CONCEPTUAL SITE MODEL

LOWER PASSAIC RIVER RESTORATION PROJECT

Prepared by:

Malcolm Pirnie, Inc., in conjunction with Battelle and HydroQual, Inc.

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1.0 INTRODUCTION

1.1 OBJECTIVE OF A CONCEPTUAL SITE MODEL

A conceptual site model (CSM) expresses a site-specific, contamination problem through a series of diagrams, figures, and narrative consistent with US Environmental Protection Agency (USEPA) Office of Solid Waste and Emergency Response (OSWER) remedial investigation and feasibility study guidance (USEPA, 1988). These diagrams, figures, and narrative are designed to illustrate the potential physical, chemical, and biological processes that transport contaminants from sources to receptors. Overall, a CSM provides a tool for site managers and planning teams to examine the contamination problem and to provide the basis for identifying and evaluating the potential risks to human health and the ecosystem.

A CSM is developed during the first step of the data quality objective process (DQO; USEPA, 2000) and continues to evolve throughout the project as historical and recently collected data are evaluated, DQOs are updated, and the risk assessments are refined. Typical components of a CSM include:

- Potential sources of contamination.
- Potentially contaminated media and types of contaminants expected.
- Contaminant fate and transport mechanisms and migration pathways.
- Potential exposure pathways and routes of exposure
- Potential human and ecological receptors.

Together, these CSM components and the DQOs present a current understanding of the contamination problem; outline existing data gaps and the sampling necessary to address these gaps; identify potential exposures that may result in existing human and ecological risks; and provide guidance for future project decision-making. It must be understood by all audiences that a CSM is a multidisciplinary tool that serves a critical role in risk assessment, numerical model development, project and sample planning, decision making, and ultimately in choosing a remedial strategy. For this reason, a series of diagrams, figures, and narrative may be appropriate for a complex project. These diagrams, figures, and narrative link together to represent the entire CSM, but individually, each diagram or figure may highlight a different aspect of the project.

1.2 CSM FOR THE LOWER PASSAIC RIVER RESTORATION PROJECT

The following document presents, for consideration, an initial CSM for the Lower Passaic River Restoration Project (LPRRP; refer to Section 1.1 of the Work Plan for a description of the study area; Malcolm Pirnie, 2005a). The objectives of this initial CSM are:

- To present the contamination problem of the Lower Passaic River by focusing initially on geochemical and transport processes.

- To lay the foundation and process for future revisions of the CSM.

To accomplish these objectives in a clear fashion, broad geochemical processes are presented. Exposure pathways are not presented in this CSM; hence the CSM is currently incomplete. In-depth data evaluations are also absent from this document; however, those data evaluations that were completed to date, were considered during the development of this initial CSM. These data evaluation include:

- Preliminary historical data evaluation (refer to Section 4.1 of the Work Plan; Malcolm Pirnie, 2005a).
- Preliminary geochemical evaluation (Malcolm Pirnie, 2005b).
- Evaluation of hydrodynamics and sediment transport between the Lower Passaic River, Newark Bay, and the Hackensack River (HydroQual, 2005).

Future iterations of the CSM will, however, integrate the plethora of existing data and the existing body of literature, data collected during future field investigations, and the exposure pathways and receptors noted in the Pathways Analysis Report (Battelle, 2005; and provided in Attachment 1) to construct a comprehensive CSM that addresses all aspects of the LPRRP. Examples presented in this document are intentionally generalized and serve as the foundation for future iterations of the CSM. It is likely and planned that from this initial CSM a variety of tools will evolve to suit the needs of researchers/consultants working on all aspects of the Lower Passaic River.

The Lower Passaic River, as described in the Work Plan (Section 2.0; Malcolm Pirnie, 2005a), is an estuarine system in northern New Jersey, which was heavily developed in the 1800s. By the twentieth century, urban and industrial developments surrounding the Lower Passaic River, combined with associated population growth, had resulted in poor water quality, contaminated sediments, bans on fish and shellfish consumption, lost wetlands, and degraded habitats.

This CSM is being developed as part of the DQO process outlined in the Draft Quality Assurance Project Plan (QAPP; Malcolm Pirnie, 2005c) to address the contamination problem of the Lower Passaic River. The DQOs describe the project objectives, which are:

- Collect information about sediment stability, contaminant sources, contaminated media, and geochemical data to characterize the nature and extent of contamination.
- Collect information about hydrodynamic, sediment transport and stability, and biotic processes to assess the fate and transport of contaminants in sediments, water, and biota.
- Describe the exposure pathways and receptors to evaluate human health/ecological risks and support the Natural Resource Damage Assessment (NRDA).

The CSM is integral in meeting these objectives since the CSM will provide a description of the contamination problem in the Lower Passaic River Study Area, which can be used to guide the necessary data gathering and evaluation.

1.3 DOCUMENT OVERVIEW

This document is divided into the following sections to articulate the CSM development and the process for maintaining, updating, and refining the CSM.

Section 1.0, INTRODUCTION: explains the CSM's objectives, provides a brief description of the LPRRP, and summarizes the contents of the document.

Section 2.0, DEVELOPMENT OF THE CSM: provides the basis for the development of the CSM for the Lower Passaic River and outlines relevant inventories and fluxes in the system as well as potential chemical fate and transport.

Section 3.0, UPDATING THE CSM: outlines the process by which the CSM will be maintained, updated, and refined as the project proceeds.

