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Pesticide Residue Monitoring in Sediment and Surface Water Within the South Florida Water Management District Volume 2

by

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ABSTRACT

Pesticide monitoring data are collected under the requirements of several permits and agreements as an indicator of water quality. The monitoring provides data to determine shifts or adverse trends in the quality of water being delivered to Lake Okeechobee, Everglades National Park, and the Water Conservation Areas. In addition, pesticide residue data are collected throughout the South Florida Water Management District at locations selected to determine water quality conditions at the major water control points. Special investigations are performed on selected pesticides as required and follow-up sampling is conducted based on the pesticides detected. Data were collected from 13 stations in 1984. By 1988, the network was expanded to 29 stations. Currently, water and sediment samples are collected quarterly and analyzed for 67 pesticides, herbicides and degradation products. Out of a total of 197 surface water samples, 13 percent had detectable residues, while 25 percent of the 208 sediment samples had detectable residues. The compounds detected in the water samples included atrazine and zinc phosphide while a variety of compounds, including DDT, have been detected in the sediment. None of the residues detected are considered to have adverse health or environmental effects.

Key Words. pesticide, herbicide, residue, degradation, surface water, sediment

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EXECUTIVE SUMMARY

This technical publication summarizes the results of the pesticide monitoring program conducted by the South Florida Water Management District (SFWMD) from August 1984 to July 1988. This information provides an indication of the extent of pesticide contamination within the SFWMD.

The pesticide monitoring data are collected under the requirements of the Florida Department of Environmental Regulation's Lake Okeechobee Operating Permit and North New River Canal/G-123 Backpumping Permit. Additional monitoring requirements are outlined in the Everglades National Park Memorandum of Agreement and the Miccosukee Tribe Memorandum of Agreement. The pesticide monitoring data are used as an indicator of water quality with the intent to report any values above the non-degradation standards of the memorandums of agreement. The monitoring will provide data to determine shifts or adverse trends in the quality of water delivered to Lake Okeechobee, Everglades National Park, and the Water Conservation Areas. In addition, pesticide residue data are collected throughout the SFWMD at locations selected to determine water quality conditions at the major water control points. Special investigations are performed on selected pesticides as required, and follow-up sampling is conducted based on the pesticides detected.

The original monitoring program consisted of semi-annual surveys for the compounds and stations delineated in the operating permits and memorandums of agreement. In 1987, it was determined that quarterly sampling would provide a better insight into potential pesticide contamination within the SFWMD. The monitoring program currently consists of stations located at Lake Okeechobee and Water Conservation Area inflows and outflows, Caloosahatchee River, and Everglades National Park inflows and watershed structures. Both surface water and sediment samples are collected on a quarterly basis and analyzed for 67 pesticides, herbicides and degradation products. This set of compounds includes chemicals currently utilized in the agricultural areas as well as compounds presently banned or currently restricted to non-crop areas.

Data were collected from 13 stations in 1984 and increased to 29 stations in 1988. Out of a total of 197 surface water samples and 208 sediment samples, 26 surface water samples (13 percent) and 52 sediment samples (25 percent) had detectable pesticide residues. No discernable trends concerning seasonal or spatial variations can be determined from these limited data.

Only three compounds were detected in the surface water samples: silvex, zinc phosphide, and atrazine. The silvex detection appeared to be a lab artifact, and not the result of actual water contamination. Zinc phosphide was detected only during the first two special monitoring events but not during the subsequent quarterly sampling or site specific study. Since zinc phosphide is acutely toxic, monitoring will continue during the routine sampling to determine any patterns or possible explanation for these results.

Atrazine was consistently detected in the water samples. The levels found were not considered to have any potential adverse environmental or health effects as this compound does not bioaccumulate and is not considered very toxic. The majority of the 34 detections were between 0.1 and 1.0 µg/L. Only 13 detections were greater than 1.0 µg/L, with the highest quantity 13.2 µg/L. Stations S-4, S-6, S-7, S-8,

detectable quantities on more than one occasion, indicating a greater usage of atrazine in these areas.

The majority of pesticide residues detected in the sediment consisted of DDD and/or DDE. The concentrations detected were less than those routinely found during previous SFWMD monitoring. These compounds were found fairly consistently at the same stations (S-2, S-3, S-4, S-6, S-7, S-177, S-5A, and S-99). The other compounds detected in the sediment were: diazinon, malathion, aldrin, ametryn, 2,4-D, methamidophos, paraquat, heptachlor, heptachlor epoxide, atrazine, chlorpyrifos, alpha BHC, delta BHC, alpha endosulfan, DDT, and ethion. The only compounds to be detected during more than one sampling event, in addition to DDD and DDE, were ethion and DDT. Both of these compounds were found in areas of citrus agriculture. The remainder of the compounds were detected only during one specific sampling event, but possibly at several stations. There are no State of Florida or USEPA criteria or health standards for agricultural chemical residues in the sediment.

TABLE OF CONTENTS

Abstract i

Acknowledgements ii

Executive Summary iii

List of Figures vi

List of Tables vi

Introduction 1

Materials and Methods 2

Results and Discussion 6

- Pesticides Detected in Water 6
  - Zinc Phosphide 6
  - 2,4,5-TP 9
  - Atrazine 9
- Pesticides Detected in Sediment 11
  - DDT, DDD, and DDE 11
  - Diazinon, Malathion, and Aldrin 15
  - Ametryn, Methamidophos, and 2,4-D 15
  - Paraquat 18
  - Alpha BHC and Heptachlor Epoxide 18
  - Delta BHC, Alpha Endosulfan, Ethion, Chlorpyrifos, and Atrazine 18
  - Heptachlor and Ethion 19

Summary and Conclusions 20

References 26

Appendix:

A. List of the compounds and minimum detection limits for each sampling event 29

B. Brief descriptive paragraph for each compound analyzed ... 43

Index of Pesticides 60

LIST OF FIGURES

1. Pesticide Monitoring Stations 5

LIST OF TABLES

1. Pesticide Residue Sampling Dates and Stations Within South Florida Water Management District 3

2. Summary of Zinc Phosphide Analysis 7

3. Atrazine Surface Water Data Through Third Quarter FY87/88 Sampling Event 10

4. Summary of DDT, DDD, and DDE Sediment Residues by Sampling Event and Date 13

5. Summary of Sediment Pesticide Residues by Sampling Event and Date 16

6. Summary of Positive Field Data for Surface Water and Sediment Sampling 21

7. Ranking of Sampling Stations by the Percent Positive Pesticide Residues in Water Samples Collected from August 1984 to July 1988 23

8. Ranking of Sampling Stations by the Percent Positive Pesticide Residues in Sediment Samples Collected from August 1984 to July 1988 23

9. Summary of Atrazine Surface Water Data 25

INTRODUCTION

This is the second volume of South Florida Water Management District (SFWMD) publications documenting the results of surface water and sediment pesticide monitoring within the SFWMD. Technical Publication 85-2, "Pesticide Residue Monitoring in Sediment and Surface Water Bodies Within the South Florida Water Management District" (Pfeuffer, 1985), is a compilation and evaluation of data from 1976 through 1983. This technical publication summarizes the pesticide data collected during August 1984 to July 1988 and provides a convenient source of SFWMD pesticide monitoring information. This information serves as an indication of potential selected pesticide contamination within the study area.

The SFWMD obtains some of the pesticide data as part of the requirements of the Florida Department of Environmental Regulation's (FDER) Lake Okeechobee Operating Permit and North New River Canal/G-123 Back-pumping Permit. Additional monitoring requirements aimed at complying with the non-degradation standards are outlined in the Everglades National Park Memorandum of Agreement (ENP MOA) and the Miccosukee Tribe Memorandum of Agreement (MT MOA). The monitoring will provide data to determine shifts or adverse trends in the quality of water being delivered to Lake Okeechobee, Everglades National Park, and the Water Conservation Areas.

Additional pesticide residue data are collected to determine water quality conditions at the major water control structures throughout the SFWMD. Special investigations are performed on selected pesticides as required, and follow-up sampling is conducted based on the pesticides detected.

MATERIALS AND METHODS

The original monitoring program consisted of semi-annual surveys for the compounds and stations listed in the operating permits and memorandums of agreement. Table 1 identifies the sampling dates, stations, and matrix sampled for each event, while Figure 1 identifies the station locations. In 1987 it was determined that quarterly sampling would provide a better insight into potential pesticide contamination within the SFWMD. Additional stations around Lake Okeechobee (S-191, S-65E, FECSR78, and S-235) were also added at this time. Sampling at S-190 and L3OWBR (L-3 Canal at Oil Well Bridge) was added during the Third Quarter 1987 monitoring event as specified in the MT MOA. Caloosahatchee River stations (S-78, CR-33.5T, and S-79) were added during the Second Quarter 1988 sampling. The following quarter, the three Upper Kissimmee Chain of Lakes tributary stations were added (ABOGG, BWSHNGLE, CREEDYBR). The North New River Canal/G-123 Backpumping Permit expired after the Summer 1985 sampling event. Therefore, it was not necessary to continue sampling stations L-38-I, Marsh-2, and NNR2. The monitoring program currently consists of 29 stations located at the Upper Kissimmee Chain of lakes tributaries, Lake Okeechobee and Water Conservation Area inflows and outflows, Caloosahatchee River, and Everglades National Park inflows and watershed structures.

Both surface water and sediment samples are collected quarterly and analyzed for 67 pesticides, herbicides and degradation products. This set of compounds includes chemicals currently utilized in the agricultural areas as well as compounds presently banned or currently restricted to non-crop areas. The selection of compounds to monitor is based on the availability of a suitable analytical methodology, potential environmental impact, and usage in the drainage basin. Appendix A lists the compounds analyzed and the minimum detection limits for each sampling event. Appendix B provides some technical information on each compound analyzed during the monitoring.

The water and sediment samples were collected by SFWMD personnel in sample containers provided by the contract laboratory and specifically prepared for pesticide residue sampling. Samples were collected from a small boat at mid-canal, upstream of each water control structure. Water samples were obtained near the surface; surficial sediments were obtained using a stainless steel petite Ponar dredge. Split samples and travel blanks were utilized as quality assurance checks. All samples were stored on ice or refrigerated until analyzed.

TABLE 1. Pesticide Residue Sampling Dates and Stations within South Florida Water Management District.

	Sampling Event and Date											
Station	Summer 1984 August 29 1984	Winter 1984 November 5 1984	Summer 1985 July 17-19 1985	Winter 1985 February 11-12 1986	Summer 1986 June 25-26 1986	Second Quarter FY 86/87 January 26-28 1987	Third Quarter FY 86/87 April 13-15 1987	Fourth Quarter FY 86/87 July 20-22 1987	First Quarter FY 87/88 October 26-28 1987	Second Quarter FY 87/88 February 22-24 1988	Third Quarter FY 87/88 April 11-13 1988	Fourth Quarter FY 87/88 July 25-27 1988
S-2[a]	W,S	-	W,S	W,S	W,S	W,S	W	W,S	W,S	W,S	W,S	W,S
S-3[a]	W,S	-	W,S	W,S	W,S	W,S	W	W,S	W,S	W,S	W,S	W,S
S-4[a]	W,S	-	W,S	W,S	W,S	W,S	W	W,S	W,S	W,S	W,S	W,S
S-6[a]	W,S	-	W,S	W,S	W,S	W,S	W	W,S	W,S	W,S	W,S	W,S
S-7[a]	W,S	-	W,S	W,S	W,S	W,S	W	W,S	W,S	W,S	W,S	W,S
S-8[a]	W,S	-	W,S	W,S	W,S	W,S	W	W,S	W,S	W,S	W,S	W,S
S-332[b]	-	S	S	S	S	W,S	W	W,S	W,S	W,S	W,S	W,S
S-18C[b]	-	S	S	S	S	W,S	W	W,S	W,S	W,S	W,S	W,S
S-176[b]	-	S	S	S	S	W,S	W	W,S	W,S	W,S	W,S	W,S
S-177[b]	-	S	S	S	S	W,S	W	W,S	W,S	W,S	W,S	W,S
S-178[b]	-	S	S	S	S	W,S	W	W,S	W,S	W,S	W,S	W,S
S-12C[b]	-	S	S	S	S	W,S	W	W,S	W,S	W,S	W,S	W,S
US41-25[b]	-	S	S	S	S	W,S	W	W,S	W,S	W,S	W,S	W,S
S-9[b]	-	-	S	S	S	W,S	W	W,S	W,S	W,S	W,S	W,S
L-38-1[c]	-	-	W,S	-	-	-	-	-	-	-	-	-
Marsh-2[c]	-	-	W,S	-	-	-	-	-	-	-	-	-
NNR2[c]	-	-	W,S	-	-	-	-	-	-	-	-	-
Torry Island	-	-	-	S	-	-	-	-	-	-	-	-
L-28-I	-	-	-	-	S	W,S	-	-	-	-	-	-
S-191	-	-	-	-	-	W,S	W	W,S	W,S	W,S	W,S	W,S
S-65E	-	-	-	-	-	W,S	W	W,S	W,S	W,S	W,S	W,S
FECSR78	-	-	-	-	-	W,S	W	W,S	W,S	W,S	W,S	W,S
S-235	-	-	-	-	-	W,S	W	W,S	W,S	W,S	W,S	W,S
S-31	-	-	-	-	-	W,S	W	W,S	W,S	W,S	W,S	W,S
S-5A	-	-	-	-	-	-	W	W,S	W,S	W,S	W,S	W,S
L3OWBR[d]	-	-	-	-	-	-	W	W,S	W,S	W,S	W,S	W,S
S-190[d]	-	-	-	-	-	-	W	W,S	W,S	W,S	W,S	W,S
S-99	-	-	-	-	-	-	-	-	-	W,S	W,S	W,S
S-78	-	-	-	-	-	-	-	-	-	W,S	W,S	W,S

TABLE 1. (continued)

Sampling Event and Date

Station	Summer 1984 August 29 1984	Winter 1984 November 5 1984	Summer 1985 July 17-19 1985	Winter 1985 February 11-12 1986	Summer 1986 June 25-26 1986	Second Quarter FY 86/87 January 26-28 1987	Third Quarter FY 86/87 April 13-15 1987	Fourth Quarter FY 86/87 July 20-22 1987	First Quarter FY 87/88 October 26-28 1987	Second Quarter FY 87/88 February 22-24 1988	Third Quarter FY 87/88 April 11-13 1988	Fourth Quarter FY 87/88 July 25-27 1988
S-79	-	-	-	-	-	-	-	-	-	W,S	W,S	W,S
CR-33.5T	-	-	-	-	-	-	-	-	-	W,S	W,S	W,S
ABOGG	-	-	-	-	-	-	-	-	-	-	W,S	W,S
BWSHNGLE	-	-	-	-	-	-	-	-	-	-	W,S	W,S
CREEDYBR	-	-	-	-	-	-	-	-	-	-	W,S	W,S

Key: "W" Represents that the surface water was sampled at this station.
"S" Represents that the sediment was sampled at this station.
"-" Represents that this station was not sampled.

[a] Station established for Lake Okeechobee Operating Permit.
[b] Station established for Everglades national Park Memorandum of Agreement.
[c] Station established for North New River/G-123 Backpumping Permit.
[d] Station established for Miccosukee Tribe Memorandum of Agreement.

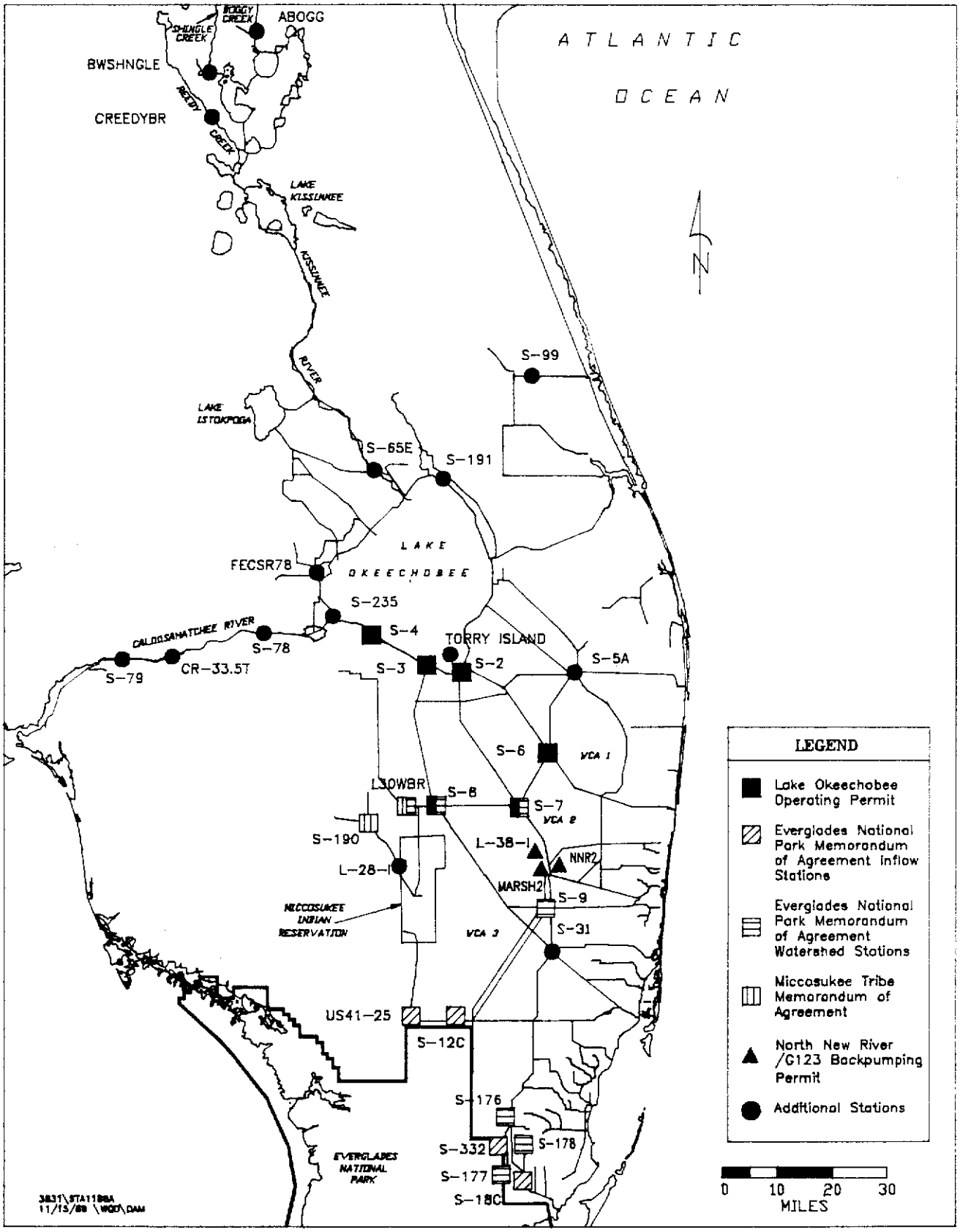

Figure 1. Pesticide Monitoring Stations

RESULTS AND DISCUSSION

For clarity, this section is split into two portions; (1) reporting the data generated from the analysis of the water samples, and (2) a section on the sediment data. The results and discussion will only cover the detected compounds.

Pesticides Detected in Water

Zinc Phosphide. A separate investigation of the rodenticide active ingredient zinc phosphide was conducted in 1986 and 1987. This monitoring effort was in response to reports concerning the application of a heavy metal poison to control cotton rats in sugarcane. Zinc phosphide has registered uses in the production of macadamia nuts, sugarcane, ornamental lawn and turf, and non-crop areas (National Pesticide Information Retrieval System (NPIRS), 1988). The purpose of this study was to determine if detectable quantities of zinc phosphide would be present in the water during the fall/early winter application season.

