FINAL REPORT

for

MODELING OF THE TRANSPORT, DISTRIBUTION, AND FATE OF PCBs AND HEAVY METALS IN THE ACUSHNET RIVER/ NEW BEDFORD HARBOR/BUZZARDS BAY SYSTEM

VOLUME III

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VOLUME III
TABLE OF CONTENTS

VOLUME III
LIST OF TABLES

VOLUME III
LIST OF TABLES
(Continued)

Page

VOLUME III
LIST OF TABLES
(Continued)

VOLUME III
LIST OF TABLES
(Continued)

VOLUME III
LIST OF TABLES
(Continued)

VOLUME III
LIST OF FIGURES

VOLUME III
LIST OF FIGURES
(Continued)

VOLUME III
LIST OF FIGURES
(Continued)

VOLUME III
LIST OF FIGURES
(Continued)

VOLUME III
LIST OF FIGURES
(Continued)

VOLUME III
LIST OF FIGURES
(Continued)

VOLUME III
LIST OF FIGURES
(Continued)

7.0 MODEL APPLICATION

7.1 INTRODUCTION

This chapter presents estimates of the long-term fate and transport of PCBs in the New Bedford Harbor system over a 10-year future period for a No-Action and various Remedial-Action scenario. Included are the following topics: long-term modeling procedure, interfacing of the physical/chemical and food chain models, No-Action scenario, sensitivity tests for the long-term modeling, procedures for modeling Remedial-Action simulations, descriptions of each Remedial-Action scenario, and the simulation results for each scenario. Each results section includes the results of the contaminant/sediment transport projections from the physical/chemical model simulations and the subsequent projections of the food chain model. The results within these sections generally compare each remedial scenario with No-Action. Also included for both models is a comparitive analysis section that examines the results from all of the remedial scenarios in relation to No-Action.

It is important to recall that a rigorous validation of the physical/chemical model was not possible, because synoptic field data collected over a several-year period were lacking. In addition, inherent in the simulation results are the effects of uncertainties in the underlying assumptions and physics included in the numerical model, model parameters, and field data used to assign initial and boundary conditions. Therefore, it is recommended that the model results be used in a comparative sense, to determine the relative effectiveness of one scenario versus another.

7.2 LONG-TERM MODELING PROCEDURES

7.2.1 Sediment/Contaminant Transport

The TEMPEST/FLESCOT (physical/chemical) model is computationally intensive--even decoupled simulations need several hours of Cray processor time to complete. The sediment/contaminant transport computations involve the solution of seven partial differential equations, with boundary conditions and routines that account for mass exchange with the bed layer. These calculations require a large amount of computer time; for example, the 95-day decouple calibration simulations (Section 5.6) required approximately 5 hours of processor time on a Cray-XMP supercomputer. For obvious economic reasons, the model was not run, even in the decoupled mode, continuously for a 10-year simulation period to calculate the long-term PCB fate. Therefore a method to extrapolate the simulation results over the 10-year future period was developed.

The work of McAnally et al. (1988) demonstrated that a linear extrapolation of the sedimentation rates computed by a two-dimensional sediment transport model could yield reasonable long-term results. Their procedure superimposed statistically representative hydrodynamic conditions to generate estimates of the growth of a river delta. The idea of using a linear extrapolation was the basis of the procedure implemented in this study to estimate the long-term fate of PCBs. For each 5-stage, 95-day simulation series (see Figure 5.72), the rate of mass change in each bed layer cell is computed. The rate of change is calculated by taking the difference of the bed-cell sediment and contaminant mass between the ends of stages 3 and 5 and dividing by the time difference. Using this rate of change, the mass of sediments and contaminant in each bed cell is extrapolated forward using a 2-year time step. This process is limited by the available mass in each cell if the rate of change is negative (mass decreasing). The extrapolated bed conditions define a new initial bed condition for the next 95-day simulation. This scheme is repeated until the 10th year is reached. Simulations for years 0, 2, 4, 6, 8, and 10 are computed using this scheme. In a given simulation scenario, the model parameters, e.g., K_d values, are held constant for each step, and the open-boundary conditions are not varied from year to year.

7.2.2 Interfacing of the Physical/Chemical and Food Chain Models

Spatial Resolution

Projections of the PCB response of the flounder and lobster and their food chains to the various remedial alternatives were determined by coupling the calibrated food chain model with the calibrated physical/chemical model. This coupling or interfacing required that differences in spatial resolution be accommodated by averaging the concentrations computed by the physical/chemical model over the segments that lie within each spatial compartment or Area of the food chain model. Because the physical/chemical model does not extend into the region of Buzzards Bay designated as Area 4 in the food chain model, averaging and subsequent projections of food chain response were restricted to Areas 1, 2 and 3 (see Figure 7.1). These areas correspond to Box Numbers 4,5 and 6, respectively in the averaging scheme used for reporting the results of the physical/chemical model (see Figure 7.2).

A direct interfacing of models was not possible for Area 3 because this area includes a portion of Buzzards Bay that is not included in the physical/chemical model. Thus the average concentration obtained from the physical/chemical model may not accurately reflect conditions over this area.

An indication that this difference in spatial averaging may be important is that the water column-dissolved PCB concentrations assigned as initial conditions to the segments of the physical/chemical model included in Area 3 were somewhat higher than the value used in the calibration of the food chain model. The average over these segments is 10.4 ng/L, whereas the value obtained from the Battelle Cruise data (see Section 6.2.3.2) and used in the food chain model calibration was 2.6 ng/L.

As a consequence of this difference in concentration, the projected response of the Area 3 food chain to the exposure concentration profile computed by the physical/chemical model includes an initial increase as the food chain

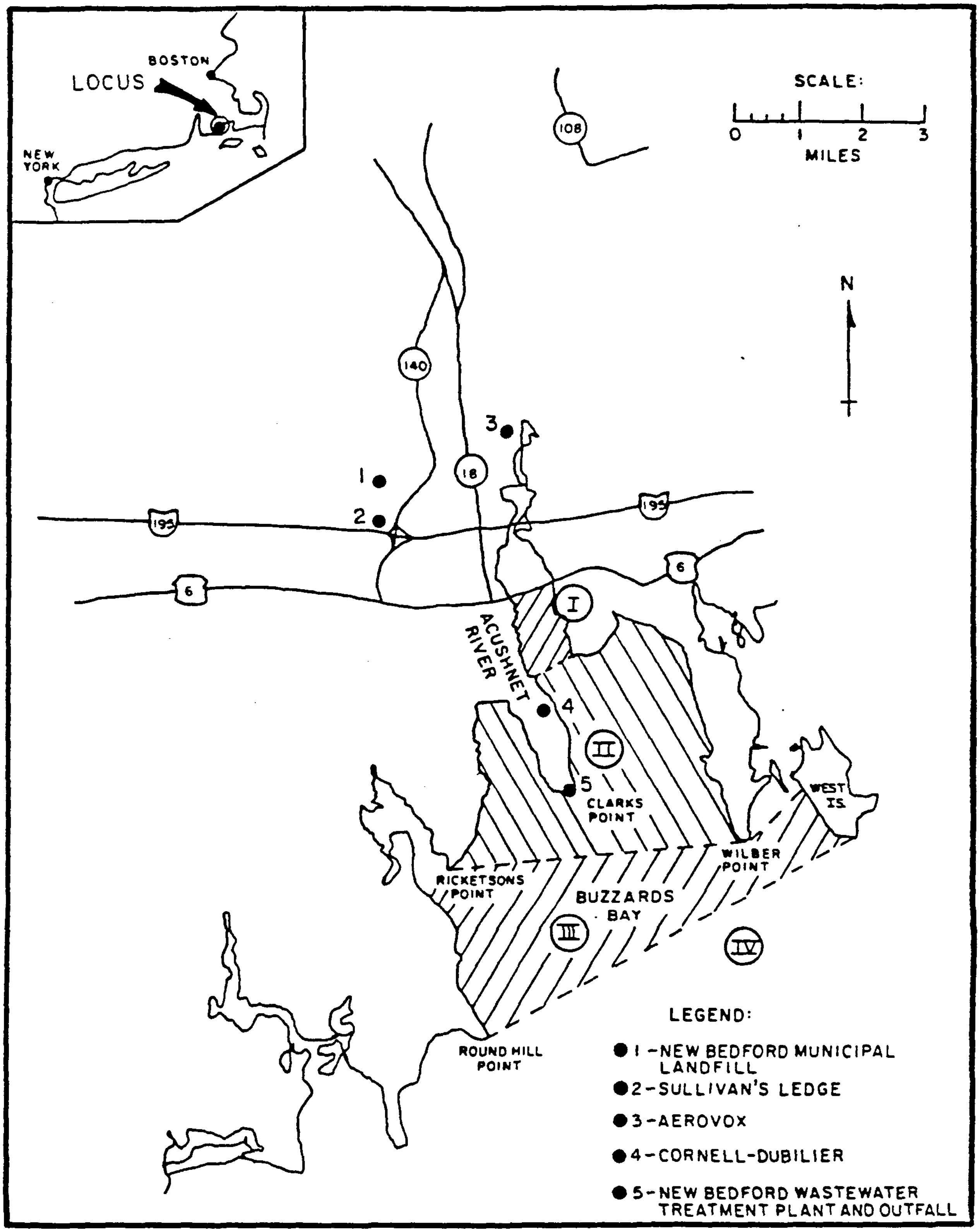


FIGURE 7.1. FOOD CHAIN MODELED AREAS

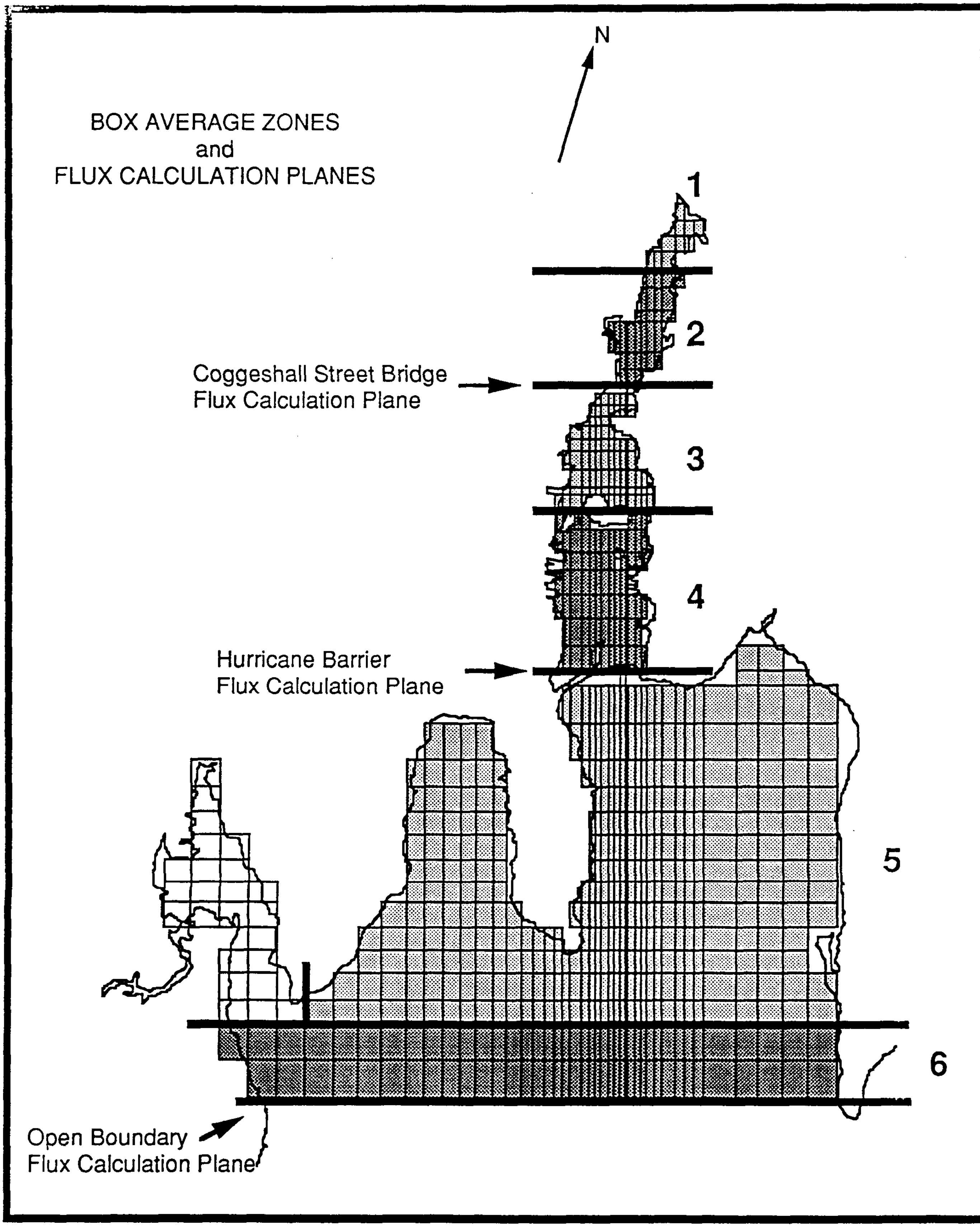


FIGURE 7.2. TEMPEST/FLESCOT BOX-AVERAGING ZONES AND FLUX CALCULATION PLANES

equilibrates with the higher exposure concentrations. Consequently, projections for Area 3 cannot be evaluated in absolute terms and the discussion of results for individual remedial alternatives is restricted to Areas 1 and 2. However, the projections for Area 3 retain value in the evaluation of the relative impact of the various remedial alternatives, and they are discussed in these terms.

Temporal Resolution

The area averages of projected water column dissolved PCB concentrations and sediment particulate PCB concentrations are the exposure concentrations for the food chain model. The ten year concentration time history for each area was composited into two year averages to form the concentration profile for the food chain model.

Conversion of Sediment Concentrations

Coupling of the two models also required conversion of the sediment PCB concentration from a sediment dry weight basis (as computed by the physical/chemical model) to an organic carbon weight basis (as used by the food chain model). Area specific conversion factors were obtained from the concentrations used in the calibration of both models. These concentrations were determined from field data and their ratio is an estimate of the fraction organic carbon (foc) of the sediment solids. Using values for dry weight PCB concentration, obtained by averaging the values from the physical/chemical model over Areas 1,2 and 3 of the food chain model, yielded the following values for sediment foc; 0.022 in Area 1, 0.023 in Area 2 and 0.037 in Area 3.

Projected Biota Concentrations

As PCB concentrations in the water column and sediment decline in response to remediation the concentrations in the biota will also decline. The relationship between the exposure concentrations and the biota concentrations at any time will be dependent on whether the species has been assumed to be at steady-state.

The lower levels of the food chain are assumed to be in equilibrium with exposure concentrations. Concentration changes in these animals will be in direct proportion to changes in water column (clams and mussels) or sediment (polychaetes) PCB concentrations, or both (crabs).

The decline in flounder and lobster PCB concentrations will ultimately be equivalent to the decline in exposure concentration. They will, however, lag the water and sediment due to the relatively slow rates of depuration of accumulated PCB. In addition, the extent of decline will be dependent on the relative contribution of water column and sediment PCB to their body burdens since these PCB sources decline at different rates.

In addition to the projections and discussions of the effect of each alternative on biota PCB concentrations in flounder and lobster, the responses of the lower levels of the food chain in the regions of the study area not included in the development and calibration of the food chain model are also presented.

Because no biota data were collected north of Pope Island the food chain model was not directly applied to the most contaminated regions of the study area. However, it is desirable that some estimate of how biota in these regions would respond to the remedial actions be determined. To accomplish this the calibrated food chain model was used to project biota concentrations at steady- state with the water column and sediment PCB concentrations in the regions designated as Boxes 1,2 and 3. These values represent estimates of the concentrations to be expected in each species of the food chain after prolonged continuous exposure to the PCBs in a particular region. It must be recognized that these values come from an extrapolation of the model to concentration levels for which it was never calibrated. Such an extrapolation is reasonable so long as the higher concentrations do not cause physiological effects that alter the bioenergetic parameter values specified in the model.

Since some or all of the species included in the model do not now reside in the most impacted areas of the upper harbor these calculations are hypothetical. However, improvements in water quality that result from remediation may allow some of the species to enter these areas.

7.3 NO-ACTION SCENARIO

7.3.1 Sediment/Contaminant Transport Results: No-Action

The No-Action scenario is the continuation of the 95-day calibration simulation described in Section 5.6.2. The long-term modeling procedure was applied to compute the results for years 2, 4, 6, 8, and 10. The results for year 0 of the No-Action scenario are identical to the calibration case. The same hydrodynamic conditions, boundary conditions, and model parameters were used in each 95-day simulation set.

Figures 7.3 through 7.6 compare the time-averaged water column simulation results for suspended sediment and total PCBs with the BOS field data. In these figures, the x axis is the distance from the northern end of the computational domain south along the grid axis, and the y-axis values are the time-series output locations (shown in Figure 5.46) nearest to this axis. The trend of the field data, decreasing PCB concentrations in the downstream direction from Wood Street bridge, is reproduced in the no-action year 0 results. By the end of the 10-year simulation, the water column PCB concentration has fallen by roughly 40% over most of the study area. A detailed picture of the spatial distribution of PCBs in the water column is given by contour plots of the depth-averaged PCB concentration (Figures B.1a through B.1f of Appendix B). These figures were made by depth-averaging the 3-dimensional model results.

The concentration of PCBs sorbed to bed sediments is shown in contour plots (Figures C.1a through C.1i of Appendix C) to decrease and redistribute from year 0 to year 10. By year 10 the PCB concentration in the hot-spot area (Figure C.1b and C.1c) has decreased significantly, but the concentration has increased in some areas toward Coggeshall Street Bridge. The effect of sediment scour on the bed-layer PCB concentration is evident in Figure C.1.c, where the area of low concentration corresponds to an area where fine sediments (silt and clay) have eroded away.

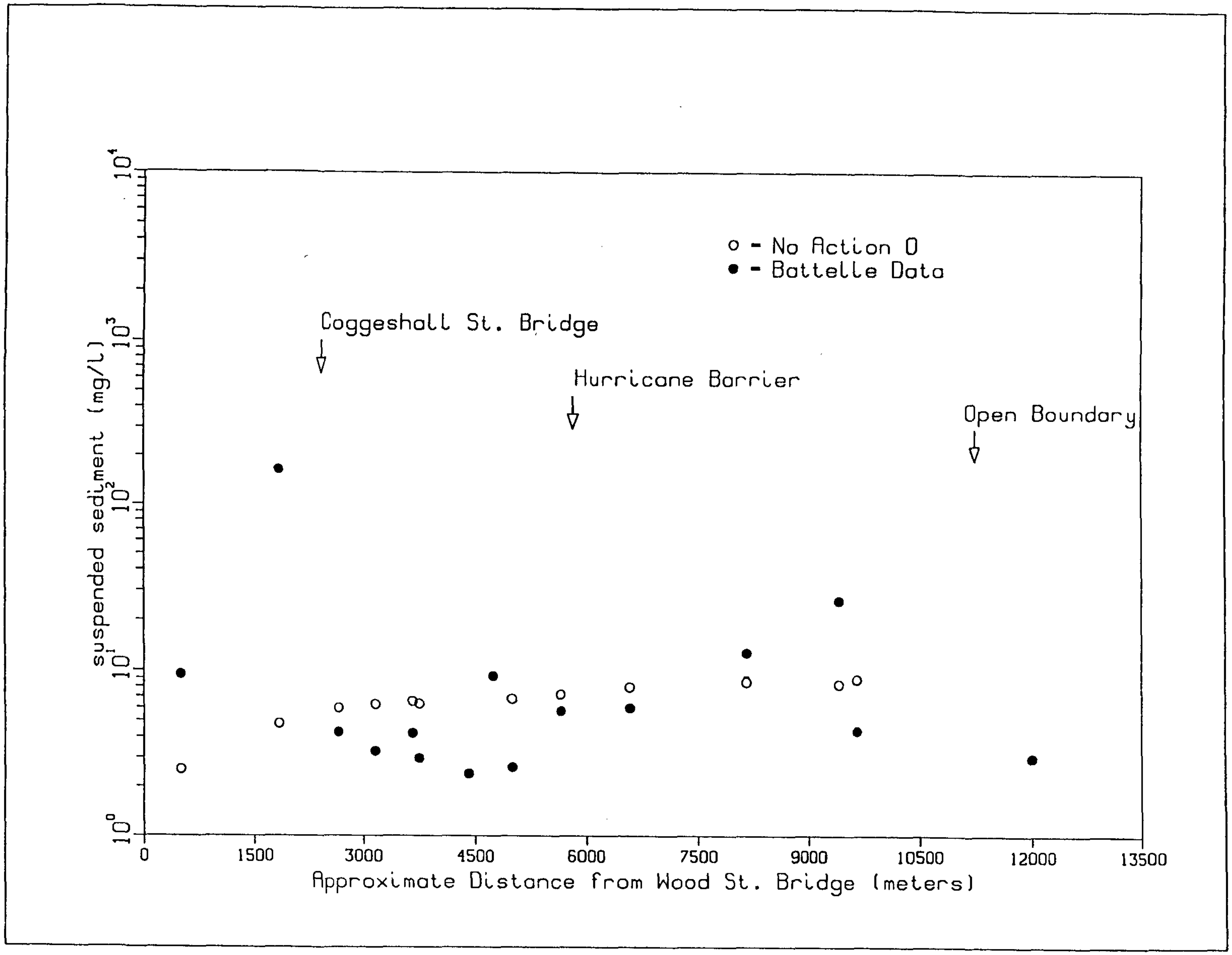


FIGURE 7.3. **AVERAGE CONCENTRATION OF SUSPENDED SEDIMENTS FOR YEAR 0 OF THE NO-ACTION SCENARIO (mg/L)**

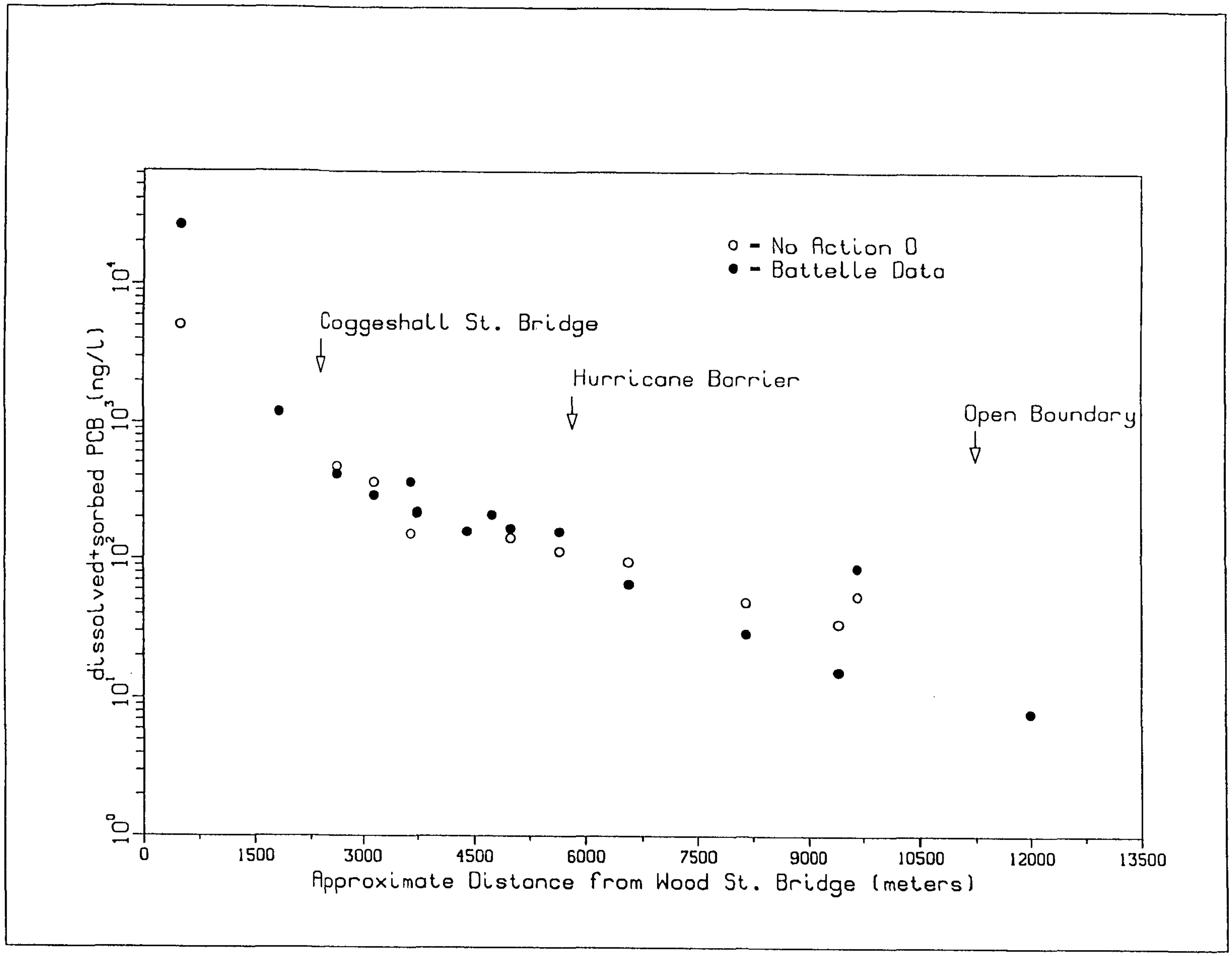


FIGURE 7.4. **AVERAGE CONCENTRATION OF TOTAL PCBs FOR YEAR 10 OF THE NO-ACTION SCENARIO (ng/L)**

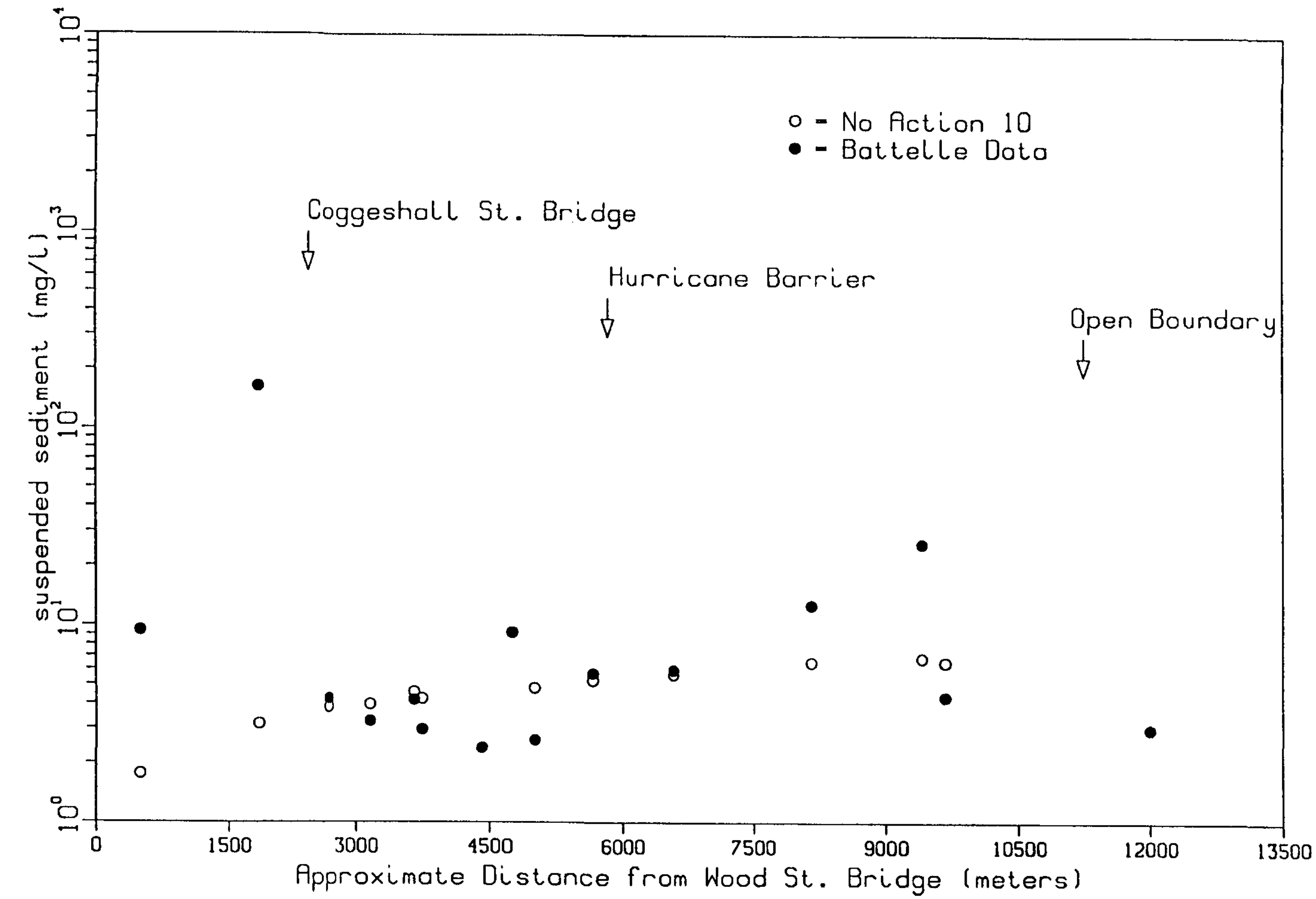


FIGURE 7.5. **AVERAGE CONCENTRATION OF SUSPENDED SEDIMENTS FOR YEAR 10 OF THE NO-ACTION SCENARIO (mg/L)**

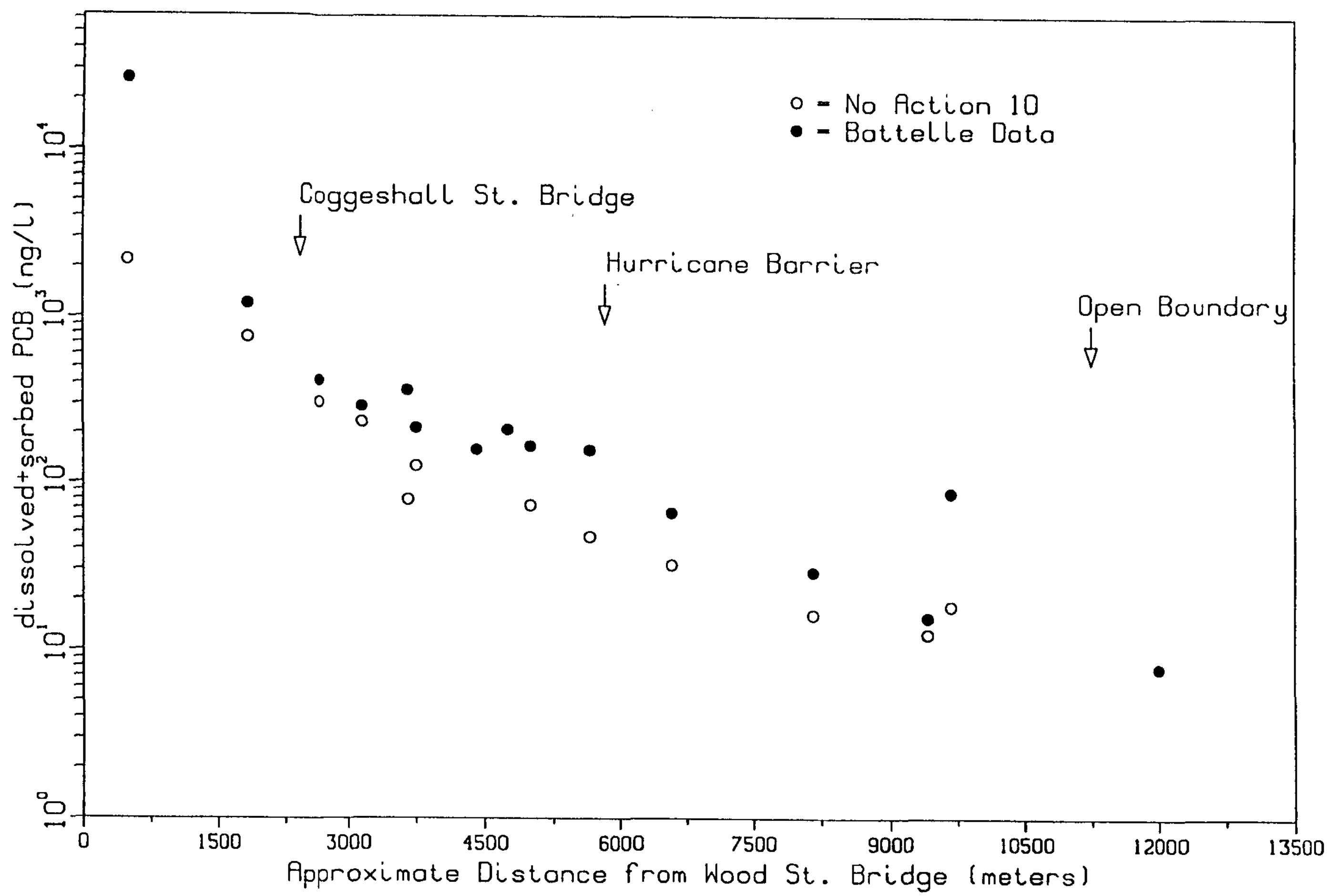


FIGURE 7.6. **AVERAGE CONCENTRATION OF TOTAL PCBs IN THE WATER COLUMN FOR YEAR 10 OF THE NO-ACTION SCENARIO (ng/L)**

The net flux of sediments and PCBs were computed at Coggeshall Street Bridge, the Hurricane Barrier, and model open boundary for the year 0 and year 10 simulations (Table 7.1).

A negative flux direction is out of the system toward Buzzards Bay. Suspended sediments are being transported up-estuary, toward Wood Street Bridge, through both the Coggeshall Street Bridge and the Hurricane Barrier, throughout the long-term simulation period. Because of uncertainties in assigning intial bed sediment distributions based on limited data, a greater volume of sediments in Year 0 are eroded and transported out of the model domain than are transported in through the open boundary. This causes a net flux of sediments out of the model in Year 0. However, by year 10 the flux direction has reversed, because the model has reached an equilibrium condition between sediments eroded from and deposited to the bed layer and those transported across the open boundary. Thus, there is a net importation of sediments from outside the model domain, as was noted by Summerhayes, et al (1977). The flux of PCBs is out of the system towards Buzzards Bay in both years 0 and 10. It is significant that the flux of PCBs through Coggeshall Street Bridge and the Hurricane Barrier remains approximately the same in years 0 and 10. The flux through the open boundary has decreased in response to the decrease in concentration of PCBs in the bed sediments outside the Hurricane Barrier and to the reversal in the suspended-sediment flux across the open boundary.

TABLE 7.1. NET FLUX (kg/TIDAL CYCLE) OF SEDIMENTS AND PCBs FOR THE YEAR 0 AND YEAR 10 NO-ACTION SCENARIO SIMULATIONS

	Coggeshall Street Bridge	Hurricane Barrier	Open Boundary
Year 0 Sediment Flux	446	1.546×10^3	-2.4641×10^4
Year 10 Sediment Flux	282	2.120×10^3	2.4968×10^4
Year 0 PCB Flux	-0.22	-0.15	-1.32
Year 10 PCB Flux	-0.20	-0.11	-0.30

The contour plots of the spatial distribution of PCBs are useful for examining the details of the simulation results, but it is difficult to discern large-scale trends from that type of presentation. To assist in the interpretation of the simulation results, the computed values in each model grid cell were averaged over large boxes. The box-averaged model results for each of the six boxes shown in Figure 7.2 are tabulated in Appendix A. As was done in the discussion of the calibration results (Section 5.6.2.5), the model results are divided into three primary regions: the upper-estuary region, represented by boxes 1 and 2, the lower-harbor region, represented by boxes 3 and 4, and the outer harbor, consisting of the area between the Hurricane Barrier and the open boundary.

Figure 7.7 shows the box-averaged water column total-PCB concentration for each 2-year interval. The PCB concentration in box 1 is decreasing continuously from year 0 to year 10. The concentrations in the other boxes generally decrease from year 0 to year 6 and then approach an equilibrium condition. Results from box 6 are not plotted because of its proximity to the open boundary.

The changes in the PCB water column concentration are driven by the changes in PCB levels in the bed layer. Box 1, which contains the hot-spot area, shows a steady decline in concentration over the 10-year simulation (Figure 7.8). A similar trend is occurring in boxes 2, 3, and 5. The steep decline in box 5 may be from overestimating the initial PCB concentration in the seabed outside of the Hurricane Barrier. The concentration change in box 5 is from 3.7 in year 0 to 1.3 ppm in year 10. Contour plots of sediment and water column PCB levels projected at the end of year 10 are presented in Figures 7.9 and 7.10 respectively.

The mass balance information in Tables 7.2 through 7.7 show the changes in sediment and PCB concentrations in the water column and bed layer. As noted earlier, the upper-estuary and lower-harbor are depositional zones for sediments. The average concentration in the upper-estuary bed layer has decreased from 390 ppm to 273 ppm by year 10. Volatilization is apparently

TABLE 7.2. SEDIMENT MASS BALANCE IN THE UPPER-ESTUARY FOR THE YEAR 0 AND YEAR 10 NO-ACTION SIMULATIONS

	Year 0	Year 10	Change
Water Column Mass (kg)	4.442×10^3	3.101×10^3	-1.341×10^3
Bed Layer Mass (kg)	4.980×10^7	5.233×10^7	2.53×10^6
Water Column Concentration (mg/L)	3.1	2.2	-0.90

TABLE 7.3. PCB MASS BALANCE IN THE UPPER-ESTUARY FOR THE YEAR 0 AND YEAR 10 NO-ACTION SIMULATIONS

	Year 0	Year 10	Change
Water Column Mass (kg)	2.9	1.6	-1.3
Bed Layer Mass (kg)	1.9430×10^4	1.4270×10^4	-5.160×10^3
Water Column Concentration (ng/L)	2.011×10^3	1.107×10^3	-904
Bed Layer Concentration (mg/kg)	390	273	-117

TABLE 7.4. SEDIMENT MASS BALANCE IN THE LOWER-HARBOR FOR THE YEAR 0 AND YEAR 10 NO-ACTION SIMULATIONS

	Year 0	Year 10	Change
Water Column Mass (kg)	8.0460×10^4	5.9450×10^4	-2.1010×10^4
Bed Layer Mass (kg)	1.658×10^8	1.794×10^8	1.36×10^7
Water Column Concentration (mg/L)	5.2	3.8	-1.4

TABLE 7.5. PCB MASS BALANCE IN THE LOWER-HARBOR FOR THE YEAR 0 AND YEAR 10 NO-ACTION SIMULATIONS

	Year 0	Year 10	Change
Water Column Mass (kg)	2.6	1.6	-1.0
Bed Layer Mass (kg)	1.733×10^3	1.373×10^3	-360
Water Column Concentration (ng/L)	169	104	-65
Bed Layer Concentration (mg/kg)	11	8	-3

TABLE 7.6. SEDIMENT MASS BALANCE IN THE OUTER HARBOR FOR THE YEAR 0 AND YEAR 10 NO-ACTION SIMULATIONS

	Year 0	Year 10	Change
Water Column Mass (kg)	9.654×10^5	8.511×10^5	-1.143×10^5
Bed Layer Mass (kg)	1.523×10^9	1.627×10^9	1.04×10^8
Water Column Concentration (mg/L)	6.0	5	-1

TABLE 7.7. PCB MASS BALANCE IN THE OUTER HARBOR FOR THE YEAR 0 AND YEAR 10 NO-ACTION SIMULATIONS

	Year 0	Year 10	Change
Water Column Mass (kg)	5.3	2.1	-3.2
Bed Layer Mass (kg)	4.674×10^3	1.67×10^3	-2.094×10^3
Water Column Concentration (ng/L)	33	13	-20
Bed Layer Concentration (mg/kg)	3	1	-2

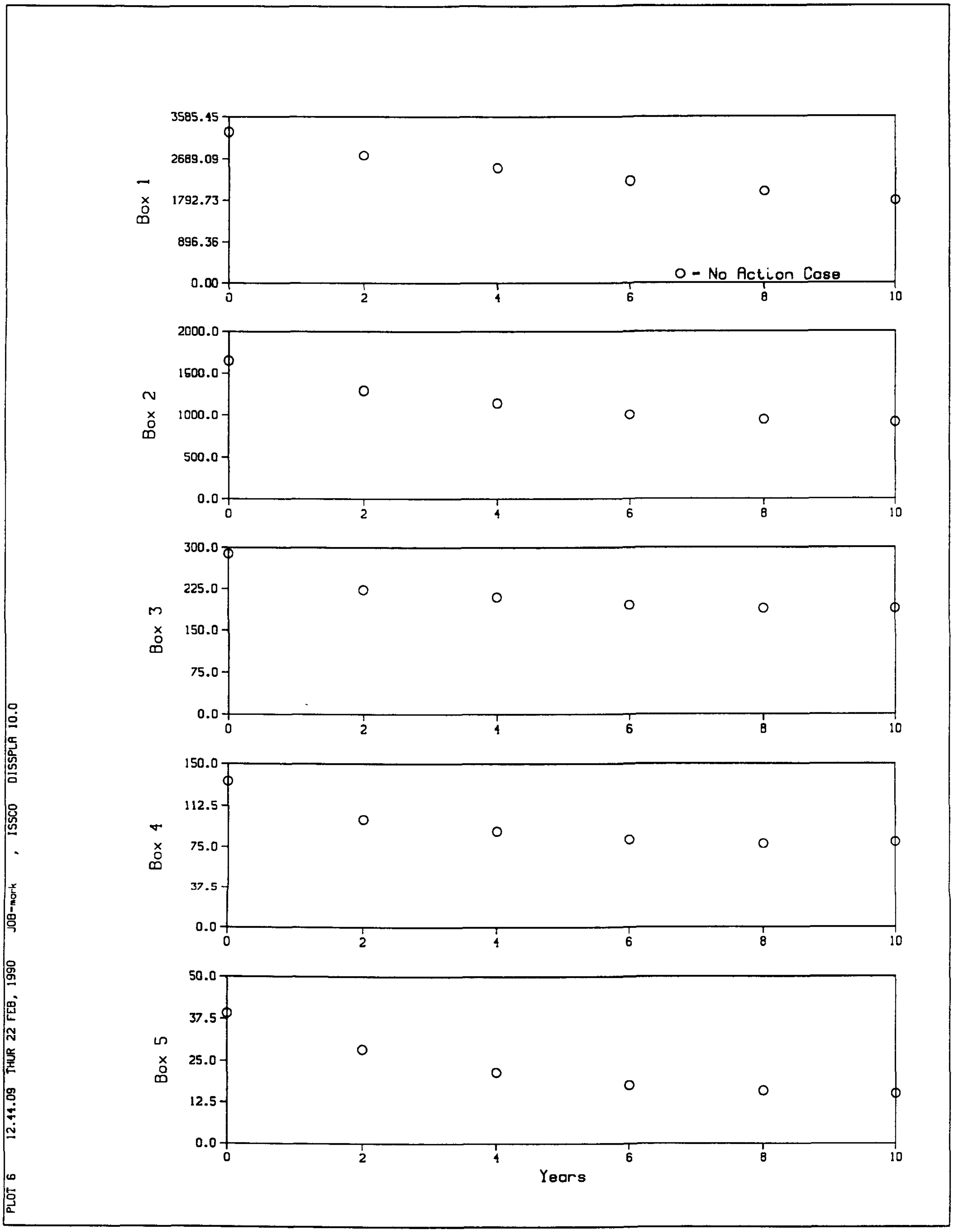


FIGURE 7.7. BOX-AVERAGED MODEL RESULTS FOR THE NO-ACTION SCENARIO TOTAL PCB CONCENTRATION IN THE WATER COLUMN (ng/L)

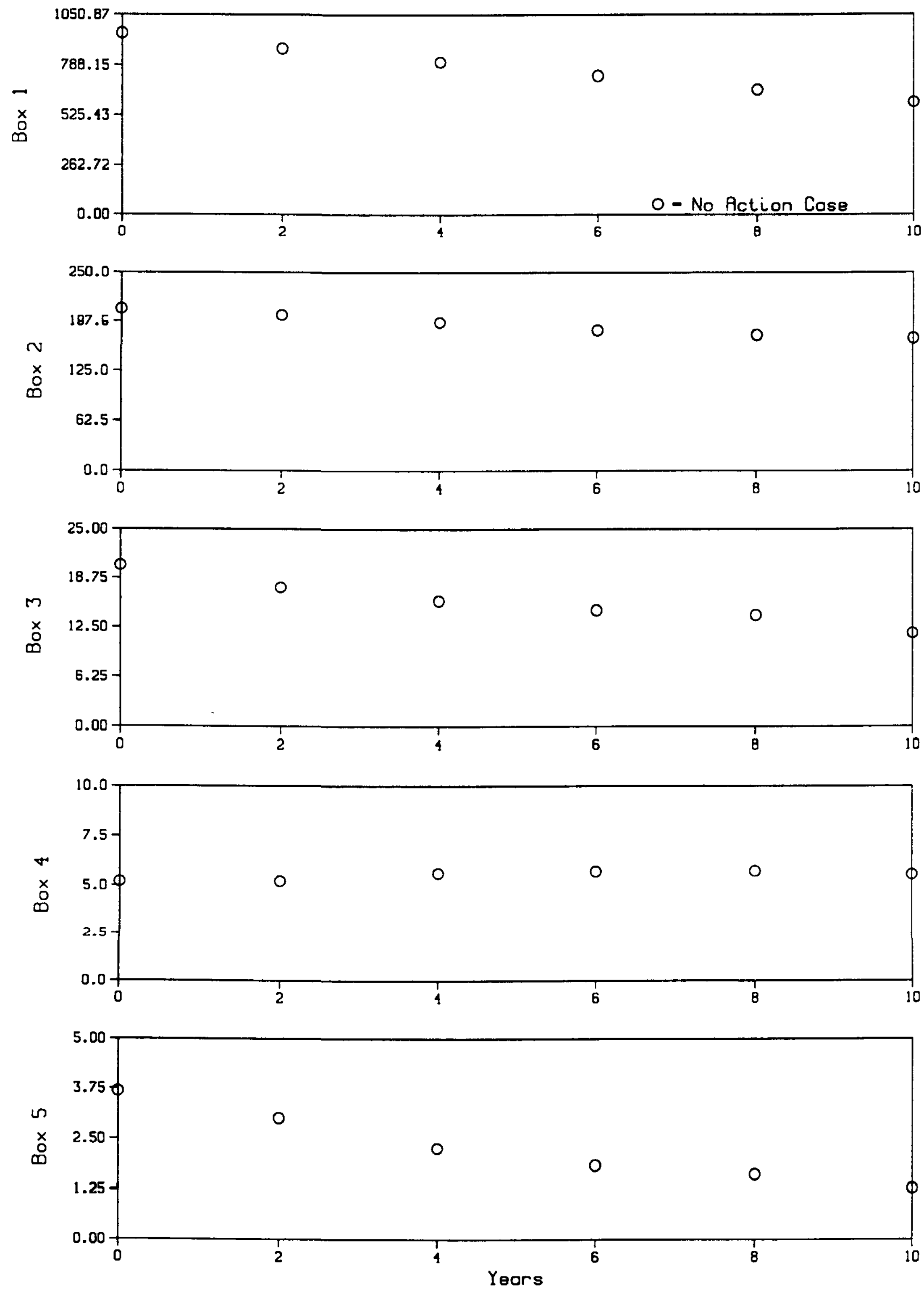


FIGURE 7.8. BOX-AVERAGED MODEL RESULTS FOR THE NO-ACTION SCENARIO TOTAL PCB CONCENTRATION (mg/kg) IN THE BED SEDIMENT LAYER

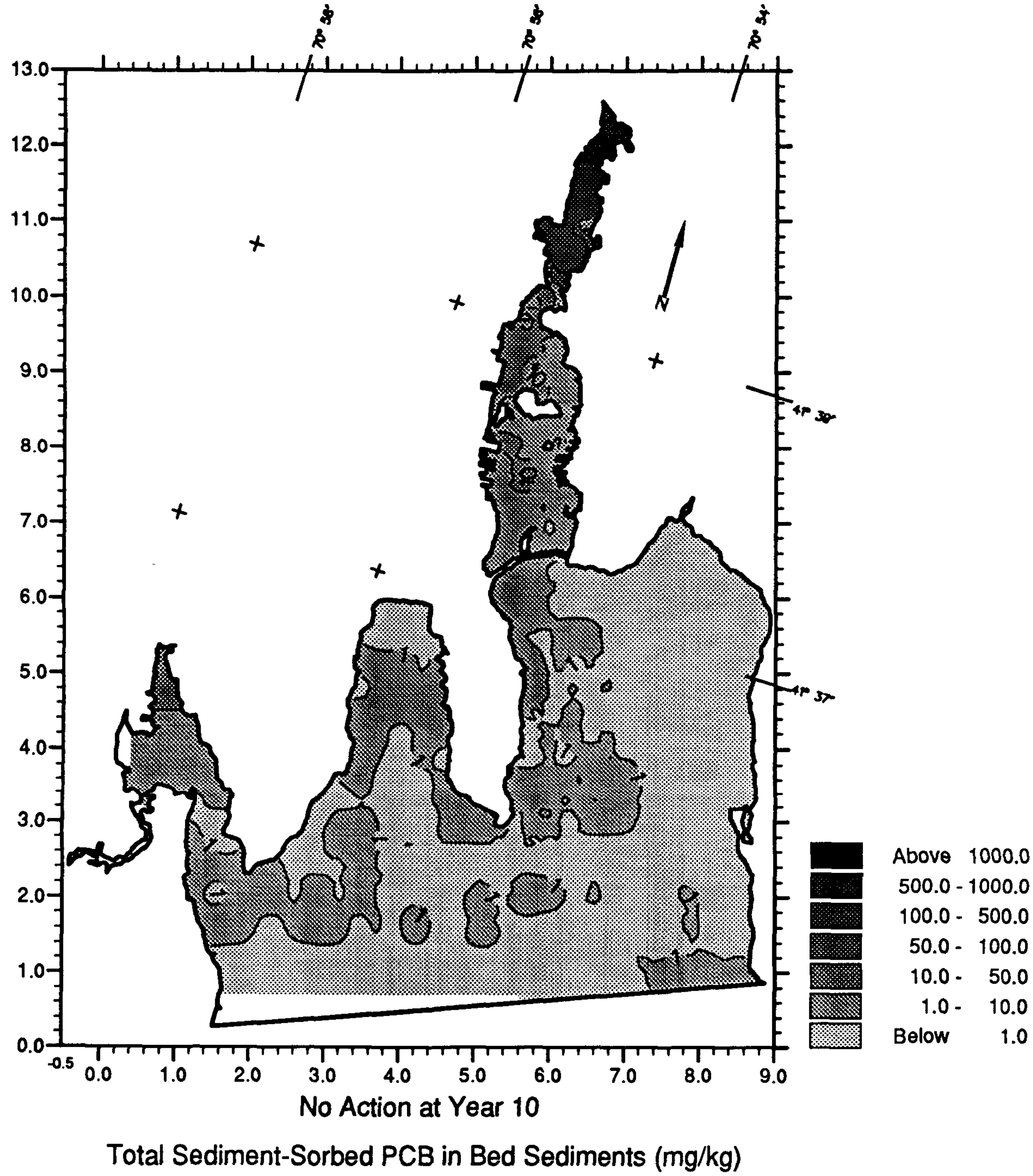


FIGURE 7.9. TOTAL BED SEDIMENT-SORBED PCB LEVELS FOR THE NO-ACTION SCENARIO AT YEAR 10, TOTAL SEDIMENT-SORBED PCB (mg/kg)

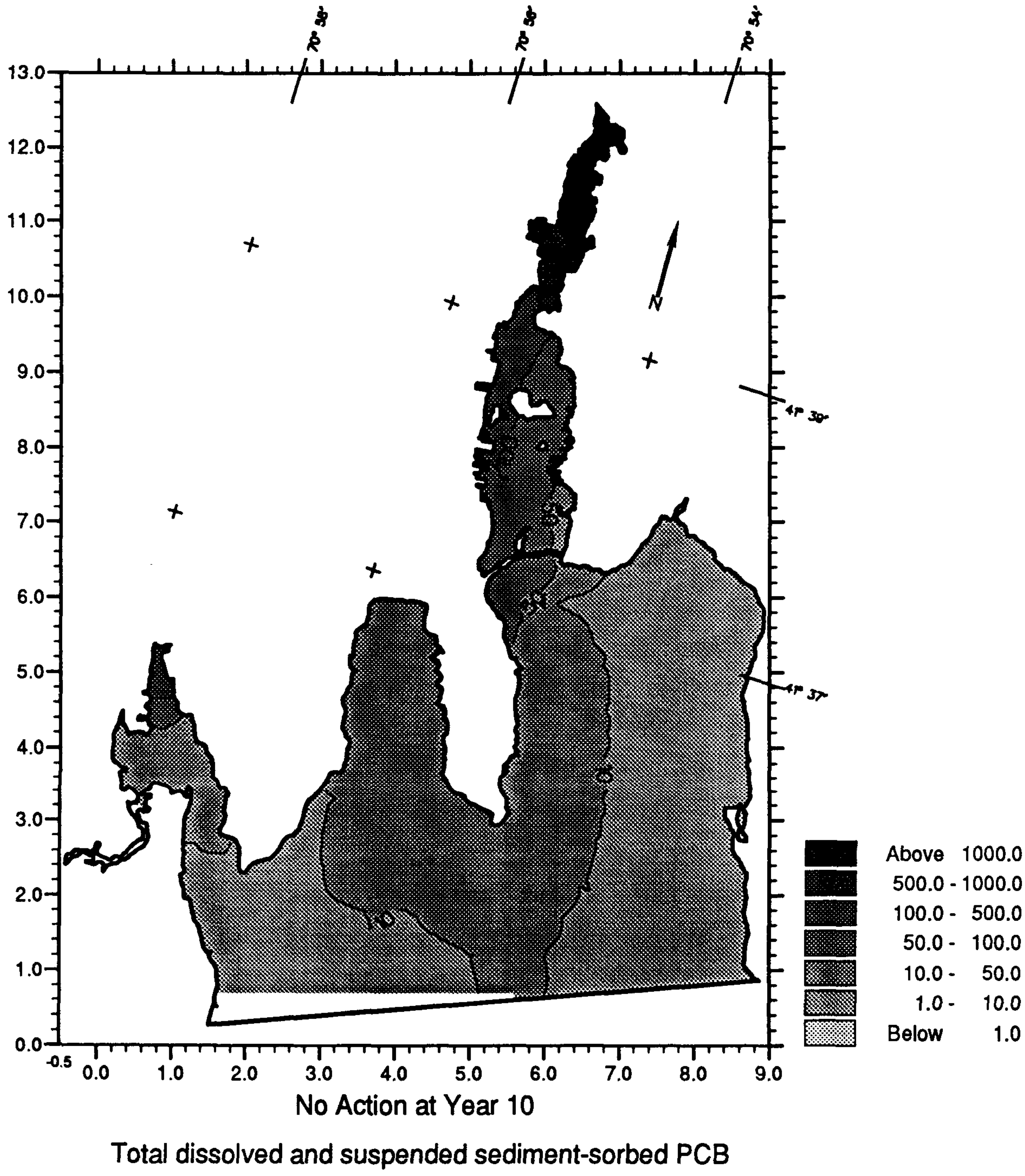


FIGURE 7.10. DEPTH-AVERAGED TOTAL WATER COLUMN PCB LEVELS FOR THE NO-ACTION SCENARIO YEAR 10, TOTAL DISSOLVED AND SUSPENDED SEDIMENT-SORBED PCB (ng/L)

the dominant transport process for PCBs in the upper-estuary. Using the average of the year 0 and year 10 net flux rates given in Table 7.1 and assuming the flux to remain constant over the 10-year period yields a mass loss of 1481 kg, or 148 kg per year, from the upper-estuary through net flux through Coggenshall St. bridge. Over the same time period the mass lost from the bed layer is 5160 kg (Table 7.3), or 516 kg per year. Therefore, approximately 3679 kg, or 368 kg per year, left the system through volatilization. The lower-harbor and the outer-harbor show similar trends of sediment deposition and declining PCB concentrations.

