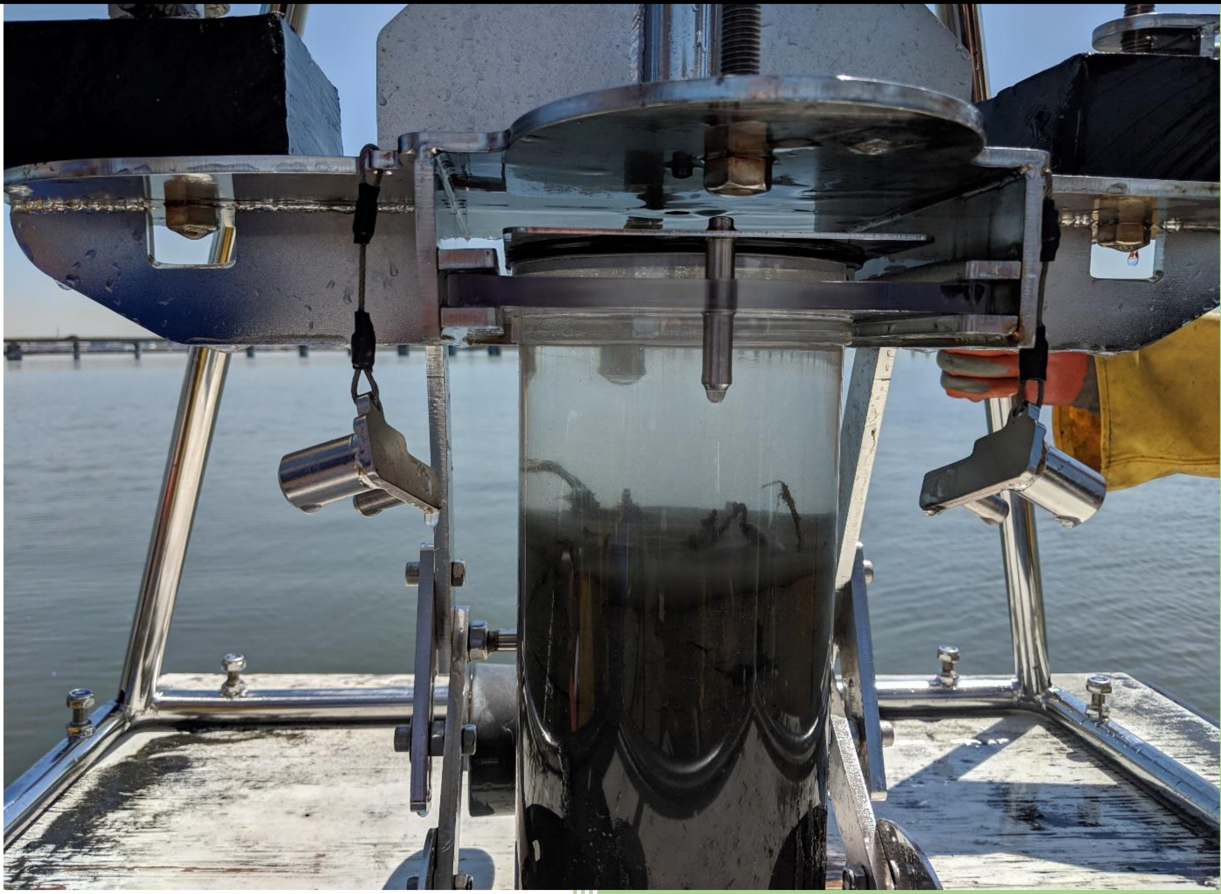
2024

Contamination Assessment and Reduction Project – Phase 2 (CARP II)

Summary of Activities and Findings



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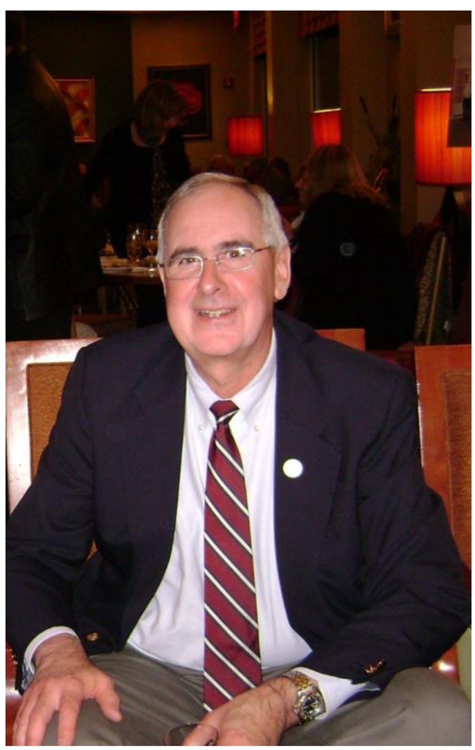
In memory of Dennis J Suszkowski

We would like to express our deepest appreciation to Dennis Suszkowski for their significant contribution to the Contamination Assessment and Reduction Project (CARP). Their leadership, insights, and dedication to an enhanced understanding of sediment processes and contaminant interactions greatly enriched the quality of this work. Their career long commitment and pursuit of policy changes and management initiatives to improve dredged material management and the overall understanding of the Hudson ecosystem had a tremendous and lasting impact.   We are truly grateful for their friendship, collaboration, and inspiration.



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Lodge, J., R.E. Landeck Miller, K.J. Farley, S. Litten, S. Douglas, S. R. Lohmann, S. Vojta, 2024*. Contaminant Assessment and Reduction Project, Phase 2, CARP II Summary Report*. Hudson River Foundation, New York, NY.
https://www.hudsonriver.org/wp-content/uploads/2024/01CARPIIsummary-report-online.pdf

Chapter 1 Background and Introduction

The Contamination Assessment and Reduction Project (CARP) is a landmark, multi-decade project bringing together federal, state, and non-government partners to better understand and reduce contamination that is causing environmental harm and economic hardships within the New York/New Jersey Harbor. The project originated in 1999 after several years of discussions through the Dredged Material Forum and the Sediment Contamination Reduction workgroup of the NY/NJ Harbor & Estuary Program (HEP). CARP's primary objectives were: 1) to identify the sources of contaminants causing dredged material disposal problems, and 2) to determine the length of time needed for dredged material to meet ocean disposal criteria [suitability for use as remediation material at the Historic Area Remediation Site (HARS)]. An additional objective was to predict the impact of planned sediment remediation activities including the Hudson River and Passaic River Superfund projects and to recommend additional actions to decrease the time needed for future dredged sediments in the Harbor to be "clean" enough to meet ocean disposal criteria. The project collected and analyzed extensive data on the contaminants in the water, biota and sediments in the Hudson Raritan Estuary and produced a suite of state-of-the-science contaminant fate and transport models, collectively called the CARP model (Lodge et al., 2015[1]). The CARP model predicted that by 2040 many of the current contaminants of concern in dredged material were expected to decrease to levels that would allow ocean placement (HARS suitability). However, polychlorinated biphenyls (PCBs) and polychlorinated dibenzo-p-dioxins and furans (PCDD/Fs) would continue to be a problem in parts of the Harbor and dredged sediments from these areas would still need to be processed and managed on contained and controlled upland sites. Depending on the scope and effectiveness of planned remedial actions, the CARP model predicted these contaminants could continue to cause exceedances in dredged material disposal criteria for four or more decades.

In 2011, the U.S. Army Corps of Engineers (USACE) convened the Dredged Material Strategic Planning Group (DMSPG) to evaluate the impacts of contaminated sediments on the cost of maintaining the navigation channels after the completion of the Harbor 50-foot Deepening Project. The DMSPG determined that in the near term (through 2030), most dredged materials in the Harbor would still not be HARS-suitable. Additionally, the DMSPG concluded that while both the CARP modeling and recent bioaccumulation testing provided evidence that dredged material quality in the Harbor was improving, more information was needed to accurately forecast future HARS suitability and provide reliable estimates of the financial resources needed to maintain the Harbor.

In response to the recommendations of the DMSPG and other stakeholders, the New Jersey Department of Transportation (NJDOT) issued an RFP to collect additional data on Harbor sediments and to evaluate and update the CARP model to address these critical dredged material management questions. CARP II was initiated by a team of researchers and project advisors (Table 1) in March 2017 to leverage CARP

[1] Lodge, J., Landeck Miller, R.E., Suszkowski, D., Litten, S., Douglas, S. 2015. Contaminant Assessment and Reduction Project Summary Report. Hudson River Foundation, New York, NY. https://www.hudsonriver.org/wp-content/uploads/2017/04/CARP-summary-report-online.pdf

financial investments by building upon the foundation of the CARP monitoring and modeling efforts. CARP II provides new and improved estimates of future dredged material quality and addresses important data and information gaps through: 1) the compilation and assimilation of relevant data collected in the years following CARP ; 2) the collection of new field measurements of contaminant inputs and ambient conditions in the Estuary; 3) the characterization and comparison of sediments in navigation channels and in adjacent off-channel area; 4) the refinement of the BSAF method for predicting bioaccumulation of sediment contaminants in dredged material test organisms; and 5) the evaluation of an alternate method for predicting HARS suitability; and 6) the evaluation, update, and refinement of the CARP sub-models.