Section 4.0, SUMMARY: summarizes the ideas and objectives presented in the document.

Section 5.0, ACRONYMS: lists the definitions and acronyms used in this document.

Section 6.0, REFERENCES: lists the references used in this document.

2.0 DEVELOPMENT OF THE CSM

The initial CSM for the LPRRP is described through a series of six figures and Section 2.0 and Section 3.0 of this text. Each figure is intended to build on the previous figure and to provide additional information on the CSM structure. Hence, initial graphics are relatively simple and later graphics are more complex. To articulate the discussion of the CSM, physical, chemical, and biological processes are separated onto different figures even though all processes co-occur. Thus, it is important that the audience view all six figures collectively as the CSM instead of focusing on one particular figure. Furthermore, as the CSM is iteratively developed, more figures will be created to describe newly added components.

2.1 ESTABLISHMENT OF RIVER SECTIONS

The 17-mile, tidal stretch of the Lower Passaic River was divided into three river sections to reflect the main geochemical and ecological settings of the river (Figure 2-1). This division was qualitatively based on available data on water chemistry, sediment characteristics, depositional environments, and habitat. The river sections include the Freshwater Section (beginning immediately downriver of the Dundee Dam), followed by the Transitional Section, and finally the Brackish Section (extending to the river mouth where it empties into Newark Bay). Note that for this document, these river sections are defined only qualitatively and generalized pending further data evaluation; hence, river miles (RM) have not been assigned to denote river section boundaries. A general description of these river sections along with Dundee Dam and Newark Bay is presented below.

2.1.1 DUNDEE DAM

The Dundee Dam (Figure 2-1) represents the upper boundary of the Lower Passaic River. The dam, which is located between Garfield and Clifton, New Jersey, is positioned at RM 17.4 (where RM 0 is defined as the mouth of the Lower Passaic River). The Dundee Dam is the limit of effective tide for the Lower Passaic River, and the water flowing over the dam is made up entirely of freshwater from upriver. Flow at the dam is currently estimated using a US Geological Society (USGS) gauging station located at Little Falls, New Jersey (approximately 12 miles upriver of the Dundee Dam) and watershed-based corrections to account for contributions between Little Falls and the Dundee Dam. Flows measured at this gauging station from 1990 to 2002 ranged from 446 cubic feet per second (cfs) to 1,802 cfs with a long-term, annual average flow of 1,121 cfs (from 1900 to 2002). Note that it is anticipated that river flow estimates at the Dundee Dam will be refined in the future using measurements recorded at a gauging station located at the dam, which is maintained by United Water and the New Jersey District Water Supply Commission.

2.1.2 FRESHWATER SECTION

The Freshwater Section (Figure 2-1) represents approximately the upper third of the Lower Passaic River where the water conditions are defined as “almost always” freshwater, or salinity values are less than 0.5 ‰ (or parts per thousand[1]). At high tide, the salt front rarely penetrates this section (occurring less than 5 percent of the tidal cycles); however, the water elevations in this section may be tidally influenced. Water and solids are preferentially transported from the Freshwater Section to the Transitional Section; additional water and solids exchange occurs with the Saddle River (RM 15.6). Sediments tend to be characterized by coarse-grained material; low sedimentation rates in this river section tend to yield relatively thin sediment beds. The Freshwater Section likely reflects a freshwater ecosystem and likely provides suitable habitat for freshwater aquatic plants (vascular and algae), macroinvertebrates, fish (bass and minnows), and wildlife species that forage on these prey types.

2.1.3 TRANSITIONAL SECTION

The Transitional Section (Figure 2-1) represents the portion of the Lower Passaic River between the Freshwater Section and Brackish Section, where the salt front typically advances under high-tide conditions (occurring greater than 80 percent of the tidal cycles). Hence, water conditions can vary from slightly brackish (*e.g.*, oligohaline with salinity values ranging from 0.5 ‰ to 5.0 ‰) to moderately brackish (*e.g.*, mesohaline with salinity values ranging from 5.0 ‰ to 18 ‰). This river section is continuously influenced by saltwater intrusion and mixing, resulting in changing water chemistry as well as flocculating and settling of dissolved organic matter and particulates. Water and solids are predominantly transported between the Transitional Section and Brackish Section due to tidal exchange. Additional exchanges occur with two major tributaries, Second River (RM 8.1) and Third River (RM 11.3). Sediment characteristics in the Transitional Section are similar to the Freshwater Section, which are dominated by coarse-grained material and relatively thin, fine-grained sediment beds. The habitat in the Transitional Section reflects a mixture of freshwater and salt-tolerant ecosystems, resulting in a high diversity of flora and fauna. This river section likely provides suitable habitat for estuarine aquatic plants (vascular and algae), macroinvertebrates (blue crab), fish (bass, shad, white perch), and wildlife species that forage on these prey types.

2.1.4 BRACKISH SECTION

The Brackish Section (Figure 2-1) represents approximately the lower third of the Lower Passaic River, where the water conditions are defined as "almost always" moderately brackish with salinity values ranging from 5.0 ‰ to 18 ‰. (For reference, ocean water has salinity values greater than 32 ‰.) At high tide, the salt front usually advances past the Brackish Section and rarely stops within this section (occurring less than 15 percent of tidal cycles). Hence, the water elevations are heavily influenced by tides. Water and solids are transported between the Transitional Section, Brackish Section, and Newark Bay due to tidal exchange. Dredging of the Lower Passaic River has created deep channels in this river section. Moreover, the lack of maintenance dredging has resulted in thick sediment beds forming in these channels, which are dominated by fine-grained material. The Brackish Section reflects a salt-tolerant ecosystem and likely provides suitable habitat for estuarine aquatic plants (vascular and algae), macroinvertebrates

[1] Salinity values are typically reported with the units of "per mil," or parts per thousand. The symbol for "per mil" is ‰. This symbolism is analogous to the percent sign (%), which reflects parts per hundred.