7.3.2 Food Chain Model Results: No-Action

7.3.2.1 Exposure Concentrations

In all areas water column exposure concentrations decline in exponential fashion under no-action. The exposure profile for the No-Action scenario (Table 7.8) illustrates the greatest declines occur in Areas 2 and 3 where concentrations drop by 58% and 54%, respectively. In Area 1 the water column concentration decreases by only 29%. As discussed earlier, the food chain model Areas 1, 2 and 3 correspond to the physical/chemical model box-averaged zones 4, 5 and 6.

The decreases in sediment PCB shown in Table 7.8 are somewhat different from that in the water column. While the 65% drop in Area 2 is consistent with the water column, the 30% decline in Area 3 is about one-half that projected for the water column. In Area 1 sediment concentrations are projected to remain approximately constant over the ten year period, whereas water column concentrations decreased significantly. This constancy is unique to Area 1. In the region of the Inner Harbor above Area 1 concentrations decline in similar fashion to the Outer Harbor and Bay; 38% in the region of the Aerovox Plant (i.e., Box #1), 19% between the Aerovox area and the Coggeshall St. Bridge (i.e., Box 2) and 43% between the Coggeshall St. Bridge and Popes Island (i.e., Box #3).

TABLE 7.8. NO-ACTION EXPOSURE CONCENTRATIONS FOR FOOD CHAIN MODEL

	Area 1		Area 2		Area 3	
Year	Water Column[a]	Bed Sediment[b]	Water Column[a]	Bed Sediment[b]	Water Column[a]	Bed Sediment[b]
0	84.89	7.8	21.92	3.7	10.41	1.0
2	72.65	8.0	17.40	3.0	8.30	0.9
4	66.35	8.4	13.39	2.3	6.7	0.8
6	61.53	8.4	10.90	1.8	5.73	0.8
8	59.38	8.4	9.82	1.6	5.09	0.7
10	60.32	8.2	9.21	1.3	4.76	0.7

[a] Water column dissolved PCB (ng/L).
[b] Sediment PCB (mg/kg dry).

Differences in response between the water column and sediment are indicative of disequilibrium. Although such a condition may exist in New Bedford Harbor, it is probable that the model is reflecting uncertainty regarding PCB concentrations in the Harbor system at the start of the projections. This uncertainty results from limitations imposed by the availability of field measurements. In any event, the overall indication is a decline in contamination that will result in a decline in lobster and flounder body burden.

7.3.2.2 Baseline Biota Concentrations

For assessment of the effectiveness of the remedial-actions in reducing PCB concentrations in biota, the body burdens computed in the calibration were used as baseline or time zero values. Table 7.9 lists these values for each species in the lobster and flounder food chains and each of the six regions within the study area. The values shown for Boxes 4, 5 and 6 are the values resulting from the calibration of the model to the biota data in these regions. The values shown for Boxes 1, 2 and 3 are values projected if each

TABLE 7.9. COMPUTED BASELINE (1984-85) CONCENTRATIONS IN BIOTA (μg/g WET WEIGHT) FROM EACH OF THE SEGMENTS OF NEW BEDFORD HARBOR

Species	Box 1*	Box 2*	Box 3*	Box 4**	Box 5**	Box 6**
Phytoplankton	103	50	7.0	2.9	0.9	0.1
Polychaete	1030	233	24	9.4	4.1	0.7
Hard Clam	37	18	2.5	1.0	0.3	0.04
Mussel	105	50	7.0	2.9	0.9	0.1
Crab	181	62	8.0	3.2	1.1	0.15
Winter Flounder	436-787	123-196	15-22	6-8.5	2.2-3.5	0.3-0.5
Lobster	nc	nc	nc	nc	0.6-0.6	.08-.08

* Values projected from the 1984-85 observed water column and sediment PCB concentrations.
** Results of calibration of the food chain model to 1984-85 biota PCB concentrations.
Note:Boxes 4, 5 & 6 correspond to Areas 1, 2 & 3, respectively, of the *food chain model*.
NC: Not calculated.

7.3.2.3 Food Chain Model No-Action Scenario

Projected concentrations under the No-Action scenario for each age class of winter flounder and lobster in relation to time are presented in Figures 7.11 to 7.13 for Areas 1, 2 and 3 respectively. In Area 1 (Figure 7.11) the PCB concentration in flounder remains nearly constant ranging from about 6 μg/g in age class 1 to about 9 μg/g in age class 6. No projection is made for lobster since the calibration did not include lobster within the Inner Harbor. The response of the flounder reflects its direct tie to the sediment through consumption of sediment dwelling organisms (i.e., the polychaetes). It is obtaining almost all of its PCB through ingestion and is thus insensitive to the 30% drop in water column PCB occurring over the ten year projection.

The edible to whole body PCB ratio in flounder of 0.18 (see Section 6.2.3.4) translates the FDA Action Limit of 2 μg/g edible to 11 μg/g whole body. Thus the older flounder in Area 1 (age classes 3 through 6) are projected to remain close to the action limit.

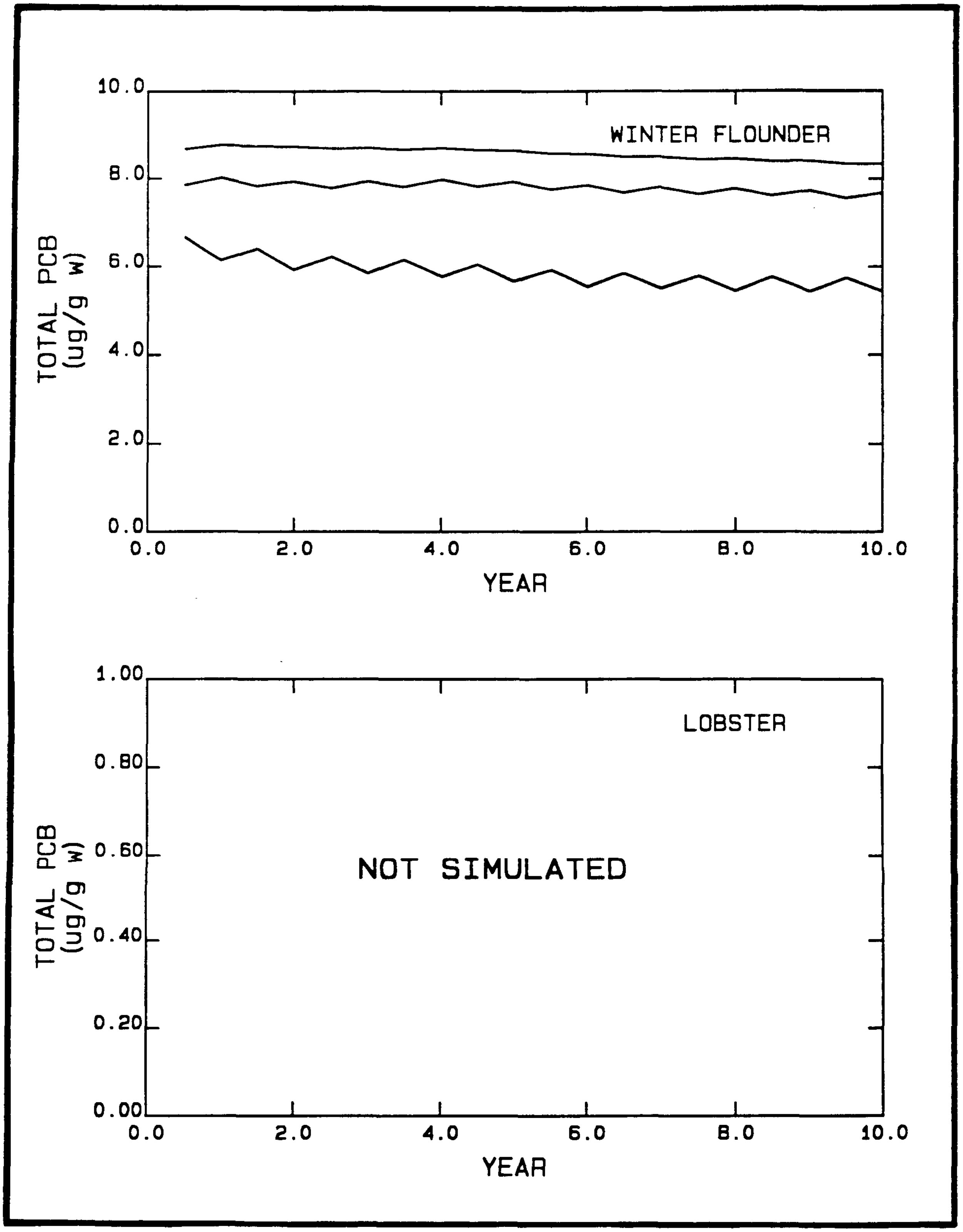


FIGURE 7.11. PCB CONCENTRATIONS IN AREA 1 FLOUNDER (AGES 0, 2, AND 5) IN RELATION TO TIME AFTER REMEDIATION FOR THE NO-ACTION SCENARIO

In Area 2 (Figure 7.12) a significant drop in concentration occurs in both the flounder and the lobster. At the end of the ten year period concentrations have declined about 60%, consistent with the water column and sediment declines.

The flounder in this area are well below the FDA Action limit even at the start of the projection. The whole body equivalent of the FDA limit for lobster is 0.22 μg/g. At the start of the projection lobster are at concentrations about three times the action limit. After 10 years they have reached levels very near the action limit. Note that the variation in concentration with age class is much less for the lobster than for the flounder, and that all of the age classes group near the action limit. This difference between the species reflects differences in bioenergetics.

Projected concentrations for the various biota after 10 years of no-action are presented below in Table 7.10. It is important to note that boxes 4, 5 and 6 correspond to Areas 1, 2 and 3 of the food chain model and represent model projections, whereever, boxes 1 through 3 represent steady state exposure conditions for biota in the northern area of the site that may or may not exist there at the present time. A comparison of the no-action estimates for these regions with the baseline values indicates that very little change is expected to occur over the 10 year period.

TABLE 7.10. COMPUTED CONCENTRATIONS IN BIOTA (μg/g WET WEIGHT) FROM EACH OF THE SEGMENTS OF NEW BEDFORD HARBOR 10 YEARS AFTER NO-ACTION

Species	Box 1*	Box 2*	Box 3*	Box 4**	Box 5**	Box 6**
Phytoplankton	103	50	7.0	2.4	0.4	0.2
Polychaete	1015	230	24	9.6	1.5	0.5
Hard Clam	37	18	2.5	0.9	0.1	0.07
Mussel	105	50	7.1	2.5	0.4	0.2
Crab	180	62	8.0	2.9	0.4	0.2
Winter Flounder	430-775	122-193	15-21	5.4-8.3	0.8-1.3	0.4-0.5
Lobster	nc	nc	nc	nc	0.2-0.2	0.1-0.1

* Values at steady-state with projected year 10 water column and sediment PCB concentrations.
** Values projected ten years after remediation.
Note:Boxes 4, 5 & 6 correspond to Areas 1, 2 & 3, respectively, of the food chain model.
NC: Not calculated.

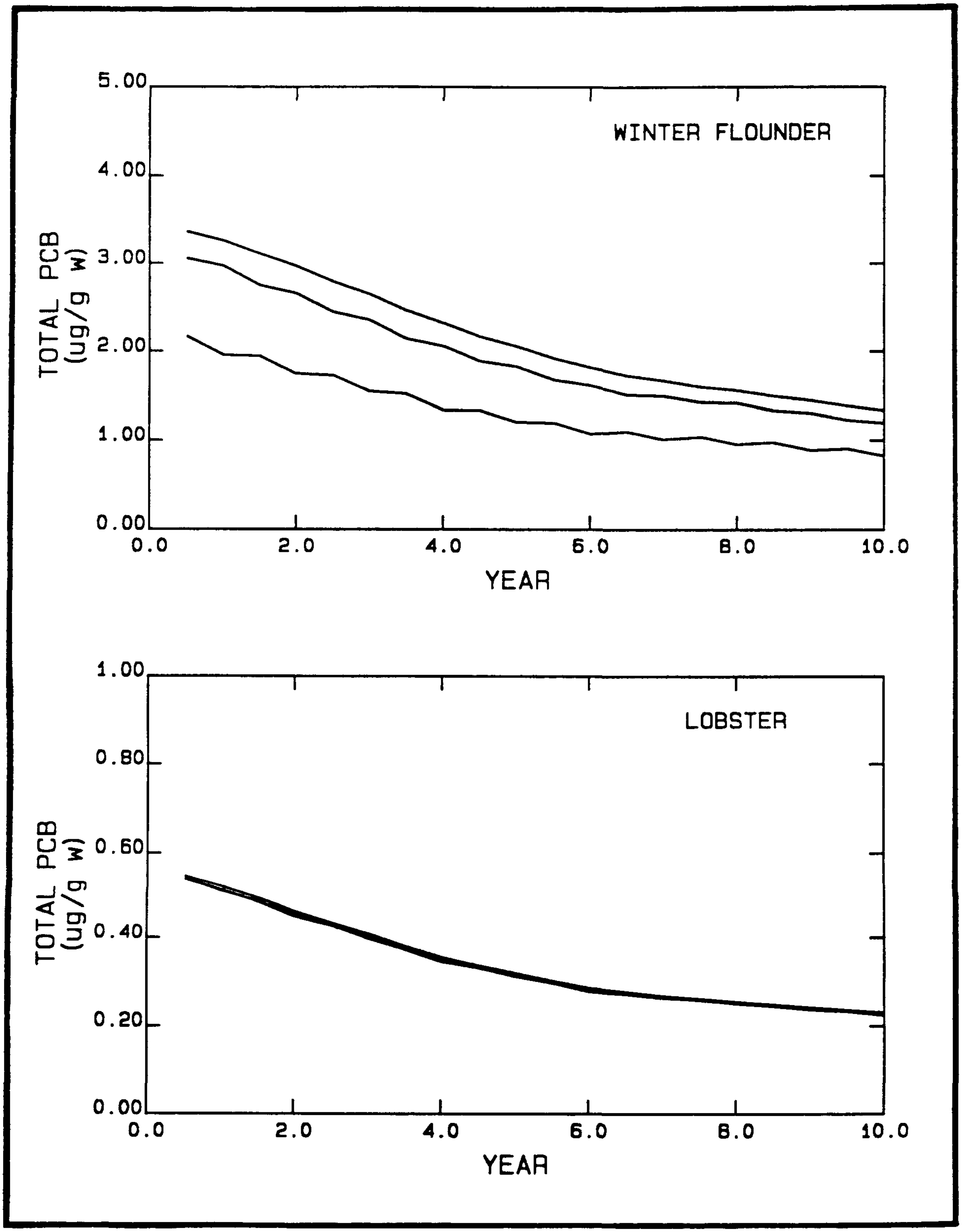


FIGURE 7.12. PCB CONCENTRATIONS IN AREA 2 FLOUNDER (AGES 0, 2, AND 5) AND LOBSTER IN RELATION TO TIME AFTER REMEDIATION FOR THE NO-ACTION SCENARIO

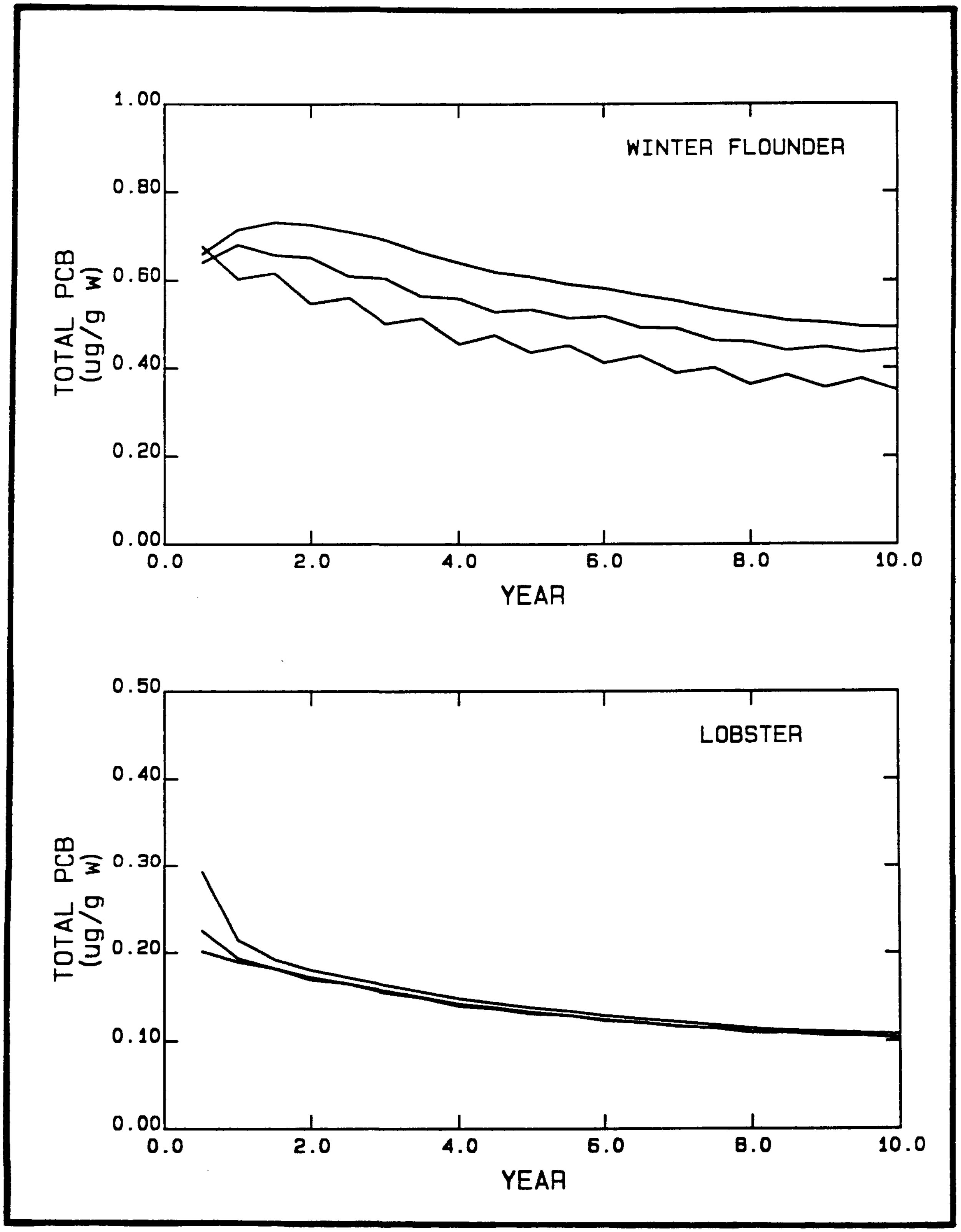


FIGURE 7.13. PCB CONCENTRATIONS IN AREA 3 FLOUNDER (AGES 0, 2, AND 5) AND LOBSTER IN RELATION TO TIME AFTER REMEDIATION FOR THE NO-ACTION SCENARIO

7.4 LONG-TERM-MODELING SENSITIVITY TESTS

Following the completion of the long-term No-Action scenario simulation, the sensitivity of the model results to changes in the open-boundary conditions and initial PCB concentration in the bed layer were evaluated. The two test simulations that were performed are described below.

Each of these tests used the same hydrodynamic conditions and long-term modeling procedures used in the No-Action scenario. Only the open-boundary or initial-bed conditions for PCBs were altered.

7.4.1 Open-Boundary-Condition Test

The influence of the open-boundary condition for PCBs was tested by running the model using a 1 ng/L dissolved and a 0.9 ng/L sediment-sorbed PCB concentration at the open boundary. The PCB open-boundary conditions used in the No-Action simulation were 2.5 ng/L and 2.3 ng/L for dissolved and sediment-sorbed PCBs, respectively. The PCB concentration was not elevated by a factor of three for the storm events as was done in the No-Action scenario. The reduced boundary concentrations were set using the average of the BOS measurements taken to the north of Cuttyhunk Island where Buzzards Bay joins the Atlantic Ocean. All other aspects of the simulation were identical to the No-Action scenario.

The average water column PCB concentrations computed in the No-Action scenario and the open-boundary test are compared in Figures 7.14 and 7.15. The results of each simulation are essentially the same inside the Hurricane Barrier, while some small differences in the concentrations near the open boundary are evident in the Year-10 results. The net flux of PCBs through Coggeshall Street Bridge and the Hurricane Barrier in the open-boundary test (Table 7.11) are nearly identical to the net fluxes calculated in the No-Action scenario (Table 7.1). As expected from the differences in concentration in the outer harbor, minor changes in the net flux through the open boundary occur. The open-boundary flux in the present test is higher than the flux computed for the No-Action scenario because of the reduced open-boundary concentration.

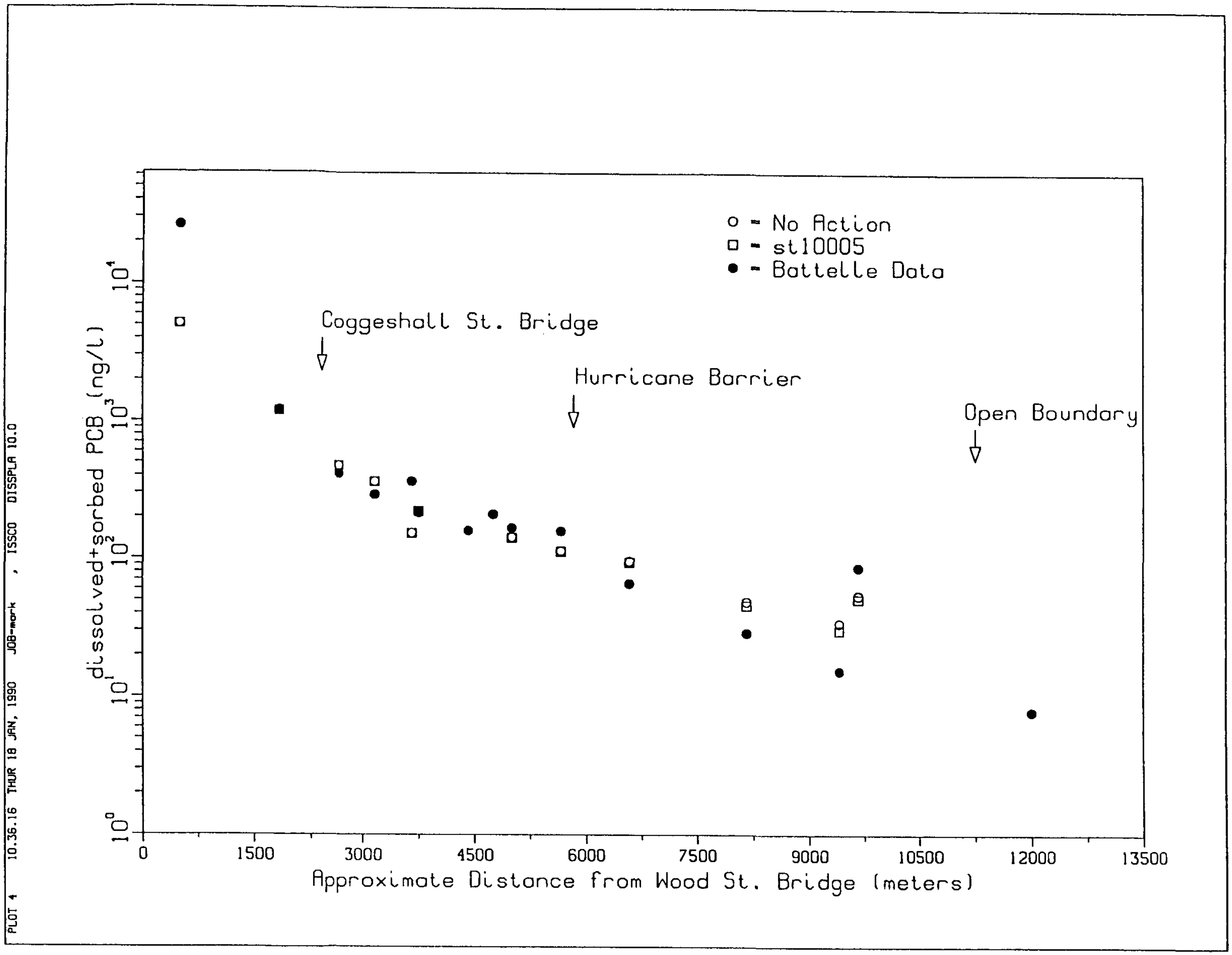


FIGURE 7.14. AVERAGE CONCENTRATION OF TOTAL PCBs IN THE WATER COLUMN FOR YEAR 0 OF THE 1 ng/L OPEN BOUNDARY CONDITION TEST. o = NO-ACTION SCENARIO, □ = OPEN BOUNDARY CONDITION TEST, • = BATTELLE OCEAN SCIENCES DATA

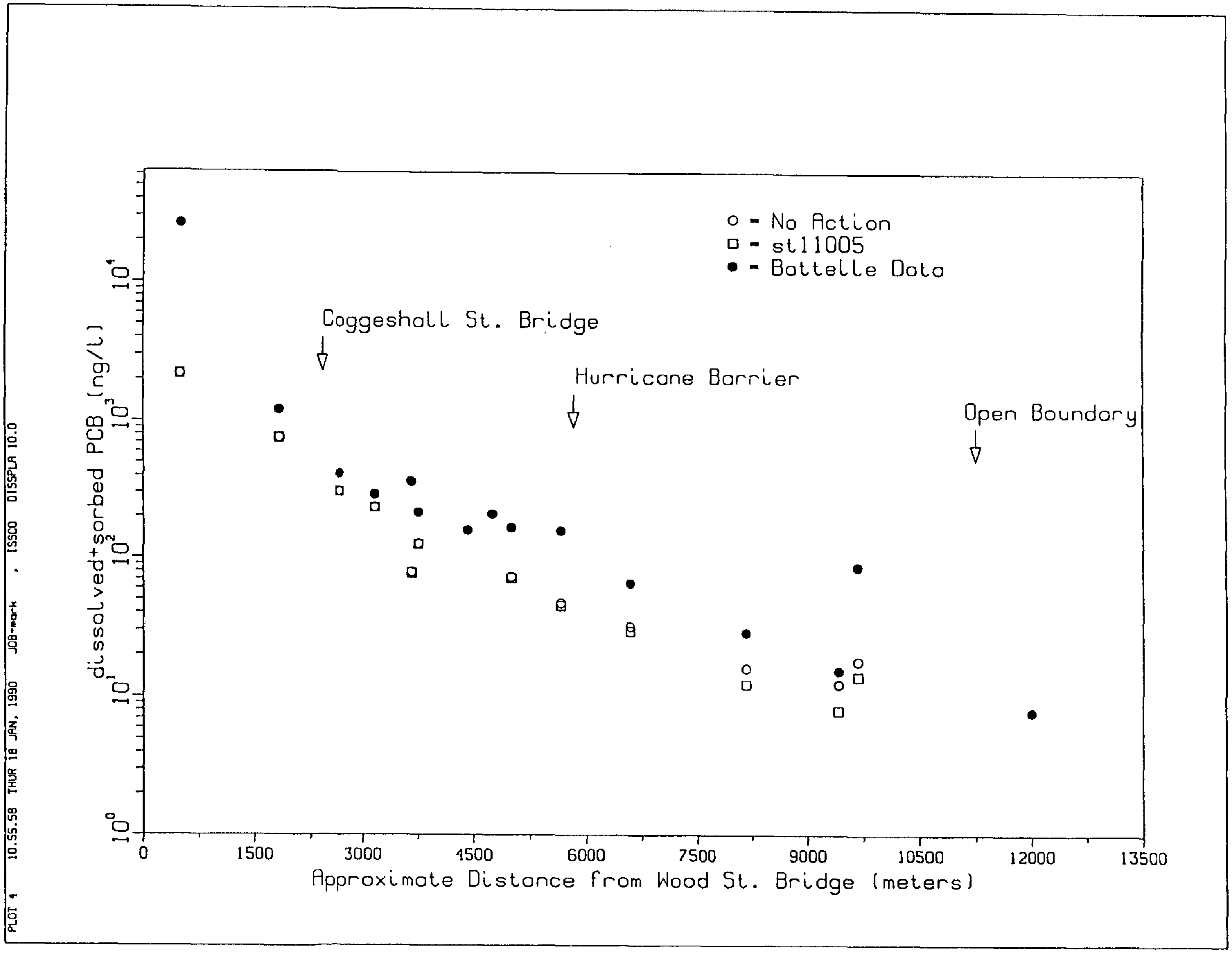


FIGURE 7.15. AVERAGE CONCENTRATION OF TOTAL PCBs IN THE WATER COLUMN FOR YEAR 10 OF THE 1 ng/L OPEN BOUNDARY CONDITION TEST. o = NO-ACTION SCENARIO, □ = OPEN BOUNDARY CONDITION TEST, • = BATTELLE OCEAN SCIENCES DATA

TABLE 7.11. NET FLUX (kg/TIDAL CYCLE) OF SEDIMENTS AND PCBs FOR THE YEAR 0 AND YEAR 10 OPEN-BOUNDARY CONDITION TEST

	Coggeshall Street Bridge	Hurricane Barrier	Open Boundary
Year 0 Sediment Flux	446	1.546×10^3	-2.4641×10^4
Year 10 Sediment Flux	282	2.120×10^3	2.4968×10^4
Year 0 PCB Flux	-0.22	-0.15	-1.40
Year 10 PCB Flux	-0.20	-0.11	-0.32

The results demonstrate that uncertainties in the PCB open-boundary condition, while present, do not significantly affect the model calculations.

7.4.2 Upper-Estuary 10-ppm Test

7.4.2.1 Sediment/Contaminant Transport Results: Upper-Estuary 10-ppm Test

Because the Remedial-Action scenarios would be modeled as changes in the initial bed-sediment conditions, the response of the model to drastic changes in the initial concentrations of PCBs in bed sediments was tested. In the present test, the initial PCB concentration in the bed sediment layer north of Coggeshall Street Bridge was set to a uniform value of 10 ppm (Figure C.2a of Appendix C). All other model conditions were identical to those used in the No-Action scenario.

The simulated suspended sediment results for this case are identical to the no-action case.

The projected water column concentration of PCBs in the upper-estuary at the end of year 0 has fallen by as much as two orders of magnitude in some areas (Figure 7.16). The water column concentrations for year 0 to the south of Coggeshall Street Bridge are comparable to the No-Action case. By the end of year 10, the 10 ppm Upper-Estuary Test concentrations throughout the lower-harbor are significantly lower than the No-Action scenario (Figure 7.17).

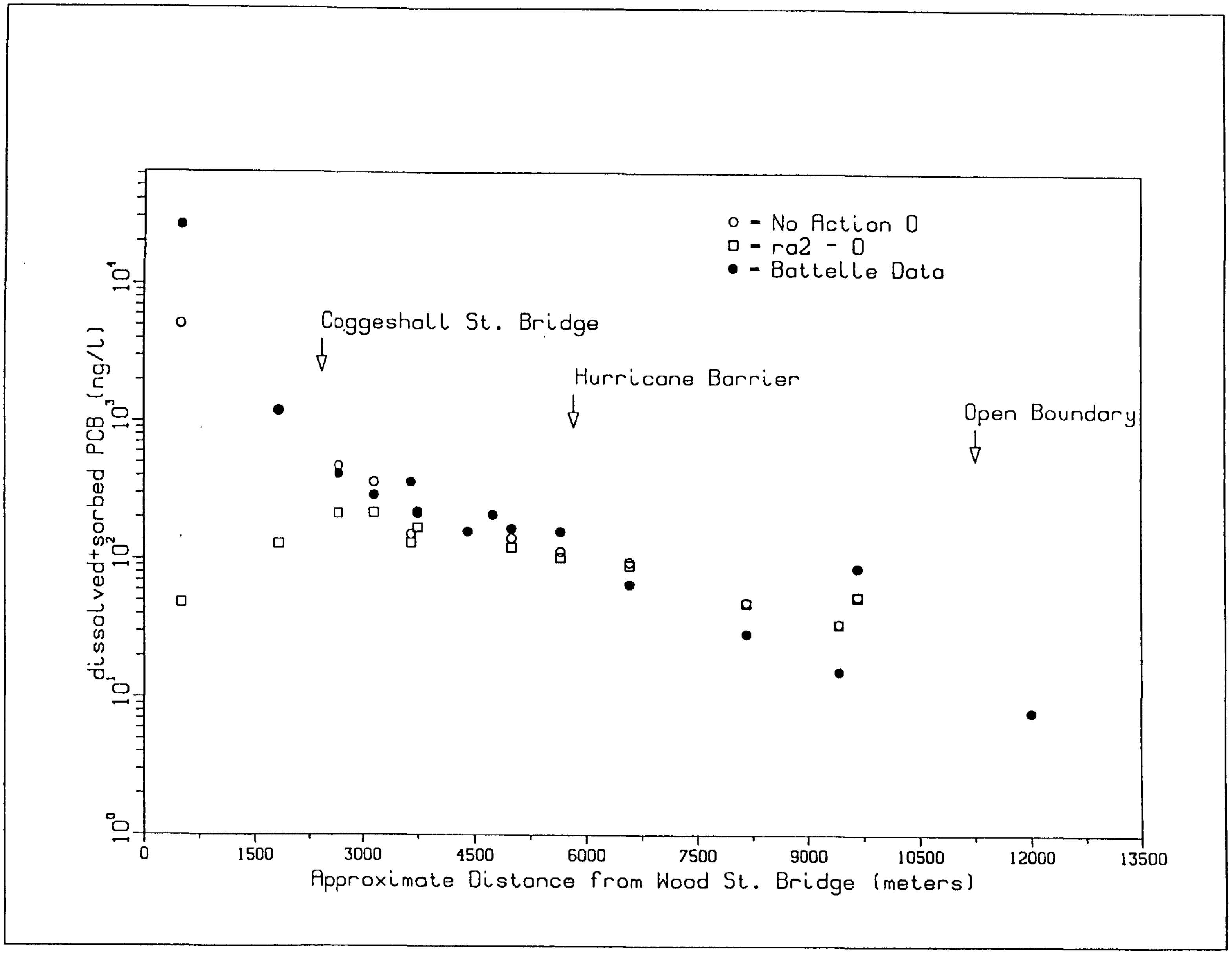


FIGURE 7.16. AVERAGE CONCENTRATION OF TOTAL PCBs IN THE WATER COLUMN FOR YEAR 0 OF THE 10-ppm UPPER-ESTUARY TEST. o = NO-ACTION SCENARIO, □ = OPEN BOUNDARY CONDITION TEST, • = BATTELLE OCEAN SCIENCES DATA

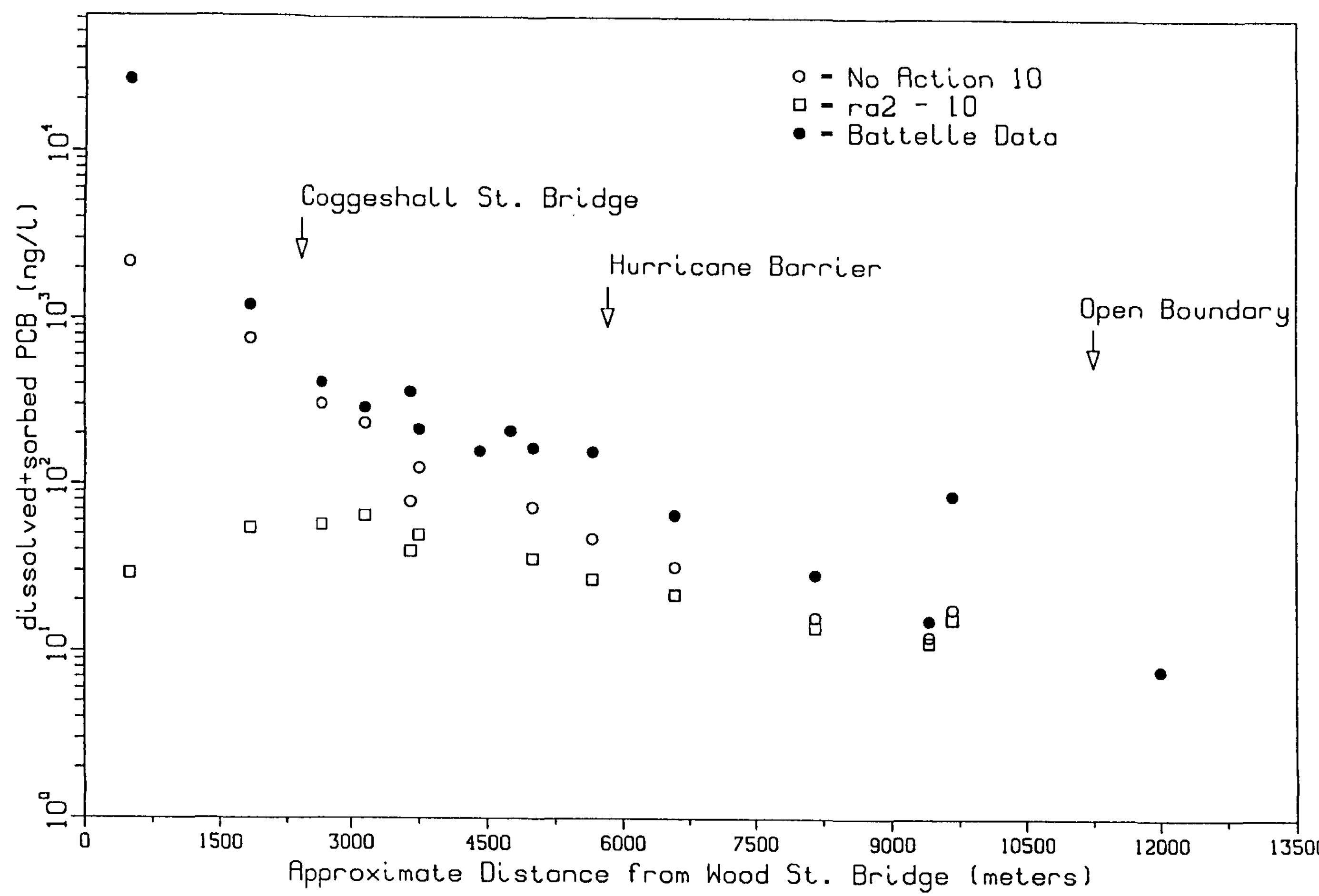


FIGURE 7.17. AVERAGE CONCENTRATION OF TOTAL PCBs IN THE WATER COLUMN FOR YEAR 10 OF THE 10-ppm UPPER-ESTUARY TEST. o = NO-ACTION SCENARIO, □ = OPEN BOUNDARY CONDITION TEST, • = BATTELLE OCEAN SCIENCES DATA

Beyond the Hurricane Barrier the results from the present case and the No-Action scenario are roughly the same.

In the 10-ppm Test, the flux of PCBs through Coggeshall Street Bridge (Table 7.12) has been drastically reduced compared with the No-Action case. The flux of PCBs has reversed and is now in the up-estuary direction (i.e., south to north). In year 0 the flux of PCBs through the Hurricane Barrier is slightly less than the No-Action value, but by year 10 it has dropped to 0.04 kg per tidal cycle as compared to 0.11 kg per tidal cycle in the No-Action case. The flux has been reduced because the source of PCBs in the upper-estuary has been removed. The flux through the open boundary is roughly the same in both cases, indicating that the PCB concentrations beyond the outer harbor are not significantly affected by the removal of PCBs from the upper-estuary.

The box-averaged model results for the water column and the bed sediment layer (Figures 7.18 and 7.19) show the immediate and lasting effect on the system of reducing the PCB concentration in the upper-estuary. Projected water column PCB levels in the upper-estuary region are reduced to a small percentage of the No-Action values, and in the lower-harbor, the 10-ppm Test Case is about 50% of the No-Action scenario. The comparitive contour plots (Figures 7.20 and 7.21) also illustrate the reduction in PCB concentrations in the bed and water column of the lower-harbor area in response to the removal of the PCB source. Outside the Hurricane Barrier, the results of each case are nearly identical.

