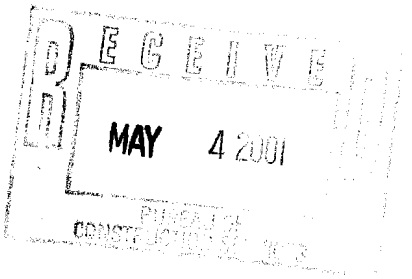
Five Year Review
Long Term Monitoring Program
Marathon Remediation Site



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May 2, 2001 95-219-04

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Attention: James F. Cronmiller

FIVE YEAR REVIEW
LONG TERM MONITORING PROGRAM
MARATHON REMEDIATION SITE

Gentlemen:

Enclosed is the first Five Year Review of the Long-Term Monitoring Program at the Marathon Remediation Site. This review covers the period from the completion of the remediation (1995) through 2000. Also included in this report are our recommendations for future monitoring of ROD Areas I, II, and III.

If you have any questions concerning the contents of this report, please contact me at (610) 558-3300.

Very truly yours,

ADVANCED GEOSERVICES CORP.

Paul F. Marano, P.E.
Senior Project Consultant

PFM:car

Enclosure

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5 YEAR REVIEW

LONG-TERM MONITORING PROGRAM

MARATHON REMEDIATION SITE
Cold Spring, New York

Prepared by:

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Prepared for:

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May 2, 2001
95-219-04

EXECUTIVE SUMMARY

Based on our evaluation of the data and our understanding of the concerns to be addressed by the Long-Term Monitoring Program, we have developed the following recommendations for future monitoring of the various areas of the Marathon Remediation Site:

AREA I

East Foundry Cove Marsh:	Discontinue the sampling of cover soil and surface water.
Constitution Marsh:	Discontinue the sampling of soil and surface water.

AREA II

Plant Grounds (VOCs):	Continue sampling wells 7S and MB-3 annually for TCE, TCA, and PCE.
Pedestal Area (Cadmium):	Discontinue the sampling of all wells.

AREA III

East Foundry Cove:	Continue the sampling of sediments annually. Discontinue the sampling of surface water.
East Foundry Pond:	Discontinue the sampling of sediments and surface water.
West Foundry Cove:	Discontinue the sampling of sediments and surface water.
Cols Spring Pier Area:	Discontinue the sampling of sediments and surface water (including the Control point).

BIOLOGICAL SAMPLING/MONITORING

Bioassay Studies:	Discontinue these studies for all species (birds, benthic invertebrates, and vegetation).
Bioaccumulation Studies:	Discontinue these studies for all species of fish.
EFCM Revegetation:	Continue visual surveys of conditions at the beginning and end of each growing season and the yearly inventory of the four established quadrats.

1.0 INTRODUCTION

This report addresses the review of the first five years of the long-term monitoring program for the Marathon Remediation Site in Cold Spring, New York. This monitoring program was required in the Records of Decision (RODs) for the site. The remediation of the site was completed in 1995, and the first sampling event was conducted in late 1995. The first full year of the long-term monitoring program was 1996. This report addresses the period from late 1995 through 2000.

The monitoring program consists of the collection and analyses of soil, sediment, surface water, and/or groundwater samples within the three ROD Areas (Areas I, II, and III) of the site. In addition, biological sampling and monitoring were conducted in portions of ROD Areas I and III.

The sampling procedures, methods, and selected sampling locations used for this program are documented in the "Long Term Monitoring Plan for the Marathon Remediation Site" dated December 20, 1995, and the supplemental plans dated February 21, 1996 and July 14, 1997. These plans were developed by Advanced GeoServices Corp. and were reviewed and approved by the U.S. Environmental Protection Agency (USEPA) and the New York State Department of Environmental Conservation (NYSDEC).

Subsequent sections of this report address the monitoring within individual ROD Areas and the biological portion of the program:

Section 2.0 - Area I
Section 3.0 - Area II
Section 4.0 - Area III
Section 5.0 - Biological Sampling/Monitoring

Each of these sections contain background information, a summary of the long-term monitoring program within the Area, an assessment of the data collected to date, and recommendations regarding future monitoring within the Area. The pertinent data for each Area (cadmium or volatile organic compound results) are presented on the attached tables. Analytical specifics (ancillary data such as percent solids, total organic carbon, etc. and validation reports) are included in the individual Sampling Event Reports and the Annual Reports issued previously.

2.0 AREA I

The Area I ROD includes East Foundry Cove Marsh and Constitution Marsh.

2.1 EAST FOUNDRY COVE MARSH

2.1.1 Background

The 14-acre East Foundry Cove Marsh (EFCM) was remediated by removing the vegetation and excavating soils with cadmium concentrations greater than 100 mg/kg. The post-excavation cadmium concentrations in EFCM range from 0.38 mg/kg to 90.0 mg/kg, with a mean value of 11.8 mg/kg (values below the detection limit were considered to be equal to the detection limit for purposes of calculating the mean).

The marsh was reconstructed by regrading the excavation surface, installing a geocomposite bentonite (Bentomat) layer, and placing one foot of cover soil. After reconstruction, EFCM was replanted with various wetland and upland plant species in accordance with the approved Marsh Revegetation Plan.

2.1.2 Long Term Monitoring Program

Sampling of the EFCM Bentomat/soil cap was performed quarterly during the first year of monitoring and semi-annually in Years 2 through 5 to monitor its effectiveness for containment of the underlying marsh soils. Composite samples of the cover soil were collected at two discreet depths (0 to 6 inches and 6 to 12 inches) at five locations (approximately one sample for every 125,000 square feet of cap). The soil samples were analyzed for total cadmium, total organic carbon, and percent solids.

One sample of surface water was also collected within the marsh to monitor the potential for transport of cadmium-containing sediments as a result of the twice-daily tidal flows. This sample was collected within the EFCM main channel at the same intervals as the soil samples. The surface water was analyzed for total and dissolved cadmium, pH, hardness, alkalinity, and total suspended solids.

The monitoring of the revegetation of EFCM is presented in Section 5.3

2.1.3 Assessment of Results

The analytical results for the EFCM cover soil samples are shown in Table 1. Approximately one-third (31.5%) of the collected samples had no detectable levels of cadmium. Regression analyses were performed on the detected concentrations of the 0 to 6 inch and 6 to 12 inch depth increments. The plots, attached in the Appendix, indicate a very slight increase in the cadmium concentrations with time for the 0 to 6 inch depth increment. This may be the result of tidal deposition of sediments from the adjacent East Foundry Cove. The plot for the 6 to 12 inch increment shows no appreciable

change with time. However, the concentrations for both increments are typically well below 1 mg/kg, significantly less than the mean value (11.8 mg/kg) of the underlying marsh soils. The Bentomat/soil cap appears to be effective as a containment system.

The analytical results for the EFCM surface water samples are shown in Table 2. Forty-two percent of the samples had no detectable levels of total cadmium. The remainder had concentrations that are typically less than 0.25 μg/l. Eighty-three percent of the filtered portions of the samples had no detectable levels of dissolved cadmium. The only two samples with detectable dissolved cadmium had concentrations of 0.1 and 0.11 μg/l. The results indicate that significant transport of cadmium-containing sediments does not occur on a regular basis.

2.1.4 Recommendations for Future Monitoring

Although there appears to be a very slight increase in the cadmium concentrations of the surface (0 to 6 inch) samples, the results are well below 1 mg/kg. The 6 to 12 inch samples show no appreciable change with time. The surface water samples have very low levels of total cadmium and the majority have no detectable levels of dissolved cadmium. We believe the effectiveness of the Bentomat/soil cap has been established, and recommend that the sampling of soil and water samples within EFCM be discontinued.

2.2 CONSTITUTION MARSH

2.2.1 Background

Only the northern quarter (about 80 acres) of Constitution Marsh (CM) is included in the long term monitoring program, as this is the area flushed by tidal action through East Foundry Cove. Constitution Marsh was classified as a No Action area in the ROD.

2.2.2 Long Term Monitoring Program

Sampling of soils was performed quarterly during the first year of monitoring and semi-annually in Years 2 through 5 in areas within CM that were shown to contain high concentrations of cadmium during pre-remediation studies. CM was not remediated; the sampling was conducted to monitor the potential for transport of cadmium-containing sediments from CM to other remediated areas as a result of the twice-daily tidal flows. Composite samples of the marsh soils were collected at a depth of 0 to 6 inches at five locations. The soil samples were analyzed for total cadmium, total organic carbon, and percent solids.

Two samples of surface water were also collected within the marsh to monitor the potential for transport of cadmium-containing sediments as a result of the twice-daily tidal flows. These samples were collected within the main CM channel at the same intervals as the soil samples. The surface water was analyzed for total and dissolved cadmium, pH, hardness, alkalinity, and total suspended solids.

2.2.3 Assessment of Results

Seventy soil samples have been collected and analyzed from CM during the monitoring program. The resulting cadmium concentrations, shown in Table 1, range from 25 to 598 mg/kg, with a mean value of 155 mg/kg. These results are within the range of 4 to 940 mg/kg and slightly less than the mean of 178 mg/kg determined prior to the remediation of the adjacent areas. A regression analyses was performed on the CM long term monitoring data. The plot, attached in the Appendix, indicates a very slight decrease in the cadmium concentrations with time. This reduction may indicate some transport of cadmium-containing sediments from CM, although the noted differences may be the result of the wide range of concentrations detected.

The analytical results for the CM surface water samples are shown in Table 2. Nineteen percent of the samples had no detectable levels of total cadmium. The remainder had concentrations that range from 0.12 to 1.6 μg/l. Sixty-seven percent of the filtered portions of the samples had no detectable levels of dissolved cadmium. The remainder had dissolved cadmium concentrations of 0.1 to 0.52 μg/l. The results indicate that significant transport of cadmium-containing sediments does not occur on a regular basis.

2.2.4 Recommendations for Future Monitoring

Although the regression analysis shows a very slight decrease of the cadmium concentrations within CM, the calculated "trend" may be the result of the wide variation in the results. The surface water samples have very low levels of total cadmium and the majority have no detectable levels of dissolved cadmium. We believe the transport of cadmium-containing sediments from CM to other remediated areas of the site has been shown to be insignificant, and recommend that the sampling of soil and water samples within CM be discontinued.

3.0 AREA II

The Area II ROD encompasses the grounds of the former manufacturing plant and its ancillary facilities.

3.1 PLANT GROUNDS

3.1.1 Background

This 11.9-acre area is the location of the former manufacturing facility and lined sediment storage area (vault). The structures and most of the underground utilities have been removed, along with about 24,000 cubic yards of contaminated soils, including the vault contents. The removed non-vault soils were sieved and the coarser portions (gravel and cobbles) were washed, tested, and reused as backfill in some of the excavations.

The focus of the long term monitoring program in this area is the volatile organic compounds (VOCs) present in the groundwater. The ROD required the excavation and enhanced volatilization of soils containing VOCs. An Explanation of Significant Differences (ESD) was subsequently issued by the USEPA that rescinded this requirement and specified continued monitoring of the groundwater for VOCs.

3.1.2 Long Term Monitoring Program

Thirteen wells within the former Plant Grounds were sampled to monitor the attenuation and/or transport of volatile organic compounds (VOCs) within the groundwater. Samples were collected semi-annually and analyzed for the VOCs detected prior to remediation: trichloroethene (TCE), 1,1,1-trichloroethane (TCA), and tetrachloroethene (PCE).

3.1.3 Assessment of Results

Assessments of the specific analyzed compounds are presented below.

3.1.3.1 **TCE**

TCE is the predominant compound detected. The analytical results are shown in Table 3. Only two of the thirteen wells (7S and MB-3) have shown elevated concentrations of TCE. The remaining eleven wells are typically either non-detect or less than 6 μg/l. In general, the TCE concentrations have been consistent since 1988 (a total of 16 sampling events); there is no indication of transport of TCE between the wells. Regression analyses were performed for wells 7S and MB-3. The plots, attached in the Appendix, show a decreasing trend with time; some attenuation of the TCE concentrations is indicated.

3.1.3.2 **TCA**

The analytical results for TCA are shown in Table 4. Only five of the thirteen wells have had detectable levels of TCA. The range of detected concentrations is 0.7 to 7.9 μg/l, with a mean value of 3.06 μg/l. In general, the concentrations have been consistent since 1993 (a total of 14 sampling events); there is no indication of transport of TCA between the wells.

3.1.3.3 **PCE**

The analytical results for PCE are shown in Table 5. Only two of the thirteen wells (7S and MB-3) have had detectable levels of PCE. The range of detected concentrations is 1.2 to 7.7 μg/l, with a mean value of 3.6 μg/l. In general, the concentrations have been consistent since 1993 (a total of 14 sampling events); there is no indication of transport of PCE between the wells.

3.1.4 Recommendations for Future Monitoring

While the analytical results show that the VOC concentrations have remained fairly consistent over the past thirteen years, the regression analyses indicate that the two locations with elevated concentrations (wells 7S and MB-3) are decreasing with time. The analytical results for the remaining wells demonstrate that transport of the VOCs has not occurred. We recommend that future VOC monitoring be limited to analyses of TCE, TCA, and PCE in wells 7S and MB-3, and that the sampling be reduced to an annual event.

3.2 PEDESTAL AREA

3.2.1 Background

The pedestal area is a localized zone within the central area of the Plant Grounds. This zone is the former location of the facility's cadmium nitrate storage tank. During the remediation of the Plant building, elevated levels of cadmium were encountered in the soils in the vicinity of the tank pedestal. These soils were removed to the groundwater table (a depth of about 22 feet). Elevated cadmium levels were present below the groundwater, but continued removal would be difficult, requiring retention systems and a significant expansion of the excavation. This condition was evaluated by Advanced GeoServices Corp. in the April 11, 1995 report "Cadmium Fate and Transport at the Former Pedestal Area." The results of this evaluation led to the issue of an ESD by the USEPA. The ESD allowed for limited soil removal followed by backfill of the excavation and the installation of a monitoring well (Well PA-1) in the pedestal area to measure the cadmium levels in the groundwater. The backfill of the pedestal area is 25 feet thick and includes several feet of limestone to provide additional buffering of infiltrating acidic rain.

3.2.2 Long Term Monitoring Program

Four wells were sampled to monitor the potential for transport of cadmium via groundwater from the Pedestal Area within the former Plant Grounds. Samples were collected semi-annually and analyzed for total and dissolved cadmium, pH, hardness, alkalinity, and total suspended solids.

3.2.3 Assessment of Results

The analytical results for the Pedestal Area monitoring are shown in Table 6. Only PA-1, the well at the source, has significant concentrations of cadmium. A review of the analytical results and the regression analyses for well PA-1 (attached in the Appendix) show the dissolved cadmium concentrations have decreased about forty to fifty percent with time. The remaining three wells are typically either non-detect or less than 1 μg/l. Regression analyses for these wells, attached in the Appendix, show a decrease in dissolved cadmium concentrations with time (7S and MB-3) or are essentially unchanged (MB-1). There is no indication of a transport of cadmium between the wells. It is apparent that the cadmium in the soil within the Pedestal Area remains in place and has not gone into suspension within the groundwater.

3.2.4 Recommendations for Future Monitoring

The analytical results and the regression analyses demonstrate that the dissolved cadmium concentrations in well PA-1 are decreasing. These data suggest that the cadmium within the soils at this location will not go into suspension. The analytical results for the remaining wells demonstrate that transport of the cadmium has not occurred. As the stability of this condition has been established by the monitoring to date, we recommend that the sampling of the groundwater for cadmium be discontinued.

4.0 AREA III

The Area III ROD includes the waters of East Foundry Cove, East Foundry Pond, West Foundry Cove, and the Cold Spring Pier Area.

4.1 EAST FOUNDRY COVE

4.1.1 Background

East Foundry Cove (EFC) is a 30-acre tidal estuary bordered by East Foundry Cove Marsh to the north and east, Constitution Island and East Foundry Pond to the south, and the Metro-North railroad embankment to the west. EFC was remediated by dredging the majority of the Cove bottom to remove contaminated sediments. The average removal depth was 18 inches. The post-dredge cadmium concentrations in EFC range from 0.74 mg/kg to 81.2 mg/kg, with a mean value of 10.9 mg/kg (values below the detection limit were considered to be equal to the detection limit for purposes of calculating the mean).

4.1.2 Long Term Monitoring Program

Sampling of the EFC sediments was performed annually to monitor the transport of cadmium-containing sediments from Constitution Marsh as a result of the twice-daily tidal flows. Composite samples of the sediments were collected on the bottom of the cove at five locations and analyzed for total cadmium, total organic carbon, and percent solids.

Samples of surface water were also collected at two of the sediment sampling locations within EFC to monitor the potential for transport of cadmium-containing sediments as a result of the twice-daily tidal flows. These samples were collected concurrently with the sediment samples. The surface water was analyzed for total and dissolved cadmium, pH, hardness, alkalinity, and total suspended solids.

4.1.3 Assessment of Results

The analytical results for EFC are shown in Table 7. The measured cadmium concentrations are highly variable, ranging from 0.34 to 277 mg/kg, with a mean value of 36.5 mg/kg. These levels are about 5 to 10 percent of the pre-remediation levels. A regression analysis performed on the EFC data is attached in the Appendix and shows an increasing trend. However, 3 of the 5 highest concentrations were measured in the last sampling event (April, 2000); when the regression analysis is conducted without the April 2000 results, the trend indicates decreasing levels of cadmium.

The analytical results for the EFC surface water samples are shown in Table 8. Seventy-five percent of the samples had no detectable levels of total cadmium. The remainder had total cadmium concentrations that range from 0.11 to 1.4 μg/l. Seventy-nine percent of the filtered portions of the samples had no detectable levels of dissolved cadmium. The remainder had dissolved cadmium

concentrations that range from 0.1 to 0.14 μg/l. The results indicate that significant transport of cadmium-containing sediments does not occur on a regular basis.

4.1.4 Recommendations for Future Monitoring

Because of the cadmium concentrations within the sediments reported during the year 2000 sampling, we believe additional monitoring is needed to establish the long-term decrease indicated by the 1996-1999 results. We recommend that the sampling of the sediments within EFC be continued annually until a trend can be established. The majority of the surface water samples have no detectable levels of total or dissolved cadmium; we recommend that the sampling of surface water within EFC be discontinued.

4.2 EAST FOUNDRY POND

4.2.1 Background

East Foundry Pond (EFP) is a 6-acre tidal estuary located between East Foundry Cove and the northern end of Constitution Marsh. EFP was remediated by dredging to remove contaminated sediments. The average removal depth was 16 inches. The post-dredge cadmium concentrations in EFP range from 1.0 mg/kg to 37.1 mg/kg, with a mean value of 8.4 mg/kg (values below the detection limit were considered to be equal to the detection limit for purposes of calculating the mean).