The aerial application of the carrier bait up to the edge of the sugarcane field enhances the possibility of the zinc phosphide entering offsite agricultural canals. Sampling was performed during the period of the year when rats were likely to be a problem; therefore, the potential for zinc phosphide being applied was at its greatest.

For the initial sampling conducted on September 23, 1986, surface water samples were obtained at the six pump stations surrounding the Everglades Agricultural Area (EAA) (S-2, S-3, S-4, S-6, S-7, and S-8). At the time of sampling, pump stations S-6, S-7, and S-8 were discharging and the samples collected at these stations could have contained water that was recently exposed to zinc phosphide. Five of the six samples contained detectable concentrations of zinc phosphide (Table 2). The detected values were not very high, ranging from 2 to 6 ppb. However, based on the structure of zinc phosphide and its anticipated rapid degradation in the water, the compound's presence in detectable quantities was unexpected. As a consequence of these results, more water samples were collected on January 14, 1987 at the original six pump stations. In addition, due to the possible adverse health effects, water samples were obtained at the Clewiston and South Bay water intake structures in Lake Okeechobee. A sample of potable tap water from the South Bay public water supply was also obtained.

Zinc phosphide was detected at all six pump stations at concentrations similar to those measured in September (Table 2). However, the water samples taken at the public water supply intake structures were below the minimum detection limit. Detections at the public water supply intakes would not be likely as discharges to the lake were minimal prior to sampling. None of the pump stations were pumping at the time of sampling.

TABLE 2. Summary of Zinc Phosphide Analysis. Units are µg/L or ppb, measured as phosphine gas.

Station	Sampling Event and Date: September 23 1986	January 14 1987	Second Quarter FY86/87 January 26 1987	Fourth Quarter FY86/87 July 21 1987	First Quarter FY87/88 October 27 1987
S-2	6	4	<1	<1	<1
S-3	2	2	<1	<1	<1
S-4	<1	2	<1	<1	<1
S-235	-[a]	-	<1	-	-
FECSR78	-	-	<1	-	-
S-65E	-	-	<1	-	-
S-191	-	-	<1	-	-
S-6	5	5	<1	<1	<1
S-7	5	6	<1	<1	<1
S-7 non-potable tap water	-	3	-	-	-
S-8	3	2	<1	<1	<1
L-28I	-	-	<1	-	-
S-9	-	-	<1	-	-
S-31	-	-	<1	-	-
S-12C	-	-	<1	-	-
US41-25	-	-	<1	-	-
S-176	-	-	<1	-	-
S-177	-	-	<1	-	-
S-178	-	-	<1	-	-
S-332	-	-	<1	-	-
S-18C	-	-	<1	-	-
S-5A	-	-	-	<1	<1
L3OWBR	-	-	-	<1	<1
S-190	-	-	-	<1	<1
Clewiston water intake structure	-	<1	-	-	-
South Bay water intake structure	-	<1	-	-	-
South Bay potable tap water	-	<1	-	-	-

[a] Station not sampled.

Pump station S-4 had a 2 µg/L zinc phosphide residue in the water column, whereas previously, zinc phosphide was below the minimum detection limit of <1 µg/L. At pump station S-2, a decrease from 6µg/L to 2 µg/L from the previous water sample was documented. The non-potable tap water at the S-7 pump station is obtained directly from the North New River Canal. This sample would be considered analogous to the surface water sample obtained at this station.

The quality assurance checks demonstrated satisfactory analyses were performed by the analytical laboratory. The duplicate samples taken at S-3 and S-8 had the same or only 1 µg/L difference between them, and the analysis of a distilled water blank showed no detectable residues.

The detected values on January 14 were not very high. However, the aerial application of the carrier bait would normally have been completed by December. It was not anticipated that detectable quantities would still be present at the stations surrounding the EAA due to the expected rapid degradation in water. Since the zinc phosphide continued to be present, this compound was added as a routine parameter to the pesticide monitoring network during the period of possible application.

Wide scale monitoring was performed on January 26, 1987 during the Second Quarter sampling to discern the possible extent of contamination. However, all residues were below the minimum detection limit, indicating that the zinc phosphide found 12 days earlier had dissipated. One explanation is the residence time or half-life of zinc phosphide in water was finally exceeded and the residue rapidly dissipated. The second possible explanation is the zinc phosphide was utilized in the sugarcane fields past the usual application period and the half-life in the water column is not as long as it appears. In the second situation, the zinc phosphide residues detected in mid-January were not of the same origin as those detected in September, but were the result of a possible additional rodenticide application near the time of sampling.

The subsequent scaled down monitoring in July 1987 (Fourth Quarter FY86/87) and October 1987 (First Quarter FY87/88) did not detect any zinc phosphide. Since zinc phosphide is routinely utilized during the fall/winter season in sugarcane, positive samples were conceivably possible for the October 1987 sampling, based on the September 1986 data. Zinc phosphide monitoring will continue during the routine sampling to discern any patterns or plausible explanation for these results.

A study was also initiated in September 1986 to examine the effect of an aerial application of zinc phosphide on canal water quality at the point of dosage. The purpose of this site-specific cooperative effort between the SFWMD, the FDER, and the grower cooperator, David Simonson, Inc., was to measure detectable levels, if any, of zinc phosphide present in a canal-type irrigation system within a sugarcane field. However, no positive results were obtained in any samples, although rain occurred on the day after application. Samples were taken immediately after application, one, three, seven, fourteen, and twenty-eight days later. This study did not provide any insight into the fate of zinc phosphide as these results appear to contradict the monitoring data.

Zinc phosphide is acutely toxic, although the potential for bioaccumulation is small. No State of Florida surface water quality standards or United States Environmental Protection Agency (USEPA) guidelines exist for zinc phosphide. To put some perspective on a compound's toxicity, it is possible to calculate the level of a contaminant in drinking water at which adverse health effects would not be

anticipated by using an USEPA developed, verified reference dose (this is comparable to an acceptable daily intake (ADI) value). Since no verified reference dose for zinc phosphide has been determined, a 0.0004 mg/Kg/day reference dose for aluminum phosphide, an outdoor fumigant for burrowing rodent control, was used to calculate a 14 ppb contaminant level. This value represents the maximum contaminant level in drinking water at which adverse health effects would not be anticipated in the average adult, based on a 70 kg body weight and the ingestion of 2 liters of water per day. This value is two to seven times higher than the measured values from the field sampling (Table 2). However, if this calculation is performed for a small child of 10 kg body weight who consumes one liter of water per day, the maximum contaminant level is 4 ppb. This value is similar to the field results and could hypothetically cause adverse health effects if a small child were to routinely consume untreated canal water. Nevertheless, from the data collected so far, zinc phosphide does not appear to have threatened drinking water supplies since the concentrations found in the EAA canals were transitory and the compound was not detected at the two water supply intakes.

2,4,5-TP. During the January 1987 (Second Quarter FY86/87) sampling event, the herbicide 2,4,5-TP (silvex) was detected in the surface water at S-177. The concentration of 0.41 ppb was just above the minimum detection limit of 0.4 ppb. This herbicide had undergone a special review or RPAR (Rebuttable Presumption Against Registration) by the USEPA and all uses were canceled in October 1983. Since the duplicate sample taken at this station did not have any detectable residue and the use of this herbicide has been canceled for over three years, this small quantity of herbicide (i.e. 0.01 ppb over the detection limit) could be a laboratory artifact. This compound was utilized as a spike for the quality assurance testing and may have been introduced into the analysis.

Atrazine. The herbicide atrazine was detected repeatedly at low levels at several stations (Table 3). The compound was first observed in water samples in 1987, but its presence prior to that time is uncertain. Atrazine analyses did not begin until 1986, and in that year the minimum detection limits were higher. When the detection limit improved from 5 and 10 ppb to 0.1 ppb in 1987-88, residues of atrazine were revealed.

Atrazine was first detected in the surface water during the April 1987 (Third Quarter FY86/87) sampling at S-4, S-5A, S-6, and S-7 at 3.5, 10.8, 4.0 and 8.9 ppb, respectively (Table 3). At the time of sample collection, none of the these pump stations were active.

This restricted use selective herbicide is registered for use on sugarcane, corn, and turf grasses. Application rates vary, with up to 4 pounds of the commercial product applied per acre. The positive field results are the reflection of sampling at the appropriate time. Atrazine can be used in sugarcane fields during the time sampling occurred. Also, approximately two weeks before sampling, roughly one inch of rain fell over the EAA, potentially triggering a runoff event which could have contained some atrazine. The half-life of atrazine is very site specific, but is reported to be approximately 10 days in the water and 45 days in the soil (United States Department of Health and Human Services (USDHHS), 1981).

TABLE 3. Atrazine Surface Water Data Through Third Quarter FY87/88 Sampling Event. Units are µg/L or ppb.

	Sampling Event and Date					
Station	Third Quarter FY86/87 April 13-15 1987	May 28 1987	Fourth Quarter FY86/87 July 20-22 1987	First Quarter FY87/88 October 26-28 1987	Second Quarter FY87/88 February 22-24 1988	Third Quarter FY87/88 April 11-13 1988
S-2	ND	0.4	ND	ND	0.3	ND
S-3	ND	0.2	ND	ND	ND	ND
S-4	3.5	0.3	ND	ND	0.3	ND
S-5A	10.8	0.4	ND	ND	1.9	12.3
S-6	4.0	1.8	ND	ND	1.0	0.9
S-7	8.9	0.2	2.91	ND	3.0	0.4
S-8	ND	0.3	0.77	ND	0.5	ND
S-190	ND	-	ND	ND	ND	1.7
L3OWBR	ND	0.2	ND	ND	ND	0.5
S-31	ND	-	ND	ND	ND	0.6[a]
S-78	-	-	-	-	0.5	ND
CR-33.5T	-	-	-	-	1.1	ND
S-79	-	-	-	-	ND	1.1
S-176	ND	-	ND	ND	ND	0.5
S-332	ND	-	ND	ND	ND	1.0
S-177	ND	-	ND	ND	ND	0.7
S-178	ND	-	ND	ND	ND	13.2
S-18C	ND	-	ND	ND	ND	0.8
Detection limit	0.1	0.2	0.1	0.1	0.1	0.1

Key: "ND" Represents that atrazine was not detected.
"-" Represents that station was not sampled.

[a] Average of two samples.

Stations S-2, S-3, S-4, S-5A, S-6, S-7, S-8, and L3OWBR were resampled on May 28, 1987 as a result of these atrazine residues. At the time of sample collection none of the pump stations were pumping. However, water from Lake Okeechobee was flowing into the agricultural area at S-2 and S-3. The atrazine residues found were substantially dissipated with the levels at or near the detection limit at all stations except S-6.

The July 1987 (Fourth Quarter FY86/87) monitoring found atrazine in the surface water at two stations, S-7 and S-8, at 2.91 and 0.77 ppb, respectively. At the time of sample collection, S-7 was pumping while S-8 discharged through the gravity gate. One week before the sampling, varying amounts of rain (over one inch at S-7) fell over the EAA potentially triggering a runoff event which could have contained some atrazine.

For the February 1988 (Second Quarter FY87/88) sampling, atrazine was found in the surface water at eight different locations. At the time of sample collection S-2, S-7, and S-8 discharged through their associated gravity gate into the agricultural areas. Trace amounts of rain occurred over the EAA the week before sampling.

Atrazine was detected again in twelve of the water samples obtained during the April 1988 (Third Quarter FY87/88) sampling event. During sampling, structures S-176, S-177, S-332, S-8, S-9, S-65E, and S-235 were all discharging into their respective canals. Structures S-2 and S-3 were under conditions of reverse flow, that is, providing water from Lake Okeechobee for irrigation. Concentrations were still low, but the areal extent of contamination increased as indicated by the additional stations with detectable residues.

Atrazine is considered only slightly toxic as the LD_{50} (a calculated oral dose of an acutely-administered substance which is expected to cause death in 50 percent of a population of a test animal species) for rats is 1,780 mg/Kg body weight. The LC_{50} (lethal concentration) for fish ranges from 6,300 to 78,000 ppb and a LC_{50} (48 hour) for freshwater invertebrates ranges from 720 to 6,700 ppb. The highest concentration found in this monitoring program (13.2 ppb) does not represent a level high enough to cause an acute toxic effect on fish or invertebrates.

No State of Florida surface water or drinking water quality standards or guidelines exist for atrazine. The USEPA has established a lifetime health advisory level of 3 ppb for atrazine in drinking water. Health advisories are established using assumptions for lifetime exposure and the consumption of drinking water. Levels of atrazine above 3 ppb would be of concern to human health if the water is used as drinking water. Some of the atrazine residues detected exceed this level and could hypothetically cause adverse health effects if untreated canal water was routinely consumed.

Pesticides Detected in Sediment

A variety of compounds have been detected in the sediment. The results of the sediment analysis are presented chronologically by the compounds detected. Pesticide residues in the sediment give an indication of the previous presence of the compound in the water column. There are no State of Florida or USEPA criteria or health standards for agricultural chemical residues in the sediment.

DDT, DDD, and DDE. During the November 1984 (Winter 1984) sampling event, only DDE, a degradation product of DDT, was detected in the sediment at stations S-177, S-178, and US41-25 at 7.3, 10, and 4.9 µg/Kg, respectively (Table 4). Stations S-177 and S-178 are

located in areas of predominately agricultural land use.

The DDE present could be a relic residue from the past use of DDT since DDT has been banned since 1974. The smaller residue at station US41-25 does not appear to be the result of agricultural use, as this area is isolated from any farming, but may be the result of the ubiquitous nature of DDT contamination. These exact sites have not been previously sampled, but DDE has been randomly detected in the sediment during other SFWMD monitoring programs (Pfeuffer, 1985).

One additional sediment/soil sample was collected at a former agricultural area on Torry Island during the Winter 1985 sampling which occurred during February 1986 (Figure 1). This sample was taken from the south end of Torry Island because high levels of pesticide residues were found on the agricultural islands (Kreamer, Torry, and Ritta) in 1977, particularly DDT, DDD, and DDE. DDT, DDD, and DDE residues ranged from 2,200 to 110,000, 580 to 10,000, and 1,300 to 9,300 µg/Kg, respectively during the 1977 sampling (Pfeuffer, 1985). For the current sampling, DDD and DDE residues were found at 4,900 and 300 µg/Kg, respectively. These levels were not as high as the original sampling, suggesting that some degradation had occurred for these compounds. None of the parent compound, DDT, was found, which may indicate that the degradation or biotransformation of this pesticide is complete. Levels of these compounds are anticipated to decrease.

Starting with the July 1987 sampling (Fourth Quarter FY86/87), DDD and DDE were detected during each subsequent quarterly sampling event (Table 4). When detections limits were lower, more residues were detected, indicating that the quantities present are low (less than 10 µg/Kg). The DDD and DDE present at these sites could be the result of the ubiquitous nature of DDT contamination. DDD and DDE are considered the degradation products of DDT, although DDD itself was utilized as an insecticide on many fruits and vegetables.

The DDT residue of 3.6 µg/Kg detected at S-99 during the February 1988 sampling (Second Quarter FY87/88), is the first detection of this compound at any station since 1984. DDT was detected again at S-79 at 3 µg/Kg during the April 1988 sampling (Third Quarter FY87/88). Both S-99 and S-79 are located in areas dominated by citrus agriculture. The source of the DDT could possibly be the result of the application of dicofol (kelthane) in the citrus areas for the control of rust mites. DDT, DDE, and other chemically related compounds have been present as a manufacturing impurity in dicofol. The USEPA issued a regulation requiring a two-stage reduction of DDT, DDD, DDE, and related compounds (DDTr) in early 1986. There was an immediate reduction to less than 2.5 percent DDTr contamination in the technical grade compound. After December 1988, all technical grade dicofol products had to contain less than 0.1 percent DDTr. Use of dicofol with DDTr contaminants greater than 0.1 percent was not permitted after March 1989.

TABLE 4. Summary of DDT, DDD, and DDE Sediment Residues by Sampling Event and Date. Units are µg/Kg.

Station	Summer 1984 August 29	Winter 1984 November 5	Summer 1985 July 17-19	Winter 1985 February 11-12	Summer 1986 June 25-26	Second Quarter FY86/87 January 26-28	Fourth Quarter FY87/87 July 20-22	First Quarter FY87/88 October 26-28	Second Quarter FY87/88 February 22-24	Third Quarter FY87/88 April 11-13	Fourth Quarter FY87/88 July 25-27
Compound	1984	1984	1985	1986	1986	1987	1987	1987	1988	1988	1988
Minimum detection limits											
P,P'DDT	2.0-4.0	0.8-2.9	5.0	100	10	2.86-84.4	6.85-66.0	16.9-93.4	1.0	1.0	1.0
P,P'DDD	0.4-4.0	0.8-2.9	5.0	100	10	1.30-84.4	6.85-66.0	10.4-57.5	0.8	0.8	0.8
P,P'DDE	0.8-2.0	1.8-5.9	5.0	100	10	1.30-84.4	6.85-66.0	10.4-57.5	0.4	0.4	0.4
S-2											
P,P'DDT	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND
P,P'DDD	ND	-	ND	ND	ND	ND	ND	ND	7.9	ND	ND
P,P'DDE	ND	-	ND	ND	ND	ND	101	59.6	10	ND	28
S-3											
P,P'DDT	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND
P,P'DDD	ND	-	ND	ND	ND	ND	ND	ND	1.6	2	ND
P,P'DDE	ND	-	ND	ND	ND	ND	18.2	ND	2.1	6	ND
S-4											
P,P'DDT	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND
P,P'DDD	ND	-	ND	ND	ND	ND	ND	ND	5.3	10	ND
P,P'DDE	ND	-	ND	ND	ND	ND	57.2	ND	12.7	8	ND
S-5A											
P,P'DDT	-	-	-	-	-	-	ND	ND	ND	ND	ND
P,P'DDD	-	-	-	-	-	-	ND	110	3.0[a]	ND	16
P,P'DDE	-	-	-	-	-	-	ND	143	2.4[a]	ND	ND
S-6											
P,P'DDT	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND
P,P'DDD	ND	-	ND	ND	ND	ND	ND	ND	5.9	41	11[a]
P,P'DDE	ND	-	ND	ND	ND	ND	ND	ND	5.2	21	9[a]
S-7											
P,P'DDT	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND
P,P'DDD	ND	-	ND	ND	ND	ND	ND	ND	5.2	ND	ND
P,P'DDE	ND	-	ND	ND	ND	ND	ND	38.0	6.4	11	ND
S-31											
P,P'DDT	-	-	-	-	-	ND	ND	ND	ND	ND	ND
P,P'DDD	-	-	-	-	-	ND	ND	ND	ND	ND	ND
P,P'DDE	-	-	-	-	-	ND	ND	ND	ND	3	ND

TABLE 4. (continued)

Station / Compound	Summer 1984 August 29 1984	Winter 1984 November 5 1984	Summer 1985 July 17-19 1985	Winter 1985 February 11-12 1986	Summer 1986 June 25-26 1986	Second Quarter FY86/87 January 26-28 1987	Fourth Quarter FY87/87 July 20-22 1987	First Quarter FY87/88 October 26-28 1987	Second Quarter FY87/88 February 22-24 1988	Third Quarter FY87/88 April 11-13 1988	Fourth Quarter FY87/88 July 25-27 1988
US41-25											
P,P'DDT	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
P,P'DDD	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
P,P'DDE	-	4.9	ND	ND	ND	ND	ND	ND	3.4	ND	ND
S-177											
P,P'DDT	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
P,P'DDD	-	ND	ND	ND	ND	ND	ND	ND	1.8	ND	ND
P,P'DDE	-	7.3	ND	ND	ND	ND	ND	ND	5.0	29	15
S-178											
P,P'DDT	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
P,P'DDD	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
P,P'DDE	-	10	ND	ND	ND	ND	ND	ND	ND	ND	ND
Torry Island											
P,P'DDT	-	-	-	ND	-	-	-	-	-	-	-
P,P'DDD	-	-	-	4,900	-	-	-	-	-	-	-
P,P'DDE	-	-	-	300	-	-	-	-	-	-	-
S-99											
P,P'DDT	-	-	-	-	-	-	-	-	3.6	ND	ND
P,P'DDD	-	-	-	-	-	-	-	-	ND	ND	ND
P,P'DDE	-	-	-	-	-	-	-	-	6.9	6	9[a]
S-79											
P,P'DDT	-	-	-	-	-	-	-	-	ND	3	ND
P,P'DDD	-	-	-	-	-	-	-	-	ND	ND	ND
P,P'DDE	-	-	-	-	-	-	-	-	ND	ND	ND

Key: "ND" Represents compound not detected.
"-" Represents station not sampled.

