ONSITE SEWAGE DISPOSAL SYSTEM RESEARCH ON THE NORTHERN PERIPHERY OF LAKE OKEECHOBEE

FINAL REPORT
Contract No. LP555

Prepared for:

STATE OF FLORIDA
DEPARTMENT OF HEALTH AND REHABILITATIVE SERVICES
Tallahassee, Florida

Prepared by:

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.
Gainesville, Florida

ESE No. 3-91-3010

February 1993

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EXECUTIVE SUMMARY

The Surface Water Improvement and Management (SWIM) Plan for Lake Okeechobee (1989) directs the District to "...develop a cooperative program with the Florida Department of Health and Rehabilitative Services (FDHRS) and the Florida Department of Environmental Regulation (FDER) and the appropriate local governments to assess the extent to which septic tanks contribute to phosphorus levels within a particular basin." The objectives of this research project are to investigate the impact of high-density onsite sewage disposal systems (OSDS) installations on water quality and overall health of man-made canals along the northern periphery of Lake Okeechobee and estimate the phosphorus loading from these systems to the lake itself. Phosphorus is of particular interest due to its behavior as a biolimiting nutrient in receiving surface waters.

Four residential subdivisions along the northern periphery of Lake Okeechobee comprise the majority of waterfront property within the Northern Basins. The subdivisions chosen for the study are as follows:

- Taylor Creek Isles,
- Treasure Island,
- Buckhead Ridge, and
- Okeechobee Hammocks.

The project was initiated by sending 800 questionnaires to a subset of residents within each subdivision. The survey was organized according to two broad categories: (1) description of the property, home, septic system and/or washing machine water disposal, water using facilities, and residents; and (2) description of land use activities. The land use activities have been divided into clothes washing and dishwashing practices; and lawn maintenance activities such as fertilizer or pesticide application practices and irrigation.

A total of 88 percent of the respondents are permanent residents; 71 percent of the seasonal residents live there during fall and winter.

The majority of homes within the four subdivisions use septic tanks to dispose of domestic wastewater. One small package treatment plant exists in the Taylor Creek Isles subdivision and services all the houses along two streets.

Seven different sites were chosen to represent background: a vacant lot; two old septic systems, Moldenhauer and Lewis (drainfields installed nearer to the canals); two newer systems, Goolsby and Spaulding (drainfields installed away from the canals); a site served by the package treatment plant, Weston; and the package treatment plant itself.

Field investigations began with the installation of monitor wells and lysimeters (soil moisture samplers) at the seven study sites, choosing surface water sampling sites, and collecting soil samples for the first part of the soil sampling efforts. The lysimeters were installed to measure the quality of the septic leachate just as it enters the water table. The monitor wells were installed just downgradient of the drainfields to measure the difference between the quality of the septic leachate and the first dilution in the groundwater. Surface water sampling stations were generally chosen to find upstream-downstream differences where possible and to observe the potential differences between water quality in canals in general versus the water quality in the canal surrounded by homes on central sewer.

The first soil sampling program was designed to investigate the changes in phosphorus content and adsorption capacity with distance (vertical and horizontal) from the drainfields. Samples were collected at increasing vertical distances below the drainfield and with increasing distance away from the drainfield at the top of the water table toward the canal. The second soil sampling program was designed to investigate the non-septic related phosphorus status of soils and/or soil horizons representative of the subdivisions.

Soils of the subdivisions can generally be characterized as being fill on top of native soils. The characteristics of the fill are somewhat variable with depth and across the landscape. Generally, the fill material was loose, structureless fine sand. Buried soils have restrictive clay layers or organic hard pans overlain by muck in some

areas. Occasionally the subsoil contains fractured limestone.

The differences in canal sediment characteristics between the four subdivisions did not appear significant. Thickness and texture of sediment, depth of the water, and the canal widths were all relatively similar. The one major difference was overall canal length. Subdivision size, age, and stage of development also differed significantly.

The first soil sampling program indicated two trends in soil phosphorus (P) concentrations. Generally, in the first trend, P appears to have accumulated in a particular location along the top of the water table under each drainfield. This area of accumulated P is 5 to 10 feet (ft) downgradient of the drainfield at the Spaulding residence. This observation is interesting considering that the unsaturated zone of soils is supposed to be the treatment zone under drainfields. The observed areas of accumulation are at the top of the water table and somewhat downgradient of the drainfield which indicates that migration of P is taking place. It appears as if a slug of P is moving through the soils at the Spaulding site.

The second trend in P concentrations can be observed by comparing the difference in concentrations between fill and Oa (organic soil horizon) materials. Total P concentrations in the fill material, on average, are less than half of the P concentrations found in the Oa samples. The primary difference between these two sample types is the percentage of organic matter, which appears to control soil P concentrations.

Exchangeable P was at least an order of magnitude smaller than total P in these samples. This observation is important because it implies that the soils have fixed the phosphorus so that it is no longer available for migration. Phosphorus in drainfield leachate is apparently only mobile for a short period of time before being fixed in the more organic materials under the drainfields.

Most of the nitrogen (N) (by several orders of magnitude) in the soil samples exists in the organic form measurable by the total Kjeldahl nitrogen (TKN) method. Soil N concentrations vary in similar magnitude and amount as soil P concentrations. The N does not appear to have a similar positional distribution as soil P; being more evenly distributed through the soil profile and along the top of the water table. This is likely a function of the greater mobility of N in soils versus lower mobility of P. Soil N concentrations do not appear to be as strongly related to soil type as does soil P. The lack of an observed pulse of N throughout the route of migration to the canal implies that the soil may have reached equilibrium with respect to N. The soil may no longer be capable of treating or attenuating N, allowing it to migrate from the drainfields to the canal.

The soil map units that were sampled as part of the second part of the soil study represent results in individual samples from organic horizons, spodic horizons, topsoil, and other subsurface horizons. It appears as if effects of fertilizer applications, historical use of the native (original) soils, and soil characteristics have a bigger effect on the N and P content of these samples because the concentrations are much closer to or at background levels.

Total P content of these samples was an average of up to an order of magnitude smaller than the total P observed in samples collected under the septic tank drainfields. The same differences were observed for the fill and native soil materials relative to the fill and organic horizon materials under the septic systems. The septic systems are clearly contributing large (relative to native soils) quantities of P to the soils of the subdivisions.

Exchangeable P was detected in only 3 of the 36 samples collected from the dominant soil map units. The same pattern of a minimal amount of exchangeable P relative to total P was exhibited in these samples as was exhibited in samples collected from under the septic tanks. This further emphasizes that the soils are capable of attenuating the P from septic systems and the leachable P.

The TKN content of these soil samples was between 2 and 4 times smaller than samples collected under the drainfields. The TKN content varied from 7 to 13,640 mg/kg. TKN concentrations do not depend on soil sample type as does soil P. The average TKN of fill samples was close to the average TKN of the native soil samples.

Phosphorus adsorption isotherms were conducted to indicate the amount of P that soils from different horizons were capable of attenuating.

Phosphorus adsorption correlated well with iron, aluminum, and total organic matter. Iron or aluminum correlates well with adsorption. This information indicates that soil characteristics such as organic matter content, iron, or aluminum content are good predictors of the ability of a soil to adsorb phosphorus.

Total P content for the 12 sediment samples collected from the bottoms of various canals ranges from 42 to 757 mg/kg. Average sediment total P is similar to average native soil total P observed in the different soil series and half of the average total P observed in soils collected under the septic tank drainfield. Samples collected in the canal surrounded by homes on septic tanks were indistinguishable from samples collected from the canal surrounded by homes hooked to the treatment plant. No trends were observed between samples collected in older versus newer parts of the subdivisions nor were trends observed between samples collected from upstream or downstream of various sections of the subdivisions.

Exchangeable phosphorus was measured in 5 of the 12 sediment samples collected from the canals. The exchangeable P concentrations have a narrow range of 0.37 to 0.94 mg/kg.

Sediment phosphorus adsorption studies showed a range of adsorption from a high of 251 mg/kg to a low of 118 mg/kg. Correlations of the adsorption with organic matter, iron, aluminum, and the highest of either of the iron and aluminum values were not evident. Adsorption of phosphorus in sediments may be controlled by calcium ions/minerals in the surface water systems. During much of the year, the pH of the canal waters appears to be alkaline. If phosphorus precipitates with calcium, correlations of P adsorption would not show a high correlation with iron, aluminum, and organic matter that appears to adsorb best under acidic conditions.

Total phosphorus levels in groundwater sampled adjacent to septic tank systems were higher than other studies. Treatment efficiency is increased with a corresponding increased distance between septic tank drainfield and water table elevations.

This observation takes on greater significance considering that the depth to water tables in these subdivisions exceed the minimum required distance criteria set forth in 10D-6 code. It appears that any additional separation between the drainfield and the water table affords some amount of additional treatment. Without groundwater criteria or observable impact to adjacent surface waters, there is no way of determining what separation distance is optimum for these areas.

The groundwater results further showed that age or construction of the septic tank was not necessarily related to groundwater quality.

Lower total phosphorus levels analyzed in canal surface waters are primarily attributable to dilution and biological uptake. All retention or loss processes must be considered as influencing these generally lower total phosphorus concentrations in surface waters than the surficial aquifer monitor wells.

The total potential (maximum) phosphorus loadings to Lake Okeechobee from Taylor Creek and Treasure Island, Buckhead Ridge, and Okeechobee Hammocks were 872, 502, and 55 kilograms (kg) per year, respectively, which is equivalent to approximately 1.5 tons per year.

The sediment total N is essentially organic or ammonia-related. All the values of $NO_2 + NO_3$ are below detection limits. The average TKN of all the sediment samples is approximately twice the TKN observed in the soil samples collected under the septic tank drainfields and an order of magnitude greater than observed in soils collected from the various soil series in the area. Although these values were significantly greater than that observed for the soils, these sediment-N values are normal for Florida streams, according to FDER data.

No sediment quality problems were observed during this study.

Sediment samples contained relatively low organic contents meaning that the nitrogen is not in the form of partially decomposed plant materials. The nitrogen is likely in the form of ammonia, accumulating in the anoxic canal sediments. With little movement of water in these canals, the ammonia could be accumulating at a gradual-slow rate and could continue to accumulate until a storm event of sufficient magnitude occurs to flush or oxygenate the sediments. Unfortunately, redox measurements of the sediments are not available to confirm this hypothesis.

Groundwater level and flow direction data suggest onsite water levels are a function of seasonal (wet/dry) changes in rainfall and canal water levels. Typically, groundwater flow is toward the canals for the major part of the year. However, reversals to this pattern have been noted. Therefore, nutrient loading conditions are also transient conditions that depend not only on the flow direction, but also on the groundwater flow rate.

Biological contaminants associated with septic tanks may exhibit a variety of characteristics including different species, surface properties, and half-lives. Septic tank leachate has been identified as a problem in many of Florida's waterbodies and a major source of groundwater contamination (FDER, 1992a). Environmental factors that may influence their subsurface migration rates through soil include soil moisture content and holding capacity, temperature, pH, organic matter, and antagonism from soil microflora. The physical process of mechanical filtering and the chemical process of adsorption may be the most significant mechanisms responsible for bacterial removal from water percolating through soil (Canter and Knox, 1984).

The total coliform measurements made as part of this study are used to determine the size of the coliform population, which provides a relative indication of water quality.

Conclusions offered for parameters governing the total coliform populations are also applicable to nutrient species analyzed in these waters. Total phosphorus, pH, and specific conductance measurements made during this study are similar to those independently recorded in this region (FDER, 1992b). It is difficult to quantify the contributions made by septic tanks to these receiving waters, although data developed for the Moldenhauer residence suggest leachate from these sources is significantly attenuated in soils within both saturated and unsaturated zones.

In summary, microbiological measurements appear primarily influenced by site-specific phenomena, such as stagnation, temperature, and inputs from both natural and anthropogenic (e.g., septic tanks) sources. Definitive analytes such as fecal coliforms or coprostanol in sediments may be considered in a more focused study to further delineate specific sources and long-term impacts (Brown and Wade, 1984).

Despite the local water flow between the isles and canals, as an integrated water system, water from these areas may ultimately discharge into Lake Okeechobee. Nutrient loadings from a septic tank drainfield may therefore be treated as a point source with nutrient concentrations in the groundwater decreasing as water moves away from the recharge points (drainfields). Thus, the nutrient loading from the study areas was determined to be more reliable by direct computation based on the data available at the recharge points or drainfields. The detailed computation is shown in Appendix C.

The nutrient concentrations analyzed in monitor well samples associated with the Moldenhauer residence generally fall within anticipated concentration ranges. This site may serve as a useful location to monitor septic tank effluent on a long-term basis, due to its status as an older, active system and monitoring data clearly indicative of nutrient enrichment of the shallow water table/associated soils. The Moldenhauer residence also has upgradient and downgradient monitor wells that assist with simultaneous comparison of background and potentially impacted areas.

The drainage system in each study area forms a complex network of residential houses in the isles bordered by finger canals. Groundwater in an isle is directly connected with surface water. Thus, the finger canals are the nearest receiving water for nutrients discharged from septic tanks within the isles.

When the water levels in the canals become greater than the groundwater levels (due to rainfall or wet/dry season), water from the canal may flow into the isles to reach an equilibrium condition. The dense network of isles and the canals has formed an integrated water system which may maintain a recharge and discharge relationship within this water system. Water from these areas may ultimately discharge into Lake Okeechobee.

The critical feature uncovered in this study is actually the construction of the drainfield at varying distances with respect to the water table. The classification of homes according to location of the drainfield is less important than its elevation relative to the location of the water table.

Direct negative relationships between septic systems and surface water quality are difficult to prove from the data collected by these investigations. If the soils between the drainfield and canals become saturated with phosphorus, the amount of phosphorus reaching canals is expected to increase which may cause more observable impacts.

Recommendations developed from this research can be organized into several groups:

- Point-of-use upgrades or retrofit in septic tank use,
- Community/system-wide upgrades or retrofits,
- Additional information gathering, and
- Additional research.

Point-of-use upgrades to systems range from installing water-conserving toilets all the way to retrofitting drainfields. Additional information on point-of-use upgrades can be obtained from Guidance on Reducing Nitrogen Loading from Septic Systems (1991), a report prepared by The Cadmus Group for EPA, Office of Drinking Water Underground Injection Control Branch.

Current technology available to incorporate or replace septic tank-based collection systems; collecting wastewater at the source and transporting it to a centralized location for processing. Okeechobee County has a contract with Craig A. Smith and Associates to perform a wastewater study concerning the upgrading of existing wastewater treatment within the County. Residences and businesses within the County are currently served by septic tanks or small localized (package) wastewater treatment plants. The current long range plans are to abandon these systems to large centralized wastewater treatment facilities (personal communication, Gary Colecchio, Craig A. Smith and Associates 1992). The study is still in progress although they have provided the following information for use in this section.

The results of this study suggested several alternatives to wastewater collection and treatment. One alternative treatment is sewage collection and treatment. This alternative uses vacuum sewers to collect and transport septic tank effluent to local treatment centers. The septic tanks will still be used for initial sewage treatment and will still have to be pumped periodically. The advantage of this system is that the individual sewage treatment plants will only have to treat liquid effluent.

Implementation of this system will remove nutrient inputs to the shallow groundwater and canals which will minimize any future sewage caused impacts to the canals.

To increase canal water quality, flushing the canal to remove stagnant water is one method. This method may be considered if the flushing is done frequently. At higher flushing frequencies, fish kill or excess loading will not occur as the water quality will not be degraded.

This research work shows that the worst case inputs of P to Lake Okeechobee from septic tanks are no greater than half a ton per year per subdivision. If additional research can identify the presence of various nutrient "sinks" between the drainfields and the Lake, these numbers may be shown to overestimate reality. On the other hand, this research project excluded the numerous small package plants and/or large community septic tanks used within the mobile home parks adjacent to the rim canal up and down US 441. If any of these systems are not being properly maintained, they may be contributing as much P as all the septic tanks within the subdivisions combined because they are located closer to the rim canal with less groundwater transport distance for dilution or attenuation of phosphorus. Hooking these small treatment plants and septic tanks to the central sewer with the individual homes may better solve the overall problem.

This research project was the first attempt at gathering water quality and soils data relative to septic tanks in this area. Additional research needs have become evident.

Additional research on soils may include:

- Assessment of the importance of calcium and magnesium to phosphorus adsorption in soils and sediments.
- Phosphorus adsorption data can be used to calculate the mass of phosphorus that can be adsorbed between the drainfield and the canal if the variability of the fill can be better characterized.

Additional research on surface water may include:

- This research was limited to being a screening of total coliforms. Measurements of other bacteriological indicators may be necessary from a human health perspective if people are using the canals for water sports.
- More investigations into the fate of nutrients in surface waters. Nutrients may well be getting into the canals but are getting taken up by aquatic organisms.

Additional research on groundwater may include:

- A long-term groundwater flow study to determine the yearly movement of groundwater. A long-term measurement will indicate the effective distance of yearly groundwater flow to better predict the migration of septic tank effluent.

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1.0 INTRODUCTION

This is the final report for Contracts LP555 and LP754 Onsite Sewage Disposal System (OSDS) Research on the Northern Periphery of Lake Okeechobee. The Surface Water Improvement and Management (SWIM) Plan for Lake Okeechobee (1989) directs the District to "...develop a cooperative program with the Florida Department of Health and Rehabilitative Services (FDHRS) and the Florida Department of Environmental Regulation (FDER) and the appropriate local governments to assess the extent to which septic tanks contribute to phosphorus (P) levels within a particular basin. Alternatives for meeting P concentration standards for each basin will be evaluated, including (but not limited to) the following: (a) lower density requirements for mandatory sewage treatment plant hookups, (b) disposal of septic tank waste through sewage treatment plants or the manufacture of fertilizer, (c) revised design, location and construction standards for septic tanks (if appropriate) to meet the ultimate off-site discharge P standard, and (d) financial and other incentives to encourage conversion of existing problematic septic tank systems to centralized sewage treatment systems."

The objectives of this research project are to investigate the impact of high-density OSDS installations on water quality and overall health of man-made canals along the northern periphery of Lake Okeechobee and to estimate the P loading from these systems to the lake itself. Four major peninsula/finger canal subdivisions have been built such that most of the properties are "water front." The water quality within the canals is less than pristine; the original hypothesis being that septic tank effluent is causing degradation of water quality.

This research project has been designed to gather as much information as possible concerning the presence of septic tank P and nitrogen (N) in soils and groundwater and P, N, and coliforms in surface waters of the important subdivisions. All field sampling and laboratory analytical work was conducted according to Environmental Science & Engineering, Inc.'s (ESE) Site Specific QA Plan and ESE's Generic QA Plan No. 860054G and McGinnes Laboratories GQAP No. 870232G. It is expected that the results of this research may lead others to focus on whatever problems they deem important.

1.1 DESCRIPTION AND HISTORY OF STUDY AREAS

The following four residential subdivisions were chosen as study areas (Figure 1-1):

- Taylor Creek Isles,
- Treasure Island,
- Buckhead Ridge, and
- Okeechobee Hammocks.

Each of these subdivisions was constructed to maximize the amount of waterfront property for the land owners. This resulted in series of parallel finger canals separated by narrow peninsulas. Of these four subdivisions, Okeechobee Hammocks is the only one without a navigable waterway to the Rim Canal. These four subdivisions contain the majority of homes with septic tanks that may ultimately drain directly into the rim canal and then into the Lake.

Construction of these subdivisions from what looks like improved pasture began in the late 1950s and early 1960s. Aerial photographs were used to construct Figures 1-2, 1-3, and 1-4. As of 1962, a small part of Treasure Island (Figure 1-2) was already inhabited while new canals were being constructed. Buckhead Ridge (Figure 1-3) had one canal running zig-zag through the area with one side fully developed. Construction of 10 canals was well underway connected to the other side of the canal. By 1962, Okeechobee Hammocks (Figure 1-4) was also in the initial phases of being developed.

The next series of aerial photos obtained were from 1971. By 1971 (Figure 1-5), about two-thirds of Treasure Island was fully developed, with the last third under construction. Taylor Creek Isles was nearing the half-way point of construction. Okeechobee Hammocks was fully constructed by 1971 (Figure 1-6) with one area showing a higher density of homes. Although the last third of the subdivision was under construction, the older area was sparsely

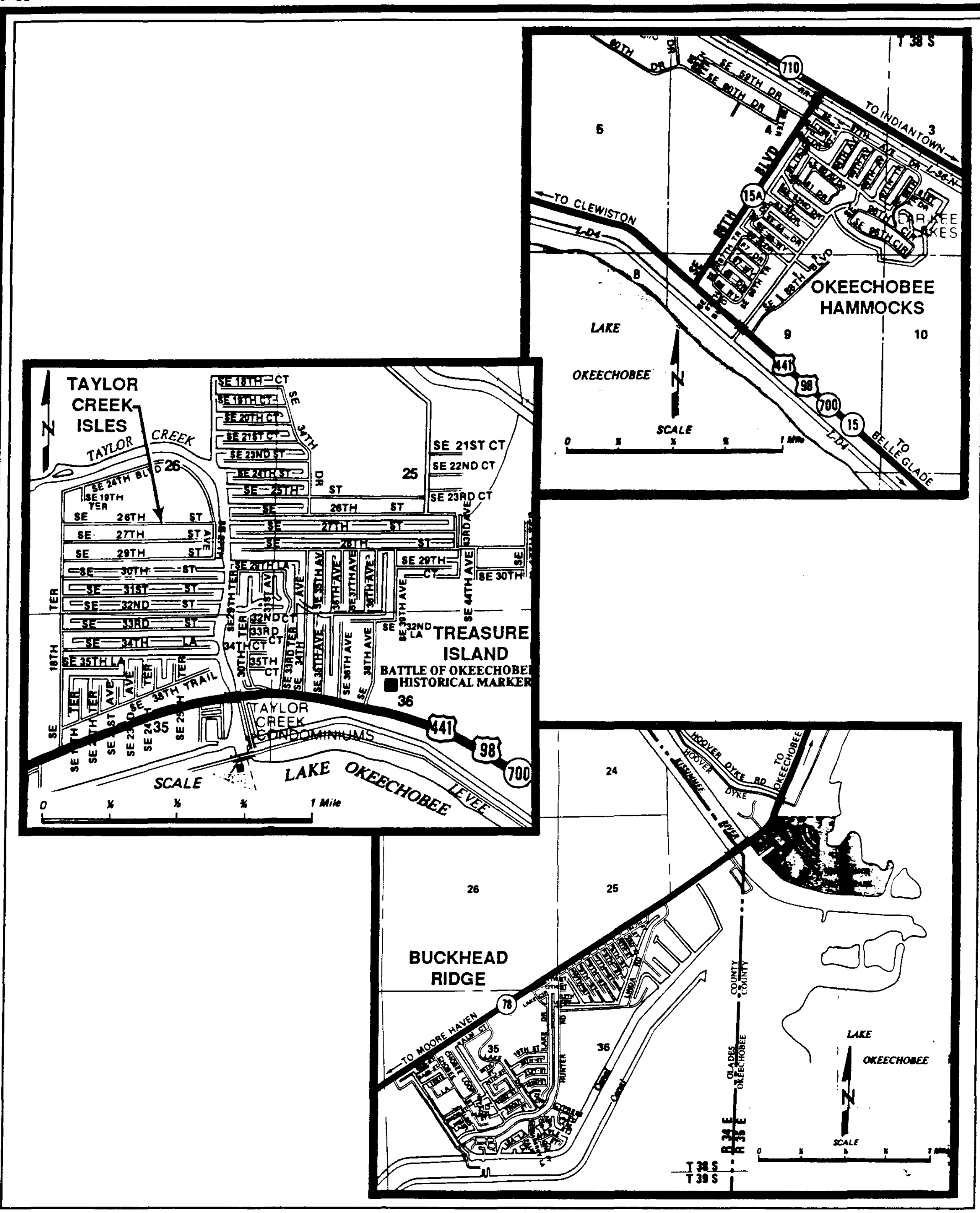

Figure 1-1
OKEECHOBEE HAMMOCKS, TAYLOR CREEK ISLES, TREASURE ISLAND, AND BUCKHEAD RIDGE SUBDIVISIONS

SOURCE: DOLPH MAP CO.,INC. 1988.

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.

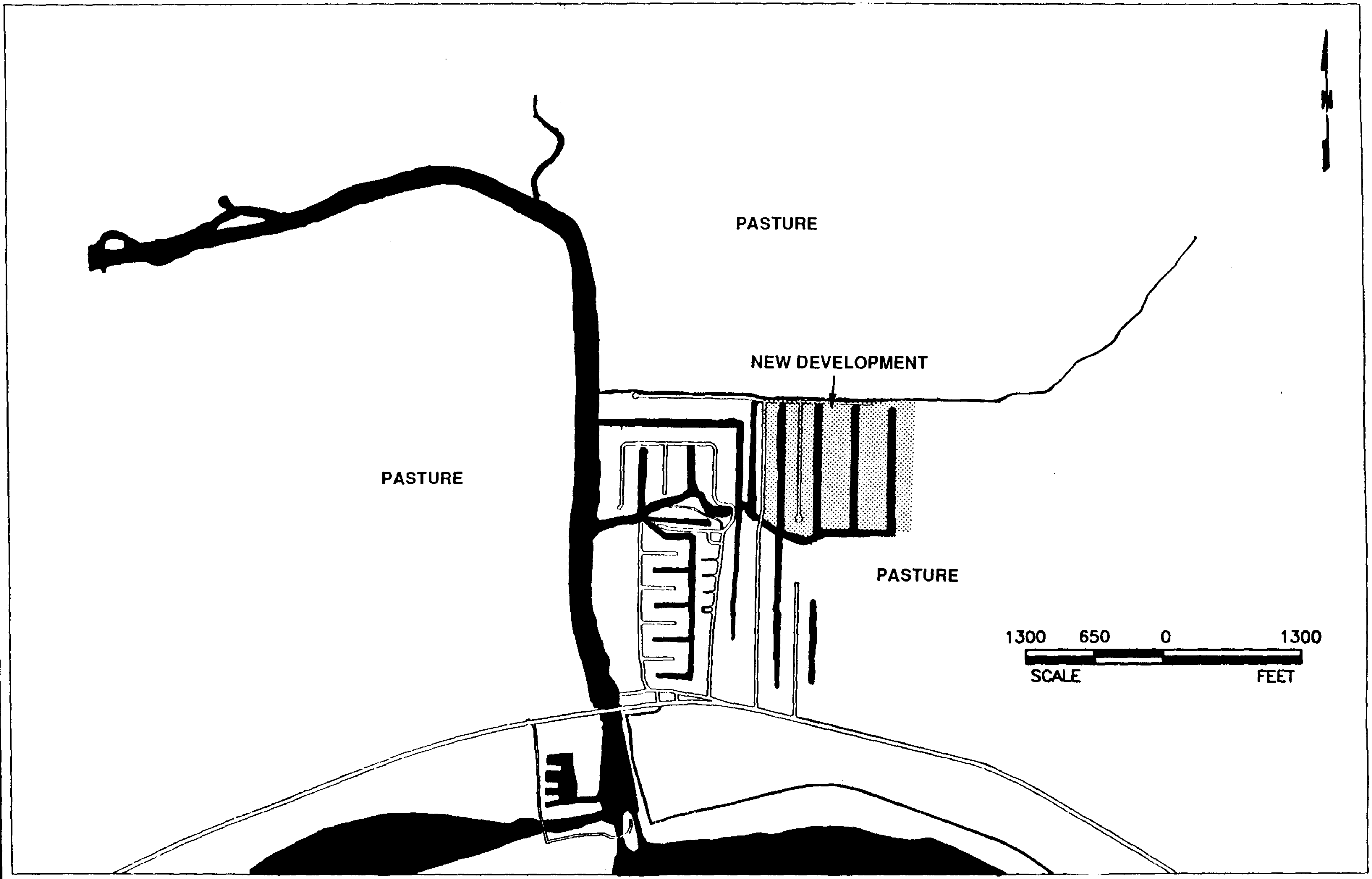

Figure 1-2
TAYLOR CREEK AND TREASURE ISLAND
SUBDIVISIONS, 1962

SOURCE: ESE.

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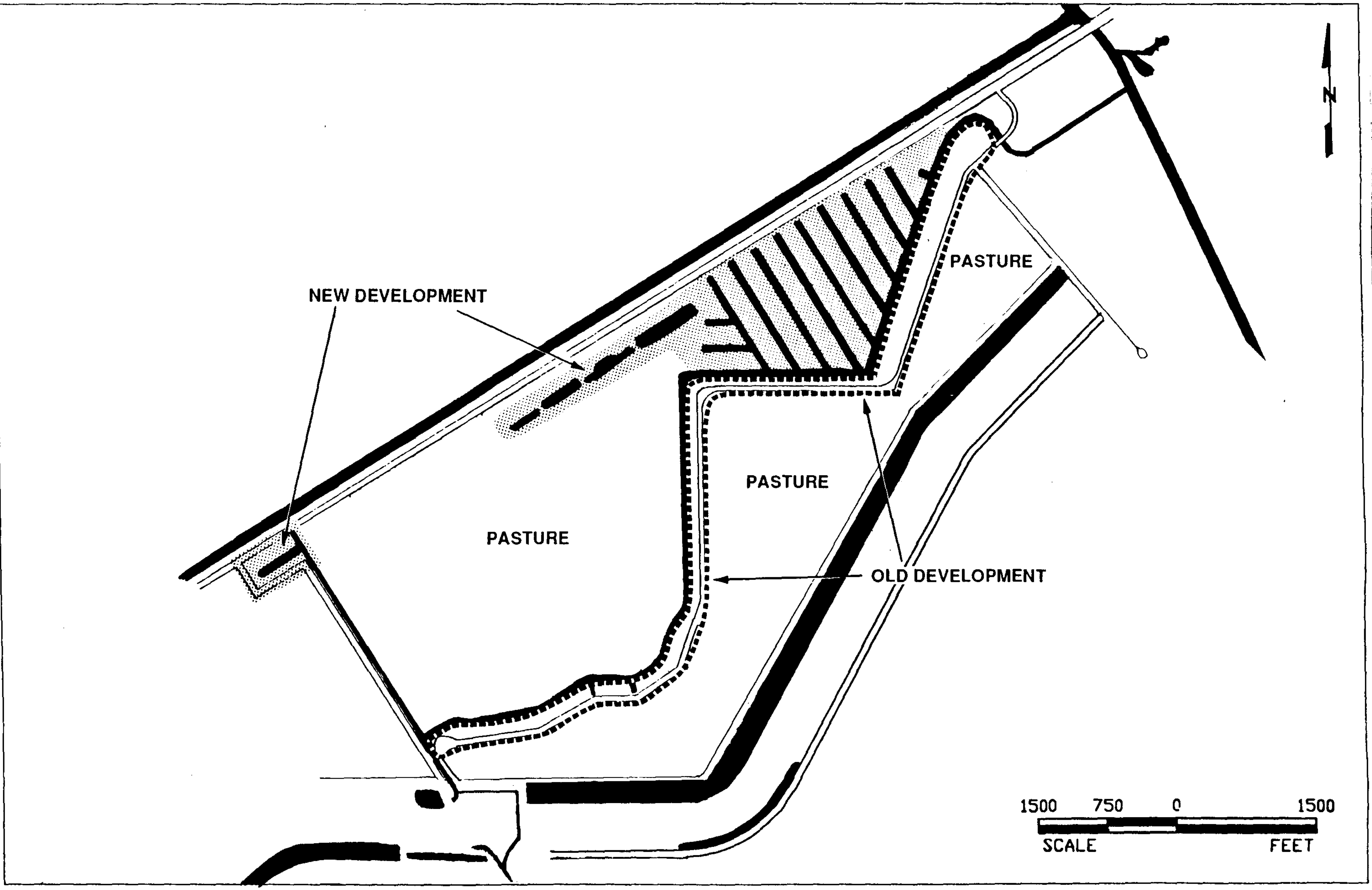

Figure 1-3
BUCKHEAD RIDGE SUBDIVISION,
1962

SOURCE: ESE.

Environmental Science & Engineering, Inc.
A CILCORP Company

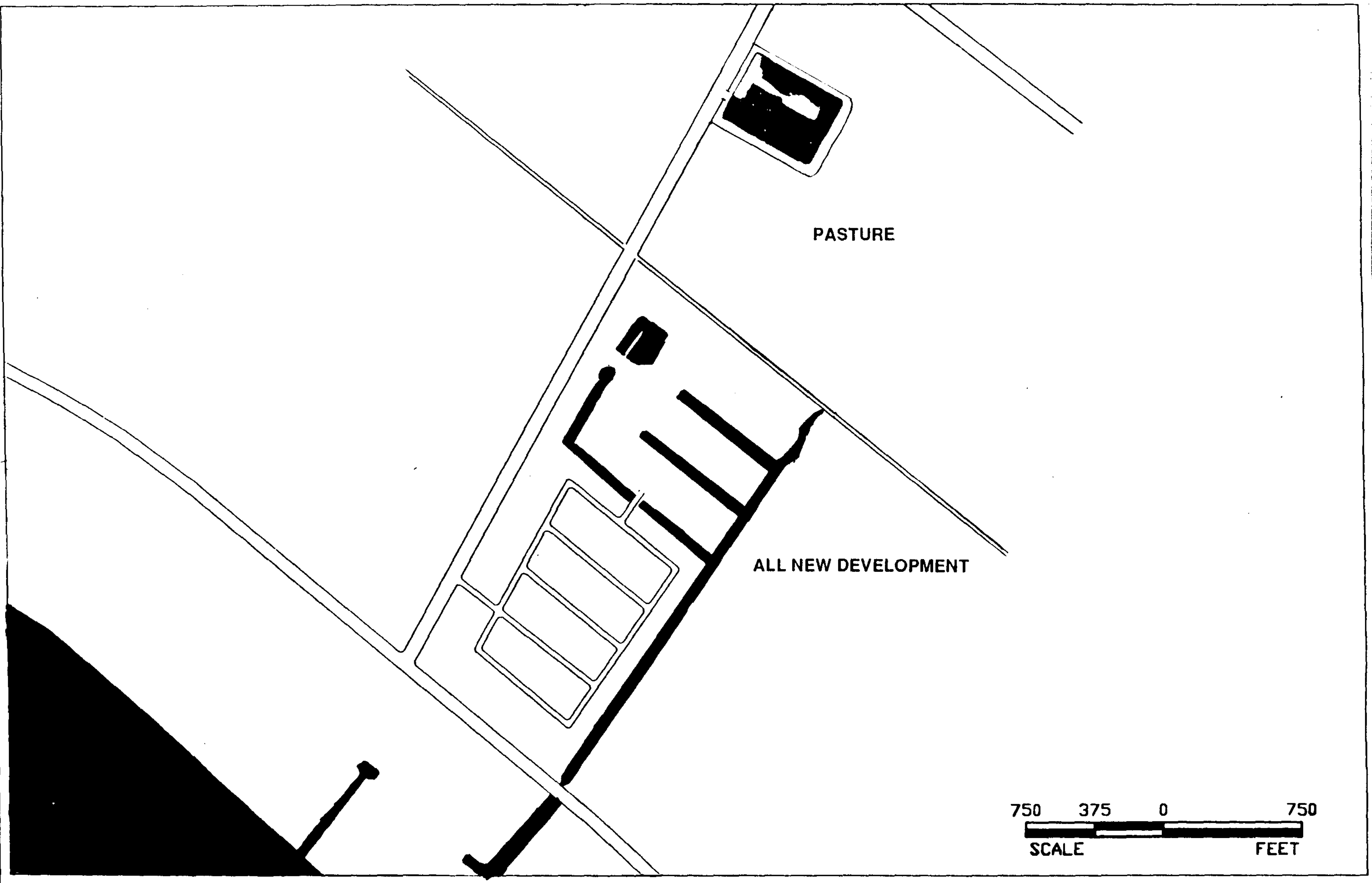

Figure 1-4
OKEECHOBEE HAMMOCKS SUBDIVISION,
1962

SOURCE: ESE.

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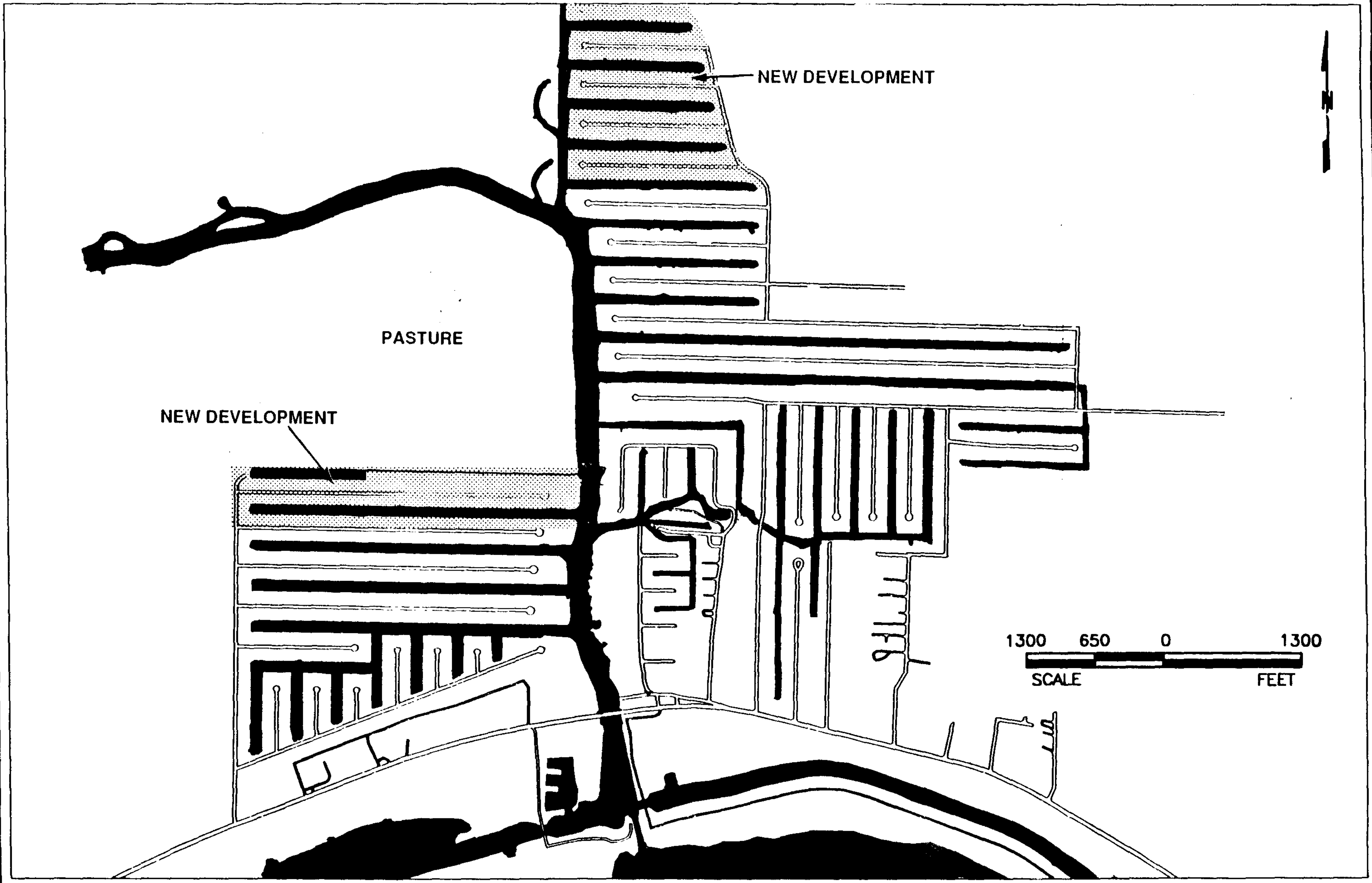

Figure 1-5
TAYLOR CREEK AND TREASURE ISLAND
SUBDIVISIONS, 1971

SOURCE: ESE.

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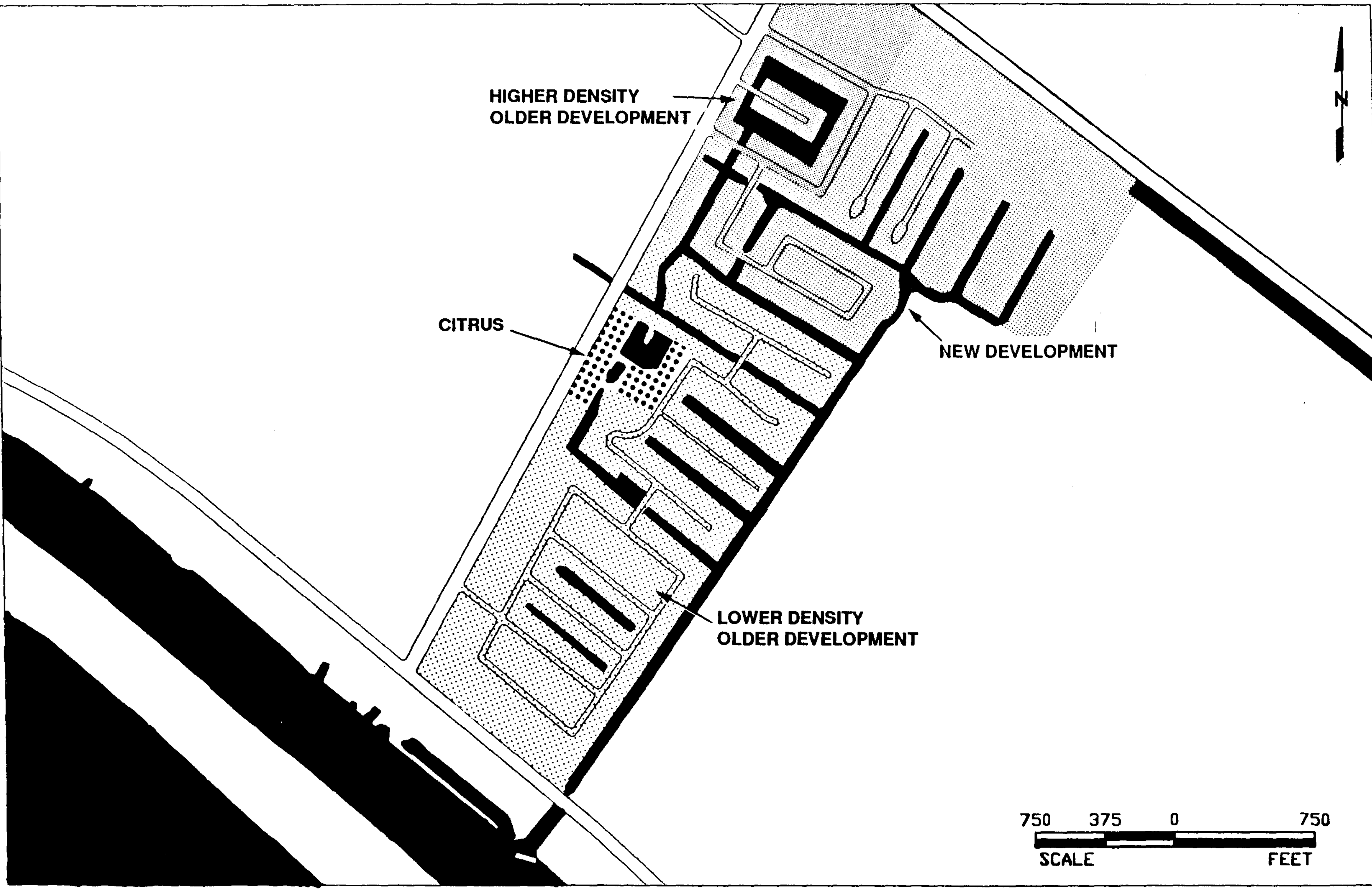

Figure 1-6
OKEECHOBEE HAMMOCKS SUBDIVISION,
1971

SOURCE: ESE.

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Engineering, Inc.

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populated. Buckhead Ridge was also nearly two-thirds constructed by 1971 (Figure 1-7).

The most recent aerial photos were taken in 1986. These were the photos used to construct the base maps used throughout the report. As late as 1986, new construction was still evident. The northernmost part of Taylor Creek Isles was just being finished (Figure 1-8) and Okeechobee Hammocks was becoming more fully built-in with homes (Figure 1-9). The only development in evidence within Buckhead Ridge were two small areas (Figure 1-10).

1.2 DESCRIPTION OF REPORT

This report presents, summarizes, and makes recommendations based on information gathered as part of Research Subjects I through V and follows the general outline in the contract. Individual items presented in this report include the following subtasks.

RESEARCH SUBJECT I
TASK 1

Subtask 1.1

Basin by basin inventory for land use (OSDSs, private and public wastewater treatment plants, lawn fertilizing, and detergent usage practices and other identified nutrient producer sources).

Subtask 1.2

Map creation of the Northern Periphery of Lake Okeechobee (limited to the Treasure Island, Taylor Creek, and Buckhead Ridge subdivisions and immediate surroundings) to indicate various wastewater disposal systems for the approximate year 1975 and the most recent year(s).

Subtask 1.3

Estimate seasonality of discharge by reviewing electricity use (if available through the local utility) to estimate the number of occupied homes.

Subtask 1.4

Preparation and execution of a survey questionnaire to validate the recent year's map as described in Section 1.2; to include questions on lawn fertilization and detergent usage.

Subtask 1.5

Comprehensive review of permits on file for existing wastewater disposal systems (OSDSs, and private and public wastewater treatment plants) and other identified nutrient producer sources.

Subtask 1.6

Literature search and written summary (will also describe analytical methods and site selection methodology).

Subtask 1.7

Selection of participants and study sites for three subdivisions. A total of seven sites with five different types of disposal systems (two old systems, two mounded, one home on central sewer, a vacant lot, and a package treatment system).

RESEARCH SUBJECT II
TASK 2

Subtask 2.1.1

Literature assessment of representative soil series for selected subdivisions (soil groupings).

Subtask 2.1.2

Characterization of sediments in canal systems, according to homogeneous septic system land uses. Characterization will include canal width, depth, and thickness of organic sediments on canal bottoms.

Subtask 2.1.3

Analysis of P content of soil samples collected near existing septic system drainfields.

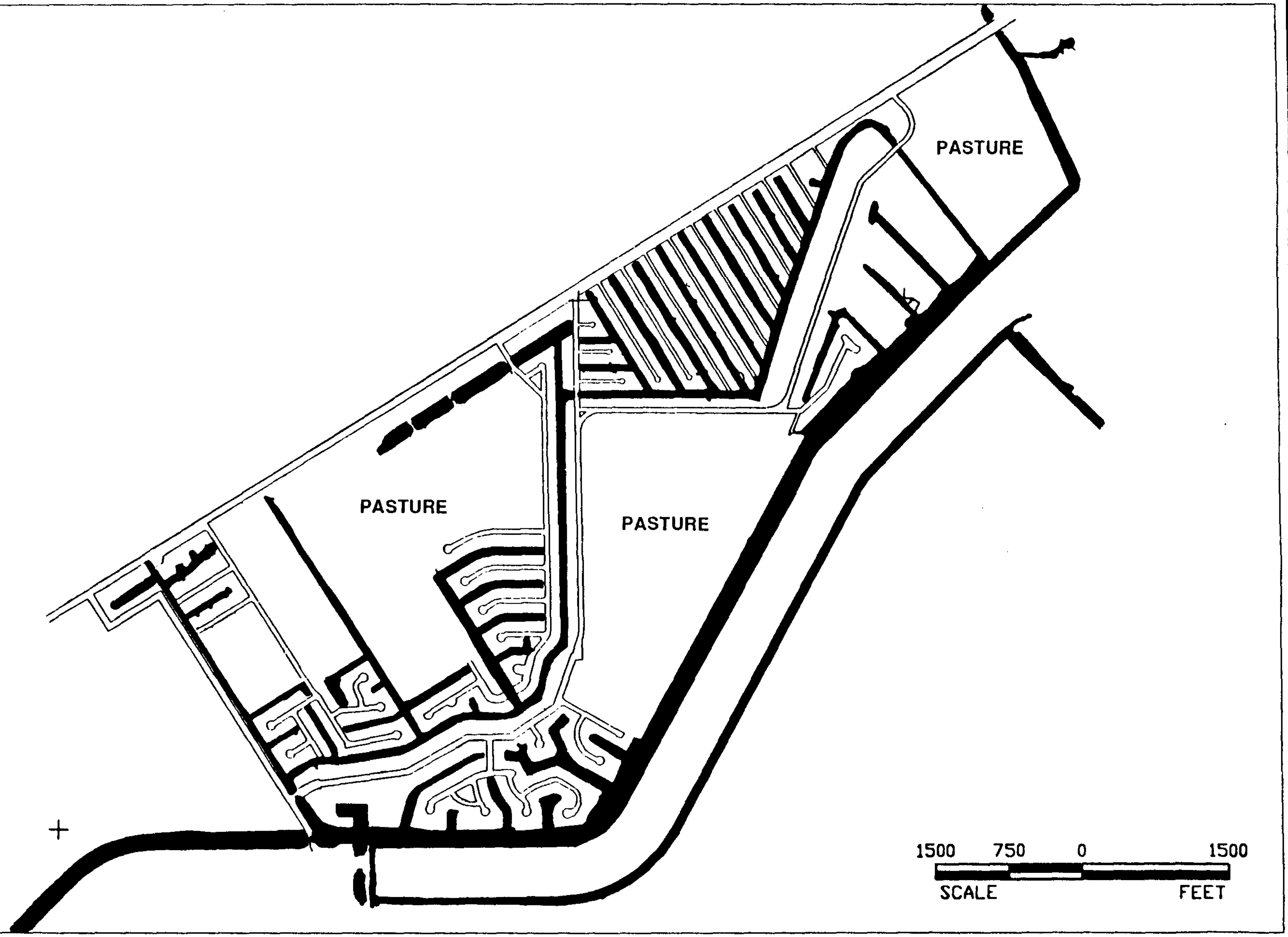

Figure 1-7
BUCKHEAD RIDGE SUBDIVISION,
1971

SOURCE: ESE.

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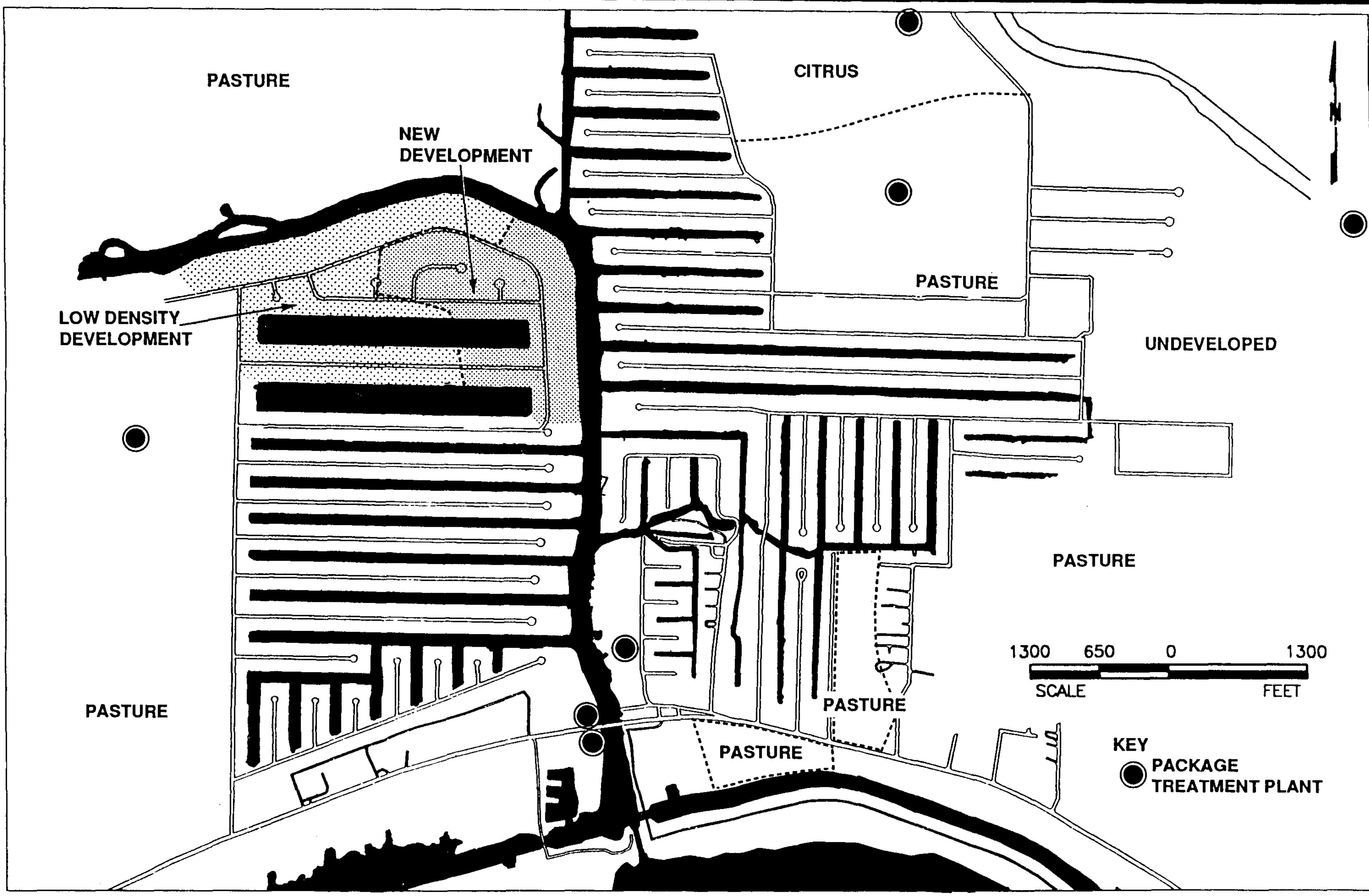

Figure 1-8
TAYLOR CREEK AND TREASURE ISLAND SUBDIVISIONS, 1986

SOURCE: ESE.

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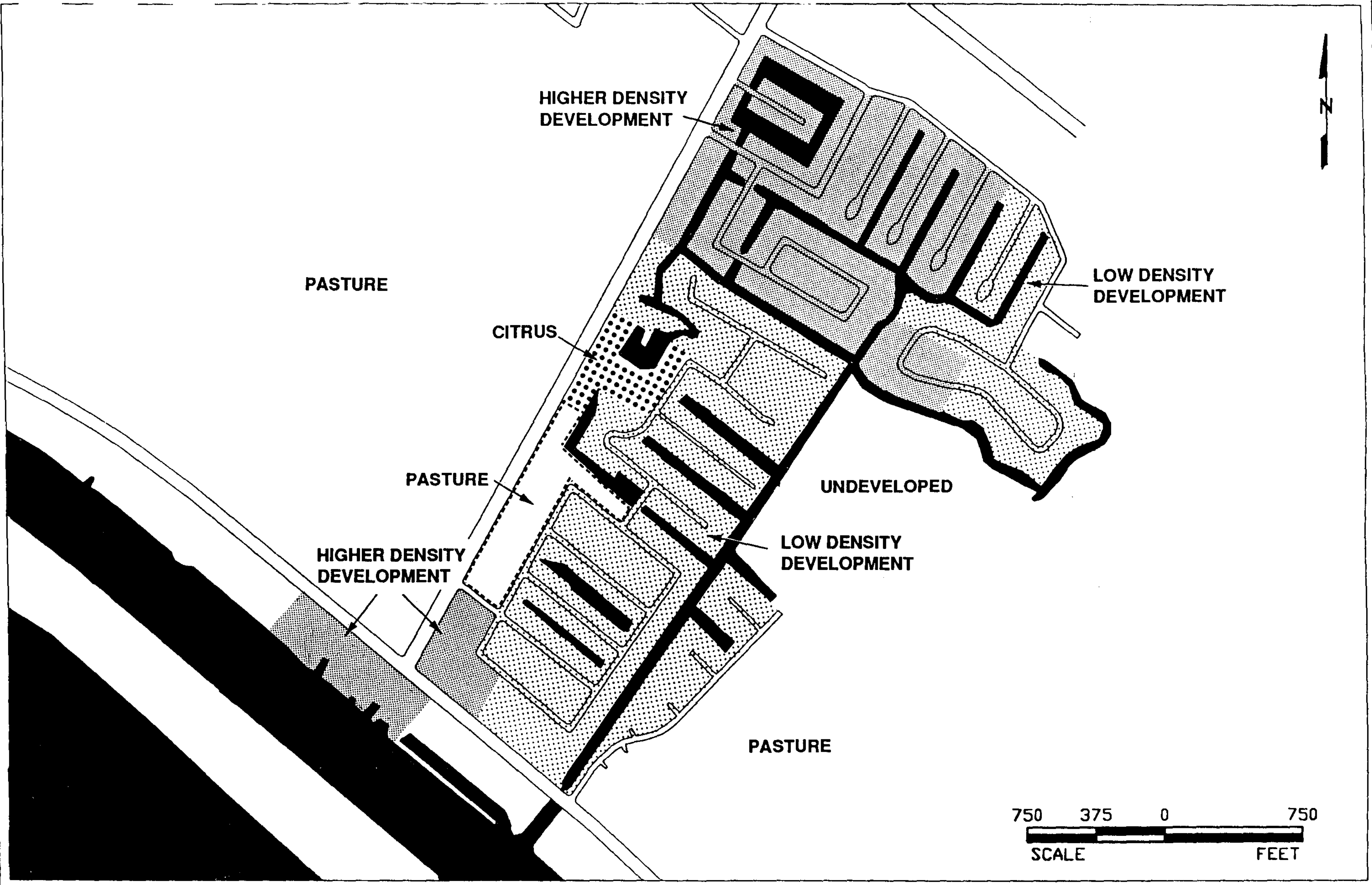

Figure 1-9
OKEECHOBEE HAMMOCKS SUBDIVISION, 1986

SOURCE: ESE.

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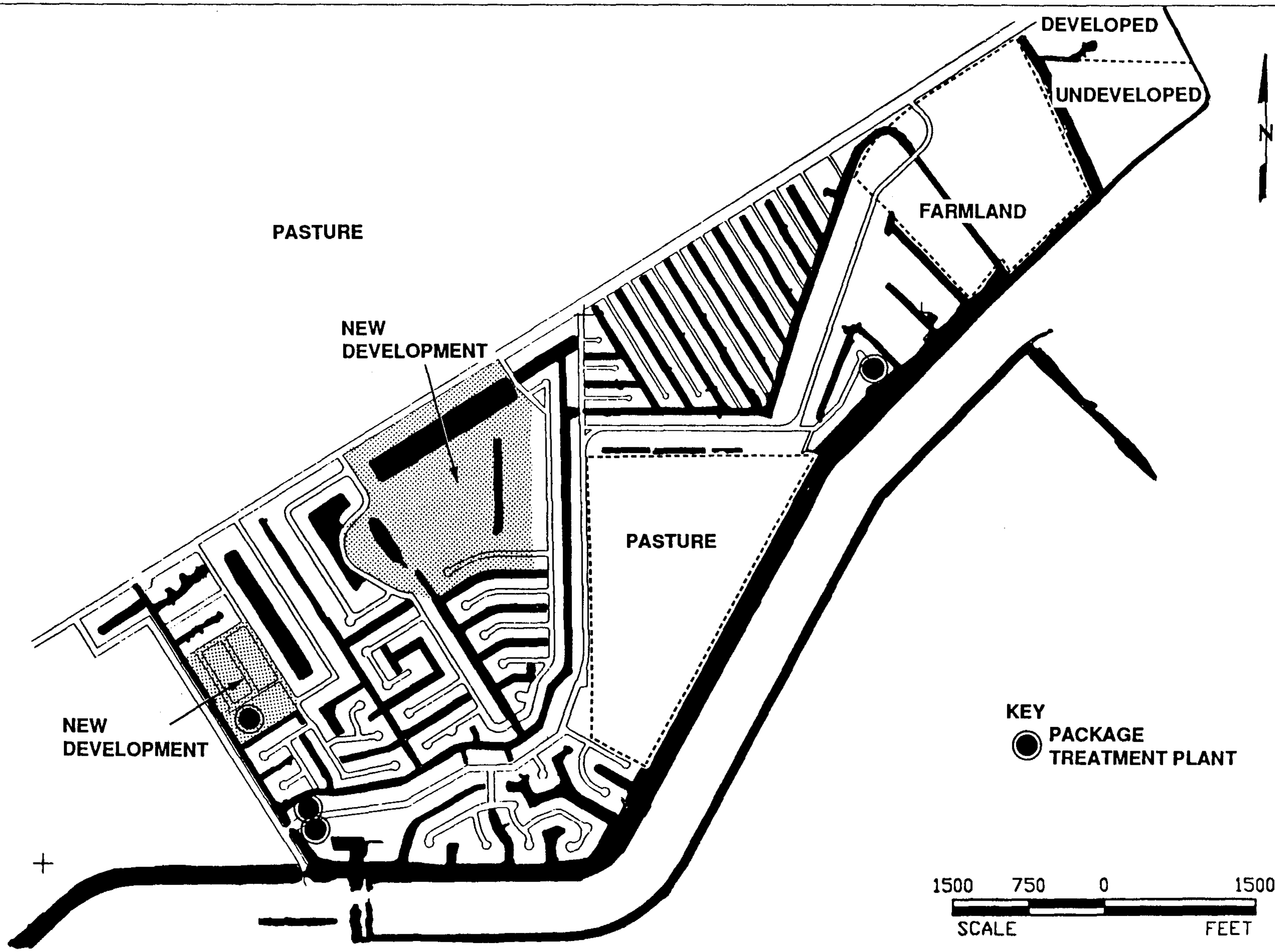

Figure 1-10
BUCKHEAD RIDGE SUBDIVISION, 1986

SOURCE: ESE.

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Subtask 2.1.4

Analysis of P sorption and P content of commonly occurring soil series/horizons throughout the area(s).

Subtask 2.1.5

Analysis of P sorption and P content of sediment samples collected from selected canals throughout the area(s).

Subtask 2.2.1

Installation of suction lysimeters, monitor wells, and piezometers at the study sites.

Subtask 2.2.2

Hydraulic conductivity measurements (slug tests) for all nine monitor wells.

Subtask 2.2.3

Determine total P and N (nitrate plus nitrite and ammonia) in soil, water, and groundwater samples taken before, during, and after the rainy season.

Subtask 2.3

Estimate the overall P content, maximum adsorptive capacity, and amount of soil storage capacity remaining for the soils and sediments within the study area(s). This is the data interpretation step of the study. Additionally, determine the health of the canal system.

RESEARCH SUBJECT III
TASK 3

Subtask 3.1

A total of nine surface water monitoring stations will be established.

Subtask 3.2

Sample surface water and make other necessary flow direction and discharge measurements. Sampling is to be accomplished with the soil and groundwater sampling efforts.

RESEARCH SUBJECT IV
TASK 4

Subtask 4.1

Estimate nutrient loading. Analyze water quality data (related to seasonal differences and storm events), water flow measurements (related to seasonal differences and storm events), and the sediment nutrient/storage capacity. The current loading will be estimated on a weighted estimate of canal water flow. Future loadings will be estimated using canal sediment storage capacity data with water quality and flow data.

RESEARCH SUBJECT V
TASK 5

Subtask 5.1

Recommendations will be given to reduce P loadings to Lake Okeechobee. The recommendations will range from the no action alternative (if no problem exists) through retrofitting OSDSs or connecting the homes to central sewer, to dredging the canals if the canal sediments are found to be heavily impacted by P.

All of the Research Subject areas have been completed and the results reported in this document. This document is not written specifically referencing the individual subtasks because of the redundancy of some of the information. Instead, Section 2.0 describes background information including the questionnaire, gives a summary of detergent uses, fertilizer and pesticide applications, and washing machine water disposal practices; and includes a map of the site identifying various waste water disposal systems. Section 3.0 provides the sampling methods. Section 4.0 presents the results. Section 5.0 contains the recommendations.

2.0 BACKGROUND

2.1 QUESTIONNAIRE

2.1.1 QUESTIONNAIRE MECHANICS

A total of 800 surveys were sent to residents of four target subdivisions (Buckhead Ridge, Taylor Creek Isles, Treasure Island, and Okeechobee Hammocks) along the northern periphery of Lake Okeechobee (Figure 1-1). Two hundred fifty-nine were returned with various quantities and quality of information.

The survey (see Appendix A) was organized according to two broad categories: (1) description of the property, home, septic system and/or washing machine water disposal, water using facilities, and residents; and (2) description of land use activities. The land use activities have been divided into clothes washing and dishwashing practices; and lawn maintenance activities such as fertilizer or pesticide application practices and irrigation.

2.1.2 SUMMARY OF RESULTS

Data from the surveys were entered into the Paradox data management database for ease of data manipulation. Because of the variety of answers and usefulness of the information, some data were edited and reentered under standardized answers. For example, several respondents use whatever dishwashing soap is on sale and indicated such with the words, "cheapest" or "on sale." To simplify summarization, all of these answers were changed to "varies." Summaries of eight categories of information are presented within the report. Few surveys were answered completely, therefore, none of the response categories contain 259 entries (total number of surveys returned).

2.1.3 DATA SUMMARIES

Individual summaries of the categories follow.

2.1.3.1 Residency

Of the total 259 responses, 228 households (88 percent) are permanent residents and 14 are temporary (3 of the temporary households were houses versus mobile homes). Seventeen households did not answer this question. Temporary or seasonal household responses were further categorized according to the season of occupancy. Fall and Winter occupancy represents the largest (71 percent), and of the households that are resident in Winter, 40 percent are also resident in the Spring. Only three temporary households indicated Summer occupancy in their own homes (one did not indicate house versus mobile home).

2.1.3.2 Laundry

From the total of 259 responses, 229 indicated they had a washing machine. Of these, 124 were directly connected to a septic tank; 72 washers (31 percent) discharged somewhere other than a septic tank; and 14 did not know where their washers drained. Only 56 people (of the 72 not discharging to septic tanks) identified the location of their washing machine discharge (Table 2-1). Some of the answers included discharge to the yard/garden, to dry wells, and to a trench.

Laundry detergent preference was indicated by 206 people/households. The primary detergent choices were selected from this group and represent 186 people/households using one or more of 34 identified brands (Table 2-2).

2.1.3.3 Dishwasher

Eighty-seven respondents use dishwashing machines. Sixty-eight of the respondents also occasionally wash dishes in the kitchen sink (indicated by the respondent giving a preference of a sink dishwashing detergent) (Table 2-3). A total of 93 households do not have a dishwashing machine and indicated a preference of a sink dishwashing detergent. The total number of households indicating the use of a sink dishwashing detergent, with or without dishwashing machines, is 161 (Table 2-4).

Table 2-1. Analysis of Washing Machine Drainage Locations

Washer Drainage Location	Respondents Indicating This Location
50-Gallon Drum	1
Separate Tank	1
Backyard	5
Canal	3
Drains in Trees	1
Dry Well	15
Flower Bed/Charcoal	1
Garden	1
Grass/Yard	13
In Back of Shed	1
In Old Septic	1
On The Ground	2
Our Gravel Bed	1
Separate Drain Field	4
Separate Container	1
Septic Tank	1
Sewer Line	2
Tank by Itself	1
Trench to Drain Field	1
TOTAL	56

Source: ESE.

Table 2-2. Laundry Detergent Brands Indicated by Respondents

Laundry Detergent Brand Name	Respondents Indicating Usage
Ajax®	1
All®	9
All-Free®	1
Amway®	1
Amway Sa8®	3
Arm & Hammer®	13
Arrow®	3
Blue Cheer®	1
Bold®	3
Bold III®	1
Borax®	1
Cheer®	10
Cheer Free®	1
Clorox®	2
Clorox 2®	1
Dash®	1
Doz®	1
Dynamo®	1
Era®	5
Fab®	3
Fresh Start®	1
Gain®	3
Ivory®	1
New Cheer®	1
Oxydol®	1
Oxydol Ultra®	1
Phosphate Free	1
Purex®	2
Sears®	1
Shaklee® Liquid	1
Surf®	10
Tide®	74
Tide® Liquid	2
Wisk®	25
Total Brands	34
Total Number of Users	186

Source: ESE.

Table 2-3. Analysis of Dishwashing Machine Detergents for All Respondents

Brand Name	Respondents Indicating Usage
Amway®	1
Calgon®	4
Cascade®	48
Dawn®	2
Electrasol®	6
Jet®	1
Kitchen Aid®	1
Palmolive®	5
Sunlight®	5
Sunlite®	2
Never Use	1
Total Brands	11
Total Number of People Using These Brands	76

Source: ESE.

Table 2-4. Analysis of Dishwashing Detergents for All Respondents.

Brand Name	Respondents Indicating Usage
Ajax®	1
Dash®	1
Dawn®	69
Dawn®/Palmolive®	1
Dove®	4
Ivory®	27
Joy®	14
Lilac®	1
Palmolive®	33
Publix®	1
Store Brand	4
Sunlight®	4
Tide®	1
Varies	2
Sink	1
Total Brands Indicated	15
Total Number of People Using These Brands	161

Source: ESE.

2.1.3.4 Fertilizer

Fertilizer use is represented by 116 households. Of those households, 109 identified the brand used; 107 the brand and frequency of application; and 93 the brand, amount of application, and frequency of application. The analysis of usage and application was calculated using the group responding to all three categories (Tables 2-5 and 2-6). General results are as follows:

1. 23 fertilizer types are used by 91 people;
2. 21 of the previous types represent 6,125 pounds used in 135 applications;
3. 48 people use fertilizers in the Spring and Fall;
4. 31 people use fertilizers once a year (either Spring or Fall); and
5. 14 people use fertilizers more than twice a year.

Making some very broad assumptions and simple calculations (e.g., 100 pounds of 6-6-6 is actually 6 lbs of N, 6 lbs of potassium as K_2O, and 6 lbs of P as P_2O_5), the 6,125 pounds of fertilizer means applications of approximately 400 pounds each of N, potassium, and P. If homeowners in the 4 subdivisions (2,940 homes) apply similar amounts of fertilizers as the percentage of respondents (44 percent) to the questionnaire, the total application of each of the three nutrients is approximately 4,000 pounds. This number is important in a relative sense; that is, that we can be fairly confident that less than 10,000 lbs of phosphate are applied to the lawns in the four subdivisions each year.

2.1.3.5 Pesticides

This category was well represented by responses from households, but the data provided were inconsistent and poorly defined. This may indicate a general lack of understanding by the users of these products of the application method, rate, and timing. Unlike fertilizer application, most people did not know how much pesticide they were using, and those who did were not sure how to represent the quantity used during application. As a result, data in this section could not adequately be quantified for volume or seasonal analysis.

The data provided did allow for some minimal analysis. Sixteen people indicated the use of a professional pest control service (Table 2-7). Those people not using a professional pest control service (64) did use commercially available compounds (Table 2-8).

2.1.4 IDENTIFICATION OF VARIOUS WASTEWATER DISPOSAL SYSTEMS

Houses along SE 29th and 30th Streets of the Taylor Creek Subdivision are tied into the package treatment plant operated by Professional Services Group (PSG) of Ft. Pierce, Florida. Apparently, a moratorium on construction of additional septic tanks was in force for some time in the 1970s (approximately 1973). These two streets were being developed at this time so rather than halting construction, the developer decided to build a package plant to treat the sewage.

The Health and Rehabilitative Services Okeechobee County Public Health Unit (HRS-OCPHU) files consisted of permits for a number of different OSDS and package treatment plants in the surrounding areas. The typical package plant services a small recreational vehicle park or small trailer court. The only treatment plant in the specific study areas (other than the PSG plant) is at Buckhead Marina. The only other files maintained by HRS are septic tank maintenance/repair permits. The permits detail the services such as pump-outs or drain field maintenance done by professionals.

2.2 SEASONAL RESIDENCY

Determining the seasonal pattern of occupancy of the four subdivisions is necessary to estimate the annual septic tank discharge and nutrient loading to the canals. The initial method proposed in the scope of work was to investigate electricity usage in the area (provided by Florida Power and Light), by examining the usage ratios during the different seasons. The hypothesis was that residency varied more than the seasonal change in electricity usage according to air conditioning usage. The hypothesis was found to be incorrect as air conditioning demand causes summer electricity usage to nearly equal winter electricity usage because of the increase in migratory residents.

Table 2-5. Analysis of Fertilizers Used by Type or Brand

Type or Brand Name	Respondents Indicating Usage
10-10-10	9
10-20-40	1
16-4-8	1
20-20-20	2
4-6-6	1
4-6-8	1
6-6-6	47
8-8-8	2
Bonus S Weed & Feed®	1
Chemical/Scotts®	1
Darganite	1
Fruit & Ornamental Trees	2
Milorganite	1
Miracle Grow®	7
Rite Green®	1
Rossers®	1
Scotts®	2
Scotts® 10-10-10	1
Scotts® 22-3-3	1
Scotts® 6-6-6	2
Scotts® Turf Builder	3
Weed & Feed	2
Unknown (Used by Yard Service)	1
Total Number of Type or Brand Indicated	23
Total Number of People Using These Types/Brands	91

Source: ESE.

Table 2-6. Analysis of Fertilizer Usage and Frequency by Type or Brand

Type or Brand	Pounds Used	Gallons Used	Applications/Year
10-10-10	910		18
10-20-40	50		1
16-4-8	60		2
20-20-20		10	2
4-6-6	200		2
4-6-8	20		2
6-6-6	3,775		78
8-8-8	200		2
Chemical/Scotts®	40		1
Darganite®	60		2
Fruit & Ornament	10		4
Fruit Tree Only	10		3
Milorganite	120		2
Miracle Grow®	40	2	12
Rite Green®	40		1
Rossers®	40		1
Scotts®	140		3
Scotts® 22-3-3	60		3
Scotts® Turfbuilder	120		6
Weed & Feed	110		2
Varies	120		2

Total Number of Type or Brand	21
Total Number of Pounds Used	6,125
Total Applications/Year	135
Total Number of Gallons Used	12
Total Applications/Year	14

Source: ESE.

Table 2-7. Profile of Professional Pest Control Usage

Professional Pest Control Name	Respondents Using Professional Pest Control
Ace Pest Control	11
Brooks Exterminator	1
Guy's Hulett (house)	1
Hi-Tech	1
Lloyd's	1
Termite Control	1

Source: ESE.

Table 2-8. Profile of Pesticides Used in Study Area

Type or Brand	Estimated Households Using This Type/Brand
7 Dust	2
Amdro	5
Ant Killer/Weed-B-Gone	1
Chinc Bug Spray	1
Diazinon	16
Diazinon for Fruit Trees	1
Diazinon/Sevin®	2
Dursban®	1
Dursban/Diazinon	1
Fire Ant	5
Fire Ant, K-Mart Brand	1
Fire Ant/Sevin/Diazinon	1
Fire Ant/Sevin Dust	1
Fleas	1
Malathion Insect Spray	1
Malathion/Diazinon	1
Malathion For Rose Garden	1
Malathion/Liquid 7	1
Malathion/Liquid 7 (Trees)	1
Ortho® Insect Control/Diazinon	1
Ortho®/Diazinon	1
Roundup®	2
Sevin Dust®	2
Sevin Dust®/Diazinon/Amdro®	1
Spectracide® For Ants	2
Weed & Feed	1
Weed Killer	1
Weed-B-Gone	5
Weed-B-Gone/Diazinon	3
3 fungicides, 4 insecticides, 1 herbicide	1
Total Number of Types or Brands	30
Total Households Using These Types or Brands	64

Source: ESE.

A second plan was devised to approximate seasonal residency from the information and data gathered for the questionnaire mailing label database and from the questionnaires themselves. The questionnaires were primarily (except for approximately 25) sent to addresses within the subdivisions so that answers could be related directly to specific locations. Out-of-state or out-of-subdivision addresses could not be correlated to street addresses as the information provided was inadequate for the correlation.

Information to create mailing labels for Treasure Island, Taylor Creek Isles, and Okeechobee Hammocks was obtained from an independent consultant retained by Okeechobee County for managing the tax database. The data consisted of tax information on each parcel of land in these subdivisions. The consultant for Glades County was not able to transfer similar data for Buckhead Ridge. Mailing labels for Buckhead Ridge were obtained directly from the Okeechobee Beach Water Association billing files.

The information used to determine seasonal residency included the mailing addresses and assessed property values from the tax information database which included Treasure Island, Taylor Creek Isles, and Okeechobee Hammocks subdivisions. The first assumption was that vacant lots could be separated from properties with homes based on an assessed property value of $30,000. The second assumption was that property owners that receive tax notices in another city or state do not reside there, and addresses within the subdivisions, therefore, represent the category of migrant tenants. This assumption, however, does not account for housing that is rented full time. These latter categories may never be defined or confirmed within the scope of this study.

Using the tax database, 1,977 properties exist in the three subdivisions. Using the $30,000 assumption for vacant lots, 472 of the properties are vacant (24 percent). Adding the additional assumption of properties with addresses inside the three subdivisions, the final category of homes with full-time residents equals 1,028 properties or 52 percent of the total properties.

For Buckhead Ridge, Okeechobee Beach Water Association mailing labels from the water bill database were used to determine full-time residency by separating addresses within the subdivision from those in another city or state. Using this assumption, 479 of 1,138 households (42 percent) were assumed to be full-time residents. This compares reasonably well with the percentage calculated for the three subdivisions using the tax database information.

These same assumptions were used to obtain the mailing labels for the questionnaire for each of the subdivisions. Assuming that the residency responses from the questionnaire are representative of the whole population, 88 percent of these assumed full-time residents actually live there full time. Using all of these assumptions, nearly 43 percent of all homes in each of the subdivisions are occupied throughout the year.

2.3 SOIL CHARACTERIZATION AND SITE SELECTION

2.3.1 SITE SELECTION

The sample site selection rationale was based on evaluating potential water quality impacts resulting from the operation of the various types of sewage disposal systems as follows:

1. Two old ("at grade") septic tank systems,
2. Two newer (mounded) septic tank systems,
3. A site served by a central sewer,
4. A vacant lot, and
5. A package treatment plant.

During the preparation of the proposal, the newer systems were assumed to be comprised of mound systems versus the old at-grade systems. After visiting each subdivision with a local septic tank installer, mound systems were found to be uncommon. The installer said that they were not necessary in these areas as the canals keep the water table acceptably low to meet Chapter 10D-6, Florida Administrative Code (F.A.C.) regulations. The installer said that mounded systems are more common for homes built away from the water where the water table is closer to the ground surface.

The primary difference between old and new systems was found to be related to the proximity of the drainfields to the canals. Type of construction was not found to be different. The majority of the drainfields (new and old) appeared to be trenches rather than beds. The trench-type of drainfield usually consisted of one or two drainfield lines containing perforated pipe surrounded by gravel. If two trenches were used, they usually extended in different directions. The septic tank installer noted that drainfields installed as beds (installed according to engineering specifications) routinely fail (clog) while the trench-type of drainfield never fail (clog).

Old versus new systems were grouped according to the drawing on the questionnaire returned by the homeowner. Rarely were these drawings to scale. Old systems were classified as having drainfields nearly adjacent to the canals (usually between the house and the canal) and newer systems have drainfields much farther away (usually on the other side of the house from the canal). The terms old and new may be somewhat misleading because it is still possible to install a drainfield as close as 50 feet (ft) from a canal (as in Buckhead Ridge) on lots that were platted prior to 1972, but not yet developed.

In the early to mid-1960s, drainfields could be installed as close as 25 ft from the canal in Buckhead Ridge. This problem was further compounded because lot lines extended to the middle of the canal. In many cases, the boundary from which to measure the setback was not clear. The setback was increased to 50 ft in the late 1960s and remained at 50 ft until 1972, when it was increased to 75 ft. The date the lot was platted determines the setback distance. Some of the vacant lots within Buckhead Ridge are too small to allow for a 75-ft setback.

The questionnaire was developed to help identify appropriate volunteers willing to offer their properties for use in this study. The first list of potential volunteers was determined based simply on whether they checked the "yes" box on the volunteer question. Many people volunteered their properties as potential study sites, most being within Taylor Creek Isles and Treasure Island. The list of potential volunteers was narrowed down based on the survey question requesting a site map of their house and septic tank. None of the maps were drawn to scale. The key criteria in this component of the selection was location of the drainfield relative to the house and canal and site accessibility. Those with drainfields identified close to the canal (between the house and canal) were placed into the "old" system category. Many more respondents were grouped in the "newer" category as the drainfields are located in the front yard or along the side of the house, away from the canal. The potential for ready site access was also determined from the drawing, although it was understood that the illustrative talents of the respondents was sometimes questionable.

