**U.S. ENVIRONMENTAL PROTECTION AGENCY, REGION 2**

June 06, 2019

BY ELECTRONIC MAIL

Robert Law, Ph.D.
de maximis, inc.
186 Center Street, Suite 290
Clinton, New Jersey 08809

Re: Re: Lower Passaic River Study Area – Administrative Settlement Agreement and Order on Consent for Remedial Investigation/Feasibility Study (Agreement) CERCLA Docket No. 02-2007-2009

Dear Dr. Law:

The Cooperating Parties Group (CPG) has adapted a suite of four previously-developed mathematical models over the course of conducting a draft Remedial Investigation for the Lower Passaic River Study Area (LPRSA). The U.S. Environmental Protection Agency (EPA) reviewed the updated modeling suite and the attached memorandum summarizes the review performed by EPA's consultant, HDR. EPA approves the suite of four models: hydrodynamic model, sediment transport model, organic carbon model, and contaminant fate and transport model for use in the Feasibility Study. The food web model will have to be reviewed separately once the calibration is completed.

Sincerely,

Diane Salkie, Remedial Project Manager
Lower Passaic River Study Area RI/FS

Cc: Zizila, F. (EPA)
Sivak, M. (EPA)
Hyatt, B. (CPG)
Potter, W. (CPG)

Attachment

# Memo

Date: April 3, 2019

Project: Lower Passaic River 17-Mile CPG Oversight

To: Diane Salkie
Elizabeth Franklin

From: Ed Garland
James Wands

Subject: Recommendation for Approval of Cooperating Parties Group Lower Passaic River Remedial Investigation Modeling Suite for Use in the Lower Passaic River Feasibility Study

## Introduction / Background

The Cooperating Parties Group (CPG) has adapted a suite of four previously developed mathematical models over the course of conducting a Remedial Investigation (RI) for the Lower Passaic River Study Area (LPRSA). The updated modeling suite requires U.S. Environmental Protection Agency (EPA) approval prior to its use in a LPR Feasibility Study (FS). This memorandum summarizes a review of the current status of the updated RI modeling suite, a review completed to assess the technical defensibility of the component models and to provide input to EPA's approval of the updated modeling suite for use in the LPR FS.

## Status of Modeling Suite

### *Overview*

The modeling suite that is the subject of this review is comprised of four models, a hydrodynamic model (HD), sediment transport model (ST), organic carbon model (OC), and contaminant fate and transport model (CFT). The component models originated as the modeling suite used in the Contaminant Assessment and Reduction Project (CARP, for New York-New Jersey Harbor Estuary), and were further developed by the EPA team as part of the RI and Focused Feasibility Study (FFS) for the Lower 8.3 Miles of the Lower Passaic River. As part of the RI/FFS for the Lower 8.3 Miles of the Lower Passaic River the suite of four models was peer reviewed. The Food Web Model (FWM) will use output from the CFT model to predict tissue concentrations once it is calibrated. The current status of each of the other four models is discussed below. Differences between the individual model components used by the EPA team to support the Record of Decision (ROD) for the Lower 8.3 miles of the LPRSA and those used by the CPG for the RI are also noted, as is the adequacy of the model calibration and suitability of each model for use in simulating FS alternatives.

Unless otherwise noted, references to figures in the following sections refer to figures in appendices of the CPG's RI report:

- Hydrodynamic Model – RI Report Appendix L
- Sediment Transport Model – RI Report Appendix M
- Organic Carbon Model – RI Report Appendix N
- Contaminant Fate and Transport Model – RI Report Appendix O

For each of the models reviewed, the CPG provided a complete set of model codes, inputs, and outputs. Each set of model outputs was reproduced using the codes and inputs provided for review.