(polychaetes, blue mussel, blue crab), fish (white perch), and wildlife species that forage on these prey types.

2.1.5 NEWARK BAY

Newark Bay (Figure 2-1) represents the lower boundary of the Lower Passaic River with average salinity values ranging from 15 ‰ to 24 ‰, depending on the season. The bay, like the Lower Passaic River, is part of the greater Hudson-Raritan Estuary. For this reason, the bay is heavily influenced by tides. Water and solids are transported between the Brackish Section of the Lower Passaic River and Newark Bay due to tidal exchange.

2.2 POTENTIAL SOURCES OF CONTAMINATION IN THE CSM

Development of the CSM involves an examination and representation of potentially contaminated media, sources of contamination, and potential migration pathways. For this CSM, each of the three river sections described above has been further subdivided into three media: sediment, water, and air (Figure 2-1). These media interact through various natural processes and are impacted by various contamination sources. A schematic flow diagram is presented in Figure 2-2 to describe how these media and sources interact. In this figure, the different media are marked with different colors (sediment marked as brown, water marked as dark blue, and air marked as light blue), sources or inventories are denoted in boxes, and release mechanisms or fluxes are marked on the arrows connecting associated inventories. At this point, the arrow length does not reflect the magnitude of the flux, and all relevant inventories were incorporated into the figures; future iteration of the CSM will prioritize these sources and fluxes based on river section. For example, the evaporation and precipitation of water, which are depicted in the figures, may not be significant fluxes, and these fluxes may be excluded in future iterations of the CSM.

2.2.1 WATER COLUMN AND AIR INVENTORIES AND FLUXES

The water column within a given river section is impacted and influenced by several potential sources and physical mechanisms, including:

- Main-stem flow originating above the Dundee Dam.
- Tidal exchange with adjacent river sections.
- Discharge of water from tributaries.
- Discharge and runoff of water from non-point sources.
- Discharge of water from point sources, including combined sewer overflow sites (CSOs), wastewater treatment plants sites, as well as permitted and accidental industrial releases.
- Exchange between porewater and the water column from diffusion and bioturbation.
- Exchange between groundwater and the water column from discharge and seepage.
- Evaporation and precipitation of water between the atmosphere and water column as well as wet and dry atmospheric deposition and volatilizations of contaminants into the water column.

2.2.2 SEDIMENT INVENTORIES AND FLUXES

The sediment within a given river section is impacted and influenced by several potential contaminant migration pathways through the environment, including:

- Transport and deposition of solids originating above the Dundee Dam.
- Resuspension and deposition of solids due to tidal exchange with adjacent river sections.
- Resuspension and deposition of solids due to tidal flow within the section.
- Resuspension and deposition of solids from the tributaries to surface sediment.
- Discharge of solids from non-point sources, including runoff to surface sediment.
- Discharge of solids from point sources, including CSOs, wastewater treatment plant sites, as well as permitted and accidental releases, to the surface sediment.
- Burial of surficial sediment to intermediate sediment beds and deep sediment beds from sedimentation and bioturbation (note that these sediment beds will be assigned vertical boundaries in future iterations of the CSM).
- Resuspension and deposition of solids between mudflats and floodplains and the surface sediment.
- Indirect interactions with groundwater and porewater.
- Remobilization of intermediate and deep sediment beds during floods or storm events.

2.2.3 POTENTIAL SOURCES IN RIVER SECTIONS

While the schematic in Figure 2-2 illustrates how potential sources and media will interact, some sources denoted on this figure will be absent or less significant within a given river section. For this CSM, potential sources are listed for each river section (Figure 2-3). However, during future revisions of the CSM, these lists will be refined and updated to reflect the different ways that the river sections are impacted.

For example, sources that may impact the water quality of the Freshwater Section and the Transitional Section include major tributaries (*e.g.*, Saddle River, Third River, and Second River), non-point sources (*e.g.*, runoff), groundwater, and porewater. Surface sediment quality in the Freshwater Section and Transitional Section may be impacted by solids that were resuspended and transported over the Dundee Dam and from major tributaries (*e.g.*, Saddle River, Third River, and Second River), floodplains, and non-point sources (*e.g.*, transported in runoff). Meanwhile, the Brackish Section's water quality may be impacted by point sources (*e.g.*, CSOs and other industrial discharge points), groundwater, and porewater in addition to tidal exchange with Newark Bay. Sediment quality may be impacted by solids originating from intermediate or deep sediment beds, mudflats, floodplains, point sources, and Newark Bay.

2.3 FATE AND TRANSPORT

To further develop the CSM, the fate and transport of chemicals is overlaid on the schematic diagram of potential sources, which was previously shown in Figure 2-3. Chemicals move between the sediment, water column, and air through a series of reactions and pathways to achieve equilibrium (Figure 2-4). Moreover, certain chemicals have the potential to bioconcentrate in biological media. These chemicals tend to be bioavailable, hydrophobic chemicals that will partition from either the sediment or water column into biological tissue. Depending on the chemical nature of these chemicals, they may bioaccumulate in the food web, resulting in higher tissue concentrations in higher trophic level receptors.