Table 1 CARP II Project Research Team and Advisors

Project Role	**Name**	**Affiliation**
Project Sponsor	Scott Douglas	New Jersey DOT
Project Co-Principal Investigator & Project Director	Dennis Suszkowski /James Lodge	Hudson River Foundation
Project Co-Principal Investigator & Project Administrator	Tony MacDonald	Monmouth University
Principal Project Modeling Engineer	Kevin Farley	Manhattan College
Project Lead Modeling Engineer	Robin Miller	HDR
Principal Investigator for BSAF and Rapid Dredged Material Assessment	Rainer Lohmann	University of Rhode Island
Principal Investigator for Field Loadings and Sediment Data Collection	Robert Miskewitz	Rutgers University
Principal Investigator for Field Data Collection and Database Management	Simon Litten	NYSDEC (retired)
Project Scientist for Field Sampling	Jim Nickels	Monmouth University
Project Scientist for Field Loadings and Sediment Data Collection	Kelly Francisco	Rutgers University
Project Scientist for Rapid Dredged Material Assessment	Simon Vojta	University of Rhode Island
Project Advisor	Mark Reiss	EPA

Important Findings of CARP I

The CARP I (1998-2006) project team collected and analyzed an unprecedented set of data to characterize contaminant levels in sediment, water, biota, and wastewater (sewage treatment plants effluents, stormwater and combined sewer overflows) throughout the estuary. These data were integrated into a series of numerical models that successfully modeled the important processes controlling the behavior of sediments including the exchange rates between the sediment bed and the water column, sediment transport, and estuarine trapping. The following key CARP 1 findings provided the foundation for the CARP II modeling work:

- Historical sources were much larger than the ongoing external sources for most contaminants.
- Legacy sediments are a continuing source of contamination and generally play a larger role than ongoing loadings in controlling contaminant levels in water, sediment, and aquatic organisms in the Estuary.

- Water, sediment, and biota contaminant levels will continue to decline even if ongoing loads remain constant.
- Burial of contaminated sediments by cleaner sediments and resuspension of sediments and transport to other areas are the dominant natural processes that lower surficial sediment concentrations over time.

Chapter 2 CARP II Data Compilation and New Data Collection Objectives and Outcomes

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Objective 1: Compile and assimilate relevant data collected in the years since the completion of CARP I

Since the original CARP sampling was completed[2], additional regulations were put in place to reduce contaminant inputs to the Estuary, a significant Superfund remedial action was completed in the Upper Hudson River, major navigation channels in the Harbor were deepened, and major hydrologic events including tropical storms Irene/Lee (2011) and Superstorm Sandy (2012) occurred. These changes and other natural and anthropogenic processes have altered contaminants levels throughout the Estuary and affected other components of the environment.

During CARP II post-2002 sediment contamination concentrations including data collected under monitoring programs, remedial investigations, and dredging projects within the Harbor were compiled from several sources and entered into a Microsoft Access database management system. The data compilation is described in Appendix A-1.

The historical data were used in the assess the accuracy of the CARP I projections for future contaminant levels in Harbor sediments. The analysis also evaluated how sediment contamination varied between navigation channels and off-channel areas. This analysis informed the design of the CARP II sampling efforts and the selection of the CARP II model grid resolution.

Reference: Appendix A-1. CARP II Historical Data Compilation and Analysis

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Objective 2: Collect new field measurements of loads and ambient conditions.

New field measurements of ambient conditions and contaminant loads to the Hudson-Raritan Estuary (HRE) from tributary heads of tide and storm water discharges were strategically collected under

[2] The majority of the CARP I data were collected from 1999 – 2002. All CARP I sampling was completed by 2006.

YCARP II. These new measurements were used to confirm and improve the loading estimates and assess the suitability of using existing measurements of contamination levels in broader sediment areas to forecast contamination in navigation channels.

I. Sampling Ambient Water, Head of Tide, and Storm Water Measurements

As was done in CARP 1, water samples were collected using Trace Organics Platform Samplers (TOPS[1]). These devices filter large volumes of water to allow investigators to quantify contaminant loading even when the ambient concentrations are below detection. In total, 34 events were sampled with TOPS; seven Harbor ambient sites, five Head-of-Tide sites each visited twice; five storm water sites each visited twice, and seven Poughkeepsie sampling events (Figure 1). These samples were analyzed for dissolved, and particle bound PCBs and PCDD/Fs. Samples were also analyzed for suspended solids, particulate organic carbon, and dissolved organic carbon.

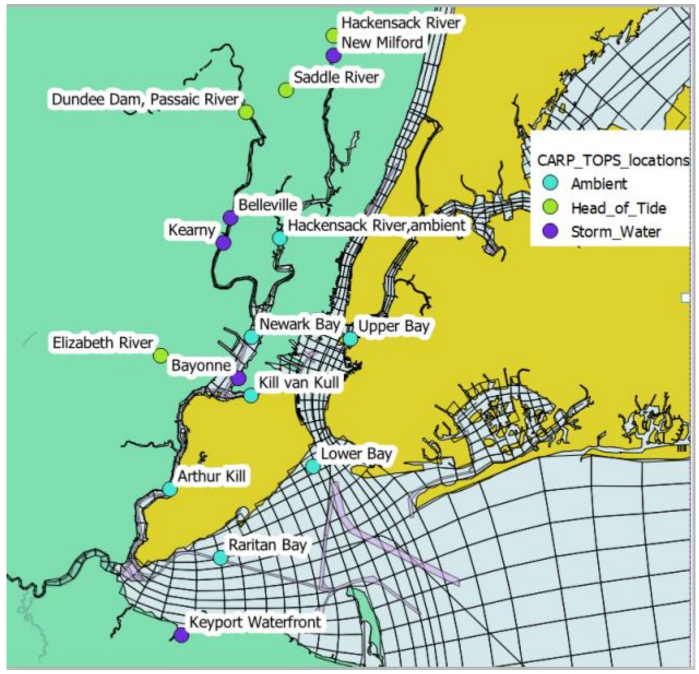

Figure 1. CARP II Sampling locations by sample type. The Poughkeepsie sampling station is located on the Hudson River approximately 100 miles north of the Battery and not shown on the figure.

These data were combined with the CARP I measurements to update contaminant loadings to inform the CARP II model. The CARP II loading estimates confirmed the accuracy of the CARP I estimated headwaters contaminant loadings for five major New Jersey tributaries: the Hackensack, Passaic, Saddle, Raritan, and Elizabeth Rivers, and for multiple urban stormwater locations. This effort provides additional evidence that the contaminant loadings used for the CARP modeling are a reasonable estimate of loads to the Harbor and can defensibly be used to model the levels of contamination in sediments within navigation channels and predict HARS suitability for various time horizons.

II. Harbor-wide Sediment Measurements

Surficial sediment samples were collected at 43 locations throughout the Harbor to evaluate how contaminant concentrations and sediment properties vary. All samples were analyzed for grain size, total organic carbon (TOC) and soot (black) carbon. At seven of the 43 locations, the samples were also analyzed for PCBs and at eight stations the samples were analyzed for PCDD/Fs. The data were used to evaluate the temporal responses across spatial gradients (i.e., from more contaminated to less contaminated regions of the harbor), and in the assessment of the initial years of CARP 2 model projections. No clear patterns in the distributions of soot carbon were observed, however, since levels of soot carbon in harbor sediments are likely to decrease in the coming decades, this dataset provides an important baseline for future evaluations of soot carbon. The data were also used to evaluate how black carbon and total organic carbon may affect bioaccumulation (Chapter 3).

Objective 3: Characterize sediments in navigation channels and in adjacent off-channel areas

III. Navigation Channel and Off-Channel Sampling

For the evaluation of sediments in navigation channels and off-channel areas, sediment core samples were collected from six locations in NY-NJ Harbor: Buttermilk Channel (BMC), Elizabeth Channel (EC), Port Jersey (PJ), Port Newark (PN), South Brother Island Channel (SB) and Ward Point Bend (RB) near the mouth of the Raritan River (Figure 2). For each location, three sediment samples were collected from both navigation channel and adjacent off-channel areas. Navigation channel sediment core samples were taken of maintenance dredged material within the navigation channel, these cores were then divided into a surface layer (0 -10 cm) sample and a deeper layer (20 - 30 cm) sample for analysis. Since off-channel sediments were expected to accumulate at slower rates, these cores were divided into a surface layer (0 -4 cm) sample and a deeper layer (6 - 10 cm) sample. This resulted in a total of 68 sediment samples taken across the Harbor.

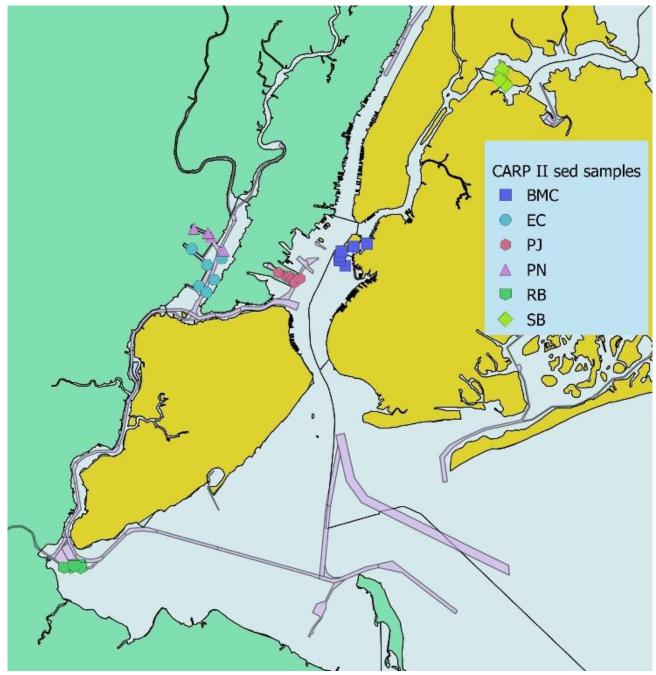

Figure 2. CARP II navigation channel and off-channel sampling locations.

IV. Analysis of Sediment Contamination, Ancillary Parameters, and Bioaccumulation

Each of the 68 sediment samples were analyzed for PCB congeners and 2,3,7,8-chlorine substituted PCDD/Fs. In addition, total organic carbon, soot (black carbon), dissolved organic carbon and Berylium-7 concentrations were measured. A subset of 20 sediment samples were also analyzed to determine PCB and PCDD/F porewater concentrations. Finally, 28-day bioaccumulation tests were performed on all 68 samples following the protocols[3] outlined in the Region 2 Testing Manual (USACE/USEPA 2016). This data was used to assess the accuracy of the CARP I model projections, and as discussed below, in the refinement of the CARP II models.

