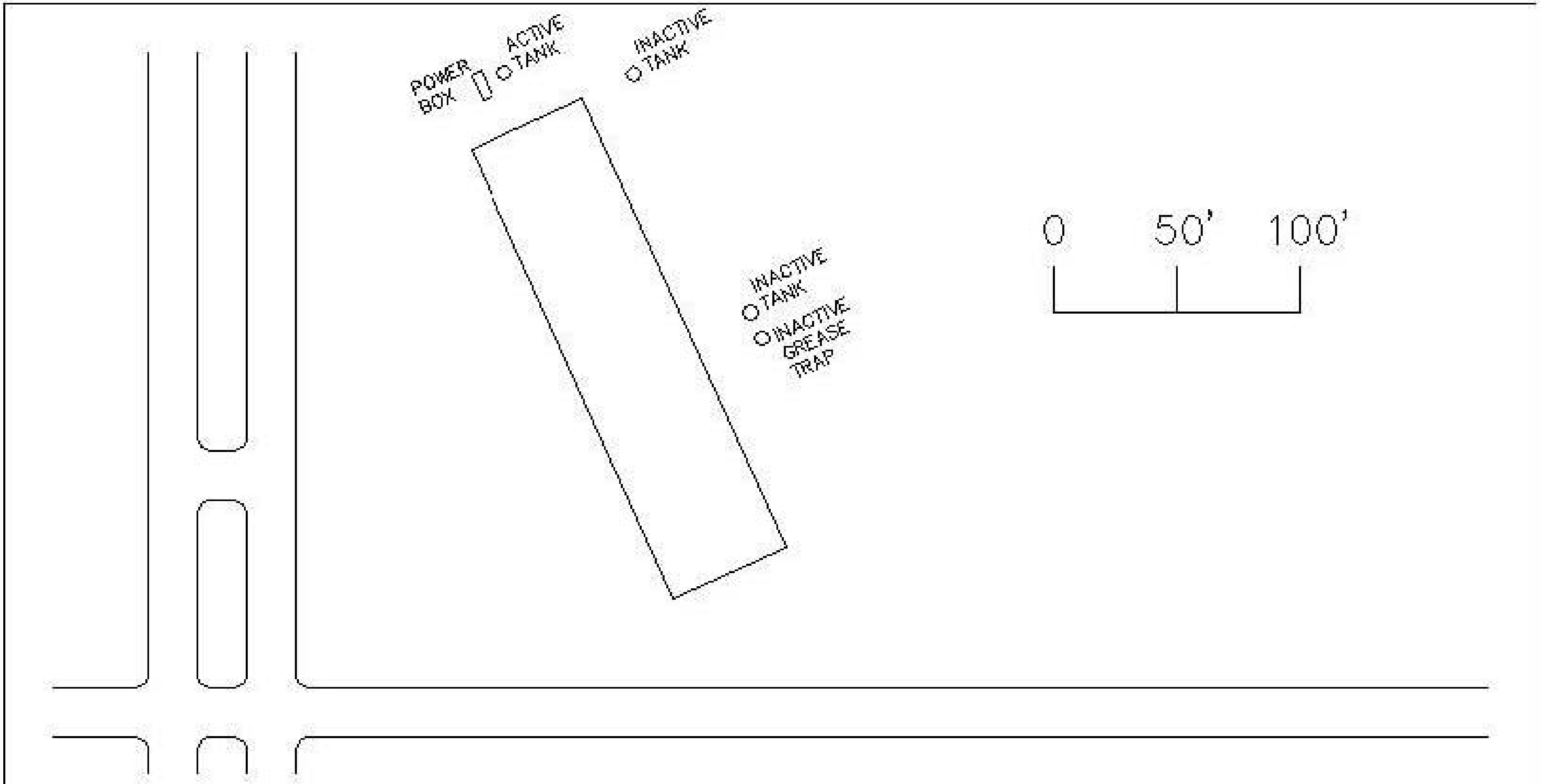


INFORMATION		
LOCATION:	P-1:	INFO:
	P-2:	INFO:
INFO:	P-3:	INFO:
AVG DAILY VOLUME	INFO:	INFO:

NAME: SITE #12
TANK DIMs
TANK SIZE
INFO: #12-SITEMAP

UNIVERSITY OF FLORIDA	
OSTDS	
FILENAME: 12-SITE	PAGE 1 OF 1


SYSTEM SCHEMATIC:
RESTAURANT
GREASE TRAP
OLD SEPTIC TANK (FROM 1960'S)
NEWER 1050 gal TANK
NEWER 1050 gal TANK
750 gal LIFT STATION
DRAINFIELD:
14 ea 95'-LONG 18"-DEEP
TRENCHES (3990 SF)
SITE #14
waste cooking oil
septic tank
CHIEFLAND
INFORMATION
LOCATION:
CHIEFLAND
P-1:
P-2:
P-x:
INFO:
INFO:
INFO:
INFO:
INFO:
INFO:
NAME: SITE #14
TANK DIMs
TANK SIZE
INFO: #14-SITEMAP
UNIVERSITY OF FLORIDA
OSTDS
FILENAME: 14-SITE
PAGE
1 OF 1



INFORMATION			NAME: SITE #15	UNIVERSITY OF FLORIDA OSTDS
LOCATION: ORANGE HGTS, FL	P-1:	INFO:	TANK DIMs	
	P-2:	INFO:	TANK SIZE	FILENAME: 15-SITE
INFO:	P-3:	INFO:	INFO: #15-SITEMAP	PAGE 1 OF 1
AVG DAILY VOLUME	INFO:	INFO:		