Figure 2-4 and Figure 2-5 present a conceptual representation of the potential reactions and pathways that could affect the fate and transport of chemicals. For simplicity these fate and transport figures are not inclusive and do not include all physical mechanisms shown on Figure 2-2 and Figure 2-3 that can affect fate and transport. The abiotic reactions and pathways are presented in Figure 2-4 as black arrows; additional biological pathways are then added to this graphic and are presented in Figure 2-5 as green arrows. [Note for a complete discussion of all biological pathways refer to the Pathways Analysis Report (Battelle, 2005).] The chemical state (*i.e.*, sorbed chemical, dissolved chemical, or vapor) is denoted in the boxes, which represent inventory while mechanisms are represented by arrows connecting associated boxes as appropriate. Both figures portray general reactions and pathways that may occur in the Transitional Section of the Lower Passaic River. However, some reactions and pathways may be absent or less significant for certain chemicals and for certain river sections. Future iterations will prioritize these reactions and pathways.

In general, potential mechanisms influencing fate and transport of a given chemical in the water and air may be advection, flocculation (aggregation) or disaggregation, sorption or desorption, degradation, volatilization, and/or deposition. In the sediment, the potential mechanisms may be sorption or desorption, resuspension, degradation, and transformations. In biota, the potential mechanisms are bioconcentration and bioaccumulation. To illustrate that chemical reactions and pathways are chemical-specific, a fate and transport model was created for a hydrophobic compound (Figure 2-6). Future iterations of the CSM will develop other chemical-specific, river section-specific fate and transport figures, as appropriate.

Hydrophobic organic chemicals, such as dichlorodiphenyltrichloroethane (DDT), have a greater affinity for the sorbed phase (Figure 2-6). As a result, these hydrophobic chemicals will concentrate in the sediments (specifically the organic matter fraction of the sediment), the organic colloidal-fraction of the water column, and the lipid content of biological tissue. Microbial reactions will cause the transformation of DDT to its metabolites, dichlorodiphenyldichloroethane (DDD) and dichlorodiphenyl-dichloroethylene (DDE); however, complete microbial or chemical degradation is less common. Since DDT, as well as other hydrophobic chemicals, does not concentrate in the dissolved phase in the water column, the transport of solids will tend to have a greater impact on surface sediment concentrations than interactions with the water column. Inventories and fluxes that significantly impact the fate and transport of DDT are shown in Figure 2-6 while less significant inventories and fluxes have been deleted, relative to Figure 2-5.

2.4 UNCERTAINTIES IN THE CSM

The diagrams presented in Figures 2-1 through 2-5 represent a preliminary CSM for the Lower Passaic River. Note that the modeling framework diagram presented in the Section 1.6 of the Draft Modeling Plan (HydroQual, 2005) and the human health and ecological exposure pathways presented in Section 3.0 of the Pathways Analysis Report (Battelle, 2005) also represents components of the CSM. These auxiliary diagrams provide additional project details not included in this discussion of the CSM, such as the interconnection of mathematical models and potential human and ecological exposure pathways, routes of exposure, and receptors. Together, however, all of these diagrams represent a comprehensive CSM that will assist in the development of appropriate study questions and decisions points (step #2 of the DQO process) as well as help to determine the appropriate field sampling needs (step #3 of the DQO process).

The CSM does, however, contain uncertainties due to data gaps that exist regarding the contamination sources on the Lower Passaic River, interactions between sediment, water column, and air, and transportation of chemicals through the system. For example, limited field data exists for river miles up-estuary of RM 7; water column and hydrodynamic data are incomplete for the entire stretch of the Lower Passaic River; and the interactions between Newark Bay and the Lower Passaic River are unresolved. Impacts from time-dependent processes and how the CSM will account for these temporal processes are still uncertain. Examples of temporal processes include: effects of storm events on the Lower Passaic River, changes in sediment deposition over time, reactions that change the bioavailability of contaminants over time, or changes due to remedial action. Additional uncertainties involve the appropriate linkage of the human health and ecological exposure pathways and receptors (Battelle, 2005) to the geochemical CSM presented in this document to construct a comprehensive CSM.

To address current limitations of the CSM, data will be collected and evaluated to resolve uncertainties and associated data gaps. Moreover, as relevant data gaps are identified during the DQO process, a procedure must be established for maintaining, refining, and updating the CSM to understand site-specific conditions.

3.0 UPDATING THE CSM

3.1 MAINTAINING AND REFINING THE CSM

The current CSM is designed to be refined and updated to address uncertainties associated with data gaps. For instance, river sections can be re-defined quantitatively following the collection and evaluation of water column data, geophysical data, and ecological community survey data. A quantitative description of river section characteristics may then lead to the establishment of river mile boundaries (or boundary ranges). An evaluation of historical data may also identify dominant sources in each river section, estimate water flow between river sections, and determine the solid load transported between the Lower Passaic River and Newark Bay. An evaluation of future sediment coring data may determine the magnitude of inventories and fluxes. This information may be reflected together in an updated CSM through a series of weighted boxes and arrows with the degree of uncertainty reflected in visual shading of colors. An updated CSM can then be combined with a refined chemical/biological fate and transport model for each benchmark chemical. These chemical-specific, fate and transport models will then be adjusted for each river section accounting for dominant sources or natural processes. An integration of the information presented in the Pathways Analysis Report (Battelle, 2005) will then complete the exposure pathway from source to receptor.