## *Hydrodynamic (HD) Model*

The HD model is used to describe hydrodynamic transport in the LPRSA and Newark Bay, and in the contiguous waters of the Hackensack River, Kill van Kull and Arthur Kill. The HD model is based on the Estuarine Coastal Ocean Model (ECOM, Blumberg and Mellor, 1980 and 1987). Application to this domain was done as the initial effort to develop the models that supported the Lower 8.3-mile ROD. Initial calibration and validation of the HD model was performed by HDR|HydroQual and documentation of the calibration and validation to measurements of water surface elevation, current velocity, temperature and salinity are contained in hydrodynamic model report (HydroQual, 2008). The model transferred to the CPG modeling team successfully reproduced the calibration of the following LPRSA data sets:

- Tierra Solutions, Inc. 1995-1996 RI data
- Rutgers University Institute of Marine & Coastal Sciences (IMCS) (led by Dr. Robert Chant) 2004 hydrographic data

The CPG conducted additional HD model validation using the following data sets:

- Rutgers University IMCS (led by Dr. Robert Chant) 2005 hydrographic data
- Physical Water-Column Monitoring (PWCM) dataset from Fall 2009 and Spring 2010
- High-flow event salinity transect collected on March 16, 2010
- Chemical Water-Column Monitoring (CWCM) data from 2012

The CPG HD model includes relatively minor differences compared to the HD model used to support the Lower 8.3-mile ROD, and those differences are in areas of the domain outside of the LPR (bathymetry changes in the Meadowlands, frictional parameter changes in the Hackensack River, Kill van Kull and Arthur Kill), which were introduced to improve the representation of the timing of the tides between those regions and Newark Bay.

Additional details of the CPG's HD model are provided in Appendix L of the CPG's RI Report[1].

## Adequacy of Calibration

### Qualitative Comparisons

Given the limited modifications that were made to the originally received HD model, the model – data comparisons presented by CPG for the calibrated model are not markedly changed from the earlier EPA results. The model was able to successfully simulate observed conditions within the LPR over a wide range of flow conditions. Two long-term monitoring deployments were completed, one during a December 2004 high upstream flow deployment (Figures 2-20 through 2-27) and another during a July – August 2005 low flow deployment (Figures 2-28 through 2-36). With limited exceptions, the simulated results were in good agreement with observations of surface and bottom velocities and salinity. There are instances where they did not agree, such as during the high flow deployment (Figure 2-25), where near bottom salinity is noticeably under-predicted at station M3. In another case, during the low flow deployment (station M2a during August 2005; Figure 2-32), the data were considered questionable because the bottom salinity was less than near surface salinity. Overall, however, good agreement was achieved between the observed and simulated results.

In contrast to the preceding extended deployments, model results were also compared to data obtained on April 5, 2005 when the upstream discharge at Little Falls achieved a peak flow rate of about 12,000 cfs following an extended period of low flow conditions. The preceding low flow conditions had allowed the salt front to intrude well into the LPR, but the marked increase in flow on April 5th caused it to be translated in the downstream direction to a location near the mouth of the LPR. The observed location of the salt front and Newark Bay salinity levels were in good agreement with the simulated model results (Figure 2-37).

### Quantitative Calibration Metrics

As part of the additional HD model validation the CPG analyzed time series data, to obtain the harmonic constants for amplitude (m) and phase (degrees) for both observed and simulated results for the fall 2009 and spring 2010 datasets. Inspection of the tabulated results for water level, velocity and salinity indicates

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[1] Unless otherwise noted, references to sections, tables and figures in the hydrodynamic model portion of this memo refer to Appendix L of the Draft Lower Passaic River Study Area Remedial Investigation/Feasibility Study, Remedial Investigation Report, dated October 2018.

that good agreement is achieved at all five LPR stations. The reported deviations between harmonic constants evaluated from the model results and data are considered to be acceptable.

Time series plots compare data and simulated results for the fall 2009 and spring 2010 data sets at each of the 5 monitored locations (RM 1.4, 4.2, 6.7, 10.2 and 13.5). Each figure shows water surface elevation, surface and bottom salinity and surface and bottom velocity. These qualitative comparisons are supplemented with posted values for root mean square and relative root mean square (RMS and RRMS) errors and coefficients of determination. The posted values provide a further quantitative demonstration of the ability of the HD model to predict these variables quite well throughout the LPR study area. For the fall 2009 dataset relative RMS errors ranged from 10.9% to 34.9% for salinity (with one exception, less than or equal 21.4%) and 8.2% - 18.9% for velocity. Coefficients of Determination ($R^2$) ranged from 0.45 – 0.86 for salinity and 0.62 – 0.90 for velocity. Analogous values for the spring 2010 dataset were as follows: relative RMS errors of 9.0% to 26.6% for salinity and 5.0% - 10.7% for velocity. Values of $R^2$ were 0.44 – 0.80 for salinity and 0.85 – 0.95 for velocity. These values are generally considered to be quite good.