[a]Average of two samples.

Diazinon, Malathion, and Aldrin. The Winter 1985 sampling, which occurred during February 1986, detected similar quantities of diazinon, malathion and/or aldrin at S-2, S-3, S-4, S-8, S-12C, and US41-25 (Table 5).

The aldrin present at these sites could be a relic residue from previous use since agricultural uses of this compound have been banned since 1974. Previous sampling from other SFWMD programs have occasionally detected aldrin in the sediment in an apparently random pattern (Pfeuffer, 1985). Both of the non-restricted use insecticides, diazinon and malathion, are registered for pest control on sod and row crops grown in the EAA. Neither of these compounds have been previously found in the sediment or surface water. Significant widespread use would be required for detection of the levels found at these sampling stations since these compounds have a relatively short aquatic half-life. Sources of these compounds could be from runoff, with the compound in solution and/or adsorbed on suspended particles, or from overspray and drift. The pesticide residues at US41-25 do not appear to be the result of agricultural use, as this area is isolated from any farming. The use of malathion for mosquito or med-fly control is highly unlikely in this area.

Ametryn, Methamidophos, and 2,4-D. The July 1987 (Fourth Quarter FY86/87) monitoring detected ametryn, methamidophos, and 2,4-D in the sediment (Table 5) at three, one, and five stations, respectively. This was the first time ametryn and methamidophos have been detected in sediment samples. Neither compound has been detected in the surface water. Ametryn is a non-restricted use selective terrestrial herbicide used on a variety of fruit crops, row crops and non-crop areas. During a runoff event, ametryn could be transported in appreciable proportion with both soil and water (Stewart, 1975). Methamidophos is a restricted use insecticide/acaricide used on a variety of row crops. No data are available on its degradation in natural waters. However, in buffered solutions, degradation is rapid with half-lives of less than seven days (USDHHS, 1981). During a runoff event, methamidophos could be transported primarily in water (Stewart, 1975). Sampling for ametryn and methamidophos started with the Winter 1985 and the Second Quarter FY86/87 sampling events, respectively.

2,4-D is a non-restricted use, selective herbicide. Reported half-lives in natural waters range from a few days to several months depending on factors such as temperature, pH, light intensity, formulation, and oxygen concentration (USDHHS, 1981). Monitoring for 2,4-D in both the water and sediment has occurred since 1976 at various locations with residues found in both the water and sediment (Pfeuffer, 1985). Surface water residues were found at S-48 (C-23, St. Lucie County), S-49 (C-24, St. Lucie County), in the Caloosahatchee River and in Lake Okeechobee during monitoring in 1979. The highest level found was 4.36 µg/L. Residues continued to be present in Lake Okeechobee during the 1980 sampling; however, the number and magnitude of the detections were less. Sediment residues were present at S-333, near the Everglades National Park, during both 1982 and 1983 sampling at 333.6 and 12.8 µg/Kg, respectively. At the time of the July 1987 sampling, 2,4-D was utilized by the SFWMD only in the area of S-191 (Taylor Creek/Nubbin Slough). Application at S-191 and other areas upstream, occurred at least five days before sampling. At the other stations (S-4, S-6, L3OWBR, and US41-25), 2,4-D had not been applied by the SFWMD for approximately one year. As the environmental half-life of 2,4-D is relatively short, its presence indicates significant usage in the private sector.

TABLE 5. Summary of Sediment Pesticide Residues by Sampling Event and Date. Units are µg/Kg.

Compound / Station	Summer 1984 August 29 1984	Winter 1984 November 5 1984	Summer 1985 July 17-19 1985	Winter 1985 February 11-12 1986	Summer 1986 June 25-26 1986	Second Quarter FY 86/87 January 26-28 1987	Fourth Quarter FY 86/87 July 20-22 1987	First Quarter FY 87/88 October 26-28 1987	Second Quarter FY 87/88 February 22-24 1988	Third Quarter FY 87/88 April 11-13 1988	Fourth Quarter FY 87/88 July 25-27 1988
2,4-D											
S-191	-	-	-	-	-	ND	763	ND	ND	ND	ND
S-4	ND	-	ND	-	ND	ND	1,960	ND	ND	ND	ND
S-6	ND	-	ND	-	ND	ND	996	ND	ND	ND	ND
L3OWBR	-	-	-	-	-	-	259	ND	ND	ND	ND
US41-25	-	ND	ND	-	ND	ND	368	ND	ND	ND	ND
Aldrin											
S-4	ND	-	ND	600	ND	ND	ND	ND	ND	ND	ND
US41-25	-	ND	ND	600	ND	ND	ND	ND	ND	ND	ND
Ametryn											
S-2	-	-	-	ND	ND	ND	98.5	ND	ND	ND	ND
S-4	-	-	-	ND	ND	ND	135	ND	ND	ND	ND
S-6	-	-	-	ND	ND	ND	194	ND	ND	ND	ND
Atrazine											
S-6	-	-	-	ND	ND	ND	ND	ND	ND	134	ND
alpha BHC											
S-191	-	-	-	-	-	ND	ND	ND	ND	0.8	ND
delta BHC											
S-7	ND	-	ND	ND	ND	ND	ND	ND	ND	23	ND
Chlorpyrifos											
S-6	-	-	-	-	ND	ND	ND	ND	ND	8	ND
Diazinon											
S-2	ND	-	ND	1,100	ND	ND	ND	ND	ND	ND	ND
S-3	ND	-	ND	1,400	ND	ND	ND	ND	ND	ND	ND
S-4	ND	-	ND	1,000	ND	ND	ND	ND	ND	ND	ND
S-8	ND	-	ND	1,100	ND	ND	ND	ND	ND	ND	ND
S-12C	-	ND	ND	1,100	ND	ND	ND	ND	ND	ND	ND
Alpha endosulfan											
ABOGG	-	-	-	-	-	-	-	-	-	0.7	ND

TABLE 5. (continued)

Compound / Station	Summer 1984 August 29 1984	Winter 1984 November 5 1984	Summer 1985 July 17-19 1985	Winter 1985 February 11-12 1986	Summer 1986 June 25-26 1986	Second Quarter FY 86/87 January 26-28 1987	Fourth Quarter FY 86/87 July 20-22 1987	First Quarter FY 87/88 October 26-28 1987	Second Quarter FY 87/88 February 22-24 1988	Third Quarter FY 87/88 April 11-13 1988	Fourth Quarter FY 87/88 July 25-27 1988
Ethion											
S-99	-	-	-	-	-	-	-	-	ND	35	64[a]
Heptachlor											
S-235	-	-	-	-	-	ND	ND	ND	ND	ND	44
CR-33.5T	-	-	-	-	-	-	-	-	ND	ND	13
Heptachlor epoxide											
S-12C	-	ND	ND	ND	ND	ND	ND	ND	1.2	ND	ND
Malathion											
S-2	ND	-	ND	3,200	ND	ND	ND	ND	ND	ND	ND
S-3	ND	-	ND	2,600	ND	ND	ND	ND	ND	ND	ND
S-4	ND	-	ND	3,800	ND	ND	ND	ND	ND	ND	ND
S-8	ND	-	ND	3,300	ND	ND	ND	ND	ND	ND	ND
US41-25	-	ND	ND	4,200	ND	ND	ND	ND	ND	ND	ND
Methamidophos											
S-31	-	-	-	-	-	ND	1,100	ND	ND	ND	ND
Paraquat											
L30WBR	-	-	-	-	-	-	ND	880	ND	ND	ND
S-190	-	-	-	-	-	-	ND	970	ND	ND	ND
S-9	-	-	-	-	-	ND	ND	1,200	ND	ND	ND

Key: "ND" Represents compound not detected.
"-" Represents compound not analyzed or station not sampled.

[a] Average of two samples.

Paraquat. The sampling during October 1987 (First Quarter FY87/88) resulted in the detection of paraquat at L30WBR, S-190, and S-9 (Table 5). This was the first time that paraquat has been detected in any sediment samples. Paraquat has not been previously detected in the surface water. Paraquat is a restricted use non-selective herbicide with fast-acting contact action, applied postemergent on a variety of row crops. Paraquat is moderately toxic to birds, slightly toxic to freshwater fish, and moderately toxic to aquatic invertebrates. The half-life of paraquat in water is approximately 23 weeks (USEPA, 1987c). The potential source of paraquat in the sediment is through suspended material containing paraquat transported into the canals via runoff. Sampling for paraquat started during the Second Quarter FY86/87 sampling event.

Alpha BHC and Heptachlor Epoxide. For the February 1988 sampling (Second Quarter FY87/88), alpha BHC and heptachlor epoxide were detected in the sediment samples (Table 5). This was the first time that these two compounds have been detected since 1984 (Pfeuffer, 1985). The levels detected are similar or lower than the historical values. Alpha BHC is one of the isomers of technical BHC (benzene hexachloride), which was used as an insecticide until suspended in 1976. The BHC isomers are quite stable to hydrolysis. Due to the lack of chemical and biological transformation processes, sorption onto particulates with subsequent deposition and transformation in the sediment may be the most important fate for BHC (Callahan, et al., 1979). Heptachlor epoxide is the oxidation product of heptachlor. Sales of heptachlor in the US were suspended in 1987 due to its potential carcinogenicity. Heptachlor epoxide is resistant to chemical and biological transformations in aquatic environments, and half-lives of over several years are probable (Callahan, et al., 1979).

Delta BHC, Alpha Endosulfan, Ethion, Chlorpyrifos, and Atrazine. These five compounds were detected in the sediment samples taken during the April 1988 (Third Quarter FY87/88) sampling event (Table 5). At the time of sampling, structures S-176, S-177, S-332, S-8, S-9, S-65E, and S-235 were all discharging into their respective canals. Structures S-2 and S-3 were under conditions of reverse flow, that is, providing water for irrigation.

This was the first time that delta BHC or alpha endosulfan had been detected since 1983. Ethion, chlorpyrifos and atrazine (in sediment) have not been previously detected (Pfeuffer, 1985). Delta BHC is another isomers of technical BHC which was used as an insecticide until suspended in 1976.

Endosulfan is a chlorinated hydrocarbon insecticide-acaricide. Technical endosulfan is a mixture of the two stereoisomeric forms, the alpha and the beta forms. Data are incomplete regarding the important processes for determining the fate of endosulfan in aquatic systems. The hydrolysis half-life of endosulfan at 20^{0}C is about a month at pH 7 and about six months at pH 5.5. Other information suggests that photolysis, oxidation, biodegradation, sorption, and volatilization may be occurring under some environmental conditions, but data for predicting the rates and relative importance of these processes in aquatic systems are not available (Callahan, et al., 1979). During a runoff event, endosulfan could be transported in appreciable proportion in the soil as part of the particle transport of sorbed endosulfan (Stewart, 1975).

Ethion is an organophosphorus insecticide-acaricide used to control a broad spectrum of insects and mites. Ethion is highly toxic to freshwater fish and very highly toxic to freshwater invertebrates. Ethion is not expected to move into water supplies, and does not persist long in the environment.

Aquatic monitoring studies rarely show evidence of ethion either in water samples or organisms, while in soil, ethion has a reported half-life of less than two months (USEPA, 1982). During a runoff event, ethion could be transported in appreciable proportion in the soil as part of the particle transport of sorbed ethion (Stewart, 1975).

Chlorpyrifos is a non-restricted use organophosphorus insecticide. Chlorpyrifos is extremely toxic to fish, birds and other wildlife. It is highly toxic to honey bees (USEPA, 1984e). Hydrolysis in water occurs very readily above pH 8.0 and occurs least readily at about pH 6.0. Hydrolysis appears to be the main route of degradation. Half-lives generally in the range of 80 to 100 days have been observed in various soils (USDHHS, 1981).

Heptachlor and Ethion. Heptachlor was detected at S-235 and CR33.5T at 44 and 13 µg/Kg, respectively, during the July 1988 sampling event (Fourth Quarter FY87/88). Ethion was detected at S-99 at 64 µg/Kg (Table 5). At the time of sampling the following structures were discharging: S-4, S-6, S-7, S-8, S-332, S-18C, S-176, S-177, S-12C, S-9, S-5A, S-65E, S-235 and S-99.

This was the second time ethion has been detected in the sediment. The previous detection (35 µg/Kg) was at the same station during the last sampling event (Third Quarter FY87/88).

Previous sediment residues of heptachlor were detected in 1982 and 1983 at S-332 and S-18C (Pfeuffer, 1985). Heptachlor is a restricted use chlorinated hydrocarbon insecticide. In 1975, the use of heptachlor for certain pests on agricultural crops was suspended due to its potential carcinogenicity leaving only registration for subterranean termite control. However, sales in the United States were suspended in August of 1987 and all registrations may be canceled by the USEPA. Heptachlor is extremely toxic to aquatic organisms and birds (USEPA, 1986c). The major fate of heptachlor in the solution phase of aquatic systems is hydrolysis with a half-life of about one to three days. Although literature information also indicates that heptachlor photolysis, volatilization, and sorption to sediments may also occur in aquatic environments, no data are available to compare these processes with the hydrolysis transformation rate (Callahan, et al., 1979). Heptachlor is considered persistent and bioaccumulative. It is not expected to leach, since it is insoluble in water and should adsorb to soil particles; thus, it should not reach underground aquifers (USEPA, 1986c). During a runoff event, heptachlor could be transported in appreciable proportion in the soil (Stewart, 1975).

SUMMARY AND CONCLUSIONS

Table 6 provides a summary of the samples with pesticide residues above the minimum detection limits. Out of a total of 197 surface water samples and 208 sediment samples collected from August 1984 to July 1988, 26 surface water samples (13 percent) and 52 sediment samples (25 percent) had detectable pesticide residues. No discernable trends concerning seasonal variations can be determined from these limited data. However, some indication of which stations are frequently impacted can be provided by ranking the stations by the percent of positive samples (Tables 7 and 8). In reviewing the ranking, caution should be used as some stations have been sampled as few as three times. The ranking provides insight into stations currently impacted or previously impacted due to the detection of the persistent compounds.

Structure S-5A appears to have been most often impacted as both the water and sediment have pesticide residues frequently detected. The Caloosahatchee River stations (S-78, S-74, and CR33.5T) also give an indication of a potential problem area. Although not sampled many times, pesticide residues have been found consistently. Stations which did not have any detectable residues included S-65E, FECSR78 (Fisheating Creek at SR78), BWSHNGLE (Shingle Creek), and CREEDYBR (Reedy Creek). Only three compounds were detected in the surface water samples: silvex, zinc phosphide, and atrazine. The silvex detection appeared to be a lab artifact, and not the result of actual water contamination.

Zinc phosphide was detected only during the first two special monitoring events, but not during the subsequent quarterly sampling or during the site specific study. Since zinc phosphide is acutely toxic, monitoring will continue during the routine sampling to determine any pattern or possible explanation for these results.

The herbicide atrazine was consistently detected in the water samples (Table 9). However, the levels found were not considered to have potential adverse environmental or health effects as this compound does not bioaccumulate and is not considered very toxic. The majority of the 34 detections were between 0.1 and 1.0 µg/L, with the largest quantity being 13.2 µg/L. For atrazine to be acutely toxic to fish or fresh water invertebrates, levels of 6,300 and 720 ppb, respectively, are required. Stations S-4, S-6, S-7, S-8, and S-5A had detectable quantities more than once, indicating a greater usage of the compound in these areas.

The majority of pesticides detected in the sediment consisted of DDD and/or DDE. The levels detected were less than those routinely found during previous SFWMD monitoring (Pfeuffer, 1985). These compounds were found consistently at the same stations (S-2, S-3, S-4, S-6, S-7, S-177, S-5A, and S-99). The other compounds detected were: diazinon, malathion, aldrin, ametryn, 2,4-D, methamidophos, paraquat, heptachlor, heptachlor epoxide, atrazine, chlorpyrifos, alpha BHC, delta BHC, alpha endosulfan, DDT, and ethion. The only compounds detected during more than one sampling event in addition to DDD and DDE were ethion and DDT. Both of these compounds were found in areas of citrus agriculture. The remainder of the compounds were detected in only one sampling event, but possibly at several stations.

TABLE 6. Summary of Positive Field Data for Surface Water and Sediment Sampling.

	Sampling Event and Date											
Station	Summer 1984 August 29 1984	Winter 1984 November 05 1984	Summer 1985 July 17-19 1985	Winter 1985 February 11-12 1986	Summer 1986 June 25-26 1986	Second Quarter FY 86/87 January 26-28 1987	Third Quarter FY 86/87 April 13-15 1987	Fourth Quarter FY 86/87 July 20-22 1987	First Quarter FY 87/88 October 26-28 1987	Second Quarter FY 87/88 February 22-24 1988	Third Quarter FY 87/88 April 11-13 1988	Fourth Quarter FY 87/88 July 25-27 1988
S-2	</<	-	</<	</2	</<	</<	</-	</2	</1	1/2	</<	</1
S-3	</<	-	</<	</2	</<	</<	</-	</1	</<	</2	</2	</<
S-4	</<	-	</<	</3	</<	</<	1/-	</3	</<	1/2	</2	</<
S-6	</<	-	</<	</<	</<	</<	1/-	</2	</<	1/2	1/4	</2
S-7	</<	-	</<	</<	</<	</<	1/-	1/<	</1	1/2	1/2	</<
S-8	</<	-	</<	</2	</<	</<	</-	1/<	</<	1/<	</<	</<
S-332	-	-/<	-/<	-/<	-/<	</<	</-	</<	</<	</<	1/<	</<
S-18C	-	-/<	-/<	-/<	-/<	</<	</-	</<	</<	</<	1/<	</<
S-176	-	-/<	-/<	-/<	-/<	</<	</-	</<	</<	</<	1/<	</<
S-177	-	-/1	-/<	-/<	-/<	1/<	</-	</<	</<	</2	1/1	</1
S-178	-	-/1	-/<	-/<	-/<	</<	</-	</<	</<	</<	1/<	</<
S-12C	-	-/<	-/<	-/1	-/<	</<	</.	</<	</<	</1	</<	</<
US41-25	-	-/1	-/<	-/2	-/<	</<	</-	</1	</<	</1	</<	</<
S-9	-	-	-/<	-/<	-/<	</<	</-	</<	</1	</<	</<	</<
L-38-1	-	-	</<	-	-	-	-	-	-	-	-	-
Marsh-2	-	-	</<	-	-	-	-	-	-	-	-	-
NNR2	-	-	</<	-	-	-	-	-	-	-	-	-
Torry Island	-	-	-	-/2	-	-	-	-	-	-	-	-
L-28-I	-	-	-	-	-/<	</<	-	-	-	-	-	-
S-191	-	-	-	-	-	</<	</-	</1	</<	</1	</<	</<
S-65E	-	-	-	-	-	</<	</-	</<	</<	</<	</<	</<
FECSR78	-	-	-	-	-	</<	</-	</<	</<	</<	</<	</<
S-235	-	-	-	-	-	</<	</-	</<	</<	</<	</<	</1
S-31	-	-	-	-	-	</<	</-	</1	</<	</<	1/1	</<
S-5A	-	-	-	-	-	-	1/-	</<	</2	1/2	1/<	</1
L3OWBR	-	-	-	-	-	-	</-	</1	</1	</<	1/<	</<
S-190	-	-	-	-	-	-	</-	</<	</1	</<	1/<	</<
S-99	-	-	-	-	-	-	-	-	-	</2	</2	</2
S-78	-	-	-	-	-	-	-	-	-	1/<	</<	</<
S-79	-	-	-	-	-	-	-	-	-	</<	1/1	</<

TABLE 6. (continued)

Station	Summer 1984 August 29 1984	Winter 1984 November 05 1984	Summer 1985 July 17-19 1985	Winter 1985 February 11-12 1986	Summer 1986 June 25-26 1986	Second Quarter FY 86/87 January 26-28 1987	Third Quarter FY 86/87 April 13-15 1987	Fourth Quarter FY 86/87 July 20-22 1987	First Quarter FY 87/88 October 26-28 1987	Second Quarter FY 87/88 February 22-24 1988	Third Quarter FY 87/88 April 11-13 1988	Fourth Quarter FY 87/88 July 25-27 1988
CR-33.5T	-	-	-	-	-	-	-	-	-	1/<	</<	</1
ABOGG	-	-	-	-	-	-	-	-	-	-	</1	</<
BWSHNGLE	-	-	-	-	-	-	-	-	-	-	</<	</<
CREEDYBR	-	-	-	-	-	-	-	-	-	-	</<	</<

Key:

"<" Represents all compounds below detection limit

"1 <" Represents number of compounds above detection limit in surface water

"< 3" Represents number of compounds above detection limit in sediment

"-" Not sampled

TABLE 7. Ranking of Sampling Stations by the Percent Positive Pesticide Residues in Water Samples Collected from August 1984 to July 1988.

