

**TECHNICAL BACKGROUND  
DOCUMENT**

Environmental Evaluation of  
Existing and Proposed Mining Operations  
VOLUME III

Occidental Chemical Agricultural Products, Inc.  
Hamilton County, Florida

Prepared by

Environmental Services & Permitting, Inc.  
P.O. Box 5489  
Gainesville, Florida 32602

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Department of the Army, Jacksonville District  
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### 3.4 Water Resources

#### 3.4.1 Surface Water Quantity\*

The analysis of surface hydrology in the study area and the upper Suwannee River basin was conducted through the use of a computerized continuous simulation watershed model, Hydrological Simulation Program - Fortran (HSPF) (Johanson et al. 1984). Simulations of the impacts of different mining alternatives are compared to the baseline conditions developed with the use of the HSPF model in Section 6.3.

HSPF was developed by Hydrocomp, Inc. under the sponsorship of EPA. It is a comprehensive model capable of detailed simulation of watershed hydrology and water quality. The hydrologic algorithms used by HSPF have a long history of development, and the model is widely accepted by hydrologists and regulatory agencies. HSPF originated from the Stanford Watershed Model (Crawford and Linsley 1966) and gradually evolved into the present state by combining the functions used by the Hydrocomp Simulation Program (Hydrocomp Inc. 1969), Nonpoint Source Model (Donigian and Crawford 1976), and Agricultural Runoff Model (Donigian and Davis 1978). The director of the EPA Environmental Research Laboratory in Athens, Georgia states: "Although data requirements are extensive and running costs are significant, HSPF is thought to be the most accurate and appropriate management tool presently available for the continuous simulation of hydrology and water quality in watersheds" (Johanson et al. 1984). The USGS also supports the HSPF system as having "the greatest capability to meet the needs of the major impact analysis" (Lumb 1982).

To examine how OXY's mining operations affect the local hydrologic patterns over the long term, pre-mining and baseline conditions in the area and future changes brought about by OXY's mining and reclamation were simulated using the HSPF model. Using area streams, the HSPF model was calibrated and verified with available USGS streamflow records and rainfall and evaporation records from the National Oceanic and Atmospheric Administration (NOAA) and subsequently used to develop pre-mining and baseline conditions. Baseline conditions are defined as those existing in January 1981. The following sections describe the data base, calibration, and verification of the HSPF model for small stream drainage systems and the Suwannee River.

##### 3.4.1.1 Data Base

The following hydrologic or hydrologically related data were used in this study.

1) Topography. USGS 7.5-minute quadrangle maps were used to determine drainage boundaries, drainage areas, and overland slopes. These served as base maps for all the geographic determinations.

2) Drainage boundaries. Drainage boundaries change throughout the mining operations. However, after mining OXY will "restore the original

\*All tables and figures for this section appear at the end of the section to facilitate reading of the text.

drainage pattern of the area to the greatest extent possible," pursuant to Ch. 16C-16.051(7)(b), FAC. Current drainage boundaries within the study area were initially determined by marking 5-ft contours on USGS 7.5-minute topographic maps. Following this step, January 1981 aerials were used to locate any ditching that would affect the drainage boundaries. This information was transferred to the USGS sheets and questionable areas checked in the field prior to plotting the final boundaries. Acreages of the baseline drainage areas are (Figure 3.4-1):

<u>Drainage System</u>	<u>Baseline Acreage</u>
Rocky Creek	33,214
Cypress Creek	18,592
Hunter Creek	8,882
Roaring Creek	6,800
Long Branch	2,913
Four Mile Branch	2,931
Swift Creek	7,291
Camp Branch	6,235
Swift Creek Mine	14,165
Suwannee River Mine	18,477

Drainage systems characterized as Swift Creek Mine and Suwannee River Mine contain all areas in which surface runoff is controlled by mining operations. The drainage area of the Suwannee River from just above its confluence with Rocky Creek to Suwannee Springs was used in the HSPF model (Figure 3.4-2). This area contains 378,563 acres. Drainage boundaries of other Suwannee River tributaries not listed above were provided by the USGS.

3) Soil characteristics. Information on soils was obtained from the soil association map printed by the Florida Department of Administration (1975) and from soil boring data and soil profiles developed by Ardaman and Associates, Inc. Post-mining soil conditions were determined from previously reclaimed areas. Section 3.1.4 contains detailed information on the soils within the study area.

4) Stream/river morphology. Stream cross-sectional data and stream segment lengths were obtained from the USGS for several streams within the study area and for three Suwannee River sites where there are gauging stations. Stream lengths and slopes were also determined from USGS maps. Stream cross-sections were measured at six additional sites on the Suwannee River by OXY surveyors. The cross sections were used to determine the storage volume within various sections of the river. This information is necessary to accurately simulate flow at various points along the river.

5) Precipitation. Hourly precipitation data were obtained from NOAA for sites at Tallahassee, Florida (1959-1979, continuous), Dowling Park, Florida (1944-1975) and Fargo, Georgia (1973-1981). A modified record at Tallahassee was used to drive the HSPF model when simulating the

Suwannee River basin. Closer sites were not used due to lapses in the periods of record (see Section 3.4.1.4). Other hourly records were available but at greater distances from the study area.

Daily precipitation data also were obtained from NOAA for Jasper, Live Oak, and Lake City, Florida (Table 3.4-1). These data were used to create hourly precipitation records through an algorithm based on the hourly precipitation at Tallahassee (see Section 3.4.1.2). These records were used to drive the HSPF model for several small stream drainage systems in and near the study area. Precipitation data collected at stations on the project site are included in Appendix A. Recording gauges at five sites in the OXY project area (Figure 3.4-3) were not used because of their short period of record and/or lapses in the period of record.

6) Evaporation. An erratic daily evaporation record (1965 to date) was obtained for Lake City, Florida, 25 mi southeast of the study area; a longer and more consistent record (1953 to date) was obtained for Gainesville, Florida, 65 mi southeast of the study area (Table 3.4-2). The Lake City record was used for the small drainage system calibration and verification runs, while the Gainesville record was used for the Suwannee River calibration and all pre-mining, baseline, and impact simulations.

7) Streamflow. Streamflow records reported by the USGS were used to calibrate and verify the HSPF model. Daily flow and/or stage records were obtained for six USGS stations as well as five additional stations monitored by OXY consultants for this study (Tables 3.4-3 and 3.4-4, Figure 3.4-3). Flow and stage readings were taken every three or four weeks at several other stations. These were used primarily to indicate trends and develop stage-discharge relationships.

USGS streamflow data, in the form of double mass curves, were analyzed for two sets of stations on the Suwannee River (Benton vs. White Springs and White Springs vs. Suwannee Springs). Double mass analysis tests the consistency of a streamflow record at one station by comparing its cumulative monthly runoff with the concurrent accumulated values of monthly runoff at an adjacent station (Kohler 1949). If no significant addition or removal of flow occurs between the two stations for the time period of interest, a straight line plot would result. Addition or removal of flow would cause a deviation in the slope of the line.

The plot of cumulative monthly average flows for the Suwannee River at White Springs versus the cumulative flows at Benton formed a straight line from October 1975 to September 1981 (Figure 3.4-4). The coefficient of determination ( $r^2$ ) for this period was 0.999, suggesting that the expansion of OXY operations had minimal effect on flow in this river segment during this period. The pre-mining period could not be examined because the Benton station was established in 1975, approximately 10 years after OXY opened its Suwannee River Mine.

The plot of cumulative monthly average flow recorded at White Springs versus those recorded at Suwannee Springs did not indicate noticeable

change in slope for the period October 1974 to September 1981 (Figure 3.4-5). The coefficient of determination ( $r^2$ ) was 0.999, indicating that the flow contributed to the Suwannee River between White Springs and Suwannee Springs by OXY mining operations and other sources did not change appreciably for the given time period. A long-term observation of flow at these two stations was impossible due to the length of the record (7 years). Pre-mining conditions could not be examined because the Suwannee Springs station was established in 1974, approximately 10 years after OXY began mining in the area.

8) Temperature. The monthly mean maximum and minimum temperatures for the vicinity of the project area are presented in Table 3.4-5.

#### 3.4.1.2 Calibration of HSPF - Small Stream Drainage Systems

The following procedure was used to calibrate the HSPF model for small stream drainage systems in the OXY study area.

Streamflows were simulated with the surface runoff portion of the model (Section PERLND). In HSPF, PERLND is the module that simulates the water quality and quantity processes which occur on a pervious land segment. The Theissen method of weighted averages (Linsley et al. 1975) indicated that the daily rainfall at Jasper was the most appropriate record to use for the small drainage systems within the study area. This record was converted to an hourly record through an algorithm based on the characteristics of the Tallahassee hourly record. The algorithm converted daily rainfall amounts to hourly values based on summer (April-September) storms of 5 hr duration and winter (October-March) storms of 8 hr duration. A minimum intensity of 0.10 in/hr was used. The pan evaporation record at Lake City was converted to potential evapotranspiration (ET) with a conversion factor of 0.68 and used for the calibration. The pan factor was arrived at through use of an annual water budget for the study streams and actual simulations by the model in the calibration process.

Station RC-2 on Rocky Creek was selected as the primary station for calibrating the model because it had the longest record of streamflow data in the immediate study area (5 years). Total area of the Rocky Creek drainage, including Cypress Creek, is approximately 51,806 acres, and the average land slope is 2.4 ft/1000 ft. Several one-year simulations were completed using the limited streamflow records at Stations RC-5 and RO-2, but the results indicated that a longer period of record was needed because of the localized nature of rainfall in Florida. Other stations in the OXY study area were not considered for calibration because they receive regulated discharges from the mines (HC-2, SC-4, and SC-9).

The primary simulation period was October 1976 to September 1981. The model was run with 9 previous months of data to minimize the effect of the initial conditions. Flows generated by the PERLND module were compared with USGS flow data at RC-2 in order to determine the model calibration parameters (Table 3.4-6) for simulating flows in this and

other small streams in the study area and other flows entering the Suwannee River between a point just above its confluence with Rocky Creek and Suwannee Springs. The final calibration results for RC-2 produced an average streamflow that was essentially equal to the observed average streamflow over the simulation period, indicating the accuracy of the simulation effort.

The calibrated streamflows and the USGS data were also compared using cumulative frequency analysis, i.e., calculating the percent of time that the daily average flow is less than or equal to a given flow. The cumulative frequency method of analysis is especially useful when dealing in an area with varying rainfall patterns such as those in northern Florida. Temporal rainfall patterns vary greatly in the general study area and even between stations. For example, on 18 February 1981, 1.22 in of rain were recorded at Live Oak, 2.42 in were recorded at Lake City, and only 0.72 in were recorded at Jasper (NOAA records, Appendix A). Live Oak is approximately 15 mi from Jasper and 20 mi from Lake City. The gauges at SS-2 and HC-3 recorded 2.64 in and 3.22 in, respectively, on the same date. Because rainfall varied significantly within the drainage basin at a given time, the simulated streamflow based on one or a few rain gauges would not agree closely with the observed streamflow time series data. However, the statistical characteristics in a small drainage basin are not expected to vary spatially. The time series data may differ between two locations in the drainage area, but the long-term statistical parameters should remain similar. Therefore, if the model were calibrated properly based on the cumulative frequency, the simulated results would reflect the current long-term statistical characteristics.

As with the annual flows method, the cumulative frequency method indicated the model was well calibrated. The curves generated for the observed and simulated flows closely paralleled each other (Figure 3.4-6). Plotting of the flows indicates that the model tends to slightly over-simulate flow <150 cfs and slightly underestimate flow >150 cfs.

Visual observation indicated the simulated duration curves fit the observed duration curves reasonably well. The goodness of fit was quantitatively evaluated using a statistical hypothesis testing method, the Kolmogorov-Smirnov (K-S) test of model simulations (Haan 1977). Although the K-S test is not a rigorous test of complete correspondence between two cumulative distributions, it does provide an indication of overall agreement and has been used in past modeling studies (Hartigan et al. 1982, Young and Alward 1983). The fact that the model simulations passed the K-S test at its highest level of significance is a further confirmation of the validity of the model representation of the Suwannee River basin. These results, in addition to the agreement in annual flow volumes and flow frequency curves (by visual inspection), provide a complete assessment of the modeling results.

The K-S test was used to test how well the cumulative probability density distribution of the simulated flow would fit the corresponding distribution of the observed flow. It provides a means of determining

significant differences between the two distributions. A basic assumption of the K-S test is that all observations used in the test should be random variables and independent of each other. Therefore, only a subset of the data set can be used for the test so that the test result will be valid. To select the subset of the observation to be used for the K-S test, an autocorrelation analysis of the observed flow data was conducted to determine the correlation between an observation and the observation in the preceding time period. If the autocorrelation coefficient of the streamflow time series is within a predetermined confidence limit (Haan 1977):

$$(-1 + Z_{1-a/2} \sqrt{n-2})/(n-1) > R(k) > (-1 - Z_{1-a/2} \sqrt{n-2})/(n-1)$$

where,

$R(k)$  = autocorrelation coefficient

$k$  = lag between the observations being considered

$n$  = total number of observations

$a$  = confidence level

$Z_{1-a/2}$  = limit of integration so that the area under the standard normal density from 0 to  $Z$  equals  $(1-a/2)$ ,

then the sample consisting of every  $k^{\text{th}}$  observation out of the entire time series will be considered a random sample and therefore suitable for the K-S test.

The results of the autocorrelation analysis indicated that, for the sample to be independent within the 95% confidence interval, one out of the 223 daily flow data of the Suwannee River at White Springs and one out of the 71 daily flow data of Rocky Creek should be used for the K-S test.

The K-S test compares the cumulative probability density of the observed flow and the simulated flow. The difference between the two values at every flow value should not exceed a critical value, with a given significance level, in order to pass the test.

The K-S test on the Rocky Creek calibration showed a maximum probability deviation of 0.0897. The critical value is 0.2022 at the 20% significance level. Therefore, the model simulation passed the K-S test. In other words, the simulated flow has the same cumulative probability distribution as the observed flow, at the 20% significance level, which is the highest level at which the test is conventionally applied (Haan 1977).

Calibration of the HSPF model for RC-2 also was attempted on a time series basis (daily average flow versus time) using the daily Jasper rainfall record adjusted to an hourly record. However, because the

Jasper station lies outside the actual drainage basin and is approximately 15 mi from the stream gauging site at RC-2, and due to the highly variable nature of rainfall in this area, the time series plot of the simulated data could not provide a reasonable reproduction of the observed flow data (Figure 3.4-7). Several peaks occurred in the simulated data that were not in the measured data and, conversely, the simulation did not reproduce several peaks present in the measured data. This type of problem is indicative of an unrepresentative rainfall distribution record. Given the preceding, the model was calibrated and verified by three methods:

- 1) comparison of observed and simulated annual flows (mass balance),
- 2) comparison of observed and simulated cumulative frequency distributions, and
- 3) statistical analysis of the cumulative frequency distribution using the Kolmogorov-Smirnov test.

#### 3.4.1.3 Verification of HSPF - Small Stream Drainage Systems

Parameters in the PERLND module of HSPF were verified through use of the Deep Creek drainage system. Verification involves testing the model against a set of data that is independent from the data set used for calibration. The Deep Creek drainage system, lying east of the Suwannee River and across from the study area, had streamflow records and physical characteristics similar to those of RC-2. Deep Creek drains approximately 56,700 acres and has an average overland slope of 2.3 ft/1000 ft.

Deep Creek was tested using the input parameters developed for RC-2 for a 5-year period, October 1976 - September 1981. The Thiessen method indicated that the daily precipitation record for Lake City, converted to an hourly record by the algorithm discussed in Section 3.4.1.2, should be used in this case. The pan evaporation record at Lake City was also used to estimate potential evapotranspiration ( $ET = 0.68 \times \text{pan evaporation}$ ). Results were evaluated by the cumulative frequency and mass balance methods.

Results of the verification showed the average simulated flow to be 63.5 cfs, while the observed average flow for the same time period was 59.8 cfs, or a difference of 3.7 cfs (6.2%). A cumulative frequency analysis also indicated that results from the verification run were similar to observed data (Figure 3.4-8). Thus, use of both the mass balance and cumulative frequency analyses to compare verification results with observed data verified the parameter values determined in the calibration step.

#### 3.4.1.4 Calibration/Verification of HSPF - Suwannee River

The USGS daily flow record at White Springs was used to calibrate and verify the HSPF model for the Suwannee River and its drainage basin above Suwannee Springs; 20 years (1959-1979) of Tallahassee hourly precipitation data and Gainesville daily pan evaporation data were used.

This period was selected because the data were more complete than in other periods. Traditional split-sample calibration procedures were used, wherein the first half (1959-1969) of the 20-year period was used for calibration and the second half (1970-1979) was simulated, with the calibrated parameters as an independent check or verification of the simulation (Donigian 1982, Donigian 1983, Donigian et al. 1984).

The hourly rainfall record was linearly adjusted so that the average annual rainfall agreed with the average for stations nearest the study area (i.e., Jasper, Live Oak, and Lake City). The utilization of a cumulative frequency analysis enabled the use of the non-local, but climatologically similar, precipitation record at Tallahassee. The daily pan evaporation record needed no adjustment because it more closely agreed with local conditions. Initial parameter values for the PERLND module were those obtained in the small stream discharge calibration/verification step, except that topographic parameter values for the Suwannee River drainage basin were evaluated and used. The model was calibrated by comparing the cumulative frequency of daily average flows generated by the model and USGS streamflow records.

Streamflow routing with HSPF's section RCHRES (ReaCH-REServoir) was included in this phase of the modeling procedure. Streamflow routing was not used in the small drainage basin calibration and verification because of the short travel times of small streams. However, it was necessary when modeling the larger Suwannee River. The Suwannee River was segmented into seven RCHRES sections, with the first section beginning just above the confluence with Rocky Creek. The remaining sections were designed to best reflect the actual locations of the many tributaries to the Suwannee River (Figure 3.4-9). The drainage area associated with each river section is:

<u>Reach</u>	<u>Baseline Acreage*</u>	<u>Reach</u>	<u>Baseline Acreage*</u>
10	62,228	50	34,036
20	17,917	60	36,219
30	108,296	70	18,125
40	69,017		

\*Excluding mine areas.

These drainage areas do not include the areas influenced by the Suwannee River and Swift Creek mines because discharges from the mine areas are regulated by control structures; thus, the mine discharges were simulated differently from the rest of the drainage area.

Individual drainage systems emptying from the OXY study area into the Suwannee River between reach No. 10 and reach No. 40 (ending at White Springs, Florida) included Rocky Creek, Hunter Creek, Roaring Creek, Long Branch, and Four Mile Branch. Flow contributed from pervious land area was generated from the previously calibrated PERLND module of HSPF and applied to the individual drainage systems on an areal basis, e.g., the runoff generated by the 62,228 acres draining to Reach 10 was calculated

by the PERLND module and then input to the reach. Flows from other areas were also generated by the calibrated PERLND module and applied to their respective reaches.

Streamflow in the Suwannee River above reach No. 10 was accounted for in the following manner. First, a linear regression analysis was performed for USGS streamflow records of the Suwannee River at Benton vs. White Springs for the time period October 1975 - September 1981, the historical period of record at Benton (Figure 3.4-4). A high degree of correlation was apparent ( $r^2 > 0.999$ ). The resulting regression equation was used to generate a streamflow record at Benton from the White Springs data corresponding to the pertinent precipitation and pan evaporation records (October 1959 - September 1979). This record contained flow contributed by the Rocky Creek drainage area and other near-stream areas. The flows from these areas were removed from the generated Benton flow after calculation by the PERLND module of HSPF because mining activities are projected in some of these areas. This record of generated flow in the Suwannee River at Benton, less the simulated flow of Rocky Creek and the near-stream areas, was used as input to the model at reach No. 10. Flow from Rocky Creek was added as a separate input into reach No. 10. This enabled all areas potentially affected by OXY to be included in the dynamic hydrologic simulation.

Hunter Creek is currently affected by mining operations, and this effect was included in the simulation. Hunter Creek flow at HC-2 for 1978-1981 included runoff from undisturbed areas of the drainage basin and mining-related discharges. The results from a PERLND run at HC-2 for the undisturbed portion of the drainage area (using the Jasper precipitation and Lake City evapotranspiration records) were removed from the 4-year record provided by OXY. These results were averaged on a monthly basis and entered as constant monthly mining discharge to the Suwannee River at Hunter Creek.

It should be noted that there are significant areas within the drainage area of the Suwannee River Mine that have not been directly disturbed. However, the surface runoff from these areas is controlled by various structures constructed by OXY and is mingled with the mining discharges. Therefore, drainage from these areas is considered as mining discharge in the modeling process.

After the mining discharge was computed and pervious land surface runoff was simulated by the PERLND block, Suwannee River flow was simulated with HSPF's kinematic wave RCHRES module from just above its confluence with Rocky Creek downstream to White Springs. The results obtained at White Springs were compared with the USGS record for the same time period at White Springs on a cumulative frequency basis and mass balance basis. Results were reported as the cumulative frequency of daily average streamflows and as yearly averages.

Two simulation scenarios were needed to provide sufficient calibration and verification of the HSPF model and as a basis for assessing mining impacts, as mining operations were initiated halfway through the period of record used for the simulations (October 1959 - September 1979).

Thus, a range of conditions was used for an unbiased approach to the modeling process. The two simulation scenarios were performed to help account for the changes incurred by the mining operation up to January 1981. The baseline conditions included streamflow contributed by mining operations, while the pre-mining conditions assumed natural runoff characteristics for the land currently occupied by mining operations. Baseline conditions were subjected to the traditional split-sample calibration/verification procedure. Results from the two computer simulation scenarios follow. The first is for baseline conditions, or conditions present in January 1981. The second simulation is for pre-mining conditions, or conditions prior to mining.

The primary difference in the model input for the pre-mining and baseline simulations was inclusion of the areas occupied by the Swift Creek Mine and Suwannee River Mine in the baseline simulation. For the baseline runs, average monthly discharges from these areas were determined and added to the model at their respective sites in the Swift Creek and Hunter Creek locations. For the pre-mining runs, the PERLND module was used to simulate the entire basin.

For baseline conditions, traditional split-sample calibration/verification procedures were followed using the 1959-1969 flow record at White Springs for calibration and the 1970-1979 record for verification. The previously calibrated PERLND parameters and module were used with the RCHRES module to simulate total basin runoff and resulting streamflow at White Springs. During the calibration, selected minor adjustments were made to the model parameters to improve the agreement between simulated and observed flow during the 10-year calibration period. After completion of the calibration, the model was run for the 10-year verification period at White Springs using the calibrated parameters as an independent check or verification of the simulation.

The calibration/verification results at White Springs were compared to observed flow data for both yearly average values (Table 3.4-7) and cumulative frequencies (Figures 3.4-10 and 3.4-11). The average flows for calibration and verification periods were 1.6% and 5.2% higher, respectively, than observed flows. Annual differences in average flow ranged from -18.3% to +14.0% for the calibration, and -3.2% to +21.3% for the verification. Comparison on a flow frequency basis showed good correlation between simulated and observed data for both periods. The flow frequencies for the combined calibration/verification period at White Springs also showed a close correlation for the entire 20-year period that was used to assess mining impacts.

Plotting the cumulative observed yearly averages vs. the cumulative simulated yearly averages would indicate a change in slope due to mining operations if OXY had significantly changed the runoff volumes to the Suwannee River above White Springs. However, this was not true, as the double mass curve of the observed and simulated data produced a nearly straight line (Figure 3.4-12). The coefficient of determination ( $r^2$ ) was 0.999 for the 20-year period.

The K-S test (Section 3.4.1.2) on the Suwannee River at White Springs calibration/verification showed a maximum probability deviation of 0.0588 for the calibration period (1959-1969) and a maximum deviation of 0.118 for the verification period (1970-1979). The critical value at the 20% significance level was 0.318.

The K-S test was also applied to the 20-year simulation period (1959-1979). The maximum probability deviation was 0.0304 and the critical value at the 20% significance level was 0.276. Therefore, the Suwannee River calibration and verification passed the K-S test at the highest significance level conventionally used.

Pre-mining conditions were simulated to estimate watershed behavior under "natural" conditions. The simulated average flow for pre-mining conditions came within 3.8% of the actual average flow (Table 3.4-8). Yearly differences ranged from -22.6% to +22.6%. Comparison of the results on a cumulative frequency basis indicated a high level of agreement between the simulated and observed flow values (Figure 3.4-13). Further analysis of the results using an expanded scale to emphasize low flows also indicated good agreement between simulated and observed flows (Figure 3.4-14). These low flow results are particularly important when analyzing conditions in drought years. A double mass analysis of observed flow vs. simulated flow at White Springs on a cumulative monthly average basis also showed little change in slope (Figure 3.4-15). This again indicates the minimal impact of OXY's mining operations above White Springs. The coefficient of determination for the 20-year period was 0.999.

There was little difference between the calibration and verification runs for the baseline condition and for the entire 20-year period under both baseline and pre-mining conditions. The HSPF model performed reasonably well under both sets of conditions. Differences in the simulations, such as changes in the slope of the double mass curves, did not occur, suggesting that perturbations due to mining flow contributions were insignificant or, at least, unmeasurable. In either case, no adjustments of the established calibrated parameters in the PERLND module were considered necessary. The parameters needed for the RCHRES module are well-defined physical parameters (e.g., slope, length, roughness) and were empirically determined or measured.

#### 3.4.1.5 Simulation of Suwannee River at Suwannee Springs

In order to encompass the entire area potentially impacted by OXY mining operations, the HSPF model was applied to the Suwannee River watershed at Suwannee Springs for comparison of simulated and observed flows.

Streamflow arriving from reach No. 40 was routed from White Springs to Suwannee Springs, along with flow contributions from adjacent tributary streams and areas along both sides of the Suwannee River. Swift Creek and Camp Branch flows were routed into reaches No. 60 and No. 70, respectively.

The fact that both the Swift Creek and Suwannee River mines empty into the Suwannee River through Swift Creek complicated the modeling effort.

Approximations of flow contributions from both mines were determined in a manner similar to that used to estimate Hunter Creek mining discharge (Section 3.4.1.4). USGS streamflow records were available for Swift Creek at SC-4 for June 1976 - September 1981. These data included both mining discharge and runoff from undisturbed areas of the Swift Creek drainage system. Natural runoff was simulated using the PERLND module of HSPF for the undisturbed area of the drainage system, and mine discharge was calculated by subtracting the simulated natural runoff from the observed record. The calculated mine discharge during the 5-year flow monitoring period was then used to provide the average monthly mine discharge. These average monthly discharges were used repeatedly every year as flow input to the Suwannee River at reach No. 60 for baseline simulation. The modified Jasper precipitation and Lake City pan evaporation records were used to drive the model.

As with the calibration step, both baseline and pre-mining conditions were simulated and 20 years of flow data were generated, but only 5 years (water years 1974-1979) of USGS flow records were available for comparison to the model results at Suwannee Springs. The Tallahassee record was modified by multiplying all values by 0.72 to match the local total rainfall amounts for water years 1974-1979. This was done because Tallahassee rainfall was much greater than local levels during this period. This was the only time the factor 0.72 was used; for all other cases where the Tallahassee record was used, a factor of 0.80 was applied.

Analysis of the baseline and pre-mining simulations in terms of yearly and total average flows showed little difference in the two sets of results. Comparison with observed flow data showed the baseline simulation to be 4.0% higher and the pre-mining simulation 2.2% higher in terms of average streamflow for the 5-year period (Table 3.4-9). Yearly differences varied from -4.5% to +13.8% for the baseline simulation and from -7.3% to +10.9% for the pre-mining simulation. Results from both the baseline and pre-mining simulations were somewhat higher than the observed flows, but they were consistent with the results obtained for White Springs. It is probable, however, that a significant quantity of streamflow is lost to groundwater along the reach from White Springs to Suwannee Springs during certain periods when the head in the river is greater than the potentiometric head of the springs. The geological Hawthorn layer contains a predominant percentage of clay and is eroded near White Springs. The river then flows on a predominantly limestone streambed which enhances seepage until it reaches Suwannee Springs. This explanation is also confirmed by historical USGS stream records which indicate several periods of lower recorded flow at Suwannee Springs than at White Springs (Hull et al. 1981 and USGS Water Data Reports for Northwest Florida).

Comparison of flows on a cumulative frequency basis also indicated the baseline and pre-mining simulation results were only slightly different from those for observed flows (Figures 3.4-16 and 3.4-17, respectively). Simulation results were similar to the observed data at lower flows for both the baseline and pre-mining runs (Figures 3.4-18 and 3.4-19,

respectively). In general, the simulated and observed cumulative frequency curves agreed. The results indicated that mining and chemical plant discharge prevents extreme low flow conditions even during the dry season.

Double mass analysis comparing cumulative monthly average flows for the baseline simulation against observed flow data produced essentially a straight line (Figure 3.4-20). The coefficient of determination ( $r^2$ ) for both the baseline and pre-mining results was 0.999 (Figures 3.4-20 and 3.4-21). These results were expected, as the period of record (water years 1974-1979) for the simulations was entirely within the mining time span (1970-present). The double mass analysis was used to indicate changes in water management policies, which, for the most part, occurred prior to installation of the USGS gaging station at Suwannee Springs (October 1974).

As with the calibration/verification results at White Springs, the results at Suwannee Springs showed good agreement between the simulated and observed flows. This was a further confirmation that the model was sufficiently calibrated and verified and ready for use in simulating pre-mining and baseline conditions within the study area.

#### 3.4.1.6 Pre-Mining Conditions

The pre-mining hydrology was modeled to allow comparisons with post-reclamation hydrology. Cumulative frequency curves for Suwannee River flow at White Springs and at Suwannee Springs under pre-mining conditions were constructed for comparison with post-reclamation curves (Section 6.3). Cumulative frequency curves for the small drainage systems were also constructed and are presented with the post-mining frequency distributions in Section 6.3. Table 3.4-10 shows the drainage area, mean flow, and peak daily flow of the Suwannee River and small drainage systems under pre-mining conditions.

A Log-Pearson Type III analysis was used to compute the flood frequency distribution. The 2, 5, 10, 25, 50, and 100-year flood flows are shown in Table 3.4-11.

For comparison purposes, the same rainfall and evaporation record (October 1959 - September 1979) was used for pre-mining, baseline, and post-mining simulations so that the effects of mining and reclamation can be determined, keeping the same meteorological conditions.

#### 3.4.1.7 Baseline Conditions

The verified HSPF model was used to simulate baseline conditions (as of 1 January 1981) for each of the following streams at its confluence with the Suwannee River: Rocky Creek, Hunter Creek, Roaring Creek, Long Branch, Four Mile Branch, Swift Creek, and Camp Branch. The drainage systems for these streams are or will be affected by OXY mining operations. Each drainage system was simulated with the calibrated and verified model parameters and the modified Tallahassee precipitation and Gainesville pan evaporation records for October 1959 - September 1979.

The cumulative frequency curves for flows from each stream are shown in Section 6.3 along with the post-mining curves. Most of the streams have daily average flows of  $\leq 5$  cfs for at least 60% of the time (i.e., Roaring Creek, Long Branch, Four Mile Branch, and Camp Branch). Rocky Creek, which drains the largest area, experiences flows of  $\leq 5$  cfs 40% of the time. The curves for Hunter Creek and Swift Creek are somewhat different because of the mine discharges and the dampening effects of water stored in impoundments. Essentially, the relatively constant or dampened mine discharges mask the low flow periods and lower the peak flows. The monthly average flows for each stream over the simulation period are shown in Figures 3.4-22 through 3.4-28). The simulated mean and maximum flows for each drainage system under baseline conditions for the entire simulation period are presented in Table 3.4-12.

The simulated cumulative frequency curves for daily flows resulting from the calibration/verification procedure constitute the baseline conditions for the Suwannee River at White Springs. These are presented in Section 6.3 along with the curves for post-reclamation. The modified 20-year (October 1959 - September 1979) hourly precipitation record for Tallahassee and the corresponding pan evaporation record for Gainesville were used to develop a similar pair of cumulative frequency curves for the Suwannee River at Suwannee Springs (Section 6.3). The simulated average flows were 2211 cfs at White Springs and 2386 cfs at Suwannee Springs (Table 3.4-12).

Table 3.4-1. Monthly Mean Precipitation (inches) for the Vicinity of the Project Area.

Station	Record	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Dowling Park	1948-1951	1.55	3.03	3.87	3.82	3.72	4.26	5.31	6.77	2.98	4.55	0.58	2.56	43.00
Gainesville No. 083316	1903-1963	2.67	2.99	3.60	3.10	3.33	6.81	7.49	7.30	5.30	3.30	1.86	2.86	50.61
Gainesville 2 No. 083321	1953-1979	3.28	4.08	3.61	2.71	4.28	6.69	7.07	8.03	5.61	2.23	2.01	3.35	52.95
Jasper	1952-1979	4.51	4.38	4.15	4.20	4.46	7.03	6.16	6.89	5.14	2.13	2.52	3.87	55.44
Lake City	1931-1979	3.33	3.82	3.96	3.30	3.94	6.08	7.25	7.26	5.41	2.98	2.13	3.27	52.73
Live Oak	1952-1979	4.10	3.87	4.09	3.93	3.97	5.78	7.89	6.66	5.23	2.32	2.17	3.50	53.51
Tallahassee	1948-1979	4.41	4.98	5.36	4.32	5.07	6.47	9.11	7.43	6.17	3.15	3.20	4.63	64.30
Perry	1948-1979	4.22	4.43	4.90	3.95	5.09	6.68	8.62	8.77	6.22	2.39	2.84	3.66	61.77

Source: Hydrologic Information Storage and Retrieval System, University of Florida, Gainesville.

Table 3.4-2. Monthly Mean Pan Evaporation (inches) for Gainesville and Lake City, Florida.

Station	Record	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Gainesville 2	1953-1979	2.89	5.65	5.74	7.33	7.86	7.57	7.43	6.70	5.68	4.94	3.57	2.75
Lake City	1965-1979	2.70	3.97	5.81	6.86	8.08	*	7.95	6.28	6.06	4.78	3.59	3.09

\*Insufficient data.

Source: Hydrologic Information Storage and Retrieval System, University of Florida, Gainesville.

Table 3.4-3. Locations Used for Daily Flow and Stage Data.

Name	USGS No.	OXY No.	Period of Record Used
<u>USGS Stations</u>			
Rocky Creek at Belmont	02314986	RC-2	3/76-9/81
Hunter Creek at Belmont	02315005	HC-2	1/79-9/81
Swift Creek at Facil	02315520	SC-4	5/76-9/81
Suwannee River at Benton	02315000	SR-2	10/75-9/81
Suwannee River at White Springs	02315500	SR-5	2/27-9/81
Suwannee River at Suwannee Springs	02315550	SR-10	10/74-9/81
<u>OXY Study Stations</u>			
Rocky Creek		RC-5	8/80 to date
Roaring Creek		RO-2	8/80 to date
Swift Creek Swamp		SS-2	3/80 to date
Swift Creek		SC-9	3/80 to date
Eagle Lake Canal		EL001-18	12/79 to date

Table 3.4-4. Monthly Mean Flow (cfs) In the Vicinity of the Project Area.

Station	Record	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
RC-2	06/76-09/81	38.19	51.84	100.63	43.06	22.06	14.82	14.62	11.29	11.72	8.19	6.06	26.37	29.07
Benton	10/75-09/81	1907.54	1937.36	2542.87	1530.21	1232.29	1068.78	806.21	602.93	677.30	790.22	509.81	2135.12	1311.72
Deep Creek	10/76-09/81	88.45	128.34	169.21	89.07	56.91	9.57	16.12	32.00	41.91	26.55	15.62	44.31	59.84
White Springs	10/59-09/81	2077.26	3200.28	3555.99	3723.74	1754.01	1289.52	1487.81	2263.63	2258.52	1269.83	619.87	1191.72	2057.68
Suwannee Springs	10/74-09/79	2820.33	3062.87	3005.94	2281.44	2060.44	1521.81	1416.85	1567.62	1388.49	898.05	496.43	2236.06	1896.36

Source: USGS records.

Table 3.4-5. Monthly Means of Maximum and Minimum Temperatures (°F) for the Vicinity of the Project Area.

Station	Record	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Gainesville 2	1953-1979	68.5	70.6	76.8	82.8	87.7	90.4	91.4	91.4	89.1	82.7	75.9	70.1	81.5
		44.1	44.9	50.8	56.8	63.2	68.9	71.1	71.1	71.1	69.5	60.3	51.7	45.5
Jasper	1952-1979	65.2	67.5	75.4	82.2	87.4	90.8	92.1	92.0	88.9	81.3	73.6	66.8	80.5
		39.0	40.4	46.6	53.2	59.7	65.7	69.9	68.8	66.2	55.7	46.1	39.5	54.6
Lake City	1931-1979	66.6	68.8	74.6	81.0	87.1	90.7	90.9	91.1	88.2	81.3	73.4	67.6	80.1
		42.8	44.4	49.4	55.7	62.3	68.2	70.5	70.5	68.2	59.0	49.2	43.6	57.1
Live Oak	1952-1979	65.7	68.8	75.2	82.1	87.6	90.6	91.5	91.4	88.7	82.0	74.4	68.1	80.7
		40.9	43.0	49.0	55.7	62.0	68.0	70.8	70.4	68.0	57.2	48.3	42.2	56.6
Tallahassee	1948-1979	64.0	66.3	72.6	79.9	86.2	90.1	90.6	90.4	87.6	80.4	71.5	65.6	78.8
		40.7	41.9	47.7	54.2	62.2	68.9	71.5	71.6	68.7	56.7	46.1	41.4	56.0

Source: Hydrologic Information Storage and Retrieval System, University of Florida, Gainesville.

Table 3.4-6. HSPF Calibrated Model Parameters.

Parameter	Value	Description
LZSN	5.30 in	Lower zone nominal storage
INFILT	0.15 in/hr	Index to infiltration capacity
LSUR	800 ft	Length of assumed overland flow plane
SLSUR	0.0024	Slope of assumed overland flow plane
AGWRC	0.94/day	Active groundwater recession rate
INFEXP	2.00	Exponent in infiltration equation
INFILD	2.00	Ratio between maximum and minimum infiltration capacities
DEEPPFR	0.12	Fraction of groundwater inflow to deep groundwater, lost from the simulation
BASETP	0.08	Fraction of remaining potential evapotranspiration (ET) from baseflow
AGWETP	0.45	Fraction of remaining potential ET from active groundwater storage if available
CEPSC	0.25 in	Interception storage capacity
UZSN	1.20 in	Upper zone nominal storage
NSUR	0.35	Manning's n for assumed overland flow plane
INTFW	2.00	Interflow inflow parameter
IRC	0.90/day	Interflow recession parameter
LZETPM-JAN	0.40	Lower zone ET parameter for each month
FEB	0.40	
MAR	0.40	
APR	0.50	
MAY	0.70	
JUN	0.80	
JUL	0.80	
AUG	0.80	
SEP	0.80	
OCT	0.70	
NOV	0.60	
DEC	0.40	

Table 3.4-7. Suwannee River Calibration/Verification, Average Flow at White Springs, Observed Flow Data and Baseline Conditions Simulation.

Calibration				Verification			
Water Year*	Observed Flow (cfs)	Simul. Flow (cfs)	% Diff.	Water Year*	Observed Flow (cfs)	Simul. Flow (cfs)	% Diff.
1960	2229	2218	-0.5	1970	3311	3513	+6.1
1961	2125	1992	-6.3	1971	1662	1690	+1.7
1962	1052	963	-8.5	1972	2568	2485	-3.2
1963	1037	980	-5.5	1973	4614	4740	+2.7
1964	4340	4465	+2.9	1974	850	935	+10.0
1965	3779	4086	+8.1	1975	2607	2796	+7.2
1966	3379	3486	+3.2	1976	1275	1423	+11.6
1967	1482	1436	-3.1	1977	2374	2544	+7.2
1968	208	170	-18.3	1978	1657	1711	+3.3
1969	1232	1405	+14.0	1979	1101	1336	+21.3
Avg.	2086	2120	+1.6	Avg.	2202	2317	+5.2
TOTAL AVERAGE					2144	2219	+3.5

\*October to September.

Table 3.4-8. Suwannee River Simulation, Average Flow at White Springs, Observed Flow Data and Pre-Mining Conditions Simulation.

Water Year*	Observed Flow (cfs)	Simul. Flow (cfs)	% Diff.	Water Year*	Observed Flow (cfs)	Simul. Flow (cfs)	% Diff.
1960	2229	2221	-0.4	1970	3311	3535	+6.8
1961	2125	1986	-6.5	1971	1662	1693	+1.9
1962	1052	955	-9.2	1972	2568	2485	-3.2
1963	1037	974	-6.1	1973	4614	4763	+3.2
1964	4340	4488	+3.4	1974	850	938	+10.4
1965	3779	4117	+8.9	1975	2607	2814	+7.9
1966	3379	3503	+3.7	1976	1275	1432	+12.3
1967	1482	1433	-3.3	1977	2374	2560	+7.8
1968	208	161	-22.6	1978	1657	1715	+3.5
1969	1232	1416	+14.9	1979	1101	1350	+22.6
TOTAL AVERAGE					2144	2227	+3.8

\*October to September.

Table 3.4-9. Suwannee River Simulation of Flow at Suwannee Springs.

Water Year*	Observed (cfs)	Simul. Baseline (cfs)	% Difference
1975	2698	2804	+3.9
1976	1399	1430	+2.2
1977	2432	2592	+6.6
1978	1793	1712	-4.5
1979	1159	1319	+13.8
Total average	1896	1971	+4.0

Water Year*	Observed (cfs)	Simul. Pre-Mining (cfs)	% Difference
1975	2698	2781	+3.1
1976	1399	1390	-0.6
1977	2432	2568	+5.6
1978	1793	1663	-7.3
1979	1159	1285	+10.9
Total average	1896	1937	+2.2

\*October to September.

Table 3.4-10. Drainage Area and Flow Summary Under Pre-mining Conditions.

Drainage System	Area (acres)	Q mean (cfs)	Q max (cfs)	$\frac{s}{\bar{Q}}$ (cfs)
Rocky Creek	51,806	68.8	3,285.0	131.9
Hunter Creek	15,280	20.3	968.9	38.9
Roaring Creek	13,744	18.3	871.5	34.4
Long Branch	2,913	3.9	184.7	7.4
Four Mile Branch	2,931	3.9	185.9	7.5
Swift Creek	27,134	36.0	1,720.6	69.1
Camp Branch	5,499	7.3	348.7	13.9
Suwannee River at White Springs	1,606,859	2,219	38,260	3,011
Suwannee River at Suwannee Springs	1,714,760	2,362	39,730	3,166

Q = flow.

s = standard deviation.

Table 3.4-11. Flood Flow Analysis Under Pre-mining Conditions.

Drainage System	Flood Flow (cfs)					
	2*	5*	10*	25*	50*	100*
Rocky Creek	541	1,431	2,302	3,729	5,030	6,519
Hunter Creek	160	422	679	1,100	1,484	1,923
Roaring Creek	144	380	611	990	1,335	1,730
Long Branch	30	81	129	210	283	366
Four Mile Branch	31	81	130	211	285	369
Swift Creek	283	750	1,206	1,953	2,635	3,415
Camp Branch	57	152	244	396	534	692
Suwannee River at White Springs	9,897	15,649	18,324	20,629	21,781	22,585
Suwannee River at Suwannee Springs	10,588	16,448	19,021	21,120	22,097	22,755

\*Return period in years.

Table 3.4-12. Drainage Area and Flow Summary Under Baseline Conditions.

Drainage System	Area (acres)	Q mean (cfs)	Q max (cfs)	$\frac{s}{\bar{Q}}$ (cfs)
Rocky Creek	51,806	68.8	3,284.0	131.9
Hunter Creek	8,882	21.2	573.0	21.2
Roaring Creek	6,800	9.0	431.0	17.3
Long Branch	2,913	3.9	184.9	7.4
Four Mile Branch	2,931	3.9	186.0	7.5
Swift Creek	7,291	68.9	506.2	28.7
Camp Branch	6,235	8.3	395.2	15.9
Suwannee River at White Springs	1,607,123*	2,211	37,800	2,959
Suwannee River at Suwannee Springs	1,714,853*	2,386	38,960	3,075

Q = flow.

s = standard deviation.

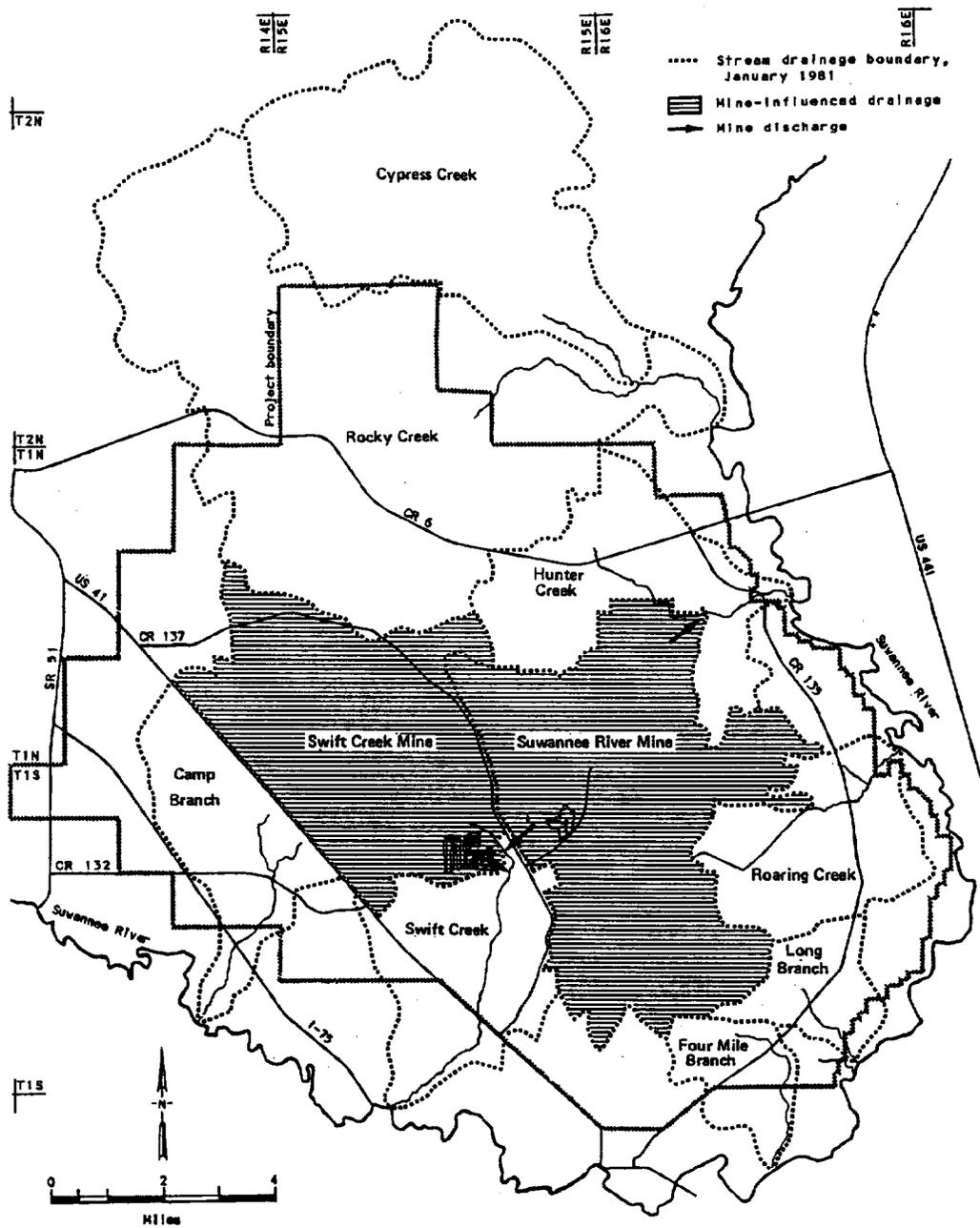


Figure 3.4-1. OXY Small Stream Drainage Boundaries under Baseline Conditions.

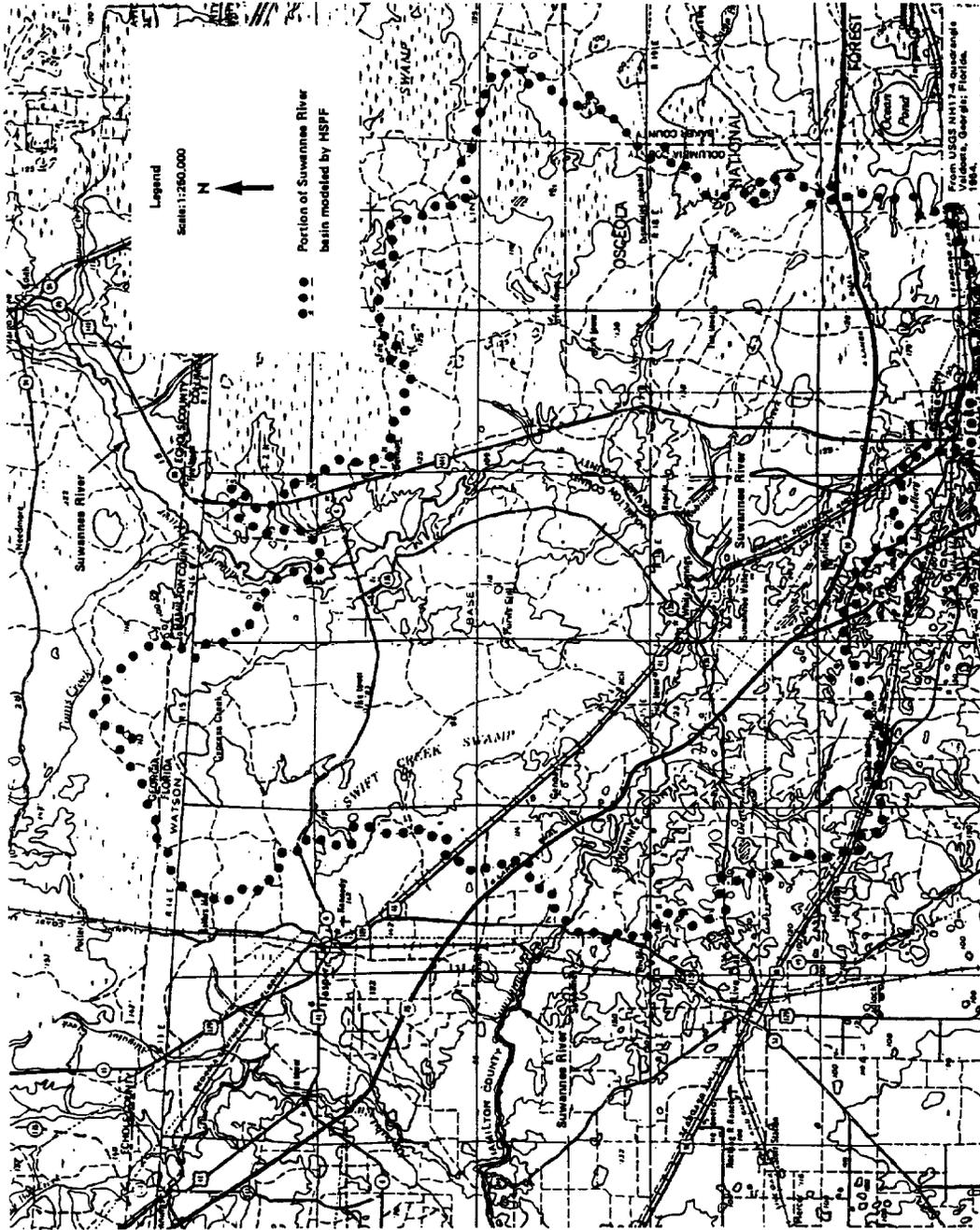
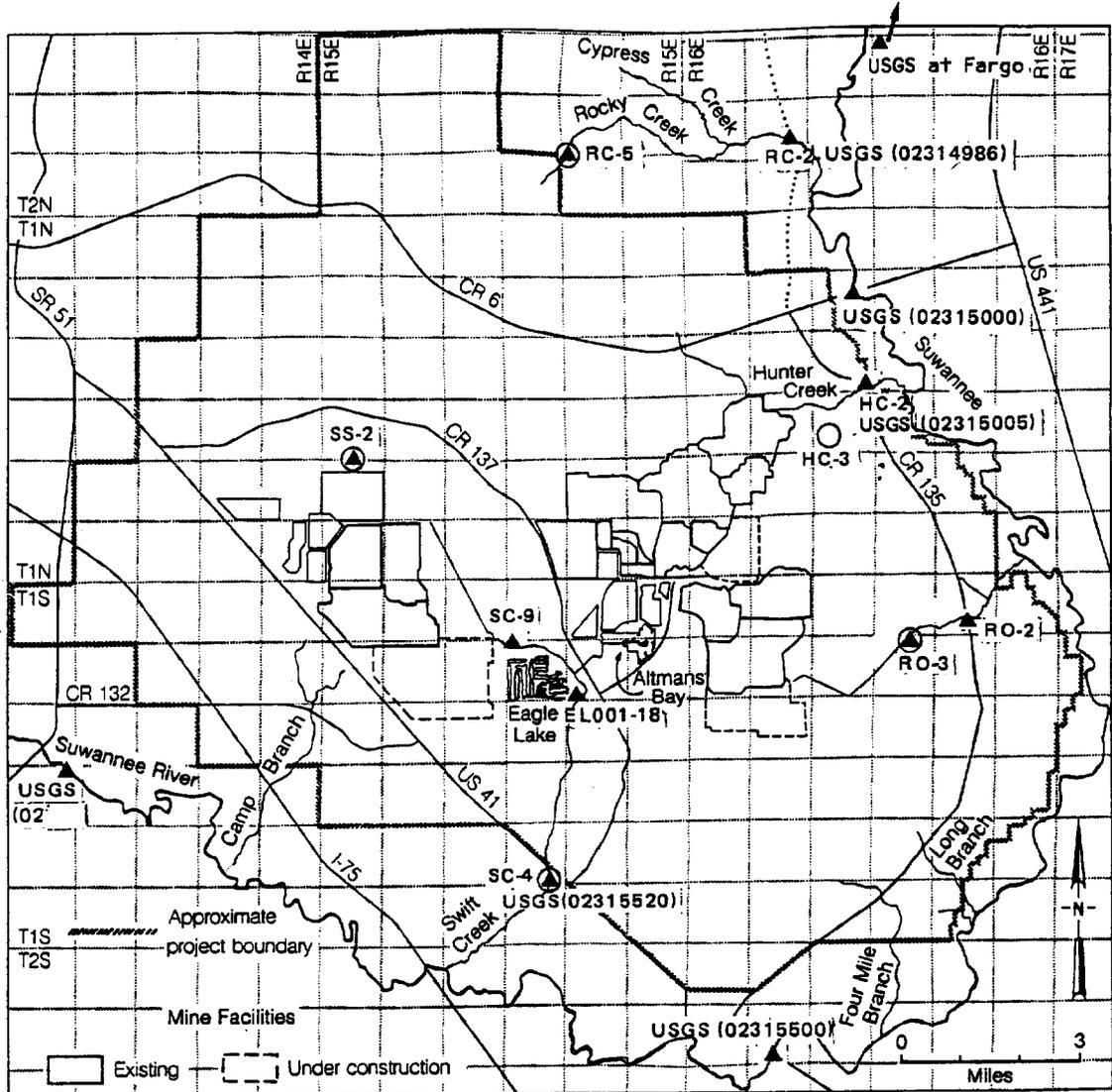


Figure 3.4-2. Portion of the Suwannee River Basin Modeled by HSPF.



NOTE: Does not reflect all areas affected by mining or mine support activities. See Figure 1.1-2.

- ▲ Daily flow and/or stage station
- Rainfall station

Figure 3.4-3. Rainfall Stations and Daily Flow and/or Stage Stations.

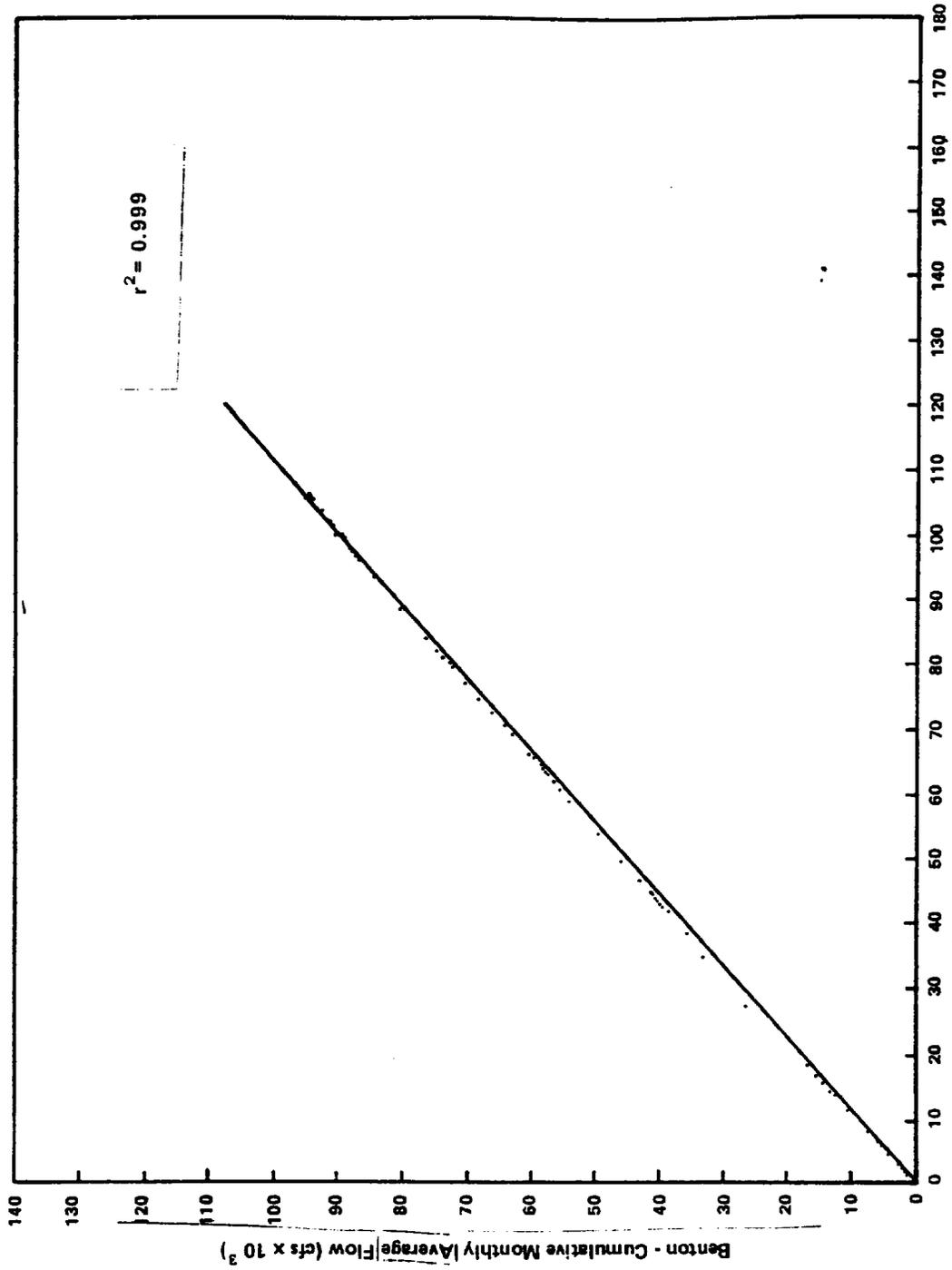


Figure 3.4-4. Double Mass Analysis for Suwannee River at Benton vs. Suwannee River at White Springs, Observed Data, October 1975-September 1981.

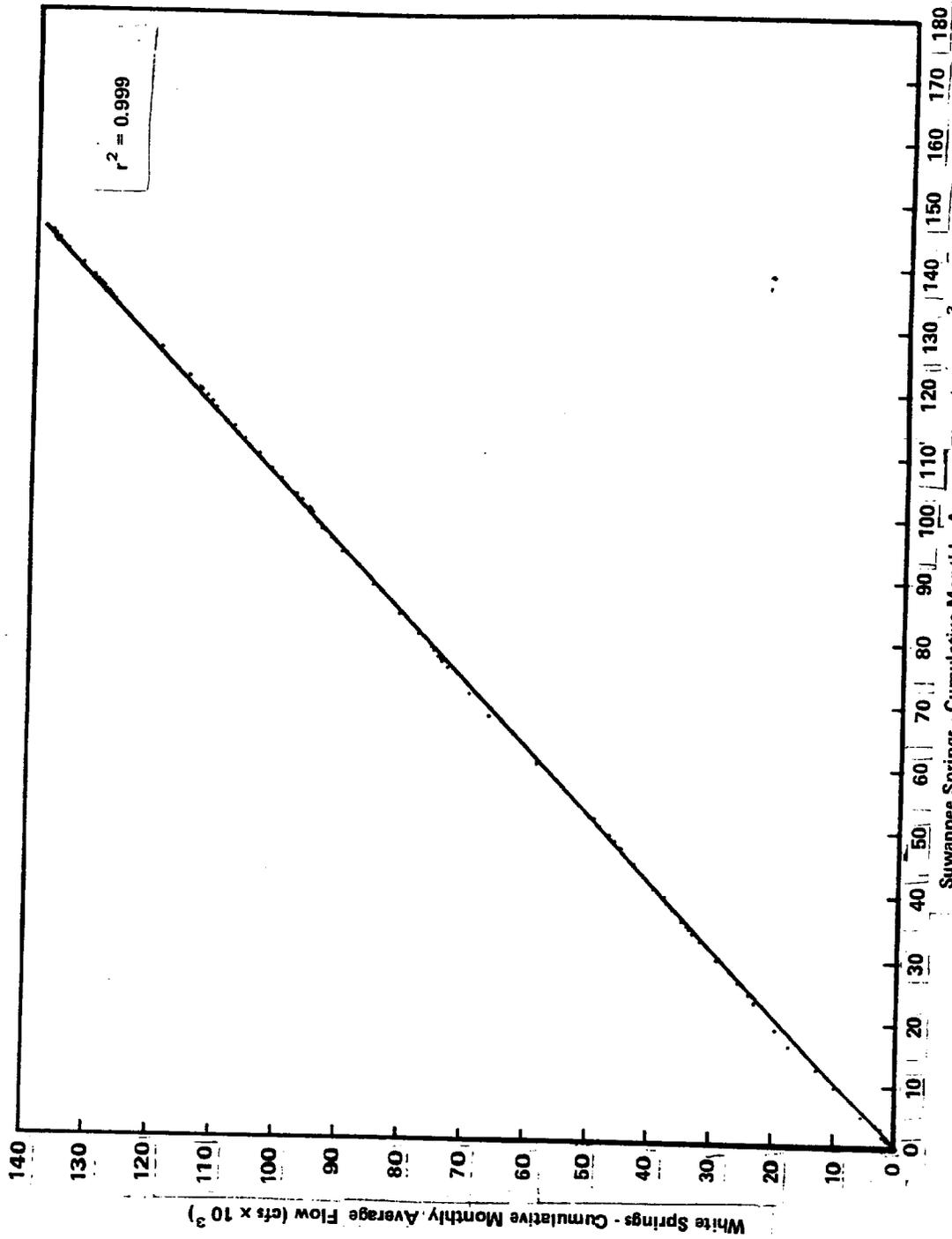


Figure 3.4-5. Double Mass Analysis for Suwannee River at White Springs vs. Suwannee River at Suwannee Springs, Observed Data, October 1974-September 1981.

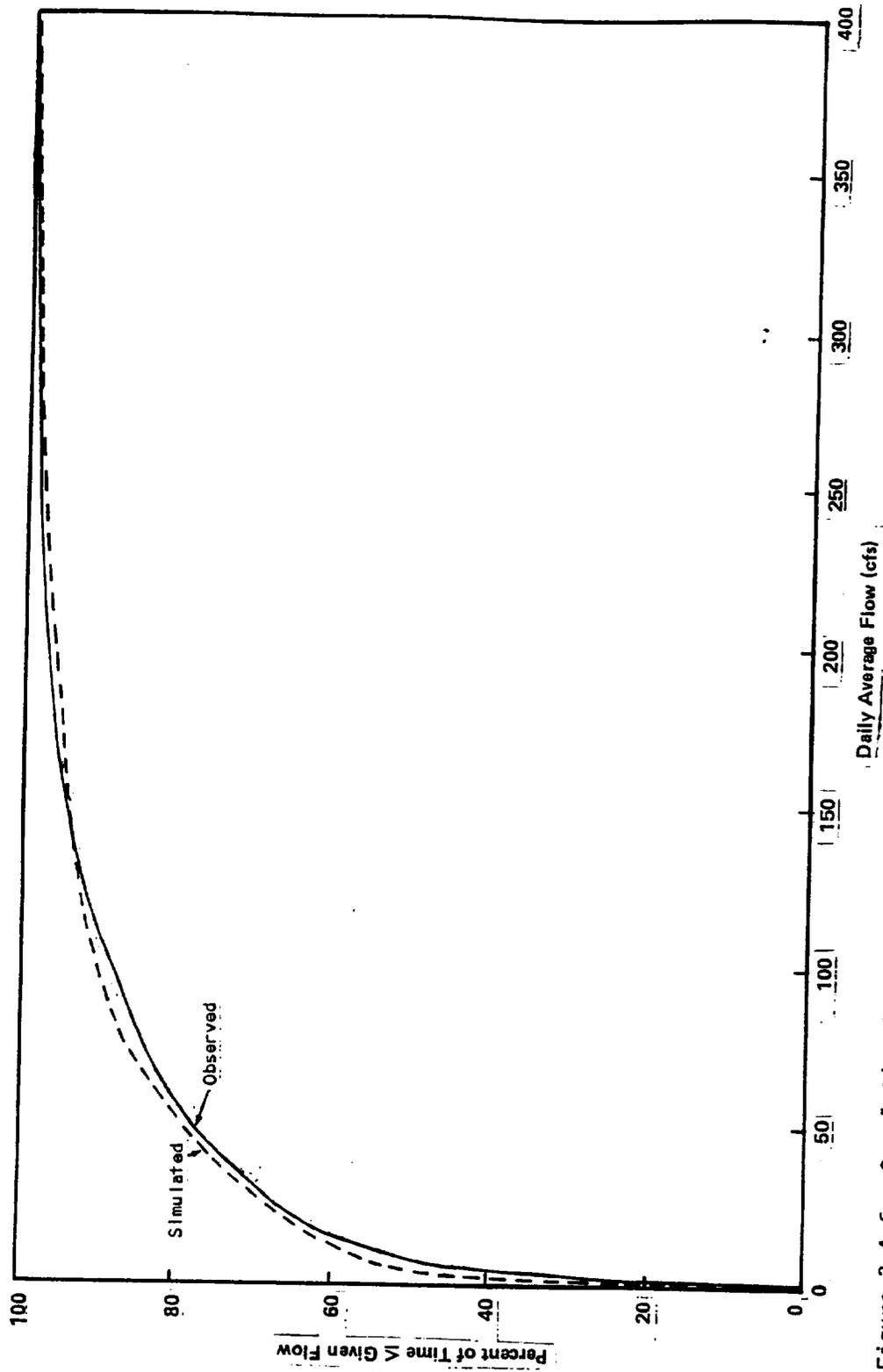


Figure 3.4-6. Cumulative Frequency Analysis for Rocky Creek at RC-2, HSPF Calibration/Verification, October 1976-September 1981.



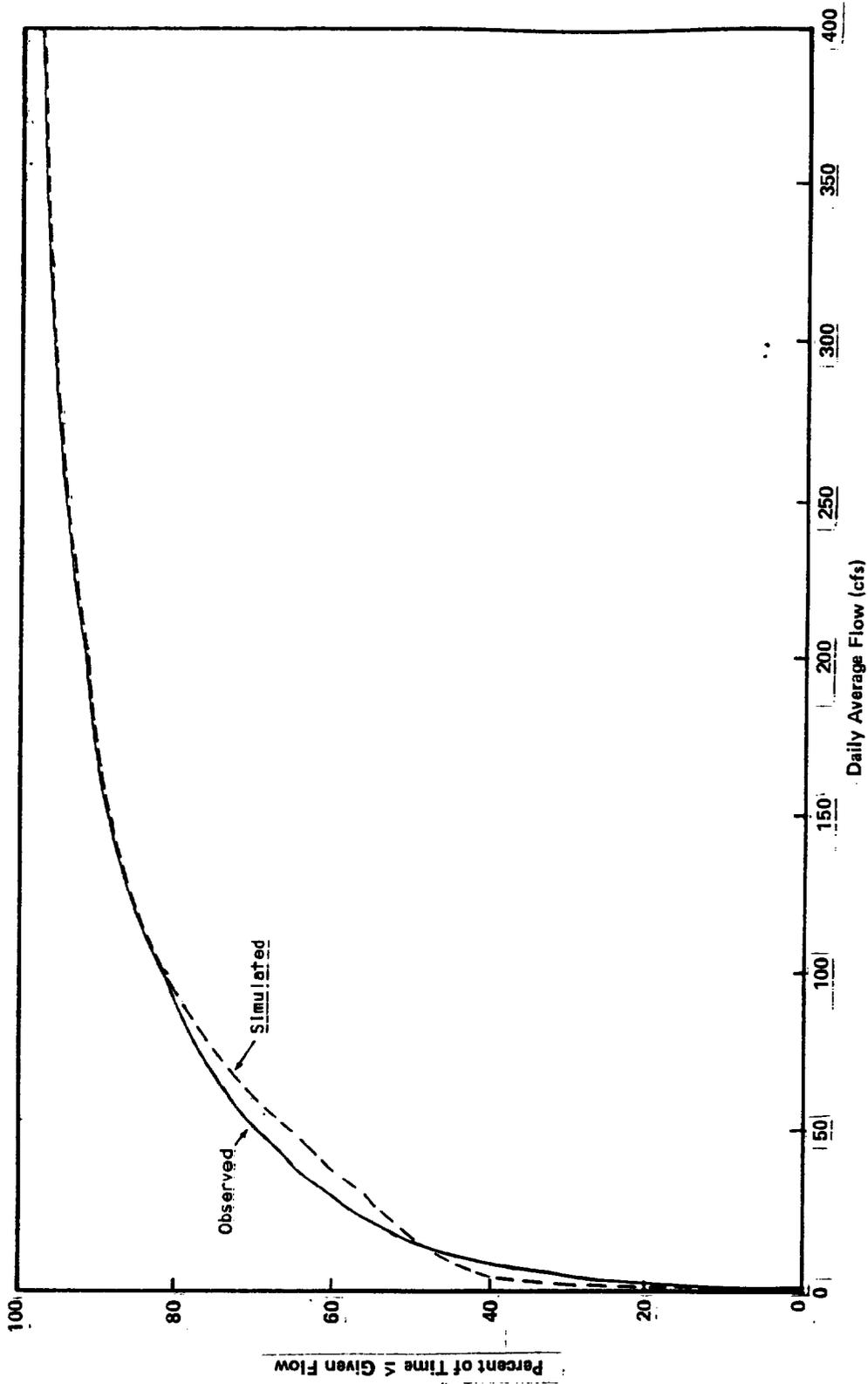


Figure 3.4-8. Cumulative Frequency Analysis for Deep Creek, HSPF Verification, October 1976-September 1981.



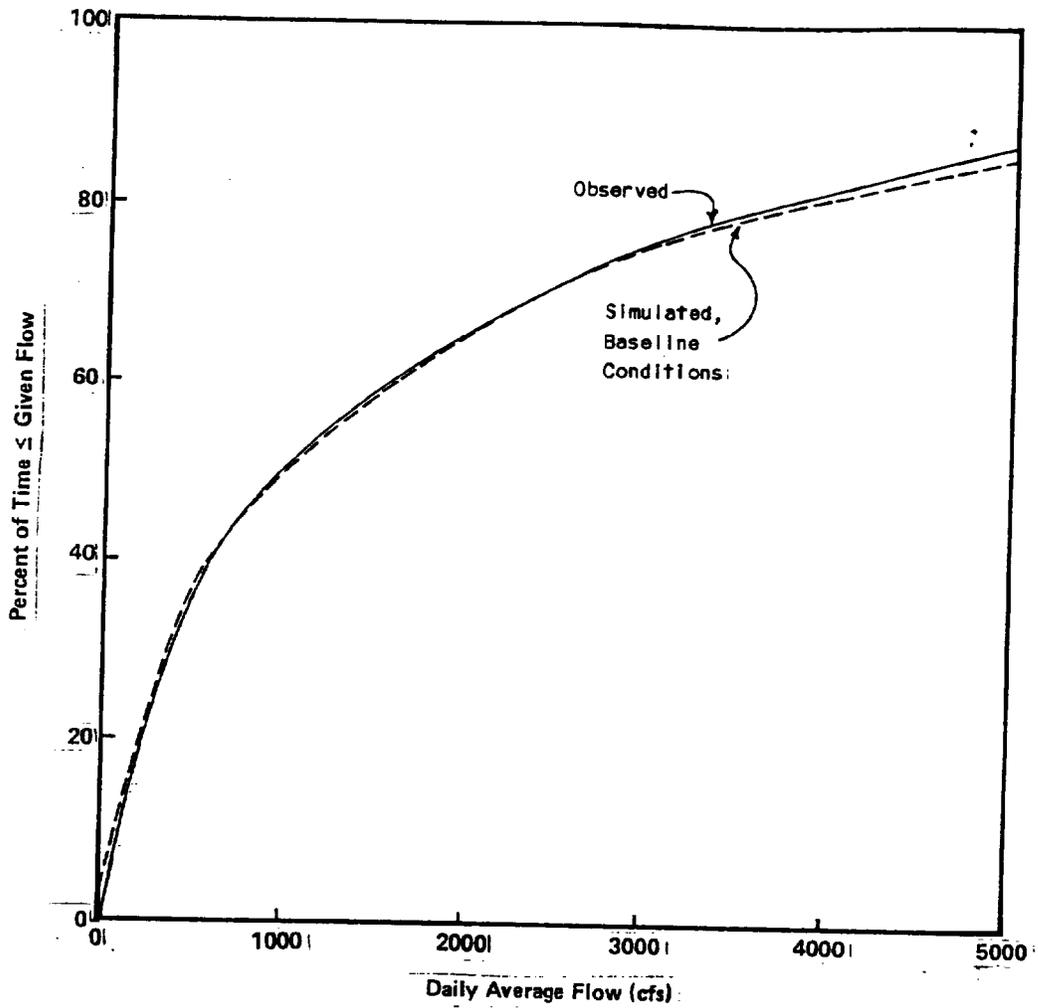


Figure 3.4-10. Cumulative Frequency Analysis for Suwannee River at White Springs under Simulated Baseline Conditions, HSPF Calibration, October 1959-September 1969.

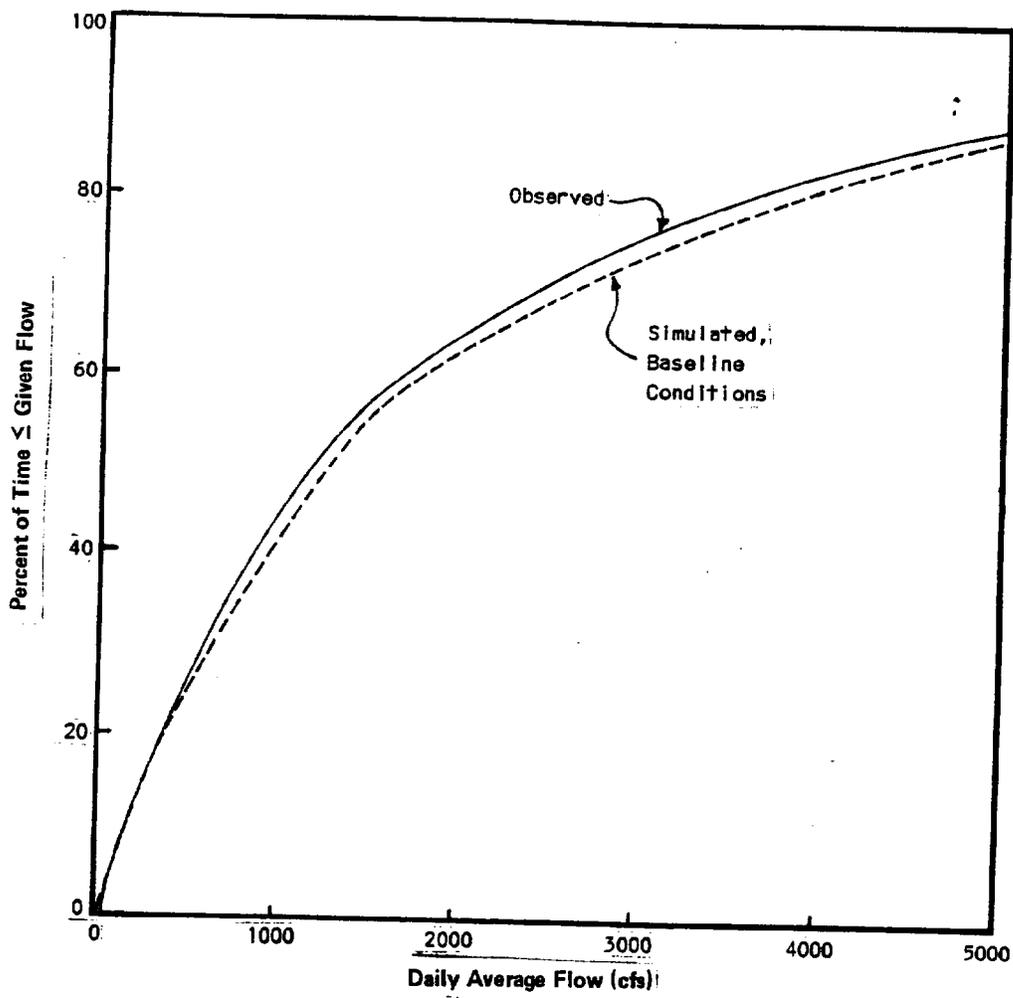


Figure 3.4-11. Cumulative Frequency Analysis for Suwannee River at White Springs under Simulated Baseline Conditions, HSPF Verification, October 1970-September 1979.

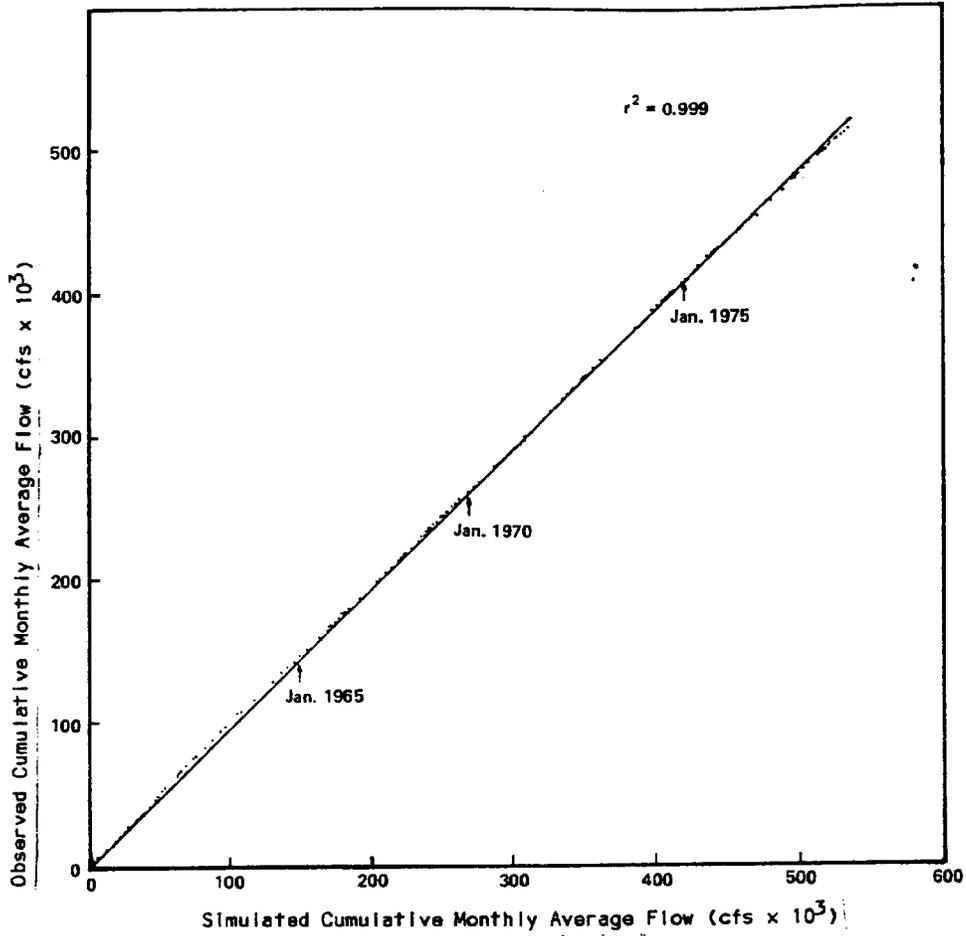


Figure 3.4-12. Double Mass Analysis for Suwannee River at White Springs, Observed Flow vs. Simulated Flow under Baseline Conditions, October 1959-September 1979.