### Suitability for FS Use

The HD model is considered to be appropriate for use for two reasons. First, the calibrated model was able to achieve generally good agreement between simulated current velocity and salinity distributions and field monitoring results, both vertically and longitudinally, over a wide range of flow, temperature and tidal conditions. In addition to this, the model was also successful at predicting these same variables for several independent datasets that were not previously used for model calibration purposes. As such, it is considered to be appropriate for use in the suite of models that have been developed and applied to the LPR. Future refinements will likely include increases in model grid resolution for sediment transport and contaminant fate and transport considerations.

## *Sediment Transport (ST) Model*

The CPG's ST model is very similar to the ST model used to support the Lower 8.3-Mile ROD. It incorporates the SEDZLJ bed model (Jones and Lick, 2001) within the computational framework of the ECOM HD model. The SEDZLJ bed model was adapted by the EPA team for use on the LPRSA by including a bed consolidation model (Sanford, 2008). The integrated HD and ST modeling framework is referred to as the ECOM-SEDZLJS model. Appendix M of the CPG's RI Report[2] provides a comprehensive documentation of the CPG's application, including parameterization and calibration performance.

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[2] Unless otherwise noted, references to sections, tables and figures in the sediment transport model portion of this memo refer to Appendix M of the Draft Lower Passaic River Study Area Remedial Investigation/Feasibility Study, Remedial Investigation Report, dated October 2018.

## Differences between the CPG's ST Model and the EPA Model used to Support the Lower 8.3 Mile ROD

In an effort to shorten run times, the CPG ran the HD and ST models in decoupled mode. That is, the HD model and ST model are run separately. The HD model is started first and its output is used by the ST model. HD model cell depths are periodically updated based on feedback from ST output, but with a time lag of ~15 days. Because the differences in bathymetry are typically small, use of a ~15 day time lag is inconsequential.

The CPG added an additional grain size class (relative to the EPA model) to represent silts and clays separately (the EPA model combined silts and clays into a single size class based on computational time considerations). The CPG model also distinguishes between flocculated silts and clays from open tidal boundaries versus unflocculated silts and clays from freshwater boundaries. With silts and clays represented separately, the CPG model uses constant settling velocities for each, whereas the EPA model used concentration-dependent settling velocities for the combined silt-plus-clay class to represent the effect of temporal variations in the composition of the two particles types.

The EPA model assigned vertically uniform grain size distributions in the initial sediment bed, and the CPG model included a refinement to specify vertical variations in the grain size of the initial sediment bed.

The CPG model included refinements to represent the effect of navigation scour in the LPR reach from RM 1.4 to Newark Bay, and within the navigation channel from the eastern end of the Kill van Kull through the Port Newark and Port Elizabeth channels. The model is configured so only sediment deposited on top of the initial bed can be eroded by navigation scour. A wind-wave model was also introduced for the Newark Bay portion of the domain to compute additional bed shear stress due to wind-waves, resulting in improved sediment dynamics in shallow regions of Newark Bay.

## Adequacy of Calibration

Documentation of the CPG's model application and calibration (Appendix M of the RI Report) includes a series of attachments that present independent data analyses, from which calibration parameters were derived:

- Attachment C – Re-entrainment Rate Analysis – presents the derivation of the erosion properties of the fluff layer (including variations in resuspension through the spring-neap tidal cycle).
- Attachment D – Gust Microcosm Data and Comparison to Re-entrainment Rate – presents an independent comparison of the results derived from the analysis presented in Attachment C to site-specific near-surface erosion measurements from Gust Microcosm experiments.
- Attachment E – Sedflume Data Analysis – presents an analysis performed to derive erosion properties of the sediment bed from data obtained in Sedflume erosion experiments.

- Attachment F – Settling Velocity Analysis – presents an analysis using the Rouse-approach to calculate settling velocities used in the model calibration.