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[3] Dredged material testing methods were modified to use less sediment, keeping the sediment to water ratio consistent with the standard protocols.

V. Summary Findings from the Comparison of Navigation Channel to Off-Channel Sediments

The sampling was designed to examine variations in sediment contamination with depth and to determine whether contamination differs between navigation channels and off-channels areas. A primary goal of this objective was to determine if the new CARP II modeling grid would need to explicitly resolve the navigation channels and if the CARP I vertical segmentation should be increased. The analysis revealed no clear pattern in sediment contamination between channel and non-channel areas or when comparing the top (surface) to the bottom (lower) core segments. The concentrations of PCBs, PCDD/Fs, (and other sediment properties) were generally similar, suggesting the sediments in these areas were deposited in similar time horizons during which loadings did not change significantly. These results suggest that there is no need to explicitly resolve individual channels or include additional vertical segmentation to capture contaminant responses in the navigation channels and off-channel areas. However, as described in Section II of Chapter 4, the CARP model grid was extended to capture previously excluded channel areas and to enhance resolution throughout the model domain for improved hydrodynamic model calibration and representation of water movement.

Reference: Appendix A-2. CARP II Sampling and Analysis Program and Database

Chapter 3 Sediment Bioaccumulation Estimates and Prediction of HARS Suitability

Objective 4: Refine method for predicting bioaccumulation of sedimentary contaminants in dredged material test organisms

Decisions regarding dredged material's suitability for ocean management rely on the application of various bioassay tests to assess its potential to result in toxicity and contaminant uptake in aquatic organisms. Accumulation of PCBs and dioxins/furans (particularly 2,3,7,8-TCDD) by the testing organism, *Alitta* (formerly *Nereis) virens* in 28-day laboratory exposures is the most common determinant of whether a dredged material is suitable for placement at the HARS.

Due to their expense and complexity, 28-day bioaccumulation tests are not well suited for routine application as a monitoring tool. Because HARS determinations are often made on the basis of the outcome of these tests, members of the Port community would benefit from affordable and practicable alternative tools to predict whether their specific dredged materials are likely to pass these tests.

Previous studies on PCB and PCDD/F accumulation in test organisms utilized Biota Sediment Accumulation Factors (BSAFs) to relate contaminant concentrations in sediments to contaminant accumulation in the organisms. These BSAFs have been used to predict organism residue levels expected to result in test organisms exposed to a given sediment using only sediment measurements. However, large variations in BSAFs reported for 28-day bioaccumulation tests for NY-NJ Harbor (Farley et al. 1999, HydroQual 2007) and at other sites throughout the United States (McLeod et al. 2007, Burkhard et al. 2013) limit the confidence in these predictions.

The primary goals of Objective 4 were: 1) to evaluate the current bioaccumulation potential of Harbor sediments; and 2) to determine BSAFs that can be used to improve estimates of PCB and PCDD/F accumulation in *A. virens* laboratory tests using CARP II projected future sediment contamination levels, and 3) to evaluate the effects of total organic carbon, black carbon, lipid content, and PCB and PCDD/F chemical structure on BSAFs.

I. Methods

For the first goal, 28-day bioaccumulation test results were conducted for total PCBs, 2,3,7,8-TCDD, and total Toxic Equivalents (TEQs) and compared to dredged material bioaccumulation guidelines for HARS placement (113 ppb for total PCBs, 1 ppt for 2,3,7,8-TCDD and 4.5 ppt for total TEQs).

Paired tissue wet weight and sediment dry weight concentrations from the 28-day bioaccumulation tests were used to determine the BSAFs for each of the 68 sediment samples. The median (50th percentile) and 90th percentile BSAF values were calculated from these data and compared to BSAFs previously developed from dredged material testing data (Table 2-6 in Appendix A-8) for select PCB homologs and for 2,3,7,8-TCDD. The application of these BSAFs for future projection scenarios is described below in Chapter 5 and in Appendix A-8.

In addition, to evaluate the effects of total organic carbon, black carbon, lipid content, and PCB and PCDD/F chemical structure on BSAFs, a more detailed evaluation of sediment-water partition coefficients (K_p's) and 28-day organism-water partition coefficients (BAFs) was performed using the 20 sediment samples with porewater measurements. These results were used in developing congener-specific BSAFs to better understand the effects of organic carbon, black carbon and congener structure on the chemical accumulation in the test organisms.

II. *28-day Bioaccumulation Test Results*

CARP II bioaccumulation test results for *A. virens* for PCBs and 2,3,7,8-TCDD TEQs are shown in Figure 3. Current dredged material management guidelines for HARS disposal are represented by the red and blue dashed lines. As shown in the top portion of Figure 3, bioaccumulation test results in four of the 68 sediment samples exceeded the Total PCB dredged material management guideline of 113 ppb. Of note, the four sediment samples with bioaccumulation test results that exceeded the 113 ppb guideline were collected outside the navigation channel (outside Port Jersey, Buttermilk and Port Newark channels). Steady-state bioaccumulation results for sediments within the navigation channel were typically one third to one half of the 113 ppb guideline.

Bioaccumulation test results for all Port Newark Channel (PNC) sediment samples, including both in-channel and off-channel samples, exceeded the 1 ppt guideline for 2,3,7,8-TCDD as shown in the bottom portion of Figure 3. In addition, bioaccumulation in navigation channel and off-channel areas of Elizabeth Channel (EC) exceeded or were close to exceeding the 2,3,7,8-TCDD guideline (1 ppt).

Bioaccumulation from one sample outside Port Newark Channel (PNC-OC-1-L) exceeded the total TEQ guideline of 4.5 ppt. TEQs of the bioaccumulation test results for the CARP II samples are dominated by 2,3,7,8-TCDD, followed by 1,2,3,7,8-PeCDD, 2,3,7,8-TCDF, 2,3,4,7,8-PeCDF and dioxin-like PCBs.

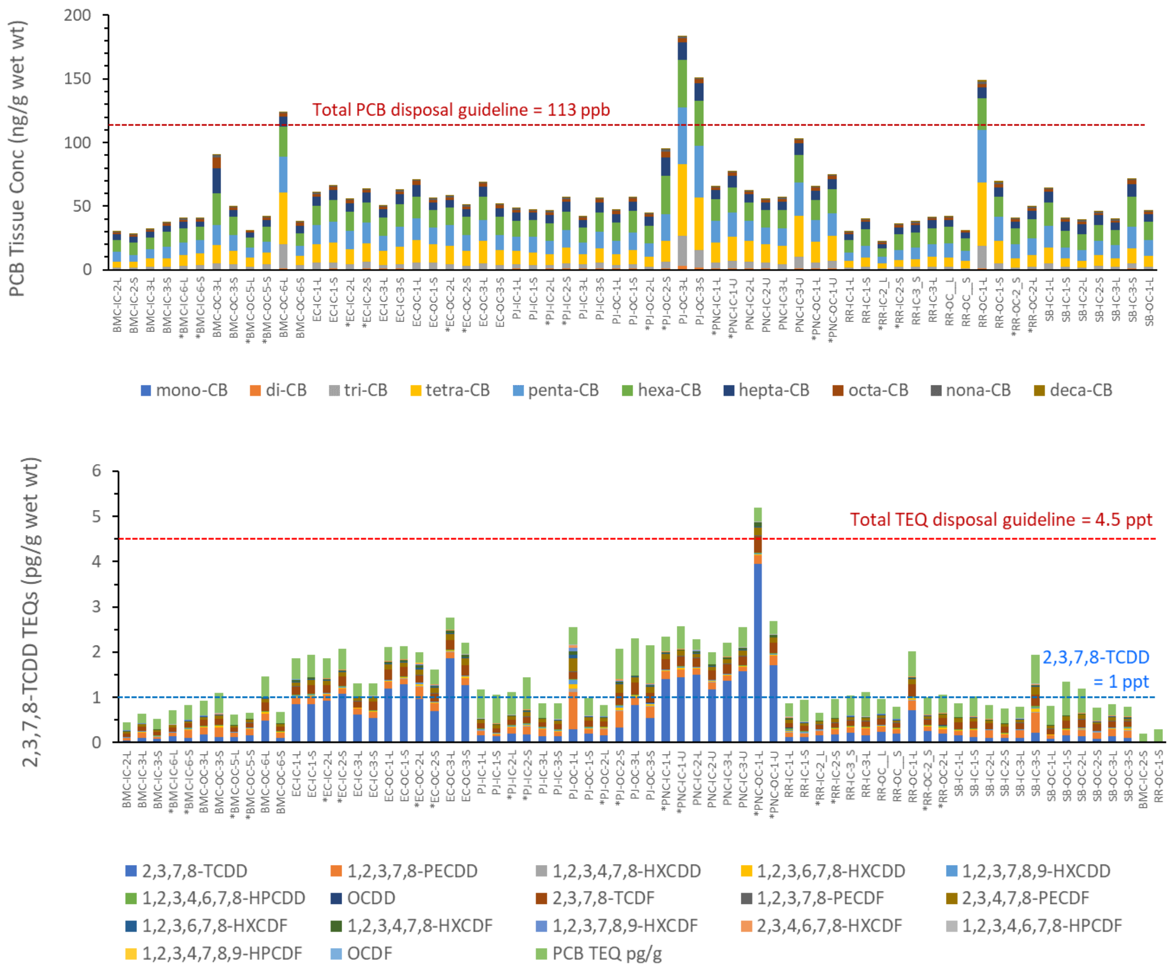

Figure 3 CARP II estimates of tissue concentrations in *A. virens* for PCB homologs (top) and 2,3,7,8-TCDD Toxic Equivalents (TEQ; bottom) from 28-day bioaccumulation testing. Current dredged material management guidelines for HARS disposal are also represented by the red and blue dashed lines on the figure.