4.2.2 Long Term Monitoring Program

Sampling of the EFP sediments was performed annually to monitor the transport of cadmium-containing sediments from Constitution Marsh as a result of the twice-daily tidal flows. Composite samples of the sediments were collected on the bottom of the pond at two locations and analyzed for total cadmium, total organic carbon, and percent solids.

A surface water sample was also collected at one of the sediment sampling locations within EFC to monitor the potential for transport of cadmium-containing sediments as a result of the twice-daily tidal flows. This sample was collected concurrently with the sediment samples. The surface water was analyzed for total and dissolved cadmium, pH, hardness, alkalinity, and total suspended solids.

4.2.3 Assessment of Results

The analytical results for EFP are shown in Table 7. The measured cadmium concentrations are highly variable, ranging from 0.4 to 130 mg/kg, with a mean value of 37.4 mg/kg. A regression analysis performed on the EFP data, attached in the Appendix, indicates that cadmium levels are decreasing with time.

The analytical results for the EFP surface water samples are shown in Table 8. Twenty-nine percent of the samples had no detectable levels of total cadmium. The remainder had total cadmium concentrations that range from 0.32 to 2.8 μg/l, and are typically less than 0.5 μg/l. Twenty-nine percent of the filtered portions of the samples had no detectable levels of dissolved cadmium. The remainder had dissolved cadmium concentrations that range from 0.21 to 0.56 μg/l. The results indicate that significant transport of cadmium-containing sediments does not occur on a regular basis.

4.2.4 Recommendations for Future Monitoring

Although variable, the analytical results establish no long-term build up of cadmium as a result of sediment transport from CM. The regression analysis indicates that the cadmium concentrations within the EFP sediments are decreasing. The majority of the surface water samples have either very low or non-detectable levels of total and dissolved cadmium. We recommend that the sampling of sediments and surface water within EFP be discontinued.

4.3 WEST FOUNDRY COVE

4.3.1 Background

West Foundry Cove (WFC) is contiguous to the Hudson River and is bordered by the Village of Cold Spring and the Cold Spring Pier Area to the north, the Metro-North railroad embankment to the east, and Constitution Island to the south. West Foundry Cove was classified as a No Action area in the ROD.

4.3.2 Long Term Monitoring Program

Sampling of the WFC sediments was performed annually. WFC was not remediated; it was believed that the cadmium-containing bottom sediments would eventually become capped with additional river sediment, rendering them immobile. The sampling was conducted to monitor the progress of this capping. (The cadmium concentrations at the bottom of the cove should decrease as additional material is deposited). Composite samples were collected on the bottom of the cove at five locations. The sediment samples were analyzed for total cadmium, total organic carbon, and percent solids.

Samples of surface water were also collected at two of the sediment sampling locations within WFC to monitor the potential for transport of cadmium-containing sediments as a result of the river flows. These samples were collected concurrently with the sediment samples. The surface water was analyzed for total and dissolved cadmium, pH, hardness, alkalinity, and total suspended solids.

4.3.3 Assessment of Results

Thirty-five soil samples have been collected and analyzed from WFC during the monitoring program. The resulting cadmium concentrations, shown in Table 7, range from 1.3 to 143 mg/kg, with a mean value of 34.4 mg/kg. These results are less than the range of 1.1 to 569 mg/kg and the mean of 43.9 mg/kg determined prior to the remediation of the adjacent areas. This reduction may indicate some capping of the cadmium-containing sediments in WFC, although the noted differences may be the result of the wide range of concentrations detected.

The analytical results for the WFC surface water samples are shown in Table 8. Seventy-five percent of the samples had no detectable levels of total cadmium. The remainder had total cadmium concentrations that range from 0.2 to 1.2 μg/l. Eighty-eight percent of the filtered portions of the samples had no detectable levels of dissolved cadmium. The remainder had dissolved cadmium concentrations of 0.12 to 0.2 μg/l. The results indicate that significant transport of cadmium-containing sediments does not occur on a regular basis.

4.3.4 Recommendations for Future Monitoring

The analytical results show a slight decrease of the cadmium concentrations within WFC; this "trend" may be caused by the wide variation in the results, however. As the anticipated capping is dependent upon the long-term conditions (flow velocities, suspended sediments, etc.) within the Hudson River that are inconsistent and cannot be accurately monitored, this capping may require dozens of years to achieve or may not occur at all. Although the capping of the WFC sediments cannot be established by the results to date, these results do suggest that the sediments have been immobilized. Considering these conditions, we recommend that the monitoring of the WFC sediments be discontinued. The majority of the surface water samples have no detectable levels of total or dissolved cadmium; we also recommend that the sampling of surface water within WFC be discontinued.

4.4 COLD SPRING PIER AREA

4.4.1 Background

The Cold Spring Pier Area (CSPA) is a portion of the Hudson River situated between the Village of Cold Spring and the main river channel, north of West Foundry Cove. The CSPA was remediated by a combination of dredging and excavation to remove contaminated sediments. The post-remediation cadmium concentrations in the CSPA range from 2.5 mg/kg to 35.7 mg/kg, with a mean value of 15.0 mg/kg.

4.4.2 Long Term Monitoring Program

Sampling of the CSPA sediments was performed annually to monitor the transport of cadmium-containing sediments as a result of the river flows. Composite samples of the sediments were

collected on the river bottom at two locations and analyzed for total cadmium, total organic carbon, and percent solids.

Surface water samples were also collected at the sediment sampling locations within CSPA to monitor the potential for transport of cadmium-containing sediments as a result of the river flows. These samples were collected concurrently with the sediment samples. The surface water was analyzed for total and dissolved cadmium, pH, hardness, alkalinity, and total suspended solids.

To provide for a comparison against background levels within the river, one sediment and one surface water sample were also collected at a Control point approximately 150 yards upstream of CSPA. These samples were collected concurrently with the CSPA sampling, and similar analyses were conducted.

4.4.3 Assessment of Results

The analytical results for CSPA are shown in Table 7. The measured cadmium concentrations typically range from 0.28 to 42.7 mg/kg, with one anomalous measurement of 994 mg/kg in March, 1996. The mean concentration (without the anomalous value) is 10.2 mg/kg, less than the post-remediation levels at those locations. A regression analysis was performed on the CSPA data (minus the anomalous value). The plot, attached in the Appendix, indicates a very slight increasing trend; however, this increase may be the result of the wide range of concentrations detected. A regression analysis that included the anomalous value was also performed. This plot, also attached in the Appendix, shows a decrease of cadmium levels with time.

The results for the Control point are also shown in Table 7. These measurements, collected upstream from the Marathon site, also show a wide variation in cadmium concentrations; the range of values is 1.5 to 103 mg/kg, with a mean concentration of 21.7 mg/kg.

The analytical results for the CSPA surface water samples are shown in Table 8. Eighty-six percent of the samples had no detectable levels of total cadmium. The remainder had total cadmium concentrations that range from 0.11 to 0.2 μg/l. All of the filtered portions of the samples (100%) had no detectable levels of dissolved cadmium. The Control point surface water samples show similar trends. The results indicate that significant transport of cadmium-containing sediments does not occur on a regular basis.

4.4.4 Recommendations for Future Monitoring

When the one anomalous value is eliminated, the analytical results for CSPA and the Control point indicate that there is a slight decrease in the cadmium levels within these sediments. Although the regression analysis for the CSPA sediments shows a very slight increasing trend, this increase is on the order of 1 to 2 mg/kg; considering the concentration levels measured, this can be considered to be no change. In addition, the majority of the CSPA and Control point surface water samples have no detectable levels of total and dissolved cadmium. We recommend that the sampling of sediments and surface water within CSPA and the Control point be discontinued.

5.0 BIOLOGICAL SAMPLING/MONITORING

The biological sampling consists of bioassay and bioaccumulation studies. The re-establishment of vegetation is also monitored in EFCM.

5.1 BIOASSAY STUDIES

5.1.1 Background

The majority of the bioassay studies are centered in Area I (EFCM and CM), with other samples collected from portions of Area III (EFC and WFC). No biological sampling/monitoring is required for Area II. The historic bioassay data (i.e., collected prior to the remediation) are shown in Table 9.

5.1.2 Long Term Monitoring Program

Bioassay studies were performed to determine if the remediation has been effective in reducing the cadmium exposure of selected regional species. The target species included birds (Canada geese, wood ducks, swallows, and marsh wrens), benthic invertebrates (oligocheate worms and chironomid midge larvae), and vegetation (cattails and water chestnuts). Most of these species were collected annually. (The marsh wrens were collected in Years 1 and 5). Mammals (muskrats) were also included in the original program, but were not sampled as they have not yet become established in EFCM.

5.1.3 Assessment of Results

The results of the bioassay studies are presented in Table 9 and individual species are discussed below.

5.1.3.1 **Wood Ducks**

The cadmium concentrations within the wood ducks range from 0.05 to 2.4 mg/kg (livers) and 0.16 to 17.4 mg/kg (kidneys), with mean concentrations of 0.74 mg/kg and 4.76 mg/kg, respectively. These results are similar to the results of the four specimens collected for the historic study. Regression analyses were conducted on the liver and kidney data. These plots, attached in the Appendix, indicate that cadmium levels are decreasing with time.

5.1.3.2 **Canada Geese**

The cadmium concentrations within the Canada geese range from 0.04 to 8.1 mg/kg (livers) and 0.04 to 14.2 mg/kg (kidneys), with mean concentrations of 1.53 mg/kg and 4.16 mg/kg, respectively. There are no historic data for the Canada geese. Regression analyses were conducted on the liver and kidney data. These plots, attached in the Appendix, indicate that cadmium levels are decreasing

with time.

5.1.3.3 **Swallows**

The cadmium concentrations (whole body) of the swallows range from not detected to 9.27 mg/kg, with a mean concentration of 0.18 mg/kg. These results are significantly less than the results of the two samples collected for the historic study (1.17 and 4.75 mg/kg). A regression analysis was conducted on the swallow data. This plot, attached in the Appendix, indicate a decrease of cadmium with time.

5.1.3.4 **Marsh Wrens**

The cadmium concentrations (whole body) of the marsh wrens range from 0.13 to 1.62 mg/kg, with a mean concentration of 0.39 mg/kg. These results are significantly less than the results of the historic study (0.29 to 10.53 mg/kg, with a mean concentration of 1.8 mg/kg). As the wrens were only collected in Years 1 and 5, no regression analyses was performed.

5.1.3.5 **Benthic Invertebrates**

The cadmium concentrations of the benthic invertebrates within EFC range from 0.46 to 11.2 mg/kg, with a mean concentration of 4.37 mg/kg. If the one anomalous measurement (11.2 mg/kg, from 1997) is disregarded, the mean value decreases to 2.66 mg/kg. (The historic data ranges from 0.57 to 4.54 mg/kg). The cadmium concentrations of the invertebrates within EFC have exhibited a significant decreasing trend since 1997. A regression analysis was also performed on the data from EFC and is attached in the Appendix. This plot also shows a decrease with time.

The cadmium concentrations of the benthic invertebrates in CM range from 1.61 to 5.5 mg/kg, with a mean concentration of 2.60 mg/kg. These concentrations have also exhibited a decrease since 1997, although the trend is not as significant.

5.1.3.6 **Cattails**

The cadmium concentrations within the cattails in EFCM range from not detected to 0.394 mg/kg, with a mean concentration of 0.141 mg/kg. A regression analysis was performed on the cattail data. The plot, attached in the Appendix, shows a very slight increase with time. (This increase coincides with the slight increase noted in the cadmium concentrations measured in the EFCM cover soils). However, the concentrations are still well below 1 mg/kg.

The cadmium concentrations within the cattails in CM range from 0.23 to 1.1 mg/kg, with a mean concentration of 0.51 mg/kg. These results are slightly less than the historic data (0.052 to 1.45 mg/kg, with a mean concentration of 0.62 mg/kg).

5.1.3.7 **Water Chestnuts**

The cadmium concentrations of the water chestnuts within EFC range from 1.46 to 6.5 mg/kg, with a mean concentration of 3.91 mg/kg. This value is about 25 percent of the historic mean value (15.6 mg/kg). A regression analysis was conducted on the EFC data. The plot, attached in the Appendix, indicate that cadmium levels are decreasing with time.

The cadmium concentrations of the water chestnuts within CM range from 2.5 to 10 mg/kg. The data shows a decrease in the mean concentrations since 1998.

The cadmium concentrations of the water chestnuts within WFC range from 0.868 to 2.0 mg/kg. The data shows that the mean concentrations have been fairly consistent since 1997.

5.1.4 Recommendations for Future Monitoring

The analytical results and regression analyses demonstrate that the cadmium concentrations within the birds, benthic invertebrates, and vegetation have decreased with time. Although the regression analysis for the EFCM cattails shows a very slight increase, the present cadmium concentrations are still well below 1 mg/kg. These results, which have included several generations of the monitored species, have established the reduction of cadmium exposure among regional biota. We recommend that the bioassay studies for the various species of birds, benthic invertebrates, and vegetation be discontinued.

5.2 BIOACCUMULATION STUDIES

5.2.1 Background

The bioaccumulation studies were performed in portions of Area III (EFC, CSPA, and WFC). In addition, a control test was conducted in 2000 in Manitou Bay, an estuary that is several miles upstream of the Marathon Remediation Site. The historic bioaccumulation data (i.e., collected prior to the remediation) are shown in Table 10.

5.2.2 Long Term Monitoring Program

Bioaccumulation studies were performed to confirm if the reduction in cadmium within the sediments would result in a reduced exposure to regional species. Fish (killifish and crayfish) were utilized for these studies. The bioaccumulation studies were conducted in Years 1, 3, and 5 (1996, 1998, and 2000).

5.2.3 Assessment of Results

The results of the bioaccumulation studies are presented in Table 10 and are discussed below.

5.2.3.1 **Killifish**

The cadmium uptake of the killifish ranges from 0 to 189 percent in EFC and CSPA, with all measured concentrations less than 0.1 μg/g. This is a significant decrease from the pre-remediation uptake of 483 and 455 percent, respectively. The uptake of killifish within WFC is 600 percent; in all cases, the cadmium concentrations are less than 0.1 μg/g. No cadmium uptake was measured in the control sample in Manitou Bay.

5.2.3.2 **Crayfish**

The cadmium uptake of the crayfish ranges from 120 to 440 percent in EFC and CSPA, with all measured concentrations less than 0.25 μg/g. This is a significant decrease from the pre-remediation uptake of 915 and 1,300 percent, respectively. The uptake of killifish within WFC is 140 percent; in all cases, the cadmium concentrations are less than 0.1 μg/g. No cadmium uptake was measured in the control sample in Manitou Bay.

5.2.4 Recommendations for Future Monitoring

The bioaccumulation studies demonstrate a significant decrease in the cadmium uptake of the killifish and crayfish. These results, which have included several generations of the monitored species, have established the reduction of cadmium exposure among regional fish. We recommend that the bioaccumulation studies be discontinued.

5.3 MONITORING OF EFCM REVEGETATION

5.3.1 Background

After the remediation of EFCM, the marsh was reconstructed as described in Section 2.1.1. This area was replanted with wetland and upland plant species, with a ROD requirement of 85% coverage of the marsh in five years (at the end of the 2000 growing season).

5.3.2 Long Term Monitoring Program

The monitoring of the EFCM revegetation includes visual surveys of conditions at the beginning and end of each growing season and a yearly inventory of four established quadrats within the marsh.

5.3.3 Assessment of Results

The initial growing season (Summer 1995) was significantly impacted by perdition; large areas of cattail plantings were consumed by geese during and immediately after their installation. In addition, the marsh experienced severe ice scour during the very cold winter of 1995-96, resulting in uprooting of some of the plantings that had become established. Corrective actions have been implemented during the past several seasons, including the installation of fencing to decrease tidal

flow velocities (and facilitate the establishment of vegetation), transplanting of mature cattails from other established areas within EFCM, and the importation of beetles for biological control of undesirable vegetation (purple loosestrife).

A summary of the vegetation inventories for 1996 through 2000 for each quadrat are included as Tables 11 through 14. In general, an organic sediment layer has built up at the marsh ground surface. With this build up, the vegetation has become established and has expanded into previously bare areas of the marsh. There are still portions of the marsh that are sparsely vegetated, however, these areas are becoming more established each year.

5.3.3.1 **Quadrat A**

A total of twenty-one species were observed in Quadrat A during the five-year period. Eight were present in 1996, and fifteen were present in 2000. There have been significant increases in narrow-leaved cattails, mild water pepper, and water plantain with time within this quadrat.

5.3.3.2 **Quadrat B**

Quadrat B lies within the remaining bare area of EFCM. A total of twenty-one species have been observed in this quadrat; however, the number of species (and the corresponding percentage of cover) has decreased with time. A significant cover of smartweed had been present during the initial years, but this coverage has been reduced. Presently, about forty percent of the quadrat is bare, and another fifty percent (the southern half) is low-lying and covered by European water chestnut.

5.3.3.3 **Quadrat C**

Quadrat C is densely vegetated. There were eight predominant species during the initial year, and as many as twenty species were observed in 2000. The majority of the coverage during the initial years was three-square and umbrella sedge, but purple loosestrife has become dominant (up to forty-five percent coverage within the quadrat).

5.3.3.4 **Quadrat D**

Quadrat D is also densely vegetated and has been from the initial year. The early years (1996 and 1997) had predominant cattail growth, with as much as ninety percent of the quadrat covered by this species. Common reed has become established with time, from two percent coverage in 1996 and 1997 to one hundred percent coverage in 2000.

5.3.4 Recommendations for Future Monitoring

Although the vegetation within EFCM is becoming established, it has not achieved the ROD-required 85% coverage at this time. We recommend that the monitoring of the EFCM revegetation be continued as originally planned (i.e., visual surveys of conditions at the beginning and end of each growing season and a yearly inventory of the four established quadrats) until the required coverage is achieved throughout the marsh. In addition, corrective actions such as the installation of fencing and transplanting of vegetation should be implemented as needed.