Station	Rank	Percent	Positive Samples/Samples Analyzed
S-5A	1	50	3/6
S-7	2	36	4/11
S-78	3	33	1/3
S-79		33	1/3
CR-33.5T		33	1/3
S-177	4	29	2/7
S-6	5	27	3/11
S-4	6	18	2/11
S-8		18	2/11
L3OWBR	7	17	1/6
S-190		17	1/6
S-332	8	14	1/7
S-18C		14	1/7
S-176		14	1/7
S-178		14	1/7
S-31		14	1/7
S-2	9	9	1/11

TABLE 8. Ranking of Sampling Stations by the Percent Positive Pesticide Residues in Sediment Samples Collected from August 1984 to July 1988.

Station	Rank	Percent	Positive Samples/Samples Analyzed
S-99	1	100	3/3
S-5A	2	60	3/5
S-2	3	50	5/10
ABOGG		50	1/2
S-3	4	40	4/10
S-4		40	4/10
S-6		40	4/10
S-177		40	4/10
US41-25		40	4/10
L3OWBR		40	2/5
S-191	5	33	2/6
S-31		33	2/6
S-79		33	1/3
CR-33.5T		33	1/3
S-7	6	30	3/10
S-12C	7	20	2/10
S-190		20	1/5
S-235	8	17	1/6
S-9	9	11	1/9
S-8	10	10	1/10
S-178		10	1/10

TABLE 9. Summary of Atrazine Surface Water Data. Units are ppb.

	Sampling Event and Date												
Station	Summer 1984 August 29 1984	Winter 1984 November 5 1984	Summer 1985 July 17-19 1985	Winter 1985 February 11-12 1986	Summer 1986 June 25-26 1986	Second Quarter FY 86/87 January 26-28 1987	Third Quarter FY 86/87 April 13-15 1987	May 28 1987	Fourth Quarter FY 86/87 July 20-22 1987	First Quarter FY 87/88 October 26-28 1987	Second Quarter FY 87/88 February 22-24 1988	Third Quarter FY 87/88 April 11-13 1988	Fourth Quarter FY87/88 July 25-27 1988
S-2	NA	-	NA	ND	ND	ND	ND	0.4	ND	ND	0.3	ND	ND
S-3	NA	-	NA	ND	ND	ND	ND	0.2	ND	ND	ND	ND	ND
S-4	NA	-	NA	ND	ND	ND	3.54	0.3	ND	ND	0.3	ND	ND
S-6	NA	-	NA	ND	ND	ND	4.0	1.8	ND	ND	1.0	0.9	ND
S-7	NA	-	NA	ND	ND	ND	8.9	0.2	2.91	ND	3.0	0.4	ND
S-8	NA	-	NA	ND	ND	ND	ND	0.3	0.77	ND	0.5	ND	ND
S-332	-	NA	NA	NDS	NDS	ND	ND	-	ND	ND	ND	1.0	ND
S-18C	-	NA	NA	NDS	NDS	ND	ND	-	ND	ND	ND	0.8	ND
S-176	-	NA	NA	NDS	NDS	ND	ND	-	ND	ND	ND	0.5	ND
S-177	-	NA	NA	NDS	NDS	ND	ND	-	ND	ND	ND	0.7	ND
S-178	-	NA	NA	NDS	NDS	ND	ND	-	ND	ND	ND	13.2	ND
S-12C	-	NA	NA	NDS	NDS	ND	ND	-	ND	ND	ND	ND	ND
US41-25	-	NA	NA	NDS	NDS	ND	ND	-	ND	ND	ND	ND	ND
S-9	-	-	NA	NDS	NDS	ND	ND	-	ND	ND	ND	ND	ND
L-38-1	-	-	NA	-	-	-	-	-	-	-	-	-	-
Marsh-2	-	-	NA	-	-	-	-	-	-	-	-	-	-
NNR2	-	-	NA	-	-	-	-	-	-	-	-	-	-
Torry Island	-	-	-	NDS	-	-	-	-	-	-	-	-	-
L-28-1	-	-	-	-	NDS	ND	-	-	-	-	-	-	-
S-191	-	-	-	-	-	ND	ND	-	ND	ND	ND	ND	ND
S-65E	-	-	-	-	-	ND	ND	-	ND	ND	ND	ND	ND
FECSR78	-	-	-	-	-	ND	ND	-	ND	ND	ND	ND	ND
S-235	-	-	-	-	-	ND	ND	-	ND	ND	ND	ND	ND
S-31	-	-	-	-	-	ND	ND	-	ND	ND	ND	0.6*	ND
S-5A	-	-	-	-	-	-	10.8	0.4	ND	ND	1.9	12.3	ND
L3OWBR	-	-	-	-	-	-	ND	0.2	ND	ND	ND	0.5	ND
S-190	-	-	-	-	-	-	ND	-	ND	ND	ND	1.7	ND

TABLE 9. (continued)

Sampling Event and Date

Station	Summer 1984 August 29 1984	Winter 1984 November 5 1984	Summer 1985 July 17-19 1985	Winter 1985 February 11-12 1986	Summer 1986 June 25-26 1986	Second Quarter FY 86/87 January 26-28 1987	Third Quarter FY 86/87 April 13 15 1987	May 28 1987	Fourth Quarter FY 86/87 July 20 22 1987	First Quarter FY 87/88 October 26-28 1987	Second Quarter FY 87/88 February 22-24 1988	Third Quarter FY 87/88 April 11-13 1988	Fourth Quarter FY87/88 July 25-27 1988
S-99	-	-	-	-	-	-	-	-	-	-	ND	ND	ND
S-78	-	-	-	-	-	-	-	-	-	-	0.5	ND	ND
S-79	-	-	-	-	-	-	-	-	-	-	ND	1.1	ND
CR-33.5T	-	-	-	-	-	-	-	-	-	-	1.1	ND	ND
ABOGG	-	-	-	-	-	-	-	-	-	-	-	ND	ND
BWSHNGLE	-	-	-	-	-	-	-	-	-	-	-	ND	ND
CREEDYBR	-	-	-	-	-	-	-	-	-	-	-	ND	ND
DETECTION LIMIT				5	10	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1

Key: "NA" Represents not analyzed
"-" Represents station not sampled.
"ND" Represents not detected.
"NDS" Represents not detected, only sediment sample analyzed.

[3]Average of two samples.

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Appendix A

List of the compounds and minimum detection limits for each sampling event.

Summer 1984 Sampling Event (08/29/84)
Analysis performed by Technical Services, Inc. Jacksonville, Florida (Lab #82145). Herbicides were analyzed by Standard Methods, 15th Edition, Method 509b. Other pesticides were analyzed by EPA Method 608. The compounds analyzed in the surface water and sediment samples included:

	Sediment	Water
2,4-D	1.0[a]	1.0[b]
2,4,5-T	-[c]	0.5
2,4,5-TP (silvex)	0.2	0.5
aldicarb	1000	
aldrin	0.2 - 0.5	
alpha BHC	0.1 - 0.2	
beta BHC	0.1 - 1.0	
gamma BHC (lindane)	0.1 - 0.3	
delta BHC	0.02-0.05	
chlordane	2.0 - 6.0	
P,P'-DDD	0.8 - 2.0	
O,P'-DDD	0.8 - 2.0	
P,P'-DDE	0.4 - 4.0	
O,P'-DDE	0.6 - 1.0	
P,P'-DDT	2.0 - 4.0	
O,P'-DDT	2.0 - 4.0	
diazinon	2.0 - 6.0	
dieldrin	0.4 - 1.0	
alpha endosulfan	0.07-0.2	
beta endosulfan	0.7	
endosulfan sulfate	2.0 - 4.0	
endrin aldehyde	1.0 - 3.0	
ethion	3.0 - 8.0	
heptachlor	0.2 - 0.5	
heptachlor epoxide	0.27-0.7	
dicofol (kelthane)	3.0 - 6.0	
malathion	3.0 - 6.0	
methoxychlor	3.0-10.0	
mirex	1.0 - 3.0	
parathion	0.8 - 2.0	
PCB (polychlorinated biphenyls)	7.0-18.0	
tetradifon (tedion)	3.0 - 8.0	
toxaphene	5.0 - 6.0	
trithion (carbophenothion)	3.0 - 7.0	

[a] Range of or minimum of detection limit in µg/Kg or ppb.
[b] Minimum of detection limit in µg/L or ppb.
[c] Not analyzed.

Winter 1984 Sampling Event (11/05/84)
Analysis performed by Environmental Science and Engineering, Inc. Gainesville, Florida (Certification #EL0024). Testing and analysis performed in accordance with Test Methods for Evaluating Solid Waste, EPA-SW-646, 1980. The compounds analyzed in the sediment samples included:

	Sediment
2,4-D	0.8 - 31[a]
2,4,5-T	1.4 - 5.4
2,4,5-TP (silvex)	1.2 - 4.8
aldrin	1.9 - 7.4
alpha BHC	0.4 - 1.5
beta BHC	0.4 - 1.5
gamma BHC (lindane)	0.4 - 1.5
delta BHC	0.4 - 1.5
chlordane	3.8 - 15
chlorpyrifos	2.9 - 11
P,P'-DDD	0.8 - 2.9
P,P'-DDE	1.8 - 5.9
P,P'-DDT	0.8 - 2.9
demeton	4.3 - 17
diazinon	2.42 - 9.41
dieldrin	0.8 - 2.9
alpha endosulfan	0.4 - 1.5
beta endosulfan	0.8 - 2.9
endrin	0.8 - 2.9
endrin aldehyde	0.8 - 2.9
guthion (azinphos-methyl)	25 - 97
heptachlor	1.9 - 7.4
heptachlor epoxide	0.4 - 1.5
malathion	6.1 - 24
methyl parathion	3.9 - 15
parathion	6.1 - 24
PCB (polychlorinated biphenyls)	1.5 - 5.9
toxaphene	4.1 - 16
trithion (carbophenothion)	3.8 - 15

[a] Range of minimum detection limit in μg/Kg dry weight or ppb.

Summer 1985 Sampling Event (07/17-19/85)
Analysis performed by Technical Services, Inc. Jacksonville, Florida (Lab #82145). Herbicides were analyzed by Standard Methods, 15th Edition, Method 509b. Other pesticides were analyzed by EPA Method 608. The compounds analyzed in the surface water and sediment samples included:

	Sediment	Water
2,4-D	500[a]	50[b]
2,4,5-T	300	30
2,4,5-TP (silvex)	300	30
aldicarb	1.0	-[c]
aldrin	1.0	0.01
alpha BHC	1.0	0.01
beta BHC	2.0	0.02
gamma BHC (lindane)	1.0	0.01
delta BHC	1.0	0.01
chlordane	2.0	0.02
P,P'-DDD	5.0	0.05
O,P'-DDD	5.0	0.05
P,P'-DDE	5.0	0.05
O,P'-DDE	5.0	0.05
P,P'-DDT	5.0	0.05
O,P'-DDT	5.0	0.05
diazinon	50	0.5
dieldrin	5.0	0.05
alpha endosulfan	5.0	0.05
beta endosulfan	5.0	0.05
endosulfan sulfate	10	0.1
endrin	5.0	0.05
endrin aldehyde	10.0	0.1
ethion	10.0	0.1
guthion (azinphos-methyl)	100.0	1.0
heptachlor	1.0	0.01
heptachlor epoxide	2.0	0.02
dicofol (kelthane)	50	0.5
malathion	50.0	0.5
parathion	20.0	0.2
PCB 1016	10.0	0.1
PCB 1221	10.0	0.1
PCB 1232	10.0	0.1
PCB 1242	10.0	0.1
PCB 1248	10.0	0.1
PCB 1254	10.0	0.1
PCB 1260	10.0	0.1
PCB 1262	10.0	0.1
tetradifon (tedion)	10.0	0.1
toxaphene	50.0	0.5
trithion (carbophenothion)	10.0	0.1

[a] Minimum detection limit in µg/Kg or ppb.
[b] Minimum detection limit in µg/L or ppb.
[c] Not analyzed.

Winter 1985 Sampling Event (02/11-12/86)
Analysis performed by Enviropact, Inc. Hialeah, Florida (Lab #86119). Analysis performed in accordance with EPA, ASTM, Standard Methods or other approved methods. The compounds analyzed in the surface water and sediment samples included:

	Sediment	Water		Sediment	Water
alachlor	500[a]	5[b]	ethion	100	1
aldicarb	100	1	guthion	100	1
aldrin	100	0.005	(azinphos-methyl)		
ametryn	500	5	heptachlor	100	0.005
ametryn	500	5	heptachlor epoxide	100	0.005
atrazine	500	5	dicofol (kelthane)	100	1
alpha BHC	100	0.005	malathion	100	1
beta BHC	100	0.005	methomyl	500	5
gamma BHC	100	0.005	methoxychlor	100	0.1-0.3
(lindane)			parathion	100	1
delta BHC	100	0.005	PCB 1016	100	0.001
carbaryl	500	5	PCB 1221	100	0.001
carbofuran	500	5	PCB 1232	100	0.001
chlordane	100	0.05	PCB 1242	100	0.001
P,P'-DDD	100	0.03	PCB 1248	100	0.001
O,P'-DDD	100	0.01	PCB 1254	100	0.001
P,P'-DDE	100	0.01-0.03	PCB 1260	100	0.001
O,P'-DDE	100	0.01	perthane	100	1
P,P'-DDT	100	0.03	prometryn	500	5
O,P'-DDT	100	0.03	propham	500	5
diazinon	100	1	simazine	500	5
dieldrin	100	0.01	tetradifon (tedion)	100	1
alpha endosulfan	100	0.01	trithion	100	1
beta endosulfan	100	0.01	(carbophenothion)		
endosulfan sulfate	100	0.3	toxaphene	100	0.05
endrin	100	0.01			
endrin aldehyde	100	0.03			

[a] Minimum detection limit in µg/Kg or ppb.
[b] Range of or minimum detection limit in µg/L or ppb.

Summer 1986 Sampling Event (06/25-26/86)
Analysis performed by Orlando Laboratories, Inc., Orlando, Florida (Lab #83141). Analysis performed in accordance with EPA, ASTM, Standard Methods or other approved methods. The compounds analyzed in the surface water and sediment samples included:

	Sediment	Water		Sediment	Water
2,4-D	200-2000[a]	10[b]	heptachlor	10	-
2,4,5-T	-[c]	1	heptachlor epoxide	10	-
2,4,5-TP (silvex)	20-200	-	dicofol (kelthane)	10	-
alachlor	200	20	malathion	10	-
aldicarb	50	-	methomyl	5000	-
aldrin	10	-	methyl bromide	1	-
ametryn	100	10	methyl parathion	10	-
atrazine	100	10	methoxychlor	1000	-
alpha BHC	10	-	metolachlor	200	-
beta BHC	10	-	metribuzin	100	10
gamma BHC (lindane)	10	-	mevinphos	100	-
			oxamyl	100	-
delta BHC	10	-	parathion	10	-
carbaryl (sevin)	10000	-	PCB 1016	10	-
carbofuran	500	-	PCB 1221	10	-
chlordane	10	-	PCB 1232	10	-
chloropicrin	10	-	PCB 1242	10	-
chlorpyrifos	10	-	PCB 1248	10	-
chlorothalonil	300	-	PCB 1254	10	-
P,P'-DDD	10	-	PCB 1260	10	-
P,P'-DDE	10	-	perthane	10	-
P,P'-DDT	10	-	phorate	100	-
diazinon	10	-	prometryn	50	5
dieldrin	10	-	simazine	70	7
alpha endosulfan	10	-	trifluralin	200	20
beta endosulfan	10	-	trithion (carbophenothion)	10	-
endosulfan sulfate	10	-			
endrin	10	-	toxaphene	50	-
endrin aldehyde	10	-			
ethoprop	50	-			
ethion	10	-			
fonofos (dyfonate)	50	-			
guthion (azinphos-methyl)	10	-			

[a] Range of or minimum detection limit in µg/Kg or ppb.
[b] Minimum detection limit in µg/L or ppb.
[c] Not analyzed.

Zinc phosphide Special Sampling Events (9/23/86 and 1/14/87)

Surface water analysis performed by Everglades Laboratories, Inc., West Palm Beach, Florida (Lab #86122). Method utilized the acidification of sample to hydrolyze the zinc phosphide and generate phosphine gas. The phosphine gas is sampled from the head space and measured by gas chromatography with a flame photometric detector (Okuno et al., 1975). Minimum detection limit: 1.0 µg/L or ppb.