III. *CARP II Biota-Sediment Accumulation Factors (BSAFs)*

Median and 90th percentile BSAF values are presented in Table 2 for select PCB homologs and 2,3,7,8-TCDD. As shown, the BSAFs previously derived from dredged material testing data are roughly an order of magnitude higher than the 90th percentile value for di-CB, more than a factor of two higher than the 90th percentile value for tetra-CB, and within a factor of two of the 90th percentile values for hexa-CB, octa-CB and 2,3,7,8-TCDD. These results underscore the fact that BSAFs cannot be accurately represented by a single number, likely attributed to variation in sediment and organism properties. The range of BSAFs now available with varying degrees of conservatism will have utility for different aspects of dredged material management such as strategically deciding when or where to conduct testing.

Table 2 Median and 90th percentile BSAFs from CARP II bioaccumulation tests compared to BSAFs previously derived from NY/NJ Harbor dredged material testing data for select PCB homologs and 2,3,7,8-TCDD.

	Median BSAFs	90th Percentile BSAFs	Previously derived BSAFs
di-CB	0.0091	0.0182	0.243
tetra-CB	0.064	0.126	0.300
hexa-CB	0.189	0.397	0.496
octa-CB	0.144	0.332	0.216
2,3,7,8-TCDD	0.036	0.067	0.052

IV. Refined Method for BSAF Evaluations

Additional more detailed evaluations of bioaccumulation were performed by separately considering sediment-water partitioning (K_p's) and organism-water partitioning (BAFs). Relationships were developed using PCB congener data for the 20 sediment samples with porewater measurements. For PCBs, results showed that sediment-water partition coefficient (K_p) was a function of the sediment organic carbon content[4], black carbon content, the octanol-water partition coefficient (K_{ow}) and the number of ortho-substituted chlorines[5]. Results for the organism-water partition coefficient (BAF) were simply a function of the lipid content of the organism and the octanol-water partition coefficient (K_{ow}).

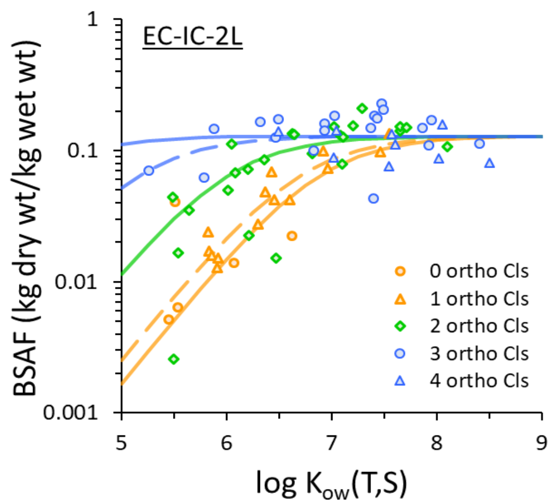

Figure 4 BSAF model fit for sediment sample EC-IC-2-L from Elizabeth Channel based on the global BSAF relationship.

Since the BSAF can be expressed in terms of the organism-water partition coefficient (BAF) divided by the sediment-water partition coefficient (K_p), a global BSAF relationship for PCBs was developed from the BAF and K_p relationships described above[6]. Typical results are shown in Figure 4 for a sediment sample from the Elizabeth Channel. For log K_{ow} < 7, lower BSAFs for PCBs with '0' ortho-substituted chlorines

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[4] The amorphous organic carbon content (f_{aoc}) is calculated from the measurements of the total organic carbon content (f_{TOC}) minus the black carbon content (f_{BC}).

[5] The number of ortho-substituted chlorines affects the dihedral angle (which is the angle between the benzene rings in the PCB molecular). Note: a perfectly planar congener would have a dihedral angle equal to "0".

[6] The global BSAF relationship for PCBs is given as: $BSAF = \frac{BAF}{K_p} = \frac{\beta_2 f_{lipid} K_{ow}}{\beta_1 f_{aoc} K_{ow} + a_1 f_{BC}(90° - dihedral\ angle)}$ where the coefficients are given as: β_2=0.284, β_1 = 1.04 and $a_1 = 1.57 \times 10^6$.

are attributed to the strong binding of the '0' ortho-substituted PCBs to black carbon. As the number of ortho-substituted chlorines increase, the BSAF values are shown to increase accordingly. For log $K_{ow} > 7$, the five model lines merge indicating binding of PCBs to sediments is expected to become more dependent on partitioning to amorphous organic matter (f_{aoc}) as log K_{ow} increases. Based on these detailed evaluation results, the relatively lower CARP II median and ninetieth percentile BSAFs for di-CB and tetra-CB presented in Sections II and III above were likely associated with the presence of black carbon in the Harbor sediments used for 28-day bioaccumulation testing during CARP II.

Direct application of the PCB BSAF relationship to PCDD/Fs showed that the observed BSAFs for 2,3,7,8-TCDD and the other tetra- and penta-CDD/Fs are generally within a factor of two (of the PCB-derived relationship. Additional factors (not included in the PCB BSAF relationship) would need to be considered in describing the observed BSAFs for the more chlorinated PCDD/F congeners. However, based on results in the bottom portion of Figure 3, the more chlorinated PCDD/F congeners are not expected to affect dredged material management decisions.

References: Appendix A-3. CARP II Sediment Bioaccumulation Estimates and Prediction of HARS Suitability
Appendix A-8 CARP II Model Future Projections Report

Objective 5: Evaluate methods for predicting HARS suitability:

The primary goal of this objective was to develop and test methods to provide a rapid and reliable indication of the bioaccumulation potential of contaminants in dredged sediments. The team wanted to identify a quicker, simpler (and less expensive) approach that would allow investigators to screen sediment for the likelihood of being able to pass the HARS criteria. Under this task, the Lohmann Lab at the University of Rhode Island tested the use of thinner low-density polyethylene (LDPE) passive samplers (7, 14 or 25µm) to speed up equilibration for a much quicker (on the time scale of several days to a week) sample testing approach. The studies were conducted for both polychlorinated biphenyls (PCBs) and polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs).

I. Methods:

In contrast to the traditional geochemical approaches, where porewater concentrations are predicted indirectly, passive sampling techniques can directly measure the freely dissolved concentrations of hydrophobic organic contaminants (bioavailable fraction). Porewater concentrations were determined by a passive sampling equilibrium experiment performed under controlled laboratory conditions, while the standard (regulatory) 28-day bioaccumulation test was used to derive lipid-based concentrations in sedimentary biota. Using the CARP II data for PCBs and PCDD/Fs in both porewater and in sediment dwelling biota, new partitioning coefficients were derived (see Objective 4) and applied. The newly derived partitioning coefficients between passive samplers and sediment biota lipid concentrations were used to improve the performance of the bioaccumulation prediction model by reducing the relative mean standard error (RMSE) of the biota concentration values estimated by the measured porewater concentration.

II. Application of rapid testing method

The passive sampling technique developed here successfully demonstrated the potential for a quick and reliable screening tool for bioaccumulation potential of contaminants in dredged sediments. The empirical data, collected under CARP II, was utilized to derive partitioning correlations between passive samplers and sediment biota lipid concentrations of target contaminants. These newly derived relations were used to demonstrate the capability of the LDPE sampler to successfully predict the concentrations of the pollutants in biota.

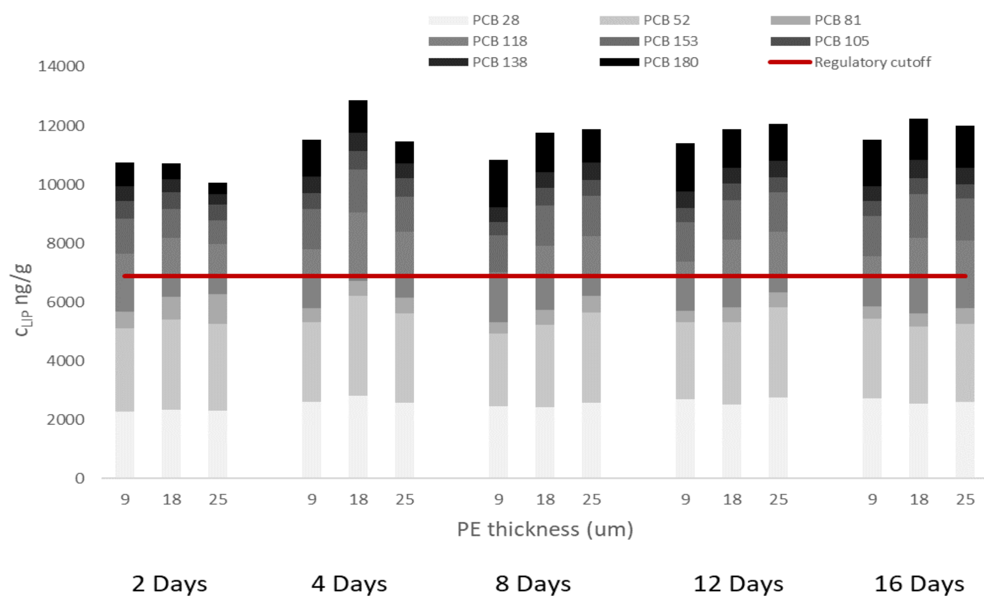

Figure 5 Comparison of sum of measured PCBs from the Hackensack River converted to concentrations

The screening process was tested in a time-sensitive laboratory equilibration experiment, which showed that after only two days, most PCB congeners already reached equilibrium. Thus, for screening purposes a laboratory incubation period of the sediment with a polyethylene passive sampler of 18 or 25µm thickness for 2-4 days is sufficient. The LDPE concentration obtained can be compared to the US EPA regulatory cutoff criterion to predict how the sediment might fare under the full 28-day test. This technique could also be used to monitor Harbor sediments for progress on bioaccumulation without the time and expense of the full testing protocol.

In the case of the Hackensack River sediments shown on Figure 5, for all LDPE sheets and all deployment lengths, total PCBs are above the regulatory cut-off, and there is no observed benefit to deploying the LDPE sheets beyond 4 days. In this hypothetical example, we would suggest not undertaking the time and expense of the full 28-day bioaccumulation test, emphasizing that the sediment would be unlikely to pass the HARS criteria for ocean placement.