The survey also resulted in a response from a person living in a home serviced by the package treatment plant. This person provided the name of a neighbor as another possible volunteer. No other possibilities of sites within the group of homes hooked up to the package plant were found. Vacant lots were selected by a separate site visit based on interviews of various realtors. Two possible sites were identified, both in Taylor Creek Isles. All were lots along Taylor Creek. Several lots are part of the Army Corp dredge spoil right-of-way, directly east of Southeast 26th, 27th, and 29th Streets. Another lot is directly north of Southeast 18th Terrace. The operators of the package treatment plant, serving several streets within Taylor Creek Isles, were contacted concerning use of their property for the study of potential impact of sewage treatment plant on groundwater quality.

The last criterion used for site selection was ensuring that sites were selected from each of the subdivisions under study. The primary goal of the last criterion was to locate widely separated sites within individual subdivisions and at least one site in each subdivision. In using this criterion to find sites, it was hoped that a wide range of soil characteristics (if the characteristics are expressed below the dredged fill) would be represented. Study of a variety of native soils can only be documented after the buried soils of each of the study sites have been compared.

Table 2-9 is the final list of study sites prepared after a site visit to determine site accessibility.

2.3.2 SOIL DESCRIPTION

2.3.2.1 General Soil Characteristics

The soil types of the four subdivisions were identified using the U.S. Department of Agriculture-U.S. Soil Conservation Service (USDA-SCS) soil survey of Okeechobee and Glades Counties, Florida. All soils were mapped prior to construction of the canals and represent original, native soil characteristics. The current conditions and characteristics of the mapped soils are changed because of the dredge material that has been deposited during the canal and lot construction. Thickness of the fill material varies so the mapped soil characteristics may or may not influence septic tank performance, depending on where the water table is relative to the top of the original soil.

In general, the native soils of the region range from somewhat poorly drained to very poorly drained sands and peats or mucks. Most of the area, if not for the dredge and fill material would be categorized as freshwater marsh, low-lying, and nearly level in the soil surveys. The surface horizon of the soils is generally high in organic matter content and is less than 12 inches thick over mineral soil. During the wet season, these (native) soils are covered by water and remain wet throughout the year.

The originally mapped soils found in the Treasure Island subdivision are predominately Delray fine sand and Okeelanta peat. Typically, Delray fine sand is a very poorly drained soil with a surface horizon high in organic matter and slightly acidic with a slightly alkaline subsurface. The texture is fine sand to the argillic horizon (Bt) which ranges in texture from fine sandy loam to loamy fine sand. Permeability is rapid near the surface and slow in the subsurface.

Okeelanta peat is also a very poorly drained soil, with a peat texture to a depth of 28 inches below which it becomes sandy. The peat is slightly acidic near the surface and neutral in the subsurface horizons with rapid permeability throughout. Other soils described within the subdivision are Pompano fine sand and Seewee fine sand. These soils are not extensive in the area.

The soils mapped in the Taylor Creek subdivision are also predominantly Delray fine sand and Okeelanta peat. Other soils identified within the subdivision are Terra Ceia peat and Seewee fine sand, both of limited extent. The presence of Terra Ceia peat may be significant in attenuating P in septic tank leachate as it typically has a thick layer of black muck to a depth of 80 inches or more.

The Okeechobee Hammocks subdivision, prior to construction of the canals, was dominated by Immokalee fine sand and Delray fine sand. The Immokalee fine sand is a poorly drained soil with a strongly acidic surface horizon and a fine sand texture throughout. A poorly developed, weakly cemented, and strongly acidic spodic horizon (Bh) is present in the subsurface. Small amounts of Pompano fine sand and Myakka fine sand are also identified within the subdivision. Soils within this subdivision are slightly drier than those in the other subdivisions because of a slightly higher elevation.

Soils identified in the area of the Buckhead Ridge subdivision (prior to construction of the canals) are dominated by the Malibar fine sand, Tequesta muck, and Boca fine sand series. Malibar fine sand is a poorly drained soil with an 8-inch-thick surface horizon high in organic matter; slightly acid near the surface and moderately alkaline in the subsurface. Typically, Malibar fine sand has an argillic horizon at approximately 42 inches, with a fine sandy-loam texture. There is rapid permeability near the surface and slow permeability in the subsurface. The Tequesta muck is a very poorly drained soil with a surface horizon of black muck that is strongly acidic. The subsurface ranges from neutral to mildly alkaline. Permeability is rapid near the surface and moderate in the subsurface. The Boca fine sand is also a poorly drained soil with a thin, highly acidic surface horizon. An argillic subsurface horizon is sometimes present and the soil is shallow to limestone bedrock. Solution holes within the bedrock are common.

Table 2-9. Study Sites

OLD SYSTEMS	
Harry Moldenhauer 85 Linda Rd Buckhead Ridge	3 wells and 1 lysimeter (Figure 2-1)
Roger Lewis 3241 SE 24th Street Treasure Island	1 well and 1 lysimeter (Figure 2-2)
NEW SYSTEMS	
Zedra Goolsby 1821 SE 24th Blvd. Taylor Creek Isles	1 well and 1 lysimeter (Figure 2-3)
Michael Spaulding 9039 SE 64th Dr Okeechobee Hammocks	1 well and 1 lysimeter (Figure 2-4)
CENTRAL SEWER	
Bill Weston 2334 SE 30th St Taylor Creek Isles	1 well and 1 lysimeter (Figure 2-5)
VACANT LOT	
Adjacent to Goolsby	1 well and 1 lysimeter (Figure 2-3)
PACKAGE PLANT	
Professional Services Group	Several wells and 1 lysimeter (Figure 2-6)

Note: Each of the study sites is identified on maps of the subdivisions.

Source: ESE.

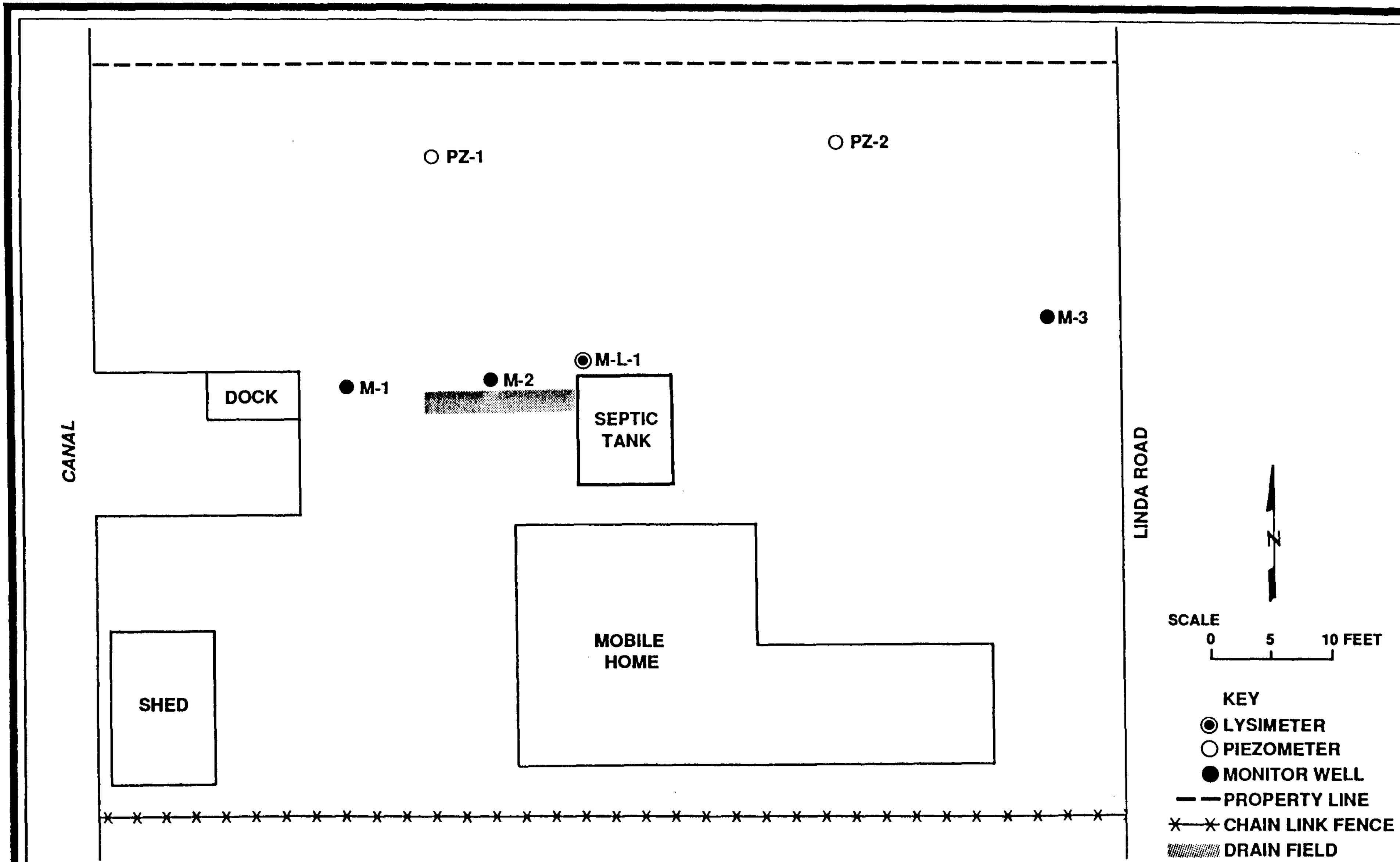

Figure 2-1
OLD SYSTEM
MOLDENHAUER SITE

SOURCE: ESE

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.

OKEE SS 293 MH

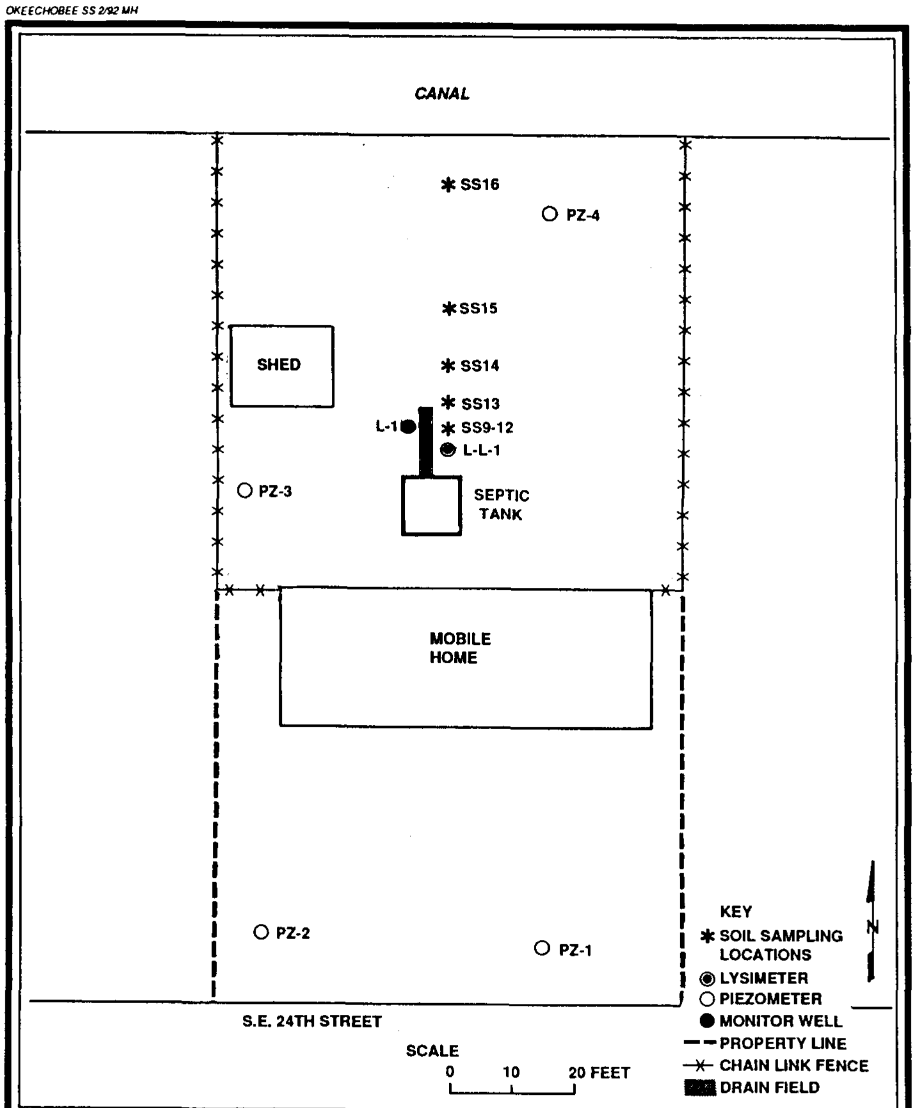

Figure 2-2
OLD SYSTEM
LEWIS SITE

SOURCE: ESE.

ENVIRONMENTAL SCIENCE
& ENGINEERING, INC.

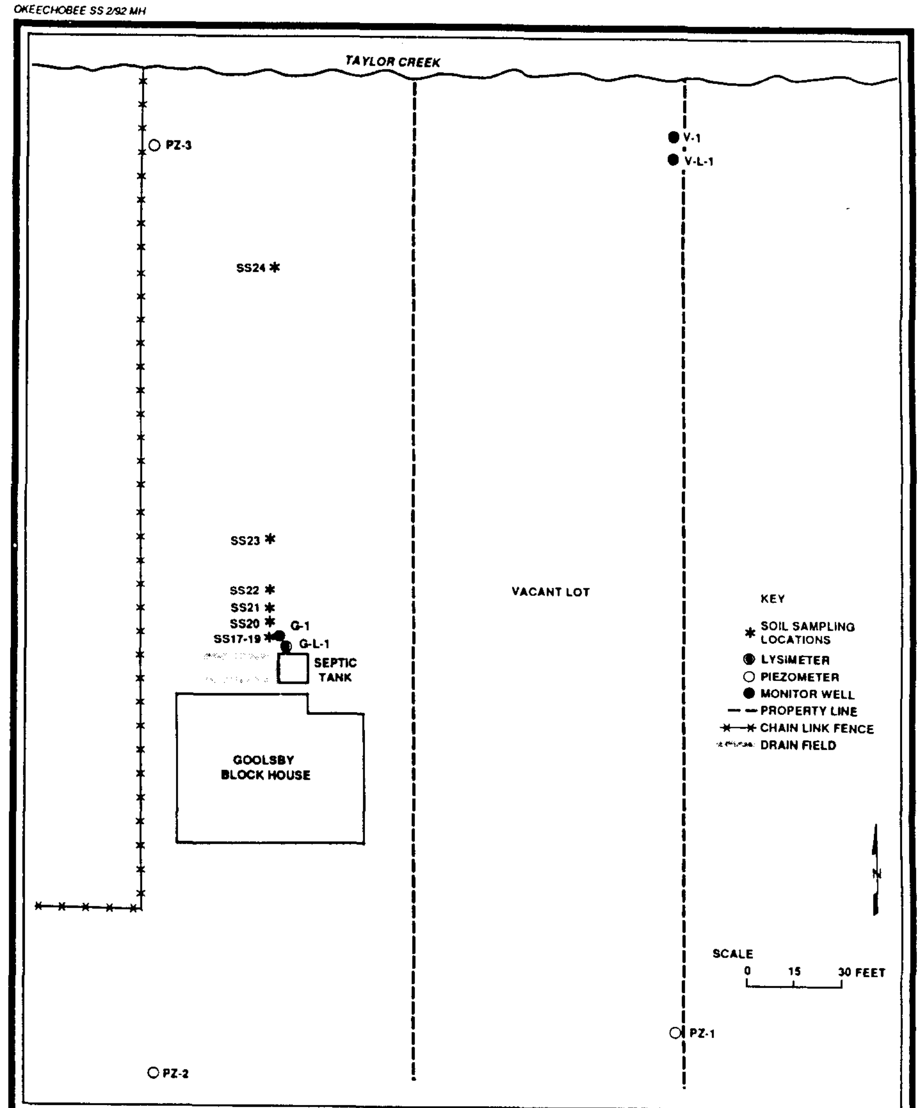

Figure 2-3
NEW SYSTEM, GOOLSBY SITE
AND VACANT LOT

SOURCE: ESE.

ENVIRONMENTAL SCIENCE
& ENGINEERING, INC.

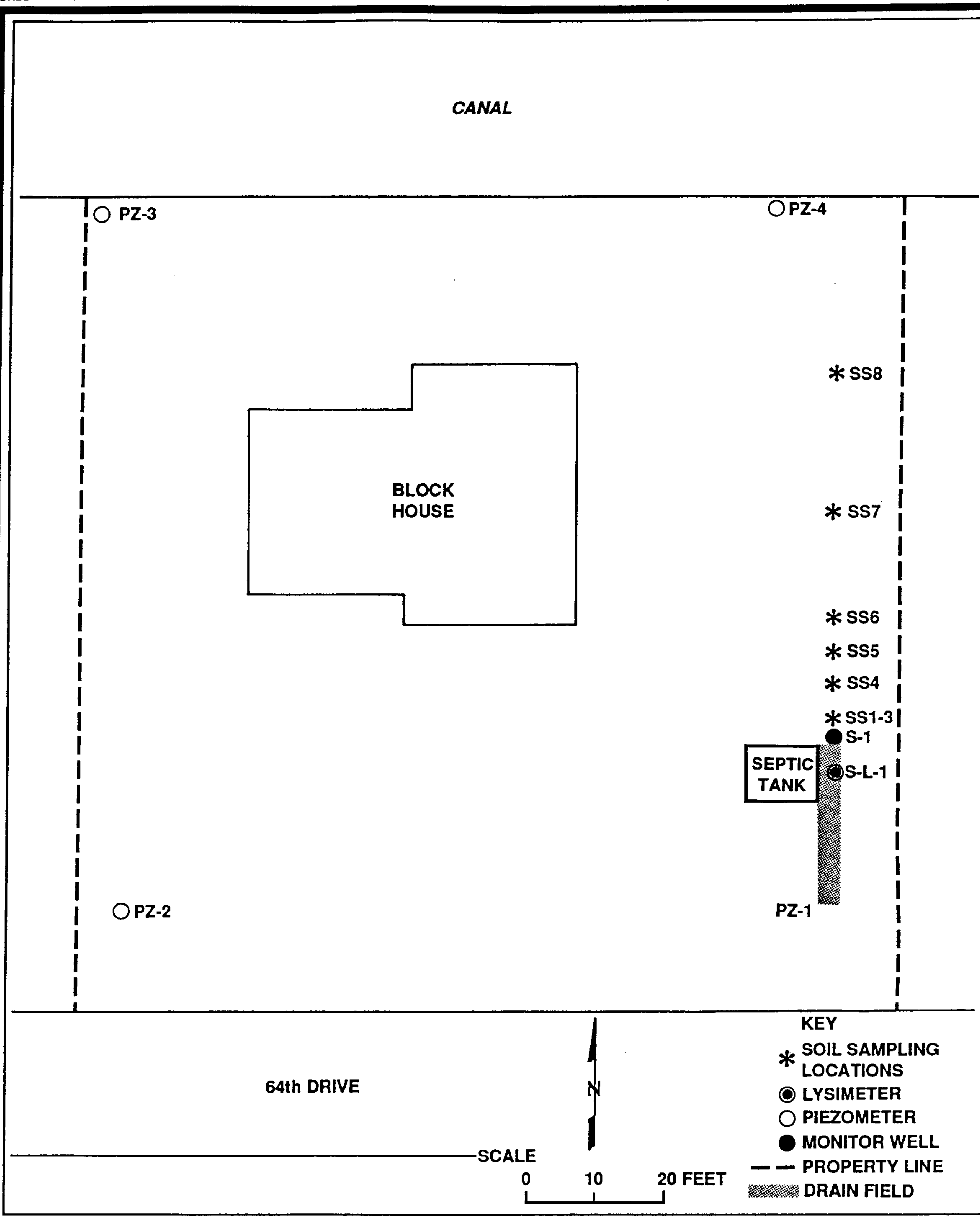

Figure 2-4
NEW SYSTEM
SPAULDING SITE

SOURCE: ESE.

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.

OKEESS 9/91 MH

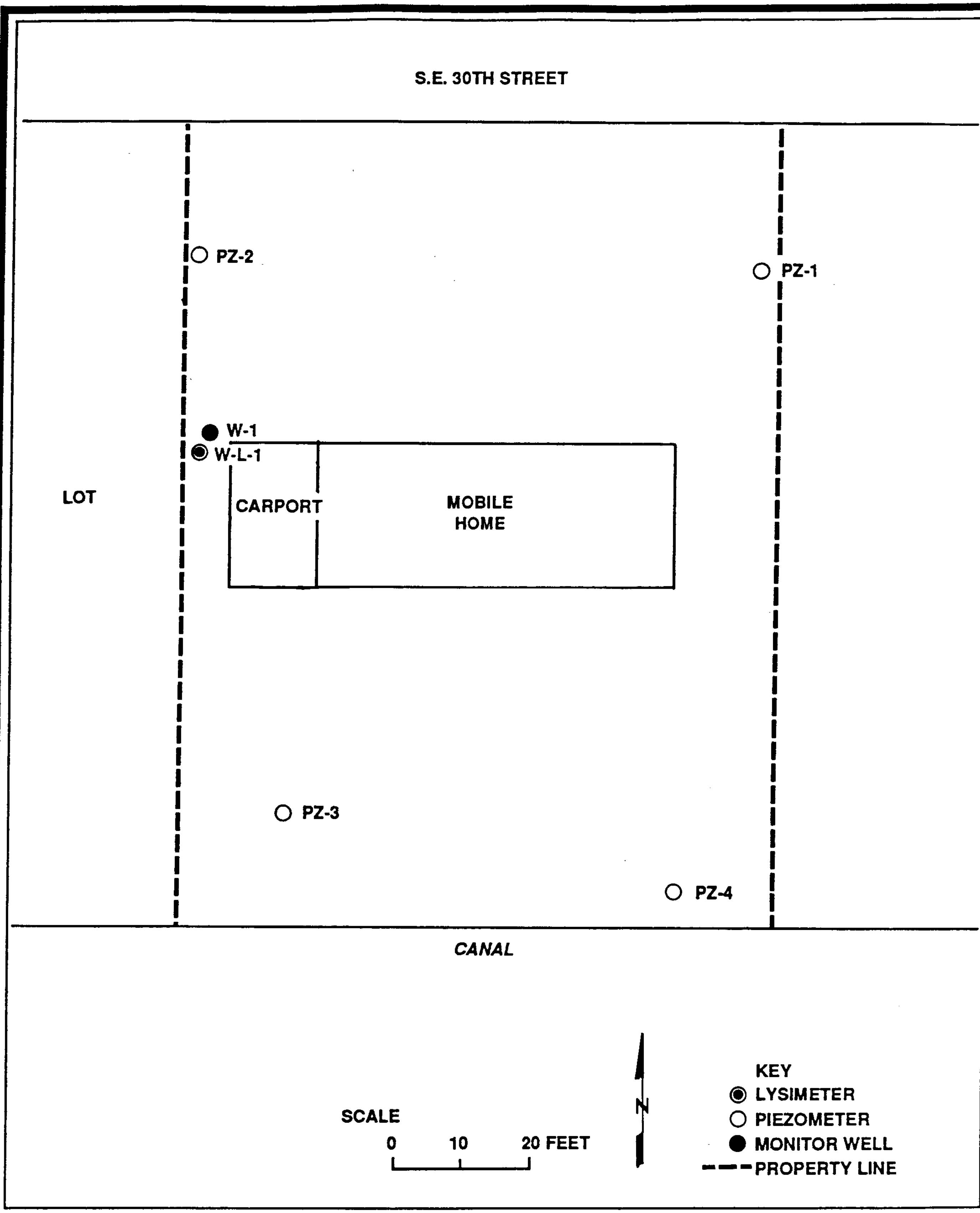

Figure 2-5
CENTRAL SEWER
WESTON SITE

SOURCE: ESE.

ENVIRONMENTAL SCIENCE
& ENGINEERING, INC.

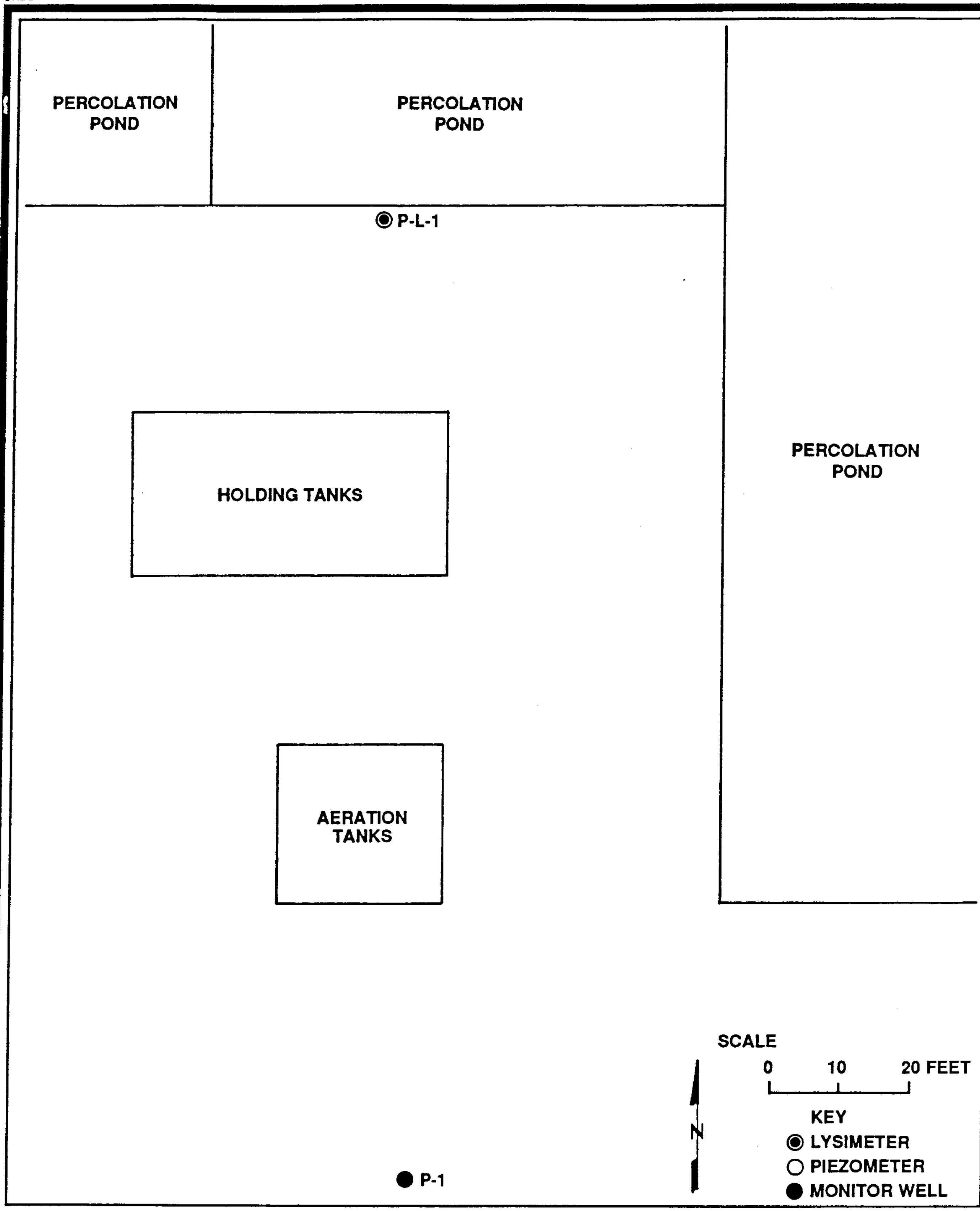

Figure 2-6
PACKAGE PLANT

SOURCE: ESE.

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& ENGINEERING, INC.

2.3.2.2 Site-Specific Soil Descriptions

Soil characteristics were investigated at each of the study sites as part of each year's soil sampling program. Soil descriptions for each of the properties are presented in the following subsections. The fill material that comprises the majority of the soil within each subdivision could not be described according to standard soil characterization terminology because of the non-systematic variability of colors and textures. Fill colors and textures vary according to the method and sequence of excavation and dumping of materials during the construction of the canals.

Spaulding Residence

The Spaulding residence is within the Okeechobee Hammocks subdivision. The soil profile at this site consisted of fill material approximately 54 inches thick overlying 28 inches of muck. The texture of the fill is primarily fine sand with some small pockets of loamy material. Pockets of white sand and pockets of fine sand high in organic matter are also present. The color of the fill material is primarily gray and its consistency is loose. Some of the small loamy pockets have a friable consistency. The overall structure of the fill is single-grain (structureless). The depth of muck corresponds to the characteristics of the Okeelanta peat soil series which is the original soil as mapped. Below 82 inches, the soil material became sandy in texture. At the time of this survey, the water table was measured at a depth of 66 inches. The water table at this time was below the fill material and within the muck.

Lewis Residence

The Lewis residence is within the Treasure Island subdivision. The soil at this site consisted of approximately 60 to 70 inches of fill over what appeared to be native soil. The origin of the fill is quite possibly dredged material from the construction of the canals and dredging of Taylor Creek. This fill is primarily gray fine sand with pockets of white sand and what appears to be small pockets of spodic material. Its overall consistency is loose with the small pockets of spodic material being friable. The overall structure is single-grained (structureless) and in some areas has a salt and pepper appearance. A strong, but thin Bh horizon was identified at a depth of 72 to 75 inches with a lighter colored Bh horizon below 75 inches. These particular soil characteristics compare with either the Immokalee or Myakka soil series, both of which are mapped in the area. The depth measurements were taken near the house and septic tank. The property slopes substantially to the canal which caused a great variation in depth to the Bh horizon and groundwater according to position relative to this slope. The depth to both the groundwater and the Bh horizon ranged from approximately 70 inches on the top of the slope to 26 inches at the bottom of the slope. These depths to characteristic horizons appear to depend entirely on the amount of fill at the site.

Goolsby Residence

The Goolsby residence is within the Taylor Creek subdivision. The soil at this site consisted of 42 inches of fill over muck. The fill at this site looked different (not like dredge material) than the fill at either the Lewis or Spaulding sites. The difference may have been that this material looked to be much better mixed than at the other sites. It is primarily gray fine sand with few small pockets of cleaner sand. It has single-grained structure (structureless) and has a loose consistency. This muck layer was approximately 30 inches thick and in turn overlied sandy material at a depth of 72 inches. Terra Ceia peat was the soil series mapped at the site. The observed characteristics match this series or the Okeelanta peat. The depth to the groundwater was estimated to be 55 to 60 inches, near the septic tank drainfield. The depth to the groundwater varied depending on the proximity to Taylor Creek which bounded the property to the north.

Weston Residence

The Weston residence is within the Taylor Creek subdivision. The soil at this location consists of 26 inches of fill over what appears to be a transition soil between the Delray fine sand and Okeelanta peat. The fill material is also well mixed, like the Goolsby site, and consists most likely of dredge material from construction of the canals. It is primarily a gray fine sand with few small pockets and streaks of black fine sand and loamy fine sand. Overall, it has a single-grain structure (structureless) and has a loose consistency. The surface horizon of the original soil was estimated to be at a depth of 26 inches with gray sand underlying to a depth of 64 inches. At the time of this investigation the water table was estimated to be at a depth of 52 inches below the land surface.

Moldenhauer Residence

The Moldenhauer residence is located within the Buckhead Ridge subdivision. The soil at this location consisted of 36 inches of fill material over soil mapped as Malabar fine sand. The fill is well mixed and appears to be dredge material from the canals. It is primarily brownish-yellow fine sand with pockets of grayish brown loamy fine sand. Numerous shell fragments are found throughout the material. Within the pockets of loamy fine sand are few, fine, brownish-yellow and bright yellow mottles. Overall, the consistency is loose and it has single-grain structure (structureless). The observed characteristics of the soil found below the fill material match those of the Malabar fine sand series. The water table at the time of this investigation was estimated to be at a depth of 66 inches.

Vacant Lot

The vacant lot that was investigated is located in the Taylor Creek subdivision, adjacent to the Goolsby residence on the west. The soil at this site consists of 40 inches of fill over organic muck. The fill material is similar to that found at the Goolby site, likely from dredging Taylor Creek. This material, though contains few small shell fragments, well-mixed throughout. The difference consisting of The muck layer is approximately 22 inches thick. Below 62 inches is dark gray to black sandy material. The characteristics of the soil found below the fill material match those of the Okeelanta peat. The water table at the time of this investigation was found at approximately 56 inches.

Package Plant

This package plant is located just to the west of the Taylor Creek subdivision. The soil at this location was not physically investigated because of the impact auger holes would have on the perc pond next to the treatment plant was unclear. The soil is mapped as Delray fine sand (USDA-SCS Soil Survey of Okeechobee Co., FL, 1971).

2.4 LITERATURE REVIEW

The review of literature begins with a summary of Impact of On-Site Sewage Disposal Systems and Ground Water Quality by Bicki et al. (1984) because it was the most exhaustive treatise up to that time. This report was prepared for the Florida Department of Health and Rehabilitative Services (HRS). The remainder of the literature review consists of a summary of the reports published after the Bicki et al. report. This review is not intended to be as exhaustive as the previous but is intended to update the reader on the generally available literature. The last section of the literature review concerns water quality of finger canals independent of septic tank impacts. Closed-ended finger canals have problems inherent to their design and construction, without imposing additional problems of septic tank nutrients and contaminants.

2.4.1 SUMMARY OF BICKI, ET AL., 1984

The objective of Bicki et al. (1984) is to describe the effects septic systems have on the important resources of surface water and groundwater in Florida. Septic tank effluent contains a variety of constituents. Some of the most common are N, P, chloride, sulfate, sodium, toxic organics, detergent surfactants, and pathogenic bacteria and viruses. Movement of these substances is controlled by environmental factors such as soil type, depth to seasonally high water table, permeability of bedrock, system density, and redox potential.

Most authors referenced in Bicki et al. (1984) agree that groundwater contamination from septic tank effluent might occur if soils below the drainfield are water-saturated. This condition allows the P to be very mobile although it can also dilute the P in the effluent. In these instances however, dilution is not a satisfactory treatment. Under ideal, unsaturated conditions (aerobic conditions), as much as 99 percent of the P may be removed from the effluent. Using the term ideal implies that the conditions may not be common.

Aluminum, iron, and calcium are important in soil P sorption and precipitation reactions. Soil texture and mineralogy also play an important role in P removal from septic tank effluent. In general, loamy soils are more efficient in binding P than sandy soils.

Jones and Lee (1977) (as cited in Bicki et al., 1984) report that P content in groundwater poses little to no health hazard. However, Sikora and Corey (1976) (also cited in Bicki et al., 1984) state that if groundwater with these dilute concentrations of P becomes surface water through springs or seeps, the same concentrations may be high enough to cause some surface water contamination.

Numerous references in Bicki et al. (1984) report that septic tank effluent is one of the primary sources of increased N levels found in surface waters. Most authors agree that contamination and decreased surface water quality is caused by septic tank effluent reaching surrounding surface water. Density of the systems and proximity to the surface water are very important factors, as is the distance from seasonal high water table to the infiltration surface of the drain field.

Schmidt (1972 and 1977, as cited in Bicki et al., 1984), states that chloride and sulfate contamination of surface water could also be attributed to septic tank effluent. Other authors as cited in Bicki et al., 1984, state that constituents such as detergent surfactants, sodium, and toxic organics were also found to originate from septic tank effluent and could be a possible source of water contamination.

Septic tank effluent may also contain bacteria, viruses, protozoa, and helminths pathogenic to humans (Burge and Marsh, 1978) (as cited in Bicki et al., 1984). Fecal coliforms are the most common biological measurement because detection of other organisms is often too costly. Numerous factors control coliform survival (treatment) in the soil such as particle size, pH, moisture content, and the type of clay mineral. Generally, most authors agree that aerobic conditions within the drainfield will decrease coliform survival decreasing the chance of the organisms reaching the groundwater.

2.4.2 SUMMARY OF AYRES & ASSOCIATES REPORTS

Kirkner & Associates (1987) provided an assessment of the vulnerability of groundwater in 8 representative regions of the state in terms of their susceptibility to gradual long term additions of nitrate, volatile organic compounds (VOCs) and other components consistent with worst-case septic tank pollution. The report provided a quantitative objective ranking of regions of the state using a series of mathematical and computer models. These rankings were to be used in later stages of the research project. The Broward/Dade region showed the highest potential for overall movement of water contamination. Lee/Collier and Gadsden/Leon showed the least movement of water contamination. The risk and ranking were based on: (1) an area index that measured the horizontal area in which a constituent concentration exceeded the criteria; and (2) a spread index which measured the movement of the contaminant away from the source. While seepage velocity showed the greatest effect on contaminant transport, higher velocities did not necessarily increase the ranking.

Ayers & Associates (1987) evaluated the current OSDS practices within the state of Florida with regard to the soils OSDS were installed in. The objective was to identify the major soil types used for OSDS to provide direction for detailed evaluations in later research. The major questions answered were: (1) the major Florida soil types and patterns of distribution, (2) what soil types support most (75 percent) of the current and projected future OSDS, (3) what are the critical characteristics of these major soils affecting their ability to accept and treat septic tank effluent, and (4) what OSDS designs are most often used in Florida and what is the density and geographic distribution.

Ayres & Associates (1987) found that 24 of 67 counties will be responsible for 75 percent of the current and future OSDS. The most populous counties have most of the state's OSDS and are expected to generate most of the new OSDS. In these "high use" counties, soils which have one or more limitations for conventional OSDS designs are routinely used for unsewered developments. In fact, soils with severe or potentially severe limitations are routinely used for OSDS in these "high use" counties. This leads to the question of whether the septic effluent is receiving adequate treatment.

Approximately 21 percent of the state has soils with "slight" limitations and 73 percent with severe. The most prominent limitation (74 percent of the soils) is seasonal wetness or shallow groundwater. The next most common limitation (25 percent of soils) is slow permeability. Ten percent of the soils experience periodic flooding and 7 percent are shallow to bedrock. From the sum of these percentages being greater than 100 percent it is obvious that some soils have more than one limitation. Ayres & Associates (1987) also found that conventional trench and bed systems account for less than 55 percent of Florida OSDS while 44 percent are mounded or systems constructed in fill materials.

Ayres & Associates (1989) focused on monitoring the groundwater under four specific subdivisions in four hydrogeologic regimes and studied the performance of eight OSDS in two subdivisions. The objectives of this research were to determine whether OSDS use in subdivisions is seriously detrimental to groundwater quality. They concluded that groundwater concentrations of many constituents varied widely between different wells on a given date and at a given well on different dates. Wells installed near the OSDS revealed measurable concentrations of constituents commonly associated with OSDS. Groundwater quality in the vicinity of newer subdivisions has not suffered substantial, widespread contamination; though localized areas of contamination were observed in each area studied. OSDS infiltration areas in the St. John's County subdivision were commonly closer than 2 ft to groundwater during parts of the year. Total concentrations of various contaminants in soil samples collected beneath OSDS infiltration areas generally decreased considerably with depth.

2.4.3 SUMMARY OF RECENT SEPTIC TANK LITERATURE

2.4.3.1 Column Studies

Lance (1977) used soil columns to investigate the amount of P removal from sewage effluent by soil using columns packed with calcareous sand that had been exposed to sewage effluent and a mixture of this same calcareous sand and builders sand obtained from an area never exposed to sewage effluent. Removal of P was, in general, found to be directly related to the infiltration rate. The equilibrium concentration of phosphate P in the soil column could be increased or decreased by increasing or decreasing the rate of infiltration. P was being removed at first by adsorption, but when the adsorption capacity of the soil became saturated, removal of P was accomplished by a precipitation reaction. The introduction of Bermuda grass into the system increased the amount of P in the column leachate due to a plant root exudate keeping the P in solution. Results revealed that large amounts of phosphate P can be attenuated by calcareous sands if infiltration rates are carefully controlled.

Tare and Bokil (1982) investigated the effect of particle size distribution on wastewater treatment. A column study was performed using a washed river sand and soil samples from the Kanpur silt soil series. They determined that the particle size of a soil plays a very important role in septic tank effluent treatment, with the silt fraction better able to treat the effluent than the other size fractions. Although the silt was the best medium for treatment, it is less suitable than sand for drain field material because of its slow percolation rate. Wastewater effluent percolated very rapidly through the river sand without providing enough treatment to prevent groundwater contamination. For optimum treatment of septic tank effluent, the authors found that a 60 to 40 percent sand to silt mixture would be most suitable.

Smith et al. (1985) used soil columns to investigate the migration of Escherichia coli (E. coli) through the soil. Soil types used were two Typic Paleudalfs, Cumulic Haplaquoll, Fluventic Hapludoll, and Typic Udifluvent. Of the different soils studied, 22 to 96 percent of the applied bacteria were recovered in the column leachate effluent. As the amount of bacteria added was increased, the amount recovered also increased showing a direct relationship between the two. The extent of movement is strongly related to soil structure; shown in comparisons of disturbed versus undisturbed column studies. Soil structure helps to control pore geometries and pore sizes influencing the formation of macropores (large pores). Bacteria tended to move rapidly through the soil to depths at which the macropores ceased to exist. The clay and organic fraction of the soil was able to adsorb larger numbers of the cells than the sands. The authors concluded that as the number of macropores increases in a soil, the probability of groundwater contamination from a septic system could also significantly increase.

2.4.3.2 Groundwater Studies in the Field

A field study was performed by B.J. Alhajjar et al. (1989) monitoring the effects of soap detergent on groundwater quality. Groundwater was monitored at one location where a phosphate-built detergent was used and at another site where a carbonate-built detergent was used to investigate septic tank influence on groundwater quality. Results indicated that the phosphate-built detergent did not supply significant P concentrations (above acceptable levels) to the groundwater and in fact provided for more efficient total N removal due to more efficient denitrification taking place in the soil. Similarly, the carbonate-built detergent did not supply P concentrations above acceptable limits, but did increase the total N levels. The levels were increased as much as 77 percent above the levels at the first site where the phosphate-built detergent was being used. Indications are that neither type of detergent contributed to the groundwater P pollution and that properly maintained septic systems are not a source of P to the groundwater, do not supply biological contaminants to the groundwater, and do not enhance lake eutrophication. Alhajjar et al. (1989) also reported that other investigators (Fetter, 1977; Reneau and Pettry, 1976; Sawhney and Hill, 1975; Tofflemire and Chen, 1977) have observed similar results with P.

Septic systems, on the other hand, are sources of N to the groundwater and the type of detergent used does have an effect on the concentrations present in the groundwater downgradient of septic systems.

An experiment was conducted on a coastal barrier island by Cogger (1988) to evaluate septic tank effluent treatment on a typical Atlantic coast barrier island. Two fields were set up, with topographic location and depth to water being the primary differences. Different loading rates were applied to each location using a random design.

At the lower topographic location, anaerobic conditions occurred in the drainfield 20 percent of the time, resulting in less efficient effluent treatment. Where aerobic conditions prevailed, more efficient treatment was evident with more complete nitrification and decreased fecal coliform counts. Loading rates did have an effect on total N, P, sodium, chloride, potassium, and fecal coliforms found in the septic tank plume, but the water table level had a greater influence on overall septic effluent treatment. P movement seemed to be related to pore water velocity. Attenuation of bacteria and viruses was also more complete under aerobic conditions.

An 18-month field study was performed by Cogger and Carlisle (1984) to determine the effectiveness of conventional and alternative septic tank systems on wet soils. There were three alternative designs used: a low pressure pipe system, a soil replacement system, and a pressure-dosed mound system. The treatment of septic effluent was poorest in systems that were continuously saturated with groundwater. Average levels of ammonium-N (NH_4-N) were 7.3 milligrams per liter (mg/L), nitrate-N (NO_3-N) were 1.0 mg/L, and total fecal coliforms were 1,700 per liter by the most probable number (MPN) method. These values were detected in monitor wells located 1.5 meters (m) from the actual systems. Systems that were saturated only seasonally had lower values for all three parameters. The concentrations of all three constituents decreased with increased distance from the source. The greatest lateral movement occurred in the continuously saturated systems.

The low pressure pipe system maintained aerobic conditions in an area that would normally be saturated and showed improvement over conventional systems. The pressure-dosed mound system was effective when properly designed and operated. The soil replacement system showed no improvement over conventional systems. In all cases, aerobic conditions provided the most efficient treatment of septic effluent.

Robertson (1991) investigated septic system impact on groundwater and investigated the groundwater plume by monitoring two single-family homes situated on shallow sand aquifers. Elevated levels of chloride (Cl), nitrate (NO_3), sodium (Na), calcium (Ca), potassium (K), and dissolved organic carbon were observed, and depressed levels of dissolved oxygen (DO) and pH were seen in the groundwater under the systems and downgradient of the systems. At one site that has been in use for 12 years, the plume was more than 130 m long. NO_3 and sodium (Na) occurred at more than 50 percent of the source concentrations. After 1.5 years at the second site, the plume had migrated 20 m from the tile field and began to discharge into a river. Nearly complete attenuation of the NO_3 was observed within 2 m of the point of discharge to the river due to the denitrification capabilities of the organic matter-enriched riverbed sediments. For many unconfined sand aquifers, contaminant movement is extensive. Current regulations concerning separation distances between septic systems and drinking water wells may not provide adequate protection or assurance of good water quality (Robertson, 1991).

The main anthropogenic sources of nutrients for lakes are non-point sources associated with agriculture and residential areas (R. J. Gilliom, et al., 1983). A regional study of Pine Lake, located in the Puget Sound, Washington, area was performed focusing on old septic tank systems. The goals of this study were: (1) to determine if septic effluent was entering the lake from laterally flowing groundwater, (2) whether any P contained in the effluent was reaching the lake, and (3) whether the migration of P is uniform among the old systems or is occurring near only a few.

The study concluded that some P loading of Pine Lake and possibly other lakes in the region was attributed to old septic systems. The study at Pine Lake showed that effluent from old septic systems was reaching the lake by lateral flow of perched water in the soil overlying less permeable glacial till. The authors found that migration of more than 1 percent of the effluent P into the lake was rare. They noted that septic effluent typically contains 1,000 times the concentration of P found in lake water. This loading is possibly associated with a few systems located in soils saturated during the winter or wet season. Systems in these wet areas contribute P to the lake by shallow groundwater flowing into the lake and by surfacing of septic effluent, which then migrates into the lake as overland flow. These occurrences result because of the less stringent construction practices of the 1940s and 1950s. The authors stated that a long-term study is necessary to determine if P treatment efficiency of soils deteriorates with time.

Using a newly developed septic leachate detector, Kerfoot and Skinner (1981) conducted a survey along the shoreline of Crystal Lake in Michigan as part of a study to investigate methods to increase the effectiveness of septic tank systems. The authors analyzed groundwater and surface water for nutrient concentrations, investigated groundwater flow patterns, and compared algae growth to plume locations.

More than 90 wastewater plumes were found along the shoreline. A high correlation existed between the location of septic plumes and attached plant growth. Water samples obtained near the peak concentration of the outflow of some plumes contained sufficient nutrients to support aquatic plant and algae growth. Generally, attenuation of nutrients such as P and N was accomplished by the well drained and porous soils of the region. Approximately 0.7 percent of the P and 16 percent mean N were observed to breakthrough. A high correlation existed between the P loading of the lake water, calculated from observed plumes, and the areas where associated algae growth was reported.

Overall, there appears to be no significant change in surface water nutrient contents as a result of plume emergence (Kerfoot and Skinner, 1981). The location and characteristics of the emergent plumes were also directly related to groundwater flow.

P has been identified as the key element controlling the growth of algae and aquatic plants in many water bodies. One potential source of P, when evaluating nutrient loading of a water body, is septic tank wastewater disposal systems (Jones and Lee, 1979). A multi-year study was conducted to determine if significant amounts of P were transported from septic systems to local surface water. Data from a 4-year study did show that effluent migrated from the drainfield into the groundwater. Elevated levels of nitrate and ammonium did occur occasionally but it appeared that there was appreciable N removal in this particular aquifer system. No evidence of phosphate transport from septic tank effluent was found using monitor wells, even though it was a sand aquifer. It is possible that aquifer material sorption sites for P will become saturated over time but the removal of P through precipitation reactions is practically infinite. Slow movement of groundwater will allow precipitation of soluble P with calcium, iron, or aluminum. The authors state that this shows that the chemical composition of the soil and not the particle size plays an important role in P removal.

2.4.3.3 Other Florida Research Studies

Ayres & Associates (1991) studied the impacts of OSDS on groundwater and surface water within a subdivision of homes near canals. Homes are built on dredge spoils from construction of canals or from fill brought in from other areas because all the land is generally low-lying. Drainage from this subdivision flows to the Indian River Lagoon. Some of the major conclusions follow. Nutrients were significantly higher in wells adjacent to drainfields. The concentrations decreased significantly with distance away from the drainfields; enough that no significant difference existed between wells greater than 50 ft away from drainfields and the background wells. OSDS installations did not have a discernable influence on water quality in the adjacent canals. Canal water contained much higher counts of fecal coliform and fecal streptococcus than measured in groundwater. It may be more likely that wild and domestic animals are the source of the coliforms and streptococcus rather than septic tanks. Nitrate-nitrite N averaged 0.02 mg/L or less along the canal, average total P ranged from 0.05 to 0.10 mg/L and total Kjeldahl N (TKN) concentrations ranged from 0.78 to 1.15 mg/L. No differences were observed between canal sampling sites.

Nitrate-nitrite was found to be positively correlated with water table elevation; however total P was not correlated. Fertilizer appears to be as large a contributor as septic tanks to shallow groundwater N in at least one of the subdivisions. Contaminant loading to the adjacent canals was judged to be low based on the observed low concentrations of constituents in the canal piezometers and nearest upland piezometers and based on the low rates of seepage of groundwater into the canals.

Waller et al. (1987) investigated the migration of septic effluent in two different lithologies of Broward County, Florida. One site in sand and another in limestone were selected for study because these are the two major lithologies within the county. Effluent moved primarily in the vertical direction because of low hydraulic gradients and was diluted or attenuated as it moved down gradient. Effluent was detected more than 20 ft below the septic tank outlet at the sand site and more than 25 ft below the outlet at the limestone site. Indicators of effluent were near background 50 ft downgradient of the sand site and 40 ft downgradient of the limestone site. The primary controls on effluent movement from septic tank systems in Broward County are the lithology and layering of the geologic materials, hydraulic gradients, and volume and type of use the system receives.

2.4.4 REVIEW OF FINGER CANAL LITERATURE

In general, finger canals exhibit a standard set of problems, only one of them being the potential additional impacts of septic tank effluent:

1. The canals are dredged in very porous soils in low-lying areas (i.e., usually below the mean water level of the adjacent water body), so there is virtually no gravity flow from the canal to the adjacent water body except during periods of heavy surface runoff;
2. Canal depths are generally deeper than the adjacent water body, limiting the amount of flushing from wind-generated or tidal currents, and create stagnant pools and sediment sinks;
3. The canals extend long distances from the adjacent water body and dead-end (i.e., they are labyrinthine and exhibit poor flushing); and
4. The canals are surrounded by dense development which contributes road/lawn runoff and septic tank effluent or effluent from package treatment plants.

The total effect from these factors on the ecology of the canals is a significant biotic imbalance due to excessive nutrient loading from septic tanks and road/lawn runoff, accumulation of organic sediments in canal bottoms, anoxic benthic/demersal conditions, sulfide production, oxygen/thermal stratification, and concentration of toxins in water and sediments. These stresses generally reduce biological diversity and density, reducing faunal residency and encouraging explosive floral monocultures of nuisance floating macrophytes.

Deeper canals stagnate and develop anaerobic conditions (Barada and Partington, 1972) because of the box-cut configuration of excavations. Water and sediment quality is decreased when a canal system is labyrinthine, contains dead ends, and is excessively deep (Lindall and Trent, 1975; Cosser, 1989; Barada and Partington, 1972; Westman, 1975; Sykes and Hall, 1970; Lindall, Hall, and Saloman, 1973; EPA, 1975). Slow current speeds, poor flushing, and canal depths greater than adjacent water bodies are responsible for the accumulation of large quantities of fine silts and biogenic materials (Lindall and Trent, 1975). These accumulations can lead to local eutrophication in those areas (Baird, Marais, and Wooldridge, 1981). Trent, Pullen, and Moore (1972) cite the study by Taylor and Saloman (1968) on Boca Ciega Bay, Florida, where sediments found in undredged areas averaged 94 percent sand and shell and those in dredged canals averaged 92 percent silt and clay. Cosser (1989) found that sedimentation increased with increasing distance from source water on connecting canals, and was highest at dead-end locations. Cosser identifies an inverse relationship between sedimentation and tidal velocity. This research also suggests that sediment type is largely responsible for the community structure of invertebrate fauna.

With respect to hydrodynamic conditions and sediment type, factors not normally limiting in the natural estuarine or coastal environment appear to be limiting factors in tidal (finger) canals (Cosser, 1989). Temperature stratification is a saltwater canal phenomenon in canals of excessive depth and inadequate circulation. (Anaerobic conditions prevailing in freshwater canals is due to other causes.) Barada and Partington (1972) found that Secchi and transparency data have the lowest readings at the heads of canals (Paulson and Pessoney, 1975).

Finger canals are generally constructed by dredging and filling submerged lands of shallow bays and lakes, estuaries, marshes, or other wetlands essential for the production of fish and other aquatic life (Barada and Partington, 1972). Destruction of existing habitats and natural shoreline result from canal construction practices. Existing hydrology and habitats (swamps, marshes, and other shore vegetation) acting as nutrient and sediment traps are destroyed or irrevocably damaged so that these functions (as well as habitat values) are lost. The new habitat is usually inconsistent with the surrounding ecotypes and hydrodynamics; consequently, ecological and aesthetic values rapidly degrade and affect not only the canals, but also the adjacent water bodies (Barada and Partington, 1972; Time, June 28, 1971; Baird, Marais, and Wooldridge, 1981; Lindall and Trent, 1975; Westman, 1975; Trent, Pullen, and Moore, 1972).

Predevelopment flora and community structures are usually destroyed from the dredge and fill activities associated with canal construction and are replaced with species that can tolerate the comparatively deeper, nutrient-rich aquatic environment. Nutrient loading from storm runoff and lawns stimulate explosive phytoplankton growth that rapidly perish (Lindall and Trent, 1975, Westman, 1975). Detritus from the dead phytoplankton accumulates in canal bottoms increasing the biochemical oxygen demand and the nutrient load in the canal.

Over enrichment of canals and the subsequent effects on the aquatic plant community is well documented (Westman, 1975; Trent, Pullen, and Moore, 1972; Corliss and Trent, 1971; Barada and Partington, 1972; Lindall and Trent, 1975; Saenger and McIvor, date unknown; Paulson and Pessoney, 1975; Baird, Marais, and Wooldridge, 1981; EPA, 1975). Explosive growth of weeds (often exotic species with few natural predators), little plant diversity, virtual infestations of one or two species, oxygen depletion, and rapid eutrophication are common conditions in finger canals. Also, canals are suspected to be sources of noxious weed infestations which spread to adjacent waters (Barada and Partington, 1972).

Controlling the plant growth in choked canals to allow for navigation is often accomplished with the use of herbicides. Many of the herbicides used to kill (aquatic) weeds can also kill fish. Decomposing vegetation that has been killed by herbicides is responsible for many fish kills (Barada and Partington, 1972). Pesticides are also used in canals to control biting insects which often proliferate where mats of algae occur (due to over-enrichment). Data indicate that algae are efficient accumulators of pesticide residue and may be a partial source of residue in fish found in waters which contain only trace amounts of pesticides (Shultz, Yauger, and Bevenue, 1975).

Canal water depths tend to be greater than adjacent waters (Barada and Partington, 1972; Lindall and Trent, 1975; Baird, Marais, and Wooldridge, 1981; McBee and Brehm, 1979; Westman, 1975; Trent, Pullen, and Moore, 1972; Corliss and Trent, 1971; EPA, 1975) resulting in numerous negative impacts to adjacent hydrologic systems and ecosystems. The impact on plants is often a result of the canal depth being greater than the euphotic zone, precluding the establishment or re-establishment of rooted vegetation (Lindall and Trent, 1975) as well as contributing to oxygen stratification.

Biological production in canals may initially be high, but is reduced to little desirable biological production in the canal after the first year, due to sedimentation and increased biochemical oxygen demand (Barada and Partington, 1972). Paulson and Pessoney (1975) found that biochemical oxygen demand values for canals showed only slightly higher rates at the dead ends of canals, and that dissolved oxygen values were lowest in the bottoms of canals. Oxygen depletion from accelerated eutrophication due to nutrient loading is responsible for fish kills in canals (Barada and Partington, 1972). Organisms moving into and out of canal systems and areas of canal systems that discharge into adjacent water bodies must be able to survive significant changes in pH, oxygen concentration, and other chemical imbalances/concentrations (Barada and Partington, 1972). During periods of heavy rain/runoff, organisms can be impacted from accumulated or concentrated toxic constituents flushed from the canal in surface water and sediments (Barada and Partington, 1972).

Sykes and Hall (1970) (reported by Lindall and Trent, 1975), report samples from undredged areas of a canal system contained an average of 60.5 individuals and 3.8 species, whereas those from the dredged canals contained an average of 1.1 individuals and 0.6 species. Research by McBee and Brehm (1979) and Westman (1975) supports research cited elsewhere in this review regarding lowered faunal populations in canals and the negative effects of the dead-end canal design on water quality (stagnant water, low oxygen, anoxic conditions, etc.).

3.0 METHODS

3.1 SAMPLING PLAN--SOILS UNDER THE DRAINFIELD

The first soil sampling program was designed to investigate the changes in P content and adsorption capacity with distance (vertical and horizontal) from the drainfields. Samples were collected at increasing vertical distances below the drainfield and with increasing distance away from the drainfield at the top of the water table toward the canal. Three residences were chosen that provided variable soil/environment conditions and septic tank characteristics. Eight samples were taken from each site, three in a vertical sequence from the drainfield to the water table and five more equally spaced at the top of the water table, along a line starting directly under the drainfield running to the canal.

3.1.1 SOIL SAMPLING SITES

Each of the seven study sites was evaluated (on paper) to see if the expected characteristics were suitable to meet the objectives of the sampling plan. Those objectives were to determine the distribution of soil P between the bottom of the drainfield and the top of the water table and from soil samples collected along the top of the water table from under the drainfield out to the canal. Only three study sites were budgeted. The PSG package plant was ruled out because the drainfield is actually a percolation pond so it was impossible to actually collect samples from under the pond. The Buckhead Marina plant was ruled out because the environmental conditions are similar to the residences and because it is not instrumented like the residences. The Weston residence was eliminated because it is hooked up to the package plant and so would not provide information valuable to the study. The Moldenhauer residence was eliminated from consideration because the drainfield is located too close to the canal. This small separation distance may not provide enough soil treatment capacity to see a decrease in P content or capacity. The soil may be saturated with P all the way to the canal. Eliminating these potential sampling sites left three sites to be sampled, each with different and desirable soil conditions.

3.1.2 SOIL SAMPLING METHODOLOGY

The soil characteristics and the approximate depth to the water table were investigated by augering to the top of the water table or to the depth of the original soil before any soil samples were collected. This was done to measure the depth of fill above the original soil and/or the depth to the water table to plan the separation distance between samples. The soil samples were taken following one of two different procedures. Samples were collected at regular intervals to the top of the water table if the soil characteristics were consistent with depth. Soil samples were collected from different distinct soil horizons (odd depths) such as a spodic horizon or a peat or muck. The variability allowed by the two sampling plans (sampling based on measurement or based on variability of soil properties) prevented exclusion of horizons expected to trap P. For example, if a spodic horizon or peat layer existed 3 ft below the land surface and the sampling plan was written so that samples were only collected at depths of 2 and 5 ft, the sampling plan would have missed the important horizon. If an important soil horizon was encountered as part of these studies, the soil sampling plan was modified to ensure those conditions were represented.

The septic tank and drainfield were located using a tile probe to identify the correct location and depth of the first sampling location. Three samples were collected in a vertical sequence to the water table and another five samples were taken from the top of the water table in a line toward the canal. A total of eight samples was collected at each site.

3.1.2.1 <u>Spaulding Residence</u>

The first sampling site was the Spaulding residence in the Okeechobee Hammocks subdivision. Three samples were collected in a vertical sequence at the end of the septic tank drainfield. The depths were 24 to 48 inches (midway through the fill material), 55 to 66 inches (just at the top of the groundwater), and 66 to 80 inches (to collect a sample of the peat). The next three samples were collected in a horizontal plane at 5-ft intervals going away from the drainfield toward the canal. These samples were collected from approximate depths of 60 to 72 inches, 60 to 70 inches, and 67 to 78 inches respectively; however, the samples represent the same type of soil material. The fourth sample in the horizontal sequence was collected at a depth of 64 to 72 inches, 15 ft closer to the canal and the last sample was collected an additional 20 ft out at a depth of 64 to 72 inches. This location was approximately 15 ft from the edge of the canal. The edge of this canal was not well defined due to the heavy vegetation. The distance between the drainfield and canal was approximately 65 ft (Figure 2-4).

3.1.2.2 Lewis Residence

The Lewis residence in the Treasure Island subdivision was the second site to be sampled. The starting point of the vertical sequence was located next to the middle of the septic tank drainfield. Four samples were collected at increasing depths of 25 to 33 inches, 50 to 60 inches, 70 to 75 inches, and 75 to 82 inches. These depths were chosen so that samples would be collected from the top of the fill material, near the bottom of the fill material, within the first Bh horizon, and within the second Bh horizon which was below the top of the water table. Four samples were taken in a vertical sequence at this location because of the two different spodic horizons which are capable of trapping migrating P.

Two of the four samples collected along the top of the water table were collected at 5-ft intervals away from the drainfield toward the canal. These samples were collected from approximately the distance below the surface as samples collected under the drainfield (65 to 72 and 68 to 77 inches). The next sample was collected approximately 10 ft farther away, midway down the slope to the canal. This sample was collected at a depth of 48 to 60 inches which is approximately the same relative depth as the previous sample. The final sample was collected 20 ft farther down the hill, at the bottom of the hill and approximately 8 ft from the canal bulkhead. This sample was collected at a depth of 26 to 38 inches which is also at the same relative depth of the previous samples. These last four samples were composite samples collected from the two Bh horizons. With fluctuating groundwater, either of the two Bh horizons may be active in trapping P. The composite sample accounts for this possibility (Figure 2-2).

3.1.2.3 Goolsby Residence

The third sampling site was the Goolsby residence in the Taylor Creek subdivision. The vertical sequence of samples began at the adjacent to the mid point of the septic tank drainfield. The samples were collected at depths of 35 to 42 inches (the fill material), 60 to 68 inches (the muck layer), and 78 to 85 inches (the sandy material below the muck). Five other samples were collected from the top of the water table in a line between the septic tank drainfield and Taylor Creek. Three of the five samples were collected in a horizontal plane at 5-ft intervals moving away from the septic tank drainfield toward Taylor Creek. Samples were collected at depths of 55 to 65 inches, 58 to 65 inches, and 50 to 60 inches, respectively. The next sample was collected from a point 18 ft farther away, at a depth of 54 to 65 inches. The last sample was collected 83 ft beyond the previous sample, at a depth of 36 to 48 inches. All of these depths represent the same relative elevation and similar soil materials. The last sample location was approximately 63 ft from Taylor Creek (Figure 2-3).

3.2 SAMPLING PLAN--SOILS REPRESENTATIVE OF THE SUBDIVISIONS

3.2.1 SOIL SAMPLING SITES

The sample sites chosen for the second year sampling event were selected to represent the major soil types (covering the largest acreage) identified within each subdivision using county soil surveys (USDA-SCS Soil Survey of Okeechobee Co., FL, 1971 and Interim Soil Survey of Hendry Co., FL, 1991). After traveling throughout each subdivision and identifying potential sample sites, the best sampling locations were chosen based on the soil type and site accessibility. The majority of sites were vacant lots. Gaining access to occupied properties was difficult. The usual reason property owners gave for declining access was that they did not want to get involved. Each site was sampled in two locations, at opposite ends of the property as long as the soil type remained the same. Occupied properties were sampled upgradient and as far away as possible from the septic tank drainfield to avoid collecting any samples affected by septic tank leachate.

The first sample site is located on a vacant lot in the Okeechobee Hammocks subdivision on SE

62nd Drive (sample numbers OKEES3-1 through OKEES3-6). The soil at this site consists of 24 inches of fill material over native soil identified as Immokalee fine sand. The fill here is well-mixed, primarily gray fine sand. Small pockets of white fine sand and small pockets of black spodic material are mixed throughout the 24 in of fill. The origin of the fill is probably the spoil created by the construction of the canals. It looks similar to a mixed-up Immokalee fine sand profile. It is primarily single grain and has a loose consistency. Some of the small pockets of spodic material have a friable consistency. The second sample site, also a vacant lot, was also located within Okeechobee Hammocks on SE 62nd Way. Sample numbers OKEES3-7 through OKEES3-12 were collected here. The soil at this site consists of 24 inches of fill material over native soil identified as Delray fine sand. The fill at this site is well mixed, looking like it was reworked after initially being deposited. It is primarily gray fine sand with a very few pockets of dark gray fine sandy loam mixed throughout. A few streaks of black, mucky-sand were found between 12 and 16 in BLS but was not found consistently across the property or at depth. Overall, the fill is single-grain (structureless) and has a loose consistency.

Two sample sites are located within the Treasure Island subdivision. Both were mapped as Okeelanta peat by the soil survey; however, Delray fine sand was identified at both locations by the soil scientist. Samples OKEES3-19 through OKEES3-24 were collected from a vacant lot on SE 26th Street and samples OKEES3-25 through OKEES3-30 were collected from a vacant lot located on SE 20th Court.

One soil sampling site is located within the Taylor Creek subdivision. Samples OKEES3-31 through OKEES3-36 were collected from a vacant lot located on SE 24th Boulevard northeast and across Taylor Creek from the Goolsby residence. The soil at this location was mapped by the soil survey is Okeelanta peat and was confirmed during the site investigation and sampling.

The final soil sampling site is located within the Buckhead Ridge subdivision. Soil samples OKEES3-49 through OKEES3-54 were collected at the Moldenhauer residence on Hunter Road. The soil identified by the soil survey and confirmed during sampling is Malabar fine sand.

3.2.2 SOIL SAMPLING METHODOLOGY

Soil samples were collected using a 4-inch hand held bucket auger and a stainless steel bucket in which to mix the sample. At every location a composite sample was collected from the fill material. Fill material is described as Made Land by the USDA-SCS Soil Survey of Okeechobee Co.; FL, 1971. It is described as being a mixture of sandy material, mixed-up soil horizons, and geologic materials such as shells. The fill materials in these subdivisions consists primarily of material dredged up during construction of the canals. Some other materials may have been trucked in to raise the land elevation for building homes. Fill was found to have different characteristics at each location; some were major, others minor. In fact, characteristics were found to change within the same home owner's lot. This variation prohibited more classical soil characterization efforts.

Samples from the native soils were collected either from a diagnostic horizon that could be identified as characteristic of the soil series originally found at that location or from the top of the groundwater table. In six instances, samples were collected from beneath the groundwater table because of its proximity to the surface.

3.3 CANAL SEDIMENT SAMPLING

The canal sediment characterization program was designed to determine differences in sediment composition, depth, and characteristics according to age or design of the canal and to compare canals surrounded by septic systems to the canal surrounded by homes hooked to the package plant. For the purpose of these efforts, sediment is defined as material at the bottom of the canal consisting mostly of loose organic materials lying on top of firm sand or the hard rock bottom of the canal. To characterize the canal sediments in each of the four subdivisions, the canals were grouped according to similar visual characteristics such as length, width, depth, and age. This was done in the office using maps and aerial photographs of each subdivision, and onsite by visiting each subdivision. After the initial characterization, the canals and sediments were investigated by boat. Measurements included depth of water, width of the canals, and thickness of the sediments. The combination of these measurements would provide a measure of the volume of sediments on the bottom of each canal. The sediments were also classified according to physical makeup, stage of decomposition (higher decomposition is indicated in organic samples that exhibit fewer observable plant fibers), and texture.

3.3.1 SEDIMENT MEASURING TECHNIQUES

Canals in each group within the subdivisions were randomly chosen for the investigation effort conducted by boat. Canal physical characteristics such as canal length, width, and if the canal was dominated with bulkheads or no bulkheads dictated where sediment measurements were to be taken. If the canal was dominated by bulkheads, then all measurements for width were conducted between bulkheads. If the canal was dominated by banks that were sloping and vegetated with no bulkheads, then the measurements were conducted between these areas. If the canal being surveyed was predominately free of vegetation, width and depth measurements would be taken in areas free of vegetation. If the canal in question was dominated by aquatic vegetation, readings would be conducted in these areas.

An Apelco XCD600 Chart/LCS Depthsounder was used to measure water depth. This measurement was also used as the depth to the top of the sediment and recorded as one of the necessary measurements to determine the thickness of sediment. Once the location of the top of sediment was known, a 10-ft section of 2-inch PVC pipe was driven through the sediment until hard mineral bottom was contacted (pipe could not be pushed any deeper). The difference in depth measurements approximated the sediment thickness. This technique was conducted on both sides of the canal, approximately 3 to 5 ft from the canal edge and in the center of the canal. A 100-ft measuring tape was used to measure canal width. See Table 3-1 for sediment survey data.

3.3.2 MEASURING SEDIMENTS WITHIN THE SUBDIVISIONS

3.3.2.1 Taylor Creek

The first subdivision investigated was the Taylor Creek subdivision located on the west side of Taylor Creek. The two northern-most water bodies in this subdivision are actually ponds, so they were not investigated. The remaining canals within this subdivision appeared similar in length, width, and bank characteristics; the only difference is that one canal (between 29th and 30th Streets) is completely surrounded by homes hooked up to the package sewage treatment plant and another canal (between 30th and 31st Streets south of the previous) is nearly surrounded by homes hooked up to the package sewage treatment plant. These two canals were separated into a different group from the remaining canals within the subdivision thinking that the sediment characteristics may be different because of a possible difference in nutrient loads. Measurements of canal sediments were then conducted in the more northern canal (Figure 3-1). Because the remaining canals within the subdivision appeared similar to one another, the ones to be investigated were chosen randomly throughout the subdivision.

3.3.2.2 Treasure Island

The next subdivision investigated was the Treasure Island subdivision located on the east side of Taylor Creek. The wide variety of physical characteristics (appearance) of the canals in this subdivision made it more difficult to group the canals for the measurement efforts. After several attempts to group the canals according to various characteristics, similarity of length seemed to be the most consistent characteristic that could be used. Treasure Island canals were subdivided into four areas based on this characteristic (Figure 3-1).

The northern-most area of Treasure Island includes eight individual canals that looked relatively similar in appearance and age. These canals were the last to be constructed, so are newer in age compared to the canals in the rest of the subdivisions. Measurements were conducted

Table 3-1. Sediment Surveys

Site No.	Canal Width (ft)	Water Depth (ft)	Sediment Thickness (inches) Edge	Center	Edge
Taylor Creek Subdivision					
1	85	6	3	24	2
2	85	7	12	15	3
3	85	7	3	36	1
4	85	7.5	1	6	1
5	85	7	1	12	0
6	85	7	1	14	1
7	85	7.5	4	13	1
8	85	7.5	0	18	1
9	85	7.5	1	1	1
10	85	7.5	4	14	1
Treasure Island Subdivision					
1	85	8	4	24	6
2	85	8	2	12	10
3	85	6.5	3	6	1
4	85	6.5	2	14	4
5	75	5.25	1	18	3
6	75	6.5	1	14	2
7	75	5	1	1	0
8	75	6.5	2	12	2
9	80	5	22	10	2
10	80	8	2	24	4
11	80	8.5	3	10	0
12	80	9	2	18	1
13	85	11	3	24	2
14	85	9	2	20	3
15	80	10	1	14	1
16	80	8	1	10	1
17	40	4.5	3	20	6
18	40	4.5	1	14	7
19	40	5	6	12	3
20	80	7.5	3	4	3
21	80	7	9	26	6
22	--	3	--	6	--
23	40	4.5	8	24	8
24	40	4.5	4	8	1

Table 3-1. Sediment Surveys (Continued, Page 2 of 2)

Site No.	Canal Width (ft)	Water Depth (ft)	Sediment Thickness (inches) Edge	Center	Edge
Buckhead Ridge Subdivision					
1	75	6	4	22	3
2	75	9.5	9	14	3
3	75	9.5	8	17	5
4	100	7	2	24	3
5	75	9	10	26	2
6	75	9	12	14	20
7	75	10.5	5	19	2
8	75	10.5	2	16	2
9	75	8.5	2	15	2
10	80	5.5	5	5	3
11	80	8	2	6	3
12	80	8	3	4	4
13	100	8	5	9	9
14	80	9	1	6	1
15	60	5.5	2	3	1
16	75	8	2	9	1
17	60	5	3	4	4
18	45	5	1	26	1
19	45	5	3	16	2
20	45	5	8	15	1

Source: ESE.

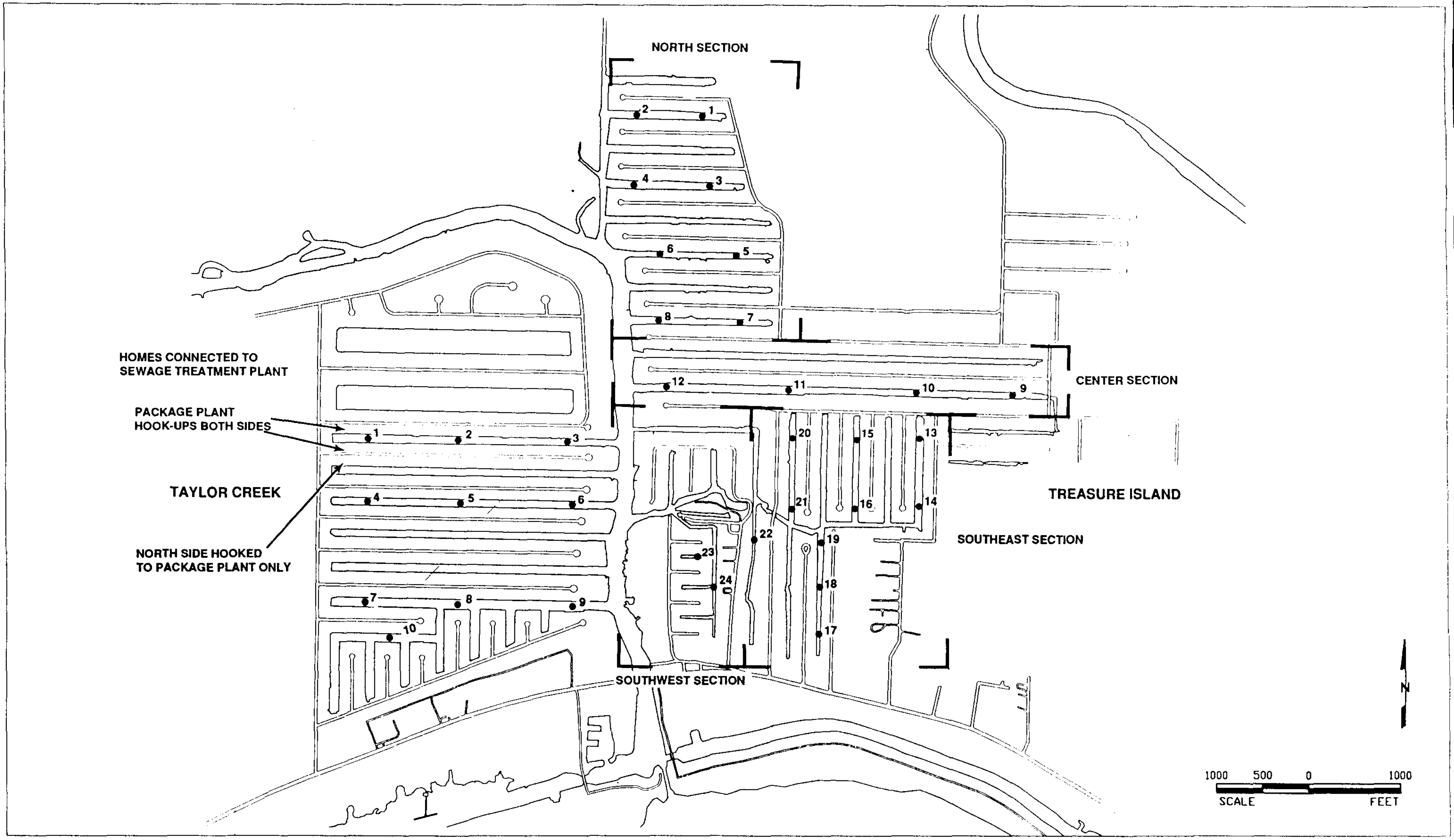

Figure 3-1
SEDIMENT SURVEY POINTS
TAYLOR CREEK AND TREASURE ISLAND SUBDIVISIONS

SOURCE: ESE.

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approximately 100 yards from either end of every other canal (four total).

The next area within Treasure Island that was investigated consisted of the two long canals located in the center of the subdivision. Because the canals were similar in length, the sediments were thought to be similar too. Only one of the two canals was investigated. Measurements were taken at four locations equally spaced throughout the entire length of the canal.

The third area investigated within the subdivision was the southeast corner. The visible differences in the canals of this area were the increased amount and density of the aquatic vegetation, and the overall length and width relative to canals in the other areas. This area did not have as many bulkheads as the other areas but most of the properties were bulkheaded. Another difference was that this area was older than the rest of the subdivision. Every other canal was investigated in this area. Measurements were taken at two locations within each canal, approximately 50 yards from either end of the canals. The only exception was that an additional measurement was taken in the middle of one canal because it was slightly longer than the others.

The fourth area of Treasure Island was the southwest corner, consisting of much shorter and narrower canals than the other areas. Due to thick aquatic vegetation, only two locations were accessible for measurement. This area was being sprayed for weed control during our investigation.

3.3.2.3 Okeechobee Hammocks

The canals within the Okeechobee Hammocks subdivision were not separated into different groups because they were relatively similar in length, width, and age. This subdivision did not appear to have been developed in multiple stages as have the other subdivisions, so all the canals were of similar age. Unlike the previous subdivisions, access to the canals within this subdivision was almost impossible due to thick, overgrown vegetation on the canal banks. Thick aquatic vegetation within the canals also made it virtually impossible for boat travel. Because of these conditions and time restrictions, no physical measurements of the sediments were performed.

3.3.2.4 Buckhead Ridge

The Buckhead Ridge subdivision was the last to be characterized. The canals within this subdivision were separated into two areas, the northeast area and the southwest area (Figure 3-2). The canals in the northeast section appeared visually similar but in the southwest section each canal appeared unique. In the northeast section, sediment characteristics were measured in four out of the nine canals along with the feeder canal or the main canal connecting them all together. Two sets of measurements were taken within the canals. Each measurement location was approximately 75 yards from either end of the canal. One canal was too short to collect measurements at two points, so only one measurement was made.

Within the southwest section of Buckhead Ridge, measurements were random in the canals because there was no pattern to the physical makeup and the configuration of the canals.

3.3.3 SEDIMENT SAMPLING TECHNIQUES

Sediment sampling locations within the four subdivisions were selected based on the physical characteristics of the canals, sediment characteristics within the canals, and geographical position of each canal. A specific location best representing the conditions within that area of the particular subdivision was then chosen. One sampling location was also selected away from any connecting canals, upstream within Taylor Creek itself.