Second Quarter FY86/87 Sampling Event (01/26-28/87)
Surface water analysis performed by University of Miami, Miami, Florida (HRS Certification #76290). Sediment analysis performed by Environmental Science and Engineering, Inc., Gainesville, Florida (HRS Certification #T82067) with methods developed from Methods for Non-Conventional Pesticide Chemical Analysis of Municipal and Industrial Wastewater, USEPA 440/1-83/079-C, January 31, 1983. Zinc phosphide analysis performed by Everglades Laboratories, Inc., West Palm Beach, Florida (Lab #86122). Analysis performed in accordance with EPA, ASTM, Standard Methods or other approved methods. The compounds analyzed in the surface water and sediment samples included:

	Sediment	Water		Sediment	Water
2,4-D	5.71-1140[a]	2.0[b]	malathion	64.8-429	0.06
2,4-DP (dichlorprop)	5.65-1130	0.8	methamidophos	130-860	0.20
2,4,5-T	5.76-1150	0.6	methomyl	260-2000	20.0
2,4,5-TP (silvex)	5.65-225	0.4	methoxychlor	6.51-4220	0.02
alachlor	25-27	0.02	methyl bromide	1.7-11	NA
aldicarb	0.27-2.0	2.0	methyl parathion	65-430	0.06
aldrin	1.30-84.4	0.002	metolachlor	14-15	0.02
ametryn	64.8-429	10.0	metribuzin	65-430	0.004
atrazine	130-858	0.10	mevinphos	64.8-429	0.10
benomyl	NA[c]	20.0	monocrotophos (azodrin)	259-1720	1.0
alpha BHC	1.30-253	0.002	oxamyl	270-2000	2.0
beta BHC	1.30-84.4	0.004	paraquat	3200-39000	3.0
delta BHC	1.30-169	0.003	parathion	64.8-429	0.06
bromacil	65-430	0.02	PCB 1016	70.6-4570	0.065
carbaryl (sevin)	280-2100	NA	PCB 1221	71-4600	0.065
carbofuran	250-1900	10.0	PCB 1232	71-4600	0.065
chlordane	7.73-501	0.01	PCB 1242	71-4600	0.065
chloropicrin	0.016-0.109	NA	PCB 1248	61-4000	0.065
chlorpyrifos	64.8-429	0.06	PCB 1254	61-4000	0.065
chlorothalonil	4.6-5.0	0.004	PCB 1260	61-4000	0.065
diazinon	64.8-422	0.06	perthane	51-56	0.02
dieldrin	1.30-84.4	0.003	phorate	64.8-429	0.03
alpha endosulfan	1.30-84.4	0.007	P,P'-DDD	1.30-84.4	0.008
beta endosulfan	1.30-84.4	0.008	P,P'-DDE	1.30-84.4	0.004
endosulfan sulfate	1.30-84.4	0.017	P,P'-DDT	2.86-84.4	0.01
endrin	2.86-84.4	0.007	prometryn	65-430	10.0
endrin aldehyde	1.30-84.4	0.018	simazine	65-430	0.10
ethion	65-430	0.10	toxaphene	153-9910	0.05
fonofos (dyfonate)	65-430	0.10	trifluralin	5.5-6.0	0.01
ethoprop	64.8-429	0.10	trithion	25-27	0.10
glyphosate	NA	100.0	(carbophenothion)		
guthion	65-430	1.0	zinc phosphide	NA	1.0
(azinphos-methyl)					
heptachlor	1.30-84.4	0.002			
heptachlor epoxide	1.30-84.4	0.003			
dicofol (kelthane)	6.5-4200	0.012			
gamma BHC (lindane)	6.51-253	0.001			

[a] Range of minimum detection limit in µg/Kg-dry weight or ppb.
[b] Minimum detection limit in µg/L or ppb.
[c] Parameter not analyzed due to lack of suitable analytical method.

Third Quarter FY86/87 Sampling Event (04/13-15/87)
Surface water analysis performed by University of Miami, Miami, Florida (HRS Certification #76290). Analysis performed in accordance with EPA, ASTM, Standard Methods or other approved methods. The compounds analyzed in the surface water samples included:

	Water		Water
2,4-D	2.0[a]	malathion	0.06
2,4-DP (dichlorprop)	0.8	methamidophos	0.20
2,4,5-T	0.6	methomyl	20.0
2,4,5-TP (silvex)	0.4	methoxychlor	0.02
alachlor	0.02	methyl parathion	0.06
aldicarb	2.0	metolachlor	0.02
aldrin	0.002	metribuzin	0.004
ametryn	10.0	mevinphos	0.10
atrazine	0.10	monocrotophos(azodrin)	1.0
benomyl	20.0	oxamyl	2.0
alpha BHC	0.002	paraquat	3.0
beta BHC	0.004	parathion	0.06
delta BHC	0.003	PCB 1016	0.065
bromacil	0.02	PCB 1221	0.065
carbofuran	10.0	PCB 1232	0.065
chlordane	0.01	PCB 1242	0.065
chlorothalonil	0.004	PCB 1248	0.065
chlorpyrifos	0.06	PCB 1254	0.065
diazinon	0.06	PCB 1260	0.065
dieldrin	0.003	perthane	0.02
alpha endosulfan	0.007	phorate	0.03
beta endosulfan	0.008	P,P'-DDD	0.008
endosulfan sulfate	0.017	P,P'-DDE	0.004
endrin	0.007	P,P'-DDT	0.01
endrin aldehyde	0.018	prometryn	10.0
ethion	0.10	simazine	0.10
fonofos (dyfonate)	0.10	toxaphene	0.05
ethoprop	0.10	trifluralin	0.01
glyphosate	100.0	trithion	0.10
guthion	1.0	(carbophenothion)	
(azinphos-methyl)			
heptachlor	0.002		
heptachlor epoxide	0.003		
dicofol (kelthane)	0.012		
gamma BHC (lindane)	0.001		

[a] Minimum detection limit in µg/L or ppb.

Fourth Quarter FY86/87 Sampling Event (07/20-22/87)
Surface water analysis performed by University of Miami, Miami, Florida (HRS Certification #76290). Sediment analysis performed by Environmental Science and Engineering, Inc., Gainesville, Florida (DER/HRS Certification #E82067) with methods developed from Methods for Non-Conventional Pesticide Chemical Analysis of Municipal and Industrial Wastewater, USEPA 440/1-83/079-C, January 31, 1983. Zinc phosphide analysis performed by Everglades Laboratories, Inc., West Palm Beach, Florida (Lab #86122, 86109, E86048). Analysis performed in accordance with EPA, ASTM, Standard Methods or other approved methods. The compounds analyzed in the surface water and sediment samples included:

	Sediment	Water		Sediment	Water
2,4-D	79.1-384[a]	2.0[b]	malathion	13.7-132	0.06
2,4-DP(dichlorprop)	68-361	0.8	methamidophos	270-1400	0.20
2,4,5-T	66.7-354	0.6	methomyl	200-1000	20.0
2,4,5-TP (silvex)	68.0-361	0.4	methoxychlor	6.85-66.0	0.02
alachlor	88-850	0.02	methyl bromide	50-300	1.0
aldicarb	0.06-0.30	2.0	methyl parathion	14-130	0.06
aldrin	6.85-66.0	0.002	metolachlor	68-660	0.02
ametryn	13.7-132	10.0	metribuzin	14-130	0.004
atrazine	13.7-132	0.10	mevinphos	29.2-290	0.10
benomyl	NA[c]	20.0	monocrotophos	274-2640	1.0
alpha BHC	6.85-66.0	0.002	(azodrin)		
beta BHC	6.85-66.0	0.004	oxamyl	110-560	2.0
delta BHC	6.85-66.0	0.003	paraquat	2200-16000	3.0
bromacil	14-530	0.02	parathion	13.7-132	0.06
carbaryl (sevin)	60-320	NA	PCB 1016	171-1650	0.065
carbofuran	100-530	10.0	PCB 1221	170-1700	0.065
chlordane	6.85-66.0	0.01	PCB 1232	170-1700	0.065
chloropicrin	0.332-2.03	1.0	PCB 1242	170-1700	0.065
chlorpyrifos	13.7-132	0.06	PCB 1248	170-1700	0.065
chlorothalonil	65-630	0.004	PCB 1254	170-1700	0.065
diazinon	13.7-132	0.06	PCB 1260	170-1700	0.065
dieldrin	6.85-66.0	0.003	perthane	68-660	0.02
alpha endosulfan	6.85-66.0	0.007	phorate	13.7-132	0.03
beta endosulfan	6.85-66.0	0.008	P,P'-DDD	6.85-66.0	0.008
endosulfan sulfate	6.85-66.0	0.017	P,P'-DDE	6.85-66.0	0.004
endrin	6.85-66.0	0.007	P,P'-DDT	6.85-66.0	0.01
endrin aldehyde	6.85-66.0	0.018	prometryn	14-130	10.0
ethion	14-130	0.10	simazine	14-130	0.10
fonofos (dyfonate)	14-130	0.06	toxaphene	698-6730	0.05
ethoprop	13.7-132	0.06	trifluralin	79-760	0.01
glyphosate	NA	100.0	trithion	68-660	0.10
guthion	17.5-264	1.0	(carbophenothion)		
(azinphos-methyl)			zinc phosphide	NA	1.0
heptachlor	6.85-66.0	0.002			
heptachlor epoxide	6.85-66.0	0.003			
dicofol (kelthane)	34-330	0.012			
gamma BHC(lindane)	6.85-66.0	0.001			

[a] Range of minimum detection limit in µg/Kg-dry weight or ppb.
[b] Minimum detection limit in µg/L or ppb.
[c] Parameter not analyzed due to lack of suitable analytical method.

First Quarter FY87/88 Sampling Event (10/26-28/87)
Surface water analysis performed by University of Miami, Miami, Florida (HRS Certification #E76071). Sediment analysis performed by Environmental Science and Engineering, Inc., Gainesville, Florida (DER/HRS Certification #E82067) with methods developed from Methods for Non-Conventional Pesticide Chemical Analysis of Municipal and Industrial Wastewater, USEPA 440/1-83/079-C, January 31, 1983. Zinc phosphide analysis performed by Everglades Laboratories, Inc., West Palm Beach, Florida (Lab #86122, 86109, E86048). Analysis performed in accordance with EPA, ASTM, Standard Methods or other approved methods. The compounds analyzed in the surface water and sediment samples included:

	Sediment	Water		Sediment	Water
2,4-D	371-2070[a]	2.0[b]	malathion	65.0-359	0.06
2,4-DP (dichlorprop)	63.9-356	0.8	methamidophos	520-2900	0.20
			methomyl	92-510	20.0
2,4,5-T	62.7-350	0.6	methoxychlor	20.8-115	0.02
2,4,5-TP (silvex)	63.9-356	0.4	methyl bromide	28-140	1.00
alachlor	52-290	0.02	methyl parathion	26-140	0.06
aldicarb	0.06-0.34	2.0	metolachlor	130-720	0.02
aldrin	10.4-57.5	0.002	metribuzin	26-140	0.004
ametryn	26.0-144	10.0	mevinphos	104-575	0.10
atrazine	26.0-144	0.10	monocrotophos(azodrin)	520-2870	1.0
benomyl	NA[c]	20.0	oxamyl	100-560	2.0
alpha BHC	19.5-108	0.002	paraquat	760-830	3.0
beta BHC	11.7-64.6	0.004	parathion	65.0-359	0.06
delta BHC	13.0-71.8	0.003	PCB 1016	268-1480	0.065
bromacil	260-1400	0.02	PCB 1221	270-1500	0.065
carbaryl (sevin)	56-310	NA	PCB 1232	270-1500	0.065
carbofuran	95-520	10.0	PCB 1242	270-1500	0.065
chlordane	13.0-71.8	0.01	PCB 1248	270-1500	0.065
chloropicrin	0.567-2.85	1.00	PCB 1254	270-1500	0.065
chlorpyrifos	26.0-144	0.06	PCB 1260	270-1500	0.065
chlorothalonil	260-1400	0.004	perthane	270-1400	0.02
diazinon	65.0-359	0.06	phorate	26.0-144	0.03
dieldrin	10.4-57.5	0.003	P,P'-DDD	10.4-57.5	0.008
alpha endosulfan	10.4-57.5	0.007	P,P'-DDE	10.4-57.5	0.004
beta endosulfan	10.4-57.5	0.008	P,P'-DDT	16.9-93.4	0.01
endosulfan sulfate	10.4-57.5	0.017	prometryn	26-140	10.0
endrin	10.4-57.5	0.007	simazine	26-140	0.10
endrin aldehyde	10.4-57.5	0.018	toxaphene	1330-7330	0.05
ethion	26-140	0.10	trifluralin	13-72	0.01
ethoprop	26.0-144	0.06	trithion (carbophenothion)	52-290	0.10
fonofos (dyfonate)	26-144	0.06			
glyphosate	NA	100.0	zinc phosphide	NA	1.0
guthion (azinphos-methyl)	65.0-359	1.0			
heptachlor	10.4-57.5	0.002			
heptachlor epoxide	10.4-57.5	0.003			
dicofol (kelthane)	52-290	0.012			
gamma BHC (lindane)	11.7-64.6	0.001			

[a] Range of minimum detection limit in µg/Kg-dry weight or ppb.
[b] Minimum detection limit in µg/L or ppb.
[c] Parameter not analyzed due to lack of suitable analytical method.

Second Quarter FY87/88 Sampling Event (02/22-24/88)
Surface water and sediment analysis performed by University of Miami, Miami, Florida (HRS Certification #E76071). Analysis performed in accordance with EPA, ASTM, Standard Methods or other approved methods. The compounds analyzed in the surface water and sediment samples included:

	Sediment	Water		Sediment	Water
2,4-D	200.0[a]	2.0[b]	malathion	6.0	0.06
2,4-DP(dichlorprop)	80.0	0.8	methamidophos	20.0	0.20
2,4,5-T	60.0	0.6	methomyl	2000.0	20.0
2,4,5-TP (silvex)	40.0	0.4	methoxychlor	2.0	0.02
alachlor	2.0	0.02	methyl bromide	NA	1.00
aldicarb	2.0	2.0	methyl parathion	6.0	0.06
aldrin	0.2	0.002	metolachlor	2.0	0.02
ametryn	1000.0	10.0	metribuzin	0.4	0.004
atrazine	10.0	0.10	mevinphos	10.0	0.10
benomyl	2000.0	20.0	monocrotophos	100.0	1.0
alpha BHC	0.2	0.002	(azodrin)		
beta BHC	0.4	0.004	oxamyl	200.0	2.0
delta BHC	0.3	0.003	paraquat	30.0	3.0
bromacil	1000.0	0.02	parathion	6.0	0.06
carbaryl (sevin)	100.0	5.0	PCB 1016	6.5	0.065
carbofuran	1000.0	10.0	PCB 1221	6.5	0.065
chlordane	1.0	0.01	PCB 1232	6.5	0.065
chloropicrin	NA[c]	1.00	PCB 1242	6.5	0.065
chlorpyrifos	6.0	0.06	PCB 1248	6.5	0.065
chlorothalonil	1000.0	0.004	PCB 1254	6.5	0.065
diazinon	6.0	0.06	PCB 1260	6.5	0.065
dieldrin	0.3	0.003	perthane	2.0	0.02
diuron	1000.0	10.0	phorate	3.0	0.03
alpha endosulfan	0.7	0.007	P,P'-DDD	0.8	0.008
beta endosulfan	0.8	0.008	P,P'-DDE	0.4	0.004
endosulfansulfate	1.7	0.017	P,P'-DDT	1.0	0.01
endrin	0.7	0.007	prometryn	1000.0	10.0
endrin aldehyde	1.8	0.018	simazine	10.0	0.10
ethion	10.0	0.10	toxaphene	5.0	0.05
ethoprop	6.0	0.06	trifluralin	1.0	0.01
fonofos (dyfonate)	6.0	0.06	trithion	10.0	0.10
glyphosate	NA	100.0	(carbophenothion)		
guthion	100.0	1.0			
(azinphos-methyl)					
heptachlor	0.2	0.002			
heptachlor epoxide	0.3	0.003			
dicofol (kelthane)	1.2	0.012			
gamma BHC (lindane)	0.1	0.001			
linuron	1000.0	10.0			

[a] Minimum detection limit in µg/Kg-dry weight or ppb.
[b] Minimum detection limit in µg/L or ppb.
[c] Parameter not analyzed due to lack of suitable analytical method.

Third Quarter FY87/88 Sampling Event (04/11-13/88)
Surface water and sediment analysis performed by University of Miami, Miami, Florida (HRS Certification #E76071). Analysis performed in accordance with EPA, ASTM, Standard Methods or other approved methods. The compounds analyzed in the surface water and sediment samples included:

	Sediment	Water		Sediment	Water
2,4-D	2000.0[a]	2.0[b]	malathion	6.0	0.06
2,4-DP (dichlorprop)	800.0	0.8	methamidophos	20.0	0.20
			methomyl	2000.0	20.0
2,4,5-T	600.0	0.6	methoxychlor	2.0	0.02
2,4,5-TP (silvex)	400.0	0.4	methyl bromide	NA	1.00
alachlor	2.0	0.02	methyl parathion	6.0	0.06
aldicarb	80.0	2.0	metolachlor	2.0	0.02
aldrin	0.2	0.002	metribuzin	0.4	0.004
ametryn	1000.0	10.0	mevinphos	10.0	0.10
atrazine	10.0	0.10	monocrotophos (azodrin)	100.0	1.0
benomyl	2000.0	20.0			
alpha BHC	0.2	0.002	oxamyl	200.0	2.0
beta BHC	0.4	0.004	paraquat	10.0	3.0
delta BHC	0.3	0.003	parathion	6.0	0.06
bromacil	1000.0	0.02	PCB 1016	6.5	0.065
carbaryl (sevin)	100.0	5.0	PCB 1221	6.5	0.065
carbofuran	1000.0	10.0	PCB 1232	6.5	0.065
chlordane	1.0	0.01	PCB 1242	6.5	0.065
chloropicrin	NA[c]	1.00	PCB 1248	6.5	0.065
chlorpyrifos	6.0	0.06	PCB 1254	6.5	0.065
chlorothalonil	1000.0	0.004	PCB 1260	6.5	0.065
diazinon	6.0	0.06	perthane	2.0	0.02
dieldrin	0.3	0.003	phorate	3.0	0.03
diuron	1000.0	10.0	P,P'-DDD	0.8	0.008
alpha endosulfan	0.7	0.007	P,P'-DDE	0.4	0.004
beta endosulfan	0.8	0.008	P,P'-DDT	1.0	0.01
endosulfan sulfate	1.7	0.017	prometryn	1000.0	10.0
endrin	0.7	0.007	simazine	10.0	0.10
endrin aldehyde	1.8	0.018	toxaphene	5.0	0.05
ethion	10.0	0.10	trifluralin	1.0	0.01
ethoprop	6.0	0.06	trithion (carbophenothion)	10.0	0.10
fonofos (dyfonate)	6.0	0.06			
glyphosate	NA	100.0			
guthion (azinphos-methyl)	100.0	1.0			
heptachlor	0.2	0.002			
heptachlor epoxide	0.3	0.003			
dicofol (kelthane)	1.2	0.012			
gamma BHC (lindane)	0.1	0.001			
linuron	1000.0	10.0			

[a] Minimum detection limit in ppb.
[b] Minimum detection limit in ppb.
[c] Parameter not analyzed due to lack of suitable analytical method.