TABLE 7.12. NET FLUX (kg/TIDAL CYCLE) OF SEDIMENTS AND PCBs FOR THE YEAR 0 AND YEAR 10 10-ppm UPPER-ESTUARY TEST

	Coggeshall Street Bridge	Hurricane Barrier	Open Boundary
Year 0 Sediment Flux	446	1.546×10^3	-2.4641×10^4
Year 10 Sediment Flux	282	2.120×10^3	2.4968×10^4
Year 0 PCB Flux	0.065	-0.11	-1.30
Year 10 PCB Flux	0.001	-0.04	-0.26

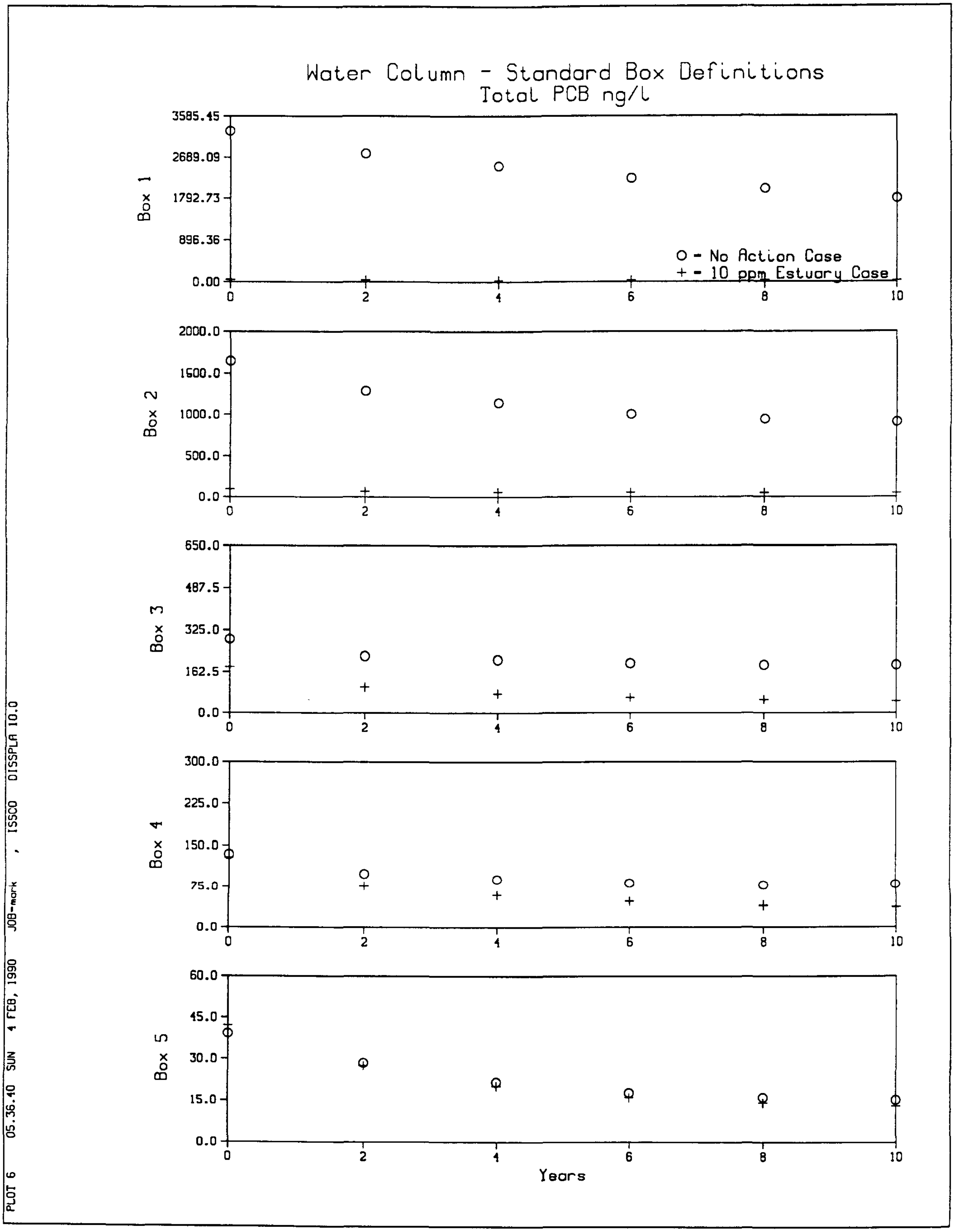


FIGURE 7.18. BOX-AVERAGED MODEL RESULTS FOR THE 10-ppm UPPER-ESTUARY TEST. TOTAL PCB CONCENTRATION (ng/L) IN THE WATER COLUMN. O = NO-ACTION SCENARIO, + = 10-ppm UPPER-ESTUARY TEST

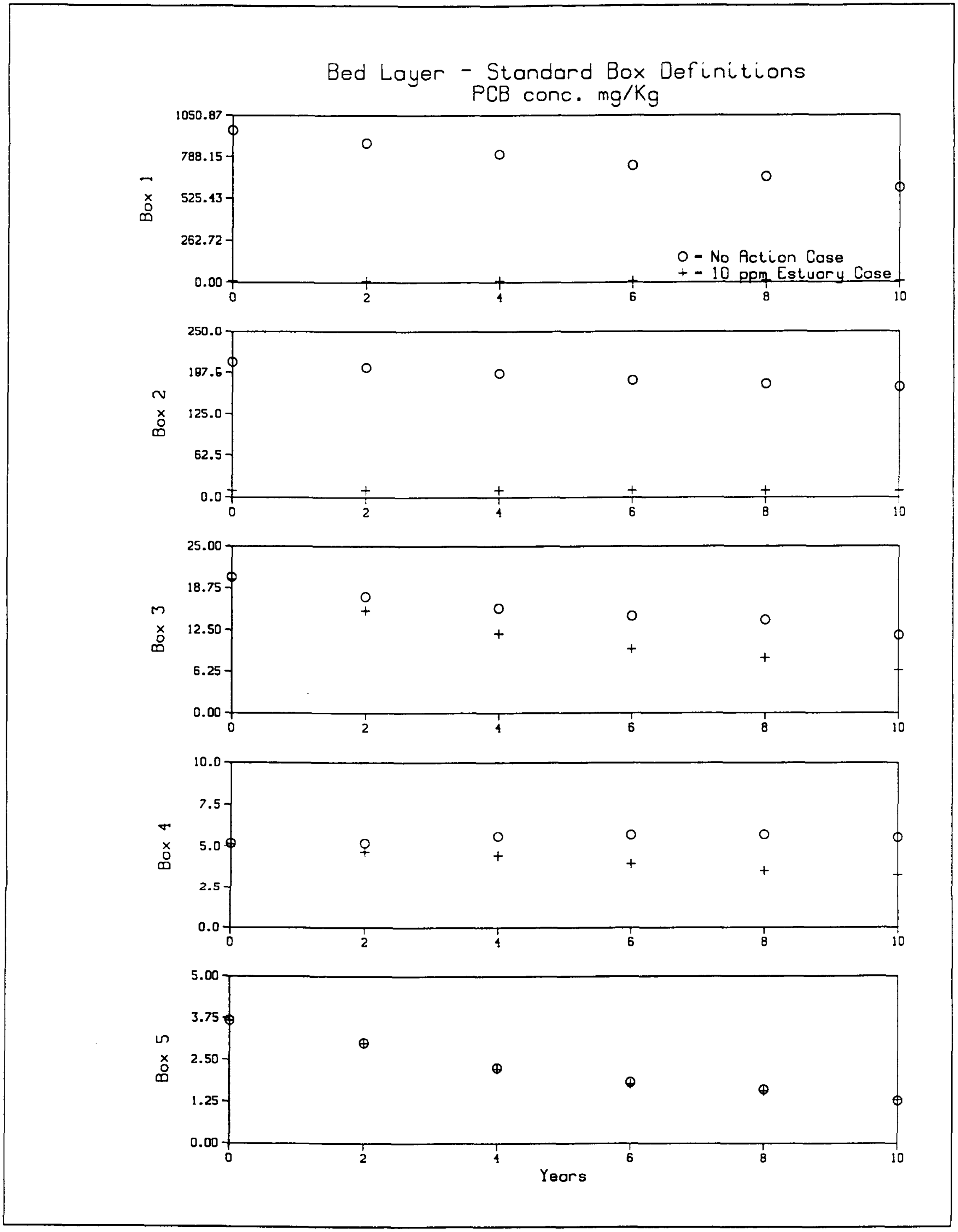


FIGURE 7.19. BOX-AVERAGED MODEL RESULTS FOR THE 10-ppm UPPER-ESTUARY TEST. TOTAL PCB CONCENTRATION (mg/kg) IN THE BED SEDIMENT LAYER. 0 = NO-ACTION SCENARIO, + = 10-ppm UPPER-ESTUARY TEST

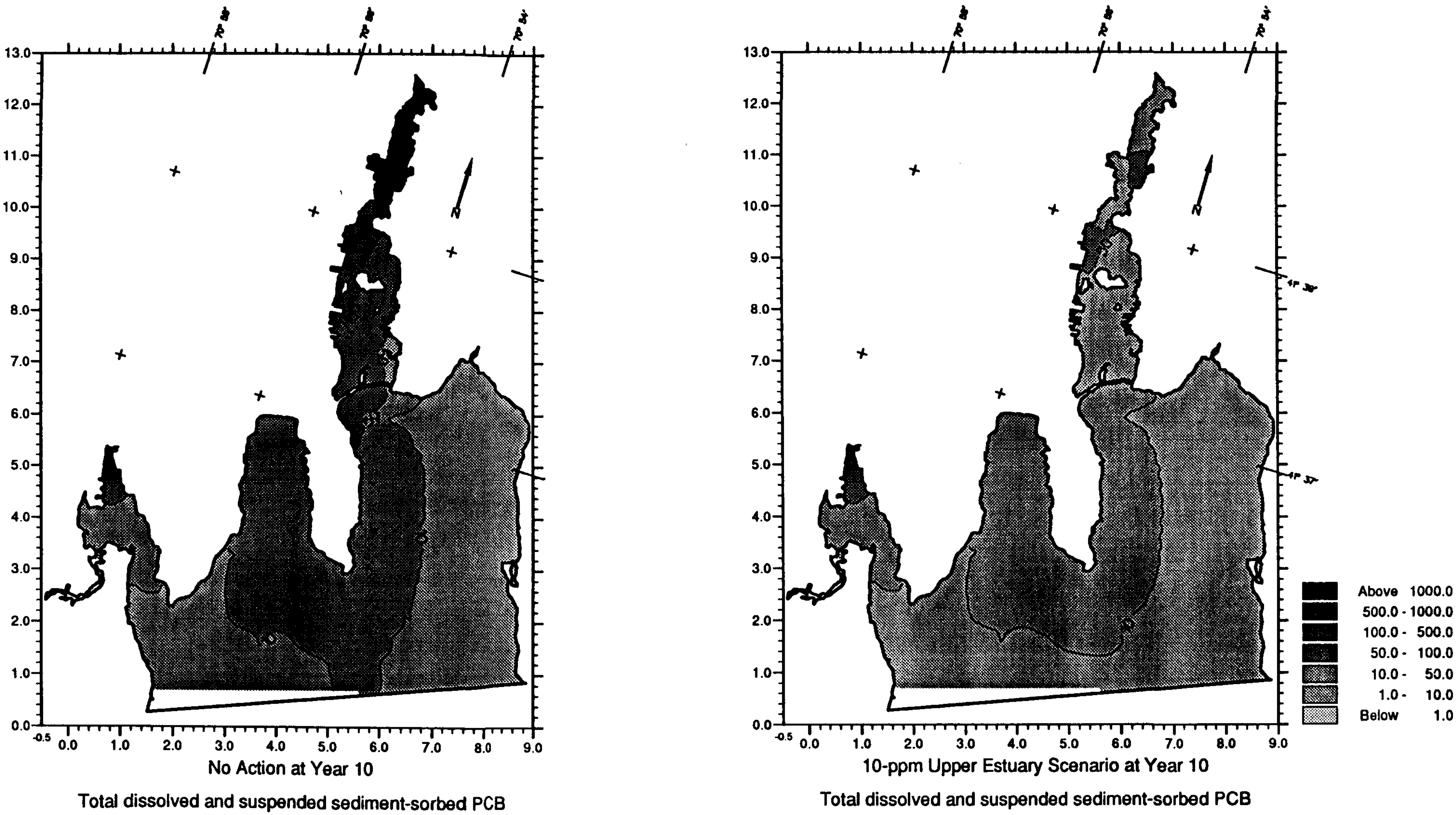


FIGURE 7.20. COMPARISON OF DEPTH-AVERAGED TOTAL WATER COLUMN PCB LEVELS FOR THE NO-ACTION SCENARIO AND THE 10-ppm TEST CASE AT YEAR 10, TOTAL DISSOLVED AND SUSPENDED SEDIMENT-SORBED PCB (ng/L)

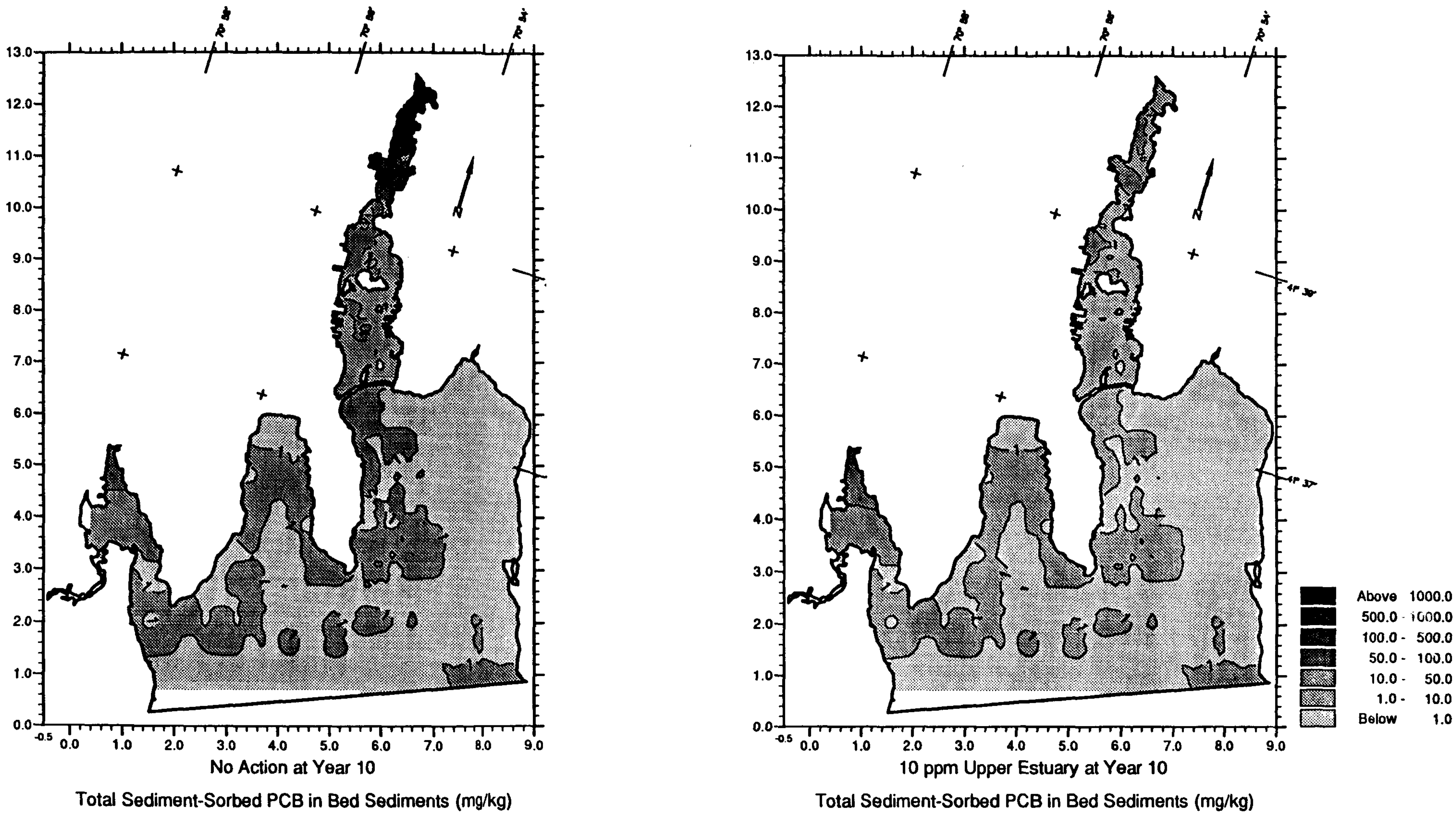


FIGURE 7.21. COMPARISON OF TOTAL BED SEDIMENT-SORBED PCB LEVELS FOR THE NO-ACTION SCENARIO AND THE 10-ppm TEST CASE AT YEAR 10, TOTAL SEDIMENT-SORBED PCB (mg/kg)

The PCB mass balance (Tables 7.13 through 7.18) and detailed contour plots (Figures B.2 and C.2) provide a more detailed picture of the test results.

The results of the 10-ppm Upper-Estuary Test show the model reacting in a consistent and expected manner to a large change in the initial bed conditions. Therefore it was concluded that Remedial-Action scenarios can be modeled as changes in the initial bed-sediment conditions.

TABLE 7.13. SEDIMENT MASS BALANCE AND AVERAGE CONCENTRATION IN THE UPPER-ESTUARY FOR THE YEAR 0 AND YEAR 10 10-ppm UPPER-ESTUARY TEST

	Year 0	Year 10	Change
Water Column Mass (kg)	4.442×10^3	3.101×10^3	-1.341×10^3
Bed Layer Mass (kg)	4.980×10^7	5.233×10^7	2.53×10^6
Water Column Concentration (mg/L)	3.1	2.2	-0.9

TABLE 7.14. PCB MASS BALANCE AND AVERAGE CONCENTRATION IN THE UPPER-ESTUARY FOR THE YEAR 0 AND YEAR 10 10-ppm UPPER-ESTUARY TEST

	Year 0	Year 10	Change
Water Column Mass (kg)	0.13	0.06	-0.07
Bed Layer Mass (kg)	494	500	6
Water Column Concentration (ng/L)	87	44	-43
Bed Layer Concentration (mg/kg)	10	10	0

TABLE 7.15. SEDIMENT MASS BALANCE AND AVERAGE CONCENTRATION IN THE LOWER-HARBOR FOR THE YEAR 0 AND YEAR 10 10-ppm UPPER-ESTUARY TEST

	Year 0	Year 10	Change
Water Column Mass (kg)	8.0460×10^4	5.9450×10^4	-2.1010×10^4
Bed Layer Mass (kg)	1.658×10^8	1.794×10^8	1.360×10^7
Water Column Concentration (mg/L)	5.2	3.8	-1.4

TABLE 7.16. PCB MASS BALANCE AND AVERAGE CONCENTRATION IN THE LOWER-HARBOR FOR THE YEAR 0 AND YEAR 10 10-ppm UPPER-ESTUARY TEST

	Year 0	Year 10	Change
Water Column Mass (kg)	2.2	0.6	-1.6
Bed Layer Mass (kg)	1.708×10^3	788	-920
Water Column Concentration (ng/L)	141	39	-102
Bed Layer Concentration (mg/kg)	10	4	-6

TABLE 7.17. SEDIMENT MASS BALANCE AND AVERAGE CONCENTRATION IN THE OUTER-HARBOR FOR THE YEAR 0 AND YEAR 10 10-ppm UPPER-ESTUARY TEST

	Year 0	Year 10	Change
Water Column Mass (kg)	9.654×10^5	8.511×10^5	-1.143×10^5
Bed Layer Mass (kg)	1.523×10^9	1.627×10^9	1.040×10^8
Water Column Concentration (mg/L)	6.0	5.3	-0.7

TABLE 7.18. PCB MASS BALANCE AND AVERAGE CONCENTRATION IN THE OUTER-HARBOR FOR THE YEAR 0 AND YEAR 10 10-ppm UPPER-ESTUARY TEST

	Year 0	Year 10	Change
Water Column Mass (kg)	5.7	1.8	-3.9
Bed Layer Mass (kg)	4.672×10^3	2.869×10^3	-1.803×10^3
Water Column Concentration (ng/L)	35	12	-23
Bed Layer Concentration (mg/kg)	3	2	-1

7.4.2.2 Food Chain Results: Upper-Estuary 10-ppm Test

The resulting exposure concentrations for Areas 1, 2 and 3 of the food chain model to this test case are identical to the Upper-Estuary scenario that is presented later in Section 7.5.2. The food chain exposure concentrations and resulting biota projections are presented and discussed therein.

7.5 REMEDIAL-ACTION SCENARIO SIMULATIONS

The information required to model a given Remedial-Action scenario included the definition of the shoreline, bathymetry, and concentration of PCBs sorbed to bed sediments after remediation. This information was specified by the REM III team for each scenario. For each scenario, the Remedial-Action was modeled as a change in the initial concentration of PCBs in the bed sediment layer following remediation, and the redefinition of the shoreline if necessary. Potential PCB releases during the implementation of the remedial scenarios were not modeled. Bed-level changes that could be caused by potential dredging or capping activities were not modeled because the proposed depth changes were generally smaller than the vertical thickness of the model grid cells. The composition of the bed sediments (grain size distribution) and transport properties (critical shear stresses) are assumed to be unchanged following remedial activities.

To accommodate for remedial scenarios that potentially utilizing dredging and shoreline sediment disposal, so-called confined disposal facilities (CDFs) were incorporated into the model shoreline. The construction of CDFs, represented as solid cells in the model grid, substantially changed the location of the shoreline in the harbor. Because the configuration of boundary cells was changed, the hydrodynamics used in the decoupled transport simulations were recomputed using the altered shoreline. The tide and wind boundary conditions used in the hydrodynamics calculations were identical to those used in the No-Action simulations.

The following Remedial-Action scenarios were modeled:

- Hot-Spot scenario. The grid cells encompassing the PCB hot-spot area were remediated to a residual sediment PCB concentration of 10 ppm.
- Upper-Estuary scenario. The area between Coggeshall and Wood Street Bridges was cleaned up to a residual sediment PCB level of 1 to 10 ppm. This scenario included CDFs along the shoreline north of the Coggeshall Street Bridge.

- Lower-Harbor scenario. This scenario specified the cleanup of the region between the Hurricane Barrier and the Coggeshall Street Bridge to a residual sediment PCB level of 1 to 10 ppm. Since this scenario included CDFs both north and south of the Coggeshall Street Bridge, the hydrodynamics were recalculated.
- 1-ppm scenario. The initial bed-sediment PCB concentration over the entire model domain was set to 1 ppm. This scenario used the Lower-Harbor scenario hydrodynamics.
- 50-ppm scenario. All locations within the Hurricane Barrier with a concentration of 50 ppm or greater were cleaned up to a residual sediment PCB level of 1 to 10 ppm. This scenario used the Lower-Harbor scenario hydrodynamics.
- 500-ppm scenario. All locations within the Hurricane Barrier with a concentration of 500 ppm or greater were cleaned up to a residual sediment PCB level of 1 to 250 ppm. This scenario used the Lower-Harbor scenario hydrodynamics.

All of the Remedial-Action scenarios use the same model parameters and open-boundary conditions used in the No-Action scenario. For example, the water column and bed K_d values were not changed from scenario to scenario.

The results of each Remedial-Action simulation could be described at length in a manner similar to the No-Action scenario (Section 7.3), but to avoid repetition only the essential model results for each scenario are discussed. For completeness, the full details of each simulation have been made available in the form of figures and tables.

7.5.1 Hot-Spot Scenario

The Hot-Spot scenario simulates the cleanup of the area of highest PCB concentrations in the upper-estuary. The residual PCB concentration in the bed sediments following remediation is 10 ppm. These new initial conditions, shown in a contour plot (Figure C.3a), can be compared to the no-action initial conditions (Figure C.1a), in which the bed sediment PCB concentrations exceed 1500 ppm in the hot-spot area. Because no CDFs were specified in the scenario definition, the Hot-Spot and No-Action scenarios share the same hydrodynamics.

7.5.1.1 Sediment/Contaminant Transport Results: Hot-Spot Scenario

Directly over the hot-spot area (approximately 500 m from Wood Street Bridge), the water column PCB concentration shows an immediate decline at the end of year 0 to about 1800 ng/L as compared to 5000 ng/L in the No-Action case (Figure 7.22). By the end of year 10 the difference is much less, 1100 ng/L in the Hot-Spot scenario versus 2200 ng/L for the No-Action scenario (Figure 7.23). These figures illustrate that there is little difference between the water column PCB concentrations computed in the Hot-Spot and No-Action scenarios at distances further than 1000 m downstream of the Wood Street Bridge. This result suggests that the water column PCB concentrations are in local equilibrium with PCBs bound to nearby bed sediments.

The differences noted above are also evident in the box-averaged results for the water column (Figure 7.24) and bed layer (Figure 7.25). Only box 1 shows significant differences between the Hot-Spot and No-Action scenarios. The concentrations in this region are approximately 50% of the No-Action values. These results are also illustrated in the comparative contour plots of the projected PCB levels in the water column and sediment at year 10 following remediation (Figures 7.26 and 7.27).

The computed net fluxes of PCBs through the Coggeshall Street Bridge and the Hurricane Barrier (Table 7.19) are only slightly reduced from the No-Action values. For example, the net flux in year 10 through the Coggeshall Street bridge is 0.18 and 0.20 kg per tidal cycle down-estuary in the Hot-Spot and No-Action scenarios, respectively.

TABLE 7.19. NET FLUX (kg/TIDAL CYCLE) OF SEDIMENTS AND PCBs FOR THE YEAR 0 AND YEAR 10 HOT-SPOT SCENARIO SIMULATIONS

	Coggeshall Street Bridge	Hurricane Barrier	Open Boundary
Year 0 Sediment Flux	446	1.545×10^3	-2.4641×10^4
Year 10 Sediment Flux	282	2.120×10^3	2.4856×10^4
Year 0 PCB Flux	-0.21	-0.14	-1.32
Year 10 PCB Flux	-0.18	-0.10	-0.29

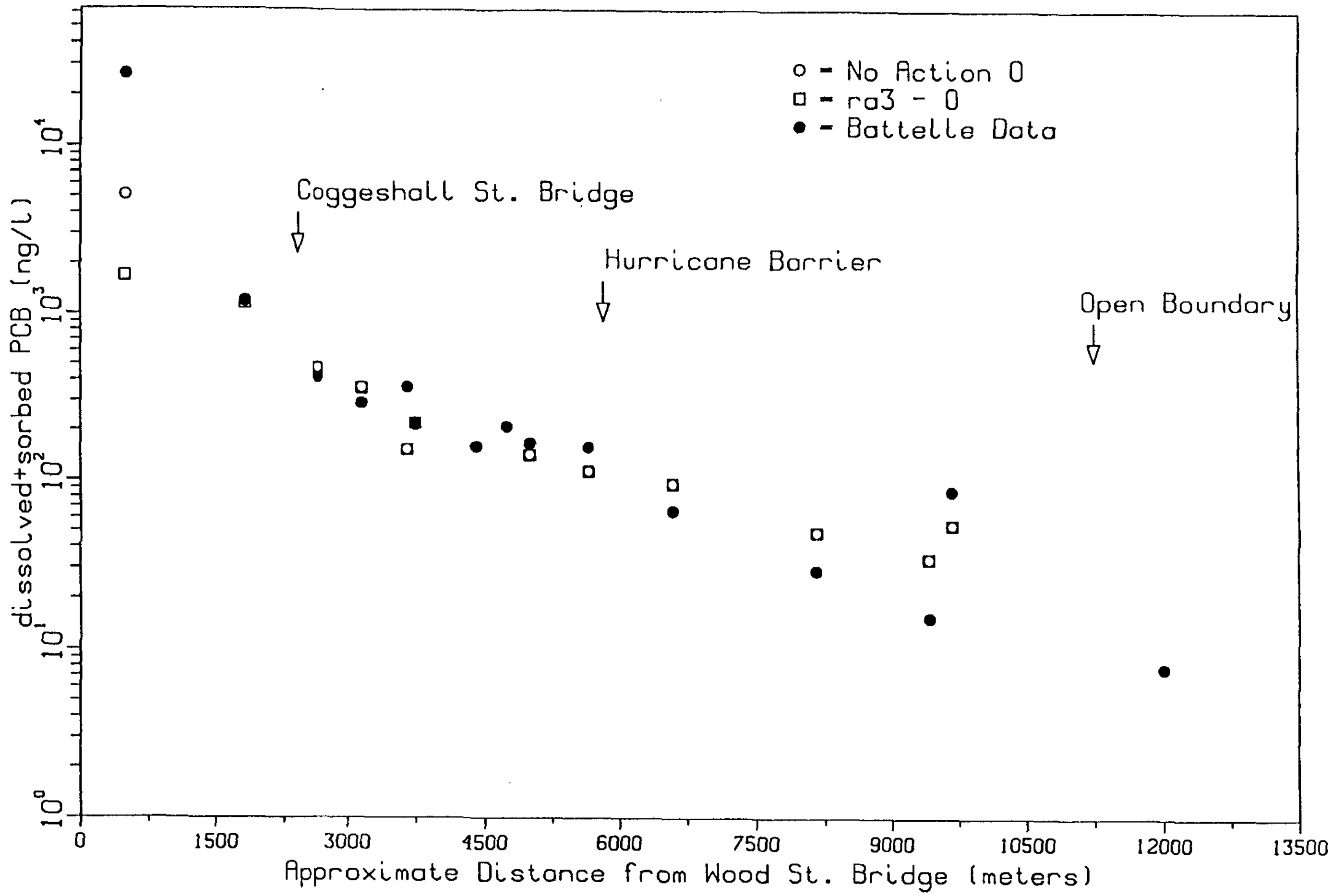


FIGURE 7.22. AVERAGE CONCENTRATION OF TOTAL PCBs IN THE WATER COLUMN FOR YEAR 0 OF THE HOT-SPOT SCENARIO (ng/L). o = NO-ACTION SCENARIO, □ = HOT-SPOT SCENARIO • = BATTELLE OCEAN SCIENCES DATA.

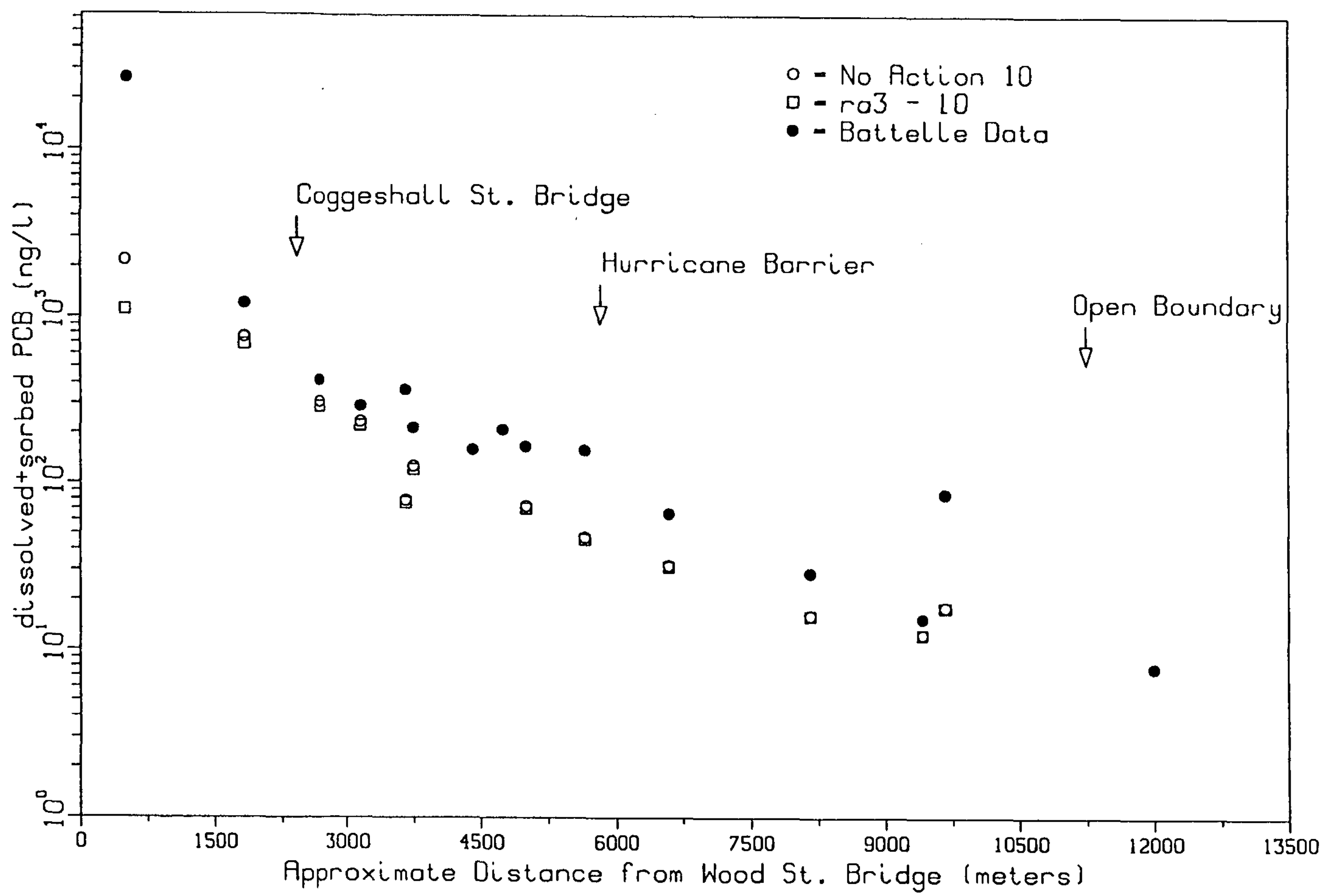


FIGURE 7.23. **AVERAGE CONCENTRATION OF TOTAL PCBs IN THE WATER COLUMN FOR YEAR 10 OF THE HOT-SPOT SCENARIO (ng/L). o = NO-ACTION SCENARIO, □ = HOT-SPOT SCENARIO • = BATTELLE OCEAN SCIENCES DATA.**

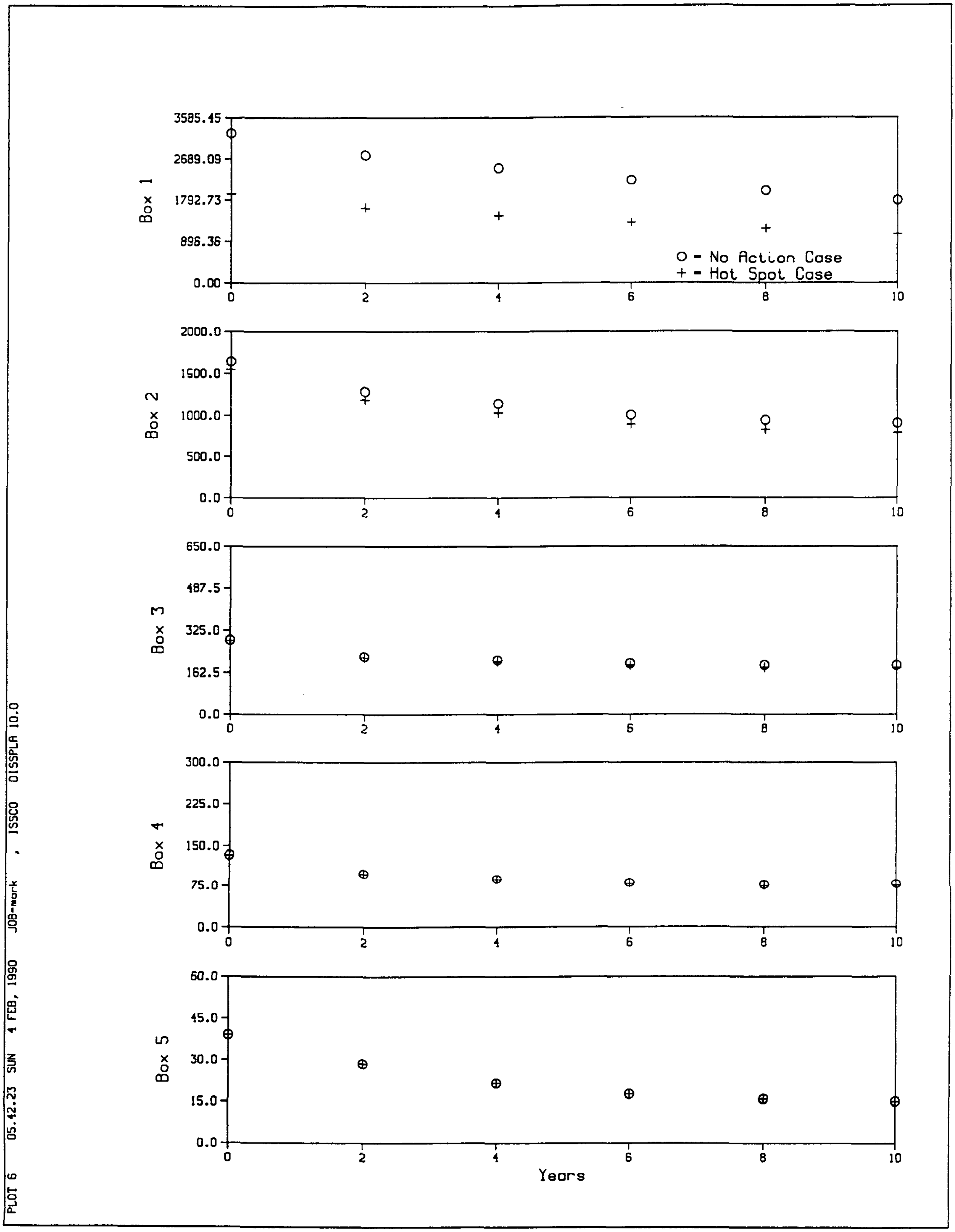


FIGURE 7.24. BOX-AVERAGED MODEL RESULTS FOR THE HOT-SPOT SCENARIO. TOTAL PCB CONCENTRATION (ng/L) IN THE WATER COLUMN. o = NO-ACTION SCENARIO, + = HOT-SPOT SCENARIO.

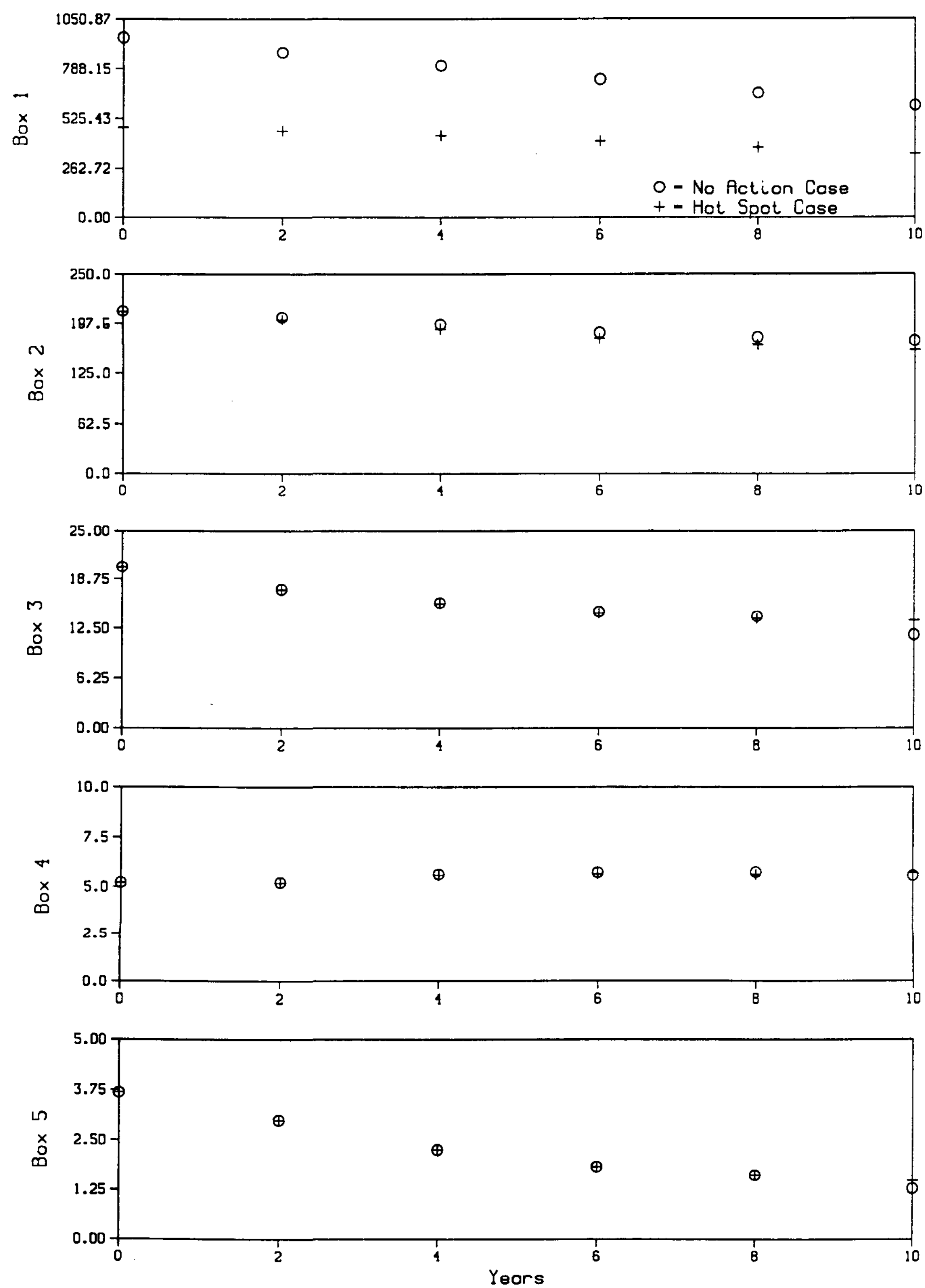


FIGURE 7.25. BOX-AVERAGED MODEL RESULTS FOR THE HOT-SPOT SCENARIO. TOTAL PCB CONCENTRATION (mg/kg) IN THE BED SEDIMENT LAYER. o = NO-ACTION SCENARIO, + = HOT-SPOT SCENARIO.

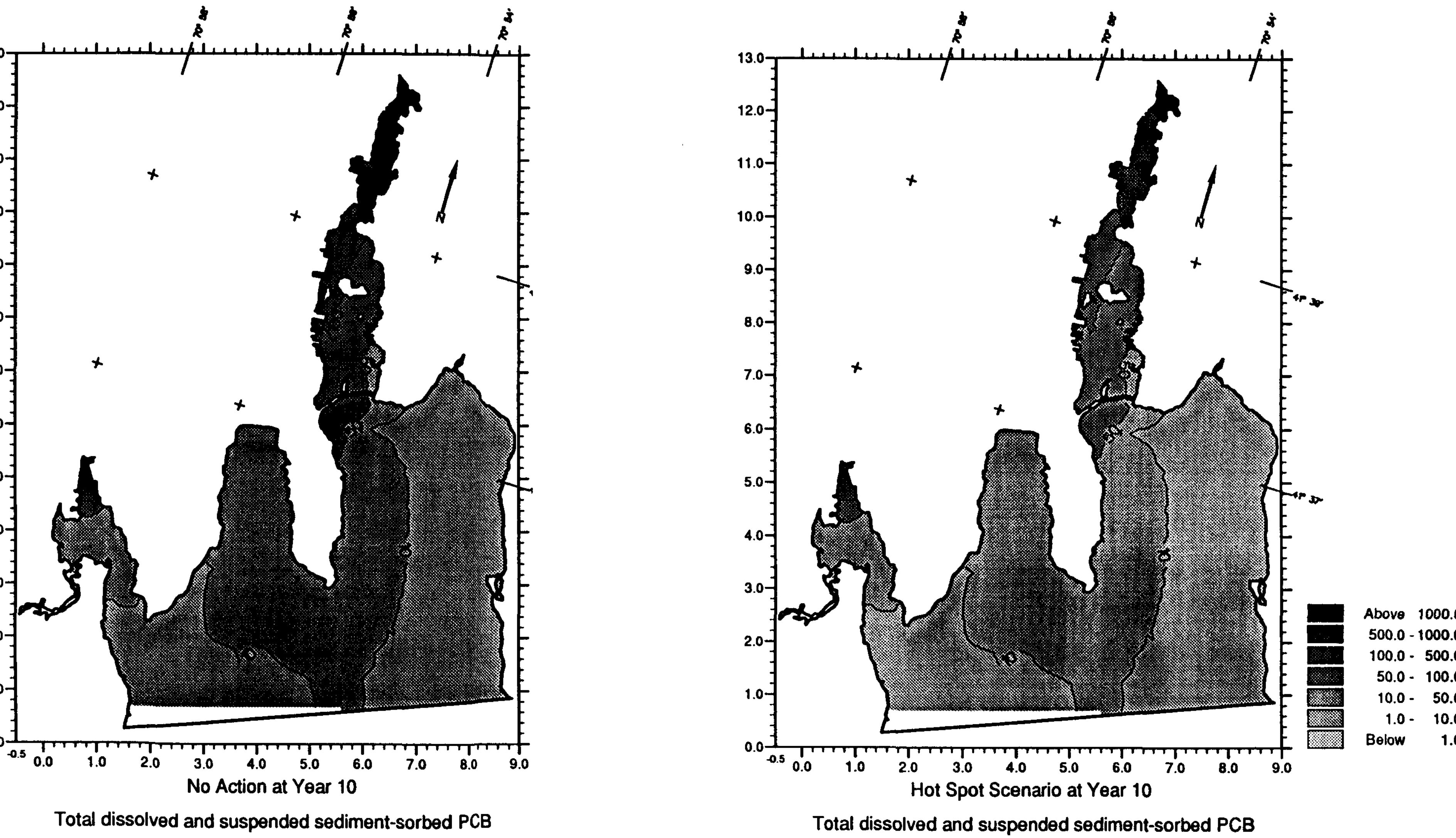


FIGURE 7.26. COMPARISON OF DEPTH-AVERAGED TOTAL WATER COLUMN PCB LEVELS FOR THE NO-ACTION AND HOT SPOT SCENARIOS AT YEAR 10, TOTAL DISSOLVED AND SUSPENDED SEDIMENT-SORBED PCB (ng/L)

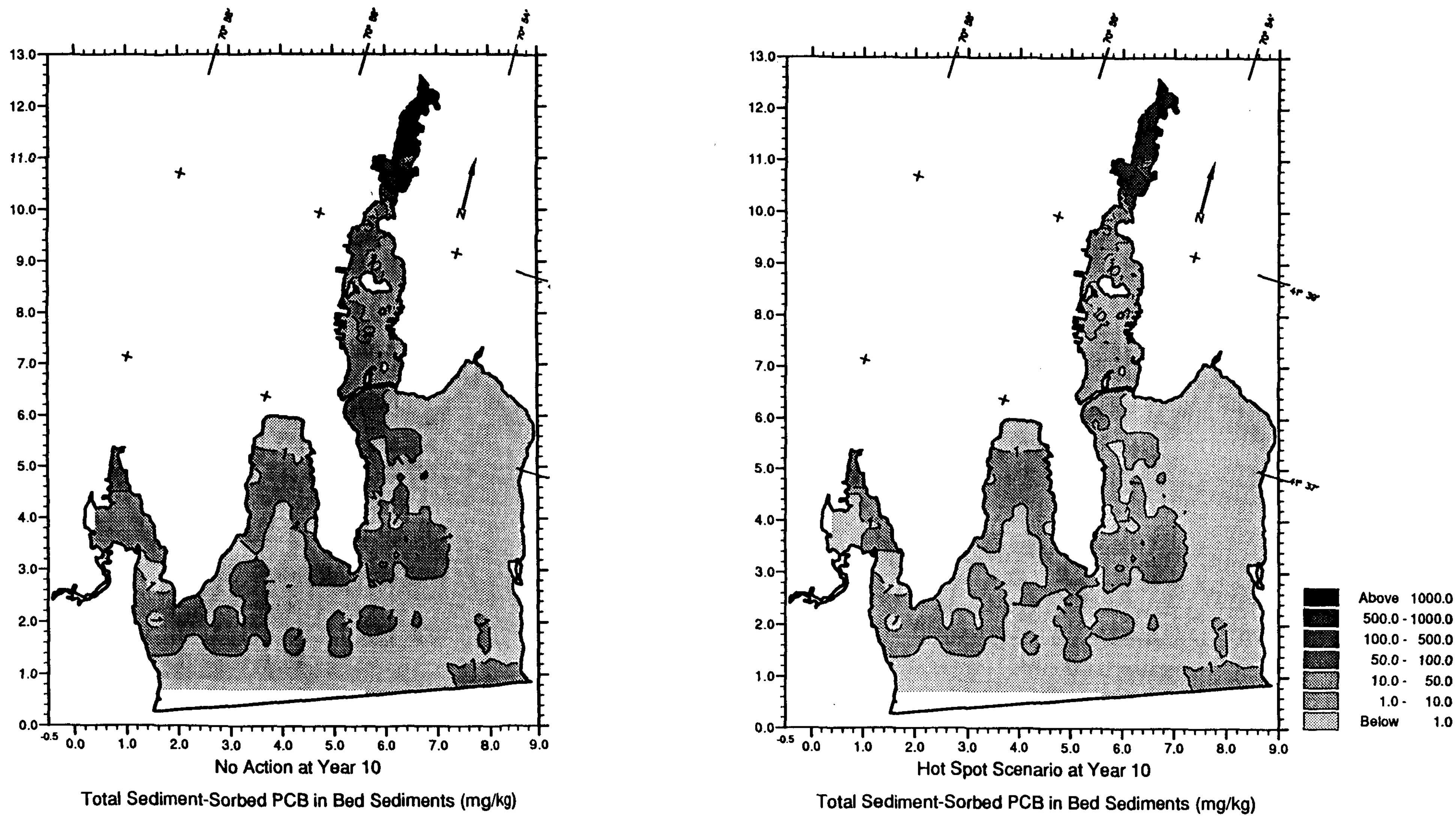


FIGURE 7.27. COMPARISON OF TOTAL BED SEDIMENT-SORBED PCB LEVELS FOR THE NO-ACTION AND HOT SPOT SCENARIOS AT YEAR 10, TOTAL SEDIMENT-SORBED PCB (mg/kg)

Although the Hot-Spot scenario reduces the year-0 mass of PCBs in the upper-estuary to 13,530 kg (Table 7.21) from 19,430 kg in the No-Action scenario (Table 7.3), the average concentration in the bed sediments does not drastically change. In the lower- and outer-harbor areas the PCB mass balance for each scenario is almost identical.

Table 7.20 and Tables 7.22 through 7.25 show other data for the Hot-Spot scenario. The average suspended-sediment concentrations for year 0 and year 10 are identical to the No-Action scenario.

TABLE 7.20. SEDIMENT MASS BALANCE AND AVERAGE CONCENTRATION IN THE UPPER-ESTUARY FOR YEAR 0 AND YEAR 10 HOT-SPOT SIMULATIONS

	Year 0	Year 10	Change
Water Column Mass (kg)	4.442×10^3	3.101×10^3	-1.342×10^3
Bed Layer Mass (kg)	4.980×10^7	5.233×10^7	2.530×10^6
Water Column Concentration (mg/L)	3.1	2.2	-0.9

TABLE 7.21. PCB MASS BALANCE AND AVERAGE CONCENTRATION IN THE UPPER-ESTUARY FOR THE YEAR 0 AND YEAR 10 HOT-SPOT SIMULATIONS

	Year 0	Year 10	Change
Water Column Mass (kg)	2.3	1.2	-1.1
Bed Layer Mass (kg)	1.3530×10^4	1.0450×10^4	-3.080×10^3
Water Column Concentration (ng/L)	1.634×10^3	850	-784
Bed Layer Concentration (mg/kg)	272	200	-72

TABLE 7.22. SEDIMENT MASS BALANCE AND AVERAGE CONCENTRATION IN THE LOWER-HARBOR FOR THE YEAR 0 AND YEAR 10 HOT-SPOT SIMULATIONS

	Year 0	Year 10	Change
Water Column Mass (kg)	8.0460 10^4	5.9450 x 10^4	-2.1010 x 10^4
Bed Layer Mass (kg)	1.658 x 10^8	1.794 x 10^8	1.360 x 10^7
Water Column Concentration (mg/L)	5.2	3.8	-1.4

TABLE 7.23. PCB MASS BALANCE AND AVERAGE CONCENTRATION IN THE LOWER-HARBOR FOR THE YEAR 0 AND YEAR 10 HOT-SPOT SIMULATIONS

	Year 0	Year 10	Change
Water Column Mass (kg)	2.6	1.5	-1.1
Bed Layer Mass (kg)	1.732 x 10^3	1.498 x 10^3	-234
Water Column Concentration (ng/L)	168	99	-69
Bed Layer Concentration (mg/kg)	11	8	-3

TABLE 7.24. SEDIMENT MASS BALANCE AND AVERAGE CONCENTRATION IN THE OUTER-HARBOR FOR THE YEAR 0 AND YEAR 10 HOT-SPOT SIMULATIONS

	Year 0	Year 10	Change
Water Column Mass (kg)	9.654 x 10^5	8.511 x 10^5	-1.143 x 10^5
Bed Layer Mass (kg)	1.523 x 10^9	1.627 x 10^9	1.040 x 10^8
Water Column Concentration (mg/L)	6.0	5.3	-0.7

TABLE 7.25. PCB MASS BALANCE AND AVERAGE CONCENTRATION IN THE OUTER-HARBOR FOR THE YEAR 0 AND YEAR 10 HOT-SPOT SIMULATIONS

	Year 0	Year 10	Change
Water Column Mass (kg)	5.3	2.1	-3.2
Bed Layer Mass (kg)	4.674×10^3	2.407×10^3	-2.267×10^3
Water Column Concentration (ng/L)	33	13	-20
Bed Layer Concentration (mg/kg)	3	1	-2

7.5.1.2 Food Chain Results: Hot-Spot Scenario

Exposure Profile

Remediation of the hot-spot results in a significant decline in water column dissolved and sediment PCB concentrations within the region of the hot-spot. However, as discussed above, these changes in concentration outside of this region are nearly identical to those projected under the No-Action scenario. After 10 years, slightly greater decreases are projected in the water column where the concentrations are 58.1, 8.0 and 4.5 ng/L in Areas 1, 2 and 3 of the food chain model (Table 7.26), respectively, versus values of 60.3, 9.2 and 4.8 ng/L, respectively under No-Action. As expected, sediment exposure PCB concentrations are essentially the same for both the No-Action and Hot-Spot scenarios in each of the three modeled areas.