TABLES

TABLE 1

CADMIUM CONCENTRATIONS (mg/kg)
AREA I SOIL/COVER SOIL SAMPLES

SAMPLE LOCATION	PRE-REMED.[1]	LTM SAMPLING EVENT											
		11/95	3/96	6/96	9/96	4/97	10/97	4/98	11/98	4/99	11/99	4/00	10/00
CM-1S		62	150	147	243	100	159	310	529	65.4	94.5	146J	434J(320J)
CM-2S	70 samples	130	133	74.7	147	70.9	146	79.8	191	134	251J (116J)	94.2J	25.1J
CM-3S	4 to 940	140J (270J)[2]	149	598	487	156 (179)	254	184 (195)	95.9	82.3	87.6	59.3J(69.4J)	27.9J
CM-4S	178 mean	140	130 (126)	106	53.1	230	181	76.8	141	95.2	95.4	82.1J	104J
CM-5S		120	242	73.0 (71.2)	68.8J (34.9J)	85.3	217 (230)[2]	134	156	162	91.9	137J	109J
EFM-1(0-0.5')	N/A[3]	0.31U	0.174	0.153	0.093	0.284	0.216(J)	0.2J(0.11J)	0.11U	0.13	0.23U	0.1J	0.11UJ
(0.5'-1')	N/A	0.3U	0.053	0.071	0.106	0.227	0.274	0.11UJ	0.11U	0.13	0.24U	0.01J	0.11UJ
EFM-2(0'0.5')	N/A	0.27U(0.27U)[4]	0.138	0.123	0.276	0.341	0.163	0.29J	0.13U	0.24	0.25J	0.14J(0.16J)	0.65J(0.29J)
(0.5-1')	N/A	0.31U	0.162	0.109	0.3	0.588	0.124	0.24J	0.15U	0.23	0.33J	0.36J	0.2J
EFM-3(0-0.5')	N/A	0.29U	0.049(0.068)	0.148	0.218J	0.378	0.219	0.31J	0.11U	0.17	0.48	0.11UJ	0.21J
(0.5-1')	N/A	0.28U	0.045	0.138	0.182J	0.413J	0.284	[5]	0.11U	0.16	1.2	0.16J	0.12J
EFM-4(0-0.5')	N/A	0.27U	0.091	0.145	0.135	0.226	0.227	0.51J	0.12U	0.33	0.24U (0.23U)	0.12UJ	0.15J
(0.5-1')	N/A	0.32U	0.084	0.263	0.161J	0.409	0.318	0.21J	0.12U	0.12U	0.23U	0.12UJ	0.11UJ
EFM-5(0-0.5')	N/A	0.28U	0.117	0.415J(0.113J)	0.144J(0.41J)	0.118(0.155)	0.256(0.212)[4]	0.35J	0.16U	0.15	0.21U	2.1J	0.12J
(0.5-1')	N/A	0.28U	0.059	0.475J(0.214J)	0.115J(0.291J)	0.145	0.181	[5]	0.11U	0.11U	0.22U	0.11UJ	0.12J

NOTES:

(1) Samples obtained by Malcolm-Pirnie and others prior to the Remedial Action. These are the reported data closest to the present LTM sampling location.

(2) Duplicate was listed as CM-6 (blind duplicate) for analysis.

(3) Long term monitoring samples in East Foundry Cove Marsh are collected within the cover soil placed as part of the Marsh restoration.

(4) Duplicate was listed as EFM-6 (blind duplicate) for analysis.

(5) Sample jars broken during transit.

TABLE 2

TOTAL AND DISSOLVED CADMIUM CONCENTRATIONS (µg/l)
AREA I SURFACE WATER SAMPLES

SAMPLE LOCATION	LTM SAMPLING EVENT																					
	11/95		3/96		6/96		9/96		4/97		10/97		4/98		11/98		4/99		11/99		4/00		10/00	
	TOTAL CD	DISS. CD	TOTAL CD	DISS. CD	TOTAL CD	DISS. CD	TOTAL CD	DISS. CD	TOTAL CD	DISS. CD	TOTAL CD	DISS. CD	TOTAL CD	DISS. CD	TOTAL CD	DISS. CD	TOTAL CD	DISS. CD	TOTAL CD	DISS. CD	TOTAL CD	DISS. CD	TOTAL CD	DISS. CD
CM-1W[1]	1.6	0.2U	0.2U	0.2U	1.12	0.5U	0.66	0.5UJ	0.68	0.5U	0.5UJ	0.5U	0.2	0.1U	0.55	0.1	0.6	0.15	0.35 (0.32)	0.1U (0.1U	0.39J	0.23J	0.56J	0.14J
CM-2W[1]	0.2U	0.2U	0.2U	0.2U	0.857	0.5U	0.98J (1.51J)[2]	0.5UJ(0.5UJ)[2]	0.74J	0.52	0.5U	0.5U	0.15	0.1U	0.65	0.15	0.75	0.21	0.22J	0.1U	0.48J	0.33J	1J(.12J)	0.1U(0.52J)
EFM-1W[1]	0.2U	0.2U	0.2U	0.2U	0.66	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.11	0.1U	0.12	0.1U	0.17	0.1	0.21	0.1U	0.11J	0.1U	0.23J	0.11J

NOTES:

(1) EFM and CM samples were collected in the main channel of East Foundry Cove Marsh and Constitution Marsh, respectively.
(2) CM-2W duplicate was listed as CM-3W (blind duplicate) for analysis.

TABLE 5

TETRACHLOROETHENE (PCE) CONCENTRATIONS (µg/l)
AREA II (PLANT GROUNDS) GROUNDWATER

WELL[1]	SAMPLING EVENTS													
	11/93[2]	2/94[2]	10/94[2]	11/95[3]	6/96	10/96	4/97	10/97	4/98	11/98	4/99	11/99	4/00	10/00
7S	1.2J	5.2	ND(4)	7.7	3	1.3	0.4UJ(7.2J)	3.1	4.5	5.6J	6.3	4.8J(4.3J)[5]	4.0 (3.6)	5.4 (5.2)[5]
MB-3	ND	ND	ND	3.2J	3	0.4U	ND	3.6	2.6	2.2J	2.7	2.2J	3.3	2.7

NOTES:

(1) All other wells had non-detect results for all sampling events.
(2) Sampling performed by Advanced GeoServices Corp. during the Remedial Action.
(3) First long term monitoring sampling event.
(4) ND=Not detected (detection limit=5 µg/l) for 1993 through 1995 samples, and 2 µg/l from 1996 to the present).
(5) 7S duplicate was a blind duplicate listed as 7I for analysis

TABLE 6

TOTAL AND DISSOLVED CADMIUM CONCENTRATIONS (µg/l)
AREA II (PEDESTAL AREA) GROUNDWATER

WELL	LTM SAMPLING EVENT																			
	11/95		6/96		10/96		4/97		10/97		4/98		11/98		4/99		11/99		04/00		10/00	
	TOTAL CD	DISSOLVED CD	TOTAL CD	DISSOLVED CD	TOTAL CD	DISSOLVED CD	TOTAL CD	DISSOLVED CD	TOTAL CD	DISSOLVED CD	TOTAL CD	DISSOLVED CD	TOTAL CD	DISSOLVED CD	TOTAL CD	DISSOLVED CD	TOTAL CD	DISSOLVED CD	TOTAL CD	DISSOLVED CD	TOTAL CD	DISSOLVED CD
PA-1	920J[1]	2200J[1]	1540J	552J	880J	744	880	670J	1940(224)	500(508)	406	395	466	386	1200	416	614	422	442	386	10,200	297
MB-1	2.4	0.29	2.86J	.78J	1.74J	0.58	0.8	0.51J	1.04	0.5U	[2]	[2]	0.69	0.17	0.8	0.43	2	1.1	1.3	0.27J	.21J	.1U
MB-3	2.9	0.34	1.21J	0.5UJ	1.20J	0.5U	3.19	0.5UJ	0.5U	0.5U	0.48	0.1U	0.48	0.1	0.68	0.1U	0.39	U	0.55J	0.1U	.18J	.1U
7S	2	1.9	1.72J	.71J	1.09J	0.5U	0.64	0.5UJ	0.75	0.5UJ	1.6	0.11	0.67	0.27	0.53	0.26	0.52	0.19	0.39J	0.1U	1.3J	.1U

NOTE:

(1) Results considered unreliable as reported dissolved cadmium concentration was greater than reported total cadmium concentration.
(2) Well dry during sampling event.

FIELD pH MEASUREMENTS

	1994[2]	11/95	6/96	10/96	4/97	10/97	4/98	11/98	4/99	11/99	04/00	10/00
All Wells (mean)	8.5	7.5	6.3	7.1	7.0	8.0	7.9	6.8	7.7	7.5	7.3	7.3
Well PA-1	--	6.4	5.9	6.6	6.55	7.3	7.0	6.5	6.9	6.9	6.8	6.7
Well 7S[3]	7.8	7.4	6.2	7.0	6.5	7.5	7.4	6.1	7.5	7.7	7.2	7.0
Well MB-3[3]	8.6	6.8	6.4	6.9	7.1	7.5	7.3	6.5	7.3	7.7	7.3	7.0

(2) during remediation
(3) downgradient from PA-1

TABLE 7

CADMIUM CONCENTRATIONS (mg/kg)
AREA III SEDIMENT SAMPLES

SAMPLE LOCATION	PRE-REMED.[1]	POST-REMED.[2]	LTM SAMPLING EVENT						
			11/95	3/96	6/96	4/97	4/98	4/99	4/00
EFC-1S	171	15.7	16J(52J)	7.08	6.91	0.386	14.2J	20.8	14.2J (13.5J)
EFC-2S	873	19.4	85	14.4J(29.0J)	7.76	46.4	46.3J	58.7	96.9J
EFC-3S	127	4.0	6	1.55	3.15	21.5(16.0)	7J	0.34	0.83J
EFC-4S	998	12.9	190	0.959	50.6	104	2.9J	67.1	277J
EFC-5S	43.1	6.3	42	21.2	9.69J(4.01J)	0.454	75J	9.4	100J
EFP-1S	14.2	6.0	130	15.9	5.7	5.56	106J	38.8	3.9J
EFP-2S	722	6.6	60	25.2	28.1	2.07	27.4J	74	0.4J
CSPA-1S	221	11.0	0.28U	34.9	7.17	2.66	2.6	2.6	1.5J
CSPA-2S	11.6	24.9	3.4	994	4.26	22.8	4.9	3.3	42.7J
CONTROL	4.8	---	24	7.1	6.34	103	1.5	8.3	2J
WFC-1S		---	17	12.7	7.41	6.25	5.3J	63.6	1.3J
WFC-2S	89 samples	---	11	11.7	20	5.48	6.9J	83.5	92.5J
WFC-3S	1.1 to 569	---	77	21.7	10.4	11.8	8.9J	143	10.8J
WFC-4S	43.9 mean	---	27	14.5	4.54	19.8	17.9J	49.5	1.4J
WFC-5S		---	85	16.4	61.4	31.2	55.7J	137	52.8J

NOTES:

(1) Samples obtained by Malcolm-Pirnie and others prior to the Remedial Action. These are the reported data closest to the present LTM sampling location.

(2) Average value of either the two closest post-remediation sample node locations or the analytical results of the various testing agencies (Sevenson, IQAT, and USCOE) for the same node location.

TABLE 8

TOTAL AND DISSOLVED CADMIUM CONCENTRATIONS (µg/l)
AREA III SURFACE WATER SAMPLES

SAMPLE LOCATION	LTM SAMPLING EVENT													
	11/95		3/96		6/96		4/97		4/98		4/99		4/00	
	TOTAL CD	DISSOLVED CD	TOTAL CD	DISSOLVED CD	TOTAL CD	DISSOLVED CD	TOTAL CD	DISSOLVED CD	TOTAL CD	DISSOLVED CD	TOTAL CD	DISSOLVED CD	TOTAL CD	DISSOLVED CD
EFC-1W	0.2U(0.2U)	0.2U(0.2U)	0.2U	0.2U	0.5U	0.5U	0.5UJ	0.5U	0.19(0.19)	0.1U(0.11)	0.27	0.1	0.11J(0.1U)	0.1U
EFC-2W	0.47	0.2U	0.2U(0.2U)	0.2U(0.2U)	0.5U(0.5U)	0.5U(0.5U)	0.5UJ(0.5U)	0.5UJ(0.5U)	1.4	0.14	0.39	0.12	0.14J	0.1U
EFP-1W	0.32	0.21	0.2U	0.2U	0.5U	.560	0.52	0.5U	2.8	0.33	0.59	0.26	0.39J	0.21J
CSPA-1W	0.2U	0.2U	0.2U	0.2U	0.5U	0.5U	0.5U	0.5U	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U
CSPA-2W	0.2	0.2U	0.2U	0.2U	0.5U	0.5U	0.5U	0.5UJ	0.1U	0.1U	0.11	0.1U	0.1U	0.1U
CON-W	0.2U	0.2U	0.2U	0.2U	0.5U	0.5U	0.5U	0.5U	0.1U	0.1U	0.13	0.1U	0.1J	0.1U
WFC-1W	0.2U(0.2U)	0.2U	0.2U	0.2U	0.5U	0.5U	0.5UJ	0.5U	1.2	0.1U	0.27	0.1U	0.1U	0.1U
WFC-3W	0.22U(0.2U)	0.2U	0.2U	0.2U	0.5U	0.5U	0.5UJ	0.5U	0.52	0.2	0.2	0.12	0.16J	0.1U

NOTES:

(1) EFC, EFP, CSPA, and WFC locations correspond to sediment sampling locations.

TABLE 9

CADMIUM CONCENTRATIONS (mg/kg)
BIOLOGICAL TISSUE SAMPLES

SPECIES	HISTORIC DATA (PRE-REMEDIATION)	LONG-TERM MONITORING DATA				
		1996	1997	1998	1999	2000
WOOD DUCK (liver) # of samples	4	5	5	5	5	5
Cd range (mg/kg, WW)	0.61 - 0.94	0.12 - 2.4	0.05 - 1.3	0.56 - 1.4	0.05 - 1.2	0.0938 - 1.43
mean Cd (mg/kg, WW)	0.76	1.0	0.42	1.06	0.54	0.66
WOOD DUCK (kidney) # of samples	4	5	5	5	5	5
Cd range (mg/kg, WW)	1.20 - 12.0	1.5 - 9.0	0.81 - 17.4	1 - 7.5	0.16 - 6.1	0.243 - 9.94
mean Cd (mg/kg, WW)	4.45	6.5	5.14	4.6	3.15	4.42
SWALLOWS (whole body) # of samples	2	5	4	no samples collected	3	5
Cd range (mg/kg, WW)	1.174 - 4.75	0.1 - 0.42	0.1 - 0.27	-	0.11 - 0.22	ND - 9.265
mean Cd (mg/kg, WW)	2.96	0.24	0.19	-	0.17	0.13

TABLE 9
(Continued)

SPECIES	HISTORIC DATA (PRE-REMEDIATION)	LONG-TERM MONITORING DATA				
		1996	1997	1998	1999	2000
MARSH WREN (whole body) # of samples	8	5	no sampling	no sampling	no sampling scheduled	2
Cd range (mg/kg, WW)	0.29 - 10.53	0.13 - 0.31	scheduled	scheduled	-	.156 - 1.62
mean Cd (mg/kg, WW)	1.8	0.20		-	-	0.88
CANADA GEESE (liver) # of samples	no data	5	7	4	3	2
Cd range (mg/kg, WW)	–	0.82 - 5.7	0.04 - 8.1	0.07 - 3	0.35 - 1.1	0.117 - 0.992
mean Cd (mg/kg, WW)	–	2.4	1.77	1.06	0.77	0.55
CANADA GEESE (kidney) # of samples	no data	5	7	4	3	2
Cd range (mg/kg, WW)	–	0.88 - 10.5	0.04 - 22.9	0 .07 - 14.2	0.48 - 5.3	0.101-2.93
mean Cd (mg/kg, WW)	–	5.2	4.80	4.19	2.63	1.52

TABLE 9
(Continued)

SPECIES	HISTORIC DATA (PRE-REMEDIATION)	LONG-TERM MONITORING DATA				
		1996	1997	1998	1999	2000
BENTHIC INVERTEBRATES (one sample @ each location)						
EFC (mg/kg, WW)	0.570	0.78	11.2	7.7	1.7	0.456
Oligochaete (mg/kg, WW)	2.205	–	–	-	-	
Chironamid (mg/kg, WW)	4.545	–	–	-	-	
CM (mg/kg, WW)	–	2.3	5.5	1.9	1.7	1.61
CATTAILS (CM)						
# of samples	11	1	5	5	5	5
Cd range (mg/kg, DW)	0.052 - 1.45	–	0.31 - 0.8	0.23 - 1.1	0.3 - 0.71	0.251 - 0.422
mean Cd (mg/kg, DW)	0.62	1.2	0.53	0.56	0.44	0.375
CATTAILS (EFCM)						
# of samples	7	4	20	20	20	20
Cd range (mg/kg, DW)	0.107 - 16.50	0.05 - 0.13	0.12 - 0.31	0.05 - 0.13	ND - .394	ND - 0.58
mean Cd (mg/kg, DW)	3.31	0.08	0.16	0.07	0.177	0.170

TABLE 9
(Continued)

SPECIES	HISTORIC DATA (PRE-REMEDIATION)	LONG-TERM MONITORING DATA				
		1996	1997	1998	1999	2000
WATER CHESTNUT (EFC)						
# of samples	4	1	5	5	5	4
Cd range (mg/kg, DW0	1.670 - 47.40	–	2.2 - 4.5	4 - 6.5	2.5 - 5.5	1.46 - 2.42
mean Cd (mg/kg, DW)	15.6	4.5	3.50	5.3	4.32	2.00
WATER CHESTNUT (CM)						
# of samples	1	1	5	5	5	5
Cd range (mg/kg, DW)	–	–	3.7 - 5.6	7.8-10	3-4.8	2.5 - 4.92
mean Cd (mg/kg, DW)	2.96	7.3	4.52	9	4.1	3.24
WATER CHESTNUT (WFC)						
# of samples	no data	1	5	5	5	5
Cd range (mg/kg, DW)	–	–	1.4 - 2.0	1 - 1.4	1.3 - 1.89	0.868 - 1.97
mean Cd (mg/kg, DW)	–	2.4	1.60	1.2	1.61	1.36

NOTES:

- Detection limits were used for non-detect samples when computing mean Cd values.
- WW = wet weight basis
- DW = dry weight basis
- Historic values for oligochaete and chironamid invertebrates were quoted from an Acres report referencing a 1984 study by J. Levinton
- CM = Constitution Marsh
- EFCM = East Foundry Cove Marsh
- EFC = East Foundry Cove
- WFC = West Foundry Cove

TABLE 10
CADMIUM BIOACCUMULATION DATA (μg/g)

KILLIFISH

DAY	EAST FOUNDRY COVE				COLD SPRING AREA				WEST FOUNDRY COVE			MANITOU BAY
	Pre-Remed.[1]	1996	1998	2000	Pre-Remed. [1]	1996	1998	2000	1996	1998	2000	2000
1	0.12	0.06	<0.02	<0.031	0.11	0.06[2]	<0.009	<0.031	0.06[2]	<0.009	<0.031	<0.031
14	0.44	<0.05	<0.03	0.039	0.05	<0.04	<0.009	(3)	<0.04	0.012	<0.031	<0.031
28	0.33	0.04	<0.02	(3)	0.06	<0.04	0.023	(3)	<0.04	0.064	(3)	<0.031
40	0.58			-	0.50			-			-	-
42		0.09	<0.017	(3)		<0.04	<0.017	(3)	(3)	0.054	(3)	<0.031

CRAYFISH

DAY	EAST FOUNDRY COVE				COLD SPRING AREA				WEST FOUNDRY COVE			MANITOU BAY
	Pre-Remed.[1]	1996	1998	2000	Pre-Remed. [1]	1996	1998	2000	1996	1998	2000	2000
1	0.2	<0.05	0.04	<0.031	0	<0.05	<0.009	<0.031	<0.05	0.035	<0.031	<0.031
14	1.25	0.13	0.15	.053	0.16	<0.04	<0.009	<0.034	<0.04	0.038	<0.031	<0.031
28	1.42	0.16	0.057	(3)	0.83	0.07	0.041	<0.031	0.07	0.048	0.181	<0.031
40	1.83			-	2.08			-			-	-
42		0.22	0.108	(3)		0.06	0.033	<0.031	0.07	(3)	0.037	<0.031

(1) Values interpolated from figures 29, 36, and 38 of the August 1985 Draft Remedial Investigation Report prepared by ACRES International.
(2) Average of samples taken from two locations used as the source of the killifish specimens.
(3) Car was empty on scheduled sampling date.