Fourth Quarter FY87/88 Sampling Event (07/25-27/88)
Surface water and sediment analysis performed by University of Miami, Miami, Florida (HRS Certification #E76071). Analysis performed in accordance with EPA, ASTM, Standard Methods or other approved methods. The compounds analyzed in the surface water and sediment samples included:

	Sediment	Water
2,4-D	2000.0[a]	2.0[b]
2,4-DP (dichlorprop)	800.0	0.8
2,4,5-T	600.0	0.6
2,4,5-TP (silvex)	400.0	0.4
alachlor	2.0	0.02
aldicarb	80.0	2.0
aldrin	0.2	0.002
ametryn	1000.0	10.0
atrazine	10.0	0.10
benomyl	2000.0	20.0
alpha BHC	0.2	0.002
beta BHC	0.4	0.004
delta BHC	0.3	0.003
bromacil	1000.0	0.02
carbaryl (sevin)	100.0	5.0
carbofuran	1000.0	10.0
chlordane	1.0	0.01
chloropicrin	NA[c]	1.00
chlorpyrifos	6.0	0.06
chlorothalonil	1000.0	0.004
diazinon	6.0	0.06
dieldrin	0.3	0.003
diuron	1000.0	10.0
alpha endosulfan	0.7	0.007
beta endosulfan	0.8	0.008
endosulfan sulfate	1.7	0.017
endrin	0.7	0.007
endrin aldehyde	1.8	0.018
ethion	10.0	0.10
ethoprop	6.0	0.06
fonofos (dyfonate)	6.0	0.06
glyphosate	NA	100.0
guthion (azinphos-methyl)	100.0	1.0
heptachlor	0.2	0.002
heptachlor epoxide	0.3	0.003
dicofol (kelthane)	1.2	0.012
gamma BHC (lindane)	0.1	0.001
linuron	1000.0	10.0
malathion	6.0	0.06
methamidophos	20.0	0.20
methomyl	2000.0	20.0
methoxychlor	2.0	0.02
methyl bromide	NA	1.00
methyl parathion	6.0	0.06
metolachlor	2.0	0.02
metribuzin	0.4	0.004
mevinphos	10.0	0.10
monocrotophos (azodrin)	100.0	1.0
oxamyl	200.0	2.0
paraquat	10.0	3.0
parathion	6.0	0.06
PCB 1016	6.5	0.065
PCB 1221	6.5	0.065
PCB 1232	6.5	0.065
PCB 1242	6.5	0.065
PCB 1248	6.5	0.065
PCB 1254	6.5	0.065
PCB 1260	6.5	0.065
perthane	2.0	0.02
phorate	3.0	0.03
P,P'-DDD	0.8	0.008
P,P'-DDE	0.4	0.004
P,P'-DDT	1.0	0.01
prometryn	1000.0	10.0
simazine	10.0	0.10
toxaphene	5.0	0.05
trifluralin	1.0	0.01
trithion (carbophenothion)	10.0	0.10

[a] Minimum detection limit in ppb.
[b] Minimum detection limit in ppb.
[c] Parameter not analyzed due to lack of suitable analytical method.

Appendix B

A brief descriptive paragraph for each compound analyzed.

2,4-D: 2,4-D is a phenoxy-aliphatic non-restricted use selective herbicide registered for use on rice, sugarcane, corn, ornamental turf and lawn grasses, pastures, and non-crop areas as well as aquatic applications (NPIRS, 1988). Reported half-lives in environmental waters range from a few days to several months depending on factors such as temperature, pH, light intensity, formulation and oxygen concentration. 2,4-D is relatively rapidly degraded in the environment with residue half-lives generally not exceeding several weeks in plants, soil, and water (USDHHS, 1981). It is eliminated rapidly by animals and is not bioaccumulated. 2,4-D is moderately toxic with an acute oral LD_{50} for rats of 375 mg/Kg body weight (Toxicity Category II)(Berg, 1985).

2,4-DP: 2,4-DP or dichlorprop is a phenoxy-aliphatic systemic herbicide used for brush control on ornamental turf and lawn grasses, right-of-way, and other non-crop sites (NPIRS, 1988). 2,4-DP is slightly toxic with an acute oral LD_{50} for rats of 800 mg/Kg body weight (Toxicity Category III)(Berg, 1985).

2,4,5-T: 2,4,5-T is a phenoxy-aliphatic selective herbicide with no registered uses in Florida (NPIRS, 1988). Uses in the United States are restricted at this time (USDHHS, 1981). 2,4,5-T is moderately toxic with an acute oral LD_{50} for rats of 500 mg/Kg body weight (Toxicity Category II)(Berg, 1985). During a runoff event, 2,4,5-T could be transported in appreciable proportion in the water (Stewart, 1975).

2,4,5-TP: 2,4,5-TP or silvex is a phenoxy-aliphatic herbicide which had registered uses for rice, range, and non-crop sites (fencerows, industrial sites, vacant lots, etc.). All uses in the United States are cancelled at this time. 2,4,5-TP is slightly toxic with an acute oral LD_{50} for rats of 650 mg/Kg body weight (Toxicity Category III)(Berg, 1985). During a runoff event, 2,4,5-TP could be transported in appreciable proportion with both soil and water (Stewart, 1975).

Alachlor: Alachlor is an acetanilide compound used as a preemergence herbicide for controlling annual grasses and certain broadleaf weeds in corn, peas, beans, and potatoes (Thomson, 1983; NPIRS, 1988). Alachlor is slightly toxic with an acute oral LD_{50} for rats of 1,800 mg/Kg body weight (Toxicity Category III)(Berg, 1985). Soil half-lives in the lab range from 4 to 21 days and half-lives in the field of 18 and 15 days have been reported (Cohen, et al., 1984). During a runoff event, alachlor could be transported in appreciable proportion with both soil and water (Stewart, 1975).

Aldicarb: Aldicarb is a carbamate systemic restricted use insecticide, acaricide, and nematicide for soil use on citrus, potatoes, sugarcane, and ornamental crops (NPIRS, 1988). Aldicarb (Temik 10G) is highly toxic by oral, dermal, and inhalation routes of exposure (Toxicity Category I), with an acute oral LD_{50} for rats of 7.0 mg/Kg body weight (Berg, 1985). Aldicarb is highly toxic to mammals, birds, estuarine/marine organisms, and freshwater organisms. LC_{50} values for the bluegill sunfish and rainbow trout have been reported as 50 µg/L and 560 µg/L, respectively (USEPA, 1984a). Aldicarb exhibits a half-life in water from 5 to 15 days. Aldicarb degrades in soil under both aerobic and anaerobic conditions, with a half-life of 1 to 28 weeks (USDHHS, 1981). Aldicarb has been found to leach in fine to coarse textured soils, including those soils with a high organic matter content, and may reach ground water (USEPA, 1984a). During a runoff event, aldicarb could be transported in appreciable proportion in the water (Stewart, 1975).

Aldrin: Aldrin is a chlorinated hydrocarbon restricted use insecticide used primarily to control soil insects (Berg, 1985). All of these uses were cancelled in October 1974, with the exception of termite control. As of

August 1987, all sales of aldrin were suspended. Its manufacture has been discontinued in the United States. Aldrin has an acute oral LD_{50} for rats of 40-60 mg/Kg body weight (Toxicity Category I)(Berg, 1985). Aldrin is highly toxic to aquatic organisms and birds (USEPA, 1986a). Volatilization half-lives of less than a few days are likely in aquatic systems when sorption to biota and subsequent biotransformation to dieldrin do not occur rapidly. Photosensitized and photooxidation processes may also be important fates for aldrin, but insufficient information is available to assess how general and reliable these processes are for environmental assessments (Callahan, et al., 1979). During a runoff event, aldrin could be transported in appreciable proportion in the soil (Stewart, 1975).

Ametryn: Ametryn is a non-restricted use triazine compound with selective terrestrial herbicide use on potatoes, corn, sugarcane, bananas, plantains, pineapple, grapefruit, oranges, and non-crop areas (NPIRS, 1988). Technical ametryn (pure) is slightly toxic with an acute oral LD_{50} for rats of 1,750 mg/Kg body weight (Toxicity Category III)(Berg, 1985) . Ametryn has a low LC_{50} toxicity for fish. Ametryn, based on published adsorption partition coefficient values for this compound and similar compounds, would be moderately persistent in soils (half-life between 20 and 100 days) with the compound being slightly or moderately mobile. During a runoff event, ametryn could be transported in appreciable proportion with both soil and water (Stewart, 1975).

Atrazine: Atrazine is a restricted use triazine compound with selective terrestrial herbicide use on pineapple, sugarcane, corn, rangelands, ornamental turf and lawn grasses, and non-crop areas (NPIRS, 1988). Atrazine is only slightly toxic with the technical compound having an acute oral LD_{50} for rats of 1,780 mg/Kg body weight (Toxicity Category III)(Berg, 1985). Degradation is very dependent on soil type, moisture content, atrazine concentration, temperature, and soil depth. Although atrazine is somewhat persistent because of strong adsorption to clay or organic matter, it is degraded to hydroxy-atrazine, as well as other metabolites, in soils, water, tolerant plants, and animals (USDHHS, 1981). The half-life of atrazine is very site specific but is approximately 10 days in the water and 45 days in the soil. Leaching is minimal in clay and high-organic soils due to adsorption. The low to moderate vertical mobility of atrazine reduces the possibility of ground water contamination. Contamination due to runoff is more likely (USDHHS, 1981). During a runoff event, atrazine could be transported in appreciable proportion with both soil and water (Stewart, 1975).

Benomyl: Benomyl is a non-restricted use benzimidazole carbamate compound (Buchel, 1983). Benomyl is a systemic fungicide with registered uses on citrus, bananas, mangos, papayas, pineapple, beans, avocados, rice, tomatoes, celery, cucumbers, sugarcane, squash, cabbage, ornamental plants, turf and lawn grasses (NPIRS, 1988). Benomyl is almost non-toxic with an acute oral LD_{50} for rats of greater than 9,590 mg/Kg body weight (Toxicity Category IV)(USDHHS, 1981). Aqueous degradation of benomyl is relatively rapid, with complete conversion to its major degradation product, methyl 2-benzimidazolecarbamate (MBC) in 1 week. The half-life of benomyl residues are approximately 3 to 6 months on turf and 6 to 12 months on bare soil. Benomyl is essentially immobile in soil with no leaching or movement from treatment site (USDHHS, 1981). During a runoff event, benomyl could be transported in appreciable proportion in the soil (Stewart, 1975).

BHC (Hexachlorocyclohexane or Benzene Hexachloride): BHC is a chlorinated hydrocarbon insecticide composed of several isomers. Technical

BHC is a mixture of alpha, beta, gamma, and delta-isomers. Production of technical BHC was suspended in 1976. All domestic registrations for BHC have been voluntarily canceled and the registrants have amended their registrations and reformulated their products to incorporate lindane (at least 99 percent pure gamma isomer) rather than BHC (USDHHS, 1981). The fate of the alpha, beta, and delta-isomers in aquatic systems is determined by their availability to biotransformation processes. Although sorption to suspended sediment and biota is not extensive, sorption is probably an important process for ultimately transporting BHC to anaerobic sediments where transformations occur due to the lack of chemical and biological transformation in aerobic systems (Callahan, et al., 1979).

Bromacil: Bromacil is a substituted uracil compound used as a pre-and postemergent herbicide on citrus, pineapple, and numerous non-crop areas (NPIRS, 1988). Bromacil is almost non-toxic with an acute oral LD_{50} for rats of 5,200 mg/Kg body weight (Toxicity Category IV)(Berg, 1985). Bromacil is degraded at a moderate rate in soil, with an estimated half-life of approximately 7 months. Bromacil is highly mobile in soil, leaching to depths of 18 to 24 inches (USDHHS, 1981). During a runoff event, bromacil could be transported in appreciable proportion in the water (Stewart, 1975).

Carbaryl: Carbaryl is a insecticidal carbamate compound registered for use on rice, tomatoes, celery, peppers, broccoli, cabbage, beans, corn, cucumbers, eggplant, endive, lettuce, parsley, radish, squash, ornamental plants and trees, ornamental turf and lawn grasses, non-crop areas, and citrus crops (NPIRS, 1988). Carbaryl is moderately toxic with an acute oral LD_{50} for rats of 225 mg/Kg body weight (Toxicity Category II). Carbaryl is extremely toxic to aquatic invertebrates and certain estuarine organisms. An LC_{50} value for Daphnia pulex of 6.4 ppb has been reported. It is moderately toxic to fish and has only low toxicity to birds. LC_{50} values for the bluegill sunfish and rainbow trout have been reported as 6.76 ppm and 1.95 ppm, respectively. The half-life appears to range from 7 to 28 days in aerobic and anaerobic soils, respectively (USEPA, 1984b). During a runoff event, carbaryl could be transported in appreciable proportion with both soil and water (Stewart, 1975).

Carbofuran: Carbofuran is a broad spectrum restricted use systemic carbamate insecticide and nematicide registered for use on potatoes, corn, rice, sugarcane, squash, and cucumbers (NPIRS, 1988). Carbofuran is highly toxic with an acute oral LD_{50} for rats of between 3.8 and 34.5 mg/Kg body weight (Toxicity Category I). Carbofuran is characterized as very highly toxic to fish, highly toxic to freshwater invertebrates, and very highly toxic to birds. Carbofuran degrades fairly slowly in un-sterile, neutral, or acid aerobic soils, with half-lives ranging from one to eight weeks. It is more stable in sterile soil, and unstable under alkaline conditions. Under anaerobic conditions, carbofuran is more stable and may take twice as long to degrade. Carbofuran is mobile in soil, particularly sandy soil with a high percolation rate. It has been found in shallow aquifers under or near treated fields at levels up to 50 ppb (USEPA, 1984c). Runoff studies indicate losses of less than 2 percent with carbofuran residues remaining in water rather than sediment (USDHHS, 1981).

Chlordane: Chlordane is a chlorinated hydrocarbon previously used as a contact insecticide. Chlordane is moderately toxic with an acute oral LD_{50} for rats of between 283 to 590 mg/Kg body weight (Toxicity Category II)(Buchel, 1983). Technical chlordane is a mixture of numerous isomers of chlordane and closely related compounds and by-products. About one-half of the composition consists of the two major isomers of chlordane; no other individual

component exceeds about one-tenth of the total product. The oil solution type formulation was used almost exclusively for subterranean termite control applications, and emulsifiable concentrates, granules, dusts, and wettable powders for termite control and certain agricultural purposes (Berg, 1985). However, all sales were suspended by the USEPA in August of 1987, pending the outcome of the evaluation of potential human health risks. Volatilization, sorption to sediment, and bioaccumulation are important fates for the chlordane isomers in aqueous environments. The chlordane isomers also undergo photosensitized isomerization, but no information is available to determine whether such reactions may occur in aquatic systems. Although biotransformations of chlordane may be important for the ultimate transformation of chlordane, these processes are likely to be very slow in the environment (Callahan, et al., 1979). During a runoff event, chlordane could be transported in appreciable proportion in the soil (Stewart, 1975).

Chloropicrin: Chloropicrin is a restricted use soil fumigant used for the control of weeds, nematodes, and certain fungal diseases (Thomson, 1983). Registered uses include pineapples, potatoes, rice, cabbage, endive, lettuce, sugarcane, ornamental plants, tomatoes, celery, cucumbers, eggplant, radishes, squash, corn, broccoli, peppers, ornamental turf and lawn grasses, non-crop areas, and citrus (NPIRS, 1988). Chloropicrin is moderately toxic with an acute oral LD_{50} for rats of 250 mg/Kg body weight (Toxicity Category II) (Berg, 1985).

Chlorothalonil: Chlorothalonil is a broad spectrum chlorinated hydrocarbon fungicide. Registered uses include papayas, ornamental plants, celery, corn, cucumbers, squash, tomatoes, cabbage, ornamental turf and lawn grasses, potatoes, beans, and broccoli (NPIRS, 1988). Chlorothalonil is almost non-toxic with an acute oral LD_{50} for rats of $>10{,}000$ mg/Kg body weight (Toxicity Category IV)(Berg, 1985). However, chlorothalonil is highly toxic to fish and aquatic invertebrates, with low amounts of residues affecting the reproduction of these organisms. Chlorothalonil breaks down in aerobic soil with a half-life of 1 to 2 months. This breakdown appears to be primarily the result of microbial degradation, since chlorothalonil is relatively stable to hydrolysis and photolysis. Chlorothalonil is immobile in most soil types, except sand in which it is moderately mobile (USEPA, 1984d).

Chlorpyrifos: Chlorpyrifos is a non-restricted use organophosphorus insecticide with registered uses on bananas, squash, eggplant, cucumbers, tomatoes, broccoli, cabbage, corn, citrus, ornamental turf and lawn grasses, peppers, endive, lettuce, potatoes, radishes, beans, ornamental plants, and non-crop areas (NPIRS, 1988). Chlorpyrifos is moderately toxic with an acute oral LD_{50} for rats of 118 mg/Kg body weight (Toxicity Category II)(USDHHS, 1981). Chlorpyrifos is extremely toxic to fish, birds and other wildlife. It is highly toxic to honey bees (USEPA, 1984e). Hydrolysis in water occurs very readily above pH 8.0 and occurs least readily at about pH 6.0. Hydrolysis appears to be the main route of degradation. Half-lives generally in the range of 80 to 100 days have been observed in various soils. Chlorpyrifos is not leached in soil (USDHHS, 1981).

DDD: DDD, although considered a degradation product of DDT, is also a chlorinated hydrocarbon insecticide formerly used on many fruits and vegetables. The major fate processes for DDD in aquatic environments are bioaccumulation and sorption to sediments and biota. Volatilization will also be an important process for loss of DDD from aquatic systems, with DDD half-lives on the order of a few days to several weeks. DDD is quite stable to chemical transformations in aquatic

environments, and biotransformation is probably the process resulting in the ultimate degradation of DDD in the environment (Callahan, et al., 1979).

DDE: DDE is formed as a degradation product of DDT and is not manufactured as a commercial product. The major fate processes for DDE in aquatic environments are bioaccumulation and sorption to sediment and biota. Laboratory studies suggest that in aquatic environments, DDE may have volatilization half-lives of several hours and photolysis half-lives of several days; the observed persistence of DDE in such environments may be due to the fact that DDE is mainly formed from DDT under biological conditions in which DDE in the sorbed state is then not available for volatilization or photolysis (Callahan, et al., 1979).

DDT: DDT is a chlorinated hydrocarbon compound formerly used as an insecticide. All uses have been canceled as of January 1, 1973. Technical DDT comprises mainly a mixture of two DDT isomers: PP' and OP' with the PP' isomer being the dominant isomer. There is ample evidence to demonstrate that DDT is very persistent in the environment. The dominant fate processes in aquatic environments are volatilization and sorption to biota and sediment, with the importance of sorption being determined by the amount of suspended particulate available in the water body. The ultimate transformation of DDT in the aquatic environment is probably by biotransformation, although one study indicates that indirect photolysis may also be a significant loss process for DDT in a natural water, with a photolysis half-life on the order of a week. Photolysis of DDT in the gas phase has also been reported, but since DDT has been widely found throughout the biosphere, atmospheric transformations appear to be slow. There is also abundant evidence to demonstrate that bioaccumulation of DDT is a significant process in the environment (Callahan, et al., 1979).

Demeton: Demeton is a restricted use organophosphorus insecticide and acaricide. Demeton is highly toxic with an acute oral LD_{50} for rats between 8.2 and 14 mg/Kg body weight (Toxicity Category I)(Berg, 1985). Demeton is also highly toxic to birds, fish and freshwater invertebrates (USEPA, 1985a). Demeton is not considered a persistent pesticide as it is relatively short-lived in the soil and water. Residues are subject to degradation via hydrolysis to compounds of lesser toxicological concern (USDHHS, 1981). During a runoff event, demeton could be transported in appreciable proportion in the water (Stewart, 1975).

Diazinon: Diazinon is a non-restricted use organophosphorus insecticide and nematicide with a variety of registered uses. These include field, fruit, vegetable, ornamentals, livestock, range, pasture, lawns, household outdoor and indoor applications. Diazinon is slightly toxic with an acute oral LD_{50} for rats of 1,186 mg/Kg body weight (Toxicity Category III)(Berg, 1985). However, diazinon is very highly toxic to birds, fish, and aquatic invertebrates (USEPA, 1985b). During a runoff event, diazinon could be transported in appreciable proportion with both soil and water (Stewart, 1975).