To accomplish this CSM refinement, appropriate study questions, including risk hypotheses and questions aimed at evaluation of risk-based remediation, have been and will be established. Then, historical data will be evaluated and appropriate field data will be collected to address the study questions and to increase the understanding of the system. Due to the complexity of the LPRRP, future iterations of the CSM may include separate models to highlight different aspects of the project. These individual models may focus on sources, release and media, human health exposure pathways and receptors, and ecological exposure pathways and receptors. Updated versions of the CSM will be posted on the Passaic River Estuary Management Information System (PREmis; an internal database) for review by the partner agencies. Following partner agency review, CSMs may be posted on the public website (www.ourpassaic.org) for review and comment by stakeholders. Previous versions of the CSM will be archived and available via PREmis.

3.2 UPDATING THE CSM WITH HISTORICAL DATA

The CSM can be updated in several fashions using existing literature and historical data, including a geochemical data review to understand contaminant fate and transport, a geophysical data review to build confidence in the feasibility study and restoration effort, or a biological data review to assess expose pathways and receptors. Each of these literature and historical data reviews will involve development of questions to guide the review, an evaluation of historical data, and a presentation of results that leads to an updated version of the CSM.

To update the geochemical component of the CSM, a historical geochemical data evaluation is necessary to address the questions listed below. These geochemical questions build on the work and recommendations developed in the Draft Technical Memorandum: Preliminary Geochemical Evaluation (Malcolm Pirnie, 2005b). Each question below is followed by one or more evaluation tasks that are designed to address the question. Note that some tasks are listed multiple times since they address more than one geochemical question. The listed tasks should not be considered exhaustive, and additional tasks may be warranted based on the evolving findings from the stated analyses. Note that these geochemical questions are not the DQO questions listed in the Draft QAPP (Malcolm Pirnie, 2005c). These geochemical questions were designed explicitly for the evaluation of historical geochemical data. One result of this geochemical evaluation is to prioritize geochemical data gaps and quantify uncertainties.

1) **What more can be known about the fate and transport of solids in the Passaic River?**
   a) What is the long-term net amount of solids eroded / deposited within each section of the Lower Passaic River?
      i) Building on the bathymetric comparisons previously conducted (Malcolm Pirnie, 2005b), determine net gain of solids or net loss of solids over each river section and across the entire river; estimate a solids mass balance for the river.
      ii) Use radionuclide data to establish local deposition rates over the full 17-mile stretch of the Lower Passaic River.
   b) What is the impact of a major flow event on the movement of solids and contaminants downriver?
      i) Using the available lead-210 (Pb-210) data, date the discontinuities that are observed in the sediment cores – match these dates to major flooding events.
      ii) Map the location of these discontinuities.
   c) What are the dynamics of the estuarine mixing processes that can maintain relatively homogeneous concentrations in some benchmark chemicals (*e.g.*, 2,3,7,8 tetrachlorodibenzo-p-dioxin; 2,3,7,8-TCDD) while apparent concentration gradients exist for other benchmark chemicals (*e.g.*, polycyclic aromatic hydrocarbons; PAHs)?
      i) Compare the sources, locations, loadings mechanisms, and transport mechanisms of different benchmark chemicals to determine or estimate conditions that yield homogeneous mixing.

2) **What is the nature and extent of historical contamination in the Lower Passaic River?**
   a) What is the extent of contamination in the sediment beds?
      i) Continue work started in the Draft Technical Memorandum (Malcolm Pirnie, 2005b) to map the concentration of contaminants in the sediments, including polychlorinated biphenyls (PCBs) and heavy metals.
      ii) Use total DDT and Pb-210 data to infer the vertical extent of 2,3,7,8-TCDD contamination in the Lower Passaic River. Pb-210 measurements will be used to identify depositional and non-depositional environments; total DDT data

will be used to identify the depth of contamination since the peak loading of total DDT is expected to occur at greater depths than the 2,3,7,8-TCDD peak loading.

iii) Calculate the mass per unit area (MPA) for each benchmark chemical to estimate an inventory and to identify areas of concern (use of this calculation does not imply that MPA will necessarily be used or recommended as an action criterion in subsequent phases of the project).

b) What are the impacts of contaminated Passaic River surface water on adjacent or connected waterbodies within the broader study area, including Newark Bay, the Hackensack River, and the Kills?

   i) If a sufficient amount of data is available, evaluate surface water quality in the Lower Passaic River and adjacent waterbodies.

c) What is the relationship between the contaminant load in the dissolved-phase and the suspended-phase for six benchmark chemicals and one ratio (*i.e.*, Total DDT, 2,3,7,8-TCDD, Total PAHs, Total PCBs, Mercury and Lead, and the ratio of 2,3,7,8-TCDD to Total Tetra-CDD)?

   i) Compare the dissolved-phase concentration and corresponding suspended-phase concentration versus river mile; plot the ratio of the dissolved-phase to the sum of the dissolved-phase plus suspended-phase.

   ii) Identify the chemical-specific, distribution coefficient for the dissolved-phase and the suspended-phase.

   iii) Examine the relationship between the contaminant loads in the suspended-phase and the contaminant loads in surficial sediment.