Reference: **Appendix A-4. CARP II Rapid Assessment of Dredged Material Quality**

Chapter 4 Refinement and Application of CARP Sub-Models

Objective 6: Evaluate, update and refine the CARP I sub-models

As part of CARP I, a detailed numerical model was developed to evaluate the effects of external loads and in-place sediments on future contaminant concentrations in water, sediment, and biota in NY-NJ Harbor (HydroQual 2007a, b, and 2008). The CARP I model captured the vast complexities of NY-NJ Harbor based on detailed descriptions of hydrodynamics, sediment transport, organic carbon production, contaminant fate processes and bioaccumulation dynamics. Inputs to the model included multiple tributaries, sewage treatment plants, combined sewer overflows, stormwater outflows, atmospheric deposition, and the ocean boundary as well as contamination of in-place sediments.

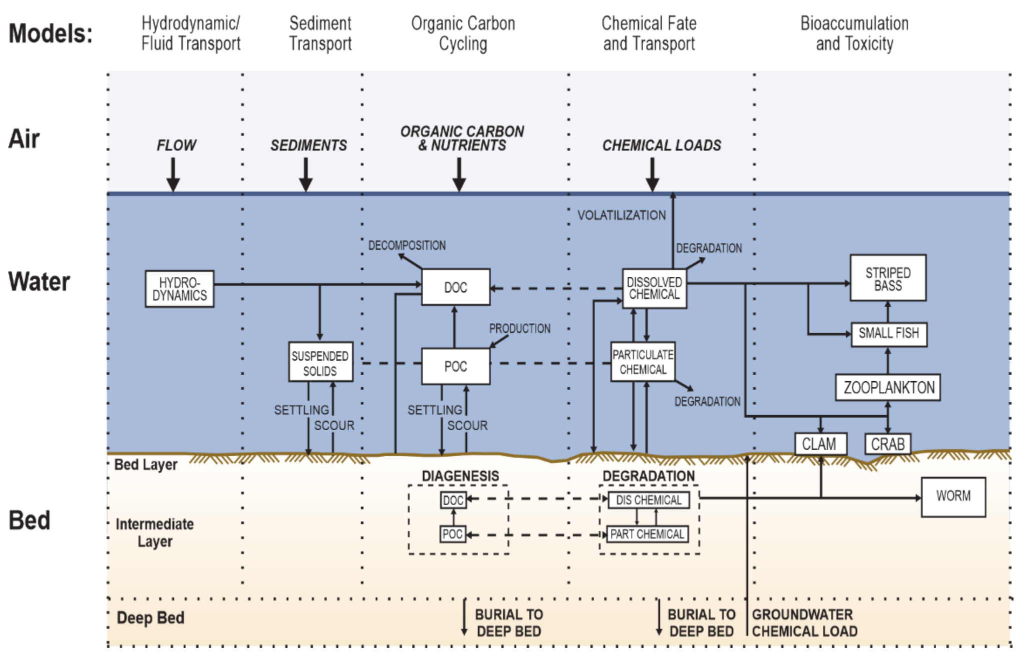

Figure 6 Illustration of the relationship between the various CARP numerical models as well as the various media considered (i.e., air, water, sediment, and biota).

Under CARP II, the CARP I model was further refined to incorporate greater spatial resolution and updated forcing functions. The latter included several extreme flow events that were not a part of the original CARP I model calibration. Performance testing of the refined CARP II model was carried out over a longer 18-year period (1998 – 2016). This longer time horizon was particularly important in testing the temporal predictive capability of the CARP model. Features of the CARP numerical models are described in the section below with emphasis on refinements completed during CARP II.

I. CARP II Numerical Modeling Features

The CARP I model was developed as a series of linked mechanistic sub-models describing fully time-variable and three-dimensional hydrodynamics, sediment transport – organic carbon production, contaminant fate, and bioaccumulation (Figure 6). The models constructed for CARP were developed around a spatial domain covering the entire Hudson/Raritan Estuary as well as Long Island Sound and the New York Bight. The contaminant classes considered for CARP I modeling include PCBs, 2,3,7,8-chlorine substituted PCDD/Fs, organochlorine pesticides related to DDT and chlordane, PAHs, and the metals cadmium, mercury, and methylmercury. Based on CARP I results which showed the importance of PCBs and PCDD/Fs on dredged material disposal options, CARP II evaluations focused on only these chemicals.

II. CARP II Hydrodynamic Transport Modeling

Hydrodynamic transport modeling for CARP initially involved applying a previously calibrated and validated hydrodynamic transport model, the System Wide Eutrophication Model (SWEM) (Landeck Miller and St. John, 2006), for the CARP 1998-2002 data collection period. The model is driven by measured water levels at the open ocean boundary, meteorological forcings, spatially and temporally varying surface heat fluxes and freshwater fluxes from the numerous rivers, wastewater treatment

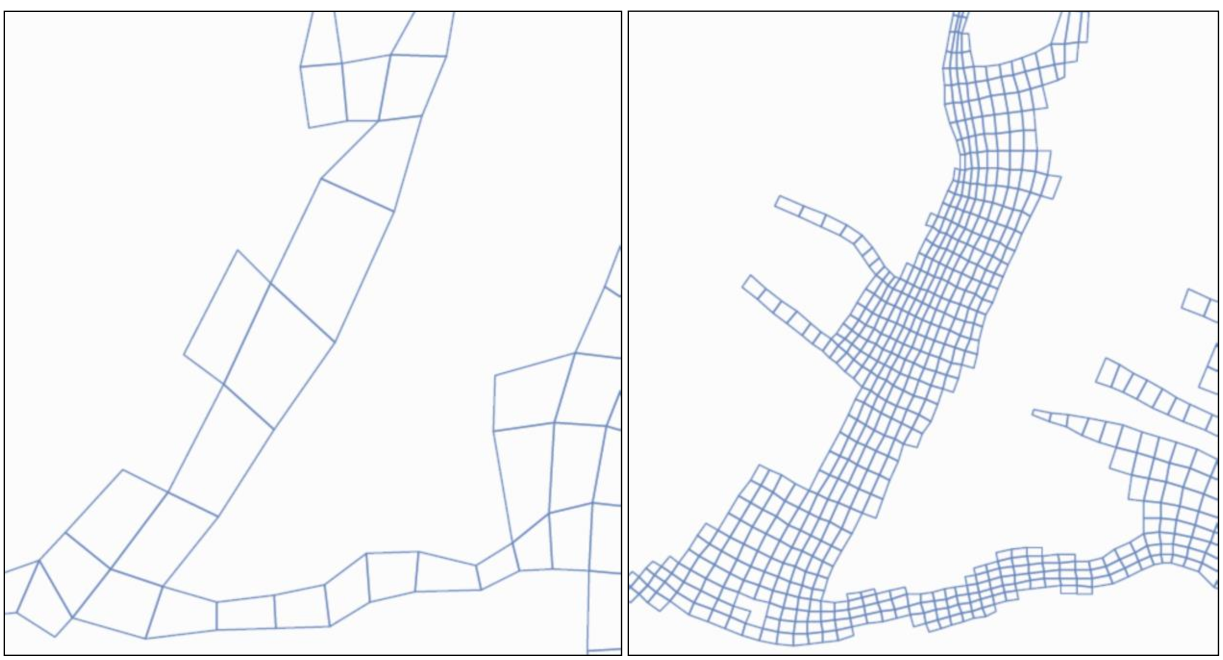

Figure 7 Newark Bay and the Kill van Kull, including a portion of Upper NY Bay, view of CARP I 49 x 84 (left) and CARP II I27 x 205 (right) model computational grids.

plants, combined sewer overflows, runoff from the land, and landfills that enter the NY/NJ Harbor Estuary, Long Island Sound, and the New York Bight. The hydrodynamic model solves a coupled system of differential, prognostic equations describing conservation of mass, momentum, heat, and salt. Skill assessments of the performance of the hydrodynamic model under 1998-2002 conditions were made using data collected during CARP I as well as data collected by other agencies in ongoing, routine monitoring programs.

Under CARP II, the CARP model computational grid was greatly expanded from 49 x 84 computational elements to a 127 x 205 computational grid to provide greater spatial resolution and coverage. For example, the Port Elizabeth and Port Newark Channels, which were not resolved in the CARP I model computational grid, are included in the CARP II model computational grid (Figure 7). In addition to increased model computational grid resolution, the CARP II hydrodynamic modeling considered an expanded range of modeled calibration conditions including numerous severe storm and hurricane events occurring between 1998 and 2016. CARP II hydrodynamic modeling also employed time-varying bathymetry representing several Harbor deepening milestones; an improved method for estimation of ungauged tributary and watershed inflows; and updates to inflow water temperatures, bottom friction, open boundary elevations, wind stress, and heat flux calculations.

Detailed information on the development, update, and application of the CARP hydrodynamic model is included in appendices below and in the CARP I (HydroQual, 2007a) report.

References: Appendix A-5. CARP II Loadings Report
Appendix A-6. CARP II Models Update Report

III. CARP II Sediment Transport and Organic Carbon Production Modeling

The CARP I sediment transport/organic carbon production model was one of the first attempts to apply a sediment transport model to a domain as large and complex as the NY/NJ Harbor - Bight - Sound system. The CARP II updates to sediment transport and organic carbon production model began with refined estimates of suspended sediment, organic carbon, and nutrient loadings associated with inputs of non-saline water into the model. These included tributary heads-of-tide, overland runoff and associated stormwater and combined sewer discharges, outflows from the Meadowlands, and the effluents from water resource recovery facilities and landfill leachates for the 1998 to 2016 period.

The other modifications to the sediment transport and organic carbon production model were related to the increased model grid resolution. The spatially varying sediment transport and organic carbon production model settling and coagulation functions which are dependent on variations in salinity and fluid shearing rates, independent of model grid resolution, were not updated. However, several model parameters and constants controlling resuspension were modified during model recalibration. These included initial bed thickness, water column vertical mixing rates, biological mixing rates in the sediment bed, and base light extinction in the marsh areas along the Hackensack River.