To collect the sediment sample with the least amount of disturbance to the sample itself, two different methods were tried. A petite ponar dredge was the first sampling tool to be used. This dredge created a lot of turbulence at the water-sediment interface causing the uppermost thin layer of fine silty muck to be lost into suspension. The second, more favorable method, was to gently lower a 4-inch piece of PVC pipe to the bottom, push it through the sediment, cap it and pull the pipe up with the sample inside. This

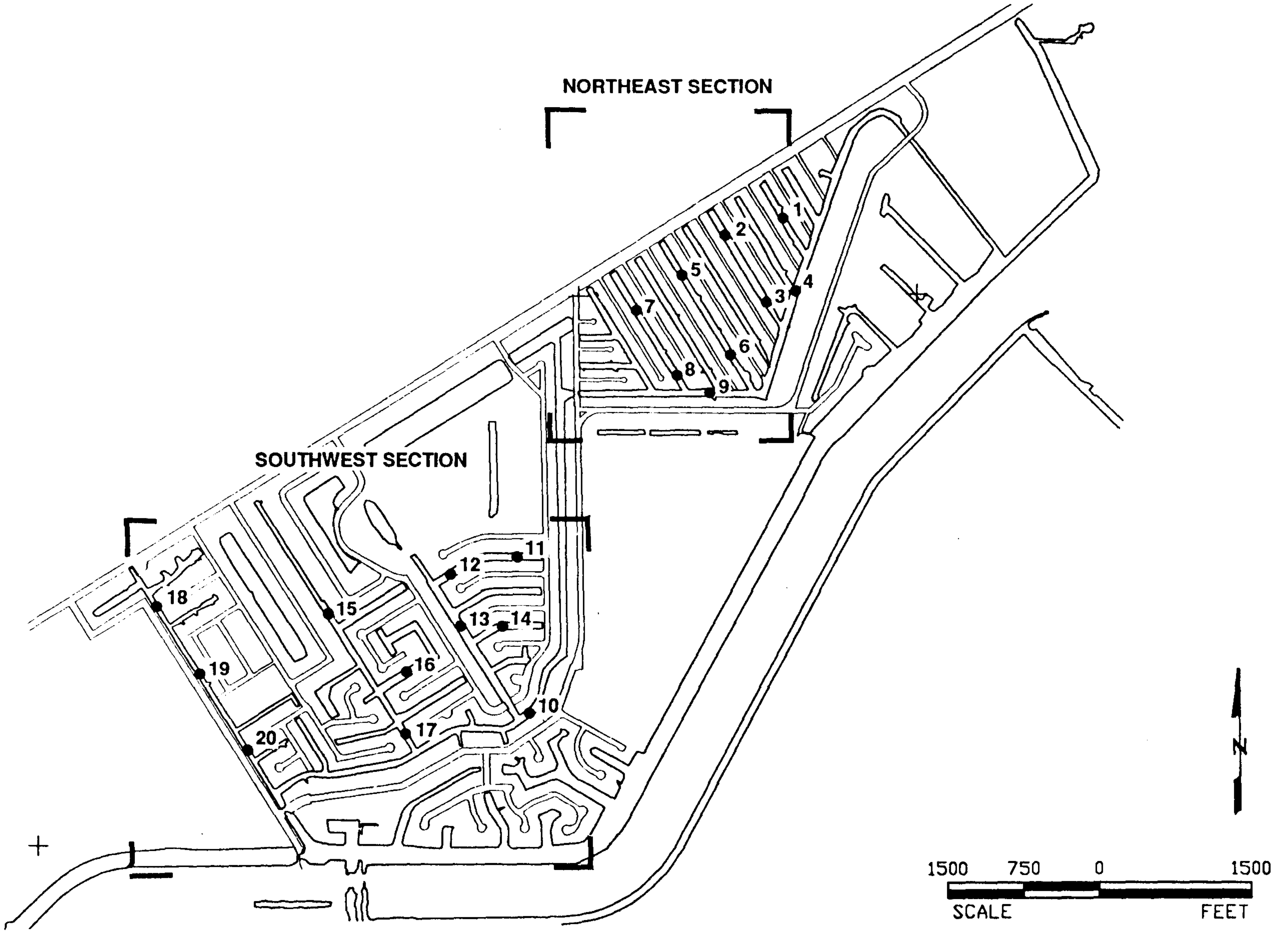

Figure 3-2
SEDIMENT SURVEY POINTS
BUCKHEAD RIDGE SUBDIVISION

SOURCE: ESE.

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P01-1

method was determined to cause the least amount of disturbance and by pushing the pipe through the sediments it was easier to determine when the hard bottom of the canal had been reached. The bottom of the sediment was arbitrarily determined to be the depth at which the sediments began to feel consolidated (PVC pipe insertion was noticeably more difficult).

At each sampling location, three samples were collected and combined into one composite sample. One-third of each sample was collected 5 ft from one side of the canal, one-third collected from the center, and the final one-third collected from the opposite side of the canal. The samples were placed into a stainless steel container, mixed well, then placed into glass containers for transport. This sampling technique was used to give a good cross sectional sample of each canal.

3.3.4 COLLECTING SEDIMENTS

The first sample (OK01) collected was within Taylor Creek itself approximately 50 yards downstream of the Goolsby residence on SE 24th Boulevard (Figure 3-3). The physical makeup of this sample was mostly sand and shell mixed with some organic matter. A very thin muck layer was situated on top of the sediment. Buildup of a substantial amount of organic sediment is probably not possible because of the heavy boat traffic on the creek.

In the Taylor Creek subdivision, four sediment samples were collected. Two samples (OK02 and OK03) were collected in the canal between SE 29th Street and SE 30th Street where homes are connected to a package wastewater treatment plant. One sample (OK02) was collected from the east end of the canal and one sample (OK03) collected from the west end of the canal. The sample (part water and part sediment) collected from the east end of this canal had very small globules of unknown substance floating to the surface of the water and dispersing. The globules did not leave a sheen on top of the water as would a petroleum product. This material could not be identified.

One sample (OK04) was collected in the canal between SE 31st Street and SE 32nd Street. Another sample (OK05) was collected in the canal located between SE 21st Street and SE 23rd Avenue. Each of these three canals are similar, the only difference being that these latter two canals are surrounded by homes on septic tanks while the first is surrounded by homes hooked to the package plant. A comparison of sediments from these canals should show the effects of septic tanks on sediment P content and adsorption capacity.

Within the Treasure Island subdivision, one sample (OK06) was collected in the northern section and one sample (OK07) collected in the southeastern section in order to compare the newer part (northern section) of the subdivision to the older part (Figure 3-3). Since the sediment characteristics were consistent throughout the subdivision, sampling locations were selected based on the age of the canal. The first sample (OK06) was collected in the canal located between SE 23rd Street and SE 24th Street, near the Lewis residence within a newer part of the subdivision. The second sample (OK07) was collected in the canal between SE 36th Avenue and SE 37th Avenue, which is the older of the two canals. At both locations, very small globules were noted floating to the surface of the water in the sample and then dispersing, similar to that observed in the sample collected from the canal not impacted by septic tanks. Samples collected at these locations also smelled of hydrogen sulfide.

The sampling locations for the Okeechobee Hammocks subdivision were selected based solely on geographic location. The first site (sample OK08) is located in the northern region of the main canal just east of SE 60th Drive (Figure 3-4). This location appears to best represent the northern half of the subdivision. The second sampling location (sample OK09) is within the canal between SE 63rd Drive and SE 64th Drive, representing the southern half of the subdivision. The samples collected at both sites had very similar characteristics, containing more mineral matter than muck. The canal bottoms at both locations were also dominated by a thick root mat.

OKEECHOBEE SS 2/92 MH

P03-17

Figure 3-3
SEDIMENT SAMPLING LOCATIONS
TAYLOR CREEK AND TREASURE ISLAND SUBDIVISIONS

SOURCE: ESE.

ESE Environmental Science & Engineering, Inc.
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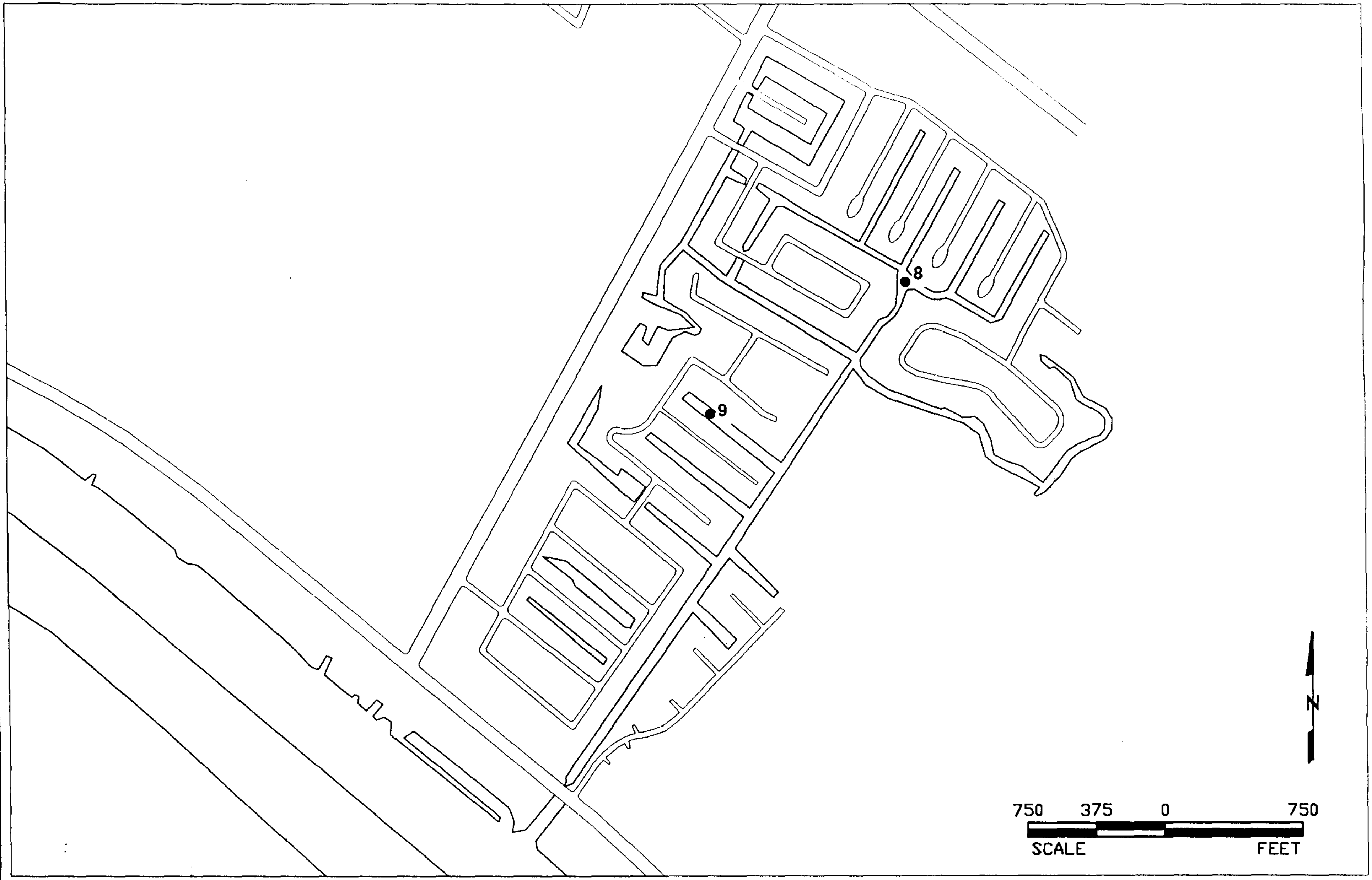

Figure 3-4
SEDIMENT SAMPLING LOCATIONS
OKEECHOBEE HAMMOCKS SUBDIVISION

SOURCE: ESE.

ESE
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Sediment sampling locations were selected in the Buckhead Ridge subdivision based on sediment characteristics and age of the canals. Since the sediment characteristics differed significantly between the two major areas of the subdivision, the northeast (oldest) section and the southwest section, one sample was collected in each area and one sample was collected within the main connecting canal for a total of three samples (Figure 3-5). The first (OK10) was collected in the northeast section between 7th street and 8th Street. This sample was high in organic matter and smelled of hydrogen sulfide. The second sample (OK11) was collected in the main connecting canal between Linda Road and Lake Drive near the Moldenhauer residence. The third (OK12) was collected in the southwest section between 22nd Street and 23rd Street. These last two samples were found to have very similar characteristics.

3.4 SOIL AND SEDIMENT CHARACTERIZATION PROCEDURES

The collected soil and sediment samples were stored in a refrigerated compartment [0 to 4 degrees Celsius (°C)] before they were analyzed. Prior to storage, representative amounts were taken, analyzed for moisture content, and then later subjected to the following analysis.

- Moisture Content - Percent moisture each sample was determined based on ASTM D2974-87 by drying the sample in an oven at 103° to 105°C for 24 hours. The weight loss after drying was used in calculating the moisture content.

- Total P (P) - Total P content was analyzed according to USATHAMA Method KF14 (Determination of Total Phosphate in Soil by Autoanalyzer) after digesting the soil sample in the presence of sulfuric acid and ammonium persulfate. The digestate was then subjected to colorimetric analysis via an automated ascorbic acid reduction method.

- Nitrite + Nitrate - The soil or sediment was prepared by mixing the sample with a mixture of sodium bicarbonate and sodium carbonate based on USATHAMA Method KF10. The filtered extract was analyzed by converting nitrate into nitrite by cadmium reduction method. The nitrite was then colorimetrically determined with the aid of Technicon Analyzer.

- TKN - TKN was determined using Method 351.1 from EPA Methods for Chemical Analysis of Water and Wastes (1983). The sample was initially digested with concentrated H_2SO_4, K_2SO_4, and $HgSO_4$. The ammonia generated from the sample was calculated from the acid-base titration procedure and expressed in terms of N.

- Total N - Total N was calculated from the sum of the concentrations of nitrogen dioxide (NO_2) + nitrate (NO_3) and TKN.

- Total Organic Matter (TOM) - TOM was determined according to ASTM D 2974-87 by measuring the percent weight loss after heating the samples to 440°C in a muffle furnace.

- Exchangeable P - Soil suspensions [2 grams (g) soil: 20 milliliter (mL) 1 M ammonium chloride (NH_4Cl)] were prepared and equilibrated for 1 hour by continuously shaking on a mechanical shaker. After centrifugation, the supernatant liquid was separated, filtered, acidified, and then analyzed for soluble reactive P (dissolved orthophosphate) using an automated ascorbic acid reduction method. This exchangeable P analysis was based on the method of Graetz and Reddy (1991).

- Extractable Iron (Fe) and Aluminum (Al) - Iron and aluminum were extracted according to the method of Graetz and Reddy (1991). A 25 mL mixture of 0.1 M oxalic acid and 0.175 M ammonium oxalate was used in extracting non-crystalling (amorphous) Fe and Al from 0.5 g soil samples. After continuous shaking for 4 hours, the soil suspension was centrifuged, filtered, and then analyzed using Inductively Coupled Argon Plasma (ICAP) instrument.

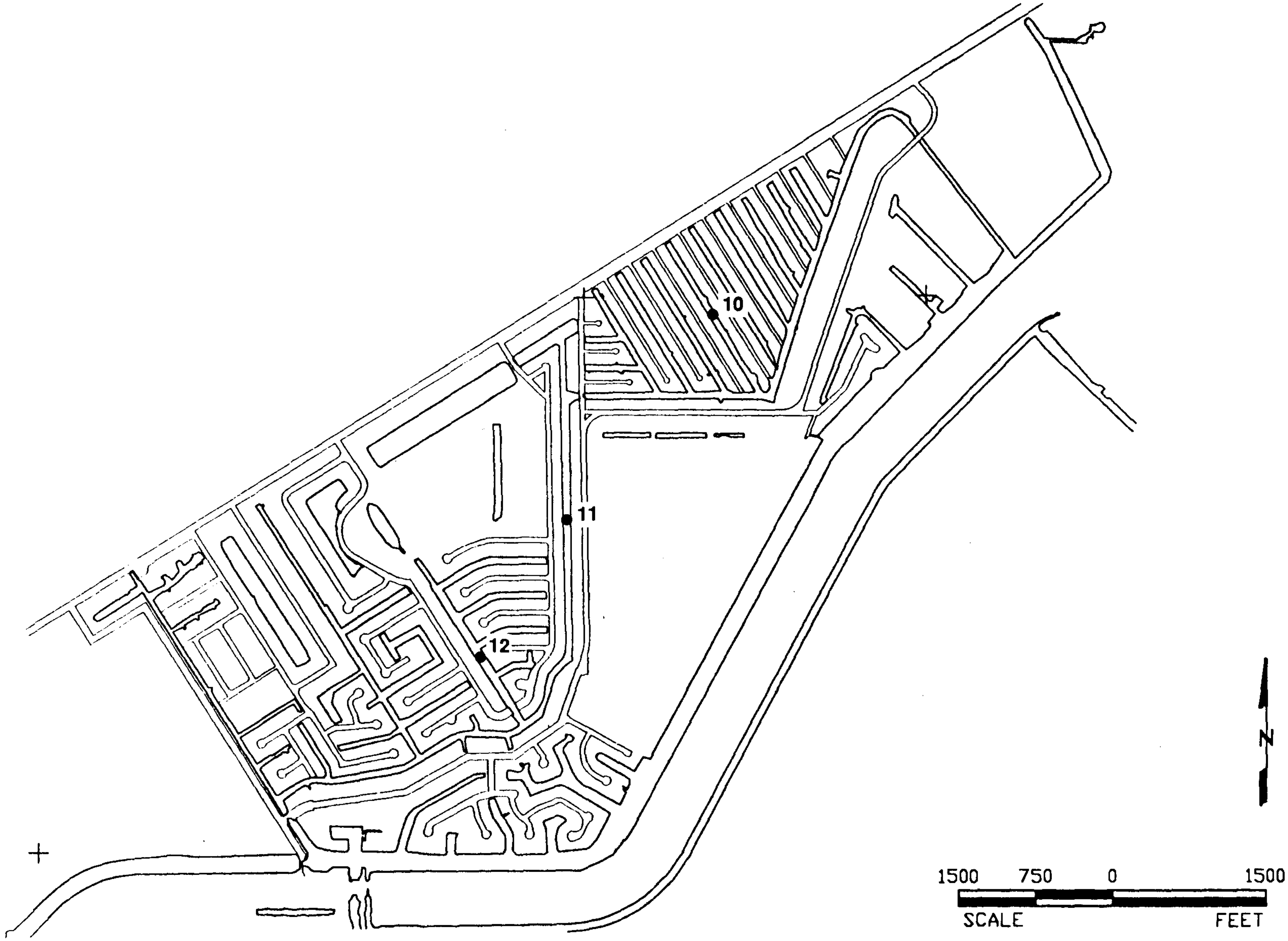

Figure 3-5
SEDIMENT SAMPLING LOCATIONS
BUCKHEAD RIDGE SUBDIVISION

SOURCE: ESE.

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- Phosphate Adsorption Isotherm - A batch incubation procedure of Graetz and Reddy (1991) was used in evaluating adsorption isotherms. Two grams of air-dried soil were equilibrated with 20 mL of 0.01 M potassium chloride (KCl) solution containing 5, 10, and 50 micrograms P per milliliter (μg P/mL) [prepared using potassium phosphate (KH_2PO_4) analytical reagent]. These concentrations were selected based on the exchangeable P data and environmental concentrations of P in surface waters located in the vicinity of the study areas. After a 24-hour equilibrium period, the soil solution was centrifuged. The supernatant liquid was removed, filtered, acidified, and analyzed for orthophosphate using an automated ascorbic acid reduction procedure. The P lost from the solution was assumed to be sorbed by the soil. The solution concentrations and amounts of phosphate retained by the soil were then evaluated according to two adsorption isotherms:

  (1) Freundlich

  $$Cs = K\,Ce^{\frac{1}{n}} \text{ which can be logarithm transformed to}$$

  $$\log Cs = \log K + \frac{1}{n} \log Ce \tag{3-1}$$

  where: Cs = sorbed concentration of P in the solid phase (mg/kg),
  Ce = solution concentration of P (mg/L), and
  K and n = Freundlich adsorption coefficient expressing the sorption capacity of the soil (kg/L) and the adsorption intensity, respectively.

  (2) Langmuir

  $$\frac{Ce}{Cs} = \frac{1}{bQ} + \frac{Ce}{Q} \tag{3-2}$$

  where: Q = P adsorption maximum (mg/kg), and
  b = a constant related to binding energy (L/mg).

  Values of the constants K and 1/n of Freundlich's isotherm were evaluated by plotting log Cs against log Ce to obtain the slope and intercept. For Langmuir isotherm, the plot of Ce/Cs against Ce yielded a slope and an intercept which, in turn were equated to 1/bQ and 1/Q, respectively.

  Values of exchangeable P, extractable Al and Fe, and adsorbed P concentrations were calculated by taking into account the initial concentration of each analyte detected in the blank or control solutions.

3.5 SURFACE WATER QUALITY SAMPLING STATIONS

Surface water quality sampling stations were selected based on the following criteria:

1. Sampling upstream water quality,
2. Sampling downstream water quality exiting a subdivision, and
3. Sampling water within individual canals.

The sampling efforts are limited to sampling stations within Buckhead Ridge, Taylor Creek Isles, and Okeechobee Hammocks. Sample stations were not selected within Treasure Island because the conditions appeared similar to Taylor Creek Isles located on the opposite side of Taylor Creek. Sampling station locations are identified on the site maps (Figures 3-6, 3-7, and 3-8). The description of sampling rationale for each station follows.

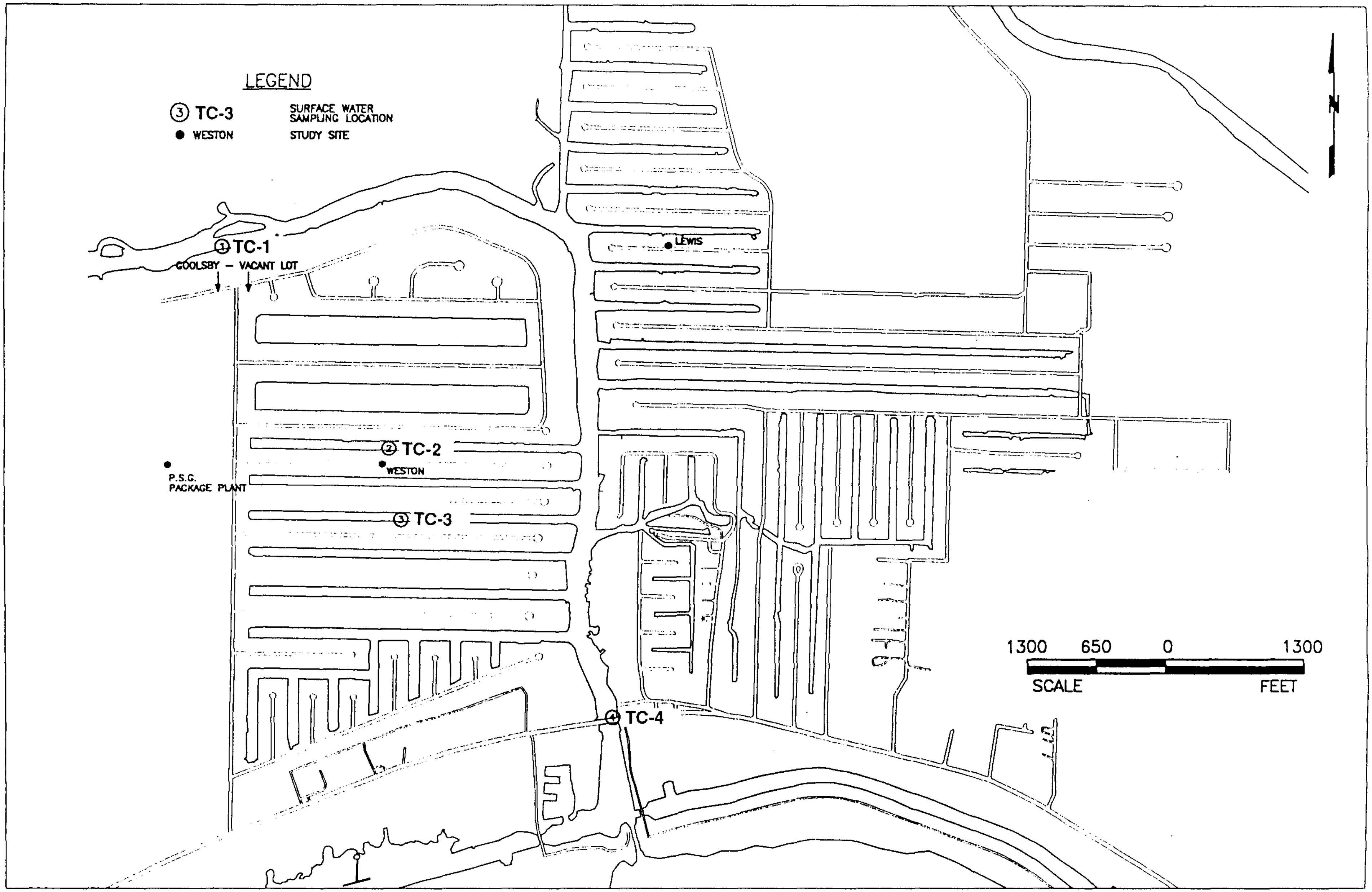

Figure 3-6
MAP OF TAYLOR CREEK ISLES AND TREASURE ISLAND SUBDIVISIONS SHOWING SURFACE WATER SAMPLING STATIONS AND STUDY SITES

SOURCE: AERIAL PHOTO, 1986; ESE.

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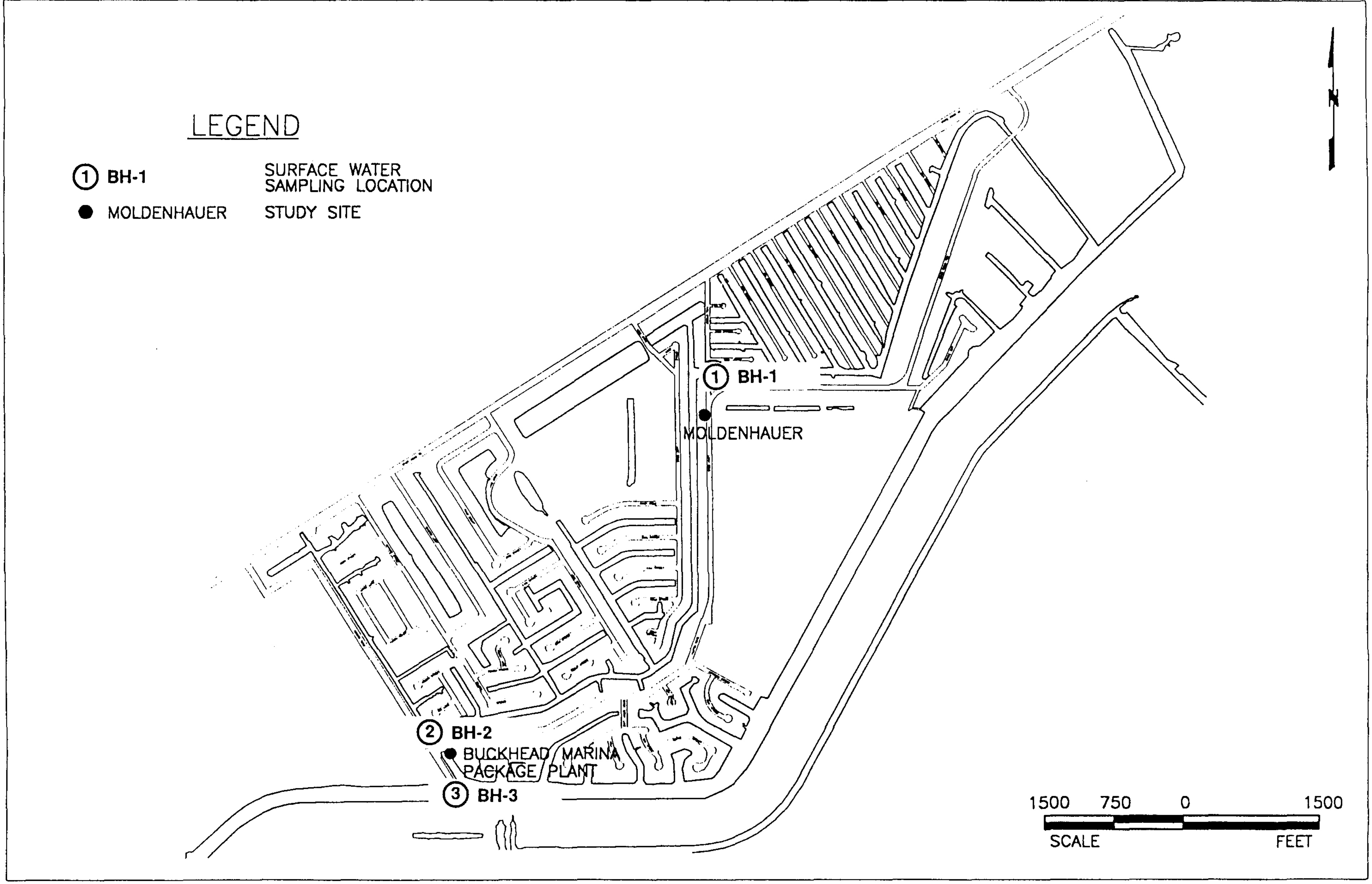

Figure 3-7
MAP OF BUCKHEAD RIDGE SUBDIVISION SHOWING SURFACE WATER SAMPLING STATIONS AND STUDY SITES

SOURCE: AERIAL PHOTO, 1986; ESE.

Environmental Science & Engineering, Inc.
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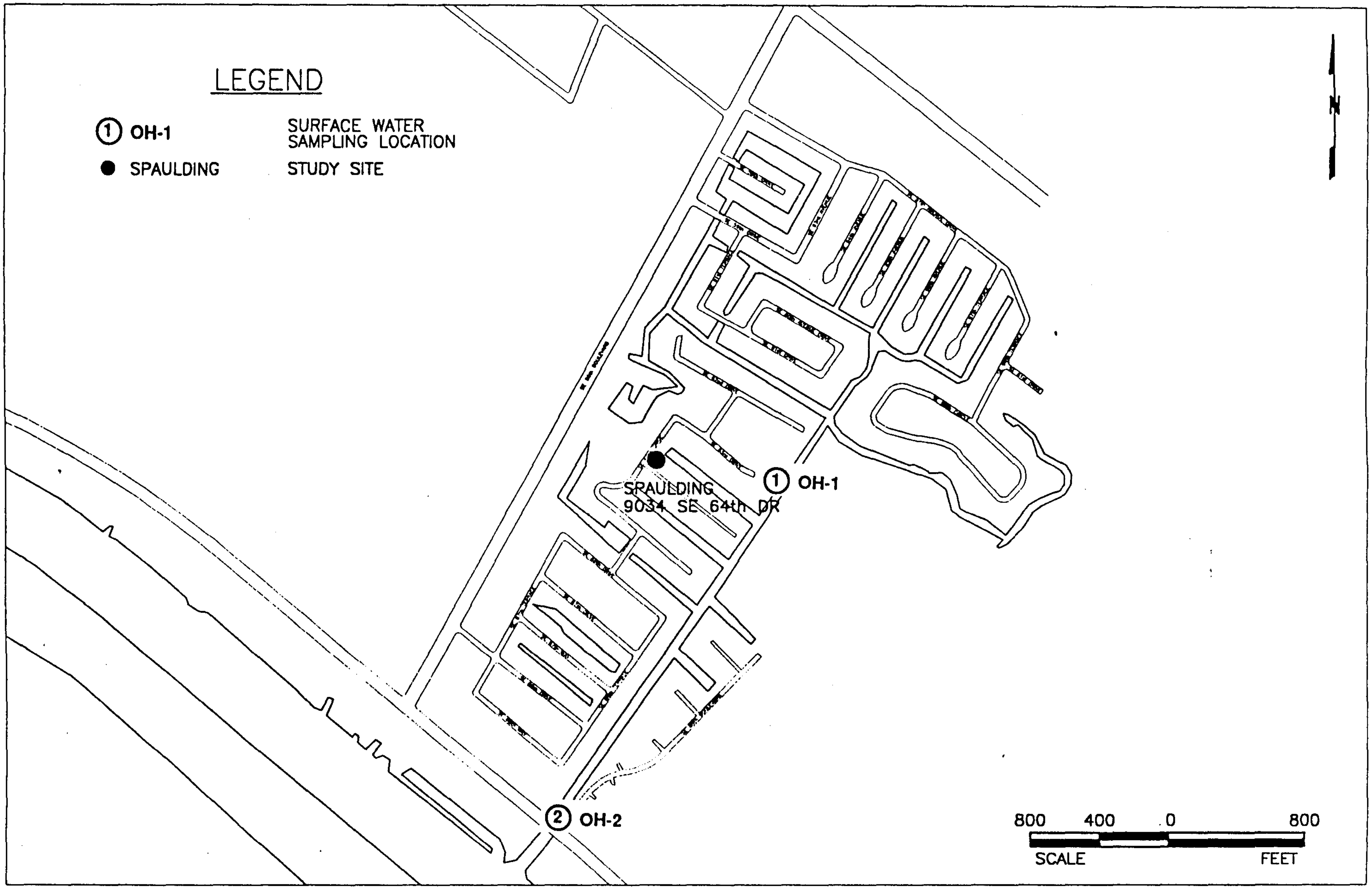

Figure 3-8
MAP OF OKEECHOBEE HAMMOCKS SUBDIVISION SHOWING SURFACE WATER SAMPLING STATIONS AND STUDY SITES

SOURCE: AERIAL PHOTO, 1986; ESE.

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3.5.1 TAYLOR CREEK ISLES SAMPLING LOCATIONS

Four stations were selected within or adjacent to Taylor Creek Isles.

TC-1: This station is located on Taylor Creek upstream of both Taylor Creek Isles and Treasure Island subdivisions and was selected to observe the quality of water entering the area. This sampling location will serve as the background or baseline sample location.

TC-2: This station was selected to observe the quality of water in a canal that is not surrounded by septic tanks. The houses on 29th and 30th Streets are connected to a package sewage treatment plant located approximately one-quarter mile east of the area. Water within the canal between these streets should only be affected by non-septic tank sources such as pesticides, fertilizers for nutrients, and house pets or wildlife for coliforms.

TC-3: This station was selected near TC-2 but on a canal surrounded by houses with septic tanks. The close proximity of this location with the previous location should provide a comparison of septic tank inputs without the variability associated with major changes in environmental conditions.

TC-4: This station was selected near the confluence of Taylor Creek and the rim canal to observe the quality of water that is likely flowing out of the two subdivisions. This sampling location can be compared with the background station (TC-1) to investigate whether Taylor Creek water quality increases, decreases, or remains stable after passing the adjacent finger canals.

3.5.2 BUCKHEAD RIDGE

Three stations were selected within Buckhead Ridge. The canal plan appears to be separated into three sections: one bounded by Linda Road and U.S. Highway (U.S.) 78, another west and northwest of Hunter Road, and the third south of both Hunter Road and Cypress Street.

BH-1: This station was selected to observe the water quality from the section bounded by Linda Road and U.S. 78. Information from this station will indicate the combined effects of being far from a canal discharge location (distant from a potential flushing point) and being downstream from a significant number of active septic tanks. This location will also be a background location for the area west of Hunter Road.

BH-2: This station was selected to observe the water quality leaving the area bounded by Hunter Road and U.S. 78, but also represents the downstream water quality from the area previously described. This sampling location represents the combined effects of both of these major areas of the subdivision.

BH-3: This station was selected to observe the overall water quality coming from the entire Buckhead Ridge area. This location will represent the quality of water potentially entering the rim canal.

3.5.3 OKEECHOBEE HAMMOCKS

Two sampling locations were chosen for the Okeechobee Hammocks subdivision.

OH-1: This station was selected to observe the water quality midway into the subdivision along one of the main canals.

OH-2: This station was selected to observe the overall water quality leaving the Okeechobee Hammocks area and potentially entering the rim canal.

3.6 MONITOR WELL INSTALLATION

To evaluate potential groundwater quality impacts resulting from each type of septic tank system used in the Lake Okeechobee study area, monitor wells were installed at various locations throughout the subdivisions. The sites chosen for the study are the same as described previously for the soil sampling program. The activities involved in these efforts consist of finding the plume of septic tank effluent, installing monitor wells to sample the groundwater within the plume, installing piezometers, conducting groundwater elevation surveys to confirm groundwater flow direction, slug testing to measure the hydraulic conductivity of the aquifer, and installing suction lysimeters to sample the soil water directly under the drainfields.

3.6.1 MONITOR WELL INSTALLATION

Monitor wells were installed at each of the six sites used for this study. The well designations for the sites are as follows: Moldenhauer (M), Lewis (L), Goolsby (G)/Vacant lot (V), Spaulding (S), and Weston (W). A package wastewater treatment plant with existing monitor wells was also included as part of this study. Table 3-2 specifies the type of system and the number of wells installed at each site. Monitor well locations were chosen based on conductivity measurements, local topography, and inferred groundwater flow direction at each site, with respect to the location of the septic tank/drainfield system. The exact location of the monitor well relative to the drainfield was finalized using conductivity measurements of groundwater accessed from soil borings.

Three wells (M-1, M-2, and M-3), were installed at the Moldenhauer site, as shown on Figure 2-1. The wells were located as follows: M-1 downgradient, M-2 immediately downgradient (source well), and M-3 upgradient of the septic tank. Monitor wells M-1 and M-3 were installed to a depth of 12 feet below land surface (ft-bls), and M-2 was installed to a depth of 11 ft-bls.

Monitor wells for the Lewis, Goolsby, and Spaulding sites (wells L-1, G-1, and S-1, shown in Figures 2-2, 2-3, and 2-4, respectively) were all installed downgradient from each respective septic tank and drainfield. Monitor well G-1 was installed to a depth of 14 ft-bls, and L-1 and S-1 were installed to a depth of 17 ft-bls.

Monitor wells for the vacant lot and Weston sites (wells V-1 and W-1, shown in Figures 2-3 and 2-5, respectively) were installed to evaluate two kinds of background conditions. Well W-1 was located on a lot at a residence served by a public sewer system and was installed to a depth of 16 ft-bls. Samples from this well should reflect impacts from fertilizer or other nonseptic tank source of nutrients. The V-1 well was installed on a vacant lot, next to the Goolsby residence, to a depth of 12 ft-bls. Samples from this well should show actual background groundwater quality without septic tank or nonseptic tank nutrient inputs. The Package Plant well location is provided on Figure 2-6.

Each monitor well was installed using 8-inch-diameter hollow-stem auger flights. Prior to well installation, all PVC well screens and casings were decontaminated by steam cleaning. The wells were constructed of 2-inch-diameter, Schedule 40 PVC, with threaded joints and a 10-ft section of 0.010-inch slot screen. The annular space between the well screen and borehole was filled with clean, washed 20/30 silica sand to a depth approximately 1 ft above the top of the well screen. A minimum 0.5-ft layer of clean, washed, fine sand was placed as a seal above the sand pack. The remaining annular space was filled to land surface with cement. Each monitor well was finished flush to land surface with a concrete pad (2 ft x 2 ft x 2 inches). A protective manhole casing and cover, with a locking water-tight cap, was provided. The manhole covers were adequately labeled to distinguish them as monitor wells. Well completion diagrams and geologic boring logs that the ESE field geologist developed are provided in Appendix B. Well completion information is summarized in Tables 3-3 through 3-8.

Following monitor well installation, the wells were developed by purging with a centrifugal pump. Development was discontinued after enough sand and silt-sized particles were removed to satisfy the site geologist. The correct downgradient locations for the wells were confirmed by measuring the conductivity of the development water. As long as the conductivity was greater than 1,000 micromhos per centimeter (μmho/cm), it was assumed that the wells were within the drainfield's plume.

Table 3-2. Septic Tank Sites - Monitoring Points

Name	Type of System	No. of Monitoring Wells	No. of Piezometers	No. of Lysimeters
Moldenhauer	Old	3	2	1
Lewis	Old	1	4	1
Spaulding	New	1	4	1
Goolsby	New	1	4	1
Vacant Lot	N/A	1	1	1
Weston	Central Sewer	1	4	1
Package Plant	Percolation Ponds	2	2	1

Source: ESE, 1991.

Table 3-3. Moldenhauer Site Monitoring Well/Piezometer Data

Well/ Piezometer Number	Depth (ft)	Screened Interval	Top of Casing Elevation (ft)	Depth to Water 10/24/91 (ft)	Water Elevation 10/24/91 (ft)	Depth to Water 6/8/92 (ft)	Water Elevation 6/8/92 (ft)	Depth to Water 9/2/92 (ft)	Water Elevation 9/2/92 (ft)	Hydraulic Conductivity (ft/day)
M-1	12.0	2-12	100.00	3.85	96.15	4.16	95.84	3.80	96.20	12.9
M-2	12.0	2-12	100.44	4.33	96.11	4.65	95.79	4.03	96.41	9.8
M-3	12.0	2-12	101.07	5.09	95.98	5.45	95.62	4.24	96.83	4.3
PZ-1	5.0	0-5	100.60	4.44	96.16	4.64	95.96	4.37	96.23	NM
PZ-2	5.0	0-5	100.65	4.62	96.03	4.69	95.96	4.16	96.49	NM

Note: NM = not measured

Elevations referenced to an arbitrary datum of 100.00 ft set for M-1.

Source: ESE, 1992.

Table 3-4. Lewis Site Monitoring Well/Piezometer Data

Well/ Piezometer Number	Depth (ft)	Screened Interval	Top of Casing Elevation (ft)	Depth to Water 10/24/91 (ft)	Water Elevation 10/24/91 (ft)	Depth to Water 6/8/92 (ft)	Water Elevation 6/8/92 (ft)	Depth to Water 9/2/92 (ft)	Water Elevation 9/2/92 (ft)	Hydraulic Conductivity (ft/day)
L-1	17.0	7-17	100.00	6.56	93.44	6.79	93.21	6.63	93.37	18.9
PZ-1	8.0	3-8	100.19	6.63	93.56	6.96	93.23	6.47	93.72	NM
PZ-2	7.0	2-7	101.26	6.68	93.58	6.84	93.42	6.56	93.70	NM
PZ-3	8.0	3-8	100.15	6.63	93.52	6.92	93.23	6.67	93.48	NM
PZ-4	4.0	0-4	95.90	2.42	93.48	2.68	93.22	2.69	93.21	NM

Water levels referenced to an arbitrary datum of 100.00 ft set for L-1.

Source: ESE, 1992.

Table 3-5. Goolsby Site Monitoring Well/Piezometer Data

Well/ Piezometer Number	Depth (ft)	Screened Interval	Top of Casing Elevation (ft)	Depth to Water 10/24/91 (ft)	Water Elevation 10/24/91 (ft)	Depth to Water 6/8/92 (ft)	Water Elevation 6/8/92 (ft)	Depth to Water 9/2/92 (ft)	Water Elevation 9/2/92 (ft)	Hydraulic Conductivity (ft/day)
G-1	14.0	4-14	102.98	3.88	99.10	4.99	97.99	3.41	99.57	5.9
PZ-1	5.0	0-5	102.23	3.47	98.76	4.35	97.88	2.41	100.06	NM
PZ-2	4.5	0-4.5	101.85	2.77	99.08	3.70	98.15	1.67	100.18	NM
PZ-3	3.5	0-3.5	100.41	2.25	99.16	2.67	97.74	2.19	98.22	NM
V-1	13.0	3-13	100.00	2.03	97.97	2.33	97.67	2.02	97.98	6.7

Water levels referenced to an arbitrary datum of 100.00 ft set for V-1.

Source: ESE, 1992.

Table 3-6. Spaulding Site Monitoring Well/Piezometer Data

Well/ Piezometer Number	Depth (ft)	Screened Interval	Top of Casing Elevation (ft)	Depth to Water 10/24/91 (ft)	Water Elevation 10/24/91 (ft)	Depth to Water 6/8/92 (ft)	Water Elevation 6/8/92 (ft)	Depth to Water 9/2/92 (ft)	Water Elevation 9/2/92 (ft)	Hydraulic Conductivity (ft/day)
S-1	17.0	7-17	100.00	5.54	94.46	4.66	95.34	5.92	94.08	23.3
PZ-1	6.0	1-6	99.39	4.48	94.91	2.71	96.68	3.41	95.98	NM
PZ-2	6.0	1-6	99.84	4.04	95.80	3.85	95.99	5.01	94.83	NM
PZ-3	6.0	1-6	99.71	4.87	94.84	4.45	95.26	5.61	94.10	NM
PZ-4	6.0	1-6	98.20	4.98	93.22	3.81	94.39	4.37	93.83	NM

Water levels referenced to an arbitrary datum of 100.00 ft set for S-1.

Source: ESE, 1992.

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Table 3-7. Weston Site Monitoring Well/Piezometer Data

Well/ Piezometer Number	Depth (ft)	Screened Interval	Top of Casing Elevation (ft)	Depth to Water 10/24/91 (ft)	Water Elevation 10/24/91 (ft)	Depth to Water 6/8/92 (ft)	Water Elevation 6/8/92 (ft)	Depth to Water 9/2/92 (ft)	Water Elevation 9/2/92 (ft)	Hydraulic Conductivity (ft/day)
W-1	16.0	6-16	100.00	5.98	94.02	6.09	93.91	5.97	94.03	19.5
PZ-1	5.0	0-5	98.94	4.62	94.32	4.75	94.19	4.36	94.58	NM
PZ-2	6.0	1-6	99.30	5.11	94.19	5.14	94.16	4.72	94.58	NM
PZ-3	6.0	1-6	98.67	4.46	94.21	4.73	93.94	4.67	94.00	NM
PZ-4	3.0	0-3	95.66	1.51	94.15	1.75	93.91	1.91	93.75	NM

Water levels referenced to an arbitrary datum of 100.00 ft set for W-1.

Source: ESE, 1992.

Table 3-8. Package Plant Site Monitoring Well/Piezometer Data

Well/ Piezometer Number	Depth (ft)	Screened Interval	Top of Casing Elevation (ft)	Depth to Water 10/24/91 (ft)	Water Elevation 10/24/91 (ft)	Depth to Water 6/8/92 (ft)	Water Elevation 6/8/92 (ft)	Depth to Water 9/2/92 (ft)	Water Elevation 9/2/92 (ft)	Hydraulic Conductivity (ft/day)
P-1	17.0	Unk	100.00	3.98	96.02	6.71	93.29	5.34	94.66	12.2
PZ-1	17.09	Unk	100.06	NM	NM	NM	NM	NM	NM	NM
PZ-2	10.0	5-10	103.87	NM	NA	9.62	94.25	8.61	95.26	NM
PZ-3	8.0	3-8	101.38	NM	NM	NM	NM	6.26	95.12	NM
Perc Pond B	NA	NA	NA	NA	99.93	NA	NM	NM	NM	NM

Note: NA = not applicable.
Unk = unknown.

Water levels referenced to an arbitrary datum of 100.00 ft set for P-1.

Source: ESE, 1992.

3.6.2 PIEZOMETER INSTALLATION

Piezometers were installed at each of the sites where monitor wells were installed to facilitate evaluation of the groundwater flow direction at each site. The number of piezometers installed at each site varied depending on the number of wells located at each site, as provided in Table 3-2.

At the Moldenhauer site, two piezometers (PZ-1 and PZ-2) were installed along the northern property boundary (Figure 2-1) and located in a triangular arrangement with the three monitor wells. The Lewis, Spaulding, and Weston sites have four piezometers each (PZ-1 through PZ-4), located at the four corners of the lots. The Lewis, Spaulding, and Weston piezometer locations are shown on Figures 2-2, 2-4, and 2-5, respectively. Two piezometers (PZ-1 and PZ-2) were installed at the Package Plant as shown on Figure 2-6. The Goolsby and vacant lot sites are adjoining sites (Figure 2-3) in which three piezometers were located, one each at the northwest, southwest, and southeast corners.

Piezometers were installed with a decontaminated 4-inch ID stainless steel hand auger. As the auger was advanced, soil was removed in approximately 6-inch intervals. Augering continued to just below the water table or as deep as possible. The auger bucket was then removed and a 5-ft section of 2-inch Schedule 40 0.01-inch slotted PVC casing, attached to an appropriate length of solid 2-inch Schedule 40 PVC casing, was placed in the borehole and driven to refusal. The annulus between the 2-inch casing and the borehole was then backfilled with native sand. A slip-cap was then placed on top of the piezometer and a concrete pad and flush mount protective cover provided.

The top of casing (TOC) elevation for each completed piezometer was surveyed and referenced to an arbitrary datum of 100.00 ft established for a particular piezometer at each site. This information was used to calculate the groundwater flow direction.

3.6.3 ELEVATION SURVEY AND HYDRAULIC CONDUCTIVITY TESTING

The TOC elevation for each completed monitor well and piezometer was surveyed and referenced to an arbitrary datum of 100.00 ft established for a particular monitor well at each site. Subsequent water levels measured below the TOC were then corrected to the arbitrary datum. Water level and survey data for each site are provided in Tables 3-3 through 3-8.

Slug tests were performed on specific monitor wells at each site to evaluate the hydraulic properties of the onsite shallow aquifer. The slug test procedure involved placing a pressure transducer, which is attached to a data logger, into a well, just above the base of the well. After securing the pressure transducer cable to the well, a weighted cylinder (slug) was inserted into the well to induce groundwater level changes. The water level changes in the well were continuously recorded by the data logger. Upon removal of the slug, the water level changes in the well were also recorded by the data logger. The slug test procedure was performed twice on each well and the average value used to determine flow velocities.

The recorded data were transferred in the office from the data logger to a computer. A geologist subsequently evaluated the data to determine the hydraulic conductivity of the aquifer, based on methods developed by Hvorslev (1951), Bouwer and Rice (1976), and Bouwer (1989). Only slug-out test data were used for this analysis because of interference effects from the discharge of groundwater into unsaturated sediments during slug-in testing. Using the water level and slug test data derived from each site, estimates of groundwater flow velocities were made for each site.

4.0 RESULTS

4.1 <u>SOILS</u>

4.1.1 FIRST YEAR SAMPLING PROGRAM

The first year soil sampling program was designed to characterize the soil P and N status of the soil under various septic tank drainfields to see if P and N were accumulating somewhere under the drainfield and/or somewhere along the top of the water table out toward the canal. Soil samples were collected at near regular intervals between the bottom of the drainfields and the top of the water table and other samples collected at regular intervals along the top of the water table from the drainfield to the canal. Table 4-1 presents the values of percent moisture, total P, exchangeable P, nitrate+nitrite-N ($NO_2 + NO_3$), TKN, and TOM.

4.1.1.1 Phosphorus

The total P content of the soils varies from 72 mg/kg in samples OKEES1-17 and OKEES1-19 to 3,250 mg/kg in OKEES1-5. Two trends in soil P concentrations can be observed in the table; one trend depends on where the sample was collected and the other trend depends on soil characteristics. In general, P appears to have accumulated in a particular location along the top of the water table under each drainfield. At Goolsby and Lewis sites, that location is directly under the drainfield. This area of accumulated P is 5 to 10 ft downgradient of the drainfield at the Spaulding residence. This observation is interesting considering that the unsaturated zone of soils is supposed to be the treatment zone under drainfields. These areas of accumulation are at the top of the water table and somewhat downgradient of the drainfield which indicates that migration of P is taking place. It appears as if a slug of P is moving through the soils at the Spaulding site.

The second trend in P concentrations can be observed by comparing the difference in concentrations between fill and Oa (organic soil horizon) materials. Total P concentrations in the fill material, on average, are less than half of the P concentrations found in the Oa samples. The primary difference between these two sample types is the percentage organic matter, which appears to control soil P concentrations.

Exchangeable P (Table 4-1) was at least an order of magnitude smaller than total P in these samples. This observation is important because it implies that the soils have somehow fixed the P so that it is no longer available for migration. P in drainfield leachate is apparently only mobile for a short period of time before being fixed in the more organic materials under the drainfields. Only 4 of 24 samples exhibited detectable levels of exchangeable P; each was a sample of fill material. Exchangeable P and total P values were not comparable. Samples with low and medium levels of total P exhibited detectable exchangeable P. The samples with the highest total P should each exhibit higher levels of exchangeable P; however, these data did not substantiate this hypothesis.

4.1.1.2 Nitrogen

Most of the N in the soil samples exists in the form measurable by the TKN method. This implies that the soil samples have more organic N--several orders of magnitude more than inorganic N in the form of nitrate and nitrite. Soil N concentrations vary in similar magnitude and amount as soil P concentrations. The N does not appear to have a similar positional distribution as soil P. The soil N concentrations are more evenly distributed through the soil profile and along the top of the water table. This is likely a function of the greater mobility of N in soils versus lower mobility of P. Soil N concentrations do not appear to be as strongly related to soil type as does soil P. The average soil N concentrations (arithmetic or geometric) of the fill samples are about one third smaller than the average of the organic samples. The lack of an observed pulse of N throughout the route of migration to the canal implies that the soil may have reached equilibrium with respect to N. The soil may no longer be capable of treating or attenuating N, allowing it to migrate from the drainfields to the canal.

4.1.2 SECOND YEAR SAMPLING PROGRAM

The second year soil sampling plan was designed to determine the background (no septic tank leachate impacts) N and P status of soils that best represent the majority of land areas of the four subdivisions. In this part of the soil investigation, the analytical investigation consisted of total and exchangeable P; nitrate-N, nitrite-N, TKN, extractable aluminum and iron; TOM; moisture;

Table 4-1. Results of Soil Analyses for Samples Collected Under Septic Tank Drainfields

Sample Number	Site and Soil Series	Depth (Inches From Surface)	Horizon or Soil Type	Texture	Percent Moisture	Total Phosphorus (mg/kg)	Exchangeable Phosphorus (mg/kg)	$NO_2 + NO_3$ (mg/kg as N)	TKN (mg/kg as N)	TOM (%)
OKEES1-1		24-48	Fill	FS	0.3	196	6.4	6.3	1,910	1.4
OKEES1-2		55-66	Oa*	Muck	17.3	519	--	<0.60	780	39.5
OKEES1-3	1	66-80	Oa†	Muck	3.8	101	--	0.15	5,870	36.1
OKEES1-4		60-72	Oa*	Muck	33.7	1,590	--	0.81	616	36.8
OKEES1-5		60-70	Oa*	Muck	39.4	3,250	--	4.06	5,790	42.0
OKEES1-6		67-78	C*	FS	27.1	2,070	--	<0.14	1,000	4.8
OKEES1-7		64-72	Oa*	Muck	27.4	1,190	--	1.41	8,910	40.6
OKEES1-8		64-72	Fill*	FS	8.1	240	--	1.18	3,130	25.9
OKEES1-9		25-33	Fill	FS	0.5	219	0.6	3.81	485	61.5
OKEES1-10		50-60	Fill	FS	0.3	90	1.9	4.11	550	0.6
OKEES1-11		70-75	Bh*	FS	1.1	1,240	--	2.67	119	1.8
OKEES1-12	2	75-82	Bh†	FS	1.4	883	--	0.77	467	2.0
OKEES1-13		65-72	Fill*	FS	15.2	1,010	3.8	3.48	460	1.6
OKEES1-14		68-72	Fill*	FS	1.0	900	--		0.76	2911.9
OKEES1-15		48-60	Fill*	FS	0.6	608	--	0.15	622	1.4
OKEES1-16		26-38	Fill*	FS	0.6	381	--	0.42	333	1.4
OKEES1-17		35-42	Fill	FS	0.2	72	--	0.48	417	0.6
OKEES1-18		60-68	Oa*	Muck	4.3	1,480	--	8.57	645	9.1
OKEES1-19		78-85	C†	FS	0.5	72	--	0.36	521	2.7
OKEES1-20	3	55-65	Oa*	Muck	6.0	1,560	--	9.02	838	11.6
OKEES1-21		58-65	Oa*	Muck	4.6	731	--	5.57	102	21.5
OKEES1-22		50-60	Oa*	Muck	5.5	690	--	2.35	796	13.4
OKEES1-23		54-65	Oa*	Muck	4.0	480	--	2.22	882	20.1
OKEES1-24		36-48	Fill*	FS	4.2	675	--	0.99	499	11.4

Note: -- = not detected.
FS = fine sand.

1. Site = Spaulding. Soil type = Okeelanta Peat.
2. Site = Lewis. Soil type = Immokalee.
3. Site = Goolsby. Soil type = Okeelanta Peat.

*Sample collected at top of water table.
†Sample collected beneath water table.

Source: ESE.

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and the Langmuir Q value for P adsorption capacity; on the 36 soil samples collected from important soil series within the four subdivisions. Results are presented in (Table 4-2). Three samples were collected from each of two locations per soil series, providing duplicate results. The horizon/soil type designation will help identify the duplicate samples within the set. Compared to the soils collected under the drainfields, the samples in this group generally have lower total P and total N than the soils collected under the drainfields. The extractable iron and aluminum values will be used in assessing P adsorption.

4.1.2.1 Phosphorus

The soil series that were sampled as part of this study represent Immokalee, Delray, Fill materials, Malabar, and Okeelanta. This variety of soil series results in individual samples from organic horizons, spodic horizons, topsoil, and other subsurface horizons. Comparing or contrasting fill materials with soils is not as easy for these samples as for the previous samples. It appears as if more environmental factors have an effect on the N and P content of these samples because the concentrations are much closer to or at background levels. Some of these environmental factors include effects of fertilizer applications, historical use of the native (original) soils, and soil characteristics.

Total P concentrations were averaged by soil type (fill, surface horizon, and various subsurface horizons) to begin looking for comparisons. Depending on how the averages were calculated, the fill total P concentrations are anywhere from half to four times smaller than native soil total P concentrations. One noticeable trend (affecting P content) within the fill samples is that samples collected near the soil surface exhibited higher total P than samples of fill collected at depth (likely an effect of fertilizer applications). The characteristics of the native soil E and C horizons are similar to the fill materials--all have low TOM and exhibit similar total P content. Soil samples collected from other horizons (surface or spodic) contrast with the fill, generally having higher amounts of organic matter and/or soil total P. When samples from these horizons are excluded from the average total P contents of native soils, the average increases. The samples with higher organic matter generally contain more P.

Total P content of these samples was an average of up to an order of magnitude smaller than the total P observed in samples collected under the septic tank drainfields. The same differences were observed for the fill and native soil materials relative to the fill and organic horizon materials under the septic systems. The septic systems are clearly contributing large (relative to native soils) quantities of P to the soils of the subdivisions.

Exchangeable P was detected in only 3 of the 36 samples collected from the important soil series. The same pattern of a minimal amount of exchangeable P relative to total P was exhibited in these samples as was exhibited in samples collected from under the septic tanks. This further emphasizes that the soils are capable of attenuating the P from septic systems; somehow immobilizing the leachable P.

4.1.2.2 Nitrogen

TKN is a measure of the organic N content of the soil. The TKN content of these soil samples was between 2 and 4 times smaller than samples collected under the drainfields. The TKN content varied from 7 mg/kg in OKEES3-54 to 13,640 mg/kg in OKEES3-23. The highest TKN value represents about 1.4 percent N in OKEES3-23 on a dry-weight basis. Nitrate- plus nitrite-N are at most 20 percent of the TKN value. In general, the higher nitrate-nitrite values are associated with old native soil A horizons. Most of the other samples exhibit insignificant amounts of nitrate plus nitrite-N. TKN concentrations do not depend on soil sample type as does soil P. The average TKN of fill samples was close to the average TKN of the native soil samples.

4.1.2.3 Extractable Iron and Aluminum

Eighteen of the 36 samples were also analyzed for extractable aluminum and iron and used in the 3-point adsorption isotherm analysis for P. P isotherm data indicate the degree to which soils or sediments are capable of adsorbing P. In simple terms, small amounts of soils are placed in beakers of solutions with known amounts of P.

Table 4-2. Results of Analyses for Samples Collected From Important Soil Series

Sample Number	Subdivision and Soil Series	Depth (Inches From Surface)	Horizon or Soil Type	Texture	Percent Moisture	Total Phosphorus (mg/kg)	Exchangeable Phosphorus (mg/kg)	$NO_2 + NO_3$ (mg/kg as N)	TKN (mg/kg as N)	Q^L Value (mg/Kg)	Extractable Fe (mg/kg)	Extractable Al (mg/kg)	TOM (%)
OKEES3-1		12-24	Fill	FS	10.7	48.5	--	0.35	267	464	35	587	1.7
OKEES3-2		40-52	E	FS	3.3	2.7	--	0.52	65	N/A	N/A	N/A	<0.5
OKEES3-3	1	65-77	Bh	FS	9.0	370	2.4	0.54	233	N/A	N/A	N/A	1.8
OKESS3-4		12-24	Fill	FS	9.6	40.6	--	0.25	194	148	44	432	1.0
OKEES3-5		40-50	E	FS	3.9	3.4	--	0.71	63	$1{,}150^R$	83	7.4	0.6
OKEES3-6		70-80	Bh	FS	12.5	449	--	0.58	226	N/A	N/A	N/A	1.6
OKEES3-7		12-20	Fill	FS	25.1	121	--	11.9	525	N/A	N/A	N/A	7.4
OKEES3-8		24-30	Fill*	FS	28.6	15	--	1.60	104	41	457	18	<0.5
OKEES3-9	2	40-50	Fill†	FS	23.6	7.6	--	1.32	74	N/A	N/A	N/A	<0.5
OKEES3-10		12-20	Fill	FS	26.2	N/A	--	10.6	74	331	1,850	451	7.2
OKEES3-11		24-30	Fill*	FS	23.5	2.4	--	0.84	96	N/A	N/A	N/A	<0.5
OKEES3-12		40-50	Fill†	FS	26.9	2.2	--	0.31	177	--	77	25	0.9
OKEES3-19		20-30	Fill	FS	5.8	36.9	--	10.1	843	12.2	381	105	2.3
OKEES3-20		38-45	A	FS	41.6	407	--	22.8	215	N/A	N/A	N/A	23.1
OKEES3-21	3	55-65	C*	FS	28.2	5.7	--	1.27	3,150	N/A	N/A	N/A	0.5
OKEES3-22		20-30	Fill	FS	12.2	92.1	--	2.85	2,080	56.8	728	168	1.4
OKEES3-23		38-45	A	FS	46.6	338	--	35.1	13,600	955^R	2,750	1620	27.1
OKEES3-24		55-65	C*	FS	22.7	17.5	--	0.30	254	N/A	N/A	N/A	0.8
OKEES3-25		20-30	Fill	FS	10.6	97	--	6.23	235	N/A	N/A	N/A	4.6
OKEES3-26		42-50	A*	FS	40.3	152	--	13.6	168	347	2,150	466	8.5
OKEES3-27	4	60-70	C†	FS	35.0	6.7	--	0.44	103	N/A	N/A	N/A	2.4
OKEES3-28		20-30	Fill	FS	6.6	48.5	--	5.25	210	102	718	293	4.1
OKEES3-29		42-50	A*	FS	39.5	153	--	6.47	304	284	1,820	354	9.2
OKEES3-30		60-70	C†	FS	28.6	8.4	--	0.36	123	N/A	N/A	N/A	1.5
OKEES3-31		24-34	Fill	FS	13.6	94	0.4	11.7	7,250	N/A	N/A	N/A	2.1
OKEES3-32		45-55	Oa*	Muck	47.6	92.4	--	1.97	423	520	2,070	3330	18.8
OKEES3-33	5	65-75	C†	FS	33.0	3.8	--	0.65	237	51.3	175	71	1.7
OKEES3-34		24-34	Fill	FS	12.4	57.4	--	3.42	54	N/A	N/A	N/A	1.2
OKEES3-35		45-55	Oa*	Muck	48.7	141	--	5.01	365	431	4,380	862	18.1
OKEES3-36		65-75	C†	FS	29.6	6.6	--	0.33	66	N/A	N/A	N/A	0.9

Table 4-2. Results of Analyses for Samples Collected From Important Soil Series (Continued, Page 2 of 2)

Sample Number	Subdivision and Soil Series	Depth (Inches From Surface)	Horizon or Soil Type	Texture	Percent Moisture	Total Phosphorus (mg/kg)	Exchangeable Phosphorus (mg/kg)	$NO_2 + NO_3$ (mg/kg as N)	TKN (mg/kg as N)	Q^L Value (mg/Kg)	Extractable Fe (mg/kg)	Extractable Al (mg/kg)	TOM (%)
OKEES3-49		24-34	Fill	FS	5.5	47.1	3.3	2.71	83	N/A	N/A	N/A	<0.5
OKEES3-50		36-46	A	FS	20.0	156	--	10.3	52	65.3	270	537	2.7
OKEES3-51	6	70-78	Bw*	FS	19.3	4.5	--	3.74	6,330	--	114	66	1.3
OKEES3-52		24-34	Fill	FS	5.6	29.4	--	0.54	44	N/A	N/A	N/A	0.7
OKEES3-53		36-46	A	FS	13.3	32.7	--	2.76	204	964	350	532	1.1
OKEES3-54		70-78	Bw*	FS	17.6	1360	--	4.72	2	N/A	N/A	N/A	0.8

Note: -- = not detected.
FS = fine sand.
L = Q value from Langmuir equation.
N/A = not analyzed.
R = R^2 values too low to accept data point validity.

1. Subdivision = Okeechobee Hammocks. Soil type = Immokalee. Location = Vacant lot.
2. Subdivision = Okeechobee Hammocks. Soil type = Fill. Location = Vacant lot.
3. Subdivision = Treasure Island. Soil type = Delray. Location = Vacant lot.
4. Subdivision = Treasure Island. Soil type = Delray. Location = Vacant lot.
5. Subdivision = Taylor Creek Isles. Soil type = Okeelanta Peat. Location: Vacant lot.
6. Subdivision = Buckhead Ridge. Soil type = Malabar. Location = Moldenhauer.

*Sample collected at top of groundwater table.
†Sample collected in groundwater table.

Source: ESE.

After allowing time for equilibrium, the soils or the liquids are analyzed noting the change in P concentration. The difference in either concentration is the amount of P adsorbed by the soil. The terms "three points" means that the soil adsorption is measured at three different solution P concentrations. The three points are statistically connected by a line that is used to indicate the amount of P absorbed per amount of soil; the absorption capacity.

Table 4-2 summarizes the amounts of extractable aluminum and iron. The iron levels are generally higher than those of aluminum. Extractable iron ranges from 35 mg/kg in OKEES3-1 to 4,380 mg/kg in OKEES3-35. The values of extractable aluminum vary from 7.4 mg/kg in OKEES3-5 to 3,330 mg/kg in OKEES3-32. Only two samples (OKEES3-23 and OKEES3-32) have extractable aluminum content greater than 1,500 mg/kg.

4.1.2.4 P Adsorption Isotherms

P adsorption isotherms were conducted to indicate the amount of P that soils from different horizons were capable of attenuating. The isotherms are used with other soil P measurements such as total P and extractable P to begin to determine how much P or how much more P the soil can hold or whether the soil P is adsorbed versus precipitated in the soil. The isotherms can be a yardstick by which the extractable amounts of P can be assessed in terms of whether they should be considered a problem. Other measurements such as extractable iron and aluminum assist in this determination.

P adsorption isotherms were performed on 18 of the 36 soil samples collected from the important soil series of the area. Two of the 18 samples (OKEES3-12 and OKEES3-51) did not exhibit sorption behavior; solution concentrations of P increased, especially at lower P levels. This increase in P concentrations indicates that the soils lost P to the solutions rather than adsorbing P. Without all of the data points exhibiting adsorption, the evaluation of the batch adsorption behavior for those soil samples cannot be completed. Meaningful data (all samples adsorbed P) were obtained for the remaining 16 soil samples, which allowed the determination of adsorption constants of either Freundlich or Langmuir or both isotherms (Table 4-3). Adsorption constants are presented using both equations, although previous experience indicates that the adsorption data generated using the Langmuir equation are directly applicable and may be more reliable. The numbers within the K column indicate adsorption in units of kg P per L solution for the Freundlich equation. The numbers within the Q column indicate adsorption in units of mg P per kg soil for the Langmuir equation. The R^2 values indicate the degree to which the analytical data fit the regression line.

The fit of the Freundlich adsorption isotherm was not satisfactory for 4 of the 16 samples that exhibited adsorption (OKEES3-8, -19, -28, and -50). The analysis is based on R^2 values calculated from the regression equation. The R^2 values for OKEES3-19 are particularly low. Only 2 of the 16 samples failed to show a good fit to the Langmiur equation (OKEES3-5 and OKEES3-23). The R^2 value of 0.091 for sample OKEES3-5 is unacceptably low. The coefficient of multiple regression (R^2) for the rest of the samples are satisfactory and generally range from 0.8 to 1.0. The generally high R^2 values for these experiments indicate good reliability of the P adsorption information.

The Freundlich K and Langmuir Q constants indicate the samples' ability to adsorb P. The Q constant is more readily useable because it is in the same units as total and exchangeable P. The K constants (Freundlich) vary from 6.78 to 73.9 kg/L. OKEES3-5 has the highest Freundlich adsorption coefficient, suggesting that this sample has the greatest adsorption capacity compared to the other soil samples. The P adsorption maxima, (Q) based on Langmuir isotherm, range from 12.2 to 115 mg/kg. OKEES3-5, with the highest K, has also the highest Q.

Within acid soils, P adsorption is controlled by organic matter, iron, and aluminum. In alkaline soils, P adsorption is controlled by calcium or magnesium. The research efforts of this study were limited to the effects of iron and aluminum on adsorption. Correlation of P adsorption (Q from the Langmuir equation) with iron,

Table 4-3. Phosphorus Adsorption Data for Soil Samples Collected From Important Soil Series

Sample Number	Freundlich K	R^2	Langmuir^Q mg/kg	R^2
OKEES3-1	1.19E+01	0.954	4.64E+02	0.908
OKEES3-4	2.73E+01	0.899	1.48E+02	0.834
OKEES3-5	6.78E+00	0.963	1.15E+03	0.091
OKEES3-8	1.16E+01	0.507	4.10E+01	0.955
OKEES3-10	2.44E+01	0.998	3.31E+02	0.914
OKEES3-12	--	--	--	--
OKEES3-19	2.41E+01	0.035	1.22E+01	0.958
OKEES3-22	1.57E+01	0.992	5.68E+01	0.980
OKEES3-23	5.76E+01	0.970	9.55E+02	0.480
OKEES3-26	3.65E+01	0.999	3.47E+02	0.936
OKEES3-28	2.05E+01	0.418	1.02E+02	0.947
OKEES3-29	2.65E+01	1.000	2.84E+02	0.961
OKEES3-32	7.39E+01	1.000	5.20E+02	0.954
OKEES3-33	7.30E+00	0.927	5.13E+01	0.865
OKEES3-35	6.91E+01	0.997	4.31E+02	0.979
OKEES3-50	2.20E+01	0.290	6.53E+01	0.961
OKEES3-51	--	--	--	--
OKEES3-53	2.36E+01	0.900	9.64E+01	0.998

Note: -- = not measured.

Source: ESE.

aluminum, organic matter, and a value equal to the higher of either iron or aluminum was calculated. This latter value was chosen to account for adsorption to soil because the presence of either element enhances adsorption.

The Q value correlated equally well with either iron or aluminum with correlation coefficients of 0.64 and 0.66, respectively. When the higher of the iron or aluminum values was used instead, the correlation coefficient jumped to 0.77. Iron or aluminum correlates well with adsorption. The Q value also correlated well with TOM with a correlation coefficient of 0.76. This implies that organic matter and iron and aluminum contents interact with respect to P adsorption. This information indicates that soil characteristics such as organic matter content, iron, or aluminum content are good predictors of the ability of a soil to adsorb P.

4.2 CANAL SEDIMENT

4.2.1 SEDIMENT CHARACTERISTICS

4.2.1.1 Taylor Creek Isles

Sediment characteristics were similar throughout the subdivision. Sediment textures ranged from sandy muck to mucky sand throughout with the stage of decomposition remaining constant. Sediment thickness generally ranged from 1 to 4 inches on the canal edges, and from 6 to 26 inches in the canal centers, although extremes to these measurements were found (Table 3-1). Extremes in sediment thickness found in the canal centers ranged from less than 1 inch to greater than 36 inches, but these readings were found not to be the norm.

The physical characteristics of the canals within the Taylor Creek subdivision were all similar with the exception of the overall canal length. Canals were consistently 85-ft wide with water depth in the center of the canals ranging from 6 to 7.5 ft (Table 3-1). Nearly all of the homesites in this subdivision had a bulkhead at the canal edge.

4.2.1.2 Treasure Island

The sediments within the Treasure Island subdivision were all very similar, regardless of the wide range of canal physical characteristics that could have caused sediment thickness to vary. Sediment thickness ranged from 1 to 10 inches on the canal edges and from 4 to 24 inches in the canal centers (Table 3-1). These thicknesses were generally consistent throughout the entire subdivision. Only 14 of 88 measurements fell outside these ranges. These 14 measurements were considered to be non-representative outliers of the data. Sediment textures remained consistent throughout the subdivision ranging from sandy muck to mucky sand. Differences in length are to be gathered using the map. Canal widths varied from approximately 40 to 85 ft. Water depth was consistent through the entire subdivision, ranging from 4.5 to 8 ft. Within this subdivision, a majority of the homesites had bulkheads at the canals edge, with major differences being overall age and relative stage of disrepair. The amount and type of aquatic vegetation varied from place to place and did not appear to have any relationship to the amount of accumulated sediment on the bottom of the canal.

4.2.1.3 Okeechobee Hammocks

Sediments within the Okeechobee Hammocks subdivision were not physically measured due to the virtual inaccessible nature of the canals. After two drive-throughs and visual investigation, our experience gained during the assessment of the other subdivisions' canals led us to believe that the sediments within the canals of this subdivision were most likely similar to one another. Canal width and length were similar. Sloping vegetated canal edges were dominant; bulkhead construction was not evident within the subdivision. All of the canals within this subdivision were clogged with aquatic vegetation; some worse than others. Very small areas of open water were visible within a small number of the canals.

4.2.1.4 Buckhead Ridge

Sediments within the northeast and the southwest sections appeared to be significantly different in thickness and texture. The northeast section, the oldest of the two sections, had overall thicker sediments. The thicknesses ranged from 2 to 12 inches in the canal edges and from 14 to 26 inches in the canal centers (Table 3-1). The texture of the sediment in this area was consistently sandy muck to mucky sand. The physical makeup of the canals in the northeast section was consistent from spot to spot with canal width approximately 75 ft and water depth ranging from 7.5 to 10.5 ft. The main canal connecting all of the other canals was slightly wider, approximately 100 ft, but the sediment characteristics were the same. The edges of this canal were dominated with bulkheads in both the northeast and the southwest sections. Sediments characterized in the southwest section of Buckhead Ridge were consistent throughout the section. Sediment thickness ranged from 2 to 4 inches in the canal edges and 3 to 9 inches in the canal centers. Textures ranged from mucky sand to sandy muck and water depth ranged from 5.5 to 9 ft. The shapes and sizes of these canals differed dramatically within the area. The canal at the far western edge of the Buckhead Ridge subdivision was somewhat unique in both sediment and physical characteristics with wide variations in sediment thickness and texture. This one canal was not thought to be significant with light development confined to the east side of the canal, with the exception of the very northern end. Canal edges in the entire southwest section were dominated with bulkheads.

4.2.1.5 Sediment Measurement Summary

The differences in sediment characteristics between the four subdivisions did not appear significant. Thickness and texture of sediment, depth of the water, and the canal widths were all relatively similar. The one major difference was overall canal length. Subdivision size, age, and stage of development also differed significantly.

4.2.2 SEDIMENT ANALYTICAL RESULTS

4.2.2.1 Phosphorus

The analytical results for the 12 sediment samples collected from the bottoms of various canals are shown in Table 4-4. Total P content ranges from 42 mg/kg in OK05 to 757 mg/kg in OK04. Average sediment total P is similar to average native soil total P observed in the different soil series and half of the average total P observed in soils collected under the septic tank drainfield. The highest value was observed in the sample collected from the canal between SE 31st and SE 32nd Streets. The next highest value was observed in the sample collected upstream of the subdivisions in Taylor Creek. The results of the total P analyses do not support the hypotheses underlying the sampling scheme. Samples collected in the canal surrounded by homes on septic tanks were indistinguishable from samples collected from the canal surrounded by homes hooked to the treatment plant. No trends were observed between samples collected in older versus newer parts of the subdivisions nor were trends observed between samples collected from upstream or downstream of various sections of the subdivisions.

Exchangeable P was measured in 5 of the 12 sediment samples collected from the canals. The percentage of sediment samples with measurable extractable P was much higher than the percentage exhibited for either of the two sets of soil samples. Although several of the extractable P values for soils were well above 1 mg/kg, none of the measured values for the sediment samples exceeded 1 mg/kg. The exchangeable P concentrations have a narrow range of 0.37 to 0.94 mg/kg.

4.2.2.2 Nitrogen

The sediment sample total N is essentially organic or ammonia-related. All the values of NO_2 + NO_3 are below detection limits. Sample OK04 exhibited the highest TKN content (28,700 mg/kg), which translates into about 3 percent N. The average TKN of all the sediment samples is approximately twice the TKN observed in the soil samples collected under the septic tank

Table 4-4. Results of Analyses of Sediment Samples Collected From Various Canals Along Northern End of Lake Okeechobee

Sample Number	Sub Division	On Maps	Character istics	Percent Moisture	Total Phosphorus (mg/kg)	Exchangeable Phosphorus (mg/kg)	$NO_2 + NO_3$ (mg/kg as N)	TKN (mg/kg as N)	Q* Value (mg/kg)	Extractable Fe (mg/kg)	Extractable Al (mg/kg)	TOC (%)
OK01	Taylor Creek	N/A	Sand	41.0	387	--	<0.17	984	216	320	263	10.5
OK02	Taylor Creek	N/A	Sand	47.0	113	--	<0.19	1810	155	418	266	1.7
OK03	Taylor Creek	N/A	Sand	60.0	145	--	<0.25	3400	N/A	N/A	N/A	2.0
OK04	Taylor Creek	N/A	Sand	91.0	757	0.94	<1.11	28700	N/A	N/A	N/A	3.4
OK05	Taylor Creek	N/A	Sand	33.0	42	--	<0.15	1210	N/A	N/A	N/A	1.1
OK06	Treas Island	N/A	Sand	46.0	221	0.77	<0.19	3090	N/A	N/A	N/A	4.7
OK07	Treas Island	N/A	Sand	57.0	179	0.37	<0.23	1430	N/A	N/A	N/A	2.8
OK08	Okee Hammock	N/A	Sand	28.0	66	--	<0.14	1970	251	629	555	0.7
OK09	Okee Hammock	N/A	Sand	43.0	93	--	<0.18	547	118	382	800	3.0
OK10	Buck Ridge	N/A	Sand	60.0	225	0.64	<0.25	4780	N/A	N/A	N/A	2.4
OK11	Buck Ridge	N/A	Sand	35.0	69	--	<0.15	1700	200	236	406	2.1
OK12	Buck Ridge	N/A	Sand	45.0	55	0.86	<0.18	2010	N/A	N/A	N/A	2.2

Note: NA = not analyzed.
-- = not detected.
* = Q from Langmuir Equation

Treas Island = Treasure Island.
Okee Hammock = Okeechobee Hammock.
Buck Ridge = Buckhead Ridge.

Source: ESE.

drainfields and an order of magnitude greater than observed in soils collected from the various soil series in the area. Although these values were significantly greater than that observed for the soils, these sediment-N values are normal for Florida streams. FDER has compiled lists of typical water quality values based on STORET codes from available sampling stations. The 50th percentile value (median) for TKN in mud is 4,400 mg/kg. The average sediment TKN measured in Okeechobee is 2,238 mg/kg. This value corresponds more closely with the 40th percentile value of 2,695 mg/kg. The apparent randomness of the sediment N values implies that the source is either something else besides the septic tanks or that sediment N equilibrium is very dynamic.

All but one sediment sample exhibited an organic content of less than 4.7 percent. One sample was as high as 10.5 percent. These relatively low observed organic contents mean that the N is not in the form of partially decomposed plant materials. The N is likely in the form of ammonia, accumulating in the anoxic canal sediments. With little movement of water in these canals, the ammonia could be accumulating at a gradual-slow rate and could continue to accumulate until a storm event of sufficient magnitude occurs to flush or oxygenate the sediments. Unfortunately, redox measurements of the sediments are not available to confirm this hypothesis.

4.2.2.3 P Adsorption Isotherms

Five of the 12 sediment samples were analyzed for extractable iron and aluminum and P adsorption isotherms were calculated. The results for extractable iron and aluminum are shown in Table 4-4. Values for iron range from 236 to 629 mg/kg. For aluminum, the values vary from 263 to 800 mg/kg.

Table 4-5 shows the adsorption data for the five sediment samples. The good fit of all data to both Freundlich and Langmuir adsorption isotherms (shown by R^2 values of 0.98 to 1.00) indicates a high reliability of the data to predict P adsorption. Freundlich adsorption constants of K range from 18.5 to 96.0 kg P/L. Based on the Freundlich adsorption coefficients summarized in Table 4-5, OK08 has the highest adsorption capacity for P. Sample OK09 has the minimum adsorption capacity. Analysis of the sorption data according to the Langmuir isotherm indicates that sample OK08, where Q is 251 mg/kg, exhibits the highest P maximum of the five sediment samples. The lowest adsorption maximum was observed in OK09 (118 mg/kg).