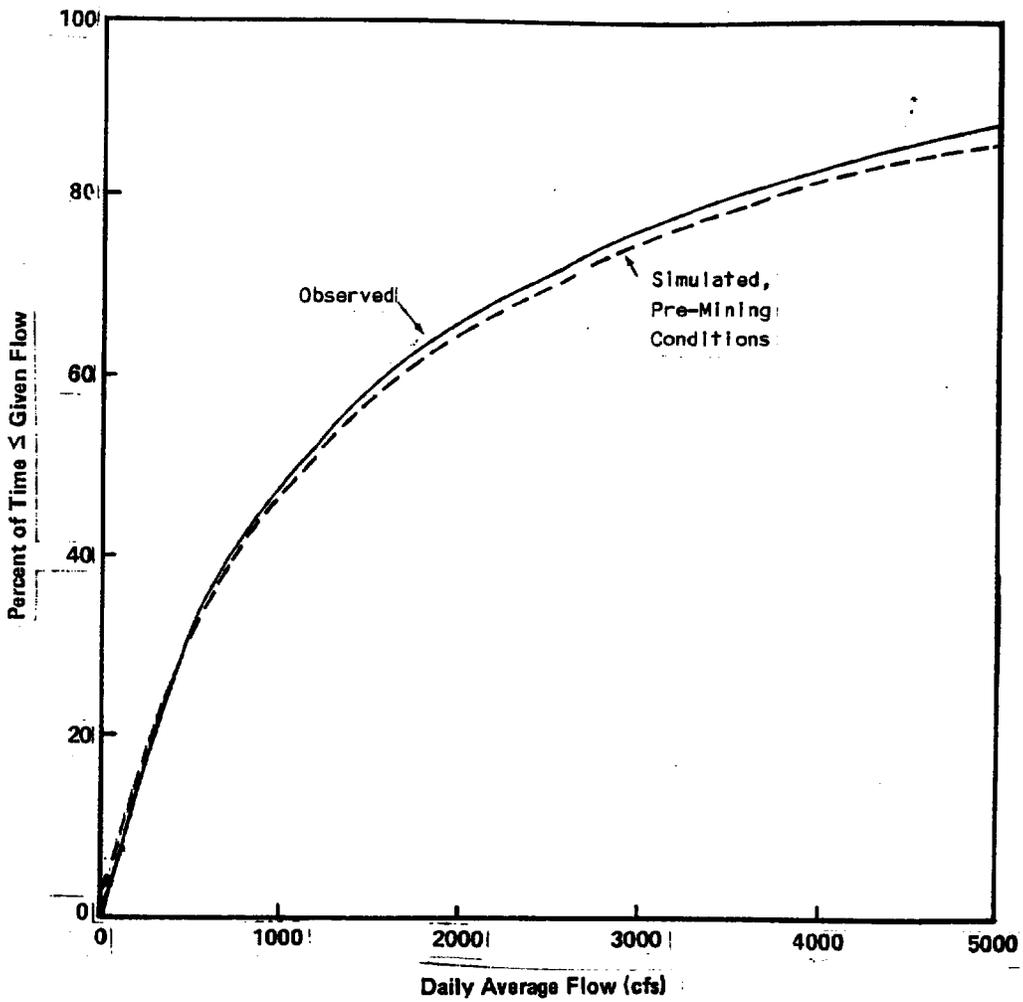


Figure 3.4-13. Cumulative Frequency Analysis for Suwannee River at White Springs under Simulated Pre-Mining Conditions, October 1959-September 1979.

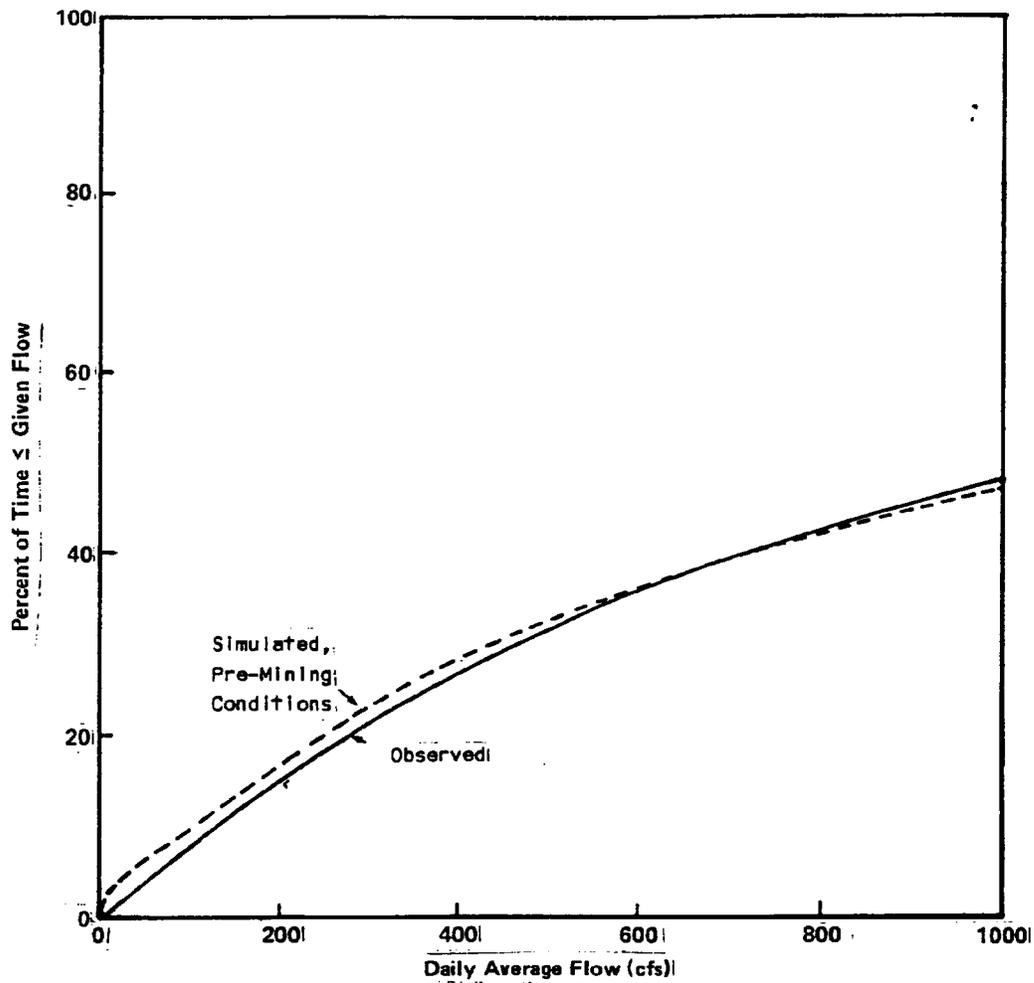


Figure 3.4-14. Cumulative Frequency Analysis for Suwannee River at White Springs under Simulated Pre-Mining Conditions, October 1959-September 1979 (expanded scale).

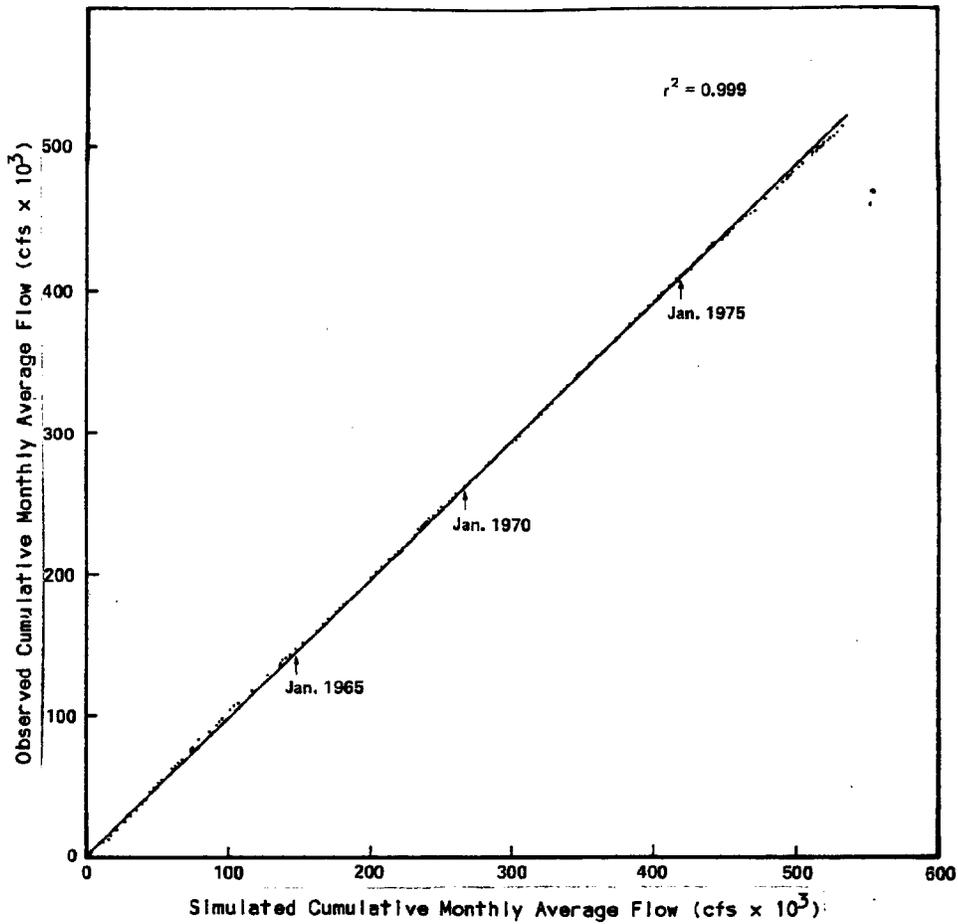


Figure 3.4-15. Double Mass Analysis for Suwannee River at White Springs, Observed Flow vs. Simulated Flow under Pre-Mining Conditions, October 1959-September 1979.

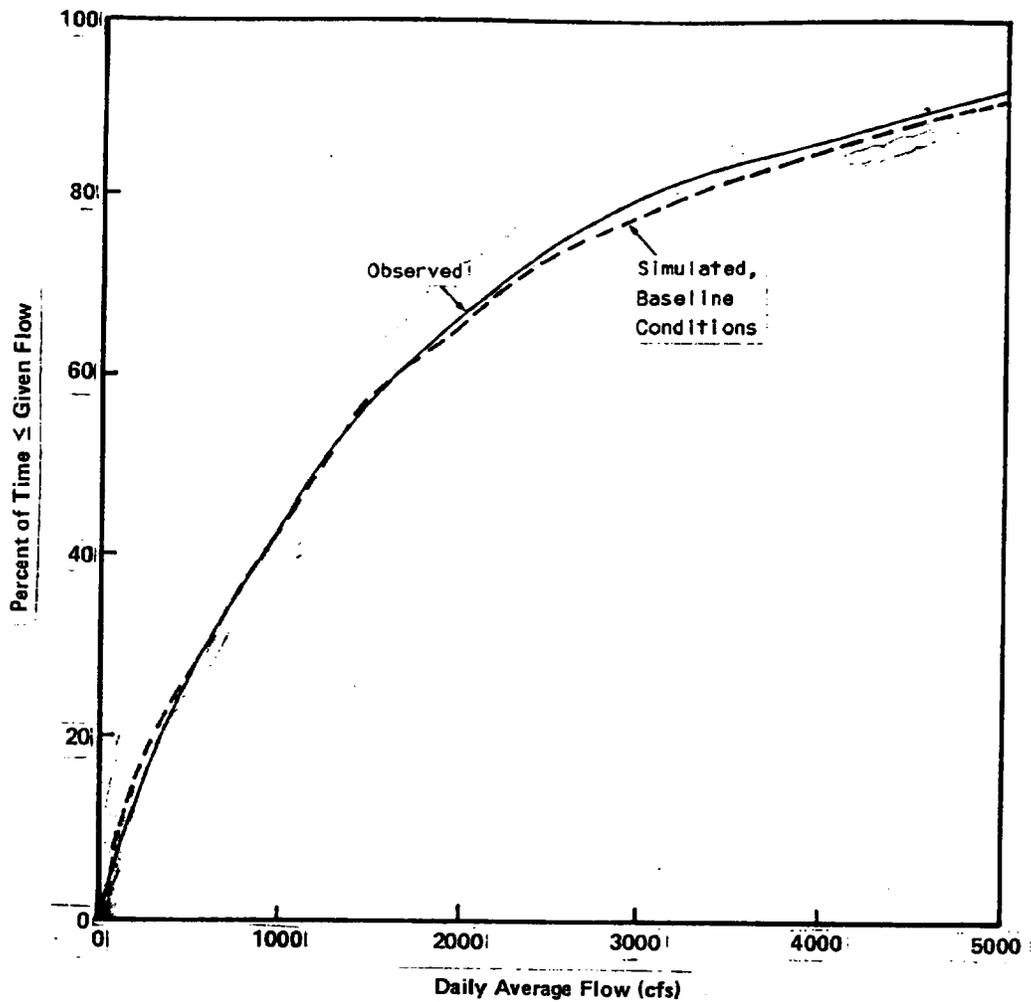


Figure 3.4-16. Cumulative Frequency Analysis for Suwannee River at Suwannee Springs under Simulated Baseline Conditions, October 1974-September 1979.

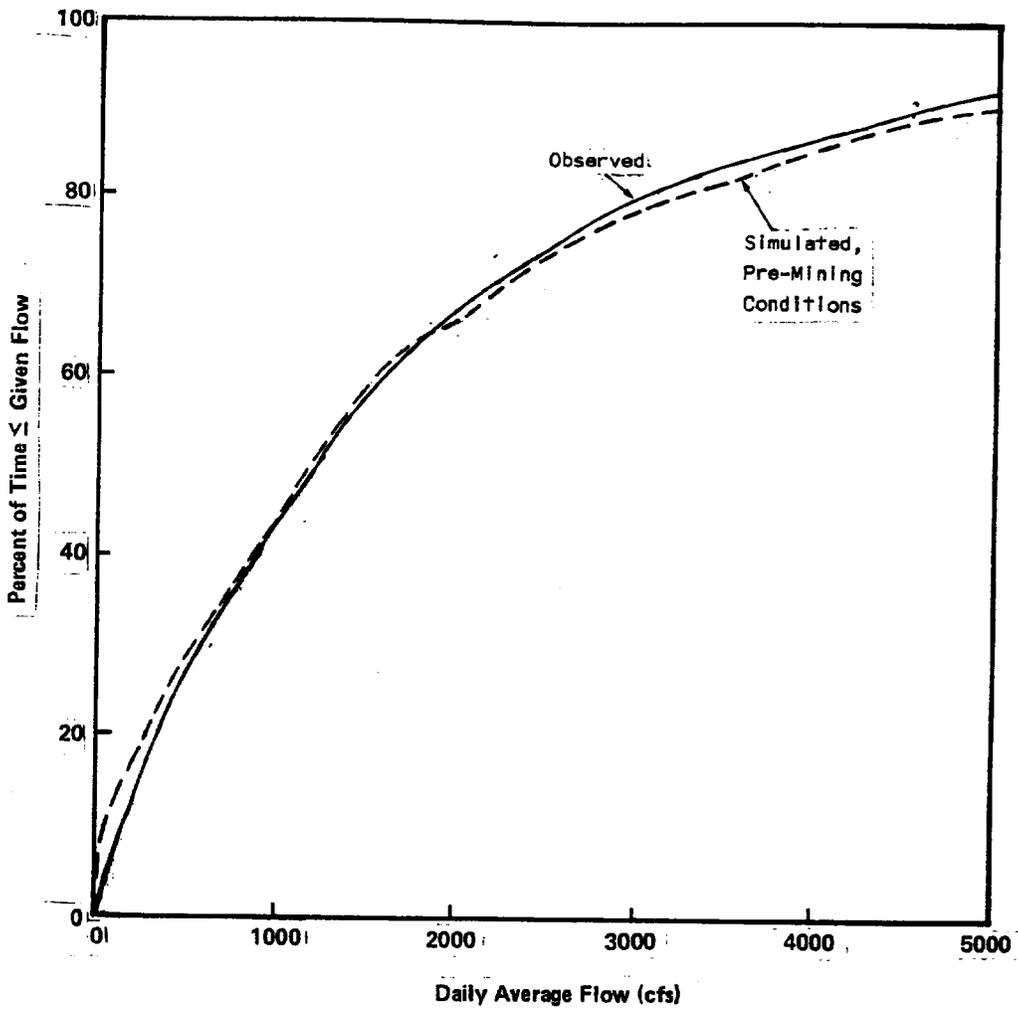


Figure 3.4-17. Cumulative Frequency Analysis for Suwannee River at Suwannee Springs under Simulated Pre-Mining Conditions, October 1974-September 1979.

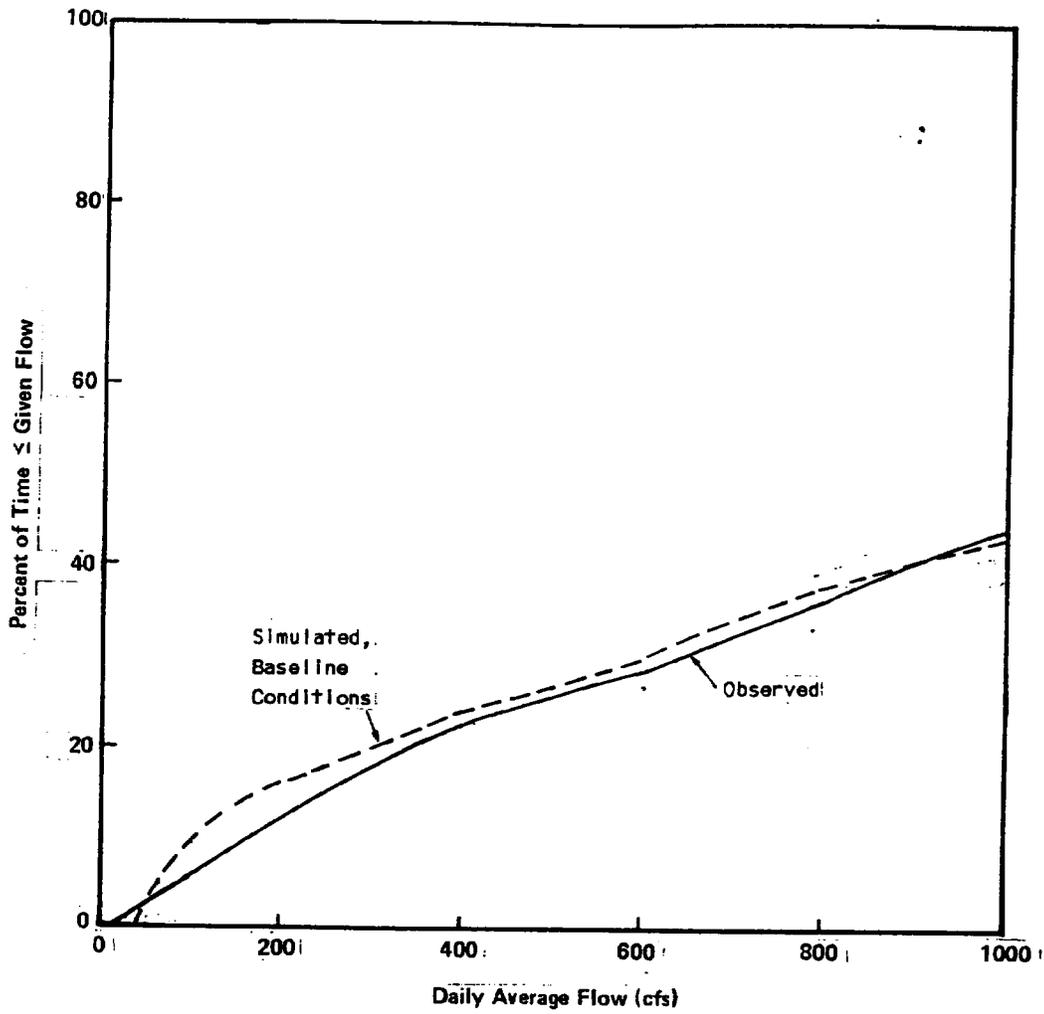


Figure 3.4-18. Cumulative Frequency Analysis for Suwannee River at Suwannee Springs under Simulated Baseline Conditions, October 1974-September 1979 (expanded scale).

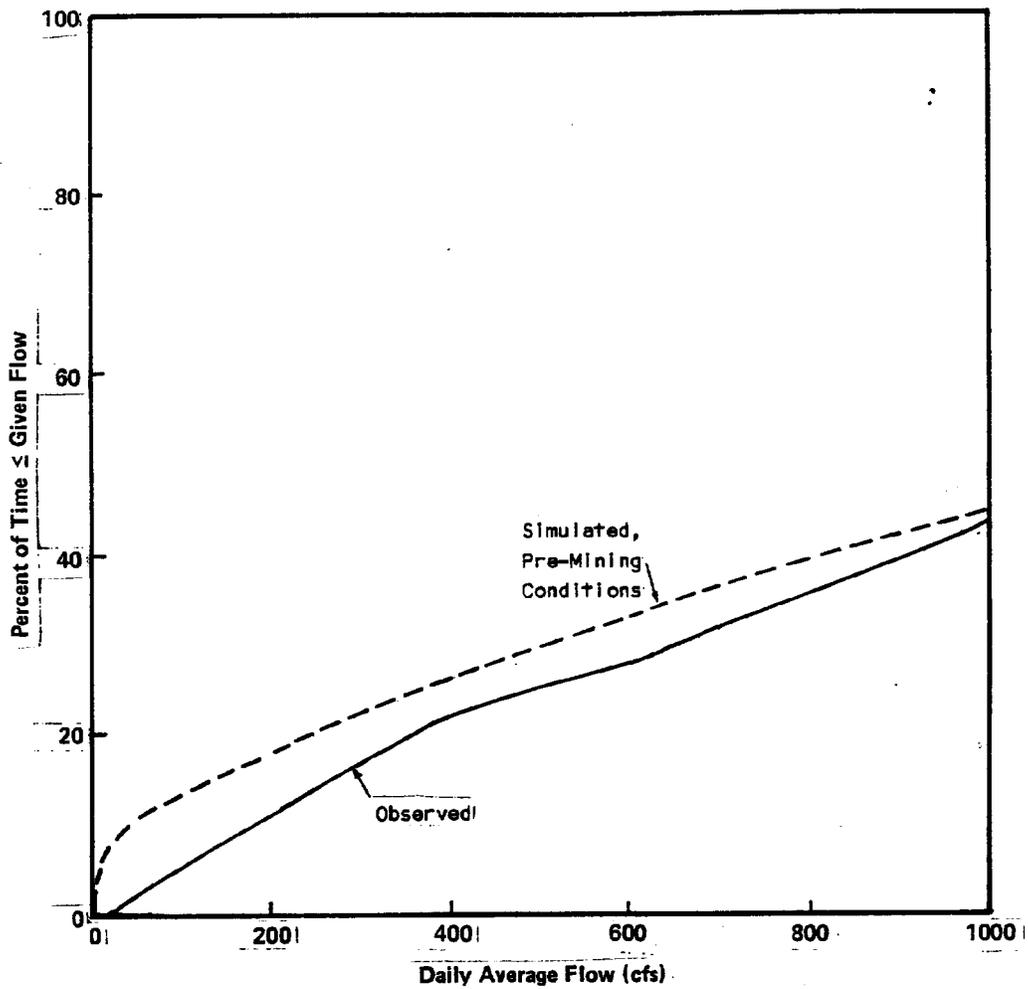


Figure 3.4-19. Cumulative Frequency Analysis for Suwannee River at Suwannee Springs under Simulated Pre-Mining Conditions, October 1974-September 1979 (expanded scale).

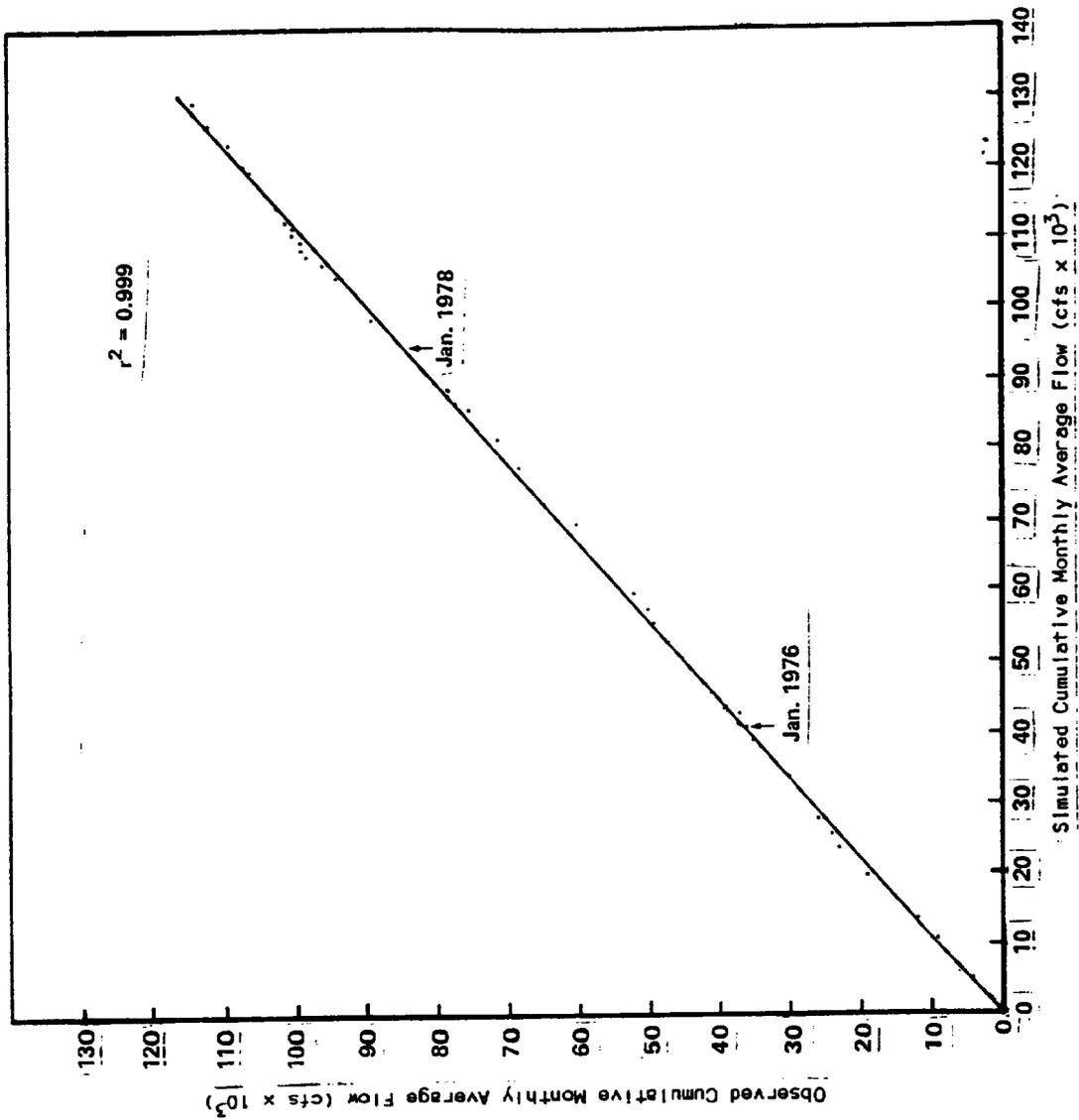


Figure 3.4-20. Double Mass Analysis for Suwannee River at Suwannee Springs, Observed Flow vs. Simulated Flow under Baseline Conditions, October 1974-September 1979.

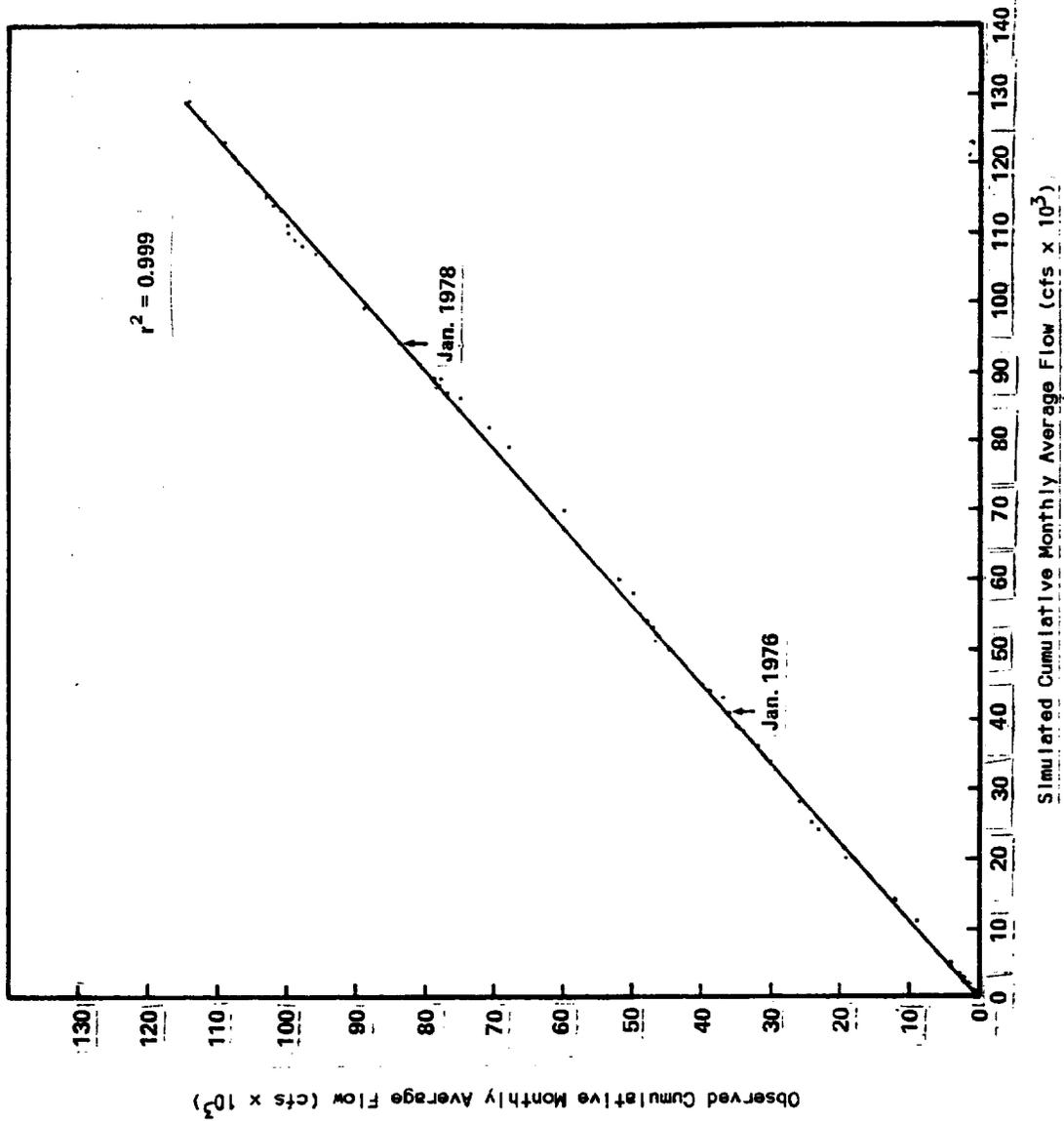


Figure 3.4-21. Double Mass Analysis for Suwannee River at Suwannee Springs, Observed Flow vs. Simulated Flow under Pre-Mining Conditions, October 1974-September 1979.

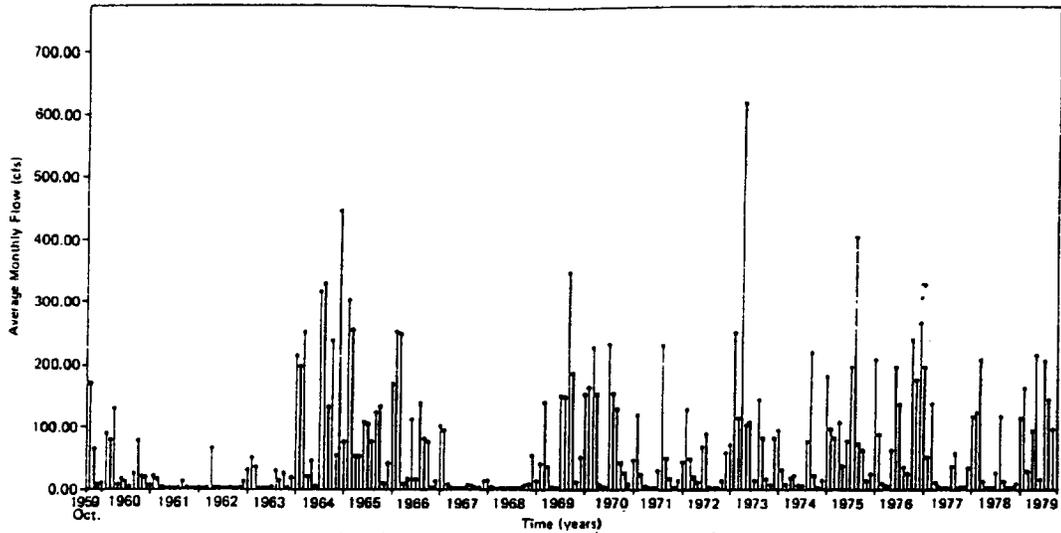


Figure 3.4-22. Monthly Average Flows, Rocky Creek, Baseline Conditions; Simulation Period October 1959-September 1979.

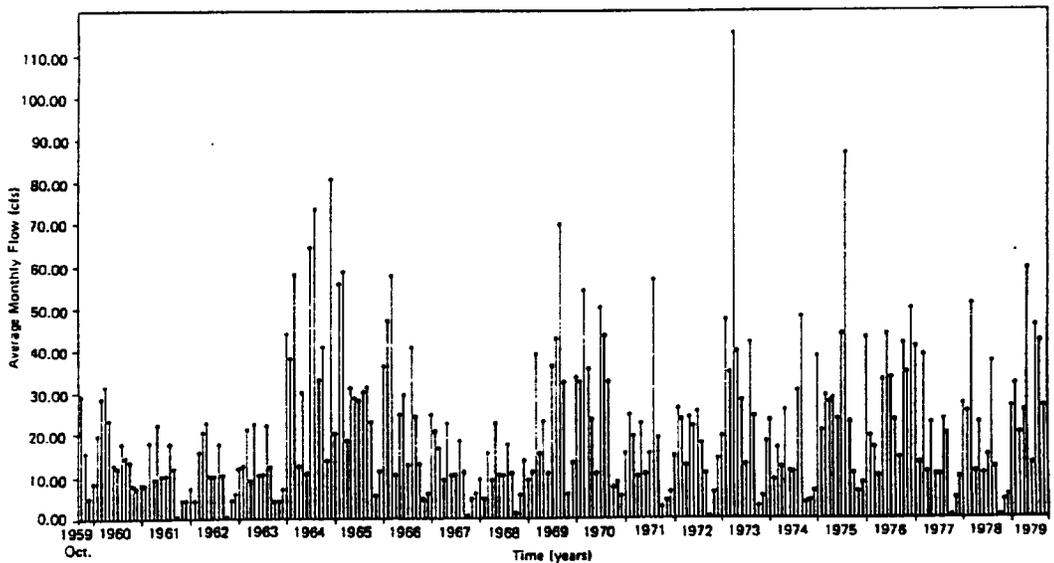


Figure 3.4-23. Monthly Average Flows, Hunter Creek, Baseline Conditions; Simulation Period October 1959-September 1979.

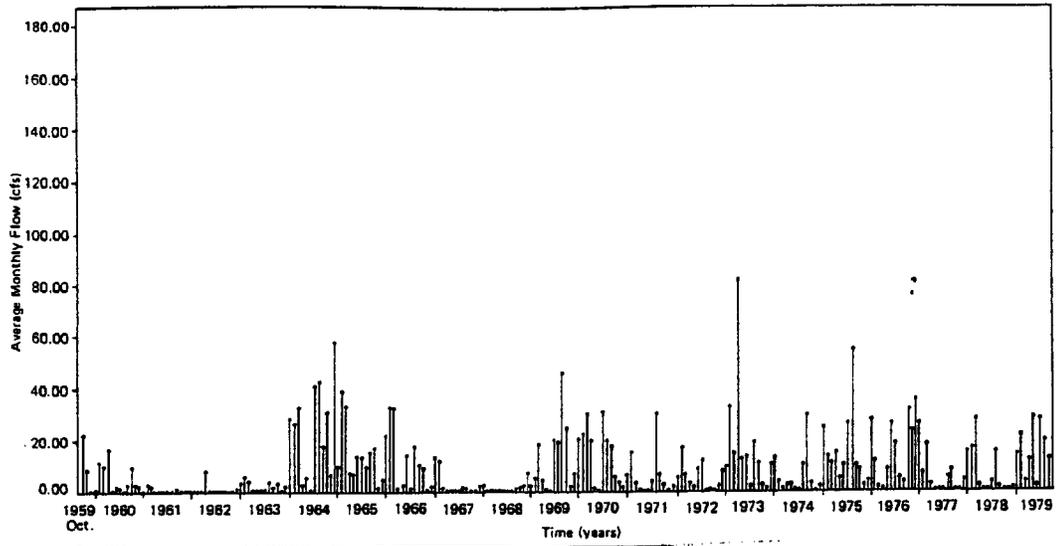


Figure 3.4-24. Monthly Average Flows, Roaring Creek, Baseline Conditions; Simulation Period October 1959-September 1979.

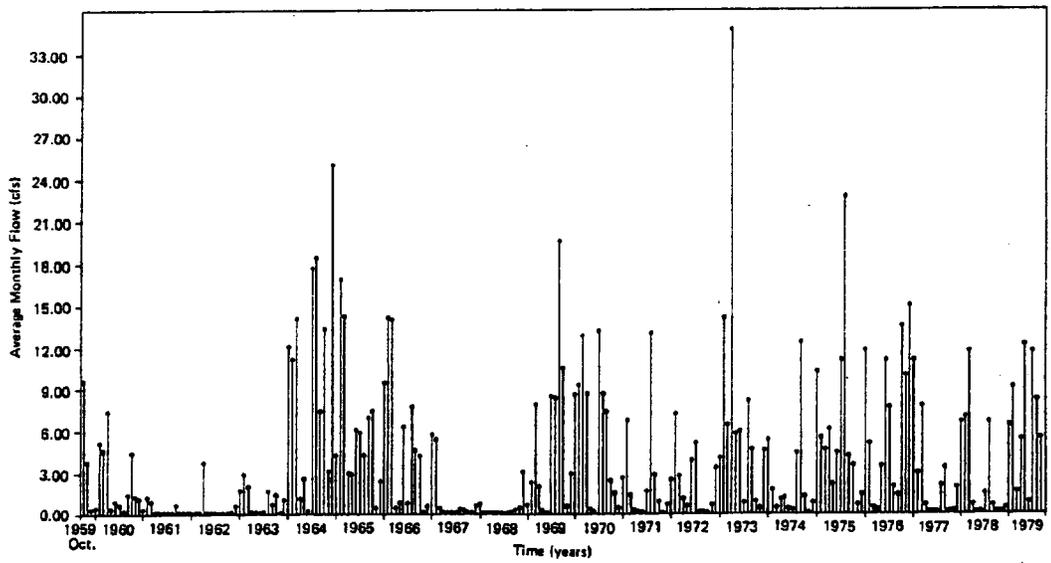


Figure 3.4-25. Monthly Average Flows, Long Branch, Baseline Conditions; Simulation Period October 1959-September 1979.

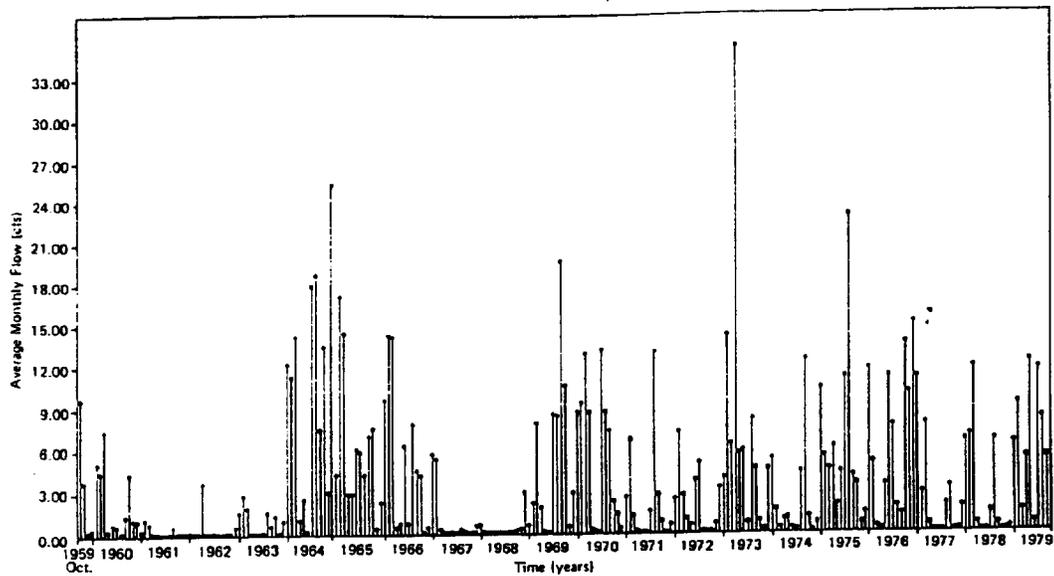


Figure 3.4-26. Monthly Average Flows, Four Mile Branch, Baseline Conditions; Simulation Period October 1959-September 1979.

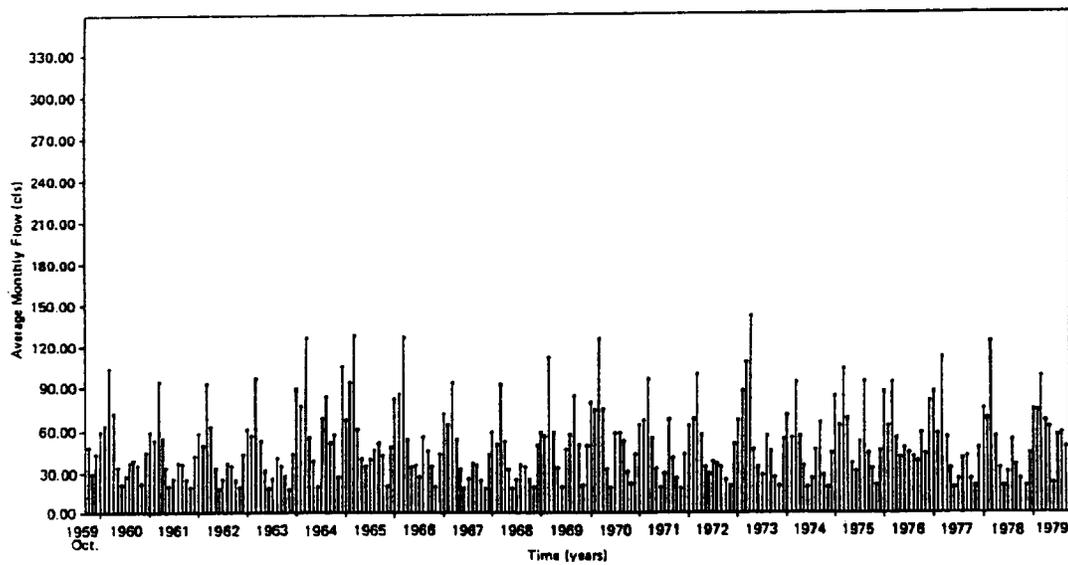


Figure 3.4-27. Monthly Average Flows, Swift Creek, Baseline Conditions; Simulation Period October 1959-September 1979.

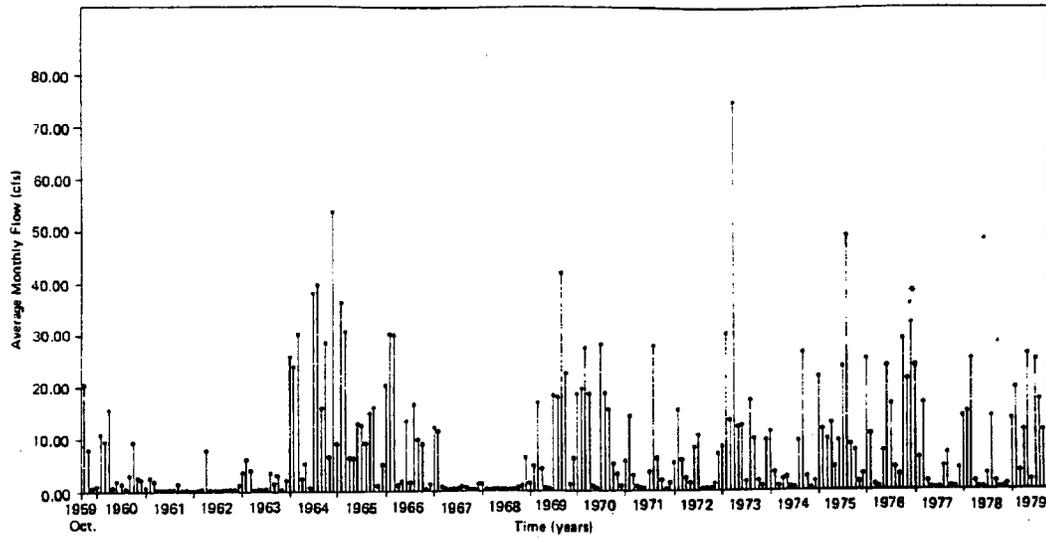


Figure 3.4-28. Monthly Average Flows, Camp Branch, Baseline Conditions; Simulation Period October 1959-September 1979.

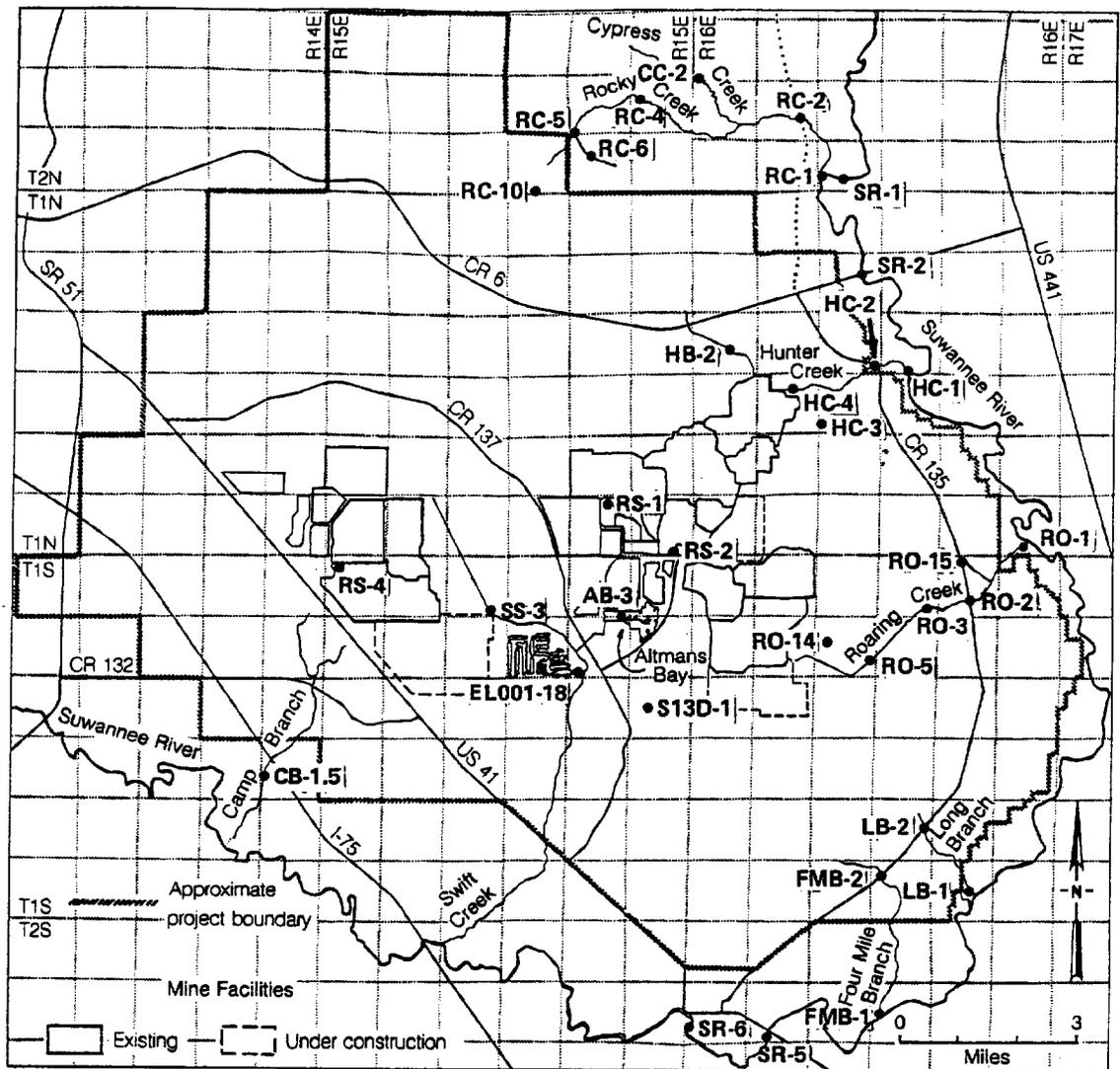
### 3.4.2 Surface Water Quality

The study area is situated within the 10,000 sq mi Suwannee River drainage basin. The headwaters of the Suwannee are located at the Okefenokee Swamp in south Georgia, below which the river forms and meanders approximately 200 mi through Florida to the Gulf of Mexico. The project boundary is approximately 150 river miles upstream from the Gulf. River flow upstream of White Springs consists mainly of surface drainage from the Okefenokee, tributary wetlands, and uplands runoff. Water quality characteristics are typical of wetland drainage: high color and low pH, hardness, alkalinity, and conductivity. Downstream of White Springs, groundwater inflow from springs and seepage from the Floridan Aquifer increase greatly (Miller et al. 1978). However, during some periods the river apparently recharges the springs (Hull et al. 1981). Tributaries to the Suwannee include numerous small streams and three major rivers: the Alapaha, Withlacoochee, and Santa Fe.

#### 3.4.2.1 Existing Water Quality Conditions

Water quality data used in this study were collected every other week from November 1979 through July 1981 and monthly from August 1981 through March 1982 (Figures 3.4-29 and 3.4-30, Table 3.4-13). A discussion of the methods and quality assurance procedures used in collection and analysis is included in Section 3.4.4.1. In addition, a summary of USGS data collected November 1968 to December 1980 (Figure 3.4-31) is presented in Appendix A. The two programs provide an extensive background data base. The USGS has published annual reports which compare data for the current year to preceding years back to 1978 (Coffin 1981, 1982; USGS 1983). In the 1982 report, Coffin states "All results of the analyses of the water quality samples collected from January through December 1980 remained within, or near, previously measured ranges, and water quality fluctuations were similar to those noted from data collected since 1971." The 1983 data release includes 1981 and 1982 data as well, but no analysis of the results was provided. Based on the time trend graphs presented, a similar statement can be made for the 1981 and 1982 values.

Suwannee River and Major Tributaries. A recently published USGS report compiled and analyzed data collected from August 1968 through December 1977 for the Suwannee River and major tributaries (Hull et al. 1981). Mean concentrations (median for pH) of selected water quality parameters at Suwannee River stations were examined in downstream order between Fargo, Georgia and Wilcox, Florida. The results indicated general trends for many parameters which are also evident in the data collected for this study (Table 3.4-14). These trends may be summarized as follows (Hull et al. 1981 and Table 3.4-14):



NOTE: Does not reflect all areas affected by mining or mine support activities. See Figure 1.1-2.

● Sampling station

Figure 3.4-29. Location of Water Quality Sampling Stations Within the OXY Study Area.

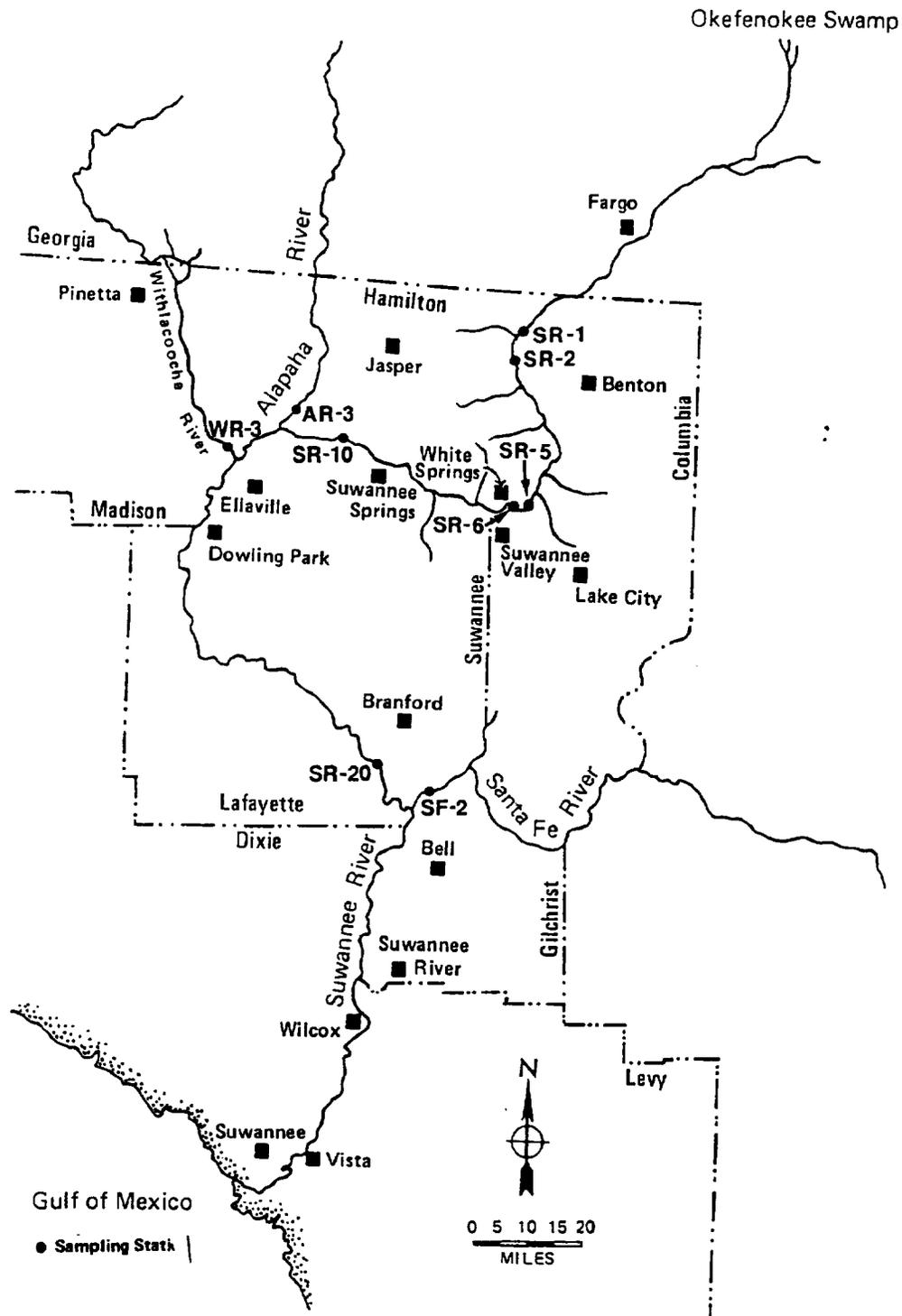


Figure 3.4-30. Location of Water Quality Sampling Stations on the Suwannee River and Major River Tributaries.

Table 3.4-13. Water Quality Sampling Stations Discussed in EIS.

Station	Location	Period Sampled
SR-1	Suwannee River, upstream of Rocky Creek	08/81, 02/82
SR-2	Suwannee River, CR 6 bridge	11/30/79 - Present
SR-5	Suwannee River at White Springs, US 41 bridge (USGS Station No. 02315500)	11/30/79 - Present
SR-6	Suwannee River at White Springs, CR 136 bridge	11/30/79 - 10/21/80
SR-10	Suwannee River just upstream of Suwannee Springs	08/25/81 - Present
AR-3	Alapaha River near the mouth	08/25/81 - Present
WR-3	Withlacoochee River near Ellaville	08/25/81 - Present
SR-20	Suwannee River at Branford, US 129 bridge	08/25/81 - Present
SF-2	Santa Fe River at US 129 bridge	08/25/81 - Present
RC-1	Rocky Creek at the mouth	11/30/79 - 04/01/80
RC-2	Rocky Creek, Woodpecker Road wooden bridge (USGS station No. 02314986)	11/30/79 - Present
CC-2	Cypress Creek approx. 0.75 mi upstream from the mouth	11/30/79 - Present
RC-4	Rocky Creek, Christie Tower Road culvert	12/09/79 - 04/29/80
RC-5	Rocky Creek, unmaintained wooden bridge	11/30/79 - Present
RC-6	Rocky Creek, Christie Tower Road culvert	12/09/79 - Present
RC-10	Rocky Creek, northeast section of Bee Haven Bay at culvert	11/30/79 - Present
HB-2	Hogans Branch at Sugar Ridge Road	11/19/81 - Present
HC-1	Hunter Creek at the mouth	11/30/79 - 04/29/80
HC-2	Hunter Creek, CR 135 bridge (USGS station)	11/30/79 - Present
HC-3	Hunter Creek, upstream side of culvert	11/30/79 - Present
HC-4	Hunter Creek near settling area No. 11	11/20/81 - Present
RO-1	Roaring Creek at the mouth	11/30/79 - 04/29/80
RO-2	Roaring Creek, CR 135 bridge	11/30/79 - Present
RO-5	Roaring Creek, wooden bridge	11/30/79 - Present
RO-14	Swamp headwaters to Roaring Creek	12/28/79 - Present
RO-15	Roaring Creek, CR 135 culvert	01/11/82 - Present
LB-1	Long Branch at the mouth	12/09/79 - 04/01/80
LB-2	Long Branch, CR 135 bridge culvert	11/30/79 - Present
FMB-1	Four Mile Branch at the mouth	01/09/80 - 04/29/80
FMB-2	Four Mile Branch, CR 135 bridge culvert	11/30/79 - Present
SS-3	Swift Creek downstream of swamp near creek control structure	05/12/80 - Present
CB-1.5	Camp Branch at CR 225A	11/30/81 - Present
EL001-18	Eagle Lake, exit control structure-- discharge to Swift Creek	04/29/80 - Present
AB-3	Altman's Bay, exit control structure	05/12/80 - Present
S13D-1	Section 13D Lake, exit control structure	11/30/79 - Present
RS-1	Recirculating water, Suwannee River Chemical Complex	05/12/80 - Present
RS-2	Recirculating water, Suwannee River Chemical Complex	05/12/80 - 01/15/80
RS-4	Recirculating water just before entering pumps, Swift Creek Chemical Complex	08/19/81 - Present

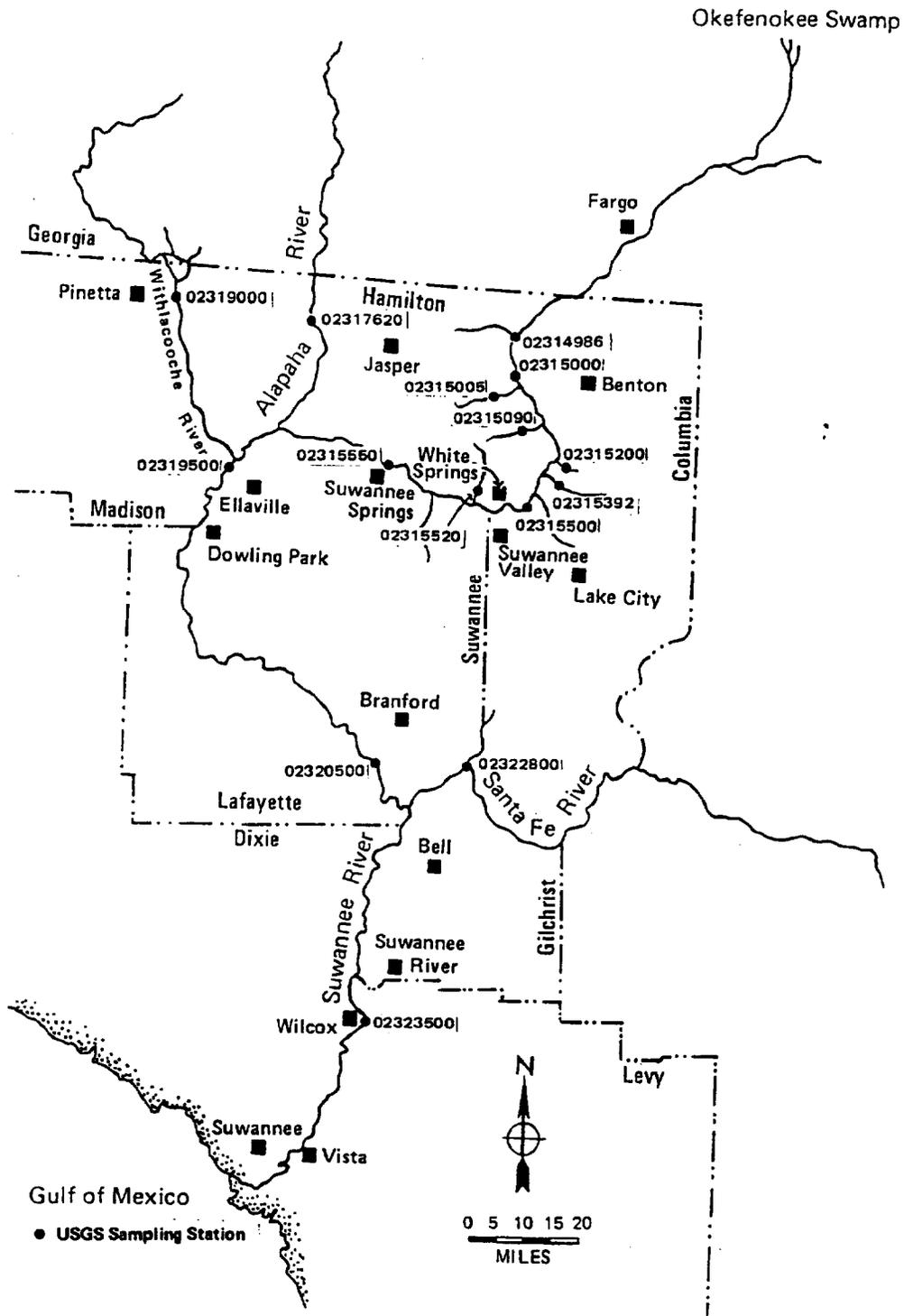


Figure 3.4-31. Location of USGS Water Quality Sampling Stations in the Suwannee River Drainage Basin.

Table 3.4-14. Summary Data for Selected Chemical Surface Water Parameters Measured at Stations on the Suwannee River (November 1979 - March 1982).

Parameter	SR-2			SR-5			SR-6			SR-10			SR-20		
Flow (cfs)	0	-	-	0	-	-	0	-	-	0	-	-	0	-	-
Conductivity, field (umhos/cm)	36 <sup>1</sup> 36 <sup>2</sup>	53 <sup>3</sup>	54 <sup>4</sup> 78 <sup>5</sup>	34 38	63	69 140	10 42	64	68 123	8 50	202 440	8 83	331	267 360	
Alkalinity as CaCO <sub>3</sub> (mg/l)	42 0	0	0.7 9.8	43 0	0	5.6 35.0	18 0	0	0.1 2.6	8 0	31.9 35.5	68.0	8 5.3	133.0 151.0	97.5
Total hardness as CaCO <sub>3</sub> (mg/l)	43 4	10	11 21	43 5	17	21 54	18 8	12	14 25	8 28	72 83	116	8 28	151 174	122
pH, field	30 2.8	3.5	3.4 <sup>6</sup> 6.4	28 2.8	5.0	3.7 6.6	6 3.3	3.7	3.6 5.6	8 4.2	5.0 6.0	6.9	8 6.4	7.8	6.9 8.1
Fluoride (mg/l)	43 0.01	0.03	0.05 0.19	43 0.02	0.06	0.13 0.52	18 0.02	0.04	0.05 0.15	8 0.16	0.97 1.07	1.74	8 0.09	0.19	0.22 0.33
Sulfate (mg/l)	43 0	0	0	43 0	0	2.5 26.2	18 0	0	0	8 0	39.9 44.1	126.4	8 0	24.7	17.3 30.8
Total phosphate as P (mg/l)	42 0.01	0.06	0.07 0.24	42 0.02	0.11	0.18 0.56	18 0.05	0.08	0.10 0.24	7 0.78	2.66 3.49	4.31	8 0.12	0.29	0.34 0.67
Total dissolved phosphate as P (mg/l)	43 0	0.05	0.09 0.57	43 0.01	0.10	0.16 0.53	18 0.04	0.07	0.09 0.16	8 0.58	2.49 2.72	4.21	8 0.02	0.31	0.32 0.60
Orthophosphate as P (mg/l)	43 0.01	0.06	0.08 0.49	43 0.04	0.15	0.18 0.52	18 0.06	0.11	0.14 0.26	8 0.51	2.22 2.40	4.20	8 0.14	0.22	0.28 0.52
Dissolved oxygen (mg/l)	42 6.0	7.3	7.9 13.9	41 5.5	7.5	8.1 12.2	16 5.3	7.4	8.0 11.0	8 4.2	7.2 7.3	9.0	8 4.8	6.4	6.4 8.6
Total suspended solids (mg/l)	43 0	1.2	1.9 10.3	43 0	1.0	1.9 18.0	18 0	1.7	2.5 8.3	8 0.8	3.9 2.9	10.0	8 0.7	2.3	2.8 6.3
Total dissolved solids (mg/l)	43 69	100	99 130	43 59	106	109 161	18 80	99	101 140	8 141	187 191	265	8 101	195	176 221
Color (Pt-Co units)	43 200	300	319 480	43 200	300	316 500	18 260	310	342 460	8 185	300 288	450	8 23	80	105 215
Tannin-lignin (mg/l)	43 4.93	7.24	7.21 9.00	43 3.57	7.05	6.75 8.57	18 6.14	7.59	7.50 8.54	8 2.84	4.99 4.73	7.39	8 0.67	2.05	2.15 3.62
Ammonia as N (mg/l)	42 0.01	0.02	0.03 0.15	43 0.01	0.03	0.08 0.93	18 0.01	0.04	0.06 0.17	6 0.02	0.56 0.48	1.42	8 0.01	0.07	0.08 0.15
Nitrate/nitrite as N (mg/l)	43 0	0.01	0.02 0.06	43 0.01	0.05	0.06 0.20	18 0.01	0.02	0.03 0.10	8 0.15	0.71 0.83	1.17	8 0.15	0.75	0.63 1.05
Total organic nitrogen as N (mg/l)	42 0.54	0.97	0.98 1.47	42 0.62	0.93	0.95 1.43	18 0.44	1.02	1.05 1.60	7 0.74	1.80 1.01	6.46	8 0.20	0.41	0.44 0.94
Total nitrogen as N (mg/l)	43 0.60	1.04	1.02 1.53	42 0.68	1.04	1.09 1.70	18 0.62	1.15	1.14 1.68	8 1.23	2.78 2.21	7.63	8 0.66	1.25	1.16 1.44
Total organic carbon as C (mg/l)	43 27.0	45.7	48.2 80.1	40 27.7	45.8	46.2 86.0	17 31.4	44.7	49.2 94.5	8 27.5	43.3 42.7	56.4	8 12.4	26.2	26.2 34.5
Dissolved organic carbon as C (mg/l)	43 23.8	43.8	44.7 81.7	40 23.4	44.0	44.1 73.4	17 34.9	46.0	48.6 73.0	8 23.1	41.1 42.0	56.5	8 8.4	30.8	26.1 35.9
Particulate organic carbon as C (mg/l)	43 0	2.9	5.8 36.3	40 0	1.6	3.8 44.4	17 0	0	6.9 55.9	8 0	3.1 3.8	4.8	8 0	1.5	2.7 9.5
Chlorophyll a (mg/m <sup>3</sup> ) (pheophytin-corrected)	25 0	1.16	1.91 7.85	26 0	0.94	3.29 56.94	1 0.40	-	0.40	8 0	4.47 1.76	26.03	8 0	0.19	0.78 2.40

<sup>1</sup>Number of samples.

<sup>2</sup>Minimum value.

<sup>3</sup>Median.

<sup>4</sup>Mean.

<sup>5</sup>Maximum value.

<sup>6</sup>Based on hydrogen ion concentration.

Parameters exhibiting  
no or variable trends

Parameters increasing  
downstream

Turbidity	Conductivity	Nitrate
Temperature	Alkalinity	Calcium
Dissolved oxygen	Total hardness	Magnesium
BOD <sub>5</sub>	Sulfate	Bicarbonate
Chloride	pH	Sodium
Nitrite	Total dissolved solids	Potassium
Fluoride	Total organic carbon	Strontium

Color, tannin-lignin, and iron decreased with distance downstream. Mean concentrations of total phosphate as P and orthophosphate as P generally increased from Fargo, Georgia to Suwannee Springs (SR-10) and then decreased to Wilcox. Ammonia values were highest at Fargo (0.16 mg/l) and Suwannee Springs (0.18 mg/l), whereas all other stations ranged between 0.04 and 0.08 mg/l (Hull et al. 1981).

The majority of water quality changes that occur downstream are related to the change in major input waters, from organic/acidic wetlands drainage in the upper reaches to springs and groundwater seepage, high in dissolved inorganic constituents, in the lower reaches. Parameters associated with phosphate chemical plant discharges, such as phosphate, ammonia, and fluoride, were elevated in the Suwannee downstream of Swift Creek and subsequently decreased downstream.

The Alapaha, Withlacoochee, and Santa Fe rivers enter the Suwannee well below the study area. Limited data for these rivers were collected in connection with the present study (Table 3.4-15). According to Hull et al. (1981), Alapaha water quality at Statenville (USGS No. 2317500) was generally similar to that of the upper Suwannee. The ultimate contribution of the Alapaha to the Suwannee is difficult to assess, however, because much of the flow travels underground through sinkholes and is believed to resurge again through a spring known as the Alapaha Rise.

Water quality in the Withlacoochee at Pinetta (USGS No. 02319000) is considered to be similar to the Suwannee River at Suwannee Springs in dissolved major inorganic constituents, except sodium and potassium which were higher in the Withlacoochee (Hull et al. 1981). Nitrate concentrations also were reported to be similar to the Suwannee at Suwannee Springs, but most other nutrient concentrations were similar to the Suwannee at White Springs.

Water quality variation in the Santa Fe River is similar to that in the Suwannee River in that the upper reaches and headwaters are characterized by organic/acidic wetlands drainage, while downstream the input is from springs and spring-fed tributaries. At the confluence with the Suwannee, the groundwater characteristics of the Santa Fe water quality predominate.

All waters examined in the study area have been designated by the FDER as Class III waters, which provide for the recreation, propagation, and management of fish and wildlife [Chapter 17-3.09 of the Florida Administrative Code (FAC)]. Water Quality Standards for Class III waters are listed in Ch. 17-3.121, FAC (Table 3.4-16). The Suwannee River has been

Table 3.4-15. Summary Data for Selected Chemical Surface Water Parameters Measured at Stations on Major Rivers Draining to the Suwannee River (August 1981 - March 1982).

Parameter	AR-3			WR-3			SF-2		
Flow (cfs)	0	-	-	0	-	-	0	-	-
Conductivity, field ( $\mu$ mhos/cm)	3 <sup>1</sup> 52 <sup>2</sup>	52 <sup>3</sup>	57 <sup>4</sup> 67 <sup>5</sup>	8 67	280	223 330	8 290	350	343 398
Alkalinity as CaCO <sub>3</sub> (mg/l)	3 0.2	0.5	1.0 2.2	8 9.7	111.5	85.8 134.0	8 108.0	143.5	138.8 150.0
Total hardness as CaCO <sub>3</sub> (mg/l)	3 11	12	13 17	8 18	96	80 130	8 134	171	164 178
pH, field	3 4.4	4.5	4.6 <sup>6</sup> 7.1	8 6.2	7.0	6.7 8.1	8 6.5	7.1	7.0 9.3
Fluoride (mg/l)	3 0.04	0.04	0.05 0.06	8 0.06	0.15	0.15 0.24	8 0.10	0.16	0.15 0.22
Sulfate (mg/l)	3 0	0	0 0	8 0	16.3	12.0 22.9	8 0	26.9	24.3 30.8
Total phosphate as P (mg/l)	3 0.03	0.11	0.09 0.13	8 0.10	0.15	0.17 0.27	8 0.04	0.09	0.09 0.13
Total dissolved phos- phate as P (mg/l)	3 0.06	0.08	0.08 0.09	7 0.07	0.15	0.16 0.25	7 0.06	0.10	0.13 0.36
Orthophosphate as P (mg/l)	3 0.06	0.07	0.08 0.10	8 0.05	0.09	0.11 0.22	8 0.01	0.08	0.07 0.12
Dissolved oxygen (mg/l)	3 7.6	9.4	9.1 10.3	8 4.2	5.8	6.2 8.9	7 3.9	5.7	5.6 6.8
Total suspended solids (mg/l)	3 4.3	7.0	7.6 11.5	8 0	2.0	4.6 18.8	8 0.8	1.3	2.0 4.0
Total dissolved solids (mg/l)	3 83	87	91 104	8 81	186	160 223	8 194	215	217 241
Color (Pt-Co units)	3 185	210	207 225	8 45	110	108 155	8 10	24	41 130
Tannin-lignin (mg/l)	3 3.44	3.46	3.60 3.91	8 1.90	3.01	3.32 4.64	8 0.38	0.58	0.84 1.93
Ammonia as N (mg/l)	3 0.04	0.05	0.08 0.16	8 0.01	0.05	0.06 0.12	8 0.01	0.02	0.04 0.09
Nitrate/nitrite as N (mg/l)	3 0.06	0.06	0.06 0.07	8 0.01	0.54	0.44 0.80	8 0.38	0.51	0.49 0.56
Total organic nitrogen as N (mg/l)	3 0.18	0.50	0.64 1.25	8 0.01	0.34	0.38 1.02	8 0	0.22	0.22 0.65
Total nitrogen as N (mg/l)	3 0.41	0.60	0.79 1.36	8 0.38	0.89	0.88 1.30	8 0.53	0.76	0.74 1.18
Total organic carbon as C (mg/l)	3 21.5	26.1	24.6 25.3	8 14.6	26.4	30.3 72.2	8 8.1	17.0	20.8 33.8
Dissolved organic carbon as C (mg/l)	3 21.2	22.0	22.7 24.9	8 15.2	22.4	27.6 52.0	8 6.0	19.2	19.2 36.2
Particulate organic carbon as C (mg/l)	3 0.3	1.2	1.9 4.3	8 0	5.6	6.3 20.2	8 0	3.6	3.1 7.1
Chlorophyll a (mg/m <sup>3</sup> ) (pheophytin-corrected)	3 0	0	0.01 0.02	8 0	0.39	0.63 2.35	8 0	0.18	0.44 1.78

<sup>1</sup>Number of samples.

<sup>2</sup>Minimum value.

<sup>3</sup>Median.

<sup>4</sup>Mean.

<sup>5</sup>Maximum value.

<sup>6</sup>Based on hydrogen ion concentration.

Table 3.4-16. FDER Water Quality Criteria (Ch. 17-3, FAC).

Parameter	Standards
<u>Surface Waters: General Criteria (Ch. 17-3.061, FAC)</u>	
Arsenic	≤0.05 mg/l
BOD	Shall not exceed values to cause dissolved oxygen to be depressed below class criteria, nor to produce nuisance conditions.
Chromium	≤0.05 mg/l total after mixing in stream (0.50 mg/l hexavalent or 1.0 mg/l total in effluent discharge).
Copper	≤0.5 mg/l
Detergents	≤0.5 mg/l
Fluorides	≤10.0 mg/l
Lead	≤0.05 mg/l
Nutrients	Discharge of nutrients shall be limited as needed to prevent violations of other standards contained in Ch. 17-3, FAC.
Oils and greases	≤5.0 mg/l; no iridescent oil shall be present which interferes with the taste, odor, or use of waters.
pH	Shall not vary >1 unit above or below natural background, provided the pH is not lowered to <6 units or raised to >8.5 units. If natural background is <6 units, the pH shall not vary below or vary >1 unit above natural background. If natural background is >8.5 units, the pH shall not vary above or vary >1 unit below natural background.
Trichlorophenol	≤1.0 µg/l, unless higher values are shown not to be chronically toxic.
Chlorinated creosols	≤1.0 µg/l, unless higher values are shown not to be chronically toxic.
2-chlorophenol	≤1.0 µg/l, unless higher values are shown not to be chronically toxic.
2,4-dichlorophenol	≤1.0 µg/l, unless higher values are shown not to be chronically toxic.

Table 3.4-16 (Continued).

Parameter	Standards
Pentachlorophenol	≤1.0 µg/l, unless higher values are shown not to be chronically toxic.
2,4-dinitrophenol	≤1.0 µg/l, unless higher values are shown not to be chronically toxic.
Phenol	≤1.0 µg/l, unless higher values are shown not to be chronically toxic.
Radium-226/228	≤5 pCi/l
Gross α + radium-226	≤15 pCi/l
Specific conductance	Not to increase more than 100% above background or to a maximum level of 500 µmhos/cm in waters <500 µmhos/cm, and 50% above background or to a maximum level of 5000 µmhos/cm in waters ≥500 µmhos/cm.
Deleterious substance	None shall be present.
Substances resulting in nuisance species	None shall be present.
Turbidity	≤29 NTU above background.
Zinc	≤1.0 mg/l
<u>Surface Waters: Class III (Ch. 17-3.121, FAC)</u>	
Alkalinity	≥20 mg/l as CaCO <sub>3</sub>
Ammonia (un-ionized)	≤0.02 mg/l
Beryllium	≤0.011 mg/l in waters with a hardness ≤150 mg/l, and ≤1.10 mg/l in harder waters.
Cadmium	≤0.8 µg/l in waters with a hardness <150 mg/l, and ≤1.2 µg/l in harder waters.
Chlorine	≤0.01 mg/l total residual.
Coliforms, fecal	≤200 per 100 ml monthly average, nor exceed 400 per 100 ml in 10% of samples, nor exceed 800 per 100 ml on any day.

Table 3.4-16 (Continued).