Detailed information on the development, update, and application of the CARP sediment transport/organic carbon production model is included in appendices below and in the CARP I report (HydroQual, 2007b).

References: Appendix A-5. CARP II Loadings Report
Appendix A-6. CARP II Models Update Report

IV. CARP II Contaminant Fate and Transport and Bioaccumulation Modeling

The CARP contaminant fate and transport and bioaccumulation models originate from a simpler mathematical model of the long-term behavior of PCBs in the Hudson River Estuary (Thomann et al., 1989) and an integrated model of organic chemical fate and bioaccumulation in the Hudson River Estuary (Farley et al., 1999; 2006), collectively called the Thomann-Farley model. CARP contaminant fate and transport model kinetics, collectively referred to as RCATOX, include separate routines for hydrophobic organic, divalent metal and methylmercury contaminant groups. CARP bioaccumulation model kinetics within RCATOX include calculations of both Biota Accumulation Factors (BAFs) and Biota Sediment Accumulation Factors (BSAFs) from site-specific data as well as more detailed steady-state and time variable mechanistic equations which help explain the behavior of observed BAFs and BSAFs at several pelagic and benthic trophic levels.

The CARP II update of the CARP I contaminant fate and transport model began with updates to PCB homolog and PCDD/F loadings associated with inputs of non-saline water into the model. The updated sources are described below (Section V). CARP II updates specific to the contaminant fate and transport model include initial bed contaminant concentrations and a revised phase partitioning coefficient for di-PCB. The calibration update method included a model validation check (robustness challenge) in which the calibrated models were applied for six additional PCB homologs and fifteen PCDD/F congeners without adjustments to methods or the information passed forward from the hydrodynamic transport and sediment transport and organic carbon production models. Additional calibration, validation, and projection skill assessments for the CARP II contaminant fate and transport model involved measurements from numerous programs for PCB and PCDD/F collected between October 1998 and September 2022, over twenty-four water years[7]. The critical measurement programs include those compiled for the post-audit evaluations, compilations from contemporary maintenance dredging projects and from the new CARP II sampling.

Detailed information on the development, update, and application of the CARP contaminant fate and transport models are included in appendices below and in the CARP I report (HydroQual, 2008). CARP II BSAFs are presented above in Chapter 3 and the CARP I bioaccumulation modeling is described in HydroQual, 2008.

References: Appendix A-5. CARP II Loadings Report
Appendix A-6. CARP II Models Update Report

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[7] A water year refers to the period between October 1 and September 30.

V. CARP II "Current" (Year 2022) Contaminant Conditions

For CARP I, contaminant conditions were established based on the CARP I 1998-2002 sampling effort which produced an extensive dataset characterizing levels of contaminants in sediment, water, biota, and external loading sources throughout the Estuary. This was the first time that all the major sources of contaminants of concern to the NY/NJ Harbor Estuary were comprehensively identified and quantified. These data, along with the CARP I models, provided the basis for determining the relative importance of the various external sources and the role of the continuing inputs and legacy contamination stored in bed sediments for multiple hydrophobic organic and metal contaminants.

For CARP II, contaminant loading conditions were updated through water year 2022. The CARP II data compilation (Objective 1) and 2019-2022 CARP II focused field collection and laboratory analysis program (Objectives 2-3) expanded the contaminant loading concentration data set for PCBs and PCDD/Fs from 1998-2002 to 1998-2016. The expanded data set for contaminant loading concentrations along with improved loading estimation methods provided the necessary information for specifying the contemporary contaminant loading conditions.

Representative examples of sediment loading estimates developed during CARP II are displayed in Figure 8. For head-of-tide loads, higher sediment loads (and the associated contaminant loads) were delivered to the Estuary during wet (i.e., high loading) years. The years with high suspended sediment and contaminant loadings occurred after the conclusion of CARP I, especially in the 2010-11 water year. The summation of CARP II annual total PCB and PCDD loading estimates from head-of-tide showed large annual variations, ranging from 137 to 717 kg/year for total PCB and from 0.673 to 2.57 g/year for 2,3,7,8-TCDD.

For comparison, the summation of CARP II annual total PCB and PCDD loading estimates for stormwater, combined sewer overflow, treated effluents from wastewater treatment plants, and landfill leachate are

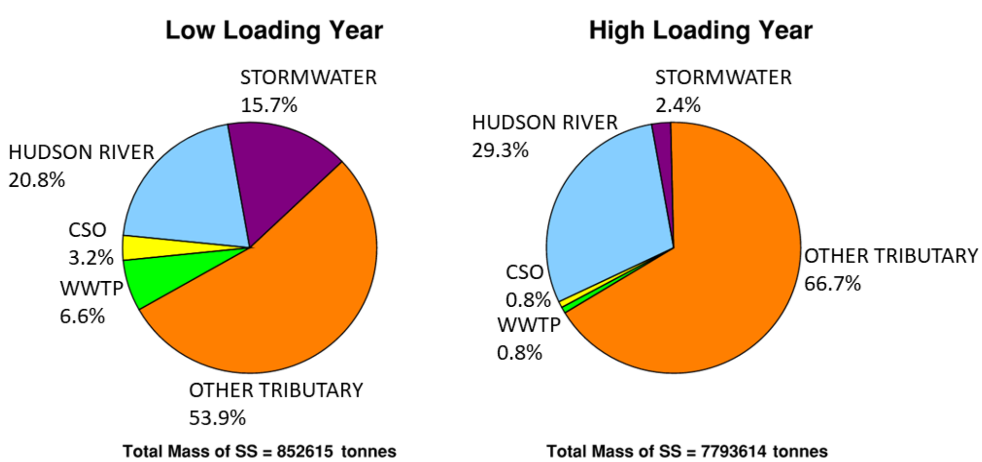


Figure 8 Variation in source distribution of non-atmospheric external loadings of sediment for 1998-2016

relatively consistent across the eighteen water years (1998-2016) ranging from 193 to 296 kg/year for total PCB and 8.0×10^{-4} to 1.5×10^{-3} kg/year for 2,3,7,8-TCDD.

Detailed information on the CARP loadings development and resultant external contaminant loading estimates is included in Appendix A-5; in the CARP I Contaminant Fate and Transport and Bioaccumulation Sub-models, Final Report (HydroQual, 2008); in Appendix A-7 of Lodge et al., 2015; and in CARP I external loading source pie chart diagrams in Appendix A-8 of Lodge et al., 2015.

Reference: Appendix A-5. CARP II Loadings Report

Chapter 5 CARP II Modeling Results

Overall, the development and calibrations of hydrodynamic and sediment transport/organic carbon production sub-models in the study area were sufficiently detailed, and the controlling processes were effectively modeled, to successfully force the contaminant fate and transport model. The eighteen water-years of CARP II model calibrations for the PCB homologs and PCDD/F congeners demonstrate that source, sink, transport, and transformation terms are satisfactorily represented. Calibration and projection simulation skill assessments for PCB homologs and PCDD/F congeners further indicate that the model has the time dynamic correct for exchange processes between the water column and sediment bed, a critical requirement for projecting future conditions. Specific CARP II model results are described in the sections below.

I. CARP I Model Post Audit

CARP I modeling work culminated with evaluations of future scenarios of the expected contaminant levels in the Harbor for more than three-decades after 2002. Scenarios were conducted with and without the implementation of the Upper Hudson River and Lower Passaic River remediation projects. The outcomes of these evaluations are highly dependent on the time behavior of the model. A post-audit evaluation of these future scenarios was undertaken to assess the reliability of the CARP I model time responses for Harbor water and sediment concentrations (i.e., the biota exposure concentrations necessary for HARS disposal determinations) for 2002 to 2016. Specifically, the reliability of the CARP I model was tested by comparing actual field measurements from 2002 to 2016 to the original CARP I model projections developed in 2002.

The CARP II post-audit measurements indicate a high degree of variability in organic carbon-normalized PCB and PCDD/F concentrations in the sediment bed within the spatial resolution of a CARP I model grid cell. Some, but not all, of the observed variability in field measurements is likely caused by variations across sampling programs such as differences in sample collection, handling, and processing and uncertainties in analytical chemistry laboratory results associated with differences in the analytical methods applied and laboratory-specific performance.

Despite the variation in the measurements, the observed regional spatial gradients (central tendency) of organic carbon normalized PCB and PCDD/F concentrations in the sediment bed are consistent with known loading sources. Higher PCB concentrations observed in the sediment bed of southern Newark Bay and broader Harbor areas (compared to the lower PCB concentrations observed in northern Newark Bay and the Lower Passaic River) are consistent with the known Upper Hudson River PCB source. Similarly, the decline in measured 2,3,7,8-TCDD concentrations moving away from the Lower Passaic River is consistent with the known source of 2,3,7,8-TCDD on the Lower Passaic River. The post-audit measurements were also suggestive of declining contaminant levels over time; however, the variability in coincident measurements confounded the ability to draw definitive conclusions regarding the rates of measured contaminant-specific and location-specific declines. Under the CARP II modeling effort, the observed variability in field measurements compiled for the post-audit was mitigated in part by evaluating sediment bed measurements at the higher spatial resolution of CARP II model grid cells (as compared to CARP I model grid cells used for the post-audit) and by incorporating additional measurements for later years from contemporary navigational dredging projects and CARP II monitoring to better define the temporal trends.

During the post-audit the in-channel and off-channel measurements were considered separately. For most locations, there is a high degree of overlap between the two types of measurements. This suggests that there is not a clear line of evidence necessitating that the CARP model computational grid should include segmentation to separately resolve navigation channel and off-channel locations. Conceptually, similarities and differences observed for measured contaminant concentrations for proximal in-channel and off-channel sediment bed locations should be related to the timing of dredging activity within the Harbor area. It would be expected that measured in-channel and off channel sediment bed contaminant concentrations are more similar for areas of the Harbor not recently subject to maintenance dredging, such as the Lower Passaic River, as compared to areas with active maintenance dredging, such as Newark Bay. Additional discussion of in-channel and off-channel sediment bed contaminant concentration measurements is provided in Appendix A-2.