As with the sorption isotherms for the soil samples, the Q values from the Langmuir equations are used here to best represent P adsorption. Correlations of the Q values with organic matter, iron, aluminum, and the highest of either of the iron and aluminum values were calculated to look for comparisons if evident. Unlike the soil samples, sediment P adsorption did not correlate well with any of the measured sediment characteristics. The correlation coefficients for aluminum and iron were -0.37 and 0.36, respectively. When the highest of either value was used, the correlation was even more negative with a correlation coefficient of -0.40. The correlation coefficient of P adsorption with sediment organic matter was 0.12, indicating less correlation.

Adsorption of P in sediments may be controlled by calcium ions/minerals in the surface water systems. During much of the year, the pH of the canal waters appears to be alkaline. If P precipitates with calcium, correlations of P adsorption would not show a high correlation with iron, aluminum, and organic matter that appears to adsorb best under acidic conditions.

4.3 GROUNDWATER

4.3.1 GROUNDWATER FLOW

This section includes a discussion of: (1) the sediments encountered at each site, (2) the dry season groundwater flow direction and rate (October 24, 1991 and June 8, 1992), (3) September 1992 wet season groundwater flow direction and rate, and (4) a comparison/ evaluation of transient groundwater conditions observed from August 1991 through September

Table 4-5. Phosphorus Adsorption Data for Sediment Samples Collected From Various Canals

Sample Number	Freundlich K	R^2	Langmuir^Q mg/kg	R^2
OK01	3.27E+01	1.00	2.16E+02	0.994
OK02	2.28E+01	0.992	1.55E+02	0.982
OK08	9.60E+01	0.997	2.51E+02	0.999
OK09	1.85E+01	1.00	1.18E+02	0.995
OK11	4.30E+01	0.982	2.00E+02	0.983

Source: ESE.

1992. Groundwater flow rates were estimated using the following equation:

$$V = \frac{ki}{n}$$

where: V = groundwater flow velocity [feet per day (ft/day)],
k = hydraulic conductivity (ft/day),
i = hydraulic gradient (unitless), and
n = aquifer porosity (0.20 from Fetter, 1980).

4.3.1.1 Moldenhauer Site

The sediments encountered to a depth of 12 ft during the installation of monitor wells MW-1 and MW-2 generally consisted of gray to light-brown, fine- to medium-grained silica sand with traces of shell. Within boring MW-2, a limestone gravel that was believed to be part of the drainfield was encountered at approximately 3 ft. In boring MW-3, the sediment profile was significantly different and consisted of light gray to brown fine-grained silica sand to a depth of about 4 ft. A brown silty fine-grained silica sand, underlain by a brown shelly limestone, was encountered between 4 and 8 ft. The limestone was underlain by a layer of light-brown fine-grained silica sand to 12 ft. A thin layer of gray sandy clay was encountered between 10 and 11 ft.

Groundwater levels measured in the monitor wells and piezometers on October 24, 1991, ranged from 95.87 to 96.17 ft, based on an assigned datum of 100 ft set for monitor well M-1. The groundwater flow direction at this time was generally toward the east, as depicted in Figure 4-1. Based on the referenced flow velocity equation and using site data provided in Table 3-3, the groundwater flow velocity was estimated to be approximately 0.19 ft/day or about 69 feet per year (ft/yr) at this time.

Groundwater levels measured on June 8, 1992, ranged from 95.62 to 95.96 ft, based on the MW-1 datum. The groundwater flow direction at this time was generally toward the southeast, as depicted in Figure 4-2. Based on the referenced equation and using site data provided in Table 3-3, the groundwater flow velocity for this date was estimated to be approximately 0.68 ft/day or about 250 ft/yr. The groundwater levels measured at this time are considered representative of end of dry season conditions as reflected by the site hydrograph (Figure 4-3).

The final groundwater level measurements were taken on September 2, 1992, near the end of the wet season. These water levels ranged from 96.83 to 96.20 ft. The flow direction was toward the west in the direction of the canal at the rear of the parcel. The groundwater flow velocity at this time was estimated to be about 0.6 ft/day or about 220 ft/yr. As evidenced by the data sets, the groundwater flow direction and velocity represent transient conditions that are seasonably dependent. This condition must therefore influence nutrient loading from the septic tank system to the canal on a seasonal basis.

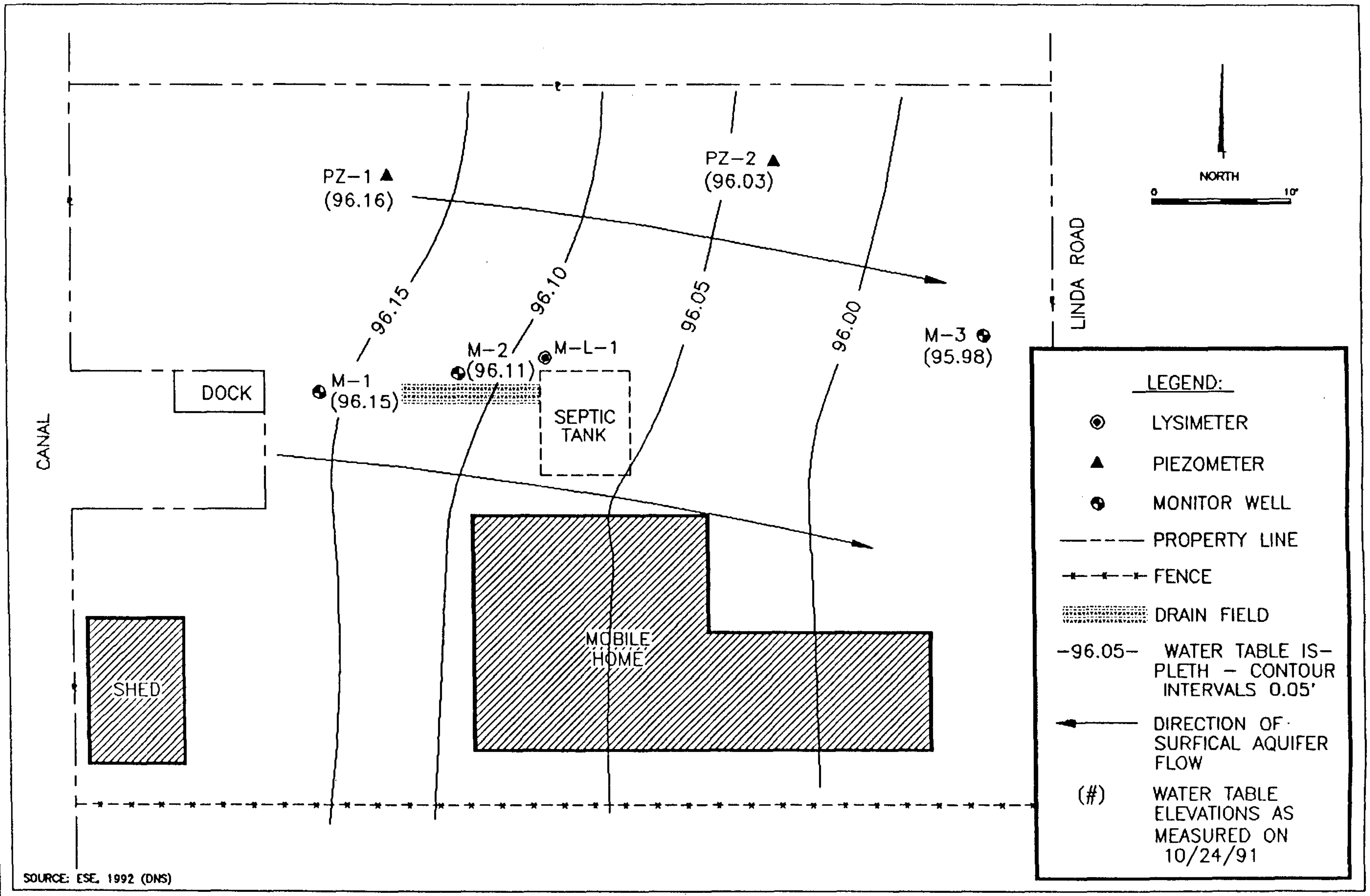
Long-term water levels measured during this project are plotted in Figure 4-3. Water levels depicted include the three monitor wells, M-1, M-2 and M-3, and piezometers PZ-1 and PZ-2. Groundwater level fluctuations were greatest in monitor well M-3 (approximately 2 ft) and the least in monitor well M-1 (approximately 1 ft), suggesting canal water levels were fairly constant during the year and groundwater flow directions are influenced by recharge due to rainfall.

4.3.1.2 Lewis Site

Sediments encountered during the installation of one monitor well (L-1) at the Lewis site consisted of a thin layer of highly organic silt and sand underlain by brown to gray, to light gray, to white fine-grained silica sand to a depth of approximately 6 ft. Sediments encountered from 6 to 17 ft-bls consisted of mostly brown fine-grained silica sand with traces of silt and organic material.

Water levels measured within the onsite monitor well and piezometers on October 24, 1991, ranged from approximately 93.44 to 93.58 ft (Table 3-4)

ACAD FILE: 3913010\FIGURE41

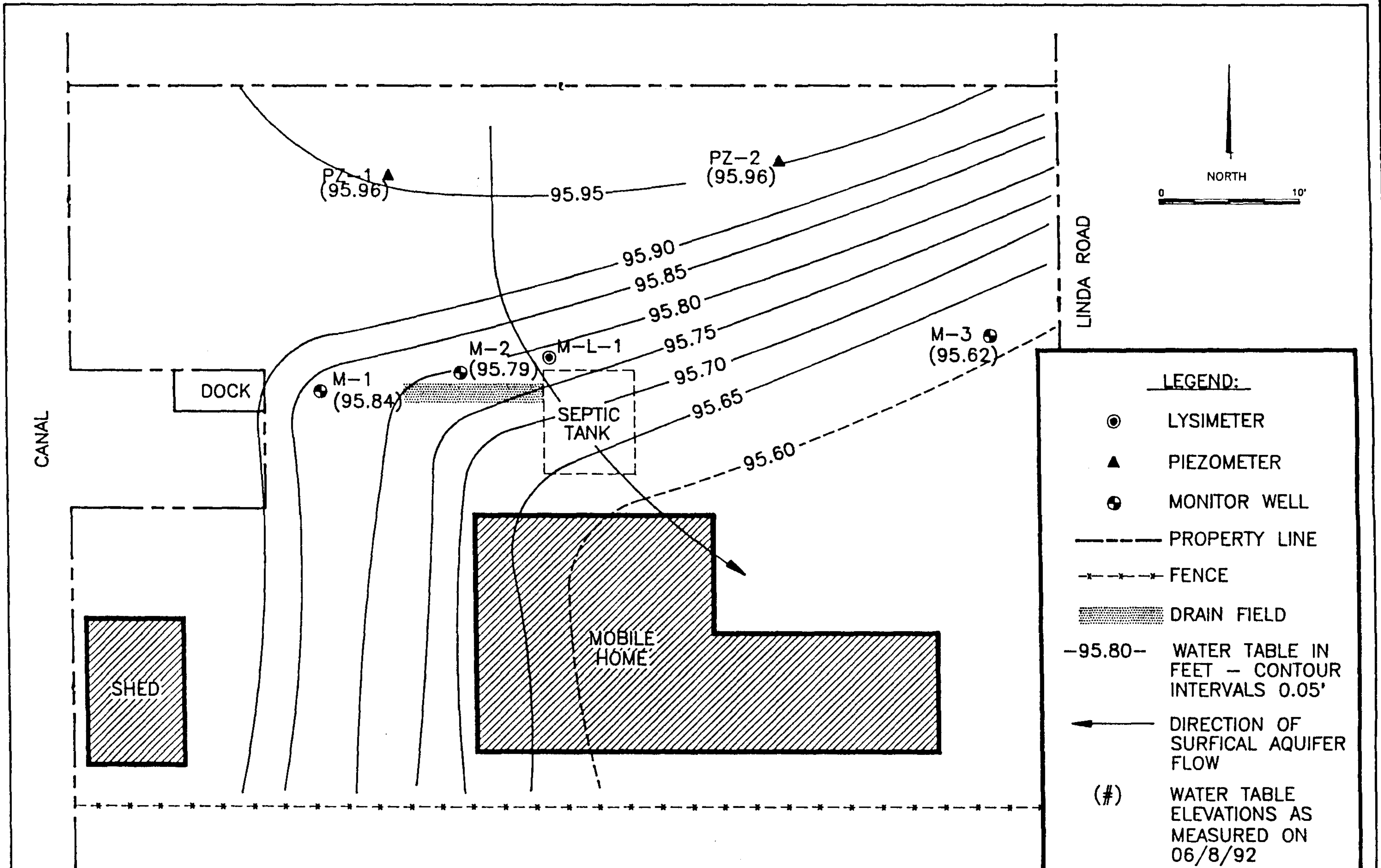


SOURCE: ESE, 1992 (DNS)

FIGURE 4-1
OLD SYSTEM – WATER TABLE CONTOUR MAP 10/24/91
MOLDENHAUER SITE
OKEECHOBEE, FLORIDA

Environmental Science & Engineering, Inc.

ACAD FILE: 3913010\FIGURE41



SOURCE: ESE, 1992 (DNS)

FIGURE 4-2
OLD SYSTEM – WATER TABLE CONTOUR MAP 06/8/92
MOLDENHAUER SITE
OKEECHOBEE, FLORIDA

Environmental Science & Engineering, Inc.

ACAD FILE:3913010\WATERTB2

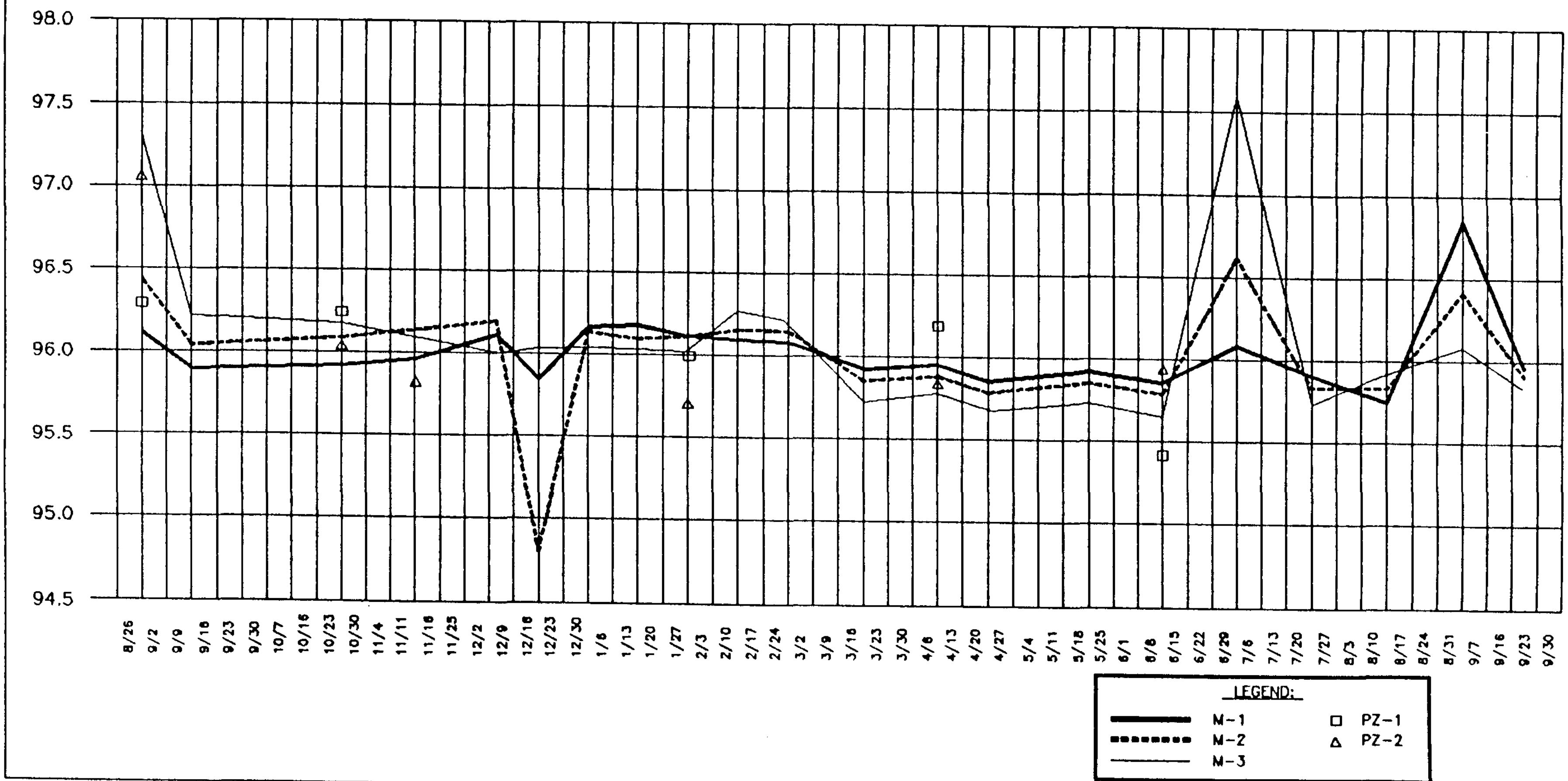


FIGURE 4-3
MOLDENHAUER SITE
WATER TABLE HYDROGRAPH
OKEECHOBEE, FLORIDA

Environmental Science & Engineering, Inc.

with respect to an assigned datum of 100 ft set for well L-1. As illustrated in Figure 4-4, the groundwater flow direction is generally toward the north. The estimated hydraulic gradient is 1.57×10^{-3} ft/ft. Using these data, an estimated hydraulic conductivity value of 18.8 ft/day, and assuming a porosity value of 0.2 for the site, the groundwater flow velocity is estimated to be approximately 0.15 ft/day or about 55 ft/yr.

Water levels measured within the onsite monitor well and piezometers on June 8, 1992, ranged from approximately 93.21 to 93.42 ft with respect to the 100 ft datum established for well L-1. As illustrated in Figure 4-5, the groundwater flow direction is generally toward the northeast. The estimated hydraulic gradient is 5.0×10^{-3} ft/ft. Using the data and estimated hydraulic conductivity and porosity data for the site, the groundwater flow velocity is estimated to be 0.47 ft/day or about 171 ft/yr in the southern portion of the site under dry season conditions. In the northern half of the site, virtually no gradient exists, and, therefore, the groundwater flow is minimal.

Water levels measured within the observation network on September 2, 1992 (Table 3-4) ranged from 93.21 to 93.72 ft with respect to the 100.00 datum. The water table contour map for September 2, 1992, (Figure 4-6) indicates groundwater flow is toward the northeast in the general direction of the canal at the rear of the site. Given the observed water levels, the hydraulic gradient is estimated to be 3.93×10^{-3} ft/ft. Assuming hydraulic conductivity and porosity values used in the previous onsite flow velocity evaluations, the groundwater flow velocity is estimated to be about 0.37 ft/day (135 ft/yr) under wet season conditions.

Long-term water levels measured during this project are shown in Figure 4-7. Water levels shown include monitor well L-1 and piezometers PZ-1 through PZ-4. The greatest groundwater fluctuation, approximately 1.0 ft, occurred in December 1991 and June 1992. Typically, the lowest onsite water levels were measured in monitor well L-1, adjacent to the septic tank system. Water levels measured adjacent to the canal displayed the least fluctuation, indicating these levels are probably held constant during most of the year.

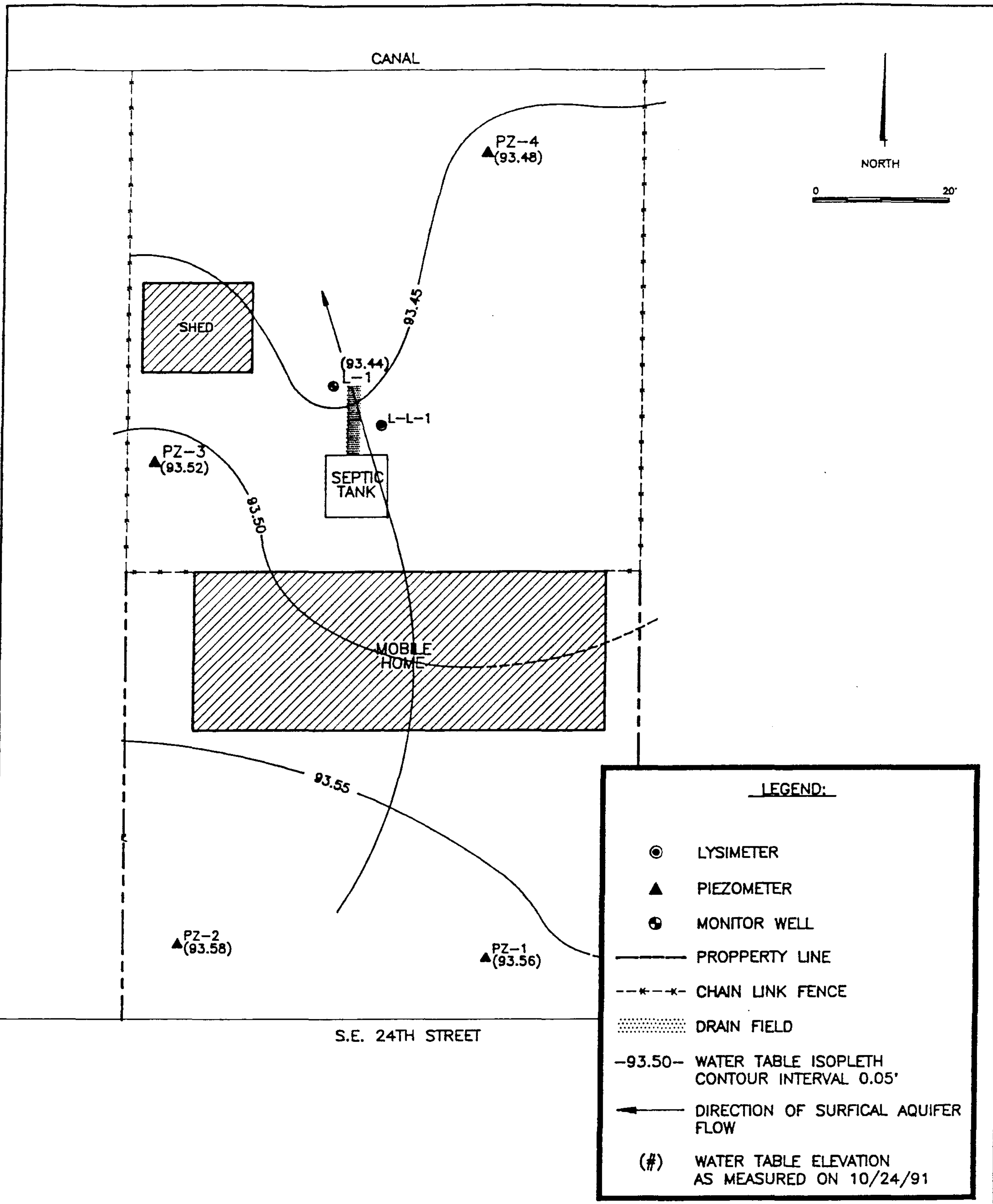
4.3.1.3 Goolsby Site and Vacant Lot

Because these sites are adjacent to each other, discussions regarding each site's site specific hydrogeology are combined. Sediments encountered at these sites, through the performance of borings G-1 and V-1, consist of a variable 2- to 4-ft layer of gray to brown fine-grained silica sand (fill material) overlying approximately 2 to 3 ft of black, highly organic peat. Within boring G-1, sediments underlying the peat consisted of gray to brown fine-grained silica sand to a depth of 14 ft. Within boring V-1, the sediments encountered underlying the peat consisted of a brown silty fine-grained silica sand underlain by light brown to brown fine-grained silica sand.

Groundwater levels measured on October 24, 1991, ranged approximately from 97.97 to 99.10 ft with respect to a relative datum of 100 ft set for well V-1 (Table 3-5). As shown in Figure 4-8, the groundwater flow direction from the septic tank is generally toward the north in the direction of Taylor Creek at the rear of the site. Using these water level data and an estimated hydraulic gradient of 1.17×10^{-2} ft/ft, and an average hydraulic conductivity value of 6.3 ft/day, the groundwater flow velocity is calculated to be approximately 0.37 ft/day or about 135 ft/yr.

End-of-dry-season groundwater levels obtained on June 8, 1992, ranged from 97.67 to 98.15 ft with respect to the 100 ft datum designated for well V-1. As shown in Figure 4-9, the groundwater flow direction from the septic tank is toward the northeast toward Taylor Creek. Using these water level data and an estimated hydraulic gradient of 3.2×10^{-2} ft/ft, and an average hydraulic conductivity value of 6.3 ft/day, the groundwater flow velocity is approximately 1.0 ft/day or about 365 ft/yr during dry season conditions.

End-of-wet-season water levels measured on September 2, 1992, (Table 3-5 and Figure 4-10) ranged from 97.98 ft in the rear of the site (V-1) to 100.18 ft in the front of the site (PZ-2). Based on these measurements, the groundwater flow



SOURCE: ESE, 1992 (DNS)

FIGURE 4-4
OLD SYSTEM – WATER TABLE CONTOUR MAP 10/24/91
LEWIS SITE
OKEECHOBEE, FLORIDA

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&
ENGINEERING, INC.

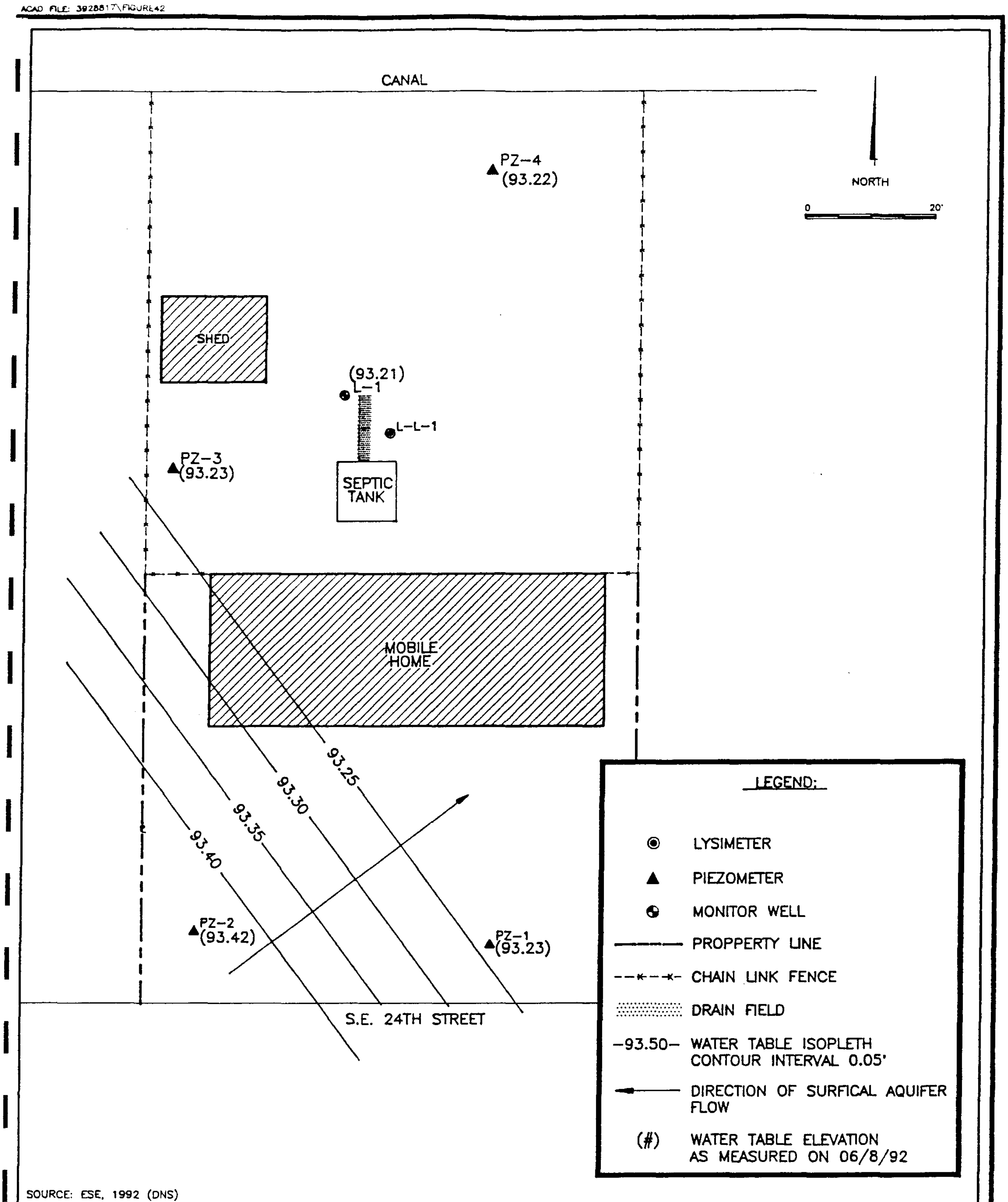
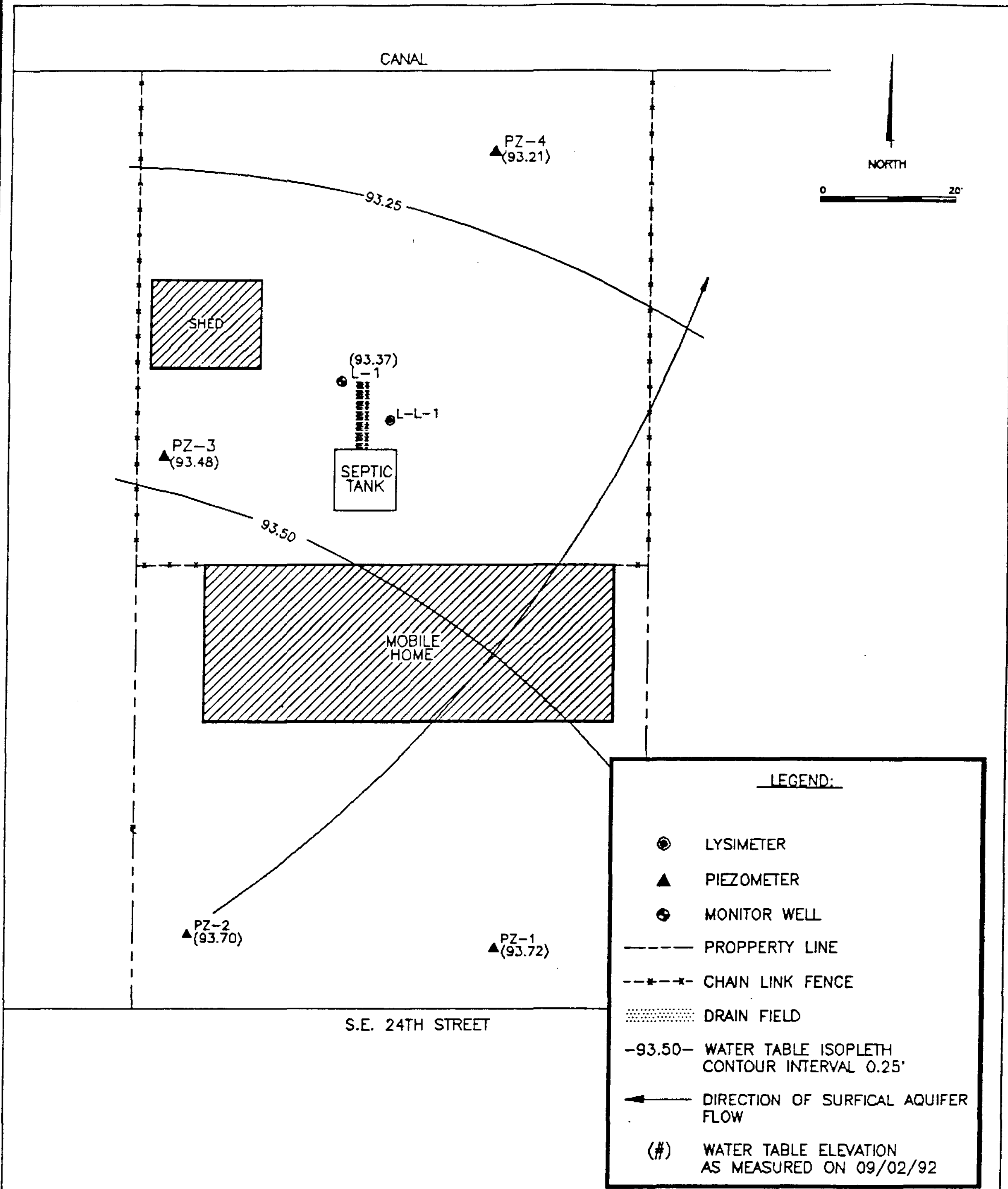


FIGURE 4-5
OLD SYSTEM – WATER TABLE CONTOUR MAP 06\8\92
LEWIS SITE
OKEECHOBEE, FLORIDA

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.

ACAD FILE: 3928817\FIGURE42



SOURCE: ESE, 1992 (DNS)

FIGURE 4-6
OLD SYSTEM – WATER TABLE CONTOUR MAP 09/02/92
LEWIS SITE
OKEECHOBEE, FLORIDA

Environmental Science & Engineering, Inc.

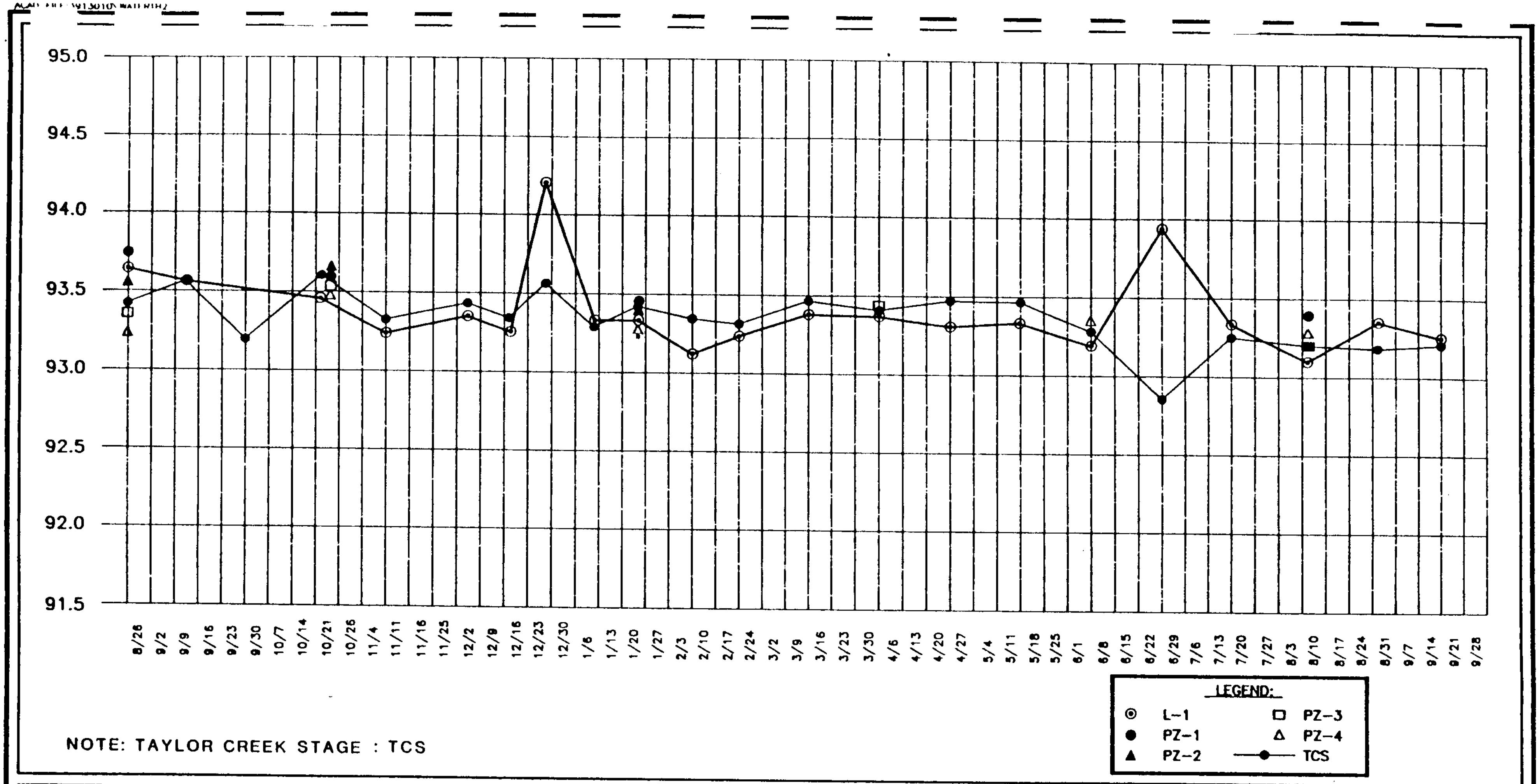


FIGURE 4-7
LEWIS SITE
WATER TABLE HYDROGRAPH
OKEECHOBEE, FLORIDA

ESE Environmental Science & Engineering, Inc.

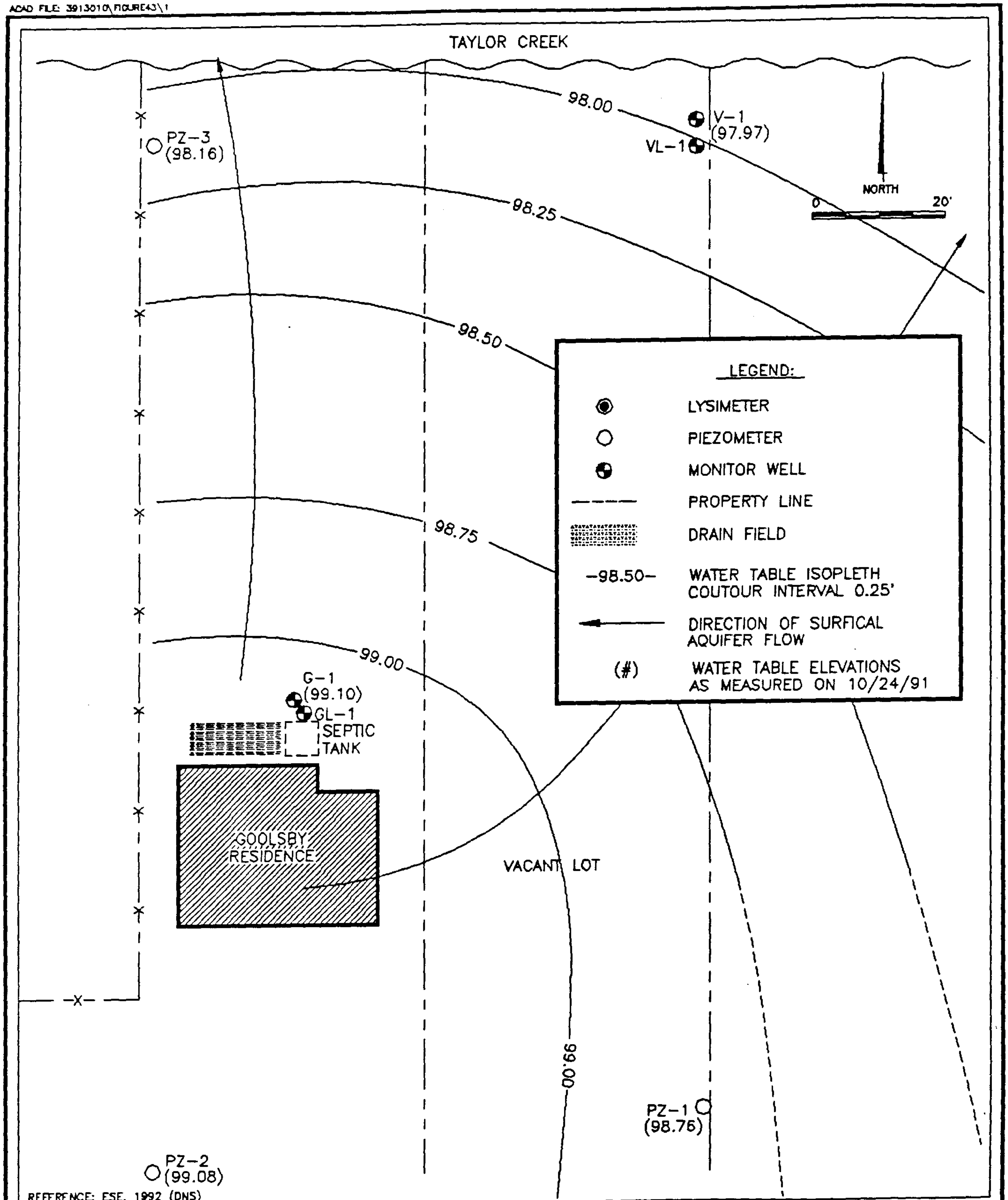


FIGURE 4-8
NEW SYSTEM – WATER TABLE CONTOUR MAP 10/24/91
GOOLSBY SITE AND VACANT LOT
OKEECHOBEE, FLORIDA

Environmental Science & Engineering, Inc.

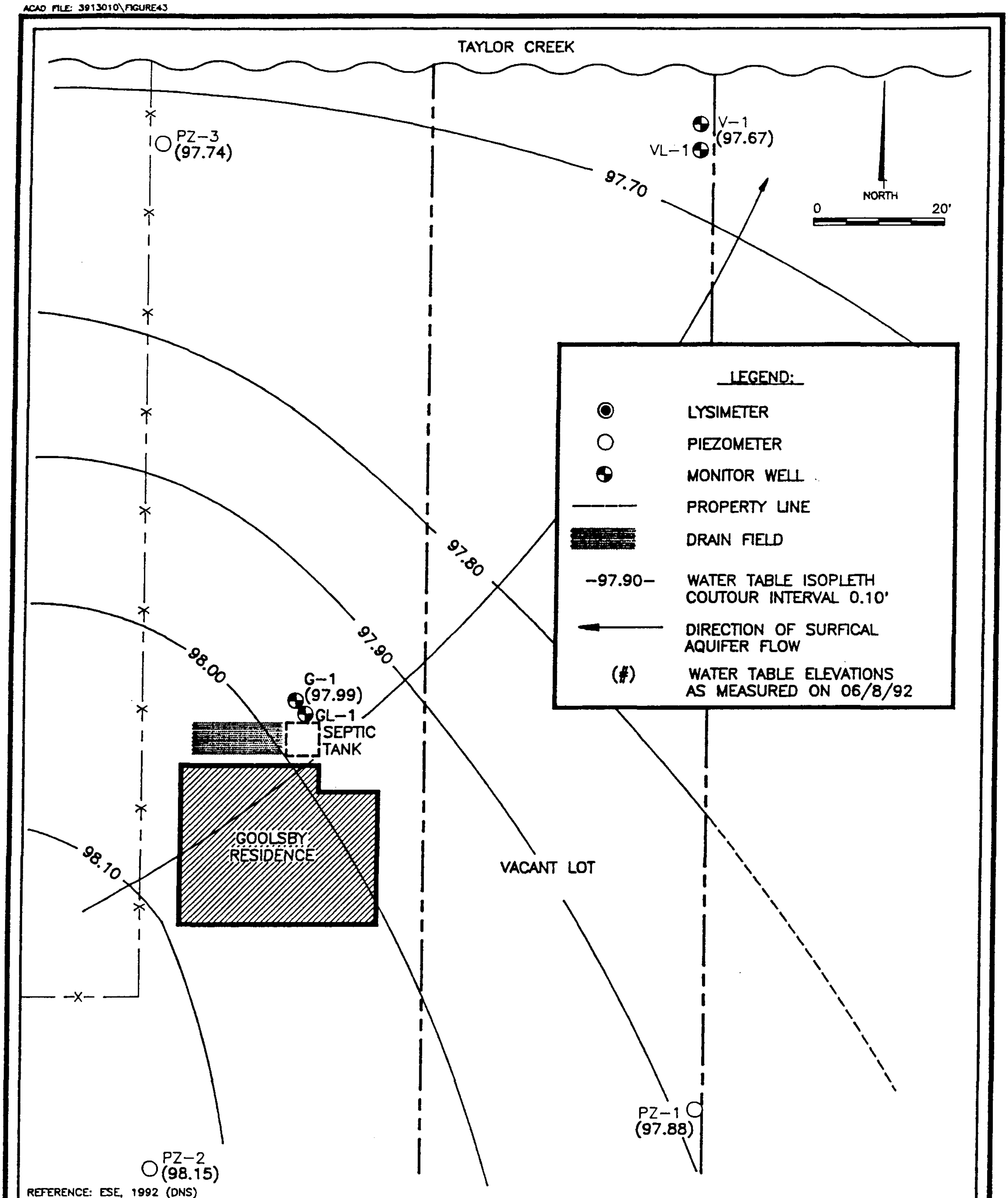


FIGURE 4-9
NEW SYSTEM – WATER TABLE CONTOUR MAP 06/8/92
GOOLSBY SITE AND VACANT LOT
OKEECHOBEE, FLORIDA

ENVIRONMENTAL SCIENCE
&
ENGINEERING, INC.

ACAD FILE: 3913010\FIGURE43

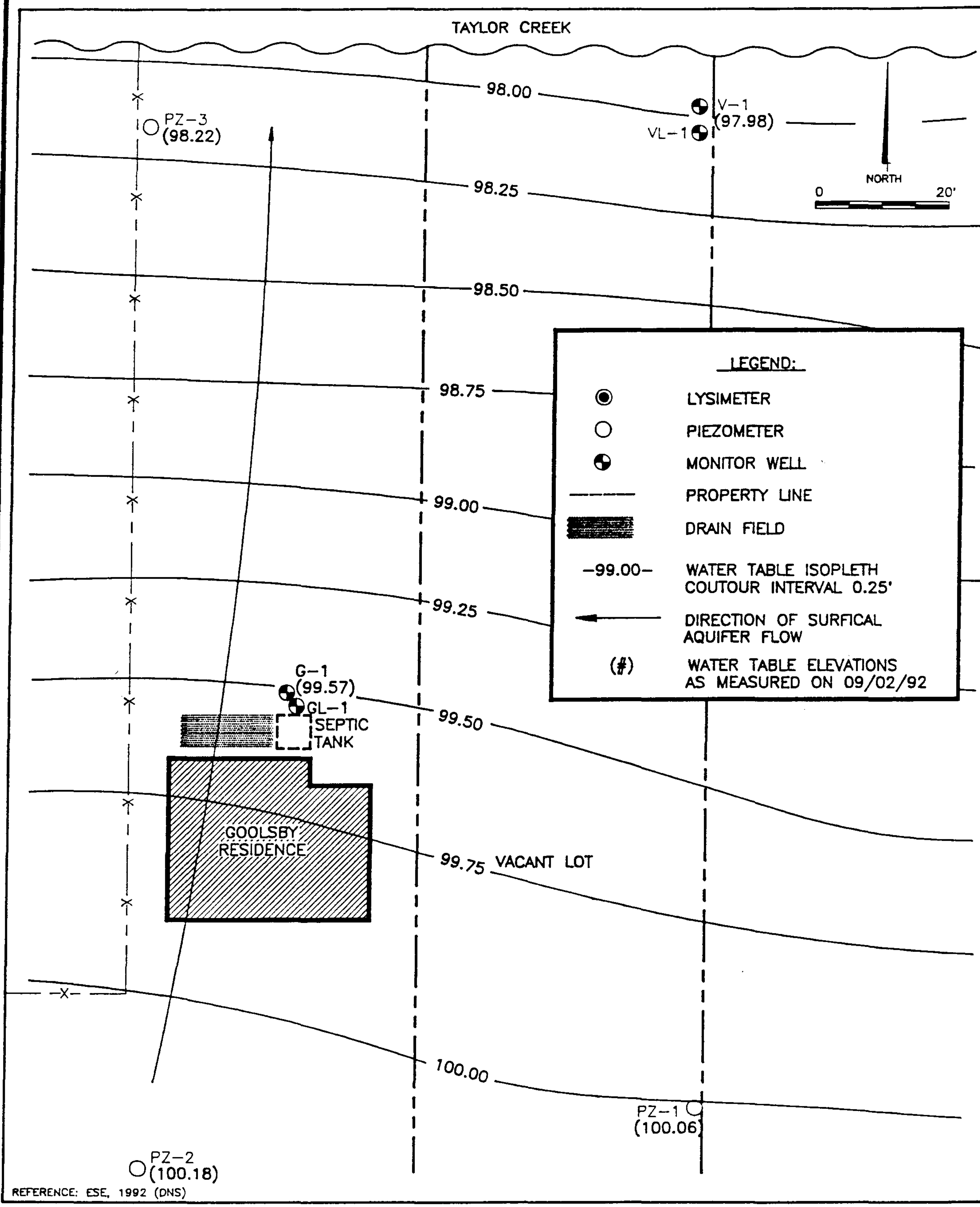


FIGURE 4-10
NEW SYSTEM – WATER TABLE CONTOUR MAP 09/02/92
GOOLSBY SITE AND VACANT LOT
OKEECHOBEE, FLORIDA

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&
ENGINEERING, INC.

direction is toward the north. The estimated hydraulic gradient across the site at this point was 1.27×10^{-2} ft/ft. Given this gradient and assuming porosity and hydraulic conductivity values previously used for this site, the groundwater flow velocity is estimated to be 0.4 ft/day or about 145 ft/yr. Flow velocity calculations show that as the dry season progresses, the head differential between the canal and site increase, thus increasing the gradient and resultant flow velocity during the dry season.

Long-term groundwater elevations shown on the hydrograph (Figure 4-11) indicate seasonal groundwater levels fluctuate approximately 1 ft adjacent to Taylor Creek and more than 2 ft at the greatest distance from the creek. Water levels near the septic tank fluctuated almost 4 ft during the monitoring period. Long-term water levels indicate year-round groundwater flow is predominantly in a northerly direction from the septic tank toward Taylor Creek.

4.3.1.4 Spaulding Site

The upper 4 ft of sediment encountered at this site consisted of gray fine-grained silica sand and brown silty fine sand and is considered fill material. These sediments were underlain by black peat with some tree limbs from 4 to 8 ft. The peat was underlain by gray fine-grained silica sand with traces of organic material to a depth of 17 ft.

Water levels measured on October 24, 1991, ranged from 93.22 to 95.08 ft with respect to a designated datum of 100 ft set for well S-1 (Table 3-6). Using October 24, 1991 data, a water table contour map (Figure 4-12) was developed. As illustrated, the groundwater flow direction is generally toward the northeast in the direction of a canal located at the rear of the site. The estimated hydraulic gradient from the septic tank drainfield to the canal is approximately 1.38×10^{-2}, as calculated along the flow path length and assuming an aquifer hydraulic conductivity of 23.3 ft/day, a hydraulic gradient of 1.38×10^{-2}, and an aquifer porosity of 0.20. The estimated groundwater flow velocity is approximately 1.6 ft/day or about 585 ft/yr. The extreme flow velocity is in response to the relatively steep hydraulic gradient measured across the site, particularly from the septic tank to the canal.

End-of-dry-season water level data obtained on June 8, 1992, ranged from 94.39 to 96.68 ft, based on the datum of 100.00 ft established for well S-1. As shown in Figure 4-13, the groundwater flow direction is generally toward the north in the direction of the canal located at the rear of the site. The dry season hydraulic gradient was estimated to be 1.23×10^{-2} ft/ft. The estimated groundwater flow velocity is approximately 1.43 ft/day or about 525 ft/yr during the dry season. The high groundwater flow velocity estimate is a function of the steep hydraulic gradient measured across the site.

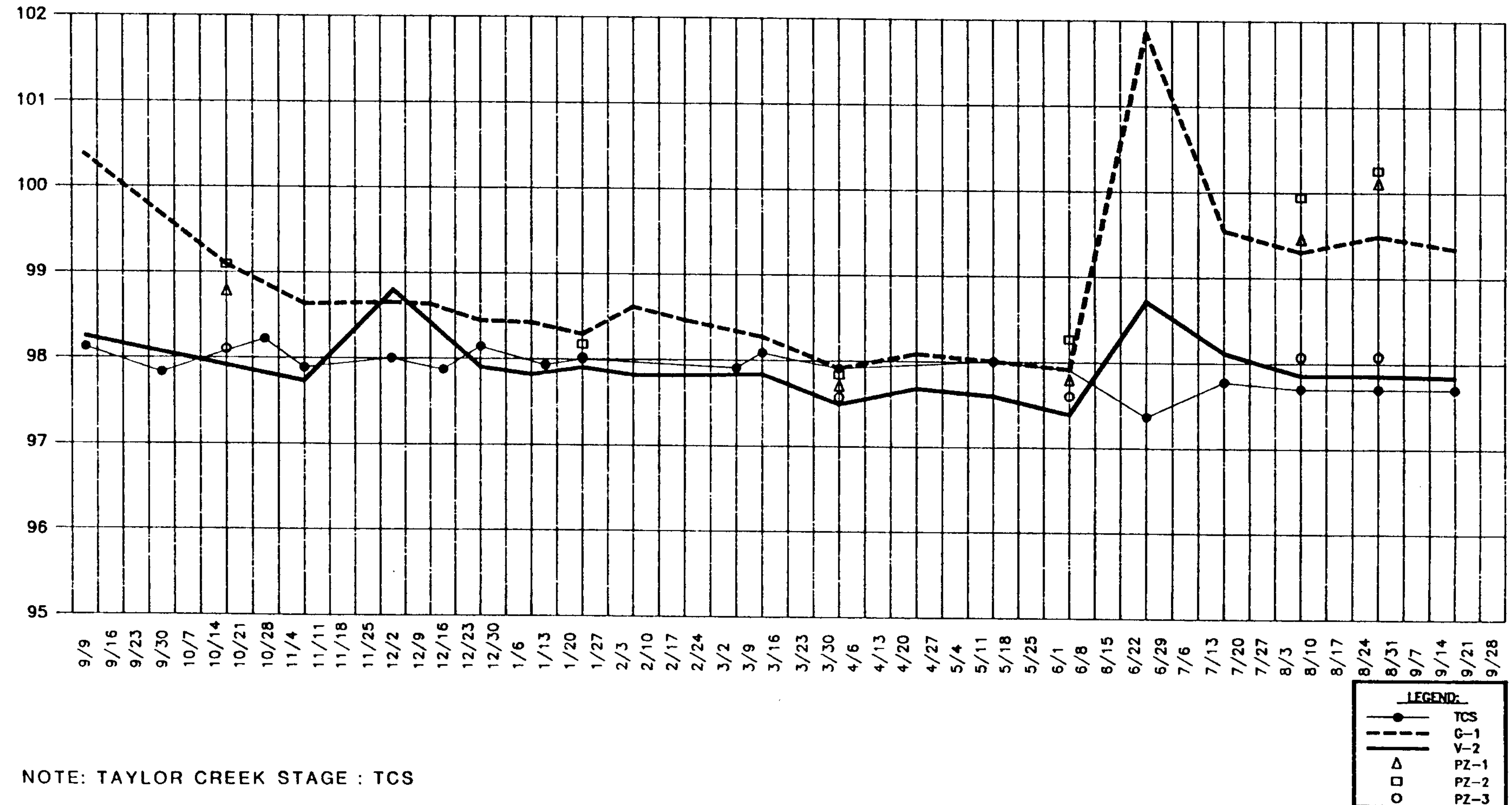
End-of-wet-season water levels measured on September 2, 1992, are provided in Table 3-6 and are illustrated on Figure 4-14. The groundwater flow direction continues toward the north. The calculated hydraulic gradient from the septic tank drainfield to the canal is estimated to be 3.33×10^{-3} ft/ft. Given this gradient and other assumptions provided in Table 3-6, the groundwater flow velocity is estimated to be 0.39 ft/day or about 140 ft/yr.

The seasonal water level fluctuation at this site is depicted in Figure 4-15. As shown by the hydrograph, water-level fluctuation adjacent to the septic tank drainfield (S-1) was approximately 2.5 ft, and water levels adjacent to the canal fluctuated about 2.25 ft. Based on the water levels recorded during this study, groundwater flow was predominantly from the septic tank to the canal.

4.3.1.5 Weston Site

The sediments encountered during drilling of one soil boring at this site consisted of gray fine-grained silica sand (fill material) to a depth of approximately 3.5 ft, underlain by approximately 1 ft of highly organic peat. From approximately 4.5 to 15.5 ft-bls, soil consisted of brown to gray, fine- to very fine-grained silica sand. From 15.5 to 16.0 ft-bls, a gray very fine-grained silica sand with shells was encountered.

ACAD FILE:3913010\WATERTBL



NOTE: TAYLOR CREEK STAGE : TCS

FIGURE 4-11
GOOLSBY SITE
WATER TABLE HYDROGRAPH
OKEECHOBEE, FLORIDA

Environmental
Science &
Engineering, Inc.

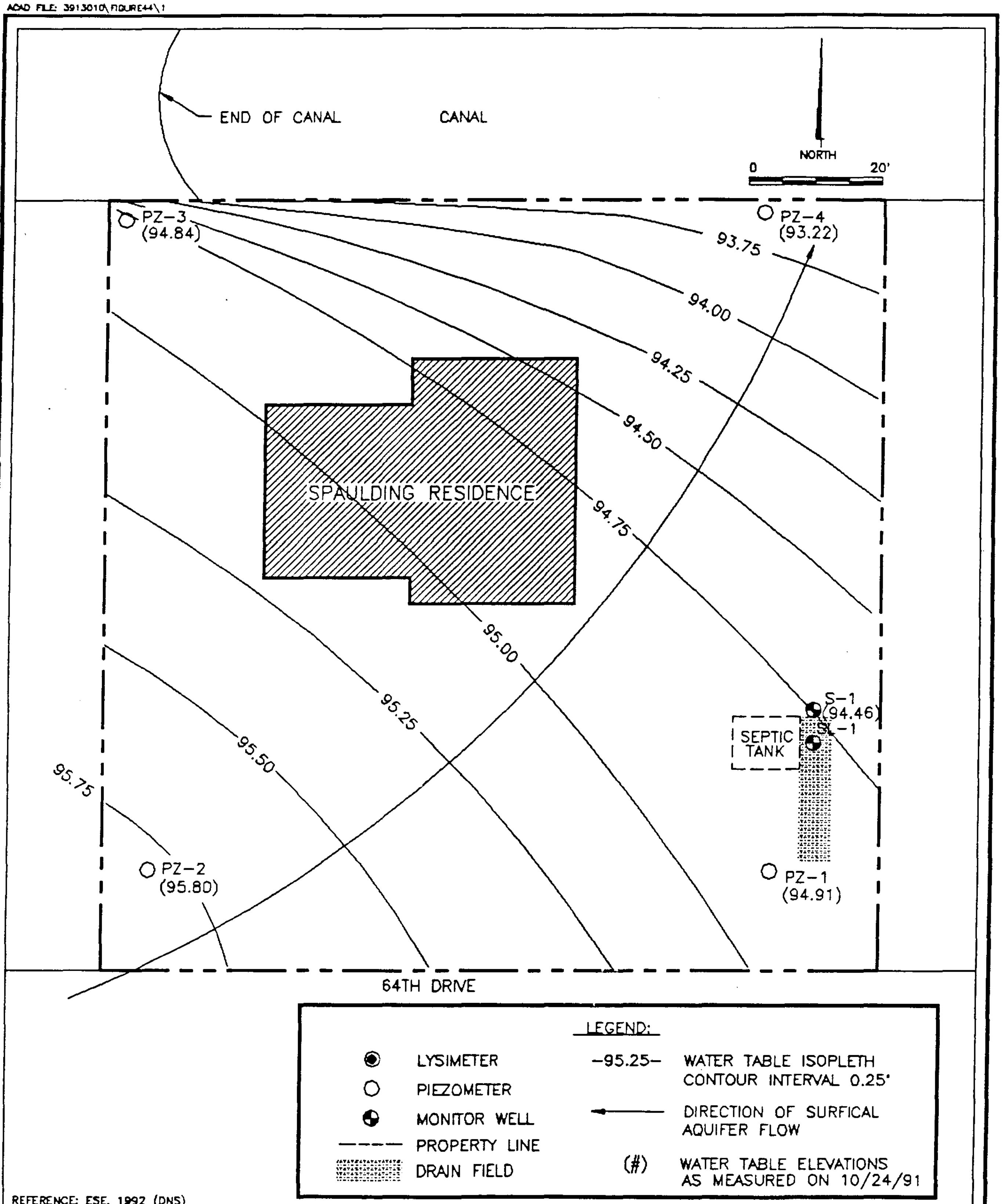
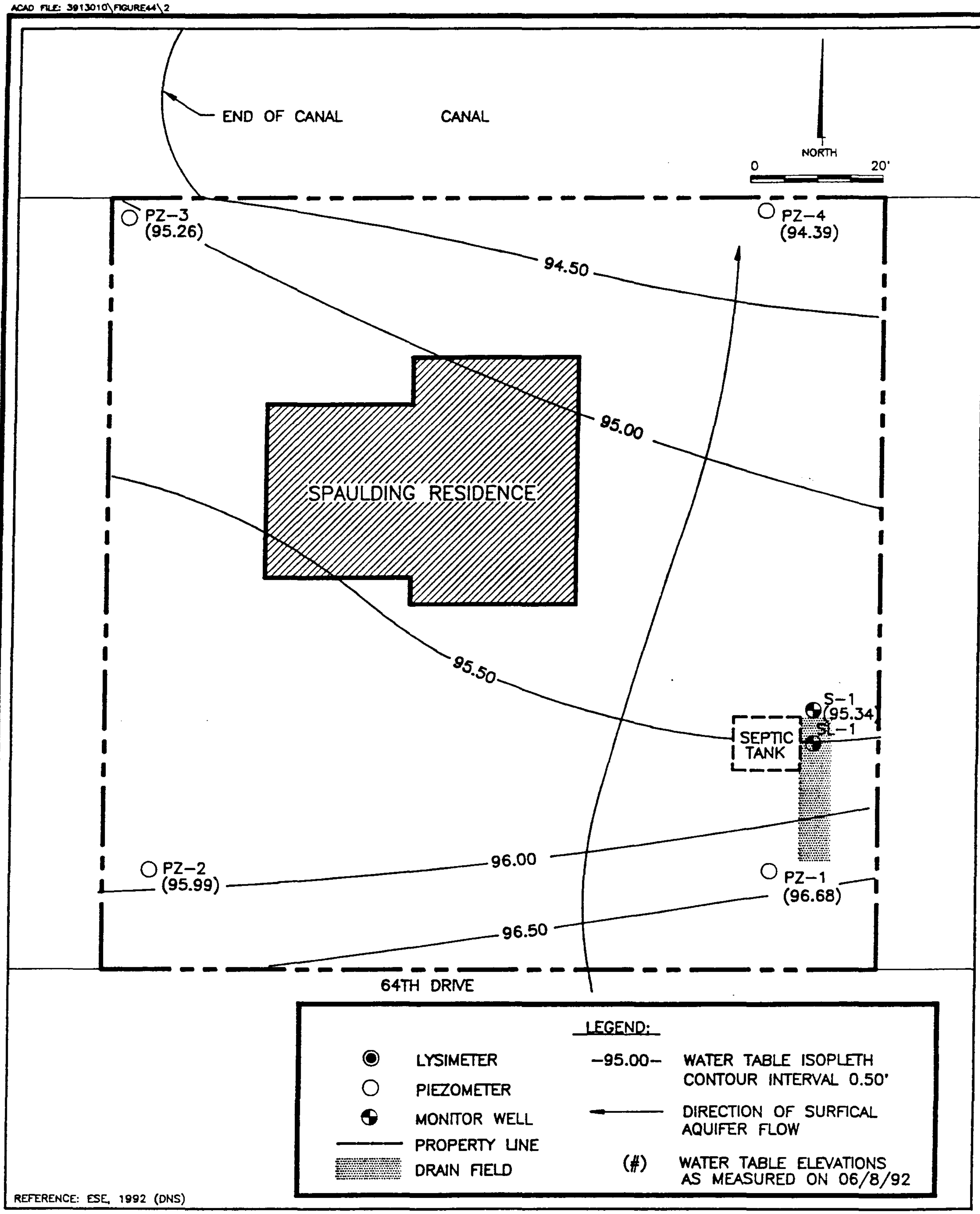


FIGURE 4-12
NEW SYSTEM - WATER TABLE CONTOUR MAP 10/24/91
SPAULDING SITE
OKEECHOBEE, FLORIDA

Environmental
Science &
Engineering, Inc.

ACAD FILE: 3913010\FIGURE44\2

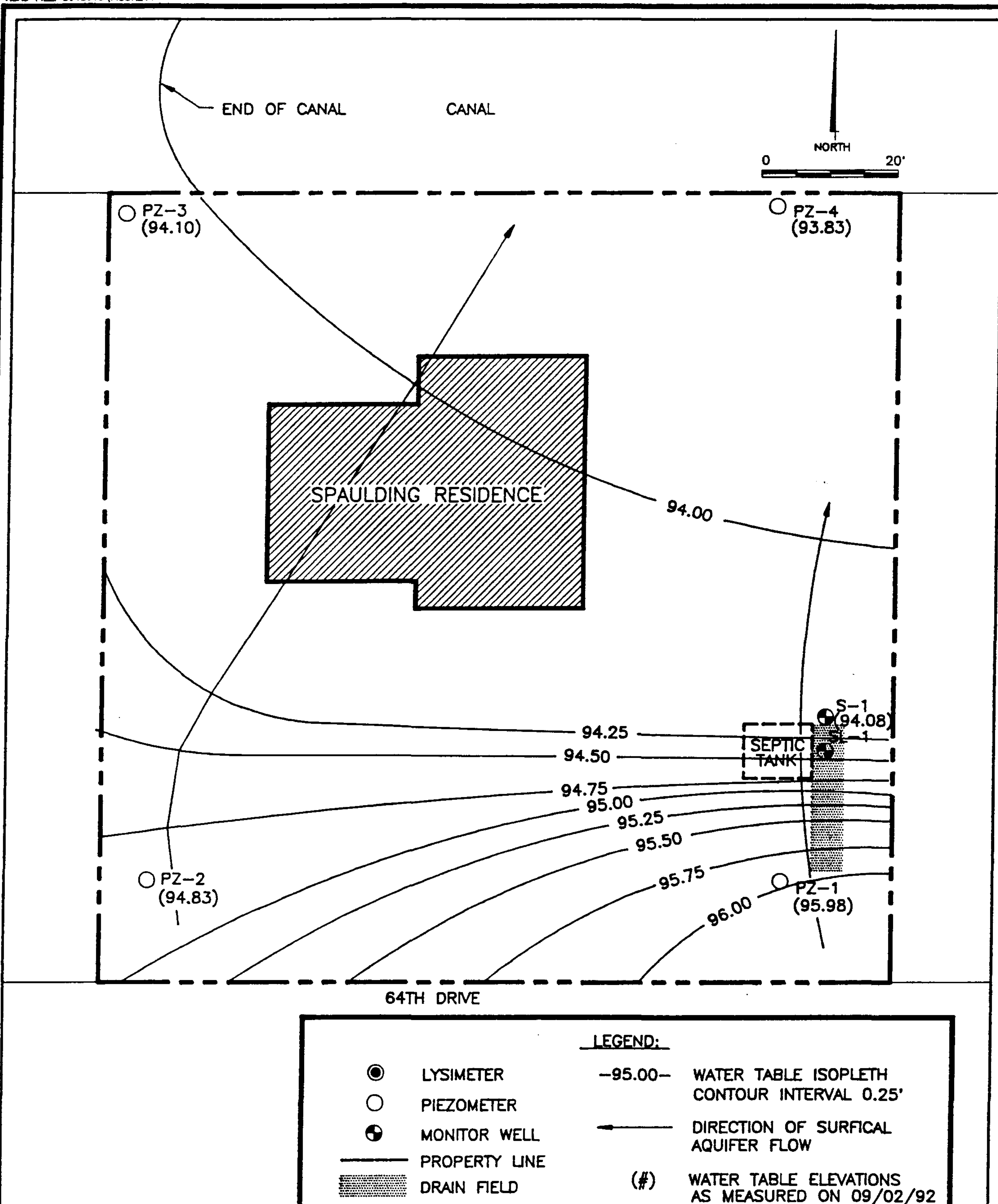


REFERENCE: ESE, 1992 (DNS)

FIGURE 4-13
NEW SYSTEM – WATER TABLE CONTOUR MAP 06/8/92
SPAULDING SITE
OKEECHOBEE, FLORIDA

ENVIRONMENTAL SCIENCE
&
ENGINEERING, INC.

ACAD FILE: 3913010\FIGURE44



REFERENCE: ESE, 1992 (DNS)

FIGURE 4-14
NEW SYSTEM – WATER TABLE CONTOUR MAP 09/02/92
SPAULDING SITE
OKEECHOBEE, FLORIDA

ENVIRONMENTAL SCIENCE
&
ENGINEERING, INC.

ACAD FILE:3913010\WATERTB6

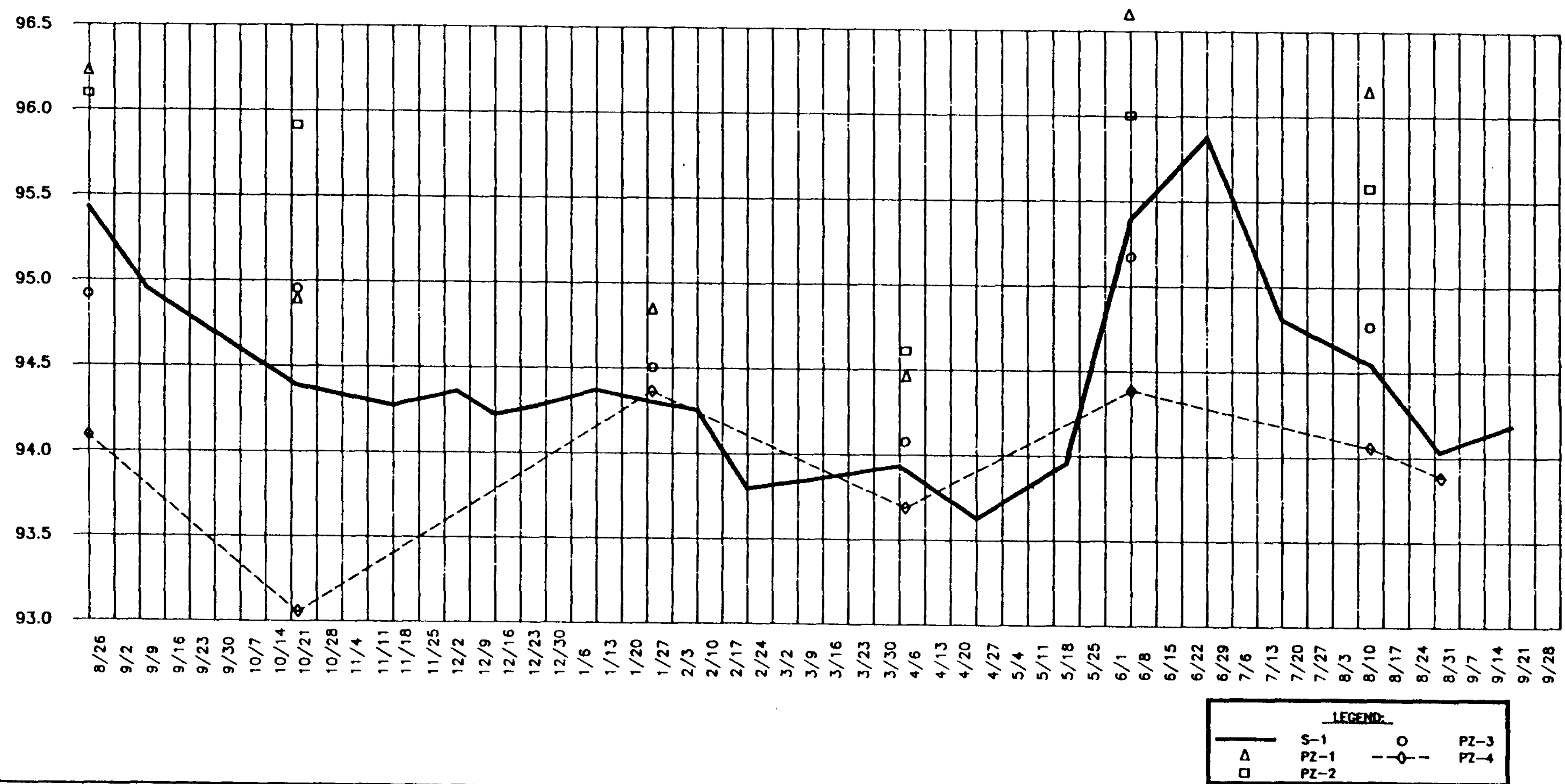


FIGURE 4-15
SPAULDING SITE
WATER TABLE HYDROGRAPH
OKEECHOBEE, FLORIDA

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Science &
Engineering, Inc.

Groundwater levels measured on October 24, 1991, ranged from approximately 94.02 (W-1) to 94.32 ft (PZ-1) with respect to the relative datum of 100 ft set for monitor well W-1 (Table 3-7). Based on these water levels, a water table contour map (Figure 4-16) was developed, which indicates the predominant flow direction is toward the southwest in the northern half of the site and to the northwest in the rear of the site. The hydraulic gradient at this time was approximately 1.67×10^{-3} ft/ft from the canal to the front of the site. Using these data and an estimated hydraulic conductivity of 19.5 ft/day for the shallow aquifer, and a porosity of 0.2, the groundwater flow rate across the site is estimated to be approximately 0.16 ft/day, or 59 ft/yr.

End-of-dry-season water levels, measured on June 8, 1992, ranged from 93.91 to 94.19 ft, based on the datum assigned to well W-1. Using these water levels, groundwater flow, shown in Figure 4-17, is toward the south-southwest. The estimated dry season hydraulic gradient is approximately 3.11×10^{-3} ft/ft. Assuming an estimated hydraulic conductivity of 19.5 ft/day and a porosity value of 0.2, groundwater flow velocity is estimated to be approximately 0.303 ft/day, or about 110 ft/yr during the dry season.

End-of-wet-season water levels were measured on September 2, 1992, and referenced to the 100 ft datum established for W-1, as shown on Table 3-7. A water table contour map, Figure 4-18, was constructed using these data and indicates groundwater flow is toward the south. The hydraulic gradient calculated from these data is estimated to be 6.5×10^{-3} ft/ft. The groundwater flow velocity is further estimated to be approximately 0.63 ft/day (230 ft/yr), assuming the previous hydraulic conductivity and porosity values used for the previous site hydraulic analyses.

A hydrograph, Figure 4-19, depicts the range in water levels at each monitoring point during this study. The hydrograph indicates that the septic tank monitor well W-1 fluctuated above and below canal water levels during the year, and, therefore, groundwater flow varied toward and away from the canal during the monitoring period. Based on the hydrograph, onsite groundwater flow and probably nutrient loading appear to be a transient condition subject to seasonal water levels and rainfall.

4.3.1.6 Package Site

The sediments underlying the Package Plant site were not evaluated during this investigation. The site has an existing monitoring plan permit through the Florida Department of Environmental Regulation (FDER) and, therefore, monitor wells and soil borings were not completed.

Initial water levels (Table 3-8) measured at the Package Plant on October 24, 1991, ranged from 99.93 ft at percolation pond B to 96.02 ft at P-1 (MW-1), with respect to a relative datum of 100 ft set for P-1. The apparent groundwater flow direction at this time was toward the south (Figure 4-20). The estimated hydraulic gradient is 1.63×10^{-2} ft/ft. Hydraulic conductivity test data indicate the permeability of sediments in the area of P-1 to be approximately 12.2 ft/day. Given the hydraulic gradient, estimated aquifer permeability, and assuming a porosity of 0.2, the groundwater flow velocity is estimated to be about 1.0 ft/day, or about 365 ft/yr at this time. This condition reflects the mounding effects of percolation pond B on the water table aquifer at this site and the influence of the percolation ponds on the groundwater flow velocity.

End-of-dry-season water level data obtained from well P-1 and piezometer PZ-1 on June 8, 1992, were 93.29 and 94.25 ft, respectively, based on a datum of 100.00 ft set for well P-1 (Table 3-8). The dry season hydraulic gradient is estimated to be approximately 4.7×10^{-3} (Figure 4-21). Given an estimated hydraulic conductivity of 12.2 ft/day, the dry season groundwater flow velocity is estimated to be approximately 0.29 ft/day or about 106 ft/yr. The observed gradient does not reflect the influence of the percolation pond system on shallow aquifer water levels.

End-of-wet-season water level data obtained on October 28, 1992, indicated percolation pond system still influences groundwater flow. As shown in Figure 4-22, groundwater flow on October 28, 1992, was generally toward the south.

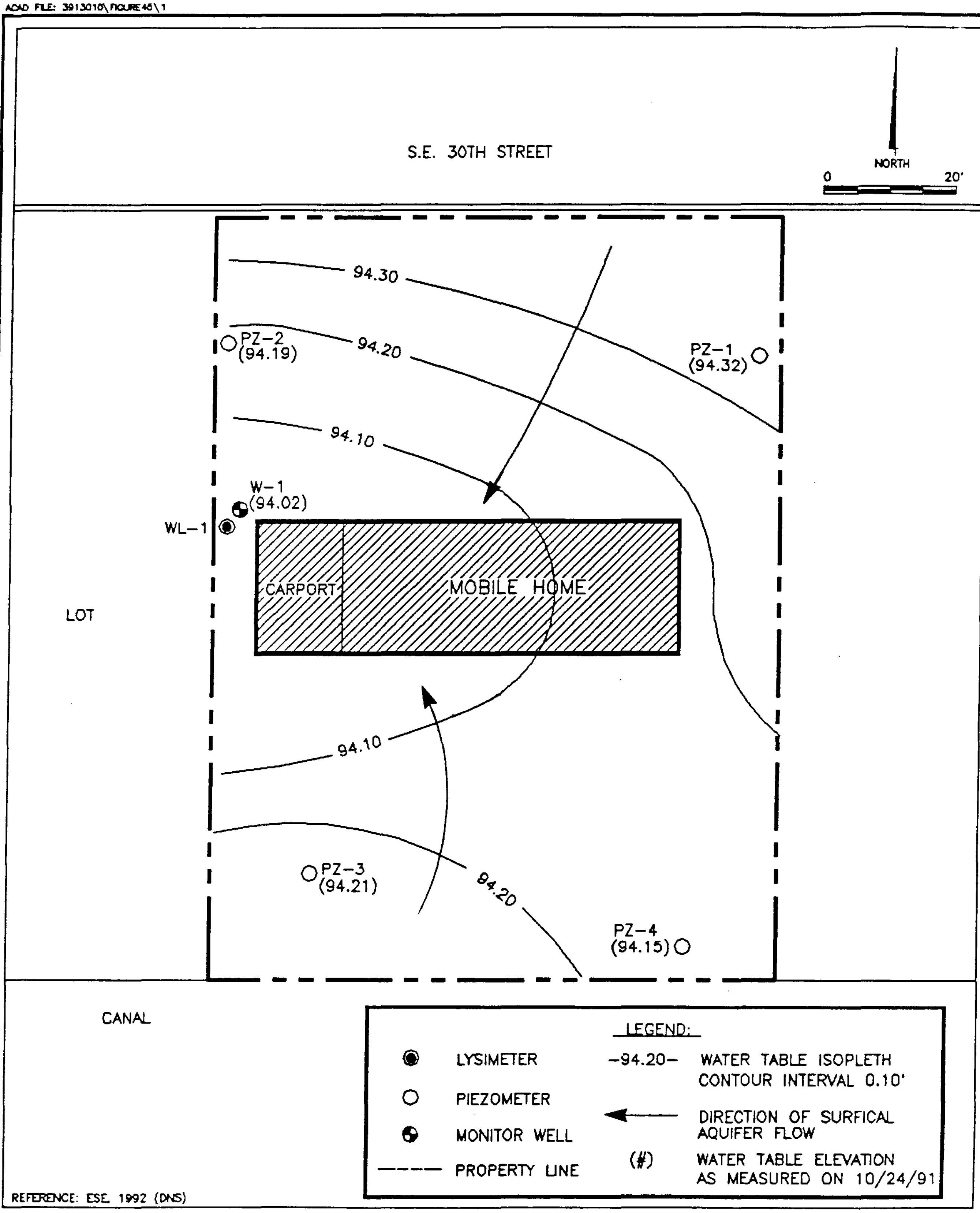

FIGURE 4-16
CENTRAL SEWER – WATER TABLE CONTOUR MAP 10/24/91
WESTON SITE
OKEECHOBEE, FLORIDA

Environmental Science & Engineering, Inc.