TABLE 11

Biological Inventory										
Gould Electronics Inc.										
Quadrant A										
Species	Year									
	1996		1997		1998		1999		2000	
	# of Plants	% Cover	# of Plants	% Cover	# of Plants	% Cover	# of Plants	% Cover	# of Plants	% Cover
Water Purslane (*Ludwigia palustris*) & Speedwell (*Veronica* sp.)	-	50	-	40 to 45	-	47.5	-	<1	-	3
Saltmarsh Fleabane (*Pluchea purpurascens)*	4	-	-	2	199	4.75	-	61.25	-	5
Bentgrass (*Agrostis* sp.)	-	10	0	-	-	15	-	15	-	7
Narrow-leaved Cattail (*Typha angustifolia*)	1	-	25	-	53	10.25	87	10	114	18.75
Mild Water Pepper (*Polygonum hydropiperoides*)	22	-	-	-	220	9.25	127	1.5	217	5.25
Wild Millet (*Echinochloa* sp.)	32	-	87	-	76	8.75	-	2.75	-	<1
Spikerush (*Eleocharis* 2 sp.)	6	-	-	3	-	6.25	-	41	-	35.25
Three-square (*Scirpus americanus)*	-	-	19	-	158	2.5	-	2	-	21
Purple Loosestrife (*Lythrum salicaria*)	-	-	32	-	40	1.5	67	2.75	51	21.25
Water Plantain (*Alisma* sp.)	3	-	5	-	6	<1	13	<1	32	1.25
Arrowhead (*Sagittaria latifolia*)	6	-	1	-	3	-	3	-	1	-
Tickseed (*Bidens* sp.)	-	-	-	-	2	-	0	-	10	-
Water Parsnip (*Sium suave)*	-	-	1	-	0	-	0	-	0	-
Twig Rush (*Cladium mariscoides*)	2	-	45	-	0	-	17	-	18	-
Broad-leaved Cattail (*Typha latifolia)*	-	-	0	-	0	-	0	-	0	-
Water Hemp (*Acnidacannabina*)	-	-	-	-	-	-	6	-	15	-
Sedge (*Cyperus* sp.)	5	-	165	-	-	-	17	<1	2	-
Wild Rice (*Zizania aquatica*)	-	-	-	-	-	-	3	-	2	-
Smartweed (*Polygonum* sp.)	-	-	-	-	-	-	4	-	1	-
Dodder (*Cuscuta gronovii*)	-	-	-	-	-	-	-	<1	-	<1
Pickerelweed (*Pontedaria cordata*)	1	-	-	-	-	-	-	-	-	-

TABLE 12

Quadrat B										
Species	Year									
	1996		1997		1998		1999		2000	
	# of Plants	% Cover	# of Plants	% Cover	# of Plants	% Cover	# of Plants	% Cover	# of Plants	% Cover
Water Hemp (*Acnida cannabina)*	38	all specie	5	-	0	-	0	-	0	-
Mild Water Pepper (*Polygonum hydropiperoides*)	18	app. 1%	-	-	-	-	-	-	-	-
Purple Loosestrife (*Lythrum salicaria*)	13	or less	1	-	0	-	0	-	0	-
Arrow Arum (*Peltandra virginica*)	8		1	-	0	-	0	-	1	-
Wild Millet (*Echinochloa* sp.)	5		3	-	0	-	70	2.5	9	<1
Water Pepper (*Polygonum hydropiper*)	3		-	-	-	-	-	-	-	-
Nodding Smartweed (*Polygonum lapathifolium*)	2		-	60	-	15	-	4.25	48	5
Buttercup (*Ranunculum* sp.)	1		-	-	-	-	-	-	-	-
Water Plantain (*Alisma* sp.)	1		-	-	-	-	-	-	-	-
Curled Dock (*Rumex crispus*)	1		-	-	-	-	-	-	-	-
Pickerelweed (*Pontedaria cordata*)	1		-	-	-	-	-	-	-	-
Plantain (*Plantago* sp)?	1		-	-	-	-	-	-	-	-
Water Purslane (*Ludwigia palustris*)	-	-	-	-	-	-	-	-	-	-
Speedwell (*Veronica* sp.)	-	-	-	<1	2	<1	-	<1	-	<1
Smartweed (*Polygonum* sp.)	-	-	-	60	-	15	-	4.25	48	5
Saltmarsh Fleabane (*Pluchea purpurascens)*	-	-	14	-	50	15	250	17.5	45	5
Wild Rice (*Zizania aquatica*)	-	-	4	-	0	-	0	-	0	-
Arrowhead (*Sagittaria latifolia*)	-	-	1	-	1	-	1	-	1	-
Seaside Goldenrod (*Solidago sempirvirens)*	-	-	-	-	13	1	30	1	-	<1
Narrow-leaved Cattail (*Typha angustifolia*)	-	-	-	-	2	-	2	-	0	-
Mermaid Weed (*Prosperinaca* sp)	-	-	-	-	-	-	-	-	1	-

TABLE 13

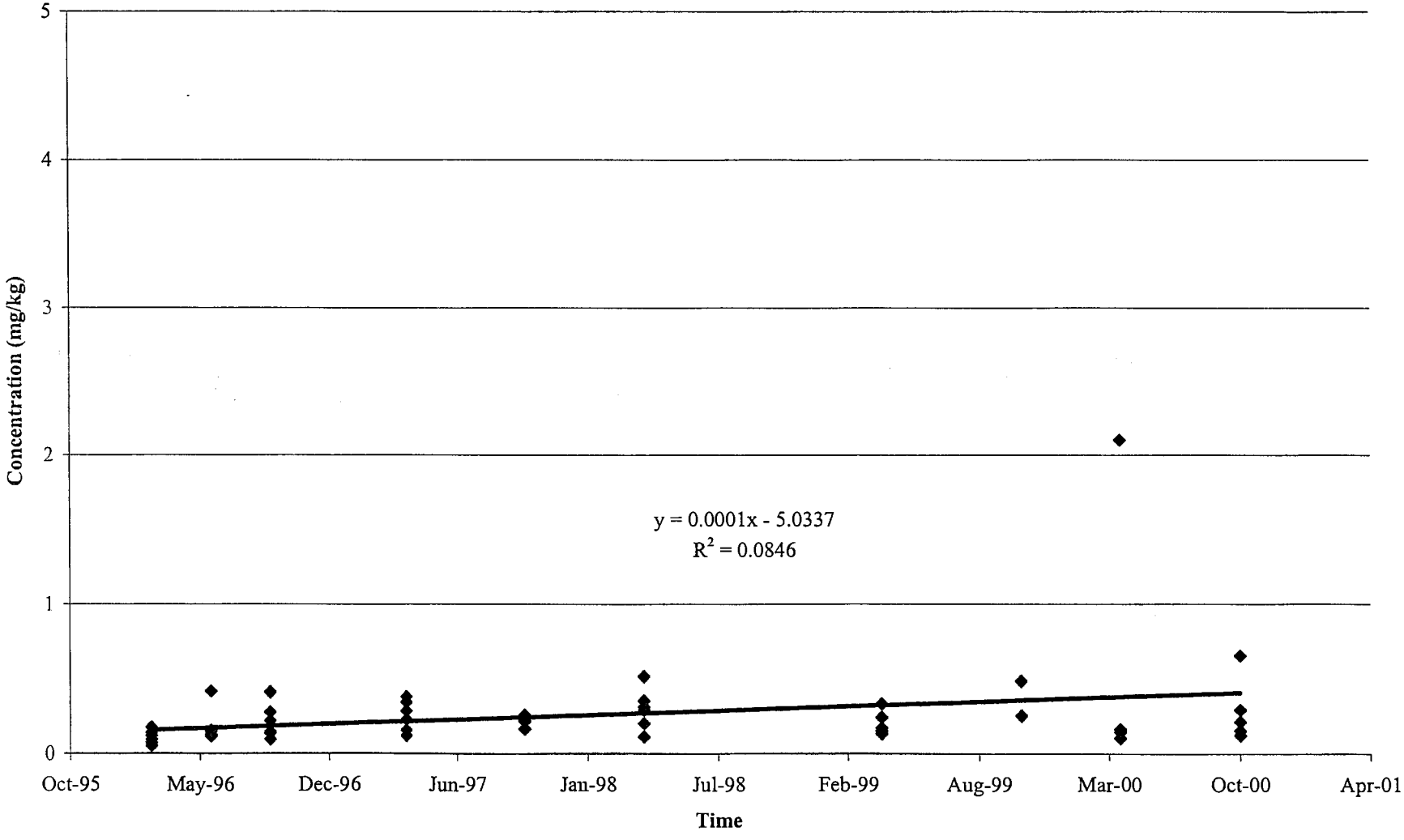
Quadrat C										
Species	Year									
	1996		1997		1998		1999		2000	
	# of Plants	% Cover	# of Plants	% Cover	# of Plants	% Cover	# of Plants	% Cover	# of Plants	% Cover
Three Square *(Scirpus americanus)*	-	45 - 50%		15%		5.75%		6.50%	-	12%
Umbrella Sedge *(Cyperus sp.)*	-	15%		45 - 50%	33	-	0	-	0	-
Umbrella Sedge *(Cyperus sp.)*	-	8 - 10%	8	-	7	-	2	-	0	-
Wild Millet *(Echinochloa sp.)*	-	<5%	-	1%	22	-	250	2%	0	-
Water Hemp *(Acnida cannabina)*	22	-	12	-	3	-	0	-	4	-
Broad Leaved Cattail *(Typha latifolia)*	15	-	32	-	63	9%	37	3.50%	27	1.50%
Purple Loosestrife *(Lythrum salicaria)*	10	-	70	-	133	21.25%	220	33.75%	152	44.25%
Swamp Rose Mallow *(Habiscus palustris)*	5	-	1	-	-	-	-	-	-	-
Pickerelweed *(Pontedaria cordata)*	3	-	-	-	-	-	-	-	-	-
Chickweed *(Stellaria or Cerastium)*	2	-	-	-	-	-	-	-	-	-
Arrow Arum *(Peltandra virginica)*	2	-	3	-	0	-	0	-	0	-
Smartweed *(Polygonum sp.)*	2	-	-	-	-	-	-	-	-	-
Arrowhead *(Sagittaria latifolia)*	1	-	-	-	6	-	0	-	0	-
Goldenrod *(Solidago sp.)*	1	-	2		2	-	40	<1%	46	<1%
Goldenrod *(solidago sp.)* ?	1	-	-	-	-	-	-	-	-	-
Cocklebur *(Xanthium sp.)*	1	-	1	-	3	-	1	-	1	-
Willow *(Salix sp.)*	1	-	-	-	-	-	3	5%	3	10%
Poplar *(Populus)*	1	-	-	-	-	-	-	-	-	-
Clover *(Trifolium sp.)*	1	-	-	-	-	-	-	-	-	-
Nodding Smartweed *(Polygonum lapathifolium)*	1	-	-	-	-	-	-	-	-	-
Switchgrass *(Panicum virgatum)*	-	<1%	-	-	-	-	-	-	-	-
Water Purslane *(ludwigia palustris)*	-	<1%	-	5%	-	4.75%		<1%	-	<1%
Saltmarsh Fleabane *(Pluchea purpurascens)*	-	-	100	-	122	1.25%	± 800	31%	-	27%
Mild Water Pepper *(Polygonum hydropiperoides)*	-	-	20	-	4	-	0	-	3	-
Pink Knotweed *(Polygonum pennsylvanicum)*	-	-	20	-	7	-	2	-	1	-
Indian Tobacco *(Lobelia inflata)*	-	-	16	-	-	-	-	-	-	-
StickTight *(Bidens sp.)*	-	-	2	-	27	-	1	-	1	-
Willow Herb *(Epilobium sp.)*	-	-	2	-	1	-	2	-	0	-
Curled Dock *(Rumex crispus)*	-	-	1	-	1	-	0	-	0	-
Bent Grass *(Agrostis sp.)*	-	-	-	<1%	-	1%	4	<1%	-	<1%
Plantain *(Plantago sp.)*	-	-	1	-	1	-	1	-	1	-
Rush *(Juncus sp.)*	-	-	1 clump	-	2 clumps	-	4 clumps	-	0	-
Spotted Touch-me-not *(Impatiens capensis)*	-	-	1	-	-	-	-	-	-	-
Buttercup *(Ranunculum sp.)*	-	-	1	-	-	-	0	0%	-	-
Rice Cutgrass *(Leersia oryzoides)*	-	-	-	-	-	6.50%	-		-	1.50%
Fescue *(Festuca sp.)*	-	-	-	-	-	3%	-	0%	-	0%
Panicgrass *(Panicum sp.)*	-	-	-	-	-	<1%	-	-	0	-
Sneezeweed *(Helenium autumnale)*	-	-	-	-	1	-	0	-	14	-
Boneset *(Eupatoria perfoliatum)*	-	-	-	-	1	-	74	-	14	-
Water Parsnip *(Sium suave)*	-	-	-	-	1	-	0	-	7	-
Dodder *(Cuscutta gronovii)*	-	-	-	-	-	-	-	<1%	-	<1%
Water Horehound *(Lycopus americanus)*	-	-	-	-	-	-	-	5	7	-
Wild Mint *(Mentha arvensis)*	-	-	-	-	-	-	-	3	0	-
Clearweed *(Pilea sp.)*	-	-	-	-	-	-	-	-	5	-
Common Reed *(Phragmites communis)*	-	-	-	-	-	-	-	-	4	-
Cardinal Flower *(Lobelia cardinalis)*	-	-	-	-	-	-	-	-	1	-

TABLE 14

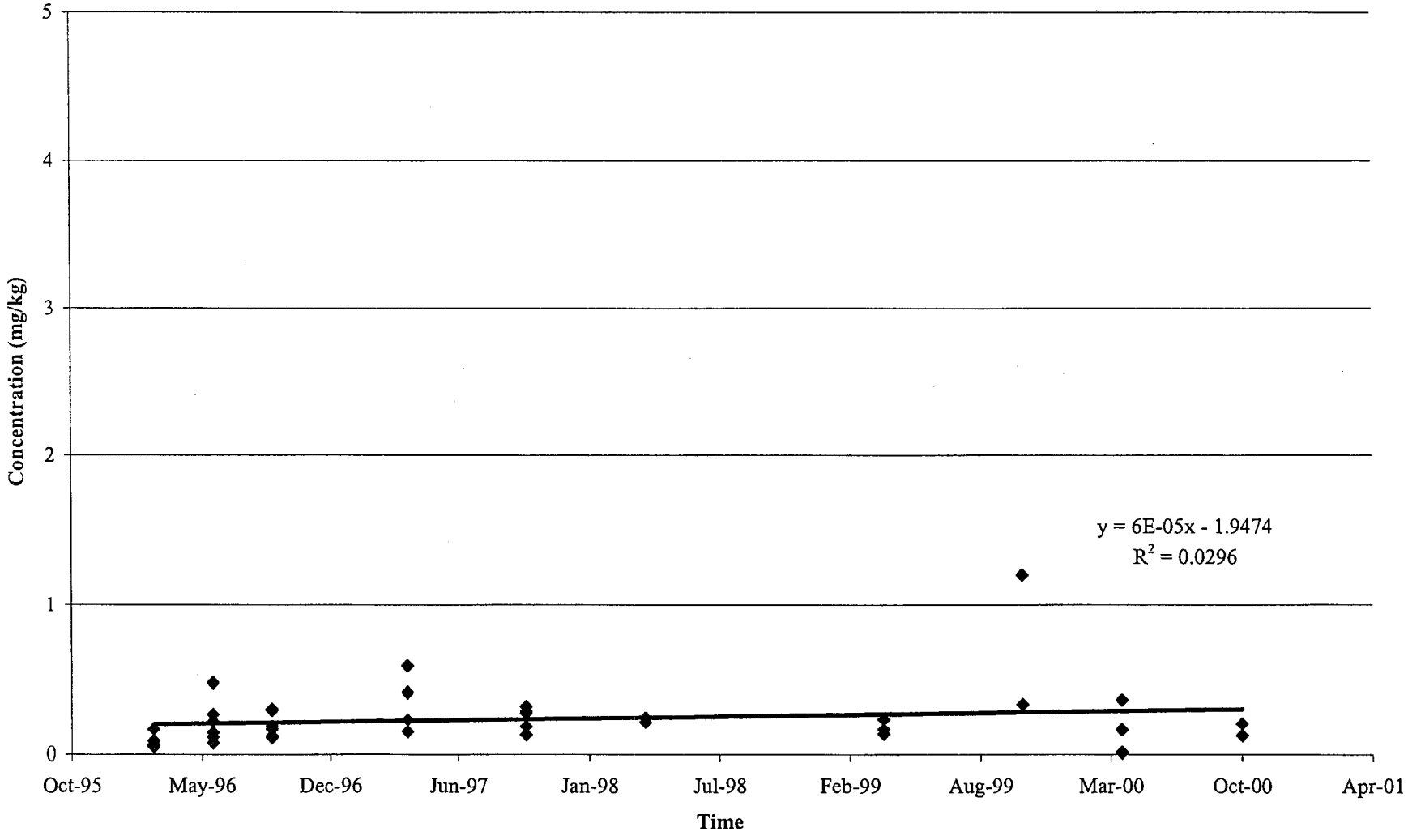
Quadrat D										
Species	Year									
	1996		1997		1998		1999		2000	
	# of Plants	% Cover	# of Plants	% Cover	# of Plants	% Cover	# of Plants	% Cover	# of Plants	% Cover
Broad Leaved Cattail *(Typha latifolia)*	173	90%	-	75%	29	5.50%	4	<1	-	0
Common Reed *(Phragmites communis)*	45	2%	-	20%	-	56.25%	-	90%	-	100%
Water Hemp *(Acnida cannabina)*	13	-	12	-	0	-	0	-	-	0
Smartweed *(Polygonum sp.)*	10	-	-	-	-	-	-	-	-	-
Arrow Arum *(Peltandra virginica)*	5	-	7	-	7	<1%	8	1%	-	1
Pickerelweed *(Pontedaria cordata)*	4	-	3	-	2		3	-	-	1
Arrowhead *(Sagittaria latifolia)*	3	-	34	-	46	2%	0	-	-	0
Mild Water Pepper *(Polygonum hydropiperoides)*	2	-	-	-	-	-	-	-	-	-
Willow Herb *(Epilobium sp.)*	2	-	-	-	-	-	-	-	-	-
Water Pepper *(Polygonum hydropiper)*	1	-	55	-	65	3.75%	12	-	-	0
Unidentified	-	<1%	-	-	-	-	-	-	-	-
StickTight *(Bidens sp.)*	-	-	7	-	-	-	-	-	-	-
Water Parsnip *(Sium suave)*	-	-	1	-	1	-	0	-	-	0
Spike Rush *(Eleocharis sp.)*	-	-	-	<1%	-	<1%	0	-	-	0
Tickseed *(Bidens sp.)*	-	-	-	-	0	-	0	-	-	0