The ST model calibration period includes a variety of hydrodynamic conditions during the collection of the calibration data sets, which include:

- CPG's Fall 2009 and Spring 2010 PWCM program
- CPG's CWCM program (salinity and suspended solids concentration [SSC] data included in program)
- Sommerfield and Chant's 2008-2009 monitoring program (Sommerfield and Chant 2010)
- March 2010 high flow event (collected by Dr. Robert Chant of Rutgers Univ. for the CPG)
- Bathymetric changes over the periods covering the 2007, 2008, 2010, 2011, and 2012 multi-beam surveys
- Surficial bed sediment composition from the various datasets (see Appendix M, Section 4.2.1)

Appendix M of the CPG's RI report presents a balanced assessment of the model calibration, and HDR agrees with the CPG's observations and conclusions, which are summarized in section 5.7 of Appendix M as follows:

> The CPG's ST model has been calibrated and compared against a number of metrics and datasets including water column SSC and fluxes, bathymetric change, and bed composition. The model results have also been reviewed and compared to data over a variety of time-scales – intra- and inter-tidal, and under a variety of flow regimes, ranging from low-flow conditions characterized by depositional processes, to extreme high-flows such as a 1 in 25-year and 1 in 90-year event. The model performance has also been assessed for a number of processes identified in the data. The model calibration process was also chosen such that the two parameters adjusted as part of the calibration process, namely the critical shear stress of the parent layers in the bed and the settling velocity of the sediment entering from the Kill van Kull and Arthur Kill, could be calibrated independently. In other words, the regimes under which these parameters were calibrated were mutually exclusive, ensuring that the choice of the value for one parameter does not influence the resulting calibration achieved for the other parameter. In addition, the parameter calibration was also constrained within the range of site-specific values established from measurements and data analysis. This also served to ensure a realistic set of parameter calibration values. The calibrated model has also been applied to simulate the historical infill that has been observed within the navigation channel of the LPR since the last major dredging events in 1949 and 1983.

SSC simulations for the spring 2010 PWCM dataset are particularly important. Although a number of inconsistencies between model and data are acknowledged by CPG, the performance of the model with respect to simulation of important fate-controlling features of sediment transport in the system is reasonably good. One example of this is the demonstrated ability of the model to simulate the transition that occurs following flushing of the fluff layer from the system by the 1-in-25 year March 16, 2010 high flow event. Following this event, the model is able to simulate the re-establishment of the fluff layer and the characteristic intra-tidal dynamics of SSC data over about a 3 – 4 week period of time. Because this period had not been included in the calibration of the model, this capability is viewed as a confirmation of the adequacy of the model framework (i.e., a bed consisting of a fluff layer that is susceptible to erosion overlying a more consolidated substrata) as well as a validation of the model calibration. The ability of the model to simulate the recovery of the LPR system from such a high flow event, and simulate conditions where sediment dynamics are controlled by a very different set of processes that are operative during sustained low flow conditions (i.e., develop and intra-tidal interactions with a fluff layer), supports an expectation that the model will respond in an appropriate manner during extended multi-year simulations, including long-term multi-decade projections of remedial alternatives.

The CPG report also presents comparisons of areas with net erosion and deposition throughout the LPR (Section 5.4.6). Relatively detailed comparisons at the spatial scale of a model grid cell indicate discrepancies may occur. Such discrepancies are in some cases attributable to sub-grid scale features, such as bridge abutments, which are not represented in the model. In spite of such deviations between model and data, when spatial average results are considered over a broader scale and longer time periods the model and data are generally consistent. For example, for the period of 2007 – 2011 both model and data indicate that the reach from RM 2 – RM 14 tends to be erosional, while the downstream reach, RM 0 – RM 2 (where the cross-sectional area widens), tends to be depositional (Figures 68 and 69). The bathymetric results also indicate that some reaches that are characterized as depositional during low flow periods may become erosional during subsequent high flow periods. This situation is consistent with a system that is approaching a dynamic equilibrium over longer term periods of time.

## Suitability for FS Use

The ST model has been calibrated for a variety of datasets representing a reasonably wide range of freshwater discharge conditions (a very low flow condition to a 1-in-25 year high-flow event) and tidal conditions. Comparisons between model and data include water column SSC (estimated based on ABS and OBS) and fluxes estimated from ABS-based SSC and ADCP velocity measurements. The model was able to simulate these results reasonably well, on average. Comparisons were also made of simulated and observed changes in bathymetry, indicative of longer-term net sedimentation rates, and changes in bed composition. In some instances, the model performed relatively well, being able to simulate wide-scale infilling upstream of RM 2 and deposition downstream of RM 2, as was observed between 2010 and 2011. Scour attributed to Hurricane Irene was over-predicted in some localized areas. Such limitations reflect, in part, inherent constraints on the development and application of a complex ST model to a system such as the LPR. These include practical limitations on model grid resolution relative to fine-scale features (e.g., bridge abutments) within the study area, limitations on the spatial coverage of Sedflume erosion data, and uncertainty of erosion properties with depth in the sediment subsequent to large erosion events.