3) What is the fate and transport of each benchmark chemical in the Passaic River?

a) How is the transport of solids affecting the fate and transport of benchmark chemicals?

   i) Identify a chemical fingerprint unique for Newark Bay and trace this fingerprint into the Passaic River. Possible fingerprints include DDT and metabolites, polychlorinated dibenzodioxin/furan (PCDD/F) congener ratios, and heavy metal ratios.

   ii) Incorporate findings of task 1)(a)(i).

   iii) Estimate mass of benchmark chemicals using the average surface concentrations and net gain or loss of solids.

   iv) Map the ratio of benchmark chemicals to cesium-137 (Cs-137) along the Lower Passaic River to identify sources.

   v) Examine variations in the ratio of total DDT/2,3,7,8-TCDD in previously determined erosional and depositional environments to evaluate the fate and transport of total DDT and 2,3,7,8-TCDD.

   vi) Compare benchmark metal concentrations to one another to identify those that are inversely or directly related – draw inferences regarding the fate and transport of the metals compared.

b) What ratios are characteristic of a given waterbody that can be used to fingerprint contaminant transport?

   i) Incorporate findings of task 3)(a)(i).

   ii) Use principal component analysis of PAHs and PCBs to attempt to identify source fingerprints; and examine specific ratios across the Lower Passaic River and into adjacent waterbodies to evaluate fate and transport.
c) What is the history of contamination for each benchmark chemical?
   i) Building on the bathymetric and radionuclide analyses previously conducted (Malcolm Pirnie, 2005b), examine cores from depositional areas to determine chronology and loading of additional benchmark chemicals.
   ii) Incorporate findings of task 2)(a)(ii).

4) How closely linked is the contamination in the Lower Passaic River and Newark Bay?
   a) Is the Passaic River receiving contamination from Newark Bay?
      i) Incorporate findings of task 3)(a)(i).
   b) What is the concentration gradient from the Lower Passaic River to Newark Bay?
      i) Using historical sediment data, solve algebraic equations to estimate the relative magnitude of the loading of benchmark chemicals from the Lower Passaic River to Newark Bay.

5) What are the impacts of contaminants in the Lower Passaic River on its biota?
   a) What is the impact of surficial sediment on the biota for six benchmark chemicals and one ratio (*i.e.*, Total DDT, 2,3,7,8-TCDD, Total PAHs, Total PCBs, mercury and lead, and the ratio of 2,3,7,8-TCDD to Total Tetra-CDD)?
      i) Examine the relationships between the concentrations in surficial sediment and in biological tissue.
      ii) Evaluate the bioavailability of contaminants by examining field-collected samples and laboratory-controlled toxicity tests.

3.3 UPDATING THE CSM WITH FIELD DATA

The CSM and DQO questions were established to assist in identifying important data gaps that exist in the historical data set and to guide the future field sampling efforts. [A complete listing of the DQO questions for the LPRRP is provided in Attachment 1.1 of the QAPP (Malcolm Pirnie, 2005c).] The DQOs are the foundation for the Field Sampling Plans (FSPs) Volumes 1 through 3, which are designed to collect appropriate data to satisfy the DQOs and update the CSM. Hence, all future updates of the CSM will be linked to the fundamental DQO questions, which are provided in Attachment 1.1 of the QAPP (Malcolm Pirnie, 2005c).

The CSM will be updated after the collection, validation, and evaluation of appropriate field data. It is anticipated that an update will occur following the geophysical survey, sediment sample classification, and sediment physical properties testing effort (see Figure 3-20 of FSP Volume 1; Malcolm Pirnie, 2005d); sediment coring programs (see Figure 3-21 of FSP Volume 1); and the water column sampling (see Figure 3-24 of FSP Volume 1). It is also anticipated that as data are collected and evaluated, additional investigations will be identified and conducted, resulting in further updates of the CSM.

Additional CSM updates will occur with the refinement of the human health and ecological exposure pathways diagram (Battelle, 2005) following an upcoming Passaic River Ecological Risk Assessment Workshop. As part of this CSM update, it is anticipated that food webs will be constructed for each river section and appropriate receptors will be assigned for each food web. Future iterations of the CSM will also connect the geochemical CSM and the human health and ecological exposure pathways (*e.g.*, ingestion, dermal contact, root sorption) to illustrate a complete pathway from source to receptors (*e.g.*, fisherman and piscivorous bird). Examples of how field information will feed the human health and ecological evaluations include: an examination of geochemical data to identify exposure point concentrations in sediment and surface water as well as to forecast temporal trends for contaminants; and an examination of geophysical data to identify transient areas in sediment beds and to identify where exposure is likely to occur.

4.0 SUMMARY

The CSM provides a tool for site managers and planning teams to examine the contamination problem, to determine an appropriate sampling plan, and to evaluate potential risk to human health and the ecosystem. The CSM will evolve throughout the project as historical data and field data are evaluated and as the DQOs are updated and refined.

For the Lower Passaic River CSM, the river was qualitatively divided into three river sections (Freshwater Section, Transitional Section, and Brackish Section) based on water chemistry, sediment characteristics, depositional environments, and habitat. These river sections interact with each other due to freshwater flow down river and tidal exchange. Moreover, external sources impact each river section by introducing additional water and solids. The CSM was further developed by considering reactions that move chemicals between various media of the Lower Passaic River. Typical reactions include sorption/desorption, resuspension/deposition, degradation, volatilization/deposition, and bioaccumulation.