APPENDICES

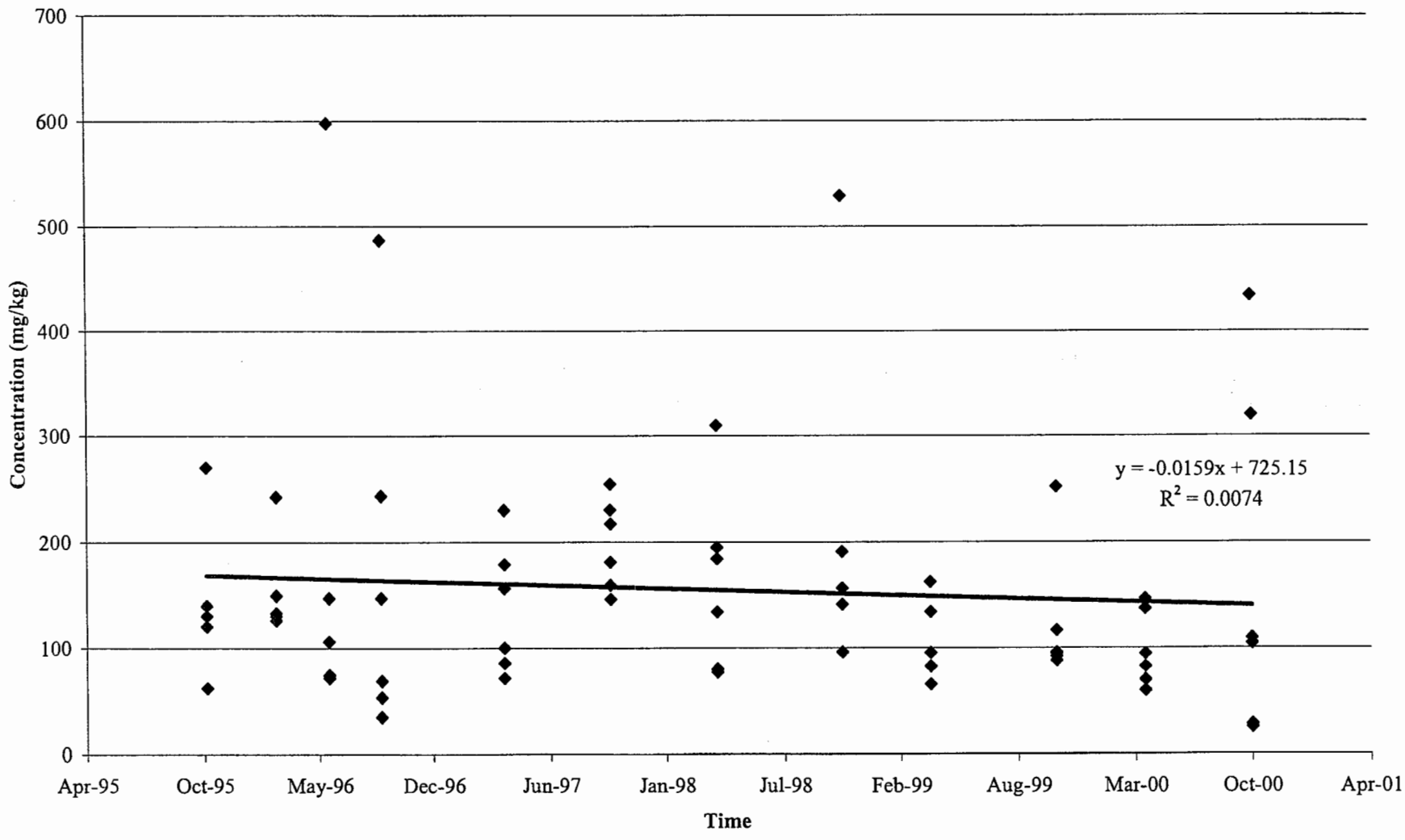
EFM (0-0.5') Regression Analysis
Cadmium



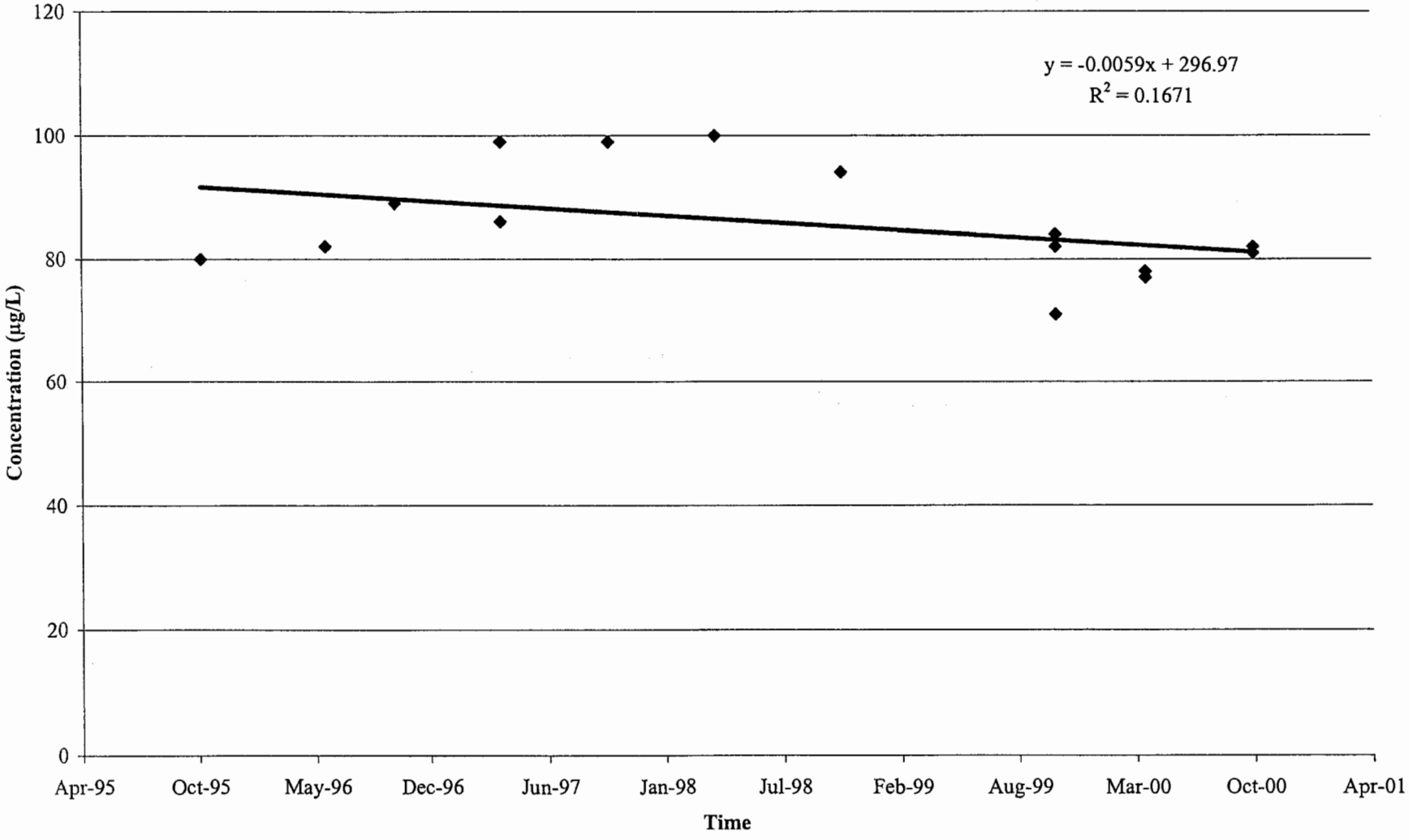
EFM (0.5-1') Regression Analysis
Cadmium



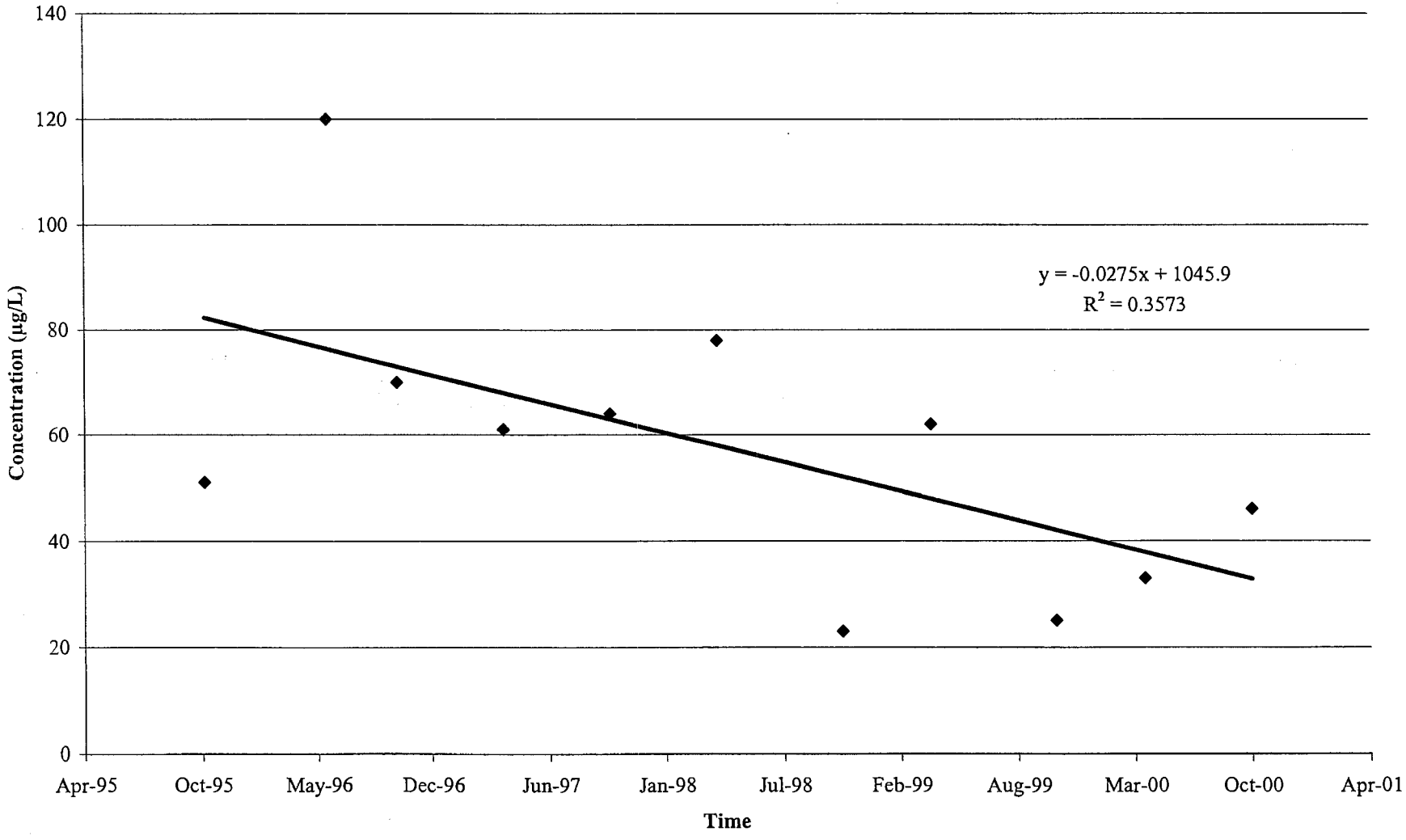
CM Soil Regression Analysis
Cadmium



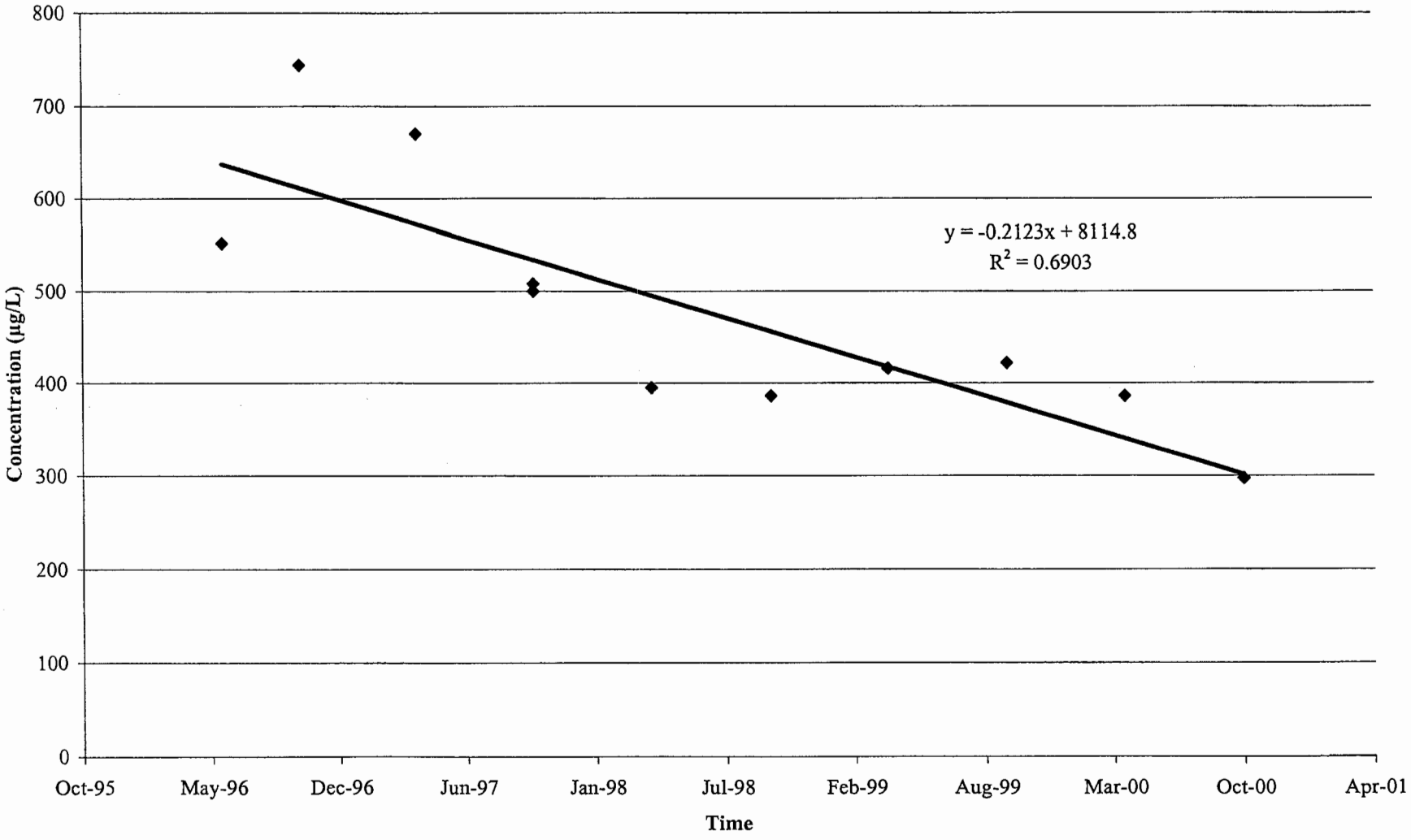
Well 7S Regression Analysis
Trichloroethene