Overcoming ST model limitations will require the collection of additional data and the incorporation of additional refinements to the modeling framework based on the information obtained. As it currently stands, the ST model incorporates the important physical processes that control sediment transport in the LPR (see, Section 2, System Understanding) and, with limited exceptions (e.g., over-prediction of scour during Hurricane Irene, the exact spatial location of the salt front, transient temporal dynamics of the fluff layer), it performs well in reproducing the major transport features and processes evident in the data over larger spatial scales. Overall, the performance of the ST model is considered to be reasonable and this performance supports its use as a component of the LPR FS modeling suite. Future refinements will likely include increases in model grid resolution and improvements in the simulation of erosion and deposition at finer spatial scales.

### *Organic Carbon (OC) Model*

The dissolved organic carbon (DOC) and particulate organic carbon (POC) content of the water column and sediment are important fate-controlling characteristics of the system because they influence the distribution of contaminants between the freely dissolved, DOC-complexed and particulate (algal carbon- and detrital carbon-complexed) phases. This in turn has a direct bearing on the ultimate transport, fate and bioavailability of chemicals within the system. As such, the modeling suite includes an OC sub-model.

EPA originally provided the CPG with a relatively complex eutrophication model (Sediment Transport – System Wide Eutrophication Model, ST-SWEM) that had been previously applied in the FFS for the Lower 8.3 miles. This eutrophication sub-model was based upon a relatively detailed algal kinetic modeling framework. Based on an analysis of the OC dynamics in the system the CPG proposed a simplification of that detailed approach, which was accepted by EPA. The details of the simplification are presented in Section 2 of the OC model Appendix[3].

## Differences between the CPG's OC Model and the EPA Model used to Support the Lower 8.3 Mile ROD

The CPG completed several analyses that were directed at reducing the overall complexity of the original OC model. This in turn reduced the computational requirements of the model without materially sacrificing the representation of POC and its impact on contaminant fate in the subsequent CFT model. Pursuant to these analyses, the CPG adopted an EPA-approved simplification of the full eutrophication model that had originally been provided. The simplified model treats all OC inputs as conservative substances. The inputs that differ from the ROD model are:

- Bed sediment OC (based on RI/FS sediment OC measurements, assumed to be associated with the cohesive sediment fraction)

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[3] Unless otherwise noted, references to sections, tables and figures in the organic carbon model portion of this memo refer to Appendix N of the Draft Lower Passaic River Study Area Remedial Investigation/Feasibility Study, Remedial Investigation Report, dated October 2018.

- Spatially varying and temporally constant DOC (based on observed patterns)

The CPG demonstrated that use of either the original or updated OC models yielded generally comparable results, both with respect to OC levels in the system (Figures 2-3), and with respect to spatial and temporal changes in contaminant concentrations in the system (Figures 5-8 and 10-15).

## Adequacy of Validation

CPG describes various analyses that were performed as a basis for initial OC model setup, including initial conditions, boundary conditions, loads to the system, and model linkages to the HD and ST models (Section 4). The agreed upon approach results in an OC model that does not have any calibration parameters that can be adjusted within the model, and therefore the model was compared to data as a validation of the simplified approach. This validation step makes comparisons of model and data to confirm that the preceding simplified OC modeling approach results in good agreement between model and data.

### *Qualitative Comparisons*

CPG relied upon use of cross-plots, probability plots and spatial plots to make comparisons of model results to data for chlorophyll-a, water column POC and sediment fraction of OC ($f_{OC}$). With respect to chlorophyll-a levels, cross-plots of model and data for summer and winter conditions (Figures 25 and 26) indicate comparable orders of magnitude. Although the model does not provide a high degree of explanatory power with respect to point-to-point comparisons at a fixed location, the results are qualitatively similar with respect to a general decrease in higher concentrations in the downstream direction. More importantly, the probabilistic comparisons at different locations (Figures 27 and 28) within the study area indicate reasonably good agreement between model and data, for both summer and winter conditions, with the seasonal differences (summer versus winter) also well reproduced by the model. Again, there is also an overall trend of decreasing concentrations in the downstream direction. Consistency in spatial profiles is more clearly seen on the spatial plots (Figure 29).