Overall, statistical evaluation of the post-audit model showed model results to be within factors of two and three of the field measurements. These results are not dissimilar from the original calibration display metrics accepted by the Model Evaluation Group for the CARP I model calibration (HydroQual, 2008. The CARP I model calibration display metrics were factors of two, three, five, and ten based on 10-day averaged model results at the resolution of a model grid cell and spatially and temporally discrete measurements.

The post-audit evaluation of CARP I results also assessed if the measurements compiled in 2019 for the post-audit evaluation contradicted conclusions concerning HARS suitability reached based on CARP I 2002 measurements and model results. Post-audit measurements of 2,3,7,8-TCDD and PCB concentrations were screened against the CARP I HARS suitability endpoints. In the case of PCB's, the post-audit measurements support the previous conclusions reached under CARP I that bed sediments in the Hackensack, portions of the Lower Passaic, Newark Bay, Kills and much of the broader Harbor would not be HARS suitable in 2019. This comparison provides an additional line of evidence regarding the reliability of CARP I model projections. In the case of 2,3,7,8-TCDD, some of the post-audit measurements, mostly in off-channel areas of the Arthur Kill and Kill van Kull, were found to be above HARS suitability criteria, which is contrary to CARP I model predictions which suggested attainment in these waterways. This finding underscored the need for CARP II modeling to address model grid representation of the Kills and other areas and the use of actual rather than estimated meteorological conditions and hydrographs for all loading sources.

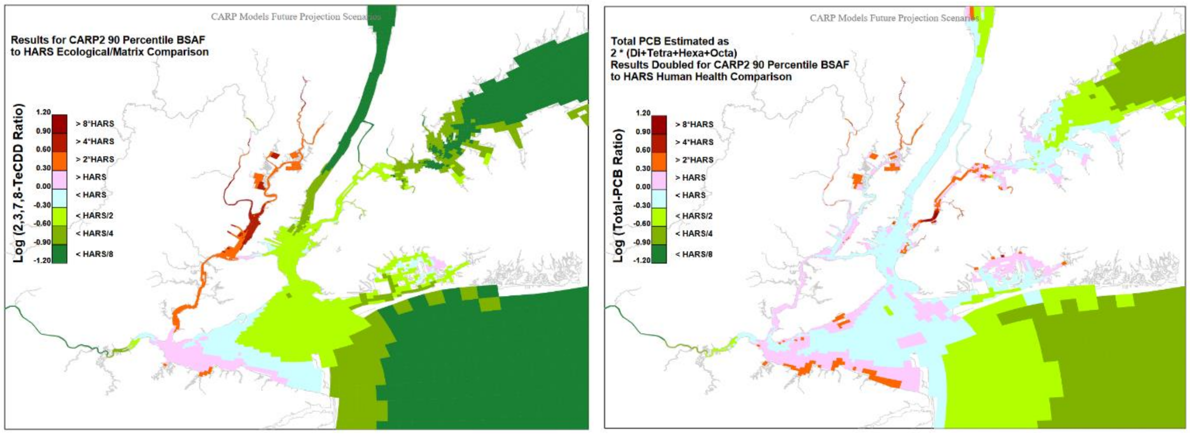
In summary, while the post-audit evaluation demonstrated that CARP I model projections of contaminant concentrations in Harbor water and bed sediments are still largely valid, there is a wide range of variability in the measurements. This motivated CARP II work to modify the modeling approach and further consider measurements from contemporary maintenance dredging projects.

Reference: Appendix A-7. CARP II Post-Audit Report

II. CARP II Model Future Scenarios Evaluation

The CARP I loadings component analysis results emphasized that legacy sediment contamination is a major factor controlling levels of PCB and PCDD/F contamination in the Harbor. Multiple sediment remediation projects in the Estuary are currently being studied or were completed after CARP I. Several of the largest projects including those in the Upper Hudson River, Lower Passaic River, Newark Bay, and Lower Hackensack River were modeled as part of the CARP II future scenarios evaluation.

The CARP I model scenarios were intended to demonstrate the potential for the remediation projects at these sites to influence future water and sediment quality in the Harbor. Of particular interest is the status of Harbor sediment quality relative to the tissue-based numeric criteria used to determine suitability of dredged material for use at the HARS and whether sediment quality improves throughout the Harbor. The CARP II scenarios evaluated the effect of the removal (such as though remedial dredging, capping, upland remediation, etc.) of sediments from these sites on the suitability of future sediments throughout the Harbor for potential placement at the HARS following maintenance dredging in the future. During CARP II, two modeling scenarios were completed for estimating future sediment bed concentrations of PCBs and 2,3,7,8-TCDD. Scenario Projection 1 evaluated the expected benefits of implementing two Lower Passaic River ROD Superfund projects and Scenario Projection 2 evaluated the additional benefits of a hypothetical full remediation of the Lower Hackensack River and Newark Bay complex. Both scenarios began in water year 2016-17, the end of the CARP II model calibration period, and continued through the 2038-39 water year to yield conditions for year 2040 planning. The model calibration period reflected conditions before the onset and during remedial dredging operations conducted on the Upper Hudson River. The post-dredging remediated condition for the Upper Hudson River was included in the final year of the model calibration period and for the entirety of both CARP II



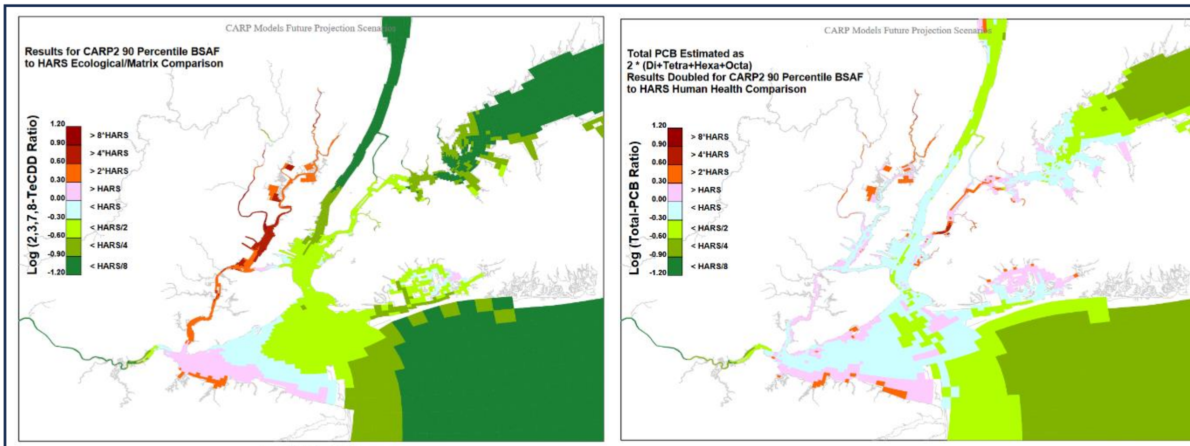
A. 2,3,7,8-TCDD 2022 Conditions

B. Total PCB Modeled 2022 Conditions

Figure 9 Projected Current (2022-2023) Conditions - ratio of sediment 2,3,7,8-TCDD (A) and Total PCB (B) to the criterion for placement at HARS.

future projection scenarios. Implementation of two Lower Passaic River remediation projects were modeled as being completed in the 2030-31 water year in both future projection scenarios. While additional remedial projects in Newark Bay and Hackensack River have yet to be established, idealized full remediations (i.e., remediation to zero residual, bank-to bank) of the study areas were modeled as being completed in the 2030-31 water year and were included only in the second CARP II future-projection scenario.

Figure 9 shows the modeled current (2022) levels of 2,3,7,8-TCDD and Total PCB in sediments. The expected levels of contamination are shown as multiples of the HARS guidelines with a red/pink (i.e., fail HARS criteria) and green/blue (i.e., pass, suitable for placement at the HARS) color scale. The intensity of the color illustrates the magnitude of passing or failing the HARS guidelines. Model results in Figure 9A show that sediments in the Lower Passaic, the Hackensack, Newark Bay, Arthur Kill, and the southern portion of Raritan Bay, are all in exceedance of HARS criteria for 2,3,7,8-TCDD. Model results shown in Figure 9B show some exceedances for Total PCB in those areas and in the East River and portions of Jamaica Bay.



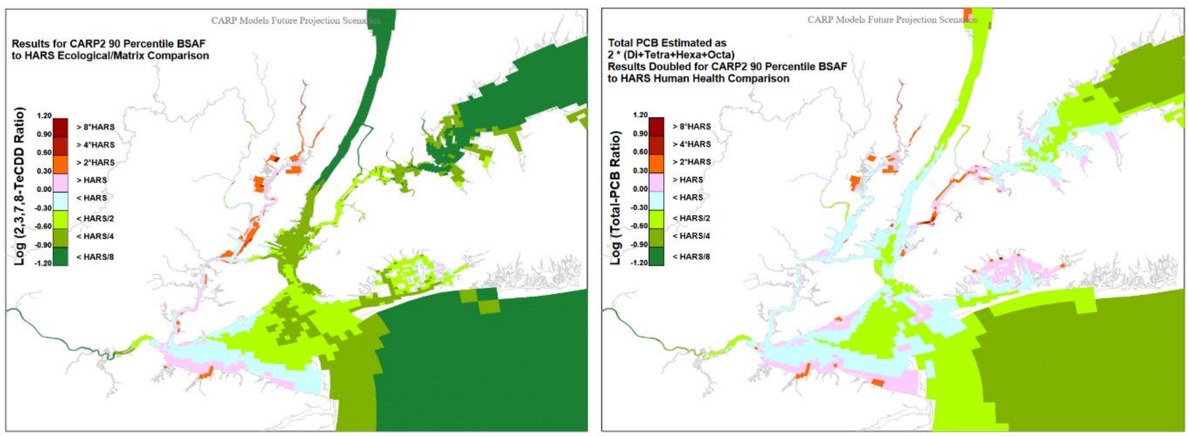
A. 2,3,7,8-TCDD 2030 Projection

B. Total PCB 2030 Projection

Figure 10 Projected Future (Year 2030) Conditions - ratio of sediment 2,3,7,8-TCDD (A) and Total PCB (B) to the criterion for placement at HARS.