Well MB-3 Regression Analysis
Trichloroethene



Well PA-1 Regression Analysis
Dissolved Cadmium



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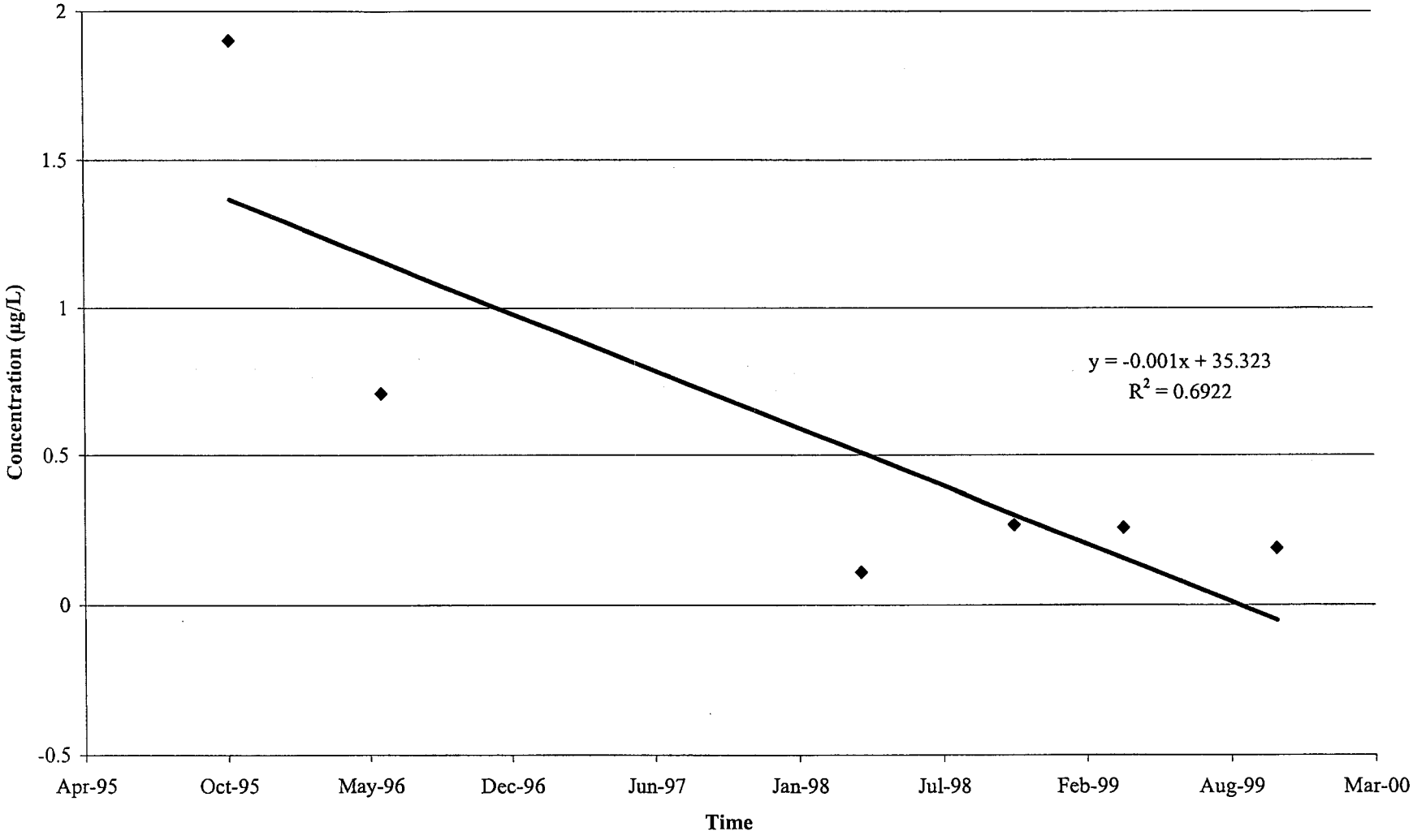

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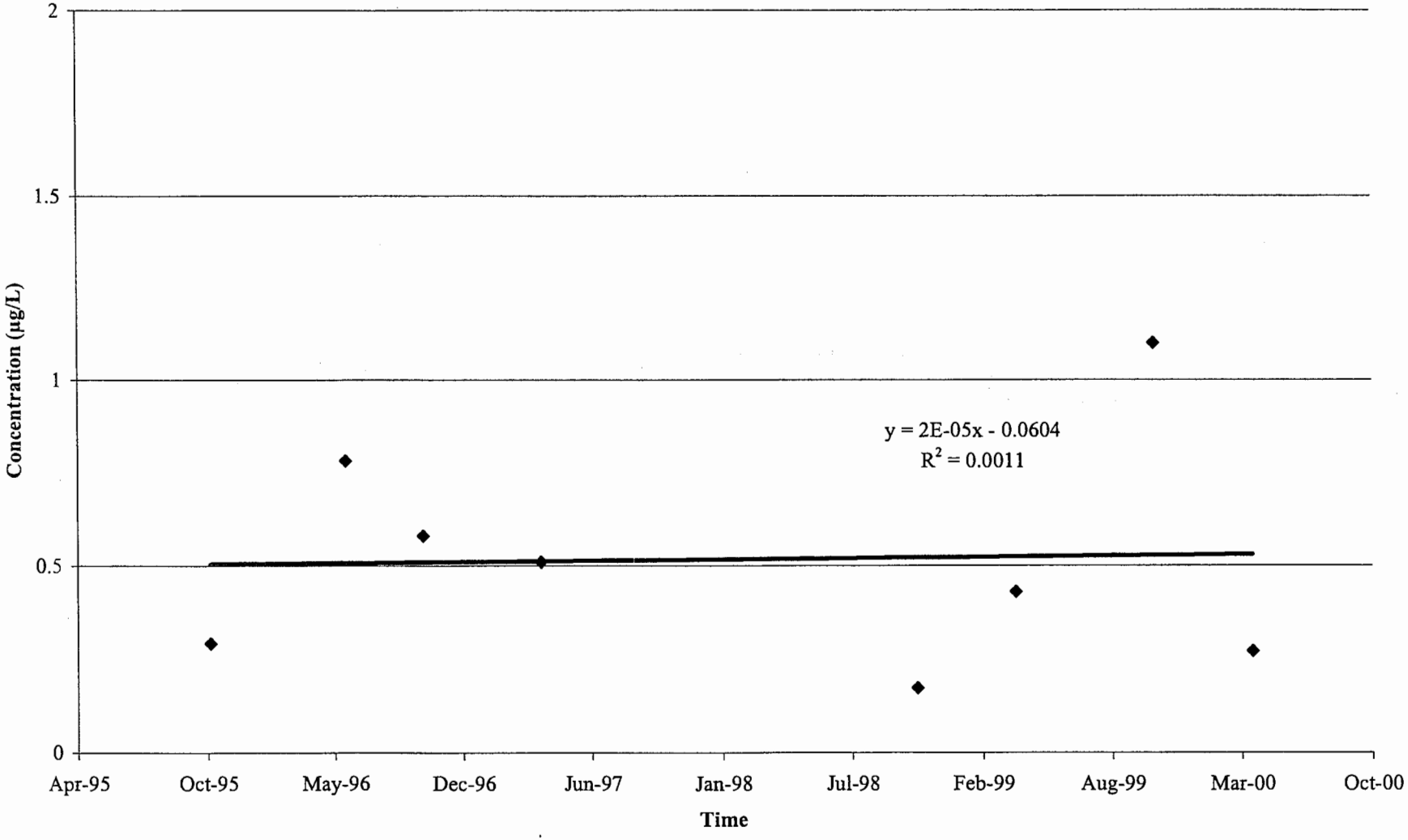

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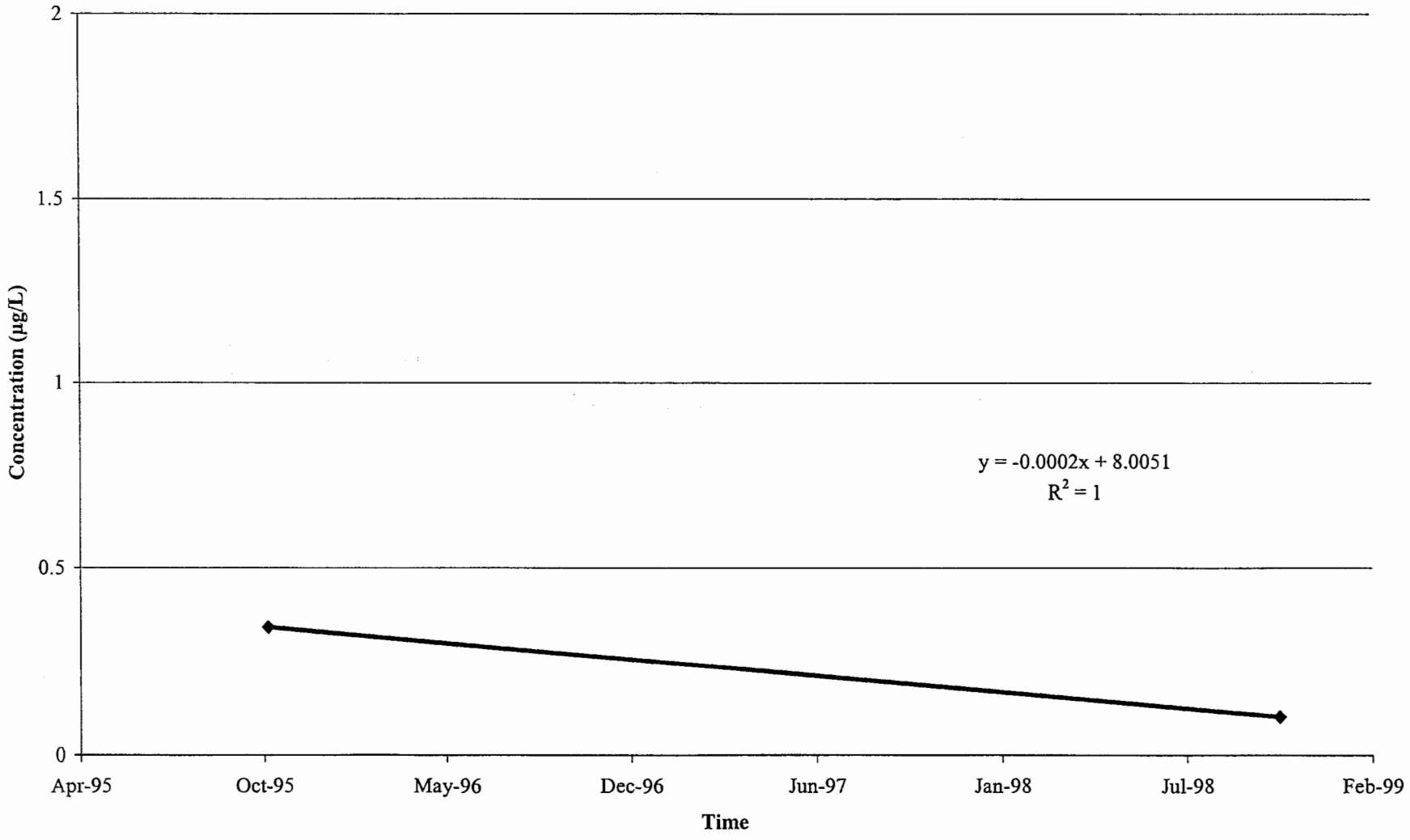
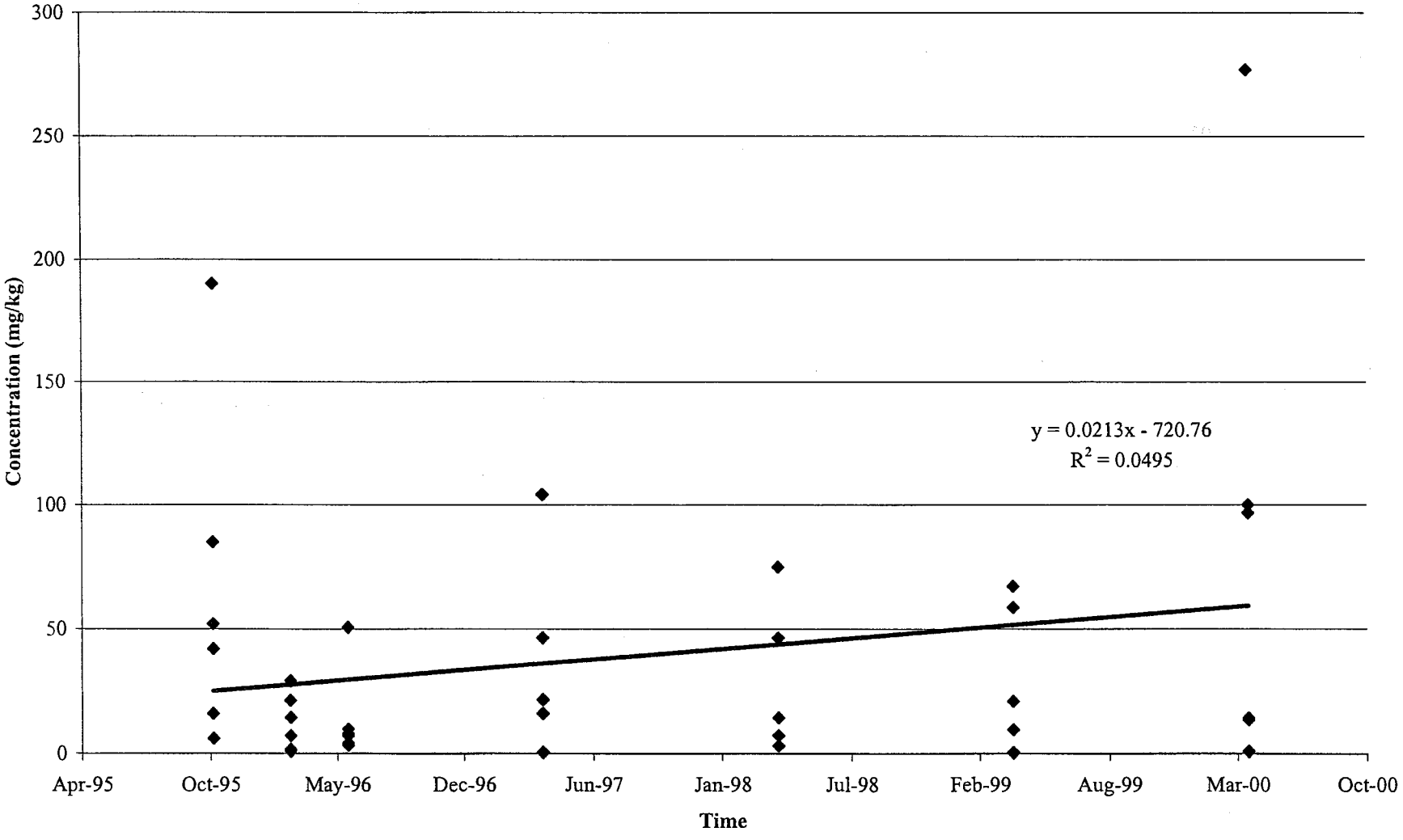
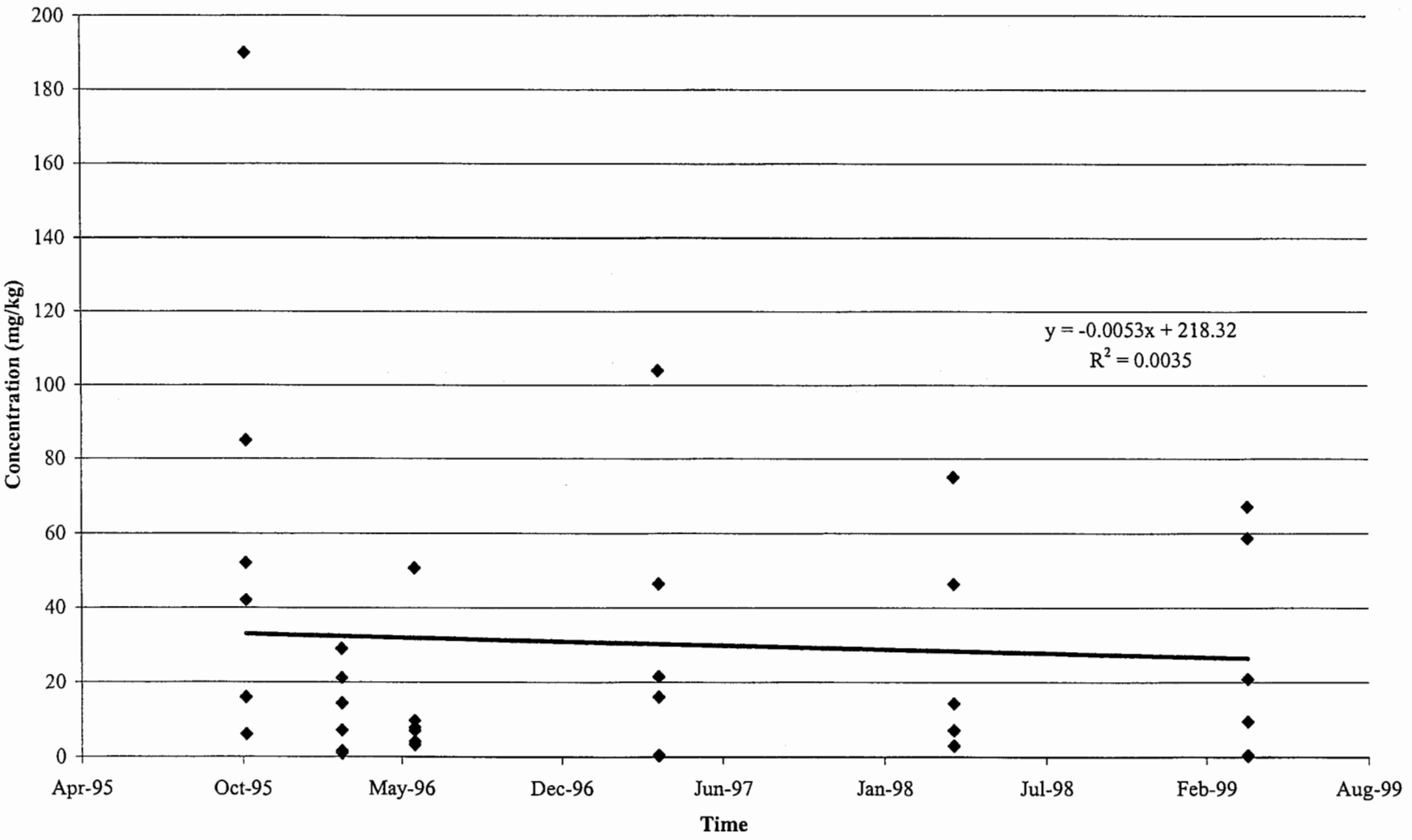