Parameter	Standards
Coliforms, total	≤1000 per 100 ml monthly average, nor exceed 1000 per 100 ml in more than 20% of samples in a single month, nor exceed 2400 per 100 ml at any time.
Copper	≤0.03 mg/l
Cyanide	≤5.0 µg/l
Dissolved gases	≤110% of saturation value for gases at the existing atmosphere and hydrostatic pressure.
Dissolved oxygen	≥5 mg/l
Iron	≤1.0 mg/l
Lead	≤0.03 mg/l
Mercury	≤0.2 µg/l
Nickel	≤0.1 mg/l
Nutrients	Concentrations shall not be altered so as to cause an imbalance in natural populations of aquatic flora or fauna.
Pesticides and Herbicides	
Aldrin + dieldrin	≤0.003 µg/l
Chlordane	≤0.01 µg/l
DDT	≤0.001 µg/l
Demeton	≤0.1 µg/l
Endosulfan	≤0.003 µg/l
Endrin	≤0.004 µg/l
Guthion	≤0.01 µg/l
Heptachlor	≤0.001 µg/l
Lindane	≤0.01 µg/l

Table 3.4-16 (Continued).

Parameter	Standards
Malathion	≤0.1 µg/l
Methoxychlor	≤0.03 µg/l
Myrex	≤0.001 µg/l
Parathion	≤0.04 µg/l
Toxaphene	≤0.005 µg/l
pH	Shall not vary >1 unit above or below natural background, provided the pH is not lowered to <6 units or raised to >8.5 units. If natural background is <6 units, the pH shall not vary below or vary >1 unit above natural background. If natural background is >8.5 units, the pH shall not vary above or vary >1 unit below natural background.
Phthalate esters	≤3.0 µg/l
PCB's	≤0.001 µg/l
Selenium	≤0.025 mg/l
Silver	≤0.07 µg/l
Transparency	Depth of compensation point for photosynthetic activity not to be reduced by more than 10% compared to background.
Zinc	≤0.03 mg/l

designated as an Outstanding Florida Water (Ch. 17-3.041, FAC). No specific criteria have been established for this classification as yet; therefore, Class III criteria were used to evaluate Suwannee River data.

For purposes of evaluating existing water quality conditions relative to the standards, two comprehensive samplings (August low flow and February medium flow) were conducted (Tables 3.4-17 through 3.4-20) in addition to the monthly monitorings (Tables 3.4-14 and 3.4-15). Water samples from each station were analyzed for a complete set of Class III standard parameters. Values of these and USGS data which did not meet State Water Quality Standards were enumerated, and parameters with at least one deviation from the standard appear in Table 3.4-21.

The increase in alkalinity concentrations in the Suwannee with distance downstream, due to groundwater input, is apparent in Table 3.4-21. Alkalinity concentrations were below the 20 mg/l standard in 100% (SR-2), 86% (SR-5), 28% (SR-10), and 7% (SR-20) of the samples collected both for this study and by the USGS combined. Alkalinity is important for freshwater aquatic life because it buffers pH changes, and its components, carbonate and bicarbonate, complex some toxic heavy metals and markedly reduce their toxicity (EPA 1976).

Few dissolved oxygen values failed to meet the 5.0 mg/l minimum standard (0-7% of all samples, excluding SR-1) at the Suwannee River stations.

High coliform levels were present at SR-1 during both comprehensive monitorings. Both fecal coliform values exceeded the 800/100 ml standard; one of the total coliform samples exceeded the 2400/100 ml limit and the second equaled the limit. The causes of these high levels upstream of the project boundary are unknown. Farther downstream at SR-5, both total and fecal coliform levels were above the standards during the low flow comprehensive sampling but were below the limit during the high flow monitoring. Coliform levels were below the standards at the remaining downstream Suwannee River stations (SR-10 and SR-20). A single total coliform value was reported by USGS at SR-5, SR-10, and SR-20, each on different dates.

Background levels of mercury in the Suwannee appeared to be naturally high relative to the 0.2 µg/l State standard. USGS data at White Springs (SR-5), Suwannee Springs (SR-10), and Branford (SR-20) exceeded the standard in 72%, 64%, and 74% of the samples, respectively. These higher concentrations were probably from natural or nonpoint sources as opposed to a specific industrial source. Mercury may enter an ecosystem via natural pathways such as the physical and chemical breakdown of rocks and minerals containing mercury (Reeder et al. 1979). Nonpoint sources of mercury include the burning of fossil fuels (Reeder et al. 1979) and agricultural activities (EPA 1976).

All complex organics were below the detectable limits of the analytical methods. However, detection limits for the majority of the parameters were higher than the applicable State standards. Lower limits were achieved for many parameters during the second comprehensive sampling but remained above State criteria. It is extremely difficult to attain detection limits equal to or lower than the criteria for these parameters using standard analytical techniques. FDER agrees that the detection

Table 3.4-17. Results of Comprehensive Water Quality Monitoring, 18-25 August 1981.

Parameter	SR-1	SR-5	SR-10	WR-3	SR-20	SF-2
<b>MISCELLANEOUS</b>						
Flow (cfs)	-	45.5	201	-	-	-
Conductivity, field ( $\mu$ mhos/cm)	50	102	440	300	340	340
Alkalinity as CaCO <sub>3</sub> (mg/l)	0.0	18.0	35.0	128.5	139.0	139.0
Total hardness as CaCO <sub>3</sub> (mg/l)	17	41	105	124	165	170
pH, field	5.0	6.2	6.8	7.4	7.3	6.9
Fluoride (mg/l)	0.14	0.34	1.71	0.24	0.31	0.22
Sulfate (mg/l)	0	18.6	126.4	17.6	24.7	26.2
Total phosphate as P (mg/l)	0.19	0.39	4.31	0.17	0.35	0.13
Total dissolved phosphate as P (mg/l)	0.16	0.46	4.21	0.15	0.34	0.10
Orthophosphate as P (mg/l)	0.15	0.42	4.20	0.06	0.36	0.04
Temperature, field (°C)	28	28	29	24	24	23
Dissolved oxygen (mg/l)	4.6	6.3	6.4	5.0	5.6	5.0
BOD <sub>5</sub> (mg/l)	1	1	2	1	ND	1
Total suspended solids (mg/l)	1.6	0	6.8	0.4	1.6	2.6
Total dissolved solids (mg/l)	102	123	265	178	191	210
Transparency (m)	0.55	0.76	0.55	1.04	>1.55	>1.46
Color (Pt-Co units)	550	275	205	60	27	33
Tannin-lignin (mg/l)	5.68	4.41	2.92	2.34	0.67	0.61
Ammonia as N (mg/l)	0.06	0.05	-	0.05	0.15	0.05
Un-ionized ammonia as N (mg/l)	ND	ND	-	ND	ND	ND
Nitrate/nitrite as N (mg/l)	ND	0.05	1.17	0.64	0.85	0.56
Total organic nitrogen as N (mg/l)	1.39	0.70	6.46++	0.01	0.44	0
Total nitrogen as N (mg/l)	1.46	0.80	7.63	0.70	1.44	0.56
Total organic carbon as C (mg/l)	40.1	48.1	27.5	14.6	12.4	15.3
Dissolved organic carbon as C (mg/l)	37.1	32.0	23.1	20.6	8.4	24.9
Particulate organic carbon as C (mg/l)	3.0	16.1	4.5	0	4.0	0
Chlorophyll a (mg/m <sup>3</sup> ) (pheophytin-corrected)	2.38	0.58	26.03	0.78	0.38	0.55
Oil and grease (mg/l)	1	ND	1	ND	ND	ND
Surfactants (methylene blue active substances) (mg/l)	0.01	ND	ND	ND	ND	ND
Total cyanide (mg/l)	0.03	ND	ND	ND	ND	ND
Fecal coliform (MPN/100 ml)	1100	1500	43	43	9	210
Total coliform (MPN/100 ml)	2400	1500	200	460	23	2400
<b>METALS</b>						
Aluminum (mg/l)	0.39	0.32	0.39	0.11	0.17	0.11
Arsenic (mg/l)	ND	ND	0.003	ND	ND	ND
Barium (mg/l)	ND	ND	ND	ND	ND	ND
Beryllium (mg/l)	ND	ND	ND	ND	ND	ND
Cadmium (mg/l)	0.01	0.01	0.01	0.01	0.01	0.01
Chromium (mg/l)	ND	ND	ND	ND	ND	ND
Copper (mg/l)	ND	ND	ND	ND	ND	ND
Iron (mg/l)	0.56	0.52	0.39	0.12	0.11	0.13
Lead (mg/l)	ND	ND	ND	ND	ND	ND
Mercury ( $\mu$ g/l)	ND	0.28	ND	ND	ND	0.29
Nickel (mg/l)	ND	ND	ND	ND	ND	ND
Selenium (mg/l)	ND	ND	ND	ND	ND	ND
Silver (mg/l)	ND	ND	ND	ND	ND	ND
Zinc (mg/l)	ND	0.007	0.011	0.005	0.006	0.005
<b>ORGANICS**</b>						
	ND	ND	ND	ND	ND	ND
<b>RADIATION</b>						
Radium-226 (pCi/l)	1.1±0.6*	ND	ND	ND	ND	1.8±1.6
Gross alpha (pCi/l)	1.2±1.2	1.1±0.7	6.8±3.6	1.6±1.2	2.4±1.7	2.9±2.0

ND - Not detectable (See Table 3.4-18 for detection limits.)

\* - Too shallow to sample.

\*\* - Results of all organics analyses were below the detectable limits at all stations. Refer to Table 3.4-18 for list of parameters analyzed and detection limits.

+ - 95% confidence limits.

++ - Value is for total Kjeldahl nitrogen (ammonia + organic); the total ammonia value was higher than the Kjeldahl value and is believed to be erroneous.

Note: AR-3 was dry at the time of sampling.

Table 3.4-18. Detection Limits for Comprehensive Water Quality Monitoring, August 1981.

Parameter	Detection Limit	Parameter	Detection Limit
<b>MISCELLANEOUS</b>		<b>ORGANICS</b>	
Total suspended solids (mg/l)	1	Polychlorinated biphenyls (mg/l)	0.002
Un-ionized ammonia as N (mg/l)	0.01	Aldrin (mg/l)	0.00008
Nitrate/nitrite as N (mg/l)	0.01	Dieldrin (mg/l)	0.0001
Oil and grease (mg/l)	1	Chlordane (mg/l)	0.001
Surfactants (MBAS) (mg/l)	0.01	2,4-D (mg/l)	0.0005
Total cyanide (mg/l)	0.03	2,4,5-TP (silvex) (mg/l)	0.00008
Fecal coliform (MPN/100 ml)	3	DDT o,p (mg/l)	0.0006
		DDT p,p (mg/l)	0.0006
		Demeton (mg/l)	0.004
		Endosulfan I (mg/l)	0.0002
		Endosulfan II (mg/l)	0.0002
		Endrin (mg/l)	0.0002
		Heptachlor (mg/l)	0.00008
		Lindane (mg/l)	0.00008
		Methoxychlor (mg/l)	0.001
		Mirex (mg/l)	0.0005
		Toxaphene (mg/l)	0.001
		Guthion (mg/l)	0.05
		Malathion (mg/l)	0.003
		Ethyl parathion (mg/l)	0.0005
		Methyl parathion (mg/l)	0.0005
		Dimethyl phthalate (mg/l)	0.002
		Diethyl phthalate (mg/l)	0.002
		Benzyl-butyl phthalate (mg/l)	0.002
		Di-n-butyl phthalate (mg/l)	0.002
		Bis (2-ethylhexyl) phthalate (mg/l)	0.008
		Di-n-octyl phthalate (mg/l)	0.008
		Trichlorophenol (mg/l)	0.001
		Chlorinated cresol (mg/l)	0.001
		2-chlorophenol (mg/l)	0.001
		2,4-dichlorophenol (mg/l)	0.001
		Pentachlorophenol (mg/l)	0.001
		2,4-dinitrophenol (mg/l)	0.001
		Phenol (mg/l)	0.001
<b>METALS</b>			
Arsenic (mg/l)	0.002		
Barium (mg/l)	0.50		
Beryllium (mg/l)	0.05		
Cadmium (mg/l)	0.01		
Chromium (mg/l)	0.02		
Copper (mg/l)	0.02		
Lead (mg/l)	0.1		
Mercury ( $\mu$ g/l)	0.2		
Nickel (mg/l)	0.02		
Selenium (mg/l)	0.002		
Silver (mg/l)	0.01		
Zinc (mg/l)	0.005		
<b>RADIATION</b>			
Radium-226 (pCi/l)	0.6		
Uranium (pCi/l)	3		

Table 3.4-19. Results of Comprehensive Water Quality Monitoring, 15-18 February 1982.

Parameter	SR-1	SR-5	SR-10	AR-3	WR-3	SR-20	SF-2
<b>MISCELLANEOUS</b>							
Flow (cfs)	-	-	-	-	-	-	-
Conductivity, field ( $\mu$ mhos/cm)	76	85	50	52	67	83	320
Alkalinity as $\text{CaCO}_3$ (mg/l)	0	0	0	0.2	9.7	14.4	129.0
Total hardness as $\text{CaCO}_3$ (mg/l)	9	20	28	12	18	28	154
pH, field	3.6	5.9	4.9	7.1	8.1	8.1	9.3
Fluoride (mg/l)	0.02	0.09	0.16	0.04	0.06	0.09	0.10
Sulfate (mg/l)	0	0	0	0	0	0	30.3
Total phosphate as P (mg/l)	0.11	0.27	0.89	0.11	0.12	0.19	0.08
Total dissolved phosphate as P (mg/l)	0.10	0.33	0.79	0.09	0.07	0.21	0.07
Orthophosphate as P (mg/l)	ND	0.24	0.58	0.10	0.07	0.23	0.13
Temperature, field ( $^{\circ}\text{C}$ )	17	17	15	13	13	14	20
Dissolved oxygen (mg/l)	7.9	8.6	8.5	9.4	8.1	8.6	5.7
BOD <sub>5</sub> (mg/l)	2	2 <sup>++</sup>	3	2	2	2	ND
Total suspended solids (mg/l)	3.8	6.0	5.3	4.3	5.8	5.5	0.8
Total dissolved solids (mg/l)	140	132	150	83	81	101	208
Transparency (m)	-	*	-	0.91	0.60	0.73	-
Color (Pt-Co units)	400	400	400	210	155	200	37
Tannin-lignin (mg/l)	7.87	7.44	6.94	3.91	2.95	3.62	1.01
Ammonia as N (mg/l)	0.08	0.25	0.02	0.04	0.05	0.08	0.02
Un-ionized ammonia as N (mg/l)	ND	ND	ND	ND	0.02	ND	0.01
Nitrate/nitrite as N (mg/l)	0.03	0.12	0.22	0.54	0.13	0.15	0.41
Total organic nitrogen as N (mg/l)	1.03	0.93	1.09	0.50	0.52	0.43	0.35
Total nitrogen as N (mg/l)	1.14	1.30	1.33	0.60	0.70	0.66	0.78
Total organic carbon as C (mg/l)	55.5	54.6	56.4	26.1	19.0	22.3	8.1
Dissolved organic carbon as C (mg/l)	53.1	45.9	53.2	24.9	24.2	34.0	6.0
Particulate organic carbon as C (mg/l)	2.4	8.7	3.2	1.2	0	0	2.0
Chlorophyll a ( $\text{mg}/\text{m}^3$ ) (pheophytin-corrected)	0	1.98	1.77	0	0	2.32	0
Oil and grease (mg/l)	-	-	-	-	-	-	-
Surfactants (methylene blue active substances) (mg/l)	ND	ND	ND	ND	ND	ND	ND
Total cyanide (mg/l)	ND	ND	ND	ND	ND	ND	ND
Fecal coliform (MPN/100 ml)	1100	460	93	27	150	75	1100
Total coliform (MPN/100 ml)	>2400	1100	150	44	1100	210	4600
<b>METALS</b>							
Aluminum (mg/l)	0.6	0.4	0.6	0.6	0.8	0.6	0.2
Arsenic (mg/l)	ND	ND	ND	ND	ND	ND	ND
Barium (mg/l)	ND	ND	ND	ND	ND	ND	ND
Beryllium (mg/l)	ND	ND	ND	ND	ND	ND	ND
Cadmium (mg/l)	ND	ND	ND	ND	ND	ND	ND
Chromium (mg/l)	ND	ND	ND	ND	ND	ND	ND
Copper (mg/l)	ND	ND	ND	ND	ND	ND	ND
Iron (mg/l)	0.50	0.56	0.56	0.78	1.00	0.72	0.14
Lead (mg/l)	ND	ND	ND	ND	ND	ND	ND
Mercury ( $\mu\text{g}/\text{l}$ )	ND	ND	ND	ND	ND	ND	ND
Nickel (mg/l)	ND	0.02	0.02	ND	0.02	ND	ND
Selenium (mg/l)	ND	ND	ND	ND	ND	ND	ND
Silver (mg/l)	ND	ND	ND	ND	ND	ND	ND
Zinc (mg/l)	ND	0.03	0.02	ND	0.02	ND	ND
ORGANICS **	ND	ND	ND	ND	ND	ND	ND
<b>RADIATION</b>							
Radium-226 (pCi/l)	0.09 $\pm$ 0.06 <sup>+</sup>	0.10 $\pm$ 0.06	0.05 $\pm$ 0.05	0.18 $\pm$ 0.06	0.06 $\pm$ 0.05	-	-
Radium-228 (pCi/l)	<1.4	2.0 $\pm$ 1.5	<1.0	<1.2	<0.7	<2.0	-
Gross alpha (pCi/l)	<1.5	2.0 $\pm$ 0.6	<1.5	1.4 $\pm$ 1.4	<1.2	<2.1	<0.9
Gross beta (pCi/l)	4.3 $\pm$ 4.1	10.0 $\pm$ 4.4	4.4 $\pm$ 3.1	6.9 $\pm$ 3.9	6.3 $\pm$ 3.1	8.2 $\pm$ 4.1	6.6 $\pm$ 4.4

ND - Not detectable (See Table 3.4-20 for detection limits).

\* - Too shallow to sample.

\*\* - Results of all organic analyses were below the detectable limits at all stations. Refer to Table 3.4-20 for list of parameters analyzed and detection limits.

+ - 95% confidence limits.

++ - Sample collected March 1982.



Table 3.4-21. Values Not Meeting FDER Water Quality Standards in the Suwannee River and River Tributaries.

Parameter	No. of deviations/No. of samples														
	SR-1	SR-2	USGS1	SR-5	USGS2	SR-10	USGS3	SR-20	USGS4	AR-3	USGS5	WR-3	USGS6	SF-2	USGS7
Alkalinity	2/2	42/42	13/13	38/43	22/27	3/8	4/17	2/8	19/295	2/3	3/3	1/8	0/5	0/8	0/5
Dissolved oxygen	1/2	0/42	0/40	0/41	3/59	1/8	5/74	1/8	7/114	0/3	0/3	1/8	2/2	1/7	0/4
Fecal coliform	2/2	-	-	1/2	-	0/2	-	0/2	-	0/2	-	0/2	-	0/2	-
Total coliform	1/2	-	-	1/2	1/9	0/2	1/43	0/2	1/39	0/2	-	0/2	-	0/2	-
Mercury	0/2	-	-	1/2	13/18	0/2	9/14	0/2	29/59	0/2	-	0/2	-	1/3	-

- 1 USGS No. 2315000, at SR-2.
- 2 USGS No. 2315500, at SR-5.
- 3 USGS No. 2315550, at SR-10.
- 4 USGS No. 2320500, at SR-20.
- 5 USGS No. 2317630, at AR-3.
- 6 USGS No. 2319300, at WR-3.
- 7 USGS No. 2322800, at SF-2.

Source: OXY EIS Data, November 1979 - March 1982.  
USGS, January 1954 - October 1981.

limits are unreasonable for routine studies and they do not attempt to reach the limits except in special cases (pers. comm. FDER chemist, Tallahassee, Florida).

Tributary Stations Not Receiving OXY Discharge. Streams discussed in this section include major tributaries that do not receive mine or chemical plant discharge: Rocky Creek, Roaring Creek, Long Branch, Deep Creek, Four Mile Branch, and Camp Branch (Figure 3.4-29). All originate within the project boundary except for Deep Creek which enters from the east side of the Suwannee River. Rocky Creek has a 52 sq mi drainage basin which is unaffected by phosphate mining. A major tributary to Rocky Creek is Cypress Creek which drains a 29 sq mi area. The current Roaring Creek drainage basin is 11 sq mi. Approximately half of the pre-mining basin has been mined or prepared for mining; thus, much of the normal drainage to the creek has been eliminated. Long Branch and Four Mile Branch each have drainage basins of 5 sq mi and were unaffected by mining during sampling. Camp Branch's 10 sq mi drainage area has been disturbed by mining activities in the upper headwater region. The stream flows through a sinkhole just before entering the Suwannee and travels the remaining distance to the river underground. Deep Creek drains an 89 sq mi drainage basin at USGS station No. 2315200 located 4 mi upstream of Deep Creek's confluence with the Suwannee River (Coffin 1982).

Of the six streams, Rocky Creek (RC-2) and Four Mile Branch (FMB-2) appeared to exhibit the strongest characteristic of organic/acidic drainage (Tables 3.4-22 through 3.4-26). At both stations, median pH and mean alkalinity were much less than for the other four tributaries at Stations RO-2, LB-2, CB-1.5, and USGS No. 02315200 (Deep Creek). Similarly, mean concentrations of color, tannin-lignin, total organic carbon, and total organic nitrogen were higher at RC-2 and FMB-2 than at the other four stations. Concentrations of these parameters were also higher (lower for pH and alkalinity) at these two stations than mean concentrations found on the Suwannee River at SR-2.

Roaring Creek, Long Branch, and Deep Creek were fairly similar in water quality and exhibited the same organic/acidic characteristics as Rocky Creek and Four Mile Branch, only to a slightly lesser degree. These characteristics were not as evident at Camp Branch. Median pH and mean alkalinity concentrations were much higher at Camp Branch than at the other tributaries as well as the upper Suwannee (at SR-2). Mean concentrations of color and tannin-lignin were much lower at Camp Branch than at the other stations, including SR-2, while total organic carbon and organic nitrogen concentrations were slightly lower. In all the streams, organic nitrogen was the dominant nitrogen form; ammonia and nitrate/nitrite values were low. Dissolved organic carbon predominated over the particulate form. Mean phosphate concentrations were lowest in Rocky Creek and Four Mile Branch and were somewhat higher in the other three tributaries. Mean dissolved oxygen was >5.0 mg/l (State standard) at each station except for Long Branch; dissolved oxygen was highest at Camp Branch.

An examination of the ranges of mean concentrations at all tributary stations, excluding Deep Creek, indicated low levels of the following

Table 3.4-22. Summary Data for Selected Chemical Surface Water Parameters Measured at Stations on Major Tributaries Draining to the Suwannee River (November 1979 - March 1982).

Parameter	RC-1			RC-2			RC-4		
Flow (cfs)	4 <sup>1</sup> 1.6 <sup>2</sup>	10.9 <sup>3</sup>	8.8 <sup>4</sup> 11.8 <sup>5</sup>	44 0	37.6 10.2	264.0	7 2.5	4.5	6.3 13.0
Conductivity, field ( $\mu$ mhos/cm)	9 58	80	80 98	36 60	86 88	116	9 88	93	97 133
Alkalinity as CaCO <sub>3</sub> (mg/l)	10 0	0	0 0	43 0	2.4 0	28	11 0	0	0 0
Total hardness as CaCO <sub>3</sub> (mg/l)	10 10	11	14 26	43 3	16 12	42	11 3	9	15 70
pH, field	2 3.3	-	3.4 <sup>6</sup> 3.4	28 2.2	3.1 3.2	5.6	3 3.1	3.2	3.2 3.2
Fluoride (mg/l)	10 0.02	0.03	0.03 0.05	43 0.02	0.07 0.04	0.27	11 0.02	0.03	0.03 0.04
Sulfate (mg/l)	10 0	0	0 0	43 0	0	0	11 0	0	0 0
Total phosphate as P (mg/l)	10 0.01	0.07	0.08 0.18	42 0	0.06 0.04	0.29	11 0	0.02	0.03 0.10
Total dissolved phos- phate as P (mg/l)	10 0.01	0.06	0.06 0.11	43 0	0.06 0.05	0.17	11 0	0.04	0.05 0.09
Orthophosphate as P (mg/l)	10 0.05	0.12	0.16 0.33	42 0	0.08 0.06	0.23	11 0.01	0.04	0.05 0.12
Dissolved oxygen (mg/l)	10 6.2	9.2	8.8 10.8	43 2.7	7.0 6.5	11.3	11 2.3	9.5	8.2 11.0
Total suspended solids (mg/l)	10 0.2	0.9	1.3 5.0	43 0	3.2 1.1	30.3	11 0.1	1.0	1.2 2.5
Total dissolved solids (mg/l)	10 154	161	164 178	43 105	161 158	201	11 90	145	143 185
Color (Pt-Co units)	10 460	570	580 700	43 270	636 600	940	11 450	550	606 900
Tannin-lignin (mg/l)	10 9.33	10.91	10.67 12.04	43 6.06	11.66 11.35	15.74	11 9.51	10.86	11.45 16.14
Ammonia as N (mg/l)	10 0.01	0.01	0.03 0.09	43 0.01	0.03 0.03	0.13	11 0.01	0.01	0.02 0.05
Nitrate/nitrite as N (mg/l)	10 0.01	0.02	0.02 0.05	42 0.01	0.03 0.02	0.28	11 0.01	0.02	0.02 0.06
Total organic nitrogen as N (mg/l)	10 0.85	1.41	1.38 1.78	41 0.96	1.57 1.55	2.23	11 1.10	1.63	1.53 1.82
Total nitrogen as N (mg/l)	10 0.89	1.48	1.43 1.89	40 1.07	1.62 1.58	2.26	11 1.13	1.66	1.57 1.89
Total organic carbon as C (mg/l)	9 46.5	78.6	79.6 116.0	43 36.7	77.7 75.5	129.4	9 65.4	80.0	84.9 119.3
Dissolved organic carbon as C (mg/l)	9 60.6	72.3	71.5 86.3	43 35.4	71.4 71.7	110.0	9 61.5	70.5	73.8 90.4
Particulate organic carbon as C (mg/l)	9 0	5.9	12.5 54.2	43 0	7.7 3.9	58.8	9 0	2.0	14.9 57.9
Chlorophyll a (mg/m <sup>3</sup> ) (pheophytin-corrected)	0 -	-	-	24 0	1.68 0.47	8.38	0 -	-	-

<sup>1</sup>Number of samples.

<sup>2</sup>Minimum value.

<sup>3</sup>Median.

<sup>4</sup>Mean.

<sup>5</sup>Maximum value.

<sup>6</sup>Based on hydrogen ion concentration.

Table 3.4-23. Summary Data for Selected Chemical Surface Water Parameters Measured at Stations on Major Tributaries Draining to the Suwannee River (November 1979 - March 1982).

Parameter	RC-5			RC-6			RC-10		
	1	2	3	4	5	6	7	8	9
Flow (cfs)	33 <sup>1</sup> 0 <sup>2</sup>	3.3 <sup>3</sup>	13.7 <sup>4</sup> 147.4 <sup>5</sup>	42 0	0.8	2.2 9.5	20 0	2.6	6.9 63.9
Conductivity, field (umhos/cm)	27 68	108	106 150	34 88	134	138 229	32 62	90	96 165
Alkalinity as CaCO <sub>3</sub> (mg/l)	31 0	0	0 0	40 0	0	0 0	38 0	0	0 0
Total hardness as CaCO <sub>3</sub> (mg/l)	32 3	8	9 19	41 3	7	9 40	38 3	9	10 16
pH, field	26 2.2	3.0	2.8 <sup>6</sup> 3.7	27 2.4	3.0	2.9 3.7	24 2.4	3.0	2.9 3.7
Fluoride (mg/l)	32 0.01	0.04	0.05 0.13	41 0.02	0.05	0.07 0.58	38 0.01	0.03	0.03 0.09
Sulfate (mg/l)	32 0	0	1.1 5.2	41 0	0	1.6 9.4	39 0	0	1.1 6.3
Total phosphate as P (mg/l)	31 0.01	0.02	0.03 0.12	41 0	0.02	0.03 0.13	39 0	0.01	0.03 0.35
Total dissolved phosphate as P (mg/l)	32 0	0.02	0.03 0.16	41 0	0.02	0.05 0.32	38 0	0.03	0.03 0.23
Orthophosphate as P (mg/l)	30 0	0.02	0.03 0.22	38 0	0.02	0.04 0.21	37 0	0.02	0.03 0.12
Dissolved oxygen (mg/l)	32 3.4	6.0	5.9 9.6	41 2.8	5.4	5.8 8.4	38 1.7	4.7	4.8 9.8
Total suspended solids (mg/l)	32 0	1.6	3.2 21.2	41 0	2.0	3.4 24.3	38 0	0.8	1.3 8.3
Total dissolved solids (mg/l)	32 130	182	181 218	41 148	212	213 259	39 102	152	157 211
Color (Pt-Co units)	32 440	850	829 1300	41 650	1040	1051 1300	39 400	600	629 900
Tannin-lignin (mg/l)	32 5.55	14.54	14.78 21.65	41 7.85	17.11	17.31 22.98	39 8.59	13.23	13.03 25.60
Ammonia as N (mg/l)	32 0.01	0.05	0.09 0.25	39 0.01	0.10	0.13 0.52	38 0.01	0.03	0.04 0.2
Nitrate/nitrite as N (mg/l)	32 0	0.02	0.04 0.17	41 0.01	0.05	0.07 0.28	39 0	0.02	0.02 0.10
Total organic nitrogen as N (mg/l)	32 1.32	1.93	1.93 2.61	37 1.50	2.10	2.15 2.96	38 1.10	1.62	1.89 8.57
Total nitrogen as N (mg/l)	32 1.38	2.08	2.06 2.69	38 1.60	2.21	2.34 3.50	39 1.15	1.66	1.95 8.64
Total organic carbon as C (mg/l)	31 55.8	84.0	90.1 172.9	36 77.3	106.6	107.0 137.3	35 53.2	80.2	79.7 111.8
Dissolved organic carbon as C (mg/l)	31 52.8	84.2	88.4 183.8	38 70.7	97.8	97.9 122.2	36 51.7	77.2	77.3 111.3
Particulate organic carbon as C (mg/l)	31 0	2.9	4.3 15.2	37 0	8.8	12.8 122.4	35 0	2.1	4.8 23.9
Chlorophyll a (mg/m <sup>3</sup> ) (pheophytin-corrected)	25 0	0.93	2.23 13.78	25 0	1.15	2.29 19.95	21 0	1.79	5.45 58.05

1Number of samples.  
2Minimum value.  
3Median.  
4Mean.  
5Maximum value.  
6Based on hydrogen ion concentration.

Table 3.4-24. Summary Data for Selected Chemical Surface Water Parameters Measured at Stations on Major Tributaries Draining to the Suwannee River (November 1979 - March 1982).

Parameter	RO-1			RO-2			RO-5			RO-14			RO-15	
Flow (cfs)	6 <sup>1</sup> 1.6 <sup>2</sup>	5.3 <sup>3</sup>	6.0 <sup>4</sup> 11.6 <sup>5</sup>	39 0.2	1.0	3.2 22.1	44 0	0.7	2.2 23.6	0 -	-	-	2 0	0.1 0.2
Conductivity, field (µmhos/cm)	11 51	73	77 126	38 60	87	88 150	30 46	97	102 205	10 55	82	113 337	2 114	127 139
Alkalinity as CaCO <sub>3</sub> (mg/l)	12 0	0	3.8 22.0	43 0	13.0	17.6 49.0	34 0	0	0.2 3.0	11 0	0	0	2 0	0 0
Total hardness as CaCO <sub>3</sub> (mg/l)	12 12	18	22 35	44 4	34	31 56	35 3	18	18 30	11 4	11	11 21	2 12	13 13
pH, field	3 3.5	3.6	3.7 <sup>6</sup> 5.8	30 2.8	5.5	3.9 6.5	20 2.5	3.4	3.2 4.8	5 2.6	3.3	3.0 3.5	2 3.3	3.4 3.5
Fluoride (mg/l)	12 0.06	0.09	0.13 0.40	44 0.05	0.28	0.33 0.79	35 0.02	0.06	0.07 0.27	10 0.03	0.04	0.05 0.08	2 0.10	0.10 0.10
Sulfate (mg/l)	11 0	0	0	43 0	0	0	35 0	0	4.0 31.3	11 0	0	0 <sup>*</sup> 0	2 0	0 0
Total phosphate as P (mg/l)	12 0.09	0.16	0.25 0.83	44 0.06	0.54	0.68 1.66	35 0	0.06	0.07 0.33	11 0.01	0.06	0.09 0.28	2 0.01	0.01 0.01
Total dissolved phos- phate as P (mg/l)	12 0.07	0.13	0.22 0.80	44 0.06	0.53	0.65 1.58	34 0	0.05	1.04	11 0.01	0.04	0.05 0.19	2 0.01	0.01 0.01
Orthophosphate as P (mg/l)	12 0.16	0.29	0.36 0.90	44 0.12	0.67	0.73 1.59	35 0.02	0.11	0.17 0.86	11 0.02	0.08	0.12 0.46	2 0.01	0.01 0.01
Dissolved oxygen (mg/l)	12 7.0	8.3	8.5 11.2	43 2.6	6.1	6.4 11.0	35 1.4	5.1	5.8 9.6	11 1.3	5.3	5.6 10.2	2 9.3	9.4 9.5
Total suspended solids (mg/l)	12 0	3.1	3.2 8.7	44 0	1.2	2.9 47.2	35 0	2.4	7.7 36.5	11 0	5.0	10.2 37.5	2 0.2	1.3 2.4
Total dissolved solids (mg/l)	12 125	139	143 174	44 65	131	123 183	35 108	180	177 258	11 82	133	131 160	2 185	186 187
Color (Pt-Co units)	12 300	460	476 620	44 30	365	333 800	35 125	660	629 2000	11 260	370	385 700	2 500	525 550
Tannin-lignin (mg/l)	12 5.27	8.94	8.59 10.37	44 0.59	6.63	5.80 11.93	35 2.47	9.34	9.19 16.82	11 6.37	7.36	7.58 9.16	2 7.87	9.30 10.74
Ammonia as N (mg/l)	12 0.01	0.02	0.03 0.09	44 0.01	0.02	0.04 0.21	35 0.01	0.04	0.06 0.47	11 0.01	0.04	0.05 0.15	2 0.02	0.03 0.04
Nitrate/nitrite as N (mg/l)	12 0.01	0.03	0.04 0.10	44 0.01	0.05	0.06 0.14	35 0	0.02	0.03 0.13	11 0.01	0.01	0.02 0.06	2 0.03	0.03 0.03
Total organic nitrogen as N (mg/l)	12 0.69	1.34	1.24 1.71	44 0	0.86	0.98 5.00	33 0.72	1.71	1.62 2.69	11 0.87	1.46	1.59 2.58	2 1.45	1.60 1.76
Total nitrogen as N (mg/l)	12 0.84	1.38	1.31 1.79	44 0.11	0.98	1.08 5.06	33 0.73	1.80	1.71 2.97	11 0.89	1.52	1.66 2.74	2 1.52	1.66 1.81
Total organic carbon as C (mg/l)	9 17.2	53.9	56.0 104.3	42 7.3	54.4	46.8 110.0	31 26.2	79.1	74.0 132.6	8 52.2	68.4	65.1 75.6	2 66.8	78.4 89.9
Dissolved organic carbon as C (mg/l)	10 33.2	59.6	59.3 90.5	44 8.2	45.8	44.0 97.2	32 20.6	77.4	70.0 123.7	9 45.8	59.0	59.4 71.3	2 66.2	76.3 86.4
Particulate organic carbon as C (mg/l)	9 0	0	7.6 41.0	42 0	2.3	5.3 47.1	31 0	3.7	6.7 49.7	8 0	8.4	8.3 21.2	2 0.7	2.1 3.5
Chlorophyll a (mg/m <sup>3</sup> ) (pheophytin-corrected)	0 -	-	-	26 0	0.68	1.49 10.56	18 0	2.47	3.34 17.49	2 3.32	-	3.75 4.19	2 0	0 0

<sup>1</sup>Number of samples.

<sup>2</sup>Minimum value.

<sup>3</sup>Median.

<sup>4</sup>Mean.

<sup>5</sup>Maximum value.

<sup>6</sup>Based on hydrogen ion concentration.

Table 3.4-25. Summary Data for Selected Chemical Surface Water Parameters Measured at Stations on Major Tributaries Draining to the Suwannee River (November 1979 - March 1982).

Parameter	CC-2			LB-1			LB-2		
Flow (cfs)	30 <sup>1</sup> 0 <sup>2</sup>	1.0 <sup>3</sup>	4.0 <sup>4</sup> 23.6 <sup>5</sup>	4 1.7	3.2 2.8	5.4	37 0	0.1	0.4 2.7
Conductivity, field (µmhos/cm)	22 65	100	102 143	8 53	92 89	168	35 47	96	103 274
Alkalinity as CaCO <sub>3</sub> (mg/l)	27 0	0	0	9 1.6	18.9 20.0	31.0	40 0	21.0	23.9 61.0
Total hardness as CaCO <sub>3</sub> (mg/l)	27 4	12	12 18	9 20	33 34	42	40 11	36	38 72
pH, field	17 2.2	3.0	2.9 <sup>6</sup> 3.7	3 4.8	5.2 5.4	5.9	29 2.6	5.0	3.7 5.9
Fluoride (mg/l)	27 0.02	0.03	0.04 0.17	9 0.16	0.22 0.22	0.30	40 0.07	0.26	0.24 0.47
Sulfate (mg/l)	28 0	0	3.3 18.7	9 0	0	0	40 0	0	0
Total phosphate as P (mg/l)	28 0	0.03	0.06 0.34	9 0.26	0.36 0.39	0.56	40 0.06	0.49	0.50 1.69
Total dissolved phos- phate as P (mg/l)	28 0	0.03	0.05 0.19	8 0.17	0.32 0.32	0.54	37 0.06	0.40	0.48 1.67
Orthophosphate as P (mg/l)	27 0	0.06	0.08 0.36	9 0.20	0.33 0.30	0.52	40 0.13	0.46	0.48 1.25
Dissolved oxygen (mg/l)	28 1.9	6.4	6.8 11.2	11 5.2	7.6 6.6	10.4	40 0.3	3.6	3.9 9.3
Total suspended solids (mg/l)	28 0	0.8	1.2 4.3	9 0.3	3.1 1.0	10.8	40 0	1.5	6.8 71.5
Total dissolved solids (mg/l)	27 105	157	155 217	9 81	109 109	133	40 64	125	124 155
Color (Pt-Co units)	28 270	570	590 940	9 150	296 280	500	40 90	325	333 800
Tannin-lignin (mg/l)	28 5.54	10.94	10.43 15.37	9 2.94	5.37 5.37	7.38	40 1.64	4.95	5.26 10.16
Ammonia as N (mg/l)	29 0.01	0.02	0.07 0.91	9 0.01	0.04 0.02	0.07	40 0.01	0.04	0.05 0.16
Nitrate/nitrite as N (mg/l)	28 0.01	0.02	0.02 0.08	9 0.01	0.02 0.02	0.08	40 0	0.01	0.02 0.07
Total organic nitrogen as N (mg/l)	29 0.51	1.58	1.49 2.18	9 0.42	0.88 0.83	1.37	40 0.29	0.75	0.86 2.80
Total nitrogen as N (mg/l)	28 0.60	1.66	1.60 2.20	9 0.46	0.94 0.92	1.40	40 0.35	0.81	0.94 2.91
Total organic carbon as C (mg/l)	26 36.4	75.9	77.3 141.2	8 23.8	39.5 38.2	55.4	39 13.9	45.1	42.4 65.1
Dissolved organic carbon as C (mg/l)	26 36.7	74.5	72.7 108.7	9 19.6	37.6 40.4	51.1	39 14.2	36.2	38.2 86.9
Particulate organic carbon as C (mg/l)	26 0	1.9	7.7 67.1	8 0	4.0 2.2	13.1	38 0	4.0	5.4 20.6
Chlorophyll a (mg/m <sup>3</sup> ) (pheophytin-corrected)	12 0	0	0.37 1.96	2 0	0.18 -	0.36	23 0	0.01	1.04 9.79

<sup>1</sup>Number of samples.

<sup>2</sup>Minimum value.

<sup>3</sup>Median.

<sup>4</sup>Mean.

<sup>5</sup>Maximum value.

<sup>6</sup>Based on hydrogen ion concentration.

Table 3.4-26. Summary Data for Selected Chemical Surface Water Parameters Measured at Stations on Major Tributaries Draining to the Suwannee River (November 1979 - March 1982).

Parameter	FMB-1			FMB-2			CB-1.5		
Flow (cfs)	6 <sup>1</sup>		1.4 <sup>4</sup>	41		1.3	5		3.7
	0.3 <sup>2</sup>	1.3 <sup>3</sup>	3.1 <sup>5</sup>	0	0.2	7.5	1.0	2.1	10.4
Conductivity, field (µmhos/cm)	4		72	26		66	5		126
	57	72	89	37	61	182	88	146	150
Alkalinity as CaCO <sub>3</sub> (mg/l)	7		4.9	30		3.3	5		36.5
	0	1.3	18.0	0	0	22.0	14.8	44.0	50.0
Total hardness as CaCO <sub>3</sub> (mg/l)	7		23	31		20	5		58
	13	22	35	6	19	42	43	63	68
pH, field	1		4.0 <sup>6</sup>	19		3.4	4		5.7
	4.0	-	4.0	2.5	3.7	4.8	5.2	6.1	6.8
Fluoride (mg/l)	7		0.11	31		0.08	5		0.38
	0.08	0.10	0.18	0.05	0.07	0.12	0.27	0.40	0.48
Sulfate (mg/l)	7		0	31		0	5		0
	0	0	0	0	0	0	0	0	0
Total phosphate as P (mg/l)	7		0.10	31		0.06	5		0.70
	0.02	0.10	0.18	0.01	0.04	0.34	0.21	0.81	0.90
Total dissolved phos- phate as P (mg/l)	6		0.21	30		0.04	5		0.66
	0.07	0.11	0.70	0.01	0.04	0.09	0.30	0.76	0.84
Orthophosphate as P (mg/l)	7		0.16	31		0.05	5		0.60
	0.08	0.18	0.23	0	0.04	0.20	0.21	0.71	0.85
Dissolved oxygen (mg/l)	7		9.3	31		5.6	5		8.7
	6.9	8.7	11.4	1.9	5.5	9.6	6.9	8.2	10.7
Total suspended solids (mg/l)	7		4.4	31		1.8	5		1.2
	0	0.6	28.0	0	0.2	36	0.2	0.7	3.0
Total dissolved solids (mg/l)	7		130	31		137	5		157
	107	134	150	99	135	214	125	141	236
Color (Pt-Co units)	7		419	31		485	5		189
	300	370	550	250	470	860	35	110	370
Tannin-lignin (mg/l)	7		8.36	31		9.01	5		2.93
	6.63	8.23	9.84	4.69	9.45	11.70	0.70	1.98	5.29
Ammonia as N (mg/l)	7		0.04	31		0.04	5		0.09
	0.01	0.04	0.11	0.01	0.03	0.18	0.01	0.08	0.18
Nitrate/nitrite as N (mg/l)	7		0.01	31		0.02	5		1.28
	0.01	0.01	0.02	0	0.01	0.08	0.36	1.39	1.94
Total organic nitrogen as N (mg/l)	7		1.18	31		1.21	5		0.79
	0.80	1.08	1.53	0.82	1.13	2.77	0	0.67	1.79
Total nitrogen as N (mg/l)	7		1.24	31		1.27	5		2.15
	0.85	1.18	1.59	0.84	1.20	2.83	1.80	2.23	2.36
Total organic carbon as C (mg/l)	5		49.3	30		57.8	5		33.6
	38.1	50.4	57.1	28.3	58.6	75.6	14.6	40.1	43.0
Dissolved organic carbon as C (mg/l)	6		58.5	31		57.0	5		28.9
	47.2	55.9	79.8	27.4	56.1	80.1	13.4	34.6	37.6
Particulate organic carbon as C (mg/l)	5		0.6	30		4.4	5		4.7
	0	0	2.9	0	1.4	32.7	1.1	5.4	6.7
Chlorophyll a (mg/m <sup>3</sup> ) (pheophytin-corrected)	0		-	14		1.24	5		1.06
	-	-	-	0.22	0.98	4.24	0	0.59	2.35

<sup>1</sup>Number of samples.

<sup>2</sup>Minimum value.

<sup>3</sup>Median.

<sup>4</sup>Mean.

<sup>5</sup>Maximum value.

<sup>6</sup>Based on hydrogen ion concentration.

parameters: conductivity (66-138  $\mu$ hos/cm), hardness (9-58 mg/l), fluoride (0.03-0.38 mg/l), sulfate (0-4 mg/l), total suspended solids (1.2-10.2 mg/l), and total dissolved solids (109-213 mg/l). USGS data for most of these parameters were not available for Deep Creek (USGS No. 2315200). Mean values for conductivity and fluoride from 1968-1980 were 228  $\mu$ hos/cm and 1.4 mg/l, respectively (Coffin 1982).

Due to the larger drainage basins of Rocky and Roaring creeks, several stations were located on each to assess differences in water quality throughout the length of the streams (Figure 3.4-29). On Rocky Creek, mean concentrations of total organic carbon, total organic nitrogen, total ammonia, total dissolved solids, tannin-lignin, and color were higher at Station RC-6 than at the other stations. The drainage basin at RC-6 may not drain as well as the other areas; thus, the prolonged contact of standing water with vegetation results in greater leaching of organic material.

Dissolved oxygen generally increased with distance downstream, as the water, which is initially low in dissolved oxygen in headwater wetlands, subsequently is physically aerated downstream as a result of turbulence created by water flowing over roots, limbs, or other obstructions in the channel. Other parameters varied between stations or exhibited no major trends. Water quality at Cypress Creek (CC-2) was similar to that at Rocky Creek at RC-2.

On Roaring Creek, fewer samples were collected at the uppermost station (RO-14), located within the headwater wetlands, than at the consecutive downstream stations (RO-5 and RO-2) because RO-14 was usually observed to be dry. Fewer samples were also collected at RO-1 (mouth of Roaring Creek), as the station was eliminated from the program in April 1980 due to backwater from the Suwannee River during high flows. Therefore, most Roaring Creek data were collected at RO-2 and RO-5. Water quality at RO-2 differed somewhat from RO-5, probably due to groundwater input downstream of RO-5. RO-2 was not observed to be dry during the sampling period, whereas RO-5 was dry on several occasions. Median pH and mean alkalinity, hardness, and fluoride were higher at RO-2 than at RO-5 and increased during decreases in flow, particularly below 1 cfs. In addition, color, tannin-lignin, and total organic carbon decreased much more markedly at RO-2 with decreases in flow. These differences have a significant effect on means data because approximately 50% of the samples were collected at a flow rate of  $\leq 1$  cfs. Conductivity and total dissolved solids would also be expected to be affected at low flow by groundwater input, but means for both parameters were higher at RO-5. Although mean conductivity was lower at RO-2, individual concentrations were higher at flows  $< 1$  cfs versus higher flows. Concentration of total dissolved solids appeared to vary independently of flow rates. Total phosphate and orthophosphate concentrations were higher at RO-2 and increased during low flows, suggesting further that the difference may be due to groundwater input.

Mean concentrations of sulfate, total suspended solids, ammonia, and nitrate/nitrite exhibited little or no difference between RO-2 and RO-5. Total organic nitrogen was higher at RO-5 while dissolved oxygen was lower at RO-5 than at RO-2. Even though the data are limited to two stations, areal differences in dissolved oxygen are expected to follow

the same trend observed at Rocky Creek, with low headwater concentrations increasing downstream.

Based on USGS data and results of the monthly and comprehensive samplings performed at the tributary stations (Tables 3.4-22 through 3.4-28), parameters that did not meet the FAC standards at least once were enumerated (Table 3.4-29). Numbers of values not meeting alkalinity criteria were similar to those for the upper Suwannee; values failed to meet the minimum 20 mg/l standard in 81-100% of the samples at RC-2, RC-6, RC-10, RO-5, FMB-2, and Deep Creek (USGS No. 2315200). Approximately half of the samples at RO-2 and LB-2 exhibited alkalinity less than the standard, and only one of the samples collected at CB-1.5 had a concentration less than 20 mg/l. These low alkalinity values are due to natural conditions and are not a result of man's activity.

The frequency of samples not meeting the dissolved oxygen standard was greater for the tributary streams than for the Suwannee River and was greater at stations closer to headwaters. Long Branch at LB-2, which did not meet the standard in 77% of the samples, is located close to the headwaters and experiences little turbulence. All complex organics at all stations were below the detectable limits. Values exceeding coliform criteria occurred only at RC-2 (2 of 35 samples), RO-2 (2 of 3 samples), and Deep Creek (1 of 9 samples). At least one mercury value exceeded the standard at over half the stations (RC-2, RC-6, RO-2, RO-5, and Deep Creek).

Data collected from tributary stations were examined to evaluate any seasonal variability. Based on the two-year sampling period, no obvious trends are discernable. It is expected that most temporal differences would be controlled by discharge rates and residence times of leachate waters held in swamps and poorly drained upland areas.

Stations Receiving Mine and Chemical Plant Discharge. The following waterbodies are discussed in this section.

- 1) Hunter Creek, a Suwannee River tributary, receives mine-related discharges. Swift Creek receives mine drainage but also receives chemical plant discharge waters which would not be representative of the proposed new discharges. Impacts of chemical plant discharge waters on Swift Creek and the Suwannee River were addressed in the Swift Creek EIS (EPA 1978a).
- 2) Eagle Lake, a reclaimed lake, receives both mine and chemical plant discharge. Mine discharges consist of recirculating waters, pit dewatering waters, and runoff from sand tailings, disturbed areas, and natural areas. This waterbody is included for purposes of examining maximum level input to study area tributaries. The proposed waterbodies of this type will not receive chemical plant discharge. The combination of the discharge components will depend on the location of the lake relative to the mining and reclamation processes.
- 3) Altmans Bay and Section 13 Lake, reclaimed lakes, receive all five mine discharge components but no chemical plant discharge.

Table 3.4-27. Results of Comprehensive Water Quality Monitoring, 18-25 August 1981.

Parameter	RC-2	RC-5	RC-6	RO-2	LB-1
<b>MISCELLANEOUS</b>					
Flow (cfs)	0.50	0	0	0.30	0.57
Conductivity, field ( $\mu$ mhos/cm)	87	105	112	150	86
Alkalinity as CaCO <sub>3</sub> (mg/l)	21.5	0	0	44.0	27.5
Total hardness as CaCO <sub>3</sub> (mg/l)	42	6	7	50	40
pH, field	5.6	2.9	2.7	5.8	5.9
Fluoride (mg/l)	0.26	0.11	0.14	0.67	0.30
Sulfate (mg/l)	0	0	0	0	0
Total phosphate as P (mg/l)	0.17	0.06	0.06	1.53	0.56
Total dissolved phosphate as P (mg/l)	0.17	0.05	0.05	1.55	0.54
Orthophosphate as P (mg/l)	0.19	0.10	0.07	1.55	0.52
Temperature, field (°C)	25	24	24	23	24
Dissolved oxygen (mg/l)	4.1	7.2	5.6	2.6	5.4
BOD <sub>5</sub> (mg/l)	6	3	2	2	3
Total suspended solids (mg/l)	13.8	1.0	4.6	0.7	1.6
Total dissolved solids (mg/l)	143	214	227	95	96
Transparency (m)	0.05	0.24	*	*	*
Color (Pt-Co units)	650	1300	1300	50	150
Tannin-lignin (mg/l)	9.6	20.43	21.54	1.06	2.94
Ammonia as N (mg/l)	0.06	0.25	0.22	0.06	0.07
Un-ionized ammonia as N (mg/l)	ND	ND	ND	ND	ND
Nitrate/nitrite as N (mg/l)	0.28	0.03	0.03	0.11	0.08
Total organic nitrogen as N (mg/l)	1.70	2.38	1.69	0	0.76
Total nitrogen as N (mg/l)	2.04	2.66	1.94	0.16	0.91
Total organic carbon as C (mg/l)	51.1	83.5	88.3	10.2	23.8
Dissolved organic carbon as C (mg/l)	61.0	95.0	99.5	8.7	19.6
Particulate organic carbon as C (mg/l)	0	0	0	1.5	4.3
Chlorophyll a (mg/m <sup>3</sup> ) (pheophytin-corrected)	8.33	10.78	0	0	0
Oil and grease (mg/l)	2	ND	1	1	3
Surfactants (methylene blue active substances) (mg/l)	ND	ND	ND	ND	ND
Total cyanide (mg/l)	ND	ND	ND	ND	ND
Fecal coliform (MPN/100 ml)	140	75	ND	1500	30
Total coliform (MPN/100 ml)	64	460	7	>24000	60
<b>METALS</b>					
Aluminum (mg/l)	1.26	1.04	0.83	0.17	0.17
Arsenic (mg/l)	ND	ND	ND	ND	ND
Barium (mg/l)	ND	ND	ND	ND	ND
Beryllium (mg/l)	ND	ND	ND	ND	ND
Cadmium (mg/l)	0.01	0.01	0.01	0.01	0.01
Chromium (mg/l)	0.03	ND	ND	ND	ND
Copper (mg/l)	ND	ND	ND	ND	ND
Iron (mg/l)	0.91	0.69	0.65	0.49	0.43
Lead (mg/l)	ND	ND	ND	ND	ND
Mercury ( $\mu$ g/l)	ND	ND	0.49	ND	ND
Nickel (mg/l)	ND	ND	ND	ND	ND
Selenium (mg/l)	ND	ND	ND	ND	ND
Silver (mg/l)	ND	ND	ND	ND	ND
Zinc (mg/l)	0.036	0.009	0.009	0.006	0.014
ORGANICS**	ND	ND	ND	ND	ND
<b>RADIATION</b>					
Radium-226 (pCi/l)	ND	ND	ND	ND	ND
Gross alpha (pCi/l)	1.9±1.9 <sup>+</sup>	1.1±0.7	0.7±0.7	0.6±0.6	1.2±0.8

ND - Not detectable (See Table 3.4-18 for detection limits.)

\* - Too shallow to sample.

\*\* - Results of all organics analyses were below the detectable limits at all stations. Refer to Table 3.4-18 for list of parameters analyzed and detection limits.

+ - 95% confidence limits.

Note: CC-2, RC-10, RO-5, and RO-14 were dry at the time of sampling.

Table 3.4-28. Results of Comprehensive Water Quality Monitoring, 15-18 February 1982.

Parameter	RC-2	RC-5	RC-6	RC-10	RO-2	RO-5	RO-15	LB-1	CB-1.5
MISCELLANEOUS									
Flow (cfs)	77.17	20.51	5.01	9.88	2.91	1.38	0.04	3.73	10.58
Conductivity, field ( $\mu$ mhos/cm)	98	120	148	125	80	121	114	70	78
Alkalinity as CaCO <sub>3</sub> (mg/l)	0	0	0	0	0	0	0	16.3	13.1
Total hardness as CaCO <sub>3</sub> (mg/l)	9	7	6	11	23	25	12	30	38
pH, field	4.9	3.4	3.4	3.7	4.6	3.8	3.5	5.4	6.1
Fluoride (mg/l)	0.04	0.03	0.04	0.03	0.11	0.06	0.10	0.17	0.19
Sulfate (mg/l)	0	0	0	0	0	0	0	0	0
Total phosphate as P (mg/l)	0.01	ND	ND	ND	0.24	0.03	ND	0.39	0.30
Total dissolved phosphate as P (mg/l)	0.02	ND	ND	ND	0.35	0.02	ND	0.41	0.29
Orthophosphate as P (mg/l)	0.01	ND	ND	ND	0.21	0.02	ND	0.26	0.35
Temperature, field (°C)	18	18	17	17	17	16	19	16	18
Dissolved oxygen (mg/l)	6.5	6.0	5.4	5.4	8.0	5.6	9.3	6.5	8.4
BOD <sub>5</sub> (mg/l)	2	4	1	2	1	3	2	2	4
Total suspended solids (mg/l)	1.2	0.2	1.2	0.2	0.3	7.2	0.2	0.5	4.8
Total dissolved solids (mg/l)	173	213	209	196	183	189	185	107	144
Transparency (m)	0.53	0.79	0.34	0.64	*	*	*	*	0.43
Color (Pt-Co units)	500	740	1000	800	480	500	550	330	450
Tannin-lignin (mg/l)	11.35	12.68	13.38	12.09	8.06	7.47	10.74	5.85	6.75
Ammonia as N (mg/l)	0.02	0.07	0.18	0.12	0.03	0.03	0.04	0.02	0.05
Un-ionized ammonia as N (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND
Nitrate/nitrite as N (mg/l)	0.04	0.07	0.13	0.06	0.04	0.02	0.03	0.02	0.26
Total organic nitrogen as N (mg/l)	1.50	1.96	2.18	1.87	0.75	1.39	1.45	0.42	1.17
Total nitrogen as N (mg/l)	1.56	2.10	2.49	2.05	0.82	1.44	1.52	0.46	1.48
Total organic carbon as C (mg/l)	73.9	96.5	97.6	96.7	61.2	72.1	89.9	39.5	49.9
Dissolved organic carbon as C (mg/l)	68.5	81.3	82.6	94.6	64.8	70.4	86.4	37.6	43.5
Particulate organic carbon as C (mg/l)	5.4	15.2	15.0	2.1	0	1.7	3.5	1.9	6.4
Chlorophyll a (mg/m <sup>3</sup> ) (pheophytin-corrected)	2.02	5.55	11.11	7.09	0.58	3.61	0	0.36	0
Oil and grease (mg/l)	-	-	-	-	-	-	-	-	-
Surfactants (methylene blue active substances) (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total cyanide (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fecal coliform (MPN/100 ml)	93	75	460	23	64	93	4	120	93
Total coliform (MPN/100 ml)	2400	290	2400	34	64	460	150	210	1100
METALS									
Aluminum (mg/l)	0.8	0.6	0.8	0.5	0.8	1.2	0.8	0.2	0.8
Arsenic (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND
Barium (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND
Beryllium (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cadmium (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chromium (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND
Copper (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND
Iron (mg/l)	0.53	0.37	0.37	0.35	0.62	0.52	0.73	0.50	0.70
Lead (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND
Mercury ( $\mu$ g/l)	1.1	0.3	ND	ND	0.4	0.6	0.4	1.0	0.9
Nickel (mg/l)	ND	0.02	0.06	ND	0.02	ND	ND	ND	ND
Selenium (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND
Silver (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND
Zinc (mg/l)	0.02	ND	ND	ND	0.03	0.02	0.03	0.11	0.01
ORGANICS**	ND	ND	ND	ND	ND	ND	ND	ND	ND
RADIATION									
Radium-226 (pCi/l)	0.11±0.05 <sup>+</sup>	<0.04	<0.06	0.05±0.05	0.08±0.05	0.06±0.06	0.07±0.04	0.12±0.05	0.07±0.05
Radium-228 (pCi/l)	<1.5	<1.3	<1.9	0.8±0.8	0.5±0.5	<1.8	1.0±1.0	1.9±1.9	<2.6
Gross alpha (pCi/l)	<1.8	1.3±1.5	<0.9	<1.9	<2.7	<3.0	<1.4	<1.9	2.7±1.9
Gross beta (pCi/l)	4.7±3.1	5.4±3.7	3.5±2.8	7.5±4.1	3.5±3.1	12.3±4.2	5.5±4.0	3.9±3.3	6.0±4.0

ND - Not detectable (See Table 3.4-20 for detection limits.)

\* - Too shallow to sample.

\*\* - Results of all organics analyses were below the detectable limits at all stations. Refer to Table 3.4-20 for list of parameters analyzed and detection limits.

+ - 95% confidence limits.

Note: RO-14 and FMB-2 were dry at the time of sampling.

Table 3.4-29. Values Not Meeting FDER Water Quality Standards at Tributary Stations.

Parameter	No. of deviations/No. of samples										
	RC-2	USGS1	RC-6	RC-10	RO-2	USGS2	RO-5	LB-2	FMB-2	CB-1.5	USGS3
Alkalinity	39/44	24/25	41/41	38/38	23/44	5/10	34/34	19/39	28/29	1/4	22/27
Dissolved oxygen	7/43	11/67	14/40	21/38	10/44	2/5	15/34	30/39	12/29	0/5	3/59
Fecal coliform	0/2	-	0/2	0/2	1/2	-	0/2	0/2	0/2	0/2	-
Total coliform	0/2	2/35	0/2	0/2	1/2	1/1	0/2	0/2	0/2	0/2	1/9
Mercury	1/2	5/5	1/2	0/2	1/2	-	1/1	0/2	0/2	0/2	13/18

1USGS No. 2314986, at RC-2.

2USGS No. 2315090, at RO-2.

3USGS No. 2315200, Deep Creek.

Source: OXY EIS data, November 1979 - March 1982.  
USGS, October 1970 - October 1981.

Four stations were established in the 14 sq mi Hunter Creek drainage basin (Figure 3.4-29). The eastern and southeastern headwaters of the basin have been disturbed by phosphate mining activities. The northern portion of the basin drains an area undisturbed by mining. Drainage to each station is as follows:

- HB-2 - waters undisturbed by mining
- HC-3 - waters in canal which receives the majority of its water from the recirculating water system (RS)
- HC-2 - waters from HB-2, HC-3, eastern RS, and natural runoff
- HC-1 - all Hunter Creek drainage (mouth of creek)

Mean concentrations for all parameters were very similar for Stations HC-2 and HC-3, both of which were different from HB-2 (Table 3.4-30). Mean concentrations at HC-1 were similar to HC-2 and HC-3 for all parameters except sulfate, phosphate, dissolved oxygen, and total nitrogen, which were somewhat higher at HC-1. Mean data for Stations HB-2 and HC-1 versus HC-2 and HC-3 should be compared with caution due to the disparity in the number of observations between the stations (Table 3.4-30).

Mean values for conductivity, alkalinity, total hardness, and pH were higher at HC-2 and HC-3 than in the unaffected tributaries and the Suwannee River but were lower than expected concentrations from most springs discharging to the river. Total dissolved solids, sulfate, and fluoride concentrations were higher than concentrations expected in most springs in the Suwannee basin as well as in the tributaries. Reduced input from swamp drainage (a major component of the unaffected tributaries) is indicated by less color and lower concentrations of tannin-lignin and total organic carbon.

Nutrients and total suspended solids in Hunter Creek (at HC-2 and HC-3) were higher than in the upper Suwannee River and in the unaffected streams except for Camp Branch (CB-1.5), where nitrate/nitrite was higher than at Hunter Creek. Mean concentrations of dissolved oxygen were well above the 5.0 mg/l State standard.

The majority of mining input waters to Hunter Creek originate from the recirculating water system (RS). Two representative points were monitored at the Suwannee River Mine (Stations RS-1 and RS-2) and one point at the Swift Creek Mine (Station RS-4) (Figure 3.4-29). These waters are expected to represent a typical source of recirculated waters from clay disposal systems in future discharges to the Suwannee River.

Three reclaimed lakes were monitored; these are expected to represent conditions of water quality that may be discharged through the tributaries to the Suwannee River. In addition to recirculating water system input, these lakes receive various combinations of different mining waters, several of which may not be present in all of the proposed new discharges. In particular, of the three lakes, Eagle Lake receives chemical plant discharge which would not be in the proposed discharges evaluated by this study.

Table 3.4-30. Summary Data for Selected Chemical Surface Water Parameters Measured at Stations on Major Tributaries Draining to the Suwannee River (November 1979 - March 1982).

Parameter	HC-1			HC-2			HC-3			HB-2*		
Flow (cfs)	5 <sup>1</sup> 4.8 <sup>2</sup>	9.8 <sup>3</sup>	10.8 <sup>4</sup> 21.1 <sup>5</sup>	43 0.4	10.4	17.0 74.3	43 0	1.5	6.9 59.0	4 0.6	2.5	2.8 5.8
Conductivity, field (µmhos/cm)	8 160	378	348 459	37 61	248	262 475	37 70	300	275 462	5 67	80	77 87
Alkalinity as CaCO <sub>3</sub> (mg/l)	10 2.5	31.5	27.7 53.0	43 0	29.0	28.0 58.0	44 0	29.5	27.7 58.0	5 0	0	0 0
Total hardness as CaCO <sub>3</sub> (mg/l)	10 37	132	123 177	44 25	106	106 178	44 22	123	114 184	5 7	10	10 13
pH, field	2 6.0	-	6.2 <sup>6</sup> 6.6	29 3.7	6.3	5.0 7.3	30 2.8	6.2	4.1 7.7	5 2.7	3.9	3.3 4.8
Fluoride (mg/l)	10 0.54	1.60	1.54 2.41	44 0.35	1.51	1.46 2.86	44 0.18	1.55	1.50 2.93	4 0.09	0.10	0.10 0.12
Sulfate (mg/l)	10 21.0	117.0	108.2 180.0	44 0	83.2	80.9 172.1	44 0	90.0	90.6 163.1	5 0	0	0 0
Total phosphate as P (mg/l)	9 1.70	3.16	3.12 4.10	43 0.20	2.12	2.10 4.10	43 0.24	1.85	2.08 4.80	5 0.01	0.02	0.03 0.05
Total dissolved phos- phate as P (mg/l)	10 0.80	2.93	2.77 4.25	42 0.30	2.05	2.01 4.25	41 0.09	1.88	1.98 4.55	5 0.01	0.03	0.03 0.05
Orthophosphate as P (mg/l)	10 0.90	2.94	2.71 3.85	44 0.34	2.09	2.07 4.10	44 0.33	1.95	2.05 4.35	5 0.01	0.03	0.03 0.04
Dissolved oxygen (mg/l)	10 5.2	8.6	8.3 10.2	44 4.0	6.8	7.1 10.6	44 3.8	7.4	7.2 10.8	5 5.6	6.1	7.0 10.6
Total suspended solids (mg/l)	10 3.7	6.5	11.3 43.3	44 0.8	8.7	10.2 31.5	44 1.8	8.1	9.0 26.7	5 0.2	1.7	1.6 3.0
Total dissolved solids (mg/l)	10 164	269	255 326	44 122	216	221 333	44 123	240	239 378	5 132	148	146 158
Color (Pt-Co units)	10 32	143	156 320	43 25	125	145 520	44 15	63	137 650	5 300	450	414 500
Tannin-lignin (mg/l)	10 1.01	2.85	3.39 6.09	44 0.90	2.50	3.30 9.71	44 0.40	1.58	2.87 11.18	5 6.70	8.41	8.15 9.44
Ammonia as N (mg/l)	9 0.21	1.54	1.62 2.81	41 0.04	0.57	1.10 6.61	43 0.05	0.61	1.09 4.63	5 0.01	0.02	0.06 0.22
Nitrate/nitrite as N (mg/l)	10 0.25	0.51	0.58 1.38	43 0.04	0.42	0.49 1.48	44 0.04	0.20	0.26 1.36	5 0.01	0.03	0.02 0.03
Total organic nitrogen as N (mg/l)	9 0.24	1.30	1.36 2.87	41 0	1.12	1.15 3.08	43 0	1.22	1.23 1.89	5 0.35	1.05	1.01 1.55
Total nitrogen as N (mg/l)	10 1.45	3.63	3.59 6.41	43 1.14	2.22	2.56 6.93	44 0.90	2.16	2.80 12.84	5 0.60	1.11	1.09 1.59
Total organic carbon as C (mg/l)	10 20.0	32.1	33.7 46.2	44 16.4	30.4	34.0 68.5	41 13.7	29.9	33.1 81.6	5 50.7	57.5	62.0 75.1
Dissolved organic carbon as C (mg/l)	10 21.0	33.5	32.9 47.9	44 14.0	28.7	31.3 65.2	41 10.3	25.9	30.7 90.2	5 48.7	52.4	52.0 55.7
Particulate organic carbon as C (mg/l)	10 0	0	4.1 11.9	44 0	1.4	4.2 30.0	41 0	2.4	4.5 24.8	5 0.2	8.5	10.0 20.1
Chlorophyll a (mg/m <sup>3</sup> ) (pheophytin-corrected)	0 -	-	-	26 0	3.42	18.34 150.24	25 0	7.15	10.90 52.00	5 0	1.73	1.32 2.91

\*Branch of Hunter Creek which does not receive mine water.

<sup>1</sup>Number of samples.

<sup>2</sup>Minimum value.

<sup>3</sup>Median.

<sup>4</sup>Mean.

<sup>5</sup>Maximum value.

<sup>6</sup>Based on hydrogen ion concentration.

Summary data for the RS stations and lakes appear in Tables 3.4-31 and 3.4-32. Reclaimed lake stations are located at the discharge control structure of each lake. As in the case of Hunter Creek, mean total dissolved solids, conductivity, alkalinity, hardness, and sulfate, and median pH at the lake and RS stations were higher than in the unaffected streams and in the Suwannee River. Parameters indicative of swamp drainage (i.e., pH, alkalinity, color, tannin-lignin) were lower than in Hunter Creek. Color, tannin-lignin, and total organic carbon were higher at Eagle Lake than at all the other lake and RS stations as well as Stations HC-2 and HC-3. This is due to the large contribution of these constituents from Swift Creek Swamp.

Mean concentrations of total phosphate as P and orthophosphate as P varied among stations. Altmans Bay (AB-3), RS-1, and RS-2 exhibited higher concentrations, whereas S13D-1 and RS-4 exhibited concentrations lower than in Hunter Creek and only slightly higher than in Roaring Creek, Long Branch, and Camp Branch. Total organic nitrogen concentrations were fairly similar among lake and RS stations and were slightly higher than in Hunter Creek, the unaffected tributaries, and the upper Suwannee (SR-2). Nitrate/nitrite concentrations generally were slightly higher at the lakes versus RS waters and Hunter Creek stations.

Mean concentrations of fluoride and total suspended solids were fairly variable between lakes and RS stations. With the exception of Eagle Lake, these parameters were higher at all stations compared to Hunter Creek. Dissolved oxygen was variable among stations. Mean dissolved oxygen at Altmans Bay, RS-1, and RS-4 was higher than at Hunter Creek, Roaring Creek (RO-2), and the upper Suwannee River (SR-2). Section 13 Lake had the lowest mean. As is expected, there was greater dissolved oxygen variability in the lakes and slow-moving RS waters as compared to the tributaries and the Suwannee River.

Number of deviations from State standards, based on results of the monthly and comprehensive samplings (Tables 3.4-30 through 3.4-34), are listed in Table 3.4-35. Fewer numbers of samples for alkalinity had values below the standard at lake, RS, and Hunter Creek stations than at the unaffected tributary stations. Numbers of mercury and coliform deviations were similar to those for the unaffected tributaries and the Suwannee River. Few dissolved oxygen values did not meet the standard at Hunter Creek (12%) and Altmans Bay (6%), while several values at EL001-18 (45%), S13D-1 (59%), and the RS stations (30-43%) failed to meet the standard (i.e., were <5.0 mg/l). One iron value at HC-3 and two at HC-2 (USGS) exceeded the 1.0 mg/l FDER limit. Un-ionized ammonia deviations ranged from 3-18% of the samples collected at each station.

Criteria for evaluating conductivity and pH data were based on background conditions (Table 3.4-16). Due to the lack of background data for Hunter Creek, these criteria cannot be directly applied. To compare the levels of these two parameters in Hunter Creek with background levels, data from the unaffected tributaries (RC-2, RO-2, FMB-2, and LB-2) were used to approximate background conditions. These four stations were selected as being most representative, neither extreme upstream nor downstream conditions, of water quality in the unaffected

Table 3.4-31. Summary Data for Selected Chemical Surface Water Parameters Measured at Stations on OXY Recirculating Water System (November 1979 - March 1982).

Parameter	RS-1			RS-2			RS-4		
Flow (cfs)	0	-	-	0	-	-	0	-	-
Conductivity, field ( $\mu$ mhos/cm)	27 <sup>1</sup> 300 <sup>2</sup>	420 <sup>3</sup>	423 <sup>4</sup> 700 <sup>5</sup>	25 218	420	402 662	8 360	460	453 530
Alkalinity as CaCO <sub>3</sub> (mg/l)	32 34.0	57.5	57.2 81.0	30 23.0	44.0	52.7 276.0	7 66.0	75.0	74.8 81.5
Total hardness as CaCO <sub>3</sub> (mg/l)	31 135	173	172 212	29 105	159	160 364	7 149	199	191 222
pH, field	26 6.0	6.7	6.5 <sup>6</sup> 7.2	23 5.9	6.6	6.5 8.4	7 6.3	6.6	6.7 7.8
Fluoride (mg/l)	32 0.05	2.56	2.50 4.52	30 0.03	2.38	2.32 3.28	7 1.54	1.80	1.92 2.56
Sulfate (mg/l)	32 76.4	123.4	128.4 189.5	30 26.8	102.6	109.5 177.0	7 74.5	143.4	129.8 167.2
Total phosphate as P (mg/l)	32 0.64	2.86	5.55 77.60	30 1.36	3.44	4.44 23.75	7 0.25	0.95	1.19 2.91
Total dissolved phos- phate as P (mg/l)	32 0.44	2.29	4.75 69.80	30 0.55	3.02	4.13 23.54	7 0.26	0.70	0.68 1.09
Orthophosphate as P (mg/l)	31 0.62	2.52	5.15 68.34	30 1.34	3.70	4.39 19.10	7 0.14	0.95	0.83 1.29
Dissolved oxygen (mg/l)	32 2.1	8.5	8.6 19.9	30 0.5	6.8	6.9 14.4	8 3.5	8.2	7.7 11.6
Total suspended solids (mg/l)	31 0.2	12.0	16.2 110.5	29 6.0	19.7	25.6 123.0	7 6.2	15.0	21.0 62.0
Total dissolved solids (mg/l)	31 204	290	293 500	29 189	280	280 436	7 234	312	317 396
Color (Pt-Co units)	32 20	27	29 60	30 10	24	37 250	7 10	11	12 15
Tannin-lignin (mg/l)	32 0.53	1.09	1.07 1.74	30 0.43	0.76	0.88 2.39	7 0.42	0.64	0.66 0.93
Ammonia as N (mg/l)	32 0.01	0.37	2.39 18.51	30 0.03	1.38	1.57 4.20	7 0.07	0.70	0.90 3.23
Nitrate/nitrite as N (mg/l)	32 0.01	0.05	0.15 0.67	30 0.01	0.45	0.87 4.35	7 0.02	0.35	0.40 0.75
Total organic nitrogen as N (mg/l)	32 0	1.03	1.32 4.98	29 0.17	1.67	1.77 6.22	7 0.18	1.02	1.12 2.33
Total nitrogen as N (mg/l)	31 0.72	2.08	3.33 9.62	29 1.45	3.96	4.20 9.98	7 0.49	2.38	2.42 4.49
Total organic carbon as C (mg/l)	31 12.0	23.0	27.3 52.2	28 12.0	22.6	26.5 49.0	7 13.4	22.2	22.6 31.1
Dissolved organic carbon as C (mg/l)	31 9.0	17.9	23.5 56.7	28 6.0	17.4	21.7 57.1	7 14.4	17.5	19.6 33.3
Particulate organic carbon as C (mg/l)	31 0	4.0	6.3 21.3	28 0	5.5	6.7 27.4	7 0	1.8	3.9 9.3
Chlorophyll a (mg/m <sup>3</sup> ) (pheophytin-corrected)	26 0	31.98	70.43 820.57	23 0	51.67	59.35 197.70	7 15.60	54.11	50.03 98.31

<sup>1</sup>Number of samples.

<sup>2</sup>Minimum value.

<sup>3</sup>Median.

<sup>4</sup>Mean.

<sup>5</sup>Maximum value.

<sup>6</sup>Based on hydrogen ion concentration.

Table 3.4-32. Summary Data for Selected Chemical Surface Water Parameters Measured at Stations on OXY Reclaimed Lakes (November 1979 - March 1982).

Parameter	EL001-18			A8-3			S130-1			SS-3		
	23 <sup>1</sup> 2.5 <sup>2</sup>	23.9 <sup>3</sup>	20.7 <sup>4</sup> 42.5 <sup>5</sup>	0	-	-	3	0	0	33	16.7	21.4
Flow (cfs)												
Conductivity, field (µmhos/cm)	27 119	260	270 477	27 215	338	330 380	32 100	283	485	31 159	355	337 642
Alkalinity as CaCO <sub>3</sub> (mg/l)	33 11.6	64.0	59.9 99.0	32 19.0	50.5	49.5 68.0	41 0.0	58.0	358.0	32 16.1	79.5	74.4 139.0
Total hardness as CaCO <sub>3</sub> (mg/l)	33 57	117	118 166	32 92	136	134 154	40 64	115	149	32 13	129	122 197
pH, field	26 5.4	6.9	6.4 <sup>6</sup> 9.1	26 5.3	7.6	6.5 9.0	25 3.3	6.1	7.8	29 5.1	6.3	5.9 7.5
Fluoride (mg/l)	33 0.72	1.30	1.30 1.90	32 0.02	2.23	1.98 2.75	41 0.03	1.82	2.81	38 0.31	1.25	1.32 2.32
Sulfate (mg/l)	33 0	60.7	61.2 94.4	32 68.1	87.7	87.5 107.8	41 0	65.7	93.1	38 0	74.6	67.7 119.9
Total phosphate as P (mg/l)	32 0.52	5.50	5.64 1.90	32 3.00	5.50	5.64 9.62	41 0.34	0.80	1.85	37 0.78	2.10	2.25 5.02
Total dissolved phos- phate as P (mg/l)	32 0.53	1.16	1.15 1.96	32 1.79	4.95	4.85 8.67	41 0.46	0.80	1.42	36 0.70	1.30	1.54 3.45
Orthophosphate as P (mg/l)	33 0.76	1.38	1.43 2.62	32 1.82	5.32	5.19 8.17	40 0.34	0.94	4.50	31 0.79	2.16	2.19 4.88
Dissolved oxygen (mg/l)	33 1.2	6.0	6.2 14.8	31 2.4	8.7	9.1 14.6	40 0.2	4.4	12.2	38 0.2	1.6	2.4 8.4
Total suspended solids (mg/l)	33 3.6	8.2	9.0 18.0	32 2.3	15.4	15.6 40.0	41 0.5	8.3	55.4	32 0.0	7.6	14.6 102.0
Total dissolved solids (mg/l)	33 161	218	227 307	32 189	241	240 341	41 86	215	326	32 174	261	258 320
Color (Pt-Co units)	33 80	210	231 500	32 10	28	54 225	41 20	54	290	32 175	380	420 940
Tannin-lignin (mg/l)	33 1.77	3.77	3.68 7.21	32 0.31	0.80	1.08 3.34	41 0.60	1.39	5.32	32 3.08	7.21	7.61 19.66
Ammonia as N (mg/l)	33 0.01	0.53	1.35 8.02	32 0.02	0.25	0.97 6.21	40 0.02	0.42	5.66	32 0.05	2.72	3.91 12.63
Nitrate/nitrite as N (mg/l)	32 0.01	0.57	0.95 4.38	32 0.01	0.65	1.01 4.10	40 0.01	1.17	4.60	32 0.02	0.09	0.14 0.52
Total organic nitrogen as N (mg/l)	33 0	1.30	2.08 23.09	31 0	1.67	1.62 4.22	40 0	1.18	2.65	32 0	1.42	2.01 18.13
Total nitrogen as N (mg/l)	32 1.10	2.68	4.33 23.14	31 1.05	2.95	3.49 9.22	40 0.68	3.66	8.34	32 1.55	4.47	5.64 29.42
Total organic carbon as C (mg/l)	33 17.0	36.6	41.3 93.2	32 13.2	29.1	32.9 64.9	41 12.1	29.2	62.2	32 26.5	48.1	51.0 88.9
Dissolved organic carbon as C (mg/l)	33 17.9	33.0	34.8 65.7	32 12.0	22.0	25.0 52.2	41 9.5	25.3	48.6	32 19.4	45.6	44.8 66.6
Particulate organic carbon as C (mg/l)	33 0	4.8	8.2 59.9	32 0	6.4	8.3 40.5	41 0	3.1	30.8	32 0	3.6	6.9 35.2
Chlorophyll a (mg/m <sup>3</sup> ) (pheophytin-corrected)	26 0	20.04	30.87 238.86	26 8.22	56.92	71.24 228.37	23 0	9.67	109.51	26 0	9.16	19.12 140.90

<sup>1</sup>Number of samples.