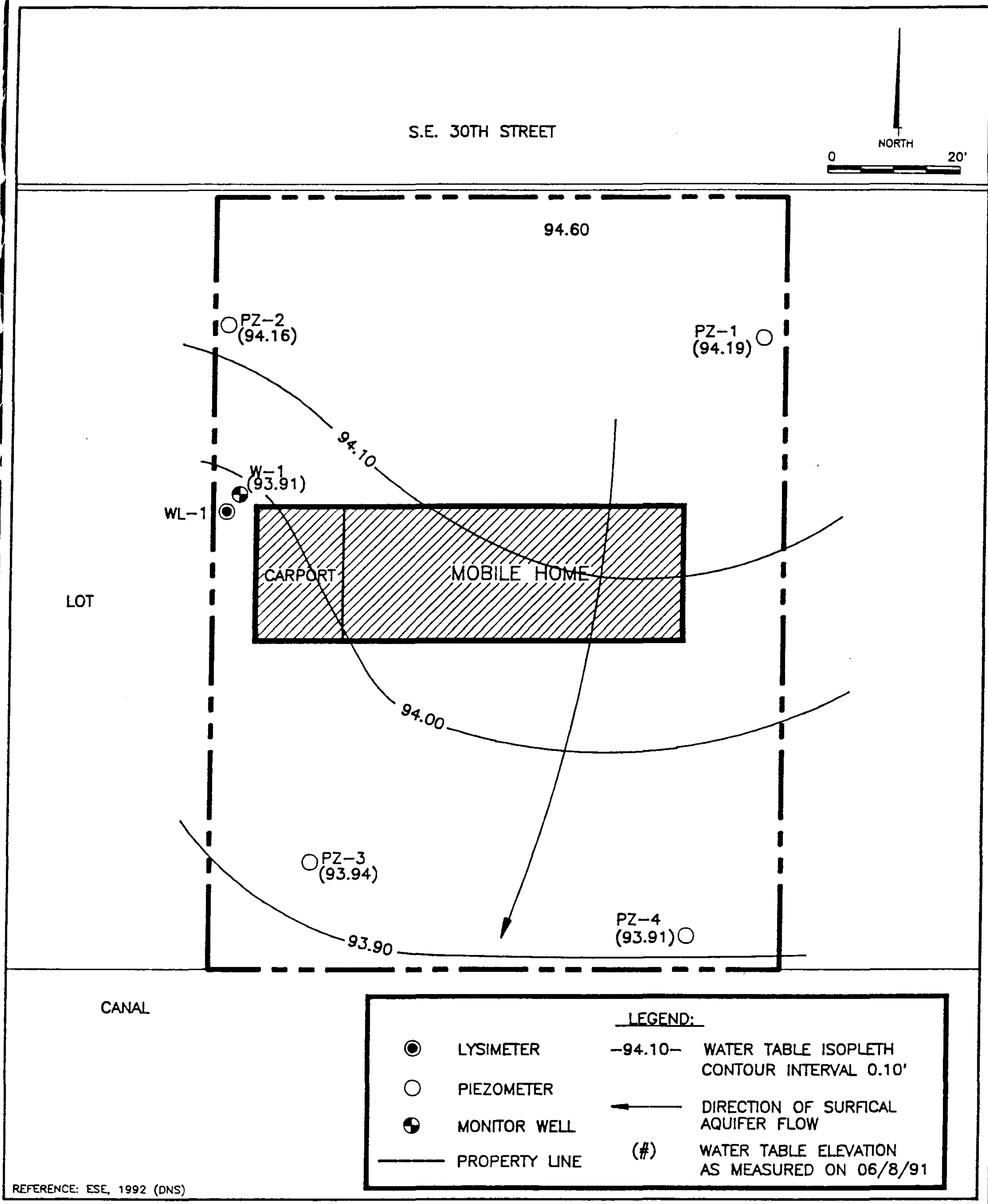

FIGURE 4-17
CENTRAL SEWER – WATER TABLE CONTOUR MAP 06/8/92
WESTON SITE
OKEECHOBEE, FLORIDA

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&
ENGINEERING, INC.

ACAD FILE: 3913010\FIGURE45

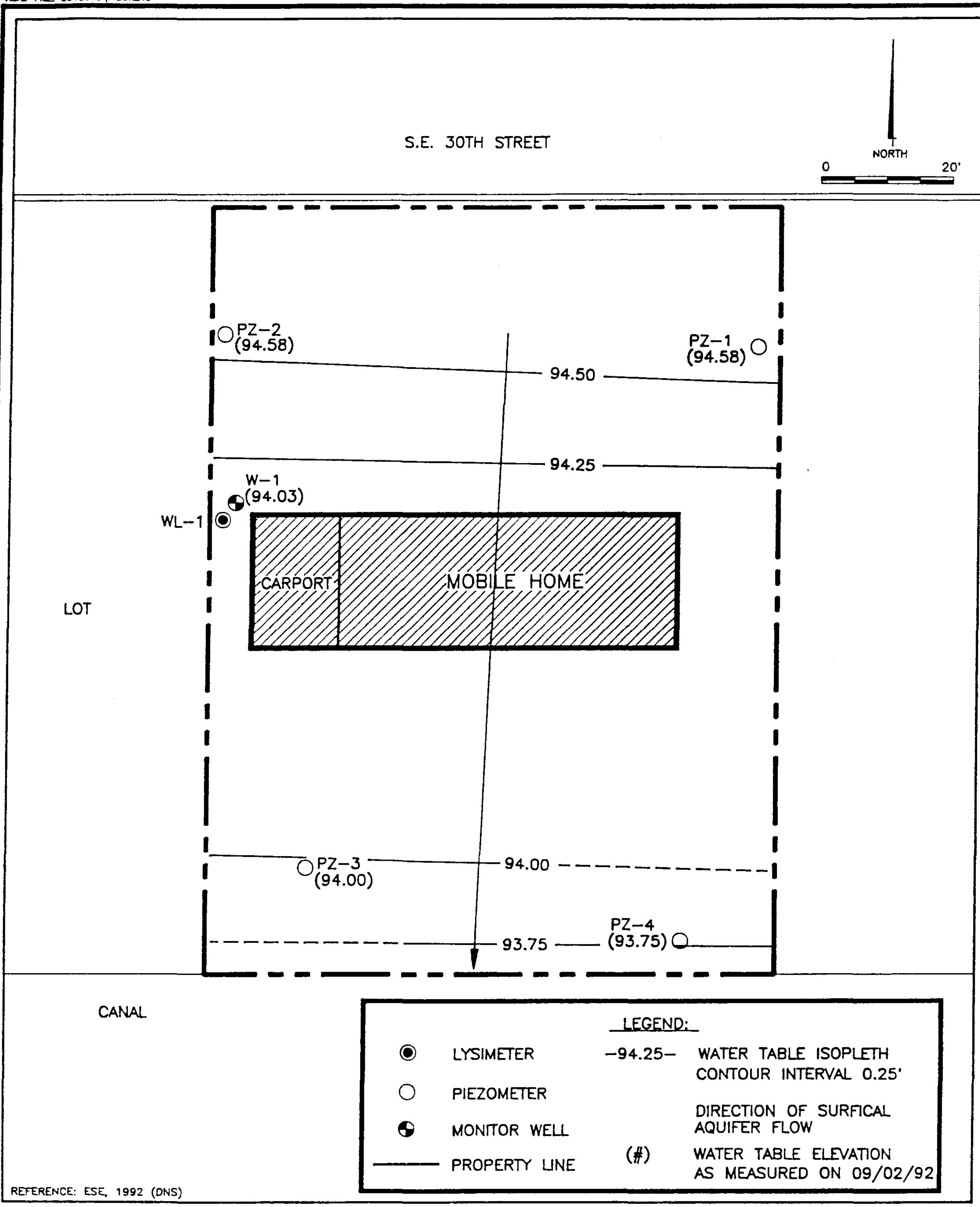

FIGURE 4-18
CENTRAL SEWER – WATER TABLE CONTOUR MAP 09/02/92
WESTON SITE
OKEECHOBEE, FLORIDA

ENVIRONMENTAL SCIENCE
&
ENGINEERING, INC.

ACAD FILE:3913010\WATERTB4

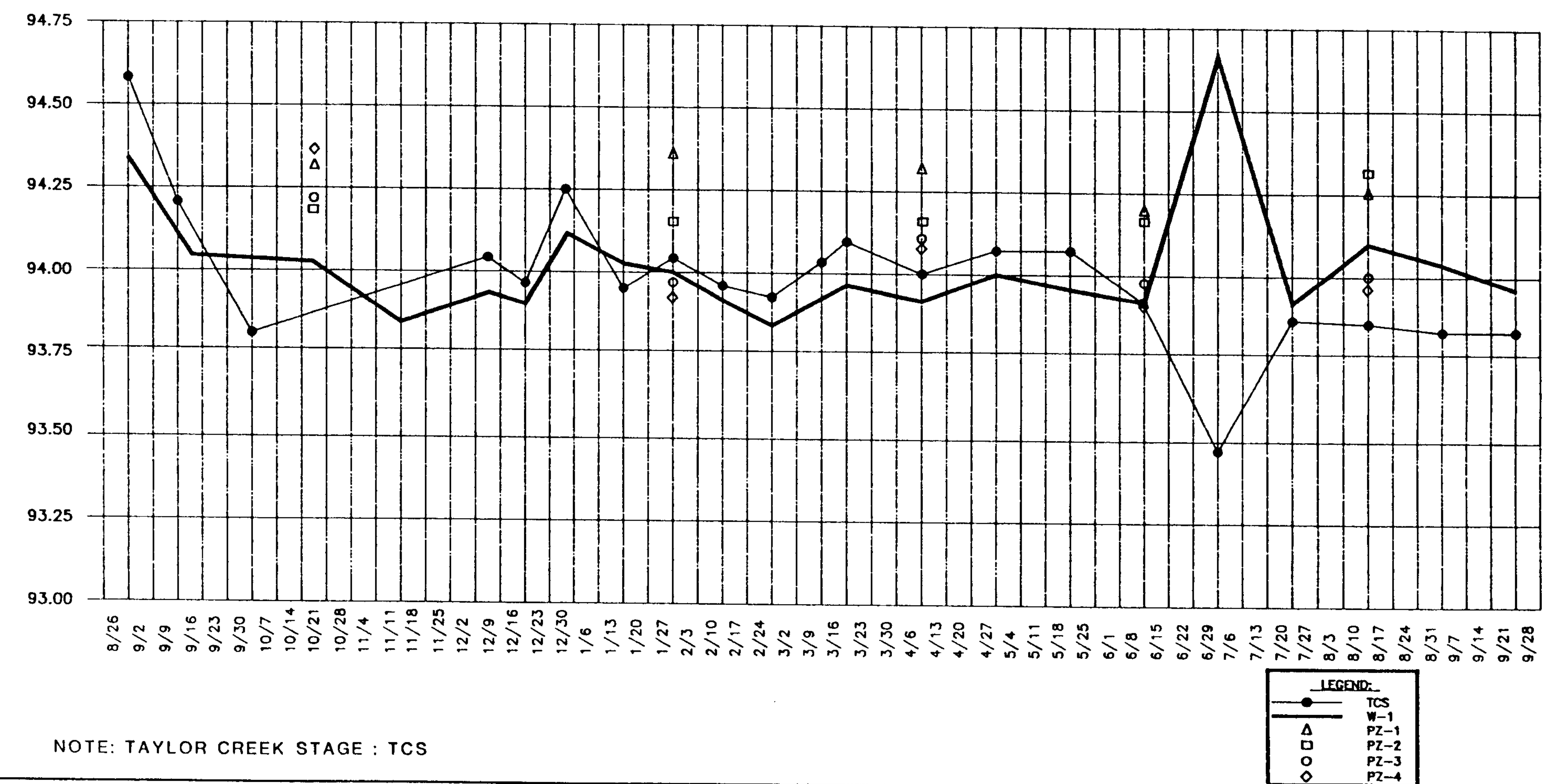

FIGURE 4-19
WESTON SITE
WATER TABLE HYDROGRAPH
OKEECHOBEE, FLORIDA

Environmental Science & Engineering, Inc.

ACAD FILE: 3913010\FIGUR46A

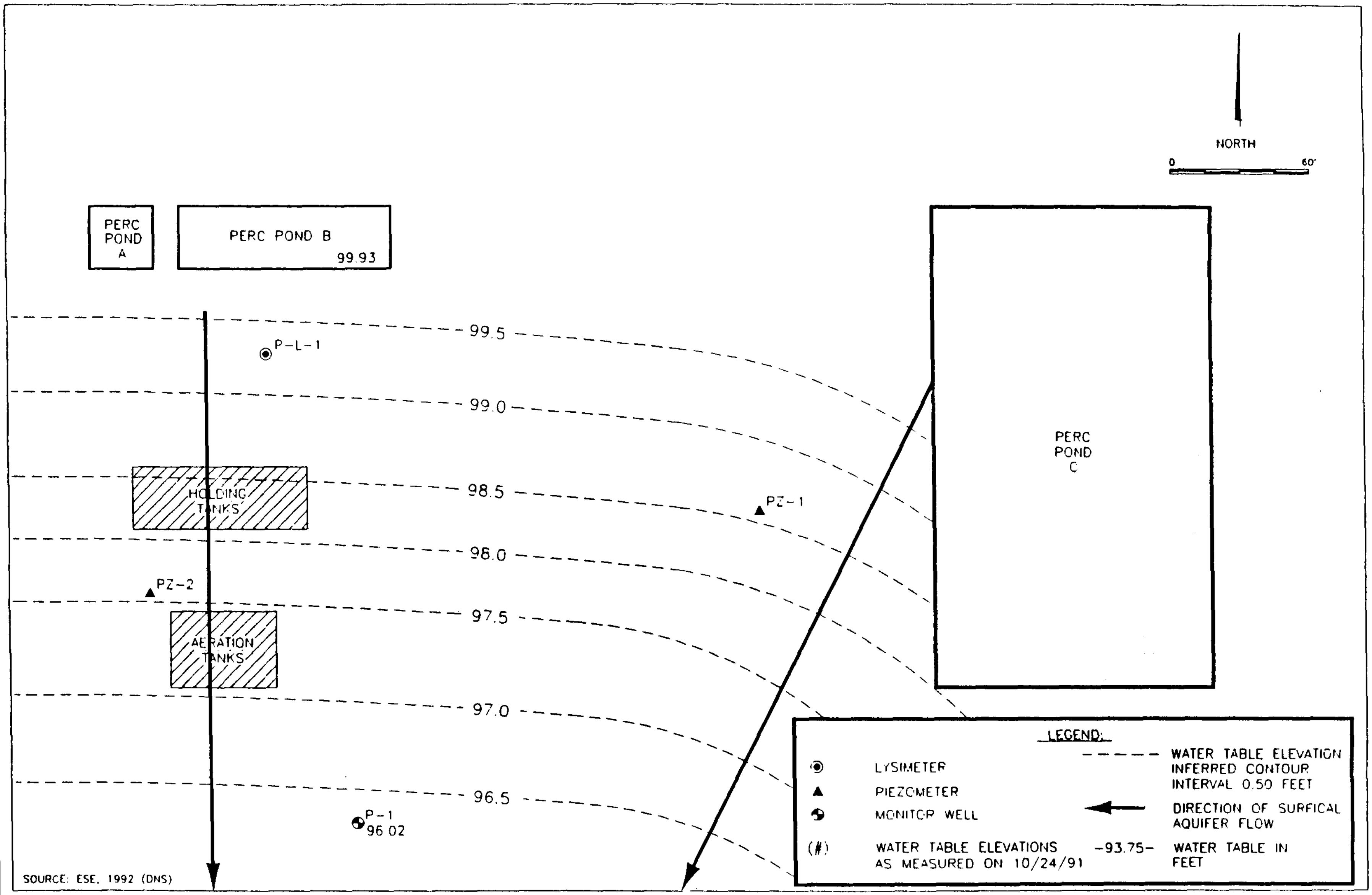

FIGURE 4-20
SITE MAP - WATER TABLE CONTOUR MAP 10/24/91
PACKAGE PLANT
OKEECHOBEE, FLORIDA

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Science &
Engineering, Inc.

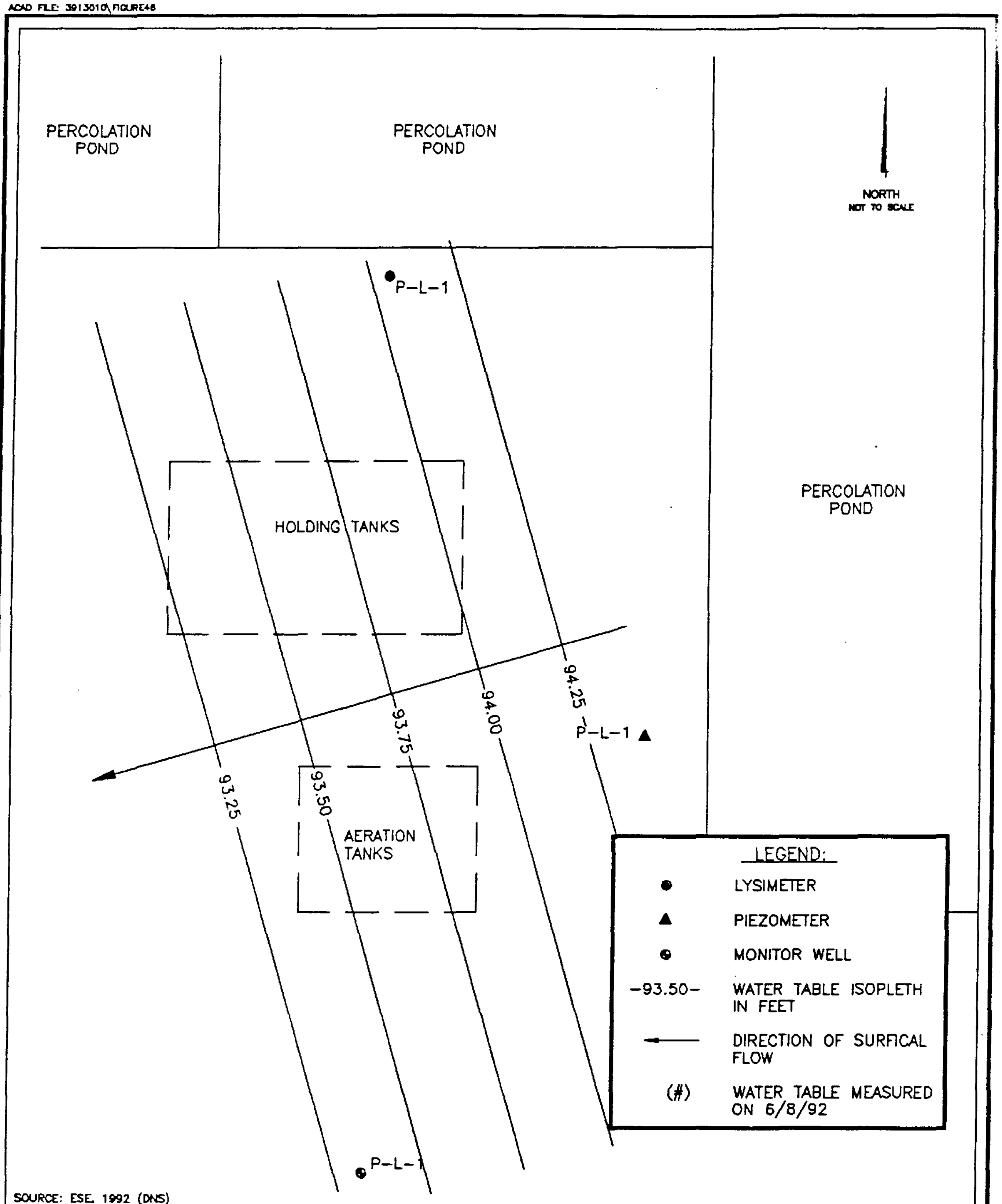

FIGURE 4-21
PACKAGE PLANT
WATER TABLE CONTOUR MAP, JUNE 8, 1992

Environmental Science & Engineering, Inc.

ACAD FILE: 3913010\FIG5-23

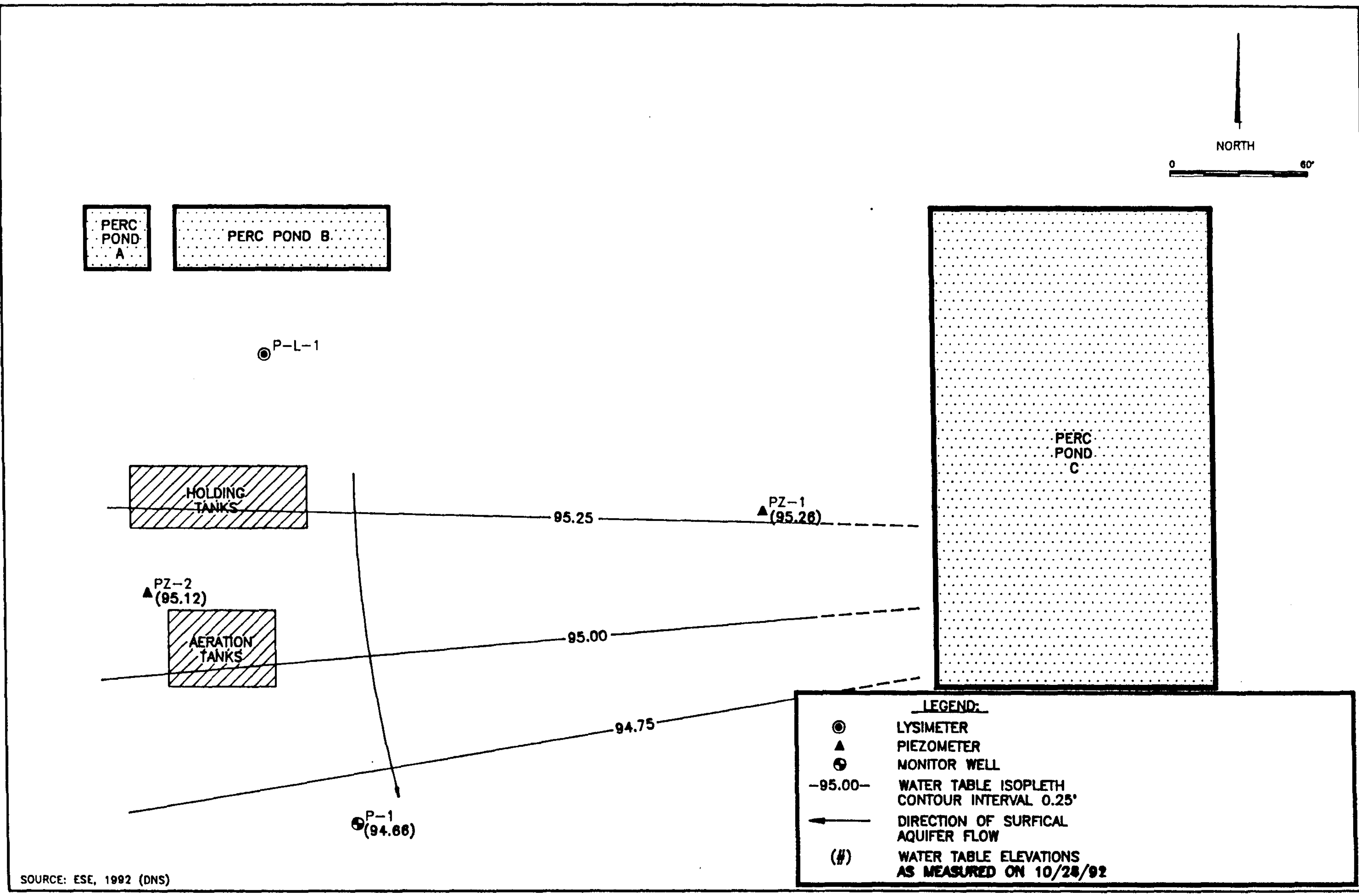

FIGURE 4-22
SITE MAP – WATER TABLE CONTOUR MAP 10/28/92
PACKAGE PLANT
OKEECHOBEE, FLORIDA

Environmental Science & Engineering, Inc.
A CILCORP Company

The hydraulic gradient is estimated to be approximately 4.3 x 10^{-3} ft/ft. Given an estimated hydraulic conductivity of 12.2 ft/day (Table 3-8), the groundwater flow velocity at this time is estimated to be approximately 0.267 ft/day or about 97 ft/yr.

Figure 4-23 provides a hydrograph depicting the range of water levels within monitor well P-1 during the entire monitoring period. Water level fluctuations observed over the monitoring period were approximately 4.5 ft, which occurred during an extreme rainfall event in June 1992. Water levels illustrated in Figure 4-23 display a seasonal trend, being lowest in the dry season and highest in the wet season. The dominant groundwater flow direction during the monitoring period was toward the south.

In summary, groundwater level and flow direction data suggest onsite water levels are a function of seasonal (wet/dry) changes in rainfall and canal water levels. Typically, groundwater flow is toward the canals for the major part of the year. However, reversals to this pattern have been noted. Therefore, nutrient loading conditions are also transient conditions that depend not only on the flow direction, but also on the groundwater flow rate.

4.4 SURFACE WATER

4.4.1 MICROBIOLOGICAL ANALYSES

Biological contaminants associated with septic tanks may exhibit a variety of characteristics, including different species, surface properties, and half-lives. Septic tank leachate has been identified as a problem in many of Florida's waterbodies and a major source of groundwater contamination (FDER, 1992a). Environmental factors that may influence their subsurface migration rates through soil include soil moisture content and holding capacity, temperature, pH, organic matter, and antagonism from soil microflora. The physical process of mechanical filtering and the chemical process of adsorption may be the most significant mechanisms responsible for bacterial removal from water percolating through soil (Canter and Knox, 1984). The following discussion focuses on surface water monitoring data that may be influenced by those variables affecting septic tank leachate.

The total coliform measurements made as part of this study are used to determine the size of the coliform population, which provides a relative indication of water quality. Organisms in this bacteriological group are rod-shaped gram negative bacteria that ferment lactose at 35°C (FDER, 1989a). The total coliform procedure is often used in conjunction with other tests to discriminate between fecal and nonfecal bacterial contamination. The predominant species in the fecal coliform group is Escherichia coli, indicative of the possible presence of enteric pathogens associated with seepage from faulty septic tanks, domestic sewage, or runoff from upstream agricultural operations.

4.4.1.1 Taylor Creek Isles

Four monitoring stations at Taylor Creek Isles were sampled for total coliforms. Analytical data associated with this site are presented in Tables 4-6 to 4-9 and Figures 4-24 to 4-27. A description of this subdivision's microbiological characteristics during the period of monitoring follows.

The upstream Taylor Creek station, TC-1, was chosen as a background location, removed from potential Taylor Creek Isles septic tank impacts. Coliform levels measured at this site generally increased throughout the monitoring period, with the highest densities recorded during the spring, followed by a return to previously identified levels. Water quality standards for total coliform bacteria in Class III surface waters should not exceed 1,000 per 100 mL in more than 20 percent of monthly samples, pursuant to Section 17-302.560(5), F.A.C. Since monthly averages are based upon a minimum of 10 samples taken over a 30-day period, this standard may only be postulated. Likely exceedances of this criterion may be noted during the first part of 1992, however. While no discernable correlation between bacteriological and nutrient trends may be made, increasing temperature measurements may influence population growth through enhanced metabolic activity.

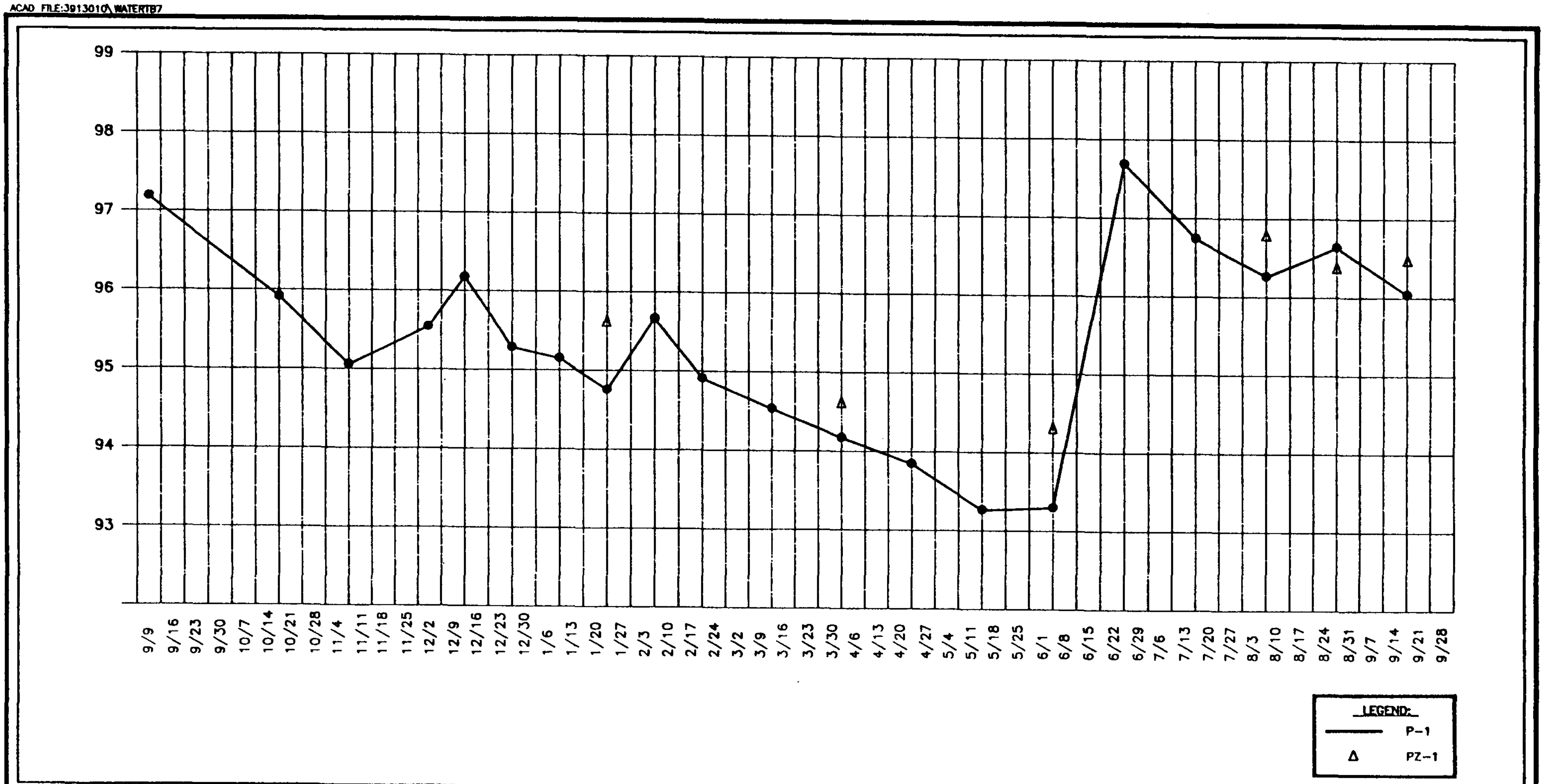

FIGURE 4-23
PACKAGE PLANT SITE
WATER TABLE HYDROGRAPH
OKEECHOBEE, FLORIDA

Environmental Science & Engineering, Inc

Table 4-6. Taylor Creek Surface Water Sampling Results For Station 1.

Sampling Event	Sampling Date	PHOS	NO23	NH34	SC	PH	COLI
1	9/9/91	0.408	0.391	0.761	NA	NA	2000
2	9/30	0.38	0.182	0.674	NA	NA	3000
3	10/21	0.302	0.336	0.293	560	6.9	NS
4	11/11	0.196	ID	ID	500	7.4	3400
5	12/2	0.229	0.005	0.045	735	7.4	9000
6	12/16	0.27	0.239	0.075	1000	6.8	NS
7	12/30	0.273	0.073	0.105	500	6.5	5000
8	1/13/92	0.259	0.01	0.061	770	7.2	NS
9	1/27	0.255	0.028	0.078	580	6.7	3000
10	2/10	0.303	0.005	0.01	520	6.7	NS
11	2/24	0.337	0.027	0.085	260	7.4	16000
12	3/16	0.164	0.023	0.059	590	7.1	5000
13	4/6	0.351	0.005	0.021	980	7.3	32000
14	4/27	0.31	0.005	0.041	960	7	NS
15	5/18	0.274	0.005	0.038	1050	8	10000
16	6/8	0.264	0.005	0.03	1050	7.8	10000
17	6/29	0.486	0.297	0.334	215	7.6	NS
18	7/20	0.64	0.069	0.054	376	7.8	4400
19	8/10	0.411	0.086	0.333	298	8.5	6000
20	8/31	0.52	0.215	0.402	NA	8.8	NS
21	9/21	0.453	0.338	0.236	615	6.3	1000
Mean		0.337	0.118	0.187	642	7.3	7844
Max		0.64	0.391	0.761	1050	8.8	32000
Min		0.164	0.005	0.01	215	6.3	1000

Table 4-7. Taylor Creek Surface Water Sampling Results for Station 2.

Sampling Event	Sampling Date	PHOS	NO23	NH34	SC	PH	COLI	TEMP
1	9/9/91	0.379	0.083	0.618	NA	NA	1600	NA
2	9/30	0.373	0.081	0.323	NA	NA	16000	NA
3	10/21	0.298	0.193	0.139	630	6.9	NS	27
4	11/11	0.193	ID	ID	550	7.9	2600	19
5	12/2	0.247	0.033	0.04	680	7.4	3000	20
6	12/16	0.284	0.03	0.117	980	6.6	NS	19
7	12/30	0.253	0.025	0.099	510	6.5	1700	19.2
8	1/13/92	0.199	0.01	0.074	735	6.5	NS	17
9	1/27	0.2	0.005	0.031	590	6.5	230	22.4
10	2/10	0.234	0.005	0.01	530	6.8	NS	20
11	2/24	0.356	0.005	0.07	240	7.2	1300	24.5
12	3/16	0.25	0.005	0.021	820	7.3	3000	23
13	4/6	0.23	0.005	0.02	1180	7.4	440	24
14	4/27	0.276	0.005	0.035	1060	7.9	NS	25.5
15	5/18	0.223	0.005	0.023	1220	7.2	4400	29.5
16	6/8	0.16	0.005	0.032	1150	7.4	1400	34.5
17	6/29	0.284	0.005	0.01	710	7	NS	31.5
18	7/20	0.562	0.029	0.123	420	7.4	280	34
19	8/10	0.482	0.049	0.206	393	8.7	2200	30
20	8/31	0.396	0.061	0.269	NA	8.6	NS	NA
21	9/21	0.367	0.098	0.073	300	6.5	460	31
Mean		0.297	0.037	0.117	706	7.3	2759	25.1
Max		0.562	0.193	0.618	1220	8.7	16000	34.5
Min		0.16	0.005	0.01	240	6.5	230	17

Note:

PHOS	= Total Phosphorous (mg/L).	PH	= pH (Standard Units).
NO23	= Nitrate+Nitrite (mg/L).	COLI	= Coliforms (Count).
NH34	= Ammonia+Ammonium (mg/L).	TEMP	= Temperature (Degrees Celsius).
SC	= Specific Conductance (uMhos/cm).	NA	= Not Analyzed
NS	= No Sample Collected.	ID	= Invalid Data

Table 4-8. Taylor Creek Surface Water Sampling Results for Station 3.

Sampling Event	Sampling Date	PHOS	NO23	NH34	SC	PH	COLI	TEMP
1	9/9/91	0.43	0.106	0.618	NA	NA	1600	NA
2	9/30	0.385	0.058	0.277	NA	NA	2800	NA
3	10/21	0.258	0.19	0.145	610	7.4	NS	27
4	11/11	0.263	ID	ID	580	7.8	5500	20
5	12/2	0.249	0.046	0.044	690	7.3	12000	21
6	12/16	0.282	0.044	0.148	990	6.8	NS	19
7	12/30	0.243	0.04	0.091	500	6.7	16000	20.8
8	1/13/92	0.211	0.005	0.158	725	6.6	NS	19
9	1/27	0.21	0.005	0.029	590	6.4	800	23.1
10	2/10	0.221	0.005	0.01	530	7	NS	22
11	2/24	0.35	0.012	0.068	358	7.2	16000	24.8
12	3/16	0.23	0.005	0.01	820	7.2	3000	24
13	4/6	0.195	0.005	0.01	1090	7.5	4800	24.5
14	4/27	0.232	0.005	0.032	1040	7.9	NS	25.5
15	5/18	0.187	0.005	0.026	1220	7	7000	29.5
16	6/8	0.147	0.005	0.022	1210	7.4	3400	33.5
17	6/29	0.398	0.222	0.085	690	7	NS	31
18	7/20	0.6	0.048	0.18	428	7.3	1800	33.5
19	8/10	0.446	0.049	0.288	403	8.75	3400	30.9
20	8/31	0.417	0.12	0.243	NA	8.6	NS	NA
21	9/21	0.334	0.087	0.097	310	6.7	4800	31.5
Mean		0.299	0.054	0.129	711	7.29	5922	25.6
Max		0.6	0.222	0.618	1220	8.75	16000	33.5
Min		0.147	0.005	0.01	310	6.4	800	19

Table 4-9. Taylor Creek Surface Water Sampling Results for Station 4.

Sampling Event	Sampling Date	PHOS	NO23	NH34	SC	PH	COLI	TEMP
1	9/9/91	0.387	0.264	0.69	NA	NA	4000	NA
2	9/30	0.37	0.065	0.407	NA	NA	9000	NA
3	10/21	0.207	0.165	0.144	490	7.4	NS	26.5
4	11/11	0.153	ID	ID	500	7.5	3400	19
5	12/2	0.23	0.124	0.094	700	7.5	5000	20
6	12/16	0.279	0.102	0.158	1000	6.7	NS	19
7	12/30	0.187	0.119	0.131	510	6.6	3000	20.9
8	1/13/92	0.162	0.045	0.07	700	6.7	NS	17
9	1/27	0.164	0.097	0.091	550	6.5	16000	22
10	2/10	0.204	0.072	0.01	520	6.9	NS	21.5
11	2/24	0.261	0.052	0.026	300	7.1	3000	24.8
12	3/16	0.298	0.005	0.023	720	7.2	16000	22
13	4/6	0.171	0.005	0.01	1020	7.4	10000	24.5
14	4/27	0.197	0.005	0.037	1000	8.1	NS	24
15	5/18	0.179	0.005	0.025	1000	7	10000	28.5
16	6/8	0.125	0.019	0.028	1100	7.2	32000	33
17	6/29	0.524	0.284	0.389	281	7	NS	29.5
18	7/20	0.593	0.131	0.243	430	7.1	32000	33
19	8/10	0.44	0.182	0.358	417	8.61	18000	29.7
20	8/31	0.4	0.175	0.347	NA	8.3	NS	NA
21	9/21	0.392	0.133	0.099	250	6.9	2200	30.5
Mean		0.282	0.103	0.169	638	7.3	11685	24.7
Max		0.593	0.284	0.69	1100	8.61	32000	33
Min		0.125	0.005	0.01	250	6.5	2200	17

Note:

PHOS = Total Phosphorous (mg/L).
NO23 = Nitrate+Nitrite (mg/L).
NH34 = Ammonia+Ammonium (mg/L).
SC = Specific Conductance (uMhos/cm).
NS = No Sample Collected.
PH = pH (Standard Units).
COLI = Coliforms (Count).
TEMP = Temperature (Degrees Celsius).
NA = Not Analyzed
ID = Invalid Data

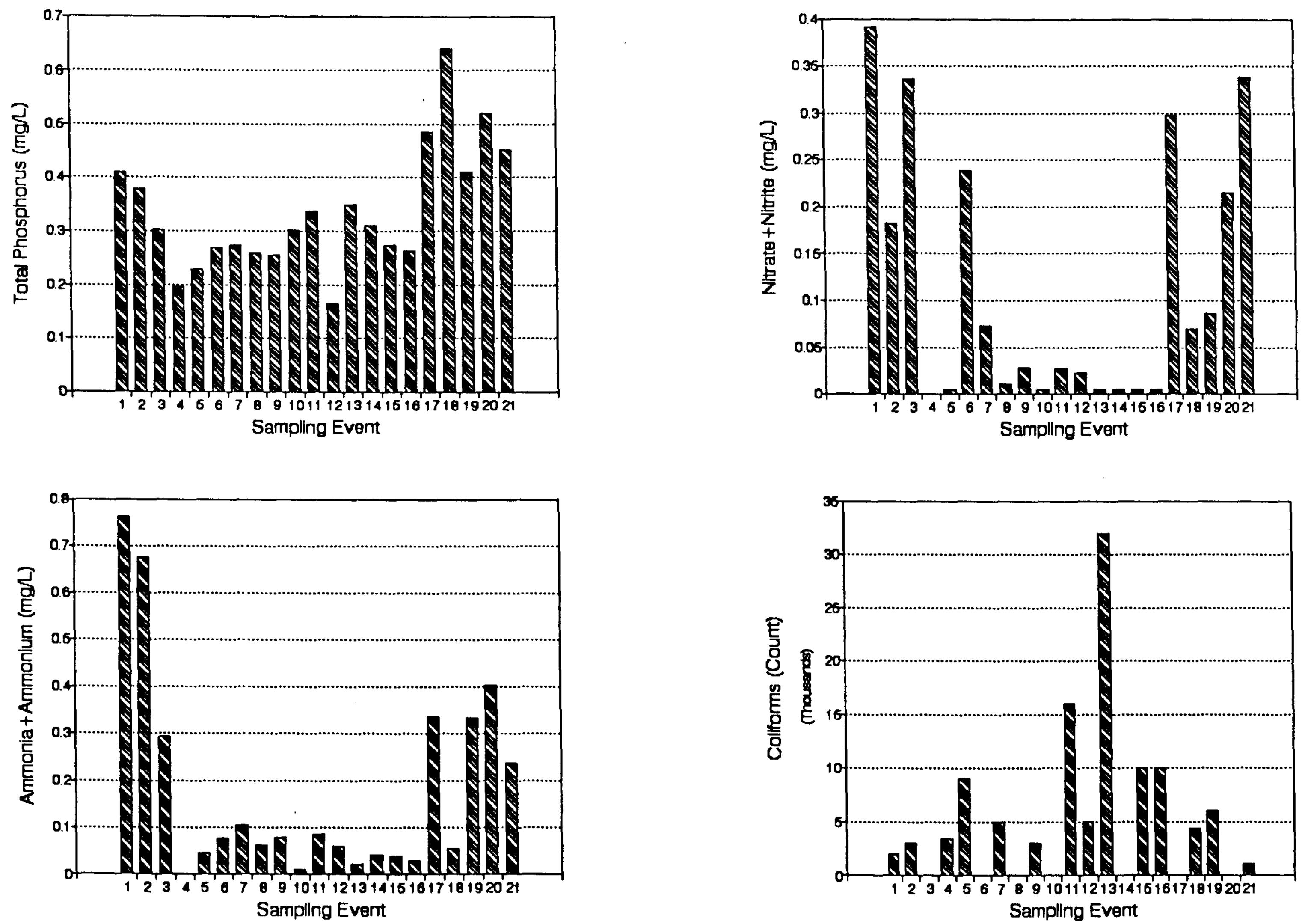

Figure 4-24 (1 of 2)
TAYLOR CREEK SURFACE WATER QUALITY GRAPHS
STATION 1

SOURCE: ESE.

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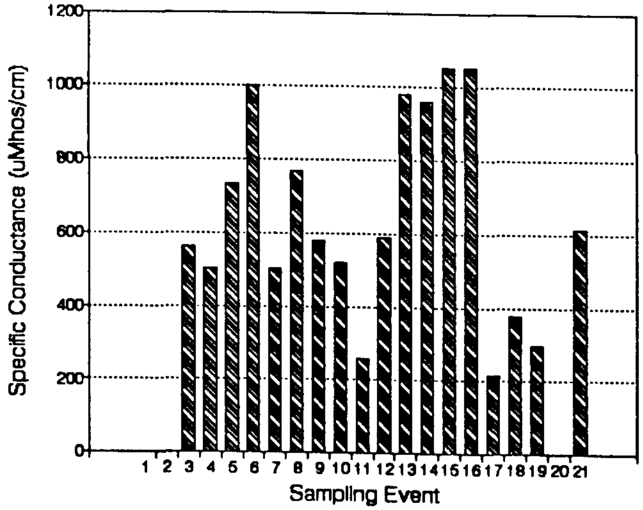

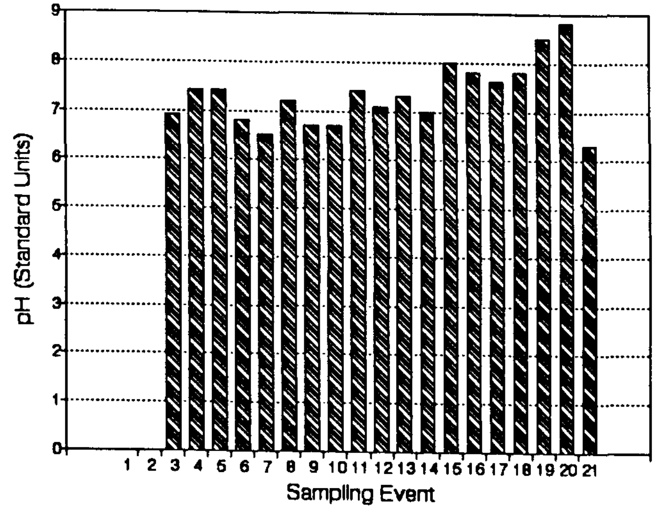

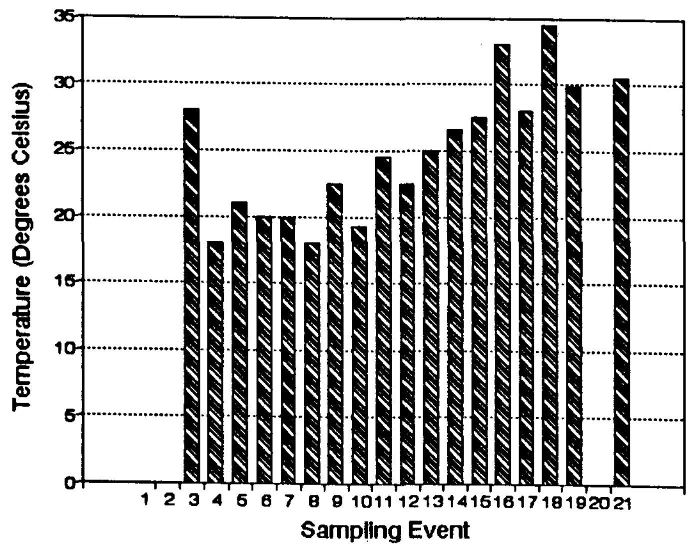

Figure 4-24 (2 of 2)
TAYLOR CREEK SURFACE WATER QUALITY GRAPHS
STATION 1

SOURCE: ESE.

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.

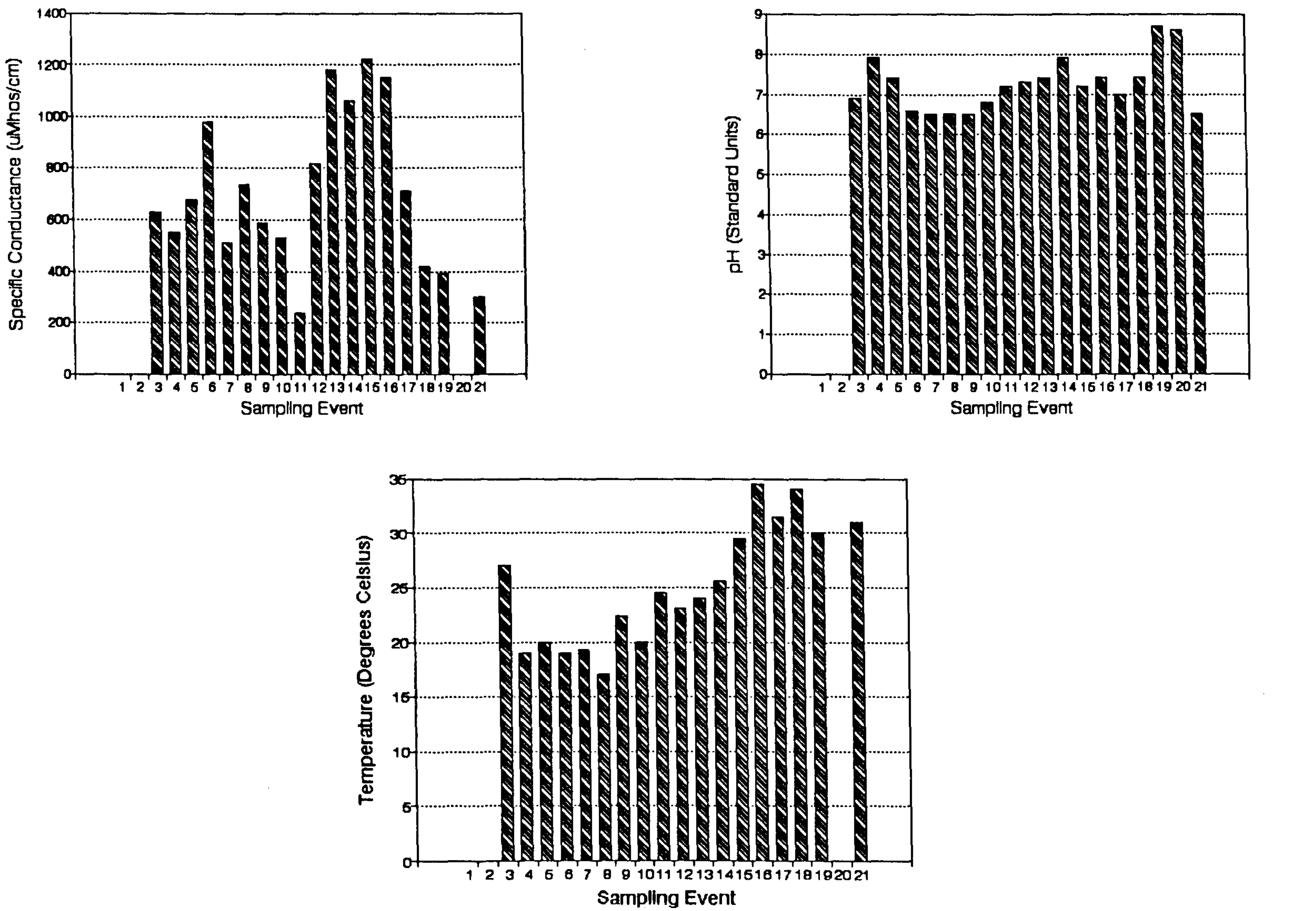

Figure 4-25 (1 of 2)
TAYLOR CREEK SURFACE WATER QUALITY GRAPHS
STATION 2

SOURCE: ESE.

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.

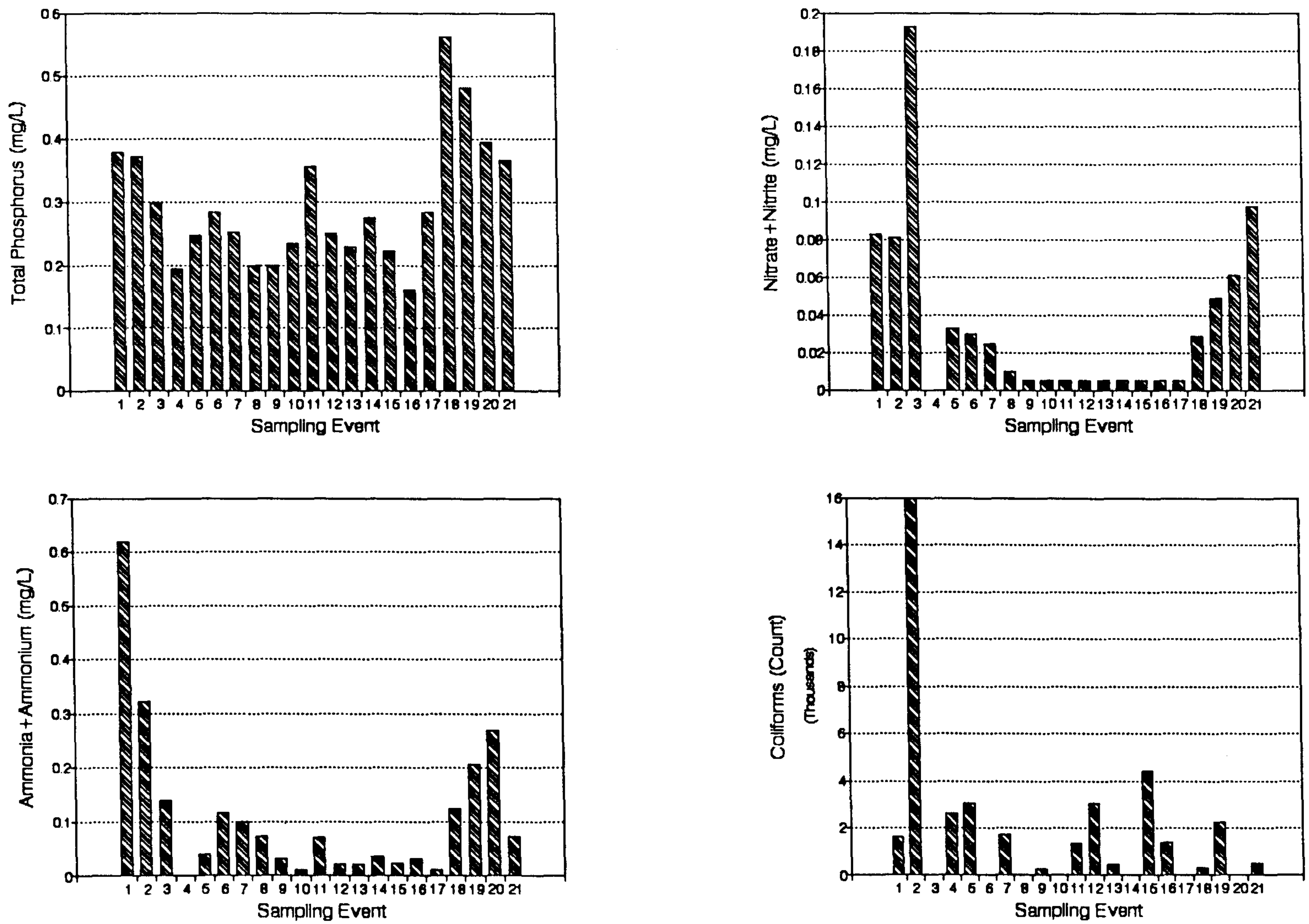

Figure 4-25 (2 of 2)
TAYLOR CREEK SURFACE WATER QUALITY GRAPHS
STATION 2

SOURCE: ESE.

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.

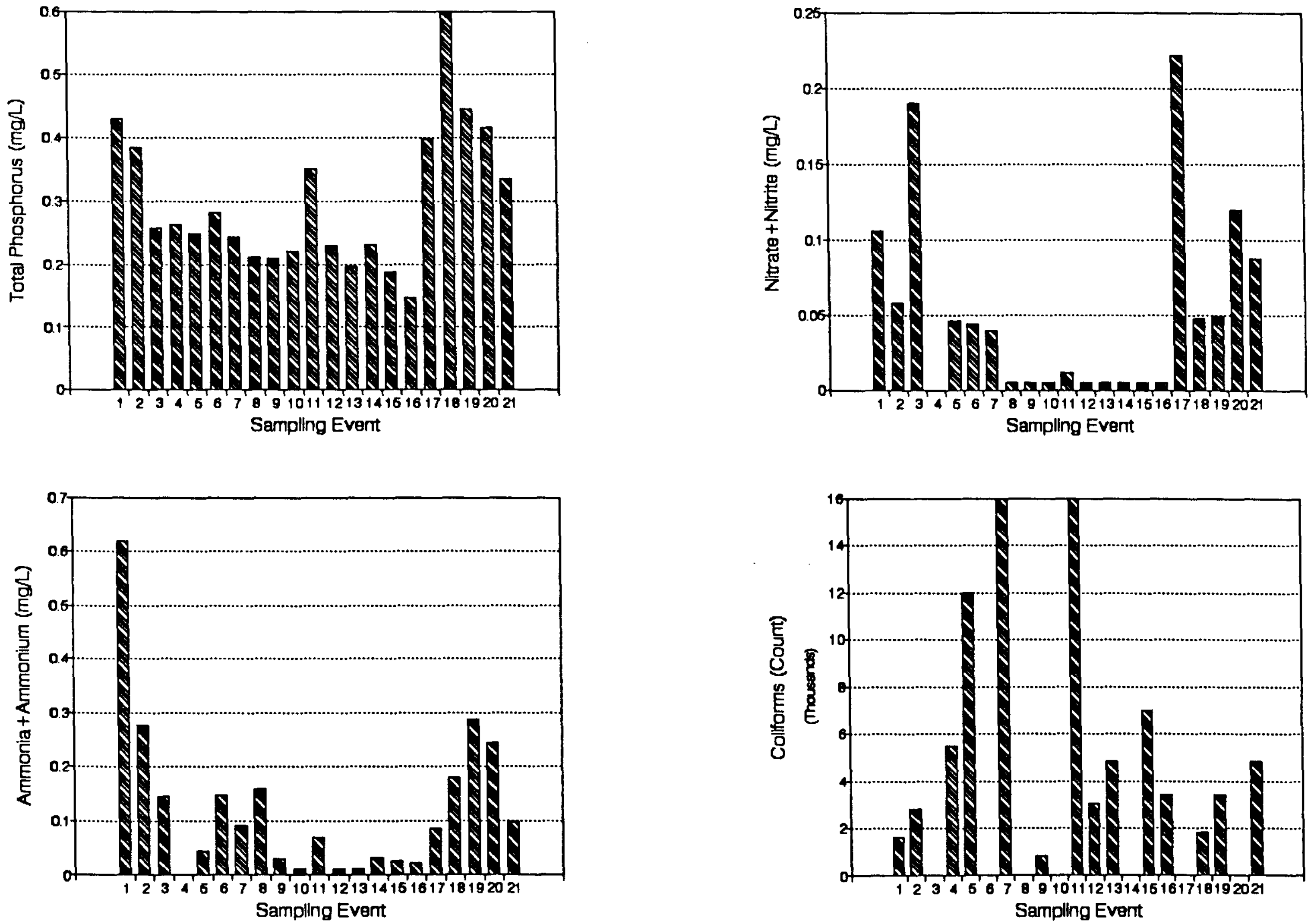

Figure 4-26 (1 of 2)
TAYLOR CREEK SURFACE WATER QUALITY GRAPHS
STATION 3

SOURCE: ESE.

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.

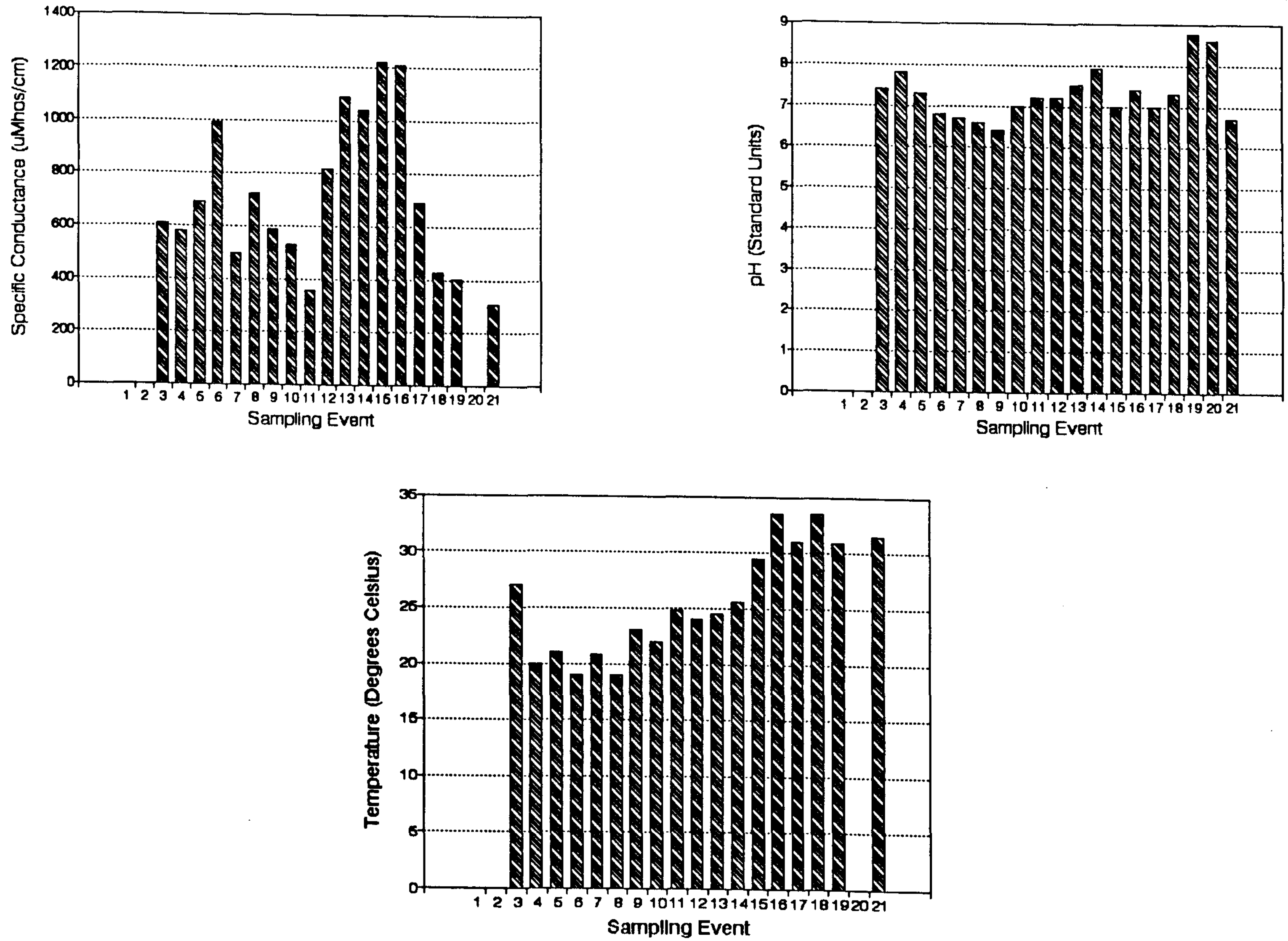

Figure 4-26 (2 of 2)
TAYLOR CREEK SURFACE WATER QUALITY GRAPHS
STATION 3

SOURCE: ESE.

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.

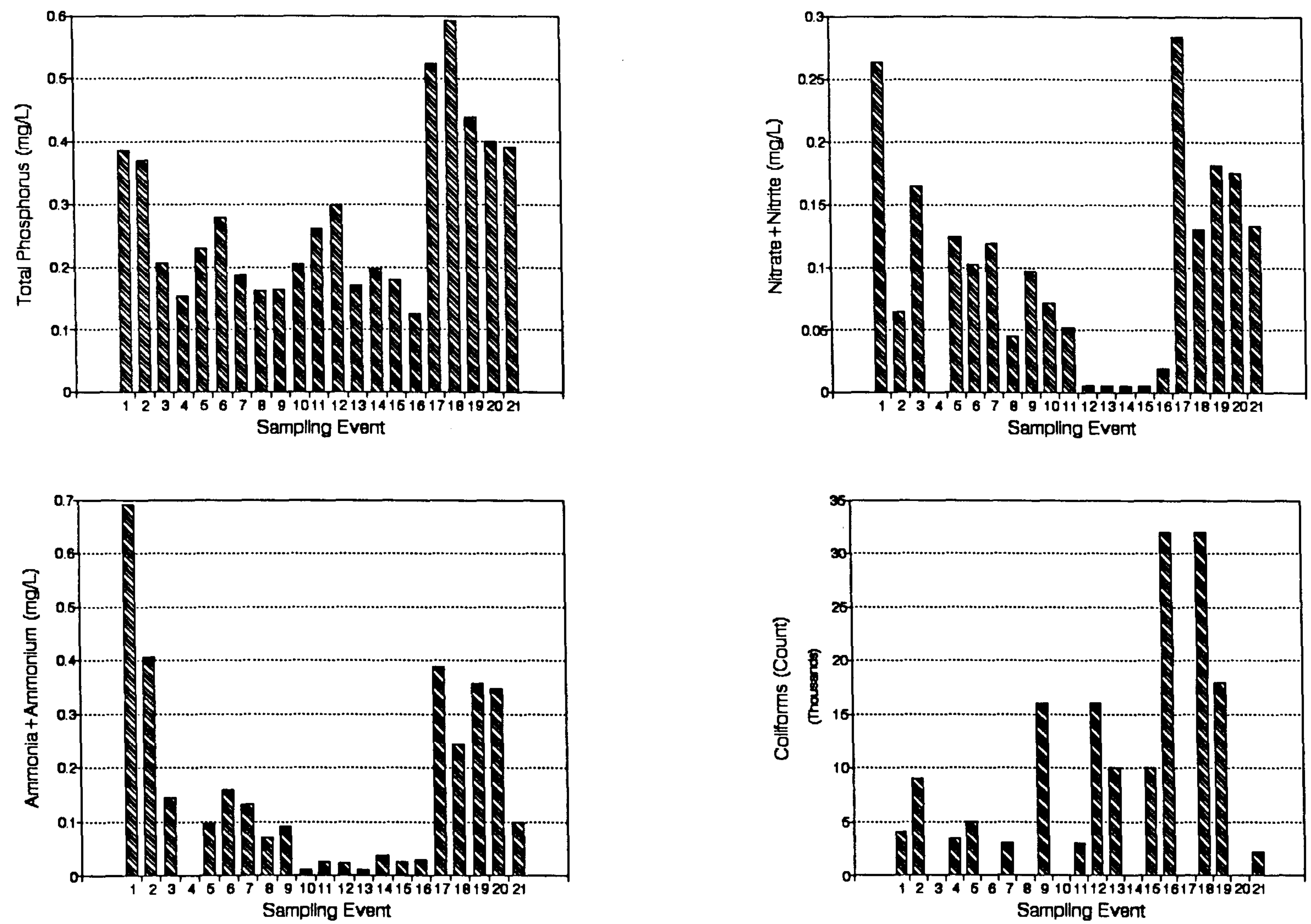

Figure 4-27 (1 of 2)
TAYLOR CREEK SURFACE WATER QUALITY GRAPHS
STATION 4

SOURCE: ESE.

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.

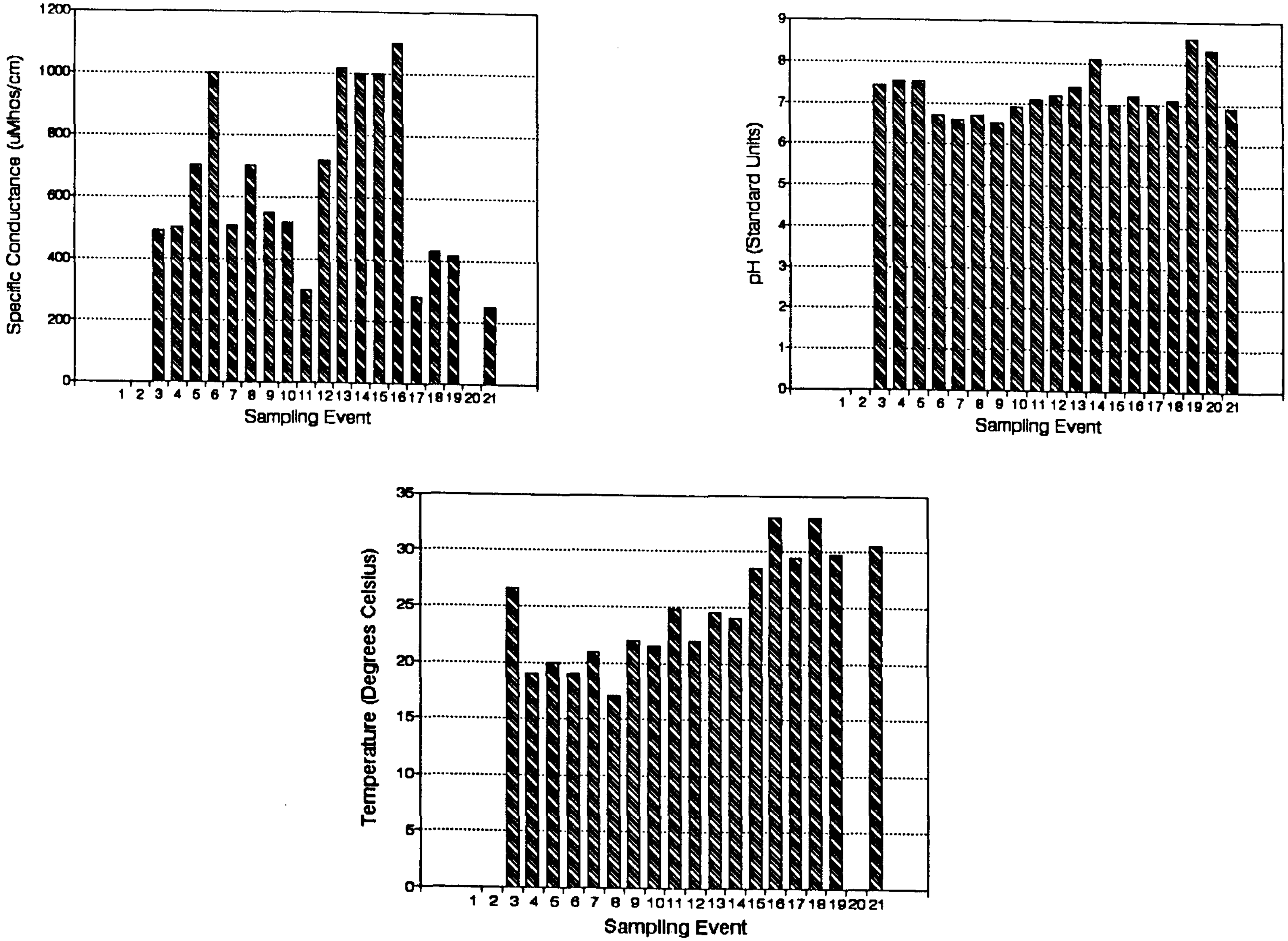

Figure 4-27 (2 of 2)
TAYLOR CREEK SURFACE WATER QUALITY GRAPHS
STATION 4

SOURCE: ESE.

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The Weston site (TC-2) was selected to observe surface water quality adjacent to a residence on a central sewer. Total coliform analyses associated with this sample location indicate levels within water quality criteria throughout the monitoring period. This site's isolation from mainstream Taylor Creek may contribute to those low readings, since contributions of total coliform from upstream sources are minimized. Therefore, the diversion of this residence's domestic waste to a central collection system may have a positive impact on surface water quality with respect to total coliforms. The median value of this parameter in Florida streams based upon data from 1980 to 1989 is 718 MPN/100 mL (FDER, 1992b).

Monitoring station TC-3 represents a canal sampling site surrounded by residences using septic tanks. Consistent with findings presented in the April 1992 status report, this site continued to manifest greater coliform population densities than TC-2. The close, downgradient proximity of canal waters to these septic tanks and associated drainfields suggests their presence may contribute to these higher concentrations. This is especially pertinent given this site's similar sample time and temperature to other stations monitored within the Taylor Creek Isles subdivision.

The Taylor Creek monitoring station TC-4 monitors water quality influenced by upstream sources, including the Taylor Creek Isles and Treasure Island subdivisions. Total coliform measurements associated with this site did not demonstrate levels representative of additive contributions from upstream stations. Population densities recorded during several sampling events suggest instances where this station's downstream location may favor concentrations in excess of upgradient monitoring sites (Figures 4-24 and 4-27), although this may be influenced by localized conditions. Overall estimates of total coliform contributions from septic tank installations appears in Table 4-10.

4.4.1.2 Buckhead Ridge Subdivision

Three monitoring locations within this subdivision were chosen for sampling of total coliforms. One of these sites, BH-1 (Table 4-11 and Figure 4-28), was chosen to represent an internal site representative of waters subject to impacts from older septic tank systems (e.g., Moldenhauer residence). The downstream monitoring locations, BH-2 (Table 4-12 and Figure 4-29) and BH-3 (Table 4-13 and Figure 4-30), represent respective points upstream and downstream of the Buckhead Marina Package Plant. Figure 3-5 provides a map of these sampling locations.

Consistent with data reported in the April 1992 report, total coliform levels in the BH-1 samples were generally greater than those observed in downstream samples. Water stagnation favors microbial growth and resultant population densities at this location. These hydrographic conditions, coupled with septic tank contributions, may contribute to these measurements. With mean values associated with septic tank effluent of 3.4×10^6 total coliforms/100 mL (Table 4-10) (FDER, 1989a), leachate from these installations may explain the observed high concentrations at BH-1.

No pattern of upstream versus downstream total coliform measurements was observed at monitoring stations BH-2 and BH-3. This may be influenced by varying intermittent flows and stagnant conditions, as well as localized inputs.

4.4.1.3 Okeechobee Hammocks

The two sampling stations chosen for this subdivision included OH-1 and OH-2. The former station was selected to monitor water quality midway into the subdivision along one of the main canals, and OH-2 was situated to observe water quality exiting this residential area before discharge to the rim canal.

Total coliforms associated with station OH-1 varied throughout the sampling events (Table 4-14 and Figure 4-31). Review of these graphic data indicates an increase of water temperature may have favored population growth. Some correlation of increased total coliforms with higher concentrations of total P may also be visualized, indicative of increased productivity in these surface waters. The slightly higher pH values recorded during these latter sampling

Table 4-10. Inorganic and Bacteriological Water Quality - Septic Tank Effluent

		Concentration Range mg/L	Mean mg/L
	Inorganic		
	Suspended Solids	10 - 695	49
	BOD_5	7 - 330	190
	COD	25 - 780	327
	Total Phosphorus (as P)	0.7 - 99	13
	Ortho Phosphate (as P)	3 - 20	11
	Total Nitrogen (as N)	9 - 125	45
	Ammonium (as N)	0.1 - 91	31
*	Nitrate (as N)	0.1 - 74	0.4
	Biological		
	Total Coliform/100 ml	$2.5 - 4.4 \times 10^6$	3.4×10^6
	Fecal Coliform/100 ml	$2.9 - 6.2 \times 10^5$	4.2×10^5
	Fecal Streptococci/100 ml	$8.0 \times 10^3 - 2.0 \times 10^5$	4.0×10^4
	Pseudomonas aeruginosa/100 ml	$3.8 - 19.0 \times 10^3$	8.6×10^3

* Primary drinking water standard of 10 mg/L established in Section 17-550.310(1)(a), F.A.C.

Source: FDER, 1989.

Table 4-11. Buckhead Ridge Surface Water Sampling Results for Station 1

Sampling Event	Sampling Date	PHOS	NO23	NH34	SC	PH	COLI	TEMP
1	9/9/91	0.188	0.019	0.038	NA	NA	900	NA
2	9/30	0.127	0.019	0.213	NA	NA	16000	NA
3	10/21	0.219	0.05	0.031	990	7.6	NS	26
4	11/11	0.124	ID	ID	1050	7.1	6000	22
5	12/2	0.093	0.005	0.02	1020	6.8	4400	18
6	12/16	0.114	0.175	0.022	980	7.2	NS	18
7	12/30	0.125	0.02	0.046	1000	6.6	16000	18.6
8	1/13/92	0.105	0.013	0.057	920	6.8	NS	18
9	1/27	0.11	0.005	0.059	990	6.2	5000	21
10	2/10	0.143	0.005	0.023	850	6.5	NS	18
11	2/24	0.15	0.005	0.155	1020	7.3	9000	24.4
12	3/16	0.104	0.005	0.028	1080	7.3	5000	21
13	4/6	0.143	0.014	0.029	1100	7.6	4800	22.5
14	4/27	0.126	0.005	0.038	800	8.1	NS	24
15	5/18	0.137	0.005	0.026	970	8.2	10000	27.5
16	6/8	0.084	0.005	0.044	900	7.5	4400	33
17	6/29	0.11	0.095	0.068	800	7.3	NS	29
18	7/20	0.205	0.005	0.036	716	7.6	600	31.5
19	8/10	0.174	0.012	0.042	622	8.5	6000	28.9
20	8/31	0.177	0.005	0.036	NA	9.2	NS	NA
21	9/21	0.279	0.005	0.038	650	7	2600	30
Mean		0.145	0.023	0.053	915	7.4	6479	23.9
Max		0.279	0.175	0.213	1100	9.2	16000	33
Min		0.084	0.005	0.02	622	6.2	600	18

Table 4-12. Buckhead Ridge Surface Water Sampling Results for Station 2.

Sampling Event	Sampling Date	PHOS	NO23	NH34	SC	PH	COLI	TEMP
1	9/9/91	0.43	0.019	0.283	NA	NA	6000	NA
2	9/30	0.167	0.005	0.442	NA	NA	5000	NA
3	10/21	0.2	0.052	0.606	1380	7.3	NS	28
4	11/11	0.147	ID	ID	1190	7.2	1000	19
5	12/2	0.147	0.25	0.059	1100	6.9	2200	18
6	12/16	0.155	0.201	0.048	1020	6.9	NS	17
7	12/30	0.142	0.119	0.064	1070	6.5	3000	18.7
8	1/13/92	0.123	0.028	0.064	920	6.6	NS	18
9	1/27	0.136	0.005	0.048	1020	6.4	1300	21
10	2/10	0.168	0.005	0.022	890	6.4	NS	18.3
11	2/24	0.128	0.012	0.229	960	7	1700	24.8
12	3/16	0.107	0.005	0.037	1110	7.6	2400	20.5
13	4/6	0.079	0.005	0.01	1160	7.4	2800	23.5
14	4/27	0.113	0.005	0.037	830	8.1	NS	23.5
15	5/18	0.067	0.005	0.027	990	8.1	660	28
16	6/8	0.078	0.005	0.031	900	7.6	1000	33
17	6/29	0.345	0.026	0.196	550	7.7	NS	28
18	7/20	0.7	0.016	0.19	602	7.6	10000	32.5
19	8/10	0.512	0.005	0.522	548	8.36	1400	29.2
20	8/31	0.248	0.005	0.279	NA	9.3	NS	NA
21	9/21	0.228	0.025	0.075	810	6.8	1000	30.5
Mean		0.210	0.04	0.164	947	7.36	2818	23.9
Max		0.7	0.25	0.606	1380	9.3	10000	33
Min		0.067	0.005	0.01	548	6.4	660	17

Note:

PHOS = Total Phosphorous (mg/L).
NO23 = Nitrate+Nitrite (mg/L).
NH34 = Ammonia+Ammonium (mg/L).
SC = Specific Conductance (uMhos/cm).
NS = No Sample Collected.
PH = pH (Standard Units).
COLI = Coliforms (Count).
TEMP = Temperature (Degrees Celsius).
NA = Not Analyzed
ID = Invalid Data

Table 4-13. Buckhead Ridge Surface Water Sampling Results for Station 3.

Sampling Event	Sampling Date	PHOS	NO23	NH34	SC	PH	COLI	TEMP
1	9/9/91	0.566	0.011	0.33	NA	NA	1600	NA
2	9/30	0.16	0.013	0.454	NA	NA	1700	NA
3	10/21	0.192	0.052	0.524	1400	7.2	NS	27
4	11/11	0.17	ID	ID	995	7.5	340	19.5
5	12/2	0.144	0.398	0.032	1050	7.2	9000	20
6	12/16	0.153	0.005	0.059	1020	6.8	NS	18
7	12/30	0.135	0.151	0.069	990	6.7	5000	19
8	1/13/92	0.12	0.015	0.059	780	7.2	NS	17
9	1/27	0.114	0.005	0.075	1010	6.4	2400	21.3
10	2/10	0.127	0.005	0.01	890	6.8	NS	18.9
11	2/24	0.108	0.01	0.072	980	7	3000	24
12	3/16	0.08	0.005	0.027	1110	7.5	1100	21
13	4/6	0.054	0.005	0.01	1090	7.5	1200	23.5
14	4/27	0.069	0.005	0.035	860	6.1	NS	25.5
15	5/18	0.069	0.005	0.026	980	8.1	2800	27
16	6/8	0.064	0.005	0.044	900	7.2	600	33.5
17	6/29	0.264	0.025	0.077	590	7	NS	30
18	7/20	0.641	0.013	0.18	615	7.3	6000	32
19	8/10	0.502	0.005	0.576	546	7.98	2800	29.6
20	8/31	0.311	0.025	0.522	NA	8.9	NS	NA
21	9/21	0.241	0.027	0.071	615	7.2	460	31
Mean		0.204	0.039	0.163	912	7.3	2714	24.2
Max		0.576	0.398	0.576	1400	8.9	9000	33.5
Min		0.054	0.005	0.010	546	6.1	340	17.0

Note:

PHOS	= Total Phosphorous (mg/L).	PH	= pH (Standard Units).
NO23	= Nitrate+Nitrite (mg/L).	COLI	= Coliforms (Count).
NH34	= Ammonia+Ammonium (mg/L).	TEMP	= Temperature (Degrees Celsius).
SC	= Specific Conductance (uMhos/cm).	NA	= Not Analyzed
NS	= No Sample Collected.	ID	= Invalid Data

Table 4-14. Okeechobee Hammocks Surface Water Sampling Results for Station 1.