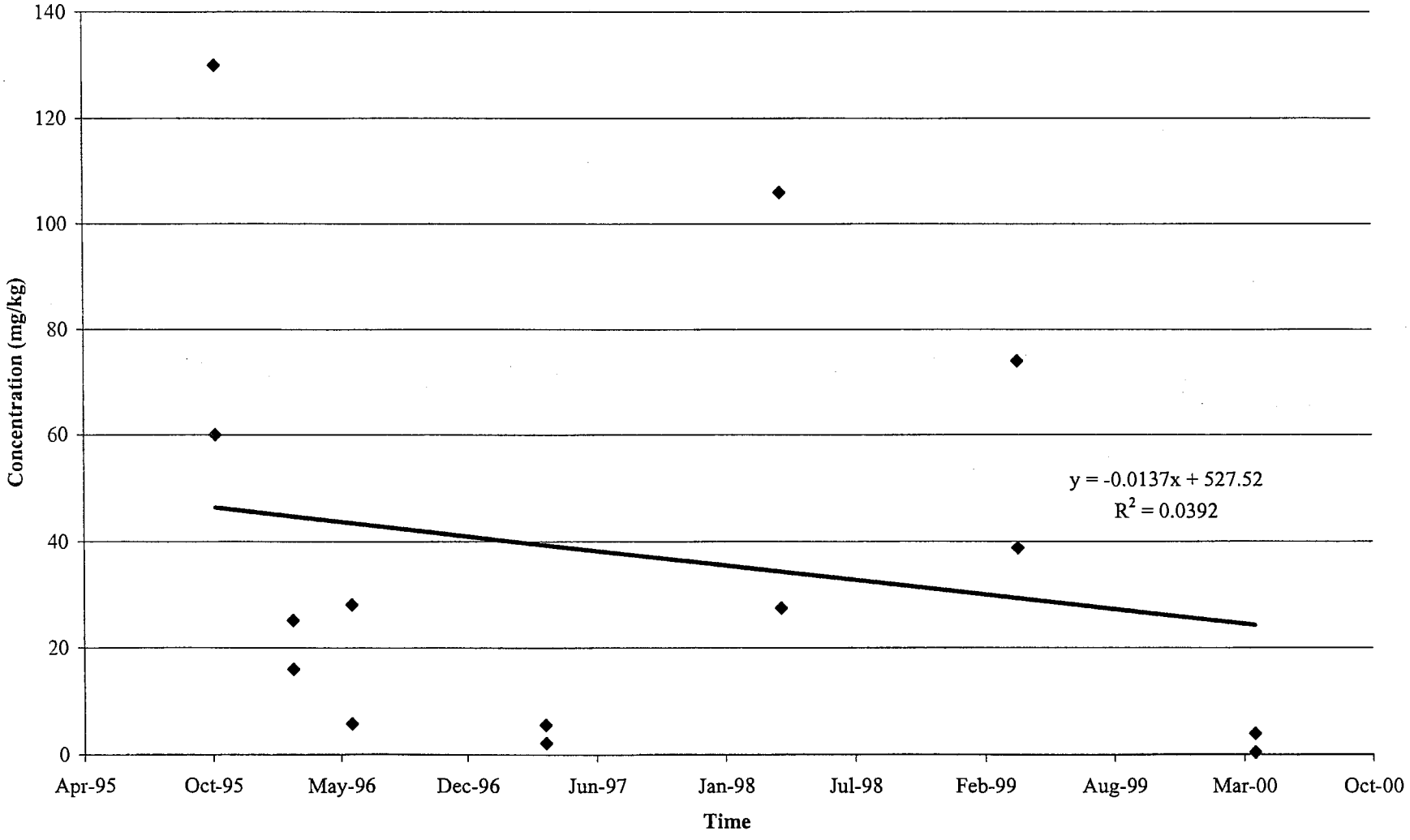
EFC Sediment Regression Analysis
Cadmium



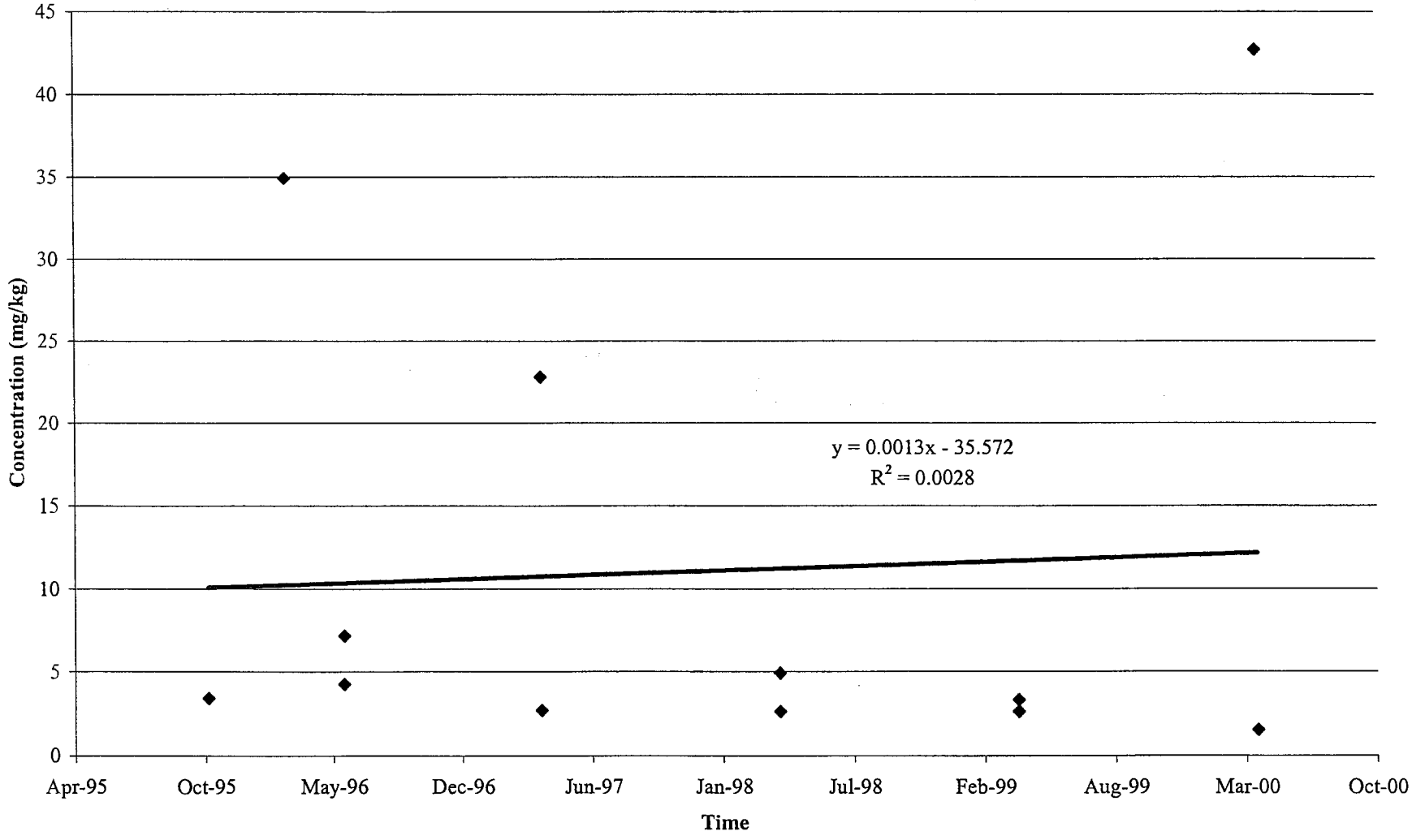
EFC Sediment 1995-1999 Regression Analysis
Cadmium



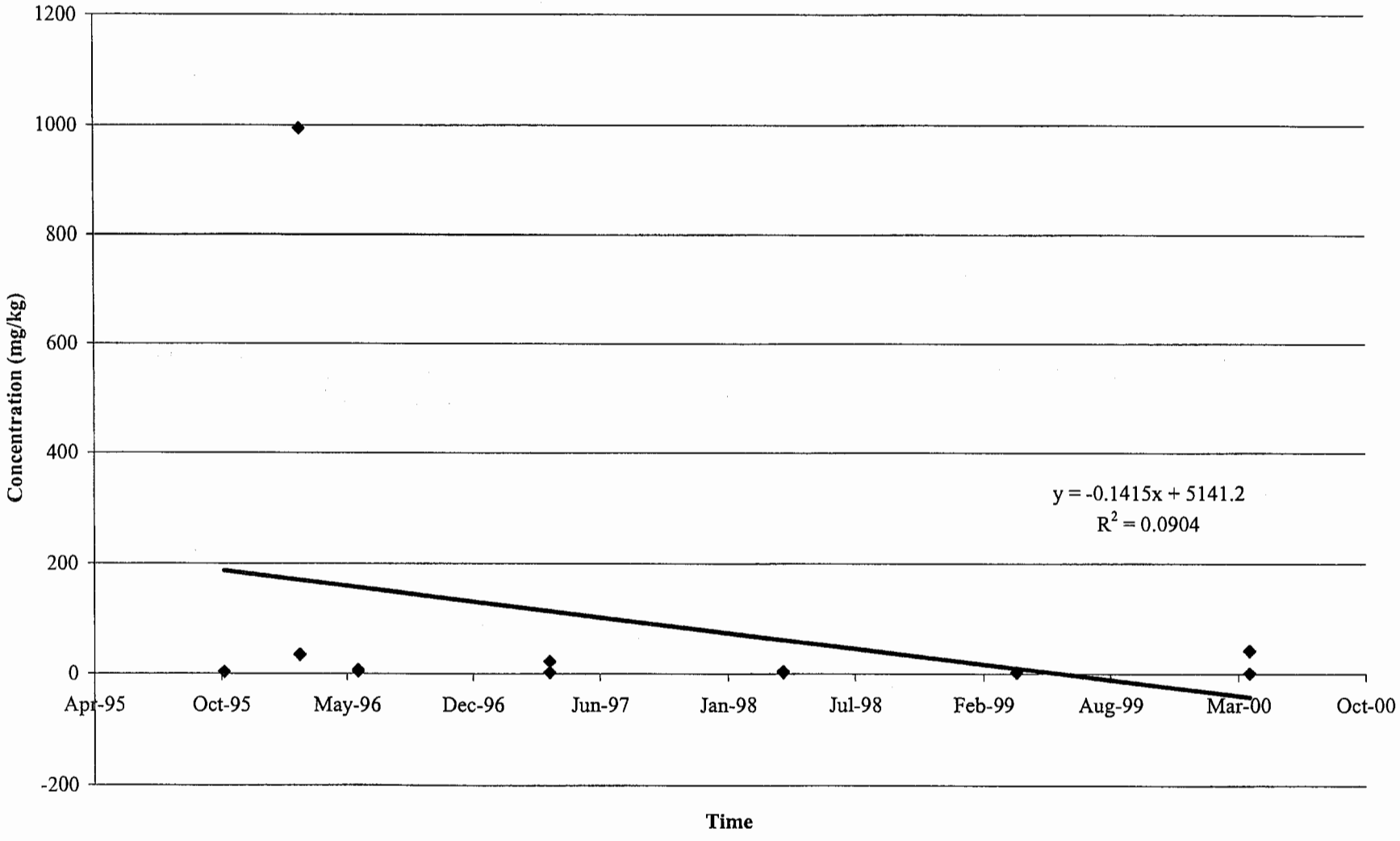
EFP Sediment Regression Analysis
Cadmium



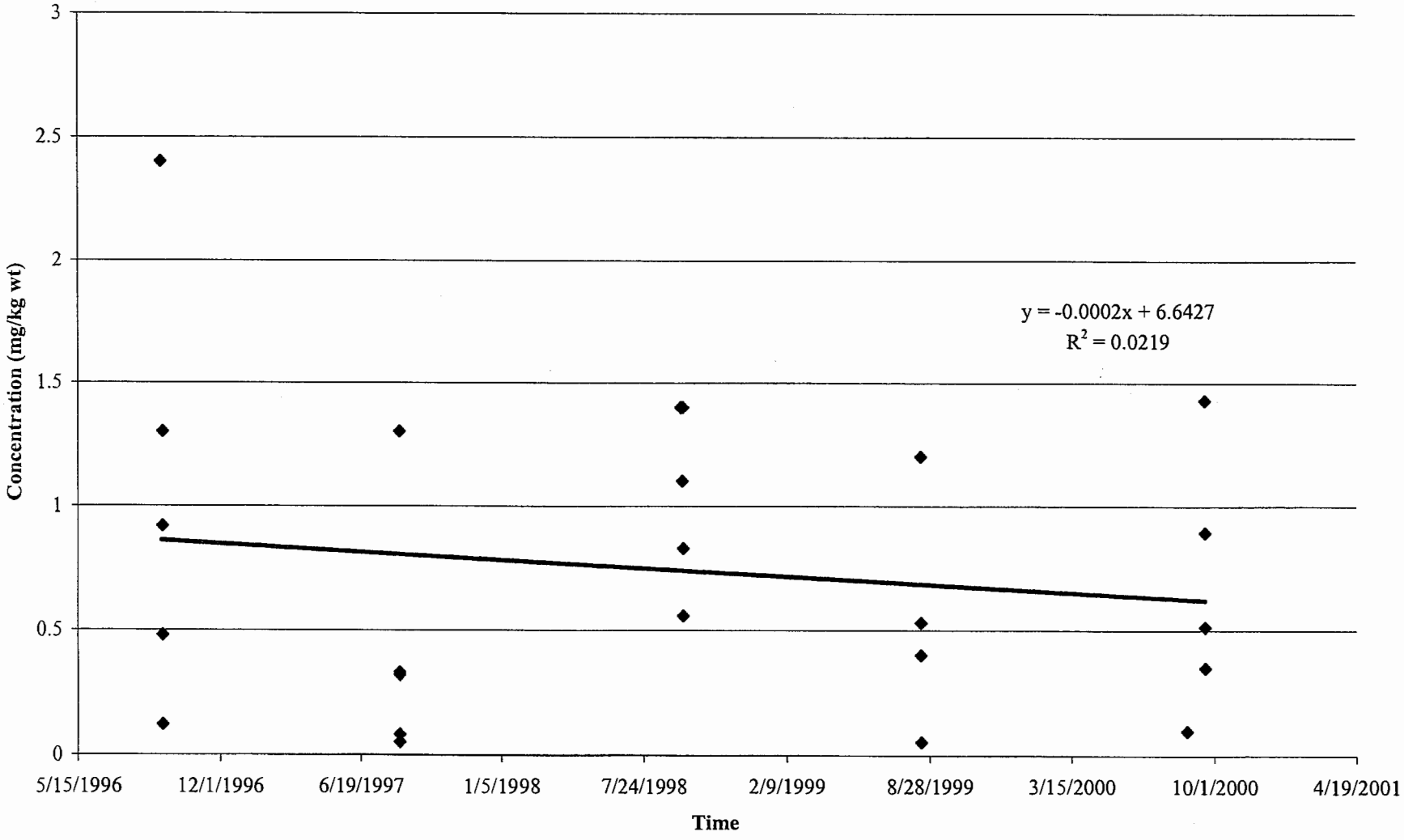
CSPA 1S and 2S (minus outlier 994 mg/kg) Regression Analysis
Cadmium



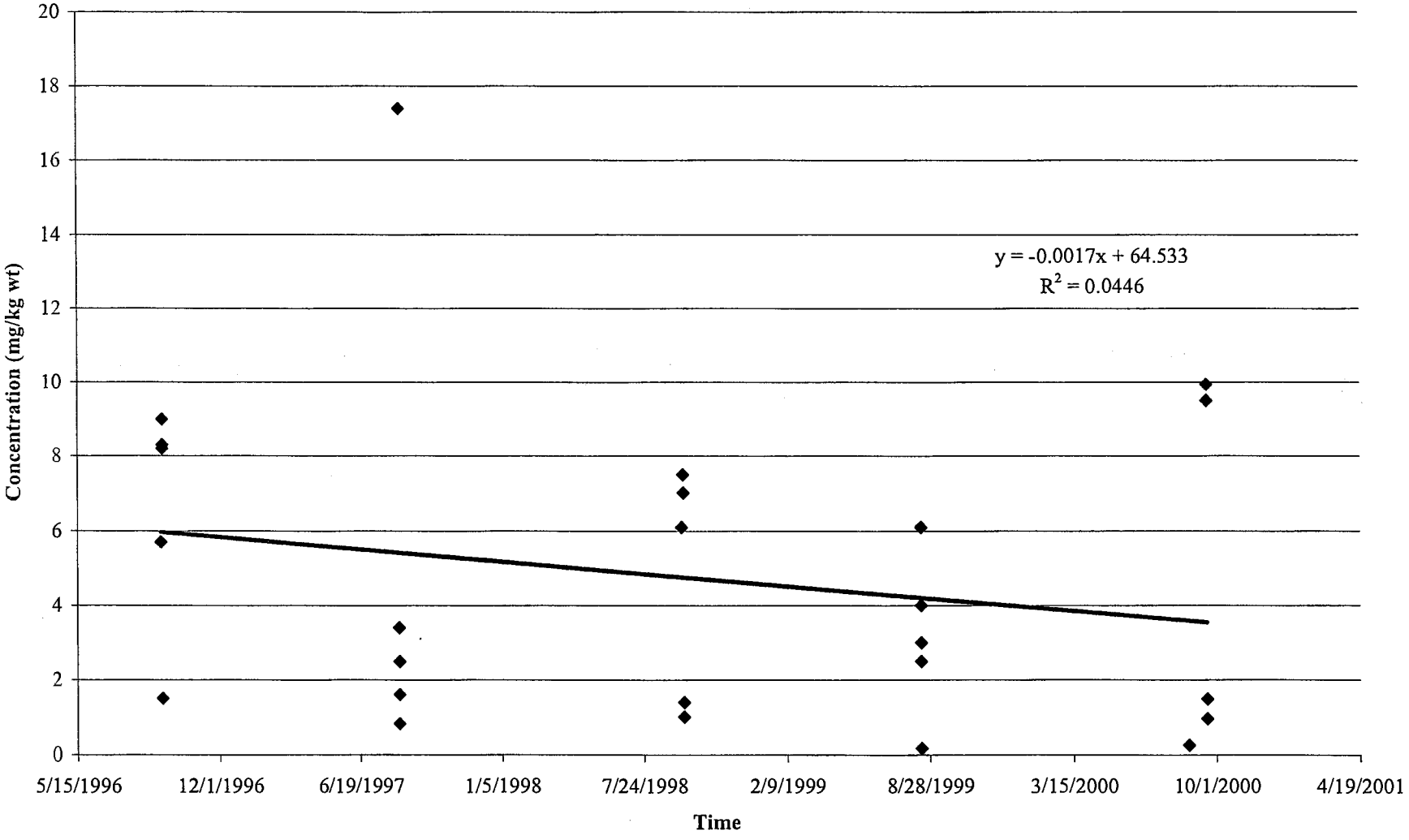
CSPA 1S and 2S Sediment Regression Analysis
Cadmium