TABLE 7.26. HOT-SPOT EXPOSURE CONCENTRATIONS FOR FOOD CHAIN MODEL

	Area 1		Area 2		Area 3	
Year	Water Column[a]	Bed Sediment[b]	Water Column[a]	Bed Sediment[b]	Water Column[a]	Bed Sediment[b]
0	84.58	7.8	23.97	3.7	11.24	1.0
2	72.04	7.9	16.87	3.0	8.18	0.9
4	65.34	8.3	12.62	2.2	6.53	0.8
6	60.15	8.3	9.97	1.8	5.515	0.8
8	57.58	8.2	8.74	1.6	4.84	0.7
10	58.10	8.2	7.97	1.3	4.48	0.7

[a] Water column dissolved PCB (ng/L).
[b] Sediment PCB (mg/kg dry).

Food Chain Model Projections

Projected concentrations for the Hot-Spot scenario for each age class of winter flounder and lobster in relation to time are presented in Figures 7.28 to 7.30 for Areas 1, 2 and 3 respectively. Since the projected water column and sediment PCB concentrations are essentially identical to the values projected under No-Action, the projected biota concentrations are also nearly identical. In Area 1 (Figure 7.28), the PCB concentration in flounder remains constant ranging from about 6 μg/g in age class 1 to about 8 to 9 μg/g in age class 6. As for the no-action case, the older flounder in Area 1 (age classes 3 through 6) are projected to remain close to the FDA Action Limit of 2-ppm PCBs in the edible tissue portion of the fish.

As in No-Action, a significant drop in concentration occurs in both the flounder and the lobster in Area 2 (Figure 7.29). At the end of the ten year period concentrations have declined about 60%, consistent with the water column and sediment declines. The flounder in this area are initially about a factor of two to three below the FDA Action Limit and they decline to about a factor of ten below the limit after ten years. The lobster decline from about three times higher than the Action Limit to concentrations on the order of the limit.

A decline of 65% in PCB concentrations was generally projected for biota within the northern reaches of the estuary (Box 1). This projection was based on steady state exposure conditions for biota, hypothetically, within this region (Table 7.27). Similar to the exposure profile, these changes diminish in a southlerly direction and are essentially the same as No-Action south of Popes Island.

TABLE 7.27. COMPUTED CONCENTRATIONS IN BIOTA (μg/g WET WEIGHT) FROM EACH OF THE SEGMENTS OF NEW BEDFORD HARBOR 10 YEARS AFTER REMEDIATION OF THE HOT-SPOT TO 10-ppm

Species	Box 1*	Box 2*	Box 3*	Box 4**	Box 5**	Box 6**
Phytoplankton	35	26	5.2	2.3	0.4	0.2
Polychaete	360	168	16	9.5	1.7	0.5
Hard Clam	12	9.2	1.9	0.8	0.1	0.07
Mussel	35	26	5.3	2.4	0.4	0.2
Crab	62	37	5.8	2.8	0.5	0.2
Winter Flounder	150-270	80-134	10-15	5.3-8.2	0.9-1.4	0.4-0.5
Lobster	nc	nc	nc	nc	0.3-0.3	0.1-0.1

* Values at steady-state with projected year 10 water column and sediment PCB concentrations.
** Values projected ten years after remediation.
Note: Boxes 4, 5 & 6 correspond to Areas 1, 2 & 3, respectively, of the food chain model.
NC = Not calculated.

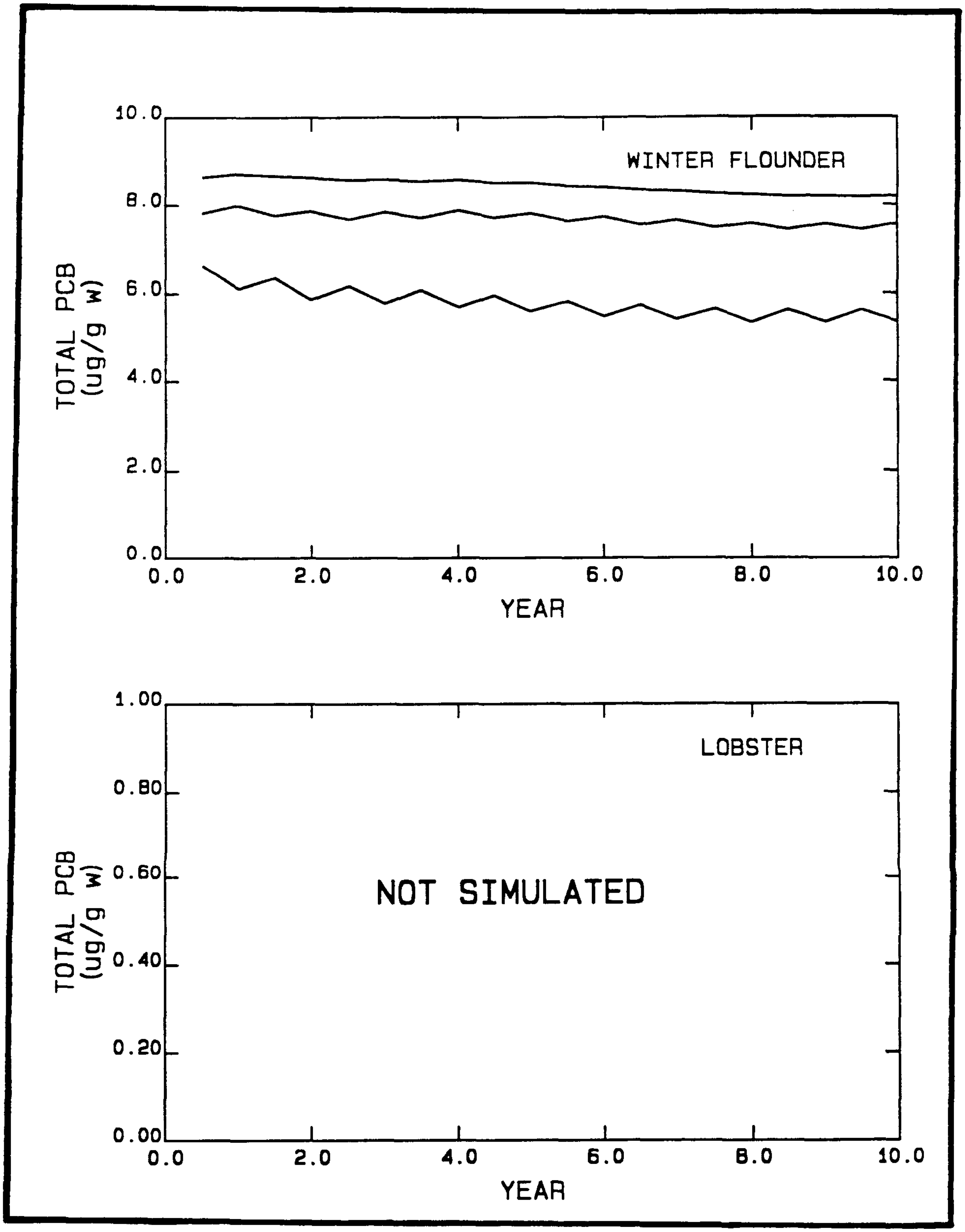


FIGURE 7.28. PCB CONCENTRATION IN AREA 1 FLOUNDER (AGES 0, 2, AND 5) IN RELATION TO TIME AFTER REMEDIATION FOR THE HOT SPOT SCENARIO

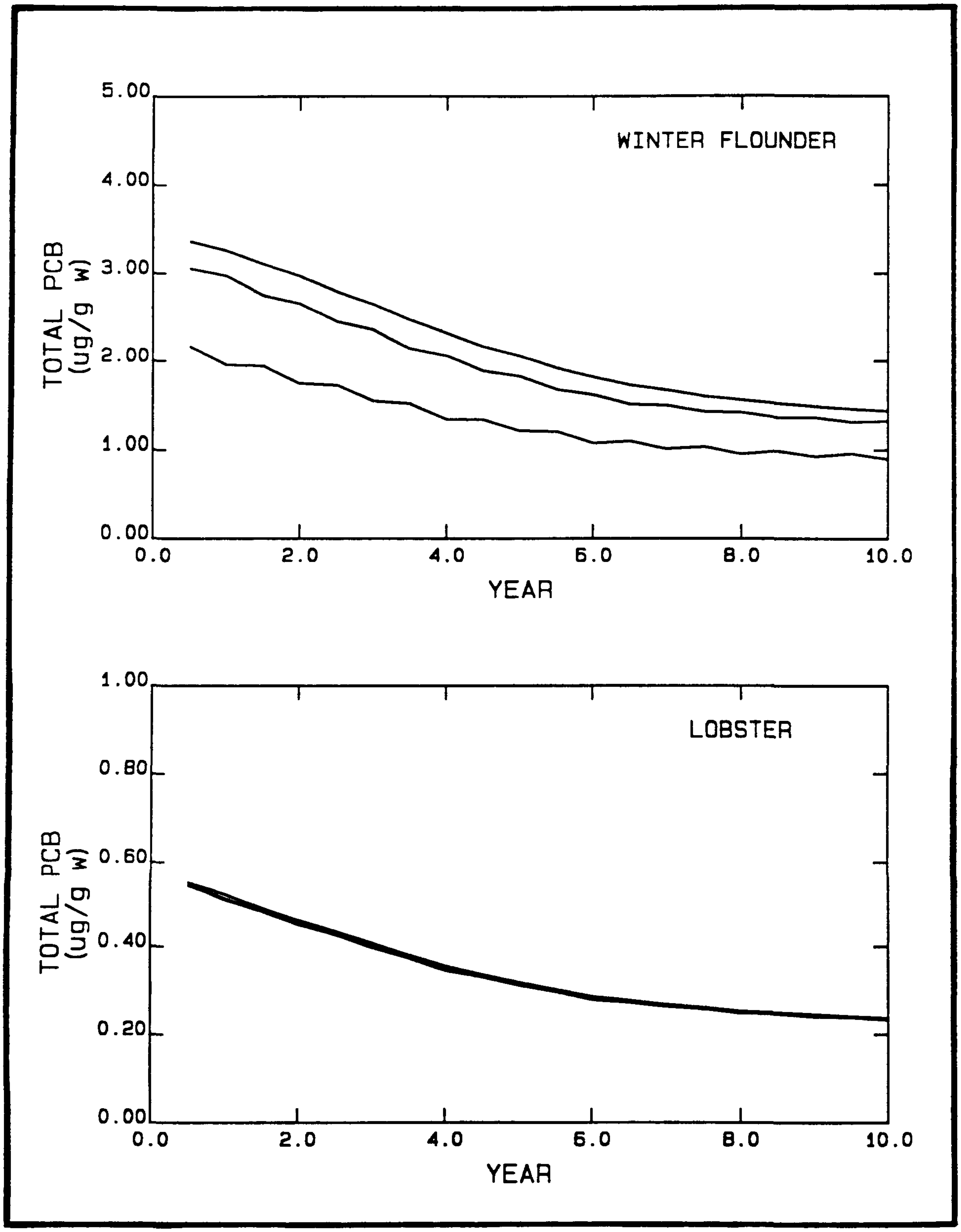


FIGURE 7.29. PCB CONCENTRATION IN AREA 2 FLOUNDER (AGES 0, 2, AND 5) AND LOBSTER IN RELATION TO TIME AFTER REMEDIATION FOR THE HOT SPOT SCENARIO

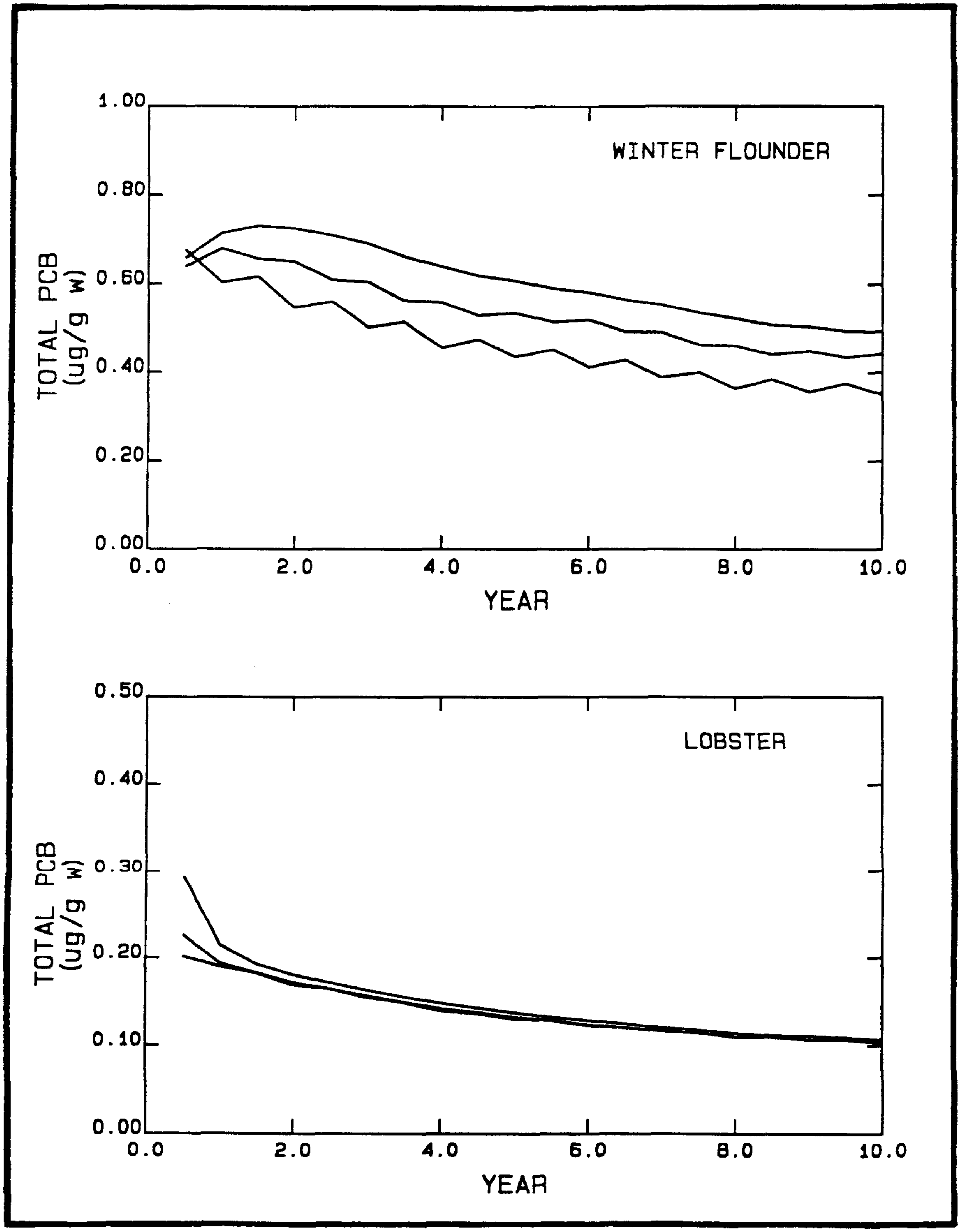


FIGURE 7.30. PCB CONCENTRATION IN AREA 3 FLOUNDER (AGES 0, 2, AND 5) AND LOBSTER IN RELATION TO TIME AFTER REMEDIATION FOR THE HOT SPOT SCENARIO

7.5.2 Upper-Estuary Scenario

In the Upper-Estuary scenario, the cleanup of the area between the Coggeshall and Wood Street Bridges to a residual PCB concentration of 1 to 10 ppm was considered. As part of this scenario, CDFs along the eastern and western shores of the upper-estuary were included in the model. The initial PCB concentration and the changes in the shoreline due to the CDFs are shown in Figure C.4a of Appendix C.

Because of the CDFs, the hydrodynamics were recomputed to incorporate the new location of the shoreline. The calculation procedure described in Section 5.6.2.1 was used in this scenario. The main features of the flow field were the same as in the no-action-scenario hydrodynamics. In fact, the model's time-series output for each case showed no significant differences. Vector plots of the upper-estuary hydrodynamics are shown in Figures D.44 through D.47 of Appendix D.

7.5.2.1 Sediment/Contaminant Transport Results: Upper-Estuary Scenario

The positive effect of removing the PCBs from the upper-estuary is seen clearly in Figures 7.31 and 7.32, which show water column PCB concentrations for year 0 and 10 respectively. The projections indicate that by the end of year 10, the water column PCB concentrations in all areas north of the Hurricane Barrier will be markedly lower than in the No-Action scenario (Figure 7.33). The box-averaged bed layer concentrations (Figure 7.34) show that the lower-harbor region is cleaning itself up once the primary source of PCBs in the upper-estuary is removed. The comparative water column and bed sediment contour plots (Figure 7.35 and 7.36) also illustrate these projected improvements and suggest that there will be little or no impact on the water column or bed layer concentrations outside the Hurricane Barrier.

The flux of PCBs through Coggeshall Bridge (Table 7.28) is very small and is in the reverse direction from the No-Action scenario. This reversal means that PCBs from the contamination remaining in the lower-harbor are migrating

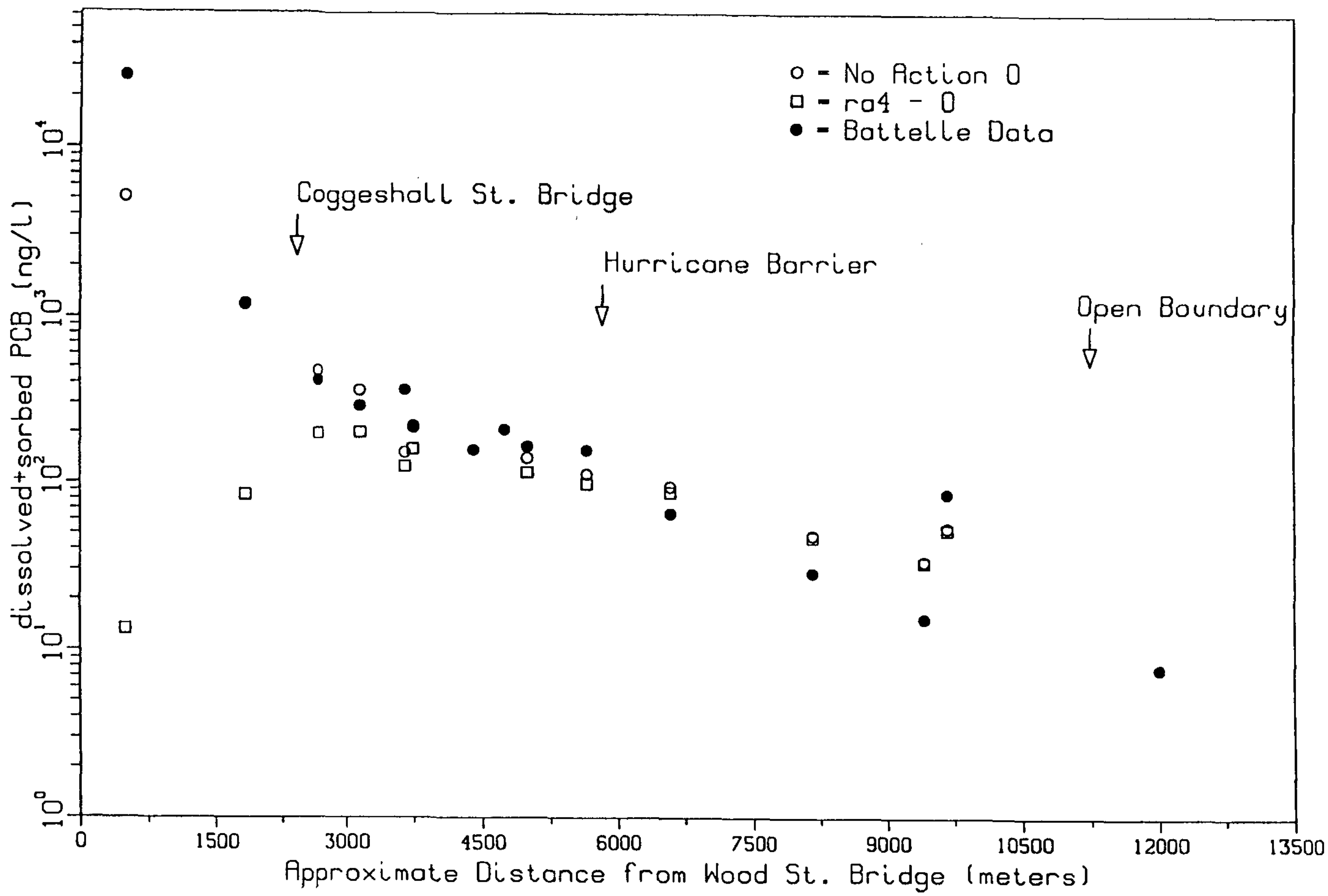


FIGURE 7.31. AVERAGE CONCENTRATION OF TOTAL PCBs IN THE WATER COLUMN FOR YEAR 0 OF THE UPPER-ESTUARY SCENARIO (ng/L). o = NO-ACTION SCENARIO, □ = UPPER-ESTUARY SCENARIO, • = BATTELLE OCEAN SCIENCES DATA.

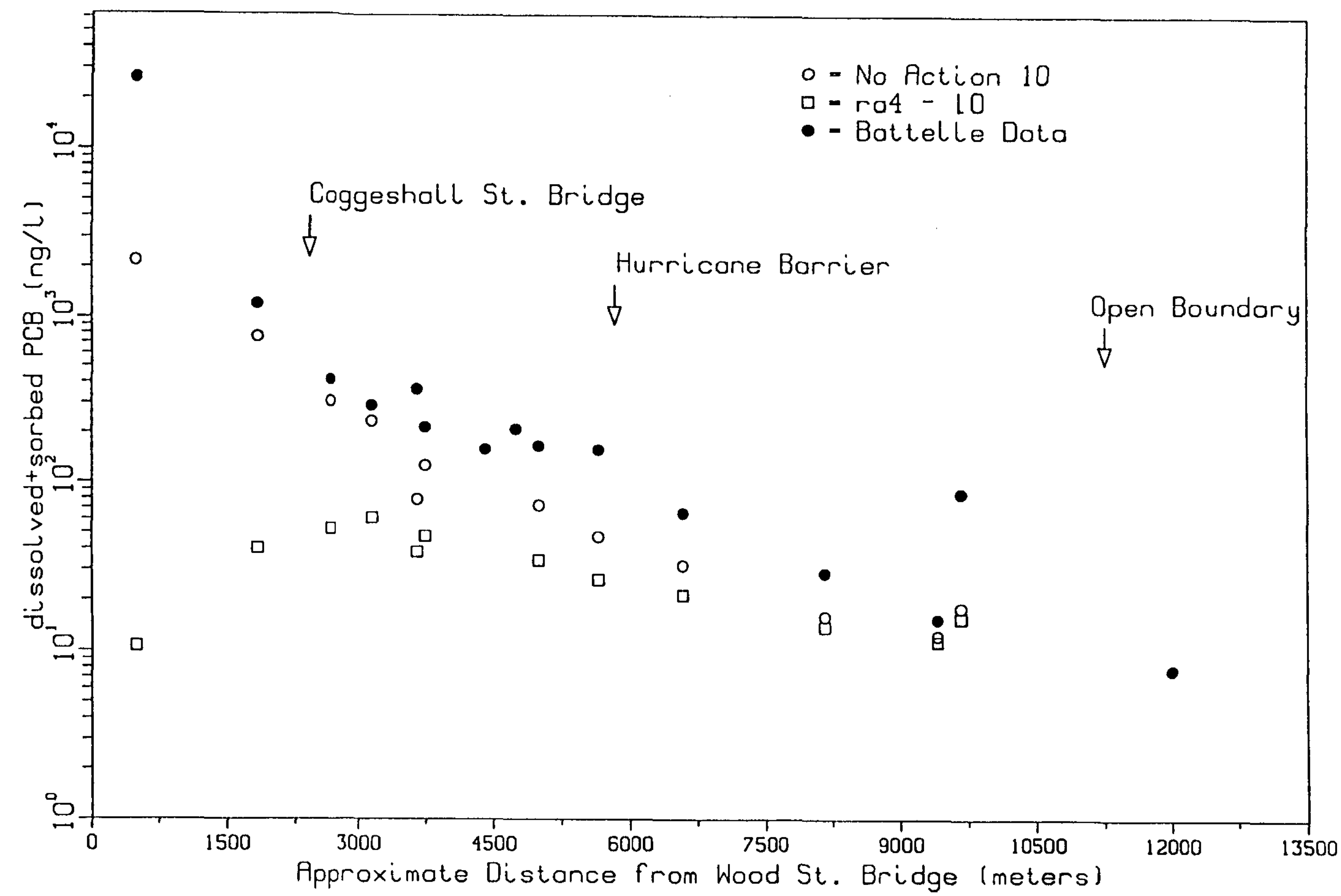


FIGURE 7.32. AVERAGE CONCENTRATION OF TOTAL PCBs IN THE WATER COLUMN FOR YEAR 10 OF THE UPPER-ESTUARY SCENARIO (ng/L). o = NO-ACTION SCENARIO, □ = UPPER-ESTUARY SCENARIO, • = BATTELLE OCEAN SCIENCES DATA.

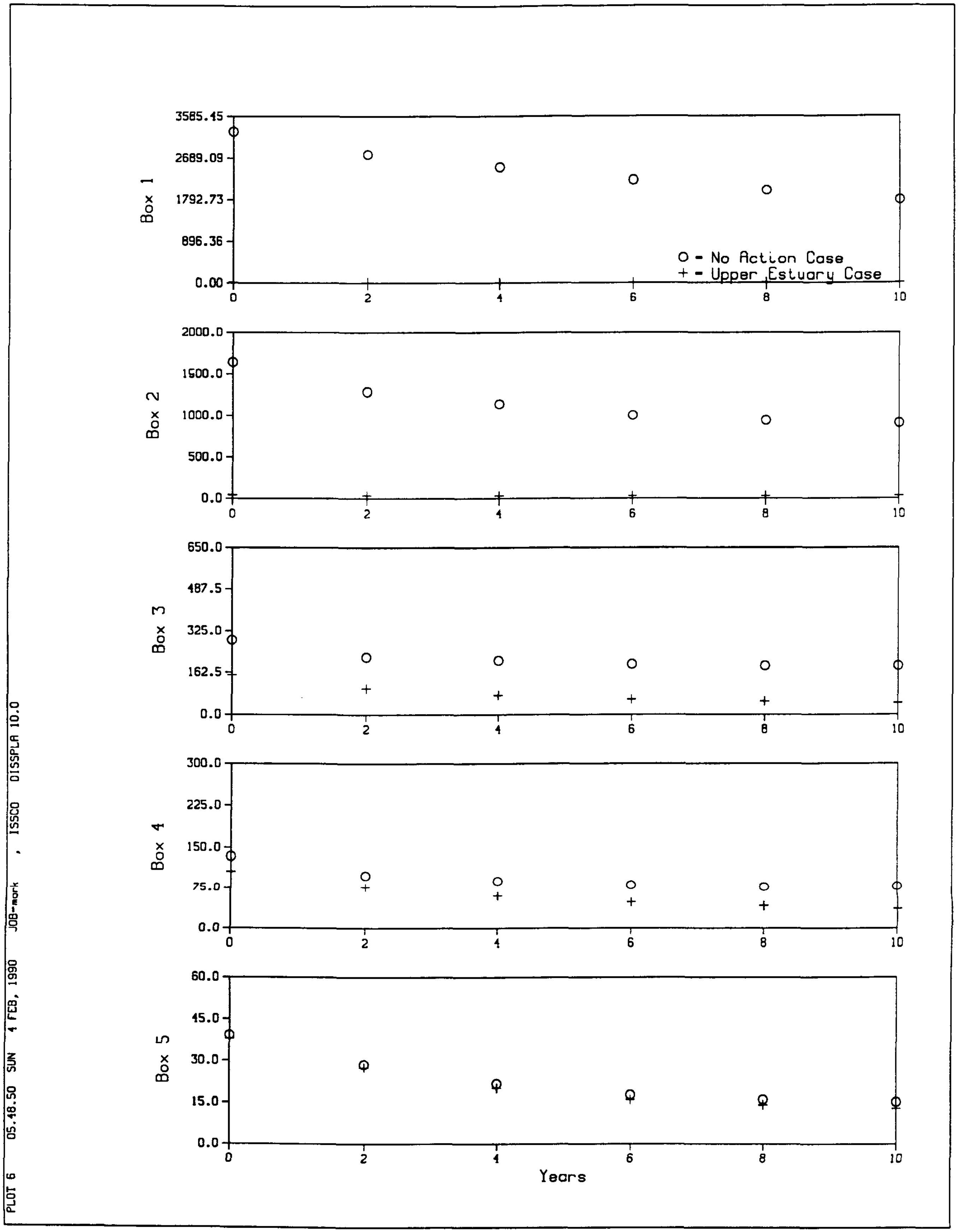


FIGURE 7.33. BOX-AVERAGED MODEL RESULTS FOR THE UPPER-ESTUARY SCENARIO. TOTAL PCB CONCENTRATION (ng/L) IN THE WATER COLUMN. o = NO-ACTION SCENARIO, + = UPPER-ESTUARY SCENARIO.

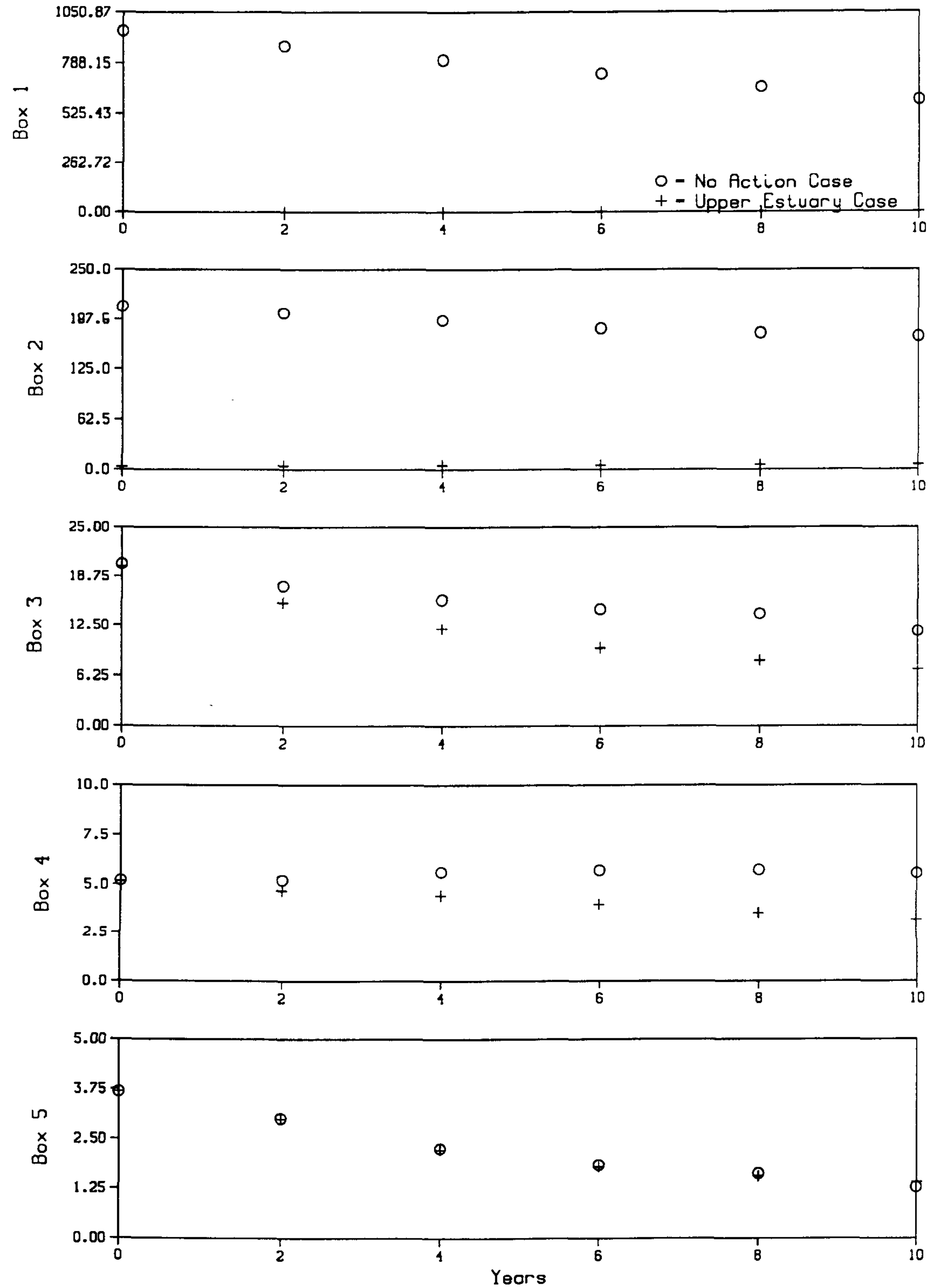


FIGURE 7.34. BOX-AVERAGED MODEL RESULTS FOR THE UPPER-ESTUARY SCENARIO. TOTAL PCB CONCENTRATION (mg/kg) IN THE BED SEDIMENT LAYER. o = NO-ACTION SCENARIO, + = UPPER-ESTUARY SCENARIO.

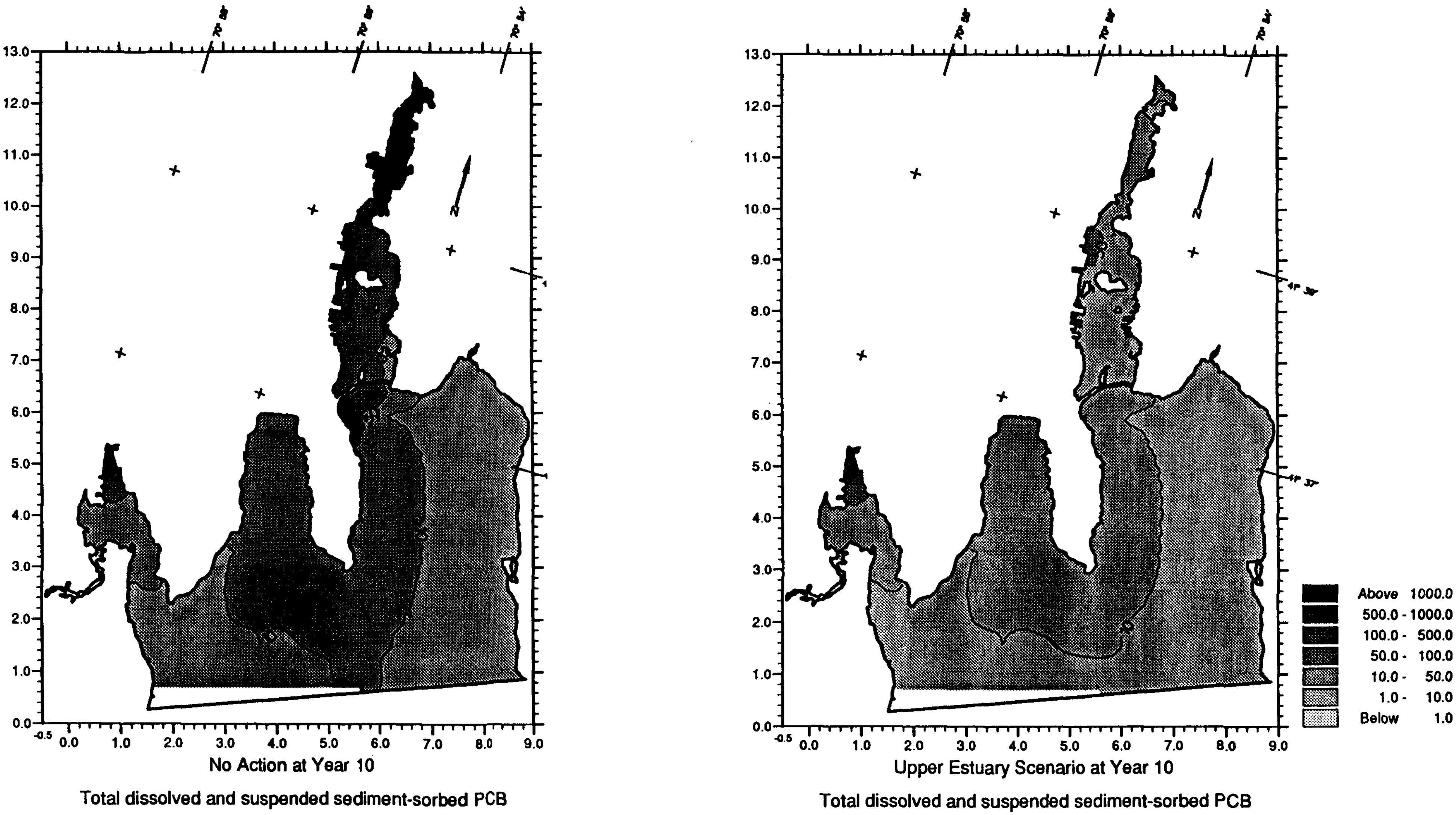


FIGURE 7.35. COMPARISON OF DEPTH-AVERAGED TOTAL WATER COLUMN PCB LEVELS FOR THE NO-ACTION AND UPPER ESTUARY SCENARIOS AT YEAR 10, TOTAL DISSOLVED AND SUSPENDED SEDIMENT-SORBED PCB (ng/L)

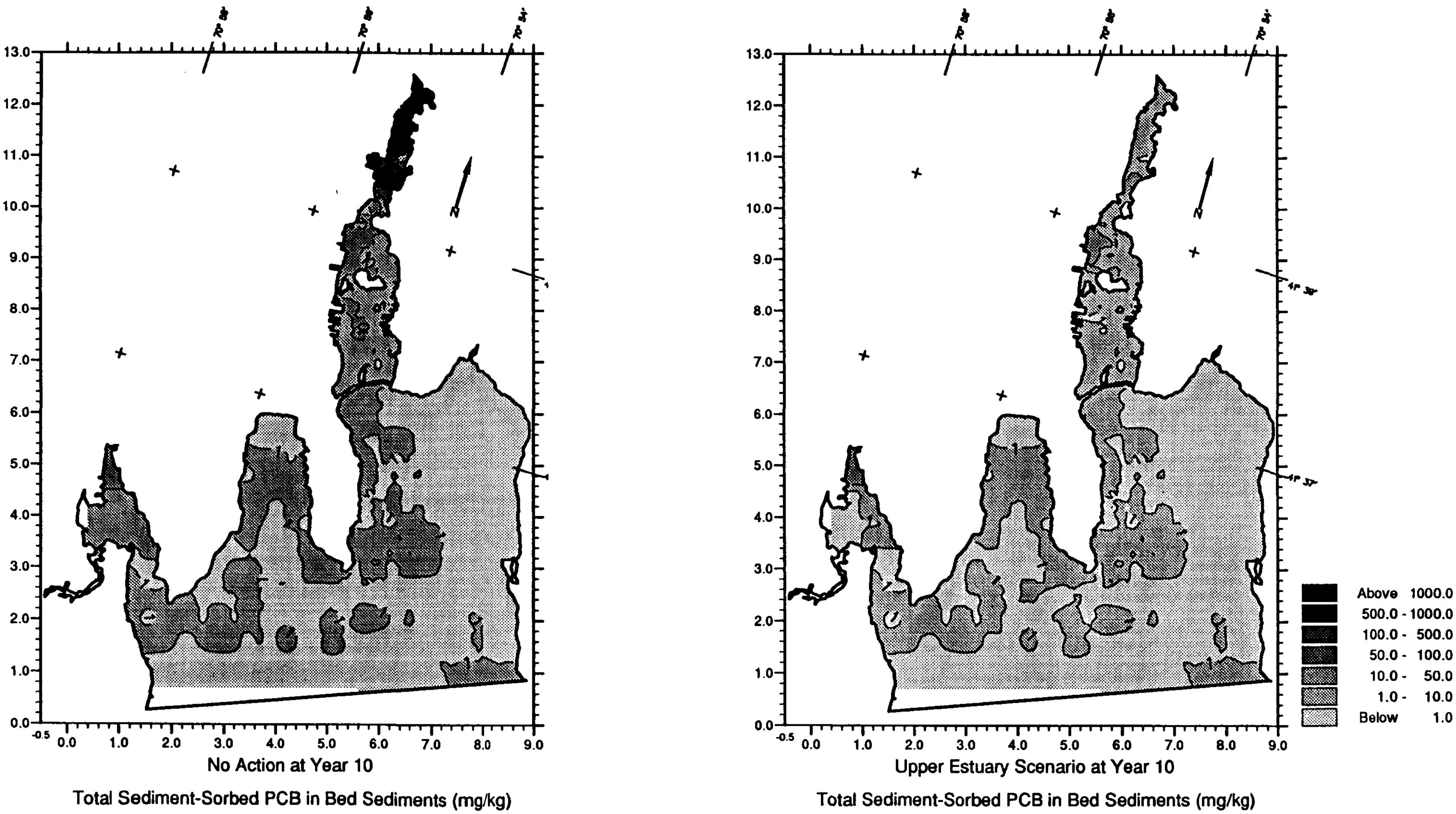


FIGURE 7.36. COMPARISON OF TOTAL BED SEDIMENT-SORBED PCB LEVELS FOR THE NO-ACTION AND UPPER ESTUARY SCENARIOS, AT YEAR 10, TOTAL SEDIMENT-SORBED PCB (mg/kg)

up the estuary and being transferred to the relatively clean sediments there. Tables 7.28 and 7.30 show that PCBs are being reintroduced into the upper-estuary. Note that at year 10 the flux of PCBs through the Hurricane Barrier has been reduced by nearly a factor of three compared with the No-Action scenario.

Tables 7.29, and 7.31 through 7.34 show other data for the Upper-Estuary scenario. The suspended-sediment concentrations computed in the upper-estuary case are only slightly different than in the No-Action case because of the minimal effect of the CDFs on the velocity field.

TABLE 7.28. NET FLUX (kg/TIDAL CYCLE) OF SEDIMENTS AND PCBs FOR THE YEAR 0 AND YEAR 10 UPPER-ESTUARY SCENARIO SIMULATIONS

	Coggeshall Street Bridge	Hurricane Barrier	Open Boundary
Year 0 Sediment Flux	348	1.97×10^3	-2.3137×10^4
Year 10 Sediment Flux	247	2.08×10^3	2.485×10^4
Year 0 PCB Flux	0.06	-0.10	-1.28
Year 10 PCB Flux	0.002	-0.04	-0.25

TABLE 7.29. SEDIMENT MASS BALANCE AND AVERAGE CONCENTRATION IN THE UPPER-ESTUARY FOR THE YEAR 0 AND YEAR 10 UPPER-ESTUARY SIMULATIONS

	Year 0	Year 10	Change
Water Column Mass (kg)	3.218×10^3	2.582×10^3	-636
Bed Layer Mass (kg)	4.137×10^7	4.357×10^7	2.2×10^6
Water Column Concentration (mg/L)	2.6	2.1	-0.5

TABLE 7.30. PCB MASS BALANCE AND AVERAGE CONCENTRATION IN THE UPPER-ESTUARY FOR THE YEAR 0 AND YEAR 10 UPPER-ESTUARY SIMULATIONS

	Year 0	Year 10	Change
Water Column Mass (kg)	0.04	0.03	-0.01
Bed Layer Mass (kg)	121	202	81
Water Column Concentration (ng/L)	35	25	-10
Bed Layer Concentration (mg/kg)	3	5	2

TABLE 7.31. SEDIMENT MASS BALANCE AND AVERAGE CONCENTRATION IN THE LOWER-HARBOR FOR THE YEAR 0 AND YEAR 10 UPPER-ESTUARY SIMULATIONS

	Year 0	Year 10	Change
Water Column Mass (kg)	7.48×10^4	5.97×10^4	-1.51×10^4
Bed Layer Mass (kg)	1.659×10^8	1.797×10^8	1.380×10^7
Water Column Concentration (mg/L)	4.8	3.8	-1.0

TABLE 7.32. PCB MASS BALANCE AND AVERAGE CONCENTRATION IN THE LOWER-HARBOR FOR THE YEAR 0 AND YEAR 10 UPPER-ESTUARY SIMULATIONS

	Year 0	Year 10	Change
Water Column Mass (kg)	1.8	0.6	-1.2
Bed Layer Mass (kg)	1711	816	-895
Water Column Concentration (ng/L)	117	37	-80
Bed Layer Concentration (mg/kg)	10	5	-5

TABLE 7.33. SEDIMENT MASS BALANCE AND AVERAGE CONCENTRATION IN THE OUTER HARBOR FOR THE YEAR 0 AND YEAR 10 UPPER-ESTUARY SIMULATIONS

	Year 0	Year 10	Change
Water Column Mass (kg)	9.596×10^5	8.516×10^5	-1.08×10^5
Bed Layer Mass (kg)	1.523×10^9	1.627×10^9	1.040×10^8
Water Column Concentration (mg/L)	6.0	5.3	-0.7

TABLE 7.34. PCB MASS BALANCE AND AVERAGE CONCENTRATION IN THE OUTER HARBOR FOR THE YEAR 0 AND YEAR 10 UPPER-ESTUARY SIMULATIONS

	Year 0	Year 10	Change
Water Column Mass (kg)	5.1	1.8	-3.3
Bed Layer Mass (kg)	4.673×10^3	2.315×10^3	-2.358×10^3
Water Column Concentration (ng/L)	32	11	-21
Bed Layer Concentration (mg/kg)	3	1	-2

7.5.2.2 Food Chain Model Results: Upper-Estuary Scenario

Exposure Profile

The food chain exposure profile for the Upper-Estuary scenario (Table 7.35) illustrates that the removal of sediment PCB from the area north of the Coggeshall Street Bridge has a dramatic effect on projected water column and sediment concentrations throughout the entire region north of the Hurricane Barrier. In Area 1 of the food chain model (i.e., the area between the Hurricane Barrier and Popes Island), water column concentrations are projected to decline to 25.5 ng/L ten years after remediation. This value is 58% lower than projected under the No-Action scenario. Exposure concentrations in Areas 2 and 3 are about the same as those projected under no-action.

TABLE 7.35. UPPER-ESTUARY EXPOSURE CONCENTRATIONS FOR FOOD CHAIN MODEL

	Area 1		Area 2		Area 3	
Year	Water Column[a]	Bed Sediment[b]	Water Column[a]	Bed Sediment[b]	Water Column[a]	Bed Sediment[b]
0	70.81	7.8	21.44	3.7	10.29	1.0
2	55.58	7.1	16.85	3.0	8.17	0.9
4	43.21	6.6	12.59	2.2	6.52	0.8
6	34.63	5.8	9.94	1.8	5.51	0.8
8	29.47	5.1	8.73	1.6	4.84	0.7
10	25.45	4.5	7.92	1.4	4.47	0.7

[a] Water column dissolved PCB (ng/L).
[b] Sediment PCB (mg/kg dry).

Food Chain Projections

In response to the Upper-Estuary remedial scenario, the food chain model projections indicate an additional decline over No-Action for flounder north of the Hurricane Barrier.

Within Area 1 of the food chain model, the projected young-of-the-year flounder concentration whole body 10 years after remediation is 2.6 μg/g (Figure 7.37). This value is about 60% less than the 1984-85 baseline concentration of 6 μg/g and about 50% less than the projected No-Action concentration after 10 years. For older fish the percentage reduction is slightly less. The projected concentration for five year old fish is 4.4 μg/g, about 50% less than both the 8.5 μg/g baseline and 8.3 μg/g No-Action concentrations. On an edible (fillet) basis these projected concentrations are equivalent to about 0.5 and 0.8 μg/g, respectively.

The projections for flounder and lobster in the two model areas south of the Hurricane Barrier (Areas 2 and 3) for the 10 years following remediation are presented in Figures 7.38 and 7.39 respectively. The results for both lobster and flounder as well as their food chains are essentially the same as those projected under No-Action.

Significant reductions in biota concentrations north of Popes Island are also projected under the Upper-Estuary scenario (Table 7.36). This decline is consistent with the projected change in water column and sediment concentrations with this region.