<sup>2</sup>Minimum value.

<sup>3</sup>Median.

<sup>4</sup>Mean.

<sup>5</sup>Maximum value.

<sup>6</sup>Based on hydrogen ion concentration.

Table 3.4-33. Results of Comprehensive Water Quality Monitoring, 18-25 August 1981.

Parameter	HC-2	HC-3	SS-3	EL001-18	AB-3	RS-1	RS-2	RS-4
<b>MISCELLANEOUS</b>								
Flow (cfs)	7.8	0.01	12.0	-	-	-	-	-
Conductivity, field (umhos/cm)	380	325	172	270	321	380	440	415
Alkalinity as CaCO <sub>3</sub> (mg/l)	49.0	32.0	26.0	50.0	55.5	63.0	32.0	78.0
Total hardness as CaCO <sub>3</sub> (mg/l)	143	113	56	119	133	159	167	169
pH, field	6.4	6.2	5.6	7.3	8.9	6.8	6.5	6.6
Fluoride (mg/l)	2.17	1.50	1.15	1.34	2.34	2.49	2.72	2.05
Sulfate (mg/l)	101.1	82.1	0	54.9	84.5	107.6	142.0	96.9
Total phosphate as P (mg/l)	2.53	1.21	3.07	1.31	3.52	2.45	4.62	0.88
Total dissolved phosphate as P (mg/l)	2.33	1.04	2.65	1.24	1.79	2.29	4.15	0.62
Orthophosphate as P (mg/l)	2.34	1.21	2.48	1.17	3.31	2.20	4.40	0.64
Temperature, field (°C)	25	24	27	30	31	31	29	28
Dissolved oxygen (mg/l)	5.3	5.2	1.0	4.9	11.2	9.7	1.6	3.5
BOD <sub>5</sub> (mg/l)	5	4	6	5	11	6	6	9
Total suspended solids (mg/l)	10.3	3.8	5.0	3.6	27.3	7.7	19.7	23.7
Total dissolved solids (mg/l)	266	230	267	196	231	269	300	275
Transparency (m)	0.73	*	0.18	1.22	0.55	0.52	-	0.73
Color (Pt-Co units)	44	32	940	130	10	32	12	11
Tannin-lignin (mg/l)	1.14	0.90	19.66	1.98	0.63	1.10	0.64	0.64
Ammonia as N (mg/l)	0.18	0.39	2.43	0.07	0.22	0.05	0.39	0.07
Un-ionized ammonia as N (mg/l)	ND	ND	ND	ND	0.10	ND	ND	ND
Nitrate/nitrite as N (mg/l)	0.48	0.38	0.07	0.12	0.28	ND	0.21	0.75
Total organic nitrogen as N (mg/l)	1.73	1.68	2.63	1.47	2.70	1.10	1.66	1.56
Total nitrogen as N (mg/l)	2.39	2.45	5.13	1.66	3.20	1.16	2.26	2.38
Total organic carbon as C (mg/l)	26.6	31.4	88.9	25.6	23.0	20.9	19.1	19.2
Dissolved organic carbon as C (mg/l)	19.4	23.6	60.0	23.3	23.8	17.2	20.2	17.4
Particulate organic carbon as C (mg/l)	7.2	7.9	28.8	3.3	0	3.7	0	1.8
Chlorophyll a (mg/m <sup>3</sup> ) (pheophytin-corrected)	27.73	2.44	0	14.42	80.18	17.28	62.84	41.06
Dil and grease (mg/l)	ND	2	5	4	2	1	1	ND
Surfactants (methylene blue active substances) (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND
Total cyanide (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND
Fecal coliform (MPN/100 ml)	150	120	240	43	110	-	-	2100
Total coliform (MPN/100 ml)	360	>24000	11000	93	200	-	-	2900
<b>METALS</b>								
Aluminum (mg/l)	0.72	1.04	0.61	0.17	0.17	0.83	0.72	0.83
Arsenic (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND
Barium (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND
Beryllium (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND
Cadmium (mg/l)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Chromium (mg/l)	ND	ND	ND	ND	ND	ND	0.03	ND
Copper (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND
Iron (mg/l)	0.36	1.08	0.88	0.08	0.04	0.28	0.23	0.30
Lead (mg/l)	0.10	ND	ND	ND	ND	ND	ND	ND
Mercury (ug/l)	ND	0.23	ND	ND	0.36	0.38	ND	ND
Nickel (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND
Selenium (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND
Silver (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND
Zinc (mg/l)	0.011	0.014	0.023	0.025	ND	0.005	ND	0.005
ORGANICS**	ND	ND	ND	ND	ND	ND	ND	ND
<b>RADIATION</b>								
Radium-226 (pCi/l)	ND	ND	ND	<0.6	<0.6	1.7±0.9	<0.6	<0.6
Gross alpha (pCi/l)	1.0±1.0*	0.8±0.8	2.8±2.8	3.6±3.5	1.4±1.2	2.1±1.8	2.0±2.0	9.3±3.4

ND - Not detectable (See Table 3.4-18 for detection limits.)

\* - Too shallow to sample.

\*\* - Results of all organics analyses were below the detectable limits at all stations.

Refer to Table 3.4-18 for list of parameters analyzed and detection limits.

+ - 95% confidence limits.

Note: S13D-1 was dry at the time of sampling.

Table 3.4-34. Results of Comprehensive Water Quality Monitoring, 15-18 February 1982.

Parameter	HC-2	HC-3	HC-4	HB-2	EL001-18	AB-3	S130-1	RS-1
<b>MISCELLANEOUS</b>								
Flow (cfs)	74.30	59.03	12.64	5.77	21.83	-	-	-
Conductivity, field ( $\mu$ mhos/cm)	370	400	120	70	265	345	245	500
Alkalinity as CaCO <sub>3</sub> (mg/l)	28.5	36.5	14.8	0	48.5	44.0	60.0	74.5
Total hardness as CaCO <sub>3</sub> (mg/l)	139	156	34	7	106	133	98	156
pH, field	6.0	5.8	5.8	3.9	7.0	7.0	6.3	6.7
Fluoride (mg/l)	1.80	2.05	0.65	0.09	0.72	1.60	1.40	3.05
Sulfate (mg/l)	123.7	150.0	30.5	0	83.8	97.0	45.4	128.6
Total phosphate as P (mg/l)	3.77	4.49	0.92	0.02	1.57	9.22	0.59	5.42
Total dissolved phosphate as P (mg/l)	3.86	4.39	0.91	0.03	1.32	8.67	1.09	4.61
Orthophosphate as P (mg/l)	3.60	3.75	1.00	0.04	1.47	8.10	1.01	4.50
Temperature, field (°C)	17	16	18	18	17	17	16	19
Dissolved oxygen (mg/l)	8.3	9.4	2.9	6.1	7.4	8.0	3.2	3.2
BOD <sub>5</sub> (mg/l)	17	9	9	3	2	6 <sup>++</sup>	5	19 <sup>+</sup>
Total suspended solids (mg/l)	19.6	15.0	4.0	1.7	4.8	20.2	19.5	7.8
Total dissolved solids (mg/l)	311	329	144	140	170	207	182	215
Transparency (m)	-	-	0.58	-	0.40	0.41	0.15	0.67
Color (Pt-Co units)	94	55	325	470	300	130	225	33
Tannin-lignin (mg/l)	2.03	1.16	6.07	8.62	4.72	1.81	1.75	1.10
Ammonia as N (mg/l)	2.70	2.40	2.80	0.03	0.06	0.05	0.10	18.51
Un-ionized ammonia as N (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND
Nitrate/nitrite as N (mg/l)	1.09	1.12	0.05	0.03	1.19	1.38	0.83	0.16
Total organic nitrogen as N (mg/l)	1.05	1.18	1.59	1.05	0.92	1.00	0.71	<0.10
Total nitrogen as N (mg/l)	4.84	4.70	4.44	1.11	2.17	2.43	1.64	18.51
Total organic carbon as C (mg/l)	28.5	16.9	41.2	57.5	27.6	32.2	25.8	16.0
Dissolved organic carbon as C (mg/l)	18.0	18.1	34.6	49.0	34.6	22.6	23.6	25.7
Particulate organic carbon as C (mg/l)	10.5	0	6.6	8.5	0	9.6	2.2	0
Chlorophyll a (mg/m <sup>3</sup> ) (pheophytin-corrected)	150.24	41.99	16.95	1.73	0	48.86	7.18	8.78
Oil and grease (mg/l)	-	-	-	-	-	-	-	-
Surfactants (methylene blue active substances) (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND
Total cyanide (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND
Fecal coliform (MPN/100 ml)	93	93	1100	460	40	23	93	39
Total coliform (MPN/100 ml)	460	150	2400	2400	230	>2400	1100	>2400
<b>METALS</b>								
Aluminum (mg/l)	0.3	0.4	0.8	0.7	0.8	1.0	6.5	0.4
Arsenic (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND
Barium (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND
Beryllium (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND
Cadmium (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND
Chromium (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND
Copper (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND
Iron (mg/l)	0.26	0.22	0.56	0.41	0.64	0.64	1.32	0.58
Lead (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND
Mercury ( $\mu$ g/l)	ND	0.3	0.2	0.7	0.4	ND	0.2	1.1
Nickel (mg/l)	0.02	0.02	ND	ND	0.02	ND	ND	0.10
Selenium (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND
Silver (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND
Zinc (mg/l)	0.02	0.02	0.02	0.02	0.01	0.02	0.04	0.01
ORGANICS**	ND	ND	ND	ND	ND	ND	ND	ND
<b>RADIATION</b>								
Radium-226 (pCi/l)	0.25±0.07 <sup>+</sup>	0.14±0.06	0.08±0.05	0.15±0.06	0.52±0.10	0.12±0.07	0.95±0.04	0.09±0.05
Radium-228 (pCi/l)	<1.4	<3.1	1.4±1.0	<1.6	1.8±1.8	<1.5	<2.5	<2.6
Gross alpha (pCi/l)	<1.5	<2.1	1.7±1.5	1.7±1.5	<2.9	<1.6	4.6±2.4	<1.6
Gross beta (pCi/l)	<4.0	4.8±4.2	5.3±3.9	4.5±3.8	11.3±4.4	4.5±3.6	11.9±4.5	5.4±3.1

ND - Not detectable (See Table 3.4-20 for detection limits.)

\*\* - Results of all organics analyses were below the detectable limits at all stations.

Refer to Table 3.4-20 for list of parameters analyzed and detection limits.

+ - 95% confidence limits.

++ - Sample collected March 1982.

Table 3.4-35. Values Not Meeting FDER Water Quality Standards in Reclaimed Lakes (EL001-18, AB-3, S13D-1), Recirculating Waters (RS-1, RS-2, RS-4), and Hunter Creek (HC-2, HC-3).

Parameter	No. of deviations/No. of samples									
	USGS <sup>1</sup>	HC-2	HC-3	EL001-18	AB-3	S13D-1	RS-1	RS-2	RS-4	RS-4
Conductivity <sup>2</sup>	2/78	0/37	0/37	*	*	*	*	*	*	*
Alkalinity	6/15	14/43	10/43	1/34	2/33	3/40	1/33	0/30	1/13	
pH <sup>3</sup>	3/78	0/29	2/30	*	*	*	*	*	*	*
Dissolved oxygen	11/67	2/43	5/43	15/33	2/31	24/41	10/33	11/31	3/7	
Un-ionized ammonia	5/70	1/41	2/43	6/33	4/32	3/38	5/32	5/30	1/7	
Fecal coliform	-	0/2	0/2	0/2	0/2	0/2	0/2	0/2	1/1	
Total coliform	10/35	0/2	1/2	0/2	0/2	0/2	0/2	0/2	1/1	
Iron	2/12	0/2	1/2	0/2	0/2	0/2	0/2	0/2	0/2	
Mercury	9/12	0/2	1/2	1/2	0/2	0/2	1/2	0/2	0/2	

<sup>1</sup>USGS No. 2315005, at HC-2

<sup>2</sup>Deviations based on values which exceeded 500 µmhos/cm.

<sup>3</sup>Deviations based on values which exceeded 7.5.

\*No adequate background conditions available for assessment.

Source: OXY EIS data, November 1979 - March 1982.

USGS, November 1957-December 1981.

tributaries on site. Parameters requiring background conditions for determining compliance were not evaluated for lake stations and the recirculating water systems because no adequate background data were available. There are no natural lakes within the project area which could be used for background. Recirculating water system stations are within the OXY process water system and have no counterpart that could be used to represent background conditions.

The maximum conductivity value recorded for the four stations was 274  $\mu\text{mhos/cm}$  measured at LB-2. Applying the State criteria, the maximum allowable levels above "background" would be 500  $\mu\text{mhos/cm}$ . Values exceeding this limit were enumerated for Hunter Creek stations (Table 3.4-35).

All conductivity values measured in Hunter Creek for this study were below 500  $\mu\text{mhos/cm}$ . Two USGS values, one in 1975 and another in 1976, exceeded 500  $\mu\text{mhos/cm}$ . All USGS values since 1976 were below 500  $\mu\text{mhos/cm}$ . All reclaimed lake values were  $<500 \mu\text{mhos/cm}$ , whereas each of the RS stations had one or two values which exceeded 500  $\mu\text{mhos/cm}$ .

The pH range for the four unaffected tributaries was 2.2-6.5. Applying the FDER criteria using this range as "background" results in a theoretical range of 2.2-7.5 which would have to be maintained in receiving waters following the discharge of mining effluent. With the exception of two pH values at HC-3, all other measurements on Hunter Creek for this study fell within this range. Only 3 of 78 USGS values at HC-2 exceeded the upper limit.

Summary. Recent Suwannee River data (1981-1982) were within, or near, previously measured ranges of data collected since 1971. Water quality upstream of White Springs (SR-5) was characterized by high color, low pH, hardness, alkalinity, and conductivity, and low concentrations of sulfate, phosphate, and fluoride. Downstream of White Springs, the OXY Swift Creek discharge and groundwater input increased, causing a shift in the levels of many constituents. Color decreased while pH, hardness, alkalinity, conductivity, and sulfate increased. Three constituents associated with mining (phosphate, ammonia, and fluoride) were elevated immediately downstream from Swift Creek and subsequently decreased farther downstream.

Of the six "unaffected" study area tributaries examined (Rocky Creek, Roaring Creek, Deep Creek, Long Branch, Four Mile Branch, and Camp Branch), the water quality characteristics of Camp Branch were somewhat dissimilar to the other five tributaries which enter the river upstream of White Springs. Upstream of White Springs, water quality was similar among the five tributaries and the river. The only stream which receives mine discharge, Hunter Creek, differed from the five upper Suwannee tributaries in two major ways:

- 1) The reduced organic/acidic character of the Hunter Creek water was more similar to the lower Suwannee in pH, hardness, alkalinity, conductivity, and sulfate; however, Hunter Creek levels were higher than those in the unaffected tributaries.

- 2) Phosphate, ammonia, and fluoride concentrations were higher in Hunter Creek due to the mine discharge. However, mean concentrations of these parameters in the Suwannee River at White Springs (SR-5), downstream of Hunter Creek, were similar to levels in the Suwannee River at Benton (SR-2), upstream of Hunter Creek, which indicates no net effect on the Suwannee River due to the OXY mining discharge to Hunter Creek.

Naturally occurring deviations from State Water Quality Standards exist for alkalinity, dissolved oxygen, coliforms, and mercury, based on background data for the Suwannee River and unaffected tributaries. Most dissolved oxygen values met the 5.0 mg/l standard in the Suwannee, whereas many measurements in the unaffected tributaries did not. For the tributaries, 16-77% of the dissolved oxygen measurements did not meet the standard.

In Hunter Creek, deviations from State Water Quality Standards were similar to those of unaffected streams, except fewer alkalinity values failed to meet the 20 mg/l minimum and a few iron and un-ionized ammonia values exceeded the standards. Data from the unaffected tributaries were used to estimate background to assess the levels of conductivity and pH in Hunter Creek relative to the standards. Based on the estimated background levels, the standards were met more than 93% of the time.

#### 3.4.2.2 Biological Indicators of Water Quality

Biological data are often used to evaluate water quality. The organisms inhabiting a stream or lake are exposed to a range of conditions and may yield important information on water quality over time. Biological indicators of water quality are addressed in Section 3.3.4.

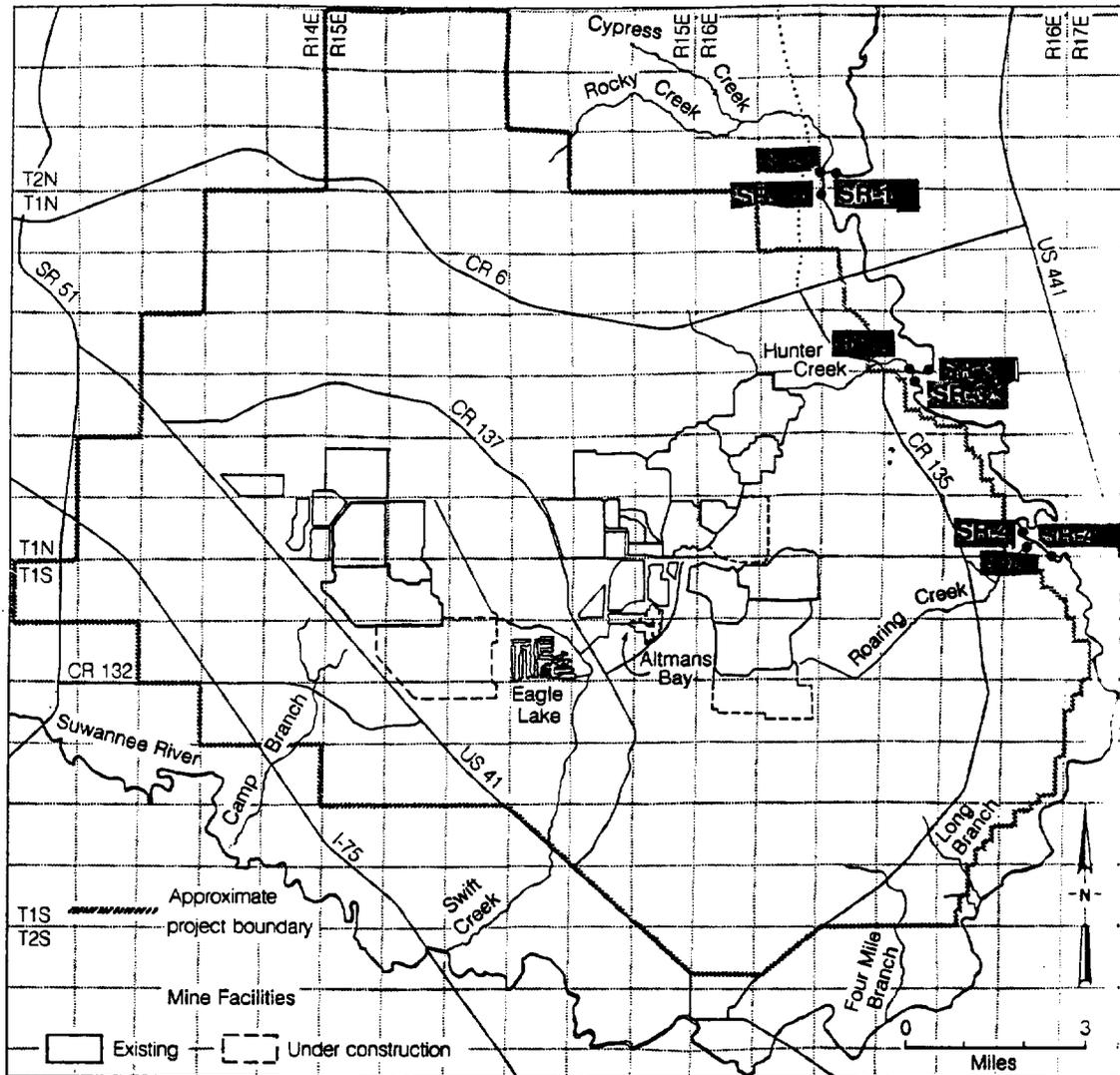
#### 3.4.2.3 Influence of the Major Tributaries on the Suwannee River

The effects of the tributaries on the Suwannee River were estimated by examination of:

- 1) one year of mean concentration data at the confluence of selected tributaries;
- 2) tributary mass loadings to the river, by date, for monitoring during low, medium, and high flow periods; and
- 3) the volume of particulate nutrients discharged from the tributaries.

##### 3.4.2.3.1 River Concentrations at Tributary Confluences

Suwannee River water quality data discussed in Section 3.4.2.1 included the Suwannee River at Benton (SR-2) and at White Springs (SR-5). Additional data, for an earlier period of record, were available for the Suwannee River at the confluences of Rocky, Hunter, and Roaring creeks. Monitoring was performed every two weeks for one year at three locations for each confluence (Figure 3.4-32):



NOTE: Does not reflect all areas affected by mining or mine support activities. See Figure 1.1-2.

• Sampling station

Figure 3.4-32. Location of Water Quality Stations for the November 1978 to October 1979 Monitoring.

- 1) Suwannee River upstream of the tributary;
- 2) Mouth of the tributary; and
- 3) Suwannee River downstream of the tributary.

Each sample was a composite of nine grab samples collected at three locations across the river at three depths per location.

River constituents above and below each tributary were compared using mean data which are expected to cover typical hydrological variation such as low, median, and high flow levels (Table 3.4-36). On the average, no measurable change in river constituents occurred as a result of the Rocky or Roaring creek discharges. Differences between the upstream and downstream river values were either zero or very slight.

Comparison of concentrations upstream of Hunter Creek at SR-3 with downstream concentrations at SR-4 near Roaring Creek revealed measurable, but slight, increases in all parameters except dissolved oxygen. These increases are not necessarily attributable to the Hunter Creek discharge, as the values measured at SR-4 were higher than levels found immediately downstream of the Hunter Creek confluence at SR-3.1. Differences in the river between SR-3 and SR-3.1 were similar to those observed above and below Rocky and Roaring creeks except for conductivity. Mean conductivity downstream of Hunter Creek was only slightly increased, from 82  $\mu\text{mhos/cm}$  to 96  $\mu\text{mhos/cm}$ .

During the low flow period of this study (8-607 cfs, USGS station at SR-2), additional samples were collected on the Suwannee River between Hunter and Roaring creeks at Station SR-3.2, approximately 0.5 mi downstream of SR-3.1, and at SR-3.3, approximately 0.5 mi downstream of SR-3.2. These data were not included in the comparison of means because there were only eight sampling dates, all during a low flow period. The data illustrate that the increases in parameter concentrations from SR-3.1 to SR-4 were not necessarily a result of input from Hunter Creek (Table 3.4-37). For example, on 29 December 1978, values for conductivity, hardness, and fluoride at SR-4 were not only higher than at SR-3.1, SR-3.2, and SR-3.3, but they were also higher than the concentrations discharged from Hunter Creek.

Groundwater seepage and/or small streams that enter the Suwannee between the two tributaries are probable sources of the increases. Although major groundwater input to the river begins to increase downstream of White Springs, seepage has been observed upstream of Roaring Creek during low flow sample collections.

#### 3.4.2.3.2 Mass Loadings of Chemical Constituents

The contribution of chemical constituents by a tributary is best examined by determination of the mass loadings. In addition, loadings can be used to assess the relative contribution of chemical constituents from major branches within larger study area tributaries.

Multiple stations were established to assess within-tributary variation on Rocky, Roaring, and Hunter creeks. Raw data and median values, which

Table 3.4-36. Mean Concentration Data from Samples Collected Every Two Weeks from November 1978 to October 1979.

Parameter	RC-1		HC-1		RO-1	
	SR-1	SR-1.1	SR-3	SR-3.1	SR-4	SR-4.1
Conductivity, field ( $\mu$ mhos/cm)	76	135 75	82	324 96	94	157 94
Alkalinity as CaCO <sub>3</sub> (mg/l)	6.0	24.5 5.6	7.7	37.0 8.2	11.3	25.4 12.0
Total hardness as CaCO <sub>3</sub> (mg/l)	22	44 22	24	129 25	34	42 32
Fluoride (mg/l)	0.08	0.13 0.09	0.07	1.68 0.10	0.14	0.35 0.14
Sulfate (mg/l)	0.2	0 0	0.2	88.9 0.2	4.3	0.6 4.4
Total phosphate as P (mg/l)	0.10	0.16 0.04	0.07	2.32 0.10	0.20	0.63 0.18
Dissolved oxygen (mg/l)	7.4	7.1 7.3	7.6	7.7 7.7	7.6	7.9 7.6
Nitrate as N (mg/l)	0.02	0.03 0.02	0.02	0.53 0.03	0.05	0.08 0.04
Ammonia as N (mg/l)	0.22	0.22 0.25	0.21	0.57 0.23	0.25	0.24 0.25

Table 3.4-37. Concentration Data Collected on the Suwannee River between Hunter and Roaring Creeks During Low Flow, 1978/1979.

Parameter	Date	HC-1	SR-3	SR-3.1	SR-3.2	SR-3.3	SR-4
Conductivity, field ( $\mu\text{mhos/cm}$ )	11/14/78	248	161	269	106	112	124
	11/28/78	142	104	107	-	-	131
	12/11/78	141	102	108	109	109	128
	12/29/78	235	98	115	112	114	266
	01/08/79	-	-	-	-	-	-
	01/23/79	-	-	-	-	-	-
	02/05/79	182	67	72	72	74	80
	02/20/79	432	101	104	101	98	89
	Alkalinity as $\text{CaCO}_3$ (mg/l)	11/14/78	51	32	34	40	41
11/28/78		54	39	34	36	41	44
12/11/78		48	33	33	34	35	44
12/29/78		44	24	26	28	29	43
01/08/79		55	31	33	34	34	36
01/23/79		43	19	21	21	23	32
02/05/79		36	1	10	13	12	12
02/20/79		42	0	0	0	0	0
Total hardness as $\text{CaCO}_3$ (mg/l)		11/14/78	86	40	44	50	52
	11/28/78	64	48	46	50	50	64
	12/11/78	66	48	50	50	48	62
	12/29/78	100	40	44	48	50	122
	01/08/79	122	42	46	48	48	62
	01/23/79	114	44	40	44	42	64
	02/05/79	78	24	30	28	29	36
	02/20/79	170	16	20	14	16	22
	Fluoride (mg/l)	11/14/78	0.44	0.21	0.22	0.24	0.24
11/28/78		0.42	0.21	0.26	0.29	0.28	0.25
12/11/78		0.42	0.12	0.12	0.11	0.13	0.12
12/29/78		0.84	0.15	0.22	0.22	0.23	1.00
01/08/79		1.10	0.12	0.18	0.19	0.19	0.27
01/23/79		0.90	0.12	0.19	0.18	0.19	0.33
02/05/79		0.66	0.10	0.10	0.14	0.11	0.10
02/20/79		2.00	0.10	0.11	0.13	0.11	0.10
Sulfate (mg/l)		11/14/78	0	0	0	0	0
	11/28/78	0	0	0	0	0	0
	12/11/78	0	0	0	0	0	0
	12/29/78	51	0	0	0	0	0
	01/08/79	62	0	0	0	0	66
	01/23/79	73	0	0	0	0	22
	02/05/79	19	0	0	0	0	22
	02/20/79	177	0	0	0	0	0

Table 3.4-37 (Continued).

Parameter	Date	HC-1	SR-3	SR-3.1	SR-3.2	SR-3.3	SR-4
Total phosphate as P (mg/l)	11/14/78	0.74	0.19	0.23	0.25	0.27	0.38
	11/28/78	0.95	0.19	0.15	0.20	0.11	0.15
	12/11/78	0.66	0.24	0.27	0.20	0.18	0.20
	12/29/78	1.40	0.07	0.45	0.21	0.20	1.90
	01/08/79	1.60	0.42	0.29	0.59	0.28	0.37
	01/23/79	1.53	<0.01	0.03	0.15	0.15	0.48
	02/05/79	0.06	0.01	0.03	0.03	0.01	0.02
	02/20/79	3.08	0.15	0.13	0.17	0.18	0.15
Dissolved oxygen (mg/l)	11/14/78	8.6	8.8	9.4	8.2	8.4	7.6
	11/28/78	9.1	9.0	8.0	8.0	8.0	9.0
	12/11/78	11.4	10.0	9.4	9.8	9.9	8.8
	12/29/78	11.1	11.0	11.0	11.0	11.2	9.6
	01/08/79	11.4	10.0	11.2	10.4	10.9	10.1
	01/23/79	-	-	-	-	-	10.1
	02/05/79	11.5	10.9	11.4	11.5	11.3	10.7
	02/20/79	10.8	10.1	10.2	10.2	10.2	10.2
Nitrate as N (mg/l)	11/14/78	0.14	0.02	0.02	0.04	0.02	0.01
	11/28/78	0.25	0.12	0.12	0.19	0.18	0.12
	12/11/78	0.21	0.04	0.04	0.05	0.08	0.05
	12/29/78	0.36	0.02	0.06	0.08	0.09	0.32
	01/08/79	0.44	0.04	0.05	0.08	0.09	0.11
	01/23/79	0.66	0.01	0.05	0.06	0.07	0.33
	02/05/79	0.33	0.03	0.03	0.05	0.04	0.03
	02/20/79	1.30	0.01	0.03	0.04	0.04	0.03
Ammonia as N (mg/l)	11/14/78	0.14	0.02	0.03	0.02	0.02	0.02
	11/28/78	0.25	0.01	0.02	0.06	0.03	0.04
	12/11/78	0	0.04	0.40	0.06	0.06	0.02
	12/29/78	0.17	0.05	0.02	0.03	0.02	0.50
	01/08/79	0.81	0.02	0.09	0.12	0.07	0.05
	01/23/79	0.26	0.02	0.04	0.06	0.05	0.05
	02/05/79	0.03	0.02	0.04	0.08	0.01	0.01
	02/20/79	1.92	0.02	0.05	0.04	0.04	0.04

are expected to estimate central tendency more accurately than the mean, were utilized to assess the loadings instead of comparing two-year means between stations as in previous analyses (Section 3.4.2.1). Use of means in calculating loadings, which are based on flow rates, may not yield representative values due to incomplete sets of high flow measurements. Stream flow was impossible to measure at some stations during extreme high flow.

Median loadings were calculated by determining the median concentration and median flow and computing the mass using the following calculation:

$$\text{Mass (kg/day)} = \text{flow (cfs)} \times \text{conc. (mg/l)} \times 2.45 \text{ (conversion constant)}.$$

In instances of extreme high flow when actual flow was not measured, the missing flow data were assumed to be higher than the highest measured flows and were included in the calculation. Thus, medians calculated in this manner compensated for the missing high flows.

Comparisons between stations were made by date to isolate flow-related trends. To facilitate handling of a large volume of data, only data from selected sampling dates were used for analysis. Dates were selected based on the available hydrograph for a particular stream (e.g., the RC-2 hydrograph was used for Rocky Creek). Two dates were randomly selected from each low, medium, and high flow period for each station with complete data records.

Relative Contributions of Chemical Constituents. On Rocky Creek, input from both forks of the major headwater branch (RC-10 and RC-6) as well as input from Cypress Creek (CC-2) were measured. Mass loadings of total nitrogen as N (TN), total organic carbon as C (TOC), and total dissolved solids (TDS) appeared to be controlled by the volume of flow, i.e., loadings increased with increased flow rates as evidenced by data collected during low, medium, and high flows (Table 3.4-38). Loadings of TN, TOC, and TDS were greater from the RC-10 fork which carries a greater volume of flow than the RC-6 fork. Concentrations of all three parameters were highest at the most downstream station, RC-2.

Cypress Creek contributed less TN, TOC, and TDS than RC-6 during low flow; however, the reverse was generally true during medium flows (high flows could not be measured at CC-2). Median values for the three parameters were higher at CC-2 compared to RC-6.

Mass total phosphate (TP) loadings were generally low throughout Rocky Creek and did not necessarily increase directly with flow rates. Contributions from the various forks (including CC-2) were similar.

Two stations were monitored on Roaring Creek: RO-2 and RO-5 upstream of RO-2 and just downstream of a major branch draining headwater areas. Mass loading trends were similar to those in Rocky Creek, i.e., TN, TOC, and TDS loadings increased directly with increases in flow and were generally higher at the more downstream station, RO-2; however, medians for TOC and TDS were higher at RO-5 (Table 3.4-39). Phosphate loadings did not increase sharply with flow, and loadings were higher at RO-2 compared to RO-5.

Table 3.4-38. Mass Loadings (kg/day) of Selected Parameters on Rocky Creek.

Parameter	Station	Low Flow		Medium Flow		High Flow		Median 1979-82
		12/15/80	1/26/81	2/16/81	4/21/81	3/9/81	4/1/81	
Total phosphate	RC-2	0.3	0.2	<2	0.6	26.4	13.9	0.7
	CC-2	0.1	<0.1	<0.4	0.4	-	-	0.1
	RC-5	-	0.1	<1	<0.4	14.4	<2	0.1
	RC-6	0.1	<0.1	<0.1	0.1	0.4	<0.2	<0.1
	RC-10	0.1	<0.1	1.3	<0.2	-	-	0.1
Total nitrogen	RC-2	62.0	14.2	225.1	108.2	653.6	490.3	36.4
	CC-2	0.8	0.5	84.4	37.4	-	-	6.5
	RC-5	46.8	12.2	150.9	67.6	498.3	313.1	12.2
	RC-6	7.4	2.8	35.3	26.7	49.7	37.3	4.1
	RC-10	16.2	3.8	79.4	32.1	-	-	16.2
Total organic carbon	RC-2	2,100	743	11,785	4,458	49,517	31,103	1,902
	CC-2	45	23	3,012	808	-	-	294
	RC-5	2,256	658	7,322	3,100	24,046	15,991	577
	RC-6	317	166	1,597	1,273	2,780	1,802	180
	RC-10	760	237	4,132	1,379	-	-	759
Total dissolved solids	RC-2	4,967	1,587	28,136	10,199	79,595	48,685	4,067
	CC-2	77	68	6,364	3,725	-	-	539
	RC-5	5,026	1,346	17,171	6,716	49,465	28,073	1,333
	RC-6	563	276	2,981	2,598	4,451	3,452	396
	RC-10	1,597	402	8,127	3,043	-	-	1,425
Flow (cfs)	RC-2	11.2	4.1	69.6	23.0	215.1	141.9	
	CC-2	0.3	0.2	18.0	7.4	-	-	
	RC-5	11.0	3.3	44.6	16.2	147.4	88.1	
	RC-6	1.2	0.6	5.4	5.6	9.1	9.5	
	RC-10	4.0	1.2	26.1	7.6	-	-	

Note: Detection limits vary with flow rates.

Table 3.4-39. Mass Loadings (kg/day) of Selected Parameters on Roaring Creek.

Parameter	Station	Low Flow		Medium Flow		High Flow		Median 1979-82
		1/9/80	4/21/81	2/19/80	3/30/80	3/9/81	4/1/81	
Total phosphate	RO-2	1.3	1.7	1.2	2.2	3.2	10.3	1.7
	RO-5	0.1	0	0.2	0.6	0.4	1.2	<0.1
Total nitrogen	RO-2	5.6	5.7	15.3	15.1	46.4	65.0	4.3
	RO-5	4.1	2.5	13.1	12.4	16.9	27.0	3.3
Total organic carbon	RO-2	267	229	1237	709	2286	3500	87
	RO-5	205	88	433	502	1286	1341	129
Total dissolved solids	RO-2	662	531	1889	1483	4448	8234	395
	RO-5	502	199	1173	1136	1727	3365	417
Flow (cfs)	RO-2	1.8	1.6	4.6	3.8	13.1	22.1	
	RO-5	0.9	0.4	2.3	2.6	4.0	7.9	

On Hunter Creek, loadings data were available from stations HC-2 and HC-3, the drainage patterns of which were described in Section 3.4.2.1. Station HC-2 is on the main branch of the creek while HC-3 is on an up-stream side tributary. As Hunter Creek is affected by mine water input, one station can be under high flow conditions while the other is at low flow. For example, on 9 March 1981, HC-2 was considered under high flow while HC-3 was under low flow conditions (Table 3.4-40). Thus, for comparison, selection of low, medium, and high flow periods was based on conditions at HC-2.

Mass loadings for all four parameters in Hunter Creek tended to be higher during higher flows, but a uniform, direct relationship was not exhibited. In particular, values measured during "high flow" on 9 March 1981 did not follow this trend, probably due to the low input from HC-3. The contribution of loadings from HC-3 to HC-2 varied considerably, from 5 to 100% for the four parameters measured at six sampling periods. However, median values for all four parameters were consistently higher at HC-2.

Relative Contributions of Tributaries. To compare the relative contribution of each study area tributary, loadings data were examined at a single station for each stream; the stations selected were those closest to the mouth, with reasonable access, but not normally flooded by Suwannee River backwater (RC-2, RO-2, LB-2, FMB-2, and HC-2). Mass TN, TOC, and TDS loadings were generally highest at RC-2, followed by HC-2 and RO-2, although median TN and TDS loadings were highest at HC-2 (Table 3.4-41). Loadings at Long Branch (LB-2) and Four Mile Branch (FMB-2), the smallest of the five streams, were generally lower for all four parameters. With the exception of Hunter Creek, this ranking is probably related to the size of the streams' drainage basins and thus their respective flow rates rather than to differences in water quality.

HC-2 had the highest mass TP loadings during all three flow rates and the highest median TP value. TP values at RO-2 were higher than at RC-2 during low flow, but the reverse was true during medium and high flow rates; medians were higher at RO-2 than RC-2.

To assess the significance of the tributaries' contributions to the Suwannee River, loadings data from the river near the mouth of each tributary are needed. However, with a few exceptions, river flows were available only at bridge locations (SR-2 and SR-5) due to the difficulty of measuring flows at depths that cannot be waded. Water quality data for these locations were also limited. To compensate for these limitations, the following procedures were used in analyzing the effects of tributary discharge to the river:

- 1) Concentrations of chemical parameters downstream from a tributary were calculated from available upstream data (and tributary data), and vice versa, according to the following equation:

$$C_{dw} = \frac{C_t Q_t + C_{up} Q_{up}}{Q_t + Q_{up}} \quad \text{where}$$

Table 3.4-40. Mass Loadings (kg/day) of Selected Parameters on Hunter Creek.

Parameter	Station	Low Flow*		Medium Flow*		High Flow*		Median 1979-82
		6/16/80	11/10/80	4/29/80	8/18/80	7/28/80	3/09/81	
Total phosphate	HC-2 C	8.3	10.4	204.9	93.5	335.2	19.0	43.6
	HC-3	7.8	0.7	177.1	51.2	163.3	1.5	2.5
Total nitrogen	HC-2	6.5	14.1	197.1	220.8	426.2	112.9	50.0
	HC-3	5.1	1.2	142.1	110.4	136.3	8.8	7.5
Total organic carbon	HC-2	80	152	2,061	1,023	3,234	3,284	792
	HC-3	97	8.0	917	988	1,771	346	96
Total dissolved solids	HC-2	1,029	1,101	17,368	14,602	36,032	12,730	5,333
	HC-3	1,023	77	12,640	9,336	18,587	920	706
Flow (cfs)	HC-2	2.0	2.4	26.6	23.8	48.9	36.8	
	HC-3	1.6	0.2	16.4	12.7	23.0	2.5	

\*Based on flow at HC-2 (see text).

Table 3.4-41. Mass Loadings (kg/day) Comparison Among Tributaries.

Parameter	Station	Low Flow		Medium Flow		High Flow		Median 1979-82
		1/23/80	9/30/80	3/03/80	5/26/80	3/17/80	3/09/81	
Total phosphate	RC-2	0	0.2	9.6	1.7	58.2	26.4	0.7
	RO-2	3.4	1.0	2.2	0.4	21.1	3.2	1.7
	LB-2	0.4	0	0.5	0.1	2.2	0.1	0.1
	FMB-2	0.1	0	0.2	0.1	3.8	0.2	<0.1
	HC-2	0	4.2	26.7	388.2	364.6	19.0	43.6
Total nitrogen	RC-2	61.5	10.4	157.7	-	1,183.6	653.6	36.4
	RO-2	35.1	0.3	15.1	10.1	11.1	46.4	4.3
	LB-2	1.0	0	1.1	0.5	9.0	1.6	0.3
	FMB-2	2.1	0	2.6	6.2	22.6	9.1	0.6
	HC-2	18.4	0	48.7	361.0	367.6	112.8	50.0
Total organic carbon	RC-2	6,028	202	7,800	4,598	49,060	49,517	1,902
	RO-2	0	15	709	455	6,238	2,286	87
	LB-2	69	0	56	30	265	79	19
	FMB-2	174	0	101	363	877	501	33
	HC-2	659	42	247	5,255	6,318	3,284	792
Total dissolved solids	RC-2	5,635	392	16,519	8,525	99,607	79,595	4,067
	RO-2	3,367	51	1,483	1,031	13,962	4,448	395
	LB-2	195	0	177	64	790	199	53
	FMB-2	370	0	268	638	2,129	1,074	74
	HC-2	1,948	350	2,169	36,779	30,380	12,730	5,333

$C_{dw}$  = predicted concentration in the Suwannee downstream of the tributary (mg/l)  
 $C_t$  = concentration of parameter in the tributary (mg/l)  
 $Q_t$  = tributary flow rate (cfs)  
 $C_{up}$  = concentration of parameter in the Suwannee, upstream of the tributary (mg/l)  
 $Q_{up}$  = flow rate in the Suwannee (USGS data) upstream of the tributary (cfs)

- 2) Data from Station SR-2 were used as downstream data for Rocky Creek and upstream data for Hunter Creek.
- 3) The flow rate in the river upstream of Roaring Creek was estimated by using the flow measured at SR-2 with the addition of a 2% increase, based on flow relationships simulated for upper reaches of the river (Section 3.4.1).
- 4) Actual concentration data in the river upstream of Roaring Creek were unavailable. The calculated concentrations in the river downstream of Hunter Creek were used to approximate levels in the river upstream of Roaring Creek. The concentrations of many parameters in the river immediately upstream of Roaring Creek had been observed to be different than those in the river just downstream of Hunter Creek (Section 3.4.2.3.1). However, the waters are considered similar enough to be used as a basis for determining to what degree Roaring Creek affects the levels of constituents downstream in the river.
- 5) For brevity, changes in river concentrations due to loadings from Long Branch and Four Mile Branch were not calculated. It was assumed that changes would be less than for Roaring Creek due to the smaller drainage areas and thus lower flow rates of Long Branch and Four Mile Branch.

It is desirable to evaluate the tributary loadings close to the mouth (RC-1, HC-1, and RO-1) because flow rates normally increase with distance downstream, and concentration may decrease as a result of faunal/floral uptake. However, this was not feasible during medium and high flows due to backwater from the river; therefore, most of the data used were from stations located just upstream (RC-2, HC-2, and RO-2, Table 3.4-42). For comparison, a set of data available from stations located at the mouth and a set collected at the more upstream location were used for low flow analysis. Results of the calculations appear in Table 3.4-43.

In addition to TP, TN, TOC, and TDS, fluoride (F) and sulfate ( $SO_4$ ) contributions, which are generally elevated in Hunter Creek, were examined.

Rocky and Roaring Creeks. Based on the calculations, discharge from Rocky and Roaring creeks had very slight, if any, effect on the Suwannee River for the parameters measured. For both tributaries, there were no differences between the upstream and downstream river concentrations of

Table 3.4-42. Concentrations of Selected Parameters Used to Calculate Changes in the Suwannee River (Table 3.4-43) During Low, Medium, and High Flows.

Date	Station	Flow (cfs)	TP (mg/l)	TN (mg/l)	TOC (mg/l)	TDS (mg/l)	F (mg/l)	SO <sub>4</sub> (mg/l)
<u>Low Flow</u>								
01/23/80	RC-1	19.0	0.01	1.20	88.1	158	0.03	0
	RO-1	11.6	0.12	3.90	-	128	0.10	0
	HC-1	4.8	-	1.45	46.2	164	0.54	21
	SR-2	734	0.04	1.20	67.1	96	0.03	0
09/30/80	RC-2	1.1	0.07	3.93	76.4	148	0.05	0
	RO-2	0.3	1.46	0.39	21.5	72	0.67	0
	HC-2	0.8	2.10	-	20.7	174	1.35	56
	SR-2	71	0.08	1.05	80.0	69	0.04	0
<u>Medium Flow</u>								
03/03/80	RC-2	43.5	0.09	1.48	73.2	155	0.04	0
	RO-2	3.8	0.23	1.61	75.6	158	0.10	0
	HC-2	3.6	3.05	5.57	28.2	248	1.42	111
	SR-2	2380	0.06	1.17	73.8	88	0.04	0
05/26/80	RC-2	23.5	0.03	-	79.8	148	0.03	0
	RO-2	2.3	0.08	1.80	80.7	183	0.07	0
	HC-2	55.6	2.85	2.65	38.6	270	1.99	136
	SR-2	1940	0.03	1.02	54.9	113	0.02	0
<u>High Flow</u>								
03/17/80	RC-2	264.0	0.09	1.83	75.8	154	0.03	0
	RO-2	41.0	0.21	0.11	62.1	139	0.05	0
	HC-2	52.7	2.40	2.42	41.6	200	0.89	58
	SR-2	4530	0.08	1.26	50.4	118	0.02	0
03/09/81	RC-2	215.1	0.05	1.24	93.9	151	0.05	0
	RO-2	13.1	0.10	1.45	71.4	139	0.09	0
	HC-2	36.8	0.21	1.25	36.4	141	0.54	25
	SR-2	3460	0.01	0.92	45.7	105	0.03	0

Table 3.4-43. Effects of Rocky, Hunter, and Roaring Creek Loadings on the Suwannee River.

Parameter	Tributary Station	River Location <sup>1</sup>	Derivation of Value	Low Flow		Medium Flow		High Flow	
				1/23/80	9/30/80 <sup>2</sup>	3/03/80	5/26/80	3/17/80	3/09/81
Total phosphate as P (mg/l)	RC-1	Upstream	Calculated	0.04	0.08	0.06	0.03	0.08	0.01
		Downstream	Measured	0.04	0.08	0.06	0.03	0.08	0.01
		Difference <sup>3</sup>		0	0	0	0	0	0
	RO-1 <sup>4</sup>	Upstream	Calculated	-	0.10	0.06	0.11	0.11	0.01
		Downstream	Calculated	-	0.10	0.06	0.11	0.11	0.01
		Difference		-	0	0	0	0	0
	HC-1	Upstream	Measured	-	0.08	0.06	0.03	0.08	0.01
		Downstream	Calculated	-	0.10	0.06	0.11	0.11	0.01
		Difference		-	0.02	0	0.08	0.03	0
Total nitrogen as N (mg/l)	RC-1	Upstream	Calculated	0.76	1.00	1.16	-	1.22	0.90
		Downstream	Measured	0.76	1.05	1.17	1.02	1.26	0.92
		Difference		0	0.05	0.01	-	0.04	0.02
	RO-1	Upstream	Calculated	0.76	-	1.18	1.07	1.27	0.92
		Downstream	Calculated	0.77	-	1.18	1.07	1.26	0.92
		Difference		0.01	-	0	0	-0.01	0
	HC-1	Upstream	Measured	0.76	-	1.17	1.02	1.26	0.92
		Downstream	Calculated	0.76	-	1.18	1.07	1.27	0.92
		Difference		0	-	0.01	0.05	0.01	0
Total organic carbon as C (mg/l)	RC-1	Upstream	Calculated	66.5	80.1	73.8	54.6	48.8	42.5
		Downstream	Measured	67.1	80.0	73.8	54.9	50.4	45.7
		Difference		0.6	-0.1	0	0.3	1.6	3.2
	RO-1	Upstream	Calculated	67.1	79.7	72.5	53.4	49.8	45.6
		Downstream	Calculated	-	79.5	72.5	53.4	49.9	45.7
		Difference		-	-0.2	0	0	0.1	0.1
	HC-1	Upstream	Measured	67.1	80.0	73.8	54.9	50.4	45.7
		Downstream	Calculated	67.0	79.7	72.5	53.4	49.8	45.6
		Difference		-0.1	-0.3	-1.3	-1.5	-0.6	-0.1

Table 3.4-43 (Continued).

Parameter	Tributary Station	River Location <sup>1</sup>	Derivation of Value	Low Flow		Medium Flow		High Flow	
				1/23/80	9/30/80 <sup>2</sup>	3/03/80	5/26/80	3/17/80	3/09/81
Total dissolved solids (mg/l)	RC-1	Upstream	Calculated	94	68	87	113	116	102
		Downstream	Measured	96	69	88	113	118	105
		Difference <sup>3</sup>		2	1	1	0	2	3
	RO-1 <sup>4</sup>	Upstream	Calculated	96	70	88	117	119	105
		Downstream	Calculated	96	70	88	117	119	105
		Difference		0	0	0	0	0	0
	HC-1	Upstream	Measured	96	69	88	113	118	105
		Downstream	Calculated	96	70	88	117	119	105
		Difference		0	1	0	4	1	0
Fluoride (mg/l)	RC-1	Upstream	Calculated	0.03	0.04	0.04	0.02	0.05	0.03
		Downstream	Measured	0.03	0.04	0.04	0.02	0.05	0.03
		Difference		0	0	0	0	0	0
	RO-1	Upstream	Calculated	0.03	0.05	0.04	0.07	0.03	0.04
		Downstream	Calculated	0.03	0.05	0.04	0.07	0.03	0.04
		Difference		0	0	0	0	0	0
	HC-1	Upstream	Measured	0.03	0.04	0.04	0.02	0.02	0.03
		Downstream	Calculated	0.03	0.05	0.04	0.07	0.03	0.04
		Difference		0	0.01	0	0.05	0.01	0.01
Sulfate (mg/l)	RC-1	Upstream	Calculated	0	0	0	0	0	0
		Downstream	Measured	0	0	0	0	0	0
		Difference		0	0	0	0	0	0
	RO-1	Upstream	Calculated	21	0.4	0	0	0	0
		Downstream	Calculated	21	0.4	0	0	0	0
		Difference		0	0	0	0	0	0
	HC-1	Upstream	Measured	0	0	0	0	0	0
		Downstream	Calculated	1	0.6	0.2	4	0.7	0.3
		Difference		1	0.6	0.2	4	0.7	0.3

<sup>1</sup>Relative to tributaries.

<sup>2</sup>Collected from RC-2, RO-2, and HC-2.

<sup>3</sup>Downstream value minus upstream value.

<sup>4</sup>River concentration data based on values calculated downstream of HC-1. River flow based on a 2% increase in the value measured at SR-2.

total phosphate, fluoride, and sulfate. There was also no difference in the TDS concentrations above and below Roaring Creek, whereas slight changes in TDS concentrations occurred in the river at Rocky Creek. For both tributaries, there were only slight changes in total nitrogen and total organic carbon concentrations in the river on some dates and no measurable changes on other dates.

Most changes observed downstream from either tributary were increases. To assess the significance of the changes, a comparison can be made to differences considered insignificant in laboratory analyses of replicates. For example, the TOC concentration (calculated) upstream of RC-1 on 9 March 1981 was 42.5 mg/l, while downstream the value was 45.7 mg/l, a difference of 3.2 mg/l. Quality control samples with a TOC concentration of 4.9 mg/l were measured in an EPA study with a precision of  $\pm 3.93$  (EPA 1979a). It follows that a difference in TOC of 4 mg/l is insignificant at a level of  $\geq 5$  mg/l. Standard deviations (s) for concentrations of other parameters determined by EPA (1979a) are:

<u>Parameter</u>	<u>Conc.</u>	<u>s</u>
Total P	0.04	0.019
	0.29	0.087
TOC	4.9	3.93
Total N	2.28	0.56
Kjeldahl N	1.89	0.54
Nitrate/nitrite	0.39	0.02
Fluoride	0.85	0.03
Sulfate	8.6	2.3

Hunter Creek. For the six sampling dates considered, discharge from Hunter Creek did not appreciably affect the concentrations of TN, TOC, TDS, and F. The differences between the levels upstream and downstream of the tributary were either zero or were similar to differences observed for the unaffected tributaries (Rocky and Roaring creeks). All changes were increases in downstream concentrations, except for TOC which decreased downstream of Hunter Creek. All changes are insignificant in terms of precision, with the exception of an increase in sulfate on 26 May 1980 from 0 mg/l upstream to 4 mg/l downstream. Although this increase was "measurable," a concentration of 4 mg/l is not expected to have any ecological significance and is much lower than levels in the Suwannee downstream of White Springs.

Theoretical differences in total phosphate in the river upstream and downstream of Hunter Creek were 0 mg/l for one medium and one high flow collection. A TP value was not available on 23 January 1980 due to a laboratory error. Concentrations of TP increased downstream of Hunter Creek on the remaining sampling dates, the greatest increase occurring during medium flow. Although the data suggest that TP concentrations may be elevated under certain conditions, the absence of excessive growths of aquatic macrophytes and nuisance algal blooms indicates that factors other than phosphate are limiting in the system.

Data collected on the six sampling dates, selected at random within the three flow categories, are considered to represent typical conditions, but probably would not represent the full range of variability which occurs. The effect of Hunter Creek on the Suwannee River is expected to be greatest when the tributary to river flow ratio is highest, which probably occurs during low river flow.

To evaluate the effect of Hunter Creek on the river under worst-case conditions, water quality data were reviewed for the date with the highest tributary to river flow ratio. The difference between the concentration at SR-2 upstream of Hunter Creek and the calculated downstream value was calculated for each parameter (Table 3.4-44). In this extreme case, the Hunter Creek discharge comprised approximately 35% of the river volume immediately downstream. As expected, a greater change in constituents was noted compared to values in Table 3.4-43 due to this maximum tributary to river flow ratio. The increased concentrations immediately downstream of Hunter Creek decreased to background levels at White Springs (SR-5), except for total phosphate and fluoride which also decreased but remained elevated compared to background. Based on cumulative frequency curves (Section 3.4.1), it is expected that the river would be this low (approximately 10 cfs) only 3% of the time.

#### 3.4.2.3.3 Particulate Nutrient Drift

The Suwannee River is considered heterotrophic because it imports the majority of its organic material from outside the system. Allochthonous materials (leaves, fruit, small particulate matter) and tributary input are expected to be greater than autochthonous sources of primary production (periphyton, macrophytes, and phytoplankton) within the river itself. Particulate drift was monitored to evaluate the contribution of tributary streams to the Suwannee River.

Drift samples were collected once during low flow conditions (September 1981) and once under medium flow (March 1982). Samples were taken 1) at the mouth of major tributaries draining to the Suwannee River to determine the export of each stream, 2) in the Suwannee near each tributary to evaluate relative quantities of drift, and 3) at multiple locations within a tributary to examine possible areal differences in particulate transport (Figure 3.4-33).

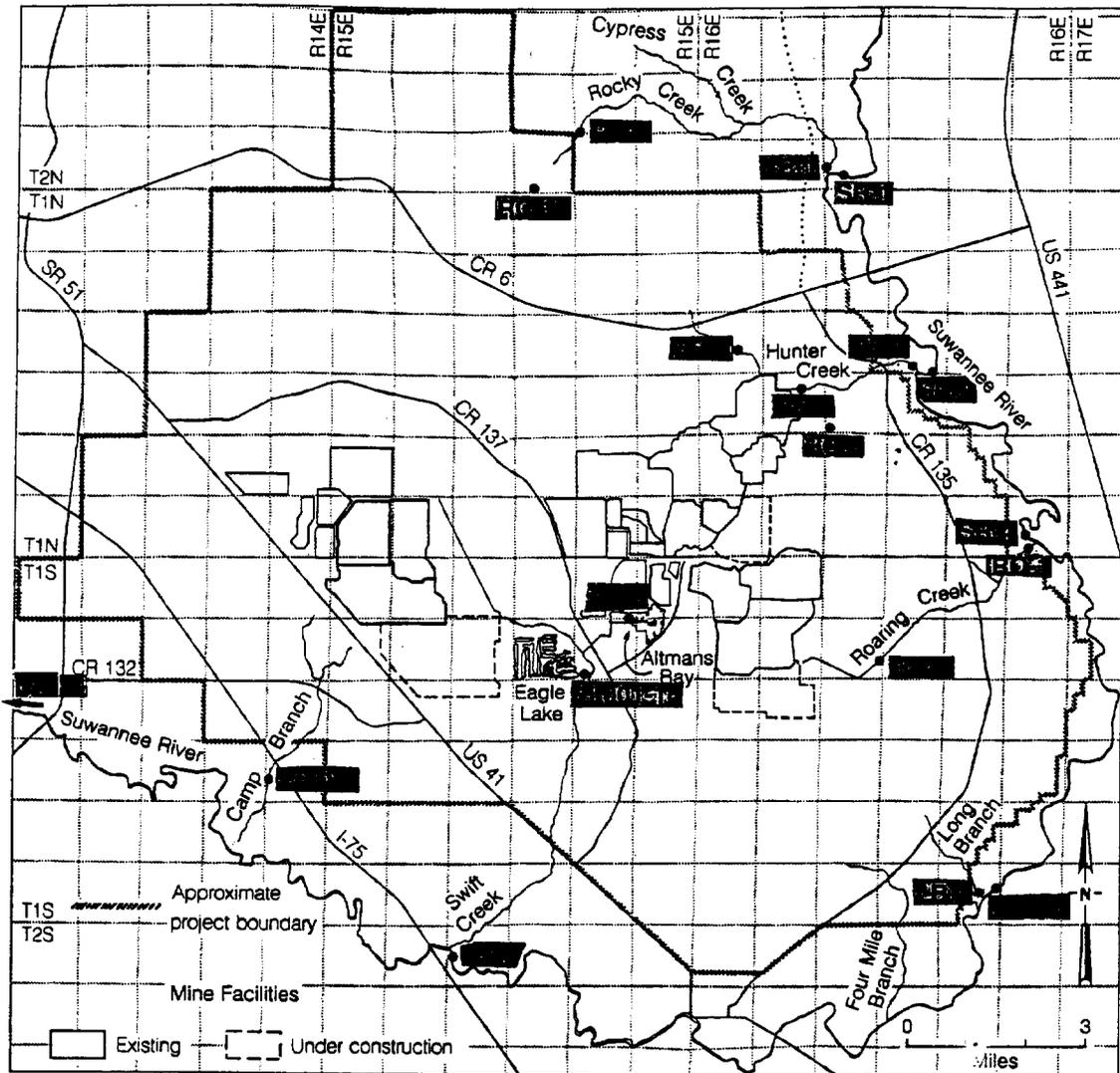
Results of the drift sampling appear in Table 3.4-45. A lesser volume of water was sampled during the low flow collection due to the slow velocities which required a lengthy collection period. The greater volume sampled during medium flow resulted in a greater mass (g) of particulate material collected at medium flow for most stations. Few clear trends in the variation of chemical constituents between the two sampling periods were discernable. Concentrations ( $\text{mg}/\text{m}^3$ ) of particulate nutrients were less during the medium flow than the low flow collection at SR-1, RC-1, RC-5, HC-1, SR-4.5, LB-1, CB-1.5, and EL001-18.

To assess differences in particulate drift at various points along a stream's length, two or more collection points were established on the larger tributaries (Rocky, Roaring, and Hunter creeks). On Rocky Creek,

Table 3.4-44. Effects of Hunter Creek Discharge on the Suwannee River  
During a Period of Extreme Low River Flow (13 July 1981).

Parameter	HC-2	SR-2	Downstream*	Difference	SR-5
Flow (cfs)	6.6	12	19	-	24
Total phosphate as P (mg/l)	1.00	0.14	0.45	0.31	0.43
Total nitrogen as N (mg/l)	1.43	1.04	1.18	0.14	0.98
Total organic carbon as C (mg/l)	20	28	25	-3	28
Total dissolved solids (mg/l)	149	94	114	20	96
Fluoride (mg/l)	0.99	0.13	0.44	0.31	0.37
Sulfate (mg/l)	37	0	13	13	0

\*Calculated river value downstream of Hunter Creek.



NOTE: Does not reflect all areas affected by mining or mine support activities. See Figure 1.1-2.

• Sampling station

Figure 3.4-33. Location of Nutrient Drift Sampling Stations.

Table 3.4-45. Results of Particulate Nutrient Sampling Using Drift Nets (September 1981 and March 1982).

	SR-1		RC-1		RC-5		RC-10		SR-3		HC-1		HC-3	
	1981	1982	1981	1982	1981	1982	1982	1982	1981	1982	1981	1982	1981	1982
	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Stream discharge (cfs)	~ 54*	~ 1008*	~ 4*	~ 16*	1.4	12.0	4.2	~ 76*	~ 1024*	~ 7*	~ 24*	0.2	13	
Stream discharge (cms)	~ 2*	~ 28.0*	~ 0.1*	~ 0.5*	0.04	0.3	0.1	~ 2.2*	~ 29*	~ 0.2*	~ 0.7*	0.01	0.4	
Volume of water sampled (m <sup>3</sup> )	132	1504	92	1545	44	492	461	751	1137	261	3854	204	576	
	818	818			268		944			2058		390		
Wt. of air-dried sample (g)	2.9	7.8	0.2	2.5	3.5	1.9	37.0	0.1	5.9	4.1	41.8	0.6	29.4	
	5.4	1.4			2.7		3.0			22.9		15.0		
Total phosphate as P in air-dried sample (mg/kg)	1124	3712	1667	2061	1001	1273	65	2900	8372	3851	3039	4394	1915	
	2418	1864			1137		5636			3445		3155		
Total phosphate as P (mg per m <sup>3</sup> of water)	0.025	0.009	0.003	0.003	0.081	0.024	0.142	0.001	0.015	0.060	0.033	0.014	0.098	
	0.017	0.003			.053		0.008			0.047		0.056		
Total nitrogen as N in air-dried sample (mg/kg)	6670	23088	19459	24161	8805	10055	11652	21764	25029	18929	7902	18981	10081	
	14879	21810			9430		23397			13416		14531		
Total nitrogen as N (mg per m <sup>3</sup> of water)	0.147	0.057	0.047	0.039	0.714	0.039	0.935	0.003	0.060	0.294	0.086	0.060	0.516	
	0.102	0.043			0.377		0.032			0.190		0.288		
Total carbon as C in air-dried sample (mg/kg)	226	202000	160765	87000	123820	91000	110000	166922	265000	94828	37000	128350	140000	
	139679	123883			107410		215961			65914		134175		
Total carbon as C (mg per m <sup>3</sup> of water)	1.71	0.92	0.39	0.14	10.04	1.68	8.83	0.03	0.80	1.47	0.40	0.40	7.15	
	1.32	0.27			5.86		0.41			0.76		3.78		

\*Discharge measurement from nearest available station.

Table 3.4-45 (Continued).

	HC-4		HB-2		SR-4		RO-1		RO-5		SR-4.5		LB-1	
	1982	1982	1981	1982	1981	1982	1981	1982	1981	1982	1981	1982	1981	1982
Stream discharge (cfs)	2.8	0.6	-	-	-	~ 0.6*	5*	4.7	~ 169	~ 1683	0.1	0.2	0.1	0.2
Stream discharge (cms)	0.1	0.02	-	-	-	~ 0.02*	0.1*	0.1	~ 4.8	~ 47.6	0.001	0.01	0.001	0.01
Volume of water sampled (m <sup>3</sup> )	1105	239	185	2049	10	1291	651	951	21	896	23	1491	23	1491
			1117						459		757			
Wt. of air-dried sample (g)	7.2	1.9	0.6	13.8	0.1	41.0	8.9	2.1	2.8	2.4	1.3	7.3	1.3	7.3
			7.2		20.6						4.3			
Total phosphate as P in air-dried sample (mg/kg)	1130	1825	3047	4185	**	1154	2037	1474	4033	2754	1413	2679	1413	2679
			3616								2046			
Total phosphate as P (mg per m <sup>3</sup> of water)	0.007	0.014	0.009	0.014	**	0.037	0.019	0.143	0.009	0.076	0.077	0.013	0.077	0.013
			0.012								0.045			
Total nitrogen as N in air-dried sample (mg/kg)	41192	8138	5584	29714	**	7745	10976	9712	25119	17416	12781	14695	12781	14695
			17649								13738			
Total nitrogen as N (mg per m <sup>3</sup> of water)	0.268	0.065	0.017	0.507	**	0.246	0.103	0.940	0.055	0.498	0.701	0.072	0.701	0.072
			0.262								0.387			
Total carbon as C in air-dried sample (mg/kg)	180000	70000	43403	256000	44329	40000	200000	72815	220000	146408	117570	130000	117570	130000
			149702		42165						123785			
Total carbon as C (mg per m <sup>3</sup> of water)	1.17	0.56	0.13	0.84	0.57	1.27	1.38	7.07	0.48	3.77	6.44	0.64	6.44	0.64
			0.48		0.92						3.54			

\*Discharge measurement from nearest available station.

\*\*Insufficient sample for analysis.

Table 3.4-45 (Continued).

	SR-7		EL001-18		AB-3	CB-1.5		SR-10	
	1981	1982	1981	1982	1982	1981	1982	1981	1982
	X		X			X		X	
Stream discharge (cfs)	~241*	~1908*	27.3	32.9	-	~3	3.3	323.6	1960.0
Stream discharge (cms)	~7*	~54*	0.8	0.9	-	~0.1	0.1	9.2	55.5
Volume of water sampled (m <sup>3</sup> )	218	1400	51	585	5006	25	578	163	1334
	809		318			301		749	
Wt. of air-dried sample (g)	0.9	16.1	2.9	33.2	8.8	1.0	3.3	1.2	88.9
	8.5		18.1			2.2		45.0	
Total phosphate as P in air-dried sample (mg/kg)	1923	4479	6688	2905	1800	1358	4931	1747	5095
	3201		4797			3145		3421	
Total phosphate as P (mg per m <sup>3</sup> of water)	0.008	0.026	0.380	0.160	0.003	0.056	0.028	0.013	0.167
	0.017		0.270			0.042		0.090	
Total nitrogen as N in air-dried sample (mg/kg)	4034	31845	75815	5822	34630	10620	16672	3503	20691
	17940		40819			13646		12097	
Total nitrogen as N (mg per m <sup>3</sup> of water)	0.016	0.191	4.310	0.328	0.061	0.435	0.095	0.025	0.690
	0.104		2.319			0.265		0.358	
Total carbon as C in air-dried sample (mg/kg)	36710	435000	64759	51000	200000	143893	67000	41867	166000
	235855		578795			105447		103934	
Total carbon as C (mg per m <sup>3</sup> of water)	0.15	2.84	8.98	2.89	0.35	5.90	0.38	0.30	5.4
	1.49		5.93			3.14		2.85	

\*Discharge measurement from nearest available station.

collections were made at RC-1, RC-5, and RC-10; RC-10 was not added to the study until 1982. Nutrient drift ( $\text{mg}/\text{m}^3$ ) was highest at RC-10 and decreased downstream at RC-5 and RC-1. This trend was also evident when flow rates were used to calculate mass loadings ( $\text{kg}/\text{day}$ ), indicating that dilution was not a factor (Table 3.4-46). It is not expected that the majority of materials entering the upper reaches of the creek would drift downstream to the Suwannee. Very little, if any, of the particulate material upstream of RC-10 could make its way downstream. Upper Rocky Creek has been dredged by local timber interests. In the immediate vicinity of RC-10, a large wide channel has been dredged which serves as a settling basin. Water exiting the channel must sheet flow across approximately 0.5 mi of wooded wetlands prior to re-entering the Rocky Creek channel. Thus, any particulate material from upstream would be settled or filtered in the wide, relatively deep channel or during overland sheet flow through the wetland area. Even without this situation in Rocky Creek, particulate material from headwater areas is not expected to provide significant particulate material to the Suwannee River. Particulate material from headwater areas undergoes biological and chemical degradation as it moves downstream. Upstream material is deposited in pooled sections of the streams and eddies.

At the two Roaring Creek stations (RO-1 and RO-5) nutrient drift concentrations ( $\text{mg}/\text{m}^3$ ) were fairly similar during medium flow, though phosphate and nitrogen were higher at RO-1. During low flow conditions, RO-5 was dry and flow at RO-1 was very low. Loadings during medium flow were similar between the two stations, except nitrogen mass at RO-1 was 2X that measured at RO-5.

Hunter Creek drainage basin stations were sampled at HC-1, HC-3, HB-2, and HC-4. HC-3 and HC-4 receive mine drainage, HB-2 drains an undisturbed area, and HC-2 receives the combined input from the four stations. Stations HC-4 and HB-2 were not added to the monitoring program until 1982. Based on the medium flow period, nutrient drift concentrations ( $\text{mg}/\text{m}^3$ ) on Hunter Creek were fairly variable between stations, though generally greatest at HC-3 and lowest at HB-2. However, on a loadings basis, nutrients were clearly greater at HC-3 followed by HC-1, HC-4, and HB-2.

Comparison of tributaries draining to the Suwannee at stations located at the mouth (RC-1, RO-1, LB-1, CB-1.5, HC-1) indicated that Rocky Creek was generally lowest in concentration ( $\text{mg}/\text{m}^3$ ) for all three particulate nutrients. Long Branch was highest in nutrient concentrations during the low flow collection, whereas Roaring Creek was slightly higher than the other stations during medium flow. Low flow Roaring Creek phosphate and nitrogen data were not available due to insufficient sample size for analysis. Low flow carbon concentrations in Roaring Creek were low compared to Long Branch and Camp Branch. Hunter Creek values varied between the range of concentrations observed in the streams unaffected by mining. Among the three nutrients, carbon was exported from these tributaries in the greatest quantities, followed by nitrogen, and then phosphate. This is expected, considering the drift sources (detritus, leaves, macroinvertebrates).

Table 3.4-46. Particulate Drift Loadings (kg/day), September 1981 and March 1982.

Station	Total Phosphate		Total Nitrogen		Total Carbon	
	1981	1982	1981	1982	1981	1982
RC-1	<0.1	0.1	0.4	1.7	3.4	6.0
RC-5	0.3	0.6	2.5	0.6	34.7	43.5
RC-10	*	1.2	*	8.1	*	76.3
HC-1	1.0	2.0	5.1	5.2	25.4	24.2
HC-3	<0.1	3.4	<0.1	17.8	0.4	247.1
HC-4	*	0.6	*	2.3	*	10.1
HB-2	*	<0.1	*	0.1	*	1.0
RO-1	**	0.3	**	2.1	1.0	11.0
RO-5	*	0.2	*	0.9	*	11.9
LB-1	<0.1	<0.1	0.1	0.1	0.1	0.6
CB-1.5	0.5	0.2	3.8	0.8	51.0	3.3
EL001-18	26.3	12.4	298	25.5	38.7	225

\*Not sampled in 1981.

\*\*Insufficient sample for analysis.

Relative rankings of the tributaries in terms of nutrient drift concentrations change when flow rates are considered. Greatest loadings (kg/day) of particulate nutrients during the low flow collection occurred at HC-1, with the exception of carbon at CB-1.5. The highest phosphate and nitrogen values among stations unaffected by mining were also recorded at CB-1.5. During the medium flow collection, nutrient loading at unaffected streams was highest at RO-1. Loadings were generally lowest at Long Branch during both collection periods.

The outlet from Eagle Lake (EL001-18) generally had greater nutrient concentrations ( $\text{mg}/\text{m}^3$ ) and mass loadings than the tributaries. Nutrient drift concentrations exported from Altmans Bay during the medium flow collection were within the range of values reported for the tributary stations. No flow data were available to calculate loadings.

Comparison of nutrient drift concentrations ( $\text{mg}/\text{m}^3$ ) at Suwannee River stations revealed no clear trends. Concentrations of drift appeared to be a localized phenomenon, with no obvious increase or decrease with distance downstream. For example, SR-4.5 had high nutrient concentrations during low flow, while the nearest stations upstream (SR-4) and downstream (SR-7) exhibited fairly low concentrations. Thus, particulate nutrient concentrations ( $\text{mg}/\text{m}^3$ ) at Suwannee River stations downstream from tributaries did not appear to be greatly influenced by exports from the tributaries. To estimate the importance of the tributaries in maintaining particulate nutrient concentrations in the Suwannee River, percent contribution was calculated by dividing the mass loadings exported for each tributary by the sum of the tributary loadings and the Suwannee River loadings immediately upstream of the tributary (Table 3.4-47). Camp Branch was not included because it travels underground before reaching the Suwannee and the actual contribution is unknown.

With the exception of Hunter Creek during low flow conditions, the percent contribution of each stream was low (Table 3.4-47). Tributaries unaffected by mining contributed  $\leq 3.2\%$  of the nutrient drift present in the Suwannee immediately downstream. Hunter Creek contributed  $>80\%$  of the nutrients during low flow. These high percentages for Hunter Creek reflect the fact that SR-3 had the lowest concentrations of nutrient drift of all stations measured during low flow. At medium flow, Hunter Creek contributed  $<5\%$  of the particulate nutrients to the Suwannee River immediately downstream of the confluence.

The remaining balance of particulate nutrients present in the Suwannee River (generally  $>95\%$ ) originates from sources other than the tributaries located in the study area. Such sources include:

- 1) leaves, fruits, and branches from riparian vegetation, as well as windblown materials from upland species;
- 2) overland runoff carrying organic materials from nearby upland and wetland areas;

Table 3.4-47. Estimated Contribution (%) of Particulate Nutrient Drift (kg/day) from Tributaries during Low (September 1981) and Medium (March 1982) Flows.

Station	Period	Flow (cfs)	% Contribution to the Suwannee River		
			Phosphate	Nitrogen	Carbon
RC-1	1981	6.2	0.8	2.1	1.5
	1982	1.6	0.5	1.1	<0.5
RO-1	1981	0.7	-	-	3.2
	1982	<0.5	1.2	<0.5	0.7
LB-1	1981	<0.5	<0.5	<0.5	<0.5
	1982	<0.5	<0.5	<0.5	<0.5
HC-1	1981	8.9	92.2	90.6	84.2
	1982	2.3	4.8	3.2	1.2

- 3) autochthonous sources; although small relative to the above sources, contributions are expected from periphyton, zooplankton, macrophytes, and faunal metabolites; and
- 4) other tributaries.

In addition to comprising >95% of the particulate nutrient drift, sources other than the tributaries are expected to supply organic material which is somewhat fresher and more readily decomposed. Although Rocky Creek data indicate that much of the drift from upper reaches does not travel to the Suwannee, eventually a certain percentage is expected to reach the river. By the time these materials enter the Suwannee, they probably are of reduced value due to biological or physical action on them while traveling downstream.

### 3.4.3 Groundwater

#### 3.4.3.1 Geohydrological Setting

Three aquifer systems have been identified in the study area based on lithology, stratigraphy, water chemistry, and water level conditions. The Surficial Aquifer comprises the saturated part of the clastic materials within the undifferentiated marine terrace deposits and the matrix zone (i.e., Hawthorn Member A, Section 3.1.3.3). The Secondary Artesian Aquifer comprises the permeable units within the Hawthorn Formation. The Floridan Aquifer comprises the Oligocene-age and older limestone units. In the study area, the top of the Suwannee Formation is judged to be the top of the Floridan Aquifer.

The aquifer systems in the study area, especially the Surficial and Secondary Artesian aquifers, do not exhibit simple, relatively homogeneous systems. In the Surficial Aquifer sand grades into silty sand and/or clayey sand which grades into clays (in descending order). At the bottom of the aquifer, zones of permeable sand and/or phosphate pebble layers are present. Therefore, permeable zones are near the surface and near the bottom of the aquifer, with relatively impermeable zones in between. Alternating zones of permeable rock, hard dolomite, or tight clay lenses typify the Secondary Artesian and Floridan aquifers.

Phosphate mining in the study area is within the Surficial Aquifer only. No excavation will cut into a lower aquifer system; the excavations stop at the clays or dense limestone at the bottom of the Hawthorn Member A. Based on these considerations, the primary areas of concern are: 1) the characteristics of the Surficial Aquifer and 2) the interconnections between the Surficial Aquifer and the other aquifer systems and surface waters.

Recharge to the Floridan Aquifer is important. Baseflow of streams is derived from aquifer outflows and depends on the stratigraphic position of each aquifer with respect to the surface waterbody's streambed profile. The Suwannee River is connected to all three aquifer systems depending on location within the study area. Above Big Shoals (River Mile 180) the river is connected only to the Surficial Aquifer; between Big Shoals and White Sulphur Springs at White Springs the river is connected predominantly to the Secondary Artesian Aquifer; below White Springs the river is connected predominantly to the Floridan Aquifer.

A spring, broadly defined, is a concentrated groundwater outflow to surface waters. The terms spring and seep are utilized herein for characterizing springs. A spring is limited to concentrated groundwater outflow from the Floridan Aquifer to the surface water; a seep is limited to concentrated groundwater outflow from the other two aquifers to surface waters. Seeps typically occur at the bottom of a permeable zone at the permeable-impermeable zone interface.

Several references were utilized extensively in determining the groundwater hydrology and interconnection between aquifer systems (Rosenau et al. 1977, EPA 1978a, Ceryak et al. 1982, USGS in press). Ceryak et al. (1982) report that the Surficial Aquifer maintains the highest water

levels relative to mean sea level. The Secondary Artesian Aquifer has water levels at altitudes between those of the Surficial Aquifer and the Floridan Aquifer. The Floridan Aquifer may display two distinct water level characteristics in the study area: it is artesian where it underlies the Secondary Artesian Aquifer and nonartesian where the Hawthorn Formation is thin or nonexistent.

Methods used in assessing the groundwater resources in the OXY project area are discussed in Section 3.4.4.2.

#### 3.4.3.2 Water Quantity

Surficial Aquifer. The Surficial Aquifer comprises the saturated part of the undifferentiated marine terrace deposits, plus Member A of the Hawthorn Formation, and consists chiefly of fine-grained quartz sand (Section 3.1.3.3). In potential mining areas the Surficial Aquifer is defined as the overburden and the matrix; however, layers of silts and clays are also typically found in the aquifer. Following is a generalized profile of the aquifer (Figures 3.1-15 and 3.1-16, Section 3.1.4.2):

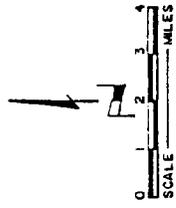
<u>Depth (ft)</u>	<u>Description</u>
0-5	Light gray to dark brown fine sand and slightly silty or slightly clayey fine sand
5-15	Gray to grayish brown to yellowish brown clayey fine sand
15-37	Bluish gray to grayish brown and greenish slightly clayey to clayey phosphatic fine sand

The aquifer has limited thick, clean, areally extensive sand deposits. Some of the most permeable zones occur in the matrix zone. The thicker, sandier zones occur along the east part of the study area, in the vicinity of TH-11 and TH-12, and in the north-central part in the vicinity of TH-3 and TH-4 (Figure 3.1-11, Section 3.1.3.3).

Based on Ardaman and Associates, Inc. test drilling plus OXY project boring data, the thickness of the Surficial Aquifer is 20-60 ft, typically 30-40 ft (Figure 3.4-34). The thickest deposits are in the northeast and east parts of the study area, north and east of TH-5, TH-7, and TH-8 and between and east of TH-10 and TH-11.

The altitude at the base of the Surficial Aquifer is 70-110 ft NGVD, typically 90-110 ft NGVD (Figure 3.4-35). This represents the lowest altitude to which mining activities would penetrate during excavation. The lowest altitudes occur in the east and northeast parts of the study area.