The CSM does, however, contain uncertainties due to data gaps regarding contamination sources on the Lower Passaic River; interactions between the sediment, water column, and air media; and transportation of chemicals through the system. To address these uncertainties and associated data gaps, historical data will be evaluated and field data will be collected and evaluated. After each data evaluation, the CSM will be updated accordingly and, as is appropriate, reflect a better understanding of the processes controlling the Lower Passaic River.

5.0 ACRONYMS

‰	parts per thousand or “per mil”
cfs	cubic feet per second
Cs-137	Cesium-137
CSM	Conceptual Site Model
CSO	Combined Sewer Overflow
DDD	Dichlorodiphenyldichloroethane
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane
DQO	Data Quality Objective
FSP	Field Sampling Plan
LPRRP	Lower Passaic River Restoration Project
MPA	Mass per Area
NRDA	Natural Resource Damage Assessment
OSWER	Office of Solid Waste and Emergency Response
PAH	Polycyclic Aromatic Hydrocarbon
Pb-210	Lead-210
PCB	Polychlorinated Biphenyl
PCDD/F	Polychlorinated dibenzodioxin/furan
PREmis	Passaic River Estuary Management Information System
QAPP	Quality Assurance Project Plan
RM	River Mile
2,3,7,8-TCDD	2,3,7,8-tetrachlorodibenzodioxin
USEPA	US Environmental Protection Agency
USGS	US Geological Society

6.0 REFERENCES

Battelle, 2005. “Pathways Analysis Report.” Prepared by Battelle under contract to Malcolm Pirnie, Inc. (White Plains, NY) for the USEPA Region 2 and USACE-New York District. May 2005.

HydroQual, 2005. “Draft Modeling Plan.” Prepared by HydroQual under contract to Malcolm Pirnie, Inc. (White Plains, NY) for the USEPA Region 2 and USACE-New York District. April 2005.

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Malcolm Pirnie, 2005b. “Draft Technical Memorandum: Preliminary Geochemical Evaluation.” Prepared by Malcolm Pirnie, Inc. (White Plains, NY) for the USEPA Region 2 and USACE-New York District. April 2005.

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USEPA, 2000. “Data Quality Objective Process for Hazardous Waste Site Investigation.” Office of Environmental Information. EPA/600/R-00/007. January 2000 (Washington, DC).

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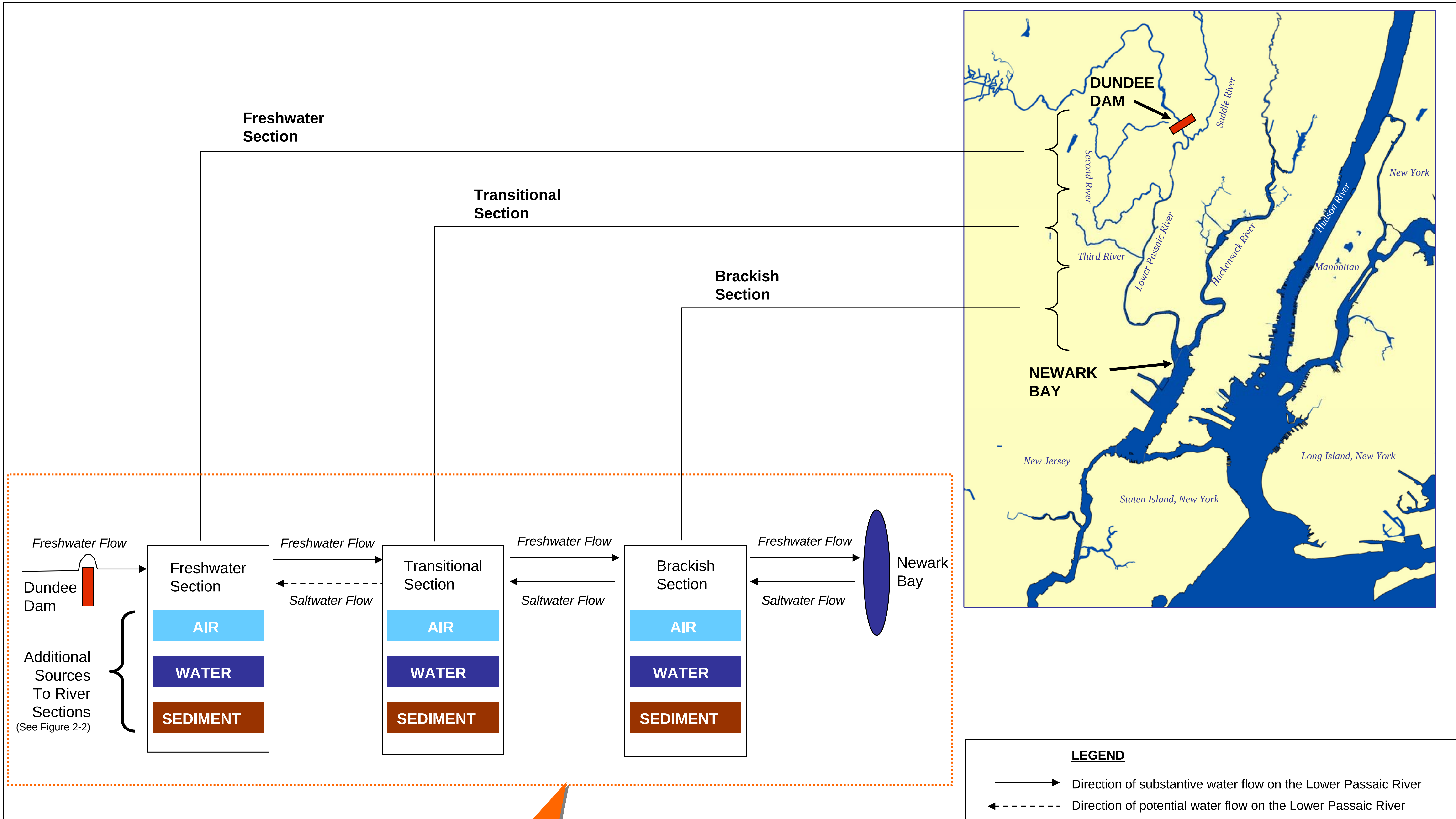