TABLE 7.36. COMPUTED CONCENTRATIONS IN BIOTA (μg/g WET WEIGHT) FROM EACH OF THE SEGMENTS OF NEW BEDFORD HARBOR 10 YEARS AFTER REMEDIATION OF THE UPPER-ESTUARY TO 10-ppm

Species	Box 1*	Box 2*	Box 3*	Box 4**	Box 5**	Box 6**
Phytoplankton	0.3	0.9	1.3	1.0	0.3	0.2
Polychaete	2.4	6.1	7.7	5.1	1.5	0.5
Hard Clam	0.1	0.3	0.5	0.4	0.1	0.06
Mussel	0.3	0.9	1.3	1.0	0.3	0.2
Crab	0.5	1.3	1.8	1.3	0.4	0.2
Winter Flounder	1.1-1.8	2.9-4.8	3.8-6.2	2.6-4.4	0.8-1.30	.4-0.5
Lobster	nc	nc	nc	nc	0.2-0.2	0.1-0.1

* Values at steady-state with projected year 10 water column and sediment PCB concentrations.
** Values projected ten years after remediation.
Note: Boxes 4, 5 & 6 correspond to Areas 1, 2 & 3, respectively, of the food chain model.
NC: Not calculated.

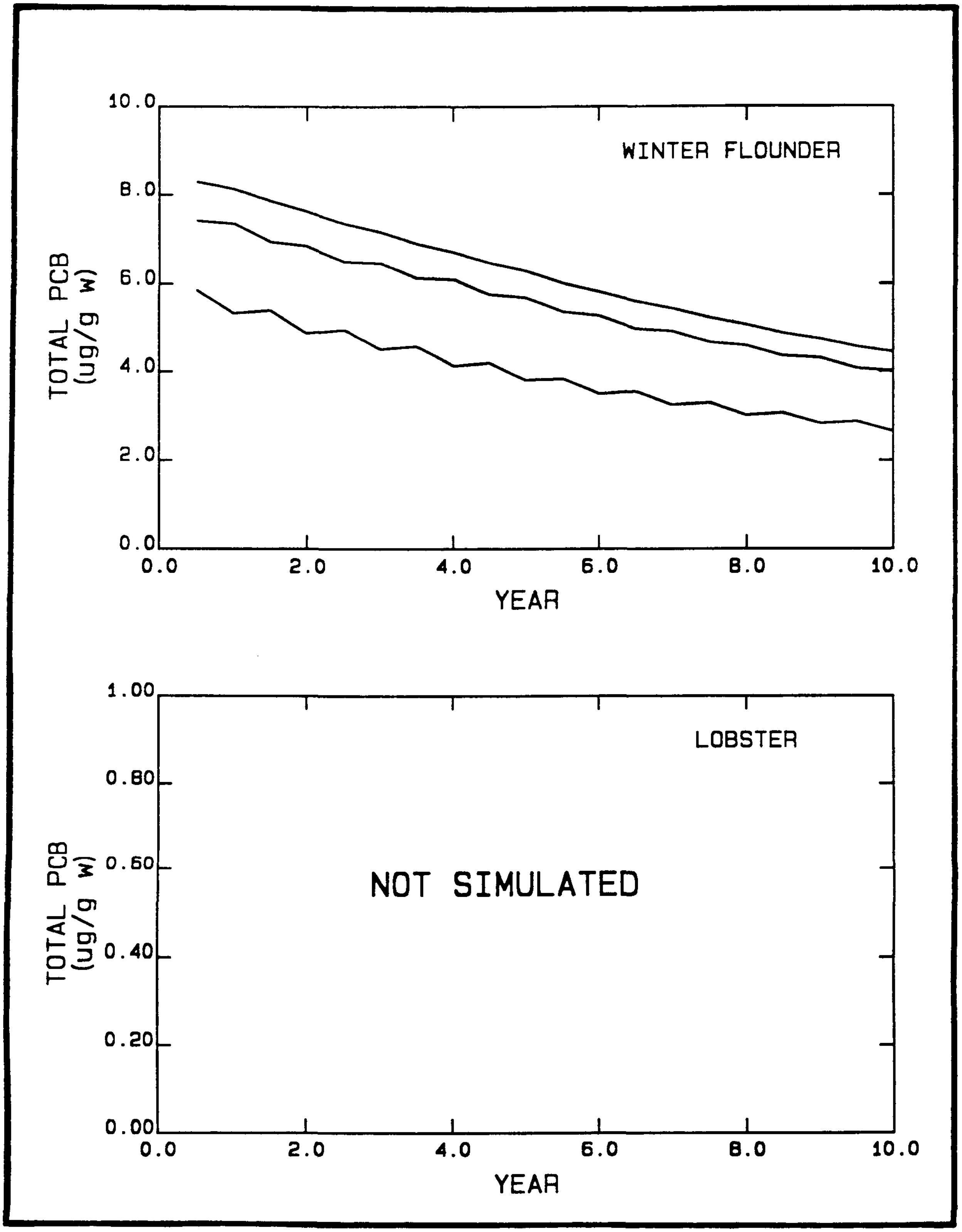


FIGURE 7.37. PCB CONCENTRATIONS IN AREA 1 FLOUNDER (AGES 0, 2, AND 5) IN RELATION TO TIME AFTER REMEDIATION FOR THE UPPER ESTUARY SCENARIO

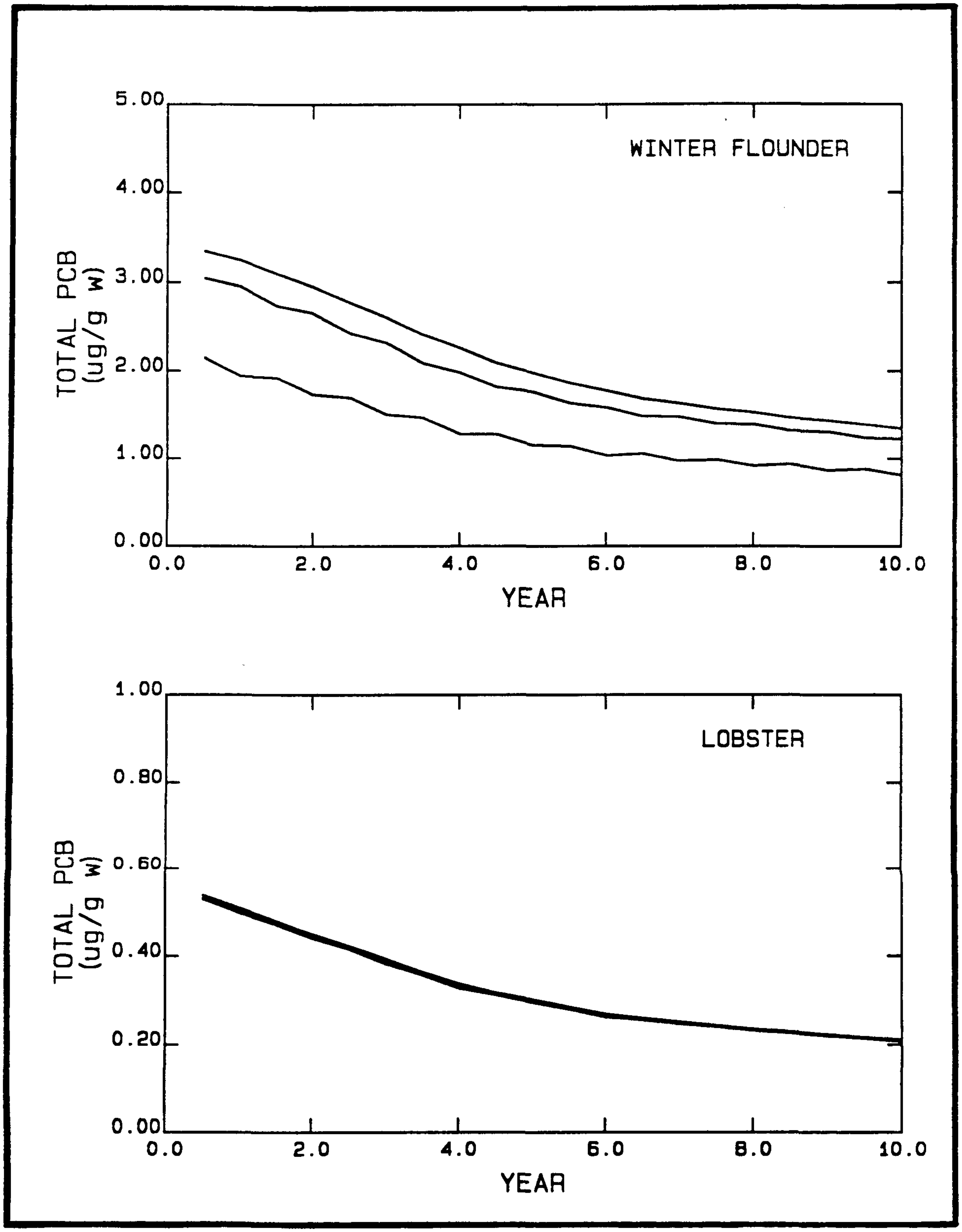


FIGURE 7.38. PCB CONCENTRATIONS IN AREA 2 FLOUNDER (AGES 0, 2, AND 5) AND LOBSTER IN RELATION TO TIME AFTER REMEDIATION FOR THE UPPER ESTUARY SCENARIO

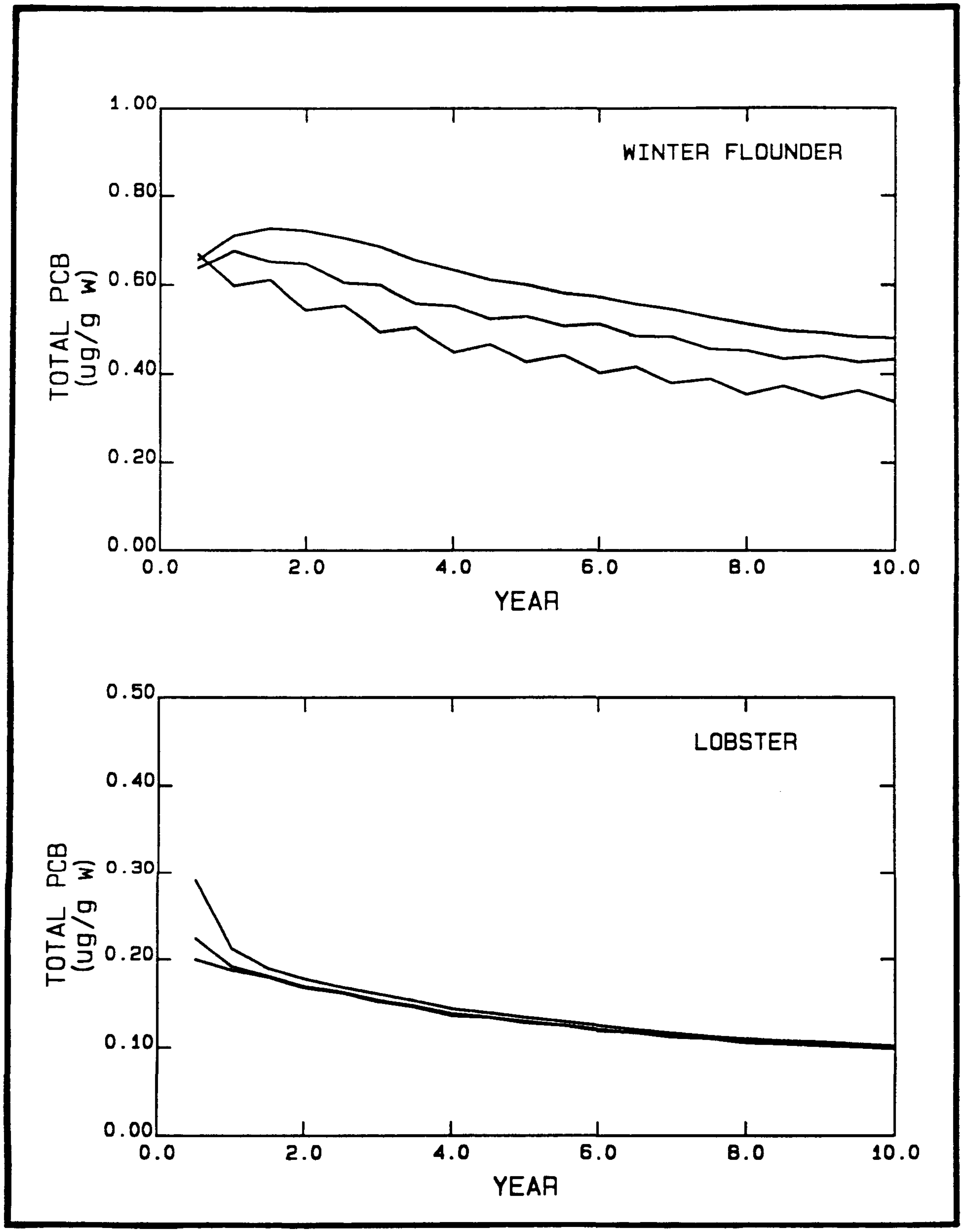


FIGURE 7.39. PCB CONCENTRATION IN AREA 3 FLOUNDER (AGES 0, 2, AND 5) AND LOBSTER IN RELATION TO TIME AFTER REMEDIATION FOR THE UPPER ESTUARY SCENARIO

7.5.3. Lower-Harbor Scenario

The Lower-Harbor scenario considers the removal of PCBs in the area between Wood Street Bridge and the Hurricane Barrier. The residual PCB concentration is in the range of 1 to 10 ppm. Initial conditions for the Lower-Harbor scenario are shown in Figures C.5a, C.5d, and C.5g of Appendix C.

The Lower-Harbor scenario includes additional CDFs, in particular, an island CDF to the north of Popes Island (Figure C.5d). A new set of hydrodynamics were computed to account for the CDFs present in the Lower-Harbor scenario. Vector plots of the Lower-Harbor hydrodynamics are shown in Figures D.48 through D.51 of Appendix D. As before, in the upper-estuary case, the use of different hydrodynamic conditions caused only minor changes in the computed suspended sediment levels and transport.

7.5.3.1 Sediment/Contaminant Transport Results: Lower-Harbor Scenario

The results of the Lower-Harbor scenario simulations are similar to those of the Upper-Estuary scenario. The scenarios are comparable in their impacts and trends, but the positive impacts of the Lower-Harbor cleanup encompass a larger geographical area.

The water column PCB concentrations inside the Hurricane Barrier are substantially lower than those of the No-Action scenario at years 0 and 10 (Figures 7.40 and 7.41). The average water column concentration for a combination of boxes 3 and 4 (the lower-harbor area) is 22 ng/L at the end of year 10 (Figure 7.42). The No-Action concentration at the end of year 10 for this region was 104 ng/L. Concentrations in the bed sediments (Figure 7.43) are also much lower, with the PCB concentration in boxes 3 and box 4 being less than 50% of the No-Action value. The comparative water column and bed sediment contour plots (Figures 7.44 and 7.45) also indicate dramatic improvements in water quality and sediment contamination north of the Hurricane Barrier. As was the case in the previous remedial scenarios, the Lower-Harbor remedial scenario is projected to have no appreciable effect on the PCB concentrations in the outer harbor area or on the net flux of PCBs through the open boundary.

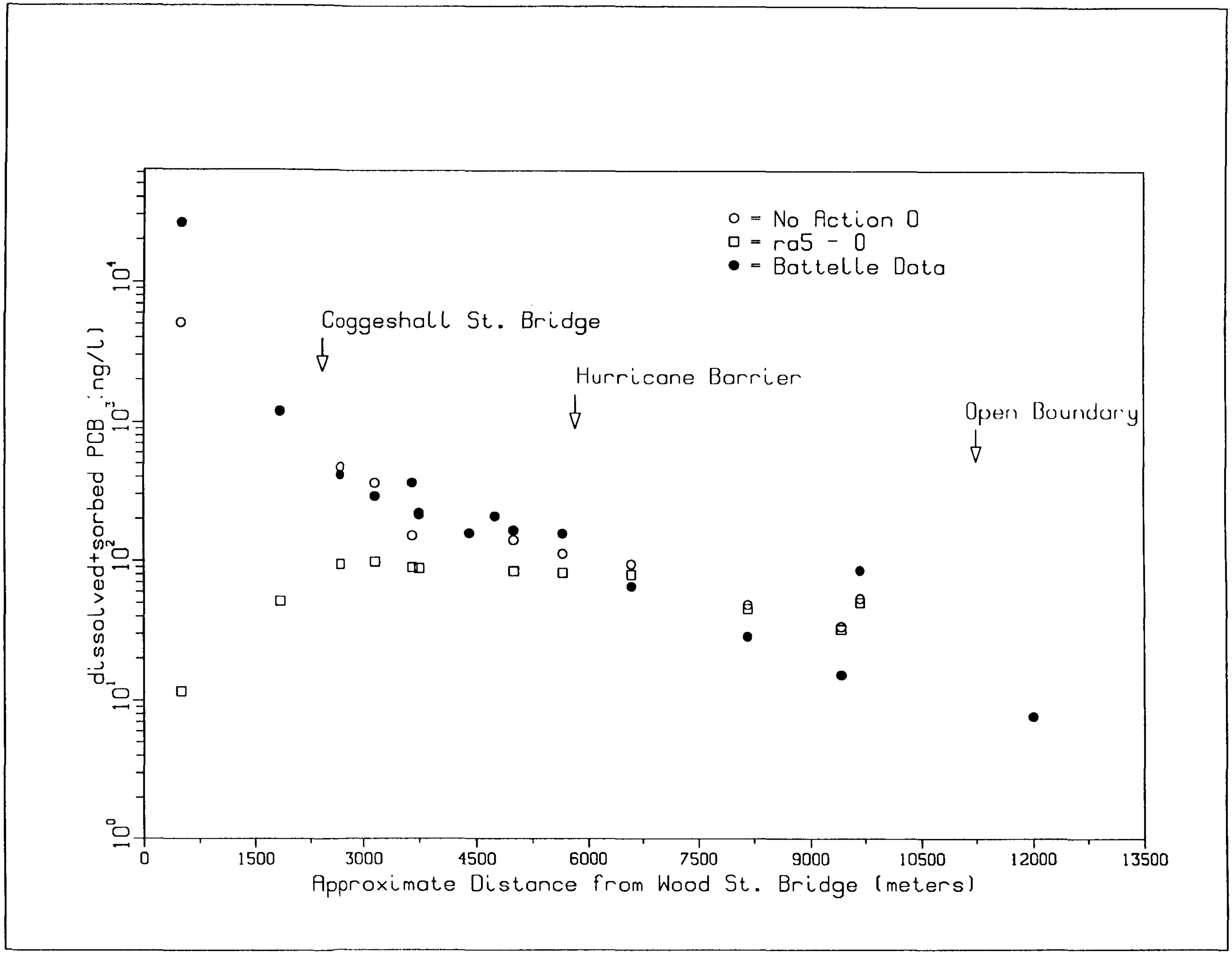


FIGURE 7.40. AVERAGE CONCENTRATION OF TOTAL PCBs IN THE WATER COLUMN FOR YEAR 0 OF THE LOWER-HARBOR SCENARIO (ng/L). o = NO-ACTION SCENARIO, □ = LOWER-HARBOR SCENARIO, • = BATTELLE OCEAN SCIENCES DATA.

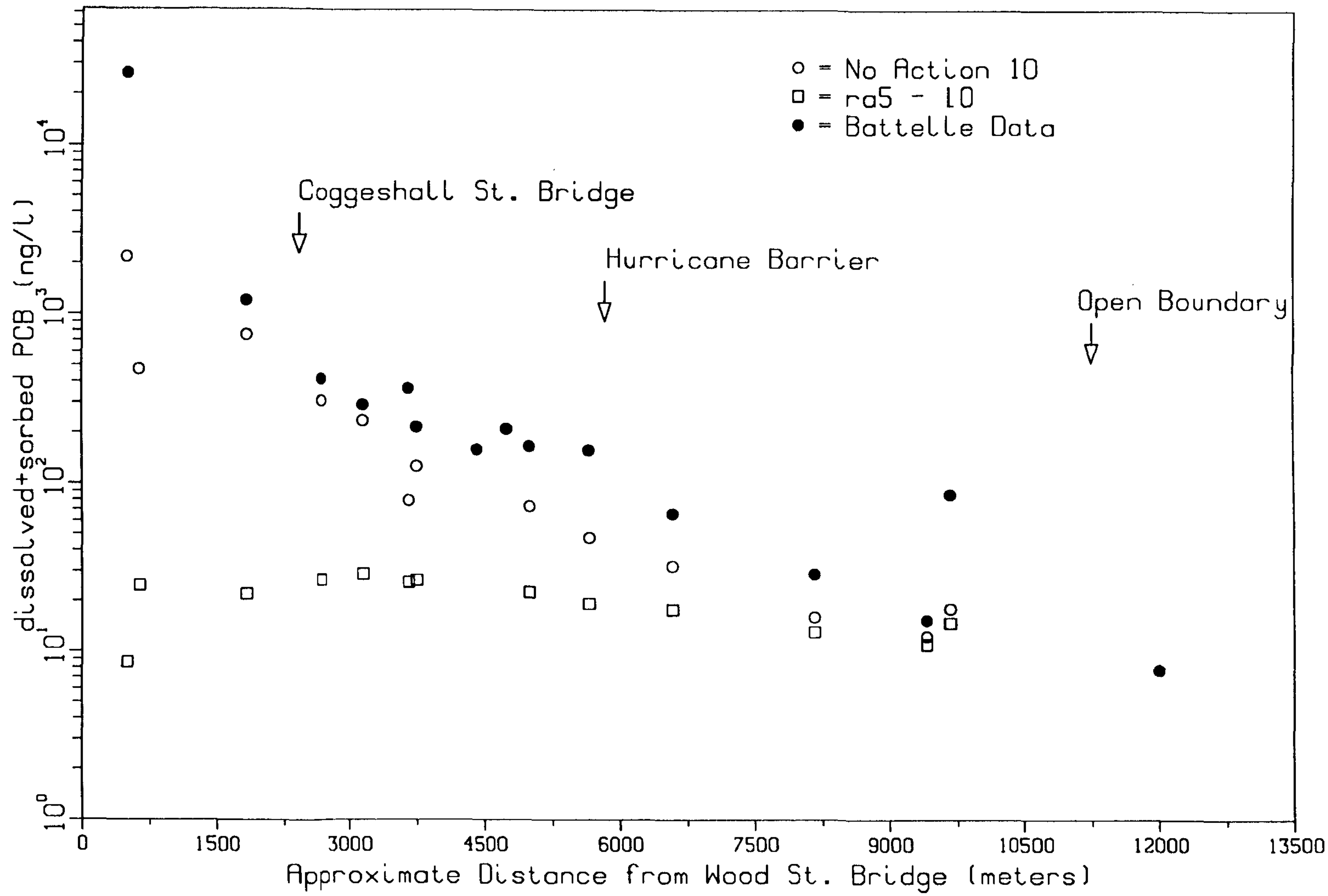


FIGURE 7.41. **AVERAGE CONCENTRATION OF TOTAL PCBs IN THE WATER COLUMN FOR YEAR 10 OF THE LOWER-HARBOR SCENARIO (ng/L). o = NO-ACTION SCENARIO, □ = LOWER-HARBOR SCENARIO, • = BATTELLE OCEAN SCIENCES DATA.**

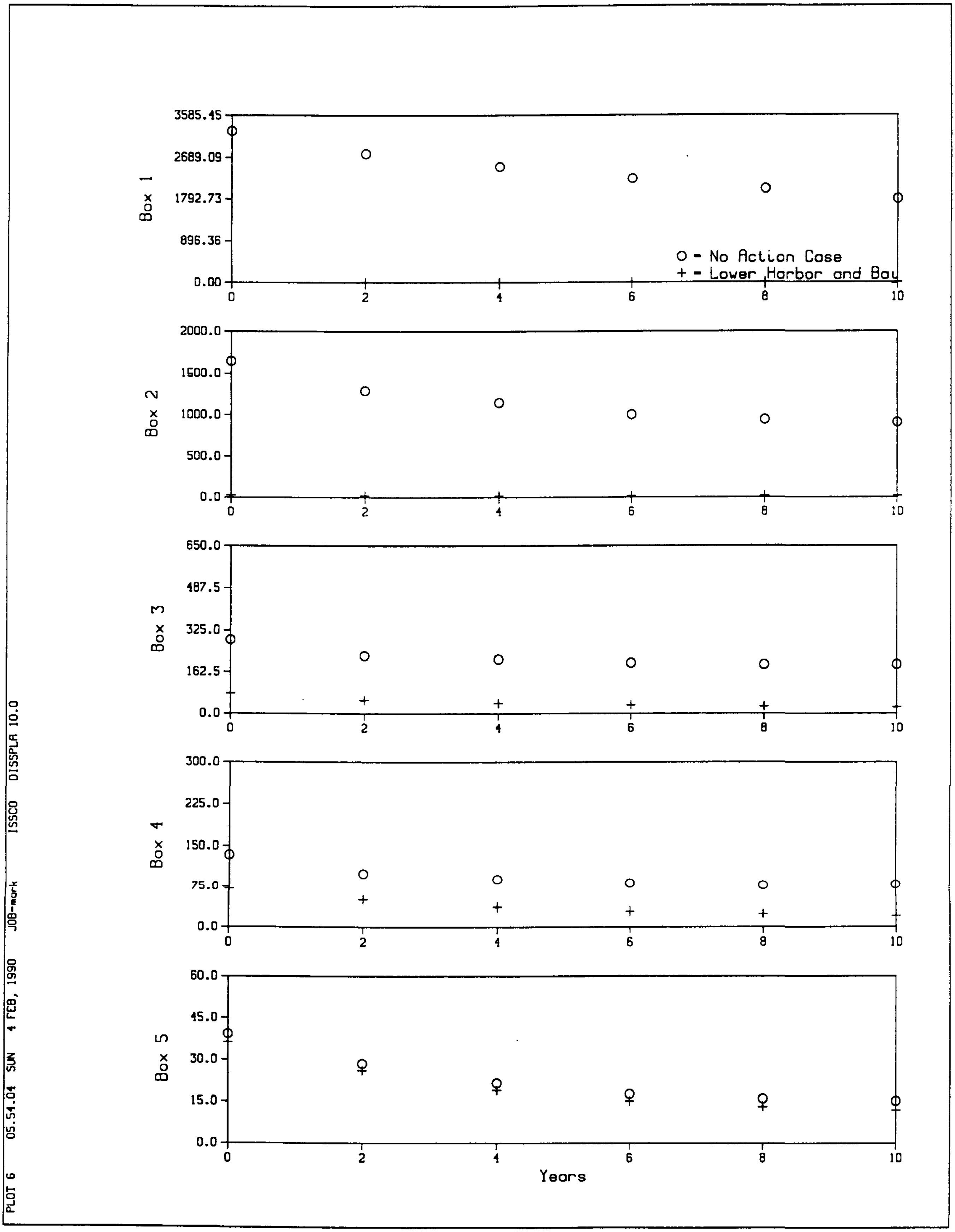


FIGURE 7.42. BOX-AVERAGED MODEL RESULTS FOR THE LOWER-HARBOR SCENARIO. TOTAL PCB CONCENTRATION (ng/L) IN THE WATER COLUMN. o = NO-ACTION SCENARIO, + = LOWER-HARBOR SCENARIO.

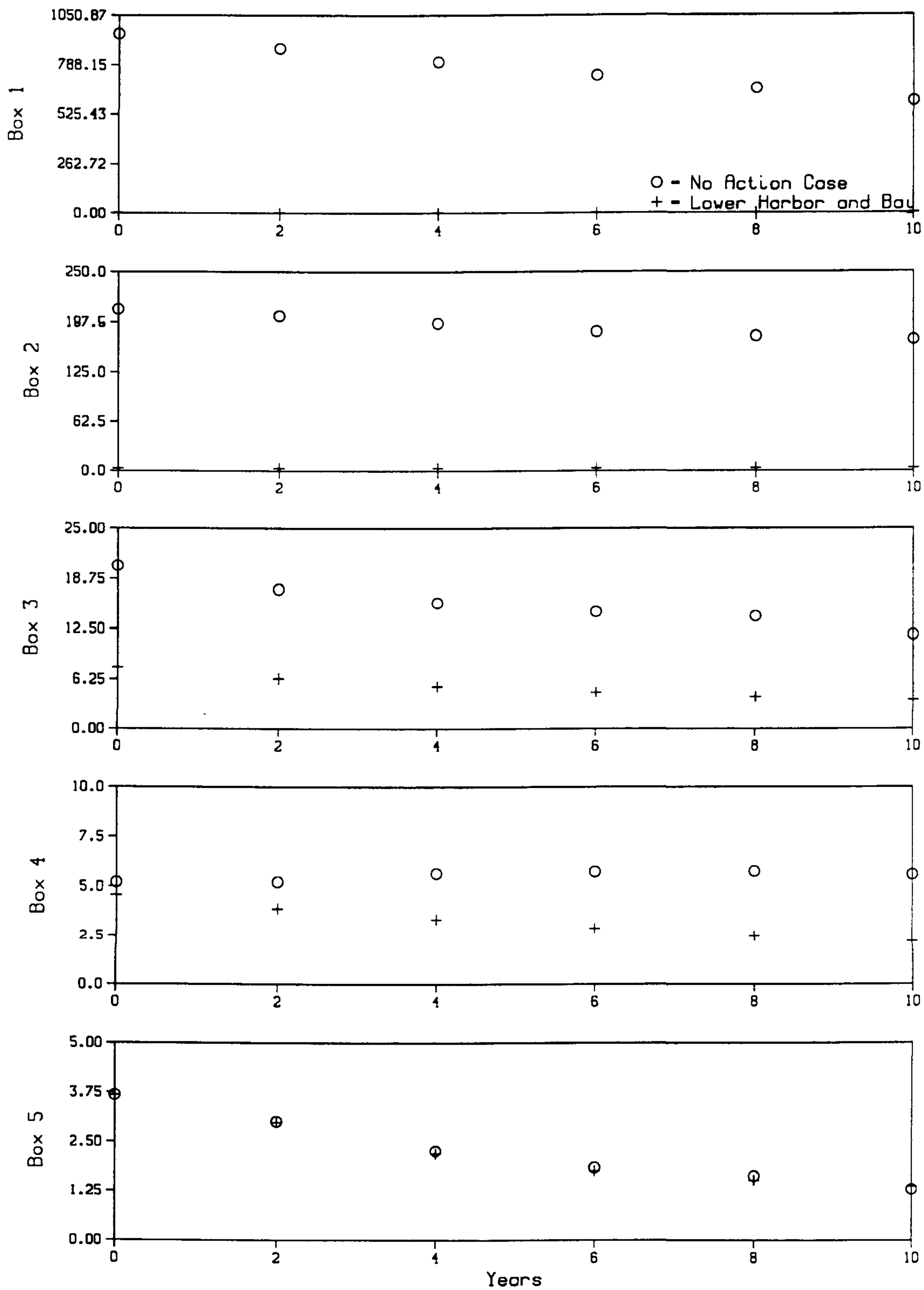


FIGURE 7.43. BOX-AVERAGED MODEL RESULTS FOR THE LOWER-HARBOR SCENARIO. TOTAL PCB CONCENTRATION (mg/kg) IN THE BED SEDIMENT LAYER. o = NO-ACTION SCENARIO, + = LOWER HARBOR SCENARIO.

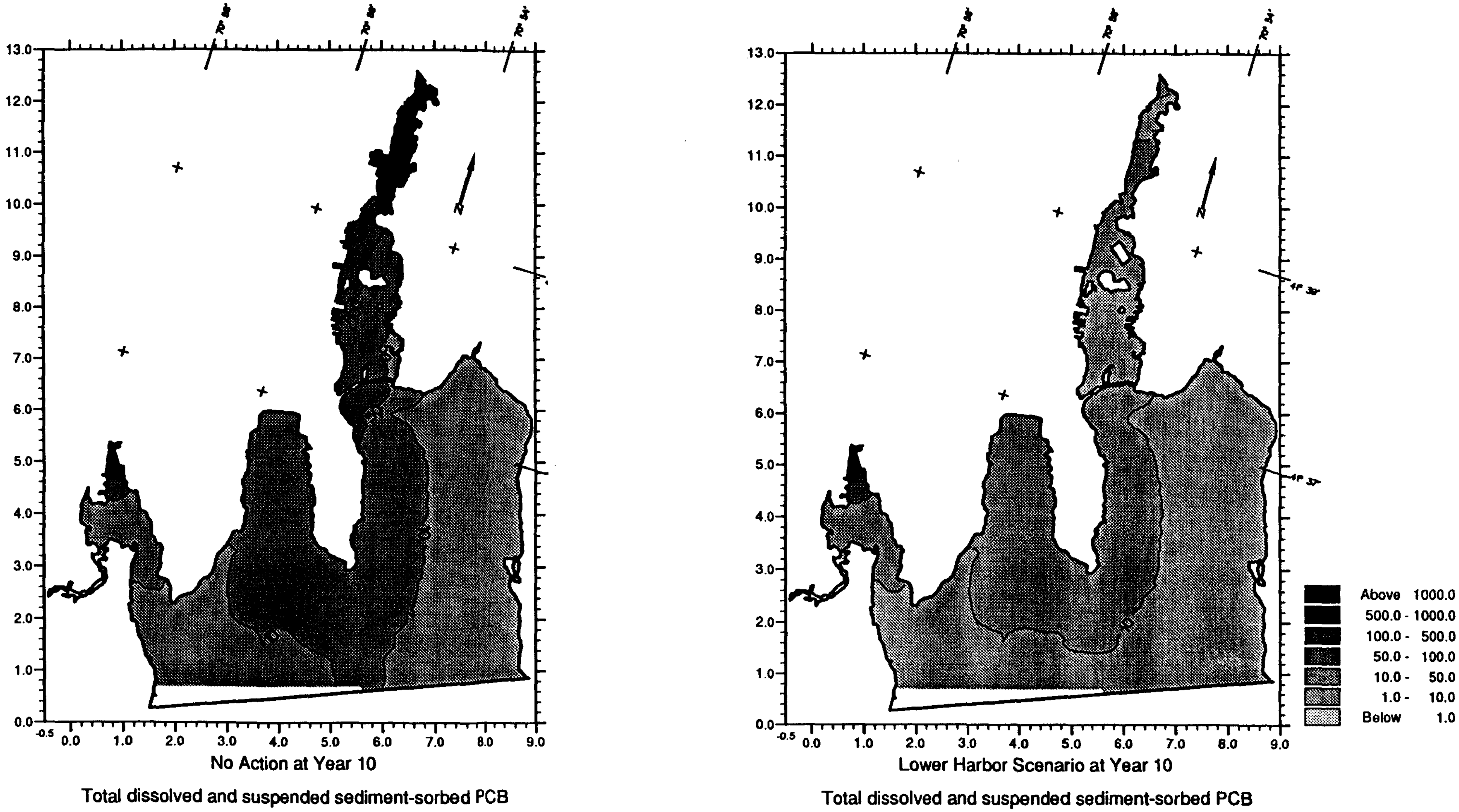


FIGURE 7.44. COMPARISON OF DEPTH-AVERAGED TOTAL WATER COLUMN PCB LEVELS FOR THE NO-ACTION AND LOWER HARBOR SCENARIOS AT YEAR 10, TOTAL DISSOLVED AND SUSPENDED SEDIMENT-SORBED PCB (ng/L)

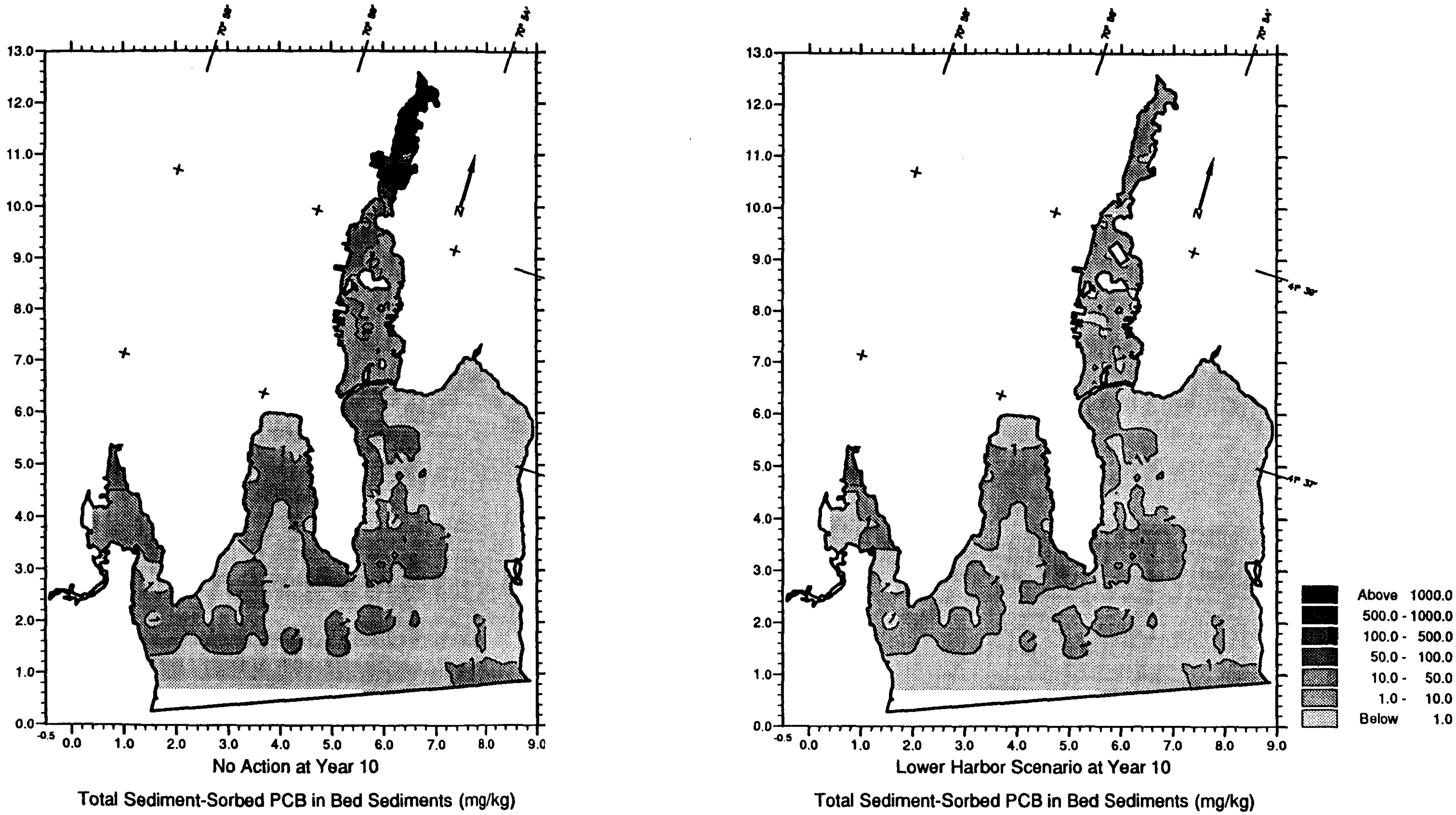


FIGURE 7.45. COMPARISON OF TOTAL BED SEDIMENT-SORBED PCB LEVELS FOR THE NO-ACTION AND LOWER HARBOR SCENARIOS AT YEAR 10, TOTAL SEDIMENT-SORBED PCB (mg/kg)

Tables 7.37 through 7.43 present the PCB and sediment flux and mass balance results for year 0 and 10 of the remedial scenario. The results in Tables 7.38 through 7.43 are presented as area averaged values for the three geographic study areas evaluated by the REM III Feasibility Study team.

TABLE 7.37. NET FLUX (kg/TIDAL CYCLE) OF SEDIMENTS AND PCBs FOR THE YEAR 0 AND YEAR 10 LOWER-HARBOR SCENARIO SIMULATIONS

	Coggeshall Street Bridge	Hurricane Barrier	Open Boundary
Year 0 Sediment Flux	327	2.110×10^3	-2.1780×10^4
Year 10 Sediment Flux	231	2.076×10^3	2.4858×10^4
Year 0 PCB Flux	0.03	-0.04	-1.25
Year 10 PCB Flux	0.001	-0.02	-0.24

TABLE 7.38. SEDIMENT MASS BALANCE AND AVERAGE CONCENTRATION IN THE UPPER-ESTUARY FOR THE YEAR 0 AND YEAR 10 LOWER-HARBOR SIMULATIONS

	Year 0	Year 10	Change
Water Column Mass (kg)	3.082×10^3	2.469×10^3	-613
Bed Layer Mass (kg)	4.136×10^7	4.338×10^7	2.020×10^6
Water Column Concentration (mg/L)	2.5	2.0	-0.5

TABLE 7.39. PCB MASS BALANCE AND AVERAGE CONCENTRATION IN THE UPPER-ESTUARY FOR THE YEAR 0 AND YEAR 10 LOWER-HARBOR SIMULATIONS

	Year 0	Year 10	Change
Water Column Mass (kg)	0.03	0.02	-0.01
Bed Layer Mass (kg)	115	126	11
Water Column Concentration (ng/L)	24	15	-9
Bed Layer Concentration (mg/kg)	3	3	0

TABLE 7.40. SEDIMENT MASS BALANCE AND AVERAGE CONCENTRATION IN THE LOWER-HARBOR FOR THE YEAR 0 AND YEAR 10 LOWER-HARBOR SIMULATIONS

	Year 0	Year 10	Change
Water Column Mass (kg)	7.161×10^4	5.844×10^4	-1.317×10^4
Bed Layer Mass (kg)	1.575×10^8	1.714×10^8	1.390×10^7
Water Column Concentration (mg/L)	4.7	3.8	-0.9

TABLE 7.41. PCB MASS BALANCE AND AVERAGE CONCENTRATION IN THE LOWER-HARBOR FOR THE YEAR 0 AND YEAR 10 LOWER-HARBOR SIMULATIONS

	Year 0	Year 10	Change
Water Column Mass (kg)	1.1	0.3	-0.8
Bed Layer Mass (kg)	869	440	-429
Water Column Concentration (ng/L)	72	22	-50
Bed Layer Concentration (mg/kg)	6	3	-3

TABLE 7.42. SEDIMENT MASS BALANCE AND AVERAGE CONCENTRATION IN THE OUTER-HARBOR FOR THE YEAR 0 AND YEAR 10 LOWER-HARBOR SIMULATIONS

	Year 0	Year 10	Change
Water Column Mass (kg)	9.551×10^5	8.517×10^5	-1.034×10^5
Bed Layer Mass (kg)	1.523×10^9	1.628×10^9	1.050×10^8
Water Column Concentration (mg/L)	6.0	5.3	-0.7

TABLE 7.43. PCB MASS BALANCE AND AVERAGE CONCENTRATION IN THE OUTER HARBOR FOR THE YEAR 0 AND YEAR 10 LOWER-HARBOR SCENARIO SIMULATIONS

	Year 0	Year 10	Change
Water Column Mass (kg)	4.9	1.7	-3.2
Bed Layer Mass (kg)	4.672×10^3	2.253×10^3	-2.419×10^3
Water Column Concentration (ng/L)	31	11	-20
Bed Layer Concentration (mg/kg)	3	1	-2

7.5.3.2 Food Chain Results: Lower-Harbor Scenario

Exposure Profile

The food chain exposure conditions for the biota projected by the physical/chemical model under the Lower-Harbor scenario are presented below in Table 7.44. The results suggest that removal of sediment PCB from all areas north of the Hurricane Barrier that exceed a concentration of 10 µg/g will substantially reduce water column and sediment concentrations throughout this area. Within Area 1 of the food chain model (i.e., the lower most segment of the Inner Harbor), water column concentrations are projected to decline to 15 ng/L after ten years, about 75% lower than projected under No Action. Similarly, the average sediment PCB concentration is projected to decline to 2.8 ug/g, about 65% lower than projected under No Action. However, the projected exposure concentrations in Areas 2 and 3 are about the same as projected under No-Action.

TABLE 7.44. LOWER-ESTUARY EXPOSURE CONCENTRATIONS FOR FOOD CHAIN MODEL

	Area 1		Area 2		Area 3	
Year	Water Column[a]	Bed Sediment[b]	Water Column[a]	Bed Sediment[b]	Water Column[a]	Bed Sediment[b]
0	43.26	6.4	20.79	3.7	10.15	0.9
2	33.65	5.5	16.12	3.0	8.00	0.9
4	25.56	4.6	11.98	2.2	6.38	0.8
6	20.48	3.9	9.43	1.8	5.39	0.8
8	17.35	3.3	8.17	1.5	4.71	0.7
10	14.80	2.8	7.38	1.4	4.34	0.7

[a] Water column dissolved PCB (ng/L).
[b] Sediment PCB (mg/kg dry).

Food Chain Projections

In Area 1 a reduction in flounder concentrations of about 65% is projected (Figure 7.46), consistent with the decline in sediment PCB. After 10 years, whole body concentrations range from about 1.6 μg/g for young-of-the-year to about 2.7 μg/g for five year olds (Table 7.45). On an edible (tissue) basis, these concentrations are equivalent to about 0.3 and 0.5 μg/g, respectively. Thus the projected concentrations are significantly below the FDA Action limit of 2 μg/g.

TABLE 7.45. COMPUTED CONCENTRATIONS IN BIOTA (μg/g WET WEIGHT) FROM EACH OF THE SEGMENTS OF NEW BEDFORD HARBOR 10 YEARS AFTER REMEDIATION OF THE UPPER- AND LOWER-HARBOR TO 10-ppm

Species	Box 1*	Box 2*	Box 3*	Box 4**	Box 5**	Box 6**
Phytoplankton	0.2	0.5	0.7	0.6	0.3	0.2
Polychaete	1.9	3.7	3.9	3.2	1.5	0.5
Hard Clam	0.08	0.2	0.3	0.2	0.1	0.06
Mussel	0.2	0.5	0.7	0.6	0.3	0.2
Crab	0.4	0.8	0.9	0.8	0.4	0.2
Winter Flounder	0.9-1.5	1.7-2.9	1.9-3.2	1.6-2.7	0.8-1.3	0.4-0.5
Lobster	nc	nc	nc	nc	0.2-0.2	0.1-0.1

* Values at steady-state with projected year 10 water column and sediment PCB concentrations.
** Values projected ten years after remediation.
Note: Boxes 4, 5 & 6 correspond to Areas 1, 2 & 3, respectively, of the food chain model.
NC: Not calculated.

For Area 2 (Figure 7.47) and Area 3 (Figure 7.48) the projected responses are essentially the same as those discussed under the No-Action and under the No-Action and Hot-Spot scenarios.