With respect to water column POC, cross-plots of model versus data for summer and winter conditions (Figures 30 and 31) indicate comparable ranges in concentrations, but somewhat limited explanatory power with respect to point-to-point comparisons at any given location. In spite of this limitation, comparisons of POC probability distributions for summer and winter months are in good agreement at each RM location sampled (Figures 32 and 33, respectively). Seasonal differences (summer versus winter) are also well simulated with POC concentrations tending to be higher during the summer months at most locations. A general pattern of increasing concentrations in the upstream reach and then a decrease further downstream towards Newark Bay is also evident on these probability plots. This spatial pattern is even more clearly evident on the spatial profiles shown on Figure 34.

The cross plots of POC vs total suspended solids (TSS) (Figures 35 and 36, respectively) are also comparable in behavior across the system (compare data plots on upper row and model results, middle row). The similarity in the results on the middle and bottom panels, the latter including algal carbon in the model results, suggests that the influence of algal carbon on POC is limited in its importance in the LPR system, particularly at downstream stations. Spatial plots of $f_{OC}$ in the surface sediment layer (Figure 37) and archive bed layers (Figure 38) indicate general consistency between model and data. Not all of the variability in the data is captured by the model. This largely reflects the spatial averaging that unavoidably occurs within each model grid cell.

Overall, the preceding comparisons indicate that the simplified OC model that has been developed for use does provide a reasonably good representation of the larger-scale features of OC concentrations that are indicated by the LPR datasets under consideration.

### *Quantitative Validation Metrics*

The CPG included quantitative validation metrics through median and mean values posted on the probability plot comparisons of model and data, for both chlorophyll-a and POC. These indicate that the results are in general agreement and comparable in magnitude across the LPR system.

## Suitability for FS Use

The CPG's OC model yields results that qualitatively are consistent with the water column and sediment data within the study area. It is also shown that the results are comparable to the EPA results based on the detailed kinetic model formulation. As such, it is reasonable to make use of CPG's OC model for FS purposes. Future refinements will likely include increases in model grid resolution, consistent with refinements of each of the model framework components.

It is important to bear in mind potential limitations of the CPG's OC model. These include the following:

- The OC model is not structured to be able to predict any changes that may occur in the OC in the water column as a result of any future changes to nutrient loads to the system that result in changes to primary productivity within the model domain.
- The model is not structured to be able to predict changes in dissolved oxygen and related changes in sediment diagenesis which could impact contaminant dynamics (e.g., mercury-methyl mercury dynamics).

Both limitations noted above would be of potential importance if substantial changes in external nutrient inputs and/or the reactivity of external POC loads to the system occur in future years. Such changes might alter the water column or sediment OC content in a way that could alter contaminant partitioning between the dissolved and particulate phases and might also alter dissolved oxygen and diagenesis dynamics in a way that could alter the speciation of chemicals (e.g. mercury). In the event that this situation was to arise, the impact of those changes would need to be addressed. For the purposes of the FS the assumption that the current nutrient loads will continue into the future is an acceptable approximation and is consistent with the Lower 8.3-mile FFS assumptions.

## *Contaminant Fate and Transport (CFT) Model*

The CFT model builds upon the HD, ST and OC model outputs. The CFT model computes the spatial variation of water column and sediment contaminant concentrations over time.

The CPG's CFT model is based upon the RCATOX modeling framework applied in the FFS for the Lower 8.3 Miles of the Lower Passaic River (LBG, 2014; USEPA, 2016). This mechanistic framework draws upon results from the predecessor HD, ST and OC models to evaluate various contaminant transport and fate controlling processes including: contaminant partitioning between dissolved (free and DOC-complexed) and particulate (algal carbon- and detrital carbon-complexed) phases in the water column and sediment, advective and dispersive transport in the water column, volatilization from the water column, dissolved and particulate transfers between the water column and sediment bed (particle deposition and resuspension and water column-porewater diffusion), and mixing, diffusion and burial within the sediment.

Additional details of the CPG's CFT model are provided in Appendix O of the CPG's RI Report[4].