The water table is the top of the Surficial Aquifer, and the shape of its surface approximately coincides with the shape of the land surface elevations (Figure 3.1-3, Section 3.1.2). Water levels (105-135 ft NGVD) are at or near land surface throughout most of the area most of the year (Figure 3.4-36, Fla. Dept. of Admin. 1975, Miller et al. 1978,



**LEGEND**

—20— THICKNESS CONTOUR, ft.

----- PROJECT BOUNDARY

Source: Oxy prospect data, September 1981

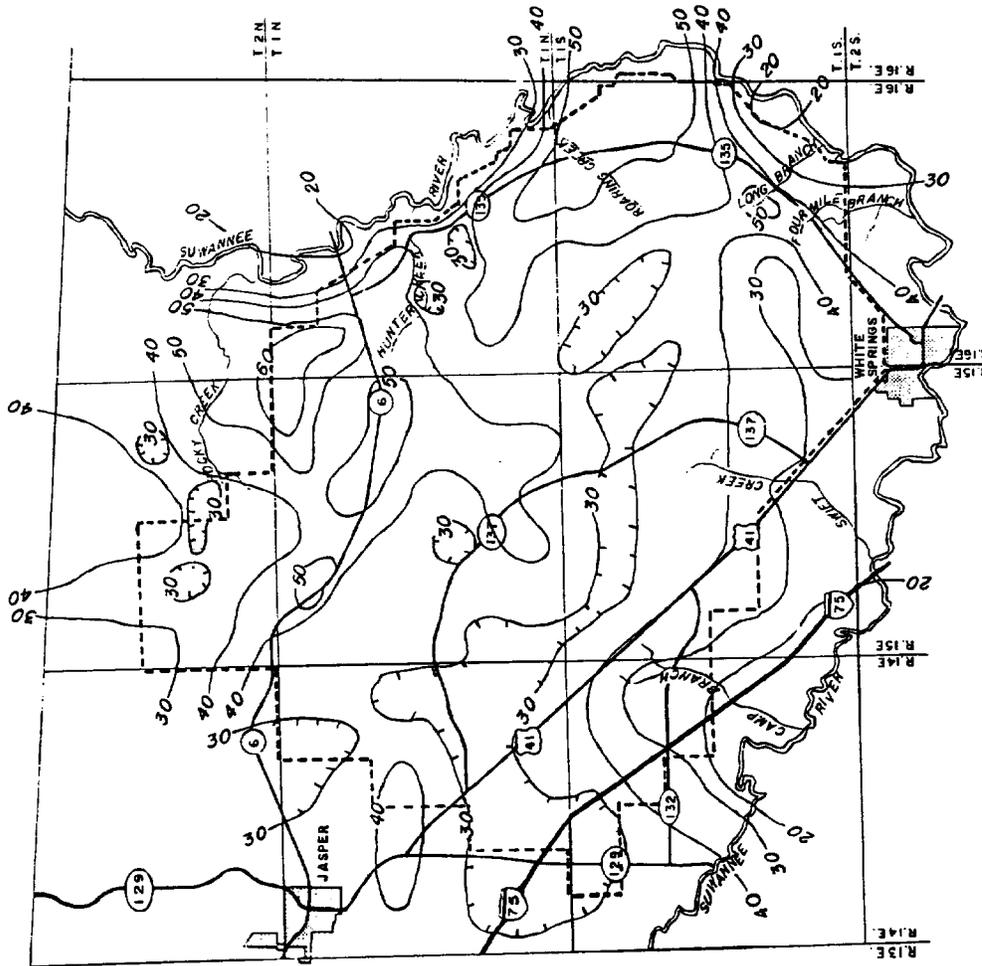
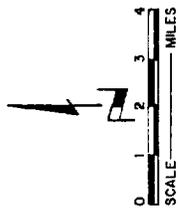


Figure 3.4-34. Thickness of the Surficial Aquifer.



**LEGEND**

—20— BASE OF THE SURFICIAL AQUIFER  
FT. N.G.V.D.

----- PROJECT BOUNDARY

Sources: Oxy prospect data

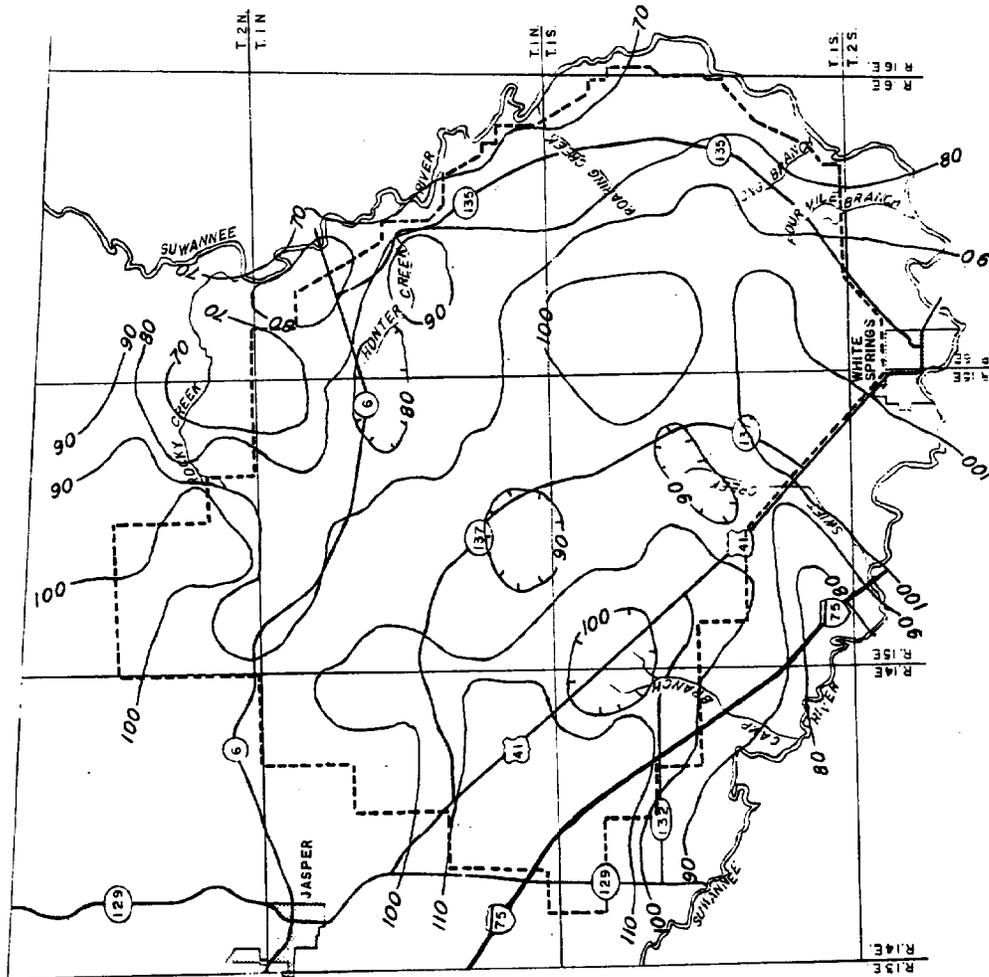


Figure 3.4-35. Altitude of the Base of the Surficial Aquifer.

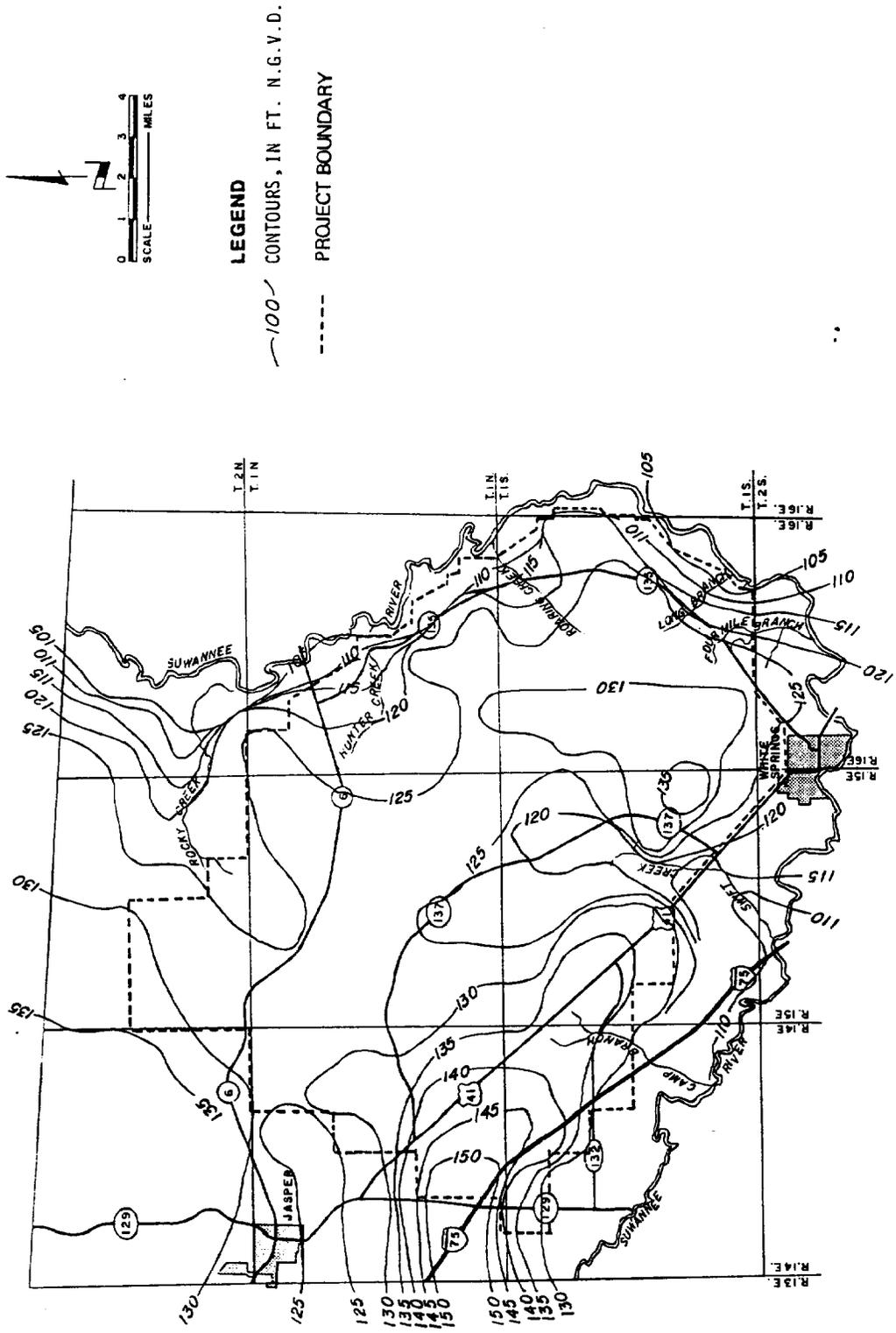


Figure 3.4-36. Generalized Altitude of the Water Table.

Hunn 1982, Ceryak et al. 1982). The regional surface slopes to the north and east. Local perturbations on the surface are evident along Swift Creek, Rocky Creek, Roaring Creek, and Hunter Creek. Obviously, groundwater flow within the Surficial Aquifer moves toward these surface waterbodies within the interior of the study area and toward the Suwannee River along the east and south edges of the study area. Swift Creek appears to intercept the most groundwater of the interior streams, based on the number and tight shape of the altitude contours in this area.

Monitoring of water table fluctuations at selected wells in the Surficial Aquifer indicates that during wet periods the water table is near the surface, and during dry periods the water table is several feet below land surface (Figure 3.4-37). The normal fluctuation between high and low water table altitudes is seldom more than 4 ft in an area unaffected by drainage or water use.

Water levels in 26 Surficial Aquifer wells were documented several times between December 1981 and April 1982 (Table 3.4-48). The maximum fluctuation between high and low water table at any site was 2.0 ft in Swift Creek Swamp. More fluctuation would be expected between extreme wet and dry periods. Four sites had pairs of wells: one well in the overburden zone and the other well in the matrix zone. The head difference between the top and bottom zone varied between -0.46 to +3.33 ft. The negative value indicates that the potentiometric surface within the matrix zone was higher than the water table. Typically, the water table was 0.5 ft higher than the potentiometric surface in the matrix zone.

In western Hamilton County, the average hydraulic conductance for clayey sands of the water table aquifer was 0.0003 ft/min (Reynolds, Smith and Hills 1974). An aquifer test in the Surficial Aquifer at the Swift Creek Chemical Complex site in Hamilton County yielded a storage coefficient of 0.00075 and a transmissivity of approximately 500 sq ft/day (EPA 1978a).

Aquifer permeability tests (falling head tests) performed at 17 wells during winter 1981-1982 yielded permeability values of 0.0036-0.000066 cm/sec or 0.22-12.0 ft/day, respectively (Figures 3.1-11 and 3.1-12, Section 3.1.3.3).

Secondary Artesian Aquifer. The Secondary Artesian Aquifer comprises Hawthorn Member B down to the top of the Floridan Aquifer (Section 3.1.3.3). Members B through D were encountered in the southwest part of the site while Members B through E were encountered in the northeast part of the site. Several points are evident concerning the characteristics of the Secondary Artesian Aquifer:

- 1) the aquifer is not areally extensive and continuous; Member C (i.e., well-sorted, fine to medium-grained sand) is probably the only zone that potentially could be an areally extensive unit within the formation;
- 2) Members B and E appear to be "impermeable" zones;

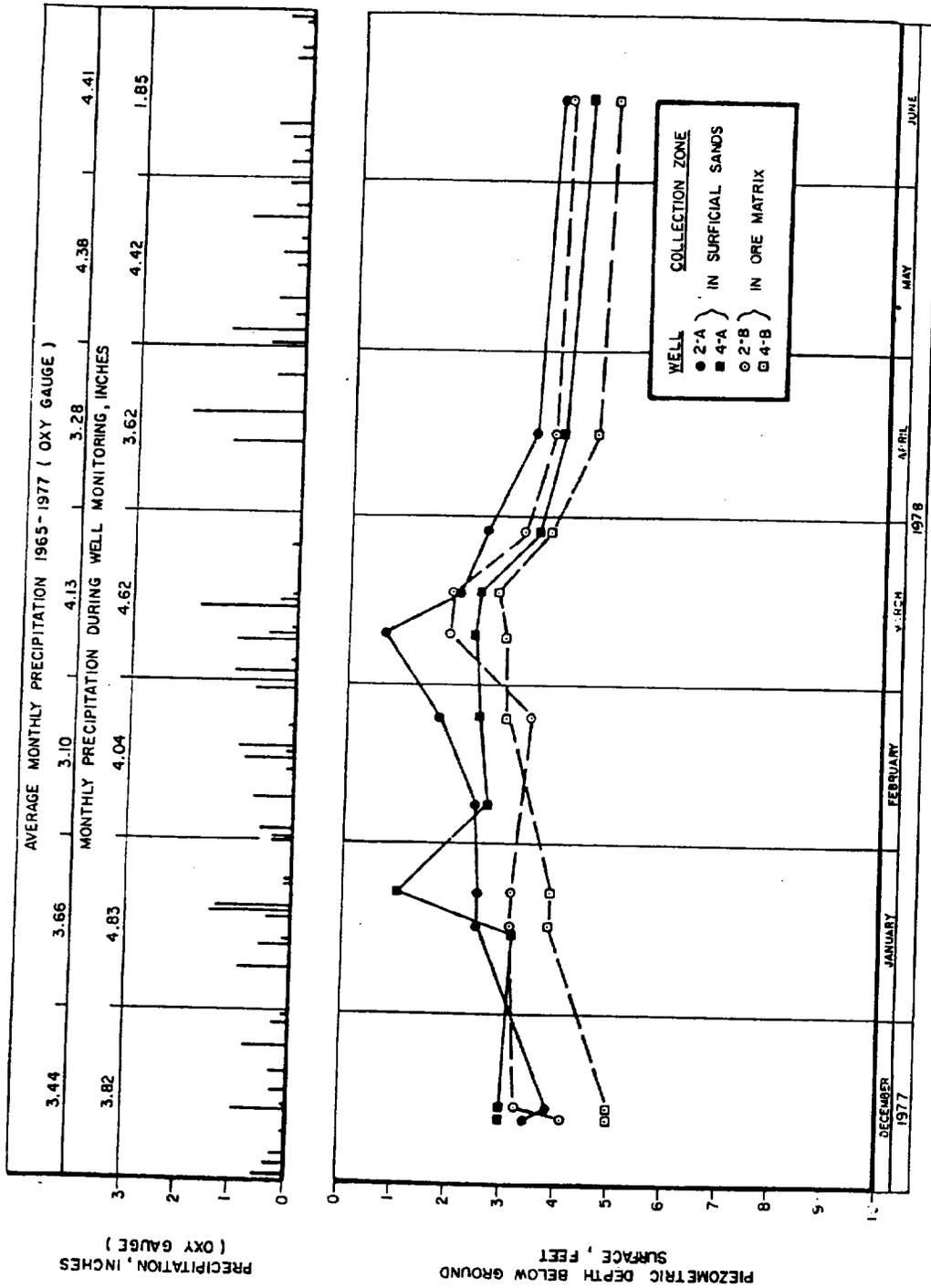


Figure 3.4-37. Fluctuations in the Groundwater Levels of the Surficial Aquifer.

Table 3.4-48. Surficial Aquifer Water Levels for 1981-1982.

Well*	Water Level (ft below ground surface)				
	At time of drilling	Feb. 1-4	Mar. 2-4	Apr. 5-8	
1	12/08/81	3.00	8.58	8.58	8.25
1A	12/09/81	3.00	8.42	8.42	7.92
2	12/09/81	9.00	7.50	7.33	7.17
3	12/14/81	4.00	1.75	1.58	1.25
4	12/21/81	5.00	2.67	3.42	3.25
5	12/28/81	4.00	2.50	2.92	3.25
5A	12/28/81	4.00	1.00	2.33	3.00
7	01/07/82	2.30	3.00	3.67	3.67
8	01/07/82	3.50	6.75	6.00	5.00
9	01/12/82	2.00	3.00	2.25	2.67
10	01/18/82	1.00	3.58	3.33	2.50
10A	01/18/82	1.00	3.58	3.42	2.96
11	01/13/82	2.30	1.83	2.67	2.58
12	01/14/82	0.00	5.50	5.83	5.67
13	01/18/82	2.00	2.42	3.58	3.42
14	02/02/82	1.30	3.42	4.00	3.58
15	01/29/82	3.50	5.00	5.08	4.83
16	01/29/82	1.50	4.00	3.25	3.67
16A	01/29/82	1.50	0.67	1.08	1.17
17	02/17/82	1.70	-	9.17	7.17
19A			-	-	7.00
19B			-	-	7.50
19C			-	-	6.50
20A			-	-	7.00
20B			-	-	13.00
Ro4BE			2.67	3.33	4.33

\*Refer to Figure 3.1-10, Section 3.1.3.3, for locations of wells.  
 Source: Ardaman and Associates, Inc.

3) Member D is judged to be a very discontinuous, minor permeable zone.

The limestone and sandstone within the Hawthorn Formation form the potential aquifer, but these zones seem to be dense and/or are thin beds interbedded with clays, not characteristics of an areally extensive aquifer system. During drilling, circulation water was not lost within the Hawthorn Formation units.

The thickness of the confining beds (25-125 ft) between the Floridan and Surficial aquifers increases from southwest to northeast (Figure 3.4-38). The Secondary Artesian Aquifer probably consists of a 10-21 ft thick Member C zone.

Water levels in the Secondary Artesian Aquifer are lower than in the Surficial Aquifer but are higher than in the Floridan Aquifer (Figure 3.4-39). The potentiometric surface in the Hawthorn Formation decreases with depth due to appreciable head losses in the confining unit. At the Swift Creek Chemical Complex site, the head difference between the Surficial Aquifer and the Floridan Aquifer was 80 ft in 1978. At the Suwannee River Chemical Complex site, the head difference between the two aquifers was 57 ft in 1978. At both sites, most of the hydraulic head difference is dissipated across one or more layers of plastic clay present within the Hawthorn Formation between 40 and 85 ft NGVD. The significant head loss experienced as water moves downward through the primary confining unit is indicative of the poor hydraulic connection that exists between the Surficial and Floridan aquifers.

The Secondary Artesian water level at the Suwannee River Mine is approximately 60-75 ft NGVD; water levels fluctuate as much as, or more than, Floridan Aquifer water levels (Figure 3.4-40, Ceryak et al. 1982).

An aquifer test on a 20-ft thick section within the C Member of the Hawthorn Formation in the Osceola National Forest yielded a transmissivity value of 15 sq ft/day and a storage coefficient of 0.00012 (Miller et al. 1978). The unit was pumped at 3.2 gpm for 336 hr. Drawdowns were documented in wells open within Hawthorn Members C and D.

A slug-discharge test performed in a 3-ft thick, permeable zone within the Hawthorn Formation near Swift Creek Mine yielded a transmissivity value of 3.0 sq ft/day (EPA 1978a). The hydraulic conductivity, assuming the 3-ft thickness, was calculated to be 0.96 ft/day (0.0003 cm/sec) which is comparable to the permeability value determined for a 20-ft thick zone (Miller et al. 1978).

Floridan Aquifer. The Floridan Aquifer is an areally extensive deposit of primarily carbonate rock deposited during the Tertiary Period. The bottom of the potable water portion of the aquifer is estimated to be >1000 ft below land surface (Ceryak et al. 1982).

The top of the aquifer is defined as the top of the Suwannee Formation (Figure 3.1-9, Section 3.1.3.3). The altitude at the top of the aquifer ranges from about +50 ft NGVD in the southwest part of the study area to -50 ft NGVD in the northeast part. The original map contours for the

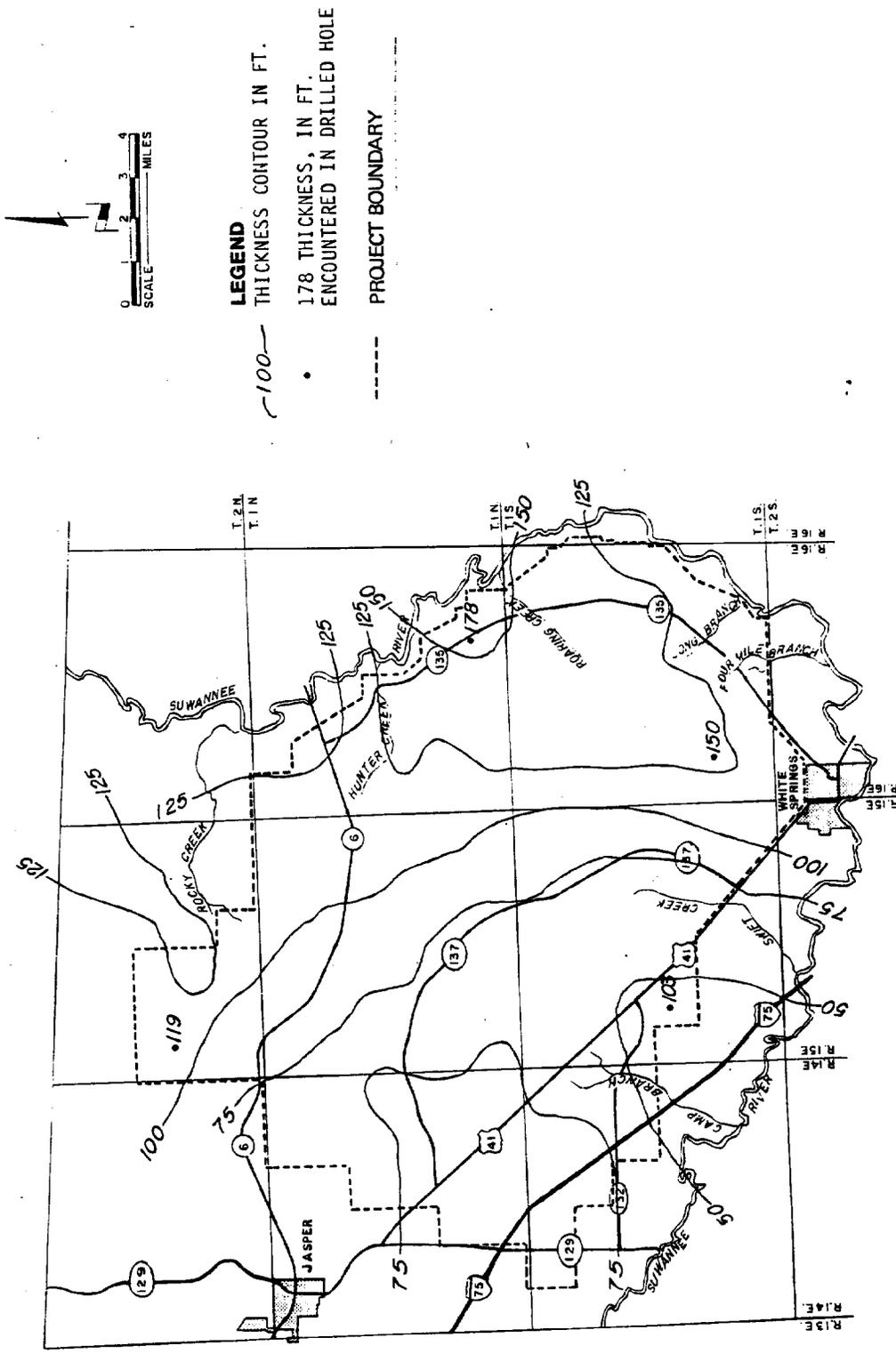


Figure 3.4-38. Thickness of the Confining Bed Overlying the Floridan Aquifer.

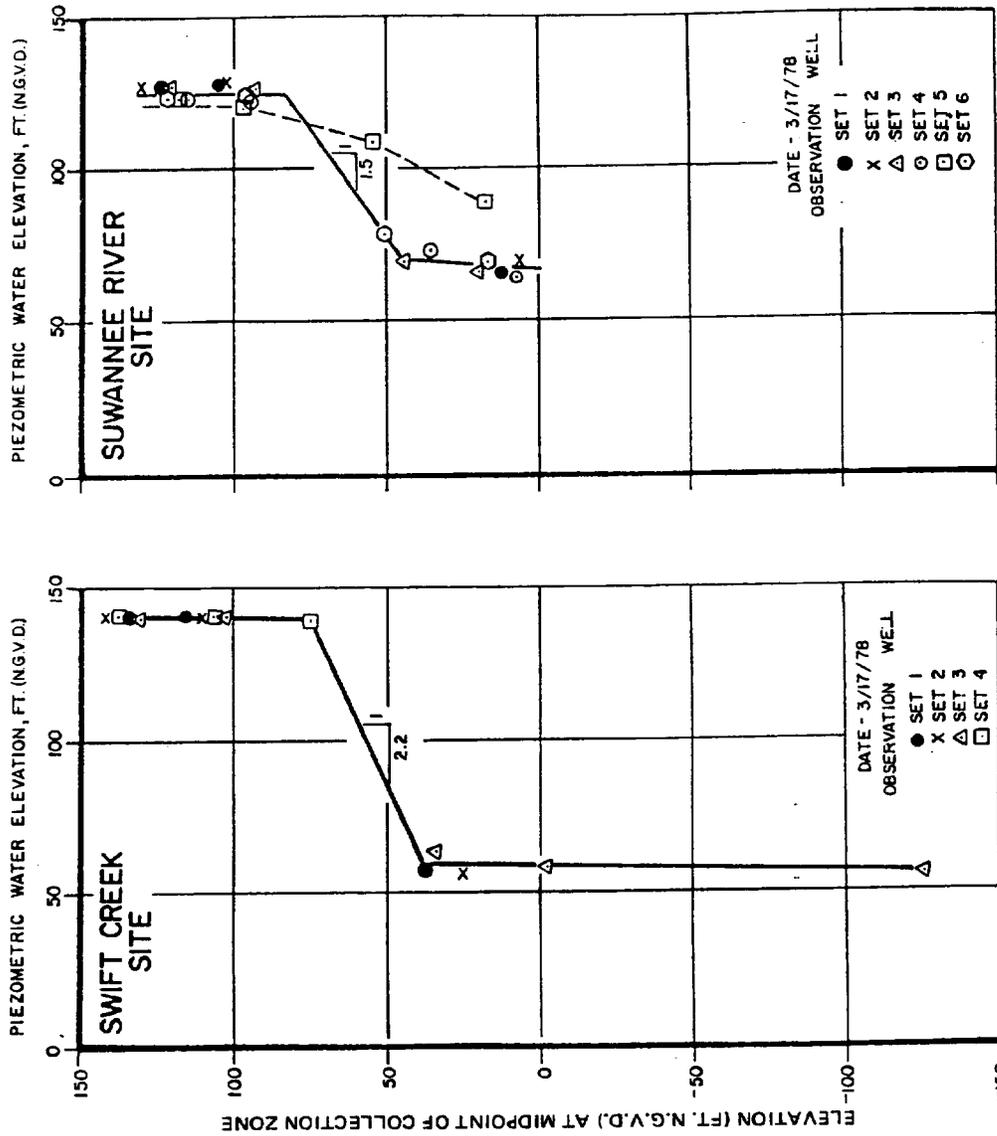
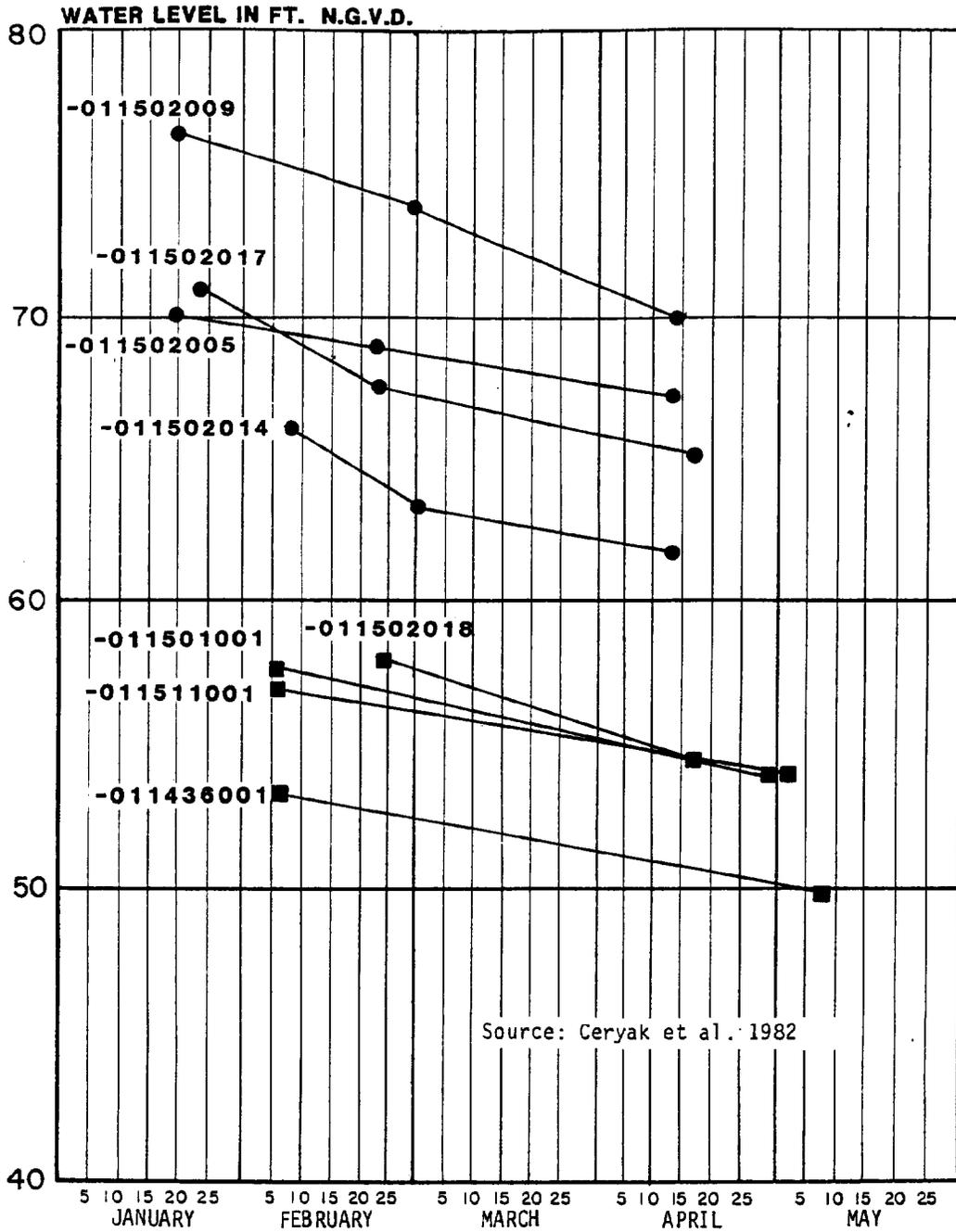


Figure 3.4-39. Piezometer Levels at Various Depths in Geologic Profile.



**LEGEND**  
**-011502009** SRWMD Well Site Identification Number  
 ● Secondary Artesian Wells  
 ■ Floridan Artesian Wells

**Figure 3.4-40. Comparison of Secondary Artesian and Floridan Aquifer Hydrographs.**

Suwannee River Water Management District (Ceryak et al. 1982) have been updated based on core samples from the deep holes monitored by Ardaman and Associates, Inc. (Figure 3.1-12, Section 3.1.3.3).

The potentiometric surface of the Floridan Aquifer ranges between +40 and +50 ft NGVD with the regional gradient (flow) trending from east to west across the study area (Figure 3.4-41). However, water movement into Hamilton County is from the north, while movement out of the county is primarily toward the south but also toward the east.

Ceryak et al. (1982) discuss the groundwater circulation phenomenon in this aquifer:

Most of the groundwater circulation takes place in the upper 200 to 300 feet of saturated limestone. Suwannee River Water Management District geophysical and drillers' logs were examined to locate cavity zones in the study area. Nearly two-thirds occurred at formational contacts. Most occurred at the contact between the Suwannee Limestone and the overlying Hawthorn, but the Ocala Limestone - Suwannee Limestone contact is also a major cavity zone. Area springs exhibit extensive horizontal cave systems at these contacts (Fisk and Exley 1977). These systems are known to extend for miles, and velocities within the conduits commonly reach five feet per second (Dave Fisk, SRWMD, personal communication, 1979).

The upper one-half of the Suwannee Limestone also contains significant cavity zones. A high degree of secondary porosity has developed in the upper Suwannee since it is the first major carbonate unit encountered by the downward percolating acidic groundwater, especially where the aquifer is in a leaky artesian or nonartesian condition. The upper portion of the Suwannee Formation is also a former erosional surface, is not as lithified as the lower Suwannee because of less compaction in early diagenesis, and probably developed a degree of secondary porosity during this weathering period.

In the areas south and east of White Springs, the Suwannee Limestone is relatively thin (less than 20 feet thick). Where this situation exists, the entire Suwannee and Upper Ocala are potentially cavernous. Cavity zones up to 25 feet thick are common. The limestone along the rivers has developed high secondary porosity partially due to dissolution by acid river waters. During flood stages, a large volume of river water recharges the Floridan Aquifer along the river corridor. In areas that are nonartesian now, or have been in the geologic past, solution cavity development takes place at the water table or within the zone of water table fluctuation. Where the aquifer is artesian, most solution takes place at the contact of the saturated carbonates with the overlying confining beds.

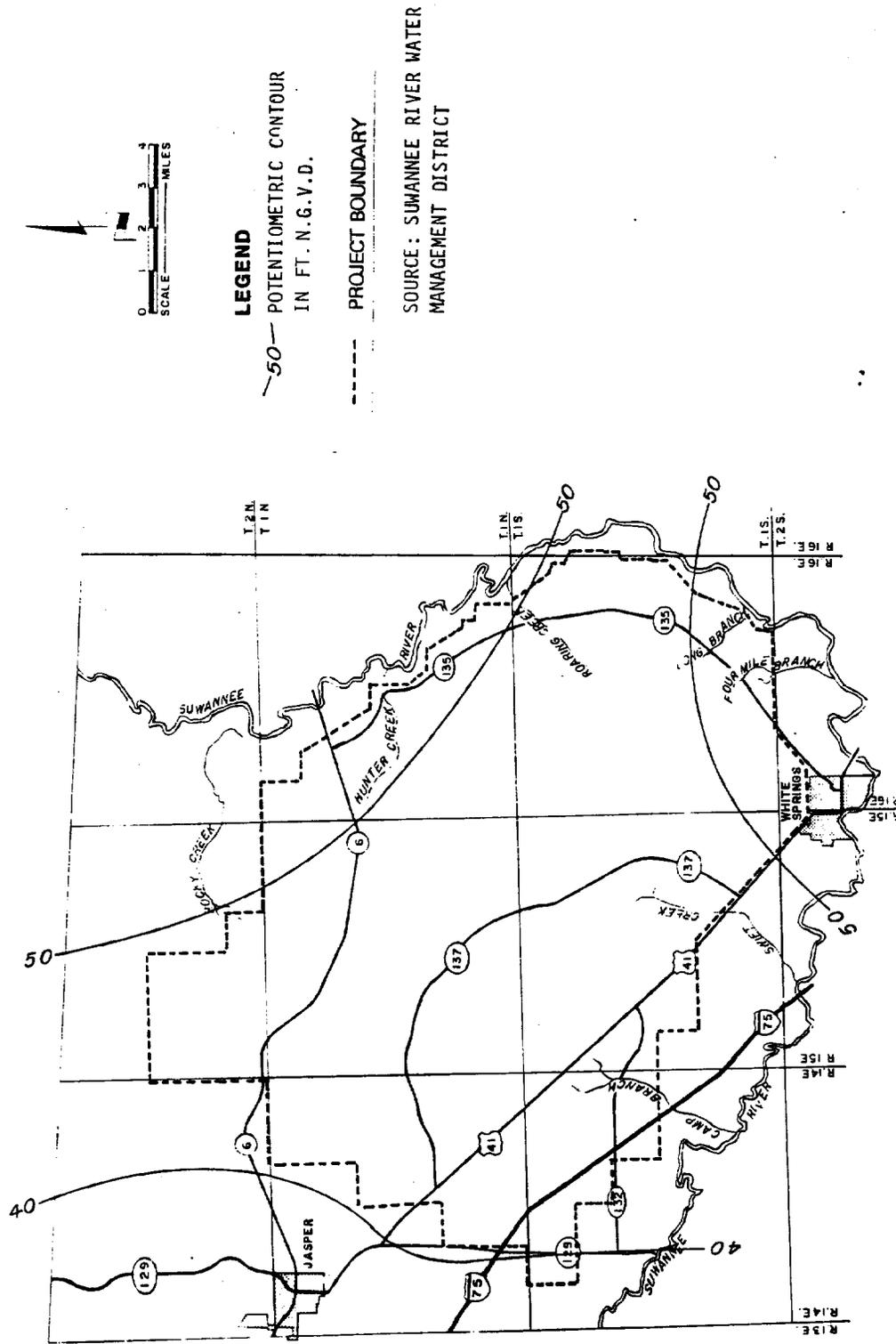


Figure 3.4-41. Potentiometric Surface of the Floridan Aquifer, November 1981.

Long-term records of water levels in a Floridan Aquifer well in Lake City indicate that the potentiometric surface has fluctuated as much as 18 ft with no apparent long-term trend (Figure 3.4-42, Miller et al. 1978).

Water levels in two Floridan Aquifer wells were measured February-April 1982. The maximum fluctuation between high and low potentiometric surface during this period was 2.8 ft (45.0-47.8 ft NGVD at USGS No. 3028350825453). For the well at the Stephen Foster Memorial Park (USGS No. 3019480824606), the USGS reports that the measured extreme range in potentiometric surface is 10.36 ft (50.81-61.17 ft NGVD). The range measured in 1982 was 51.48-52.11 ft NGVD.

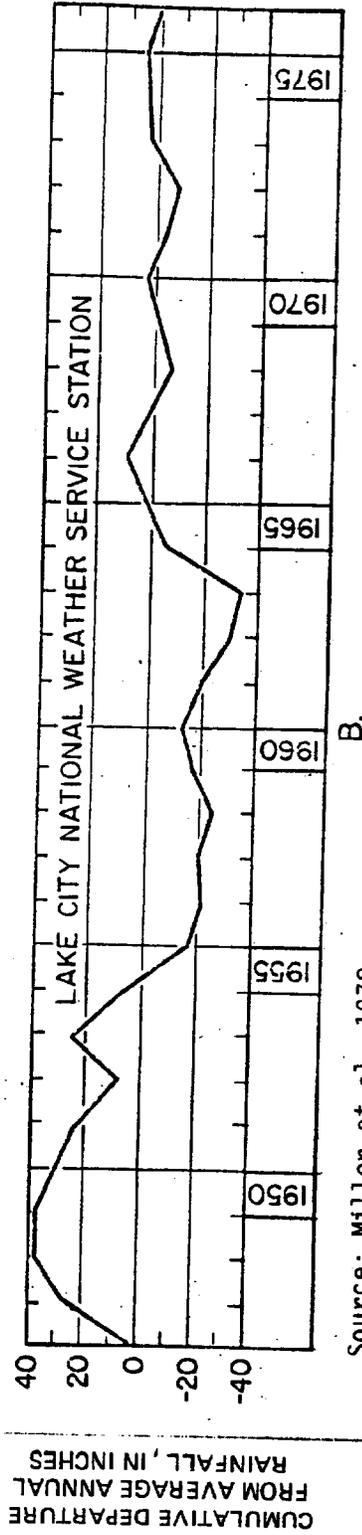
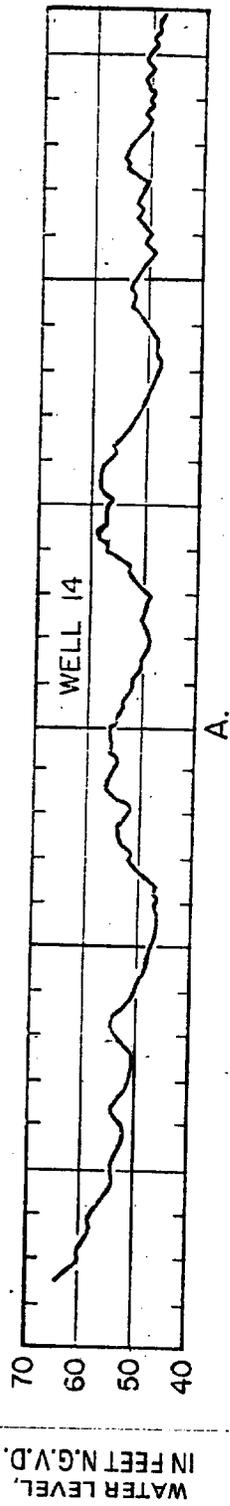
Miller et al. (1978) conducted an aquifer test on the Floridan Aquifer in the Osceola National Forest in which the aquifer was pumped at 1320 gpm for 45.5 hr. A transmissivity (T) value of 33,000 sq ft/day, a storage coefficient (S) of 0.00007, and a leakance value of 0.00069 ft/day were reported as the hydraulic properties of the aquifer. However, considering the dependence of transmissivity on the thickness of the aquifer penetrated, and through comparison with other studies conducted by Bentley (1977) and Pride et al. (1966), Miller et al. (1978) estimated the actual transmissivity and storage values to be approximately 2X the values they originally calculated (e.g., T = 66,000 sq ft/day and S = 0.0001), and the leakance value represented upward movement of Floridan Aquifer water.

In 1978 Ardaman and Associates, Inc. conducted a slug-discharge test on limestone 140-155 ft below land surface (Observation Well 3D) and reported a transmissivity value of 6.5 sq ft/day. An 18.5-hr pump test on an 800-ft deep production well within the Swift Creek Chemical Complex in 1978 yielded a transmissivity value of 190,000 sq ft/day and a coefficient of storage of 0.001 (Ceryak et al. 1982).

### 3.4.3.3 Water Quality

Surficial Aquifer. Water quality data were obtained from the Suwannee River Water Management District (SRWMD) for wells in Hamilton County (Table 3.4-49). Ceryak et al. (1982) state that the Surficial Aquifer water is characterized by relatively high values for sodium, chloride, and potassium, apparently derived from precipitation of marine aerosols, and high nitrate concentrations, which appear to be man-induced. Natural nitrate values can be as high as 5 mg/l but are often <1 mg/l (Hem 1959). Factors that contribute to high nitrate values include barnyard animal excrement, chicken and hog barns, chemical fertilizers, septic tank effluent, human waste products, and, to a lesser degree, plants that fix nitrate-nitrogen in the soil. SRWMD nitrate values ranged from 0 to 10.6 mg/l, with a mean of 3.2 mg/l.

Contrasting these high values, pH, specific conductance, alkalinity, calcium, and magnesium exhibit relatively low values when compared with waters from the Secondary Artesian and Floridan aquifers.



Source: Miller et al. 1978

Figure 3.4-42. A) Hydrograph of Well 14 Tapping the Floridan Aquifer at Lake City.  
 B) Cumulative Departure from the Average Annual Rainfall at Lake City, 1947-1976.

Table 3.4-49. Surficial Aquifer Water Quality Data, April 1976 - April 1978.

Parameter	Sample Size	Range	Mean	Std. Dev.	Var.
Salinity (ppt)	27	0 - 2.0	0.1	0.4	0.2
pH	37	4.4 - 7.7	5.6	0.8	0.6
Temperature (°C)	55	8.5 - 27.5	19.5	4.2	17.8
Conductance (µmhos/cm at 25°C)	61	23.0 - 702.0	136.5	129.6	16796.7
Alkalinity as CaCO <sub>3</sub> (mg/l)	61	0 - 170.0	13.0	32.2	1036.8
Chloride (mg/l)	61	3.1 - 92.6	13.8	13.1	172.7
Fluoride (mg/l)	61	0 - 2.6	0.2	0.4	0.2
Sulfate (mg/l)	61	0 - 2.8	10.7	36.8	1351.5
Silica (mg/l)	-	-	-	-	-
Orthophosphate as P (mg/l)	61	0 - 3.1	0.3	0.6	0.4
Nitrate as N (mg/l)	36	0 - 10.6	3.2	3.5	12.5
Nitrite as N (mg/l)	27	0 - 9.0	0.3	1.7	3.0
Ammonia as N (mg/l)	37	0 - 7.6	0.3	1.3	1.7
Calcium (mg/l)	61	0 - 38.7	6.9	7.5	55.8
Magnesium (mg/l)	61	0.4 - 20.5	3.9	4.1	17.0
Sodium (mg/l)	61	0.9 - 57.4	8.9	10.0	100.3
Potassium (mg/l)	61	0.08 - 24.3	2.4	3.6	12.8
Iron (mg/l)	10	0.09 - 18.0	3.0	5.6	31.3
Strontium (mg/l)	10	0 - 0.1	0.02	0.04	0.002

Source: SRWMD 1981.

Water quality data also were collected within the study area by Ardaman and Associates, Inc. (Table 3.4-50, Figure 3.4-43). The predominant cation is calcium, with magnesium, sodium, and iron cations each secondary in at least one groundwater analysis. The iron cation was predominant in one well open to the overburden section of the aquifer. The predominant anion is bicarbonate, although in one analysis within the matrix zone the carbonate anion was predominant. With the available data, the overburden and matrix zones of the Surficial Aquifer do not exhibit different characteristics.

Secondary Artesian Aquifer. The water quality data obtained from the SRWMD for wells in Hamilton County are summarized in Table 3.4-51. Ceryak et al. (1982) report that in terms of the major anions and cations, the aquifer water is nearly identical to the calcium-magnesium-bicarbonate Floridan Aquifer water. In addition, the Secondary Artesian Aquifer water is characterized by relatively high values for fluoride and orthophosphate as a result of dissolution of fluorapatite, the most abundant phosphate mineral present in the Hawthorn Formation.

Water quality data collected by Ardaman and Associates, Inc. from wells thought to be Secondary Artesian Aquifer water are summarized in Table 3.4-52 and Figure 3.4-43. The water is calcium-magnesium-bicarbonate type water with characteristics essentially identical to the Floridan Aquifer water.

Floridan Aquifer. The water quality data obtained from the SRWMD for wells in Hamilton County are summarized in Table 3.4-53. Ceryak et al. (1982) report that the Floridan Aquifer water is characterized by high relative values for specific conductance, calcium, alkalinity, magnesium, pH, and sulfate. This calcium-magnesium-bicarbonate type water is typical of limestone areas due to the dissolution of calcium and magnesium carbonates. The high relative values for pH correspond with the high relative alkalinity values. High specific conductivity (i.e., a measure of total dissolved solids) is in response to the high concentrations of calcium, magnesium, and bicarbonate ions in solution. The high relative values for sulfate in the aquifer water may result in the formation of hydrogen sulfide gas. Hydrogen sulfide is formed in two ways: by decomposition and reduction of organic matter in water, or by reduction of sulfate in groundwater. The former is usually associated with swampy areas with abundant vegetative matter, while in north-central Florida the latter can be associated with the dissolution of gypsum and anhydrite within the carbonates of the Floridan Aquifer.

Water quality data from two Floridan Aquifer wells sampled by Ardaman and Associates, Inc. for this study are summarized in Table 3.4-54 and Figure 3.4-43.

#### 3.4.3.4 Interconnections of Hydrological Systems

Surficial Aquifer and Other Aquifers. Even though separated by confining layers, water moves between aquifers from locations of high to low water level altitudes. The rate at which the water moves and the quantity of flow per unit area are related to the permeability of the confining layer.

Table 3.4-50. Surficial Aquifer Water Quality Data, February-April 1982.

Parameter	No. of Wells*	Range	Mean	Std. Dev.	Var.
Total dissolved solids (mg/l)	8(16)	52.0-502.0	231.6	144.6	20918
Phenolphthalein alkalinity as CaCO <sub>3</sub> (mg/l)	8(16)	0-267.5	38.4	75.4	5686
Total alkalinity as CaCO <sub>3</sub> (mg/l)	15(45)	1.6-476.0	129.8	116.9	13676
Hydroxides, OH (mg/l)	8(16)	0-51.0	4.4	12.7	161.3
Bicarbonates, HCO <sub>3</sub> (mg/l)	8(16)	2.0-354.0	129.1	105.7	11174
Carbonates, CO <sub>3</sub> (mg/l)	8(16)	0-147.0	32.8	55.9	3124
Free carbon dioxide (mg/l)	8(16)	0-50.0	17.0	19.5	380.2
Chloride (mg/l)	8(16)	5.0-36.0	13.8	8.1	65.8
Sulfate (mg/l)	8(16)	1.0-34.0	6.9	11.1	122.6
Fluoride (mg/l)	15(45)	0.02-2.84	0.33	0.57	0.32
Total phosphate as P (mg/l)	8(16)	0.01-1.28	0.23	0.40	0.16
pH	21(62)	5.10-11.55	7.40	1.68	2.83
pH <sub>s</sub>	8(16)	6.99-11.60	8.34	1.21	1.47
Stability index (2pH <sub>s</sub> -pH)	8(16)	3.5-17.5	8.55	3.71	13.8
Saturation index (pH-pH <sub>s</sub> )	8(16)	-5.9-+3.7	-0.22	2.70	7.33
Total hardness as CaCO <sub>3</sub> (mg/l)	8(16)	9.5-438.0	169.8	140.4	19725
Calcium hardness as CaCO <sub>3</sub> (mg/l)	8(16)	0.97-420.7	137.3	136.8	18708
Magnesium hardness as CaCO <sub>3</sub> (mg/l)	8(16)	6.9-84.0	32.5	23.1	532
Calcium (mg/l)	8(16)	0.39-168.5	55.0	54.8	3003
Magnesium (mg/l)	8(16)	1.68-20.4	7.9	5.6	31.4
Sodium (mg/l)	8(16)	4.40-42.5	15.6	12.1	146.6
Iron (mg/l)	8(16)	0.84-29.3	8.3	8.1	65.1
Manganese (mg/l)	8(16)	0.02-0.17	0.08	0.05	<0.01
Copper (mg/l)	8(16)	0.02-0.07	0.03	0.02	<0.01
Silica (mg/l)	8(16)	1.1-20.1	10.4	6.0	36.5
Color (Pt-Co units)	8(16)	10-300	66.5	101.0	10213
Temperature, field (°C)	21(62)	14.0-23.0	19.7	2.3	5.1
Turbidity (NTU)	8(16)	8.0-3100	578.0	830.0	688831
Nitrate nitrogen (mg/l)	8(16)	0.01-0.39	0.08	0.09	0.01
Total organic carbon (mg/l)	15(45)	2.0-124.5	31.4	28.8	830
Conductance, field (µmhos/cm at 25°C)	21(62)	47.0-1600.0	243.2	299.9	89956

\*Numbers in parentheses indicate total number of samples collected.  
 Source: Ardaman and Associates, Inc.

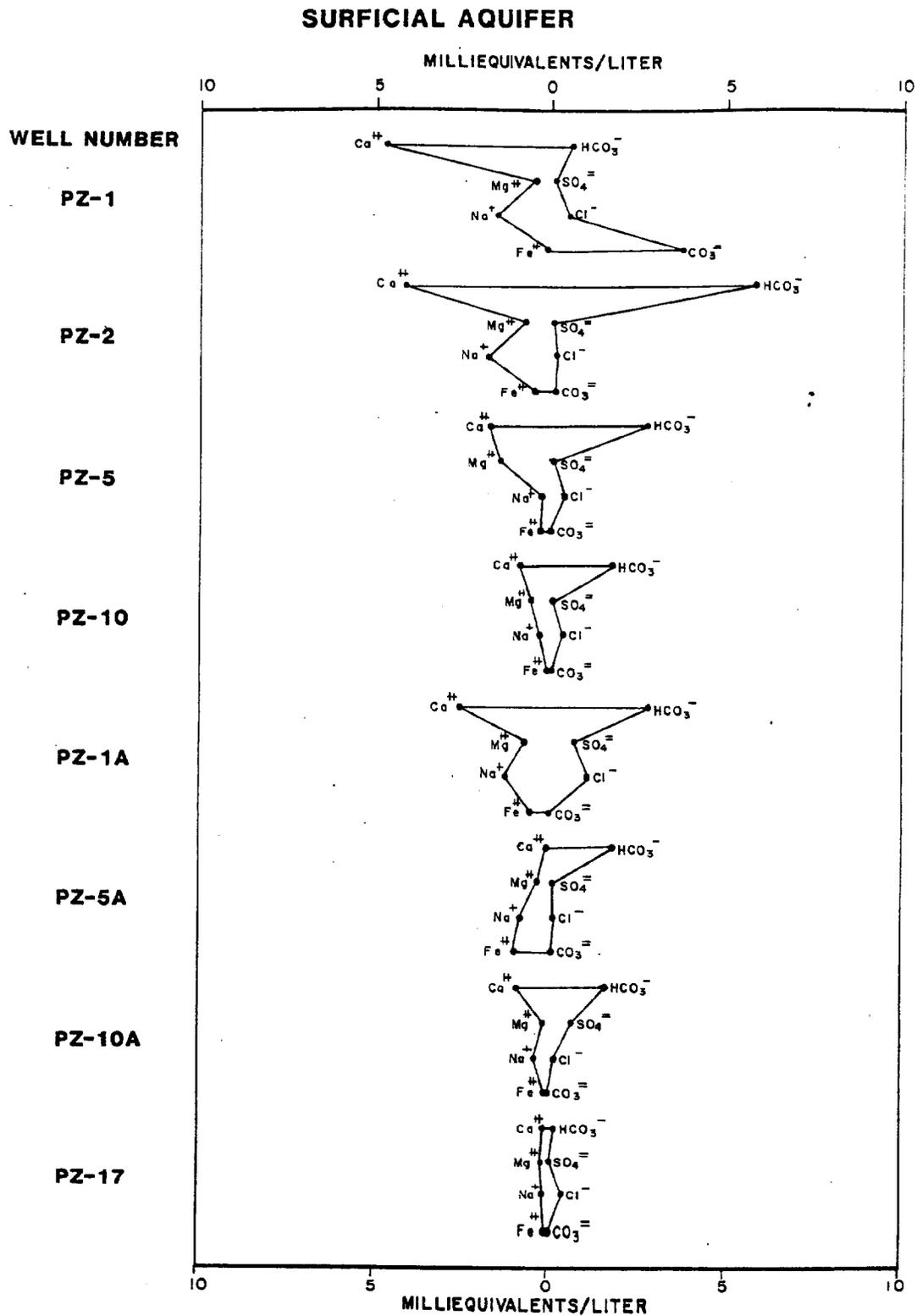


Figure 3.4-43. Stiff Diagram for Chemical Types of Aquifer Waters.

# SECONDARY ARTESIAN AQUIFER

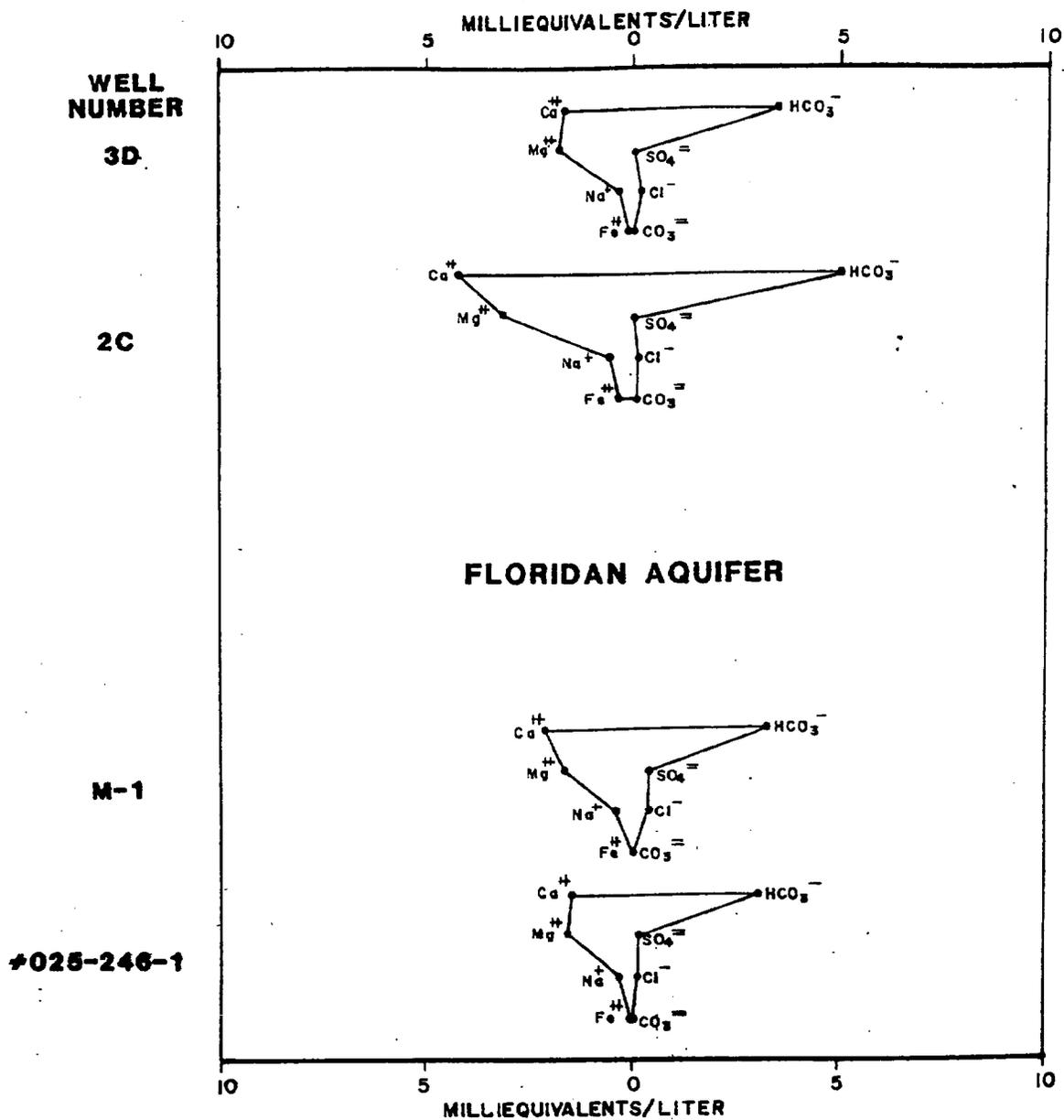


Figure 3.4-43 (Continued).

Table 3.4-51. Secondary Artesian Aquifer Water Quality Data, April 1976 - April 1978.

Parameter	Sample Size	Range	Mean	Std. Dev.	Var.
Salinity (ppt)	3	0 - 0.5	0.2	0.3	0.1
pH	14	7.5 - 9.6	8.1	0.8	0.6
Temperature (°C)	9	19.0 - 23.0	20.6	1.1	1.2
Conductance (µmhos/cm at 25°C)	15	110.0 - 524.0	276.3	110.7	12260
Alkalinity as CaCO <sub>3</sub> (mg/l)	15	85.0 - 274.0	140.5	56.2	3162.1
Chloride (mg/l)	15	4.5 - 10.9	6.8	1.8	3.4
Fluoride (mg/l)	15	0.2 - 1.0	0.6	0.2	0.1
Sulfate (mg/l)	15	0 - 117.0	14.3	30.0	902.1
Silica (mg/l)	-	-	-	-	-
Orthophosphate as P (mg/l)	15	0.013 - 3.66	0.63	0.98	0.96
Nitrate as N (mg/l)	14	0 - 0.08	0.01	0.02	<0.01
Nitrite as N (mg/l)	3	0	0	0	0
Ammonia as N (mg/l)	14	0 - 0.16	0.05	0.05	<0.01
Calcium (mg/l)	15	12.5 - 57.1	25.4	13.8	191.9
Magnesium (mg/l)	15	8.0 - 32.0	17.6	7.5	56.1
Sodium (mg/l)	15	1.8 - 20.2	7.5	5.2	26.8
Potassium (mg/l)	15	0.48 - 4.66	1.90	2.20	4.90
Iron (mg/l)	11	0.2 - 1.5	1.02	0.97	0.94
Strontium (mg/l)	11	0 - 0.2	0.04	0.07	<0.01

Source: SRWMD 1981.

Table 3.4-52. Secondary Artesian Aquifer Water Quality Data, February-April 1982.

Parameter	No. of Wells*	Range	Mean	Std. Dev.	Var.
Total dissolved solids (mg/l)	2(2)	194-258	219	28.5	814
Phenolphthalein alkalinity as CaCO <sub>3</sub> (mg/l)	2(2)	0-1	0.25	0.5	0.25
Total alkalinity as CaCO <sub>3</sub> (mg/l)	2(2)	178-274	217	45	2060
Hydroxides, OH (mg/l)	2(2)	0	0	0	0
Bicarbonates, HCO <sub>3</sub> (mg/l)	2(2)	207-311	250	49	2397
Carbonates, CO <sub>3</sub> (mg/l)	2(2)	0.5-3.4	1.9	1.3	1.7
Free carbon dioxide (mg/l)	2(2)	1.6-14.0	5.4	5.8	33.4
Chloride (mg/l)	2(2)	5.4-7.0	6.0	0.7	0.5
Sulfate (mg/l)	2(2)	1	-	-	-
Fluoride (mg/l)	2(2)	0.32-1.45	0.71	0.53	0.28
Total phosphate as P (mg/l)	2(2)	0.39-3.63	1.32	1.57	2.47
pH	2(2)	7.5-8.36	8.04	0.39	0.15
pH <sub>s</sub>	2(2)	7.22-7.83	7.54	0.27	0.07
Stability index (2pH <sub>s</sub> -pH)	2(2)	6.1-7.4	7.05	0.63	0.40
Saturation index (pH-pH <sub>s</sub> )	2(2)	0.1-1.1	+0.5	+0.43	0.19
Total hardness as CaCO <sub>3</sub> (mg/l)	2(2)	173-372	240	91.9	8442
Calcium hardness as CaCO <sub>3</sub> (mg/l)	2(2)	79.6-212	126	60	3600
Magnesium hardness as CaCO <sub>3</sub> (mg/l)	2(2)	91-160	114	32	1026
Calcium (mg/l)	2(2)	31.9-85.1	50.4	24.1	582
Magnesium (mg/l)	2(2)	22.1-39	27.7	7.8	61.8
Sodium (mg/l)	2(2)	4.15-15.3	9.1	5.0	25.4
Iron (mg/l)	2(2)	1.04-10.5	4.3	4.5	20.5
Manganese (mg/l)	2(2)	0.06-0.13	0.10	0.03	<0.01
Copper (mg/l)	2(2)	<0.02-0.02	-	-	-
Silica (mg/l)	2(2)	16.3-27.3	21.4	5.8	34.1
Color (Pt-Co units)	2(2)	10-20	12.5	5	25
Temperature, field (°C)	2(2)	18-22	19.75	2.06	4.25
Turbidity (NTU)	2(2)	45-450	191	191	36372
Nitrate-nitrogen (mg/l)	2(2)	<0.01-2.57	0.66	1.27	1.62
Total organic carbon (mg/l)	2(2)	4.0-33	16.4	14.4	208
Conductance, field (µmhos/cm at 25°C)	2(3)	295-370	324	34.3	1174

\*Numbers in parentheses indicate total number of samples collected.  
Source: Ardaman and Associates, Inc.

Table 3.4-53. Floridan Aquifer Water Quality Data, April 1976 - April 1978.

Parameter	Sample Size	Range	Mean	Std. Dev.	Var.
Salinity (ppt)	3	0	0	0	0
pH	3	7.15 - 7.30	7.25	0.09	0.01
Temperature (°C)	15	19.0 - 25.0	22.3	1.9	3.6
Conductance (µmhos/cm at 25°C)	15	220.0 - 700.0	418.3	153.0	23413
Alkalinity as CaCO <sub>3</sub> (mg/l)	15	49.0 - 291.0	189.9	62.2	3871
Chloride (mg/l)	15	3.2 - 19.1	8.6	4.8	23.5
Fluoride (mg/l)	15	0 - 0.48	0.27	0.12	0.02
Sulfate (mg/l)	15	0 - 196.0	34.2	47.0	2211
Silica (mg/l)	-	-	-	-	-
Orthophosphate as P (mg/l)	15	0.01 - 0.16	0.06	0.05	0.002
Nitrate as N (mg/l)	3	0	0	0	0
Nitrite as N (mg/l)	3	0	0	0	0
Ammonia as N (mg/l)	3	0.01 - 0.02	0.01	0.01	<0.01
Calcium (mg/l)	15	27.1 - 94.4	60.4	19.1	364.6
Magnesium (mg/l)	15	4.0 - 46.8	16.9	11.6	135.6
Sodium (mg/l)	15	1.5 - 11.2	4.9	2.7	7.5
Potassium (mg/l)	15	0.37 - 1.35	0.81	0.31	0.10

Source: SRWMD 1981.

Table 3.4-54. Floridan Aquifer Water Quality Data, February-April 1982.

Parameter	No. of Wells*	Range	Mean	Std. Dev.	Var.
Total dissolved solids (mg/l)	2(2)	204-294	247.5	49.2	2420
Phenolphthalein alkalinity as CaCO <sub>3</sub> (mg/l)	2(2)	0	0	0	0
Total alkalinity as CaCO <sub>3</sub> (mg/l)	2(2)	158-170	166.5	5.7	33
Hydroxides, OH (mg/l)	2(2)	0	0	0	0
Bicarbonates, HCO <sub>3</sub> (mg/l)	2(2)	183-207	196.5	10.2	105
Carbonates, CO <sub>3</sub> (mg/l)	2(2)	0.3-0.8	0.5	0.3	0.1
Free carbon dioxide (mg/l)	2(2)	13.0-23.0	11.2	8.8	77
Chloride (mg/l)	2(2)	5.0-14.0	9.2	4.9	24
Sulfate (mg/l)	2(2)	1-48.0	17.7	22.3	496
Fluoride (mg/l)	2(2)	0.39-0.87	0.62	0.27	0.07
Total phosphate as P (mg/l)	2(2)	0.06-0.11	0.08	0.02	<0.01
pH	2(3)	7.10-7.88	7.40	0.35	0.12
pH <sub>S</sub>	2(2)	7.66-7.83	7.76	0.07	0.01
Stability index (2pH <sub>S</sub> -pH)	2(2)	7.6-8.4	8.0	0.36	0.13
Saturation index (pH-pH <sub>S</sub> )	2(2)	-0.70-0.10	-0.20	0.38	0.14
Total hardness as CaCO <sub>3</sub> (mg/l)	2(2)	137-184	161	22	490
Calcium hardness as CaCO <sub>3</sub> (mg/l)	2(2)	73.4-101	86.2	15	218
Magnesium hardness as CaCO <sub>3</sub> (mg/l)	2(2)	63.4-83.4	74.8	8.4	71
Calcium (mg/l)	2(2)	29.4-40.3	34.5	5.9	34
Magnesium (mg/l)	2(2)	15.4-20.2	18.1	2.0	4.1
Sodium (mg/l)	2(2)	5.74-9.89	7.9	2.2	4.7
Iron (mg/l)	2(2)	0.15-0.46	0.28	0.15	0.02
Manganese (mg/l)	2(2)	0.02-0.05	0.03	0.02	<0.01
Copper (mg/l)	2(2)	0.02	0.02	0	0
Silica (mg/l)	2(2)	24.8-35.6	31.3	5.6	32.0
Color (Pt-Co units)	2(2)	10-85.0	37.5	35.7	1275
Temperature, field (°C)	2(3)	19-23	21.3	1.5	2.3
Turbidity (NTU)	2(2)	1.4-22	8.4	9.4	88
Nitrate-nitrogen (mg/l)	2(2)	0.01-0.04	0.02	0.01	<0.01
Total organic carbon (mg/l)	2(2)	4.7-9.5	7.0	2.6	6.5
Conductance, field (µmhos/cm at 25°C)	2(3)	310-400	351	41.8	1749

\*Numbers in parentheses indicate total number of samples collected.  
Source: Ardaman and Associates, Inc.

The water table and/or the potentiometric surface of each aquifer converted to an altitude is the means by which the direction of groundwater movement between aquifers is ascertained. The water table is the top of the Surficial Aquifer. The potentiometric level is the water level documented in a well sealed into and open only within a confined aquifer such as the Secondary Artesian or Floridan aquifers. The surface developed from a group of potentiometric levels within a single artesian aquifer is the potentiometric surface. When the water table is higher than the potentiometric surface, groundwater moves from the Surficial Aquifer to the Artesian Aquifer. Conversely, if the potentiometric surface is higher than the water table, then groundwater moves from the Artesian Aquifer to the Surficial Aquifer. Under the range of hydrological conditions at a given site (e.g., drought conditions, wet conditions, well-pumping), groundwater may always move from the Surficial Aquifer to the Artesian Aquifer, may always move from the Artesian Aquifer to the Surficial Aquifer, or may be in any combination in between this range of conditions.

A comparison of the potentiometric surface of the Floridan Aquifer (Figure 3.4-41) and the altitude of the water table (Figure 3.4-36) indicates that the water table is higher than the potentiometric surface of the Floridan Aquifer. Except for the area of the Suwannee River below White Springs, the comparison shows head differences between 55 and 110 ft throughout the study area. The "high" heads are in the topographically high areas just south of Jasper, and the "low" heads are below the Suwannee River at White Springs and in the lower reaches of Swift Creek (i.e., downstream of the US 41 bridge). Approximately 70-80 ft of head exist at Swift Creek Swamp and Bee Haven Bay.

A comparison of the altitude on the top of the Floridan Aquifer (Figure 3.1-9), the altitude of the potentiometric surface (Figure 3.4-41), and the generalized topography of the site (Figure 3.1-3) suggests that the Floridan Aquifer is under artesian conditions within the study area except along the Suwannee River below White Springs and perhaps within Swift Creek below US 41. The Floridan Aquifer is judged to be under non-artesian conditions when the potentiometric surface of the Floridan Aquifer is equal to or lower than the altitude on top of the Floridan Aquifer. Confining units were noted in the four "deep" test holes (Figure 3.1-12).

Figures 3.4-39 and 3.4-40 and the recent observation well readings support the conclusion that the head loss between the Surficial and Floridan aquifers is primarily within the Secondary Artesian Aquifer but more accurately within the confining beds of the Hawthorn Formation. Typically, <1 ft of head is lost through the Surficial Aquifer. The thickness of the confining beds ranges from 25-125 ft, with the thinnest beds located south and west of US 41 between White Springs on the east and Camp Branch on the west, and the thickest beds located beneath the Rocky, Hunter, and Roaring Creek basins in the northeast section of the study area.

Recharge per unit surface area is defined as the product of the hydraulic gradient through the confining beds (i.e., head loss divided by the

thickness of the confining beds) and the coefficient of vertical permeability. The vertical permeability of the confining beds on top of the Floridan Aquifer is estimated to be 0.0001-0.00001 ft/day. Recharge to the Floridan Aquifer was computed from a range of reasonable effective coefficients of vertical permeability for the confining beds, using typical values for hydraulic gradients (Table 3.4-55). The study area has been divided into northeast, south, southwest, west, and north and central regions. The northeast part includes the Roaring, Hunter, and Rocky Creek drainage basins; the south part is north of but in the vicinity of White Springs; the southwest part is south and west of US 41 between Camp Branch and White Springs; the west part is between Jasper and Camp Branch west of Swift Creek Swamp; and the north and central part includes Swift Creek Swamp and Bee Haven Bay.

Although Miller et al. (1978) were unable to reliably determine the leakance of the Hawthorn confining bed from their pumping test program in the Osceola National Forest, they were able to estimate the leakance based both on a water budget analysis and on an analysis of the water leaving the forest as underflow in the Floridan Aquifer. The water budget analysis was used to determine the amount of water available for recharge. The results of this analysis indicated a recharge range of 0-4 in/yr which agrees with the calculated values for the study area. (The study area and the Osceola National Forest are considered hydrologically similar.) The underflow analysis was used to determine the maximum amount of water flowing out of the forest through the Floridan Aquifer. The results of this analysis indicated a maximum value of 0.30 in/yr for the annual discharge rate through the Hawthorn confining unit.

An upperbound value for the recharge rate from the Floridan Aquifer may be obtained by assuming that all the underflow across a given area comes from recharge within that area. Such an analysis yields a maximum recharge rate of about 4 in/yr, but this value greatly overestimates the actual recharge rate, as the largest portion of groundwater outflow at the site does not originate from site-specific recharge but rather from groundwater underflow from outside the study area. This underflow analysis at the study area does not yield an accurate rate of discharge through the confining unit because the Floridan Aquifer at the site is characterized by a high gradient for groundwater flow and significant lateral movement, and because the existing well data are not sufficient to establish an accurate flow pattern.

Recharge to the Floridan Aquifer from the Surficial Aquifer probably averages 0.1-0.7 in/yr over the study area. In the reach of the Suwannee River below White Springs, the recharge rates could approach 4 in/yr at times because of the direct connection between aquifer and stream.

Aquifers and Streams. The streams in the study area are connected to one or more of the aquifers, depending on stratigraphic position of the stream's wetted area. The stream may recharge the groundwater or receive discharge from the groundwater, depending on the relative altitudes of water levels in aquifer and stream. A losing stream is one recharging groundwater. A gaining stream is one receiving groundwater

Table 3.4-55. Estimates of Recharge to the Floridan Aquifer from the Surficial Aquifer.

Region of Study Area	Head Difference (ft)	Thickness of Confining Beds (ft)	Vertical Permeability (ft/day)	Recharge (in/yr)
Northeast	55-80	125	0.0001	0.2
South	55-90	75-125	0.00001	0.02
Southwest	60-90	25-75	0.0001	0.3
West	85-110	75	0.00001	0.03
North and Central	70-95	75-125	0.0001	0.7
			0.00001	0.07
			0.0001	0.6
			0.00001	0.06
			0.0001	0.4
			0.00001	0.04

discharge. A stream is not considered an entire river or creek, but a stream reach in this context. For example, a portion of the Suwannee River within the study area may be a gaining stream and another portion of the river may be a losing stream. In addition, a stream reach can, under its varying hydrologic conditions, change from a gaining to a losing stream. For example, White Sulphur Spring at Stephen Foster Memorial Park alternates between a groundwater discharge and a groundwater recharge reach. Groundwater discharge can be springs and/or seeps and is considered baseflow in streamflow. Streamflow consists of surface runoff and baseflow.

Rosenau and Faulkner (1975), Rosenau et al. (1977), and Ceryak et al. (1982) identify the location and characteristics of 20 springs in the study area above the USGS gaging station at Ellaville on the Suwannee River (Table 3.4-56). All but four of the springs are an integral part of the Suwannee River. One spring discharges into the Alapaha River and three discharge into the Withlacoochee River. Four springs have been identified along the Suwannee River above Suwannee Springs. Bell Springs in Columbia County issues from limestone within the upper part of the Hawthorn Formation, while White Sulphur Spring issues from the Suwannee Formation. Wessons Iron Spring is in the lower reaches of Swift Creek below the USGS gaging station on US 41. These springs are characterized by a calcium-magnesium-bicarbonate type water quality (Table 3.4-57, Slack and Rosenau 1979).

Slack and Rosenau (1979) report that springs along the Suwannee River may discharge a chemically mixed water that is somewhat brown-colored by tannin. This occurs following a period of river flooding with subsequent inundation of the spring. When the river water surface is well above the potentiometric level of the Floridan Aquifer, the spring outlets serve as points of massive recharge of river water to the aquifer. When the river water surface declines, a mixture of river and groundwater discharges from the springs.

Miller et al. (1978) report that the drainage areas of the Suwannee River between White Springs and Ellaville increase 186%, with 77% of this increase from the Withlacoochee River and Alapaha River basins. During low flows these two tributary subwatersheds account for only 16% of the Suwannee River flow at Ellaville. Therefore, the relatively high baseflow at Ellaville is not due to the substantial increase in drainage area but to the large groundwater inflow component to Suwannee River streamflow between White Springs and Ellaville.

Ceryak et al. (1982) report that upstream from White Springs, Suwannee River flow is derived from runoff and minimal groundwater seepage from the Surficial Aquifer. River water is highly colored, acidic, has low specific conductance values, and, compared to stations farther downstream, has relatively low calcium and magnesium ion concentrations. The low calcium and magnesium values suggest that there is no carbonate aquifer influence.

Table 3.4-56. Characteristics of Springs in Study Area.

Spring	County	Connecting River and/or Creek	Location	Period of Record	Discharge <sup>1</sup> (cfs)	N <sup>3</sup>	Water Temp. (°C) <sup>1</sup>	Total Dissolved Solids (mg/l) <sup>1</sup>
1. Bell Springs	Columbia	Suwannee	NW1/4NE1/4SW1/4 Sec. 11 T2S, R16E		10 - 100			
2. White Sulphur Spring	Hamilton	Suwannee	SW1/4SW1/4NW1/4 Sec. 7 T2S, R16E	1907-1975	44	10	21	183
3. Weasons Iron Spring	Hamilton	Swift	SE1/4NW1/4NE1/4 Sec. 34 T1S, R15E					
4. Louisa Spring	Hamilton	Suwannee	NE1/4SE1/4NE1/4 Sec. 5 T2S, R15E		10			
5. Suwannee Springs	Suwannee	Suwannee	SE1/4SW1/4SE1/4 Sec. 17 T1S, R14E	1906-1973	23.4	52	21	198
6. Alapaha Rise	Hamilton	Suwannee	NW1/4SW1/4SE1/4 Sec. 35 T1N, R12E	1975-1979	6672	12		
7. Holton Spring	Hamilton	Suwannee/Holton Creek	SE1/4SE1/4SW1/4 Sec. 31 T1N, R13E		288	3		
8. Bluff Cemetery Spring	Hamilton	Alapaha	SW1/4SE1/4SE1/4 Sec. 17 T2N, R13E					
9. Anderson Spring	Suwannee	Suwannee	SW1/4NW1/4SE1/4 Sec. 35 T1S, R11E					
10. Ellaville Spring	Suwannee	Suwannee	NW1/4NW1/4SE1/4 Sec. 24 T1S, R11E	1942-1973	50	3	21	198
11. Falmouth Spring	Suwannee	Suwannee	NW1/4NW1/4NE1/4 Sec. 32 T1S, R12E	1908-1973	83	7	21	204
12. Lime Spring	Hamilton	Suwannee	NW1/4SE1/4NW1/4 Sec. 19 T1S, R12E					
13. Blue Spring	Madison	Withlacoochee	SW1/4SE1/4SW1/4 Sec. 17 T1N, R11E	1932-1973	115	6	21	148
14. Suwanneecochee Spring	Madison	Suwannee	SW1/4SW1/4NE1/4 Sec. 24 T1S, R11E	1931-1973	369	3	21	188
15. Morgans Spring	Hamilton	Withlacoochee	NW1/4NW1/4NE1/4 Sec. 10 T1S, R11E					
16. Blue Sink	Suwannee	Suwannee	NE1/4, NW1/4, NW1/4 T2S, R15E Sec. 10					
17. Boys Ranch Blue Spring	Suwannee	Suwannee	SW1/4, SW1/4, SW1/4 Sec. 4, T1S, R13E					
18. Unnamed Spring	Suwannee	Suwannee	NW1/4, SE1/4, NE1/4 Sec. 7, T1S, R12E					
19. Edwards Spring	Suwannee	Suwannee	NW1/4, NW1/4, SE1/4 Sec. 2A, T1S, R11E					
20. Adams Spring	Hamilton	Withlacoochee	NW1/4, SW1/4, NW1/4 Sec. 2, T1S, R11E					

<sup>1</sup>Mean value.