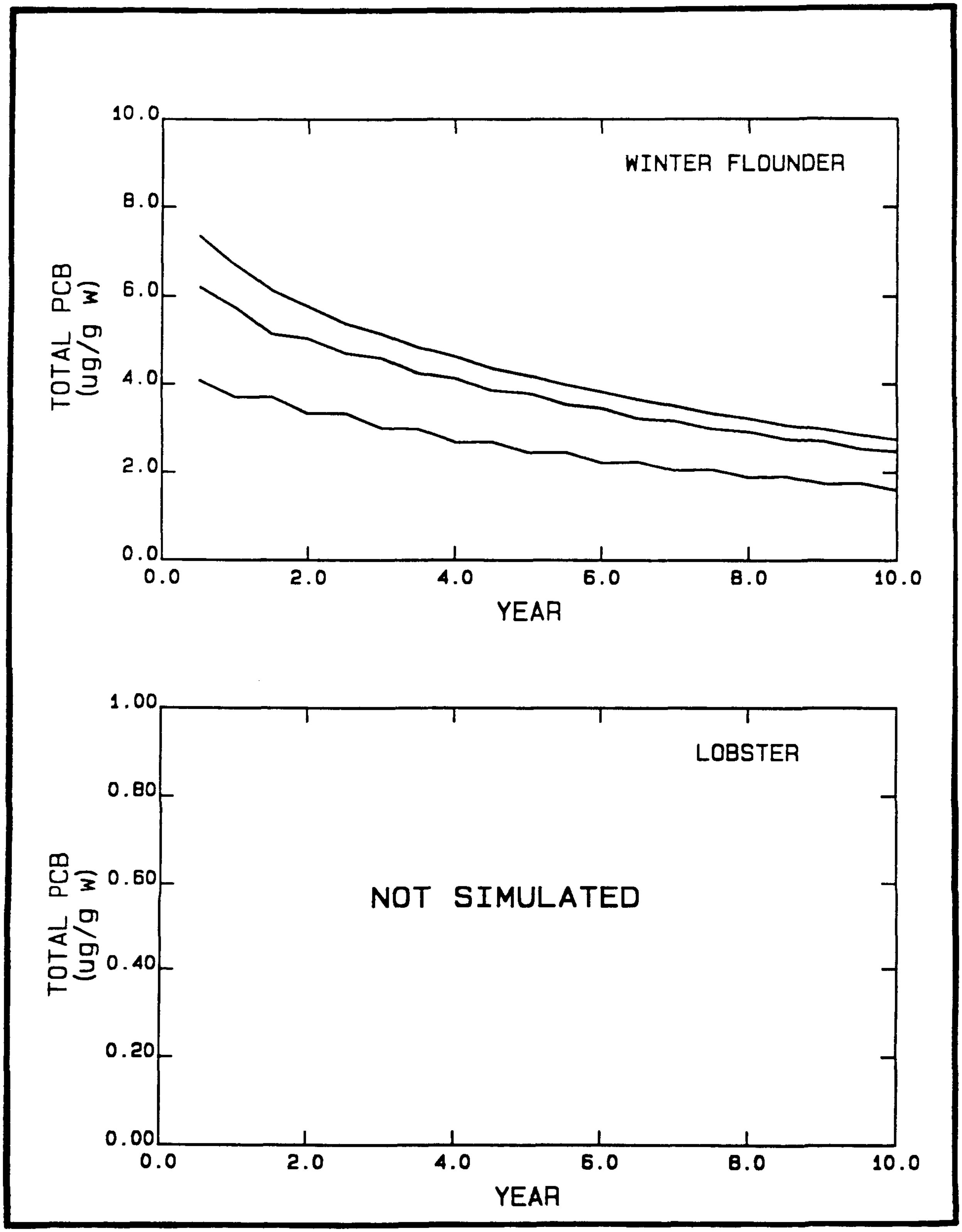


FIGURE 7.46. PCB CONCENTRATIONS IN AREA 1 FLOUNDER (AGES 0, 2, AND 5) IN RELATION TO TIME AFTER REMEDIATION FOR THE LOWER HARBOR SCENARIO

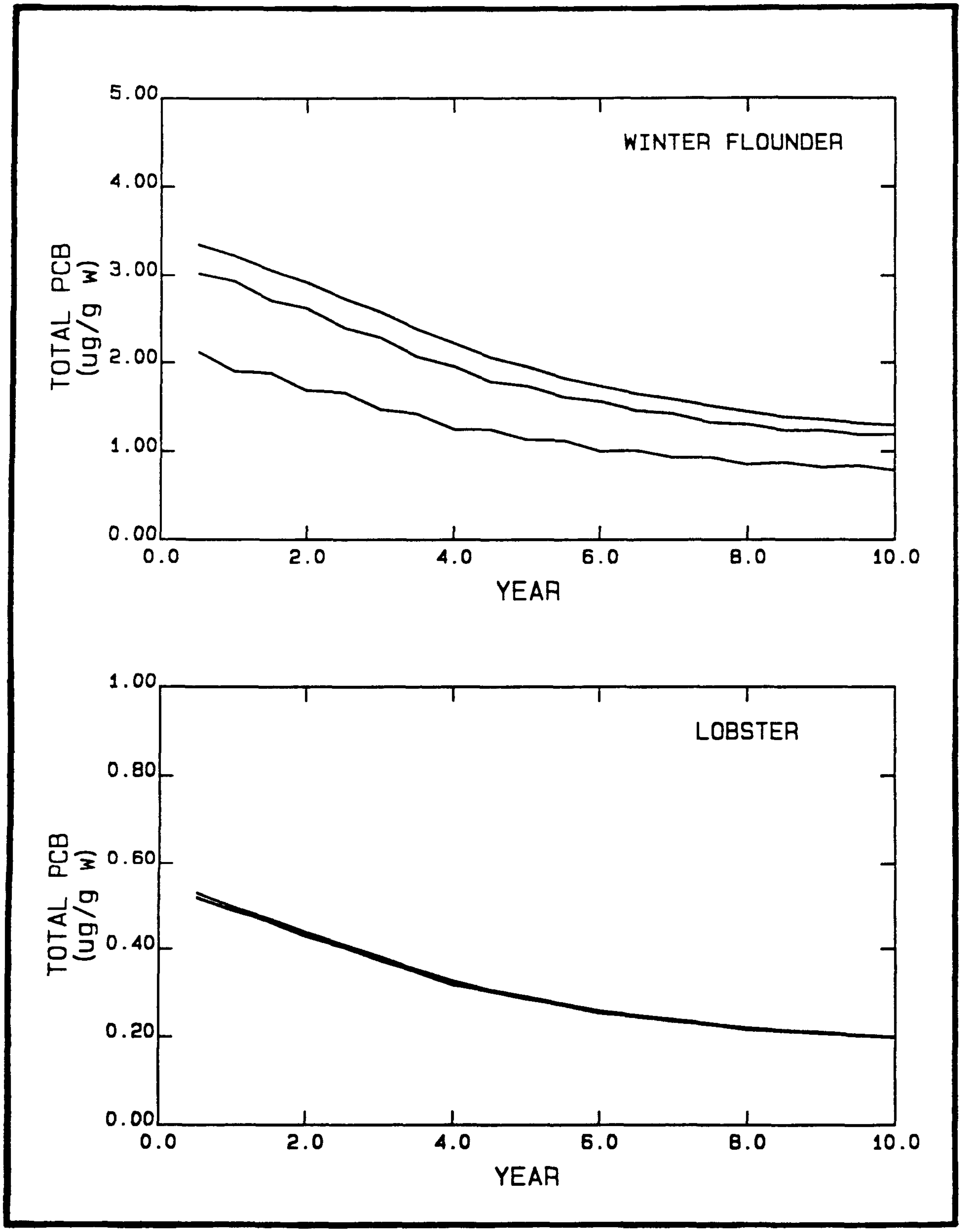


FIGURE 7.47. PCB CONCENTRATIONS IN AREA 2 FLOUNDER (AGES 0, 2, AND 5) AND LOBSTER IN RELATION TO TIME AFTER REMEDIATION FOR THE LOWER HARBOR SCENARIO

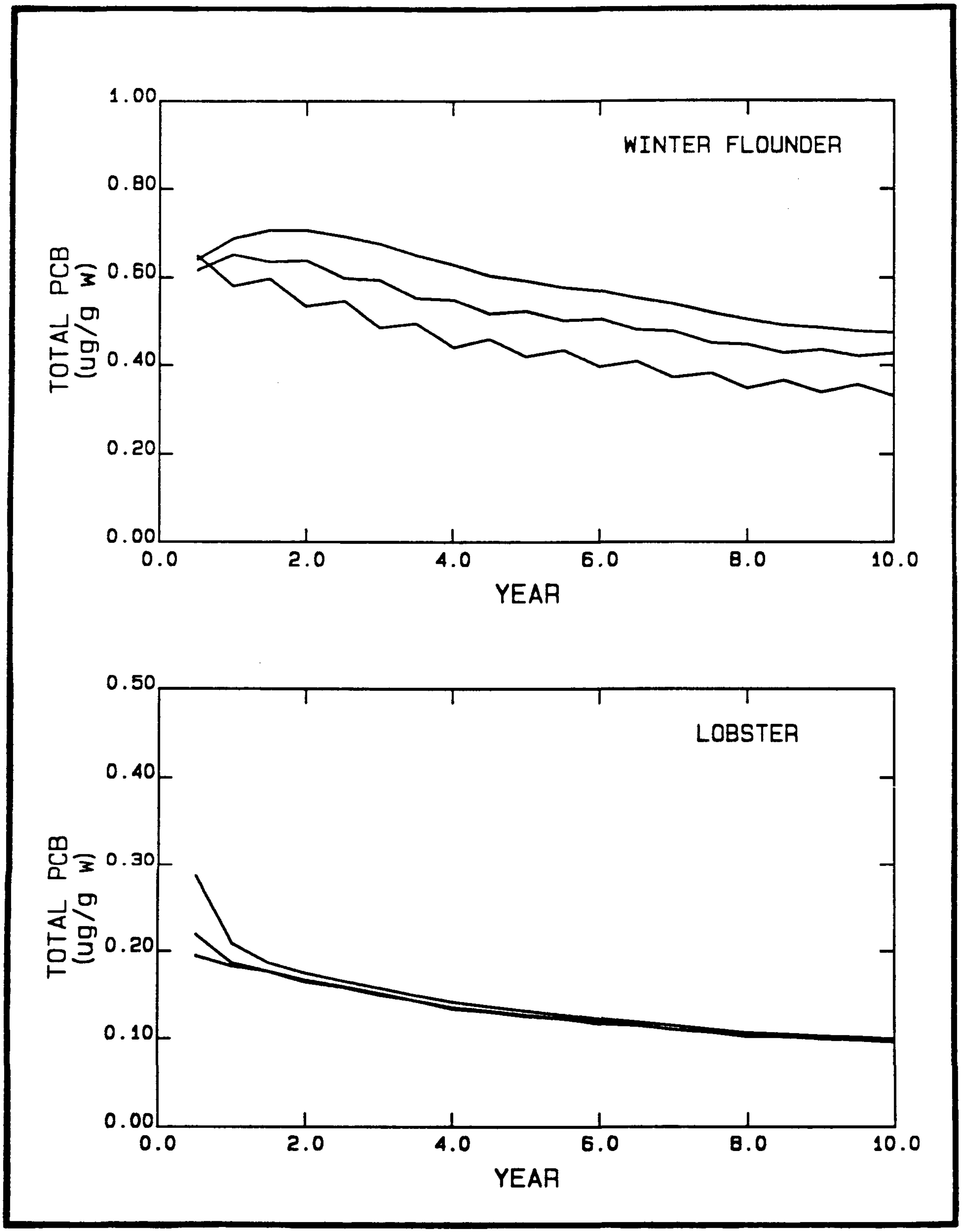


FIGURE 7.48. PCB CONCENTRATION IN AREA 3 FLOUNDER (AGES 0, 2, AND 5) AND LOBSTER IN RELATION TO TIME AFTER REMEDIATION FOR THE LOWER HARBOR SCENARIO

7.5.4 1-ppm Concentration Scenario

The 1-ppm Remedial-Action scenario simulates a cleanup action that would reduce the bed sediment concentrations of PCBs throughout the entire model domain to a residual value of 1 ppm. The initial bed-sediment PCB concentrations in all the grid cells was set to 1 ppm, and the Lower-Harbor scenario hydrodynamics were used.

7.5.4.1 Sediment/Contaminant Transport Results: 1-ppm Scenario

As expected, the model projections for the 1-ppm scenario indicate a marked difference in water column levels as compared to No-Action. A review of Figures 7.49 and 7.50 generally indicate an improvement in water quality levels of over an order of magnitude north of the Hurricane Barrier. This scenario is the only one in which a dramatic improvement in water quality for the Buzzards Bay portion of the site is projected (see Box 5 of Figure 7.51). The residual sediment PCB levels in this area have declined by a factor of 5 compared to No-Action (Figure 7.52). These improved conditions are highlighted in the comparitive water column and sediment contour plots (Figures 7.53 and 7.54) and are most likely due to the low residual sediment PCB level and large geographical area that the other remedial scenarios did not address (i.e., the region south of the Hurricane Barrier).

The net PCB fluxes, which are controlled by the water column concentration, are also greatly reduced under this scenario (Table 7.46). The PCB mass balances for the estuary, lower-harbor and upper Buzzards Bay areas are presented in Tables 7.47 through 7.49. Tables and figures for the sediment results are not shown, because they are identical to the Lower-Harbor scenario results.

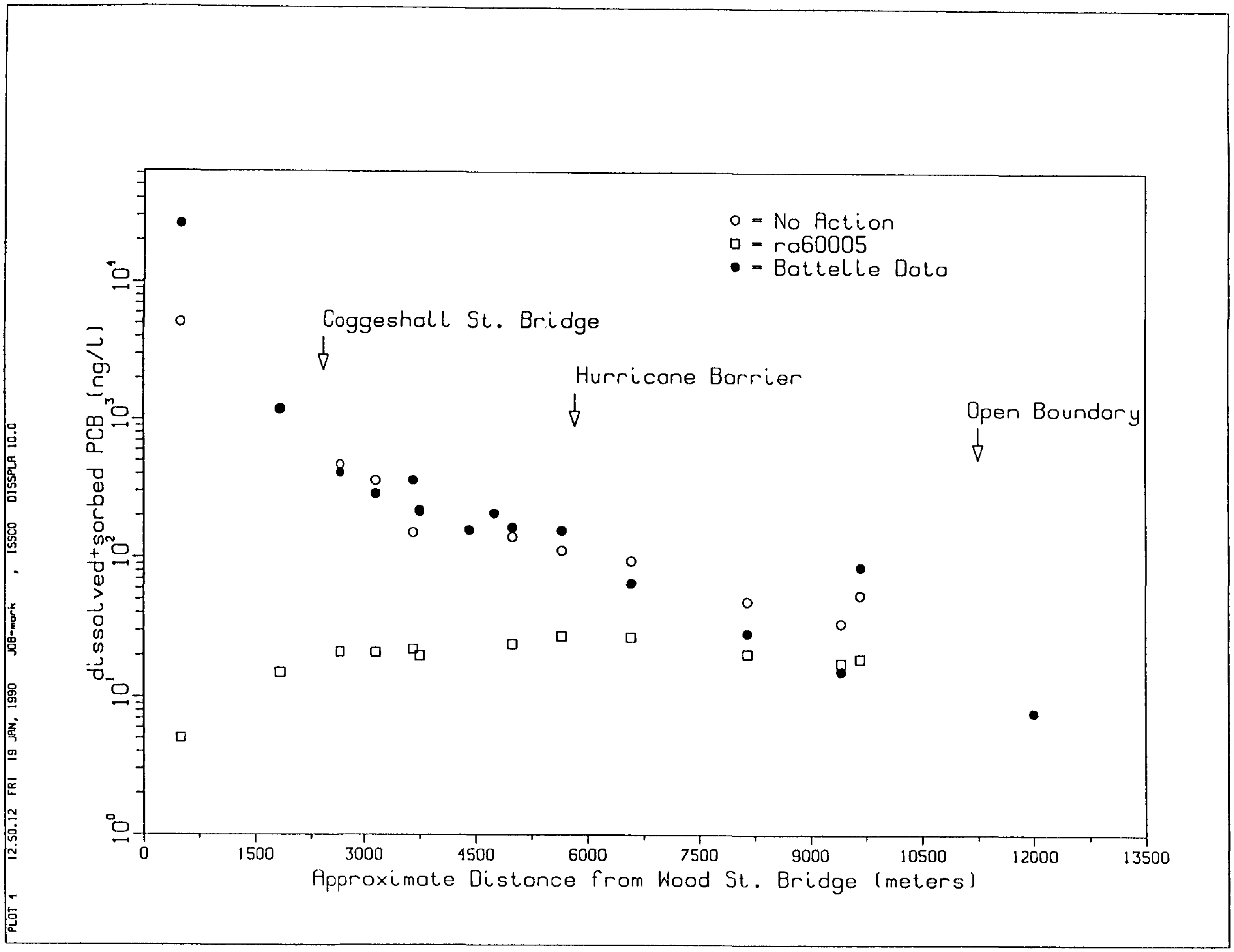


FIGURE 7.49. AVERAGE CONCENTRATION OF TOTAL PCBs IN THE WATER COLUMN FOR YEAR 0 OF THE 1-ppm SCENARIO (ng/L). o = NO-ACTION SCENARIO, □ = 1-ppm SCENARIO, • = BATTELLE OCEAN SCIENCES DATA.

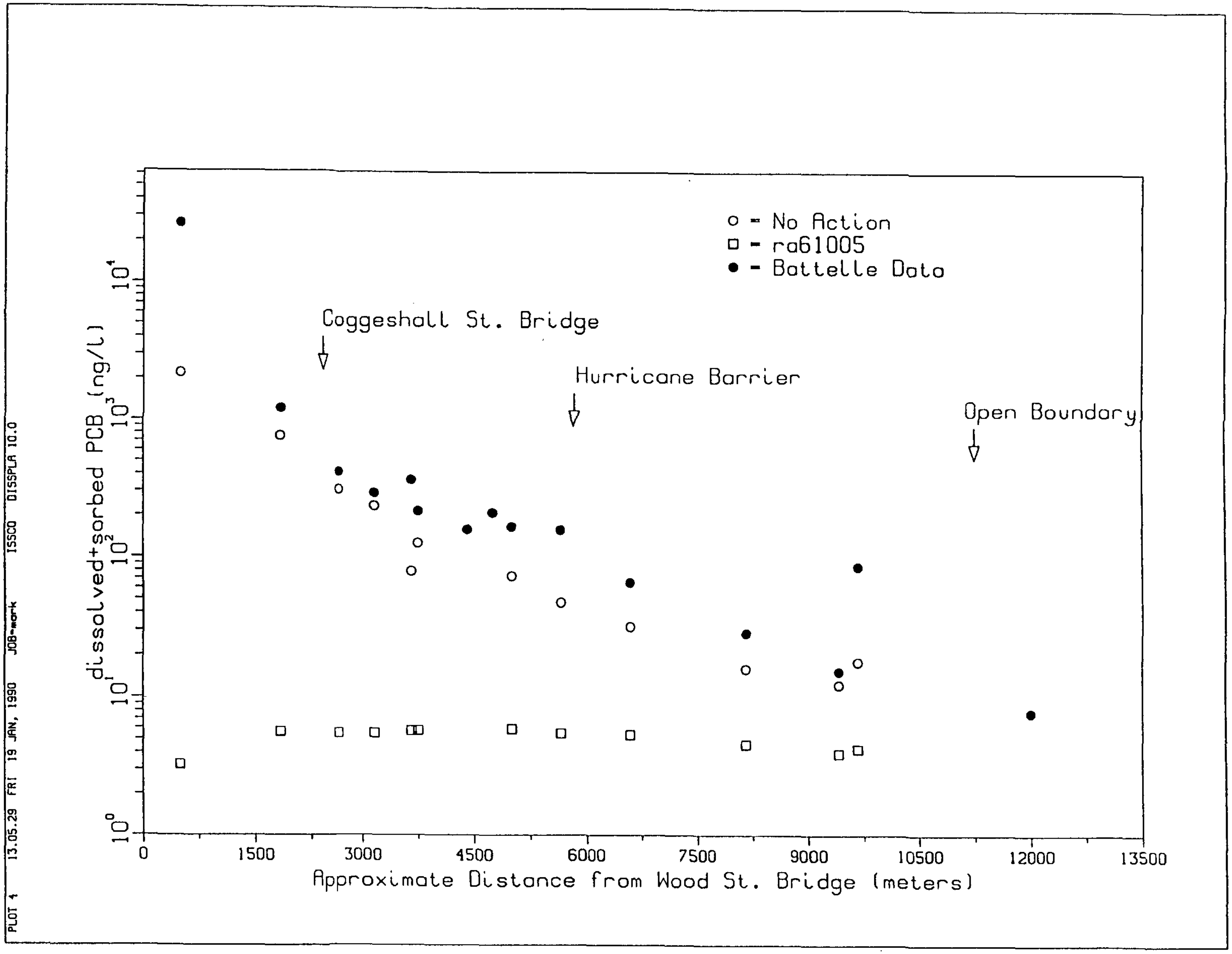


FIGURE 7.50. AVERAGE CONCENTRATION OF TOTAL PCBs IN THE WATER COLUMN FOR YEAR 10 OF THE 1-ppm SCENARIO (ng/L). o = NO-ACTION SCENARIO, □ = 1-ppm SCENARIO, • = BATTELLE OCEAN SCIENCES DATA.

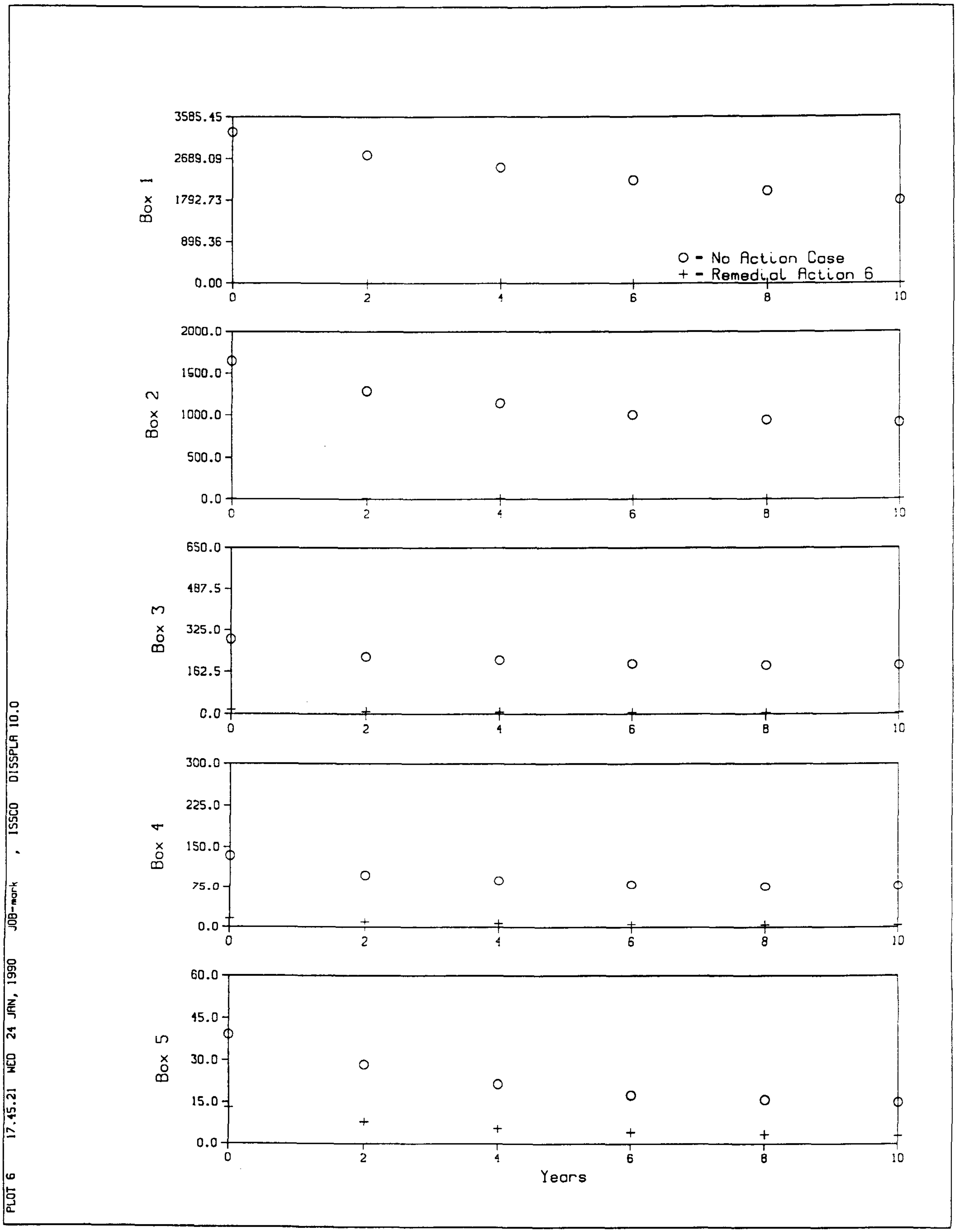


FIGURE 7.51. BOX-AVERAGED MODEL RESULTS FOR THE 1-ppm SCENARIO. TOTAL PCB CONCENTRATION (ng/L) IN THE WATER COLUMN. o = NO-ACTION SCENARIO, + = 1-ppm SCENARIO.

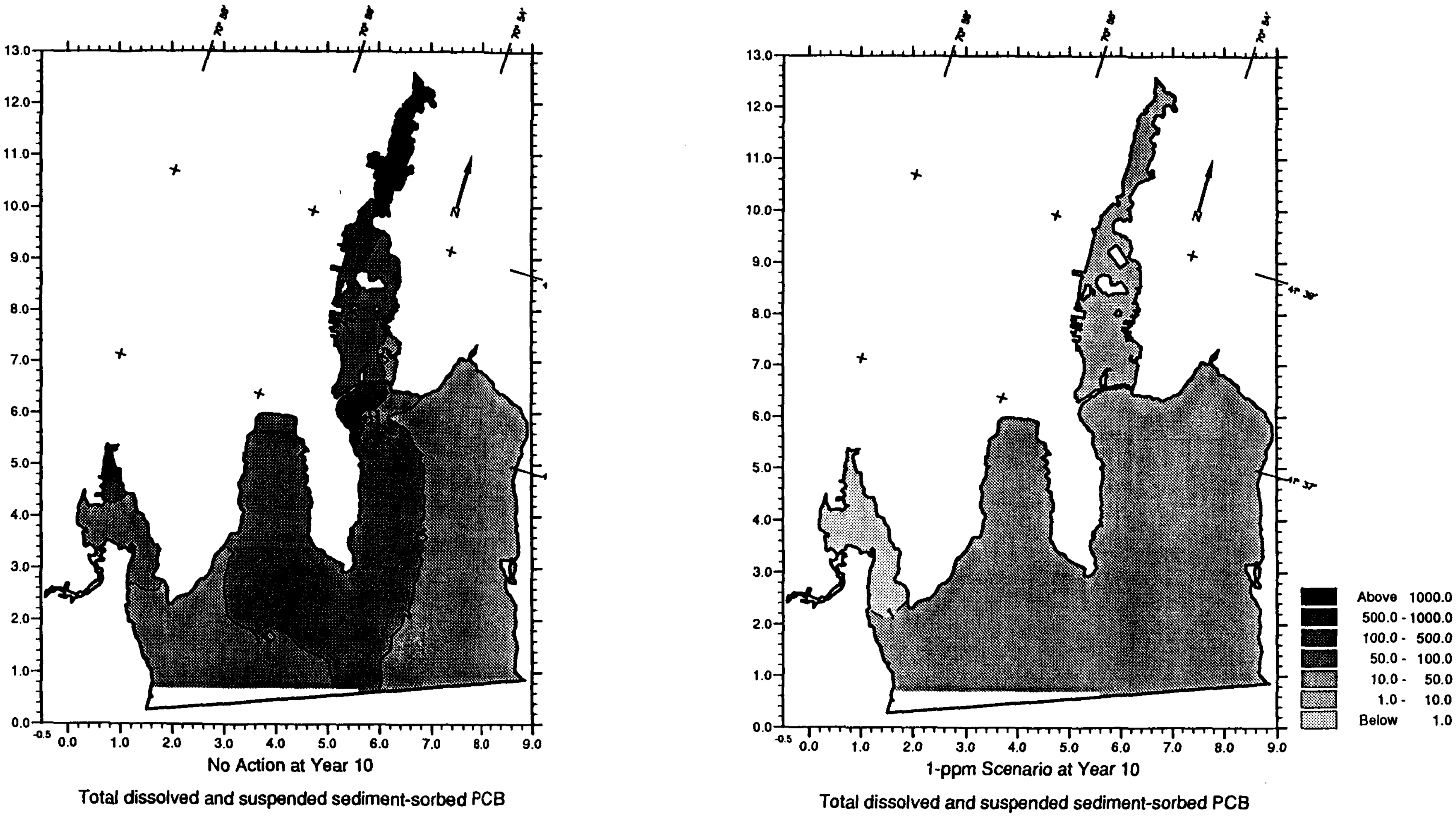


FIGURE 7.52. COMPARISON OF DEPTH-AVERAGE TOTAL WATER COLUMN PCB LEVELS FOR THE NO-ACTION AND 1-ppm SCENARIOS AT YEAR 10, TOTAL DISSOLVED AND SUSPENDED SEDIMENT-SORBED PCB (ng/L)

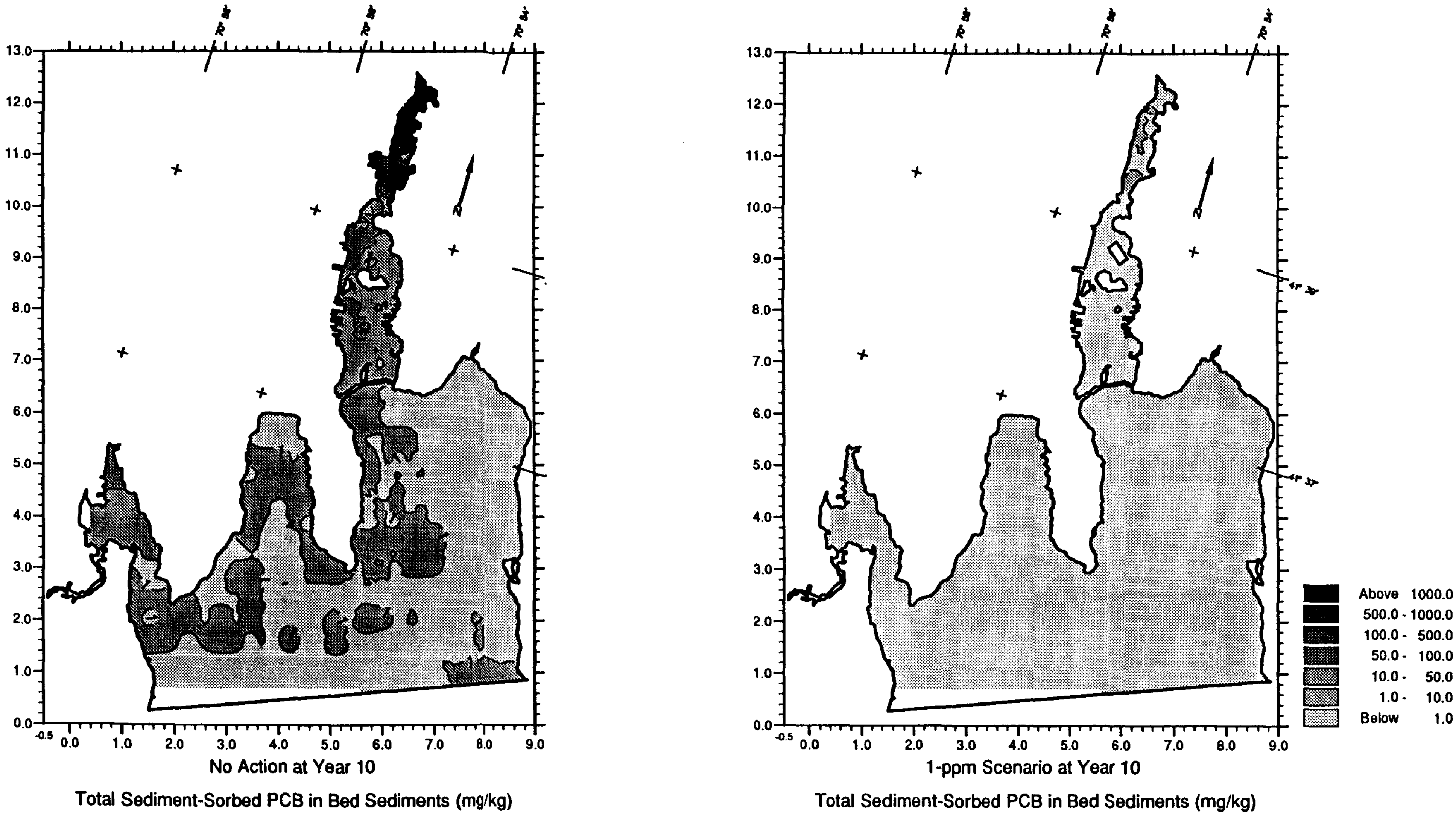


FIGURE 7.53. COMPARISON OF TOTAL BED SEDIMENT-SORBED PCB LEVELS FOR THE NO-ACTION AND 1-ppm SCENARIOS AT YEAR 10, TOTAL SEDIMENT-SORBED PCB (mg/kg)

TABLE 7.46. NET FLUX (kg/TIDAL CYCLE) OF SEDIMENTS AND PCBs FOR THE YEAR 0 AND YEAR 10 1-ppm SCENARIO SIMULATIONS

	Coggeshall Street Bridge	Hurricane Barrier	Open Boundary
Year 0 Sediment Flux	327	2.110×10^3	-2.178×10^4
Year 10 Sediment Flux	231	2.076×10^3	2.4858×10^4
Year 0 PCB Flux	0.008	0.001	-0.56
Year 10 PCB Flux	0.001	-0.002	-0.09

TABLE 7.47. PCB MASS BALANCE AND AVERAGE CONCENTRATION IN THE UPPER-ESTUARY FOR THE YEAR 0 AND YEAR 10 1-ppm SCENARIO SIMULATIONS

	Year 0	Year 10	Change
Water Column Mass (kg)	0.01	0.005	-0.005
Bed Layer Mass (kg)	41	37	-4
Water Column Concentration (ng/L)	8.5	4.2	-4.3
Bed Layer Concentration (mg/kg)	1.0	1.0	0

TABLE 7.48. PCB MASS BALANCE AND AVERAGE CONCENTRATION IN THE LOWER-HARBOR FOR THE YEAR 0 AND YEAR 10 1-ppm SCENARIO SILULATIONS

	Year 0	Year 10	Change
Water Column Mass (kg)	0.25	0.06	-0.19
Bed Layer Mass (kg)	154	79	-75
Water Column Concentration (ng/L)	16	4	-12
Bed Layer Concentration (mg/kg)	1.0	0.5	-0.5

TABLE 7.49. PCB MASS BALANCE AND AVERAGE CONCENTRATION IN THE OUTER HARBOR FOR THE YEAR 0 AND YEAR 10 1-ppm SCENARIO SIMULATIONS

	Year 0	Year 10	Change
Water Column Mass (kg)	1.8	0.4	-1.4
Bed Layer Mass (kg)	1,398 X 10^3	424	-974
Water Column Concentration (ng/L)	11	3	-8
Bed Layer Concentration (mg/kg)	0.9	0.3	-0.6

7.5.4.2 Food Chain Results: 1-ppm Scenario

Exposure Profile

The exposure conditions for the food chain model under the 1-ppm scenario are presented below in Table 7.50. The effects of this remedial scenario are wide spread and encompass all three food chain model areas. Whereas, all of the other remedial scenarios primarily impact the areas north of the Hurricane Barrier. Ten years after remediation, dissolved PCB concentrations are projected to decline to 2.5, 1.7 ng/L and Areas 1 and 2 respectively. This corresponds to a 96% and 81% reduction in water column levels for these two areas. Sediment PCB levels in these two regions are also reduced dramatically compared to No-Action.

TABLE 7.50. 1-ppm EXPOSURE CONCENTRATIONS FOR FOOD CHAIN MODEL

	Area 1		Area 2		Area 3	
Year	Water Column[a]	Bed Sediment[b]	Water Column[a]	Bed Sediment[b]	Water Column[a]	Bed Sediment[b]
0	9.02	1.00	7.71	0.91	NC	NC
2	6.10	0.82	4.98	0.67	NC	NC
4	4.64	0.73	3.44	0.48	NC	NC
6	3.61	0.63	2.53	0.38	NC	NC
8	3.01	0.54	2.02	0.31	NC	NC
10	2.53	0.46	1.71	0.27	NC	NC

[a] Water column dissolved PCB (ng/L).
[b] Sediment PCB (mg/kg dry).
Note: NC = food chain model projections not calculated for this area under this remedial scenario.

Food Chain Projections

Remediation of the entire site to a residual sediment level of 1-ppm provides a significant reduction in the projected biota levels for both Areas 1 and 2 (Figures 7.54 and 7.55). Within Area 1, young-of-the-year flounder are projected to decline to 0.3 μg/g ten years following remediation. This represents a 94% reduction compared to No-Action, similar reductions are projected for the older fish within this region. South of the Hurricane Barrier, in Area 2 of the food chain model, flounder are projected to decline by about 75% as compared to No-Action. For the five year old fish, this corresponds to a 0.05 μg/g edible tissue level. Similarly, significant reductions in the Area 2 lobster concentrations are projected under this remedial scenario. The projected levels decline by about 75% to 0.05 μg/g whereas 0.2 μg/g was the projected value for No-Action.

The residual sediment level of 1-ppm is also projected to facilitate significant reductions in PCB concentrations in all levels of the food chain within the northern portion of the site (Table 7.51). A reduction of over 99% is generally projected for north of the Coggeshall Street Bridge.

TABLE 7.51. COMPUTED CONCENTRATIONS IN BIOTA (μg/g WET WEIGHT) FROM EACH OF THE SEGMENTS OF NEW BEDFORD HARBOR 10 YEARS AFTER REMEDIATION OF THE UPPER-ESTUARY TO 1-ppm

Species	Box 1*	Box 2*	Box 3*	Box 4**	Box 5**	Box 6**
Phytoplankton	0.06	0.08	0.1	0.1	0.07	nc
Polychaete	0.9	0.9	0.6	0.5	0.3	nc
Hard Clam	0.02	0.03	0.05	0.04	0.02	nc
Mussel	0.06	0.09	0.1	0.1	0.07	nc
Crab	0.1	0.2	0.2	0.1	0.08	nc
Winter Flounder	0.3-0.7	0.4-0.7	0.3-0.5	0.3-0.5	0.2-0.3	nc
Lobster	nc	nc	nc	nc	.05-.05	nc

* Values at steady-state with projected year 10 water column and sediment PCB concentrations.
** Values projected ten years after remediation.
Note: Boxes 4, 5 & 6 correspond to Areas 1, 2 & 3, respectively, of the food chain model.
NC = Not calculated.

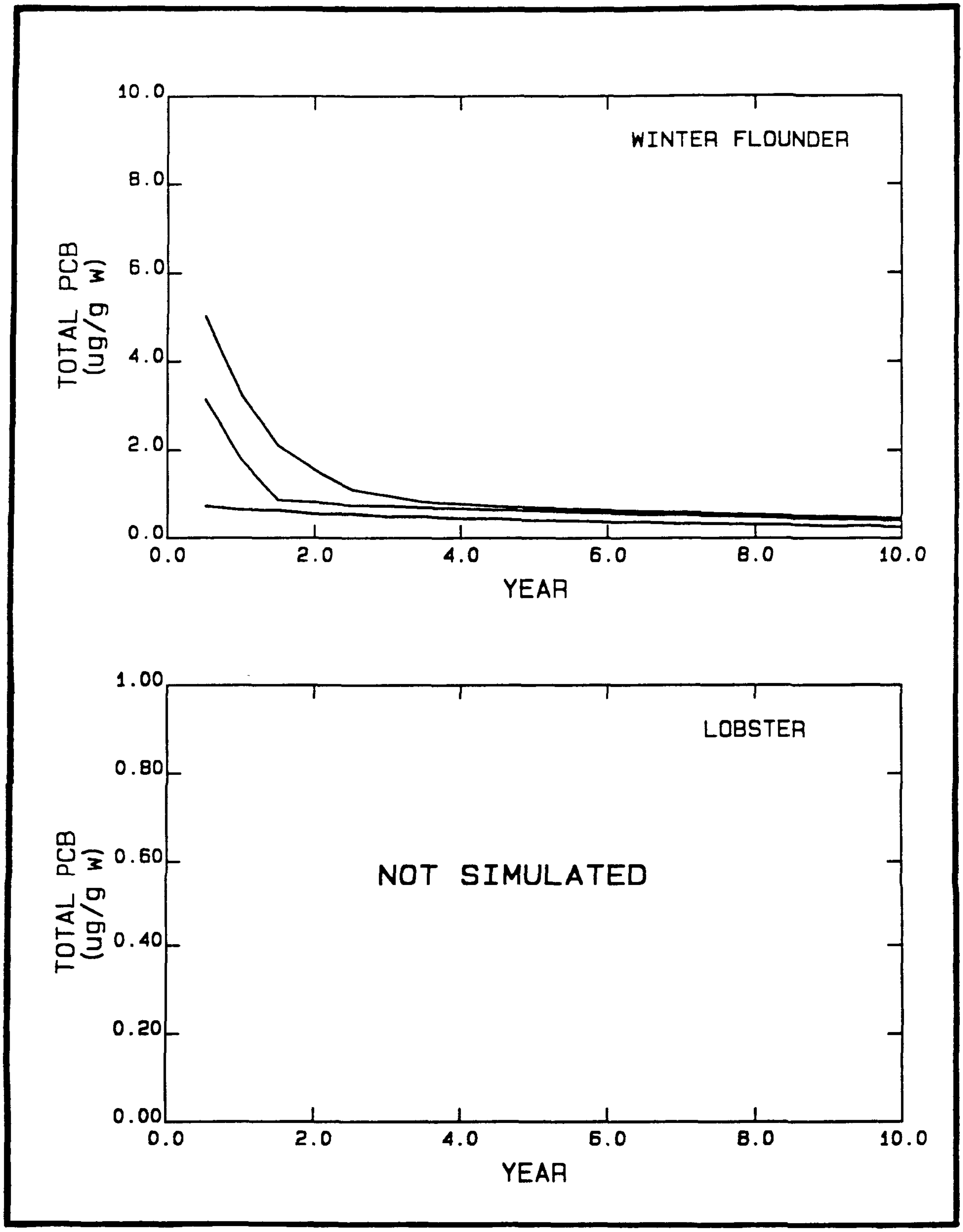


FIGURE 7.54. PCB CONCENTRATIONS IN AREA 1 FLOUNDER (AGES 0, 2, AND 5) IN RELATION TO TIME AFTER REMEDIATION FOR THE 1-ppm SCENARIO

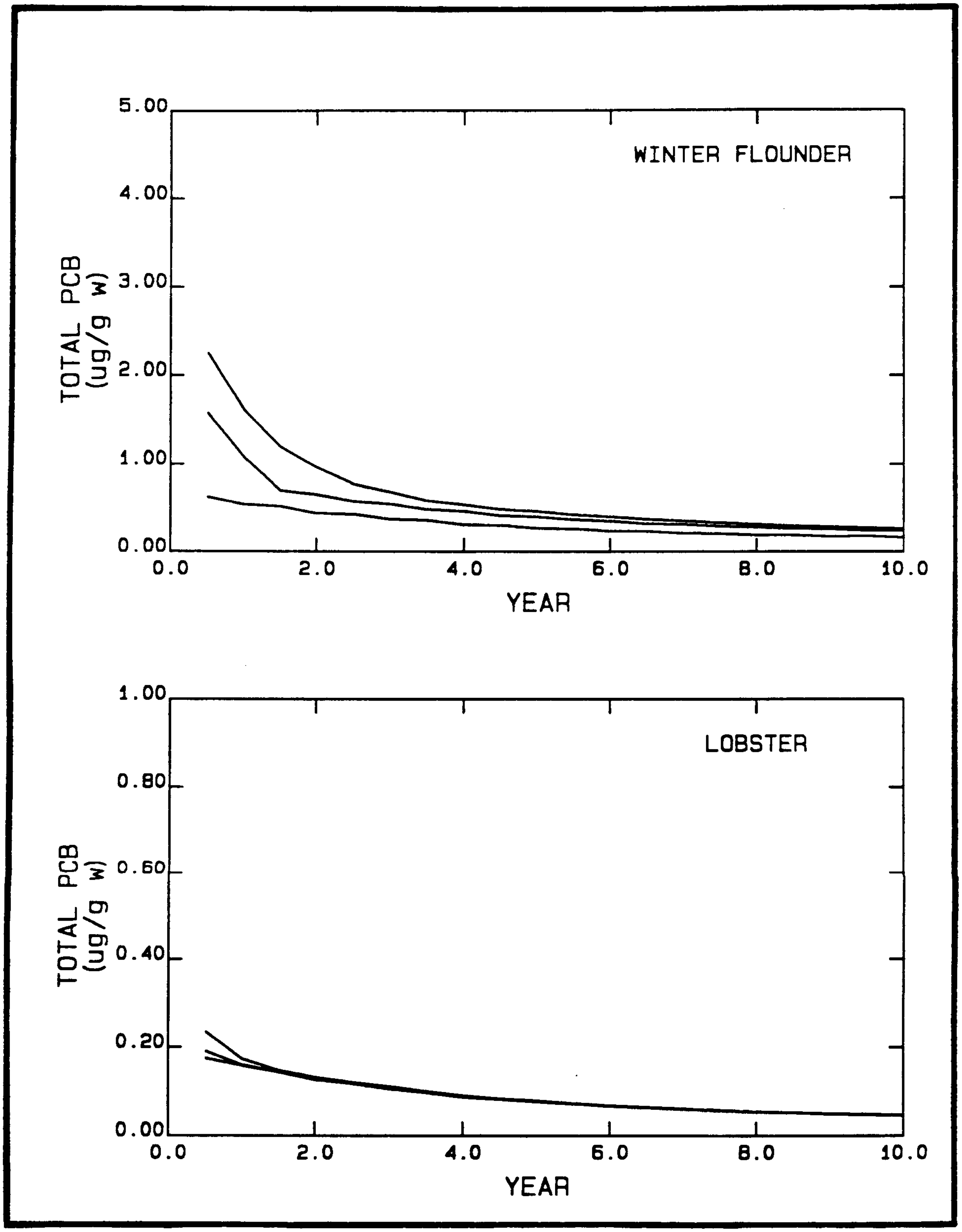


FIGURE 7.55. PCB CONCENTRATIONS IN AREA 2 FLOUNDER (AGES 0, 2, AND 5) AND LOBSTER IN RELATION TO TIME AFTER REMEDIATION FOR THE 1-ppm SCENARIO

7.5.5 50-ppm Concentration Scenario

In this scenario, all areas within the upper-estuary and lower-harbor with PCB concentrations above 50 ppm are remediated. This results in a residual sediment PCB levels of 1 to 10 ppm in these areas. The initial conditions for this scenario (Figures C.7a and C.7d of Appendix C) are quite similar to those for the Upper-Estuary scenario. The Lower-Harbor scenario hydrodynamics were used in this scenario.

7.5.5.1 Sediment/Contaminant Transport Results: 50-ppm Scenario

The results of the 50-ppm scenario generally indicate that water column PCB concentrations will be reduced to levels comparible with those projected in the Upper-Estuary and Lower-Harbor remedial scenarios. For the most part, the improvements are projected to occur north of the Hurricane Barrier and, to a lesser degree immediately south of this geographic boundary (Figures 7.56 and 7.57). In this portion of Buzzards Bay (Box 5), the projected area-averaged sediment and water column concentrations will only decline slightly as compared to No-Action. These findings are also illustrated in the comparative contour plots of water column and sediment PCB concentrations projected for No-Action and the 50-ppm scenario 10 years following remediation (Figures 7.60 and 7.61).

The net flux of sediments and PCBs projected to occur in years 0 and 10 through the three flux planes (i.e., Coggeshall Street Bridge, Hurricane Barrier and model open boundary) are presented in Table 7.52. At year 10 the net PCB flux throughout each plane is in a southerly direction and has been reduced in comparison to No-Action. The magnitude of the PCB flux reductions is similar to the response of the water column and sediment in that the greatest reduction occur north of the Hurricane Barrier.

TABLE 7.52. NET FLUX (kg/TIDAL CYCLE) OF SEDIMENTS AND PCBs FOR THE YEAR 0 AND YEAR 10 50-ppm SCENARIO SIMULATIONS

	Coggeshall Street Bridge	Hurricane Barrier	Open Boundary
Year 0 Sediment Flux	327	2.11×10^3	-2.178×10^4
Year 10 Sediment Flux	231	2.076×10^3	2.4858×10^4
Year 0 PCB Flux	0.03	-0.06	-1.26
Year 10 PCB Flux	-0.001	-0.023	-0.24

The PCB mass balance and average sediment and water column concentrations values for the three geographical study areas evaluated by the REM III team are presented in Tables 7.53 through 7.55. Suspend sediment within these three regions are not shown because they are identical to the Lower-Harbor scenario.

TABLE 7.53. PCB MASS BALANCE AND AVERAGE CONCENTRATION IN THE UPPER-ESTUARY FOR THE YEAR 0 AND YEAR 10 50-ppm SCENARIO SIMULATIONS

	Year 0	Year 10	Change
Water Column Mass (kg)	0.05	0.04	-0.01
Bed Layer Mass (kg)	289	247	-42
Water Column Concentration (ng/L)	40	28	-12
Bed Layer Concentration (mg/kg)	7	6	-1

TABLE 7.54. PCB MASS BALANCE AND AVERAGE CONCENTRATION IN THE LOWER-HARBOR FOR THE YEAR 0 AND YEAR 10 50-ppm SCENARIO SIMULATIONS

	Year 0	Year 10	Change
Water Column Mass (kg)	1.4	0.4	1.0
Bed Layer Mass (kg)	1.164×10^3	580	-584
Water Column Concentration (ng/L)	91	28	-63
Bed Layer Concentration (mg/kg)	7	3	-4

TABLE 7.55. PCB MASS BALANCE AND AVERAGE CONCENTRATION IN THE OUTER-HARBOR FOR THE YEAR 0 AND YEAR 10 50-ppm SCENARIO SIMULATIONS

	Year 0	Year 10	Change
Water Column Mass (kg)	5.0	1.8	-3.2
Bed Layer Mass (kg)	4.673×10^3	2.278×10^3	-2.395×10^3
Water Column Concentration (ng/L)	31	11	-20
Bed Layer Concentration (mg/kg)	3	1	-2

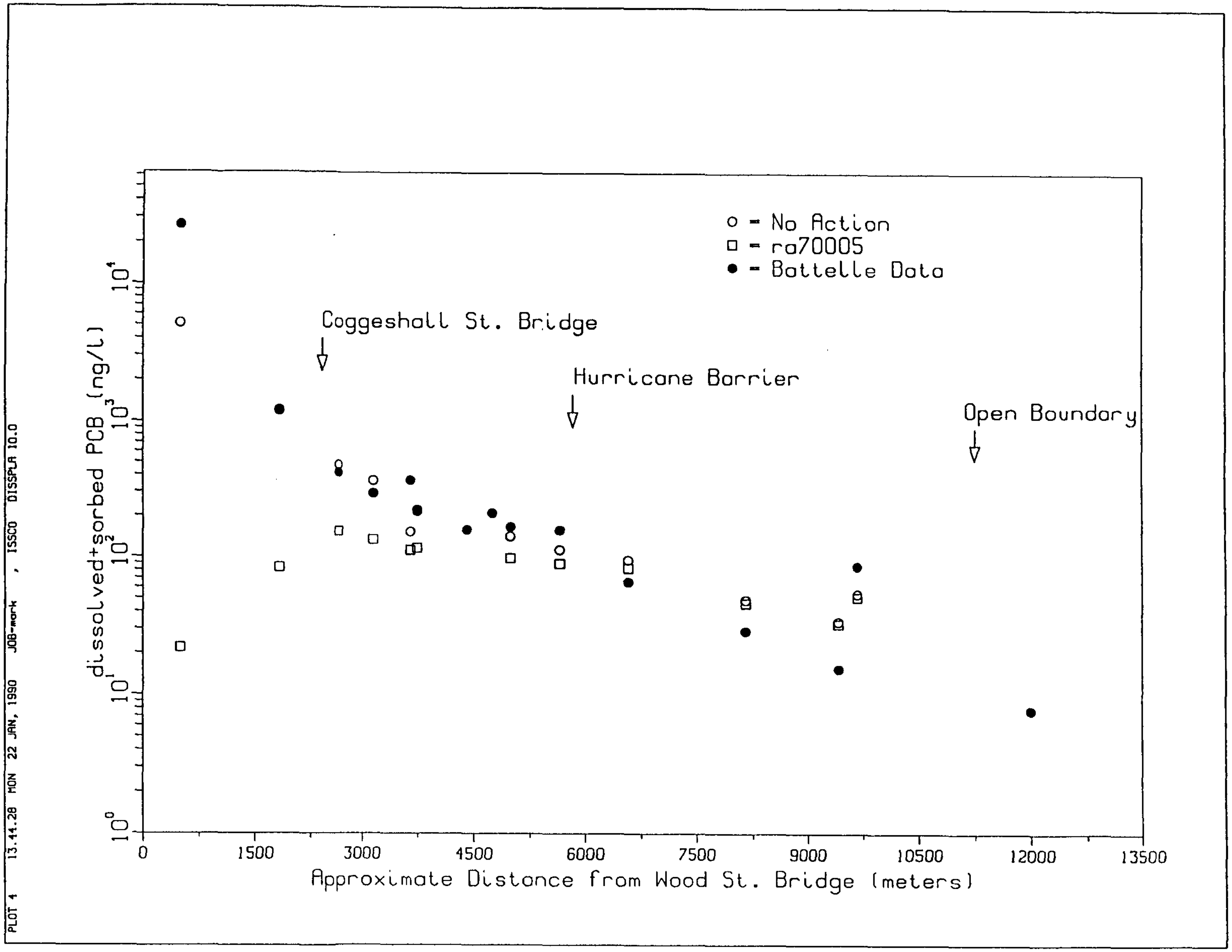


FIGURE 7.56. AVERAGE CONCENTRATION OF TOTAL PCBs IN THE WATER COLUMN FOR YEAR 0 OF THE 50-ppm SCENARIO (ng/L). o = NO-ACTION SCENARIO, □ = 50-ppm SCENARIO, • = BATTELLE OCEAN SCIENCES DATA.