Sampling Event	Sampling Date	PHOS	NO23	NH34	SC	PH	COLI	TEMP
1	9/9/91	0.365	0.023	0.087	NA	NA	900	NA
2	9/30	0.023	0.023	0.153	NA	NA	4800	NA
3	10/21	0.639	0.5	0.166	320	7.6	NS	24
4	11/11	0.477	ID	ID	650	7.4	6500	20
5	12/2	0.128	0.017	0.075	890	7.3	3750	21
6	12/16	0.183	0.014	0.053	1180	6.9	NS	19
7	12/30	0.253	0.011	0.075	640	6.5	2400	21.2
8	1/13/92	0.141	0.018	0.052	800	6.6	NS	19
9	1/27	0.197	0.005	0.128	660	6.8	16000	22
10	2/10	0.081	0.005	0.077	305	6.5	NS	19
11	2/24	0.467	0.022	0.137	350	7.2	10000	24.1
12	3/16	0.056	0.005	0.24	335	7.3	5000	19
13	4/6	0.043	0.274	0.147	348	7.7	1000	21
14	4/27	0.068	0.05	0.402	315	7.1	NS	21
15	5/18	0.069	0.005	0.07	375	8.1	1600	23.5
16	6/8	0.075	0.02	0.299	325	7.9	32000	28
17	6/29	0.21	0.005	0.146	268	7.7	NS	28
18	7/20	0.116	0.005	0.156	245	8	5600	26
19	8/10	0.818	0.037	0.296	429	8.76	32000	30.4
20	8/31	0.592	0.005	0.123	NA	8.2	NS	NA
21	9/21	0.079	0.005	0.237	170	6.1	3400	29
Mean		0.242	0.053	0.156	453	7.35	8925	23.1
Max		0.818	0.5	0.402	1180	8.76	32000	30.4
Min		0.023	0.005	0.052	170	6.1	900	19

Table 4-15. Okeechobee Hammocks Surface Water Sampling Results for Station 2.

Sampling Event	Sampling Date	PHOS	NO23	NH34	SC	PH	COLI	TEMP
1	9/9/91	2.41	0.175	0.358	NA	NA	22000	NA
2	9/30	0.107	0.005	0.081	NA	NA	6500	NA
3	10/21	0.253	0.005	0.038	680	7.3	NS	27
4	11/11	0.162	ID	ID	380	7.2	350	18
5	12/2	0.066	0.02	0.18	420	7.3	4800	20
6	12/16	0.09	0.037	0.299	300	6.8	NS	18
7	12/30	0.118	0.011	0.261	310	6.5	3000	19
8	1/13/92	0.153	0.02	0.174	440	7	NS	19
9	1/27	0.036	0.005	0.138	313	6.7	500	21.3
10	2/10	0.151	0.005	0.01	610	6.8	NS	22.1
11	2/24	0.087	0.005	0.414	520	7.4	700	24.6
12	3/16	0.146	0.005	0.025	720	7.4	3000	23.5
13	4/6	0.129	0.005	0.01	790	7.1	2200	23.5
14	4/27	0.12	0.005	0.068	650	8.1	NS	23
15	5/18	0.185	0.005	0.028	750	7.1	10000	27.5
16	6/8	0.479	0.062	0.143	700	7.1	32000	33
17	6/29	0.193	0.005	0.247	357	6.8	NS	28
18	7/20	0.192	0.005	0.204	390	7	32000	26.5
19	8/10	0.223	0.12	0.176	219	9.19	1400	28.8
20	8/31	0.136	0.025	0.15	NA	8.6	NS	NA
21	9/21	0.095	0.005	0.149	490	6.4	32000	29
Mean		0.263	0.026	0.158	502	7.25	10746	24.0
Max		2.41	0.175	0.414	790	9.19	32000	33
Min		0.036	0.005	0.01	219	6.4	350	18

Note:

PHOS	= Total Phosphorous (mg/L).	PH	= pH (Standard Units).
NO23	= Nitrate+Nitrite (mg/L).	COLI	= Coliforms (Count).
NH34	= Ammonia+Ammonium (mg/L).	TEMP	= Temperature (Degrees Celsius).
SC	= Specific Conductance (uMhos/cm).	NA	= Not Analyzed
NS	= No Sample Collected.	ID	= Invalid Data

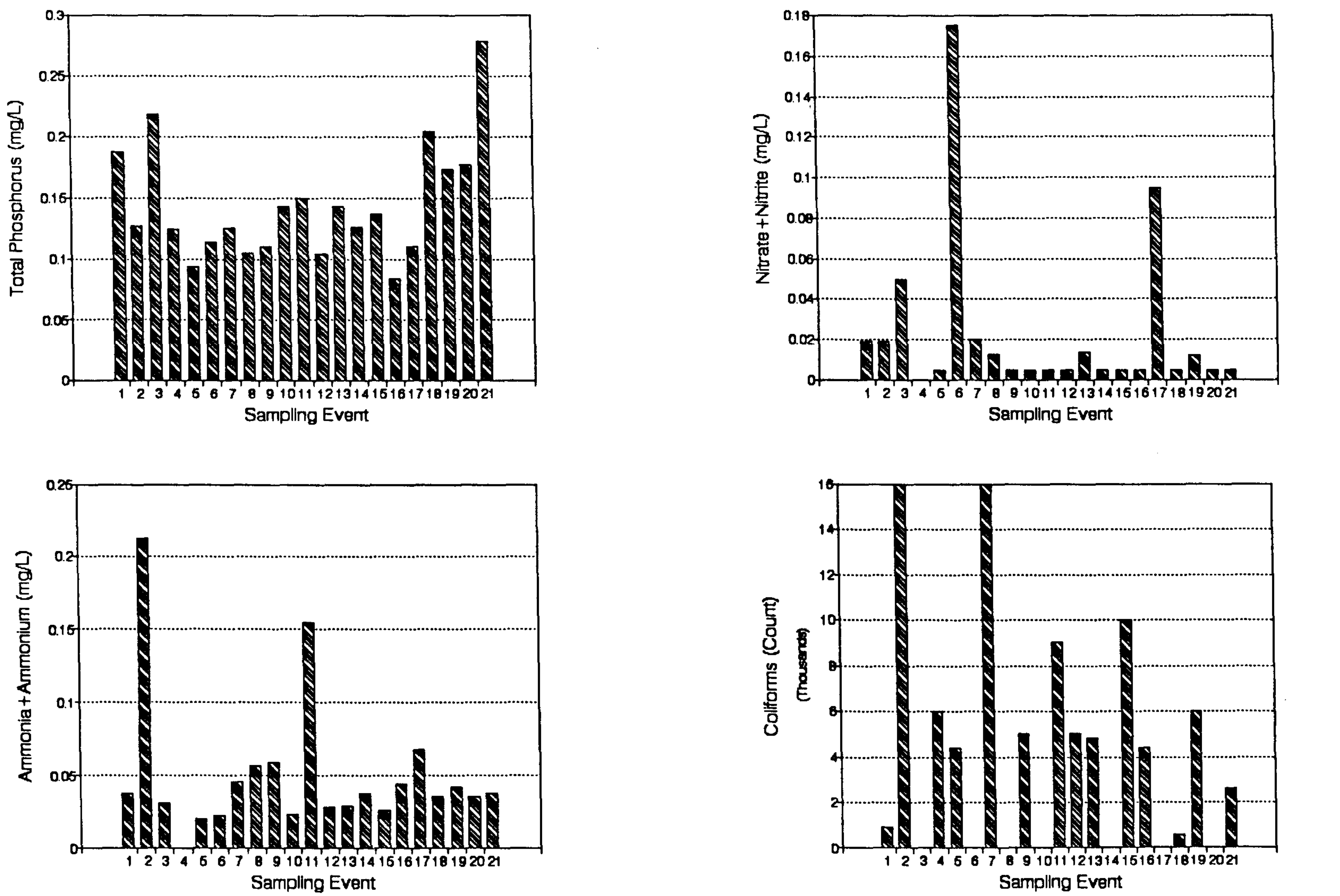

Figure 4-28 (1 of 2)
BUCKHEAD RIDGE SURFACE WATER QUALITY GRAPHS
STATION 1

SOURCE: ESE.

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.

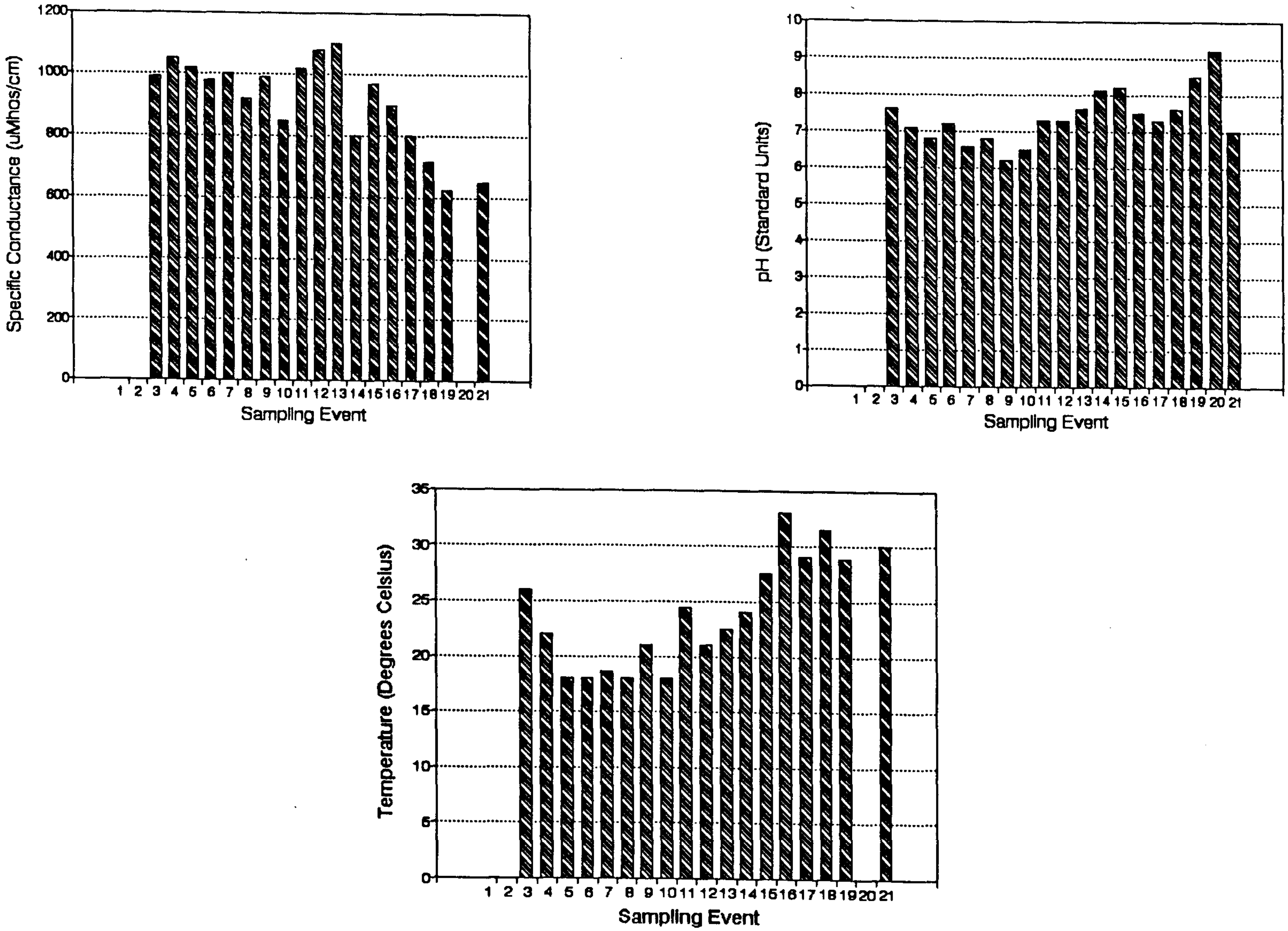

Figure 4-28 (2 of 2)
BUCKHEAD RIDGE SURFACE WATER QUALITY GRAPHS
STATION 1

SOURCE: ESE.

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.

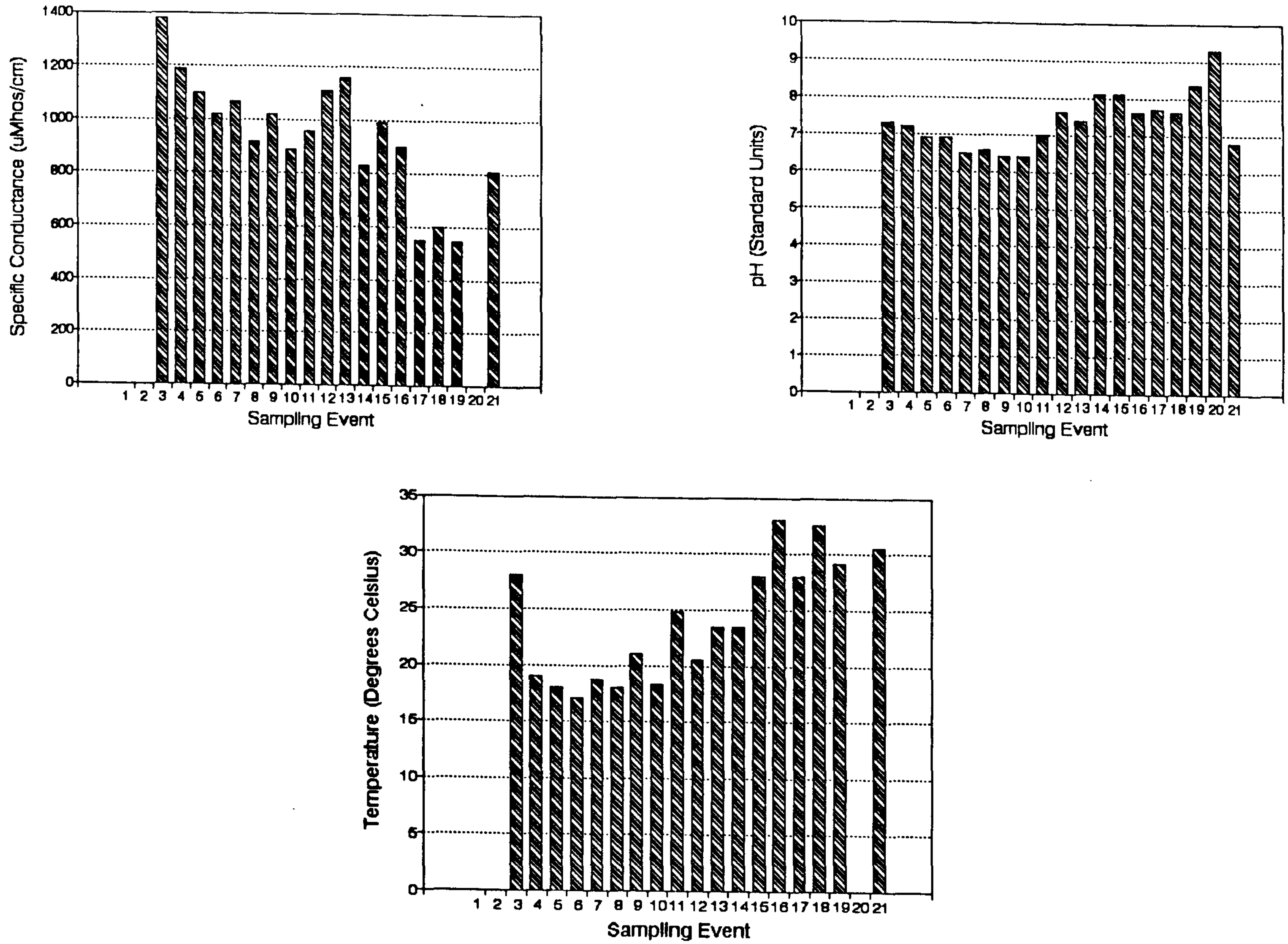

Figure 4-29 (1 of 2)
BUCKHEAD RIDGE SURFACE WATER QUALITY GRAPHS
STATION 2

SOURCE: ESE.

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.

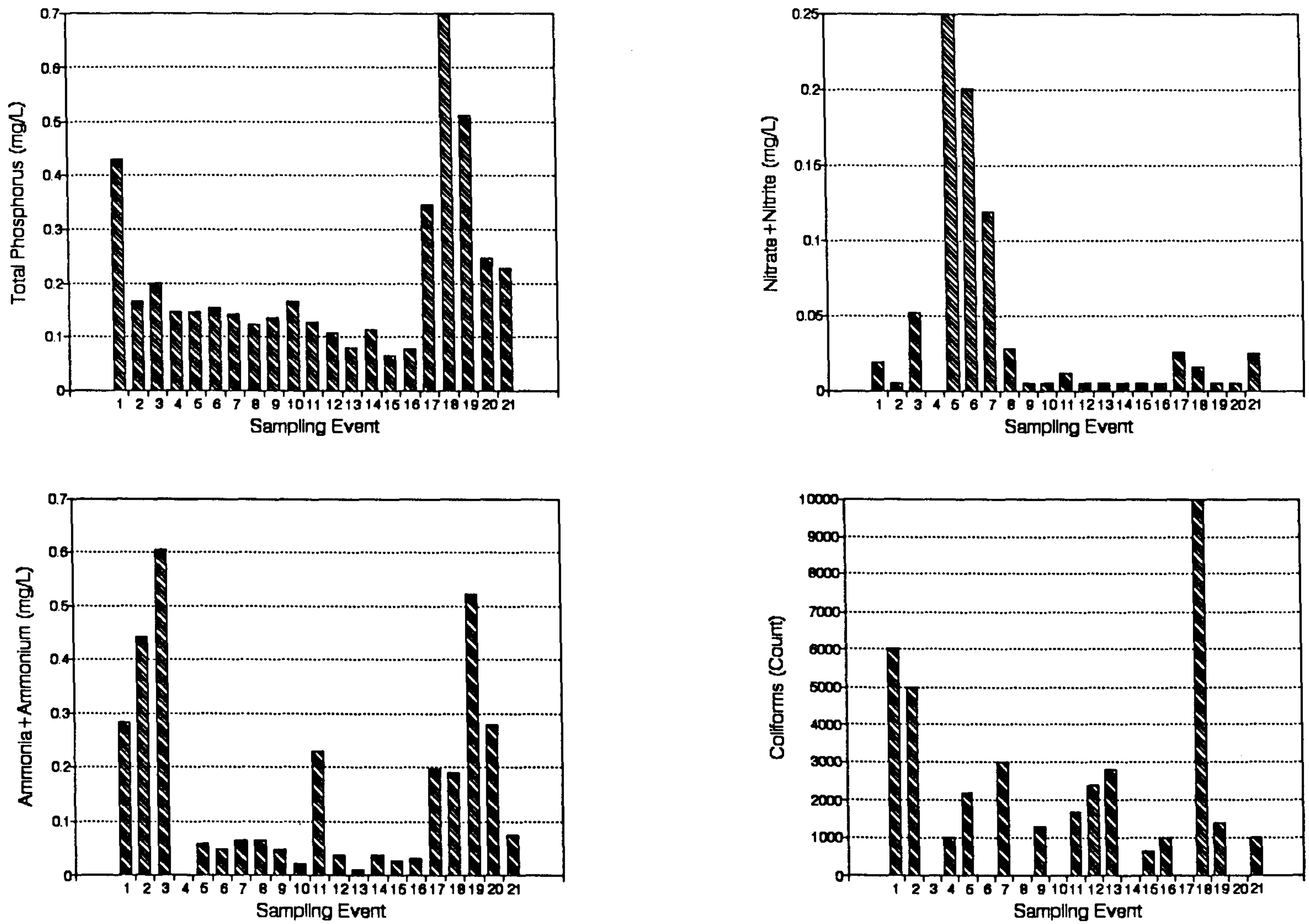

Figure 4-29 (2 of 2)
BUCKHEAD RIDGE SURFACE WATER QUALITY GRAPHS
STATION 2

SOURCE: ESE.

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.

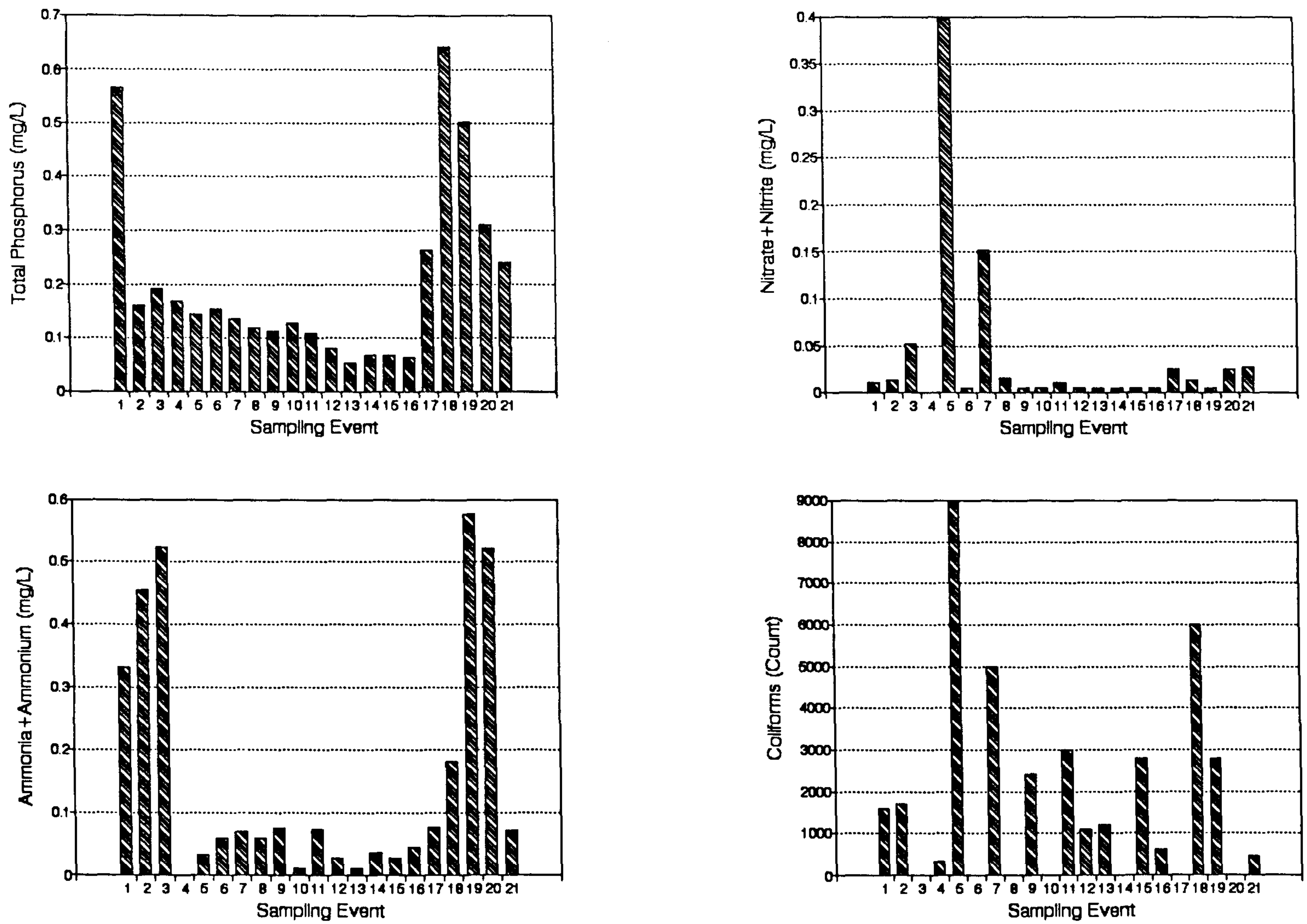

Figure 4-30 (1 of 2)
BUCKHEAD RIDGE SURFACE WATER QUALITY GRAPHS
STATION 3

SOURCE: ESE.

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.

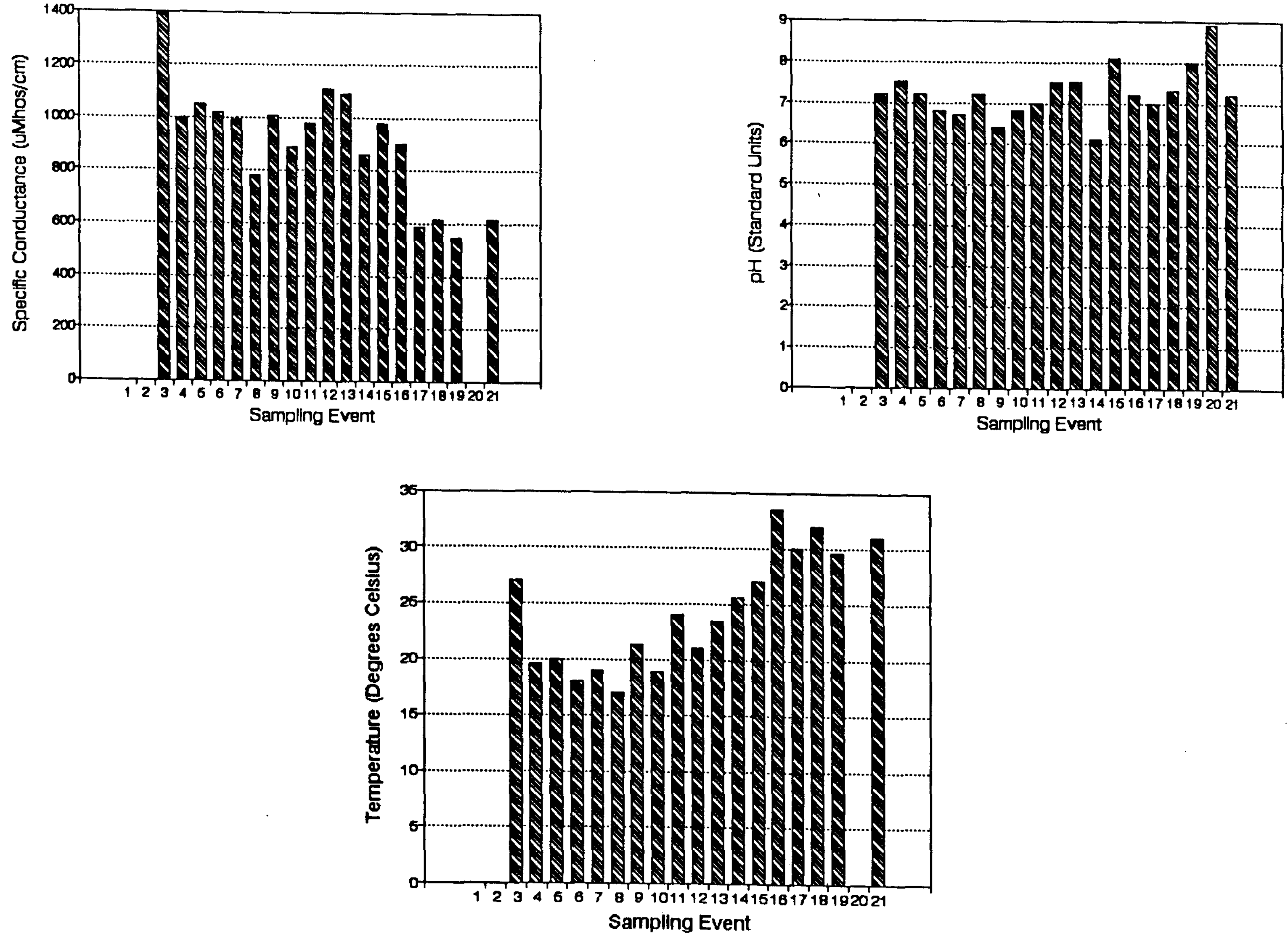

Figure 4-30 (2 of 2)
BUCKHEAD RIDGE SURFACE WATER QUALITY GRAPHS
STATION 3

SOURCE: ESE.

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.

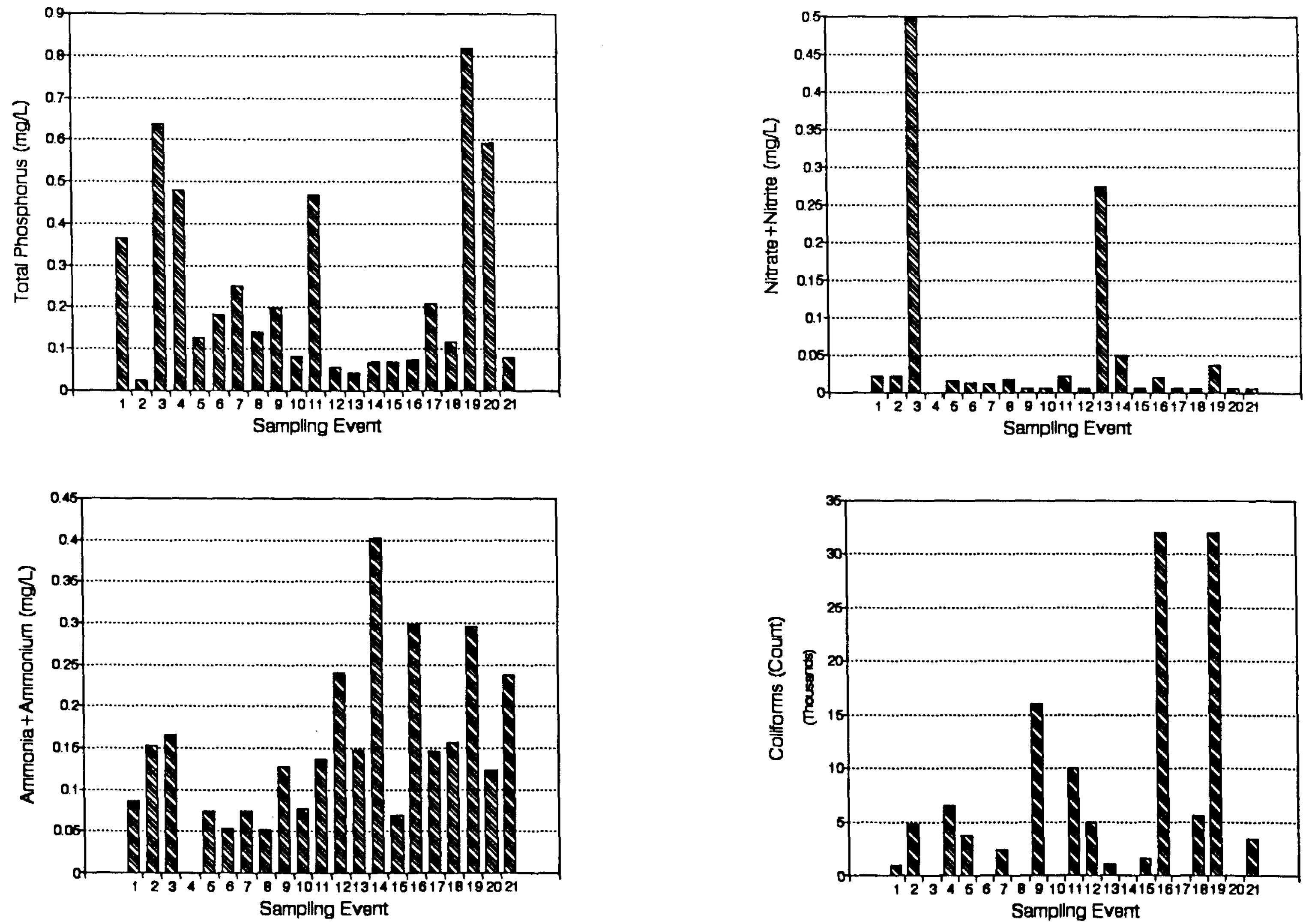

Figure 4-31 (1 of 2)
OKEECHOBEE HAMMOCKS SURFACE WATER QUALITY GRAPHS
STATION 1

SOURCE: ESE.

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.

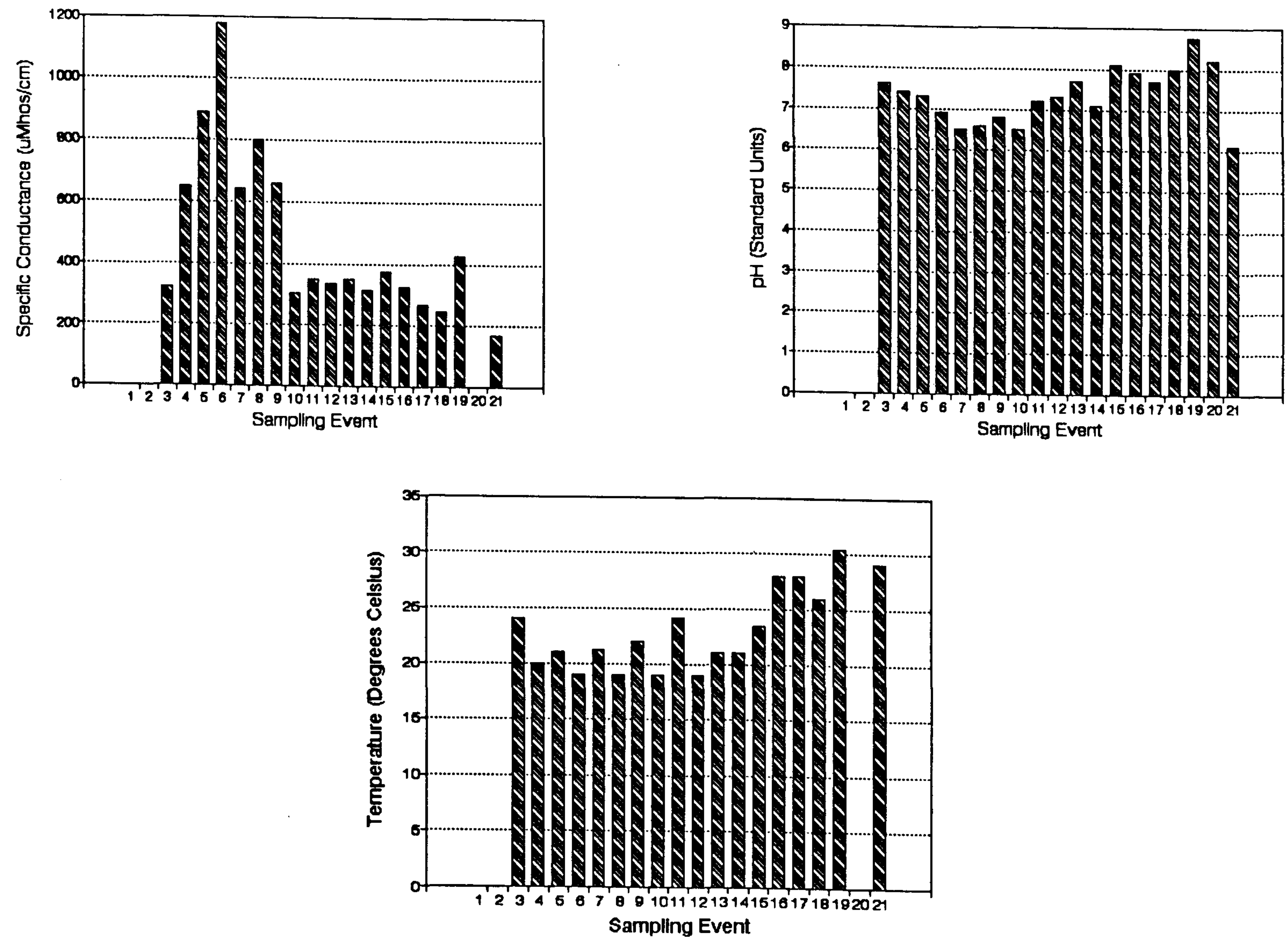

Figure 4-31 (2 of 2)
OKEECHOBEE HAMMOCKS SURFACE WATER QUALITY GRAPHS
STATION 1

SOURCE: ESE.

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.

events of higher coliforms support this increase, likely attributable to photosynthesis.

Generally, greater total coliform densities were observed at the downstream station for Okeechobee Hammocks (Table 4-15 and Figure 4-32). Similar inferences may be made for these increases in bacteria as referenced for station OH-1. For example, the highest concentrations of total P appear to foster coliform growth. The proximity of this station to the rim canal may contribute to total coliforms at this sampling location. As referenced in the first quarter report, these coliform densities appear to be influenced by localized conditions rather than physical transport processes.

In summary, microbiological measurements appear primarily influenced by site-specific phenomena, such as stagnation, temperature, and inputs from both natural and anthropogenic (e.g., septic tanks) sources. Definitive analytes such as fecal coliforms or coprostanol in sediments may be considered to further delineate specific sources and long-term impacts (Brown and Wade, 1984).

4.5 GROUNDWATER AND SURFACE WATER CHEMICAL RESULTS

Parameters measured to assess surface and groundwater conditions with respect to potential septic tank leachate included nitrate/nitrite, ammonia/ammonium, total P, pH, and specific conductance. These laboratory and in situ measurements were identified as indicators of septic tank inputs, in conjunction with total coliform bacteria. The graphic data in this section have been organized to evaluate specific study sites identified in the April 1992 annual report. Specific analyses appear in tabular format in the previous sections. This synthesis of data is designed to focus on spatial and temporal trends within and between the various study locations.

Class III water quality criteria for nutrients are not quantified, pursuant to Section 17-302.560(19), F.A.C. Disturbances of indigenous flora and faunal populations were not measured to assess this qualitative criterion.

4.5.1 OLD SEPTIC TANK SYSTEMS--DRAINFIELDS INSTALLED NEAR THE CANAL

Two sites were chosen to assess water quality impacts associated with these older septic tank systems, the Moldenhauer residence in Buckhead Ridge and the Lewis residence in Treasure Island. Three wells and one lysimeter were monitored at the former site, and one well and one lysimeter were monitored at the Lewis site.

The monitor well adjacent to the drainfield at the Moldenhauer residence, M-2, manifested higher concentrations of total P than either the upgradient well M-3, or the downgradient site, M-1 (Tables 4-16, 4-17, and 4-18 and Figures 4-33 and 4-34). These surficial aquifer monitoring data also indicate ammonia/ ammonium levels are greater near the septic tank. This phenomenon of high ammoniacal N is supportive of Nous organic waste decay, likely associated with septic tank leachate. Ammonia is the initial degradation product of this decay process, present as the protonated form with pH <9.0. Oxidation of ammonia to nitrate, nitrification, may offer explanation to increased levels of nitrate in M-1 during later sampling events. Drainfield leachate collected from ML-1 demonstrates such N transformations, where both ammonia and nitrate levels suggest oxidation is a catalyst for rapid formation of nitrate (Table 4-19 and Figure 4-34). Nitrate in the vadose zone may ultimately lead to denitrification and a resultant net loss of N to the atmosphere.

The canal water sampling station associated with the Moldenhauer location, BH-1, indicates nutrient concentrations associated with the contributing surficial aquifer are higher than these receiving waters. Factors such as dilution in surface and groundwaters downgradient of the septic tank, attenuation via soil absorption, and biological productivity may contribute to this observation. P' status as a biolimiting nutrient may be indicated for sampling events where its concentration is preferentially depleted with respect to N.

The Lewis residence surficial aquifer and lysimeter monitoring data indicate lower concentrations of

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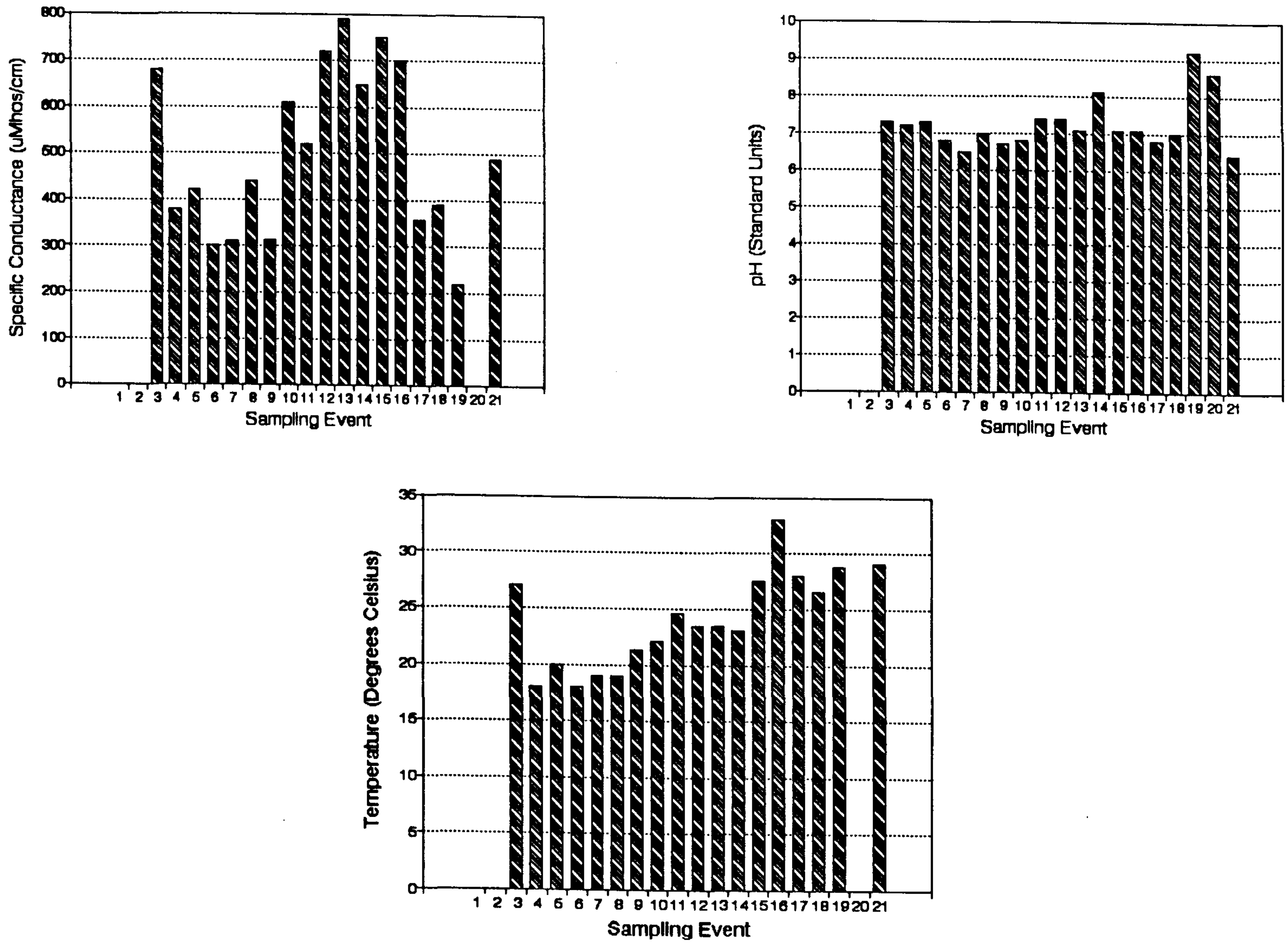

Figure 4-32 (1 of 2)
OKEECHOBEE HAMMOCKS SURFACE WATER QUALITY GRAPHS
STATION 2

SOURCE: ESE.

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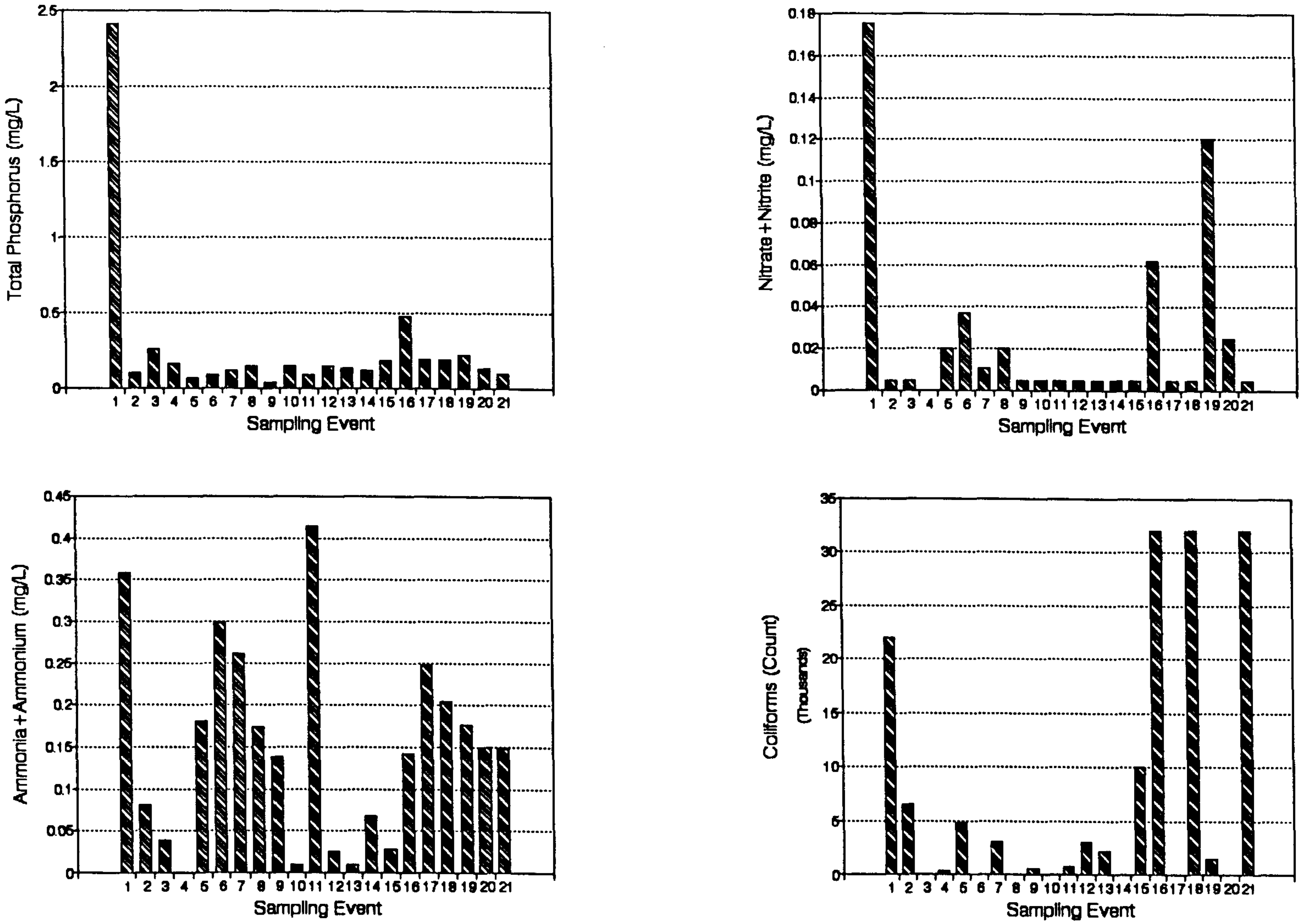


Figure 4-32 (2 of 2)
OKEECHOBEE HAMMOCKS SURFACE WATER QUALITY GRAPHS
STATION 2

SOURCE: ESE.

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.

ɪle 4-16. Moldenhauer Monitor Well 1 Sampling Results

Sampling Event	Sampling Date	PHOS	NO23	NH34	SC	PH
1	9/9/91	0.979	4.15	24.7	1490	6.6
2	9/30	0.593	1.78	22.3	980	6.7
3	10/21	0.446	1.19	21.7	1410	6.8
4	11/11	0.592	ID	ID	1300	7.1
5	12/2	0.597	0.133	15.7	950	7.3
6	12/16	0.822	0.263	13.4	1245	6.3
7	12/30	0.742	4.62	11.8	1250	8.8
8	1/13/92	1.22	0.69	9.1	840	6.3
9	1/27	0.763	0.057	11.7	1140	6.5
10	2/10	0.906	0.148	13.4	1120	6.5
11	2/24	0.566	0.303	16.2	880	7.9
12	3/16	0.862	0.273	15	1290	7
13	4/6	0.657	0.313	8.29	1195	7.8
14	4/27	0.57	0.026	9.71	900	7.2
15	5/18	0.447	0.131	7.52	915	7.5
16	6/8	0.425	0.214	6.38	790	7.4
17	6/29	0.65	27.4	4.5	850	7
18	7/20	0.839	11.1	12.1	901	7.4
19	8/10	0.947	4.63	7.24	835	10.7
20	8/31	0.429	8.2	19.3	620	7.3
21	9/21	0.329	6.82	18.4	370	6.8
Mean		0.685	3.62	13.42	1013	7.3
Max		1.22	27.4	24.7	1490	10.7
Min		0.329	0.026	4.5	370	6.3

Table 4-17. Moldenhauer Monitor Well 2 Sampling Results.

Sampling Event	Sampling Date	PHOS	NO23	NH34	SC	PH
1	9/9/91	2.22	1.44	35.2	1480	6.6
2	9/30	3.19	0.162	46.9	1400	6.7
3	10/21	4.74	2.11	63.5	1400	6.6
4	11/11	4.58	ID	ID	1380	7.2
5	12/2	5.54	3.26	69.4	950	7.2
6	12/16	4.27	0.919	63.2	1350	6.4
7	12/30	3.78	0.254	59.4	1350	8.1
8	1/13/92	4.52	2.54	67.6	1000	6.2
9	1/27	4.28	0.384	64	1290	6.7
10	2/10	4.85	0.247	67.9	1220	6.4
11	2/24	4.69	0.501	69.6	1000	6.2
12	3/16	5.02	0.077	79.1	1350	7.7
13	4/6	4.85	0.069	67	1380	7.8
14	4/27	4.44	0.005	70.1	1000	7
15	5/18	4	0.28	52	1100	7
16	6/8	2.76	0.273	40.9	920	7.2
17	6/29	3.83	0.172	62.6	990	7
18	7/20	3.79	0.11	64.3	948	7.2
19	8/10	3.82	0.974	63.9	939	8.31
20	8/31	3.54	0.089	58.7	640	7.4
21	9/21	3.73	0.098	61.4	320	6.7
Mean		4.12	0.698	61.3	1115	7.03
Max		5.54	3.26	79.1	1480	8.31
Min		2.22	0.005	35.2	320	6.2

Table 4-18. Moldenhauer Monitor Well 3 Sampling Results.

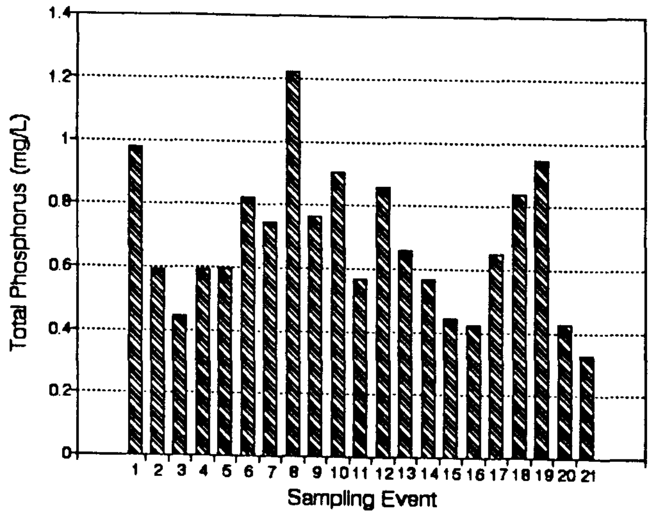
Sampling Event	Sampling Date	PHOS	NO23	NH34	SC	PH
1	9/9/91	1.26	9.36	0.073	700	7.2
2	9/30	1.32	4.96	0.262	800	6.8
3	10/21	0.313	5.07	0.051	700	7.4
4	11/11	0.549	ID	ID	710	7.4
5	12/2	0.192	12.2	0.036	600	7.8
6	12/16	0.637	10.5	0.071	980	6.7
7	12/30	0.364	7.76	0.102	1000	7.7
8	1/13/92	1.14	23.1	1.17	990	6.8
9	1/27	1.4	24.7	4.06	1030	6.8
10	2/10	1.58	40	3.21	1050	6.7
11	2/24	0.925	28.1	0.088	850	8.3
12	3/16	1.27	42.8	3.24	1190	7.3
13	4/6	0.892	26.8	1.99	1180	7.9
14	4/27	1.02	0.374	2.58	890	7.5
15	5/18	1.13	40	1.37	935	7.6
16	6/8	0.688	30.2	2.62	800	7.4
17	6/29	2.01	35	1.27	800	6.9
18	7/20	1.14	15.4	0.356	641	7.4
19	8/10	1.92	16.9	0.194	588	NA
20	8/31	1.9	6.18	0.061	380	7.6
21	9/21	0.95	5.95	0.053	540	6.6
Mean		1.076	19.27	1.140	826	7.2
Max		2.01	42.8	4.06	1190	8.3
Min		0.192	0.374	0.036	380	6.6

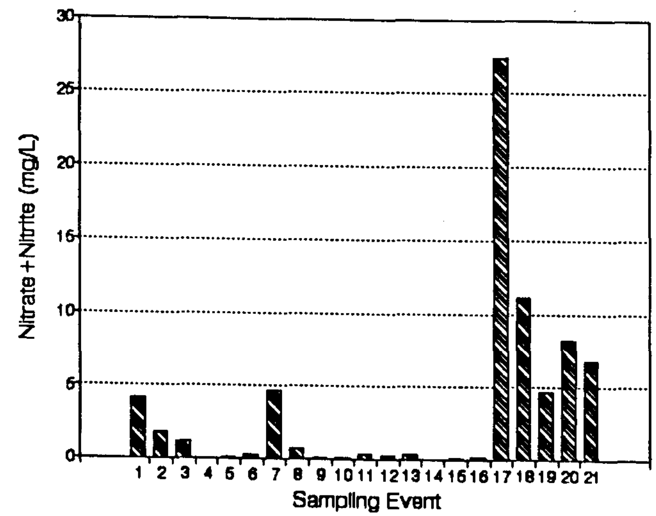
Table 4-19. Moldenhauer Lysimeter Sampling Results

Sampling Event	Sampling Date	PHOS	NO23	NH34
1	9/9/91	4.7	7.72	50.7
2	9/30	4.81	18.9	17.8
3	10/21	5	0.172	31.7
4	11/11	5.49	ID	ID
5	12/2	6.86	24.4	38.3
6	12/16	4.97	40.6	35.3
7	12/30	7.04	53.3	36.6
8	1/13/92	3.68	33.5	50.4
9	1/27	NA	NA	48.9
10	2/10	8.71	16.8	56.4
11	2/24	4.82	44	38.3
12	3/16	7.18	33.9	59.4
13	4/6	6.13	50	34.8
14	4/27	6.5	NA	37.8
15	5/18	4.63	84.2	9.48
16	6/8	4.42	NA	3.1
17	6/29	3.05	29	14.8
18	7/20	4.85	61.4	6.31
19	8/10	5.99	27.9	11.3
20	8/31	5.98	12.3	17.1
21	9/21	4.69	63	1.69
Mean		5.47	35.3	30.01
Max		8.71	84.2	59.4
Min		3.05	0.172	1.69

Note:

PHOS	= Total Phosphorous (mg/L).	PH	= pH (Standard Units).
NO23	= Nitrate+Nitrite (mg/L).	COLI	= Coliforms (Count).
NH34	= Ammonia+Ammonium (mg/L).	TEMP	= Temperature (Degrees Celsius).
SC	= Specific Conductance (uMhos/cm).	NA	= Not Analyzed
NS	= No Sample Collected.	ID	= Invalid Data





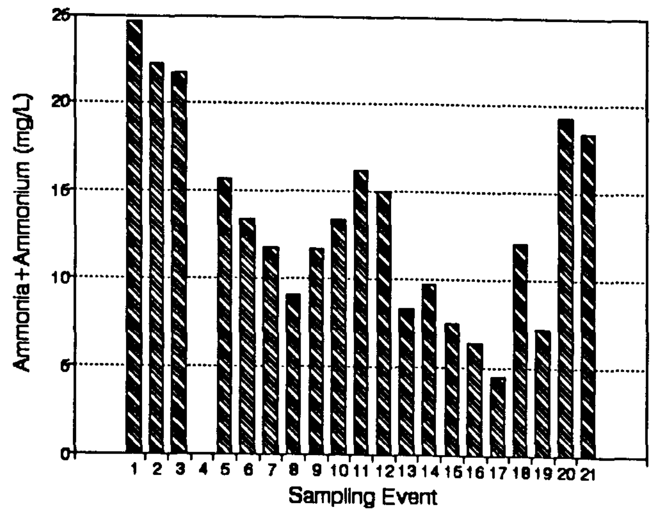


Figure 4-33 (1 of 4)
MOLDENHAUER MONITOR WELL 1 DATA GRAPHS

SOURCE: ESE.

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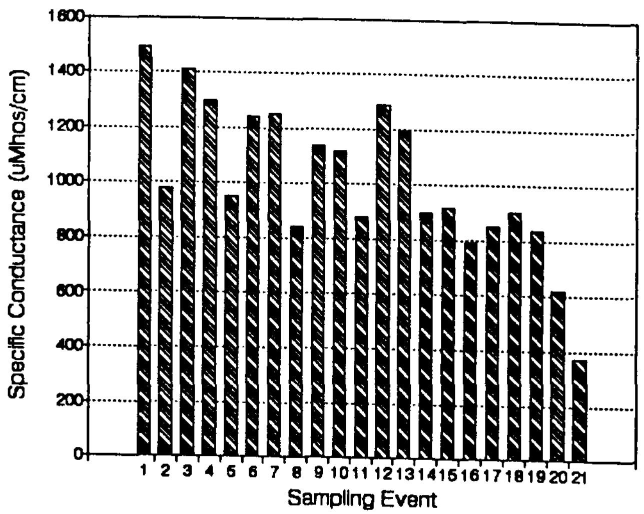

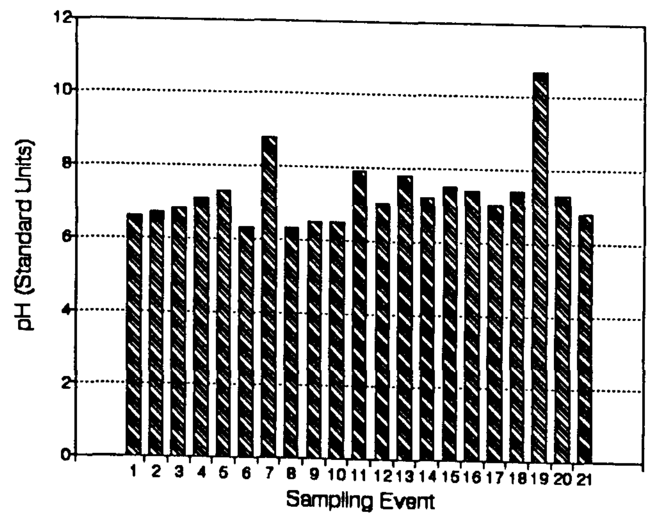

Figure 4-33 (2 of 4)
MOLDENHAUER MONITOR WELL 1 DATA GRAPHS

SOURCE: ESE.

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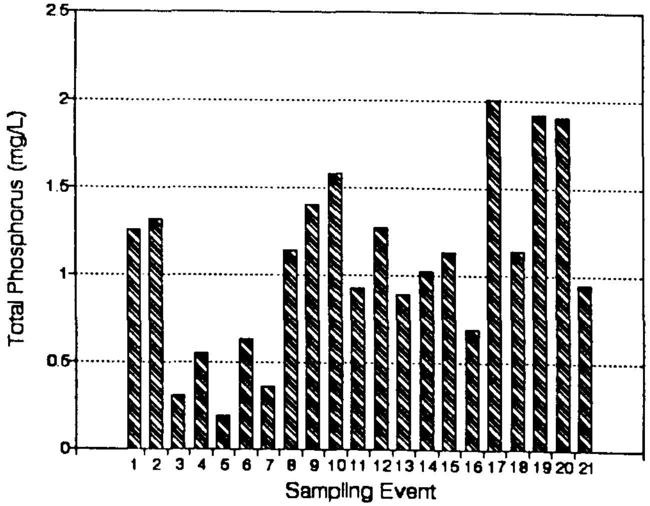
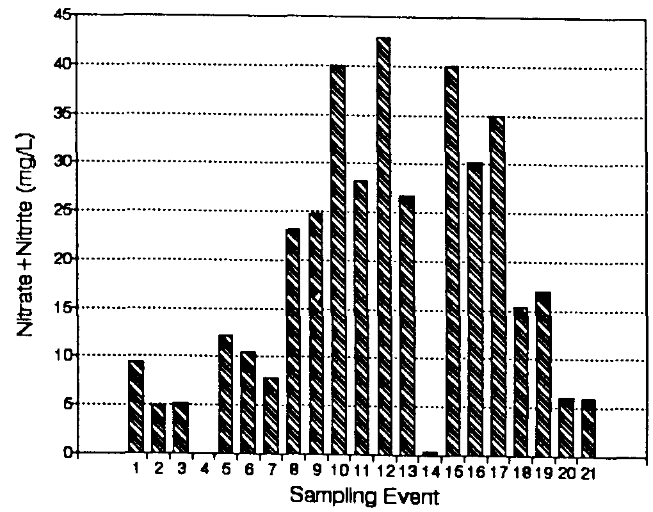




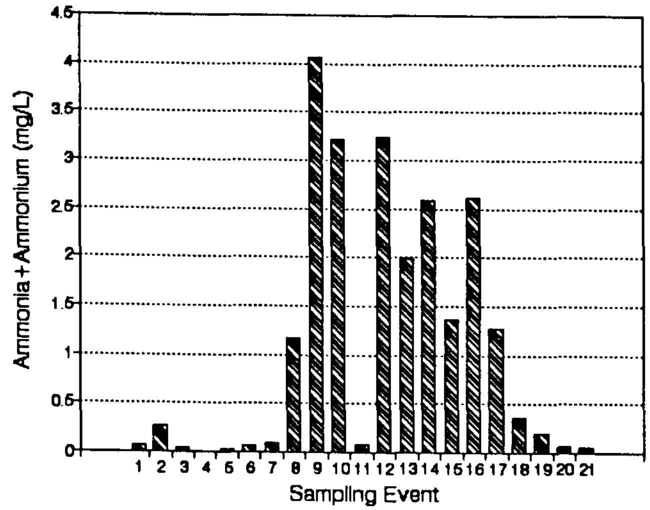
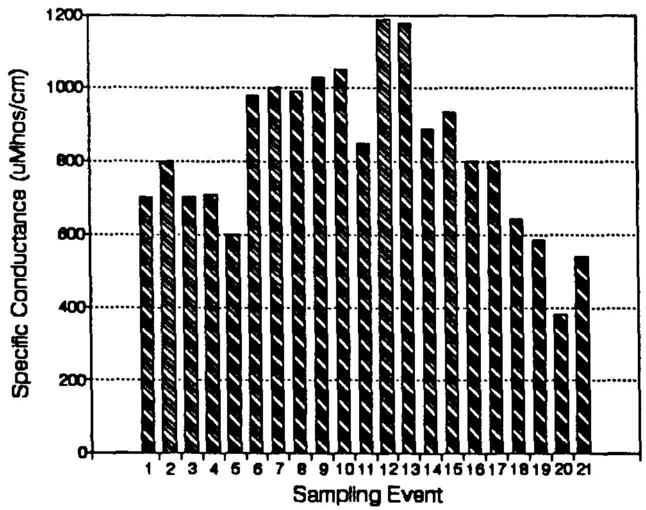


Figure 4-33 (3 of 4)
MOLDENHAUER MONITOR WELL 3 DATA GRAPHS

SOURCE: ESE.

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.



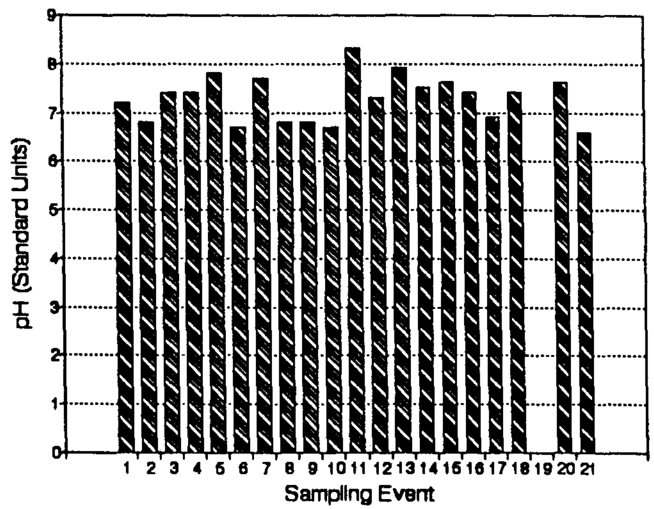


Figure 4-33 (4 of 4)
MOLDENHAUER MONITOR WELL 3 DATA GRAPHS

SOURCE: ESE.

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.

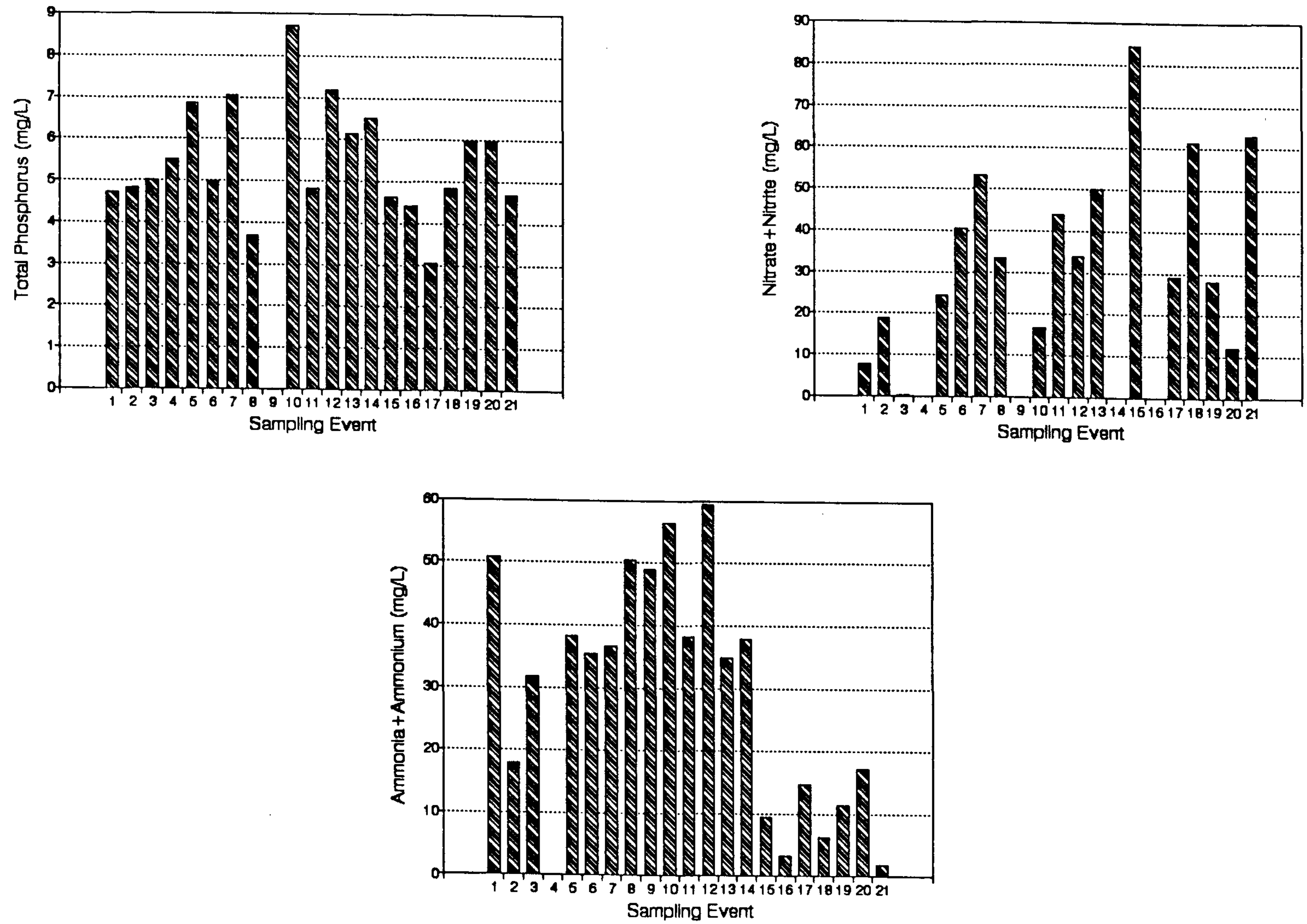


Figure 4-34 (1 of 3)
MOLDENHAUER MONITOR WELL 2 AND DRAINFIELD
LEACHATE DATA GRAPHS

SOURCE: ESE.

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.

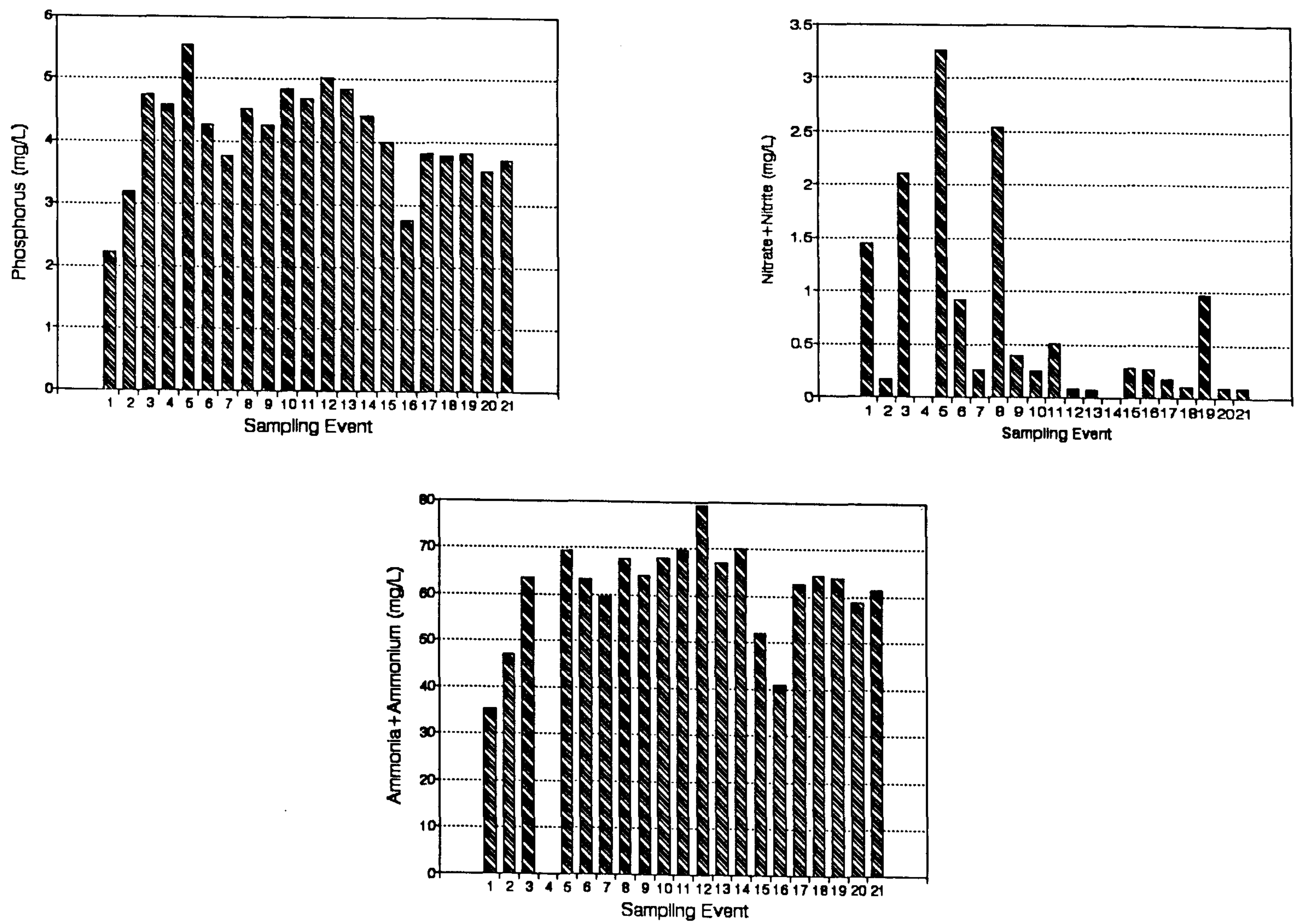
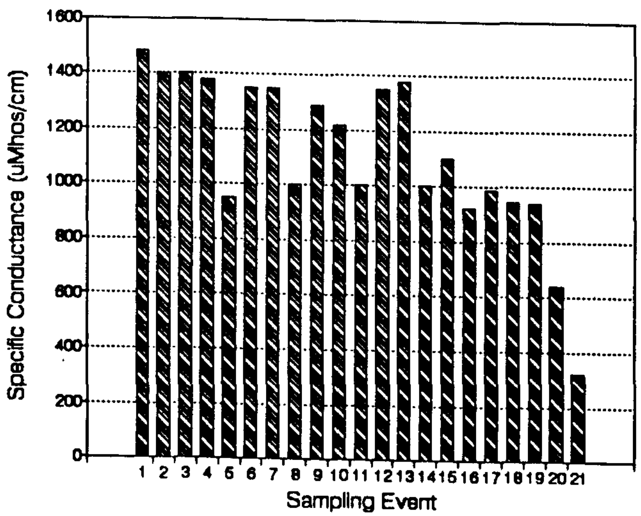


Figure 4-34 (2 of 3)
MOLDENHAUER MONITOR WELL 2 AND DRAINFIELD
LEACHATE DATA GRAPHS

SOURCE: ESE.

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.



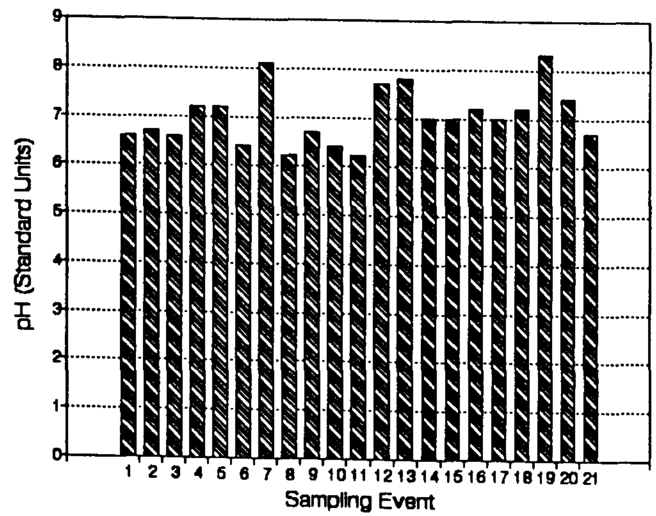


Figure 4-34 (3 of 3)
MOLDENHAUER MONITOR WELL 2 AND DRAINFIELD LEACHATE DATA GRAPHS

SOURCE: ESE.

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.

ammonia and total P exist with respect to counterpart stations at the Moldenhauer site (Tables 4-20 and 4-21 and Figure 4-35). Possible explanations for this observation range from loading differences between these residences to increased nitrification at the Lewis site. A contributing factor to these observations could be the additional 2 ft of vadose zone at the Lewis site that may enhance treatment of effluent. The generally higher specific conductance measurements at M-2 than recorded at L-1 support this former site's pronounced impact on surrounding groundwater. Total P and nitrate in pore-water at LL-1 appear to be correlated during specific sampling events, possibly influenced by P migration within capillaries and nitrification.

4.5.2 NEWER SEPTIC TANK SYSTEMS--DRAINFIELDS INSTALLED AWAY FROM THE CANAL

Two residences were chosen to monitor newer septic tank systems with drainfields installed farther away from the canal according to more recent set-back rules. These sites included the Goolsby residence in Taylor Creek Isles and the Spaulding residence in Okeechobee Hammocks. Both of these study locations consisted of one well and one lysimeter situated adjacent to the drainfields.

Total P concentrations identified in the Goolsby monitor well (Table 4-22 and Figure 4-36) averaged higher than at older sites identified in Section 7.1.1. The drainfield leachate (Table 4-23 and Figure 4-36) at this residence did not manifest any notable trends, although a high total P concentration was recorded during the first sampling event, probably attributable to particulate matter.

The Spaulding site manifested lower total P concentrations (Table 4-24 and Figure 4-37) than the Goolsby residence, similar to those observed at the older systems. However, the drainfield leachate concentrations of P noted in SL-1 were generally greater than those noted for lysimeters monitoring this media at other old and new system sites. This observation suggests that attenuation of P is associated with the increased amount of vadose zone. The generally higher concentrations of nitrate than ammonia in the vadose zone also denote oxidation is taking place in this unsaturated zone (Table 4-25 and Figure 4-37). Higher ionic strength of surficial groundwaters also appears to be correlated with increased total P and ammonia, indicated by specific conductance measurements. This in situ measurement may be considered an indicator of septic tank leachate when compared to surrounding, upgradient groundwater. The surface water sampling stations nearest these newer systems, TC-1 and OH-1, are inconclusinve regarding direct impacts of septic tank leachate, owing to nutrient attenuation in soils, transformation of nutrients, and biological uptake and hydrodynamics in the canal. Water quality impacts attributable to septic tank leachate are additionally difficult to discriminate due to atmospheric and upstream nutrient sources.

4.5.3 CENTRAL SEWER SYSTEM SITE

The Weston residence in Taylor Creek Isles was selected to monitor conditions associated with a site served by a central sewer system. One monitor well and one lysimeter were installed near this mobile home to observe water quality characteristics of the surficial aquifer and vadose zone.

Total P concentrations in monitor well W-1 (Table 4-26 and Figure 4-38) averaged less than those observed adjacent to older and newer septic tank systems. Lysimeter measurements at WL-1 (Table 4-27 and Figure 4-38) substantiate this site's lower nutrient concentrations than reported in drainfield leachate samples collected adjacent to the monitored septic tank systems. Few samples could be collected from the lysimeter installed here because, unlike the lysimeters installed under drainfields, there was very little soil pore water to sample from. These data indicate connection to the central sewer system results in lowered total P and N inputs, as anticipated. This site's low ammonia measurements also substantiate the lack of organic wastes associated with septic tank leachate.

Table 4-20. Lewis Monitor Well Sampling Results.