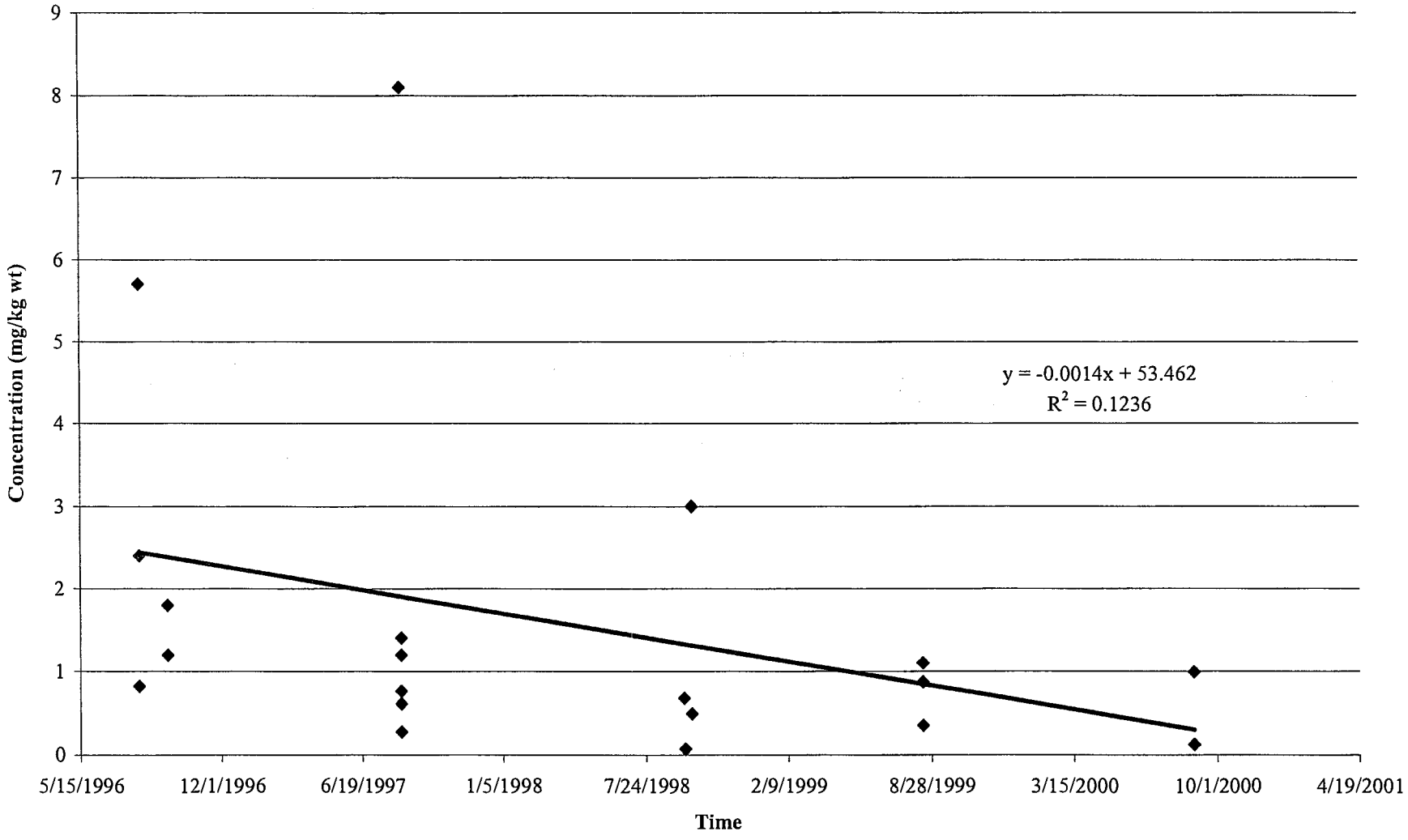
Wood Duck Liver Regression Analysis
Cadmium



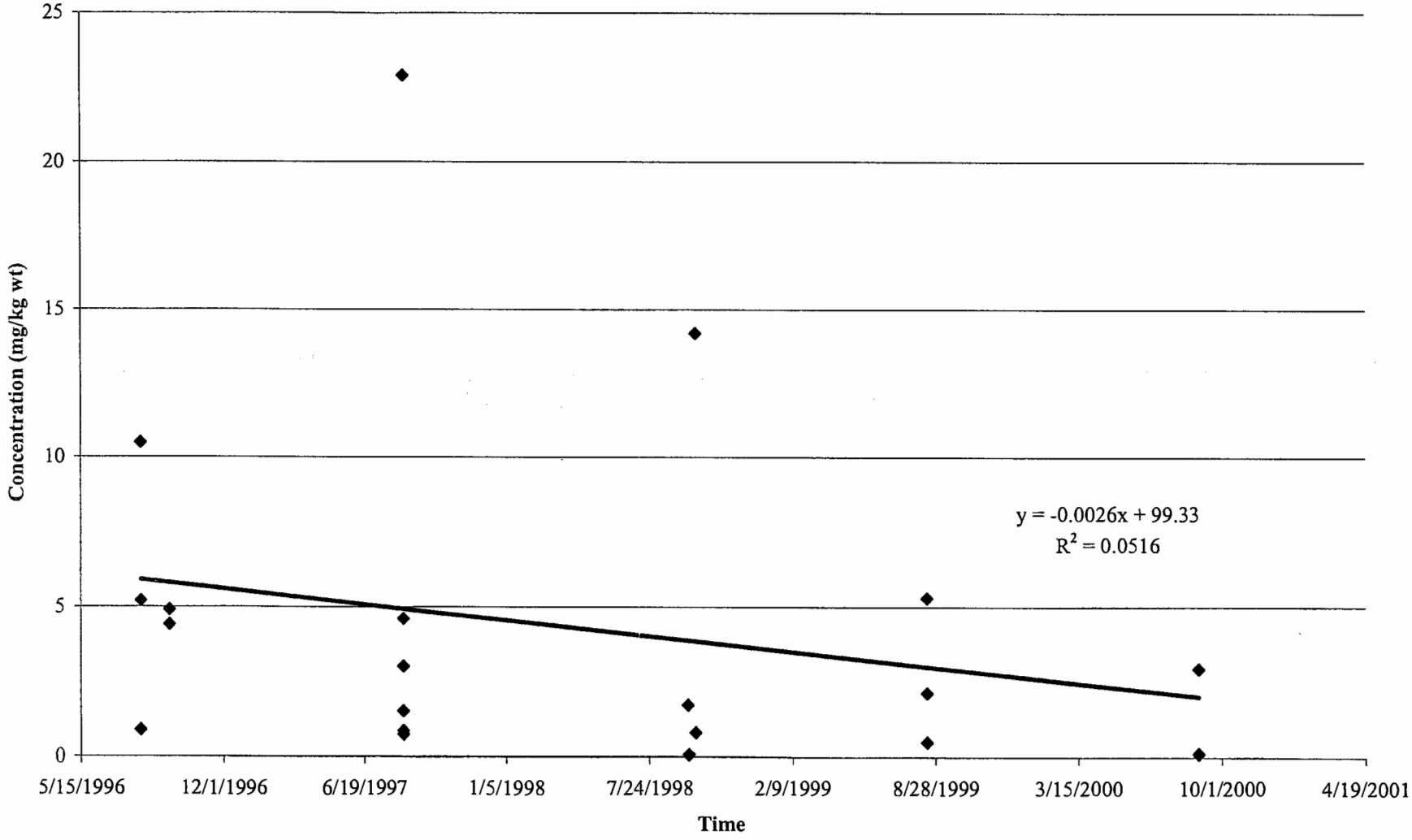
Wood Duck Kidney Regression Analysis
Cadmium



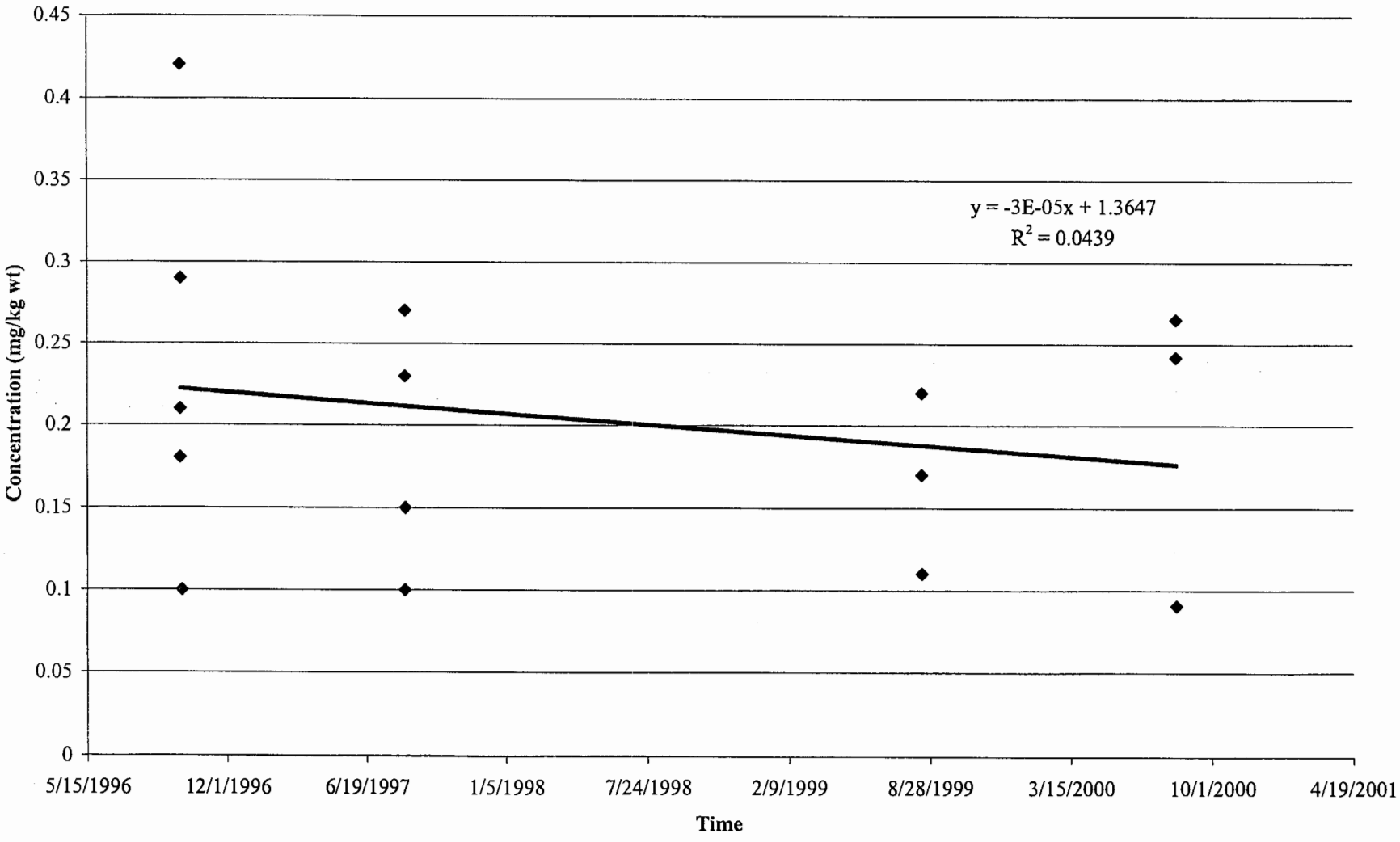
Canada Goose Liver Regression Analysis
Cadmium



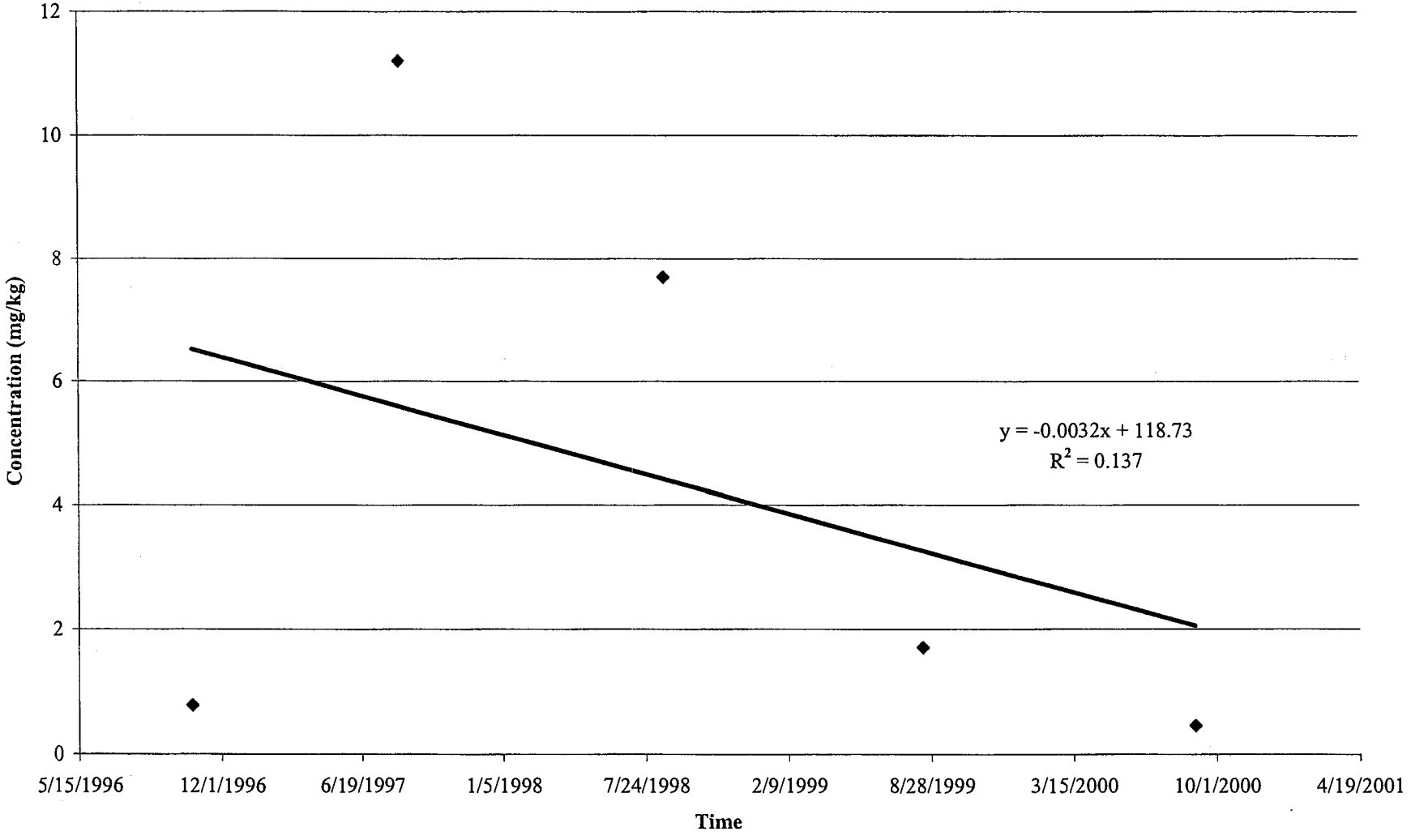
Canada Goose Kidney Regression Analysis
Cadmium



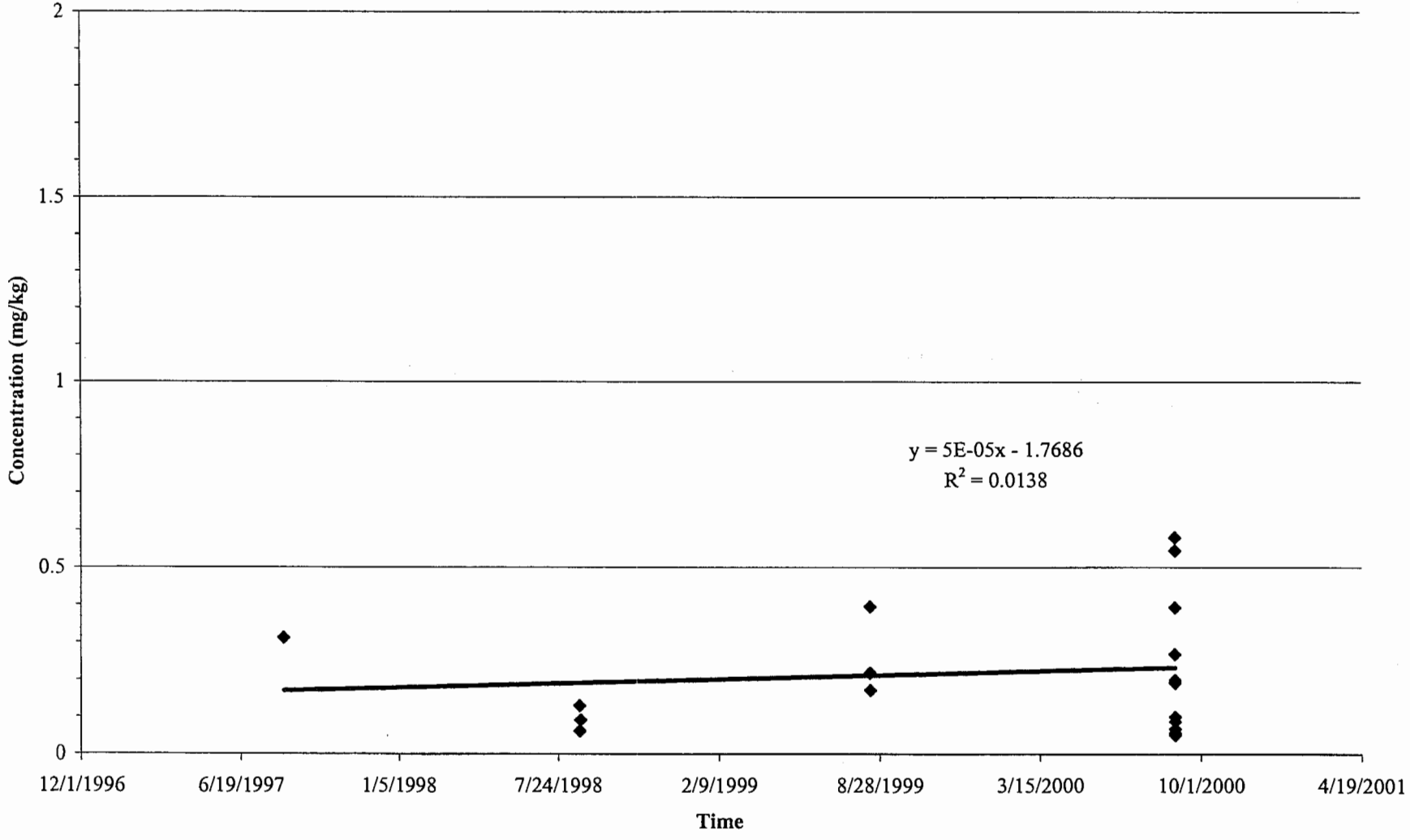
Swallow Regression Analysis
Cadmium



EFC Benthic Invertebrates Regression Analysis
Cadmium



Cattail Regression Analysis (EFCM)
Cadmium



Water Chestnut Regression Analysis (EFC)
Cadmium