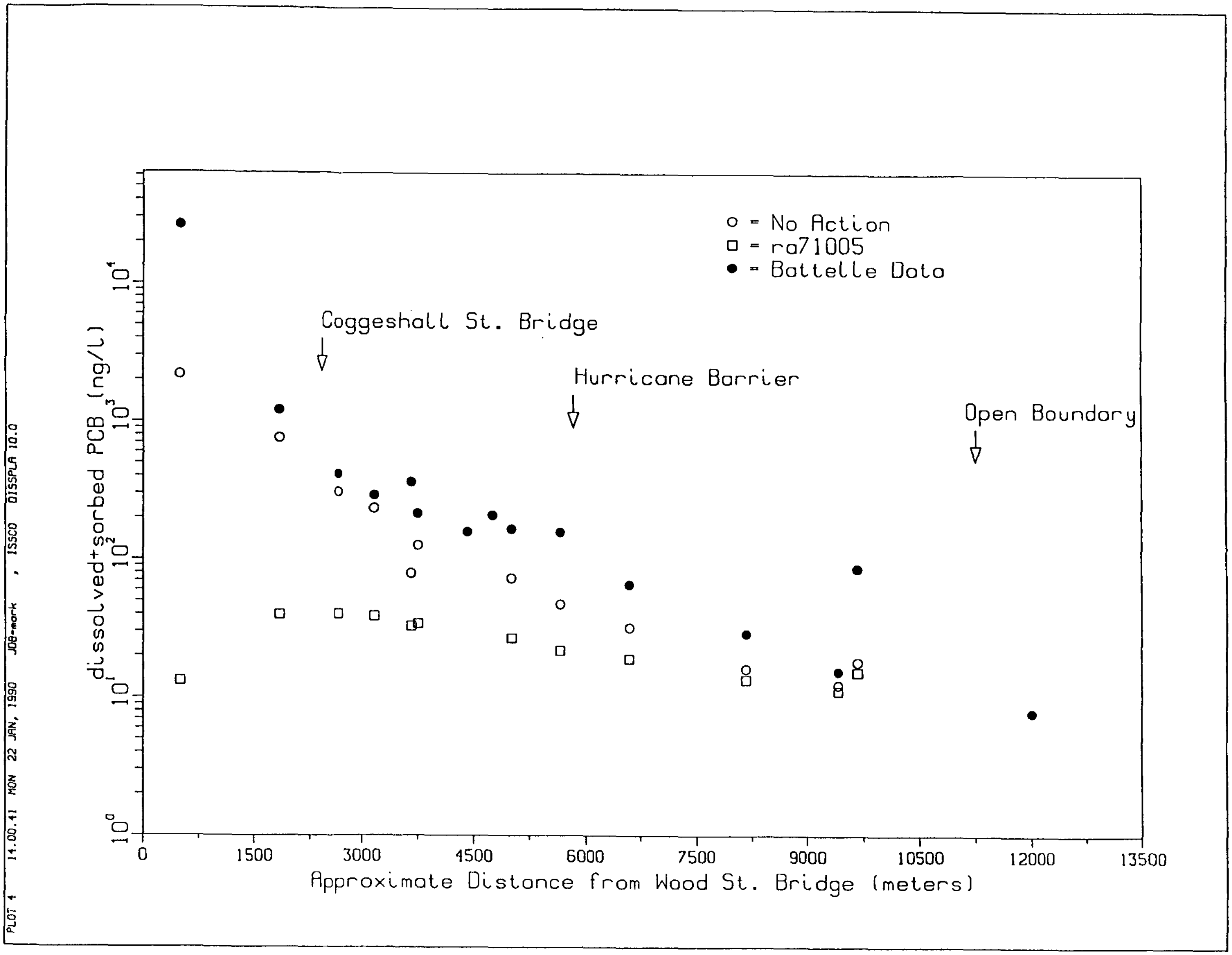


FIGURE 7.57. AVERAGE CONCENTRATION OF TOTAL PCBs IN THE WATER COLUMN FOR YEAR 10 OF THE 50-ppm SCENARIO (ng/L). o = NO-ACTION SCENARIO, □ = 50-ppm SCENARIO, • = BATTELLE OCEAN SCIENCES DATA.

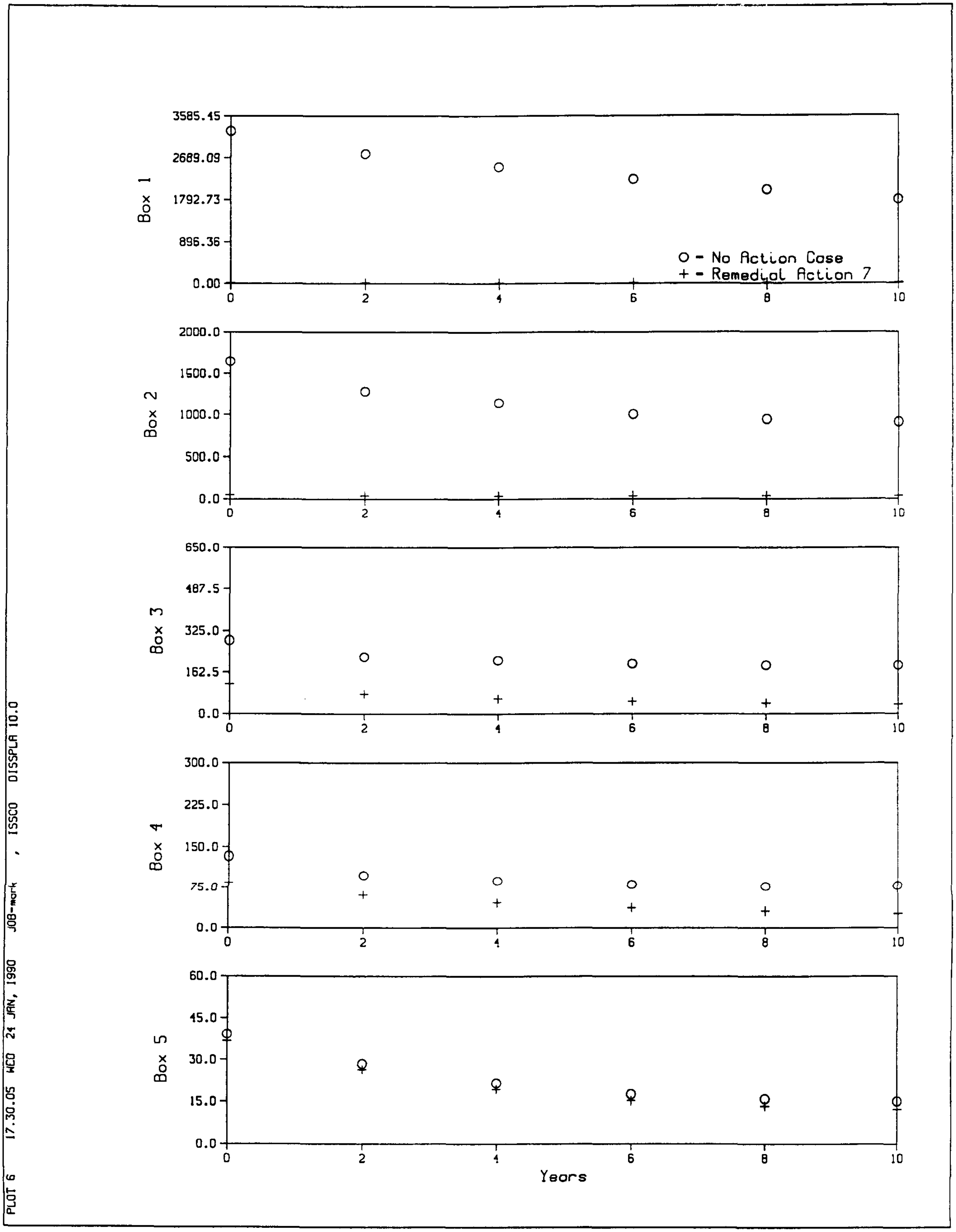


FIGURE 7.58. BOX-AVERAGED MODEL RESULTS FOR THE 50-ppm SCENARIO. TOTAL PCB CONCENTRATION (ng/L) IN THE WATER COLUMN. o = NO-ACTION SCENARIO, + = 50-ppm SCENARIO.

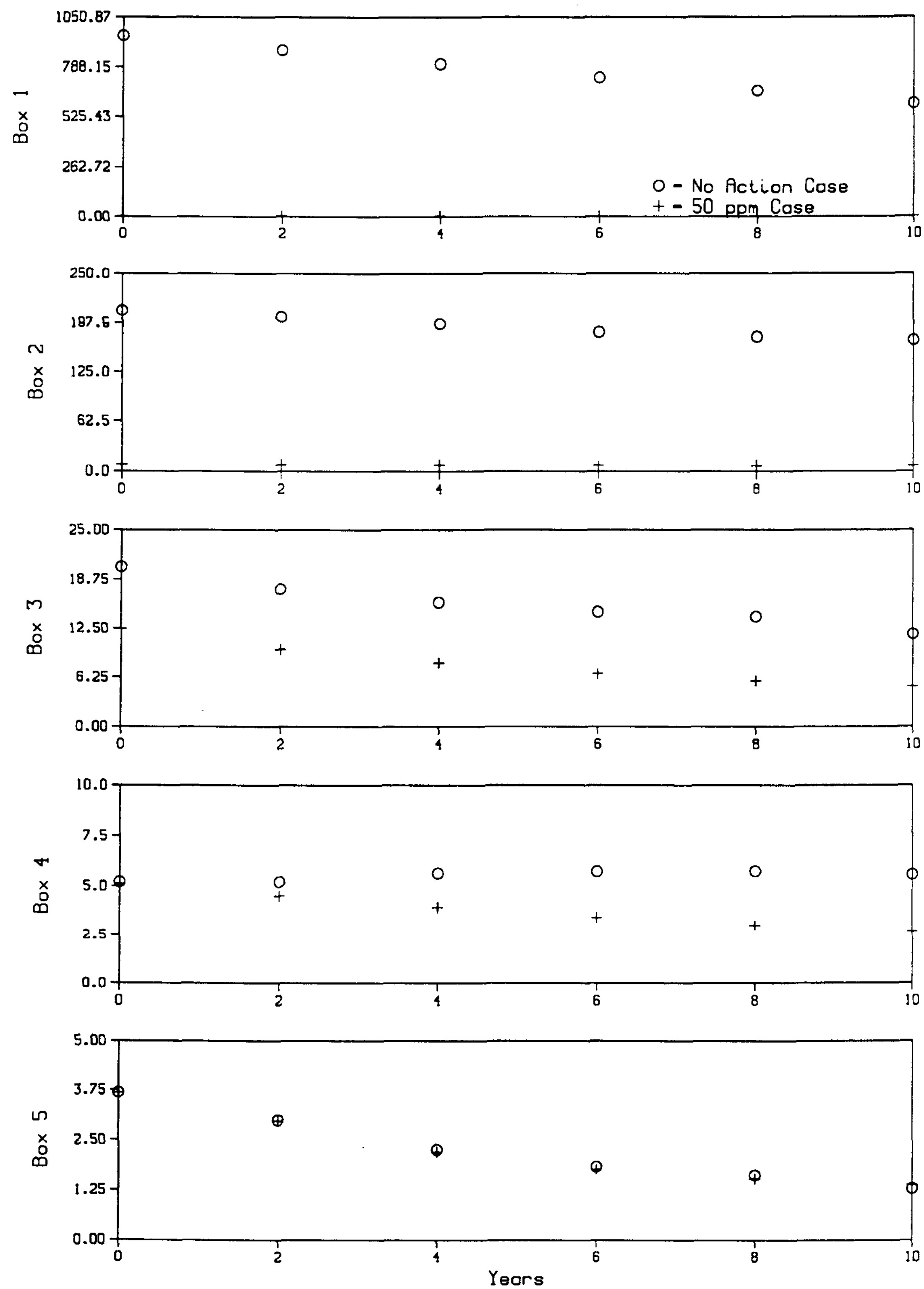
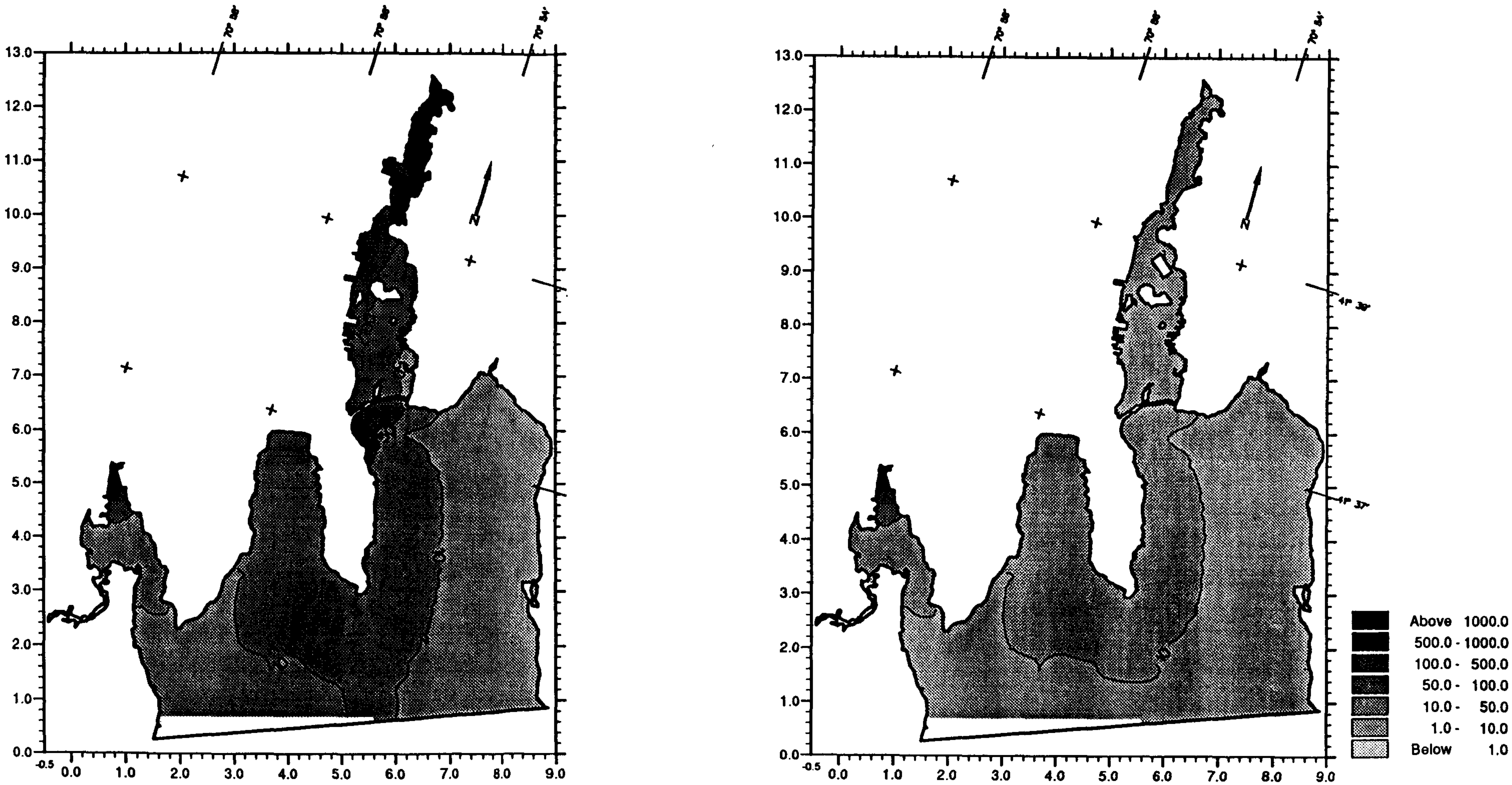


FIGURE 7.59. BOX-AVERAGED MODEL RESULTS FOR THE 50-ppm SCENARIO. TOTAL PCB CONCENTRATION (mg/kg) IN THE BED SEDIMENT LAYER. o = NO-ACTION SCENARIO, + = 50-ppm SCENARIO.



No Action at Year 10

Total dissolved and suspended sediment-sorbed PCB

50-ppm Scenario at Year 10

Total dissolved and suspended sediment-sorbed PCB

FIGURE 7.60. COMPARISON OF DEPTH-AVERAGE TOTAL WATER COLUMN PCB LEVELS FOR THE NO-ACTION AND 50-ppm SCENARIOS AT YEAR 10, TOTAL DISSOLVED AND SUSPENDED SEDIMENT-SORBED PCB (ng/L)

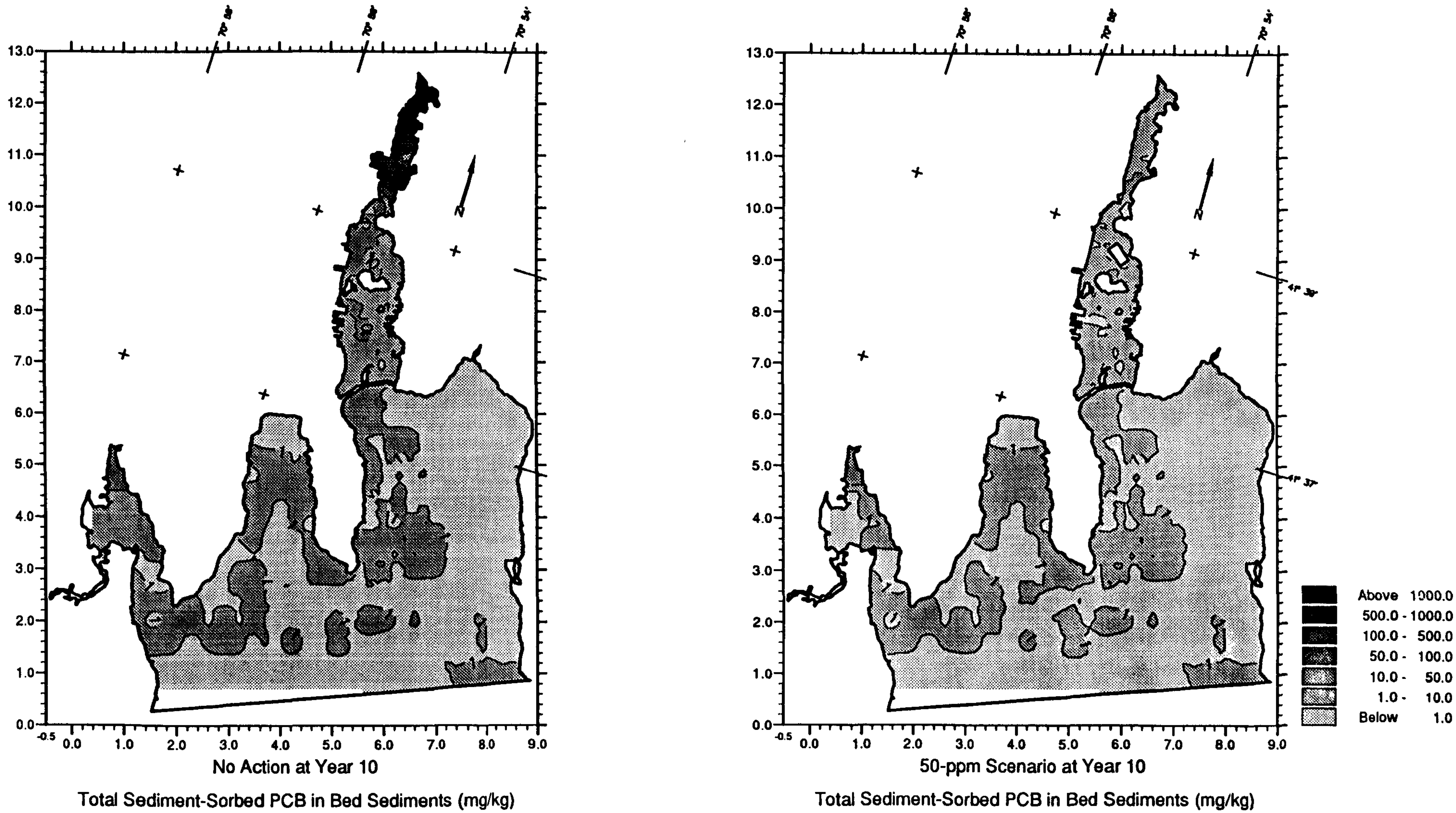


FIGURE 7.61. COMPARISON OF TOTAL BED SEDIMENT-SORBED PCB LEVELS FOR THE NO-ACTION AND 50-ppm SCENARIOS AT YEAR 10, TOTAL SEDIMENT-SORBED PCB (mg/kg)

7.5.5.2 Food Chain Results: 50-ppm Scenario

Exposure Profile

Remediation of the sediments with PCB concentrations in excess of 50 μg/g results in a pattern of reduced water column concentrations similar to the Upper-Estuary and Lower-Harbor scenarios (Table 7.56). Under this scenario, the year 10 projected dissolved PCB concentration in Area 1 has declined by 69% to 18.7 ng/L. A smaller decline of 18% below the No-Action value is projected in Area 2.

TABLE 7.56. 50-ppm EXPOSURE CONCENTRATIONS FOR FOOD CHAIN MODEL

	Area 1		Area 2		Area 3	
Year	Water Column[a]	Bed Sediment[b]	Water Column[a]	Bed Sediment[b]	Water Column[a]	Bed Sediment[b]
0	54.18	7.68	21.03	3.68	NC	NC
2	41.89	6.72	16.36	2.98	NC	NC
4	32.11	5.69	12.20	2.20	NC	NC
6	25.77	4.85	9.64	1.77	NC	NC
8	21.92	4.14	8.37	1.53	NC	NC
10	18.71	3.53	7.57	1.37	NC	NC

[a] Water column dissolved PCB (ng/L).
[b] Sediment PCB (mg/kg dry).
Note: NC = food chain model projections not calculated for this case udner this remedial scenario.

Food Chain Projections

As expected, the projected response of the biota also follow the pattern of the Upper-Estuary and Lower-Harbor scenarios. PCB concentration in young-of-the-year flounder from Area 1 are projected to decline by 63% to 2 μg/g (Figure 7.62). This corresponds to an edible tissue level of 0.36 μg/g, a factor of 5 below the FDA limit of 2 ppm. A similar reduction in the PCB concentration of older fish is also projected for Area 1.

The projections for lobster and flounder from Area 2 (Figure 7.63) do not indicate significant changes in relation to No-Action. This finding is consistent for the Remedial Action scenarios that do not change the initial bed sediment conditions south of the Hurricane Barrier.

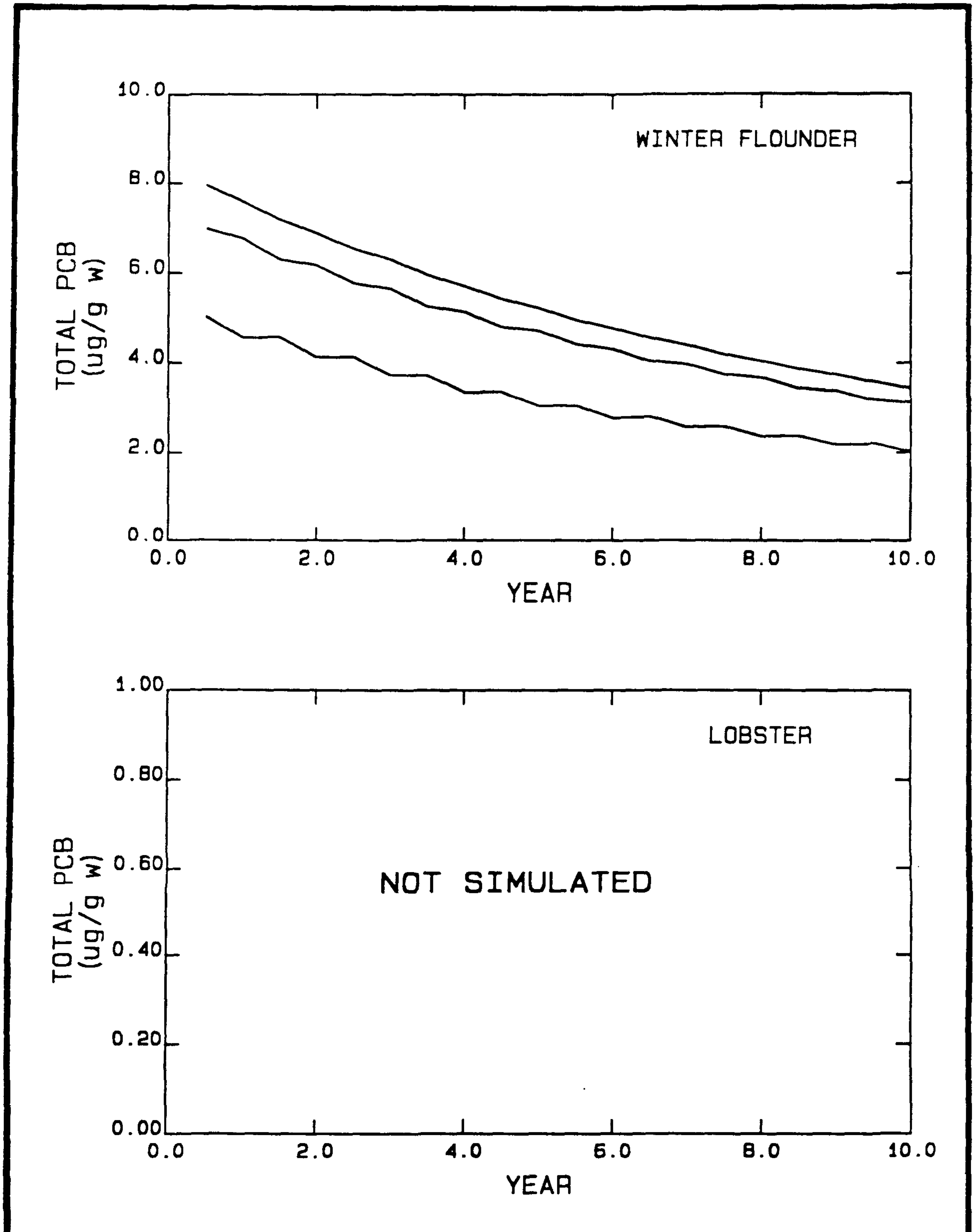


FIGURE 7.62. PCB CONCENTRATIONS IN AREA 1 FLOUNDER, (AGES 0, 2 AND 5) IN RELATION TO TIME AFTER REMEDIATION FOR THE 50-ppm SCENARIO

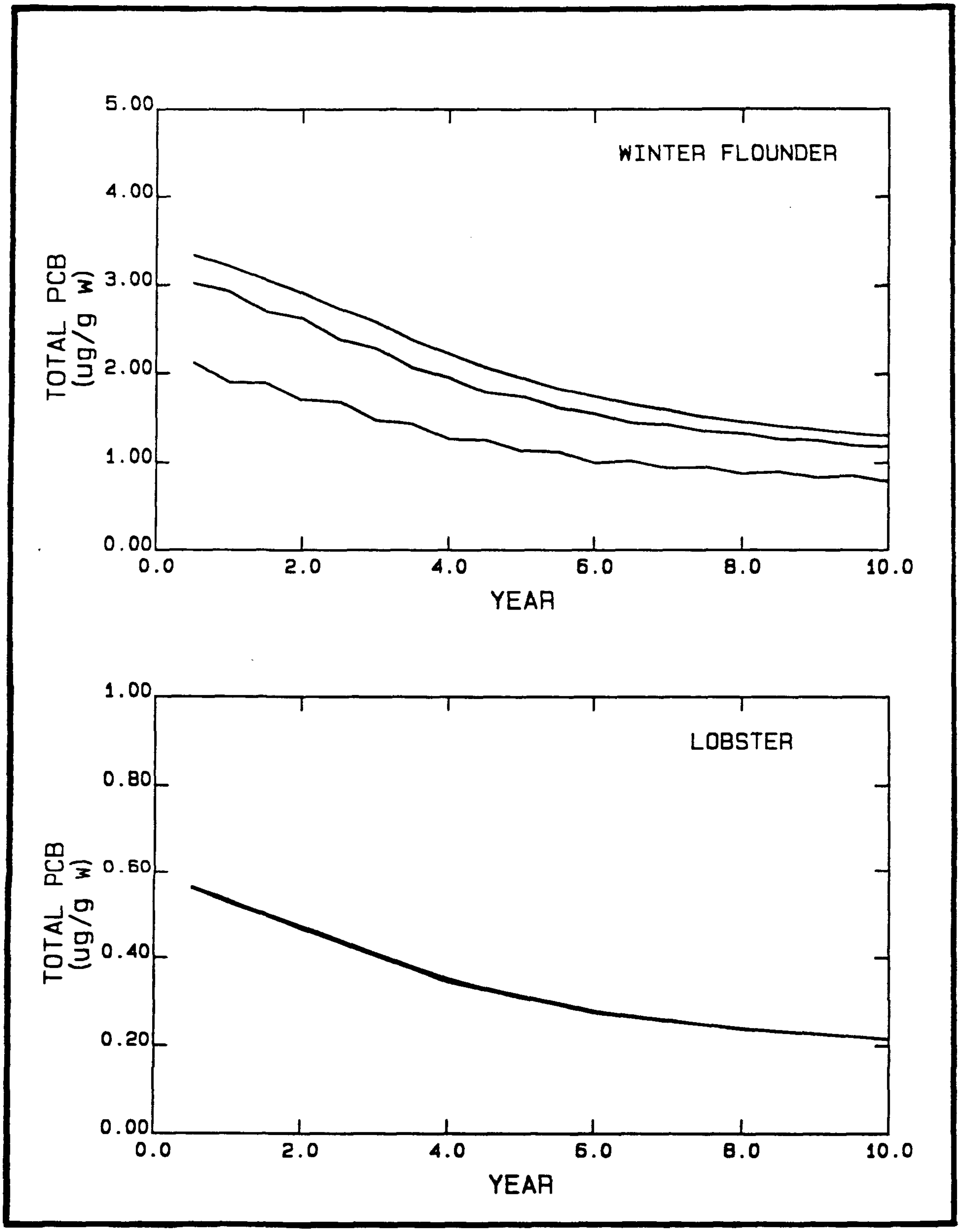


FIGURE 7.63. PCB CONCENTRATIONS IN AREA 2 FLOUNDER (AGES 0, 2 AND 5) AND LOBSTER IN RELATION TO TIME AFTER REMEDIATION FOR THE 50-ppm SCENARIO

The results for the various levels of the food chain north of Popes Island also similar to the Estuary and Lower-Harbor scenarios (Table 7.57).

TABLE 7.57. COMPUTED CONCENTRATIONS IN BIOTA (μg/g WET WEIGHT) FROM EACH OF THE SEGMENTS OF NEW BEDFORD HARBOR 10 YEARS AFTER REMEDIATION OF THE UPPER-ESTUARY TO 50-ppm

Species	Box 1*	Box 2*	Box 3*	Box 4**	Box 5**	Box 6**
Phytoplankton	0.4	1.0	1.0	0.7	0.3	nc
Polychaete	3.7	7.2	5.6	4.0	1.5	nc
Hard Clam	0.1	0.4	0.4	0.3	0.1	nc
Mussel	0.4	1.0	1.0	0.8	0.3	nc
Crab	0.7	1.5	1.4	1.0	0.4	nc
Winter Flounder	1.6-2.9	3.3-5.6	2.8-4.6	2.0-3.5	0.8-1.3	nc
Lobster	nc	nc	nc	nc	0.2-0.2	nc

* Values at steady-state with projected year 10 water column and sediment PCB concentrations.
** Values projected ten years after remediation.
Note: Boxes 4, 5 & 6 correspond to Areas 1, 2 & 3, respectively, of the food chain model.
NC: Not calculated.

7.5.6 500-ppm Concentration Scenario

The 500-ppm scenario identifies all areas in the upper-estuary with PCB bed sediment concentrations greater than 500 ppm and reduces them to residual concentrations of 1 to 10 ppm. These initial conditions (Figure C.8a of Appendix C) are intermediate between the Hot-Spot and Upper-Estuary scenarios. The Lower-Harbor scenario hydrodynamics were used in this case.

7.5.6.1 Sediment/Contaminant Results: 500-ppm Scenario

Projected water column PCB concentrations for years 0 and 10 of the 500-ppm scenario are shown in Figures 7.64 and 7.65. As expected, the results fall between the values computed in the Hot-Spot and Upper-Estuary scenarios. Tables and figures for the sediment results are not shown, because they are identical to the Lower-Harbor scenario results.

TABLE 7.58. NET FLUX (kg/TIDAL CYCLE) OF SEDIMENTS AND PCBs FOR THE YEAR 0 AND YEAR 10 500-ppm SCENARIO SIMULATIONS

	Coggeshall Street Bridge	Hurricane Barrier	Open Boundary
Year 0 Sediment Flux	327	2.11×10^3	-2.178×10^4
Year 10 Sediment Flux	231	2.076×10^3	2.4858×10^4
Year 0 PCB Flux	-0.14	-0.09	-1.27
Year 10 PCB Flux	-0.13	-0.06	-0.27

By year 10, the average concentration for the areas north of the Coggeshall Street Bridge (Boxes 1 and 2) has declined to 636 ng/L as compared to 850 ng/L for the Hot-Spot and 1107 ng/L for No-Action. The box-averaged water column and sediment concentrations also demonstrate that the major difference between the 500-ppm and No-Action scenarios is north of the Coggeshall Street Bridge (Figures 7.66 and 7.67).

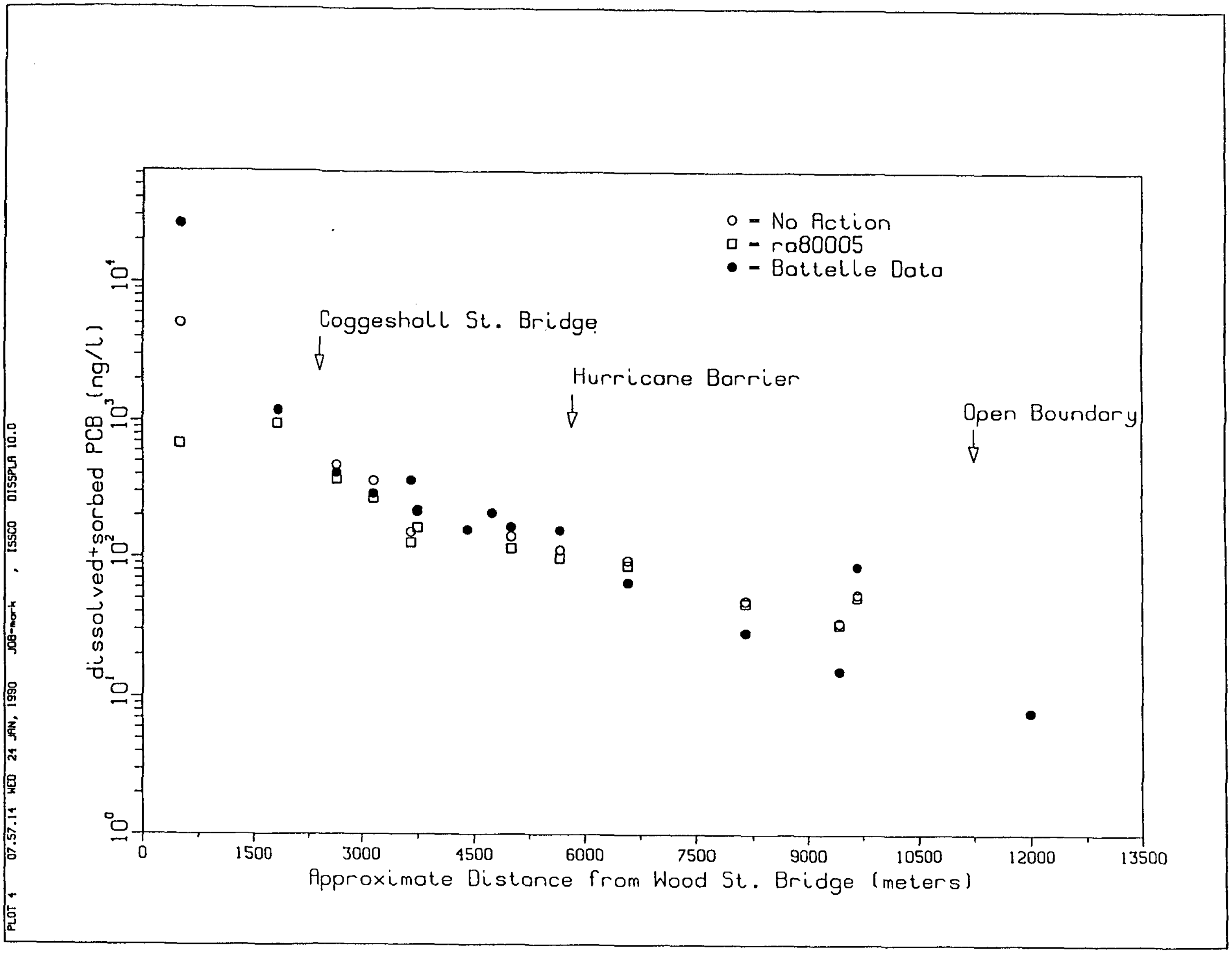


FIGURE 7.64. AVERAGE CONCENTRATION OF TOTAL PCBs IN THE WATER COLUMN FOR YEAR 0 OF THE 500-ppm SCENARIO (ng/L). o = NO-ACTION SCENARIO, □ = 500-ppm SCENARIO, • = BATTELLE OCEAN SCIENCES DATA.

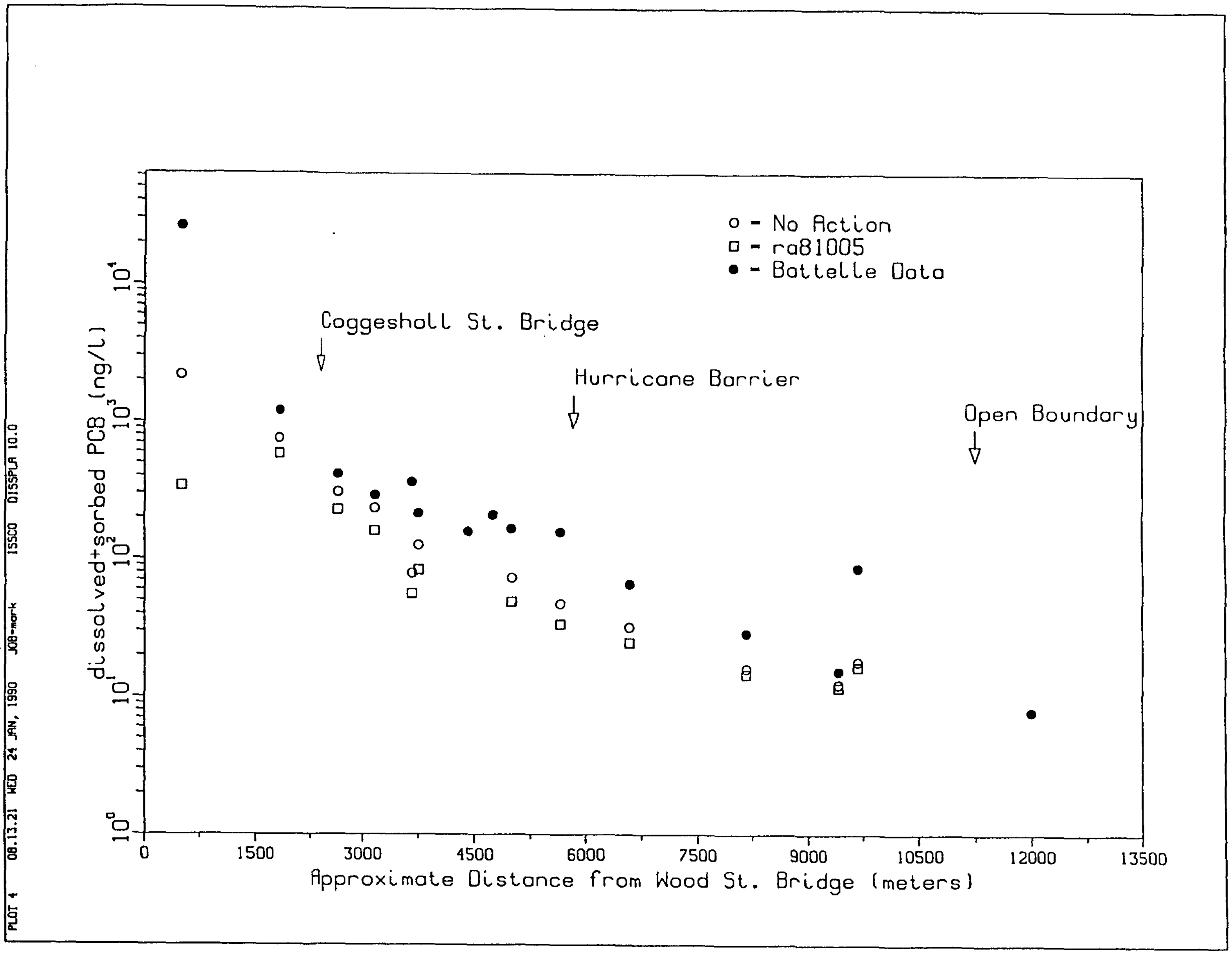


FIGURE 7.65. AVERAGE CONCENTRATION OF TOTAL PCBs IN THE WATER COLUMN FOR YEAR 10 OF THE 500-ppm SCENARIO (ng/L). o = NO-ACTION SCENARIO, □ = 500-ppm SCENARIO, • = BATTELLE OCEAN SCIENCES DATA.

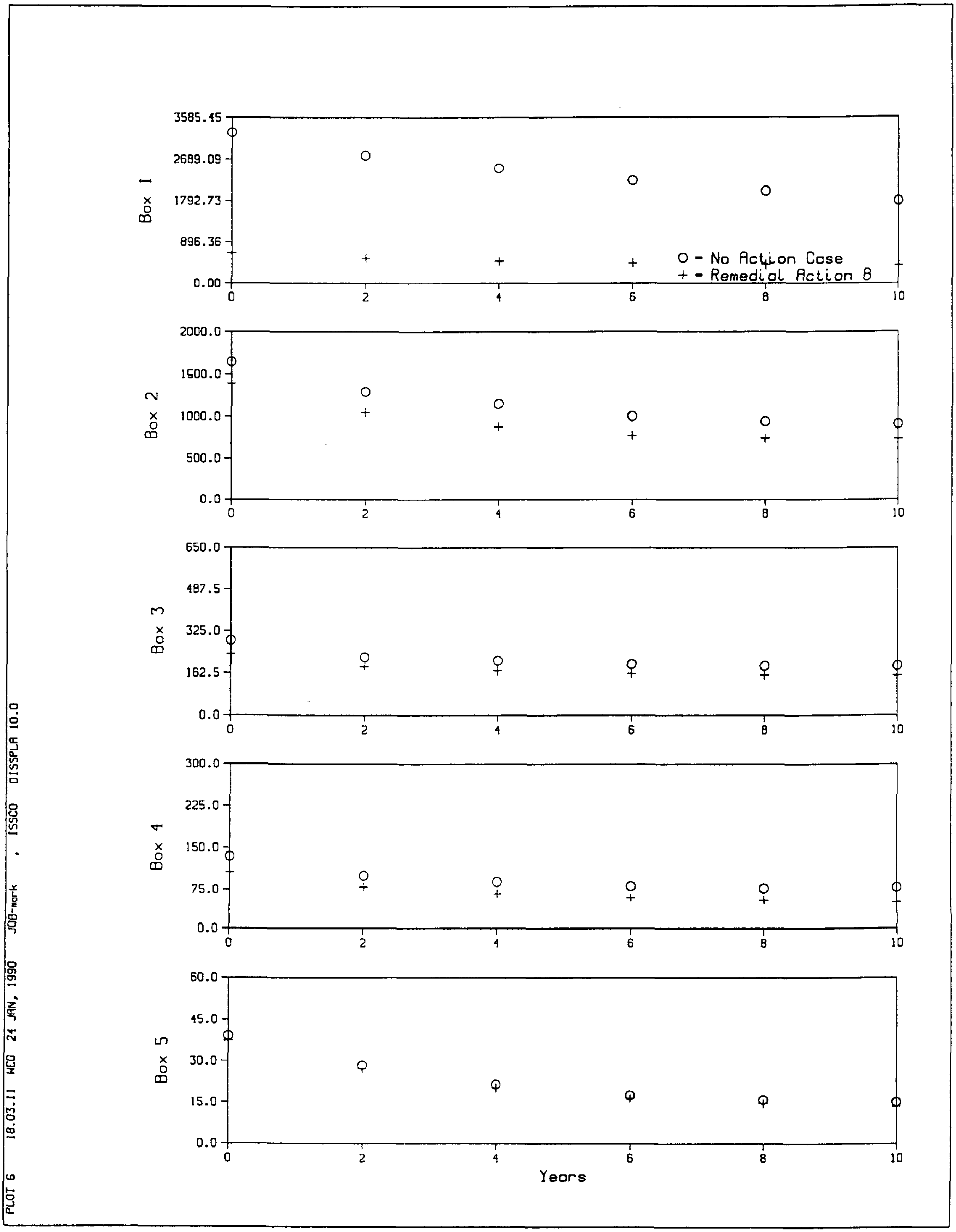


FIGURE 7.66. BOX-AVERAGED MODEL RESULTS FOR THE 500-ppm SCENARIO. TOTAL PCB CONCENTRATION (ng/L) IN THE WATER COLUMN. o = NO-ACTION SCENARIO, + = 500-ppm SCENARIO.

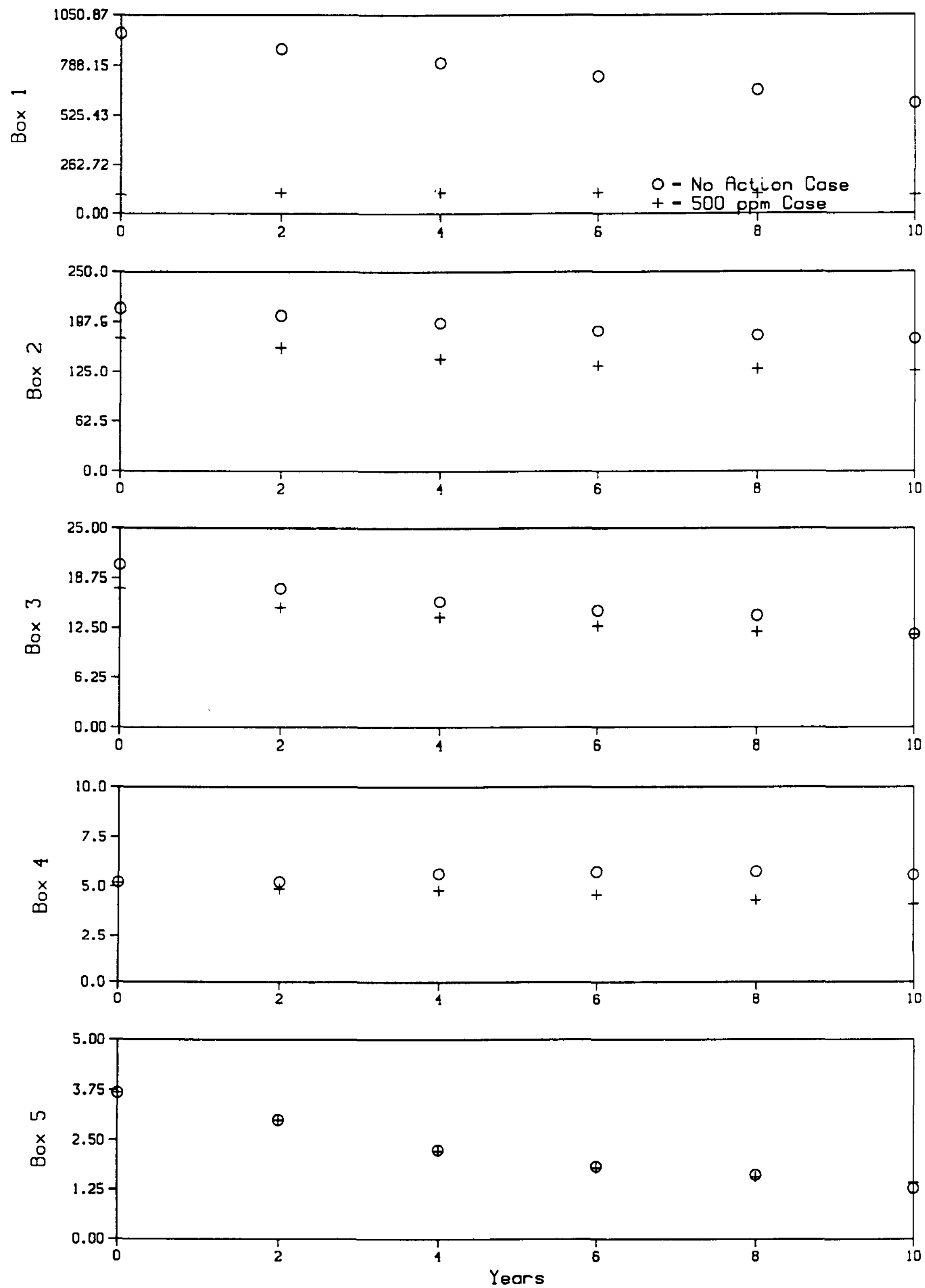


FIGURE 7.67. BOX-AVERAGED MODEL RESULTS FOR THE 500-ppm SCENARIO. TOTAL PCB CONCENTRATION (mg/kg) IN THE BED SEDIMENT LAYER. o = NO-ACTION SCENARIO, + = 500-ppm SCENARIO.