### Differences between the CPG's CFT Model and the EPA model used to Support the Lower 8.3 Mile ROD

With EPA oversight, the CPG undertook efforts to further refine the CFT model framework and its calibration to site data by incorporating several features. These features include:

- Addition of a thinner surficial sediment "fluff layer" that reduces mixing between the surficial bedded sediments and those that are resuspended on an intra-tidal basis,
- Representation of a resistantly-sorbed contaminant fraction as a way to limit desorption from resuspended sediment, over the relatively short timeframe that those particles are in the water,
- Introduction of a sediment erosion velocity formulation to improve the simulation of sorbed contaminant erosion in the presence of vertical gradients in the cohesive concentration in the bed,
- Variable sediment mixing intensity within the top 10 cm of the sediment,
- Resuspension of contaminants due to navigation scour near the mouth of the LPR and within the navigation channel in Newark Bay (this process is linked directly to the navigation scour approximation from the ST sub-model).

Additional features that were introduced into CPG's model calibration approach included:

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[4] Unless otherwise noted, references to sections, tables and figures in the contaminant fate and transport model portion of this memo refer to Appendix O of the Draft Lower Passaic River Study Area Remedial Investigation/Feasibility Study, Remedial Investigation Report, dated December 2018.

- Modified sediment bed initial conditions
  - Water year (WY) 1996 to WY2013 simulation based on 1995 to 1999 sediment data
  - WY2012 to WY2013 simulation based on a 2010 initial condition mapping (approximated from 2005 to 2013 sediment data),
- CFT simulations on the higher resolution HD model grid,
- Scaling factors at Dundee Dam and/or the Kills for selected contaminants during calibration.

## Adequacy of Calibration

Two general approaches were used to assess the model calibration. The first was to make qualitative comparisons of the consistency between measured and simulated spatial and temporal variations in concentrations in the water column and sediment. The second approach was to evaluate quantitative metrics as indices of the predictive ability of the model. The primary contaminants used by CPG for model calibration were 2,3,7,8-TCDD, tetra-PCBs, and 1,2,3,4,6,7,8-HpCDF. These compounds possessed a high frequency of detected concentrations in the sediment and water column (as needed for calibration), a wide range of sorption properties (Log $K_{OW} = 6.0 – 8.67$), and the potential to impact either human health or ecological risk (see Anchor-QEA, 2016, for further details). The three primary contaminants were supplemented with six additional contaminants that were identified for secondary consideration (1,2,3,7,8-PeCDD, 2,3,4,7,8-PeCDF, PCB-126, PCB-167, total 4,4-DDx and mercury). In addition to their direct use for assessment purposes, these nine contaminants may also be used to make regression-based estimates of the concentrations of other constituents that may be of interest during the FS. As one example, computed total PCB concentrations may be approximated from simulated concentrations of tetra-CB using a data-based regression.

The CFT model calibration approach included two temporal scales. The long term calibration (1995 through 2013) focused on the changes in sediment concentrations between the sediment data collected prior to 1999 (mostly 1995) and the data collected after 2005 (mostly CPG 2008-2013 RI data). Table 4-1 identifies these datasets. The short term calibration (2012 through 2013) focused on the water column data collected as part of the high volume and small volume CWCM programs.

Appendix O of the CPG’s RI report presents a balanced assessment of the model calibration, and HDR agrees with their observations and conclusions, which are summarized for the primary contaminants in section 4.5 of Appendix O as follows:

> The strength of the calibrated CFT model is its ability to represent the net flux of COPCs between the bed and the water column, which is demonstrated by its consistency with water column data when assessed longitudinally, vertically, and by flow regime. It is less able to match long-term changes in surface sediment COPC concentrations, though it does a reasonable job when judged on an overall average basis. The deviations between model and data at the scale of individual grid cells are a result of limitations in the ability

> to predict net deposition and erosion at this scale and likely errors in grid scale average bed COPC concentrations due to the paucity of data at this scale with which to set ICs and calibration targets needed to assess model performance. The data paucity limits the extent to which long-term surface sediment trajectories within the RM 1 to 7 reach at the scale of individual cells can be used to inform the calibration and it precludes constraining the bed trajectories outside of RM 1 to 7. A low bias is evident in depositional cells in the lower 2 to 3 miles of the river, though this bias appears not to be significant enough to impact comparisons when the RM 1 to 7 model results are aggregated on a reach-wide or shoal versus channel basis. This bias may be due to the mix of NB and LPR solids contributing to deposition near the mouth of the river, which might be biased toward lower contaminant concentration solids coming from NB.