Sampling Event	Sampling Date	PHOS	NO23	NH34	SC	PH
1	9/9/91	3.02	7.61	3.76	1000	6.6
2	9/30	3.59	10.6	0.01	820	6.6
3	10/21	2.23	0.193	3.39	880	6.8
4	11/11	0.28	4.88	4.51	780	6.7
5	12/2	2.8	4.22	5.3	930	7.2
6	12/16	2.4	1.97	6.94	720	6.5
7	12/30	2.81	2.21	6.66	700	6.5
8	1/13/92	2.61	17	1.13	790	6
9	1/27	2.06	20.5	1.44	640	6.2
10	2/10	2.18	18.7	3.26	690	6.1
11	2/24	2.06	13.7	5.21	380	6.7
12	3/16	2.23	17.5	3.81	800	7.3
13	4/6	1.75	18.2	4.17	820	7.8
14	4/27	1.82	12.6	4.68	680	6.8
15	5/18	2.08	12.4	4.64	670	7.1
16	6/8	1.9	11.9	5.29	610	7.5
17	6/29	2.62	2.51	13.5	600	7.1
18	7/20	2.46	7.07	16.5	625	6.6
19	8/10	2.05	5.41	19.1	587	8.08
20	8/31	2.05	4.33	20.8	480	7.6
21	9/21	2.21	10.4	18.2	1162	6.9
Mean		2.25	9.71	7.3	732	6.89
Max		3.59	20.5	20.8	1162	8.08
Min		0.28	0.193	0.01	380	6

Table 4-21. Lewis Lysimeter Sampling Results

Sampling Event	Sampling Date	PHOS	NO23	NH34
1	9/9/91	2.26	9.15	2.21
2	9/30	1.53	6.4	1.48
3	10/21	NS	NS	NS
4	11/11	NS	NS	NS
5	12/2	1.01	43.5	NS
6	12/16	NS	NS	NS
7	12/30	NS	NS	NS
8	1/13/92	NS	NS	NS
9	1/27	NS	NS	NS
10	2/10	NS	NS	NS
11	2/24	NS	NS	NS
12	3/16	NS	NS	NS
13	4/6	NS	NS	NS
14	4/27	1.66	38	0.038
15	5/18	NS	NS	NS
16	6/8	NS	NS	NS
17	6/29	NS	NS	NS
18	7/20	NS	NS	NS
19	8/10	NS	NS	NS
20	8/31	NS	NS	NS
21	9/21	NS	NS	NS
Mean		1.61	24.26	1.240
Max		2.26	43.5	2.21
Min		1.01	6.4	0.038

Note:

PHOS	= Total Phosphorous (mg/L).	PH	= pH (Standard Units).
NO23	= Nitrate+Nitrite (mg/L).	COLI	= Coliforms (Count).
NH34	= Ammonia+Ammonium (mg/L).	TEMP	= Temperature (Degrees Celsius).
SC	= Specific Conductance (uMhos/cm).	NA	= Not Analyzed
NS	= No Sample Collected.	ID	= Invalid Data

Table 4-22. Goolsby Monitor Well Sampling Results

Sampling Event	Sampling Date	PHOS	NO23	NH34	SC	PH
1	9/9/91	5.79	0.31	6.43	1300	6.7
2	9/30	7.99	0.459	6.6	1120	6.7
3	10/21	9.35	1.58	9	1290	6.3
4	11/11	0.221	0.355	10.5	1220	6.6
5	12/2	5.61	NA	11.1	800	6.8
6	12/16	12.8	0.07	10.3	1200	6.3
7	12/30	10.8	0.212	12.4	1180	6.7
8	1/13/92	9.37	0.348	11.3	950	6.3
9	1/27	7.13	1.82	10.9	1100	6.5
10	2/10	6.5	0.089	8.4	1010	6.1
11	2/24	7.63	0.32	11.5	650	6.2
12	3/16	7.92	0.115	11	1020	7.2
13	4/6	0.481	0.474	4.34	1100	8.1
14	4/27	6.16	0.127	12.1	900	7
15	5/18	7.35	0.016	12.8	900	7.1
16	6/8	9.8	0.177	14.5	800	7
17	6/29	6.23	0.245	5.86	740	7.1
18	7/20	7.18	0.34	9.5	806	6.7
19	8/10	9.77	0.127	10.9	585	7.18
20	8/31	9.84	0.047	7.95	550	7.4
21	9/21	8.49	0.067	10	1266	6.8
Mean		7.45	0.365	9.88	976	6.80
Max		14.5	1.82	14.5	1300	8.1
Min		0.221	0.016	4.34	550	6.1

Table 4-23. Goolsby Lysimeter Sampling Results.

Sampling Event	Sampling Date	PHOS	NO23	NH34
1	9/9/91	38.7	4.59	0.655
2	9/30	NS	4.87	0.126
3	10/21	NS	NS	NS
4	11/11	NS	NS	NS
5	12/2	NS	NS	NS
6	12/16	NS	NS	NS
7	12/30	NS	NS	NS
8	1/13/92	NS	NS	NS
9	1/27	NS	NS	NS
10	2/10	NS	NS	NS
11	2/24	NS	NS	NS
12	3/16	NS	NS	NS
13	4/6	NS	NS	NS
14	4/27	NS	NS	NS
15	5/18	NS	NS	NS
16	6/8	NS	NS	NS
17	6/29	6.85	0.005	0.605
18	7/20	3.28	0.034	0.067
19	8/10	NS	NS	NS
20	8/31	NS	NS	NS
21	9/21	NS	0.857	0.104
Mean		16.28	2.070	0.310
Max		38.7	4.87	0.655
Min		3.28	0.005	0.067

Note:

PHOS = Total Phosphorous (mg/L).
NO23 = Nitrate+Nitrite (mg/L).
NH34 = Ammonia+Ammonium (mg/L).
SC = Specific Conductance (uMhos/cm).
NS = No Sample Collected.
PH = pH (Standard Units).
COLI = Coliforms (Count).
TEMP = Temperature (Degrees Celsius).
NA = Not Analyzed
ID = Invalid Data

Table 4-24. Spaulding Monitor Well Sampling Results.

Sampling Event	Sampling Date	PHOS	NO23	NH34	SC	PH
1	9/9/91	2.17	2.72	1.06	680	6.7
2	9/30	3.77	2.16	1.23	760	6.7
3	10/21	2.51	0.424	1.23	700	7
4	11/11	0.276	1.92	1.1	620	7.1
5	12/2	2.48	3.71	0.877	780	6.8
6	12/16	2.84	3.3	1.22	605	6.8
7	12/30	3.03	2.67	1.33	620	6.7
8	1/13/92	3.77	3.97	1.11	800	6.5
9	1/27	2.6	4.35	1.16	590	6.1
10	2/10	2.69	3.17	1.24	600	5.9
11	2/24	3.5	2.76	1.15	250	6.3
12	3/16	2.76	2.04	1.22	650	7.3
13	4/6	2.26	4	1.21	700	7.9
14	4/27	2.11	2.56	1.48	560	7.1
15	5/18	2.46	4.09	1.46	510	7.1
16	6/8	3.21	11.6	1.05	610	7.5
17	6/29	2.72	2.14	1.05	520	6.9
18	7/20	2.02	0.558	1.06	473	6.8
19	8/10	2.33	1.39	1.11	930	8.72
20	8/31	2.84	2.02	1.29	450	8.2
21	9/21	3.09	1.66	1.43	598	6.6
Mean		2.64	3.010	1.19	619	6.99
Max		3.77	11.6	1.48	930	8.72
Min		0.28	0.424	0.88	250	5.9

Table 4-25. Spaulding Lysimeter Sampling Results.

Sampling Event	Sampling Date	PHOS	NO23	NH34
1	9/9/91	11	12.6	27.1
2	9/30	11.7	14	25.4
3	10/21	7.07	0.32	19.7
4	11/11	9.24	33.3	0.697
5	12/2	12.5	20.6	0.312
6	12/16	10.6	41.7	0.503
7	12/30	10.4	13.9	22.7
8	1/13/92	9.33	26.1	10.6
9	1/27	9.63	51.1	0.438
10	2/10	13.2	52.5	1.21
11	2/24	11.6	36.1	0.319
12	3/16	8.29	36.1	0.058
13	4/6	10.9	0.482	0.068
14	4/27	10.8	68.9	0.224
15	5/18	11.3	NA	0.357
16	6/8	9.88	83.1	0.073
17	6/29	10.7	7.3	7.81
18	7/20	7.08	61.5	0.045
19	8/10	6.45	85.3	0.04
20	8/31	6.7	37.9	0.034
21	9/21	5.97	NA	0.028
Mean		9.730	35.94	5.606
Max		13.2	85.3	27.1
Min		5.97	0.32	0.028

Note:

PHOS	= Total Phosphorous (mg/L).	PH	= pH (Standard Units).
NO23	= Nitrate+Nitrite (mg/L).	COLI	= Coliforms (Count).
NH34	= Ammonia+Ammonium (mg/L).	TEMP	= Temperature (Degrees Celsius).
SC	= Specific Conductance (uMhos/cm).	NA	= Not Analyzed
NS	= No Sample Collected.	ID	= Invalid Data

Table 4-26. Weston Monitor Well Sampling Results.

Sampling Event	Sampling Date	PHOS	NO23	NH34	SC	PH
1	9/9/91	0.127	0.103	0.108	990	6.7
2	9/30	1.24	20.4	0.128	895	6.8
3	10/21	0.291	0.179	0.072	890	7
4	11/11	0.062	32.7	0.172	840	6.9
5	12/2	0.605	21.8	0.059	560	7.1
6	12/16	0.761	10.8	0.051	810	6.4
7	12/30	1.33	13.9	0.114	810	6.7
8	1/13/92	0.722	22	0.058	580	6
9	1/27	0.688	16.5	0.08	790	6.4
10	2/10	1.23	17.2	0.049	780	6
11	2/24	0.912	15	0.107	360	6.4
12	3/16	0.654	16.3	0.047	800	7.1
13	4/6	0.699	12.7	0.044	780	7.9
14	4/27	0.688	11	0.059	610	7.1
15	5/18	4.12	6.86	0.033	610	7.4
16	6/8	0.764	14	0.048	560	7.4
17	6/29	0.758	13	0.022	580	7.3
18	7/20	0.479	11.5	0.045	529	7.2
19	8/10	0.12	12.7	0.05	579	7.43
20	8/31	0.96	8.54	0.041	435	7.8
21	9/21	0.45	11.9	0.039	823	7.3
Mean		0.841	13.77	0.068	696	6.97
Max		4.12	32.7	0.172	990	7.9
Min		0.062	0.10	0.022	360	6

Table 4-27. Weston Lysimeter Sampling Results.

Sampling Event	Sampling Date	PHOS	NO23	NH34
1	9/9/91	0.041	2.6	0.01
2	9/30	NS	NS	0.275
3	10/21	NS	NS	NS
4	11/11	NS	NS	NS
5	12/2	NS	NS	NS
6	12/16	NS	NS	NS
7	12/30	NS	NS	NS
8	1/13/92	NS	NS	NS
9	1/27	NS	NS	NS
10	2/10	NS	NS	NS
11	2/24	NS	NS	NS
12	3/16	NS	NS	NS
13	4/6	NS	NS	NS
14	4/27	NS	NS	NS
15	5/18	NS	NS	NS
16	6/8	NS	NS	NS
17	6/29	0.038	0.031	0.01
18	7/20	NS	NS	NS
19	8/10	NS	NS	NS
20	8/31	NS	NS	NS
21	9/21	NS	0.586	0.067
Mean		0.039	1.072	0.091
Max		0.041	2.6	0.275
Min		0.038	0.031	0.01

Note:
PHOS = Total Phosphorous (mg/L).
NO23 = Nitrate+Nitrite (mg/L).
NH34 = Ammonia+Ammonium (mg/L).
SC = Specific Conductance (uMhos/cm).
NS = No Sample Collected.
PH = pH (Standard Units).
COLI = Coliforms (Count).
TEMP = Temperature (Degrees Celsius).
NA = Not Analyzed
ID = Invalid Data

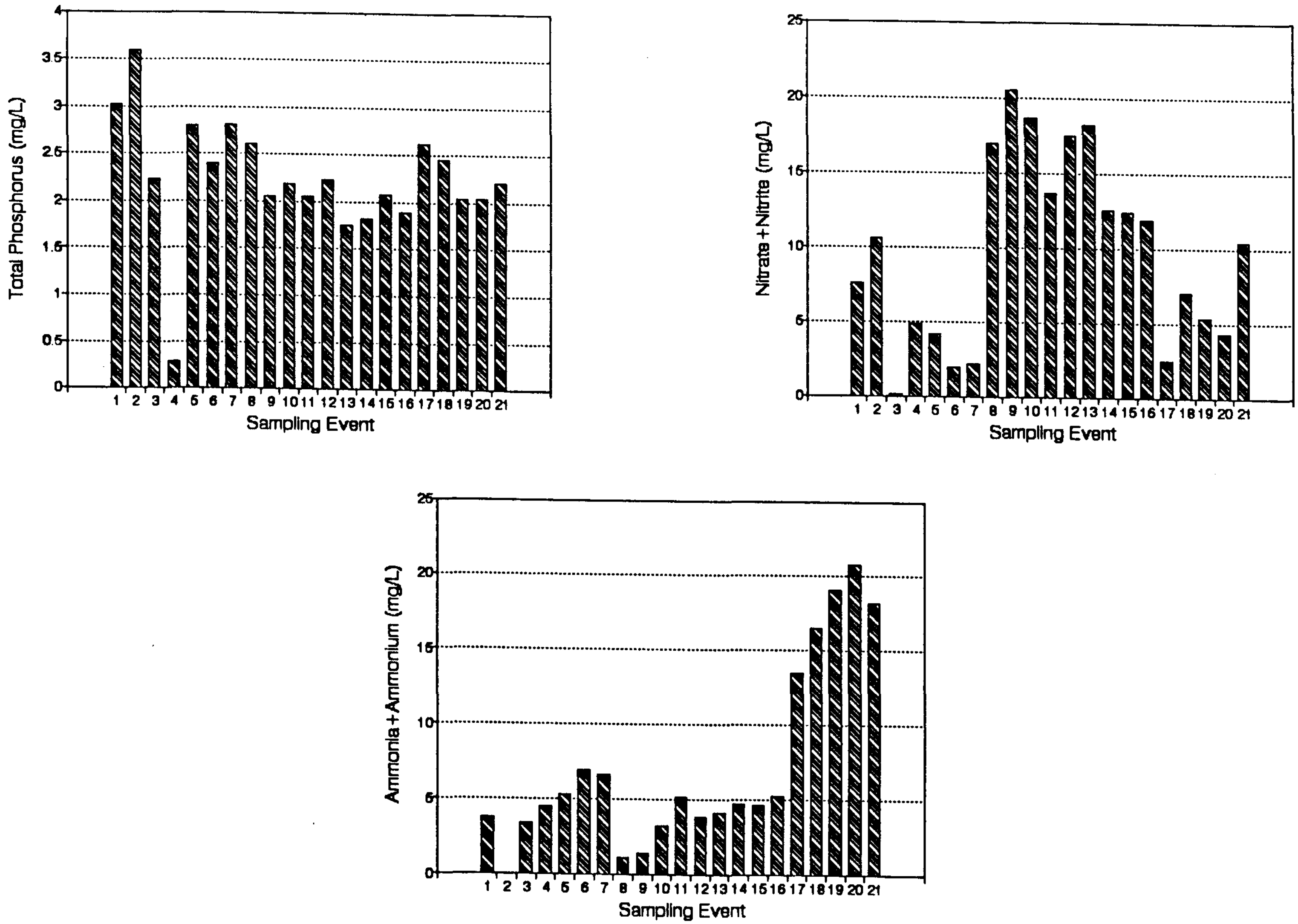
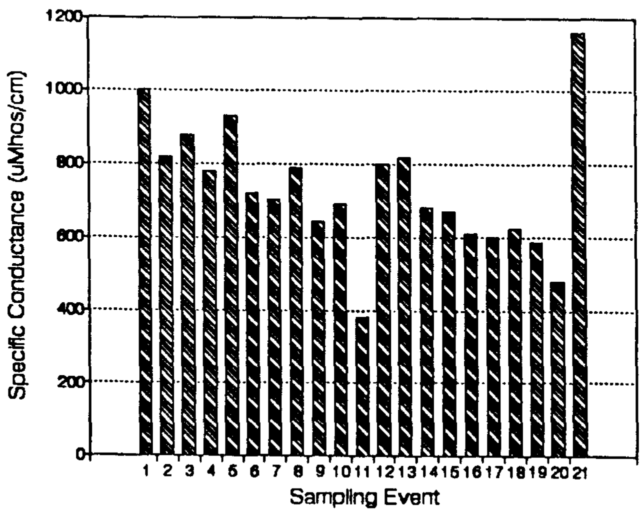


Figure 4-35 (1 of 3)
LEWIS GROUNDWATER AND DRAINAGE LEACHATE
DATA GRAPHS

SOURCE: ESE.

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.



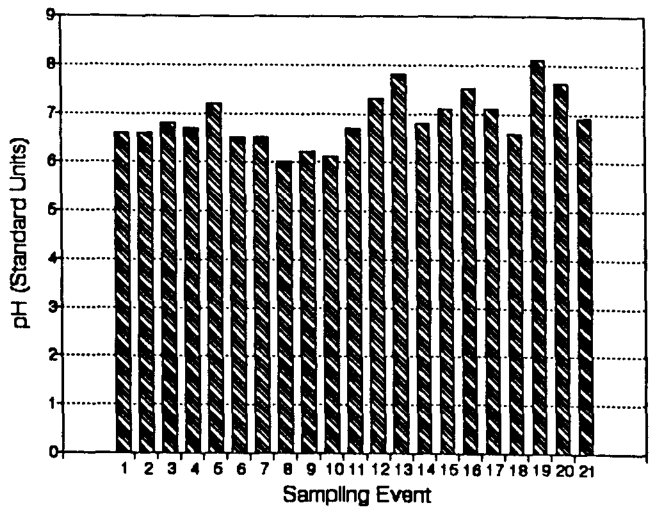


Figure 4-35 (2 of 3)
LEWIS GROUNDWATER AND DRAINAGE LEACHATE DATA GRAPHS

SOURCE: ESE.

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.

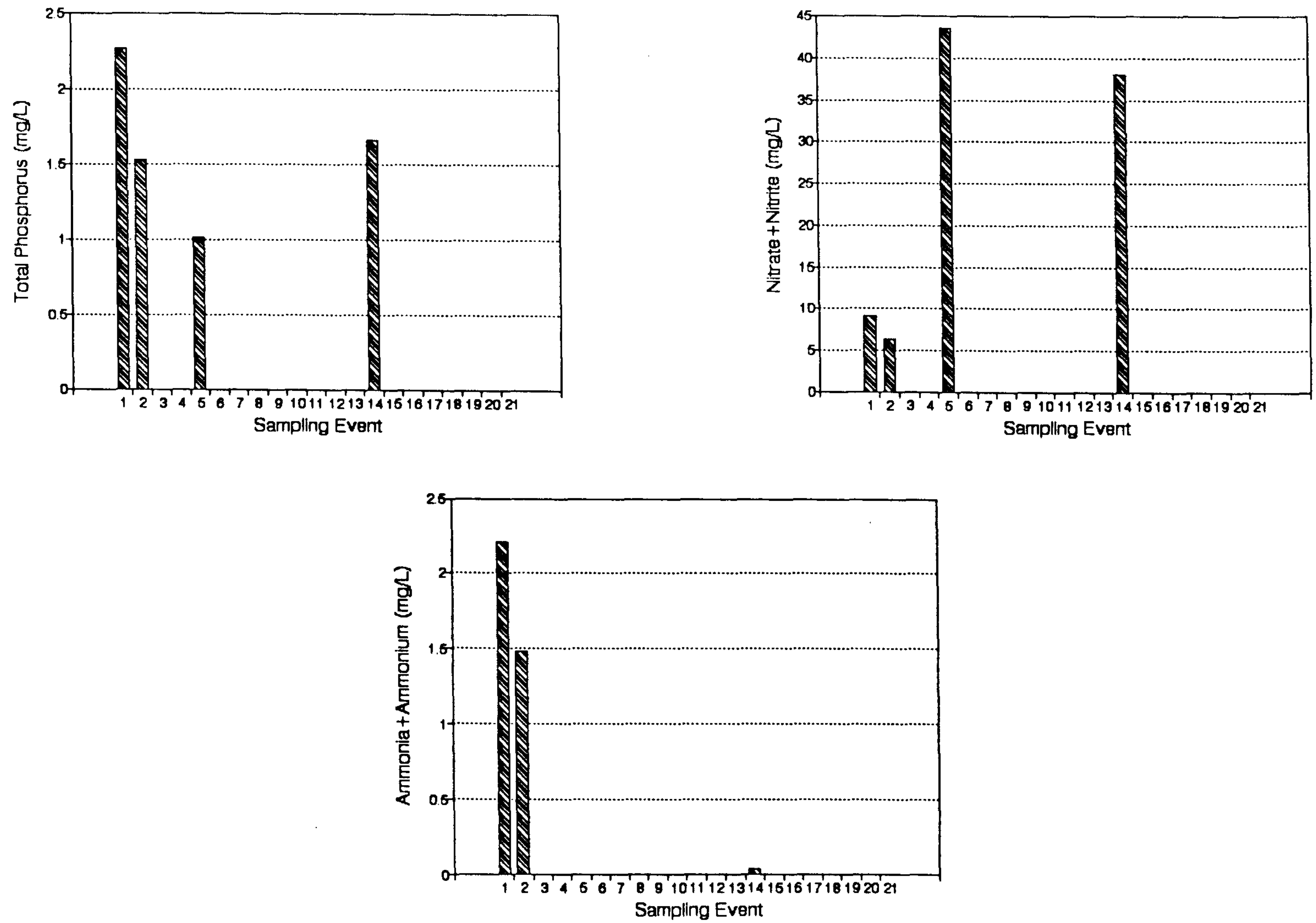
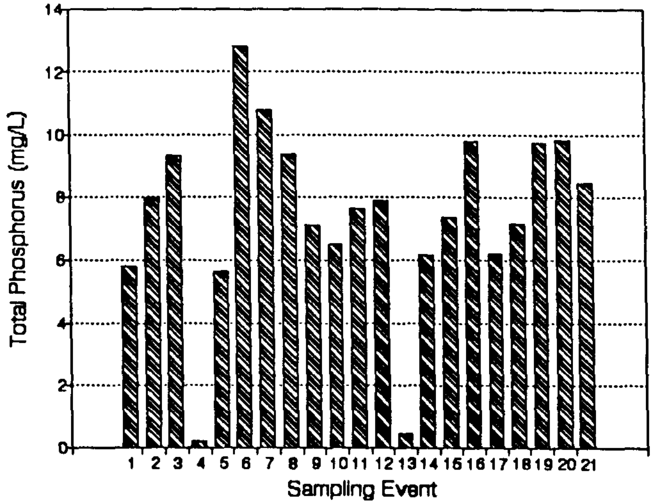
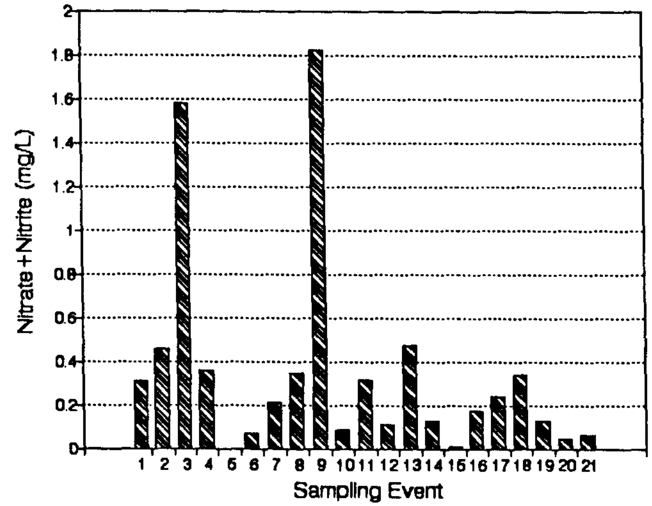


Figure 4-35 (3 of 3)
LEWIS GROUNDWATER AND DRAINAGE LEACHATE
DATA GRAPHS

SOURCE: ESE.

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.





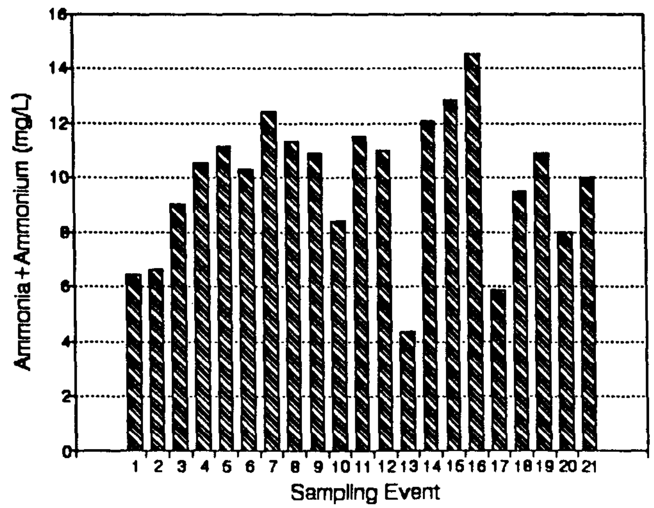
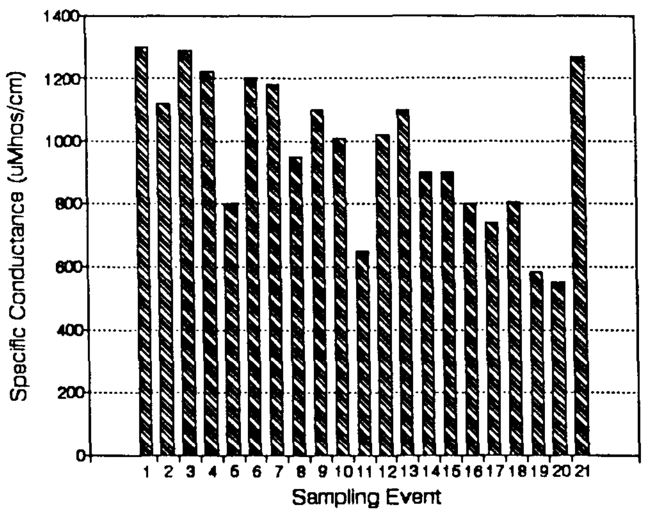


Figure 4-36 (1 of 3)
GOOLSBY GROUNDWATER AND DRAINAGE
LEACHATE DATA GRAPHS

SOURCE: ESE.

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.



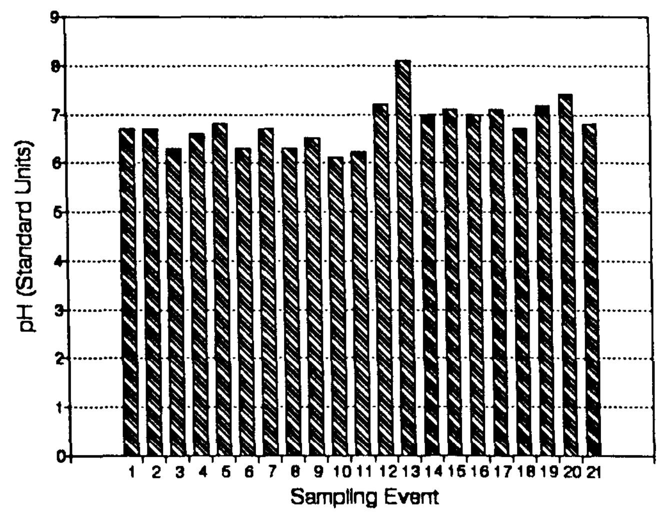


Figure 4-36 (2 of 3)
GOOLSBY GROUNDWATER AND DRAINAGE
LEACHATE DATA GRAPHS

SOURCE: ESE.

ENVIRONMENTAL SCIENCE
& ENGINEERING, INC.

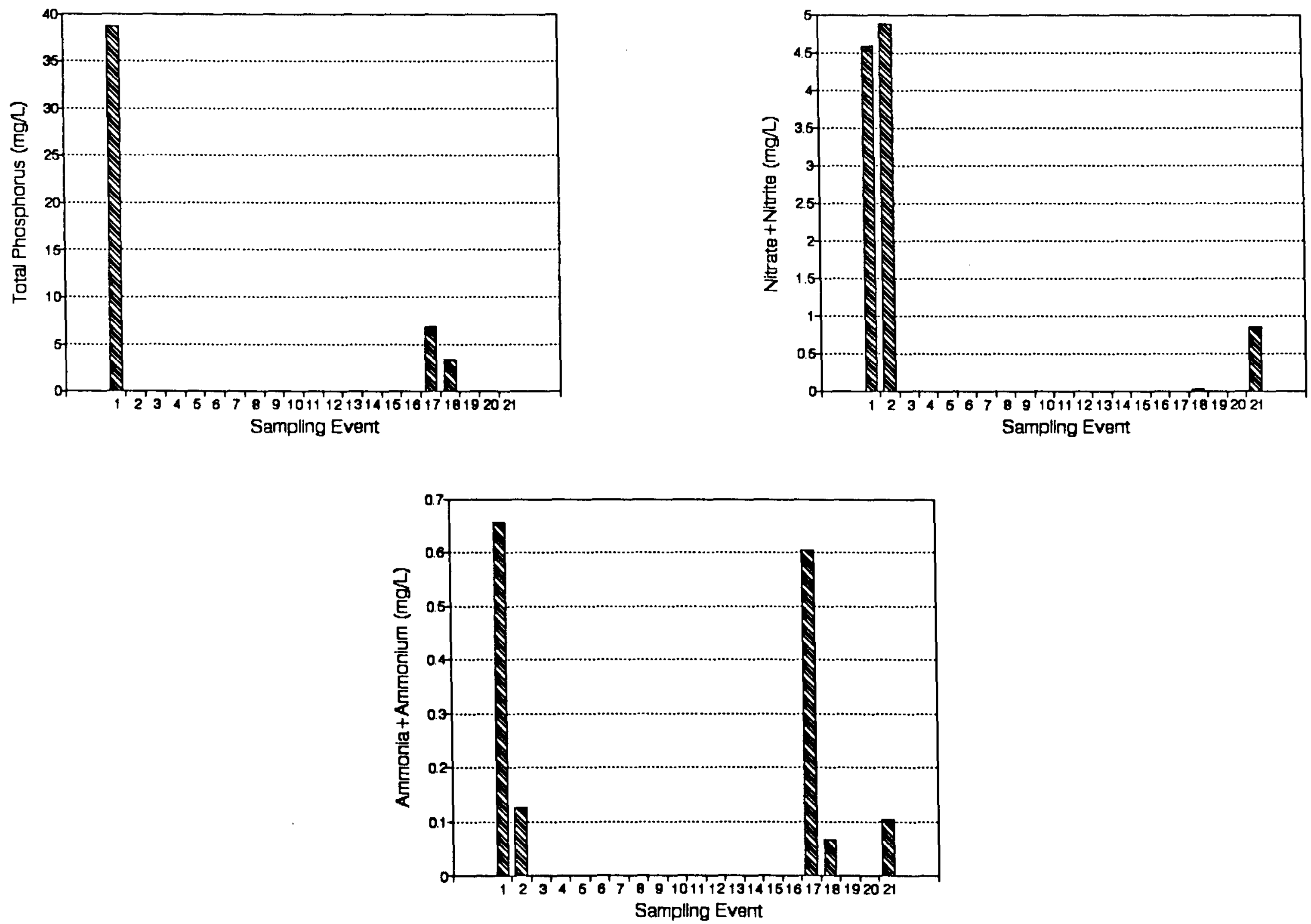


Figure 4-36 (3 of 3)
GOOLSBY GROUNDWATER AND DRAINAGE
LEACHATE DATA GRAPHS

SOURCE: ESE.

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.

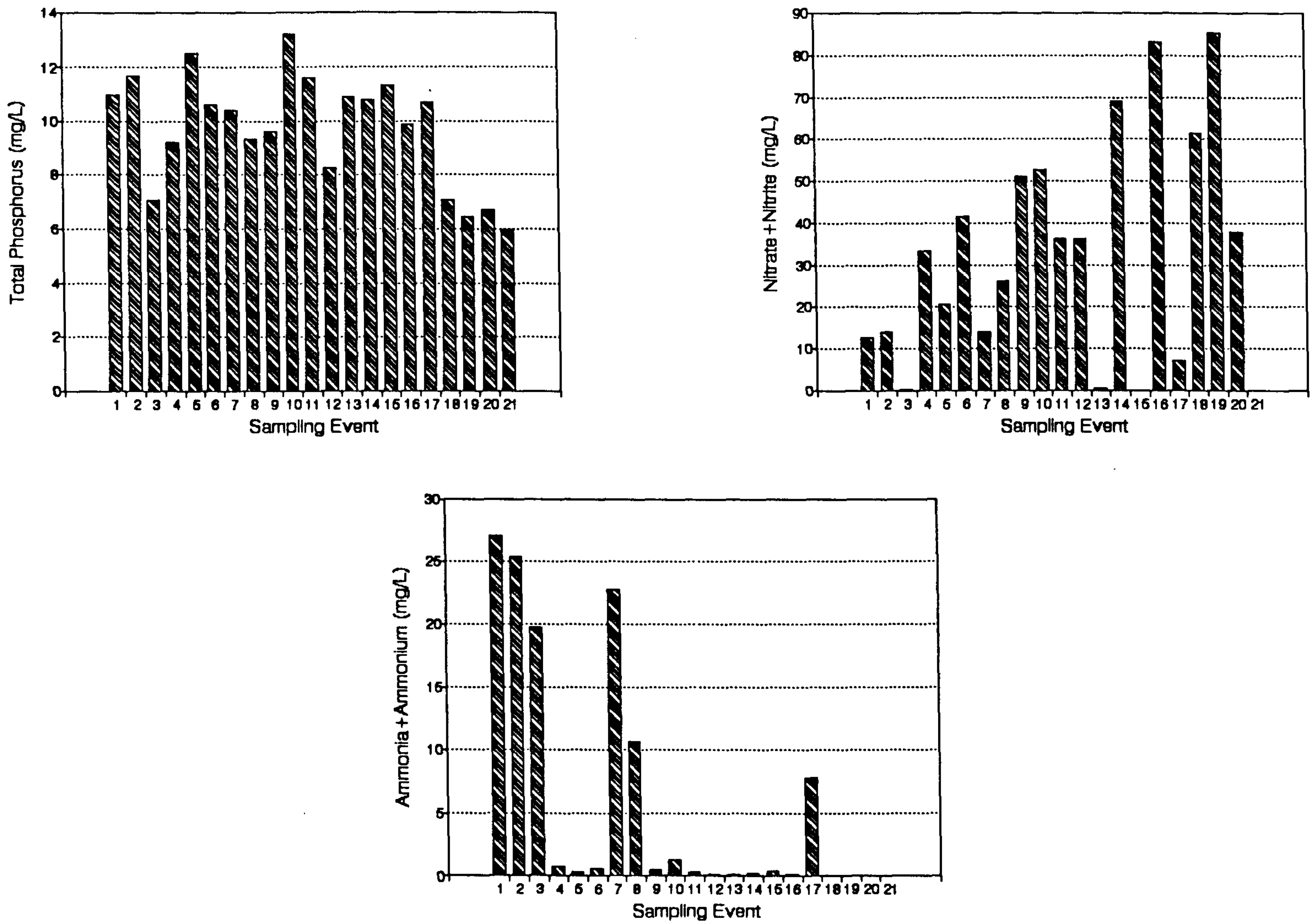
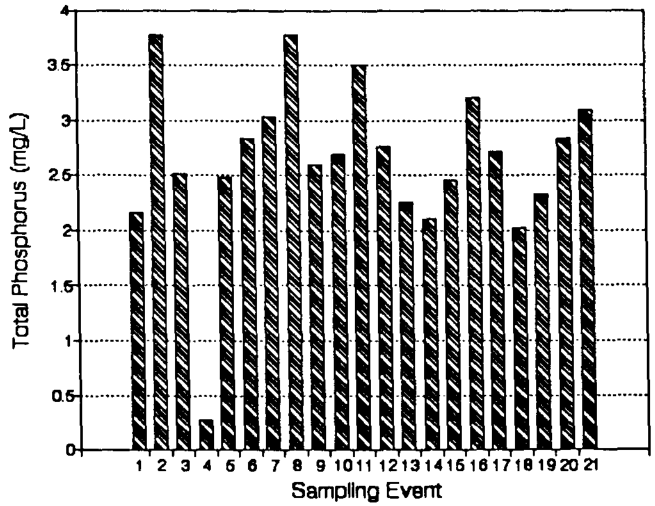
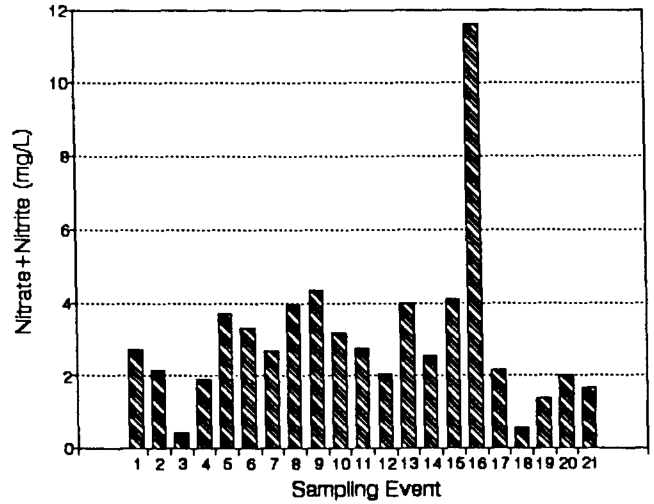


Figure 4-37 (1 of 3)
SPAULDING GROUNDWATER AND DRAINAGE
LEACHATE DATA GRAPHS

SOURCE: ESE.

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.





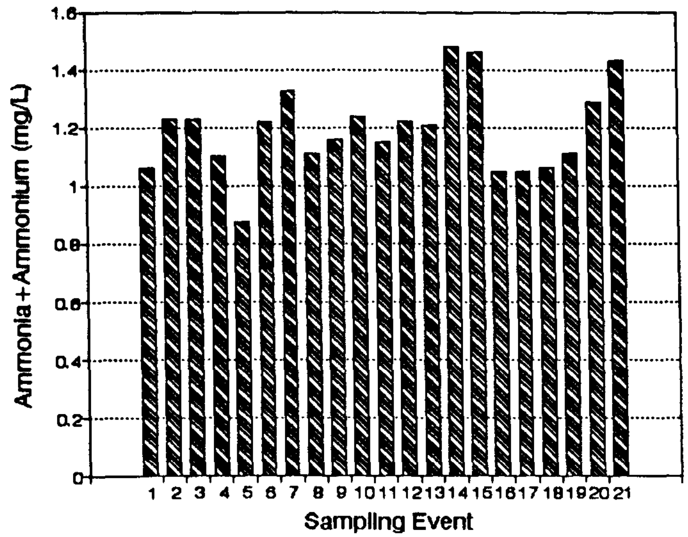
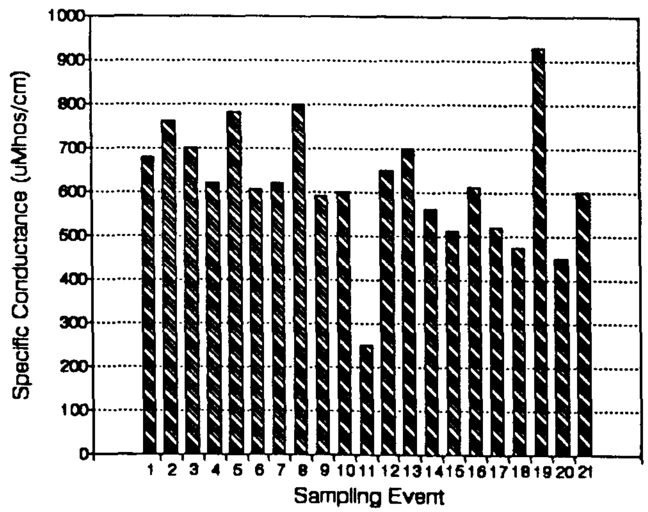


Figure 4-37 (2 of 3)
SPAULDING GROUNDWATER AND DRAINAGE LEACHATE DATA GRAPHS

SOURCE: ESE.

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.



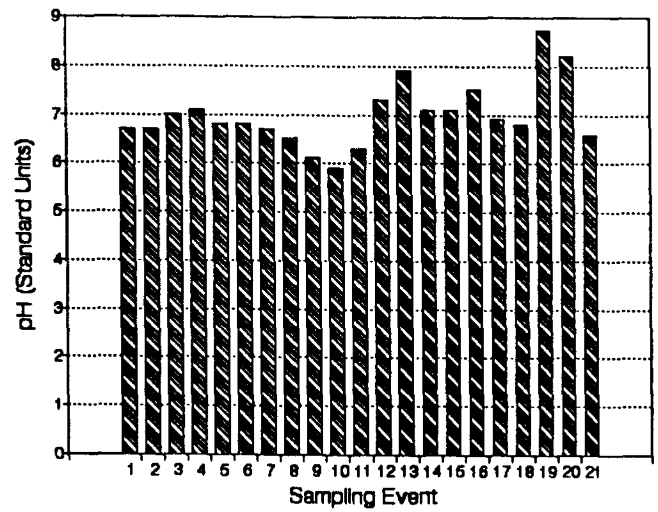


Figure 4-37 (3 of 3)
SPAULDING GROUNDWATER AND DRAINAGE
LEACHATE DATA GRAPHS

SOURCE: ESE.

**ENVIRONMENTAL SCIENCE
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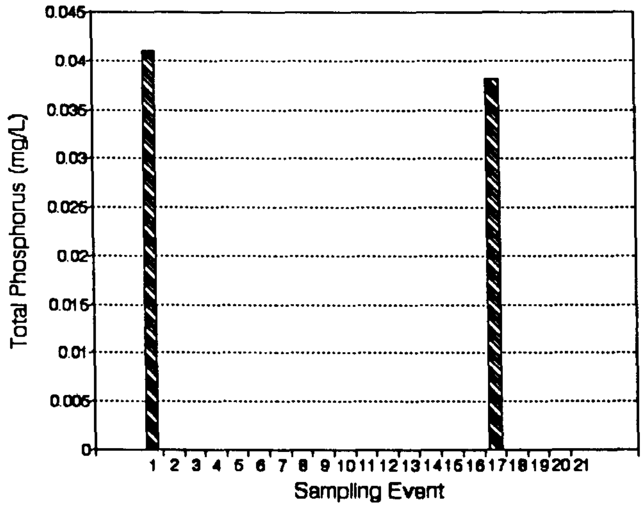
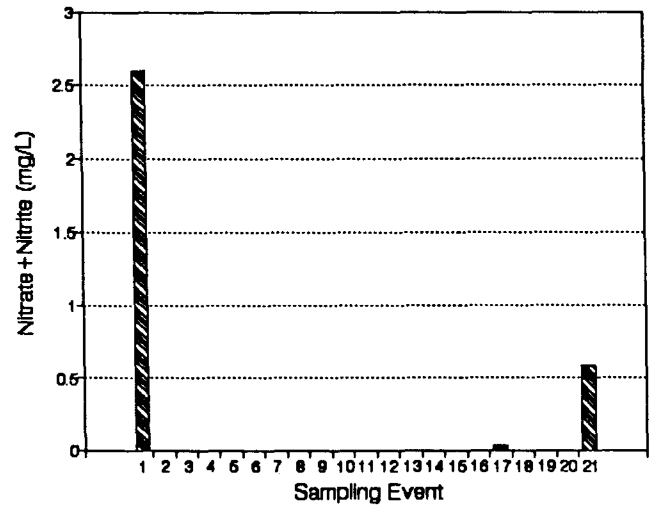




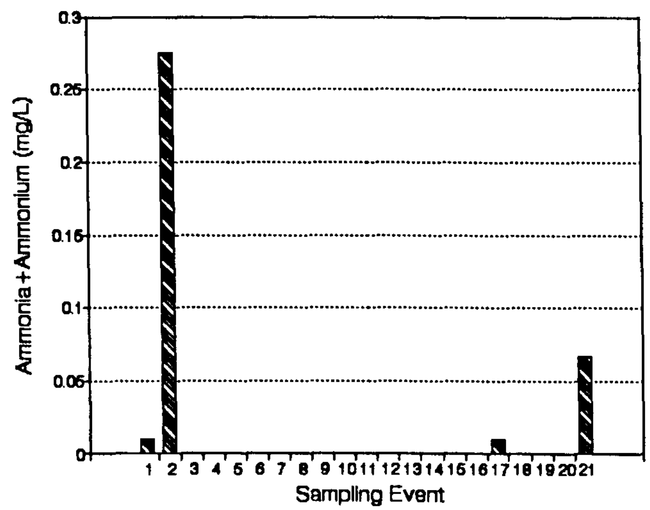


Figure 4-38 (1 of 3)
WESTON GROUNDWATER AND SOIL PORE WATER DATA GRAPHS

SOURCE: ESE.

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.

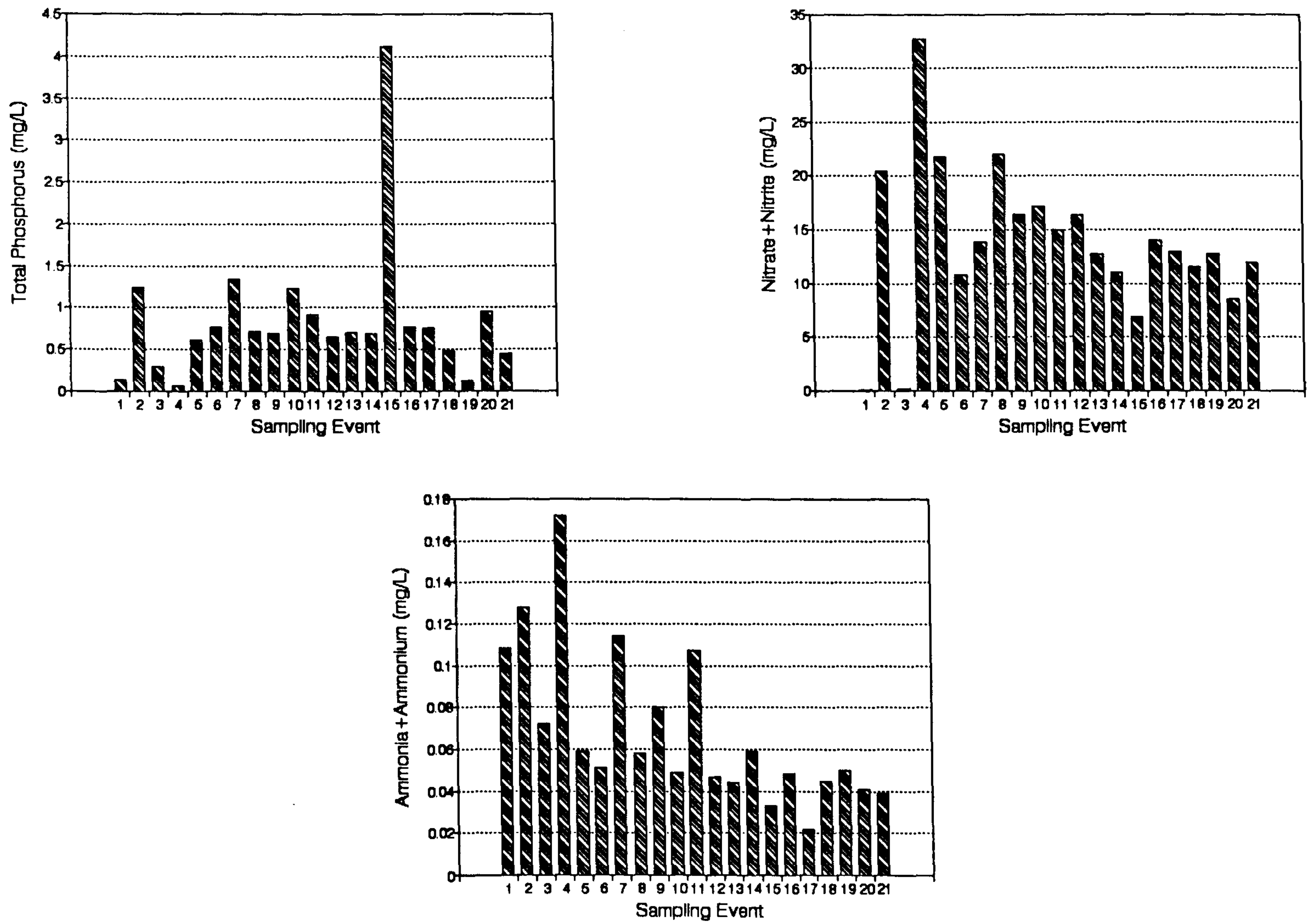
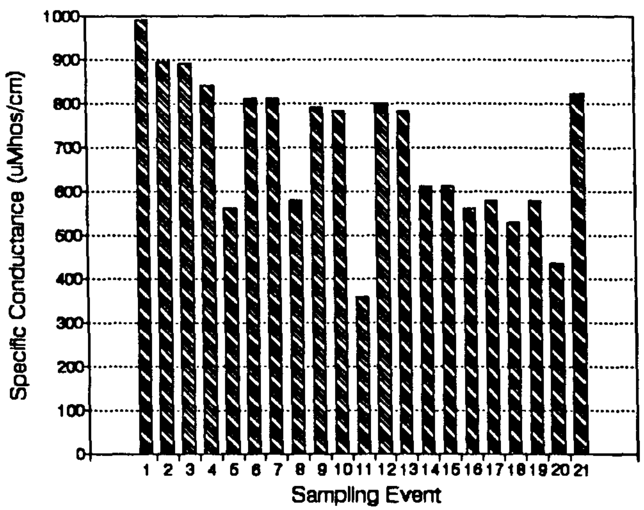


Figure 4-38 (2 of 3)
WESTON GROUNDWATER AND SOIL PORE WATER DATA GRAPHS

SOURCE: ESE.

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.



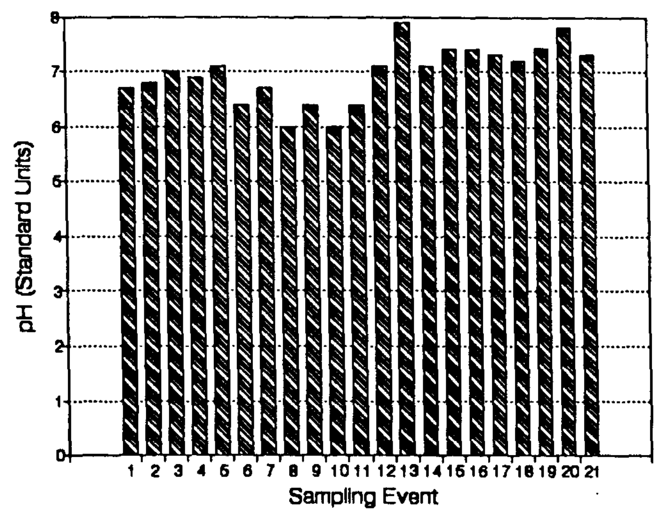


Figure 4-38 (3 of 3)
WESTON GROUNDWATER AND SOIL PORE WATER DATA GRAPHS

SOURCE: ESE.

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4.5.4 BACKGROUND SITE, VACANT LOT

A vacant lot adjacent to the Goolsby residence was chosen to monitor background water quality conditions, unaffected by septic tanks or direct application of fertilizers. One well (V-1) and one lysimeter (VL-1) were installed to monitor these control surficial aquifer and unsaturated zone soil pore-waters (in lieu of drainfield leachate).

Although nutrient concentrations (Tables 4-28 and 4-29 and Figure 4-39) of the background station were generally less than monitored old and newer septic tank sites, they were similar to those encountered at the central sewer monitor well. An exception is the higher concentrations of ammonia in the control samples, likely due to less oxygen within the shallow aquifer at this location. Total P concentrations associated with this background station's soil pore-water were surprisingly high compared to other study locations. A possible explanation is the native soils' contribution. This location also served as agricultural pastureland before its conversion to residential housing. It is, therefore, important to fully evaluate soil types as well as pollutant sources to determine the specific origin of analyzed P. The lack of ammonia associated with VL-1 removes septic tank leachate as a P source at this background location, reinforcing this N species' use as an indicator of septic tank leachate (FDER, 1989a).

4.5.5 SEWAGE TREATMENT PACKAGE PLANT

One monitor well and one lysimeter were installed adjacent to percolation ponds associated with the Professional Services Group Package Plant. These monitoring sites were established to characterize surficial aquifer and unsaturated soil pore-water quality, influenced by domestic waste treated via extended aeration with approximately 95 percent BOD reduction (Patria, 1992). This treated discharge averages 55,000 gal/day.

The monitor well near the percolation pond, P-1, manifested consistent ammonia levels throughout the monitoring period, indicative of organic wastes (Table 4-30 and Figure 4-40). Total P concentrations associated with this station averaged below the 8.0 mg/L average of phosphate (as P) associated with typical secondary effluent (FDER, 1989a). A similar relationship is observed in the soil pore-water samples (Table 4-31 and Figure 4-40), where microbial transformation of ammonia to nitrate appears limited, felt to be a function of minimal molecular oxygen in this unsaturated zone. Levels of nutrient species measured in the saturated and unsaturated zone do indicate oxidation and biodegradation is taking place within the percolation ponds, however, since groundwater ammonia levels would be higher without such treatment. Comparison of these data to old septic tank systems substantiates the benefit afforded by oxidation.

4.5.6 COMPARATIVE EVALUATION OF STUDY SITE TREATMENT EFFICIENCIES

The discussion on individual study sites has identified saturated and unsaturated groundwater quality characterized by various surrounding land uses. The spatial variation noted by review of monitoring data associated with these locations generally indicates septic tank installations in shallow water table environments have the greatest impact on groundwater quality. Comparisons of the sites installed over deeper water tables, using ammonia as an indicator of organic waste decay, suggest these systems have less impact due to the greater amount of vadose zone. As predicted, groundwaters adjacent to package plant percolation ponds show some influence of domestic waste discharge, although aerobic treatment of effluent appears to significantly reduce ammonia levels. Such oxidation is lacking in septic tank treatment systems. Although the central sewer and vacant lot sites do not show these higher levels influenced by domestic wastes, N formation and levels varied between these sites as a function of oxidation.

Total P levels in groundwater sampled adjacent to septic tank systems were higher than other study sites. Average total P concentrations associated with the G-1, M-2, S-1, and L-1 monitor wells decreased with increased average depths recorded at these sites with a correlation coefficient of r is -0.81. This relationship suggests P in drainfield leachate is somehow altered within the

Table 4-28. Vacant Lot Monitor Well Sampling Results.

Sampling Event	Sampling Date	PHOS	NO23	NH34	SC	PH
1	9/9/91	0.568	1.87	2.11	1140	6.7
2	9/30	0.94	7.61	1.57	800	6.6
3	10/21	1.73	0.513	4.59	820	6.8
4	11/11	0.09	0.07	4.37	820	6.8
5	12/2	0.812	0.413	4.05	580	7.6
6	12/16	0.557	0.099	3.95	850	6.3
7	12/30	1.02	3.39	4.3	810	6.7
8	1/13/92	0.661	0.18	4.3	970	6
9	1/27	0.789	0.78	4.29	790	6.7
10	2/10	1.19	0.537	2.46	1110	6.2
11	2/24	1.53	0.346	4.56	400	6.4
12	3/16	1.13	0.063	4.33	830	7.3
13	4/6	6.49	1.53	11.3	830	8.2
14	4/27	1.42	0.005	5.07	690	6.8
15	5/18	0.516	0.026	4.02	700	7
16	6/8	0.746	0.084	3.86	660	6.9
17	6/29	0.696	1.96	1.25	710	6.9
18	7/20	0.668	0.072	2.68	579	6.9
19	8/10	0.576	0.684	3.42	572	7.58
20	8/31	0.761	0.124	1.08	535	7.7
21	9/21	0.71	1.08	2.22	955	6.8
Mean		1.124	1.021	3.80	769	6.90
Max		6.49	7.61	11.3	1140	8.2
Min		0.09	0.005	1.08	400	6

Table 4-29. Vacant Lot Lysimeter Sampling Results.

Sampling Event	Sampling Date	PHOS	NO23	NH34
1	9/9/91	34.4	4.02	0.26
2	9/30	22.6	2.29	0.216
3	10/21	12.4	0.196	0.064
4	11/11	9.53	1.54	0.135
5	12/2	7.84	1.73	0.035
6	12/16	6.31	1.17	0.042
7	12/30	5.79	1.31	0.039
8	1/13/92	5.85	0.649	0.057
9	1/27	5.39	0.884	0.067
10	2/10	4.89	91.2	0.036
11	2/24	4.85	26.6	0.064
12	3/16	6.03	11.5	0.159
13	4/6	5.15	5.4	0.038
14	4/27	5.23	1.74	0.056
15	5/18	5.88	0.08	0.034
16	6/8	5.37	0.027	0.032
17	6/29	4.95	6.15	0.043
18	7/20	7.26	0.077	0.039
19	8/10	5.36	0.068	0.037
20	8/31	5.84	2.44	0.033
21	9/21	6.33	3.85	0.03
Mean		8.440	7.758	0.072
Max		34.4	91.2	0.26
Min		4.85	0.027	0.03

Note:

PHOS	= Total Phosphorous (mg/L).	
NO23	= Nitrate+Nitrite (mg/L).	
NH34	= Ammonia+Ammonium (mg/L).	
SC	= Specific Conductance (uMhos/cm).	
NS	= No Sample Collected.	
PH	= pH (Standard Units).	
COLI	= Coliforms (Count).	
TEMP	= Temperature (Degrees Celsius).	
NA	= Not Analyzed	
ID	= Invalid Data	

Table 4-30. Package Treatment Plant Monitor Well Sampling Results.

Sampling Event	Sampling Date	PHOS	NO23	NH34	SC	PH
1	9/9/91	1.58	0.057	0.608	690	6.7
2	9/30	0.431	0.219	1.99	1120	6.5
3	10/21	0.56	0.276	2.68	1440	6.5
4	11/11	1.65	ID	2.66	1410	6.9
5	12/2	2.16	0.145	3.88	980	7.1
6	12/16	0.488	0.578	4.54	820	6.8
7	12/30	1.1	0.638	4.45	1290	7
8	1/13/92	1.1	0.084	4.28	1050	6.6
9	1/27	0.782	1.06	3.96	1180	6.5
10	2/10	0.523	0.25	3.79	1150	6.2
11	2/24	0.43	0.363	4.04	800	6.5
12	3/16	3.49	0.166	3.88	1200	7
13	4/6	1.15	0.374	4.42	1290	7.9
14	4/27	0.817	0.195	5.69	1015	7.2
15	5/18	2.58	0.169	4.11	1020	7.3
16	6/8	2.6	0.197	4.04	940	6.2
17	6/29	0.308	0.207	2.46	800	6.8
18	7/20	0.334	0.167	3.41	961	7.2
19	8/10	1.02	0.51	3.53	965	7.47
20	8/31	1.03	0.105	3.55	685	7.6
21	9/21	0.716	0.22	4.01	1602	6.9
Mean		1.183	0.299	3.62	1067	6.9
Max		3.49	1.06	5.69	1602	7.9
Min		0.308	0.057	0.61	685	6.2

Table 4-31. Package Treatment Plant Lysimeter Sampling Res

Sampling Event	Sampling Date	PHOS	NO23	NH34
1	9/9/91	0.136	0.012	12
2	9/30	1.45	0.012	6.85
3	10/21	1.82	0.125	7.35
4	11/11	2.31	0.085	8.68
5	12/2	2.27	0.2	7.05
6	12/16	2.01	0.023	8
7	12/30	2.24	0.01	10.5
8	1/13/92	1.47	0.028	9.07
9	1/27	1.64	0.075	7.05
10	2/10	1.48	0.021	7.73
11	2/24	1.6	0.016	7.27
12	3/16	1.25	0.005	7.43
13	4/6	1.29	0.005	9.24
14	4/27	1.6	0.093	10.1
15	5/18	0.673	3.1	3.64
16	6/8	1.41	0.018	3.78
17	6/29	0.753	0.005	0.021
18	7/20	2.03	0.024	4.77
19	8/10	2.07	0.292	7.93
20	8/31	1.69	NA	4.76
21	9/21	2.58	0.21	6.86
Mean		1.608	0.218	7.147
Max		2.58	3.1	12
Min		0.136	0.005	0.021

Note:
PHOS = Total Phosphorous (mg/L).
NO23 = Nitrate+Nitrite (mg/L).
NH34 = Ammonia+Ammonium (mg/L).
SC = Specific Conductance (uMhos/cm).
NS = No Sample Collected.
PH = pH (Standard Units).
COLI = Coliforms (Count).
TEMP = Temperature (Degrees Celsius).
NA = Not Analyzed
ID = Invalid Data

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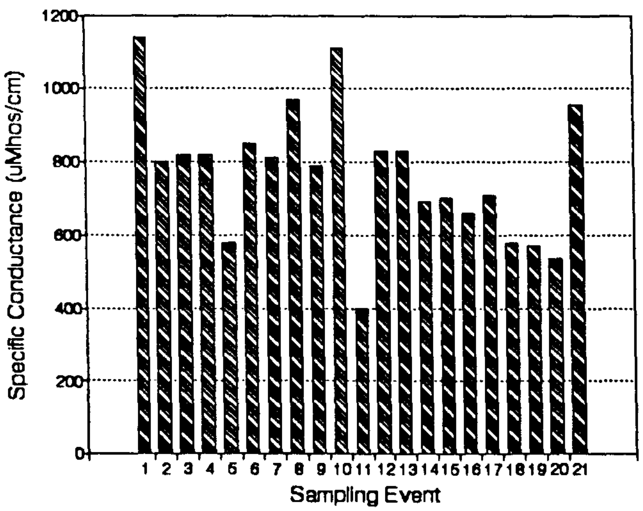

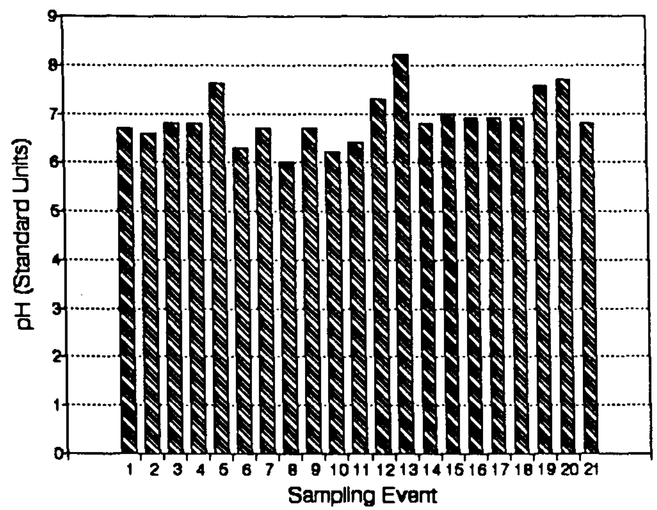

Figure 4-39 (1 of 3)
VACANT LOT GROUNDWATER AND
SOIL PORE WATER DATA GRAPHS

SOURCE: ESE.

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.

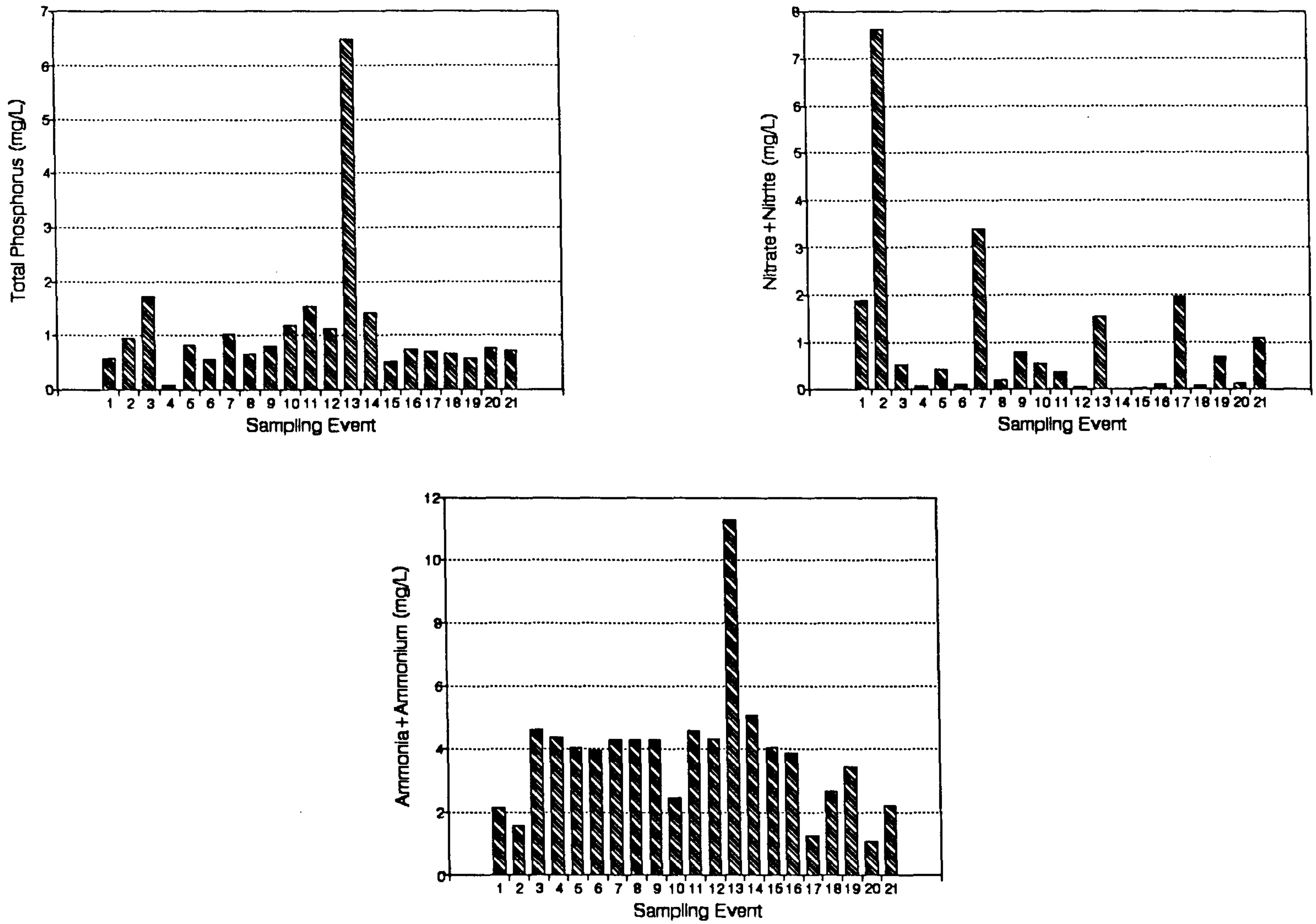

Figure 4-39 (2 of 3)
VACANT LOT GROUNDWATER AND
SOIL PORE WATER DATA GRAPHS

SOURCE: ESE.

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.

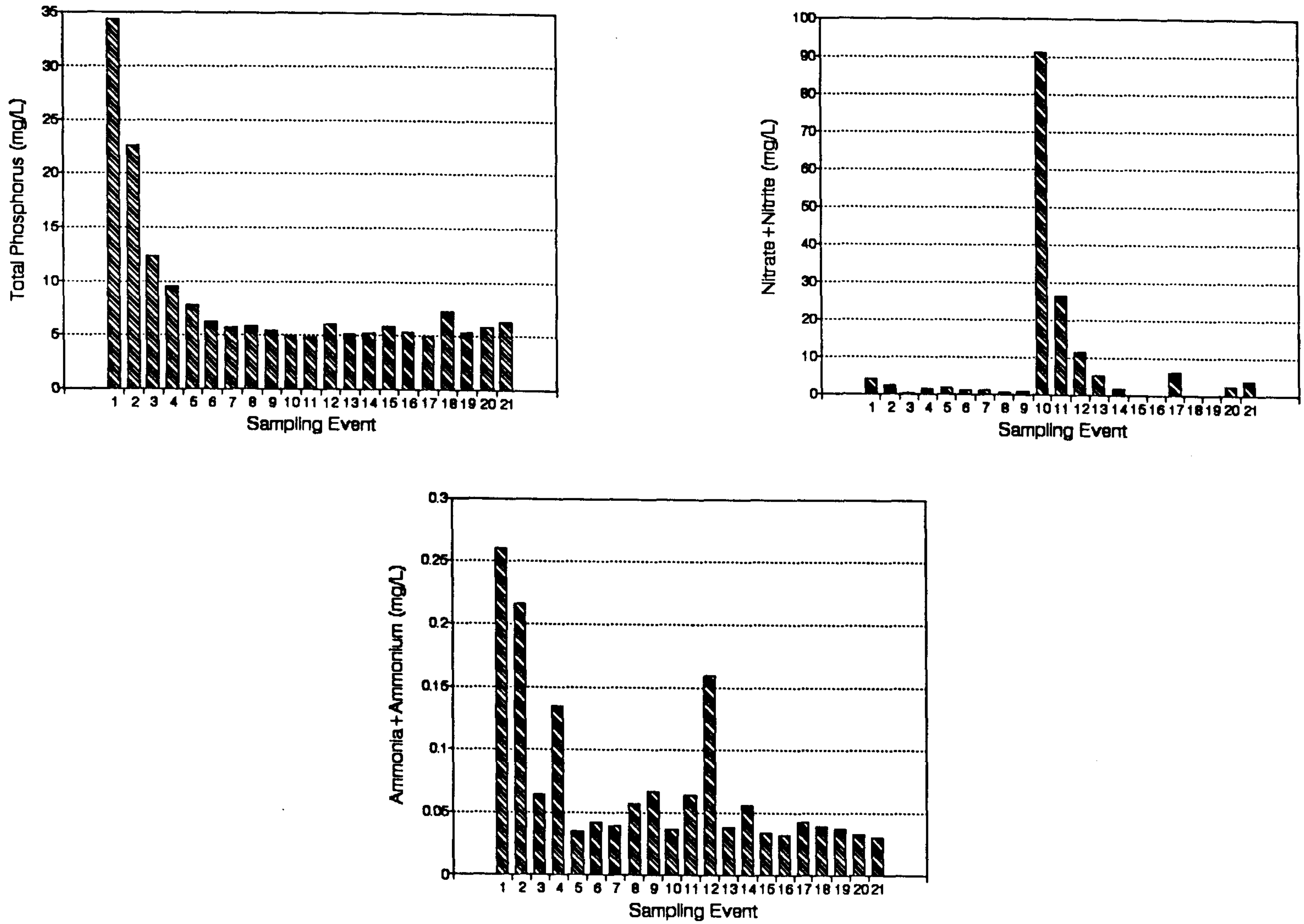

Figure 4-39 (3 of 3)
VACANT LOT GROUNDWATER AND
SOIL PORE WATER DATA GRAPHS

SOURCE: ESE.

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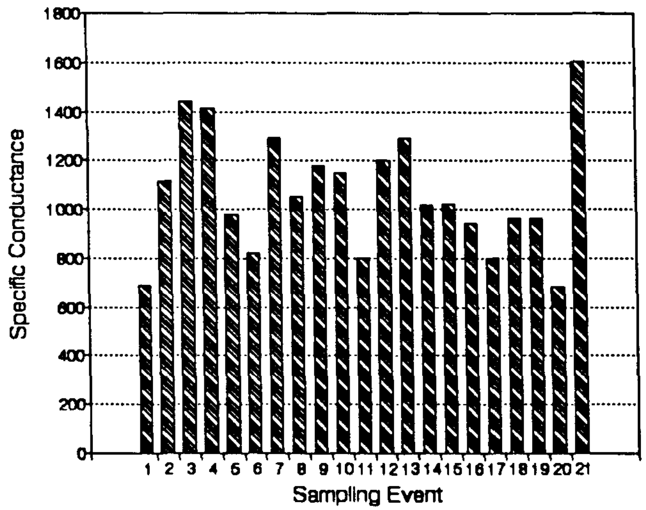


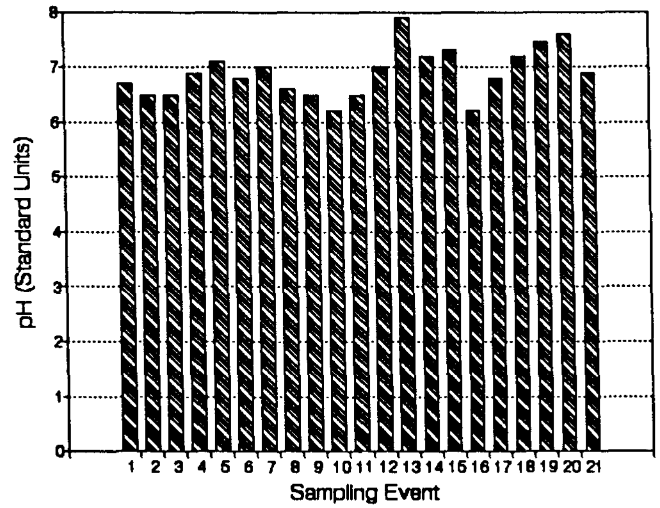
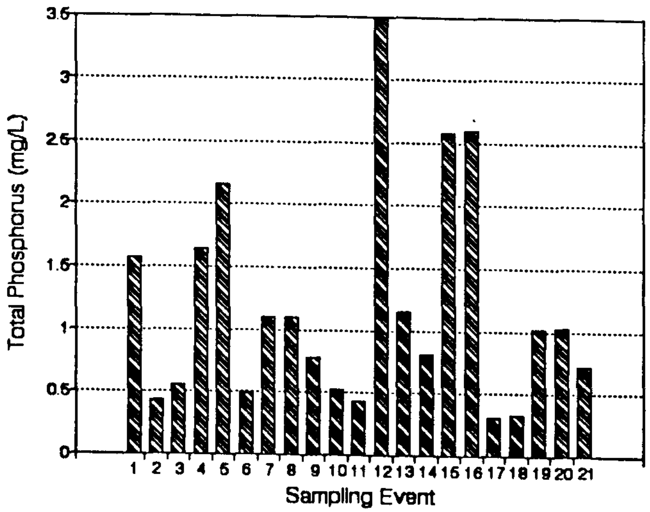
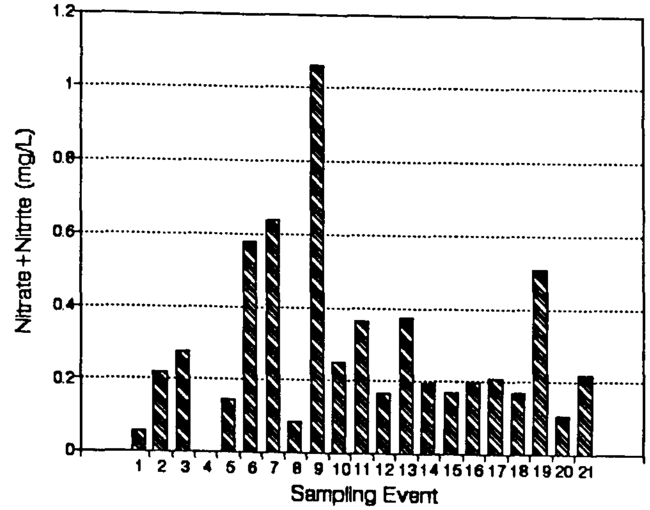


Figure 4-40 (1 of 3)
PACKAGE TREATMENT PLANT GROUNDWATER AND SOIL PORE WATER DATA GRAPHS

SOURCE: ESE.

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.





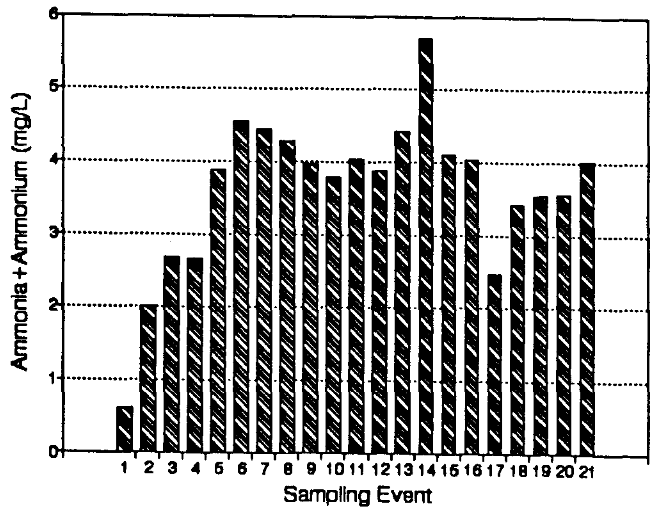


Figure 4-40 (2 of 3)
PACKAGE TREATMENT PLANT GROUNDWATER AND
SOIL PORE WATER DATA GRAPHS

SOURCE: ESE.

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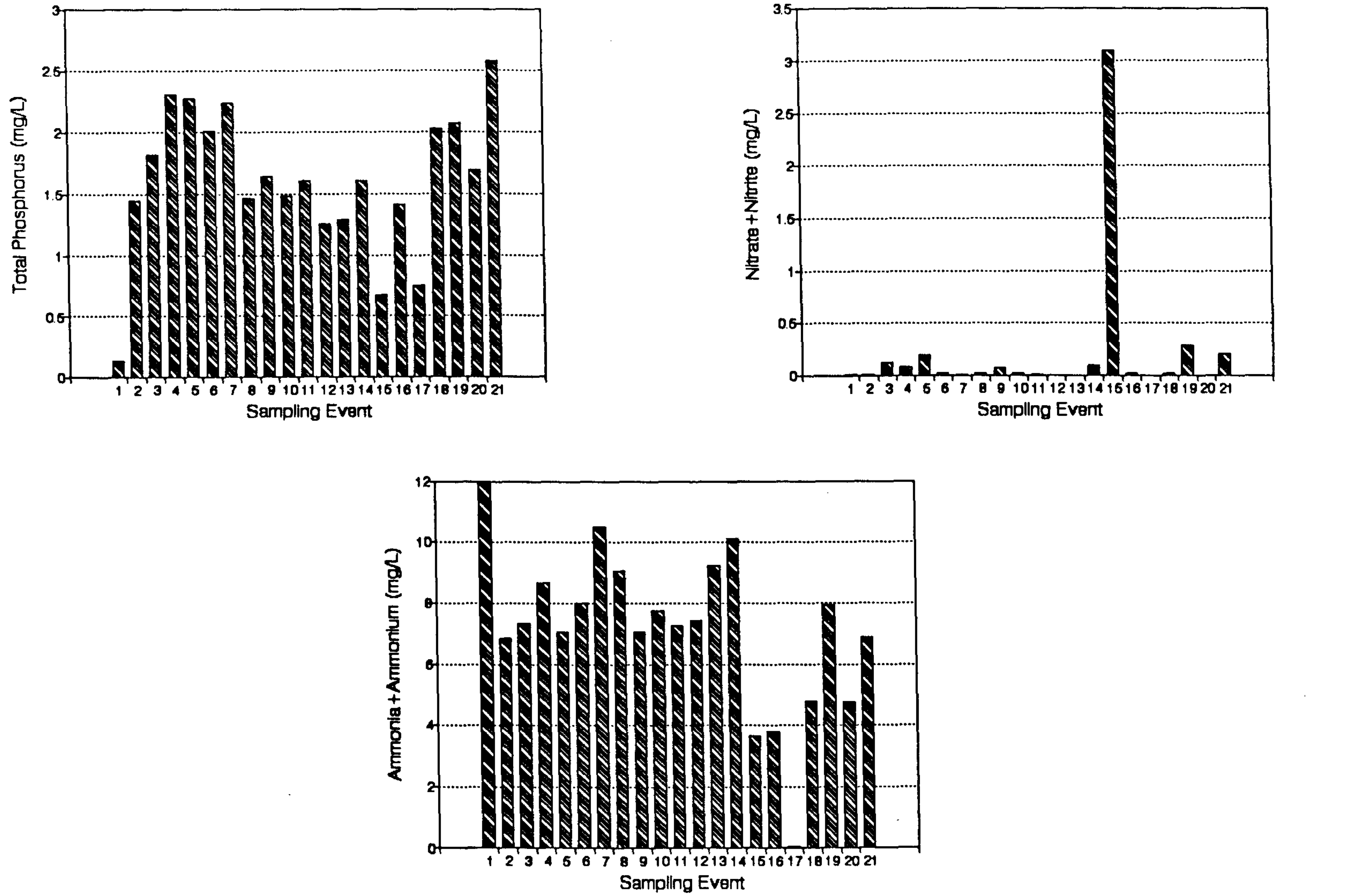

Figure 4-40 (3 of 3)
PACKAGE TREATMENT PLANT GROUNDWATER AND SOIL PORE WATER DATA GRAPHS

SOURCE: ESE.

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unsaturated soil zone so that it binds (adsorbs or precipitates) with the soil materials. Treatment efficiency is increased with a corresponding increased distance between septic tank drainfield and water table elevations.

P is of particular interest due to its behavior as a biolimiting nutrient in receiving surface waters. The lithology within the saturated zone may influence P concentrations, as noted by the background levels at V-1. Lower total P levels analyzed in canal surface waters are primarily attributable to dilution and biological uptake. Retention in soils due to phosphate ions becoming chemisorbed to organic matter or on the surfaces of iron, aluminosilicate, and calcium minerals must also be considered as an attenuation factor (Canter and Knox, 1984). In surface waters, coprecipitation of inorganic P with calcite may result in an abiotic loss of this nutrient, a process which should be discriminated from biological uptake (House, 1990). All of these processes must be considered as influencing these generally lower total P concentrations in surface waters than the surficial aquifer monitor wells.

The nutrient concentrations analyzed in monitor well samples associated with the Moldenhauer residence generally fall within anticipated concentration ranges (Tables 4-16, 4-17, and 4-18). This site, M-2, may serve as a useful location to monitor septic tank effluent on a long-term basis, due to its status as an older, active system and monitoring data clearly indicative of nutrient enrichment of the shallow water table/associated soils. The Moldenhauer residence also has upgradient and downgradient monitor wells that assist with simultaneous comparison of background and potentially impacted areas.