<sup>2</sup>Median value.

<sup>3</sup>Number of discharge measurements.

Source: Rosenau and Faulkner (1975), Rosenau et al. (1977), and Ceryak et al. (1982).

Table 3.4-57. Typical Study Area Spring Water Quality Characteristics.

Parameter	Concentrations
Specific conductance ( $\mu\text{mhos/cm}$ at 25°C)	279
pH	7.3
Calcium (mg/l)	39
Magnesium (mg/l)	8.7
Sodium (mg/l)	3.7
Bicarbonate (mg/l)	150
Sulfate (mg/l)	17
Chloride (mg/l)	3.4
Total nitrogen (mg/l)	0.39
Total phosphorus (mg/l)	0.04
Strontium (mg/l)	110
Arsenic (mg/l)	0
Cadmium (mg/l)	0
Copper (mg/l)	0
Lead (mg/l)	3
Zinc (mg/l)	20
Iron (mg/l)	10
Mercury (mg/l)	0

Source: Slack and Rosenau 1979.

Near Benton, the Suwannee River shows a higher relative concentration of chloride and sulfate anions, characteristic of the Surficial Aquifer groundwater (Ceryak et al. 1982). At White Springs, sulfate and chloride are the dominant anions, but there is a distinct bicarbonate anion grouping which reflects the geochemical influence of artesian groundwater. All samples with a high bicarbonate anion component were taken during low flow conditions (<190 cfs) when baseflow at White Springs was sustained by groundwater discharge. For the Suwannee River at Ellaville, carbonate and bicarbonate anions are predominant, with calcium dominating the cation constituents. Overall, calcium and magnesium exceed sodium and potassium; the inorganic acids exceed the organic acids; and carbonate hardness is >50% total hardness. The surface water regime in this reach of the river is strongly influenced by groundwater discharge from the carbonate aquifer, which becomes particularly significant in the reach downstream from Suwannee Springs.

Baseflow characteristics of the streams in the study area were evaluated when flow in the Suwannee River at White Springs (i.e., US 41 bridge) was 15-24 cfs, a low flow frequency of a 7-day, 4-5 year recurrence interval or of a 30-day, 5-9 year recurrence interval (Table 3.4-58, Hughes 1981). The results of the baseflow analysis indicate that the natural baseflow characteristics of streams are related to the aquifer with which the stream is connected. For example, streams connected to the Surficial Aquifer have a baseflow of 0.003-0.01 cfs per square mile of drainage area. Streams connected to the Secondary Artesian and upper Floridan aquifers have baseflows of 0.01 and 0.032 cfs per square mile, respectively. Below Suwannee Springs, the baseflow is even higher than 0.032 cfs per square mile. The gain in baseflow along the Suwannee River also is related to river mileage. For example, the increase in baseflow between CR 6 and White Springs, a distance of 24 mi, is approximately 0.375 cfs per river mile. Between White Springs (US 41 bridge) and the mouth of Swift Creek, a distance of 9 mi, the baseflow gain is approximately 1 cfs per river mile. Between the mouth of Swift Creek and Suwannee Springs, a distance of 13 mi, the baseflow gain is approximately 4 cfs per river mile. Between Suwannee Springs and the mouth of the Alapaha River, the baseflow gain is approximately 13.5 cfs per river mile.

#### 3.4.3.5 Water Use

Based on 1981 well inventory records supplied by the Suwannee River Water Management District (SRWMD 1981), of the 114 wells in Hamilton County, 54%, 14%, 13%, and 19% are in the Surficial, Secondary Artesian, Floridan, and unknown aquifers, respectively. Wells in the unknown category include those open to more than one aquifer and those with insufficient data available to-date to ascertain the proper aquifer. The following data summarize groundwater use (mgd) in Hamilton County for 1980 (SRWMD 1982):

<u>Water Use Category</u>	<u>Groundwater</u>	<u>Surface Water</u>	<u>Water Consumed</u>
Public supply	0.68	0.00	0.21
Rural	0.71	0.09	0.34
Industrial	<u>35.82</u>	<u>34.12</u>	<u>10.69</u>
Total	37.21	34.21	11.24

Table 3.4-58. Baseflow Characteristics of Streams in the Study Area.

Creek	USGS No.	Drainage Area (sq mi)	Miles Above Mouth of Suwannee River	Flow (cfs)	
				1/20/79	10/78
Rocky Creek near Belmont	02314986	50		0.25	0.15 <sup>1</sup>
Hunter Creek near Belmont	02315005	25		1.0	0.40 <sup>2</sup>
Suwannee River near Benton		2090	196		5.76 - 9.27
Deep Creek near Suwannee Valley	02315200	89		0.88	0.45 <sup>3</sup>
Robinson Creek near Suwannee Valley	02315392	27		0.52	0.21 <sup>3</sup>
Falling Creek near Winfield	02315470	53		0 <sup>3</sup>	0 <sup>3</sup>
Suwannee River at White Springs	02315500	2430	172	24	15 - 18
Suwannee River at Willow Island			168		19.4 - 21.9
Suwannee River near Blue Sink			163		24.4 - 27.5
Swift Creek near Facii	02315520	65		29	2.3
Suwannee River at Suwannee Springs	02315550	2630	150	84	83 - 84
Suwannee River at Boys Ranch		2660			156 - 171
Suwannee River between Holton Creek and Alapaha River			137		245 - 271
Alapaha River near Jennings	02317620	1680		1010	
Withlacoochee River near Pinetta	02319000	2120		1990	
Suwannee River at Ellaville	02319500	6970	127	3810	1250 - 1360

<sup>1</sup>November 2, 1978.

<sup>2</sup>October 3, 1978.

<sup>3</sup>Estimated.

Leach and Healy (1980) report that water uses in 1977 were derived from only the Floridan Aquifer; therefore, the 1980 water uses are believed to be from the Floridan Aquifer.

According to Ceryak et al. (1982), most wells completed in the Surficial Aquifer are driven or jetted; a few are dug. These wells usually consist of one 20-ft section of 1.5-2.0 in. diameter pipe. Well screens are not commonly used. A typical well has a 0.5-1.0 hp jet pump and yields 4-10 gpm.

Wells tapping the Secondary Artesian Aquifer are uncommon (Ceryak et al. 1982). Where the Secondary Artesian Aquifer exists, an overlying Surficial Aquifer typically yields as much or more water than the Secondary Artesian Aquifer. If there is a need for a large supply such as for irrigation, public supply, or industry, a deeper Floridan Aquifer well usually is drilled.

A typical domestic Floridan well is a 4-in diameter well, cased between 60 and 160 ft with 10-50 ft of open borehole penetrating the aquifer (Ceryak et al. 1982). Water levels range from 30 to 120 ft below land surface, and a 1 hp submersible pump yields 15-22 gpm with little or no drawdown. Large irrigation systems pump up to 1000 gpm from 12-in diameter wells with only a few feet of drawdown. Large industrial-use wells, cased 200 ft from land surface, with a 26-in diameter open borehole, penetrate the aquifer for 600 ft below the bottom of the casing. These wells can yield >6000 gpm with specific capacities of 400 gpm per foot of drawdown.

### 3.4.4 Methods

#### 3.4.4.1 Surface Water Quality/Quantity

Water Quantity. Flows were measured with Price AA and pygmy current meters, using the procedures outlined by the U.S. Geological Survey (Buchanan and Somers 1969). Where possible, rating curves were developed to estimate flow rates. Additional measurements were made periodically to check for shifts in the curve. Stevens water level recorders were installed at Stations RC-5, RO-2, RO-3, and EL001-18. Water level recorder readings were converted to flow rates using the rating curves, and hydrographs were constructed.

In addition to performing spin tests in the field, each current meter was calibrated periodically at the University of Florida's water flume. The meter travels along a trolley at a known velocity which is compared to the velocity measured by the meter. The calibration is performed by taking several measurements at different velocities.

Water Quality. Sampling stations were selected by determining those which appeared representative of general stream conditions. The following parameters were measured in situ:

<u>Parameter</u>	<u>Meter Used</u>
Dissolved oxygen	YSI Model 57 dissolved oxygen meter
Temperature	YSI Model 57 dissolved oxygen meter with temperature probe
pH	Orion Model 407-A specific ion meter with Model 967800 specific ion electrodes
Specific conductance	Beckman Model 6-404A conductivity meter; YSI Model 33 S-C-T meter

Manufacturer's directions were followed in the operation of each meter, and each was calibrated in the field prior to use. Because the YSI conductivity meter is not temperature-compensated, meter readings were corrected to values at 25°C using the following equation:

$$\text{Conductivity (25°C)} = \frac{\text{Conductivity (meter)}}{1 + 0.0191(\text{temp.}^\circ\text{C}-25)}$$

Collections were made monthly for selected parameters, and two comprehensive collections were made (August 1981 and February 1982) for analysis of metals and organics in addition to the parameters analyzed monthly (Table 3.4-59). Laboratory analyses were performed according to accepted procedures (Table 3.4-60).

Table 3.4-59. Parameters Analyzed for Monthly and Comprehensive Collections.

Parameter	Parameter
<b>MISCELLANEOUS</b>	<b>METALS</b>
*Flow (cfs)	Aluminum (mg/l)
*Conductivity ( $\mu$ mhos/cm)	Arsenic (mg/l)
*Alkalinity as CaCO <sub>3</sub> (mg/l)	Barium (mg/l)
*Total hardness as CaCO <sub>3</sub> (mg/l)	Beryllium (mg/l)
*pH, field	Cadmium (mg/l)
*Fluoride (mg/l)	Chromium (mg/l)
*Sulfate (mg/l)	Copper (mg/l)
*Total phosphate as P (mg/l)	Iron (mg/l)
*Total dissolved phosphate as P (mg/l)	Lead (mg/l)
*Orthophosphate as P (mg/l)	Mercury ( $\mu$ g/l)
*Temperature, field ( $^{\circ}$ C)	Nickel (mg/l)
*Dissolved oxygen (mg/l)	Selenium (mg/l)
BOD <sub>5</sub> (mg/l)	Silver (mg/l)
*Total suspended solids (mg/l)	Zinc (mg/l)
*Total dissolved solids (mg/l)	
Transparency (m)	<b>ORGANICS</b>
*Color (Pt-Co units)	Polychlorinated biphenyls (mg/l)
*Tannin/lignin (mg/l)	Aldrin (mg/l)
*Ammonia as N (mg/l)	Dieldrin (mg/l)
Un-ionized ammonia as N (mg/l)	Chlordane (mg/l)
*Nitrate/nitrite as N (mg/l)	2,4-D (mg/l)
*Total organic nitrogen as N (mg/l)	2,4,5-TP (silvex) (mg/l)
*Total nitrogen as N (mg/l)	DDT (mg/l)
*Total organic carbon as C (mg/l)	Demeton (mg/l)
*Dissolved organic carbon as C (mg/l)	Endosulfan (mg/l)
*Particulate organic carbon as C (mg/l)	Endrin (mg/l)
*Chlorophyll a (mg/m <sup>3</sup> )	Heptachlor (mg/l)
Oil and grease (mg/l)	Lindane (mg/l)
Surfactants (methylene blue active substances (mg/l)	Methoxychlor (mg/l)
Total cyanide (mg/l)	Mirex (mg/l)
Fecal coliform (MPN/100 ml)	Toxaphene (mg/l)
Total coliform (MPN/100 ml)	Guthion (mg/l)
	Malathion (mg/l)
	Parathion (mg/l)
	Phthalate esters (mg/l)
	Trichlorophenol (mg/l)
	Chlorinated cresol (mg/l)
	Phenols (mg/l)
<b>RADIATION</b>	
Radium-226 (pCi/l)	
Radium-228 (pCi/l)	
Gross alpha (pCi/l)	

\*Measured monthly; all other parameters measured in August 1981 and February 1982 comprehensive collections.

Table 3.4-60. Methods of Analysis for Sediment, Drift, and Surface Water Quality Parameters (method number in parentheses).

Parameter	Method of Analysis	
	Water	Sediment and Organic Drift
<b>MISCELLANEOUS</b>		
Flow (cfs)	Buchanan and Somers 1969	
Conductivity ( $\mu$ mhos/cm)	EPA 1979a (120.1)	
Alkalinity as CaCO <sub>3</sub> (mg/l)	EPA 1979a (310.1)	
Total hardness as CaCO <sub>3</sub> (mg/l)	EPA 1979a (130.2)	
pH, field	EPA 1979a (150.1)	APHA 1980 (423)
Fluoride (mg/l)	EPA 1979a (340.2)	
Sulfate (mg/l)	EPA 1979a (375.4)	
Total phosphate as P (mg/l)	EPA 1979a (365.1), Technicon 1976	EPA 1979a (365.3) <sup>1</sup>
Total dissolved phosphate as P (mg/l)	EPA 1979a (365.1), Technicon 1976	
Orthophosphate as P (mg/l)	Technicon 1976	
Temperature, field (°C)	EPA 1979a (170.1)	
Dissolved oxygen (mg/l)	EPA 1979a (360.1)	
BOD <sub>5</sub> (mg/l)	EPA 1979a (405.1)	
Total suspended solids (mg/l)	EPA 1979a (160.1)	
Total dissolved solids (mg/l)	EPA 1979a (160.2)	
Transparency (m)	Secchi disc	
Color (Pt-Co units)	EPA 1979a (110.2)	
Tannin/lignin (mg/l)	APHA 1980 (513)	
Ammonia as N (mg/l)	EPA 1979a (350.3)	EPA 1979a (350.3) <sup>2</sup>
Un-ionized ammonia as N (mg/l)	EPA 1976	
Nitrate/nitrite as N (mg/l)	Technicon 1973	EPA 1979a (353.1) <sup>3</sup>
Total organic nitrogen as N (mg/l)	EPA 1979a (351.2)	EPA 1979a (351.2) <sup>1</sup>
Total nitrogen as N (mg/l)	EPA 1979a (351.2), Technicon 1973	
Total organic carbon as C (mg/l)	EPA 1979a (415.1)	EPA 1979a (415.1)
Dissolved organic carbon as C (mg/l)	EPA 1979a (415.1)	
Particulate organic carbon as C (mg/l)	EPA 1979a (415.1)	
Chlorophyll a (mg/m <sup>3</sup> )	APHA 1980 (1002G)	
Oil and grease (mg/l)	EPA 1979a (413.1)	
Surfactants (methylene blue active substances) (mg/l)	EPA 1979b (425.1)	
Total cyanide (mg/l)	EPA 1979b (335.3)	
Fecal coliform (MPN/100 ml)	APHA 1980 (908B)	
Total coliform (MPN/100 ml)	APHA 1980 (908A)	

Table 3.4-60 (Continued).

Parameter	Method of Analysis	
	Water	Sediment and Organic Drift
<b>METALS</b>		
Aluminum (mg/l)	EPA 1979a (202.1)	
Arsenic (mg/l)	Perkin-Elmer 1981, EPA 1979a (206.2)	EPA 1979a (206.2) <sup>4</sup>
Barium (mg/l)	EPA 1979a (208.1)	EPA 1979a (208.1) <sup>4</sup>
Beryllium (mg/l)	EPA 1979a (210.2)	
Cadmium (mg/l)	EPA 1979a (213.1)	
Calcium (mg/l)		EPA 1980a (200.7) <sup>4</sup>
Chromium (mg/l)	APHA 1980 (303A)	EPA 1979a (218.1) <sup>4</sup>
Copper (mg/l)	EPA 1979a (220.1)	EPA 1979a (220.1) <sup>4</sup>
Iron (mg/l)	EPA 1979a (236.1)	EPA 1980a (200.7) <sup>4</sup>
Lead (mg/l)	EPA 1979a (239.1)	EPA 1979a (239.2) <sup>4</sup>
Manganese (mg/l)		EPA 1980a (200.7) <sup>4</sup>
Mercury (µg/l)	EPA 1979a (245.1)	EPA 1979a (245.5) <sup>4</sup>
Nickel (mg/l)	EPA 1979a (249.1)	
Selenium (mg/l)	EPA 1979a (270.2)	
Silver (mg/l)	EPA 1979a (272.1)	
Zinc (mg/l)	EPA 1979a (289.1)	EPA 1980a (200.7) <sup>4</sup>
<b>ORGANICS</b>		
Organochlorine pesticides (mg/l)	EPA 1979b (608)	
Chlorophenoxy acid herbicides (mg/l)	EPA 1978b	
Phenolic compounds (mg/l)	EPA 1979b (604)	
Phthalate esters (mg/l)	EPA 1979b (606)	
<b>RADIATION</b>		
Radium-226 (pCi/l)	EPA 1980b (903.1)	
Radium-228 (pCi/l)	USGS 1977 (R-1142-26)	
Gross alpha (pCi/l)	EPA 1980b (900.0)	

<sup>1</sup>Samples were weighed and digested with acids before being determined according to EPA procedures.

<sup>2</sup>Samples were distilled and determined colorimetrically according to EPA procedures.

<sup>3</sup>Samples were extracted with 2N KCl and determined colorimetrically according to EPA procedures.

<sup>4</sup>Prior to analysis, 1 g sample was weighed and acid-bombed with 2 ml aqua-regia + 2 ml distilled water. The resultant solution was distilled to 100 ml volume with distilled water.

Separate collection containers were used for major parameter groups (EPA 1973). All containers were pre-cleaned and prepared in the laboratory and rinsed in the field with sample water prior to collection. Appropriate preservatives ( $H_2SO_4$ ,  $HNO_3$ ) were added in the field or samples were placed on ice immediately after collection. Samples for dissolved organic carbon were filtered in the field using a 0.45 mm millipore filter. Grab samples were collected in mid-channel at mid-depth when possible, with the following exceptions:

- 1) Suwannee River samples could not be taken at mid-channel or mid-depth during periods of medium to high flow rates. Samples were collected by wading from the west bank to at least the flowing portion of the stream. Samples were collected approximately 0.5 m below the surface. During periods of very high flow, samples were collected from the bridge at mid-stream using a rope and bucket.
- 2) Reclaimed lake samples were collected immediately upstream of water control structures, just below the water surface.
- 3) Recirculating water station samples were collected approximately 0.5 m below the surface, a minimum of 1 m from the bank.

At sampling stations near culverts, all samples were collected upstream of the culvert.

Quality Assurance. The following quality assurance procedures were maintained during the collection and analysis of water quality samples:

- 1) Careful chain-of-custody was observed by field and laboratory personnel. Standard chain-of-custody forms were used for documentation (Figure 3.4-44).
- 2) Field calibrations were performed on all water quality meters during each sampling period. The dissolved oxygen meter was air-calibrated periodically between stations. At least once during the sampling period, the meter was cross-checked using the Winkler azide titration method. Conductivity and pH meters were checked periodically during each sampling period by calibrating against standard conductivity and pH solutions. Temperature meters were cross-checked using a quality grade thermometer.
- 3) Blanks consisting of deionized water were sent to the field and processed using the same handling procedures as the normal samples (i.e., preservatives were added, they were transported in the same ice chests, etc.). This procedure allows assessment of changes that may occur during sample handling.
- 4) A "blind" sample was collected routinely at one of the stations. This sample was submitted for laboratory analyses without a station identification number and results compared to the known samples, thereby providing a check on the precision of the analytical results.



- 5) As an internal check, EPA reference samples were analyzed routinely for major parameters.
- 6) Split sampling was performed periodically. Replicate samples were collected and sent to at least two other laboratories for comparison of analytical results.
- 7) A standard curve was run each day for the parameter to be tested. Additional standards were run after every ten samples in order to assure the continued validity of the standard curve. To monitor precision, every tenth sample was run in duplicate.

Data Sources. OXY established a water quality monitoring program in November 1979 to collect background data in the study area. Data for the period November 1979 through March 1982 were used for this EIS, although the sampling program continued through December 1982.

To supplement these data, pertinent existing data on the study area were compiled and reviewed relative to this study. Major data sources included:

- 1) USGS and FDER data obtained through the NAWDEX computer system
- 2) Additional FDER data collected as part of the Outstanding Florida Waters study (FDER 1981)
- 3) Computerized data collected and stored by the Suwannee River Water Management District (SRWMD)
- 4) Data collected as part of the Swift Creek Chemical Complex EIS (EPA 1978a)

#### 3.4.4.2 Groundwater

Standard Penetration Test (SPT) Drilling and Observation Well Installations. SPT test borings were performed at 15 sites in the study area. Twelve of these borings penetrated to the bottom of the matrix (i.e., a total depth of 15 m) and three penetrated 3 m into the top of the Floridan Aquifer (i.e., a total depth of 30 m). These holes are located throughout the total study area in such a manner as to supplement the geologic data accumulated by the Florida Bureau of Geology, Suwannee River Water Management District, and OXY.

Observation wells and/or piezometers were installed at these 15 sites to document water levels at the top and bottom of the Surficial Aquifer. A 5-cm diameter PVC well was installed at each site with 1.5 m of slotted pipe at the bottom and 0.5-1 m of casing extending above land surface. At four of these sites, a shallow and deep piezometer set was installed to document vertical hydraulic gradients.

Bimonthly In Situ Sampling. In situ measurements were taken bimonthly at 15 groundwater and 10 surface water sampling sites during baseflow conditions. Measurements at each site included conductivity, pH, temperature, alkalinity, fluoride, total organic carbon, and water level.

Water Quality Sampling. Two water quality samples were taken at 12 sites for analysis of selected parameters (Table 3.4-61). These 12 groundwater sites included the following collection zone characteristics:

<u>Number of Sites</u>	<u>Aquifer</u>	<u>Characteristics of Aquifer</u>
2	Surficial	Reclaimed lands
3	Surficial	Matrix zone
3	Surficial	Overburden zone
2	Secondary Artesian	-
<u>2</u>	Floridan	-
12		

Within the Surficial Aquifer, sample collections were equally distributed between wetlands and uplands.

Aquifer Testing. In situ permeabilities within the piezometer collection zone were documented at each piezometer using a slug test. In addition, two pumping tests were performed to document area-wide aquifer coefficients (i.e., "T" and "S"). The pumping tests documented water levels in observation wells before, during, and after a constant pumping rate of several hours from a well open to a significant portion of the Surficial Aquifer.

Table 3.4-61. Parameters for Standard Groundwater Analysis.

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Total dissolved solids at 105°C  
Phenolphthalein alkalinity as CaCO<sub>3</sub>  
Total alkalinity as CaCO<sub>3</sub>  
Carbonate alkalinity as CaCO<sub>3</sub>  
Bicarbonate alkalinity as CaCO<sub>3</sub>  
Carbonates as CO<sub>3</sub>  
Bicarbonates as HCO<sub>3</sub>  
Hydroxides as OH  
Carbon dioxide as CO<sub>2</sub>  
Chloride as Cl  
Sulfate as SO<sub>4</sub>  
Fluoride as F  
Phosphate as PO<sub>4</sub>  
pH, laboratory  
pH, in situ  
Stability index  
Saturation index  
Total hardness as CaCO<sub>3</sub>  
Calcium hardness as CaCO<sub>3</sub>  
Magnesium hardness as CaCO<sub>3</sub>  
Calcium as Ca  
Magnesium as Mg  
Sodium as Na  
Iron as Fe  
Manganese as Mn  
Copper as Cu  
Silica as SiO<sub>2</sub>  
Color (Pt-Co units)  
Odor threshold  
Turbidity (JTU)  
Total nitrate as N  
Total organic carbon as C

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### 3.5 Air Quality

The potential air pollutant emissions from phosphate rock mining are limited to fugitive particulate matter contributed by clearing, mining, transport of material, and reclamation activities. Total suspended particulate matter levels in the ambient air, measured during the period 1979-1982, are used to describe existing air quality.

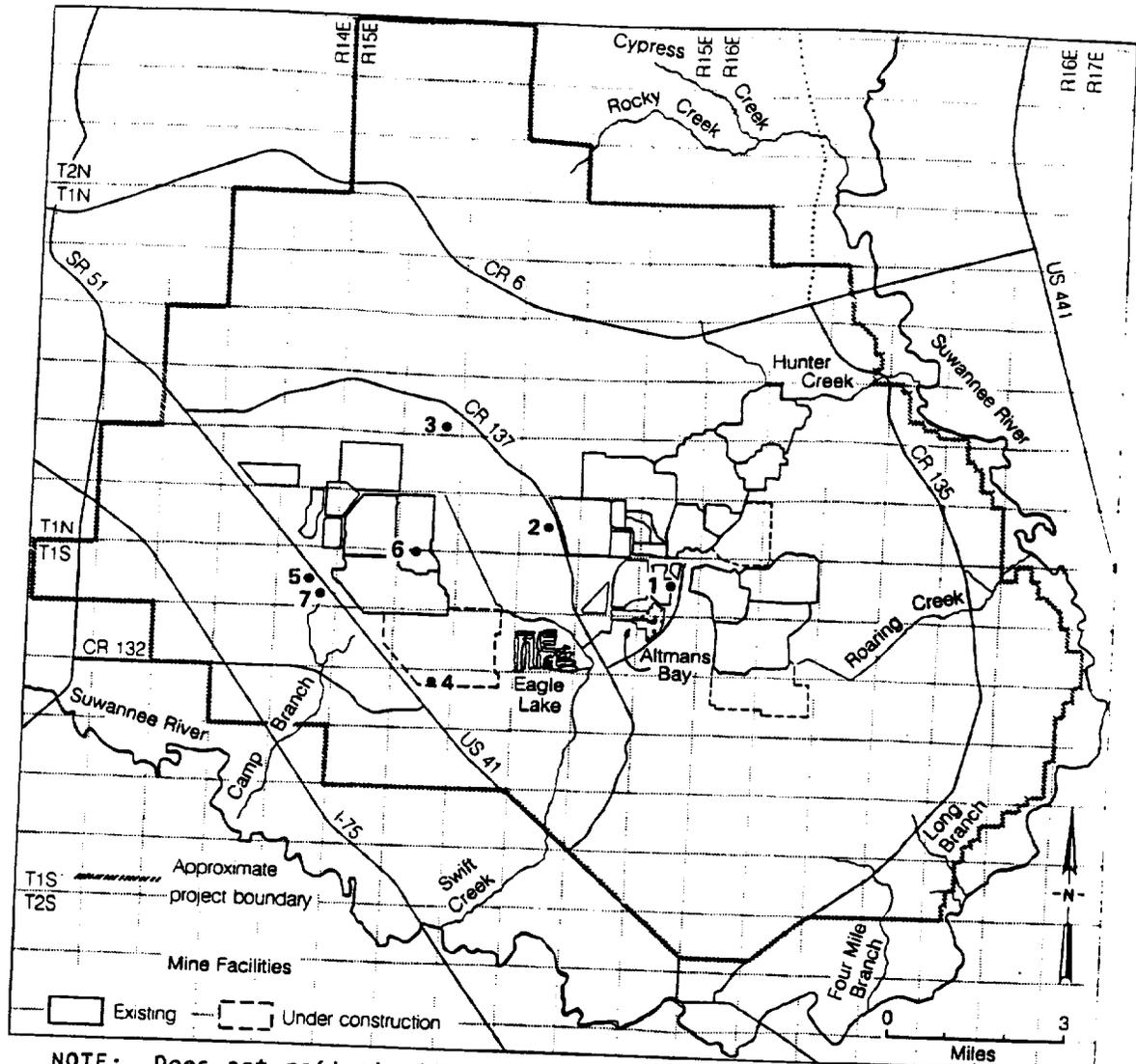
The air pollutants that will be generated by mining-related activities include fugitive particulate matter and negligible quantities of carbon monoxide, nitrogen oxides, volatile organic compounds, and sulfur dioxide. The pollutants, other than particulate matter, will result from the exhaust of mobile equipment. The emission rates of these pollutants have been estimated to be in the range of hundredths of tons per year, negligible air pollutant emission rates from the standpoint of air quality impact.

The fugitive particulate matter will result from the land clearing operations, wind erosion of barren land, reclamation activities, and vehicular traffic on unpaved mine roads. Visual observations of mining activities during the period 1979-1982 indicate that vehicular traffic on mining roads is the greatest source of fugitive particulate matter emissions.

Ambient air quality monitoring for total suspended particulate matter has been conducted at several monitoring sites in the vicinity of OXY operations since January 1979 (Figure 3.5-1, Table 3.5-1). The monitoring data from these sites for the period 1979-1982 have been summarized to describe existing ambient air quality. It should be recognized that during the period 1979-1982, mining was actively conducted at both the Swift Creek and Suwannee River mines, and the Swift Creek and Suwannee River chemical complexes were both in operation. Therefore, monitoring data used to represent existing ambient air quality include the impacts of both phosphate rock mining and chemical plant operations.

During the 1979-1982 monitoring period, some of the monitoring sites were relocated. The monitors at Sites 1 and 2 operated continuously during the entire four-year reporting period. The monitor originally located at Site 3 was relocated at Site 5 in September 1979 due to sample bias resulting from agricultural activities at Site 3. The monitor operated at Site 5 from September 1979 through the end of 1982. The monitor at Site 4 was moved to Site 6 in December 1979. During 1980, the monitor operated at Site 6 but was heavily biased by the construction of an earthen dike. The monitor was removed from this site in November 1980 when the source of electric power was removed. The monitor was relocated at Site 7 in January 1981 and operated at that site through the end of 1982.

The method used for total suspended particulate matter monitoring was the EPA-referenced high-volume air sampler method as described in 40 CFR 50. The monitors operated on a one-day-in-six schedule, which is consistent with the schedule established by EPA and adopted by state regulatory agencies.



NOTE: Does not reflect all areas affected by mining or mine support activities. See Figure 1.1-2.

• Monitoring site

Figure 3.5-1. Monitoring Sites for Total Suspended Particulate Matter, 1979-1982.

Table 3.5-1. Summary of Total Suspended Particulate (TSP) Matter Monitoring Data, 1979-1982.

Site#	Date	TSP Concentration ( $\mu\text{g}/\text{m}^3$ )							
		1979		1980		1981		1982	
		Annual <sup>1</sup>	24-Hour <sup>3</sup>	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour
1	01/79 - 12/82	52	101	43	123	48	139	33	85
2	01/79 - 12/82	41	81	38	85	35	92	30	75
3	01/79 - 09/79	37	90	-	-	-	-	-	-
4	01/79 - 12/79	38	81	-	-	-	-	-	-
5	10/79 - 12/82	45	81	36	75	31	67	23	80
6	06/80 - 10/80	-	-	*	*	-	-	-	-
7	01/81 - 12/82	-	-	-	-	34	83	26	100

1 Refer to Figure 3.5-1 for site locations.

2 Geometric mean annual TSP level.

3 Second-high annual 24-hour TSP level.

\* All data heavily biased by local construction.

The total suspended particulate matter data show annual geometric mean concentrations ranging from 23  $\mu\text{g}/\text{m}^3$  to 52  $\mu\text{g}/\text{m}^3$ . The geometric mean total suspended particulate matter concentration for all monitoring conducted during January 1979 through December 1982 was 36  $\mu\text{g}/\text{m}^3$ . The annual ambient air quality standard for total suspended particulate matter developed by the EPA and adopted by the FDER is 60  $\mu\text{g}/\text{m}^3$ .

The 24-hour total suspended particulate matter standard developed by the EPA and adopted by the FDER states that the 24-hour total suspended particulate matter concentration will not exceed 150  $\mu\text{g}/\text{m}^3$  more than once per year. Consistent with this regulation, the second-highest 24-hour total suspended particulate matter levels measured annually at each site were analyzed (Table 3.5-1). The highest second-high 24-hour total suspended particulate matter measured at any site for the monitoring period was 139  $\mu\text{g}/\text{m}^3$ . Generally, the annual second-high total suspended particulate matter concentrations at individual sites ranged between 80 and 90  $\mu\text{g}/\text{m}^3$ .

The total suspended particulate matter monitoring data collected in the vicinity of the Swift Creek and Suwannee River chemical complexes and mines show that total suspended particulate matter levels are below standards established by the EPA and adopted by the State of Florida. These data, while representing baseline conditions, also include the impacts from mining operations in the Swift Creek and Suwannee River mines and the impacts of particulate matter emissions from the Suwannee River and Swift Creek chemical complexes.

### 3.6 Noise

Extensive noise surveys were conducted for the OXY area in 1977, prior to construction of the Swift Creek Chemical Complex, and again in 1981. Measurements were made with a B & K Type 2203 Precision Sound Level Meter with a B & K Type UA0207 Windscreen attached. Calibrations were made with a B & K Type 4230 Acoustic Calibrator. Additional measurements were made with a B & K Type 1613 Octave Band Filter Set to determine frequency variations of various noise sources.

In the absence of stationary operational plants and mobile, off-road earth-moving equipment, a baseline day/night average noise level ( $L_{dn}$ ) of 40 dB was established. Current baseline noise levels depend on distance from existing noise sources. Detailed measurements were made for all significant noise sources. Noise emissions were found to be broadband in nature with no prevalent pure tones. Noise contour measurements around the significant stationary noise sources indicate noise levels at 100 ft distance range from 80 to 89 dBA (A-weighted sound level) for the principal sources, such as the sulfuric acid plant. Data for mobile equipment, including the large draglines, suggest these may be treated as point sources with noise levels at 100 ft distance in the range of 76-85 dBA for the major sources.

Measurements of noise levels at various distances from a number of stationary and mobile sources indicate that noise levels decrease 6 dB per doubling of distance from the location of the source. This result for propagation of noise is the same as the theoretical result for spherical spreading. Therefore, excess attenuation associated with relaxation phenomena, topology, and partial ground cover appears to be negligible.

Based on noise source data and the noise attenuation rate, existing noise levels in remote areas of the site, more than 1 mi from principal noise sources, are outside the  $L_{dn} = 55$  dB contour; the range is thus 40-55 dB. Noise impact will be determined as the difference in existing levels, which are presently available for specific sites, and levels created by mining operations at the specific sites, which may be predicted.

The largest impact noise levels are expected to occur over short durations (in time) at local sites during preparation of the site for ore removal.

### 3.7 Radiation

#### 3.7.1 Radiation in the Phosphate Fertilizer Industry

##### 3.7.1.1 Overview

Radionuclides (radioactive materials) occur throughout the environment. In most cases, however, the concentrations of these materials are so low that levels of radioactivity resulting from them pose no threat to human welfare. In some geological formations, however, radionuclides have been concentrated to a level that, under some conditions, results in levels of radioactivity high enough to cause concern. The underground strata including the soil, phosphate deposits, and the entire Hawthorn Formation throughout the phosphate regions in the southeastern United States are examples of geological formations that contain a concentration of radionuclides higher than found in ordinary surface soils.

Since 1975, several studies have been undertaken to evaluate the environmental impact of radionuclides associated with phosphate mining. The studies have concluded that, with a few exceptions, the levels of radiation exposure experienced as a result of phosphate mining activities are below guidelines established to protect human health and welfare. The studies have shown that the radioactive materials associated with the phosphate deposits occur throughout the entire geological formation and that the concentrations vary significantly over the entire extent of the southeastern United States deposits, which extend from central Florida through North Carolina. It has been found that levels of radioactivity in the central Florida deposits are approximately 4-5X higher than levels found in north Florida and North Carolina deposits. This, of course, significantly influences the potential for radiation exposure in these areas.

Studies to evaluate the impact of radioactivity associated with phosphate deposits on ground and surface water have concluded that the phosphate industry has had no measurable effect on the levels of radioactivity in surface waters and groundwaters, and that levels of radioactivity in the upper and lower Floridan aquifers were generally lower in areas where active phosphate mining and processing was underway than in unmined areas.

The uptake of radioactive materials by various elements of the food chain has also been shown not to be an area of concern. Studies have shown that levels of radioactivity in beef, grass, vegetables, and citrus from a reclaimed mining site were no different than levels in similar samples from an unmined area. Samples of fish and turtles collected in surface waters near another fertilizer complex showed no elevated levels of radioactivity.

The direct exposure of persons to industry-enhanced radioactive materials is generally associated with the occupancy of structures constructed on reclaimed lands. A study of this matter concluded that the higher exposure levels experienced in structures on reclaimed lands generally occurred on lands that were reclaimed prior to the 1940's.

The reclamation methods used prior to this period are no longer used. Additionally, recent changes in mining and reclamation techniques have further reduced the potential for radioactive materials associated with the phosphate matrix to be deposited near the ground surface during reclamation, and EPA has proposed construction guidelines for structures built on reclaimed lands. The mitigating measures associated with mining, reclamation, and construction and the lower levels of radioactivity occurring in the north Florida area greatly minimize the potential of exposure to elevated levels of radioactivity as a result of living on reclaimed lands in the north Florida area.

In summary, the studies conducted to date have not identified any problems associated with current practices in phosphate mining. The levels of radioactivity associated with the fertilizer industry are well within the guidelines established to protect human health and welfare. All of the levels reported are within the range of naturally occurring levels of radioactivity found throughout the United States and the world.

Milestones in the understanding and control of radioactivity associated with phosphate areas in Florida are summarized in Table 3.7-1.

#### 3.7.1.2 The OXY Site

A number of radiation studies have been performed previously in the Hamilton County area (Sholtes and Koogler 1976, Roessler et al. 1978) and on OXY property and reclaimed lands (Sholtes and Koogler 1976, EPA 1978b, Ardaman and Associates, Inc. 1981). In 1976, the Florida Phosphate Council funded a comprehensive study to assess the natural radiation exposure in phosphate-rich areas during mining, within the chemical processing complexes, and on post-mining lands (Roessler et al. 1978). The most intensive radiation study of the OXY property resulted from the EIS for the new source NPDES permit at the Swift Creek Chemical Complex (EPA 1978b). Finally, in anticipation of rules proposed by the Florida Department of Natural Resources, OXY funded a study to measure terrestrial gamma radiation over their property and to measure soil radium concentrations at several locations in 1981 (Ardaman and Associates, Inc. 1981). Procedures used in the studies conducted for this EIS are discussed in Section 3.7.11.

#### 3.7.2 Radionuclides in Phosphate Deposits

Apatite is by far the most common phosphate-containing mineral. Apatite deposits of variable phosphate content are widespread along a line extending from the North Carolina coast to central Florida. Four economically attractive deposits occur at approximately equal intervals along the line: North Carolina, South Carolina, northern Florida, and central Florida.

It is generally agreed that apatite was deposited in areas of oceanic upwelling (Sheldon 1982). This environment, being geochemically conducive to the precipitation of phosphate from seawater, produced the primary apatite deposits. Once deposited, the apatite underwent extreme reworking due to the repeated rise and fall of the sea level associated with later glaciation. The reworking processes also caused chemical

Table 3.7-1. Important Milestones in the Understanding and Control of Radioactivity Associated with the Phosphatic Ores in Florida.

Item	Date	Popular Name	Major Recommendation, Finding, Ruling	Reference
1	1954	Uranium Resources in FL	"Confidentially" addressed tonnage, grade, and concentration of uranium of Florida's phosphate rock.	Edmonds and McGinley 1954
2	1965	Background Studies, FL	"Measurements of external gamma radiation and radioactivity in air, food, and water have shown...Bone Valley phosphate deposits...a significantly higher background radiation level than the remainder of the state."	Williams et al. 1965
3	1969	Uranium Resources in the SE	"Florida may contain some 60,000 tons of U <sub>3</sub> O <sub>8</sub> ." Uranium concentrates have been produced in Florida as a byproduct." "An amazing quantity of uranium is being wasted each year."	SINB 1969
4	May 1974	EPA Reconnaissance Study	Nine recommendations concerning both surface and groundwater contamination; storage, use, and ultimate disposal of gypsum; airborne radioactivity releases; and human radiation exposure and dietary intake of radioactivity. Additional study areas were outlined.	EPA 1974b
5	1974	Effluent Guideline	Set 9 pCi/l of Ra-226 as a limitation on liquid effluents from the phosphate industry.	EPA 1974a
6	1975	EPA Indoor Working Level (WL) Study	Indicated that indoor radon daughter levels were elevated in some structures built over reclaimed lands as compared to unmined lands. See follow-up studies, Items 10 and 11.	EPA 1975b
7	Sept 1975	EPA Letter to FL Governor	Recommended as "a prudent interim measure" that new construction be discouraged on land reclaimed from phosphate mining areas. The recommendation was immediately passed on to the pertinent counties. See standards in Items 15, 19, and 21.	EPA 1975c

Table 3.7-1 (Continued).

Item	Date	Popular Name	Major Recommendation, Finding, Ruling	Reference
8	1975	Drinking Water	Set a concentration of 5 pCi/l total radium as a drinking water standard. Total radium equals Ra-226 plus Ra-228.	EPA 1975a
9	1976	Interim Gamma Criteria	EPA provided Florida with "interim recommendations" that indicated if a proposed construction site demonstrated external gamma radiation levels $\geq 10$ $\mu$ R/hr, construction should be delayed.	EPA 1976
10	1976	HRS Indoor WL Study	Determined the extent of the elevated working levels in homes, both on reclaimed and virgin lands.	FDHRS 1978
11	March 1976	Univ. of Fla. Study for FPC	An extensive assessment of human exposure via the land reclamation-to-residential development pathway and the occupational exposure potential.	Roessler et al. 1978
12	1977	Areawide EIS by EPA	An areawide EIS on the entire central Florida phosphate industry and all of its environmental interfaces including radioactivity.	EPA 1978a
13	1978	RCRA and Hazardous Waste Regulations	EPA proposed phosphate-related materials as hazardous. "Owner" could request exemption if Ra-226 was $< 5$ pCi/g. Also lands used for residential development: WL $\leq$ BKG + 0.03, Gamma $\leq$ BKG + 5 $\mu$ R/hr. See Items 16, 19, and 21 for subsequent legislation.	EPA 1978c
14	Dec 1979	Clean Air Act -- Radioactivity	EPA amended the list of primary hazardous air pollutants to include radioactivity. Phosphate mining mentioned in the discussion/justification.	EPA 1979a
15	1979	Indoor WL and Gamma Radiation Recommendations	EPA recommended that indoor WL and gamma levels in new homes not exceed average background plus the uncertainty of normal variations and the measurement capabilities. Effectively: WL Std. $\leq 0.009$ and Gamma $\leq 11$ $\mu$ R/hr.	EPA 1979b

Table 3.7-1 (Continued).

Item	Date	Popular Name	Major Recommendation, Finding, Ruling	Reference
16	1980	RCRA Exemption	Bevill Amendment exempts "solid wastes from the extraction, beneficiation and processing of ores and minerals... including coal, phosphate, and overburden from the mining of uranium ores."	EPA 1980b
17	1980	EPA to Governor Graham	EPA intends to promulgate regulations for phosphate wastes in the area of reclamation.	EPA 1980a
18	1980	FDNR Reclamation Rules	Pre-mining and post-reclamation radiation monitoring on at least a one-per-acre basis. Radioactive emissions...shall not exceed applicable standards.	FDNR 1980
19	1980	HRS Technical Guidelines	Unrestricted land use, including residential development: Gamma exposure: $\leq 10$ $\mu\text{R/hr}$ above BKG but never to exceed 20 Soil radium: $\leq 3$ pCi/g above BKG but never to exceed 5 Other limits for restrictive land use.	FDHRS 1980
20	1981	EPA Standards U Mill Tailings	Surface soils must be $\leq 5$ pCi/g Ra-226.	EPA 1981c
21	1981	Draft Model Building and Zoning Ordinance	Preconstruction: Gamma levels: $\leq 20$ $\mu\text{R/hr}$ Soil Ra-226: $\leq 5$ pCi/g Indoor: Gamma levels: $\leq 20$ $\mu\text{R/hr}$ Working levels: $\leq 0.015$ Cleared for construction: Gamma: $\leq 10$ $\mu\text{R/hr}$ Ra-226: $\leq 3$ pCi/hr	FDHRS 1981

alterations resulting in secondary apatite deposits which are generally more concentrated than the primary apatites from which they are derived.

#### 3.7.2.1 Uranium-Phosphate Mineralogy

Uranium (U) is found in most rocks and soils. Typical concentrations range from 4 parts per million (ppm) in granite and 3 ppm in acid igneous rocks to 0.6 ppm and 0.03 ppm in basic and ultrabasic igneous rocks, respectively. Limestone and other sedimentary rocks contain approximately 1 ppm of uranium. Primary apatite contains only trace amounts of uranium, generally on the order of 10-100 ppm of uranium. The secondary apatite deposits typically contain 50-200 ppm uranium, with maximum concentrations of up to 1000 ppm (mineral basis), depending on the degree of marine reworking to which the apatite was subjected.

The association between uranium and the entire Hawthorn Formation, the geological formation that contains the apatite, is less clear. Evidently, the sedimentary-marine ecology that produced the Hawthorn Formation precipitated the uranium from the waters such that the concentration of uranium generally increases near the mid-depth of the formation and then decreases gradually thereafter.

#### 3.7.2.2 Central Florida versus North Florida Uranium

The uranium content of the phosphate matrix of central Florida (composite primary and secondary apatite deposits) averages 120 ppm, with individual samples from selected strata exceeding 400 ppm uranium. The north Florida matrix samples have lower concentrations, averaging approximately 25 ppm, with individual samples showing concentrations near 100 ppm (Roessler et al. 1979, EPA 1978a).

#### 3.7.3 The Uranium Series

To understand the exposure posed by disturbing the location and the physical and chemical states of the natural radioactivity present in phosphate, a clear understanding of the complexities of the uranium decay series is required.

##### 3.7.3.1 Uranium Equilibrium

Uranium, in nature, consists of three isotopes having mass numbers of 234, 235, and 238. The latter nuclide, U-238, is the parent of a long radiological decay series and accounts for 99.28% by weight of all mineral uranium. In the U-238 series, decay proceeds serially through 13 intermediate radionuclides, called daughters, to a stable endpoint: the element lead, with a mass number of 206 (Figure 3.7-1). The specific activity of U-238 is  $0.33 \times 10^{-6}$  Curies per gram (Ci/g). Thus, 100 ppm of uranium converts to a radioactivity measurement for U-238 of  $33 \times 10^{-12}$  Ci/g or 33 pCi/g.

A condition of equilibrium is achieved if the entire series is contained in a "sealed" environment over a long period of time. Sedimentary phosphate-associated uranium appears to exist in radioactive equilibrium

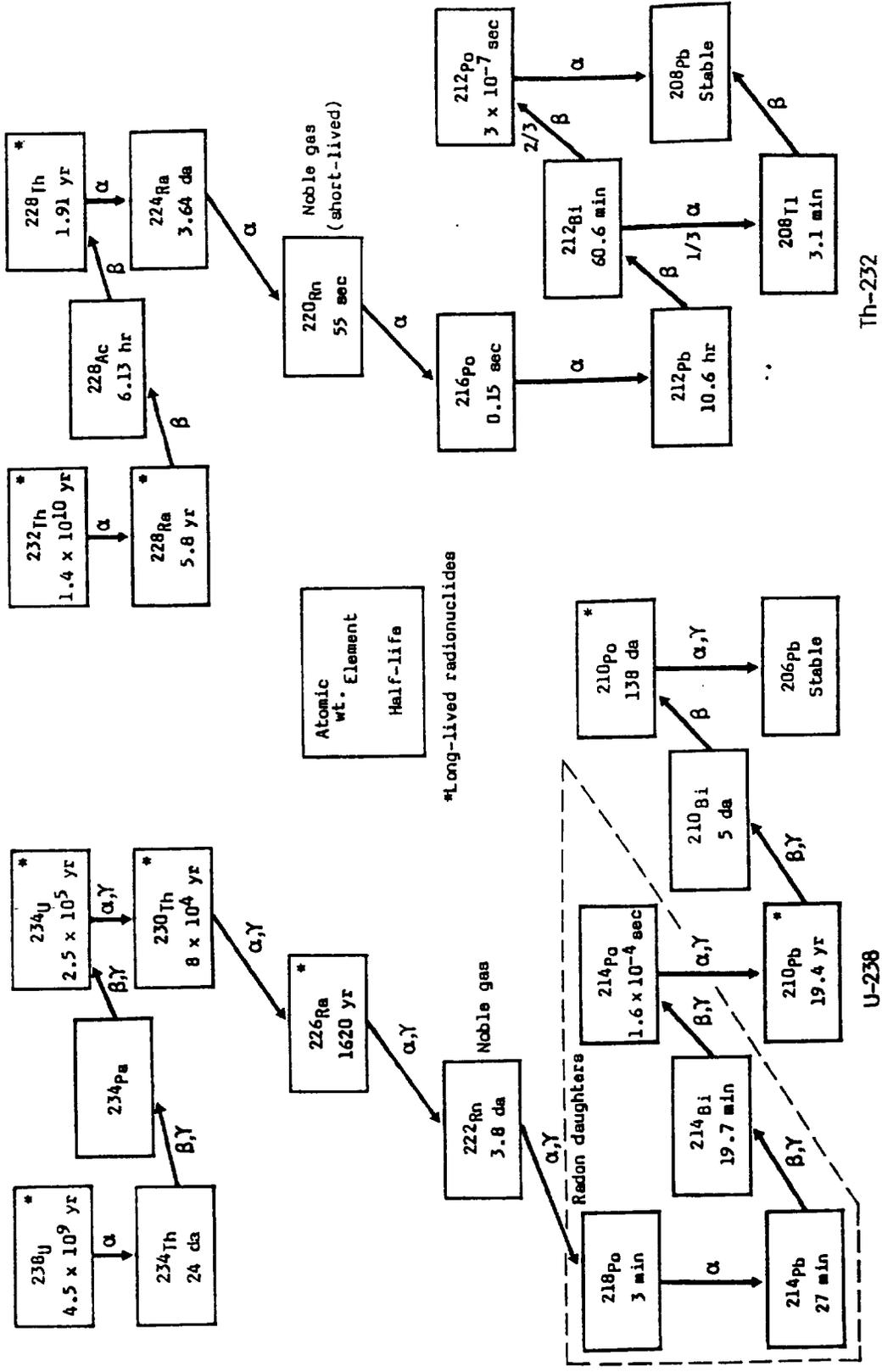


Figure 3.7-1. Decay Series for U-238 and Th-232.

with all its decay products. Equilibrium is maintained only if the materials are undisturbed. The presence of both uranium and radium in equilibrium within the leached zone, when present, is a strong indication of the insolubility of these radionuclides and their intermediates.

### 3.7.3.2 Radium

Radium-226 (Ra-226), the fifth decay product in the U-238 series, is a divalent cation with a long physical half-life (1620 years). Radium is of particular interest with regard to human exposure as it is chemically similar to calcium and tends to be incorporated biologically in the same way as calcium. Radium replacement is clearly demonstrated by the concentration of Ra-226 found in gypsum ( $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ) following the processing of phosphatic ores in a phosphoric acid plant.

Radium, like uranium, is ubiquitous in nature and is found in almost all environmental media. The average daily radium intake per person in the United States has been estimated to be 1.4 pCi (United Nations 1972).

### 3.7.3.3 Radon Progeny

The equilibrium between Ra-226, its daughter, and the rest of the uranium series is highly dependent on the mobility of radon (Rn-222), an inert gas. The four radionuclides following radon in the decay series are known as radon progeny (or daughters of radon). Because radium is a gas, there is normally a potential for the transport of radon away from the location of its parent (Ra-226) and for the overall equilibrium of the series to be disturbed. In the natural unmined state, however, most of the radon produced in a phosphate matrix does not escape the matrix. Mining and beneficiation alter the location and physical condition of minerals bearing radium and may increase the probability for radon to diffuse from the site where it is created.

Radon Emanation and Surface Flux. The ability of radon to move from the mineral or media into the void space of the soil is defined by the term "emanating power" (E), usually expressed as a percent. Typical values for emanating power in soils of both virgin and reclaimed lands associated with Florida phosphate deposits range from a few percent to 30%, with an average of approximately 18%.

The rate of movement through the soil-air interface ( $\text{pCi}/\text{m}^2/\text{sec}$ ) is termed "radon flux." This parameter is difficult to measure and is influenced by a wide variety of environmental factors.

Working Levels. When radon progeny become confined in a structure, the concept of Working Levels (WL) is used to define dose rates. The WL is an attempt to provide a simple dosimetrically meaningful expression to describe airborne radon progeny concentrations regardless of the relative proportion of the various nuclides in the series. One WL is defined as any combination of radon daughters in one liter of air that will result in the ultimate emission of  $1.3 \times 10^5$  MeV of potential alpha

energy. This potential alpha energy occurs when 100 pCi/l of radon are in equilibrium with the radon progeny. The definition of the WL concept does not require an equilibrium condition to exist.

#### 3.7.4 Individual Radionuclides

The radionuclides U-238, U-234, Th-230, Ra-226, Pb-210, and Po-210 are all long-lived radionuclides that can become dissolved in a water environment or become airborne as individual ions or attached to dust. These individual radionuclides each have a unique maximum permissible concentration in both air and water (Table 3.7-1). Th-230 is the critical airborne radionuclide and Ra-226 is the critical waterborne radionuclide.

Polonium (Po-210), the last radioactive daughter in the U-238 series, is an alpha emitter with a 138-day half-life. There has been some public concern over the potential contamination of groundwater by this radionuclide. It has been identified in groundwater where higher-than-normal gross alpha levels could not be accounted for by the alpha contributions of radium and uranium. Excessive polonium is not found in waters with normal gross alpha radioactivity (<15 pCi/l). Humans can tolerate an intake of polonium that is  $\geq 20X$  that of radium (Table 3.7-2), and no reports of gross alpha concentrations above 15 pCi/l have been found for north Florida groundwaters. Therefore, no additional analyses, investigations, or discussion of polonium are indicated for this report.

#### 3.7.5 The Thorium Series

In general, the world average concentration of thorium in various igneous rocks, limestone, and sedimentary rocks is approximately 3X that of uranium (weight basis). However, as thorium has a specific activity of about one-third that of uranium, the radioactivity of the two radionuclides in many soils and rocks is more nearly 1:1 (activity basis). In the thorium series, there are only nine intermediate radionuclides (Figure 3.7-1), the first being radium-228 (Ra-228). This nuclide is not associated with the uranium series discussed previously (Section 3.7.3). The thorium series is included in radiological assessments of phosphate mining because of the decay product, Ra-228. The thorium series also has a potential for contributing to the terrestrial gamma radiation.

Specific data on thorium in central Florida phosphate-associated media indicate the uranium/thorium activity ratio is approximately 60 (EPA 1975b, Windham 1974). In comparison, a uranium/thorium activity ratio of approximately 5 was found in the overburden, leached zone, and matrix in the Suwannee River and Swift Creek mines in north Florida (Gunning 1976). There was also evidence that the thorium in the north Florida strata was more associated with the sand fractions than with the clay.

Ra-226 to Ra-228 ratios should follow the same ratios as uranium to thorium. For example, central Florida groundwater containing 5 pCi/l Ra-226 (an easily measured level) would be expected to have Ra-228 levels of approximately 0.09 pCi/l, whereas north Florida groundwater

Table 3.7-2. Maximum Permissible Concentrations of Selected Radionuclides in Air and Water.

Radionuclide	Air (pCi/m <sup>3</sup> )	Water (pCi/l)
U-238	5	4 X 10 <sup>4</sup>
U-234	2 X 10 <sup>1</sup>	3 X 10 <sup>4</sup>
Th-230	8 X 10 <sup>-2</sup>	2 X 10 <sup>3</sup>
Ra-226	3	3 X 10 <sup>1</sup>
Pb-210	4	1 X 10 <sup>2</sup>
Po-210	2 X 10 <sup>1</sup>	7 X 10 <sup>2</sup>

\*Soluble form.  
Source: 10 CFR Part 20.

with a concentration of 5 pCi/l Ra-226 would be expected to have Ra-228 levels of near 1.0 pCi/l. The USGS analytical procedure (R-1142-76) for Ra-228 indicates the lower limit of detection is approximately 1 pCi/l  $\pm$  20% (USGS 1977). Stated in other terms, the Ra-228 in north Florida water may be just detectable if the Ra-226 levels exceed the drinking water standard of 5 pCi/l. Therefore, Ra-228 need not be addressed with regard to its potential impact in north Florida mining unless Ra-226 levels in excess of 5 pCi/l are encountered.

### 3.7.6 Environmental Gamma Radiation

The total annual radiation dose to an average United States citizen is approximately 182 millirems per year (mrem/yr) (NCRPM 1975). The environmental fraction is comprised of cosmic radiation and external and internal terrestrial radiation. The largest single fraction is contributed by external sources--the cosmic and external terrestrial sources. Nationwide this fraction contributes a dose of approximately 84 mrem/yr, while in Florida this source contributes 38-55 mrem/yr.

Cosmic radiation from outer space is absorbed primarily in the upper atmosphere; however, secondary radiation is present at ground level. Altitude is the single most important cause of dose-rate variations, with Florida (near sea level) having a lower-than-average rate (approx. 30 mrem/yr), while the higher elevations of Colorado exceed 100 mrem/yr.

The other fraction of the environmental sources is terrestrial radiation, both external and, to a limited degree, internal terrestrial radiation. These two categories can be enhanced by the technological activities of man, such as the mining and processing of ores. Other activities, such as dredging, excavation, road building, and sanitary landfilling operations, also have potential for enhancing local terrestrial radiation.

#### 3.7.6.1 Background Terrestrial Radiation Levels

In the continental United States, external terrestrial radiation arises primarily from gamma ray emissions from the thorium series, the uranium series, and potassium-40 (K-40). The latter is a naturally occurring isotope of potassium with a geological age half-life. In typical circumstances, the thorium series and K-40 combine to account for >70% of the external exposure. In Florida, however, the contribution by the uranium series probably accounts for a higher than normal percentage of the external terrestrial radiation dose. The overall average environmental radiation level in Florida (38-55 mrem/yr) is lower than the national average (84 mrem/yr), but there is a considerable range due to different land types (Table 3.7-3).

#### 3.7.6.2 Radiation at the OXY Site

Studies of terrestrial gamma radiation specifically related to the OXY project site included measurements at transects across various watershed areas and defined wetlands. A total of 392 individual gamma radiation measurements were taken along 32 drainage area transects on the OXY site (Table 3.7-4, Figure 3.7-2); of the 32 transects, 28 had

Table 3.7-3. External Gamma Radiation in Florida and Other Locations.

Location	No. of Measurements	$\mu\text{R}/\text{hr}\pm 2\alpha$	Reference
USA	327	8.5±4.1	Myrick et al. 1981
USA	1102	9.2±2.4	Levin et al. 1968
USA	107	10.9±4.9	Lindekin et al. 1972
USA	114	9.9±4.3	Beck et al. 1964
Colorado	32	14±10	Myrick et al. 1981
Colorado	11	13±1.7	Levin et al. 1968
Colorado	2	17±6.1	Lindekin et al. 1972
Colorado	15	12±4.0	Beck et al. 1964
Florida	11	4.0±3.2	Myrick et al. 1981
Florida	239	6.7±2.0	Levin et al. 1968
Florida	5	5.8±3.1	Lindekin et al. 1972
Florida, Polk County	9	5 (geom. mean)	Roessler et al. 1978
Florida, Alachua County	6	6 (geom. mean)	Roessler et al. 1978
Florida, Manatee County	200	5.1	Bolch 1979a
Florida, Polk County	NA	4.4	Post, Buckley, Schuh, and Jernigan, Inc. 1980
Florida, Manatee and Desoto County	265	4.9	ESE 1981
Florida, Hardee County	NA	5.3	EPA 1981a
Florida, Hamilton County	144	5.0	EPA 1978b
Florida, Hamilton County <sup>1</sup>	7	4.9	Ardaman and Asso- ciates, Inc. 1981

Table 3.7-3 (Continued).

Location	No. of Measurements	$\mu\text{R/hr}\pm 2\alpha$	Reference
Florida, Hamilton County <sup>2</sup>	6	6.0	Ardaman and Associates, Inc. 1981
Florida, Hamilton County <sup>3</sup>	8	5.8	Ardaman and Associates, Inc. 1981

<sup>1</sup>Unmined, not in reserves (wet when sampled).

<sup>2</sup>Unmined, shallow overburden (<15 ft).

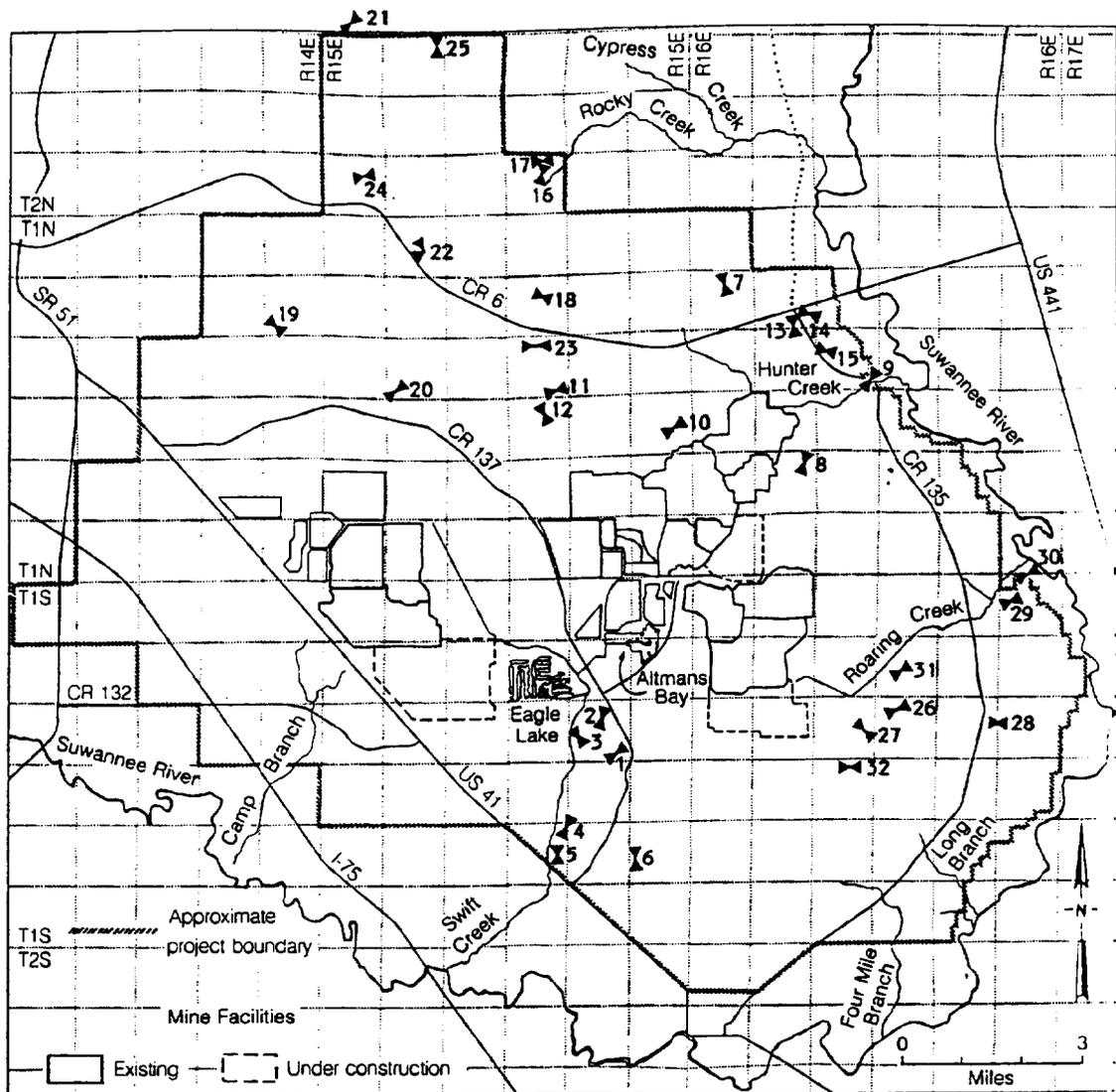
<sup>3</sup>Unmined, deep overburden (25-40 ft).

NA - Not available.

Table 3.7-4. Terrestrial Gamma Radiation Measured at Drainage Area Transects.

Map Location*	Section Numbers	Number of Measurements in Transect	Average Gamma ( $\mu\text{R/hr}$ )
<u>Swift Creek</u>			
1	14, 23	10	4.9
2	14	20	5.1
3	14	14	3.7
4	22, 27	13	2.6
5	27	10	2.1
6	25	10	5.2
<u>Hunter Creek</u>			
7	7	20	5.2
8	20, 29	12	5.2
9	16, 21	14	2.1
10	24	10	5.2
11	14, 15	14	5.2
12	22	5	5.2
13	8, 17	12	5.2
14	CR 6, CR 135	9	5.2
15	CR 135	11	5.2
<u>Rocky Creek</u>			
16	34	14	5.2
17	34	14	5.2
18	10	14	5.2
19	12	14	5.2
20	17	17	5.2
21	18	10	5.2
22	5	11	5.2
23	15	14	5.2
24	31	6	5.2
25	20	14	5.2
<u>Roaring Creek</u>			
26	15	14	5.2
27	16	14	5.2
28	13, 14	14	5.2
29	1	10	5.2
30	36	10	4.9
31	10	7	5.2
32	21	11	5.2

\*See Figure 3.7-2.



NOTE: Does not reflect all areas affected by mining or mine support activities. See Figure 1.1-2.

☛ transect

Figure 3.7-2. Transect Locations for Monitoring Radioactivity.

radiation levels of approximately 5.2 microrems per hour ( $\mu\text{R/hr}$ ). The lower averages (2.1-3.7  $\mu\text{R/hr}$ ) on four of the transects are thought to be due to high water table at the time the measurements were made.

Gamma radiation measurements also were taken along wetland and upland transects (Table 3.7-5, Figure 3.7-2) in conjunction with the habitat evaluation surveys (Section 3.3.9). Upland measurements were taken just before entering the wetland and just after leaving the wetland; these two gamma radiation levels were averaged to yield the upland value. The wetland readings were made on approximately 100-300 ft intervals and only on higher ground (in many instances surrounded by ponded areas). No readings were made over standing water. There was little difference between the upland and wetland averages using these techniques. In general, the data collected in 1982 in the project area indicate an undisturbed terrestrial gamma radiation baseline of approximately 5.2  $\mu\text{R/hr}$  which compares with a statewide baseline level of 4.4-6.4  $\mu\text{R/hr}$ .

### 3.7.7 Subsurface Radioactivity

As the origin of uranium in the phosphate matrix is similar to that of phosphate, the concentrations of uranium and Ra-226 should follow the concentrations of phosphate, i.e., low concentrations in the overburden and high concentrations in the matrix. The actual distribution, however, has been found to be slightly different.

#### 3.7.7.1 Radium-226 and Uranium Profiles

In the central Florida mining regions, the radioactivity is low at the surface, increases gradually and then more rapidly with depth, and is most concentrated in or just above the matrix. Uranium and radium are in general equilibrium.

The distribution of radioactivity within the matrix is variable; most profiles indicate a slight decrease with depth in the concentration of Ra-226 within the matrix. The profiles also indicate a wide variation in radiation levels within small distances within the matrix. Composite samples yield lower concentrations than small individual fractions.

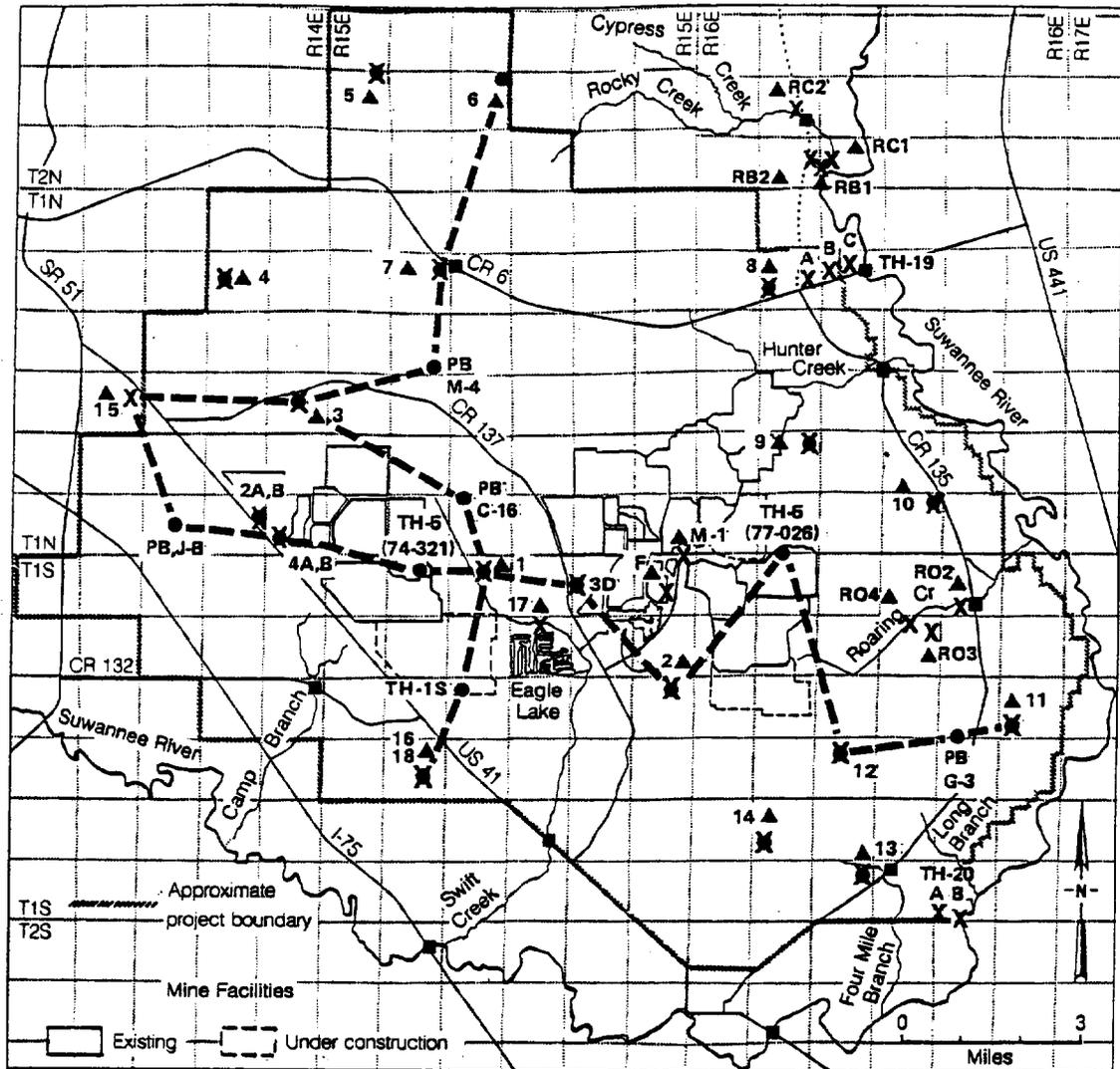
The radiation pattern for the north Florida deposits is similar to that of the central Florida deposits, based on data taken from the Swift Creek Chemical Complex EIS (EPA 1978b). Although the intervals sampled were erratic and discontinuous, a pattern emerges from the composite of the six cores. The low radiation concentration at the surface (0.5 pCi/g) increases to approximately 59 pCi/g at 27 ft. The radium data can be summarized by weighted averages: 0.5 pCi/g for topsoil, 3.6 pCi/g for overburden, and 8.6 pCi/g for the matrix. The topsoil and overburden data from north Florida are not significantly different from that in central Florida; however, the north Florida matrix has approximately 25% of the radioactivity that is in the matrix in the central Florida area.

For the present study, 16 cores were taken from test holes (TH) in the area and intensively analyzed for radioactivity (Figures 3.7-3 and

Table 3.7-5. Terrestrial Gamma Radiation on Wetland and Upland Transects.

Transect*	Wetland*	Wetland Gamma ( $\mu$ R/hr)	Upland Gamma ( $\mu$ R/hr)
<u>Swift Creek Mine</u>			
SC/1B	2550	5.2	5.2
SC/4A	2550	5.2	5.2
SC/1A	2550	5.1	5.2
<u>Camp Branch</u>			
SC/2A	2275	5.2	5.2
SC/3A	2139	5.2	5.2
SC/3B	2139	5.2	5.2
<u>Hunter Creek</u>			
HC/1A	1370	5.2	5.2
HC/2A	1378	5.2	5.2
HC/2B	1378	5.2	5.2
HC/2C	1378	5.1	5.2
HC/3A	1227	5.1	5.2
HC/3B	1227	5.1	5.2
<u>Rocky Creek</u>			
RC/1A	2734	5.1	5.2
RC 3000	2014	5.2	5.2
RC 3001	2014	5.2	5.2
RC 3002	2014	5.2	5.2
RC/2A	2696	5.1	5.2
RC/2B	2696	5.1	5.2
<u>Roaring Creek</u>			
RO/2A	1690	5.1	5.2
RO/2B	1690	5.2	5.2
RO/2C	1690	5.2	5.2

\*Refer to Section 4.0.



NOTE: Does not reflect all areas affected by mining or mine support activities. See Figure 1.1-2.

- SPT drilling sites
- X Observation well sites
- Base flow sites
- ▲ USGS No. 025-246-1 well
- Location of west-east and north-south soil profiles (see Figures 3.1-15 and 3.1-16)

Figure 3.7-3. Location of SPT Borings and Groundwater Sampling Stations.

3.7-4, Table 3.7-6). Six to eleven fractions were taken from each core, representing 5-in depths for each fraction. Analyses were made for Ra-226, U-238, Th-232, and K-40. Ra-226 concentrations shown in Table 3.7-6 were calculated by combining information from three gamma photo-peaks of Rn-222 daughters at secular equilibrium. U-238 concentrations were calculated by Th-234 gamma emissions at equilibrium and by extracting the U-235 contribution to the 185-186 Kev photopeak. Most of the literature data show an approximate Ra-226 equilibrium with U-238. In most cases, the average of the two uranium concentrations is near that of Ra-226. Error bounds are for counting statistics only. True error bounds for U-238 are larger due to the other uncertainties and the small sample size provided.

The thorium concentrations of the north Florida samples appeared to be approximately 5X lower than the uranium (and radium) concentrations on an activity basis, or approximately 20X lower on a weight basis. The same rates should apply to Ra-226 and Ra-228 concentrations and daughters of uranium and thorium. The conclusion to be drawn from the thorium data as well as from the Ra-226 data is that the Ra-228 daughter should not be present in significant concentrations in the waters in the Hamilton County area. The levels of K-40 in the core samples were, in all probability, related to the clay concentrations of the soil.

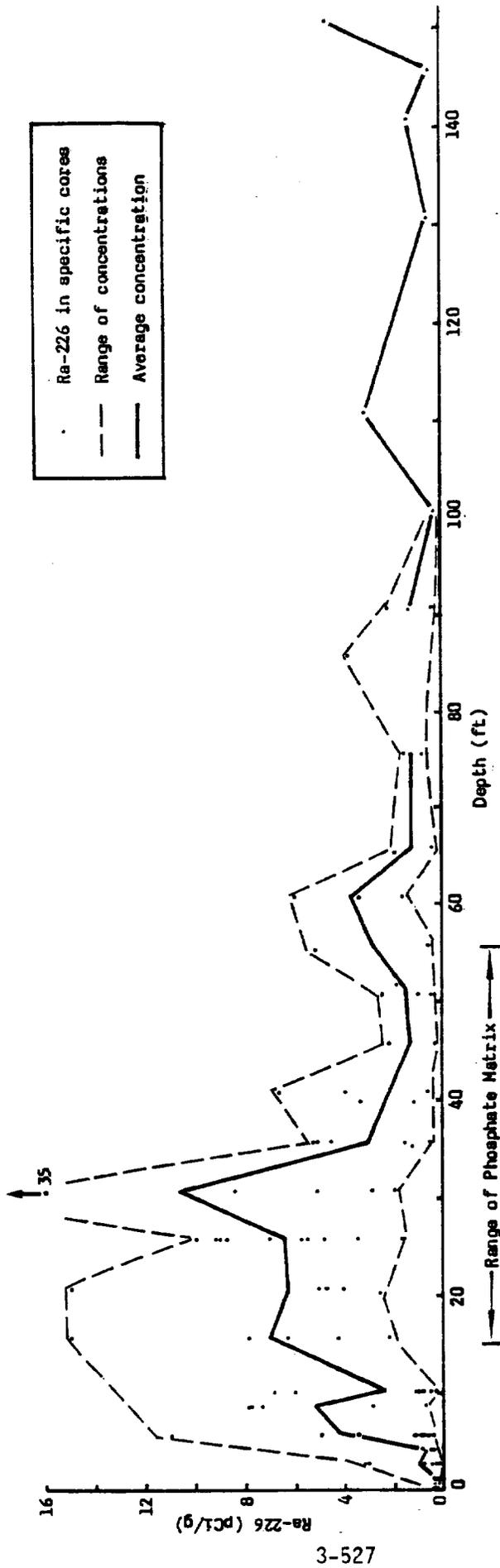
There were wide differences in Ra-226 concentrations at any single depth; however, the overall data followed a trend predicted by other data from both central and north Florida. The concentration was low at the surface ( $\leq 0.5$  pCi/g), increased with depth, and reached a maximum average concentration of approximately 11 pCi/g at 30 ft. Thereafter, the Ra-226 concentration was erratically lower, with single values as high as 6 and 5 pCi/g at depths of 60 and 150 ft, respectively. Core data from a previous OXY study (EPA 1978b) illustrating this distribution are shown in Figure 3.7-5.

The data in Table 3.7-6 were compared to data from other areas in Florida (Table 3.7-7). The topsoils in all areas have radium concentrations that are not significantly different. The overburden concentration data from the surface to top of the matrix yield an estimation of the mixed overburden concentration used for reclamation. Assuming complete mixing (including the high-activity zone just above the matrix), the mean radium concentration was determined to be 1.9 pCi/g. This concentration is slightly lower than overburden levels from the active mining region in central Florida and the proposed mines to the south and west of the Bartow, Florida area.

The most striking differences in the data in Table 3.7-7 occur in the matrix. Active mining areas in central Florida have a matrix Ra-226 concentration of approximately 26 pCi/g, while active and proposed OXY mining areas and the Estech and AMAX mines in central Florida have matrix with only 5-7 pCi/g of Ra-226.

#### 3.7.7.2 Gamma Logs

Because a major fraction of the gamma radiation level in Florida is related to the uranium series, especially Ra-226, gamma logs of wells



3-527

Figure 3.7-4. General Radium-226 Profile (0-150 ft) for Cores in the OXY Project Area.

Table 3.7-6. Radioactivity in Core Samples.