Dicofol: Dicofol or kelthane is a chlorinated hydrocarbon acaricide registered for use on ornamental plants, ornamental turf and lawn grasses, peppers, beans, tomatoes, cucumbers, eggplant, squash, corn, and citrus (NPIRS, 1988). Kelthane is moderately toxic with an acute oral LD_{50} for rats between 684 and 1,495 mg/Kg body weight (Toxicity Category II). Kelthane is highly toxic to aquatic organisms and only slightly toxic to birds, mammals, and beneficial insects. Kelthane residues may accumulate in fish as well as some rotational crops. Field studies show that kelthane persists in soils for at

least four years after application. Kelthane residues are negligibly mobile in sandy loam soil column leaching studies. The DDT analog contaminants in kelthane may cause unreasonable adverse effects in certain bird and fish species (USEPA, 1984f). During a runoff event, kelthane could be transported in appreciable proportion in the soil (Stewart, 1975).

Dieldrin: Dieldrin is a chlorinated hydrocarbon insecticide. The manufacture of dieldrin was discontinued in the United States since 1974 with all uses except termite control canceled (Berg, 1985). Sales in the United States were suspended in August of 1987 and all registrations may be canceled. Dieldrin was previously used for the control of soil insects, public health insects, and many other pests. Dieldrin is highly toxic with an acute oral LD_{50} for rats between 40 to 87 mg/Kg body weight (Toxicity Category I)(Buchel, 1983). The literature information indicates that dieldrin is persistent in the environment. The important fate processes in aquatic environments are sorption to sediment, bioaccumulation, and volatilization; the latter process may have half-lives of several hours to several days in some aquatic systems. Although direct photolysis of dieldrin in water is slow (1.5 to 2 months), photosensitized processes may result in photolysis if sensitizers are available in aquatic environments. Although dieldrin is quite resistant to biotransformation, this process will probably be an important fate for dieldrin in sediment and biota (Callahan, et al., 1979).

Diuron: Diuron is a substituted urea compound registered as a herbicide to control a wide variety of annual and perennial broadleaf and grassy weeds on both crop and non-crop sites. Registered uses include sugarcane, citrus, bananas, papayas, pineapples, and non-crop areas (NPIRS, 1988). Diuron is slightly toxic with an acute oral LD_{50} for rats of 3,400 mg/Kg body weight (Toxicity Category III). Diuron is relatively stable to hydrolysis in solutions at pH values commonly found in natural surface waters. The half life of diuron may exceed 6 months in soil (USDHHS, 1981). During a runoff event, diuron could be transported in appreciable proportion in the soil (Stewart, 1975).

Endosulfan: Endosulfan is a chlorinated hydrocarbon insecticide and acaricide registered for use on beans, tomatoes, celery, corn, cucumbers, pineapples, peppers, potatoes, eggplant, lettuce, squash, broccoli, cabbage, citrus, and ornamental plants (NPIRS, 1988). Endosulfan is moderately to highly toxic with an acute oral LD_{50} for rats between 30 and 110 mg/Kg body weight (Toxicity Category I and II)(Verschueren, 1983). Technical endosulfan is a mixture of the two stereoisomeric forms, the alpha and the beta forms. Data are incomplete regarding the important processes for determining the fate of endosulfan in aquatic systems. The hydrolysis half-life of endosulfan at 20^0C is about a month at pH 7 and about six months at pH 5.5. Other information suggests that photolysis, oxidation, biodegradation, sorption, and volatilization may be occurring under some environmental conditions, but data for predicting the rates and relative importance of these processes in aquatic systems are not available (Callahan, et al., 1979). During a runoff event, endosulfan could be transported in appreciable proportion in the soil (Stewart, 1975).

Endosulfan sulfate: Endosulfan sulfate is thought to be the corresponding cyclic sulfate from the oxidation of either isomer of endosulfan. The sulfate also appears as a metabolite of endosulfan during biotransformations (Callahan, et al., 1979; Buchel, 1983).

Endrin: Endrin is a restricted use chlorinated hydrocarbon insecticide with a registered use on non-crop areas (NPIRS, 1988). Endrin is highly toxic with an acute oral LD_{50} for rats between 7 and 15 mg/Kg body weight (Toxicity

Category I) (Berg, 1985). Little information is available for evaluating the fate of endrin in aquatic systems. Photolysis and biotransformation of endrin occur under environmental conditions, but no data are available to assess the rates of these processes in aquatic environments; biotransformation will also be affected by the microbial types and populations available to utilize endrin. No information on the sorption or volatilization of endrin from aquatic systems is available, although bioaccumulation does appear to be significant with concentration factors on the order of 10^3 to 10^4 (Callahan, et al., 1979). The half-life for endrin in soil is generally in excess of 2 years. Endrin residues are not appreciably leached. Residues are sorbed to soil particulates and appreciable transport may occur from soil erosion and runoff (USDHHS, 1981).

Endrin aldehyde: Endrin aldehyde is a transformation product of endrin of which no information has been found to evaluate the fate of endrin aldehyde in aquatic systems (Callahan, et al., 1979).

Ethion: Ethion is an organophosphorus insecticide and acaricide with some formulations classified as restricted use. Ethion is used to control a broad spectrum of insects and mites on citrus, tomatoes, beans, cucumbers, eggplant, squash, corn, and ornamental plants (NPIRS, 1988). Ethion is highly toxic with an acute oral LD_{50} for rats of 24.4 mg/Kg body weight (Toxicity Category I). Ethion is highly toxic to freshwater fish and very highly toxic to freshwater invertebrates. Ethion is not expected to move into water supplies, and does not persist long in the environment. Aquatic monitoring studies rarely show evidence of ethion either in water samples or organisms, while in soil, ethion has a reported half-life of less than two months (USEPA, 1982). During a runoff event, ethion could be transported in appreciable proportion in the soil (Stewart, 1975).

Ethoprop: Ethoprop is a restricted use organophosphorus insecticide and nematicide with registered uses on citrus, cabbage, corn, beans, sugarcane, cucumbers, bananas, pineapples, potatoes, ornamental turf and lawn grasses (NPIRS, 1988). Ethoprop is moderately toxic with an acute oral LD_{50} for rats of 56.2 mg/Kg body weight (Toxicity Category II). Ethoprop is characterized as very highly toxic to birds, marine/estuarine crustaceans, and marine/estuarine fish species. Ethoprop is not expected to contaminate drinking water supplies. It degrades fairly rapidly with half-lives of 3 to 56 days in soil. Increases in soil temperature tends to increase the dissipation rate. However, ethoprop is very mobile in sandy soil and has a potential for contaminating ground water in areas of sandy soil with a high water table (USEPA, 1985c).

Fonofos: Fonofos or dyfonate is an organophosphorus soil insecticide with some formulations classified as restricted use. Registered uses include beans, broccoli, cabbage, corn, potatoes, radishes, sugarcane, and tomatoes (NPIRS, 1988). Fonofos is highly toxic with an acute oral LD_{50} for rats between 3.16 and 18.5 mg/Kg body weight (Toxicity Category I). Fonofos is moderately to highly toxic to birds, and highly toxic to freshwater fish and salt water organisms. Fonofos is immobile in sandy loam and silt loam soils but is mobile in quartz sand. It decomposes in aerobic soils by microbes with a half-life of 3 to 16 weeks. Fonofos is non-volatile from soil but volatile from water. Fonofos is moderately persistent (USEPA, 1985d). During a runoff event, fonofos could be transported in appreciable proportion in the soil (Stewart, 1975).

Gamma BHC: Gamma BHC or lindane is a restricted use chlorinated hydrocarbon insecticide/acaricide with registered uses on beans, tomatoes, celery, cucumbers, squash, okra, broccoli, peppers, lettuce, ornamental

plants, non-crop areas, and cabbage (NPIRS, 1988). The United States production of lindane was halted in 1976, and all unformulated lindane has been imported since that time (USDHHS, 1981). Lindane is moderately toxic with an acute oral LD_{50} for rats of 88 mg/Kg body weight (Toxicity Category II). Lindane is slightly to moderately toxic to birds, and highly toxic to some aquatic organisms (USEPA, 1985e). The fate of lindane in aquatic systems will be controlled by the availability of and to biotransformation processes. Lindane transformation will be favored in biologically rich, anaerobic environments. Although sorption to suspended sediment and biota is not extensive, sorption is an important process for ultimately transporting lindane to anaerobic sediments where transformation occurs. Hydrolysis and oxidation do not appear to be important fate processes for lindane; data on the photolysis of lindane are contradictory and confusing. Lindane is only slightly bioaccumulated in organisms (Callahan, et al., 1979). During a runoff event, lindane could be transported in appreciable proportion in the soil (Stewart, 1975).

Glyphosate: Glyphosate is a broad spectrum, postemergent, translocated herbicide with both terrestrial and aquatic applications. Registered uses include avocados, rice, sugarcane, radishes, corn, broccoli, cabbage, tomatoes, lettuce, carrots, celery, citrus, cucumbers, squash, eggplant, peppers, potatoes, ornamental turf and lawn grasses, and non-crop areas as well as control of emergent type aquatic weeds (NPIRS, 1988). Glyphosate is slightly toxic with an acute oral LD_{50} for rats of 4,300 mg/Kg body weight (Toxicity Category III)(Berg, 1985). Field studies on 11 different soils, covering a full range of soil types and geographic areas, indicated an average half-life for glyphosate of 2 months. Other studies have reported half-lives of 17 to 19 weeks for sandy soil and 3 weeks in silt loam (Ghassemi, et al., 1982). Absorption of glyphosate to soil reduces its mobility through leaching and surface runoff (Sprankle, et al., 1975). Microbial degradation is the major route of degradation of glyphosate in water with a half-life of approximately 7 weeks (Ghassemi, et al., 1982). During a runoff event, glyphosate could be transported in appreciable proportion in the soil (Stewart, 1975).

Guthion: Guthion or azinphos-methyl is a restricted use organophosphorus insecticide and acaracide with registered uses on tomatoes, celery, cucumbers, sugarcane, eggplant, broccoli, cabbage, peppers, potatoes, beans, citrus, and ornamental plants (NPIRS, 1988). Guthion is highly toxic with an acute oral LD_{50} for rats of 4.4 mg/Kg body weight (Toxicity Category I). Guthion exhibits both low soil mobility and low leaching potential in a variety of soil types. In sandy soils guthion dissipates in the field fairly rapidly and is metabolized by microorganisms (USEPA, 1986b). The half-life of guthion in water ranged from over 36 days at 6^0C to about 7 days at 40^0C both at pH 8.6. Increasing the pH past 9 abruptly dropped those half-lives to about one-tenth of the original values at 6^0C and 40^0C. Residues of guthion appear to generally degrade fairly rapidly on crops and in the environment, but there is evidence that wide variations in the decline rate may occur on different crops and under various environmental conditions (USDHHS, 1981). During a runoff event, guthion could be transported in appreciable proportion in the soil (Stewart, 1975).

Heptachlor: Heptachlor is a restricted use chlorinated hydrocarbon insecticide. In 1975, the use of heptachlor for certain pests on agricultural crops was suspended due to its potential carcinogenicity leaving only registration for subterranean termite control (Berg, 1985). However, sales in the United States were suspended in August of 1987 and all registrations may be cancelled.

Heptachlor is moderately toxic with an acute oral LD_{50} for rats between 158 and 208 mg/Kg body weight (Toxicity Category II). Heptachlor is extremely toxic to aquatic organisms and birds (USEPA, 1986c). The major fate of heptachlor in the solution phase of aquatic systems will be hydrolysis to give 1-hydroxychlordene (1-HC) with a half-life of about 1 to 3 days; 1-HC will then be biotransformed to give 1-hydroxy-2,3-chlordene epoxide (1-HCE). Although literature information also indicates that heptachlor photolysis, volatilization, and sorption to sediments may also occur in aquatic environments, no data are available to compare these processes with the hydrolysis transformation rate (Callahan, et al., 1979). Heptachlor is considered persistent and bioaccumulates. Heptachlor is not expected to leach, since it is insoluble in water and should adsorb to the soil surface; thus it should not reach underground aquifers (USEPA, 1986c). During a runoff event, heptachlor could be transported in appreciable proportion in the soil (Stewart, 1975).

Heptachlor epoxide: Heptachlor epoxide is the oxidation product of heptachlor which occurs in soil and in, or on crops when treatments with heptachlor have been made. Heptachlor epoxide is resistant to chemical and biological transformations in aquatic environments, and half-lives of over several years are probable. Although sediment sorption and bioaccumulation are not appreciable, they may ultimately be relatively important processes in view of the stability of heptachlor epoxide in the environment. Photosensitized reaction and biotransformations in anaerobic sediments are possibly important processes for eventual transformation of heptachlor epoxide in aquatic environments (Callahan, et al., 1979).

Linuron: Linuron is a substituted urea compound used as a restricted use selective herbicide, applied both pre- and postemergence. Registered uses include carrots, corn, celery, and non-crop areas (NPIRS, 1988). Linuron is slightly toxic with an acute oral LD_{50} for rats of 2,600 mg/Kg body weight (Toxicity Category III). Linuron is persistent at pH values commonly found in natural surface waters (pH 6-9)(USDHHS, 1981). During a runoff event, linuron could be transported in appreciable proportion in the soil (Stewart, 1975).

Malathion: Malathion is an organophosphorus insecticide with registered uses on avocados, rice, tomatoes, mango, lime, celery, corn, cucumbers, eggplant, endive, lettuce, radish, squash, broccoli, cabbage, and citrus (NPIRS, 1988). Malathion is slightly toxic with an acute oral LD_{50} for rats of 1,375 mg/Kg body weight (Toxicity Category III)(Berg, 1985). In the soil, malathion is relatively non-persistent with 100 percent of the applied product disappearing from the soil within one week. Hydrolysis in water occurs very readily above pH 8.0 and occurs least readily at about pH 5 (Verschueren, 1983). During a runoff event, malathion could be transported in appreciable proportion in the water (Stewart, 1975).

Methamidophos: Methamidophos is a restricted use insecticide and acaricide used on a variety of row crops including broccoli, celery, lettuce, cabbage, and potatoes (NPIRS, 1988). Residues of methamidophos also arise from acephate use as methamidophos is a metabolite of acephate. Methamidophos (90 percent technical) is highly toxic with an acute oral LD_{50} for rats of 15.6 mg/Kg body weight (Toxicity Category I)(Berg, 1985). Foliar half-life for methamidophos can be up to 11 days. Foliar degradation products are non-cholinesterase-inhibiting compounds which are thought to be of lesser toxicological concern. No data are available on the degradation in natural water, however in buffered solutions degradation is rapid with half-lives less than 7 days. Limited data indicates that

methamidophos leaches readily in soil, but degrades rapidly in the process, with half-lives less than 6 days. During a runoff event, methamidophos could be transported primarily in water (USDHHS, 1981).

Methomyl: Methomyl is a restricted use carbamate compound used as a broad spectrum insecticide and nematicide with registered uses on avocados, peppers, potatoes, tomatoes, mango, celery, corn, cucumbers, eggplant, endive, papayas, beans, lettuce, parsley, squash, broccoli, cabbage, citrus, ornamental plants, and non-crop areas (NPIRS, 1988). Methomyl is highly toxic with an acute oral LD_{50} for rats between 17 and 24 mg/Kg body weight (Toxicity Category I)(Berg, 1985). Methomyl degraded in aerated river water exposed to sunlight, with a half-life of slightly less than 7 days. Degradation in soil occurs with a half-life of between 4 and 5 weeks, producing CO_2 and other materials. Only slight leaching tendencies and insignificant runoff ability have been demonstrated (USDHHS, 1981).

Methoxychlor: Methoxychlor is a chlorinated hydrocarbon insecticide with registered uses on tomatoes, corn, cucumbers, cauliflower, lettuce, carrots, beans, eggplant, endive, squash, broccoli, cabbage, peppers, potatoes, radishes, non-crop areas, and ornamental plants (NPIRS, 1988). Methoxychlor is almost non-toxic with an acute oral LD_{50} for rats of 6,000 mg/Kg body weight (Toxicity Category IV). Methoxychlor is widely used because of its long residual action against many species of insects and its low toxicity to humans and warmblooded animals (Berg, 1985). Methoxychlor has a very low accumulation rate in birds and mammals and relatively low avian toxicity. Methoxychlor is found to be degraded in natural waters in a few weeks or less (USEPA, 1986d). During a runoff event, methoxychlor could be transported in appreciable proportion in the soil (Stewart, 1975).

Methyl Bromide: Methyl bromide is a restricted use halogenated hydrocarbon fumigant with registered uses on tomatoes, eggplant, broccoli, citrus, pineapple, peppers, lettuce, carrots, cauliflower, ornamental turf and lawn grasses, ornamental plants, and non-crop areas (NPIRS, 1988). Methyl bromide has action as a acaricide, fungicide, herbicide, insecticide, nematicide, and rodenticide. Methyl bromide is moderately toxic with an acute oral LD_{50} for rats of 214 mg/Kg body weight (Toxicity Category II). Methyl bromide is not expected to run off fields to surface water because of application methods (USEPA 1986e). Most of the methyl bromide applied to soil diffuse into the atmosphere. Some hydrolysis and reaction with soil components may occur. Methyl bromide has a half-life of greater than 55 days in water near neutral pH at 15^0C. The half-life decreases rapidly with increasing temperature (USDHHS, 1981).

Methyl parathion: Methyl parathion is a restricted use organophosphorus insecticide with registered uses on tomatoes, celery, cucumbers, peppers, beans, corn, lettuce, broccoli, cabbage, and rice (NPIRS, 1988). Methyl parathion is highly toxic with an acute oral LD_{50} for rats between 4.5 and 16 mg/Kg body weight (Toxicity Category I). Methyl parathion is also considered highly toxic to aquatic invertebrates and birds. Insufficient information is available for the analysis of the environmental fate of methyl parathion (USEPA, 1986f). During a runoff event, methyl parathion could be transported in appreciable proportion with both soil and water (Stewart, 1975).

Metolachlor: Metolachlor is a chloracetanilide selective herbicide with registered uses on citrus, beans, ornamental plants, corn, and potatoes (NPIRS, 1988). Metolachlor is slightly toxic with an acute oral LD_{50} for rats of 2,780 mg/Kg body weight (Toxicity Category III). Available data are

insufficient to assess the environmental fate of metolachlor (USEPA, 1987a).

Metribuzin: Metribuzin is a non-restricted use triazine herbicide with registered uses on potatoes, carrots, corn, tomatoes, and sugarcane (NPIRS, 1988). Metribuzin is slightly toxic with an acute oral LD_{50} for rats between 2,200 and 2,345 mg/Kg body weight (Toxicity Category III). Metribuzin is moderate to slightly toxic to birds and moderately toxic to freshwater fish and invertebrates. Metribuzin in moderately adsorbed on soils with high clay and/ or organic matter content. Metribuzin is readily leached in sandy soils low in organic matter content. Microbial breakdown appears to be the major mechanism by which metribuzin is lost from soils. Half-life varies with soil type and climatic conditions, however, at normal use rates the soil half-life is 1 to 2 months. Soil degradation occurs fastest under aerobic conditions and at comparatively high temperatures. Available data show that metribuzin has a potential to contaminate ground water in soils low in organic and clay content (USEPA, 1985f). In pond studies, the half-life of metribuzin was between 2.5 and 6.5 days (USDHHS, 1981). During a runoff event, metribuzin could be transported in appreciable proportion in the water (Stewart, 1975).

Mevinphos: Mevinphos or phosdrin is a restricted use organophosphorus contact and systemic insecticide and acaricide. Registered uses include tomatoes, celery, corn, cucumbers, eggplant, lettuce, parsley, squash, okra, broccoli, cabbage, beans, potatoes, peppers, and citrus (NPIRS, 1988). Technical mevinphos is highly toxic with an acute oral LD_{50} for rats of 1.4 mg/Kg body weight (Toxicity Category I). Mevinphos is rapidly hydrolyzed in alkaline solutions with half-lives of 70 hours or less. In the soil, mevinphos appears to be decomposed primarily by chemical hydrolysis with half-lives of 3 to 12 hours (USDHHS, 1981). During a runoff event, mevinphos could be transported in appreciable proportion in the water (Stewart, 1975).