Figure 10 shows the modeled levels of 2,3,7,8-TCDD and Total PCB in sediments for the year 2030. The 2030 projections forecast continued exceedances of the HARS criteria for both 2,3,7,8-TCDD (Figure 10A) and Total PCBs (Figure 10B) for much of the Harbor area.

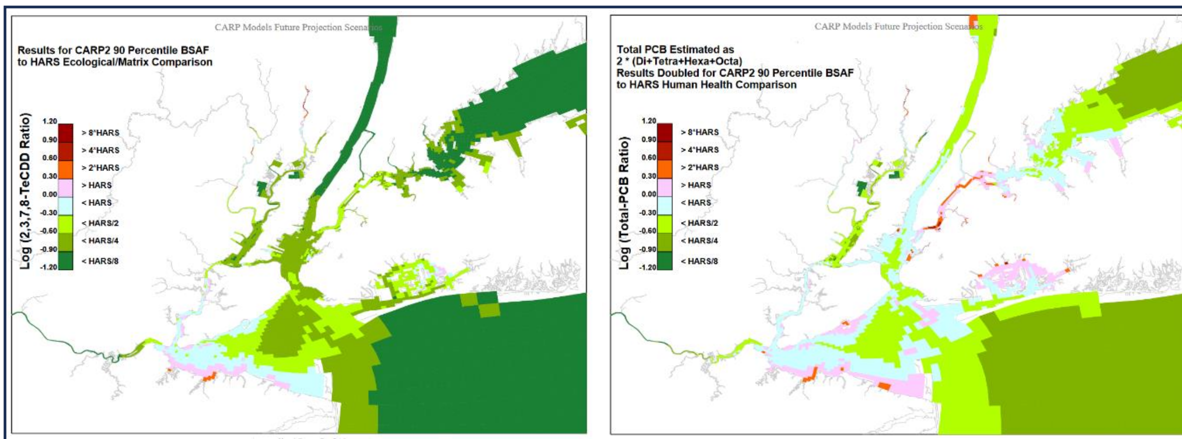
Figure 11 shows the modeled results for Scenario Projection 1 for the year 2040. Results in Figure 11A show even after the implementation of the two Superfund Records of Decision (RODs) for the Lower Passaic River in 2030, non-attainment of HARS suitability for 2,3,7,8-TCDD (Figure 11A) in the Lower Hackensack River and Newark Bay and for total PCBs (Figure 11B) in the Hackensack River, East River, and isolated shoreline locations within Jamaica Bay and Raritan Bay.



A. 2,3,7,8-TCDD 2040 Projection Scenario 1 B. Total PCB 2040 Projection Scenario 1

Figure 11 Projected Future (Year 2040) Condition with Lower Passaic River Superfund RODs Completed by October 1, 2030 (Projection Scenario 1) - ratio of sediment 2,3,7,8-TCDD (A) and Total PCB (B) to the criterion for placement at HARS**.**

Figure 12 shows the modeled results for Scenario Projection 2 for the year 2040. Results in Figure 12A show the expected benefit of the implementation of the two Superfund Records of Decision (RODs) for the Lower Passaic River and full remediation of the Lower Hackensack River and Newark Bay. Under this idealized scenario HARS suitable sediments in Newark Bay (and in most of the Harbor) for 2,3,7,8-TCDD



A. 2,3,7,8-TCDD 2040 Projection Scenario 2 B. Total PCB 2040 Projection Scenario 2

Figure 12 Projected Future (Year 2040) Conditions with Lower Passaic River Superfund RODs and Full Remediation of the Lower Hackensack River and Newark Bay Completed by October 1, 2030 (Projection Scenario 2) - ratio of sediment 2,3,7,8-TCDD (A) and Total PCB (B) to the criterion for placement at HARS.

are expected in the year 2040. However, non-attainment of HARS suitability for total PCBs (Figure 12B) is expected to persist in the East River and isolated shoreline locations within Jamaica Bay and Raritan Bay based on model results which suggest limited deposition of cleaner solids and burial of legacy contamination for those locations.

The HARS suitability determinations presented herein applied the 90^{th} percentile BSAFs developed from CARP II laboratory bioaccumulation tests (Chapter 3, Appendix A-3). HARS suitability determinations were also prepared for several alternative BSAFs. The range of BSAFs provides dredged material managers and planners with options to consider for HARS suitability screening and other planning purposes. For example, applying less conservative BSAFs might be useful for considering whether to conduct HARS suitability laboratory testing for bioaccumulation or to pursue other dredged material disposal options. More conservative BSAFs are likely to be most useful for Harbor sediment quality issues associated with ecosystem and human health.

Reference*:* **Appendix A-8. CARP II Model Future Projections Report**

Chapter 6 Summary Findings

I. CARP II Dredged Material Management Questions

CARP II was established to refine, improve, and update the CARP I assessments of the current (2022) near-term (2030), and future (2040) extent of sediment contamination in the HRE and assess the HARS suitability of the sediments within navigation channels. As discussed in the previous chapters and in the appendices of this report, CARP I models were updated in numerous ways to address these questions. Those improvements and the major findings of CARP II are briefly summarized below.

II. CARP II Bioaccumulation Prediction Improvements

Under CARP II, 28-day bioaccumulation tests were conducted on 68 sediment samples that were collected from various locations in the Harbor. The bioaccumulation test results were used to develop updated BSAFs for PCBs and PCDD/Fs. The updated BSAFs were comparable to BSAFs previously developed from dredged material testing data for more chlorinated PCBs (e.g., octa-CB) and 2,3,7,8-TCDD. However, the CARP II updated BSAF values were 2 to 10 times lower than BSAFs previously developed from dredged material testing data. A more detailed evaluation of the bioaccumulation test results showed that BSAF values were not only a function of the sediment organic carbon content, lipid content of the organism, and the octanol-water partition coefficient, but also the sediment black carbon (soot) content and the chemical structure of the contaminant (e.g., the number of ortho chlorines on PCBs). Based on these results, the lower CARP II BSAFs for the lower chlorinated PCBs were likely associated with the presence of black carbon in Harbor sediments tested for bioaccumulation during CARP II.

CARP II also developed a new rapid testing method for assessing the bioaccumulation potential of dredged material. The method is based on a 2–4-day laboratory exposure of a thin (18 or 25 µm thickness) polyethylene passive sampler to a dredged material sample to measure the bioavailable concentration of contaminants in the sediment porewater. The bioavailable concentrations are then related to the bioaccumulation potential developed as part of our evaluation of the CARP II bioaccumulation test results.

III. CARP II Numerical Modeling Improvements

The CARP II model calibration included wetter years and numerous major coastal storms from the 1998-2016 water years, providing a much more robust basis for the 2030 and 2040 future projections. Also, the inclusion of storm events in the 1998-2016 CARP II calibration addresses the issue of increased resuspension associated with storm events that was not addressed by CARP I, providing an improved basis for the hydrodynamic and sediment transport models and the 2030 and 2040 future projection scenarios. Lastly, CARP II updated the calibration of the contaminant fate and transport model with measurements collected between 1998 and 2022 as opposed to 1998 to 2002, an additional twenty years, increasing the confidence in the ability of the model to calculate the temporal trajectory of PCB and PCDD/F contaminant concentrations in in the future. These enhancements and extensions were carried out simultaneously with numerous other improvements including time-varying Harbor bathymetry and more rigorous methods for loadings estimates, sediment transport, contaminant fate and transport, and application of new BSAFs.

IV. Conclusions

As a result of the continued development and refinement of the CARP models under CARP II, the region has updated tools to evaluate the relative contributions of various contaminant sources to contaminant levels observed in the water, sediment, and biota of the Estuary. The CARP II modeling and data analyses collaborate previous findings, including:

- The Estuary is a dynamic system where, in some cases, contaminants have been transported great distances from their sources and have dispersed throughout the interconnected waterways.
- In most areas of the Estuary, ambient levels of contaminants in water, sediment, and biota will continue to decline slowly even if the ongoing loads remain constant.
- Natural processes including tidal resuspension and estuarine circulation are important in controlling the long-term trapping of particle-bound contaminants in the NY/NJ Harbor.
- Burial of contaminated sediments by “cleaner” sediments and sediment resuspension along with transport to other areas are among the dominant natural processes that result in the lowering of surficial sediment concentrations over time.
- Sediments in the Harbor still contain large quantities of persistent contaminants from historic releases and these legacy sediments are a continuing source of contamination.
- Legacy contamination generally plays a larger role in controlling contaminant levels in water, sediment, and biota in the Estuary than current external loadings.
- Navigation channel sediments in most of Harbor will remain unsuitable for ocean placement at HARS until at least 2030.

- Even after completion of Scenario 1 (two Lower Passaic River Superfund projects in 2030), sediments from the Hackensack River, Newark Bay, Arthur Kill, East River and portions of Raritan Bay and Jamica Bay are expected to remain unsuitable for ocean placement at HARS through 2040.
- As modeled under Scenario 2 (hypothesized full remediation of the Hackensack River and Newark Bay and two Lower Passaic River Superfund projects in 2030), navigation channel sediments in most areas of Harbor will attain HARS suitability by 2040.

Appendices

1. Appendix A-1. CARP II Historical Data Compilation and Analysis
2. Appendix A-2. CARP II Sampling and Analysis Program and Database
3. Appendix A-3. CARP II Sediment Bioaccumulation Estimates and Prediction of HARS Suitability
4. Appendix A-4. CARP II Rapid Assessment of Dredged Material Quality
5. Appendix A-5. CARP II Loadings Report
6. Appendix A-6. CARP II Models Update Report
7. Appendix A-7. CARP II Post- Audit Report
8. Appendix A-8. CARP II Model Future Projections Report

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