Station	Depth (ft)	Concentration (pCi/g $\pm$ 95% CL)		
		Ra-226	U-238	Th-232
TH-2	2.5-2.8	3.1 $\pm$ 0.25	<2.6	<0.13
TH-2	5.5-5.8	5.0 $\pm$ 0.21	6.4 $\pm$ 0.75	0.50 $\pm$ 0.12
TH-2	10.0-10.3	1.0 $\pm$ 0.08	0.64 $\pm$ 0.23	0.49 $\pm$ 0.04
TH-2	20.0-20.3	2.4 $\pm$ 0.14	2.8 $\pm$ 0.52	0.81 $\pm$ 0.09
TH-2	30.5-30.8	2.0 $\pm$ 0.16	2.5 $\pm$ 0.58	0.73 $\pm$ 0.11
TH-2	40.5-40.8	6.7 $\pm$ 0.33	4.2 $\pm$ 0.74	<0.19
TH-3	2.5-2.8	0.77 $\pm$ 0.10	1.1 $\pm$ 0.38	0.56 $\pm$ 0.08
TH-3	5.5-5.8	0.35 $\pm$ 0.09	<0.59	0.36 $\pm$ 0.05
TH-3	15.5-15.8	15 $\pm$ 0.39	18 $\pm$ 1.2	0.31 $\pm$ 0.17
TH-3	25.5-25.8	7.1 $\pm$ 0.35	6.6 $\pm$ 0.91	<0.19
TH-3	51.5-51.8	1.9 $\pm$ 0.15	<2.0	1.3 $\pm$ 0.12
TH-4	2.5-2.8	0.32 $\pm$ 0.09	<0.75	0.23 $\pm$ 0.07
TH-4	5.5-5.8	1.1 $\pm$ 0.08	<2.3	1.0 $\pm$ 0.15
TH-4	10.0-10.3	1.1 $\pm$ 0.08	1.7 $\pm$ 0.59	0.51 $\pm$ 0.08
TH-4	25.5-25.8	4.9 $\pm$ 0.32	5.9 $\pm$ 1.1	<0.27
TH-4	35.5-35.8	1.6 $\pm$ 0.12	2.6 $\pm$ 0.52	0.39 $\pm$ 0.79
TH-4	45.5-45.8	0.32 $\pm$ 0.07	<0.47	0.50 $\pm$ 0.06
TH-5	2.5-2.8	0.33 $\pm$ 0.09	<0.70	0.22 $\pm$ 0.72
TH-5	5.5-5.8	0.74 $\pm$ 1.4	<1.2	0.65 $\pm$ 0.10
TH-5	10.0-10.3	0.33 $\pm$ 0.07	<0.76	0.59 $\pm$ 0.06
TH-5	25.5-25.8	9.2 $\pm$ 0.98	8.2 $\pm$ 2.6	ND
TH-5	45.5-45.8	2.2 $\pm$ 0.17	1.8 $\pm$ 0.47	<2.6
TH-5	50.5-50.8	2.5 $\pm$ 0.23	<2.4	<0.10
TH-5	60.5-60.8	3.4 $\pm$ 0.27	3.8 $\pm$ 0.70	<0.16
TH-5	75.5-75.8	1.5 $\pm$ 0.21	<1.3	<0.20
TH-5	120.0-120.3	0.95 $\pm$ 0.22	<1.5	<0.20
TH-5	145.5-145.8	0.46 $\pm$ 0.96	<0.62	0.43 $\pm$ 0.12
TH-5	180.5-180.8	0.50 $\pm$ 0.07	<0.66	0.80 $\pm$ 0.08
TH-6	2.5-2.8	0.34 $\pm$ 0.13	<0.76	0.11 $\pm$ 0.04
				0.31 $\pm$ 0.08
				ND
				<0.84
				0.40 $\pm$ 0.24
				2.4 $\pm$ 0.52
				5.5 $\pm$ 0.98
				6.3 $\pm$ 0.96
				1.1 $\pm$ 0.43
				ND
				1.6 $\pm$ 0.74
				7.5 $\pm$ 1.0
				9.0 $\pm$ 1.2
				0.65 $\pm$ 0.37
				<0.55
				<0.39
				7.4 $\pm$ 1.4
				7.9 $\pm$ 0.88
				4.4 $\pm$ 0.56
				<0.84
				0.59 $\pm$ 0.46
				ND
				<2.6
				4.9 $\pm$ 0.68
				5.1 $\pm$ 0.85
				<0.72
				5.4 $\pm$ 1.4
				9.6 $\pm$ 1.7
				2.9 $\pm$ 0.54
				<0.65
				0.62 $\pm$ 0.32

Table 3.7-6 (Continued).

Station	Depth (ft.)	Concentration (pCi/g $\pm$ 95% CL)		
		Ra-226	U-238	Th-232
TH-6	5.5-5.8	1.2 $\pm$ 0.12	<0.95	<0.10
TH-6	10.0-10.3	1.1 $\pm$ 0.16	<1.6	2.0 $\pm$ 0.11
TH-6	20.5-20.8	4.8 $\pm$ 0.23	4.1 $\pm$ 0.69	0.28 $\pm$ 0.11
TH-6	30.5-30.8	35 $\pm$ 0.92	<37	<0.33
TH-6	39.5-39.8	3.4 $\pm$ 0.19	4.0 $\pm$ 0.63	<0.11
TH-7	2.5-2.8	0.23 $\pm$ 0.12	<0.64	0.07 $\pm$ 0.06
TH-7	5.5-5.8	0.38 $\pm$ 0.12	<0.63	0.31 $\pm$ 0.07
TH-7	8.5-8.8	7.9 $\pm$ 0.37	<5.8	<0.25
TH-7	10.0-10.3	6.9 $\pm$ 0.27	4.6 $\pm$ 0.76	<0.18
TH-7	20.5-20.8	5.1 $\pm$ 0.29	3.5 $\pm$ 0.68	<0.17
TH-7	25.5-25.8	5.6 $\pm$ 0.33	4.6 $\pm$ 0.86	<0.23
TH-8	2.5-2.8	0.35 $\pm$ 0.08	<0.71	0.17 $\pm$ 0.06
TH-8	5.5-5.8	0.73 $\pm$ 0.10	1.2 $\pm$ 0.51	0.70 $\pm$ 0.09
TH-8	10.0-10.3	1.1 $\pm$ 0.12	2.1 $\pm$ 0.61	0.74 $\pm$ 0.09
TH-8	30.5-30.8	2.9 $\pm$ 0.24	2.4 $\pm$ 0.73	<0.14
TH-8	40.5-40.8	0.57 $\pm$ 0.06	2.2 $\pm$ 0.72	0.51 $\pm$ 0.09
TH-8	55.0-55.3	5.2 $\pm$ 0.29	5.2 $\pm$ 0.95	<0.17
TH-8	60.5-60.8	6.0 $\pm$ 0.33	3.4 $\pm$ 0.93	<0.20
TH-9	2.5-2.8	0.42 $\pm$ 0.10	<0.68	0.35 $\pm$ 0.07
TH-9	5.5-5.8	0.90 $\pm$ 0.23	<2.2	0.97 $\pm$ 0.14
TH-9	15.5-15.8	4.3 $\pm$ 0.22	5.8 $\pm$ 0.80	0.41 $\pm$ 0.11
TH-9	25.5-25.8	10 $\pm$ 0.44	7.6 $\pm$ 1.2	<0.28
TH-9	30.5-30.8	8.5 $\pm$ 0.33	6.0 $\pm$ 0.82	<0.21
TH-9	35.5-35.8	5.2 $\pm$ 0.42	5.4 $\pm$ 1.6	<0.29
TH-9	39.5-39.8	1.2 $\pm$ 0.29	1.4 $\pm$ 1.2	<0.18
TH-10	2.5-2.8	0.15 $\pm$ 0.05	<0.66	<0.08
TH-10	5.5-5.8	0.70 $\pm$ 0.10	1.5 $\pm$ 0.52	0.95 $\pm$ 0.08
TH-10	10.0-10.3	0.48 $\pm$ 0.12	<0.95	1.1 $\pm$ 0.11
TH-10	25.5-25.8	1.7 $\pm$ 0.18	<1.9	<0.13
TH-10	35.5-35.8	5.3 $\pm$ 0.31	2.5 $\pm$ 0.70	<0.19
				K-40
				0.64 $\pm$ 0.34
				<0.39
				1.7 $\pm$ 0.60
				9.7 $\pm$ 2.1
				6.5 $\pm$ 0.97
				0.75 $\pm$ 0.34
				ND
				<1.4
				1.0 $\pm$ 0.76
				-
				4.9 $\pm$ 1.0
				0.78 $\pm$ 0.37
				<0.76
				1.3 $\pm$ 0.50
				7.5 $\pm$ 1.2
				6.1 $\pm$ 0.78
				6.3 $\pm$ 1.3
				2.3 $\pm$ 0.71
				ND
				ND
				5.6 $\pm$ 0.96
				5.2 $\pm$ 1.3
				4.4 $\pm$ 0.91
				5.1 $\pm$ 1.6
				2.2 $\pm$ 0.88
				ND
				1.6 $\pm$ 0.49
				2.1 $\pm$ 0.58
				9.5 $\pm$ 1.2
				7.5 $\pm$ 1.1

Table 3.7-6 (Continued).

Station	Depth (ft)	Concentration (pCi/g $\pm$ 95% CL)		
		Ra-226	U-238	Th-232
TH-10	60.5-60.8	1.6 $\pm$ 0.17	2.5 $\pm$ 0.65	<0.10
TH-10	85.5-85.8	3.8 $\pm$ 0.26	4.0 $\pm$ 0.89	<0.19
TH-10	110.5-110.8	3.1 $\pm$ 0.27	2.2 $\pm$ 0.73	<0.17
TH-10	220.5-220.8	0.62 $\pm$ 0.15	<0.84	<0.10
TH-11	2.5-2.8	0.38 $\pm$ 0.10	<0.83	2.4 $\pm$ 0.07
TH-11	8.5-8.8	7.4 $\pm$ 0.36	<4.0	<0.24
TH-11	15.5-15.8	2.2 $\pm$ 0.23	3.8 $\pm$ 0.78	<0.16
TH-11	25.5-25.8	3.5 $\pm$ 0.27	9.3 $\pm$ 1.4	<0.18
TH-11	30.5-30.8	5.2 $\pm$ 0.23	3.4 $\pm$ 0.62	<0.16
TH-11	40.5-40.8	4.0 $\pm$ 0.19	4.6 $\pm$ 0.66	<0.13
TH-12	2.5-2.8	0.34 $\pm$ 0.13	<0.78	0.23 $\pm$ 0.07
TH-12	5.5-5.8	0.59 $\pm$ 0.16	1.38 $\pm$ 0.66	0.90 $\pm$ 0.10
TH-12	8.5-8.8	0.71 $\pm$ 0.20	<1.1	0.85 $\pm$ 0.12
TH-12	10.0-10.3	0.92 $\pm$ 0.14	<0.84	1.5 $\pm$ 0.11
TH-12	15.5-15.8	6.4 $\pm$ 0.29	5.2 $\pm$ 0.81	<0.23
TH-12	25.5-25.8	8.8 $\pm$ 0.28	8.0 $\pm$ 0.87	<0.17
TH-12	35.0-35.3	1.3 $\pm$ 0.18	<2.0	<0.19
TH-13	1.0-1.3	0.36 $\pm$ 0.12	<1.1	<0.12
TH-13	4.0-4.3	0.92 $\pm$ 0.21	<0.89	1.4 $\pm$ 0.13
TH-13	5.5-5.8	0.86 $\pm$ 0.13	<1.5	1.7 $\pm$ 0.11
TH-13	8.5-8.8	2.9 $\pm$ 0.24	4.5 $\pm$ 0.89	2.1 $\pm$ 0.14
TH-13	20.5-20.8	4.1 $\pm$ 0.24	1.1 $\pm$ 0.43	<0.15
TH-14	0.0-1.0	0.33 $\pm$ 0.15	<1.0	0.17 $\pm$ 0.67
TH-14	5.5-5.8	0.81 $\pm$ 0.15	<0.96	0.87 $\pm$ 0.10
TH-14	25.5-25.8	9.1 $\pm$ 0.28	<5.8	<0.18
TH-14	50.5-50.8	1.0 $\pm$ 0.17	2.4 $\pm$ 0.85	<0.14
TH-14	65.0-65.3	1.9 $\pm$ 0.16	2.1 $\pm$ 0.60	<0.14
TH-14	90.5-90.8	2.2 $\pm$ 0.21	3.5 $\pm$ 0.83	<0.17
TH-14	150.5-150.8	4.7 $\pm$ 0.27	<2.5	<0.19
TH-14	170.5-170.8	1.8 $\pm$ 0.26	<1.5	<0.20
				3.1 $\pm$ 0.74
				6.1 $\pm$ 1.1
				7.8 $\pm$ 1.2
				ND
				0.76 $\pm$ 0.45
				2.2 $\pm$ 0.93
				5.9 $\pm$ 1.1
				8.1 $\pm$ 1.5
				5.9 $\pm$ 0.96
				4.3 $\pm$ 0.74
				ND
				0.71 $\pm$ 0.43
				<0.78
				<0.27
				9.0 $\pm$ 1.2
				6.0 $\pm$ 0.90
				2.8 $\pm$ 0.86
				ND
				1.4 $\pm$ 0.46
				<0.46
				<0.98
				6.3 $\pm$ 0.79
				ND
				<0.54
				3.6 $\pm$ 0.82
				8.3 $\pm$ 0.97
				4.3 $\pm$ 0.93
				6.3 $\pm$ 1.1
				ND
				<0.19

Table 3.7-6 (Continued).

Station	Depth (ft)	Concentration (pCi/g $\pm$ 95% CL)			
		Ra-226	U-238	Th-232	K-40
TH-15	1.0-1.3	0.33 $\pm$ 0.09	<2.7	0.33 $\pm$ 0.06	<0.49
TH-15	4.0-4.3	0.51 $\pm$ 0.10	<1.0	0.35 $\pm$ 0.76	<1.0
TH-15	5.5-5.8	11 $\pm$ 0.43	17 $\pm$ 1.7	0.27 $\pm$ 0.02	<0.85
TH-15	8.5-8.8	7.8 $\pm$ 0.34	<6.5	<0.22	4.7 $\pm$ 1.0
TH-15	15.5-15.8	7.9 $\pm$ 0.36	<7.5	<0.23	<1.2
TH-15	20.5-20.8	15 $\pm$ 0.46	<7.9	<0.27	ND
TH-16	0.0-1.0	0.40 $\pm$ 0.10	<0.86	0.19 $\pm$ 0.08	<0.31
TH-16	4.0-4.3	0.37 $\pm$ 0.15	<1.3	0.25 $\pm$ 0.09	<0.55
TH-16	10.0-10.3	6.1 $\pm$ 0.31	9.4 $\pm$ 1.1	<0.20	5.9 $\pm$ 1.5
TH-16	25.5-25.8	5.8 $\pm$ 0.40	8.1 $\pm$ 1.4	<0.24	2.4 $\pm$ 0.62
TH-16	35.5-35.8	0.55 $\pm$ 0.10	<0.84	<0.66	2.1 $\pm$ 0.38
TH-16	50.5-50.8	0.51 $\pm$ 0.07	<0.87	0.58 $\pm$ 0.05	ND
TH-18	55.5-55.8	0.59 $\pm$ 0.15	<0.90	<0.10	3.2 $\pm$ 0.68
TH-18	65.5-65.8	0.35 $\pm$ 0.11	<0.76	0.60 $\pm$ 0.08	1.5 $\pm$ 0.70
TH-18	75.5-75.8	0.78 $\pm$ 0.20	<1.2	<0.14	2.0 $\pm$ 0.49
TH-18	90.5-90.8	0.36 $\pm$ 0.13	<0.63	0.43 $\pm$ 0.07	1.3 $\pm$ 0.46
TH-18	100.5-100.8	0.29 $\pm$ 0.10	<0.85	0.45 $\pm$ 0.07	ND
TH-18	130.5-130.8	0.62 $\pm$ 0.20	<1.1	0.74 $\pm$ 0.13	1.6 $\pm$ 1.0
TH-18	140.5-140.8	1.4 $\pm$ 0.36	<2.1	0.76 $\pm$ 0.21	

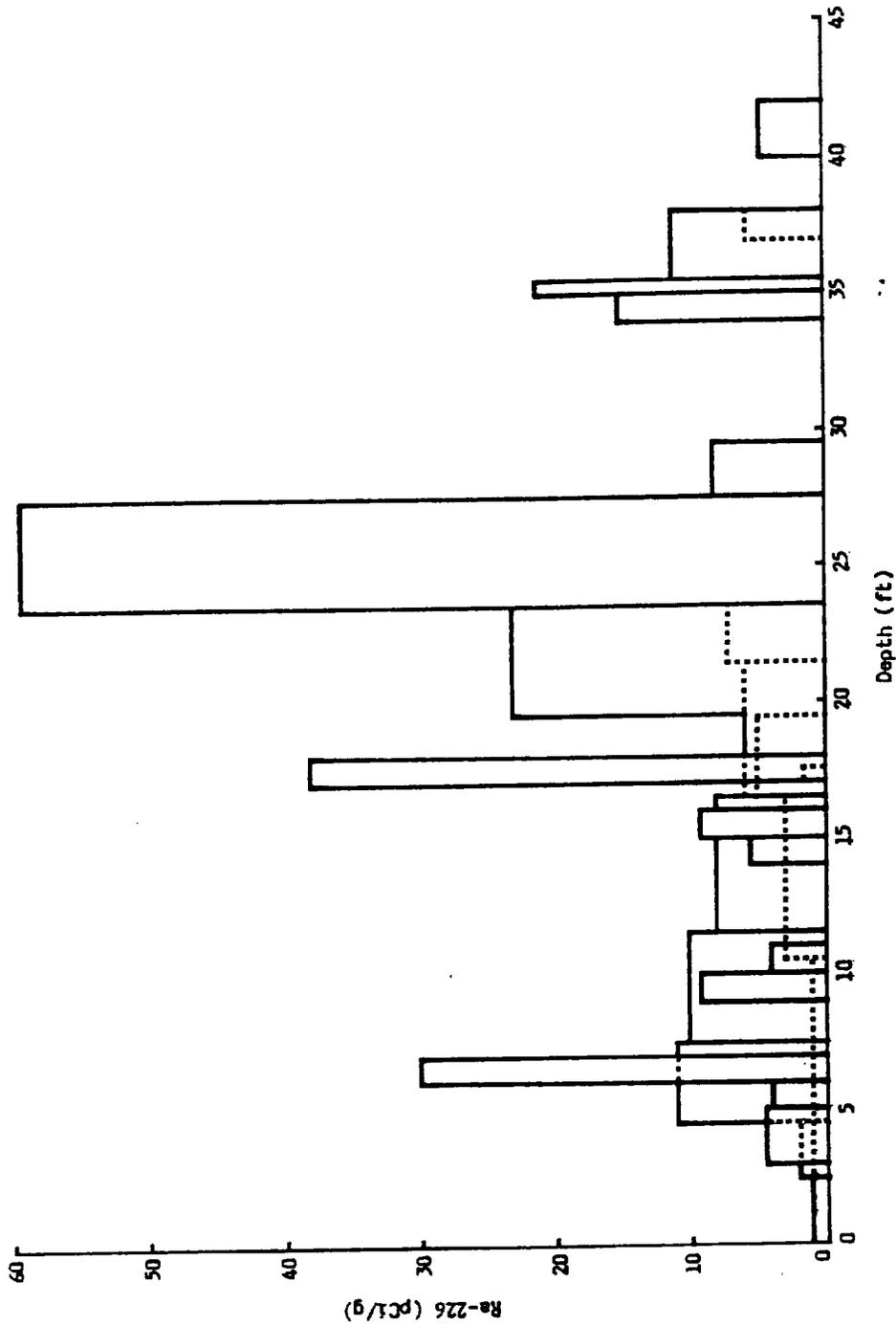


Figure 3.7-5. Radium-226 Profiles for the OXY Area, 1978 (Source: EPA 1978b).

Table 3.7-7. Radium-226 Concentrations (pCi/g) in Topsoil, Overburden, and Matrix of Mining Land.

Material Type	North Florida Wetlands Study Area	Central Florida <sup>1</sup>	Duette Site <sup>2</sup>	AMAX <sup>3</sup>
<u>Surface Soil</u>				
Geometric mean	0.44	0.5	0.5	0.6
Depth (m)	0 - 0.3	0 - 0.3	0 - 0.3	0 - 3.3
Range of individual samples	0.33 - 0.40	0.2 - 3.8	0.4 - 0.5	0.1 - 6.4
Number of samples (sites)	4	5	2	11
<u>Overburden Soil (surface to 6 ft)</u>				
Geometric mean	1.14	-	-	0.7
Range of individual samples	0.15 - 11	-	-	0.1 - 11.5
Number of samples	31	-	-	68
<u>Overburden (surface to matrix)</u>				
Geometric mean	1.94	2.5	2.5	3.0
Range of site means	-	0.5 - 7.2	-	-
Range of individual samples	0.15 - 15.0	0.2 - 30.6	0.5 - 13	0.1 - 46
Number of samples (sites)	41	8	14	11
<u>Matrix</u>				
Geometric mean	6.64	25.9	5.1	6.3
Range of site means	-	(13.2 - 84.2)	-	-
Range of individual samples	0.57 - 35	7	-	2.1 - 17.6
Number of samples	26	13	7	21

<sup>1</sup>Roesler et al. 1978.      <sup>3</sup>ESE 1981.  
<sup>2</sup>Boich 1979a.              <sup>4</sup>Arithmetic means.

should reflect the Ra-226 profiles shown in Figures 3.7-4 and 3.7-5. A gamma well log for a 300 ft deep Swift Creek Mine well is shown in Figure 3.7-6 to demonstrate the correlation between the Ra-226 profile and the gamma profile.

The existence of rather large quantities of radioactivity between the mined matrix level and the deep aquifers has not been adequately addressed in the literature, yet this activity plays an important role when evaluating the possibility of groundwater contamination by radionuclides. The gamma activity (Figure 3.7-6) and the radium concentrations (Figure 3.7-4) increase rapidly with depth to approximately 20 ft. At this depth the activity decreases to a depth just above and within the matrix. (The mineable matrix was estimated to be between the 30 and 50 ft levels.) As the origin of the matrix is known to be linked to the Hawthorn Formation, the entire Hawthorn strata, here estimated to be >300 ft thick, would also be expected to contain uranium and its daughters because of a common geologic history. The gamma log dramatically illustrates this fact (note especially the high peak at 300 ft). The importance of these data is that the mineable matrix contains only a small fraction of the total radioactivity below the ground surface.

Ra-226 in the Floridan Aquifer underlying the Hawthorn Formation has been of much interest. The relationship of the deep aquifer radium and the radioactivity in the total Hawthorn Formation is not understood; however, current levels of radium in the aquifer may be more closely related to the lower Hawthorn than to the matrix over 300 ft above. Monitor wells often draw water from locations indicating high gamma activities. Because of the existence of a higher radium content in strata from which water is drawn for monitoring purposes, it may be extremely difficult to determine Ra-226 transport from other locations in either the vertical or horizontal direction.

Eleven of the test holes shown in Table 3.7-6 were gamma logged to approximately 40 ft. Figure 3.7-7 illustrates a typical result of well logging with a gamma ray detector. The probe response (counts per second) should reflect the radioactivity of the surrounding soil strata. The trends are similar to those previously described, i.e., low top soil activity, activity increasing to a maximum near or within the matrix, a drop in activity to an intermediate level within or below the matrix, and continued activity below the matrix, sometimes with a second high peak. Figure 3.7-8 shows the gamma log of the deeper test hole (TH-14).

On the gamma logs presented in Figures 3.7-7 and 3.7-8, the concentration data for Ra-226 have been plotted at various depths. It is apparent that there is a strong correlation between the gross gamma activity and the concentration of Ra-226.

### 3.7.8 Water Quality

#### 3.7.8.1 Surface Water Radioactivity

Ra-226 concentrations in surface water in the United States are generally low (0.03-1.0 pCi/l) except for certain waters from mineral

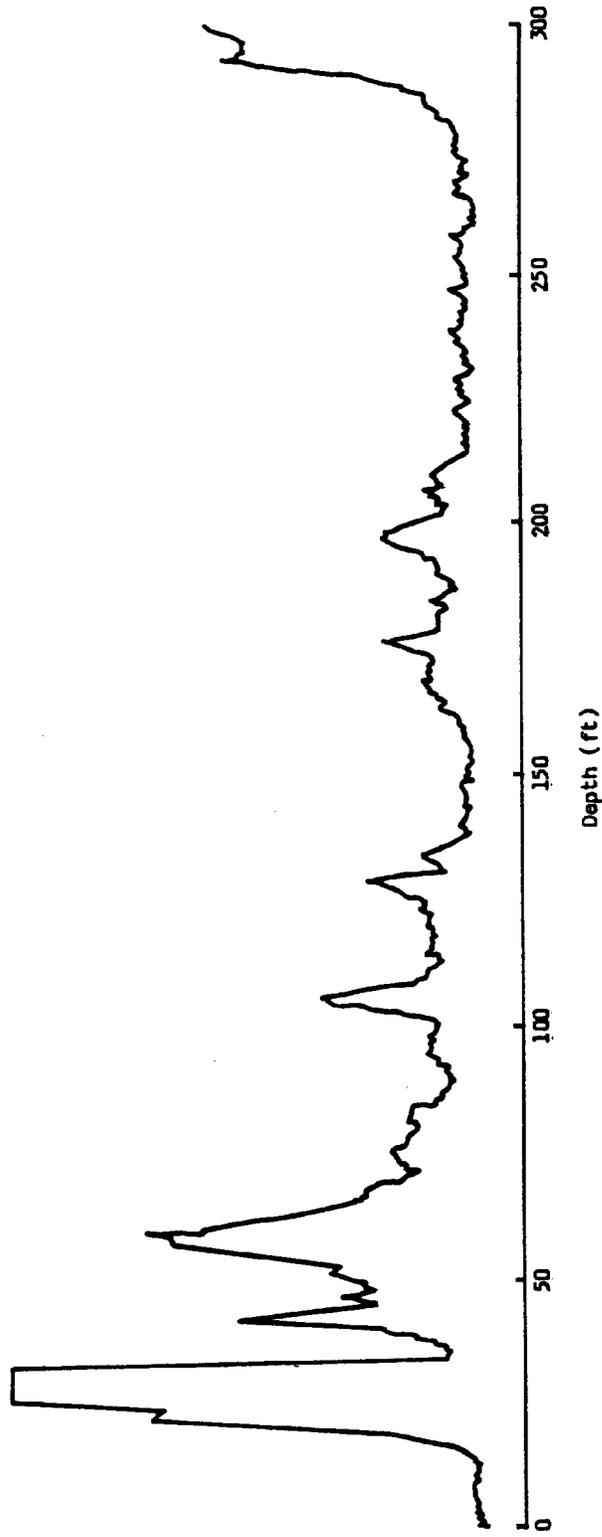


Figure 3.7-6. Gamma Log for Swift Creek, Well Set No. 3, Well E, 1 March 1978 (Source: EPA 1978b).

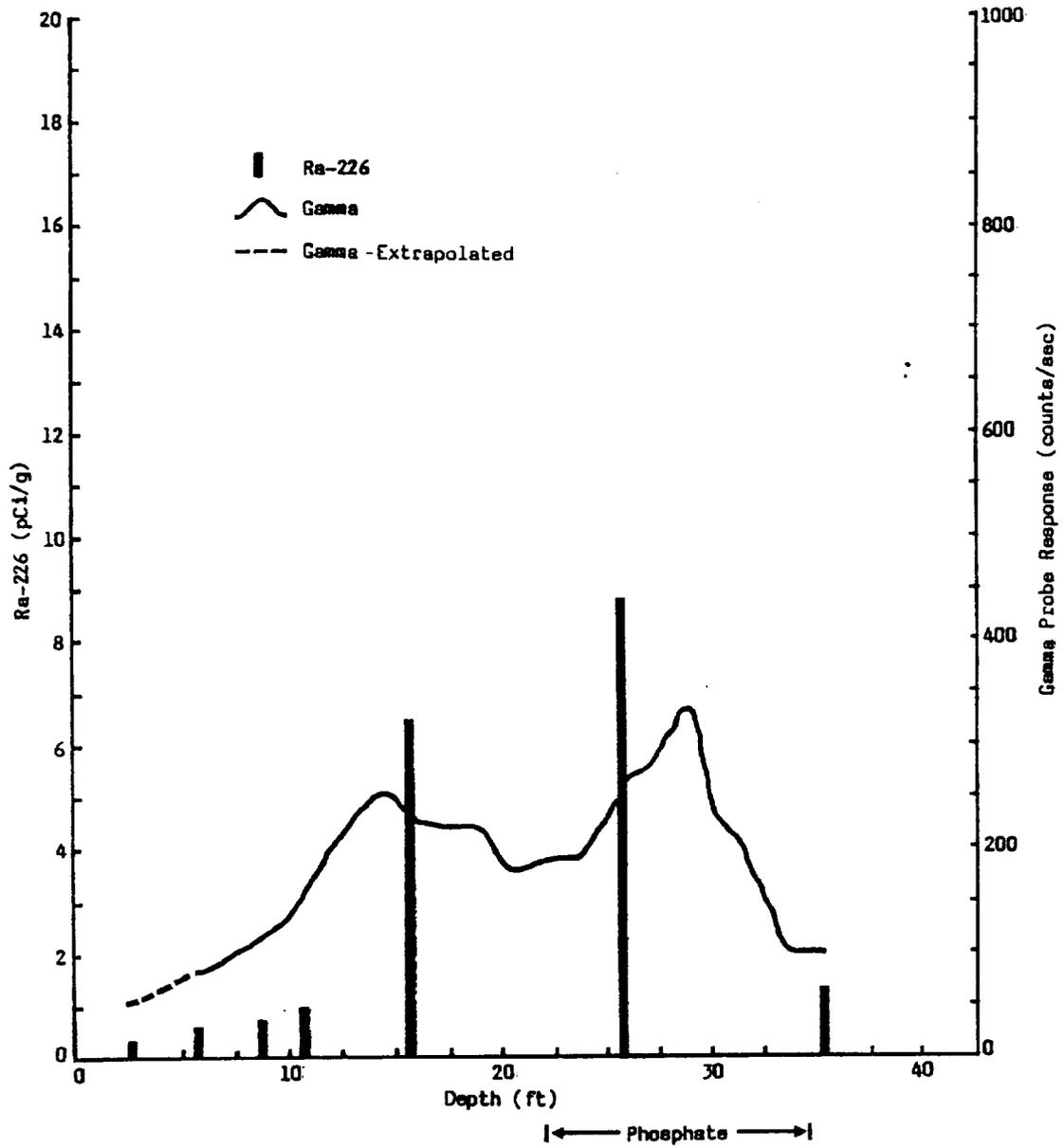


Figure 3.7-7. Gamma Log and Radium-226 Profiles for Test Hole 12.

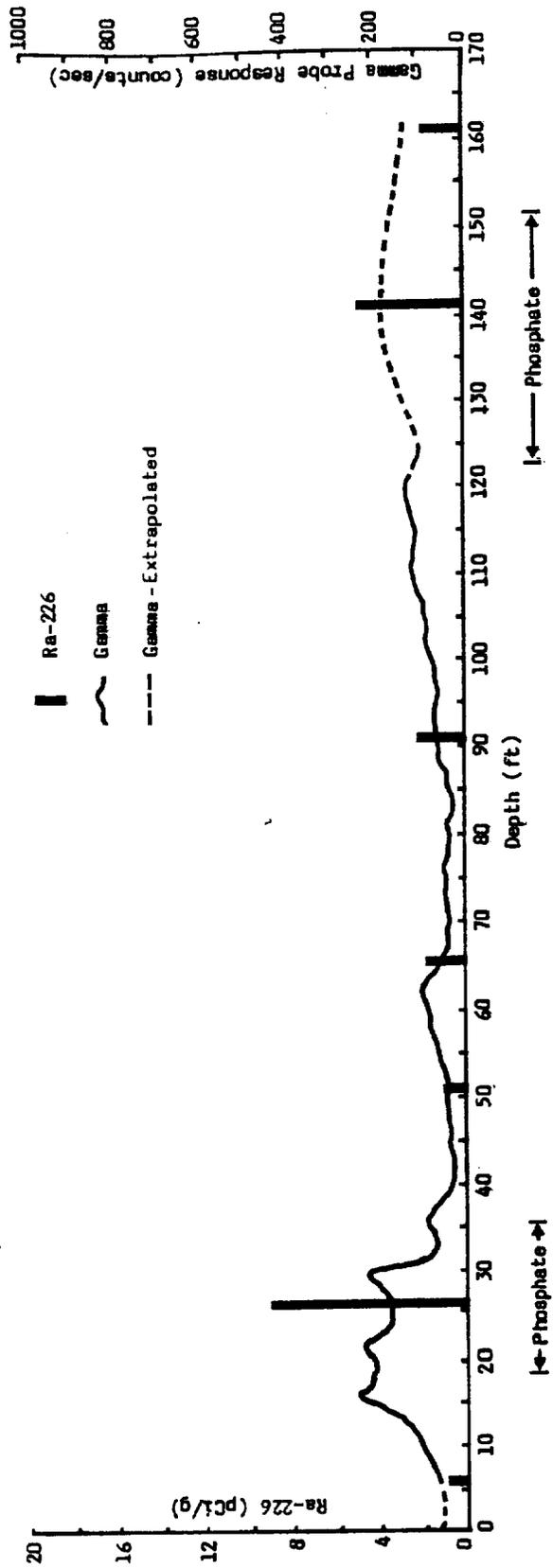


Figure 3.7-8. Gamma Log and Radium-226 Profile for Test Hole 14.

springs, waters with high solids content, and waters that drain fertilized farming areas (Table 3.7-8). The Ra-226 levels in these waters can range up to 5 pCi/l. In reviewing Ra-226 data, it is important to realize that the method of sample preparation and handling can change the concentrations by an order of magnitude. Dissolved, undissolved, or total radium may be fractionated by various filtering procedures and may be reported differently. Acid treatment techniques may change radium from an undissolved state to a dissolved form. Thus, the comparison of data presented by different authors is difficult. Order of magnitude changes at concentrations <1 pCi/l should not be considered significant without additional knowledge of the methods of analysis. The drinking water standard for radium (Table 3.7-1, Item 8) is 5 pCi/l. Imbedded in this standard is the requirement for radium analyses only when gross alpha exceeds 15 pCi/l.

The gross beta activity in hundreds of surface waters of the United States tends to average approximately 5 pCi/l with a normal range of 3-25 pCi/l. The gross alpha activity in surface waters is generally <1 pCi/l, with a small fraction of waters showing activities up to 3 pCi/l. Those waters with gross alpha concentrations >3 pCi/l generally are associated with a specific geological formation or with a contaminating source. The general guideline followed during federal monitoring programs designed to evaluate the impact of nuclear weapons testing was to look for specific radionuclides when gross beta exceeded 10 pCi/l or gross alpha exceeded 3 pCi/l. The gross alpha and gross beta data for OXY should be viewed with respect to these reference levels.

Data for uranium in surface waters are much fewer in number and geographical coverage (Table 3.7-9). Data for Ra-228 and thorium are sparse. In the Estech EIS, five water samples were analyzed and no Ra-228 was detected, the lower limit of detectability being 0.9 pCi/l (Bolch 1979a).

The sampling period for radioactivity in surface water at the OXY site spanned the period 1 August 1981 through 20 April 1982 (Table 3.7-10, Figure 3.7-2). Three types of surface water were sampled: 1) areas not receiving OXY discharge (unaffected or baseline stations), including the upper Suwannee River and some of its tributaries, 2) potentially impacted areas, including Hunter and Swift creeks and the lower Suwannee, and 3) recirculating waters or reclaimed lakes.

Unaffected Stations. For the baseline stations, gross beta activity ranged from 1.0 to 12 pCi/l with an average of 5.1 pCi/l (Table 3.7-11), and gross alpha activity ranged from 0.4 to 2.9 pCi/l with an average of 1.5 pCi/l (Table 3.7-12). Of the 48 samples analyzed for gross alpha activity, 28 had alpha activity levels that were less than the lower limit of the detection (LLD), which averaged approximately 1.6 pCi/l.

The concentration of Ra-226 in 26 surface water samples was greater than the LLD in 16 of the samples and averaged 0.15 pCi/l, compared with a standard of 5 pCi/l (Table 3.7-13). While the average LLD for Ra-228 was approximately 1.5 pCi/l, a few "positive" concentrations were reported below this level (Table 3.7-13). These concentrations, however, have errors associated with them ranging from  $\pm 53\%$  to  $\pm 100\%$ .

Table 3.7-8. Radium-226 in Surface Waters in the United States and in Florida.

Type	Location	Ra-226 (pCi/l)
Curie Spring	Boulder, Colorado	267,000
Great Salt Lake	Utah	5.0
River waters	Average North America	0.03
Mississippi River	St. Louis, Missouri	1.2-2.9
Ohio River	Pennsylvania	0.6
Surface water supply	Chicago, Illinois	0.03
Lithia Springs	Lithia, Florida	0.68
Alafia River	Lithia, Florida	0.06
Peace River	Ft. Meade, Florida	0.12
Proposed Four Corners Mine site	Hillsborough and Manatee counties, Florida	0.18
Peace River basin	Hillsborough, Polk, Manatee and Hardee counties, Florida	0.94
Lake Manatee	Discharge at Sullivan's Bridge	0.32
Lake Manatee	Manatee County, Florida	<0.8
Manatee and Myakka rivers	(S12, S25, T34S, R21E; S15, T35S, R22E)	0.1
Manatee River	At CR 6	0.8
Proposed Hookers Prairie Mine	Bradley Junction, Florida	0.8
Proposed Duette Mine	Manatee County, Florida	<0.8
		1.8
		2.4
Peace, Myakka, Alafia, and Hillsborough rivers; Lake Hancock	West Central Florida	0.23
Proposed Noranda Mine	Desoto County, Florida	0.21
Proposed AMAX Mine	Desoto and Manatee counties	0.40
Port Charlotte	Florida (Lat. 28° 08' 59" Long. 82° 13' 57")	1.1
Off-site creeks, OXY mines	Hamilton County, Florida (1977)	<0.3-0.3
Suwannee River	Hamilton County, Florida (1977)	0.8
Osceola National Forest	Columbia County, Florida (1977)	0.07

Source: Bolch 1979b.

Table 3.7-9. Uranium (U) in Surface Waters in Florida.

Type	Location	U ( $\mu\text{g}/\text{l}$ )
A creek, a river, and two lakes	Florida	0.09 (4)
Duette Mine	Manatee County, Florida	<0.12 (4)
Peace, Myakka, Alafia, and Hillsborough rivers, and Lake Hancock, Florida	West Central Florida	<0.5 (10)
Port Charlotte	Florida	3.1

\*Number in parentheses indicates number of samples collected.

Note:  $1 \mu\text{g}/\text{l} = 0.001 \text{ ppm} = 0.33 \text{ pCi}/\text{l}$  for U or U-238.

Source: Bolch 1979b.

Table 3.7-10. Surface Water Stations for Radioactivity Monitoring on the OXY Project Site.

Station	Location
<u>Unaffected</u>	
SR-1	Suwannee River above CR 6.
SR-2	Suwannee River, CR 6 bridge.
RC-2	Rocky Creek between Woodpecker Road wooden bridge (just before Suwannee River) and headwaters of Bee Haven Bay.
RC-5	
RC-6	
RC-10	
AR-3	Alapaha River near mouth.
SF-2	Santa Fe River at US 129 bridge.
RO-2	Roaring Creek between CR 135 bridge and headwaters in swamp (CR 135 culvert).
RO-5	
RO-15	
FMB-2	Four Mile Branch at CR 135 bridge culvert.
CB-1.5	Camp Branch at CR 225A.
WR-3	Withlacoochee River near Ellaville.
LB-1	Long Branch at the mouth.
HB-2	Hogans Branch at Sugar Ridge Road.
<u>Potentially Impacted</u>	
HC-1	Hunter Creek from mouth to Suwannee River plant.
HC-2	
HC-3	
HC-4	
SR-5	Suwannee River from White Springs to 10 mi below Swift Creek (Branford).
SR-8	
SR-10	
SR-20	
SC-1	From near input to Suwannee to US 41 bridge.
SC-4	

Table 3.7-10 (Continued).

Station	Location
<u>Recirculating Waters and Reclaimed Lakes</u>	
RS-1 RS-2 RS-4	Recirculating water at the Suwannee River Chemical Complex.
EL001-18	Eagle Lake at exit control structure.
AB-3	Altmans Bay at exit control structure.
S13D-1	Section 13D Lake at exit control structure.

Table 3.7-11. Gross Beta Concentrations (pCi/l) in Surface Waters of Unaffected Stations.

Station	11/11/81	12/17/81	1/20/82	2/19/82	3/23/82	4/20/82
SR-1	-	-	-	3.6±3.5	-	-
SR-2	3.0±2.5	<4.0	<4.0	6.6±4.0	3.0±2.5	3.4±3.2
AR-3	-	-	-	6.9±3.9	-	-
WR-3	-	-	-	6.3±3.1	-	-
SF-2	-	-	-	6.6±4.4	-	-
RC-2	4.9±2.8	7.9±4.3	-	4.7±3.1	-	-
RC-5	-	<3.9	5.9±3.5	5.4±3.7	2.7±2.3	-
RC-6	-	<4.0	-	3.5±2.8	-	-
RC-10	-	<3.5	-	7.5±4.1	-	-
RO-2	-	2.4±2.2	3.8±3.1	3.5±3.1	5.8±2.9	6.2±4.2
RO-5	-	5.6±2.8	-	12.0±4.2	-	-
RO-15	-	-	-	5.5±4.0	-	-
FMB-2	-	4.5±3.8	2.9±2.3	5.4±3.4	1.0±0.8	-
CB-1.5	-	2.6±2.6	5.6±5.6	6.0±4.0	7.0±3.9	10.8±5.0
LB-1	-	-	-	3.9±3.3	-	-
HB-2	-	-	-	4.5±3.8	-	-

Table 3.7-12. Gross Alpha Concentrations (pCi/l) in Surface Waters of Unaffected Stations.

Station	8/81	11/11/81	12/17/81	1/20/82	2/19/82	3/23/82	4/20/82
SR-1	1.2±1.2	-	-	-	<1.0	-	-
SR-2	-	<1.2	<1.6	<1.2	<2.2	1.7±1.1	<2.1
AR-3	-	-	-	-	1.4±1.4	-	-
WR-3	1.6±1.2	-	-	-	<1.2	-	-
SF-2	2.9±2.0	-	-	-	<0.9	-	-
RC-2	1.9±1.9	<1.0	<0.9	-	<1.8	-	-
RC-5	1.5±1.0	-	<3.0	<2.7	1.3±1.5	<1.6	-
RC-6	0.7±0.7	-	<1.3	-	<0.9	-	-
RC-10	-	-	<1.0	-	<1.9	-	-
RO-2	0.6±0.6	-	<1.4	<0.7	<2.7	<2.3	<1.6
RO-5	-	-	<1.4	-	<3.0	-	-
RO-15	-	-	-	-	<1.4	-	-
FMB-2	-	-	<1.8	<1.5	<1.9	0.4±0.4	-
CB-1.5	-	-	<1.2	<1.5	2.7±1.9	2.0±1.6	2.4±1.7
LB-1	1.2±0.8	-	-	-	<1.9	-	-
HB-2	-	-	-	-	1.7±1.5	-	-

Table 3.7-13. Radium Concentrations (pCi/l) in Surface Waters of Unaffected Stations.

Station	8/81	11/11/81	2/19/82	
	Ra-226	Ra-226	Ra-226	Ra-228
SR-1	1.1±0.6	-	0.07±0.04	0.5±0.5
SR-2	-	<0.1	0.06±0.05	<2.6
AR-3	-	-	0.18±0.06	<1.2
WR-3	<0.6	-	0.06±0.05	<0.7
SF-2	1.8±1.6	-	-	<1.8
RC-2	<0.6	0.1±0.1	0.11±0.05	<1.5
RC-5	<0.6	-	<0.04	<1.3
RC-6	<0.6	-	<0.06	<1.9
RC-10	-	-	0.05±0.05	0.8±0.8
RO-2	<0.6	-	0.08±0.05	0.5±0.5
RO-5	-	-	0.06±0.06	<1.8
RO-15	-	-	0.07±0.04	1.0±1.0
FMB-2	-	-	<0.05	-
CB-1.5	-	-	0.07±0.05	<2.6
LB-1	<0.6	-	0.12±0.05	1.9±1.0
HB-2	-	-	0.15±0.06	<1.0

It can be concluded that the background surface water stations had Ra-226 and Ra-228 concentrations which were at or less than the LLD of the analytical methods.

Potentially Impacted Stations. Gross beta activity in potentially impacted surface water samples averaged 5.5 pCi/l, with a range of 2.5-10.0 pCi/l (Table 3.7-14). Of the 33 samples analyzed for gross alpha activity, 18 showed positive concentrations (Table 3.7-15), while the remaining 15 samples had gross alpha concentrations below the average LLD (1.7 pCi/l). The highest recorded gross alpha activity from radionuclides such as Ra-226, Th-230, or Po-210 was 6.8 pCi/l.

Two different laboratories were used for conducting the Ra-226 analyses, with one recording an LLD of 0.6 pCi/l and the other an LLD of 0.07 pCi/l. All of the samples had Ra-226 concentrations of <1.0 pCi/l, with an average of the ten positive samples being 0.21 pCi/l (Table 3.7-16). The data for Ra-228 are somewhat questionable as the average LLD was 1.9 pCi/l and the average positive concentration (average of three samples) was 1.5 pCi/l. The variability in dissolved solids in the samples was likely the principal cause of the variability in the sensitivity. The Ra-228 concentrations in potentially impacted surface waters were not statistically different from the Ra-228 concentrations in background waters.

Recirculating Waters and Reclaimed Lakes. The gross beta activity in the recirculating water system and reclaimed lakes was 50% higher than the gross beta activity in the unaffected waters and the potentially impacted waters. The average gross beta activity in the recirculating water system and reclaimed lake waters was 8.0 pCi/l with a high of 14.5 pCi/l (Table 3.7-17).

Gross alpha activity was approximately 2X higher than that in the unaffected waters and approximately 50% higher than the activity in the potentially impacted waters (Table 3.7-18). The pattern of higher activity followed into the Ra-226 data; however, all of the Ra-226 concentrations were lower than the drinking water standard of 5 pCi/l (Table 3.7-19).

There appeared to be a progressive increase in gross beta activity, gross alpha activity, and Ra-226 concentrations from the unaffected waters to the potentially impacted waters to the recirculating waters and reclaimed lakes (Table 3.7-20). However, none of the waters contained a level of radioactivity that would cause concern. Radium concentrations were a fraction of drinking water standards, and levels of gross alpha and gross beta activity were within the range of activities for natural surface waters in the United States.

Suwannee River Radioactivity. Preliminary results of a surface water survey of the Suwannee River conducted by the Department of Oceanography, Florida State University, showed no detectable radiological impact by surface water discharging from the OXY property as measured by Ra-226 (Table 3.7-21). The Ra-226 concentration in the Suwannee River water was relatively constant, ranging from 0.09 to 0.13 pCi/l. This concentration compares to an average Ra-226 concentration in unaffected

Table 3.7-14. Gross Beta Concentrations (pCi/l) in Surface Waters of Potentially Impacted Areas.

Station	11/11/81	12/17/81	1/20/82	2/19/82	3/23/82	4/20/82
SR-5	2.5±1.8	3.9±3.7	-	10.0±4.4	3.4±2.2	-
SR-8	-	-	-	4.9±3.9	-	-
SR-10	-	-	5.8±3.6	4.4±3.1	4.4±3.0	4.1±4.1
SR-20	-	-	-	8.2±4.1	-	-
HC-1	3.3±2.1	-	-	-	-	-
HC-2	-	4.5±2.9	8.0±3.9	<4.0	5.8±3.0	<3.3
HC-3	-	3.2±2.7	-	4.8±4.2	3.0±3.5	6.1±3.5
HC-4	-	-	-	5.3±3.9	-	-
SC-1	-	-	-	5.5±4.1	-	-
SC-4	-	7.8±4.9	6.8±4.0	10.0±4.5	-	-

Table 3.7-15. Gross Alpha Concentrations (pCi/l) in Surface Waters of Potentially Impacted Areas.

Station	8/81	11/11/81	12/17/81	1/20/82	2/19/82	3/23/82	4/20/82
SR-5	1.1±0.7	1.1±1.0	<2.1	-	2.0±0.6	<1.0	-
SR-8	1.6±1.5	-	-	-	2.0±1.7	-	-
SR-10	6.8±3.6	-	-	<1.6	<1.5	<2.9	2.0±1.7
SR-20	2.4±1.7	-	-	-	<2.1	-	-
HC-1	-	<1.3	-	-	-	-	-
HC-2	1.0±1.0	-	<1.9	2.1±1.7	<1.5	1.9±1.8	<1.9
HC-3	0.8±0.8	-	<1.8	-	<1.2	<0.8	3.0±1.5
HC-4	-	-	-	-	1.7±1.6	-	-
SC-1	5.1±3.4	-	-	-	<2.7	-	-
SC-4	4.6±3.5	-	<2.1	1.8±1.7	3.1±2.1	-	-

Table 3.7-16. Radium Concentrations (pCi/l) in Surface Waters of Potentially Impacted Areas.

Station	8/81	11/11/81	2/19/82	
	Ra-226	Ra-226	Ra-226	Ra-228
SR-5	<0.6	<0.1	0.10±0.06	2.0±1.5
SR-8	<0.6	-	0.23±0.07	1.1±0.5
SR-10	<0.6	-	0.05±0.05	<1.0
SR-20	<0.6	-	-	<2.0
HC-1	-	0.2±0.1	-	-
HC-2	<0.6	-	0.25±0.07	<1.4
HC-3	<0.6	-	0.14±0.06	<3.1
HC-4	-	-	0.08±0.05	1.4±1.0
SC-1	<0.6	-	0.12±0.05	<2.8
SC-4	0.8±0.6	-	0.30±0.08	<1.2

Table 3.7-17. Gross Beta Concentrations (pCi/l) in Recirculating Waters (RS-1, RS-2, RS-4) and Reclaimed Lakes (EL001-18, AB-3, S13D-1).

Station	12/17/81	1/20/82	2/19/82	3/23/82	4/20/82
RS-1	<3.6	11.2±6.0	5.4±3.1	7.7±5.3	11.6±5.9
RS-2	5.9±4.8	-	-	-	-
RS-4	-	7.7±5.1	-	8.6±4.9	8.5±5.6
EL001-18	9.5±5.1	14.5±5.1	11.3±4.4	4.9±2.9	9.2±5.5
AB-3	3.1±3.1	6.1±4.1	4.5±3.6	6.5±4.1	3.2±2.0
S13D-1	5.2±3.1	8.9±3.0	11.9±4.5	8.2±4.5	11.5±5.5

Table 3.7-18. Gross Alpha Concentrations (pCi/l) in Recirculating Waters (RS-1, RS-2, RS-4) and Reclaimed Lakes (EL001-18, AB-3, S13D-1).

Station	8/81	12/17/81	1/20/82	2/19/82	3/23/82	4/20/82
RS-1	2.1±1.8	<1.4	5.6±3.6	<1.6	5.9±2.4	2.5±2.0
RS-2	2.2±2.0	<2.3	-	-	-	-
RS-4	9.3±3.4	-	4.4±3.0	-	5.4±2.9	6.8±3.2
EL001-18	3.6±3.5	<2.0	5.5±2.9	<2.9	1.6±1.2	2.4±2.0
AB-3	1.4±1.2	2.1±1.9	2.3±2.0	<1.6	3.0±2.0	2.0±0.8
S13D-1	-	<2.1	1.8±1.3	4.6±2.4	3.9±4.5	4.7±2.5

Table 3.7-19. Radium Concentrations (pCi/l) in Recirculating Waters (RS-1, RS-2, RS-4) and Reclaimed Lakes (EL001-18, AB-3, S13D-1).

Station	8/81	2/19/82	
	Ra-226	Ra-226	Ra-228
RS-1	1.7±0.9	0.09±0.05	<2.6
RS-2	<0.6	-	-
RS-4	<0.6	-	-
EL001-18	<0.6	0.52±0.10	1.8±1.8
AB-3	<0.6	0.12±0.07	<1.5
S13D-1	-	0.95±0.14	<2.5

Table 3.7-20. Radioactivity Concentrations (pCi/l) in Surface Waters.

Sample Type	Gross $\beta$	Gross $\alpha$	Ra-226
<u>Unaffected Stations</u>			
	5.1 <sup>1</sup>	1.5	0.15
	36/41 <sup>2</sup>	15/48	16/26
	<3.9 <sup>3</sup>	<1.6	<0.38
<u>Potentially Impacted Areas</u>			
	5.5	2.6	0.21
	24/26	21/37	11/21
	<3.6	<1.7	<0.55
<u>Recirculating Waters and Reclaimed Lakes</u>			
	8.0	3.8	0.82
	23/24	22/29	7/14
	<3.6	<2.0	<1.3

<sup>1</sup>Mean of positive values.

<sup>2</sup>No. of positive values/no. analyzed.

<sup>3</sup>Mean LLD.

Table 3.7-21. Suwannee River Study Ra-226 Concentrations.

Station	Location	Time	Ra-226 (pCi/l)
1	Above Hunter Creek	1/82	0.09
3a	Above Swift Creek	1/82	0.13
3b	Above Swift Creek	1/82	0.10
4a	Below Swift Creek	1/82	0.13
4b	Below Swift Creek	1/82	0.12
6	Below Withlacoochee	1/82	0.13
9	Branford	1/82	0.10
1	Above Hunter Creek	2/82	0.09
3a	Above Swift Creek	2/82	0.10

Source: Unpubl. data, Dept. of Oceanography, Florida State University.

surface water samples of 0.15-0.21 pCi/l on the OXY property and to a range of 0.09 to 1.7 pCi/l in impacted recirculating waters (Table 3.7-19).

### 3.7.8.2 Distribution Coefficients

The water management program of the OXY mining operation will determine the potential for radiological contamination of off-site surface water during the mining of the phosphate rock. The reclamation of the mined-over lands, including plans for area drainage and measures to prevent the runoff of turbid waters, will determine the potential long-term radiological impact. It is important to recognize that radium is highly insoluble compared to other minerals, and measures to control the other minerals are normally sufficient to limit the impact of Ra-226. Ra-228 need not be considered in the analyses because of the low levels of this nuclide encountered.

One method used to measure the potential for surface water or ground-water contamination is the concept of a distribution coefficient ( $K_d$ ). This coefficient relates the activity of a solid phase with the activity of the water phase in contact with the solid phase; the higher the value of  $K_d$ , the greater the potential for increased levels of activity in surface waters. The distribution coefficient is defined as

$$K_d = \frac{\text{pCi per gram in the solid phase}}{\text{pCi per liter in the liquid phase.}}$$

It is assumed that the activity in the water will be in equilibrium with the activity in the sediments within the water system.

The water was actually flowing at the sampling stations previously discussed; therefore, the equilibrium was associated with upstream sediments. The distribution coefficient concept is valid for magnitude calculations if one assumes that the sediment accumulations are likely to remain fairly constant for a considerable distance (time of flow) upstream of the sampling site.

The Ra-226 concentration in the sediments at the unaffected stations averaged 0.27 pCi/g (Table 3.7-22). The sediments at the potentially impacted stations had an average Ra-226 concentration of 0.53 pCi/g (Table 3.7-23), and the Ra-226 concentrations in the recirculating water/reclaimed lake sediments were, in general, an order of magnitude higher than concentrations found in the other two groups of sediments (Table 3.7-24).

The distribution coefficients for all of the unaffected surface water monitoring stations followed a fairly consistent pattern (Table 3.7-25). The geometric mean distribution coefficient for the nine stations is 3000 ml/g. The potentially impacted waters have a distribution coefficient of 2000 ml/g which is similar to that of the unaffected waters.

The distribution coefficient for one of the recirculating water/reclaimed lake stations was markedly different from the distribution

Table 3.7-22. Sediment Radioactivity Concentrations (pCi/g) of Unaffected Stations.

Station	Ra-226	U-238	Th-232	K-40
SR-1	0.38±0.06	<0.37	0.30±0.05	3.0±0.50
WR-3	0.23±0.05	<0.31	0.07±0.04	<0.42
SF-2	0.64±0.08	0.86±0.31	0.12±0.05	0.43±0.23
RC-2	0.39±0.06	<0.64	0.06±0.04	0.73±0.27
RC-5	0.098±0.03	<0.34	0.08±0.02	<0.31
RC-6	0.13±0.03	<0.28	0.04±0.02	<0.36
RC-10	0.15±0.02	<0.15	0.12±0.02	<0.09
RO-5	0.18±0.04	<0.64	0.09±0.03	0.18±0.13
RO-15	0.091±0.03	<0.21	0.09±0.02	0.22±0.10
CB-1	0.53±0.06	<0.37	<0.05	0.53±0.02
LB-1	0.20±0.08	<0.52	0.08±0.03	1.4±0.04
HB-2	0.18±0.06	<0.56	<0.05	<0.42

Table 3.7-23. Sediment Radioactivity Concentrations (pCi/g) in Potentially Impacted Areas.

Station	Ra-226	U-238	Th-232	K-40
SR-5	0.34±0.04	0.44±0.16	0.05±0.02	2.2±0.29
SR-8	0.21±0.04	0.36±0.20	0.05±0.02	0.75±0.25
SR-10	0.35±0.06	<0.34	0.23±0.04	1.8±0.42
SR-20	0.67±0.07	<0.67	0.35±0.05	1.2±0.36
HC-2	0.88±0.09	1.1±0.34	0.21±0.06	<0.48
HC-3	0.18±0.04	<0.30	0.07±0.03	<0.30
HC-4	0.40±0.05	0.60±0.26	0.19±0.04	<0.19
SC-1	0.65±0.07	<0.36	0.32±0.05	1.3±0.38
SC-4	1.0±0.13	2.2±0.59	0.31±0.07	<0.87

Table 3.7-24. Sediment Radioactivity Concentrations (pCi/g) in Recirculating Waters (RS-2, RS-4) and Reclaimed Lakes (EL001-18, AB-3).

Station	Ra-226	U-238		Th-232	K-40
RS-2	5.3±0.20	6.4±0.65		<0.11	<0.86
RS-4	14.0±0.27	10.3±0.77		<0.13	1.7±0.55
EL001-18	0.97±0.08	0.77±0.29	1.3±0.29	0.17±0.04	0.58±0.21
AB-3	2.9±0.13	2.6±0.45	3.7±0.43	<0.08	0.79±0.34

Table 3.7-25. Distribution Coefficients (and Geometric Means) for Radium-226 in Surface Waters.

Station	Kd (pCi/g)/(pCi/ml)
<u>Unaffected</u>	
RC-2	4,000
RC-10	3,000
SR-1	5,000
RO-5	3,000
RO-15	1,000
CB-1.5	8,000
WR-3	4,000
LB-1	2,000
HB-2	1,000
$\bar{x}$	3,000
<u>Potentially Impacted</u>	
HC-2	4,000
HC-3	1,000
HC-4	1,000
SR-5	3,000
SR-8	900
SR-10	7,000
SC-1	5,000
SC-4	3,000
$\bar{x}$	2,000
<u>Recirculating Waters and Reclaimed Lakes</u>	
EL001-18	2,000
AB-3	20,000
$\bar{x}$	10,000

coefficients for the unaffected stations and potentially impacted stations. The distribution coefficient for Station AB-3 was 20,000 ml/g. This coefficient indicates a potential for producing a higher concentration of radioactivity in the water phase per unit of activity in the solid phase; however, the distribution coefficient at Eagle Lake, a reclaimed lake, was 2000 ml/g, which is similar to the value of the distribution coefficients found in the unaffected and potentially impacted waters. These distribution coefficients will be utilized to quantify the impacts.

### 3.7.8.3 Groundwater Radioactivity

Groundwater contamination by Ra-226 or other radionuclides is a potential associated with phosphate mining operations. A review of the literature and an analysis of Ra-226 in groundwaters of central Florida are presented by Kaufmann and Bliss (1977). Three strata (the upper water table, the upper Floridan Aquifer, and the lower Floridan Aquifer) were statistically analyzed for radium during 1966 and 1973-1976. Each water resource was considered in three geographical areas of the central Florida area: mined areas containing phosphate rock, unmined areas containing phosphate rock, and unmined areas with no significant phosphate deposits (Table 3.7-26). All data for a particular set were found to be distributed lognormally; therefore, geometric means were considered for comparing the data sets. Statistical tests indicated no significant difference between the radium concentrations in the water table aquifer of the mined lands and unmined lands containing phosphate reserves. No data were available for unmined lands with no phosphate reserves.

The Ra-226 concentrations in the upper and lower Floridan Aquifer of both the mined and unmined areas with phosphate reserves were approximately equal, and concentrations in the two areas were similar in both aquifers. In unmined lands without phosphate reserves, statistical tests on the data showed that the Ra-226 concentrations in the upper Floridan Aquifer were significantly greater than the Ra-226 concentrations in this aquifer in both mined and unmined lands containing phosphate reserves. Also significant is the fact that the Ra-226 concentrations in both the upper and lower Floridan Aquifer were higher than the Ra-226 concentrations in the surface water table in both mined and unmined lands with phosphate reserves.

In their review of central Florida water quality data, Kaufmann and Bliss (1977) did not consider gamma activity logs of deep wells. Gamma activity logs show considerable radioactivity in the Hawthorn Formation overlying the Floridan Aquifer, and the logs strongly suggest that the lower Hawthorn Formation may itself be a source of Ra-226 in the Floridan Aquifer. Gamma activity logs made in areas that do not contain phosphate reserves may be useful in explaining why the Ra-226 concentration in the Floridan Aquifer in areas without phosphate reserves was greater than or equal to Ra-226 concentrations in both mined and unmined areas that contained phosphate reserves. Data from the gamma activity logs demonstrate that uranium, and therefore radium, is associated with the entire Hawthorn Formation.

Table 3.7-26. Summary of Radium-226 Data (Geometric Means) in Central Florida Aquifers.

Area Description	Water Table		Upper Floridan		Lower Floridan	
	No.	pCi/l	No.	pCi/l	No.	pCi/l
Unmined mineralized	23	0.17	5	2.30	24	2.00
Mined mineralized	12	0.55	10	1.61	6	1.96
Nonmineralized (control)	-	-	3	5.10	14	1.40

Source: Kaufmann and Bliss 1977.

Another finding by Kaufmann and Bliss was the presence of three separate groups of Ra-226 concentrations in the lower Floridan Aquifer. They mention increased solubility of radium in groundwater enriched by chlorides, potentially from saltwater intrusion due to the pumping from the lower Floridan Aquifer. Industry data support this theory (Bolch 1979a).

Kaufmann and Bliss found Ra-226 in wells in Sarasota County to be two orders of magnitude greater in the water table aquifer and almost one order of magnitude greater in the Floridan Aquifer than in similar samples collected in the Polk County area. Dissolution of Ra-226 from the upper Hawthorn Formation may account for the first finding; interaction with saltwater intrusion may account for the second finding.

Morton (1977) plotted dissolved Ra-226 versus depth for three central Florida groundwater surveys. This plot has been updated with recent data from various environmental studies (Figure 3.7-9). The pattern of Ra-226 concentrations with depth, even though the data are from numerous locations, is similar to the various gamma activity logs of deep wells. The two high concentrations shown in Figure 3.7-9 at the 700-800 ft depth and the 1200-1300 ft depth could both be associated with high salinity lenses in the aquifer.

The groundwater sampling stations utilized in the OXY study are shown in Figure 3.7-3. The radiological data (gross beta, gross alpha, and Ra-226) are summarized in Table 3.7-27 by well type and depth. The gross beta results were generally greater than the gross alpha levels which, in turn, were higher than the observed Ra-226 concentrations. In general, the Surficial Aquifer samples were at the same level of activity as those of the Secondary Aquifer, whereas the radioactivity in the Floridan Aquifer samples were generally 3-5X lower. The Ra-226 levels were lower than those observed in central Florida (Figure 3.7-9).

The potential for groundwater contamination by mining activities is minimal. The most serious radioactive contaminant, Ra-226, is found in all subsurface strata at various concentrations, including some that are much higher than the mined matrix; therefore, the problem of identifying additional contamination beyond natural causes and determining its source is exceedingly complex. The fact that Ra-226 has remained in approximate equilibrium with its precursors through centuries of groundwater infiltration and the demonstrated insolubility of Ra-226 during the extreme conditions of the slurry transport of the phosphate matrix through the beneficiation plant demonstrate that mining has a minimum impact on the radiological condition of the groundwater. Other more soluble chemical contaminants would reach unacceptable levels in the groundwater before radioactivity would become the limiting condition.

#### 3.7.9 Biological Uptake

Because Ra-226 is chemically similar to calcium, magnesium, strontium, and barium, the absorption of radium from soils and/or water and its passage up the food chain by systems normally seeking a divalent cation

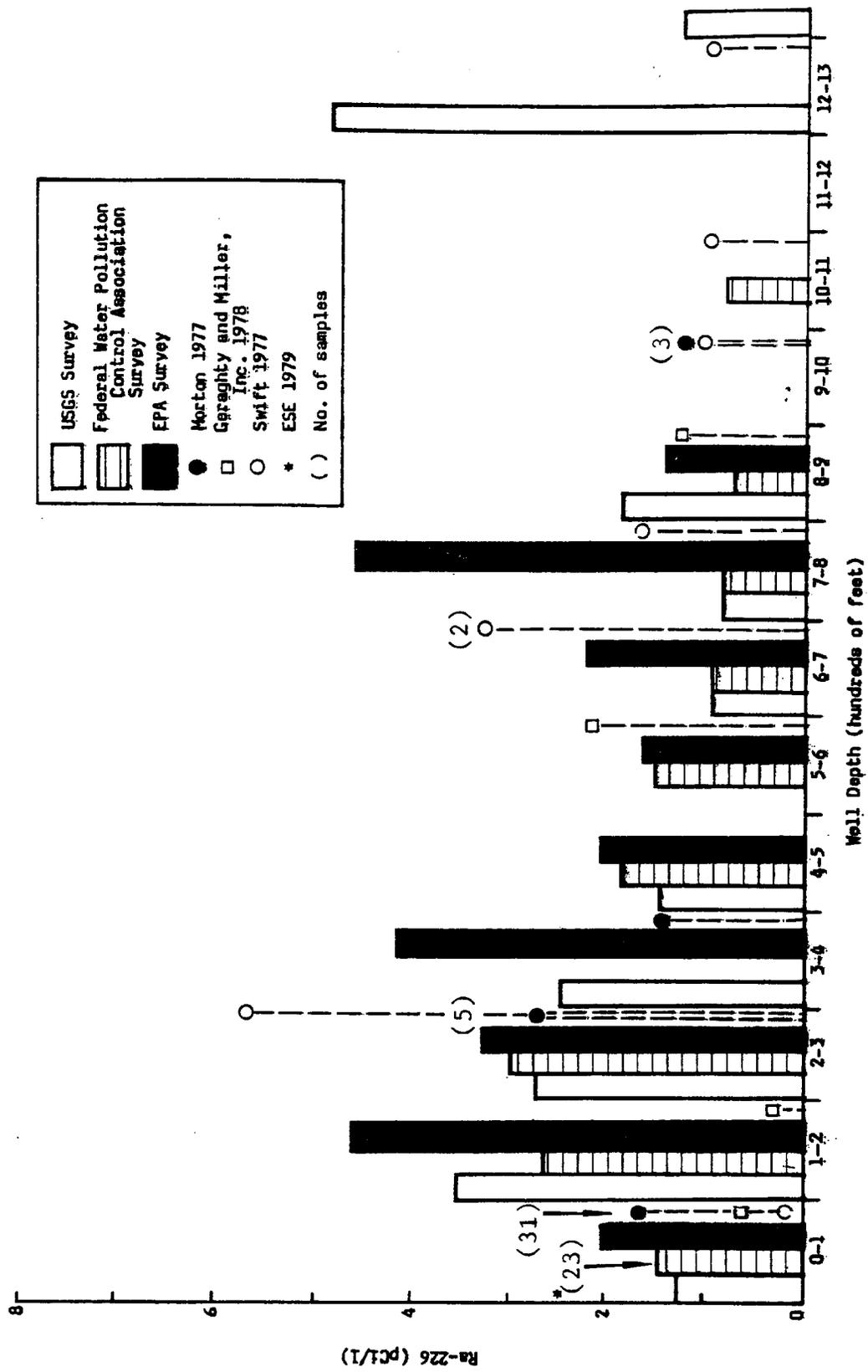


Figure 3.7-9. Radium-226 Concentrations Versus Well Depth in Well Water in Central Florida.

Table 3.7-27. Groundwater Radioactivity Concentrations (pCi/l).

Station	Aquifer	Depth (ft)	Gross $\beta$	Gross $\alpha$	Ra-226
PZ-1	Surficial	35	15 $\pm$ 5.8	5.6 $\pm$ 3.4	0.62 $\pm$ 0.19
PZ-1A	Surficial	14	22.5 $\pm$ 6.8	5.8 $\pm$ 3.6	1.48 $\pm$ 0.16
P5	Surficial	28	12 $\pm$ 5.3	3.4 $\pm$ 2.6	1.2 $\pm$ 0.15
P5A	Surficial	8	16 $\pm$ 6.2	4.3 $\pm$ 3.1	1.0 $\pm$ 0.13
P-10	Surficial	40	6.6 $\pm$ 3.9	<2.2	0.17 $\pm$ 0.06
P-10A	Surficial	18	8.1 $\pm$ 4.2	<1.2	0.33 $\pm$ 0.08
TH-2	Surficial	43	83 $\pm$ 15	13 $\pm$ 7.4	1.8 $\pm$ 0.17
2C	Secondary	130	31.0 $\pm$ 16	8.8 $\pm$ 7.9	0.14 $\pm$ 0.05
3D	Secondary	240	12 $\pm$ 5.2	<1.6	0.30 $\pm$ 0.07
M-1	Floridan	1265	6.2 $\pm$ 2.8	<1.8	0.25 $\pm$ 0.07
025-246-1	Floridan	240	3.5 $\pm$ 0.7	<1.0	0.36 $\pm$ 0.10

is possible. The critical organ affected by radium is bone, as calcium is a building block of bone.

Uptake of Ra-226 from soils is a complicated mechanism. In a study undertaken for the Estech-Duette mine EIS (Bolch 1979a), two squash crops were planted: one on reclaimed clays and one on undisturbed lands. About half a bushel of squash from each crop was dried and analyzed for Ra-226. The squash from the reclaimed clays had a lower Ra-226 concentration than the squash grown on the undisturbed land (0.0024 pCi/g versus 0.0072 pCi/g), whereas the soil Ra-226 levels were reversed (13 pCi/g for the reclaimed clay area and 0.17 pCi/g for the undisturbed land). A partial explanation of this apparent anomaly can be related to the nutrients available in the two soils. It was found that the equivalent calcium oxide level in the reclaimed clays was 10X higher than in the undisturbed soil, and the available magnesium oxide concentration in the clays was 20X higher than in the undisturbed soils. The theory relating these factors is that the plant uptake potential is for divalent cations, and the reclaimed clays have an excess of calcium and magnesium; therefore, the Ra-226, which is present in ultratrace quantities, is discriminated against. Conversely, Ra-226 uptake in nutrient-poor undisturbed soil is due to an attempt by the plant to satisfy the divalent cation demand.

Finally, fertilizer products, such as TSP, may contain up to 32 pCi/g of Ra-226, and the direct application of fertilizer products to crops may be much more important in the Ra-226 uptake pattern than the concentration of Ra-226 in the soils. Limited data are available to support this theory. The Florida Institute of Phosphate Research has approved a comprehensive crop uptake study (Ra-226 and other radionuclides).

Biological sampling was conducted at an unmined South Ft. Meade site and a reclaimed site nearby known as the Homeland Tract for a phosphate mining EIS (EPA 1981b). Ra-226 concentrations in beef, soils, grass, vegetables, and citrus samples were all at the lower limit of detection for the analytical methods employed for samples from both sites. Thus, no conclusions on uptake could be drawn.

Montalbano et al. (1983) studied Ra-226 levels in Florida ducks. Twenty ducks were captured in the settling basin of a phosphate complex and ten were captured from a freshwater marsh of Lake Okeechobee. Concentrations of Ra-226 were greater in the muscle tissue of the settling pond ducks than in the ducks from Lake Okeechobee ( $3.08 \pm 0.61$  pCi/g versus  $0.86 \pm 0.15$  pCi/g). By drawing a parallel to the drinking water standard for Ra-226, one can state that the consumption of <65 g of duck flesh at the higher Ra-226 levels every day of the year for a lifetime would not have a serious impact on human health.

A study of the waterfowl associated with the Florida phosphate clay settling areas was completed recently at the University of Florida (Stabin 1983). Stabin reviewed the literature on biological concentration of Ra-226. His findings have been summarized in Table 3.7-28. The waterfowl data from the University of Florida study (Stabin 1983) are shown in Table 3.7-29. The sediment data demonstrate that settling ponds have

Table 3.7-28. Biological Uptake Data for Ra-226.

System	Uptake Description	Qualifiers	Reference
Terrestrial plants	Radium proportional to soil concentration	High Ca <sup>++</sup> restricts uptake	Kangas 1979
Free-floating aquatic macrophytes	Radium concentrates (no numerical value)	None	Upchurch et al. 1981
Terrestrial root plants	Ra/Ca ratios higher by 1.7-7.0 in roots compared to soil water	Depends on soil chemistry inhibited by Ca <sup>++</sup> rich soils	Upchurch et al. 1981
Marine systems (fish, molluscs, crustaceans)	Radium concentrates	None	Upchurch et al. 1981
Free-floating aquatic macrophytes, Fla.	Concentration factor approx. 10,000*	None	Upchurch et al. 1981
Submerged aquatic macrophytes	Concentration factor approx. 10,000*	None	Upchurch et al. 1981
Fish	Concentration factor approx. 500*	Small species, higher conc.; larger indiv., higher conc.	Upchurch et al. 1981
Aquatic plants	Concentration factor approx. 2500	None	Thompson et al. 1972
Aquatic invertebrates	Concentration factor 250	None	Thompson et al. 1972
Fish	Concentration factor 50	None	Thompson et al. 1972
Aquatic insects and fish	Concentration factor approx. 250*	Streams receiving U mill wastes	Martin et al. 1969

\*A factor of 50 was applied to convert from dry ash data back to a wet weight basis.

Table 3.7-29. Uptake of Ra-226 by Waterfowl.

Type of Media	Natural Wetland	Settling Area
<u>North Florida</u>		
Sediment (pCi/g)	1.0 ± 0.08	14.5 ± 3.1
Water (pCi/l)		
Suspended	ND	0.42 ± 0.014
Dissolved	ND	0.049 ± 0.03
Total	ND	0.047 ± 0.03
Duck muscle (pCi/kg fresh)	2.4 ± 0.9	5.4 ± 3.4
Duck bone (pCi/kg ash)	540 ± 67	2000 ± 460
<u>Central Florida</u>		
Sediment (pCi/g)	0.2 ± 0.06	23.9 ± 3.5
Water (pCi/l)		
Suspended	ND	3.5 ± 0.27
Dissolved	0.079 ± 0.04	0.62 ± 0.27
Total	0.079 ± 0.04	4.1 ± 0.38
Duck muscle (pCi/kg fresh)	3.8 ± 1.9	7.8 ± 2.6
Duck bone (pCi/kg ash)	380 ± 47	3100 ± 970

Note: The number of samples in each unit ranged from six to sixteen for the sediments and from two to three for water and duck.

Source: Stabin 1983.

higher concentrations of Ra-226 than natural wetlands and that levels in the northern Florida ponds are significantly lower than those in central Florida sediments.

The water data show higher suspended concentrations of Ra-226 than those found in dissolved fractions. The activity in settling areas is higher than in natural wetland waters.

The muscle of ducks from settling areas appeared to have higher Ra-226 concentrations in both north and central Florida than the muscle from natural wetland ducks; however, the data did not meet Stabin's statistical criteria to conclude a difference existed. Ra-226 concentrates more in bone than in muscle. Bone concentrations in settling area ducks were significantly enhanced over concentrations in natural wetland area ducks. The observed concentration factors were on the order of 10 to 100 (pCi/kg tissue per pCi/l water) for the duck muscle and 1,000 to 10,000 for bone ash. Also, the concentration in the tissue was not observed to be proportional to the activity of suspended Ra-226 in the water.

Stabin concluded "The health hazard from even the highest conceivable consumption rate of duck muscle contaminated with Ra-226 at the levels seen from central Florida settling ponds is insignificant." Furthermore, "no action to limit public...consumption of waterfowl from Florida phosphate clay settling areas is suggested."

Various aquatic species were collected from the OXY site and analyzed for Ra-226 (Table 3.7-30). Nine of the fifteen samples collected showed "positive" Ra-226 concentrations. Four of the nine "positive" samples had a 1-sigma error equal to the Ra-226 concentration. The two "statistically positive" fish samples had Ra-226 concentrations of 0.5 pCi/g, a concentration which is lower than the Ra-226 concentration in the Lake Okeechobee ducks referenced earlier. Based on the OXY sampling, there appears to be an insignificant uptake of Ra-226 in various species of fish and turtles on the OXY site.

#### 3.7.10 Summary of Baseline Radiological Survey

The external gamma radiation is approximately 5.2  $\mu$ R/hr over unaltered dry lands on the site. Typical Florida background radiation levels range from 4.4 to 6.4  $\mu$ R/hr. Over wetlands and those lands with a very high water table the external gamma radiation is lower.

Uranium and Ra-226 measurements in soil samples confirm highest activities exist either just above or in the top of the matrix. Overburden at the OXY site has concentrations of radioactivity slightly lower than that of central Florida. The concentration of Ra-226 in the OXY matrix is much lower than older mines in central Florida but about the same as the newly proposed mines to the south and west of the current central Florida mining area. The surface soil Ra-226 at the OXY site averages 0.4 pCi/g, whereas the 0-6 ft depth composites average 1.1 pCi/g.

Table 3.7-30. Radium Levels in Biological Samples, OXY Project Area.

Station	Date	Type	Ra-226 (pCi/g)
SR-2	11/81	Largemouth bass, brook silverside*	0.1±0.1
SR-5	11/81	Largemouth bass, brook silverside*	0.5±0.2
SA-11	3/82	Largemouth bass	0.5±0.2
SA-11	3/82	Minnows ( <u>Notropis</u> sp.)	0.01±0.01
SA-11	3/82	Shad	<0.01
EL001-18	4/20/82	Largemouth bass	<0.01
EL001-18	4/20/82	Bowfin	<0.01
Pool pond	2/05/82	Florida cooter	0.01±0.01
Pool pond	2/05/82	Florida cooter	<0.1
Pool pond	2/05/82	Yellow-bellied turtle	0.02±0.01
Pool pond	2/05/82	Yellow-bellied turtle	0.01±0.01
Recirculating water (RS-1)	2/26/82	Florida cooter	0.02±0.01
Recirculating water (RS-1)	2/26/82	Florida cooter	<0.01
Recirculating water (RS-1)	2/26/82	Florida cooter	<0.01
Recirculating water (RS-1)	2/26/82	Florida cooter	0.01±0.01

\*Several very small fish were combined to yield an adequate sample.

Gamma logs show highest gamma activity levels at the top of the matrix, with some continued radioactivity through the Hawthorn Formation and with a decrease in activity within the Floridan Aquifer.

The uranium/thorium ratio in subsurface strata is much greater than the national average, averaging approximately 5 on an activity basis compared with a natural average of approximately 1. The ratio of Ra-226 to Ra-228, daughters of uranium and thorium, respectively, will be the same as the uranium/thorium ratio. As the concentration of Ra-226 in all water samples at the OXY site was  $<1$  pCi/l, the Ra-228 levels will be 5X lower, or  $<0.2$  pCi/l. The drinking water standard for radium is 5 pCi/l.