While the area averaged values south of this point do not change dramatically, the locations of the 50 ng/L and 10 ng/L isopleths in the comparative water column contour plot of No-Action and the 500-ppm scenario contour plot (Figure 7.68) suggest that removal of this PCB source area will lower the quantity of PCBs being transported through the Hurricane Barrier. This is also reflected in the projected 50% reduction in flux through the Hurricane Barrier from 0.11 kg/tidal cycle to 0.06 plot, Figure 7.69 suggest that dramatic changes in sediment concentration will only occur in the upper-estuary region of the site.

The results of PCB mass balance and area averaged concentrations for the REM III study areas are presented below in Tables 7.59 through 7.61.

TABLE 7.59. PCB MASS BALANCE AND AVERAGE CONCENTRATION IN THE UPPER-ESTUARY FOR THE YEAR 0 AND YEAR 10 500-ppm SCENARIO SIMULATIONS

	Year 0	Year 10	Change
Water Column Mass (kg)	1.5	0.8	-0.7
Bed Layer Mass (kg)	6.085×10^3	5.223×10^3	-862
Water Column Concentration (ng/L)	1.201×10^3	636	-565
Bed Layer Concentration (mg/kg)	147	120	-27

TABLE 7.60. PCB MASS BALANCE AND AVERAGE CONCENTRATION IN THE LOWER-HARBOR FOR THE YEAR 0 AND YEAR 10 500-ppm SCENARIO SIMULATIONS

	Year 0	Year 10	Change
Water Column Mass (kg)	2.0	1.1	-0.9
Bed Layer Mass (kg)	1.415×10^3	1.096×10^3	-319
Water Column Concentration (ng/L)	133	73	-60
Bed Layer Concentration (mg/kg)	9	6	-3

TABLE 7.61. PCB MASS BALANCE AND AVERAGE CONCENTRATION IN THE OUTER HARBOR FOR THE YEAR 0 AND YEAR 10 500-ppm SCENARIO SIMULATIONS

	Year 0	Year 10	Change
Water Column Mass (kg)	5.0	1.9	-3.1
Bed Layer Mass (kg)	4.675×10^3	2.336×10^3	-2.339×10^3
Water Column Concentration (ng/L)	31	12	-19
Bed Layer Concentration (mg/kg)	3	1	-2

7.5.6.2 Food Chain Results: 500-ppm Scenario

Exposure Profile

In Area 1 water column and sediment exposure conditions decline by approximately 30%, as compared to No-Action (Table 7.62). The conditions within Area 2 are projected to remain essentially the same for each case. This finding is consistent with the other remedial scenarios that only address contaminant sediment above the Hurricane Barrier.

TABLE 7.62. 500 ppm EXPOSURE CONCENTRATIONS FOR FOOD CHAIN MODEL

	Area 1		Area 2		Area 3	
Year	Water Column[a]	Bed Sediment[b]	Water Column[a]	Bed Sediment[b]	Water Column[a]	Bed Sediment[b]
0	69.67	7.77	21.36	3.68	NC	NC
2	58.02	7.32	16.77	2.99	NC	NC
4	50.68	7.04	12.75	2.23	NC	NC
6	45.37	6.60	10.26	1.80	NC	NC
8	42.25	6.11	9.05	1.57	NC	NC
10	39.94	5.70	8.30	1.42	NC	NC

[a] Water column dissolved PCB (ng/L).
[b] Sediment PCB (mg/kg dry).
NC: Not calculated.

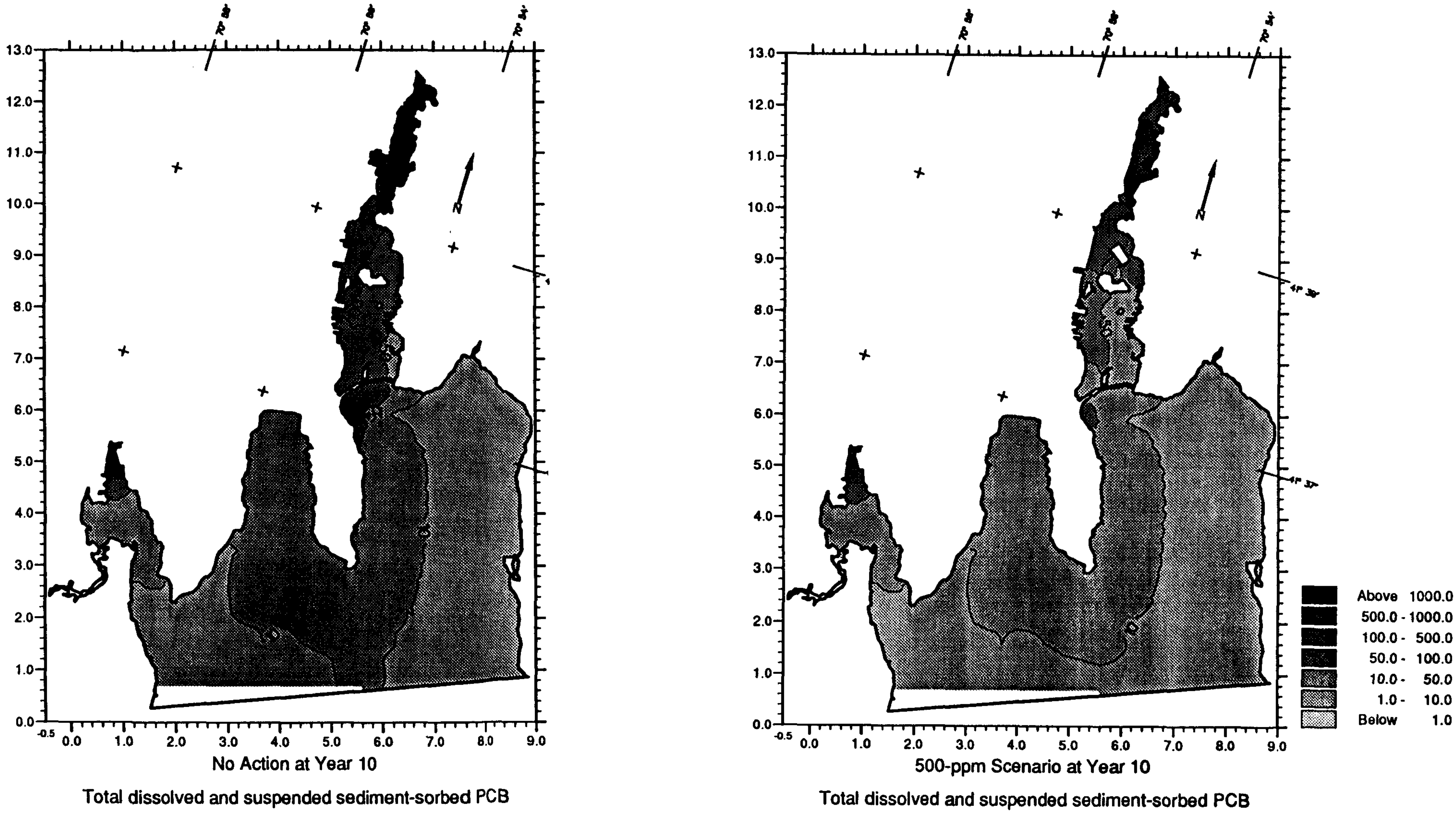
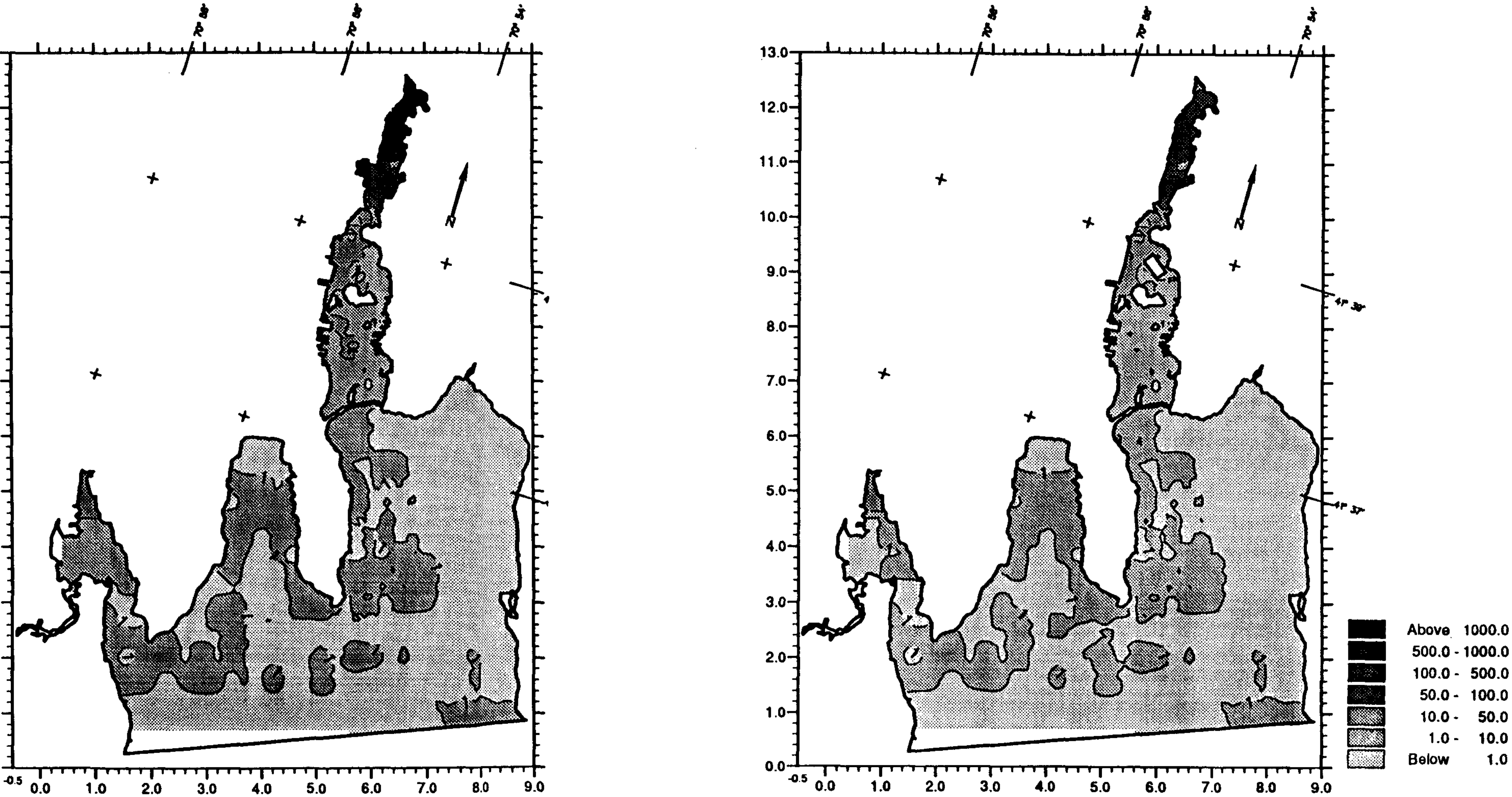


FIGURE 7.68. COMPARISON OF DEPTH-AVERAGE TOTAL WATER COLUMN PCB LEVELS FOR THE NO-ACTION AND 500-ppm SCENARIOS AT YEAR 10, TOTAL DISSOLVED AND SUSPENDED SEDIMENT-SORBED PCB (ng/L)



No Action at Year 10

Total Sediment-Sorbed PCB in Bed Sediments (mg/kg)

500-ppm Scenario at Year 10

Total Sediment-Sorbed PCB in Bed Sediments (mg/kg)

FIGURE 7.69. COMPARISON OF TOTAL BED SEDIMENT-SORBED PCB LEVELS FOR THE NO-ACTION AND 500-ppm SCENARIOS AT YEAR 10, TOTAL SEDIMENT-SORBED PCB (ng/L)

The projected flounder concentrations from Area 1 decline by about 30% as result of this remedial action. By year 10 following remediation, the year-of-the-young and five year old flounder concentrations have declined to 3.7 μg/g and 5.8 μg/g respectively (Table 7.63 and Figure 7.70). In both age classes, the edible tissue concentration is projected to be below the FDA limit. In Area 2, the flounder and lobster concentrations essentially remain at the No-Actions levels (Figure 7.71). While flounder are projected to be below the FDA limit, the lobster are expected to remain at about the limit.

TABLE 7.63. COMPUTED CONCENTRATIONS IN BIOTA (UG/G WET WEIGHT) FROM EACH OF THE SEGMENTS OF NEW BEDFORD HARBOR TEN YEARS AFTER REMEDIATION OF THE UPPER-ESTUARY TO 500 PPM

Species	Box 1*	Box 2*	Box 3*	Box 4**	Box 5**	Box 6**
Phytoplankton	12	24	4.4	1.6	0.3	nc
Polychaete	112	140	14	6.6	1.6	nc
Hard Clam	4.2	8.6	1.6	0.6	0.1	nc
Mussel	12	24	4.5	1.6	0.3	nc
Crab	20	33	4.9	1.9	0.4	nc
Winter Flounder	48-85	68-113	8.8-13	3.7-5.8	0.8-1.4	nc
Lobster	nc	nc	nc	nc	0.2-0.2	nc

* Values at steady-state with projected year 10 water column and sediment PCB concentrations.
** Values projected ten years after remediation.
Note: Boxes 4, 5 & 6 correspond to Areas 1, 2, & 3, respectively, of the food chain model.
NC = Not calculated.

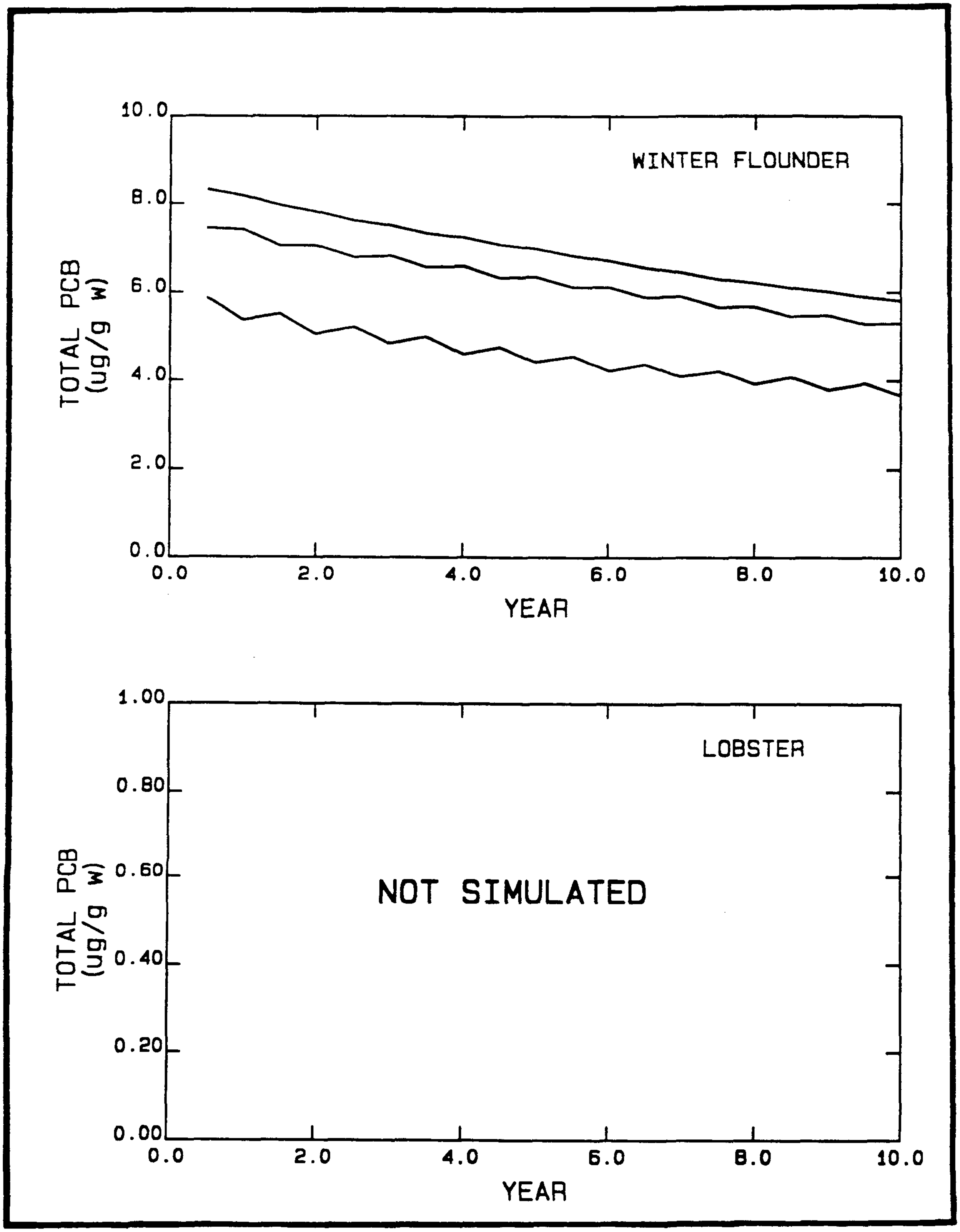


FIGURE 7.70. PCB CONCENTRATIONS IN AREA 1 FLOUNDER, (AGES 0, 2 AND 5) IN RELATION TO TIME AFTER REMEDIATION FOR THE 500-ppm SCENARIO

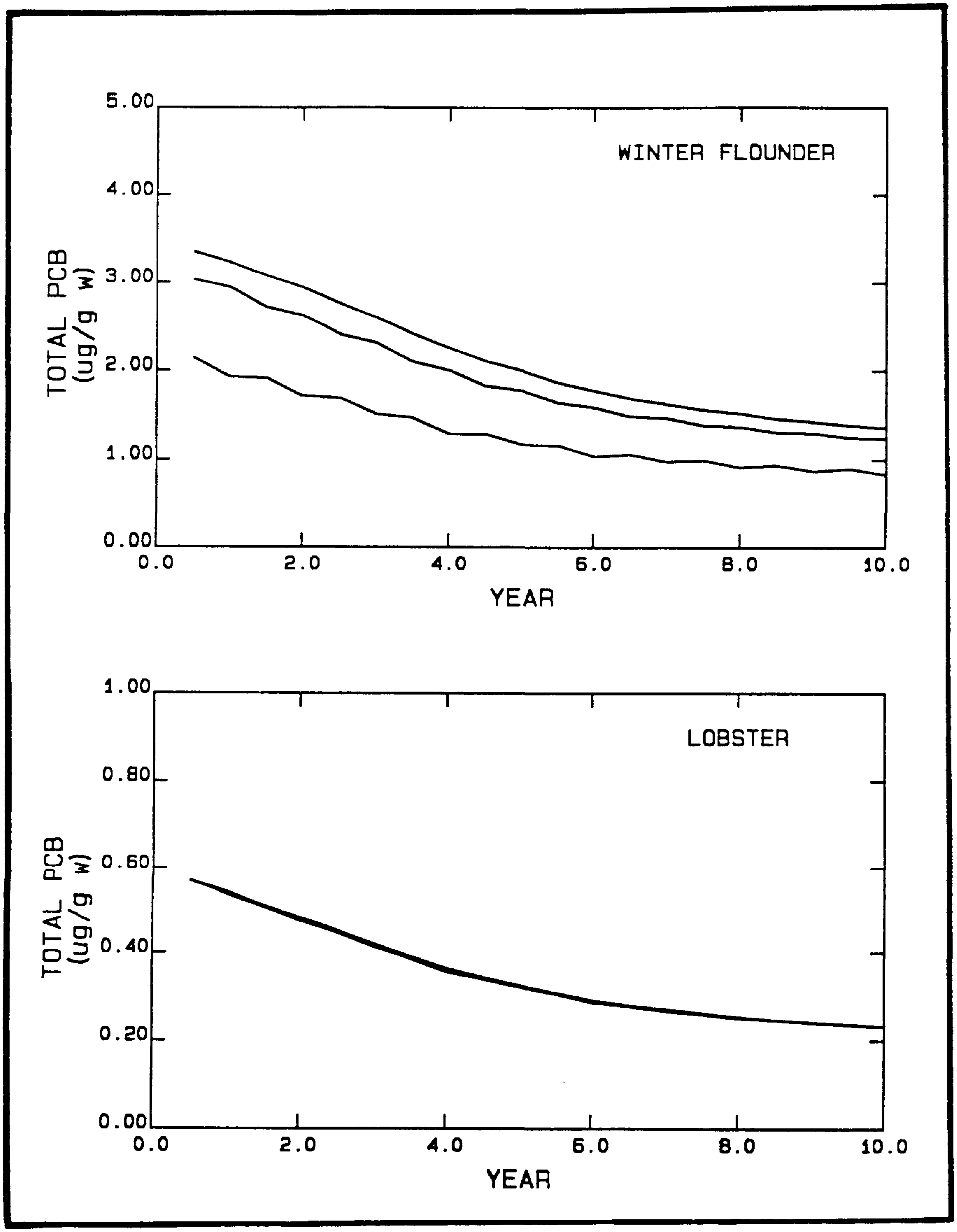


FIGURE 7.71. PCB CONCENTRATIONS IN AREA 2 FLOUNDER (AGES 0, 2 AND 5) AND LOBSTER IN RELATION TO TIME AFTER REMEDIATION FOR THE 500-ppm SCENARIO

7.6 COMPARATIVE ANALYSIS

In order to facilitate a relative comparison between No-Action and the Remedial-Action Scenarios, the results of both models are presented in a comparative format herein. As discussed earlier, due to the inherent uncertainties in performing modeling studies of this size and complexity, it is important to view the results in a comparative sense.

7.6.1 Sediment/Contaminant Transport Results

The results of the Remedial Action scenarios can be put into perspective by comparing the computed net flux (Figure 7.72) and area averaged water column (Figure 7.73) and bed sediment (Figure 7.74) concentrations at the end of the 10 year simulations. The Hot-Spot and 500-ppm scenarios can be seen to produce comparable results because of the similarity of their initial distributions of PCBs within the bed sediments. In addition, the results of these two scenarios are not markedly different from the No-Action scenario. The results of the remaining scenarios (i.e., Upper Estuary, Lower Harbor and 50-ppm) show much reduced fluxes through the Coggeshall Street Bridge and the Hurricane Barrier as well as lower water column and bed sediment concentrations as compared to the No-Action. The Remedial Action and No-Action scenarios yield similar concentrations in the outer harbor region. This suggests that the effects of a cleanup action will be localized; for example, removal of the Hot Spot will not lead to dramatically reduced water column and bed sediment concentrations in the lower harbor and/or outer harbor areas.

With the exception of the 1-ppm scenario, the results of the Remedial Action cases suggest that bed sediment and water column concentrations south of the Hurricane Barrier will not be significantly reduced as compared to No-Action. However, dramatic improvement in sediment and water quality conditions are projected for the areas north of the Hurricane Barrier under the Upper-Estuary, Lower-Harbor and 50-ppm scenarios.

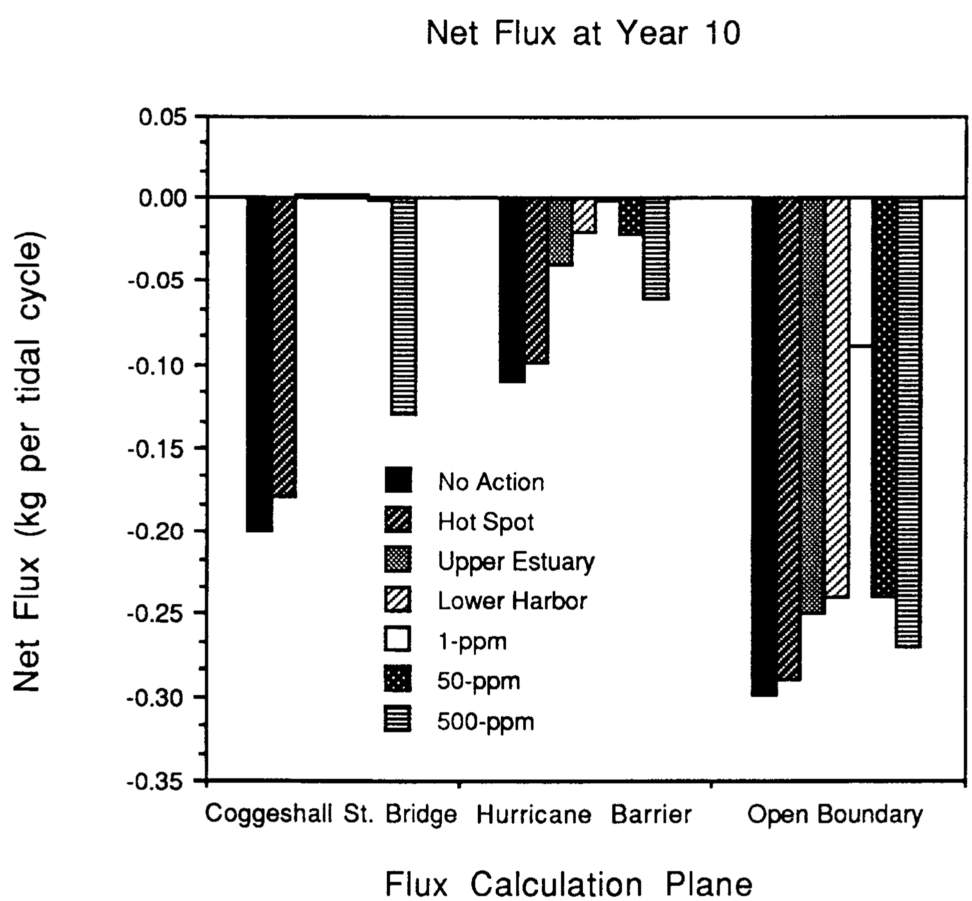


FIGURE 7.72. COMPARISON OF THE COMPUTED NET FLUX RESULTS AT YEAR 10 (kg/Tidal Cycle)

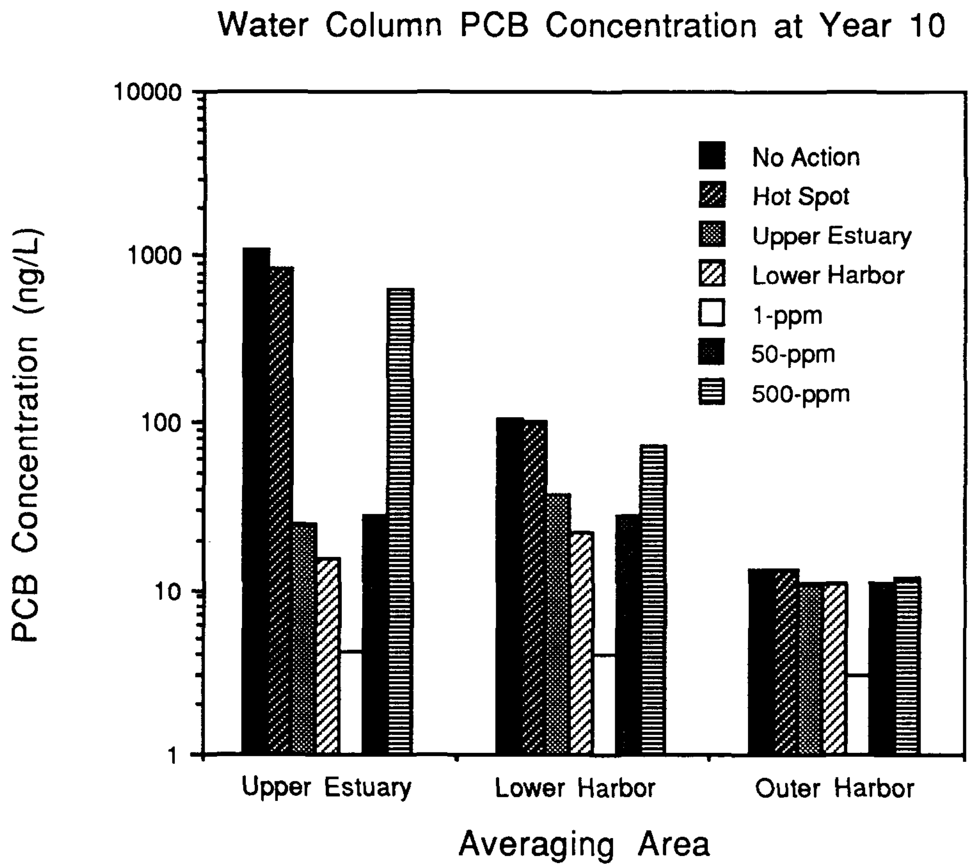


FIGURE 7.73. COMPARISON OF THE AREA AVERAGED WATER COLUMN PCB CONCENTRATION AT YEAR 10 (ng/L)

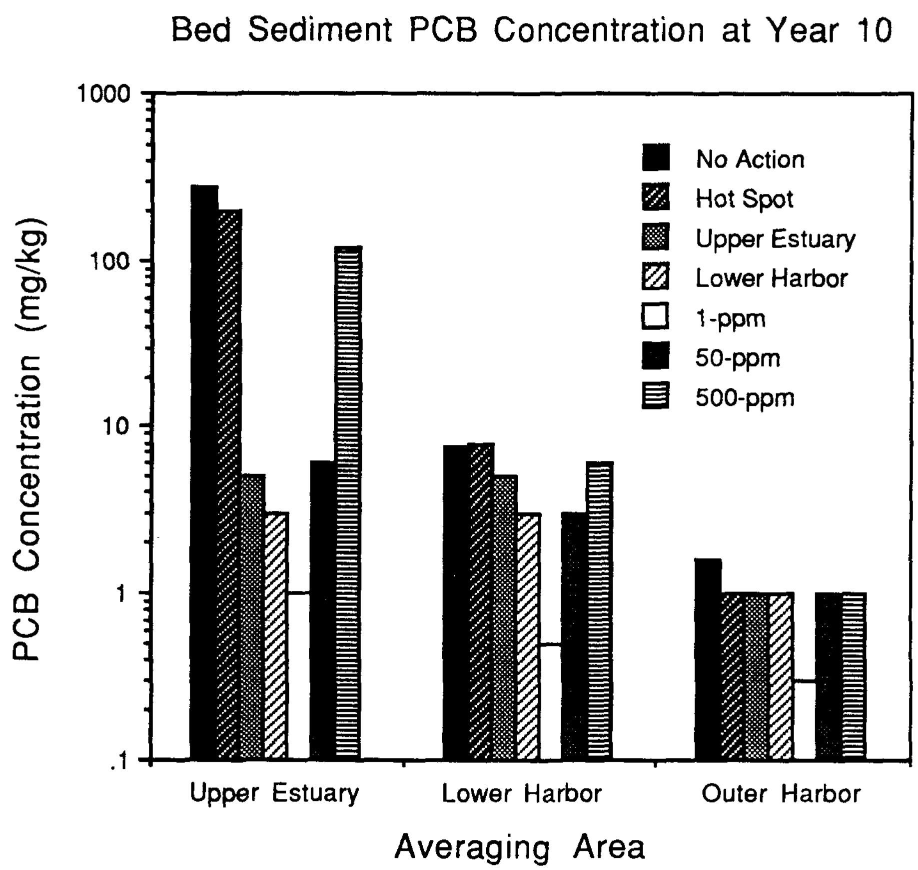


FIGURE 7.74. COMPARISON OF THE AREA AVERAGED BED SEDIMENT PCB CONCENTRATION AT YEAR 10 (mg/kg)

7.6.2 Food Chain Results

The results of the food chain model generally follow the same pattern or trend of the physical/chemical model projections. Intuitively, this makes sense as the sediment and water column projections from the physical/chemical model become the exposure concentrations for the biota.

With this in mind, we expect to see little change in biota concentrations relative to No-Action south of the Hurricane Barrier with the exception of the 1-ppm remedial scenario. This is illustrated in Figure 7.75 which presents the projected lobster concentrations for Area 2 of the food chain model (Box 5). Results from the Upper-Estuary and Lower-Harbor remedial scenarios are not presented herein, because of their similarly to the 50-ppm scenario. For the same reason only the 500-ppm case is shown, not both the 500-ppm and the Hot-Spot scenarios. The projections for steady-state species projection in this region also support this finding (Figure 7.76).

Between the Hurricane Barrier and the Coggeshall Street Bridge, there are some reductions in biota concentrations resulting from the Upper-Estuary, Lower-Harbor, 50-ppm scenarios. This is demonstrated in steady-state species concentrations for this region (Figure 7.77). The model results for flounder from Area 1, of the food chain model also support this finding. The fish from the lower portion of this region experience an average decline in concentration of 50 to 60% in response to these scenarios.

North of the Coggeshall Street Bridge the greatest decline in steady-state biota levels is associated with the 1-ppm scenario. However, significant reductions are projected for the 50-ppm scenario (Figure 7.78). Again, for comparative purposes it is assumed that the 50-ppm scenario exposure conditions are generally similar in magnitude to those of the Upper- and Lower-Estuary scenarios within this region.

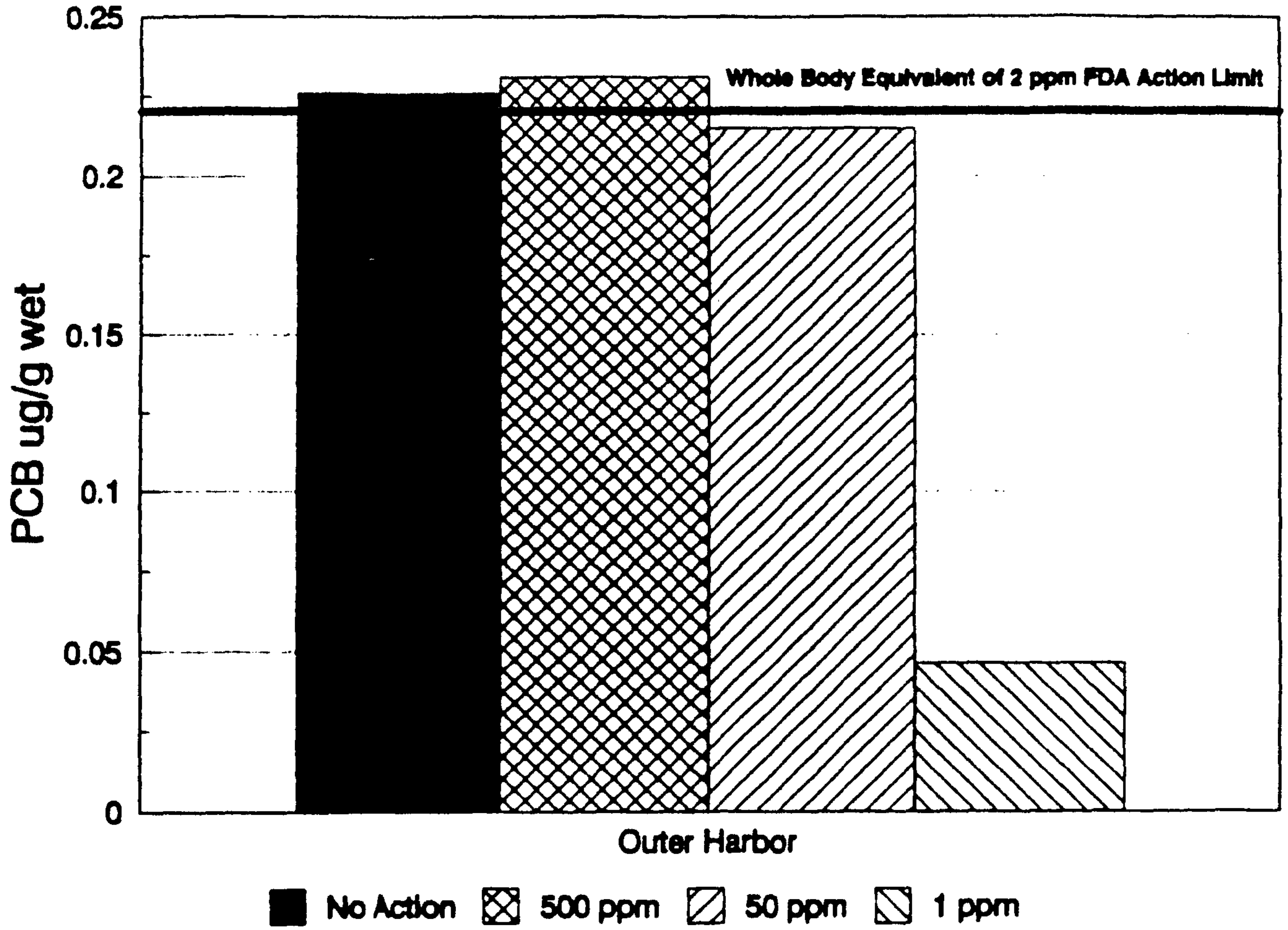


FIGURE 7.75. COMPUTED PCB CONCENTRATIONS IN LOBSTER FROM THE OUTER HARBOR, 10 YEARS AFTER REMEDIATION OF SEDIMENTS TO VARIOUS LEVELS

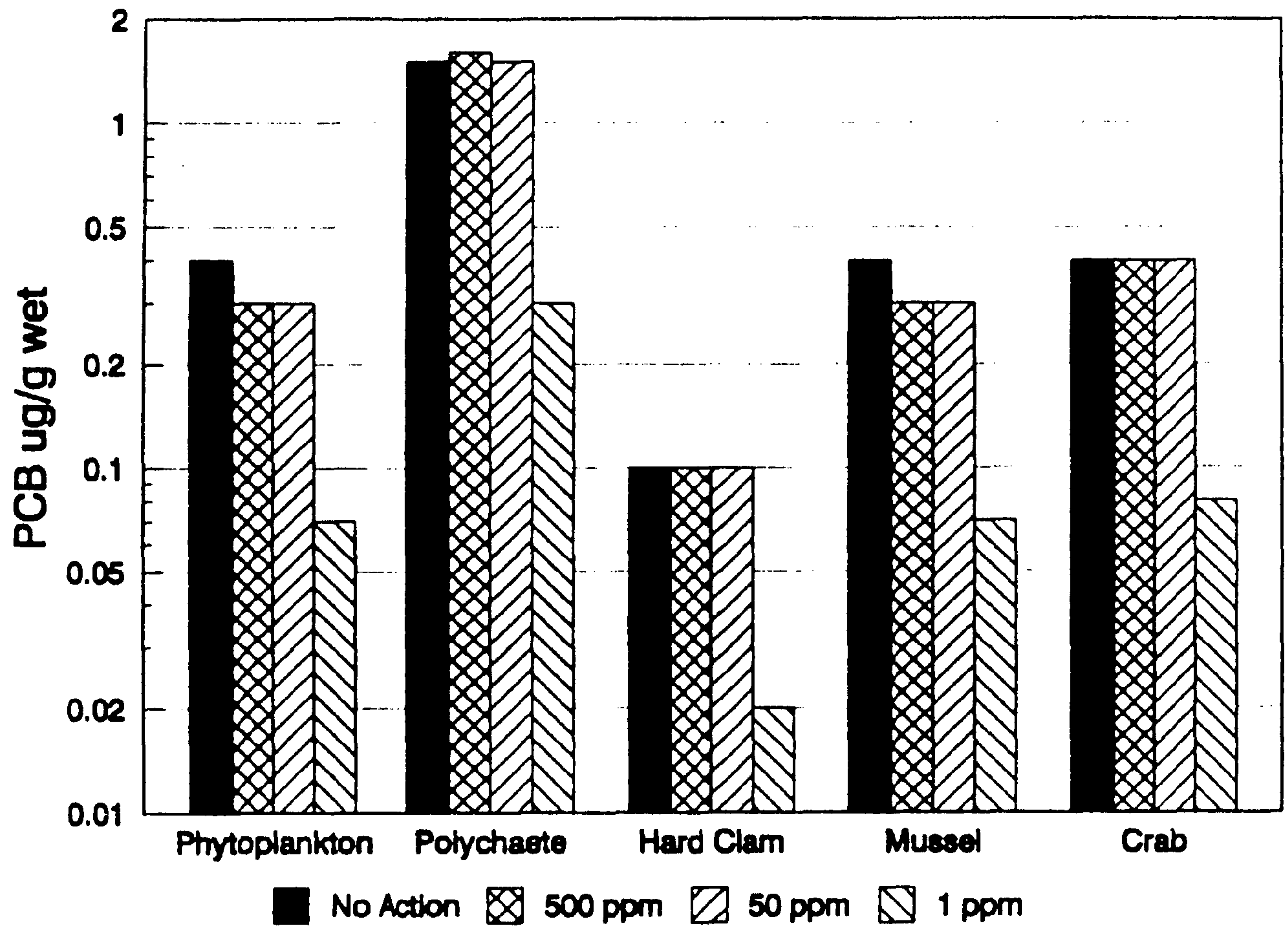


FIGURE 7.76. COMPUTED PCB CONCENTRATION IN THE STEADY-STATE SPECIES FOR THE OUTER HARBOR (BOX 5) 10 YEARS AFTER REMEDIATION OF SEDIMENTS TO VARIOUS LEVELS

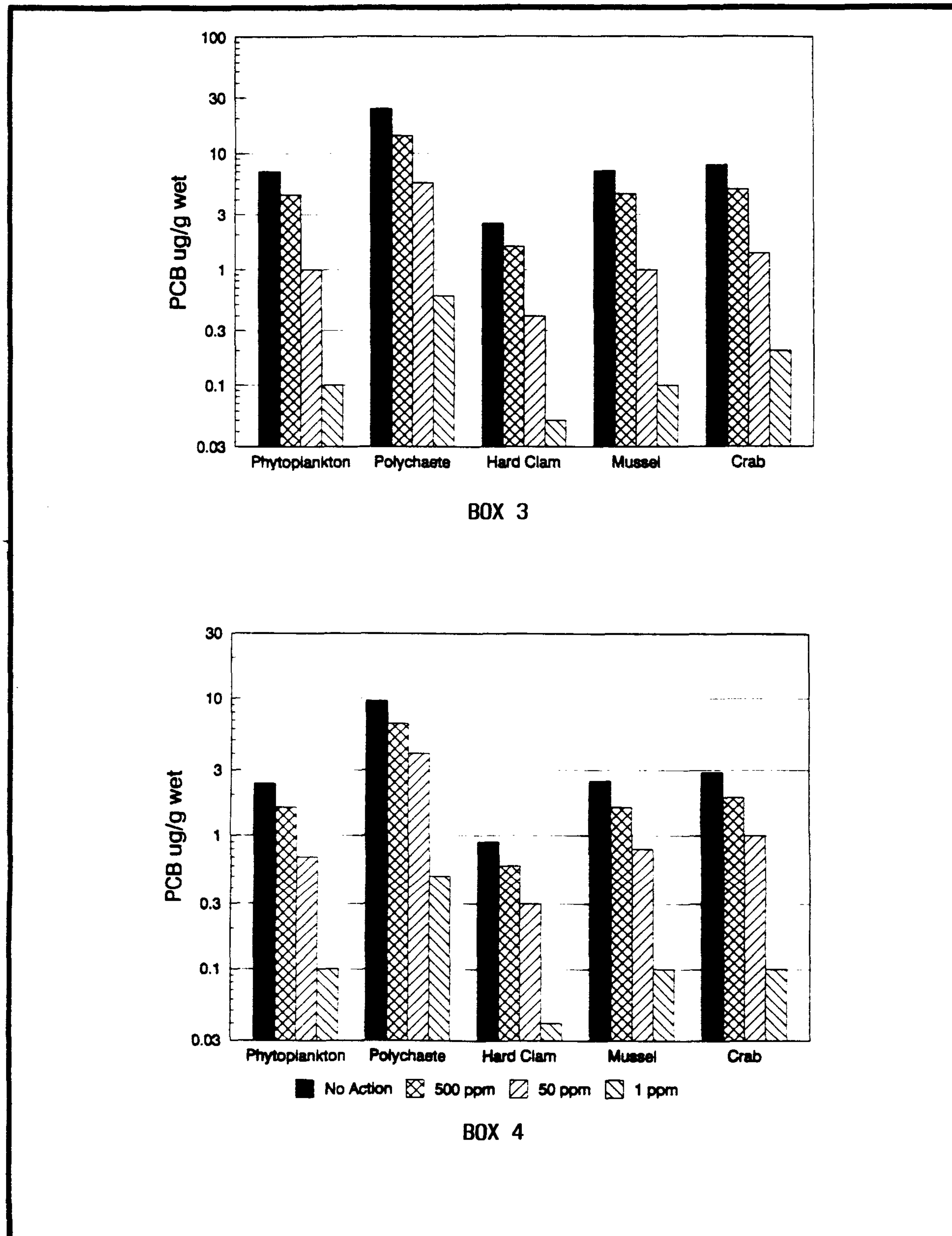


FIGURE 7.77. COMPUTED PCB CONCENTRATIONS IN THE STEADY-STATE SPECIES FOR THE REGION BETWEEN THE HURRICANE BARRIER AND POPES ISLAND (BOX 4) AND POPES ISLAND AND THE COGGESHALL STREET BRIDGE (BOX 3), 10 YEARS AFTER REMEDIATION OF SEDIMENTS TO VARIOUS LEVELS

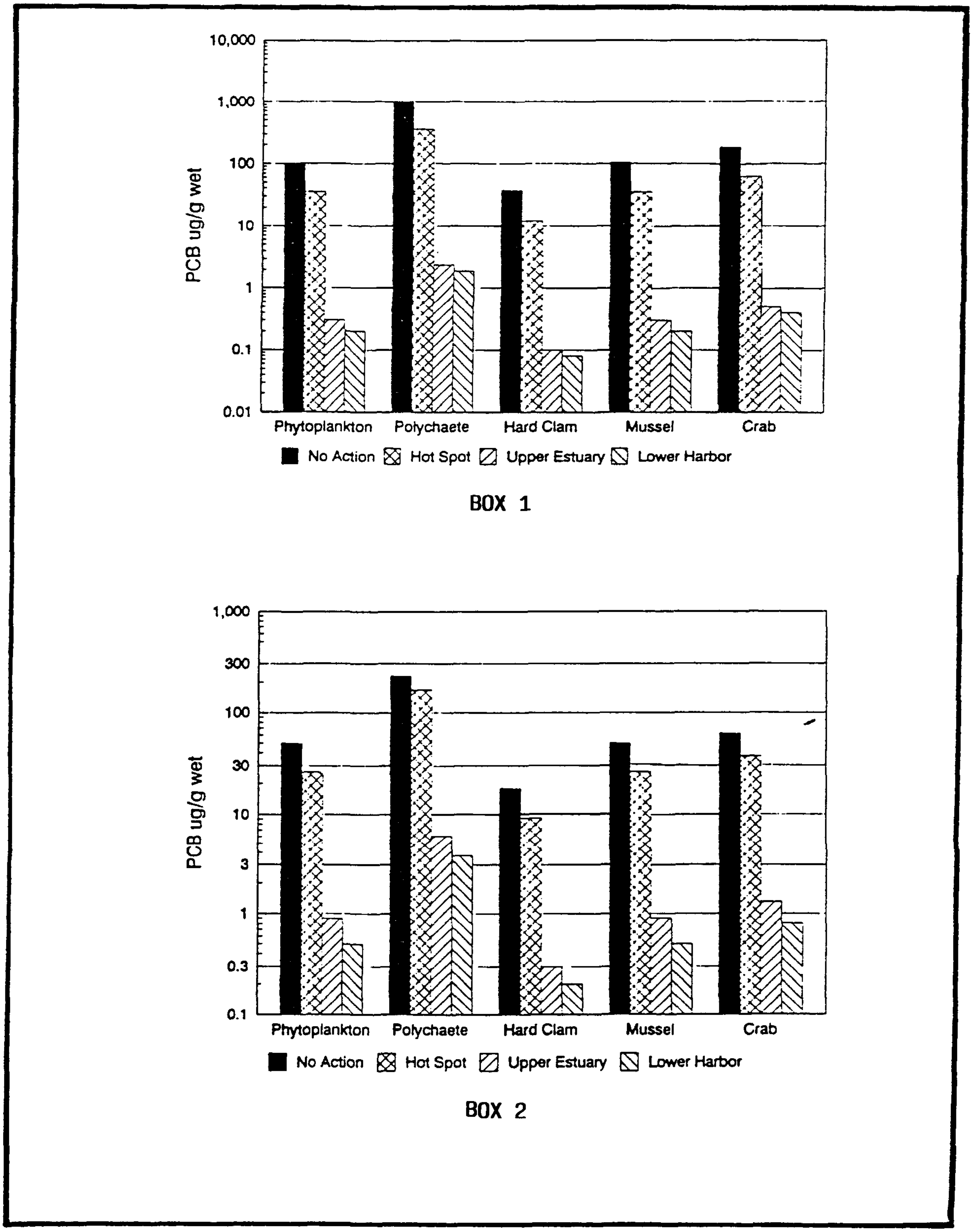


FIGURE 7.78. COMPUTED PCB CONCENTRATION IN THE STEADY-STATE SPECIES FOR THE AREA BETWEEN THE COGGESHALL AND WOOD STREET BRIDGES (BOXES 1 AND 2), 10 YEARS AFTER REMEDIATION OF SEDIMENTS TO VARIOUS LEVELS

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