The conclusions for the secondary contaminants (Section 5.4) are similar with adjustments to some of the boundary conditions and some noted limitations based on non-detected data.

The model does generally reproduce the larger scale temporal patterns in the sediments (long term calibration, e.g., Figure 4.2.1-4a) and the distribution of the concentrations in the water column over a range of flow and tide conditions across the sampled stations at surface and bottom locations (short term calibration, e.g., Figure 4.3.1-1a). When looking on a point by point basis for the sediment (e.g., Figure 4.2.1-2a) and water column (e.g., Figure 4.3.1-2a) calibrations do not perform as well.

In general the model predicts rates of change in sediment concentrations over time, which is consistent with the available data within the RM 1-7 reach. Outside of that reach the models predictive capability is more uncertain due to the lack of long term data collected in an unbiased fashion. In the case of the water column there are also no longer-term data to compare to longer-term trends predicted by the model, however, water column concentrations vary far more in the short term due to hydrodynamic conditions than they do over the longer term. The model's ability to predict larger scale long term behavior of the sediments in the system and the shorter term range of responses in the water column make it suitable for comparing FS level differences between remedial alternatives at those scales.

The CPG presents a balanced assessment of the model uncertainties and limitations in Section 7.3 of the Draft Lower Passaic River Study Area Remedial Investigation/Feasibility Study, Remedial Investigation Report, dated October 2018, which should be considered when applying the suite of models to predict the response of contaminants in the system to future conditions.

## Suitability for FS Use

The data gaps in sediment data available over decadal time scales is a factor that contributes to uncertainty in predicted contaminant concentrations in the sediment bed. The spatial scale of the model grid in the upper 9-miles of the LPRSA, relative to the spatial scale of contaminant concentrations interpolated from RI data also contributes to uncertainty in predicted future concentrations. The suitability of the CFT model for FS use is better supported for comparative evaluations rather than attempts to predict specific times to achieve future contaminant concentrations. The ability of the model to reproduce general spatial and temporal patterns of water column contaminants and larger-scale spatial and temporal changes in sediment bed contaminant concentrations provides support for use of the CFT model in comparative application for the FS. Future refinements will likely include increases in model grid resolution, consistent with refinements of each of the model framework components, and improvements in the simulation of sediment contaminant concentrations at finer spatial scales and water column contaminant concentrations at finer temporal scales. The model will benefit from increased spatial density of sediment contaminant concentration data, among additional refinements.

## Overall Assessment

As indicated in the individual assessments of the four models reviewed, it is recommended that EPA approve the suite of HD, ST, OC, and CFT models for use in the FS. The FWM will have to be reviewed separately once the calibration is completed.

## References

Anchor QEA (Anchor QEA, LLC), 2016. Memorandum to: Dr. Robert Law and Willard Potter, de maximis, Inc. Regarding: Proposed COPCs to be Calibrated in the Lower Passaic River/Newark Bay Contaminant Fate and Transport Model. December 8, 2016.

HydroQual, 2008. Final Hydrodynamic Modeling Report. Lower Passaic River Restoration Project and Newark Bay Study. Mahwah, NJ

Jones, C. and W. Lick, 2001. SEDZLJ. A Sediment Transport Model. University of California, Santa Barbara, CA.

Louis Berger Group, 2014. Focused Feasibility Study Report. Lower Eight Miles of the Lower Passaic River. White Plains, NY.

Sanford, L.P., 2008. Modeling a dynamically varying mixed sediment bed with erosion, deposition, bioturbation, consolidation, and armoring. Computers & Geosciences 34 pp. 1263–1283.

Sommerfield, C.K. and R.J. Chant, 2010. Mechanisms of Sediment Trapping and Accumulation in Newark Bay, New Jersey: An Engineered Estuarine Basin. Final Report to the Hudson River Foundation, University of Delaware, DE and Rutgers University, NJ.

US EPA, 2016. Record of Decision – Responsiveness Summary Attachment E, Lower 8.3 Miles of the Lower Passaic River, U.S. Environmental Protection Agency Region 2, New York, NY.