Ra-226 in the matrix is approximately 6.6 pCi/g or 25% of that observed in currently operated mines in central Florida. Ra-226 concentrations in OXY surface waters are  $<1$  pCi/l. These values are comparable to other surface waters in unmined areas in Florida. Ra-228 concentrations in surface waters are below normal limits of detection. Low gross alpha levels ( $<3$  pCi/l) indicate that other contributions from alpha emitters (U-238, Th-230, and Po-210) are insignificant.

Ra-226 concentrations in current recirculating water systems are approximately 7X higher than natural background. For reclaimed lakes, the Ra-226 concentration is approximately 5X higher than natural background. Both of these "impacted" systems are below drinking water standards for Ra-226 and gross alpha.

Ra-226 concentrations are 0.2-3.0 pCi/l in water table aquifers and approximately 0.3 pCi/l in deep wells. These concentrations are comparable to area data. Low gross alpha data ( $<9.0$  pCi/l) reflect small contributions from other long-lived alpha emitters.

Media such as fish and turtles have low concentrations of Ra-226, normally  $\leq 0.02$  pCi/g with a high of 0.5 pCi/g.

### 3.7.11 Analytical Methods for Radiological Analyses

The radiological evaluation of the baseline data required analysis for radionuclides in water and solid media. The radionuclide of primary interest was Ra-226. However, other radionuclides in the uranium and thorium series were of secondary importance (i.e., U-238, Th-232, and Ra-228), and water samples were screened by gross alpha and gross beta determinations. External measurements included terrestrial gamma radiation levels above the ground and gamma logging of the subsurface formations for the general determination of subsurface radioactivity.

#### 3.7.11.1 Gross Alpha

Groundwater. Plastic "cubetainers" (1-liter) were used for collecting all water samples. Samples were preserved at the time of collection with 15 ml 1N HNO<sub>3</sub> per liter of sample.

Standard drinking water procedures were used for analyzing clear samples. Samples with visible turbidity and/or debris were filtered with

a Whatman-40 filter. Standard procedures beyond this point were taken from an EPA technique (Method 900.0, EPA 1980c). Basically, an aliquot of the preserved water sample was evaporated to a small volume and transferred quantitatively to a tared 2-in stainless steel planchet. The sample residue was dried to a constant weight and counted for alpha activity on a gas-flow proportional or a scintillation detector system. Sample density on the planchet was limited to 5 mg/cm<sup>2</sup>. If the weight exceeded this volume, a smaller aliquot was taken. A suitable standard (Am-241) was used to determine the efficiency (cps/dps) of the selected counting system.

Surface Water. Gross alpha in surface water samples was analyzed using the same methods as for groundwater. Because most surface waters contain suspended and settleable solids, samples were filtered with a Whatman-40 filter and decanted to obtain the aliquot.

#### 3.7.11.2 Gross Beta

Gross beta activity was determined on the planchet that was prepared for gross alpha analysis (EPA 1980c). Calibration for efficiency was performed with a suitable standard, either Sr-90 or Cs-137.

#### 3.7.11.3 Radium

Groundwater: Ra-226. Standard drinking water procedures were used for analyzing clear samples. Samples with visible turbidity and/or debris were filtered with a Whatman-40 filter. Standard procedures beyond this were from EPA (Method 903.1, EPA 1980c). The radium in water was concentrated and separated from the sample by co-precipitation with BaSO<sub>4</sub>. The precipitate was dissolved and transferred to a radon bubbler for ingrowth. The radon, at equilibrium, subsequently was transferred to a scintillation cell. Alpha counting of Rn-222 and daughters allowed back-calculation to the original Ra-226. A Ra-226 standard was used to calibrate the system. The overall calibration constant included the transfer efficiency of the system, the counting efficiency (cps/dps), and the alpha activity contributed by the daughters at equilibrium.

Groundwater: Ra-228. Water samples requiring Ra-228 analysis were treated according to the Ra-226 procedure through the initial isolation of Ra-226. Thereafter, the actinium was removed with a Y(OH)<sub>3</sub> precipitation. The Ra-228 daughter Ac-228 was allowed to ingrow to equilibrium and then re-precipitated with Y(OH)<sub>3</sub>. The precipitate was prepared on a planchet and beta counted as a quantitation of Ac-228 and Ra-228 (Method No. R-1142-26, USGS 1977). Calibration with a standard Ra-228 solution yields a combined efficiency and recovery.

Surface Water. Ra-226 and Ra-228 in surface water samples were analyzed using the same methods as for groundwater. Because most surface waters contain suspended and settleable solids, samples were filtered with a Whatman-40 filter and decanted to obtain the initial sample.

Tissue Samples. Biological media such as fish and turtles were collected for radium analyses. Fish were collected using seines, gill

nets, dip nets, and baited lines; turtles were collected using baited funnel traps. Specimens were preserved either by freezing or by formaldehyde addition. As soon as possible after collection, the tissue was ashed and the fixed solids dissolved. The Ra-226 was then co-precipitated with BaSO<sub>4</sub>. From this point on, the analytical technique was identical to that of water samples. The final calculation may be related back to dry ash weight or wet weight of tissue.

Solid Samples. Three types of solid samples were analyzed for Ra-226: sediments, soils, and pilot plant fractions. Bottom sediments were taken at the same location as the surface water samples. Approximately 0.66 liter of material was sealed in ziplock containers. Soil samples were obtained during continuous standard penetration tests and split-spoon sampling for the top 3 m of soil and approximately every 1.5 m thereafter.

The soil was returned to the lab and oven-dried for 24 hr at 100°C. Weighed portions of the dried samples were placed in 0.5-liter Marinelli beakers which were then sealed with a bead of cement and stored at least two weeks before analysis to allow ingrowth of gaseous Rn-222 and its short-lived decay products to radioactive equilibrium with the long-lived parent Ra-226 in the sample. Ra-226 and uranium concentrations were then determined by high resolution gamma-ray spectrometry (Bolch et al. 1976). In this method, the Ra-226 content of the sample was calculated from the counts associated with the 295.2, 352.0, and 609.4 keV peaks of the Pb-214 and Bi-214 radon daughters. The gamma spectrometry system also yields concentrations of other gamma-emitting radionuclides, e.g., Th-232, K-40, and U-238 via its daughter, Th-234.

#### 3.7.11.4 Gamma Radiation

Exposure Rates. Gamma radiation measurements indicate the external radiation exposure rate to persons at a site and, more importantly, provide a rapid indication of the approximate levels and variations of near-surface radioactivity.

Gamma radiation levels above the ground were measured at 150 intervals along transects established in each major drainage basin in the study area. Measurements were made at approximately 1 m above the surface using scintillation survey meters (Model 12S Micro-R Meter, Ludlum Instrument Company). Because scintillation detectors have an energy-dependent response and the extended sources of natural radiation in the field have a different energy spectrum from calibration sources used in the laboratory, the survey meters were periodically calibrated in the field against a pressurized ionization chamber (Model RSS-111 Pressurized Ionization Chamber, Reuter-Stokes Corp.). The response of the pressurized ionization chamber is relatively independent of energy over a wide range of energies, and while it is not portable enough to be used as a survey meter, it is sufficiently transportable to be used in the field as a secondary standard.

Gamma Logs. The radioactivity profiles of wells and test borings were determined by in situ gamma ray logging. An 8-10 cm diameter PVC casing

was installed in each hole to facilitate access. Drilling mud was cleaned from the hole prior to installing the casing. The gamma ray logging equipment consisted of NaI scintillation probes, a high voltage supply, a "count-rate" instrument, and a strip chart recorder. The probe was dropped at a given drop speed and the gamma response recorded in counts per minute on an appropriate scale of the strip chart. Calibration for precision consisted of repeat measurements on a hole (beginning of the day and end of the day) to ensure reproducibility.

#### 3.7.11.5 Quality Assurance

The laboratories used for radioanalytical tests participate in the EPA Quality Assurance Cross-Check Program of the Western Environmental Laboratory, Las Vegas, Nevada. In this program, the EPA distributes samples with unknown concentrations of radionuclides near environmental levels, i.e., gamma in water, radium in water, gross alpha in water, soil samples, and air filters. Returned data are verified against known values and the means of standard deviations of the entire participating group. Blind samples also were processed to provide internal quality control and reproducibility of data, from sampling techniques through the reporting of data.

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### 3.8 Historical and Archaeological Resources

A cultural resource assessment of the OXY project area was designed and undertaken to ensure compliance with federal historic preservation mandates, including the National Historic Preservation Act of 1966 (Public Law 89-655), National Environmental Policy Act of 1969 (Public Law 91-190), Executive Order 11593, and the Advisory Council on Historic Preservation's Procedures for the Protection of Historic and Cultural Properties (36 CFR 800).

A comprehensive historical documentary survey was conducted which covered the entire Hamilton County project area and considered in detail exploration, settlement, and occupation from the sixteenth through the twentieth centuries. Working maps and a final report were made available to the archaeological surveyors in order to indicate areas of special concern as well as to aid in the identification of historic period remains which might be encountered during current or future fieldwork. Site maps were prepared and detailed survey field notes were taken (Swindell and Benton 1982), and other documents concerning the cultural history of the site were submitted to the Florida Division of Archives, History and Records Management (FDAHRM) for review and file purposes.

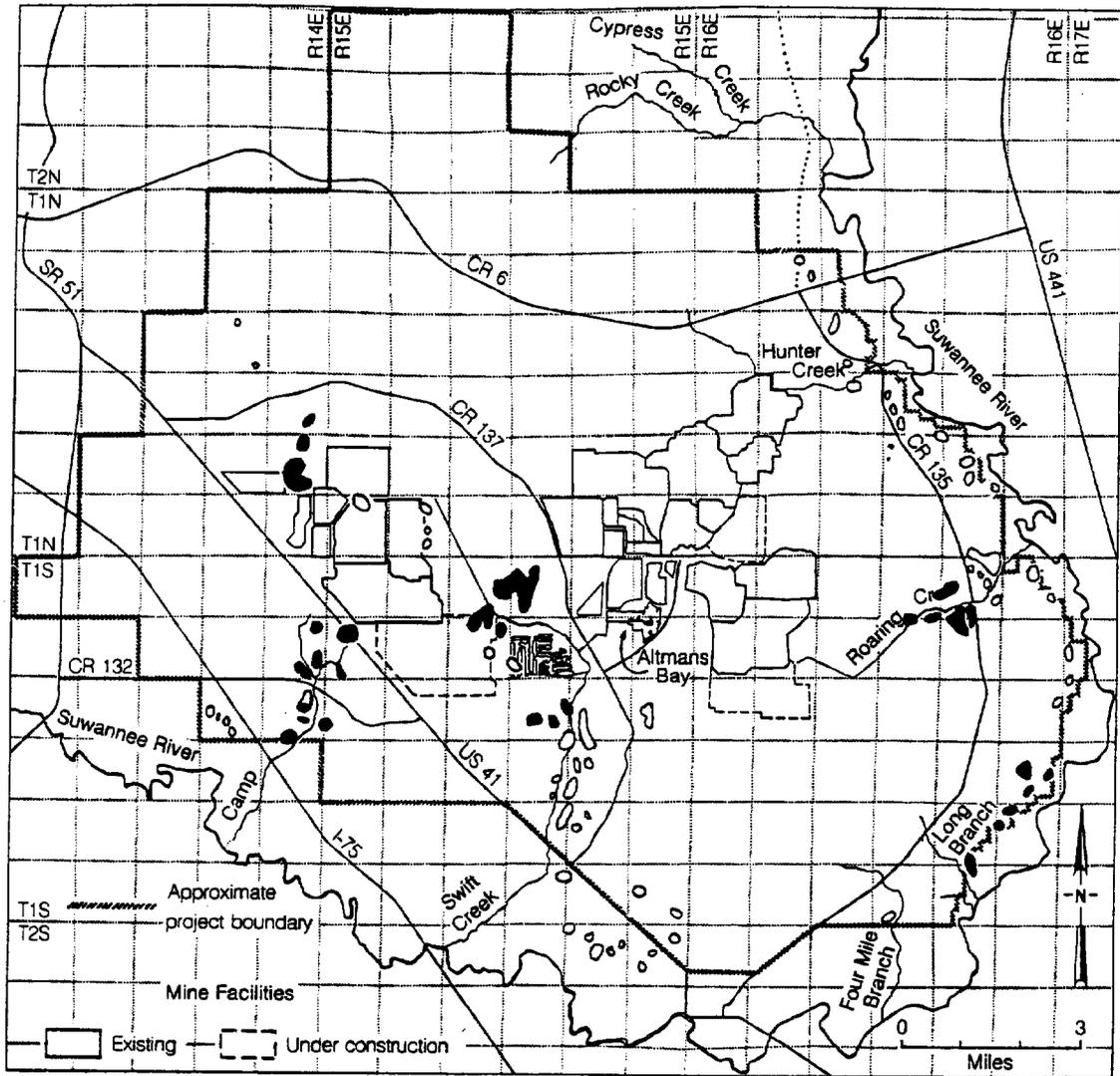
The archaeological portion of the study began with a review of existing literature and site records for the region. A check of the Florida Master Site File showed a single sand burial mound (8Ha1B) recorded within the boundary of the study area (Figure 3.8-1). The site could not be found during field survey; it may well have been destroyed by pine planting. There are no other recorded prehistoric sites of significance on the property.

In order to reduce the requisite site survey area to manageable units within the EIS project area, the FDAHRM designated areas of high archaeological site probability based on known regional and local patterns of archaeological site distribution (G.W. Percy, FDAHRM, letter to J.A. Davis, 25 February 1982). High probability areas not within the area proposed for mining were not surveyed (Figure 3.8-1). Spot checks were made in areas proposed for mining but not identified as high probability by the FDAHRM. Six archaeological sites were discovered in these areas. Methods used in the field surveys are discussed in Section 3.8.5.

#### 3.8.1 Setting

A majority of archaeological sites from Hamilton County are located on high ground either directly adjacent to the Suwannee River or on upland ridges along tributary streams. Most sites found during the survey conform to the previously known pattern of archaeological site distribution; however, some sites were found on low ridges around the perimeter of Swift Creek Swamp. Sites found on the project area lie on well-drained to fairly well-drained sandy soils with a dark organic pan or clayey substrate (Section 3.1.4).

The largest part of the survey area, particularly upland ridges and other well-drained soils, is man-modified land. Agricultural fields presently under cultivation, old fields, and improved pastures are common. A



NOTE: Does not reflect all areas affected by mining or mine support activities. See Figure 1.1-2.

- Designated areas surveyed
- Designated areas not surveyed (not in current mining plan)

Figure 3.8-1. Areas of High Archaeological Site Probability Designated by the Florida Division of Archives, History and Records Management.

number of the archaeological sites located were found in plowed fields. Large blocks of land are also managed for timber and have been planted in slash pine. These locales have been subjected to heavy disturbance by removal of native trees (including stumps) and plowing prior to pine planting. Disturbance of the soil in such areas extends usually to at least 2 ft below the original surface. Mining preparation, including graded road construction, ditching, and borrowing from pits, has also impacted areas of high archaeological site probability.

It is speculated that faunal resources available for food within the project area were rich and varied during the prehistoric period. White-tailed deer, a valuable aboriginal food resource during all culture periods after the Middle Archaic, would have been attracted to the mast produced by oaks of the upland areas. Migratory and native waterfowl, small mammals, reptiles, amphibians, and fish could have been obtained from the Suwannee River floodplain and the various streams and swamps. During the later culture periods, the rich, well-drained soils of the uplands adjacent to swamps and streams would have provided choice locations for aboriginal horticulture as well as habitation.

### 3.8.2 Summary of Current Archaeological Knowledge

The regional cultural history of north Florida and south Georgia has been discussed in detail by other authors (Milanich and Fairbanks 1980, Trowell 1979, Ruple 1976, and Tesar n.d.) and is only summarized herein. The cultural sequence of the upper Suwannee River basin follows Milanich et al. (1976).

#### 3.8.2.1 Paleo-Indian Period (before 10,000 B.C. to 8000 B.C.)

This cultural period represents the earliest human habitation in Florida and is defined on the basis of a specialized lithic technology. The most diagnostic artifacts of the tradition are lanceolate, fluted stone projectile points such as the Clovis point and its variants. Paleo-Indian sites are most common in stream beds, deep springs, and sinkholes, occasionally occurring on the continental shelf as well. To date, no upland Paleo-Indian sites are known from northern Florida; however, finds of Clovis, Santa Fe, Suwannee, and Simpson points are reported from the Suwannee, Santa Fe, and Itchetucknee rivers. There is no evidence of Paleo-Indian activity on the project site.

#### 3.8.2.2 Archaic Period (8000 B.C. to 1000 B.C.)

The Archaic Period is divided into Early, Middle, and Late stages, of which only the latter is represented in sites on the OXY property. Early and Middle Archaic periods are defined by changes in tool types. During both periods the aboriginal subsistence base was changing to exploitation of small game, shellfish, and more varied plant foods. This change in the subsistence pattern probably reflects the extinction of Pleistocene megafauna and their replacement by alternative food sources.

The majority of sites from the OXY tract date to the Late Archaic Period (2500 B.C. to 1000 B.C.) which is characterized by the use of fiber-tempered pottery. The subsistence pattern was hunting and foraging,

utilizing special-use camps and villages. Jones (pers. comm.) has recorded more than ten large Archaic sites near the project area, primarily on the lower reaches of the Swift Creek drainage and along the nearby Suwannee River. A single unnamed site near the study area, tested by Jones, revealed Middle to Late Archaic material as well as plain sand-tempered and Wakulla Check-Stamped pottery (Weeden Island period). Jones found no archaeological features or cultural stratigraphy and few discernable activity areas during his salvage work.

#### 3.8.2.3 Deptford Period (c. 1000 B.C. to 200 A.D.)

The Deptford series ceramics, sand-tempered pottery characterized by simple and Check-Stamped patterns, rapidly replaced the preceding fiber-tempered ceramics as the dominant pottery type. A single Deptford sherd was found at 8Ha83. Although a stable hunting and gathering economy and semi-sedentary village life became the norm during the Deptford period (Milanich 1973), and such sites occur in Hamilton County, none were found on the OXY tract.

#### 3.8.2.4 Weeden Island Period (A.D. 200-800)

Most of the culturally diagnostic artifacts from archaeological sites on the project area are dated to the Weeden Island period. Work by the Florida State Museum in the region and at the McKeithen site, a Weeden Island village and ceremonial complex of several acres near the Suwannee River in Columbia County, has begun to illustrate the long range and widespread occurrence of Weeden Island cultures in the region. A number of papers have resulted from this research (Cordeil 1980, Kohler 1980, Lavelle 1980, Milanich 1971, Milanich et al. 1976). Survey of the Okefenokee Swamp by Trowell (1978, 1979, 1980) provides data on Georgia sites just north of the project area.

Lavelle (1980) completed an exhaustive field survey and settlement pattern analysis in Columbia County just across the Suwannee River from the project site; she noted six site types common to the region: 1) sand burial mounds, 2) habitation sites associated with mounds, 3) dispersed habitation sites or "hamlets" representing discrete social groups, 4) task-specific sites, 5) chert quarries, and 6) clay exposures. Weeden Island period sites from the OXY tract would all seem to be hamlets according to Lavelle's definition. The possibility of the largest prehistoric site (8Ha73) being a habitation site associated with a burial mound cannot be entirely ruled out as all areas surrounding 8Ha73 were not surveyed.

Hamlet sites noted by Lavelle occur near springs within hammock environments at 115-125 ft NGVD and are located in areas that express an entire range of animal habitat diversity within 0.8 km of each site. Although the sites found in the present study do not exactly conform to this model, the OXY sites do exhibit a similarity to the general pattern.

#### 3.8.2.5 Alachua Tradition (A.D. 800-1700)

The Alachua Tradition probably represents the expansion of southeastern Georgia coastal populations (Wilmington and Savannah cultures) into

north-central Florida (Milanich and Fairbanks 1980). Such sites usually occupy hardwood forests and uplands near lakes and ponds. The subsistence pattern reflects the use of multiple environments for food collection and production. There are no pure Alachua sites on the OXY tract, but ceramics from several of the sites discovered during fieldwork may reflect Alachua Tradition occupation.

#### 3.8.2.6 Leon-Jefferson Period (A.D. 1650-1725)

The project area lies within the territory of the Historic Period Utina Indians (Milanich 1978). However, there is no evidence of Historic Period Indian occupation on the OXY tract.

#### 3.8.3 Historical Assessment

The historical documentary review for the project area:

- 1) emphasized the development of land use patterns and of individual settlements and communities;
- 2) identified and located man-made features which possess some historical significance, including roads, river crossings, church and cemetery sites, individual settlements, and villages;
- 3) identified and listed all original pre-1800 land owners so as to relate them to specific locations within the project area; and
- 4) made all such information available to field archaeologists connected with present and future studies.

The general historical pattern of land use in the project area can be characterized by sparse settlement and rural occupation through the early twentieth century. During Florida's colonial periods (before 1821) the interior portions of north Florida remained largely unexplored. Documentary evidence provided no suggestions of specific sites associated with the Spanish or Indian residents, or users of land within the project tract, throughout the First Spanish Period (1513-1763). However, it is certainly possible that hunters and cattle herders visited the area and that Indian villages or campsites were located there. The succeeding British Period saw attention focused on the Atlantic coast and the St. Johns River, and there is no evidence of specific occupation or use of the project area during this time.

By the beginning of the Second Spanish Period (1783-1821), Seminoles displaced from more northern Creek lands probably made use of the area. Regularly-used Indian trails aided later white settlement of the area and partially determined settlement patterns. By 1823 white pressure for Indian-occupied lands resulted in the Treaty of Moultrie Creek, which attempted to move the Seminoles even farther south into central Florida.

White settlement of the region depended on the early land surveys of the federal government, and because the project area is crossed by the Tallahassee Base Line and lies near the Florida-Georgia border, it

became available relatively early for public sale during the American Territorial Period (1821-1845). Surveyors' field notes, plats, and local accounts all describe a fairly poor land characterized by expanses of pine barren, broken occasionally by oak and hickory hammocks. Scattered settlement occurred during the 1820's and 1830's, but it was not until the conclusion of the Second Seminole War (1835-1842) that Seminole removal became complete and white occupation increased significantly.

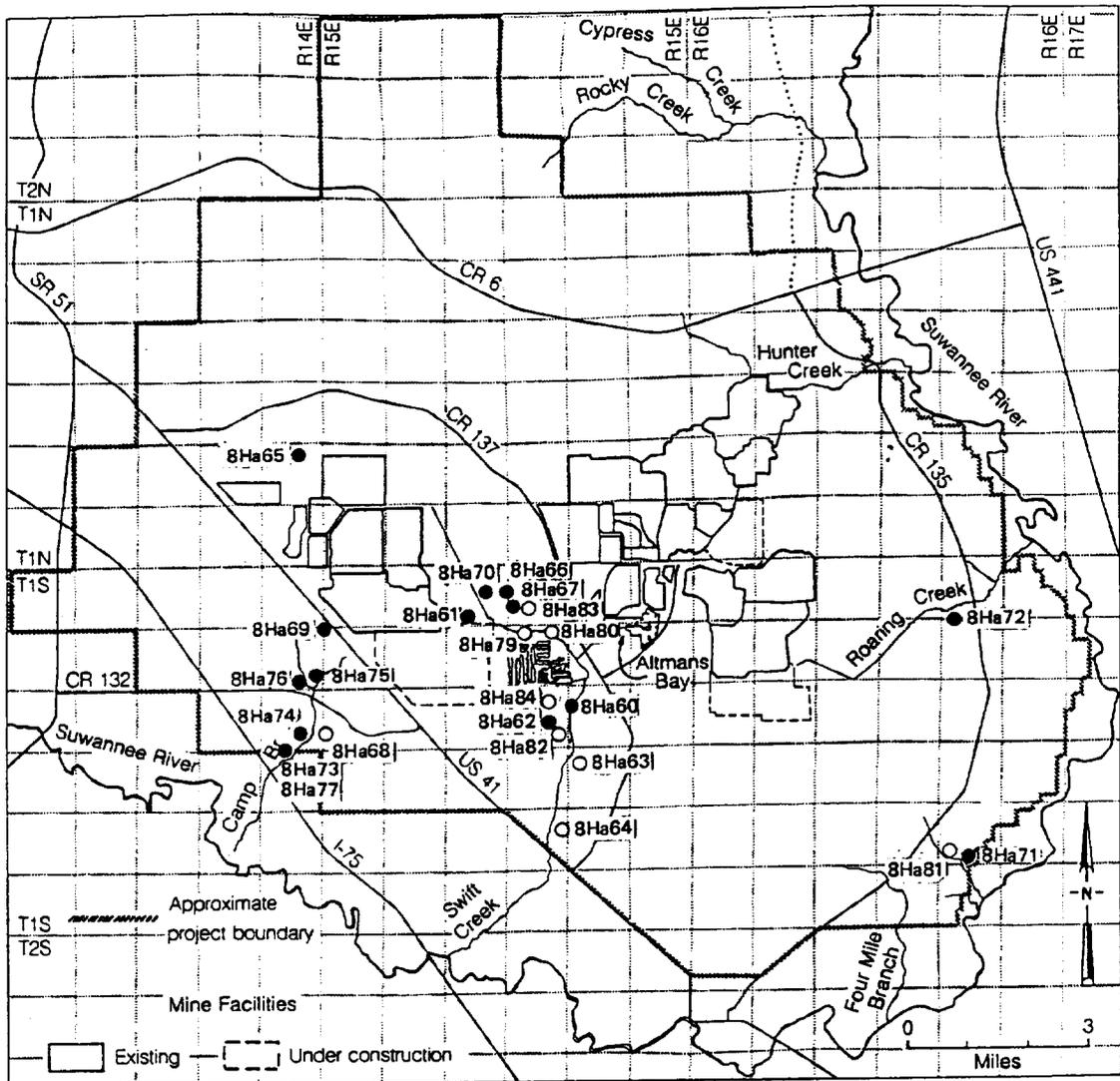
By 1850 the remaining public lands had been surveyed, and by 1870 most of the high land in the study area had passed into private ownership. Agriculture was the dominant occupation, consisting of subsistence crops as well as some rice and cotton; cattle were of average importance, compared to other north Florida counties, and grazed on open range. While no military action occurred in the study area during the Civil War, the resulting emancipation caused the decline of the cotton market, and local attention shifted to lumber and naval stores. From the last decades of the nineteenth century through World War II these forest products supported small, scattered communities centering on mills, turpentine stills, and transportation routes. Centralization of the industry after the war resulted in the abandonment of many of these rural villages. However, second and third-generation pine forests still supply a regional pulp industry.

The greatest growth of settlement occurred during the 1870's and 1880's when the virgin pine forests were being exploited for lumber and turpentine. Sawmill and still communities were often of short duration, and many are marked now only by cemeteries. No properties of National Register quality, based on historical significance, were identified during the study, and archaeological fieldwork failed to discover any buildings which might qualify for listing on the National Register on an architectural basis.

#### 3.8.4 Results and Recommendations

Thirteen new archaeological sites were discovered during the survey of high archaeological site probability areas designated by the FDAHRM for the OXY Hamilton County Tract (Figure 3.8-2). Based on the findings of the field survey and testing, none of the sites or cultural resources is considered eligible for listing on the National Register on the basis of archaeological, historical, or architectural significance. A majority (12) are prehistoric habitation sites, although three (8Ha65, 8Ha71, and 8Ha72) do contain unrelated nineteenth century historic materials (Tables 3.8-1 and 3.8-2). A single nineteenth century house site (8Ha77) was also located during fieldwork. All of the prehistoric sites were situated in generally similar topographic situations, and none represent unusual cultural or geographic patterns of settlement for the region.

It is very likely that other, yet undiscovered archaeological sites outside the present mining plan will be threatened by disturbance or destruction if these areas are ever mined due to revision of the current plan. However, such areas designated as having high site probability by the FDAHRM (Figure 3.8-1) should receive archaeological survey before mining.



NOTE: Does not reflect all areas affected by mining or mine support activities. See Figure 1.1-2.

- Sites within proposed mining area
- Sites outside proposed mining area

Note: Sites 8Ha79 through 8Ha84 were found outside the FDAHRM high probability designated areas.

Figure 3.8-2. Archaeological Sites.

Table 3.8-1. Archaeological Survey Results.

FMSF* Site Number	Field Site Number	Screened Shovel Tests	With Cultural Material	Test Excavation Units
8Ha62	OXY 3	10	7	
8Ha65	OXY 6	23	15	2
8Ha66	OXY 7	15	5	
8Ha67	OXY 8	5	1	
8Ha69	OXY 10	6	0	
8Ha70	OXY 11	6	1	
8Ha71	OXY 12	8	5	2
8Ha72	OXY 13	1	0	
8Ha73	OXY 14	2	0	4
8Ha74	OXY 15	2	0	
8Ha75	OXY 16	1	0	
8Ha76	OXY 17	1	0	
8Ha77	OXY 18	1	1	1

\* FMSF - Florida Master Site File.

Table 3.8-2. Archaeological Culture Periods Represented on the OXY Tract.

FMSF Site Number	Archaic	Dept-ford	Swift Creek	Wheeden Island	Alachua	Unidentified Prehistoric Ceramic	Historic
<b>Sites within FDAHRM designated survey areas</b>							
8Ha62	X		X	?		X	
8Ha65	X					X	X
8Ha66	X						
8Ha67	X			?		X	
8Ha69	?					X	
8Ha70	X						
8Ha71				X		X	X
8Ha72							X
8Ha73		?	X	X	X		
8Ha74							
8Ha75							
8Ha76							
8Ha77							X
<b>Sites outside FDAHRM designated survey areas</b>							
8Ha79	X		X	X	X	X	
8Ha80							
8Ha81					X	X	X
8Ha82				X		X	
8Ha83		X				X	
8Ha84						X	

#### 3.8.4.1 Site 8Ha62

Site 8Ha62, located about 50 m south of an unnamed tributary of Swift Creek (elevation 125 ft NGVD), is represented by a surface scatter of aboriginal lithics and ceramics in a plowed field. Original vegetation was probably mesic hardwood hammock. Dimensions of the site are at least 200 m E-W and 150 m N-S with a maximum depth of deposit of 60 cm below ground surface. Artifact analysis shows evidence of tool manufacture and use but gives no indication of quarrying activity at the site. It was probably used as a hunting camp or village during the Archaic, Swift Creek, and Weeden Island periods. The site shows no cultural stratigraphy and has received heavy disturbance from plowing and timbering. Due to its disturbed condition, this site is not recommended for preservation or impact mitigation.

#### 3.8.4.2 Site 8Ha65

Site 8Ha65 is located on the upland adjacent to the northwest edge of Swift Creek Swamp just west of a small unnamed pond at elevation 140 ft NGVD. The site is represented by a surface scatter of aboriginal lithics in a disturbed pine flatwoods community. Original vegetation was probably mesic hardwood hammock. Dimensions of the site are at least 150 m E-W and 200 m N-S with a maximum depth of deposit of 75 cm below surface. Two excavation units dug at the site showed no cultural stratigraphy or features. The site probably served as a hunting or special-use camp during the Middle to Late Archaic Period and during some time after 1200 B.C. Nineteenth century historic use of the area is also indicated. Due to heavy disturbances from timbering and pine planting and the lack of apparent cultural stratigraphy, the site is not recommended for preservation or further investigation.

#### 3.8.4.3 Site 8Ha66

Site 8Ha66 lies adjacent to the southeast side of Swift Creek Swamp at elevation 126 ft NGVD. The site is a surface scatter of lithics and ceramics found in an area heavily disturbed by timbering and road construction for mining. Site dimensions are at least 200 m E-W and 200 m N-S with a maximum depth of deposit of 75 cm. There is no evidence of cultural features or stratigraphy at the site. Site 8Ha66 was probably used as a hunting or special-use camp during the Late Archaic Period. Due to heavy disturbance, 8Ha66 is not recommended for preservation or impact mitigation.

#### 3.8.4.4 Site 8Ha67

Site 8Ha67 is located on an upland adjacent to the south side of Swift Creek Swamp at elevation 126 ft NGVD. The site is a surface scatter of lithics and ceramics found in an area heavily disturbed by timbering and graded road construction. Site diameter is 75 m with a maximum depth of deposit of 50 cm. There is no evidence of cultural stratigraphy or features at 8Ha67. The site probably represents a hunting or special-use camp occupied during the Late Archaic and possibly Weeden Island periods. No further investigation or preservation is recommended.

#### 3.8.4.5 Site 8Ha69

Site 8Ha69 lies at about 140 ft NGVD on the northeast side of Camp Branch Swamp and is represented by a surface scatter of lithics and ceramics. All artifacts were recovered from road ditch banks; therefore, site dimensions are not known. No clear temporal range of occupation can be estimated with available evidence. Due to heavy disturbance by grading, 8Ha69 is not recommended for preservation or impact mitigation.

#### 3.8.4.6 Site 8Ha70

Site 8Ha70 is located at an elevation of 140 ft NGVD just northeast of Swift Creek Swamp on an upland ridge. The site has a diameter of about 50 m and a depth of at least 40 cm. It is represented by a surface scatter of lithics found in an area heavily modified by timbering and road grading. There is no evidence of cultural stratigraphy or features at 8Ha70. The site was probably a hunting camp during the Late Archaic Period. No further work or preservation is recommended.

#### 3.8.4.7 Site 8Ha71

Site 8Ha71 is located on an upland just north of Long Branch at 120 ft NGVD. The site is a surface scatter of lithics and ceramics found in a plowed field. Site dimensions are 100 m N-S by 50 m E-W with a maximum depth of 85 cm. Test excavation units showed no evidence of cultural stratigraphy or features at 8Ha71, although alluvial deposits of sand had buried portions of the site. The site was probably a hunting or special-use camp during the Late Archaic and Weeden Island periods. Nineteenth century use of the area is also indicated. Due to disturbances by timbering and plowing, 8Ha71 is not recommended for preservation or impact mitigation.

#### 3.8.4.8 Site 8Ha72

Site 8Ha72 is located in an improved pasture just south of Roaring Creek at elevation 125 ft NGVD. Diameter is 50 m and the depth is unknown. A screened shovel test produced no cultural material. Site disturbances include clearing and plowing. No further work or protection is recommended.

#### 3.8.4.9 Site 8Ha73

Site 8Ha73 was found in a plowed field on a upland ridge just east of a tributary of Camp Branch near the confluence of Camp Branch and the Suwannee River. The site is approximately 130 ft NGVD and contains a surface scatter of lithics and ceramics extending >300 m N-S and approximately 150 m E-W. Maximum depth of the cultural deposit is 90 cm. Two surface concentrations of artifacts were evident; two test excavation units were placed in each. Profiles showed no clear cultural stratigraphy, and no features were found during surface collection or excavations. Artifact analysis shows evidence of tool manufacture at the site.

The site is a large, multicomponent area with prehistoric occupations during the Late Archaic, Swift Creek, Weeden Island, and Alachua periods.

The site probably was a multiple-use camp during the Late Archaic Period and continued to see use as a larger village during later occupations. The high, well-drained plateau lent itself to subsistence farming, and the close proximity of Camp Branch and the Suwannee River would have allowed the exploitation of multiple environmental zones for food resources.

However, the site has been heavily disturbed by timbering and plowing. A historic house site (8Ha77) found in the same field suggests that the hill has been farmed since the middle 1800's. Although the site represents the largest and most significant occupation found during survey of the OXY tract, it is a fairly common site type in north-central Florida, particularly on the Suwannee River and its tributary streams. Due to long disturbance of the site and the presence of similar, better preserved examples in the same region, 8Ha73 is not recommended for preservation or impact mitigation.

#### 3.8.4.10 Site 8Ha74

Site 8Ha74 lies in an old plowed field on an upland east of an unnamed creek which drains into the Suwannee River. Site dimensions are unknown as lithics were found thinly scattered over approximately 5 acres. Disturbances include timbering, plowing, and pine planting. Due to the thinly scattered and uninformative nature of the deposit, no further work or protection is recommended.

#### 3.8.4.11 Site 8Ha75

Site 8Ha75 lies east of Camp Branch on an upland heavily disturbed by timbering and pine planting at elevation 135 ft NGVD. Site dimensions are at least 50 m E-W and 100 m N-S (probably extending outside the project area) with a maximum depth of deposit of 85 cm. Artifacts were found along a drainage ditch. Screened shovel tests showed no cultural features or stratigraphy. Site 8Ha75 is not recommended for preservation or impact mitigation.

#### 3.8.4.12 Site 8Ha76

Site 8Ha76, which is probably related to the occupation at 8Ha75, lies just west of Camp Branch on an upland adjacent to the floodplain at 135 ft NGVD, with the majority of the site lying outside the project area. Site dimensions are unknown as artifacts were collected from a single small area <50 m in diameter. The site area is heavily disturbed by pine planting, timbering, and improved pasture. No further investigation or preservation is recommended.

#### 3.8.4.13 Site 8Ha77

Site 8Ha77 is a surface scatter of artifacts in the same plowed field as 8Ha73 and represents a middle to late (after 1850) nineteenth century American homestead. The surface scatter measures approximately 50 m in diameter, and the maximum depth of the cultural deposit is 30 cm. Due to heavy disturbance and the lack of any structural remains, 8Ha77 is not recommended for preservation or impact mitigation.

#### 3.8.4.14 Sites 8Ha79 through 8Ha84

Six other archaeological sites were found outside the high site probability areas designated by the FDAHRM but within areas planned for mining. These sites are all prehistoric occupations of the Late Archaic and/or Weeden Island periods, and none appear to be significantly different from sites already tested. If the present sample of tested sites is representative of local and regional site types, then it is unlikely that testing of these six sites would yield data sufficient for recommendations of National Register eligibility.

#### 3.8.5 Methods

The archaeological field survey of the OXY tract was designed to comply with a pre-project review by the FDAHRM. Based on known distribution of prehistoric sites recorded in the Florida Master Site File and results of previous archaeological surveys in nearby areas, 96 high probability locales were delineated on quadrangle sheets as requiring archaeological survey. Fieldwork concentrated on these priority areas, although other parts of the tract with high potential also were checked. By the time the archaeological field survey was begun, a historical documentary study had been completed, and quadrangle maps showing locations of historic cultural features were used in the fieldwork. The historical study revealed few significant sites, as the area had been sparsely occupied. Review of site file information showed a single recorded archaeological site (8Ha1B) within the project area and many additional prehistoric sites just south of the tract, either adjacent to the Suwannee River or near its tributary streams.

Archaeological fieldwork in the OXY project area was conducted by two archaeologists over a period of five weeks between January and May 1982. Quadrangle maps and recent aerial photography of the project area were checked before and during fieldwork. A master plan aerial photo was marked showing routes walked or driven and the location of all subsurface shovel tests. Detailed field notes were recorded daily on all tasks, observations, and collections, along with profile descriptions of all subsurface tests and sketch maps and notes on the newly discovered sites (Swindell and Benton 1982).

The field survey followed standard archaeological procedures using both vehicular and pedestrian coverage. The vehicular survey was accomplished by driving roads at speeds of <5 mph and spot-checking areas where cultural material was visible or seemed likely due to local topography and drainage patterns (e.g., upland ridges adjacent to streams). Although no systematic transect sampling was conducted, all areas delineated by the FDAHRM as requiring survey within the current mining plan were checked on foot. Nearly all land use types on the tract were surveyed, with more intensive coverage given to areas of good surface visibility, such as old fields, eroded creek and ditch banks, cattle trails, animal burrows, fence rows, and dirt roads.

### 3.8.5.1 Shovel Tests

A total of 199 shovel tests was excavated during fieldwork; unscreened tests were dug throughout the survey to determine possible site locations and soil strata (Figure 3.8-3). Unscreened tests were 30 cm diameter holes dug in a non-random manner, and fill was trowelled by hand for cultural material.

Screened shovel tests (Table 3.8-1) were conducted at each site to determine size and depth of the cultural deposit using radial transect interval testing. After the greatest surface concentration of cultural material was found, a screened shovel test was dug at its approximate center. From this first test, grid lines were shot along the cardinal points using a compass. Screened tests (60-80 cm deep) were excavated on transect lines at 20 m or 50 m intervals, depending on field conditions and surface collection results. These tests were 50 X 50 cm square, and fill was screened through 6 mm hardware cloth. Screened test intervals for each site were noted in the field book along with any interval variations due to local topography and vegetation.

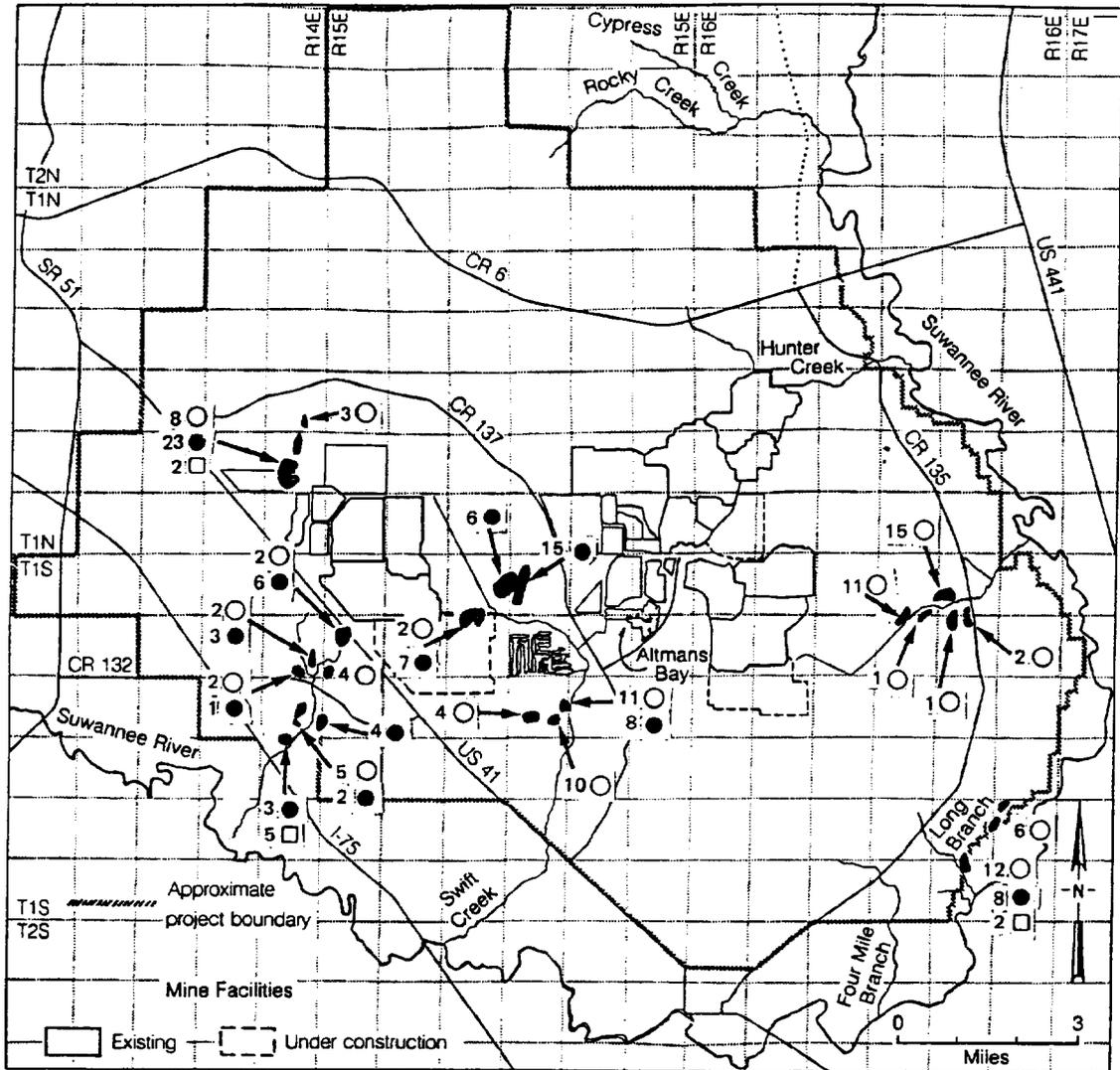
Presence or absence of cultural material was recorded in the field book along with descriptions of artifacts. Only culturally diagnostic artifacts from subsurface tests were saved. Sketch maps of estimated site boundaries, based on surface survey and screened shovel test data, and locations of screened tests were included with the site descriptions. Shovel test profiles for both screened and unscreened test holes were recorded and soil colors described using the Munsell Soil Color chart.

### 3.8.5.2 Excavation Sites

Standard archaeological excavation units were excavated at sites 8Ha65, 8Ha71, 8Ha73, and 8Ha77 (Figure 3.8-3). These tests were 1 m E-W by 2 m N-S (8Ha65, 8Ha71, and 8Ha73), 1 m E-W by 1.5 m N-S (8Ha65 and 8Ha71), or 1 m square (8Ha77) and were excavated in 15 cm arbitrary levels. Fill was screened through 6 mm mesh hardware cloth, and all artifacts were bagged separately by provenience. Test units were excavated either to sterile soil or the water table and then back-filled. Although no cultural features were found in any units, all suspect intrusions (e.g., root runs and animal burrows) were carefully examined. Scale profile maps and soil zone descriptions were recorded for each unit (Swindell and Benton 1982).

### 3.8.5.3 Laboratory Analysis

Laboratory analysis was conducted using standard archaeological procedures and references. All artifacts from surface collections and test units were washed, counted, identified (if possible), and rebagged (Appendix B). Florida Master Site forms were completed for each site recorded during fieldwork.



NOTE: Does not reflect all areas affected by mining or mine support activities. See Figure 1.1-2.

-  Designated surveyed areas
-  Unscreened shovel tests
-  Screened shovel tests
-  Excavation unit

Note: Figures indicate the number of shovel tests performed at each location.

Figure 3.8-3. Field Survey Activities.

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### 3.9 Socioeconomics

Socioeconomic impact evaluations normally address the impacts of a new employment source on income growth and resultant impacts on population growth, housing, land use, public services, and ultimately, on the tax structure and social climate of the affected area.

In contrast, the alternatives evaluated in this study address the impacts of continuation or curtailment of an existing operation. For example, one of the alternatives would terminate the OXY operations and associated employment 13-16 years early. Another alternative would allow all phosphate reserves to be recovered and the operation to continue for 21-26 years.

Although OXY's mining operation is located entirely within Hamilton County, Florida, its economic impacts are felt throughout the state, but more heavily in Hamilton, Columbia, and Suwannee counties, with unique impacts on Duval County.

#### 3.9.1 State of Florida Impacts

The company's payroll at full employment of 2150 is approximately \$48,200,000 in 1982 dollars (Tables 3.9-1 and 3.9-2). While direct employment and payroll are significant, the importance to the economy of the State of Florida and the immediate three-county area of primary impact is greater than the employment and payroll data imply.

While the population of Florida has grown by 43.5% between 1970 and 1980 (Table 3.9-3), the labor force has grown almost twice as fast (Table 3.9-4). This generally reflects the trend throughout the economy of multiple wage earners per household.

The data in Table 3.9-5 are total personal income in millions of dollars and income per person for 1970 and 1981, along with the average annual change in income over this eleven-year period. Table 3.9-6 presents income earned from current production by source of earnings. Income by place of residence (Table 3.9-5) and by place of work (Table 3.9-6) are very nearly the same for the state as a whole, but they may differ rather widely for individual counties.

To estimate the impact of OXY's operations in north Florida, input-output multipliers (Burford and Katz 1977, 1981, 1985) were computed based on payroll and expenditures within Florida and the three-county area (Table 3.9-7). This technique allows estimation of the income to people in Florida which results from the company's payroll, from its purchases of electricity and gas, payments for supplies and equipment, maintenance, and operating expenses and taxes. It is also possible to estimate the number of Floridians who could be expected to be employed as a result of these expenditures. The use of this methodology makes it possible to determine three levels of impact of such expenditures: direct impact, indirect impact, and induced impact.

Table 3.9-1. Employment and Income of the OXY North Florida Complex.

Category	1981	Full Employment
Direct employment		
Mining	771	742
Chemicals	913	955
Production support	250	241
General and administrative	110	114
Feed division	58	67
Research and development	32	31
Total	2,134	2,150
Direct salaries (total)*		\$48,200,000
Average salary per employee*		\$22,400

\*Excludes employee fringe benefits.

Source: OXY.

Table 3.9-2. Employment at OXY's North Florida Complex by Place of Residence.

Place	1981	Full Employment
Columbia County	786	790
Hamilton County	626	628
Suwannee County	493	496
Other Florida counties	108	111
Georgia	<u>121</u>	<u>125</u>
Total	2134	2150

Source: OXY.

Table 3.9-3. Population of Florida and the North Florida Impact Area.

Area	1960	1970	1980
Florida	4,951,560	6,791,418	9,746,324
% change	--	37.1	43.5
Columbia County	20,077	25,250	35,399
% change	--	25.8	40.2
Hamilton County	7,705	7,787	8,761
% change	--	1.1	12.5
Suwannee County	14,961	15,559	22,287
% change	--	4.0	43.2
3-county total	42,743	48,596	66,447
% change	--	13.7	36.7
Duval County	455,400	528,865	571,003
% change	--	16.1	8.0

Source: U.S. Bureau of the Census 1960, 1970, and 1980.

Table 3.9-4. Selected Characteristics of the Labor Force, State of Florida, and Local Impact Area (by Place of Residence), 1970 and 1980.\*

Area	Civilian Labor Force	Employed	Unemployed
Florida			
1970	2,521,245	2,426,268	94,977
1980	4,304,136	4,002,330	301,806
% change	70.7	65.0	217.8
Columbia County			
1970	9,432	9,134	298
1980	15,114	14,251	863
% change	60.2	56.0	189.6
Hamilton County			
1970	2,596	2,584	12
1980	3,389	3,162	227
% change	30.5	22.4	1,791.7
Suwannee County			
1970	5,703	5,585	118
1980	8,821	8,350	471
% change	54.7	49.5	299.2
3-county total			
1970	17,731	17,303	428
1980	27,324	25,763	1,561
% change	54.1	48.9	264.7

\*Includes all employment, such as unpaid family workers and part-time workers.

Source: U.S. Bureau of the Census 1970 and 1980.

Table 3.9-5. Total Personal Income by Place of Residence, Florida, and Area of Primary Impact, 1970 and 1981.

Area	Total Personal Income (Millions)			Per Capita Personal Income		
	1970	1981	% Change Per Year	1970	1981	% Change Per Year
Florida	\$25,254	\$103,502	13.7	\$3,690	\$10,165	9.6
Columbia County	68	258	13.0	2,637	7,115	9.4
Hamilton County	17	58	11.2	2,222	6,406	10.1
Suwannee County	39	146	12.8	2,525	6,451	8.9
3-county total	124	462	12.8	2,536	6,799	9.4
Duval County	1,952	5,847	10.5	3,432	9,927	10.1

Source: U.S. Dept. of Commerce 1983 and Florida Statistical Abstract 1974.

Table 3.9-6. Income Earned for Participation in Current Production by Place of Work, Florida, and Local Impact Area, 1981 (Thousands).

Industry	Florida	Columbia	Hamilton	Suwannee	Total 3 Counties	Duval
Farming	\$1,134,291	\$7,740	\$3,180	\$8,089	\$19,009	\$8,056
Mining	252,075	0	0**	554	554	2,059*
Construction	5,289,067	7,080	1,648	3,156	11,884	294,397
Manufacturing	8,910,263	18,543	58,008	13,442	89,993	587,042
Transportation, utilities	5,633,597	22,286	1,471	8,048	31,805	540,235
Wholesale	4,599,866	9,925	1,392*	3,601	14,918	481,702
Retail	8,315,019	22,313	4,461	12,895	39,669	510,866
Finance, insurance, real estate	4,697,597	4,232	920	3,962	9,114	522,337
Services	14,505,241	24,792	3,209	11,507	39,508	907,184
Other	636,933	1,000	164*	1,511*	2,675	13,687*
Government	10,910,653	49,304	8,269	15,978	73,551	1,131,752
Total earnings	64,884,602	167,215	82,722	82,743	332,680	4,999,317
Total wage and salary	55,256,397	134,850	68,888	57,194	260,932	4,383,646

\*Estimated. The actual values were not published to avoid disclosure. However, sufficient data were available for reasonable estimates of these values.

\*\*OXY mining data are included within manufacturing.

Source: Florida Statistical Abstract 1983.

Table 3.9-7. Annual Economic Impacts of OXY's North Florida Complex on the State of Florida (1982 Dollars).

Type of Impact	Direct	Indirect	Induced	Total
Employment <sup>1</sup>	2,150	4,519	3,354	10,023
Revenues to Florida firms <sup>2</sup>	\$90,000,000	\$23,300,000	\$235,200,000	\$348,500,000
Income	48,200,000	74,100,000	55,000,000	177,300,000
State taxes	13,500,000	10,300,000	7,700,000	31,500,000
Local taxes	<u>1,900,000</u>	<u>7,500,000</u>	<u>5,500,000</u>	<u>14,900,000</u>
Total <sup>3</sup>	\$153,600,000	\$115,200,000	\$303,400,000	\$572,200,000 <sup>4</sup>
<u>Multiplier<sup>5</sup></u>				
Employment	1.00	2.10	1.56	4.66
Revenues to Florida firms	1.00	0.22	2.62	3.84
Income	1.00	1.54	1.14	3.68
State taxes	1.00	0.76	0.55	2.37
Local taxes	1.00	3.95	2.89	7.84
Total	1.00	0.73	1.98	3.73

<sup>1</sup>Labor-years.

<sup>2</sup>These values are residuals which can be interpreted as the total revenues of Florida firms which result from OXY's operations, exclusive of salary and wage payments and state and local taxes. They represent the total of that part of revenues available for purchase of supplies and equipment, for capital investments, and for profits.

<sup>3</sup>OXY's own sales are not included in the data shown. OXY's direct purchases from Florida firms and payments of salaries, wages, and taxes are included as direct impacts.

<sup>4</sup>The total impact estimate has a 95% confidence interval of approximately +\$50,000,000.

<sup>5</sup>In the model applied here, state and local government is included as an integral part of the model.

The direct impact on income is OXY's payroll. The indirect impact includes that part of the payrolls and earnings of proprietors of Florida firms that is made possible by OXY's purchases from them, as well as that part of state and local government payrolls that is made possible by OXY's payment of state and local taxes. The indirect impact also includes the payrolls and proprietors' incomes which result when suppliers make purchases from other Florida firms in order to supply OXY's needs, as well as the payrolls and proprietors' incomes of the Florida firms which supply those firms' needs, i.e., a part of the money paid by OXY to its suppliers is used to purchase goods from other firms. These firms, in turn, use a part of this to meet their payrolls and use a part of the rest to make purchases from still other firms, with the effect on income decreasing with each succeeding round of expenditures.

The induced impact of OXY's expenditures on the incomes of Floridians results from the expenditures by OXY employees of their salaries and wages within Florida, as well as the expenditures by the employees of OXY's suppliers of that part of their income which results from OXY's original purchases. The process continues in successive rounds in a similar fashion to the indirect impacts. Thus, the indirect impact results from inter-industry trading by Florida firms in an effort to meet OXY's needs. The induced impact results from the consumer expenditures of OXY's employees and the employees of suppliers in successive rounds until all consumer-serving businesses in the state have been affected to some degree.

The total impact on income from OXY's operations may thus be several times larger than its direct payroll. Similarly, the total employment which ultimately results from the operation may be several times larger than the direct employment at the mines and plants, and the total tax impacts will be larger than the directly paid taxes.

In Table 3.9-7, the "total" impacts represent the sum of the dollar amounts of all economic activities in the State of Florida which result from the Hamilton County operation, exclusive of OXY's own sales. The "Total Direct" value (\$153,600,000) represents the total of OXY's direct expenditures in Florida, including purchases from other Florida businesses, payroll, and direct state and local tax payments. The "Indirect" and "Induced" values represent the total business activity which results indirectly from purchases among businesses induced by consumer purchases. This "total" economic impact is also broken down into four components: 1) income to people, 2) state taxes, 3) local taxes, and 4) revenues to businesses, excluding state and local taxes and wages. Table 3.9-7 also presents the impacts on employment.

In the lower part of Table 3.9-7, impact multipliers are presented for each of the entries in the upper part. These simply state each respective impact as a multiple of OXY's own direct impact. It is estimated that operation of the Hamilton County complex is responsible for approximately \$572,200,000 in total economic impact on the Florida economy.

This does not include sales, but does include purchases from other Florida businesses, as well as the additional purchases from other Florida businesses by suppliers to support their sales to OXY, and sales to individuals as a result of income created by the employment generated directly and indirectly by OXY. This is, in effect, the total annual impact on the Florida economy.

In addition to the \$48,200,000 direct payroll, the north Florida complex is responsible for \$129,100,000 of salaries and wages generated indirectly by purchases within Florida and induced by consumer expenditures of the income received. Thus, the total amount of Florida's wage and salary income that is attributable either directly or indirectly to OXY is \$177,300,000, or about 0.3% of Florida's total wage and salary income in 1981 (Table 3.9-6). For comparison, total salary and wage income earned in Columbia, Hamilton, and Suwannee counties combined was \$260,932,000 in 1981.

The direct employment of 2150 people at the Hamilton County complex generates an additional 7873 jobs, resulting in a total employment impact on Florida of approximately 10,000 jobs. Total employment covered by unemployment compensation in Florida in 1982 is shown in Table 3.9-8.

In addition to jobs and incomes to persons, OXY is indirectly responsible for additional state and local taxes. OXY contributes \$1,900,000 annually in local taxes (primarily ad valorem taxes and severance tax rebates in Hamilton County). The indirect and induced multiplier effects on businesses and incomes result in \$14,900,000 in local taxes statewide. Similarly, OXY pays \$13,500,000 in state taxes (e.g., sales tax and severance tax, less that part that goes to Hamilton County), which results directly and indirectly in collection by the state of a total of \$31,500,000 in taxes (Table 3.9-7).

Severance tax on phosphate is distributed pursuant to statute, which prescribes that 50% be designated for the State's Conservation and Recreational Lands trust fund (CARL). CARL funds are used to acquire environmentally sensitive lands. The statute also provides for the return of 5% to Hamilton County.

### 3.9.2 North Florida Local Impacts

Approximately 94% of OXY's Florida employees live within the three-county area of greatest impact. These employees take about 94% of their total payroll home to these three counties and spend a substantial proportion of this income in the three-county area.

Table 3.9-9 summarizes the total impacts in the three-county impact area and is similar to Table 3.9-7, which addresses total Florida impacts. OXY is directly and indirectly responsible for \$276,300,000 of total economic impact (not including OXY's own sales) in the three-county area. Gross sales or gross value of private business activity in the three counties in 1982 as reported to the Florida Department of Revenue

Table 3.9-8. Employment Covered by Unemployment Compensation Law by Industry and Place of Employment, 1982.

Industry	Florida	Columbia	Hamilton	Suwannee	Total 3 Counties	Duval
Agriculture, forestry, fisheries	139,084	115	20	136	271	1,529
Mining	10,267	0	0*	16	16	81
Construction	268,607	583	95	222	900	15,672
Manufacturing	469,745	1,201	2,456*	1,206	4,863	27,815
Transportation, utilities	252,948	1,242	64	440	1,746	22,441
Wholesale	216,132	553	19	192	764	20,564
Retail	797,596	2,319	339	1,202	3,860	46,811
Finance, insurance, real estate	273,253	284	58	257	599	26,639
Services	1,170,854	3,663	700	1,392	5,755	71,819
Government	249,256	808	243	473	1,524	19,392
Other	901	0	0	0	0	16
Total	3,848,640	10,768	3,994	5,536	20,298	252,779

\*All OXY's employment is classified as manufacturing, and most of Hamilton County's manufacturing employment is OXY employment.

Source: Florida Statistical Abstract 1983.

Table 3.9-9. Annual Economic Impacts of OXY's North Florida Complex on the Three-County Impact Area (1982 Dollars).

Type of Impact	Direct	Indirect	Induced	Total
Employment <sup>1</sup>	2,026	2,480	1,561	6,067
Revenues to local firms <sup>2</sup>	\$27,800,000	\$13,400,000	\$115,600,000	\$156,800,000
Income	45,400,000	30,500,000	19,200,000	95,100,000
State taxes	13,500,000	2,900,000	1,800,000	18,200,000
Local taxes	1,900,000	2,600,000	1,700,000	6,200,000
Total <sup>3</sup>	\$88,600,000	\$49,400,000	\$138,300,000	\$276,300,000
<u>Multiplier</u>				
Employment	1.00	1.22	0.77	2.99
Revenues to local firms	1.00	0.48	4.16	5.64
Income	1.00	0.67	0.42	2.09
State taxes	1.00	0.21	0.13	1.35
Local taxes	1.00	1.37	0.89	3.26
Total	1.00	0.56	1.56	3.12

<sup>1</sup>Labor-years.

<sup>2</sup>These values are residuals which can be interpreted as the total revenues of area firms which result from OXY's operations, exclusive of salary and wage payments and state and local taxes.

<sup>3</sup>OXY's own sales are not included in the data shown. OXY's direct purchases in the three-county area are included, as are payroll and taxes.

amounted to \$772,974,000 (Table 3.9-10). Thus, 36% of all gross private business (excluding OXY) is attributable directly or indirectly to OXY. In addition, OXY's direct, indirect, and induced employment in this area accounts for approximately 24% of all jobs and 36% of the total salary and wage income (Tables 3.9-4, 3.9-6 and 3.9-9).

Finally, OXY's direct, indirect, and induced impact on local taxes amounts to \$6,200,000, about 3.26 times its direct tax payments (Table 3.9-9). Whereas the direct tax impact is felt almost exclusively in Hamilton County, the indirect and induced effects are also felt in Columbia and Suwannee counties.

### 3.9.2.1 Columbia County

Columbia County has the largest population and the largest, most diversified economy of the three impact area counties (Tables 3.9-3 through 3.9-8). At full employment, OXY employs about 2150 people, 790 (37%) of whom live in Columbia County (Table 3.9-2). Columbia County is the commercial hub of the area, serving the primary retail, wholesale, service, and financial needs of the surrounding communities. Because of this, a great deal of the indirect and induced impacts are felt there. Thus, while it is not possible with currently available information to accurately break down the total three-county impact into individual county impacts, it is clear that Columbia County enjoys substantially more than the 37% of the total \$276,300,000 impact implied by the proportion of OXY employees living there, and perhaps receives more than 50% of it (Table 3.9-9).

In 1980, Columbia County had 53.3% of the three-county area population (Table 3.9-3), 55.3% of the employed labor force (Table 3.9-4), and 53.0% of the employment (Table 3.9-8). It should be noted that the employment data in Table 3.9-4 are based on individually reported employment as of April 1 in the U.S. Census for 1970 and 1980 by place of residence while the data in Table 3.9-8 are the year's averages for employment reported by employers covered by unemployment insurance by place of work. Thus, the two are not totally compatible. The data in Table 3.9-8 do not include certain categories of employment that are included in Table 3.9-4 such as self-employed people, unpaid family workers, domestic employees, certain classes of farm workers, and certain classes of government workers. Thus, the total employment shown in Table 3.9-8 is less than that shown in Table 3.9-4.

Data on personal income (Table 3.9-5) and income earned from participation in current production in 1981 (Table 3.9-6) are more comprehensive than the employment data because they include all sources of income (or earnings). By far the largest single source of income earned in Columbia County is government, both state and federal. The other industries which are dominant in Columbia County as income sources are services, retail trade, transportation/communications/public utilities, and, to a lesser degree, manufacturing.

Table 3.9-10. Gross Sales Reported to the Florida Department of Revenue in the State and Three-County Impact Area, 1981 and 1982.

Area	1981	1982
Florida	\$156,619,282,000	\$161,796,459,000
Columbia County	403,877,000	411,319,000
Hamilton County	390,700,000	168,434,000
Suwannee County	210,569,000	193,221,000
3-County Total	\$1,005,146,000	\$772,974,000

Source: Florida Statistical Abstract 1983.

### 3.9.2.2 Hamilton County

Approximately 628 OXY employees live in Hamilton County (Table 3.9-2). The total number of employed people living in Hamilton County in 1980 was 3162 (Table 3.9-4), but the total number (covered by unemployment compensation) working there in 1982 was 3994 (Table 3.9-8). Thus, more people work in Hamilton County than live there. Manufacturing, including mining in Hamilton County, accounts for >61% of all employment in Hamilton County covered by unemployment insurance, and OXY accounts for >75% of total manufacturing employment in Hamilton County.

In terms of income and earnings, people living in Hamilton County received only 12.6% of the total three-county area income, but people working in Hamilton County earned almost 25% of total earned income in the three-county area. In summary, OXY accounts directly for more than half of all income earned in Hamilton County, almost two-thirds of all salary and wage income generated in Hamilton County, and half of all manufacturing earnings in the three-county area.

### 3.9.2.3 Suwannee County

Approximately 500 OXY employees live in Suwannee County (Table 3.9-2). In terms of population (Table 3.9-3) and employed labor force (by place of residence, Table 3.9-4), Suwannee County is larger than Hamilton County but smaller than Columbia County.

In terms of place of employment and source of earned income, however, Suwannee County is similar to Hamilton County. Its covered employment is greater than that of Hamilton County, especially in the retail and service trades and other "people-serving" types of businesses. While total income by place of residence in Suwannee County is about 2.5 times as large as that in Hamilton County, earned income by the place in which it was earned is very nearly the same in the two counties, and salary and wage income earned in Hamilton County is about 20% greater than that earned in Suwannee County.

Thus, a great deal of the income of people living in Suwannee County is earned outside the county, and a significant share of it (13-15%) is earned as direct salaries and wages at the Hamilton County complex, which is responsible for a significant amount of indirect and induced earnings within Suwannee County.

### 3.9.2.4 Duval County

Although Duval County is outside the major three-county impact area, a significant portion of OXY's total impact outside the three-county area is evident in Duval County. Duval County is the largest trade center in north Florida and consequently captures a major share of the indirect and induced expenditures, incomes, and employment impacts not contained within the immediate three-county impact area. Furthermore, a substantial share of the output of the Hamilton County complex is exported

through the Port of Jacksonville, including approximately 1.34 million tons of phosphate rock and 766,000 tons of superphosphoric acid in 1980. Together, the two commodities amounted to >2.1 million tons of bulk cargo in 1980 with an economic impact of >\$23,600,000 on the Jacksonville economy. This represented approximately 3% of the total economic impact associated with the Port of Jacksonville in 1980.

### 3.9.3 Population Characteristics

Columbia County has the largest population of the three counties in the immediate impact area with 35,400 people living there in 1980. Hamilton County, with a population of only 8761 people in 1980, is one of Florida's least populated counties (ranking 61st of 67 counties). Suwannee County had a total population of 22,287 in 1980 (Table 3.9-3).

### 3.9.4 Housing

Housing within the three counties is approximately proportional to the population. Approximately 90% of available housing units are occupied year-round in each of the counties, and about 23% of occupied units are renter-occupied in all three counties.

### 3.9.5 Public Facilities and Services

Most impact studies deal with expansion of both the employment and population base of an area which usually places a burden on public facilities and services. However, the proposed action would not expand the population base nor burden any existing public facilities and services. Instead, the loss of employment would cause the under-utilization of these facilities and services and reduce ad valorem contributions. The OXY facilities are largely self-contained with respect to water supply and treatment, fire protection, security, ambulance service, sewage treatment, and health services. OXY produces 16 megawatts of power through a cogeneration facility.

#### 3.9.5.1 Education

The Columbia County School District operates nine public schools, all located in or near Lake City. Lake City Community College, a major regional facility, is also located in Columbia County. Hamilton and Suwannee counties each support five schools for basic education plus special facilities for the trainable mentally retarded (the Greenwood School in Hamilton County) and vocational training (Suwannee County). The OXY complex is itself a significant educational resource, providing skilled job training for its employees.

#### 3.9.5.2 Health Services

Health care services are provided to residents of the three-county impact area by a variety of public and private organizations. Columbia County is a major medical center with more than 600 hospital beds in

three different facilities. Hamilton and Suwannee counties each support one hospital facility. OXY provides nursing and ambulance service at its facilities.

#### 3.9.5.3 Fire Protection

Fire protection is provided in the local impact area by municipal fire departments, rural volunteer fire departments, and the Florida Division of Forestry (in the Florida Department of Agriculture and Consumer Services). Fire protection at the Hamilton County facility is normally provided by OXY's own fire fighting personnel and equipment.

#### 3.9.5.4 Police Protection

Police protection is provided by three levels of law enforcement in the impact area, namely local police departments, county sheriff's departments, and the Florida Highway Patrol. OXY has auxiliary security personnel deputized by the Hamilton County Sheriff.

#### 3.9.5.5 Water and Sewer Services

Potable water is supplied to the residents of Columbia County by both public and private systems. Within the corporate limits of Lake City and in some surrounding unincorporated areas, potable water is supplied by two community water systems owned and operated by Lake City. Wastewater treatment facilities in Columbia County include individual sewage disposal systems (primarily septic tanks), a number of private wastewater treatment plants (with daily wastewater flows exceeding 2000 gallons per day), and a municipal system, which serves most of the city plus some customers in nearby unincorporated areas.

In Hamilton County, potable water is supplied by the cities of Jasper, Jennings, and White Springs, and by individual wells. Although the public water supply systems serve some areas outside corporate limits, most of the households residing in unincorporated areas of Hamilton County obtain potable water from individual wells. Municipal sewer systems and sewage treatment plants exist in all three Hamilton County municipalities, serving most developed areas within the cities and a few areas outside the municipal limits. Septic tanks are utilized in portions of each municipality lacking sanitary sewers and in unincorporated areas. OXY provides for its own water and operates its own sewage treatment plants.

In Suwannee County, public water systems serve the developed areas of both Live Oak and Branford and some areas immediately adjacent to these municipalities. Residents of other areas rely on individual wells. There are 13 wastewater treatment plants in Suwannee County.

#### 3.9.6 Transportation

The most important roadway segment serving the impact area for the present study is CR 137, which forms a loop between White Springs and Jasper that begins and ends at US 41/SR 100/SR 25. The Suwannee River Mine and

Chemical Complex are the only major developed land uses on this highway and thus are clearly responsible for most vehicular trips. This is the only highway segment on which the complex has a major impact. The highway system in the impact area is quite adequate overall.

Mainline rail service is provided by two Seaboard Coast Line (SCL) routes and one Southern Railway Line (SRL) through the impact area. The SCL tracks linking Jacksonville to points west on the Gulf coast follow the alignment of US 90 and SR 10 through Live Oak and Lake City. The north-south SCL tracks pass through Jasper and Live Oak. These tracks continue south to Branford, then shift east to an alignment close to US 41. The SRL (Norfolk and Southern) extends roughly parallel to US 41 from Valdosta to Lake City, passing through Jasper en-route, then continues in a southeasterly direction roughly parallel to SR 100. Phosphate products from the White Springs complex are shipped via SRL. OXY provides all of its own internal road system, and the bulk of all external shipments to and from the complex is by rail.

### 3.9.7 Recreation

The total land area of publicly-controlled recreational facilities in the impact area amounts to 135,700 acres or over 200 sq mi out of 2000 sq mi in the impact area as a whole. The Osceola National Forest property in Columbia County accounts for 59% of all recreational land in Hamilton, Columbia, and Suwannee counties. Another 32% is contained in two state wildlife management areas (the Lake Butler Wildlife Management Area and the Cypress Creek area in Columbia County) and 3000 acres (2%) are contained in the Occidental Wildlife Management Area in Hamilton County.

Along with forests and wildlife management areas, the important state facilities in the impact area include three state parks and one state memorial: O'Leno State Park, Ichetucknee Springs State Park, Suwannee River State Park, and the Stephen Foster State Memorial. OXY is contributing to the development of additional recreational areas for the future through reclamation of mined-out areas, including several lakes. These will become an important recreational resource for the area.

### 3.9.8 Fiscal Structure

The fiscal structures of the three counties of immediate impact are shown in Tables 3.9-11 and 3.9-12. Table 3.9-11 presents total state tax collections at the county level along with payments back to the counties from the state. The taxes collected include sales and use taxes, gasoline taxes, motor vehicle licenses, pari-mutuel wagering taxes, document stamp taxes, and the severance tax paid by OXY in Hamilton County. The funds distributed to the counties in this table include gasoline tax, special fuels tax, mosquito control state matching funds, revenue sharing, insurance agents license funds, and beverage licenses as well as general revenue and trust fund disbursements for local school districts.

Table 3.9-11. State Taxes Collected By Or Within Counties, Fiscal Year 1981-1982 (Thousands).

Area	Taxes Collected		Funds Distributed to Counties by State		Ratio of Distribution to Taxes
	Total	Sales Tax	Rebates, Revenue Sharing	To School Districts	
Florida	\$3,693,488	\$2,805,739	\$303,680	\$2,603,219	0.787
Columbia County	9,972	6,627	4,620	12,663	1.733
Hamilton County	14,400*	5,189	1,185	4,013	0.817
Suwannee County	5,465	3,276	1,560	8,616	1.862
3-county total	29,837	15,092	7,365	25,292	1.180
Duval County	203,456	157,987	14,645	171,327	0.914

\*Includes approximately \$8 million in severance taxes paid by OXY. The Florida Statistical Abstract shows \$12,703,000 in sales tax collections in Hamilton County, but this figure was adjusted to account for refunds of overpayments.

Source: Florida Statistical Abstract 1983.

Table 3.9-12. Local Government Revenue and Expenditures Per Capita.

Area	Revenue Per Capita	Expenditure Per Capita	Total County Revenue	% from Taxes
Florida	\$447.7	\$430.3	\$4,645,190,000	29.7
Columbia County	239.0	213.0	8,840,000	36.3
Hamilton County	473.4	613.0	4,148,000	26.8
Suwannee County	258.8	259.2	6,180,000	33.7
Duval County	654.9	648.9	359,333,000	30.0

Source: Florida Statistical Abstract 1983.

More is collected by the state from Hamilton County than from either Columbia or Suwannee counties, yet less is distributed to Hamilton County than to either of the others. Both Columbia and Suwannee counties receive almost twice as much from the state as the state collects from them. Hamilton County, on the other hand, receives only about 82% of what it contributes to the state. The bulk of the tax collections from Hamilton County are directly attributable to the OXY complex there.

### 3.9.9 Land Use

Three land use types predominate in Hamilton County (Barr, Dunlop, and Associates, Inc. 1976): forestry, agriculture, and mining. Forestry operations (planted pine and clearcuts) scattered throughout Hamilton County account for approximately 56% of the land use (Table 3.9-13). These operations are concentrated in the northwest portion of the county. Agricultural operations account for 21% of the county and are mostly concentrated in the western portion. Mining activities account for 3% of the land inventoried and are presently concentrated in an area immediately north of White Springs; however, these operations are anticipated to expand to encompass the east-central portion of Hamilton County (Barr, Dunlop, and Associates, Inc. 1976). These three land uses account for approximately 80% of Hamilton County, with an additional 1% in incorporated areas, 2% in various categories such as residential, commercial, and transportation, and 17% in vegetation communities such as upland forests and wetlands (Table 3.9-13).

Within the project boundaries the major land use is forestry operations (planted pine and clearcut), accounting for approximately 34% of the project area (Table 3.9-14). Forestry operations on forested wetlands and the remaining forested areas such as upland forests (which undergo various intensities of logging) affect approximately 75% of the land in the project area. Mining activities account for approximately 16% and agricultural activities account for approximately 8%, with the remaining land in a variety of uses such as residential, commercial, and transportation (Table 3.9-14).

### 3.9.10 Literature Cited

- Barr, Dunlop, and Associates, Inc. 1976. Comprehensive planning program, Hamilton County. Vol 1: Inventory. Prepared for Hamilton County. 81 pp.
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Table 3.9-13. Land Use Profile of Hamilton County.

Code*	Description	Acres	Percent of County
110	Residential	1,883	0.6
120	Commercial	355	0.1
130	Industrial	1,010	0.3
140	Transportation	2,872	0.9
150	Communications and utilities	27	<0.1
160	Institutional	139	<0.1
170	Recreational	1,248	0.4
210	Agricultural	63,633	19.4
220	Specialty farms	5,950	1.8
420	Upland hardwood forest	2,215	0.7
430	Upland mixed forest	39,587	12.1
440	Planted forest	177,790	54.3
450	Clearcut	5,037	1.5
500	Water	820	0.3
620	Wetland hardwood forest	9,930	3.0
630	Wetland mixed forest	1,630	0.5
750	Extractive (mining)	10,127	3.1
-	Incorporated areas	3,325	1.0
	Total	327,578	100.0

\*Florida Land Use and Cover Classification System (Florida Dept. of Admin. 1976).

Source: Barr, Dunlop, and Associates, Inc. 1976.

Table 3.9-14. Land Use Profile of the OXY Project Area.

Code*	Description	Acres	Percent of County
110	Residential	76	<0.1
120	Commercial	20	<0.1
130	Industrial	13	<0.1
140	Transportation	524	0.5
150	Communications and utilities	27	<0.1
160	Institutional	7	<0.1
190	Open land	21	<0.1
210	Cropland and pastureland	7,787	7.8
220	Orchards, groves	1	<0.1
230	Pecan orchard	1	<0.1
240	Confined feeding operations	51	<0.1
320	Shrub and brushland	105	0.1
410	Upland coniferous forest	3,935	3.9
420	Upland hardwood forest	87	0.2
430	Upland mixed forest	12,399	12.4
440	Planted forest	24,861	24.8
450	Clearcut	9,195	9.2
510	Streams and canals	66	0.1
520	Lakes	17	<0.1
530	Reservoirs	434	0.4
560	Other water areas	73	<0.1
610	Wetland coniferous forest	1,970	2.0
620	Wetland hardwood forest	3,411	3.4
630	Wetland mixed forest	18,924	18.9
640	Wetland, non-forested	430	0.4
740	Altered lands (mining)	390	0.4
760	Other barren lands (mining)	15,379	15.4
	Total	100,204	100.0

\*Florida Land Use and Cover Classification System (Florida Dept. of Admin. 1976).

Source: OXY.

Florida Department of Administration. 1976. The Florida land use and cover classification system: a technical report. Division of State Planning, Bureau of Comprehensive Planning, Tallahassee, FL. 50 pp.

Florida Statistical Abstract. 1974, 1983.

U.S. Bureau of the Census. 1960, 1970, 1980. Census of population.

U.S. Department of Commerce. 1983. Survey of current business.

### 3.10 Recreation and Natural Resources of the Suwannee River

An analysis of recreational and natural resource features or activities of the Suwannee River was conducted utilizing criteria of the ACOE Recreation and Natural Resource Assessment Criteria (ACOE 1978\*). General recreation value of the Suwannee River was evaluated to be moderate (Table 3.10-1). This was due primarily to limited access to the river in the project area and lack of developed recreational areas. Specific features evaluated include:

- limited power boating;
- non-powered boating on flowing water;
- primitive camping;
- flora and unique natural features observation and study;
- boat fishing; and
- general hiking.

Results of a qualitative evaluation of these features indicated recreational values of moderate to high.

\*ACOE 1978. Army Corps of Engineers Regulation EC 1105-2-87, Appendix F, Recreation and Natural Resources.

Table 3.10-1. Determination of General Recreational Value of the Suwannee River in Proximity to the Project Area.

Criteria	Judgement Factors	Assigned Score	Maximum Score Possible
Quality and quantity of access and recreational facilities provided.	Limited access, no recreational facility development.	3	15
Recreational opportunities available.	Conditions suitable to multiple activities such as canoeing, fishing, and primitive camping.	12	15
Aesthetic, scientific, and educational values.	Attractive, aesthetic values high. Some archaeological, ecological, geological, or historical values present.	12	15
Competitive water-oriented parameters.	Several competitive water areas within 50 mi but none within 10 mi.	6	15
Market area population.	Estimated that 75% of recreational use is from within 50 mi of project area.	12	15
Operations.	Moderate water level fluctuation resulting in unstable water surface.	9	12
	TOTAL	54	87
	Value	60%	Moderate

Source: OXY consultant study data.