The surface water quality monitoring data have been discussed in terms of microbiological analyses in this section. Conclusions offered for parameters governing the total coliform populations are also applicable to nutrient species analyzed in these waters. Total P, pH, and specific conductance measurements made during this study are similar to those independently recorded in this region (FDER, 1992b). It is difficult to quantify the contributions made by septic tanks to these receiving waters, although data developed for the Moldenhauer residence suggest leachate from these sources is significantly attenuated in soils within both saturated and unsaturated zones. While no spatial relationship may be made between nutrients analyzed in surficial groundwaters and canal sample sites, some temporal observations are noted. For example, seasonal increases in surface water temperature fosters accelerated productivity, which is reinforced by observations of higher pH measurements made during this period. The nutrient loadings associated with septic tank leachate must therefore be carefully evaluated in terms of attenuation in soils before surface water impacts from this source can be adequately assessed.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 SUMMARY

5.1.1 SOILS AND SEDIMENTS

The current soil characteristics are representative of disturbed soils rather than those mapped by the Soil Conservation Service. The home sites in each subdivision were constructed during the dredging of the canals, the spoil deposited on top of the native soils. In some places, it appeared as if additional fill was brought in to the site to raise the elevations of the home sites. The unsaturated zone of the soil is mostly comprised of fill in all subdivisions. The surface horizon of the native soils usually appears somewhere close (above or below) to the water table. The actual elevations of the land surface (and depths to the water table) within each of the four subdivisions varies depending on how much fill was deposited during site construction. Although it is impossible to map the elevations of different subdivision as part of this work, it seems that elevations increase from Buckhead Ridge (on the west) to Okeechobee Hammocks on the east.

The majority of the fill materials, existing within the unsaturated zone, do not play much of a role in phosphorus attenuation. The standard literature says that septic-derived phosphorus is attenuated in the unsaturated zone of soils. This research though, shows that phosphorus moved through the unsaturated zone to accumulate at various locations along the top of the water table, either directly under or slightly downgradient of the drainfields. The phosphorus accumulations were likely a function of adsorption or precipitation with iron, aluminum, calcium, and organic matter. The zone of accumulation was always closer to the drainfields than the canals which indicates that a pulse of phosphorus is moving but hasn't reached the canals yet. Over time, phosphorus is likely to continue to increase and saturate the soils along the water table. If the phosphorus inputs are not stopped now, at some time in the future phosphorus will begin seeping into the canals at greater and greater concentrations.

None of the sediment samples exhibited the high phosphorus concentrations observed in some soil samples collected from under the drainfields. Phosphorus from septic tanks or from other nonrelated sources is not building up within the sediments of the canals. Nitrogen concentrations were only slightly elevated relative to any of the soil samples though they were well within the median range of STORET data from streams sampled in other parts of Florida. Nutrient data appeared to be random with respect to age of the canal, location of the canal (dead end or main channel), or presence and absence of septic tanks around the banks.

5.1.2 GROUNDWATER

The average depth to water at the drainfield is 48 inches blow land surface (BLS) at Goolsby and 52 inches BLS at Moldenhauer. Groundwater fluctuates from 41 to 60 inches at Goolsby and from 48 to 56 inches at Moldenhauer. The difference in fluctuations is likely due to Goolsby's house being right on Taylor Creek which would fluctuate more than the canal adjacent to Moldenhauer's. The fill material, being a mixture of soils and underlying sediments, did not exhibit evidence of a seasonal high water table.

Using an average depth of a drainfield bottom of 18 to 24 inches BLS, the separation distance between the bottom of the drainfield and the water table is (on average) 30 inches at Goolsby and 34 at Moldenhauer. Both systems appear to be constructed with the required 42 inches of appropriate soil material and the 24 inches of unsaturated depth. The other two homes within the study, Spaulding and Lewis, had drainfields constructed with a greater separation distance to the water table. The water table was greater than 60 inches from the surface, on average. Based on this characteristic, the environment under these homes is similar.

Groundwater concentrations of P increased as the water table elevation decreased, from a site to site perspective. This observation takes on greater significance considering that the depth to water tables in these subdivisions exceed the minimum required distance criteria set forth in 10D-6 code. It appears that any additional separation between the drainfield and the water table affords some amount of additional treatment. Without groundwater criteria or observable impact to adjacent surface waters, there is no way of determining what separation distance is optimum for these areas.

The groundwater results further showed that age or construction of the septic tank was not necessarily related to groundwater quality. The original plan of study was to compare old versus new septic systems with the age criteria actually being defined by the presence/absence of mounded systems. When it was discovered that mounded systems were not installed in the area, the age category changed to be defined by the location of the drainfield relative to the canal. Because of the more lax setback rules during the early construction years, older homes could have drainfields installed closer to the canals than 75 ft. The Goolsby and Spaulding sites were new sites with drainfields installed more than 75 ft from the canal. Moldenhauer's drainfield has been installed very close to the canal (old) and the Lewis residence was also determined to be an old site.

As it turned out, the differentiating characteristic among the homes was depth to the water table. Goolsby and Moldenhauer had similar, near 50-inch depths to the water table while Spaulding and Lewis had similar 60^{+}-inch depths to water. Unfortunately, this characteristic is more difficult to measure or describe than the location of the drainfield. Measuring depth to water requires some kind of monitor well at each location. This work has shown that 10-inch variations in depth to water results in different groundwater quality; though differences of this magnitude are not very visible across neighbors' yards. Elevation surveys to determine depth to water within the four subdivisions will indicate the localized areas likely to have poorer quality groundwater.

5.1.3 SURFACE WATER QUALITY

Direct negative relationships between septic systems and surface water quality are difficult to prove from the data collected by these investigations. The only sampling station and parameter to be different from other stations/parameters was station TC-2 and coliforms. Station TC-2 was located on the only canal not surrounded by homes on septic tanks. Samples from this station showed lower coliform counts than samples collected from other canals. Based on the findings of Ayres and Associates (1991), it is very unlikely that the coliform differences are evidence of direct coliform input to the canals from groundwater seepage. It is unclear, however, if other constituents in septic leachate are migrating to the other canals and indirectly enhance coliform growth or if the differences are simply caused by hydraulics.

No other differences (nutrients) between this station and any others were obvious. This observation also is similar to Ayres and Associates (1991) research on the Indian River Lagoon system. The soils data imply that nitrogen compounds may be migrating from the drainfields into the canal but the phosphorus is attenuated in soils along the top of the water table relatively close to the drainfields. In spite of these observations, it is impossible to conclude with certainty that nutrients are not getting into the canals. Biological activity within the canal water may be high enough to act as an extremely effective nutrient sink, masking the impact. If the hypothesized biological masking effect is real, it should remain effective as long as nutrient inputs stay as they are. If septic tank inputs are not stopped, the soils between the drainfield and canals will become saturated with phosphorus allowing higher amounts of phosphorus to reach the canal. The higher additions of phosphorus may overwhelm the organisms causing excessive aquatic growth and/or become easily measurable in the water column.

5.2 NUTRIENT LOADING

The drainage system in each study area forms a complex network of residential houses in the isles bordered by finger canals. Groundwater in an isle is directly connected with surface water. Thus, the finger canals are the nearest receiving water for nutrients discharged from septic tanks within the isles. This research effort did not show conclusively that nutrients from septic tanks are currently entering the surface water via groundwater seepage. At most, we can surmise from soil data that nitrogen compounds may be migrating to the canals but are not observable. These loading calculations are based on future worst-case conditions, assuming that septic tanks are still being used such that the soils along the top of the drainfield are saturated with phosphorus. This will allow maximum inputs of phosphorus into the canals.

5.2.1 RELATIONSHIP BETWEEN SURFACE WATER AND GROUNDWATER

To evaluate the flow pattern between the isles and finger canals, canal-stage data were collected from the South Florida Water Management District (SFWMD) and are plotted in Figures 4-7, 4-11, and 4-19, along with the monitor well water levels in the Taylor Creek Isles and Treasure Island area. The figures show that on an average, water flows from the canals into the isles for 31 weeks out of 56 weeks, or about 55 percent of the time; whereas water from the drainfield area (represented by the monitor wells) flows toward the canals for 25 weeks out of 56, or 45 percent of the time. The figures also show that during the winter (dry season), the canal stages are higher than the groundwater levels and lower in the summer (wet season).

Canal-stage data are not available in the Buckhead Ridge and Okeechobee Hammock areas. In these cases, a comparison was made between the piezometer/monitor well nearest to the canal and the monitor well in or near the drainfield.

For the Buckhead Ridge area, the Moldenhauer (M) site was considered. A comparison between the monitor well M-1, which is nearest to the canal, and monitor well M-2, which is in the drainfield, was made. The water level variability of M-1 and M-2 are shown in Figure 4-3. Figure 4-3 shows that out of 56 weeks, water levels of M-1 remain above that of M-2 for about 30 weeks, or 53 percent of the time. In other words, about 53 percent of the time canal water flows into the isles; whereas for the remaining 47 percent of the time, groundwater flows from the isles into the canals. Figure 4-3 shows that the canal stage is higher during the winter (dry season) than the groundwater level. This condition is reversed during the summer (wet season).

In the Okeechobee Hammock area, the Spaulding (S) site was considered to evaluate the relationship of water flow between the canals and the isles. PZ-4 (piezometer) is nearest to the canal. Groundwater level hydrographs of PZ-4 and monitor well S-1 are shown in Figure 4-15. Figure 4-15 shows that groundwater levels at PZ-4 (nearest to the canal) are below the monitor well (S-1) water levels for about 42 weeks out of 56. This means about 75 percent of the time water flows from the drainfield area to the canal and 25 percent of the time canal water flows toward the isles. In this case, the canal stage also remains higher during the winter (dry season) than the adjacent groundwater levels.

When the water levels in the canals become greater than the groundwater levels, water from the canal may flow into the isles to reach an equilibrium condition. The dense network of isles and the canals has formed an integrated water system which may maintain a recharge and discharge relationship within this water system. Despite the local water flow between the isles and canals, as an integrated water system, water from these areas may ultimately discharge into Lake Okeechobee. Nutrient loadings from a septic tank drainfield may therefore be treated as a point source with nutrient concentrations in the groundwater decreasing as water moves away from the recharge points (drainfields). Thus, the nutrient loading from the study areas was determined to be more reliable by direct computation based on the data available at the recharge points or drainfields. The detailed computation is shown in Appendix C.

5.2.2 METHODOLOGY FOR NUTRIENT LOADING COMPUTATION

The nutrient loading was computed based on the factors and variables directly related to potential groundwater impact from the septic tank drainfields in the study areas. These calculations do not imply that this loading is occurring now. Rather, these estimates represent worst-case future conditions; after the soils have been saturated with phosphorus and the septic tanks are still being used. In this computation, the following data were used to calculate the nutrient loading from the septic tanks into Lake Okeechobee through the groundwater and surface water system:

1. Number of houses in each subdivision,
2. Duration of occupancy,
3. Average number of people per house,
4. Average water use per capita per day, and
5. Average area of a septic tank drainfield.

All these data are provided in Table 5-1.

The following procedure was adopted for the computation:

1. The total amount of water used by the residents in each subdivision throughout a year was computed based on the approximate number of houses in each subdivision, average number of people per house, and average water use per capita per day. All these data are shown in Table 5-1.
2. The nutrient loading was computed by multiplying the volume of percolated water with the mean groundwater concentration beneath the drainfield.

The detailed computation of nutrient loading as phosphorus, nitrogen as $NO_2 + NO_3$ and nitrogen as $NH_3 + NH_4$ is shown in Appendix C.

Table 5-1. Various Data for Nutrient Loading Computations

Study Areas	No. of Houses[1]		No. of People Per House[1]	Water Use Per Capital[2] (Gal./Dy)	Drainfield Area[1] (ft^2)	ET From Drainfields[3] (in/yr)
	Full-Time (12 Months)	Half-Time (6 Months)				
Okeechobee Hammocks	68	91	3	44	400	39
Buckhead Ridge	403	534	3	44	400	39
Taylor Creek Isles and Treasure Island	793	1051	3	44	400	39

Sources: [1] ESE, 1992 (Aerial Photography)
[2] IFAS, 1984
[3] FAO, 1977

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The total potential (maximum) phosphorus loadings to Lake Okeechobee from Taylor Creek and Treasure Island, Buckhead Ridge, and Okeechobee Hammocks were 872, 502, and 55 kg per year, respectively. Potential nitrogen loading as NO_3 + NO_2 were 2, 420, 85, and 62, and as NH_3 + NH_4 were 1,660, 7,480, and 25 kg, respectively from these subdivisions. It should be emphasized that loadings associated with nitrogen are influenced by nitrification/denitrification processes, whereas phosphorus behaves more conservatively.

5.3 RECOMMENDATIONS

Recommendations developed from this research can be organized into several groups:

- Point-of-use upgrades or retrofit in septic tank use,
- Community/system-wide upgrades or retrofits,
- Additional information gathering, and
- Additional research.

5.3.1 POINT-OF-USE UPGRADES

Point-of-use upgrades to systems range from installing water-conserving toilets all the way to retrofitting drainfields. Additional information on point-of-use upgrades can be obtained from Guidance on Reducing Nitrogen Loading from Septic Systems (1991), a report prepared by The Cadmus Group for EPA, Office of Drinking Water Underground Injection Control Branch. Before anyone considers a point-of-use upgrade, they should check on the likelihood of central sewer installation. One upgrade that should be considered in any case is to ensure that every home has a suitable drainage system for the washing machine. Responses to the questionnaires indicated a myriad of disposal options (other than a connection to the septic tank) that may not provide adequate treatment. If disposal of sewage via central systems becomes a reality, all washing machines should be required to be connected to the system.

Alternative toilets range from the simple water conserving toilets that just decrease the amount of water entering the septic tank; to more complex toilets that compost, incinerate, or recycle. The complex toilets are expensive to install and maintain. It appears that these toilets are used when no other alternatives are available to meet strict discharge requirements.

Alternative upgrades to the disposal systems include among others, retrofitting a Ruck System or recirculating sand filters; and retrofitting drainfields with peat filters or increasing the drainfield elevation. The Ruck System seems less appropriate as a single home system because it requires more complex plumbing, tank, and drainfield. It may be better used for multiple home systems though that would require very cooperative neighbors. Recirculating sand filters are also more complex than septic tanks, requiring extensive retrofitting and construction.

Modifications to the drainfield may be the most cost effective and "livable" upgrade for the homeowners. Some of the modifications may include raising the elevation of the drainfield or reinstalling the drainfield with different, more adsorptive soil material within the unsaturated zone. Local septic tank installers mentioned that mounded drainfields are not installed unless no other alternative is possible. Apparently, the drainfields in a bed arrangement fail much more often than the trench-type drainfield. In order to raise the elevation of the trenches, they would have to be incorporated into the landscape design for visual esthetics.

The soil adsorption studies indicated that the organic soil horizons adsorbed the highest amount of phosphorus. A short term "fix" could be to replace existing trench systems with new pipes installed above a layer of muck or peat. The hydraulics would have to be calculated so that the muck accepts the percolating leachate. This kind of fix, however, will work only as long as the phosphorus adsorption capacity of the muck or peat is not exceeded. Periodic excavation and replacement will be necessary to keep the system working better than the existing soils.

5.3.2 COMMUNITY/SYSTEM UPGRADES

Okeechobee County has a contract with Craig A. Smith and Associates to perform a wastewater study concerning the upgrading of existing wastewater treatment within the County. Residences and businesses within the County are currently served by septic tanks or small localized (package) wastewater treatment plants. The current long range plans are to abandon these systems to large centralized wastewater treatment facilities (personal communication, Gary Colecchio, Craig A. Smith and Associates 1992). The study is still in progress although they have provided the following information for use in this section.

Because the wastewater is handled on an individual residence basis, no wastewater collection or transmission systems exist in areas where septic tanks are used. A network of collection mains must therefore be constructed and retrofitted to the existing residential areas where the tanks are to be abandoned. Collection systems consisting of gravity mains and small pumping stations already exist in areas served by the small package treatment plants. These plants typically process less than 125,000 gallons of wastewater per day (GPD).

Current technology available to incorporate or replace septic tank-based collection systems; collecting wastewater at the source and transporting it to a centralized location for processing is summarized in the following paragraphs.

5.3.2.1 Gravity Systems

Traditional gravity sewer systems transport household wastewater from a service line connected to the plumbing of the residence to a main collection system within the road right of way. Sanitary sewer manholes and intermediate collection mains are installed at progressively deeper elevations as the system expands which allows the wastewater to flow from one manhole to another. Substantial sewage pumping stations or "lift stations" will be required. A remedial installation of this type will require considerable excavation and installation of large diameter pipe and the lift stations in or around existing paved areas. It also requires the abandonment of the residential septic tanks. System lengths, soil conditions, and restoration costs are critical factors in the cost effective analysis for using this type of system.

5.3.2.2 Low Pressure Systems

Low pressure wastewater systems function by collecting waste from existing storage areas such as the septic tanks and discharging it under pressure into larger diameter collection (force) mains which then transport the wastewater to the treatment site. Two types of low pressure systems are currently in use, Sewage Tank Effluent Pump Systems (STEP) and Grinder Pump (GP) Systems.

The STEP system consists of the existing septic tank, a submersible effluent pump, electrical actuating controls, and an arterial collection system. The submersible pump, controlled by a combination of floats, can pass solids up to 2 inches in diameter. The effluent is pumped into a series of small diameter plastic pipes connected to larger diameter pressurized force mains which end at the treatment facility. The average life of the effluent pump is 2 years and an intermediate collection system and pumping station is usually required for force main pressures in excess of 30 pounds per square inch (PSI). A large scale installation of this type is not recommended because of the limiting useful life of the pump and frequency of repair and maintenance.

The only difference between the STEP and GP systems is that the grinder pump has a cutting blade which macerates the solids entering the unit. It too fits into the septic tank and is controlled by floats. The average life of a grinder pump, 5 to 10 years, is longer than an effluent pump.

5.3.2.3 Vacuum Systems

In vacuum collection systems, a centralized vacuum station creates a negative pressure in the small diameter collection systems which are installed in the septic tanks. A pneumatic valve within the septic system is actuated by floats that react to certain levels of effluent in the tank. In between the vacuum stations, the effluent is transported by gravity to the next lift station which also operates by vacuum. The advantage of this system over the STEP system is that this system does not require individual electronic controls or pumps within the septic tanks. The pneumatic valves require less maintenance and are easier to replace.

Implementation of any of the systems will stop nutrient inputs to the shallow groundwater and potential migration of nutrients into the canals. Implementation of a community-wide treatment system will prevent sewage-caused impacts to the canals before they become evident.

5.3.2.4 Non-Septic Related Fixes

This research work did not prove that septic tanks are causing the poor water quality visually evident. An associated cause of the problem may be a lack of periodic flushing of the canals to remove stagnant water and/or buildup of nutrient-rich sediments. Flushing the canals to replace the water appears to be a reasonable method of increasing water quality in the canals of Taylor Creek Isles and Treasure Island subdivisions. Structures do not appear to exist to readily make this happen for the Okeechobee Hammocks or the Buckhead Ridge subdivisions. Structure S-192, north of the Taylor Creek Isles and Treasure Island subdivisions was originally built to facilitate flow of excess water away from this water to flow into the L-63 Canal which then passes the S-191 structure back into Lake Okeechobee. This outlet to the north has only been used when land owners complain of excess aquatic weed buildup. During these infrequent times, the District uses that structure to flush the weeds. According to District personnel, this flushing actually creates other problems as a pulse of stagnant water moves through the system causing fish kills.

This method of flushing the canals may be considered if the flushing frequency is increased. At higher flushing frequencies, the water quality may not deteriorate enough that flushing will create other problems.

5.3.3 ADDITIONAL INFORMATION GATHERING

This research work shows that the worst case inputs of P to Lake Okeechobee from septic tanks are no greater than half a ton per year per subdivision. If additional research can identify the presence of various nutrient "sinks" between the drainfields and the Lake, these numbers may be shown to overestimate reality. On the other hand, this research project excluded the numerous small package plants and/or large community septic tanks used within the mobile home parks adjacent to the rim canal up and down US 441. If any of these systems are not being properly maintained, they may be contributing as much P as all the septic tanks within the subdivisions combined because they are located closer to the rim canal with less groundwater transport distance for dilution or attenuation of phosphorus. Hooking these small treatment plants and septic tanks to the central sewer with the individual homes may better solve the overall problem.

5.3.4 ADDITIONAL RESEARCH NEEDS

This research project was the first attempt at gathering water quality and soils data relative to septic tanks in this area. Now that some data exist, additional research needs have become evident. It will be up to the regulatory agencies to determine which research to proceed with and depends entirely on the kinds of answers they are looking for.

Additional research on soils may include:

- Assessment of the importance of calcium and magnesium to phosphorus adsorption in soils and sediments. This research was limited to aluminum and iron, neither of which were found to correlate with P adsorption in sediments.
- Phosphorus adsorption data can be used to calculate the mass of phosphorus that can be adsorbed between the drainfield and the canal if the variability of the fill can be better characterized. The measure of variability, used with P adsorption, will identify the long-term potential P loading to the canals.

Additional research on surface water may include:

- More bacteriological investigations. This research was limited to being a screening of total coliforms. Measurements of other bacteriological indicators may be necessary from a human health perspective if people are using the canals for water sports.

- More investigations into the fate of nutrients in surface waters. Nutrients may well be getting into the canals but are getting taken up by aquatic organisms. The effective buffering by these organisms may be masking the impact and delaying the visual indication of the problem.

Additional research on groundwater may include:

- A long-term groundwater flow study to determine the yearly movement of groundwater. Because the canals experience yearly changes in elevation relative to groundwater, groundwater essentially flows back and forth during different times of the year. A long-term measurement will indicate the effective distance of yearly groundwater flow to better predict the migration of septic tank effluent.

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APPENDIX A

LAKE OKEECHOBEE RESIDENTIAL CANAL STUDY

STATE OF FLORIDA
DEPARTMENT OF HEALTH AND REHABILITATIVE SERVICES

Lake Okeechobee Residential Canal Study

Dear Homeowner:

Environmental Science & Engineering, Inc. has been contracted by the Florida Health and Rehabilitative Services (HRS) to study the water quality within the residential canals of the Buckhead Ridge, Taylor Creek Isles, Treasure Island, and Okeechobee Hammocks subdivisions.

The purpose of this 2-year study is to monitor selected canals to try to understand their ecology so that steps can be taken to improve the quality of the water and the habitats which depend on it. The good health of these habitats is necessary to maintain or improve the fishing resources of Lake Okeechobee and to ensure against degraded environmental conditions which could affect your property value and the local economy. No one knows the conditions around your property better than you, that's why your responses to this survey are so important. The information will be used to help us focus on "problem" areas and make the best recommendations on how to deal with them.

The enclosed survey contains specific questions about your house, lawn, garden, and sewage disposal system. Please answer as many questions as apply to your household and return the survey in the enclosed postage-paid envelope by June 28, 1991. Your involvement is important and is necessary to ensure the quality and success of this project. If you are interested in becoming more involved in this project with us, we would like to hear from you.

If you would like more information on this program, please indicate that on the attached questionnaire or call me or Mark Boyajian in the office. We look forward to hearing from you.

Sincerely,

Mark L. Boyajian

Ed Barranco
Environmental Specialist III

Mark Boyajian
Senior Associate Scientist

Department of Health and Rehabilitative Services
(904)-488-4070

Environmental Science & Engineering, Inc.
1-(800)-874-7872 (ext. 2308)

1317 WINEWOOD BLVD. • TALLAHASSEE, FL 32399-0700

LAWTON CHILES, GOVERNOR

Lake Okeechobee Residential Canal Study Survey

RESIDENCY INFORMATION Please fill out and return by June 28, 1991

Number of years you have lived in this house: _______ years

Age of your House: _______ years

Residency: Rent ☐ Own ☐

House ☐ Modular ☐ Mobile Home ☐

☐ Permanent (year around)

☐ Temporary - indicate the season(s) of occupancy

Fall ☐ Winter ☐ Spring ☐ Summer ☐

Number of persons living at this address: _______

Indicate number of people in each age bracket:

<5____ 5-12____ 13-20____ 21-32____ 33-45____ 46-60____ >60____

Number of pets: Dogs____ Cats____

What water-using fixtures and appliances are in your house?

(If there is more than one, please indicate how many.)

Kitchen: Sink ☐ ____ Dishwasher ☐ ____ Garbage Disposal ☐ ____

Bathroom(s): Sink(s) ☐ ____ Shower(s) ☐ ____ Tub(s) ☐ ____ Toilet(s) ☐ ____

Laundry: Sink ☐ ____ Washer ☐ ____

PROPERTY INFORMATION

What is your lot size?

<1/4 acre ☐ 1/4 to 1/2 acre ☐ 1/2 to 3/4 acre ☐ 3/4 to 1 acre ☐

Other ☐ Don't Know ☐

Do you water your lawn or garden? Yes ☐ No ☐

How long each time: _______ hours _______ minutes

How often do you water: _______ days per weeks _______ days per month

Do you fertilize your lawn or garden? Yes ☐ No ☐

If yes: What kind of fertilizer do you use? ______________________________

(example: Scotts Turfbuilder or 10-10-10)

How much do you apply at each application? ______________________________

(example: one 40-pound bag)

How often do you fertilize? ______________________________

(example: once in spring and once in fall)

Do you use pesticides on your lawn or garden? Yes ☐ No ☐

If yes: What kind of pesticide do you use? ______________________________

(example: Ortho Weed-B-Gone or Diazinon)

How much do you apply? ______________________________

(example: three ounces for 1/4 acre)

How often to you apply? ______________________________

(example: Weed-B-Gone as needed, Diazinon once every two months in summer)

Do you contract a professional pest control service for your lawn or garden?

Yes ☐ No ☐

If yes, please provide the name of the service you use: ______________________

(Continued on other side)

DISPOSAL SYSTEM INFORMATION

Is your house hooked up to a septic tank on your property,

or to a sewer line that goes to a treatment plant located somewhere else?

Septic Tank ❐ Sewer Line ❐ Don't Know ❐

If you don't have a septic tank, who do you pay for wastewater services? ____________

If you have a septic tank, do you know where the tank and drainfield are located?

Yes ❐ No ❐ Don't Know ❐

If yes, can you draw a picture of your house, septic tank, and drainfield in the space below?

When was your system installed? 19 _____ Don't Know ❐

When was the system last serviced? (Month/Year) _____/_____ Don't Know ❐

Is this the original septic system? Yes ❐ No ❐ Don't Know ❐

If no, is the new system the same type or different?

Same ❐ Different ❐ Don't Know ❐

If you remember when your system was serviced, please indicate the kind of work performed:

Pumped ❐ **Drainfield fixed/replaced ❐**

Cleaned ❐ **Other ❐ ____________________**

Leaking pipes fixed/replaced ❐ **Don't Know ❐**

Washing machine water is sometimes disposed of differently than other household wastewater.

Is your washing machine hooked up to your septic tank?

Yes ❐ No ❐ Don't Know ❐

If not, do you know where it drains? Yes ❐ No ❐ Don't Know ❐

If yes, please specify where: ____________________

If you have a washing machine at your house, how often do you wash clothes?

_____ days per week, _____ loads per day. What is your favorite laundry day? _____

What is your favorite brand of laundry soap? ____________________

Do you have a dishwasher? Yes ❐ No ❐

If yes, is it: your spouse ❐ or machine ❐

What is your favorite brand of dish soap? Sink: __________ Machine: __________

We need to find volunteers to allow us access to their property for sampling septic tank drainfields and installation and sampling of shallow groundwater monitor wells periodically over the next two years. The visible part of the monitor well and the septic tank drainfield sampler will look no different than a subsurface water meter box or valve box installed flush to the ground. Except for these items, you won't know that we've been there. At the end of the study, the equipment will be removed and the property returned to original condition.

Would you like to volunteer to allow us access to your property for installation of a temporary monitor well and/or sampling of your septic tank and drainfield? Yes ❐ No ❐

Would you like more information before deciding to volunteer? Yes ❐ No ❐

If Yes was checked on either question, please provide your name and address below for us to contact you. ____

APPENDIX B

WELL COMPLETION DIAGRAMS AND GEOLOGIC BORING LOGS

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.

JOB NO. 3913010-0400 BORING NO. M-1 DATE 8/19/91 SHEET 1 OF 1

CLIENT HRS TYPE OF BORING Hollow Stem RIG

PROJECT Okeechobee Septic Tank Study BORING BEGUN 10:10 COMPLETED 10:45

LOCATION OF BORING Moldenhauer residence - near canal - down grade.

WATER LEVEL 2'

TIME 10:10 TOC ELEVATION

DATE 8/19/91 FIELD PARTY Timothy A. Stoddard

SAMPLE NO	SAMPLE DEPTH FROM-TO (IN FT)	BLOWS /6" ON SMPLR	TOTAL LENGTH OF RECOV SAMPLE	OVA, PPM LESS METHANE	DEPTH (IN FT)	SOIL GRAPH	DESCRIPTION
	0-4	Post Hole			2	▼ SP	Sand, gray fine-grained silica with trace organic silt 0-6".
							Sand, lt. brown fine to very fine-grained silica with trace shell.
					4	SP	Sand, gray, mostly fine-grained silica.
					6		Same as above with trace shell.
					8	SP	
					10		Same as above.
					12		Total depth = 12 feet
							Geologist: Timothy A. Stoddard

ENVIRONMENTAL SCIENCE & ENGINEERING, INC
SHALLOW MONITOR WELL CONSTRUCTION

LOGGED BY: Timothy Stoddard CLIENT: HRS

DRILLING CONTRACTOR: So. Fla. Testing & Drilling LOCATION: Moldenhauer - by canal.

DRILLER'S NAME: David Griffey JOB NUMBER: 3913010

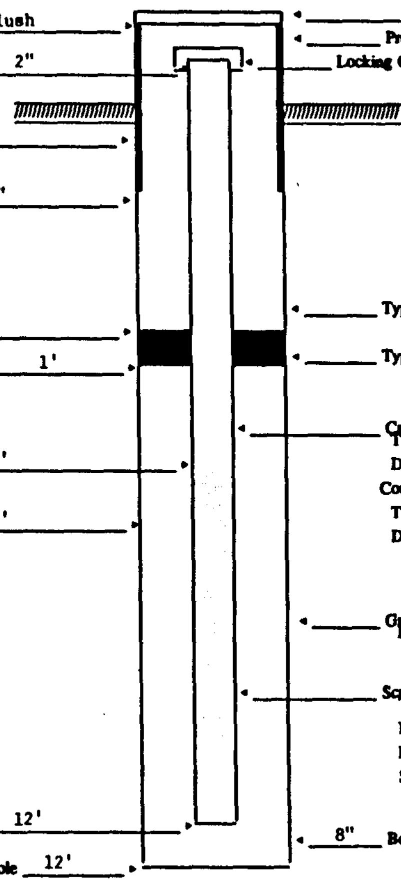
WELL NUMBER: M-1 DATE: Start: 8/19/91 Finish: 8/19/91

TOC ELEVATION: TIME: Start: 10:10 Finish: 10:45

COMMENTS (Lost circulation interval, Water level changes, Hole collapse interval, etc):

Depths in Reference to Ground Level

NOT TO SCALE



- Top of Manhole Protective Casing: Flush
- Top of Well Casing: 2"
- Top of Grout: 4"
- Bottom of Manhole Casing: 8"
- Top of Seal: 6'
- Top of Gravel Pack: 1'
- Top of Screen: 2'
- Ground Water: 2'
- Bottom of Screen: 12'
- Total Depth of Bore Hole: 12'
- Manhole Cover
- Protective Manhole Type Diameter: 8"
- Locking Cap
- Cement/Gravel Pad
- Type of Grout: Cement
- Type of Plug: Fine Sand
- Casing: Type: Schedule 40 PVC; Diameter: 2"; Couplings: 1; Type: Threaded; Depths: 2'
- Gravel Pack: Material: 20/30 Silica Sand
- Screen: Type: Schedule 40 PVC; Diameter: 2"; Length: 10'; Slot Size: 0.010"
- 8" Bore Hole Diameter

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.

JOB NO. 3913010-0400 BORING NO. M-2 DATE 8/19/91 SHEET 1 OF 1

CLIENT HRS TYPE OF BORING Hollow Stem RIG

PROJECT Okeechobee Septic Tank Study BORING BEGUN 11:00 COMPLETED 11:40

LOCATION OF BORING Moldenhauer residence - in drainfield

WATER LEVEL 1'

TIME 11:00 TOC ELEVATION

DATE 8/19/91 FIELD PARTY Timothy A. Stoddard

SAMPLE NO	SAMPLE DEPTH FROM-TO (IN FT)	BLOWS /6" ON SMPLR	TOTAL LENGTH OF RECOV SAMPLE	OVA, PPM LESS METHANE	DEPTH (IN FT)	SOIL GRAPH	DESCRIPTION
		Post				SP	Sand, gray fine-grained silica.
	0-4	Hole			2		
						GW	Gravel, limestone backfill.
					4		
							Sand, gray fine-grained silica.
						SP	
					6		
							Same as above.
						SP	
					8		
					10		
						SP	Sand, gray fine-grained silica with shell.
					12		Total depth = 12 feet
							Geologist: Timothy A. Stoddard

ENVIRONMENTAL SCIENCE & ENGINEERING, INC
SHALLOW MONITOR WELL CONSTRUCTION

LOGGED BY: Timothy Stoddard CLIENT: HRS

DRILLING CONTRACTOR: So. Fla. Testing & Drilling LOCATION: Moldenhauer-center of drainfield.

DRILLER'S NAME: David Griffey JOB NUMBER: 3913010

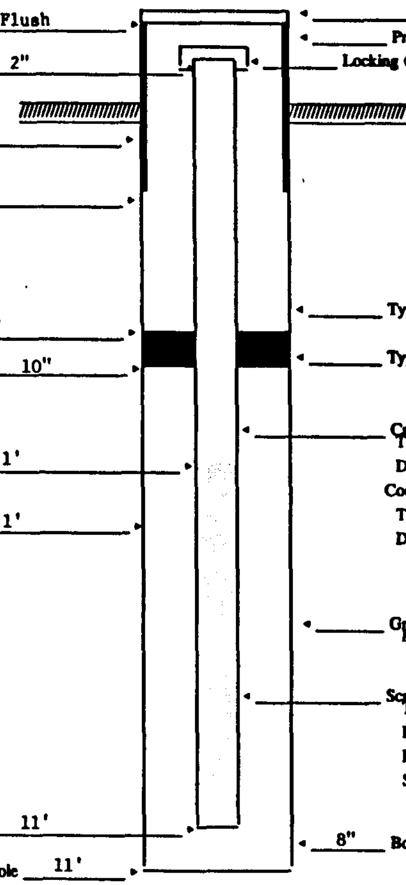
WELL NUMBER: M-2 DATE: Start: 8/19/91 Finish: 8/19/91

TOC ELEVATION: TIME: Start: 11:00 Finish: 11:40

COMMENTS (Lost circulation interval, Water level changes, Hole collapse interval, etc):

Depths in Reference to Ground Level

NOT TO SCALE



Top of Manhole Protective Casing: Flush

Top of Well Casing: 2"

Top of Grout: 4"

Bottom of Manhole Casing: 8"

Top of Seal: 6"

Top of Gravel Pack: 10"

Top of Screen: 1'

Ground Water: 1'

Bottom of Screen: 11'

Total Depth of Bore Hole: 11'

Manhole Cover

Protective Manhole Type Diameter: 8"

Locking Cap

Cement/Gravel Pad

Type of Grout: Cement

Type of Plug: Fine Sand

Casing: Type: Schedule 40 PVC

Diameter: 2"

Couplings: 1

Type: Threaded

Depths: 1"

Gravel Pack Material: 20/30 Silica Sand

Screen: Type: Schedule 40 PVC

Diameter: 2"

Length: 10'

Slot Size: .010"

8" Bore Hole Diameter

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.

JOB NO. 3913010-0400 BORING NO. M-3 DATE 8/19/91 SHEET 1 OF 1

CLIENT HRS TYPE OF BORING Hollow Stem RIG

PROJECT Okeechobee Septic Tank Study BORING BEGUN 11:55 COMPLETED 12:25

LOCATION OF BORING Moldenhauer residence

WATER LEVEL

TIME 11:55 TOC ELEVATION

DATE 8/19/91 FIELD PARTY Timothy A. Stoddard

SAMPLE NO	SAMPLE DEPTH FROM-TO (IN FT)	BLOWS 6" ON SMPLR	TOTAL LENGTH OF RECOV SAMPLE	OVA, PPM LESS METHANE	DEPTH (IN FT)	SOIL GRAPH	DESCRIPTION
	0-4	Post Hole			2	SP	Sand, lt. gray fine-grained silica with trace shell.
							Sand, lt. brown to yellow fine to very fine-grained silica.
	4-6				4		
						SM	Sand, brown silty fine-grained silica.
	6-8				6		
						LS	Limestone, lt. brown, shelly.
	8-10				8	SP	Sand, lt. brown fine-grained silica.
	10-12				10	SC	Sandy clay, gray fine-grained silica sand w/clay.
						SP	Sand, lt. brown grading to gray fine-grained silica.
					12		Total depth = 12 feet
							Geologist: Timothy A. Stoddard

ENVIRONMENTAL SCIENCE & ENGINEERING, INC
SHALLOW MONITOR WELL CONSTRUCTION

LOGGED BY: Timothy Stoddard CLIENT: HRS

DRILLING CONTRACTOR: So. Fla. Testing & Drilling LOCATION: Moldenhauer-east corner of grade of septic.

DRILLER'S NAME: David Griffey JOB NUMBER: 3913010

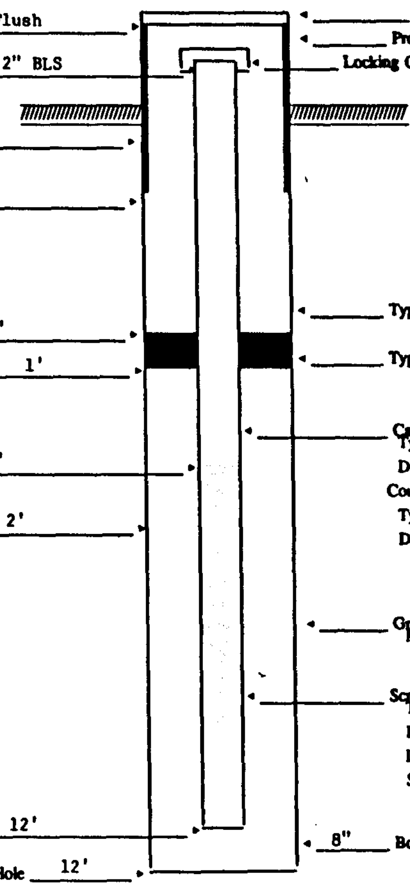
WELL NUMBER: M-3 DATE: Start: 8/19/91 Finish: 8/19/91

TOC ELEVATION: TIME: Start: 11:55 Finish: 12:25

COMMENTS (Lost circulation interval, Water level changes, Hole collapse interval, etc):

Depths in Reference to Ground Level

NOT TO SCALE



Top of Manhole Protective Casing: Flush

Top of Well Casing: 2" BLS

Top of Grout: 4"

Bottom of Manhole Casing: 8"

Top of Seal: 6"

Top of Gravel Pack: 1'

Top of Screen: 2'

Ground Water: 2'

Bottom of Screen: 12'

Total Depth of Bore Hole: 12'

Manhole Cover

Protective Manhole Type Diameter: 8"

Locking Cap

Cement/Gravel Pad

Type of Grout:

Type of Plug: Fine Sand

Casing: Type: Schedule 40 PVC
Diameter: 2"
Couplings: 1
Type: Threaded
Depths: 2'

Gravel Pack Material: 20/30 Silica Sand

Screen: Type: Schedule 40 PVC
Diameter: 2"
Length: 10'
Slot Size: 0.010"

8" Bore Hole Diameter

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.

JOB NO. 3913010-0400 BORING NO. G-1 DATE 8/20/91 SHEET 1 OF 1

CLIENT HRS TYPE OF BORING Hollow Stem RIG

PROJECT Okeechobee Septic Tank Study BORING BEGUN 10:35 COMPLETED 11:10

LOCATION OF BORING Goolsby residence - just north of center of drainfield.

WATER LEVEL 4'

TIME 10:35 TOC ELEVATION

DATE 8/20/91 FIELD PARTY Timothy A. Stoddard

SAMPLE NO	SAMPLE DEPTH FROM-TO (IN FT)	BLOWS /6" ON SMPLR	TOTAL LENGTH OF RECOV SAMPLE	OVA, PPM LESS METHANE	DEPTH (IN FT)	SOIL GRAPH	DESCRIPTION
						SP	Sand, brown fine-grained silica with trace organic silt.
	0-4	Post Hole			2		Sand, gray fine-grained silica.
	4-6				4	PT	Peat, black highly organic material with trace silt.
	6-8				6	SP	Sand, gray fine to very fine-grained silica.
	8-10				8		Same as above.
							Same as above.
	10-12				10		
							Sand, brown fine-grained silica.
	12-14				12		
							Same as above.
					14		Total Depth = 14 feet
							Geologist: Timothy A. Stoddard

ENVIRONMENTAL SCIENCE & ENGINEERING, INC
SHALLOW MONITOR WELL CONSTRUCTION

LOGGED BY: Timothy Stoddard CLIENT: HRS

DRILLING CONTRACTOR: So. Fla. Testing & Drilling LOCATION: Goolsby-just north near center of drainfield.

DRILLER'S NAME: David Griffey JOB NUMBER: 3913010

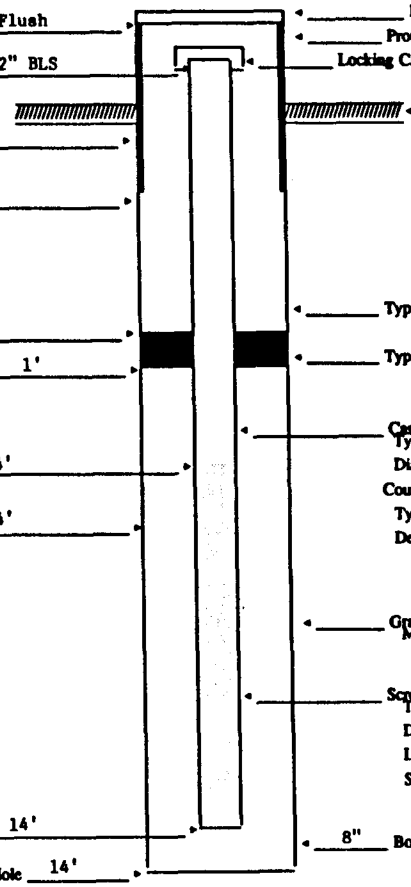
WELL NUMBER: G-1 DATE: Start: 8/20/91 Finish: 8/20/91

TOC ELEVATION: TIME: Start: 10:35 Finish: 11:10

COMMENTS (Lost circulation interval, Water level changes, Hole collapse interval, etc):

Depths in Reference to Ground Level

NOT TO SCALE



Top of Manhole Protective Casing: Flush

Top of Well Casing: 2" BLS

Top of Grout: 4"

Bottom of Manhole Casing: 8"

Top of Seal: 6"

Top of Gravel Pack: 1'

Top of Screen: 4'

Ground Water: 4'

Bottom of Screen: 14'

Total Depth of Bore Hole: 14'

Protective Manhole Type Diameter: 8"

Type of Grout: Cement

Type of Plug: Fine Sand

Casing: Type: Schedule 40 PVC
Diameter: 2"
Couplings: 1
Type: Threaded
Depths: 4'

Gravel Pack: Material: 20/30 Silica Sand

Screen: Type: Schedule 40 PVC
Diameter: 2"
Length: 10'
Slot Size: 0.010"

8" Bore Hole Diameter

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.

JOB NO. 3913010-0400 BORING NO. V-1 DATE 8/20/91 SHEET 1 OF 1

CLIENT HRS TYPE OF BORING Hollow Stem RIG

PROJECT Okeechobee Septic Tank Study BORING BEGUN 13:15 COMPLETED 13:55

LOCATION OF BORING Northeast corner of Goolsby lot.

WATER LEVEL 3'

TIME 13:15 TOC ELEVATION

DATE 8/20/91 FIELD PARTY Timothy A. Stoddard

SAMPLE NO	SAMPLE DEPTH FROM-TO (IN FT)	BLOWS /6" ON SMPLR	TOTAL LENGTH OF RECOV SAMPLE	OVA, PPM LESS METHANE	DEPTH (IN FT)	SOIL GRAPH	DESCRIPTION
						SP	Sand, brown fine-grained silica with some organic silt.
	0-4	Post Hole			2	PT	Peat, black organic material with trace silica sand.
					4	SP	Sand, gray fine-grained silica.
						PT	Peat, black, highly organic.
	4-6				6	SP/SM	Sand, brown silty fine-grained silica with organic.
							Sand, lt. brown to brown fine-grained silica.
	6-8				8		
						SP	
	8-10				10		Same as above.
	10-12				12		
					13		Total Depth = 13 feet
	12-13						
							Geologist: Timothy A. Stoddard

ENVIRONMENTAL SCIENCE & ENGINEERING, INC
SHALLOW MONITOR WELL CONSTRUCTION

LOGGED BY: Timothy Stoddard CLIENT: HRS

DRILLING CONTRACTOR: So. Fla. Testing & Drilling LOCATION: Vacant lot-northeast corner of Goolsby lot.

DRILLER'S NAME: David Griffey JOB NUMBER: 3913010

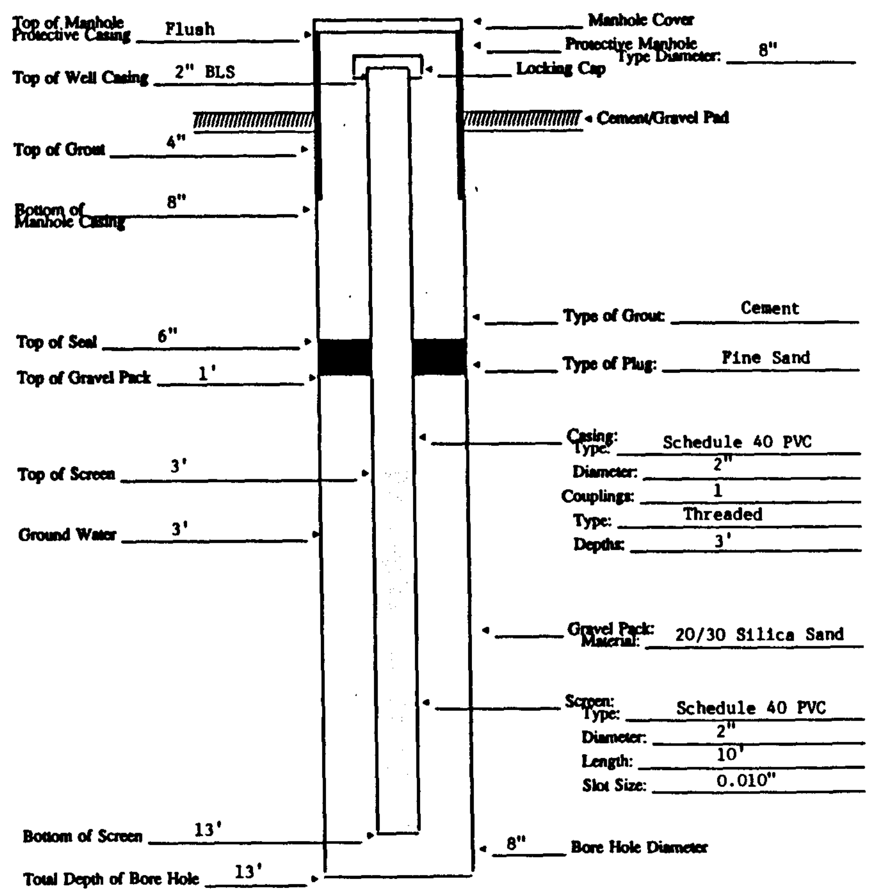
WELL NUMBER: V-1 DATE: Start: 8/20/91 Finish: 8/20/91

TOC ELEVATION: TIME: Start: 13:15 Finish: 13:55

COMMENTS (Lost circulation interval, Water level changes, Hole collapse interval, etc):

Depths in Reference to Ground Level

NOT TO SCALE



ENVIRONMENTAL SCIENCE & ENGINEERING, INC.

JOB NO. 3913010-0400 BORING NO. L-1 DATE 8/19/91 SHEET 1 OF 1

CLIENT HRS TYPE OF BORING Hollow Stem RIG

PROJECT Okeechobee Septic Tank Study BORING BEGUN 15:35 COMPLETED 16:15

LOCATION OF BORING Lewis residence - back yard.

WATER LEVEL 7'

TIME 15:35 TOC ELEVATION

DATE 8/19/91 FIELD PARTY Timothy A. Stoddard

SAMPLE NO	SAMPLE DEPTH FROM-TO (IN FT)	BLOWS 6" ON SMPLR	TOTAL LENGTH OF RECOV SAMPLE	OVA, PPM LESS METHANE	DEPTH (IN FT)	SOIL GRAPH	DESCRIPTION
							Much highly organic silt with sand.
		Post				SP	Sand, gray fine-grained silica.
	0-4	Hole			2		
						SP	Sand, very lt. gray to white fine to very fine-grained silica.
					4		
		Hand					
	4-7	Auger				SP	Sand, brown slightly silty fine-grained silica.
					6		
	7-9						Sand, brown, very fine-grained silica with trace silt and organics.
					8		
	9-11					SP	Sand, brown fine to very fine-grained silica with trace silt and organics.
					10		
	11-13						Same as above.
					12		
	13-15						
	15-17						Total Depth = 17 feet
							Geologist: Timothy A. Stoddard

ENVIRONMENTAL SCIENCE & ENGINEERING, INC
SHALLOW MONITOR WELL CONSTRUCTION

LOGGED BY: Timothy Stoddard CLIENT: HRS

DRILLING CONTRACTOR: So. Fla. Testing & Drilling LOCATION: Lewis-near center of drainfield.

DRILLER'S NAME: David Griffey JOB NUMBER: 3913010

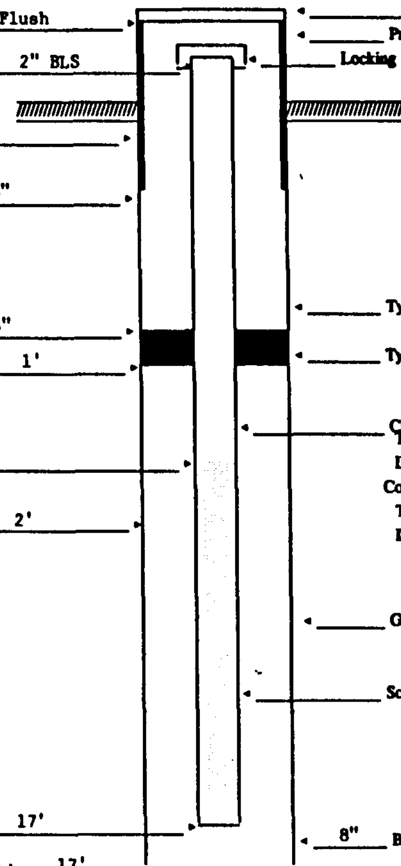
WELL NUMBER: L-1 DATE: Start: 8/19/91 Finish: 8/19/91

TOC ELEVATION: TIME: Start: 15:35 Finish: 16:15

COMMENTS (Lost circulation interval, Water level changes, Hole collapse interval, etc):

Depths in Reference to Ground Level

NOT TO SCALE



Top of Manhole Protective Casing: Flush

Top of Well Casing: 2" BLS

Top of Grout: 4"

Bottom of Manhole Casing: 8"

Top of Seal: 6"

Top of Gravel Pack: 1'

Top of Screen: 7'

Ground Water: 2'

Bottom of Screen: 17'

Total Depth of Bore Hole: 17'

Manhole Cover

Protective Manhole Type Diameter: 8"

Locking Cap

Cement/Gravel Pad

Type of Grout: Cement

Type of Plug: Fine Sand

Casing: Type: Schedule 40 PVC
Diameter: 2"
Couplings: 1
Type: Threaded
Depths: 7'

Gravel Pack: Material: 20/30 Silica Sand

Screen: Type: Schedule 40 PVC
Diameter: 2"
Length: 10'
Slot Size: 0.010"

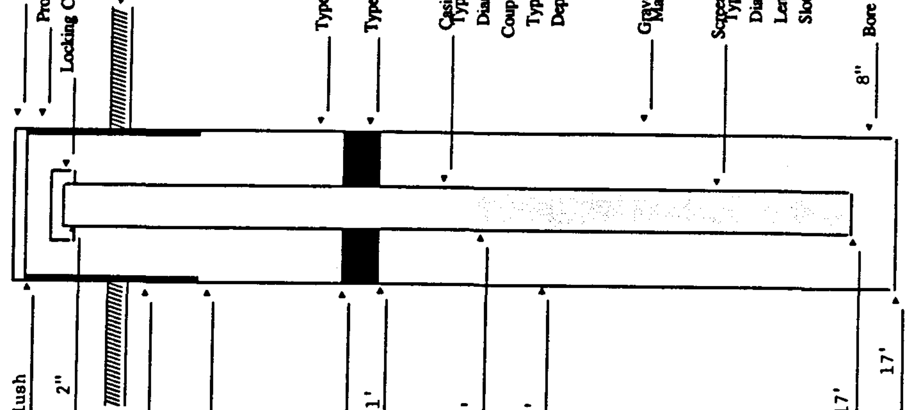
8" Bore Hole Diameter

ENVIRONMENTAL SCIENCE & ENGINEERING, INC
SHALLOW MONITOR WELL CONSTRUCTION

LOGGED BY: Timothy Stoddard
DRILLING CONTRACTOR: So. Fla. Testing & Drilling
DRILLER'S NAME: David Griffey
WELL NUMBER: S-1
TOC ELEVATION:
CLIENT: HRS
LOCATION: Spaulding-near center of drainfield.
JOB NUMBER: 3913010
DATE: Start: 8/19/91 Finish: 8/19/91
TIME: Start: 18:25 Finish: 19:20
COMMENTS (Lost circulation interval, Water level changes, Hole collapse interval, etc):

Depths in Reference to Ground Level

NOT TO SCALE



Top of Manhole Protective Casing: Flush
Top of Well Casing: 2"
Top of Grout: 4"
Bottom of Manhole Casing: 8"
Top of Seal: 6"
Top of Gravel Pack: 1'
Top of Screen: 7'
Ground Water: 7'
Bottom of Screen: 17'
Total Depth of Bore Hole: 17'

Manhole Cover
Protective Manhole Type Diameter: 8"
Locking Cap
Cement/Gravel Pad
Type of Grout: Cement
Type of Plug: Fine Sand
Casing: Type: Schedule 40 PVC
Diameter: 2"
Couplings: 1
Type: Threaded
Depths: 10'
Gravel Pack: Material: 20/30 Silica Sand
Screen: Type: Schedule 40 PVC
Diameter: 2"
Length: 10'
Slot Size: 0.010"
8" Bore Hole Diameter

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.

JOB NO. 3913010-0400 BORING NO. S-1 DATE 8/19/91 SHEET 1 OF 2
CLIENT HRS TYPE OF BORING Hollow Stem RIG
PROJECT Okeechobee Septic Tank Study BORING BEGUN 18:25 COMPLETED 19:20
LOCATION OF BORING Spaulding residence - east of drainfield.
WATER LEVEL 7'
TIME 18:25 TOC ELEVATION
DATE 8/19/91 FIELD PARTY Timothy A. Stoddard

SAMPLE NO	SAMPLE DEPTH FROM-TO (IN FT)	BLOWS /6" ON SMPLR	TOTAL LENGTH OF RECOV SAMPLE	OVA, PPM LESS METHANE	DEPTH (IN FT)	SOIL GRAPH	DESCRIPTION
						SP	Sand, gray fine-grained silica with little or no fines.
	0-4	Post Hole			2	SP/ SM	Sand, brown slightly silty fine-grained silica.
	4-8				4	PT	Peat, black highly organic material with trees.
					6		
	8-10				8	SP	Sand, gray fine to very fine-grained silica.
	10-12				10	SP	Same as above.
	12-14				12	SP	Same as above with trace organics.
	14-16				14		

Geologist: Timothy A. Stoddard

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.

JOB NO. 3913010-0400 BORING NO. S-1 DATE 8/19/91 SHEET 2 OF 2
CLIENT HRS TYPE OF BORING Hollow Stem RIG
PROJECT Okeechobee Septic Tank Study BORING BEGUN 18:25 COMPLETED 19:20
LOCATION OF BORING Spaulding residence - east of drainfield.
WATER LEVEL 7'
TIME 18:25 TOC ELEVATION
DATE 8/19/91 FIELD PARTY Timothy A. Stoddard

SAMPLE NO	SAMPLE DEPTH FROM-TO (IN FT)	BLOWS /6" ON SMPLR	TOTAL LENGTH OF RECOV SAMPLE	OVA, PPM LESS METHANE	DEPTH (IN FT)	SOIL GRAPH	DESCRIPTION
	16-17				16		Same as above.
					17		Total Depth = 17 feet

Geologist: Timothy A. Stoddard

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.

JOB NO. 3913010-0400 BORING NO. W-1 DATE 8/20/91 SHEET 1 OF 1

CLIENT HRS TYPE OF BORING Hollow Stem RIG

PROJECT Okeechobee Septic Tank Study BORING BEGUN 8:35 COMPLETED 9:15

LOCATION OF BORING Weston residence by car port.

WATER LEVEL 6'

TIME 8:35 TOC ELEVATION

DATE 8/20/91 FIELD PARTY Timothy A. Stoddard

SAMPLE NO	SAMPLE DEPTH FROM-TO (IN FT)	BLOWS /6" ON SMPLR	TOTAL LENGTH OF RECOV SAMPLE	OVA, PPM LESS METHANE	DEPTH (IN FT)	SOIL GRAPH	DESCRIPTION
							Sand, gray fine-grained silica.
	0-4	Post Hole			2	SP	
	4-6	Bucket Auger			4	PT	Peat, black organic material with trace silica sand.
	6-8				6	▽ SP	Gray to brown fine to very fine-grained silica.
	8-10				8		
							Same as above.
	10-12				10		
	12-14				12		Same as above.
	14-16				14		Same as above with trace shell.
					16		Total Depth = 16 feet
							Geologist: Timothy A. Stoddard

ENVIRONMENTAL SCIENCE & ENGINEERING, INC
SHALLOW MONITOR WELL CONSTRUCTION

LOGGED BY: Timothy Stoddard CLIENT: HRS

DRILLING CONTRACTOR: So. Fla. Testing & Drilling LOCATION: Weston-5' north & 3' west of car port.

DRILLER'S NAME: David Griffey JOB NUMBER: 3913010

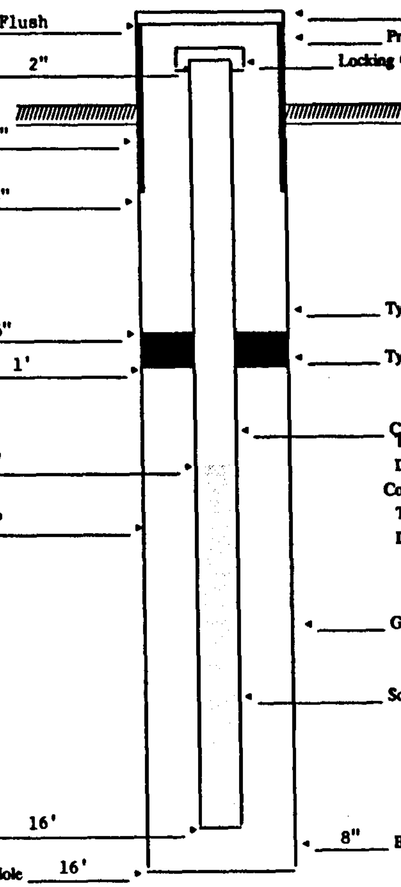
WELL NUMBER: W-1 DATE: Start: 8/20/91 Finish: 8/20/91

TOC ELEVATION: TIME: Start: 8:35 Finish: 9:15

COMMENTS (Lost circulation interval, Water level changes, Hole collapse interval, etc):

Depths in Reference to Ground Level

NOT TO SCALE



Top of Manhole Protective Casing: Flush

Top of Well Casing: 2"

Top of Grout: 4"

Bottom of Manhole Casing: 8"

Top of Seal: 6"

Top of Gravel Pack: 1'

Top of Screen: 6'

Ground Water: 6'

Bottom of Screen: 16'

Total Depth of Bore Hole: 16'

Manhole Cover

Protective Manhole Type Diameter: 8"

Locking Cap

Cement/Gravel Pad

Type of Grout: Cement

Type of Plug: Fine Sand

Casing: Type: Schedule 40 PVC; Diameter: 2"; Couplings: 1; Type: Threaded; Depths: 6'

Gravel Pack: Material: 20/30 Silica Sand

Screen: Type: Schedule 40 PVC; Diameter: 2"; Length: 10'; Slot Size: 0.010"

8" Bore Hole Diameter

ENVIRONMENTAL SCIENCE & ENGINEERING, INC

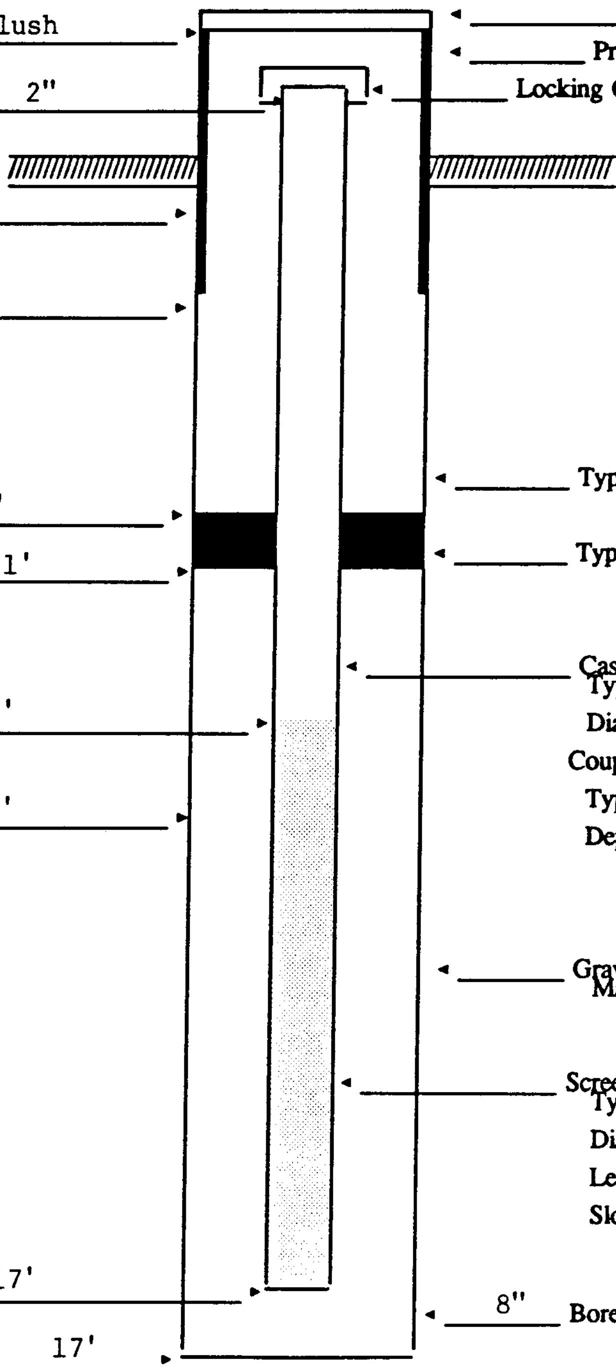
SHALLOW MONITOR WELL CONSTRUCTION

LOGGED BY:	Timothy Stoddard	CLIENT:	HRS
DRILLING CONTRACTOR:	So. Fla. Testing & Drilling	LOCATION:	Spaulding-near center of drainfield.
DRILLER'S NAME:	David Griffey	JOB NUMBER:	3913010
WELL NUMBER:	S-1	DATE: Start: 8/19/91	Finish: 8/19/91
TOC ELEVATION:		TIME: Start: 18:25	Finish: 19:20

COMMENTS (Lost circulation interval, Water level changes, Hole collapse interval, etc):

Depths in Reference to Ground Level

NOT TO SCALE



- Top of Manhole Protective Casing: Flush
- Top of Well Casing: 2"
- Top of Grout: 4"
- Bottom of Manhole Casing: 8"
- Top of Seal: 6"
- Top of Gravel Pack: 1'
- Top of Screen: 7'
- Ground Water: 7'
- Bottom of Screen: 17'
- Total Depth of Bore Hole: 17'

- Manhole Cover
- Protective Manhole Type Diameter: 8"
- Locking Cap
- Cement/Gravel Pad
- Type of Grout: Cement
- Type of Plug: Fine Sand
- Casing: Type: Schedule 40 PVC
  - Diameter: 2"
  - Couplings: 1
  - Type: Threaded
  - Depths: 10'
- Gravel Pack: Material: 20/30 Silica Sand
- Screen: Type: Schedule 40 PVC
  - Diameter: 2"
  - Length: 10'
  - Slot Size: 0.010"
- 8" Bore Hole Diameter

ENVIRONMENTAL SCIENCE
& ENGINEERING, INC.

JOB NO. 3913010-0400 BORING NO. S-1 DATE 8/19/91 SHEET 2 OF 2

CLIENT HRS TYPE OF BORING Hollow Stem RIG

PROJECT Okeechobee Septic Tank Study BORING BEGUN 18:25 COMPLETED 19:20

LOCATION OF BORING Spaulding residence - east of drainfield.

WATER LEVEL 7'

TIME 18:25 TOC ELEVATION

DATE 8/19/91 FIELD PARTY Timothy A. Stoddard

SAMPLE NO	SAMPLE DEPTH FROM-TO (IN FT)	BLOWS /6" ON SMPLR	TOTAL LENGTH OF RECOV SAMPLE	OVA, PPM LESS METHANE	DEPTH (IN FT)	SOIL GRAPH	DESCRIPTION
	16-17				16		Same as above.
					17		Total Depth = 17 feet

Geologist: Timothy A. Stoddard

ENVIRONMENTAL SCIENCE
& ENGINEERING, INC.

JOB NO. 3913010-0400 BORING NO. S-1 DATE 8/19/91 SHEET 1 OF 2

CLIENT HRS TYPE OF BORING Hollow Stem RIG

PROJECT Okeechobee Septic Tank Study BORING BEGUN 18:25 COMPLETED 19:20

LOCATION OF BORING Spaulding residence - east of drainfield.

WATER LEVEL 7'

TIME 18:25 TOC ELEVATION

DATE 8/19/91 FIELD PARTY Timothy A. Stoddard

SAMPLE NO	SAMPLE DEPTH FROM-TO (IN FT)	BLOWS /6" ON SMPLR	TOTAL LENGTH OF RECOV SAMPLE	OVA, PPM LESS METHANE	DEPTH (IN FT)	SOIL GRAPH	DESCRIPTION
						SP	Sand, gray fine-grained silica with little or no fines.
	0-4	Post Hole			2	SP/ SM	Sand, brown slightly silty fine-grained silica.
	4-8				4	PT	Peat, black highly organic material with trees.
					6		
	8-10				8	SP	Sand, gray fine to very fine-grained silica.
	10-12				10	SP	Same as above.
	12-14				12	SP	Same as above with trace organics.
	14-16				14		

Geologist: Timothy A. Stoddard

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.

JOB NO. 3913010-0400 BORING NO. W-1 DATE 8/20/91 SHEET 1 OF 1

CLIENT HRS TYPE OF BORING Hollow Stem RIG

PROJECT Okeechobee Septic Tank Study BORING BEGUN 8:35 COMPLETED 9:15

LOCATION OF BORING Weston residence by car port.

WATER LEVEL 6'

TIME 8:35 TOC ELEVATION

DATE 8/20/91 FIELD PARTY Timothy A. Stoddard

SAMPLE NO	SAMPLE DEPTH FROM-TO (IN FT)	BLOWS /6" ON SMPLR	TOTAL LENGTH OF RECOV SAMPLE	OVA, PPM LESS METHANE	DEPTH (IN FT)	SOIL GRAPH	DESCRIPTION
							Sand, gray fine-grained silica.
	0-4	Post Hole			2	SP	
	4-6	Bucket Auger			4	PT	Peat, black organic material with trace silica sand.
	6-8				6	SP	Gray to brown fine to very fine-grained silica.
	8-10				8		
							Same as above.
	10-12				10		
	12-14				12		Same as above.
	14-16				14		Same as above with trace shell.
					16		Total Depth = 16 feet
							Geologist: Timothy A. Stoddard

ENVIRONMENTAL SCIENCE & ENGINEERING, INC

SHALLOW MONITOR WELL CONSTRUCTION

LOGGED BY: Timothy Stoddard CLIENT: HRS

DRILLING CONTRACTOR: So. Fla. Testing & Drilling LOCATION: Weston-5' north & 3' west of car port.

DRILLER'S NAME: David Griffey JOB NUMBER: 3913010

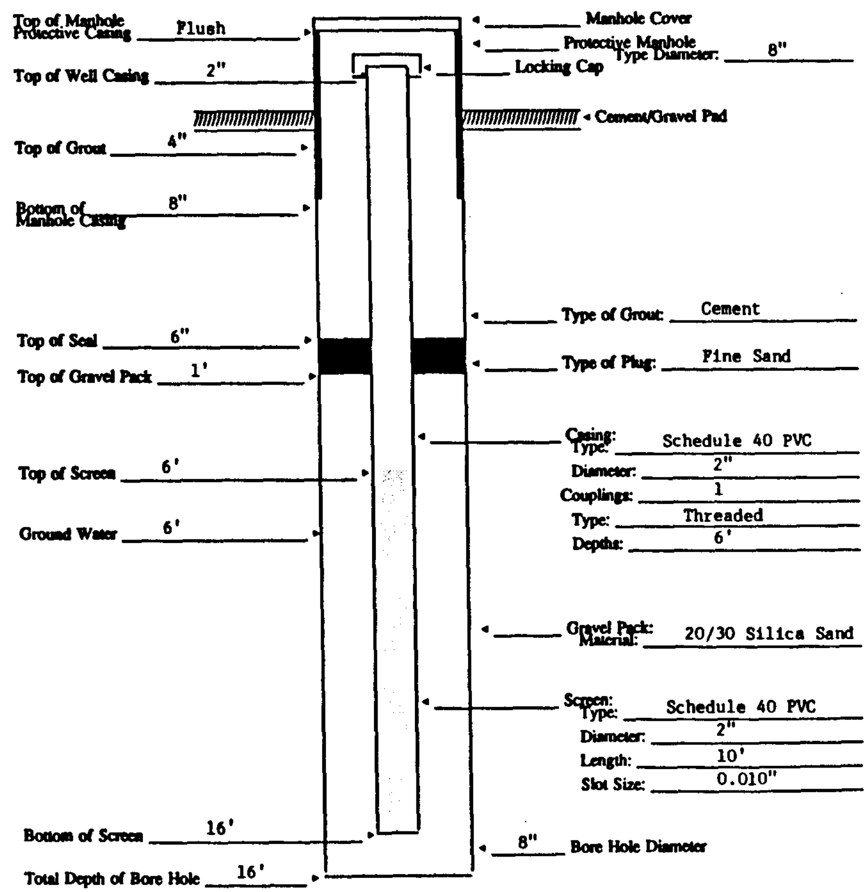
WELL NUMBER: W-1 DATE: Start: 8/20/91 Finish: 8/20/91

TOC ELEVATION: TIME: Start: 8:35 Finish: 9:15

COMMENTS (Lost circulation interval, Water level changes, Hole collapse interval, etc):

Depths in Reference to Ground Level

NOT TO SCALE



APPENDIX C

NUTRIENT LOADING

APPENDIX C

Nutrient loading from the septic tanks in the Okeechobee area may be determined based on hydrogeochemical conditions in the drainfields. The detailed calculations along with the assumptions are shown below:

1.0 Number of houses:

Okeechobee Hammocks:	159
Buckhead Ridge:	937
Taylor Creek and Treasure Island:	1,844
TOTAL:	2,940

2.0 Full-time occupancy:

Okeechobee Hammocks:	159 x 0.43	=	68
Buckhead Ridge:	937 x 0.43	=	403
Taylor Creek and Treasure Island:	1,844 x 0.43	=	793
TOTAL:			1,264

3.0 Half-time occupancy:

Okeechobee Hammocks:	159 - 68	=	91
Buckhead Ridge:	937 - 403	=	534
Taylor Creek and Treasure Island:	1,844 - 793	=	1,051
TOTAL:			1,676

4.0 Other Data:

Average area of a drainfield	=	400 ft^2
Average number of people/house	=	3
Water used per capita per day	=	44 gallons

5.0 Full-time annual water use:

Okeechobee Hammocks:	68 x 3 x 44 x 365	=	3,276,240
Buckhead Ridge:	403 x 3 x 44 x 365	=	19,416,540
Taylor Creek and Treasure Island:	793 x 3 x 44 x 365	=	38,206,740
TOTAL:		=	60,899,520 gallons

6.0 Part-time annual water use:

Okeechobee Hammocks:	91 x 3 x 44 x 365 x 0.5	=	2,192,190
Buckhead Ridge:	534 x 3 x 44 x 365 x 0.5	=	12,864,060
Taylor Creek and Treasure Island:	1,051 x 3 x 44 x 365 x 0.5	=	25,318,590
TOTAL:		=	40,374,840 gallons

7.0 Total water used:

Okeechobee Hammocks: 3,276,240 + 2,192,190
= 5,468,430 gallons

Buckhead Ridge: 19,416,540 + 12,864,060
= 32,280,600 gallons

Taylor Creek and Treasure Island: 38,206,740 + 25,318,590
= 63,525,330 gallons

8.0 Net annual percolation through drainfields:

Okeechobee Hammocks: 5.468×10^6 gallons
= 2.07×10^7 liters

Buckhead Ridge: 32.28×10^6 gallons
= 1.22×10^8 liters

Taylor Creek and Treasure Island: 63.53×10^6 gallons
= 2.40×10^8 liters

9. Average nutrient concentrations:

Okeechobee Hammocks:

$NO_2 + NO_3$	=	3.010 mg/L
$NH_3 + NH_4$	=	1.194 mg/L
Phosphorus	=	2.640 mg/L

Buckhead Ridge:

$NO_2 + NO_3$	=	0.698 mg/L
$NH_3 + NH_4$	=	61.329 mg/L
Phosphorus	=	4.116 mg/L

Taylor Creek and Treasure Island:

$NO_2 + NO_3$	=	(0.365 + 9.710 + 0.299)/3 = 3.458 mg/L
$NH_3 + NH_4$	=	(9.875 + 7.252 + 3.618)/3 = 6.915 mg/L
Phosphorus	=	(7.448 + 2.248 + 1.183)/3 = 3.626 mg/L

11.0 Nutrient loading:

Okeechobee Hammocks:

$NO_2 + NO_3$:	$(2.07 \times 10^7) \times 3.010$	=	62.3 kg
$NH_3 + NH_4$:	$(2.07 \times 10^7) \times 1.194$	=	24.7 kg
Phosphorus:	$(2.07 \times 10^7) \times 2.640$	=	54.6 kg

Buckhead Ridge:

$NO_2 + NO_3$:	$(1.22 \times 10^8) \times 0.698$	=	85.2 kg
$NH_3 + NH_4$:	$(1.22 \times 10^8) \times 61.329$	=	7,480 kg
Phosphorus:	$(1.22 \times 10^8) \times 4.116$	=	502 kg

Taylor Creek and Treasure Island:

$NO_2 + NO_3$:	$(2.40 \times 10^8) \times 10.051$	=	2,420 kg
$NH_3 + NH_4$:	$(2.40 \times 10^8) \times 6.915$	=	1,660 kg
Phosphorus:	$(2.40 \times 10^8) \times 3.626$	=	872 kg

Total Nutrient Loading:

$NO_2 + NO_3$:	62.3 + 85.2 + 2,420	=	2,570 kg
$NH_3 + NH_4$:	24.7 + 7,480 + 1,660	=	9,160 kg
Phosphorus:	54.6 + 502 + 872	=	1,430 kg
	Total:	≈	13,200 kg

APPENDIX D

SOIL AND SEDIMENT CHARACTERIZATION PROCEDURES

APPENDIX D

SOIL AND SEDIMENT CHARACTERIZATION PROCEDURES

The collected soil and sediment samples were stored in a refrigerated compartment (0-4°C) before they were analyzed. Prior to storage, representative amounts were taken, analyzed for moisture content, and then later subjected to the following analysis.

D1. Moisture Content - Percent moisture each sample was determined by drying the sample in an oven at 103-105°C for 24 hours. The weight loss after drying was used in calculating the moisture content.

D2. Total Phosphorus - Total P content was analyzed by an acid digestion of the soil sample. The digestate was then subjected to colorimetric analysis via an automated ascorbic acid reduction method.

D3. Nitrite + Nitrate - The soil or sediment was analyzed by converting nitrate into nitrite by cadmium reduction method. The nitrite was then colorimetrically determined with the aid of Technicon Analyzer.

D4. Total Kjeldahl Nitrogen - TKN was determined from the ammonia liberated from the distillation of acid digestate of the samples. The ammonia generated from the sample was calculated from the acid-base titration procedure and expressed in terms of nitrogen.

D5. Total Nitrogen - Total N was calculated from the sum of the concentrations of NO_2 + NO_3 and TKN.

D6. Total Organic Carbon - TOC was determined by measuring the percent weight loss after heating the samples to 440°C.

Analysis described above from D1 to D6 is defined as partial analysis. Full analysis included the partial analysis and analysis of the following parameters based on the method of Graetz and Reddy (1991).

D7. Exchangeable Phosphorus - Soil suspensions [2 g soil: 20 ml 1 M ammonium chloride (NH_4Cl)] were prepared and equilibrated for 1 hour by continuously shaking on a mechanical shaker. After centrifugation, the supernatant liquid was separated, filtered, acidified, and then analyzed for soluble reactive phosphorus (dissolved orthophosphate) using an automated ascorbic acid reduction method.

D8. Extractable Fe and Al - A 25 ml mixture of 0.1 M oxalic acid and 0.175 M ammonium oxalate was used in extracting non-crystalling (amorphous) Fe and Al from 0.5 g soil samples. After continuous shaking for 4 hours, the soil suspension was centrifuged, filtered, and then analyzed using Inductively Coupled Argon Plasma (ICAP) instrument.

D9. Phosphate Adsorption Isotherm - Two grams of air-dried soil were equilibrated with 20 ml of 0.01 M potassium chloride (KCl) solution containing 5, 10, and 50 milligrams phosphorus per milliliter (mg P/mL) [prepared using potassium phosphate (KH_2PO_4) analytical reagent]. These concentrations were selected based on the exchangeable phosphorus data and environmental concentrations of phosphorus in surface waters located in the vicinity of the study areas. After a 24-hr equilibrium period, the soil solution was centrifuged. The supernatant liquid was removed, filtered, acidified, and analyzed for orthophosphate using an automated ascorbic acid reduction procedure. The phosphorus lost from the solution was assumed to be sorbed by the soil. The solution concentrations and amounts of phosphate retained by the soil were then evaluated according to two adsorption isotherms:

(1) Freundlich

$Cs = K\,Ce^{1/n}$, which can be logarithmically transformed to
$\log Cs = \log K + 1/n \log Ce$ **(3-1)**
where Cs = sorbed concentration of P in the solid phase (mg/kg)
Ce = solution concentration of P (mg/L)
K and n = Freundlich adsorption coefficient expressing the sorption capacity of the soil (kg/L) and the adsorption intensity, respectively.

(2) Langmuir

$$\frac{Ce}{Cs} = \frac{1}{bQ} + \frac{Ce}{Q} \quad (3\text{-}2)$$

where Ce and Cs are as defined in equation (3-1)
Q = phosphorus adsorption maximum (mg/kg)
b = a constant related to binding energy (L/mg)

Values of the constants K and 1/n of Freundlich's isotherm were evaluated by plotting log Cs against log Ce to obtain the slope and intercept. For Langmuir isotherm, the plot of Ce/Cs against Ce yielded a slope and an intercept which, in turn were equated to 1/bQ and 1/Q, respectively.

Values of exchangeable P, extractable Al and Fe, and adsorbed P concentrations were calculated by taking into account the initial concentration of each analyte detected in the blank or control solutions.