Mirex: Mirex is a chlorinated hydrocarbon insecticide formally used for the control of the imported fire ant. All products containing mirex were cancelled in December 1977 due to the persistence of the compound. Mirex is moderately toxic with an acute oral LD_{50} for rats of between 235 and 702 mg/Kg body weight (Toxicity Category II)(Buchel, 1983).

Monocrotophos: Monocrotophos or azodrin is a restricted use organophosphorus insecticide and acaracide with registered uses on tomatoes, potatoes, and sugarcane (NPIRS, 1988). Monocrotophos is highly toxic with an acute oral LD_{50} for rats between 18 and 23 mg/Kg body weight (Toxicity Category I). Monocrotophos is very highly toxic to birds and freshwater invertebrates and moderately toxic to freshwater fish. Monocrotophos hydrolyzed rapidly with a half-life of 14 to 21 days at pH 9 and 25^{0}C, with the rate decreasing at lower pH's and increasing at higher temperatures. Degradation on soil exposed to natural sunlight is rapid with a half-life less than 7 days, and on dark control samples is slower with a half-life of approximately 30 days. Monocrotophos is mobile in soil, and although it degrades rapidly, it may possess potential for ground water contamination (USEPA, 1985g). During a runoff event, monocrotophos could be transported in appreciable proportion in the water (Stewart, 1975).

Oxamyl: Oxamyl is a carbamate insecticide, acaricide, and nematicide with some formulations classified as restricted use. Registered uses include peppers, potatoes, tomatoes, celery, cucumbers, eggplant, squash, citrus, pineapple, and ornamental plants (NPIRS, 1988). Oxamyl is highly toxic with an acute oral LD_{50} for rats between 2.5 and 3.1 mg/Kg body weight (Toxicity Category I). Oxamyl is very highly toxic

to birds. Oxamyl has been shown to leach and has been found in well water (USEPA, 1987b). The half-life of oxamyl in river water varied from 12 hours to 2 days. The half-life in soil is highly variable, ranging from 6 to 39 days in some tests, depending on location, soil type, and moisture content (USDHHS, 1981).

Paraquat: Paraquat is a restricted use bipyridylium compound registered as a non-selective herbicide, defoliant, desiccant, and plant growth regulator (USEPA, 1987c). Registered sites include tomatoes, corn, citrus, peppers, broccoli, cabbage, cauliflower, potatoes, sugarcane, bananas, papayas, pineapple, cucumbers, squash, eggplant, lettuce, beans, ornamental plants, avocados, and non-crop areas (NPIRS, 1988). Paraquat is moderately toxic with an acute oral LD_{50} for rats between 100 and 150 mg/Kg body weight (Toxicity Category II). Paraquat is moderately toxic to birds and aquatic invertebrates and slightly toxic to freshwater fish. Paraquat is stable to hydrolysis and photolysis in soil since it is rapidly and strongly bound to soil, particularly clay. Preliminary data indicates that paraquat has a half-life of greater than 2 weeks in water plus soil. Paraquat is immobile in silt loam and silty clay loam, and slightly mobile in sandy loam and potentially mobile in sandy soils extremely low in organic matter. The half-life of paraquat in water is approximately 23 weeks. Paraquat is not readily desorbed from the soil and is not likely to contaminate ground water in agricultural soils (USEPA, 1987c). During a runoff event, paraquat could be transported in appreciable proportion in the soil (Stewart, 1975).

Parathion: Parathion is a restricted use organophosphorus insecticide with registered uses on tomatoes, celery, corn, cucumbers, eggplant, lettuce, squash, okra, broccoli, cabbage, citrus, sugarcane, avocado, rice, endive, mangos, pineapple, carrots, peppers, cauliflower, potatoes, beans, ornamental plants, and radishes (NPIRS, 1988). Parathion is highly toxic with an acute oral LD_{50} for rats between 1.75 and 15.0 mg/Kg body weight (Toxicity Category I). Parathion is highly toxic to fish and birds. The available data provide insufficient information for the analysis of the environmental fate of parathion. However, parathion has little or no potential to contaminate ground water (USEPA, 1986g). During a runoff event, parathion could be transported in appreciable proportion in the soil (Stewart, 1975).

PCB (Polychlorinated biphenyls): PCB's are a diverse family of compounds with low vapor pressure, high dielectric constants, chemical inertness, and extreme thermal stability. All these properties made PCB's useful in a wide variety of applications. Commercial PCB mixtures were manufactured under a variety of trade names. The chlorine content of any product may vary from 18 to 79 percent and depends on the extent of chlorination during the manufacturing process or on the amount of isomeric mixing engaged in by individual procedures. For example, in the designation of the individual Aroclors (Monsanto TM) a set of four digits was used: the first two digits, 12, to designate that the preparation is a mixture and the second set of two numbers is used to denote the approximate chlorine content by weight. Thus, Aroclor 1242 is a mixture having an average chlorine content of 42 percent. The following Table B-1 summarizes the uses of the various mixtures analyzed for in this study (National Research Council, 1979).

Non-destructive processes which affect the distribution and transport of polychlorinated biphenyls are adsorption, volatilization, and bioaccumulation. In natural water systems, the greatest concentration of these compounds is sorbed to suspended and sediment due to the very low solubility in water. The tendency of polychlorinated biphenyls for adsorption

control of moths and carpet beetles in the dry cleaning and textile markets. Perthane is almost non-toxic with an acute oral LD_{50} for rats of 8,170 body weight (Toxicity Category IV) (Buchel, 1983). During a runoff event, perthane could be transported in appreciable proportion in the soil (Stewart, 1975).

Phorate: Phorate is a restricted use organophosphorus insecticide and nematicide with registered uses on tomatoes, corn, potatoes, lettuce, beans, and sugarcane (NPIRS, 1988). Phorate is highly toxic with an acute oral LD_{50} for rats between 1.4 and 3.7 mg/Kg body weight (Toxicity Category I). Phorate is very highly toxic to birds, freshwater fish, and aquatic invertebrates. Phorate has some potential to leach through soil and contaminate ground water, particularly where soils are sandy and aquifers are shallow (USEPA, 1985g). Phorate undergoes hydrolysis, particularly in alkaline solutions (USDHHS, 1981). During a runoff event, phorate could be transported in appreciable proportion with both soil and water (Stewart, 1975).

Prometryn: Prometryn is a selective triazine herbicide registered for use on celery (NPIRS, 1988). Prometryn is slightly toxic with an acute oral LD_{50} for rats between 1,802 and 2,076 mg/Kg body weight (Toxicity Category III). Prometryn is slightly toxic to freshwater invertebrates and moderately toxic to fish. Insufficient data are available to fully characterize the environmental fate of prometryn. Available data indicates that prometryn has hydrolytic stability and is persistent in the soil. Leaching studies indicate that prometryn has intermediate mobility in sandy loam soils and is very mobile in sandy soils (USEPA, 1987d). During a runoff event, prometryn could be transported in appreciable proportion in the soil (Stewart, 1975).

Simazine: Simazine is a triazine herbicide with registered uses on avocado, sugarcane, ornamental turf and lawn grasses, ornamental plants, non-crop areas, and citrus (NPIRS, 1988). Simazine is almost non-toxic with an acute oral LD_{50} for rats greater than 15,380 mg/Kg body weight (Toxicity Category IV). Simazine is not very toxic to nontarget insects, birds, or estuarine and marine organisms. Simazine is more readily adsorbed on muck or clay soils than in soils of low clay and organic matter content. The downward movement or leaching of simazine is limited by its low water solubility and adsorption to certain soil constituents. Little, if any, lateral movement in soil is expected, but simazine can be washed along with soil particles. In soils, microbial activity possibly accounts for decomposition of a significant amount of simazine. The average half-life of simazine under anaerobic soil and aerobic soil conditions is 12 weeks and 8 to 12 weeks, respectively. The average half-life for simazine in ponds is 30 days (USEPA, 1984g). During a runoff event, simazine could be transported in appreciable proportion in the soil (Stewart, 1975).

Tetradifon: Tetradifon or tedion is a chlorinated hydrocarbon acaricide with registered uses on ornamental plants (NPIRS, 1988). Tetradifon is almost non-toxic with an acute oral LD_{50} for rats greater than 14,700 mg/Kg body weight (Toxicity Category IV)(Berg, 1985). During a runoff event, tetradifon could be transported in appreciable proportion in both the water and soil (Stewart, 1975).

Toxaphene: Toxaphene is a restricted use insecticide consisting of a complex mixture of polychlorinated camphene derivatives containing 67 to 69 percent chlorine. As of November 1982, major continued uses for toxaphene are limited to use on cattle and sheep as dips for scabies, emergency use on armyworms, cutworms, and grasshoppers in cotton, corn, and small grains. Toxaphene is moderately toxic with an acute oral LD_{50} for rats of 69 mg/Kg body weight (Toxicity Category II) (Berg, 1985).

Table B-1. Uses of Aroclor by Type

Current Uses	1016	1221	1232	1242	1248	1254	1260
Capacitors	x	x		x		x	
Transformers				x		x	x
Former Uses							
Heat transfer				x			
Hydraulic lubricants							
Hydraulic fluids			x	x	x	x	x
Vacuum pumps					x	x	
	1016	1221	1232	1242	1248	1254	1260
Gas-transmission turbines		x		x			
Plasticizers							
Rubbers		x	x	x	x	x	
Synthetic resins					x	x	x
Carbonless paper				x			
Miscellaneous							
Adhesives		x	x	x	x	x	x
Wax extenders				x		x	
Dedusting agents						x	
Inks						x	x
Cutting oils						x	
Pesticide extenders						x	
Sealants and caulking compounds				x			

increases with the degree of chlorination and with the organic content of the absorbent. The biota are another environmental compartment into which these compounds are strongly partitioned (measured bioconcentration factors range up to 10^6). Volatilization and transport as an aerosol, followed by fallout with dust or rain, is the probable cause of the ubiquitous distribution of polychlorinated biphenyls. The more highly chlorinated species are less volatile than the lighter species. The presence of suspended solids tends to reduce volatilization, presumably because the solids adsorb the polychlorinated biphenyls and reduce the concentration in solution.

The available empirical evidence indicates that polychlorinated biphenyls, especially those with four or more chlorines, are persistent in the environment. The composition of polychlorinated biphenyls in the atmosphere is similar to that of Aroclor 1242 or 1016, while those in surface waters (mostly adsorbed to suspended solids) approach the composition of Aroclor 1254. Polychlorinated biphenyls in biota are heavier and more chlorinated still, and approximate the composition of Aroclor 1260. Thus the process controlling distribution are somewhat selective, with the lighter species more likely to volatilize and the heavier species more likely to be incorporated into sediment and biota (Callahan, et al.,1979).

Perthane: Perthane is a chlorinated hydrocarbon insecticide which was used on certain vegetable crops for looper control. The product has been discontinued (Berg 1985). It was also used in various formulations for the

Zinc phosphide: Zinc phosphide is a restricted use rodenticide with registered uses on macadamia nuts, sugarcane, ornamental lawns and turf, and non-crop areas (NPIRS, 1988). The USEPA has considered any product containing a metal phosphide to be as toxic as phosphine and has therefore placed these products in the highest toxicity category, based on acute and subchronic inhalation studies of phosphine. The usual oral effect studies were determined to be unwarranted and the USEPA has waived all of the oral acute toxicity studies. However, the acute oral LD_{50} for Zn_3P_2 of 40 mg/Kg has been reported (Sax, 1984). Zinc phosphide is practically insoluble in water. The zinc phosphide reacts with water to yield the hydroxide of the zinc metal and phosphine gas. The gas oxidizes readily to the relatively innocuous oxy-acids of phosphorus (phosphoric, phosphorous, and hypophosphorous). The normal moisture in the soil will react with the zinc phosphide to produce the same end products (USDHHS, 1981). Hilton and Robison (1972) determined that the rate of zinc phosphide decomposition in Hawaiian soils increased with increasing moisture. However, these authors also determined that zinc phosphide did not decompose in water from streams, domestic source, or the ocean. No data is available on soil mobility (USDHHS, 1981).

However, the bioaccumulation potential level in aquatic species is high and moderate in mammals (USDHHS, 1981). An inclusive assessment of the fate of the pesticide toxaphene in aquatic environments is complicated because toxaphene is a complex mixture of polychlorinated camphene derivatives of different physical properties and environmental behavior. Toxaphene is very stable to biological and chemical processes in aerobic environmental systems, but it does undergo partial reduction (loss of chloride content) in anaerobic environments. A dominant process in aquatic environments is direct sorption on sediment or sorption onto particulates followed by deposition into sediment where biological and possibly chemical reduction occurs. The rate of loss of toxaphene from aquatic systems will then be partially determined by particulate loading and quality of the water body; shallow, particulate laden, eutrophic waters give maximum transformation rates of toxaphene, with half-lives on the order of a few months for some components. The physical properties and chlorinated functionality of the individual toxaphene structures will govern which components will be sorbed and then subsequently reduced. The finding of some toxaphene components in sediments and aquatic species after several years indicates that bioaccumulation in the food chain may occur. Unless clear evidence proves otherwise, the absence of acute toxicity effects of toxaphene should not be interpreted as indicating that all toxaphene has been degraded and chronic toxic effects are absent (Callahan, et al., 1979). Toxaphene is relatively persistent in soil with half-lives ranging up to 20 years have been reported (USDHHS, 1981). During a runoff event, toxaphene could be transported in appreciable proportion in the soil (Stewart, 1975).

Trifluralin: Trifluralin is a dinitroanaline selective, preemergence herbicide with registered uses on celery, sugarcane, tomatoes, okra, broccoli, cabbage, cucumbers, beans, ornamental turf and lawn grasses, ornamental plants, peppers, cauliflower, potatoes, non-crop areas, and citrus (NPIRS, 1988). Trifluralin is almost non-toxic with an acute oral LD_{50} for rats of greater than 10,000 mg/Kg body weight (Toxicity Category IV) (Berg, 1985). Trifluralin readily decomposes when aqueous solutions are exposed to sunlight and readily volatilized and photodegraded in the soil environment. Low residues may persist in certain soils after repeated annual applications. The factors influencing the persistence of trifluralin include the soils organic matter content, its moisture, temperature, and the methods by which the herbicide was incorporated into it (USDHHS, 1981). Trifluralin is extremely resistant to leaching with little, if any lateral movement in the soil (USDHHS, 1981; Thomson, 1983). During a runoff event, trifluralin could be transported in appreciable proportion in the soil (Stewart, 1975).

Trithion: Trithion or carbophenothion is a restricted use organophosphorus insecticide and acaricide with registered uses on beans, citrus, corn, cucumbers, eggplant, squash, tomatoes, and ornamental turf and plants (NPIRS, 1988). Trithion is highly toxic with an acute oral LD_{50} for rats between 7 and 91 mg/Kg body weight (Toxicity Category I) (USDHHS, 1981). Trithion is characterized as very highly toxic to freshwater and marine/estuarine organisms and highly toxic to upland gamebirds. Preliminary data indicate that trithion is relatively immobile in sandy loam soils, however, the available data are insufficient to fully assess the environmental fate of trithion (USEPA, 1984h). A half-life of greater than 100 days has been reported for residues of trithion in soil. Trithion is 50 percent hydrolyzed in 115 days in distilled water (USDHHS, 1981). During a runoff event, trithion could be transported in appreciable proportion in the soil (Stewart, 1975).

INDEX OF PESTICIDES

metolachlor 34, 36-42, 53
metribuzin 34, 36-42, 54
mevinphos 34, 36-42, 54
mirex 30, 54
monocrotophos 36-42, 54
O,P'-DDD 30, 32-33
O,P'-DDE 30, 32-33
O,P'-DDT 30, 32-33
oxamyl 34, 36-42, 54
P,P'-DDD 30-34, 36-42
P,P'-DDE 30-34, 36-42
P,P'-DDT 30-34, 36-42
paraquat ..... iv, 17-18, 20, 36-42, 55-56
parathion 30-34, 36-42, 55
PCB 30-31, 55
PCB 1016 ..... 32-34, 36-42, 55-56
PCB 1221 ..... 32-34, 36-42, 55-56
PCB 1232 ..... 32-34, 36-42, 55-56
PCB 1242 ..... 32-34, 36-42, 55-56
PCB 1248 ..... 32-34, 36-42, 55-56
PCB 1254 ..... 32-34, 36-42, 55-56
PCB 1260 ..... 32-34, 36-42, 55-56
PCB 1262 32
perthane 33-34, 36-42,56-57
phorate 34, 36-42, 57
prometryn 33-34, 36-42, 57
propham 33
simazine 33-34, 36-42, 57
tetradifon 32-33, 57
toxaphene 30-34, 36-42, 57-58
trifluralin 34, 36-42, 58-59
trithion 30-34, 36-42, 58
zinc phosphide ..... i-iv, 6-9, 20, 35-36, 38-39, 59

INDEX OF PESTICIDES

2,4,5-T 30-32, 34, 36-42, 44
2,4,5-TP ..... iii, 9, 20, 330-32, 34, 36-42, 44
2,4-D ..... iv, 15-16, 20, 30-32, 34, 36-42, 44
2,4-DP 30-34, 36-42, 44
alachlor 33-34, 36-42, 44
aldicarb 30-34, 36-42, 44
aldrin ..... iv, 15-16, 20, 30-34, 36-42, 44
alpha BHC ..... iv, 16, 18, 20, 30-34, 36-42
alpha endosulfan ..... iv, 16, 18, 20, 30-34, 36-42
ametryn ..... iv, 15-16, 20, 33-34, 36-42, 45
atrazine ..... i, iii-iv, 9-11, 16, 18, 20, 24, 33-34, 36-42, 45
benomyl 36-42, 45
beta BHC 30-34, 36-42
beta endosulfan 30-34, 36-42
BHC 45
bromacil 36-42, 46
carbaryl 33-34, 36-42, 46
carbofuran 33-34, 36-42, 46
chlordane 30-34, 36-42,46
chloropicrin 34, 36-42, 47
chlorothalonil 34, 36-42, 47
chlorpyrifos ..... iv, 16, 18-20, 34, 36-42, 47
DDD ..... iv, 11-14, 20, 47
DDE ..... iv, 11-14, 20, 48
DDT ..... i, iv, 11-14, 20, 48
delta BHC ..... iv, 16, 18, 20, 30-34, 36-42
demeton 48
diazinon ..... iv, 15-16, 20, 30-34, 36-42,48
dicofol 30-34, 36-42, 48
dieldrin 30-34, 36-42, 49
diuron 40-42, 49
endosulfan 18, 49
endosulfan sulfate 30, 32-34, 36-42, 49
endrin 31-34, 36-42, 49
endrin aldehyde 30-34, 36-42, 50
ethion ..... iv, 17-20, 30-34, 36-42, 50
ethoprop 34, 36-42, 50
fonofos 34, 36-42, 50
gamma BHC 30-34, 36-42, 50
glyphosate 36-42, 51
guthion 31-34, 36-42, 51
heptachlor ..... iv, 17, 19-20, 30-34, 36-42, 51
heptachlor epoxide ..... iv, 17-18, 20, 30-34, 36-42, 52
kelthane 30-34, 36-42
linuron 40-42, 52
malathion ..... iv, 15, 20, 30-34, 36-42, 52
methamidophos ..... iv, 15, 17, 20, 52
methomyl 53
methoxychlor 30, 33-34, 36-42, 53
methyl bromide 36, 36, 38-42, 53
methyl parathion 31, 34, 36-42, 53