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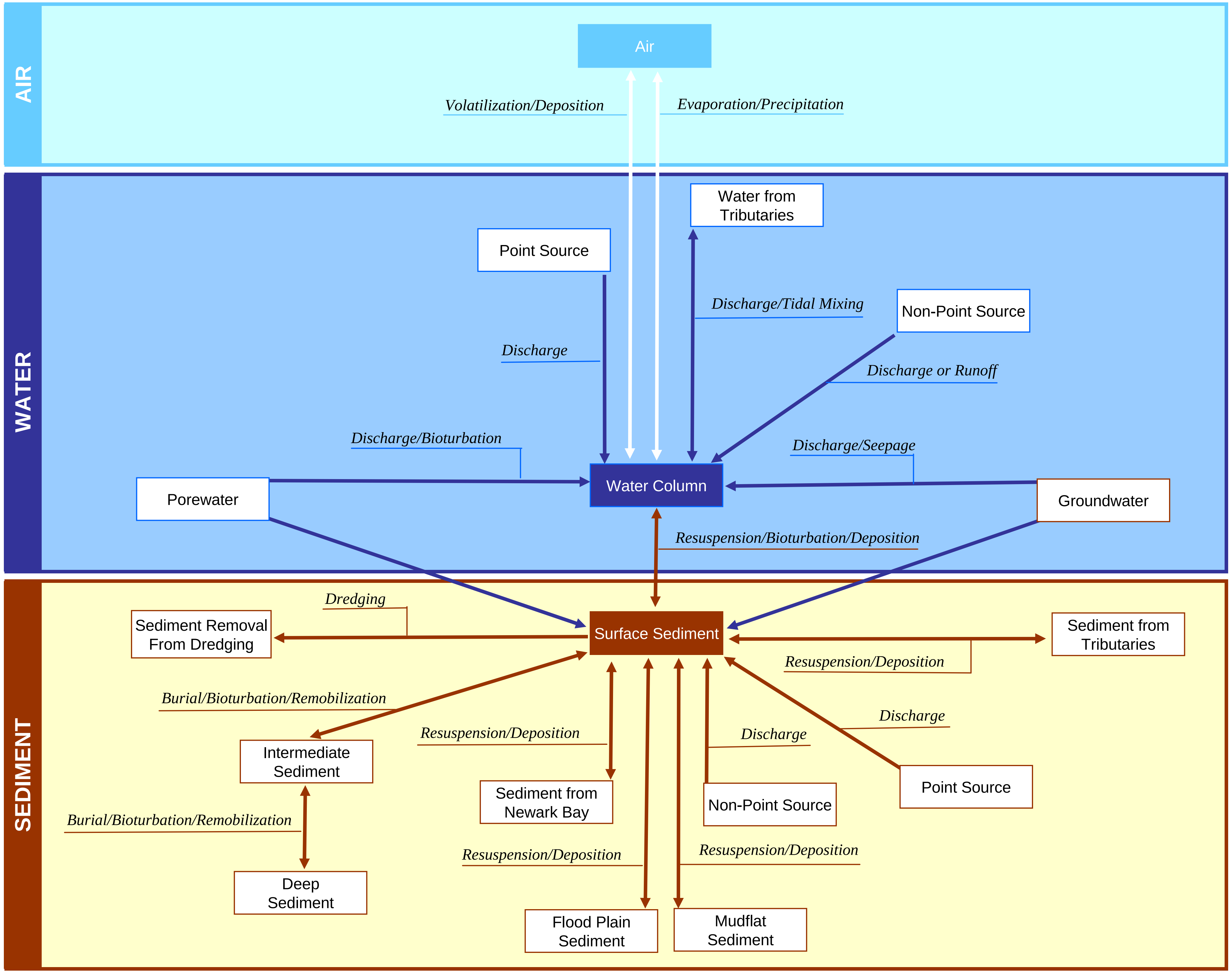
River Sections for the Lower Passaic River

Figure 2-1

Conceptual Site Model
Lower Passaic River Restoration Project

Version 2005-08-02



NOTES

Figure 2-2 is intended to depict substantive physical processes that affect the transport of contaminants between different media. Some physical processes may be less significant or absent in certain river sections. Future iterations of the CSM will prioritize these physical processes. Note that the chemical fate and transport processes are depicted in subsequent figures.

The color scheme used in Figure 2-2 reflects different media, including air (light blue), water (dark blue), and sediment (brown), and it represents the media depicted in Figure 2-1.

LEGEND

Groundwater — Sources of air, water, or sediment to the Lower Passaic River

Release mechanisms connecting associated inventories (bi-directional arrows are marked with two mechanisms separated by a slash mark)

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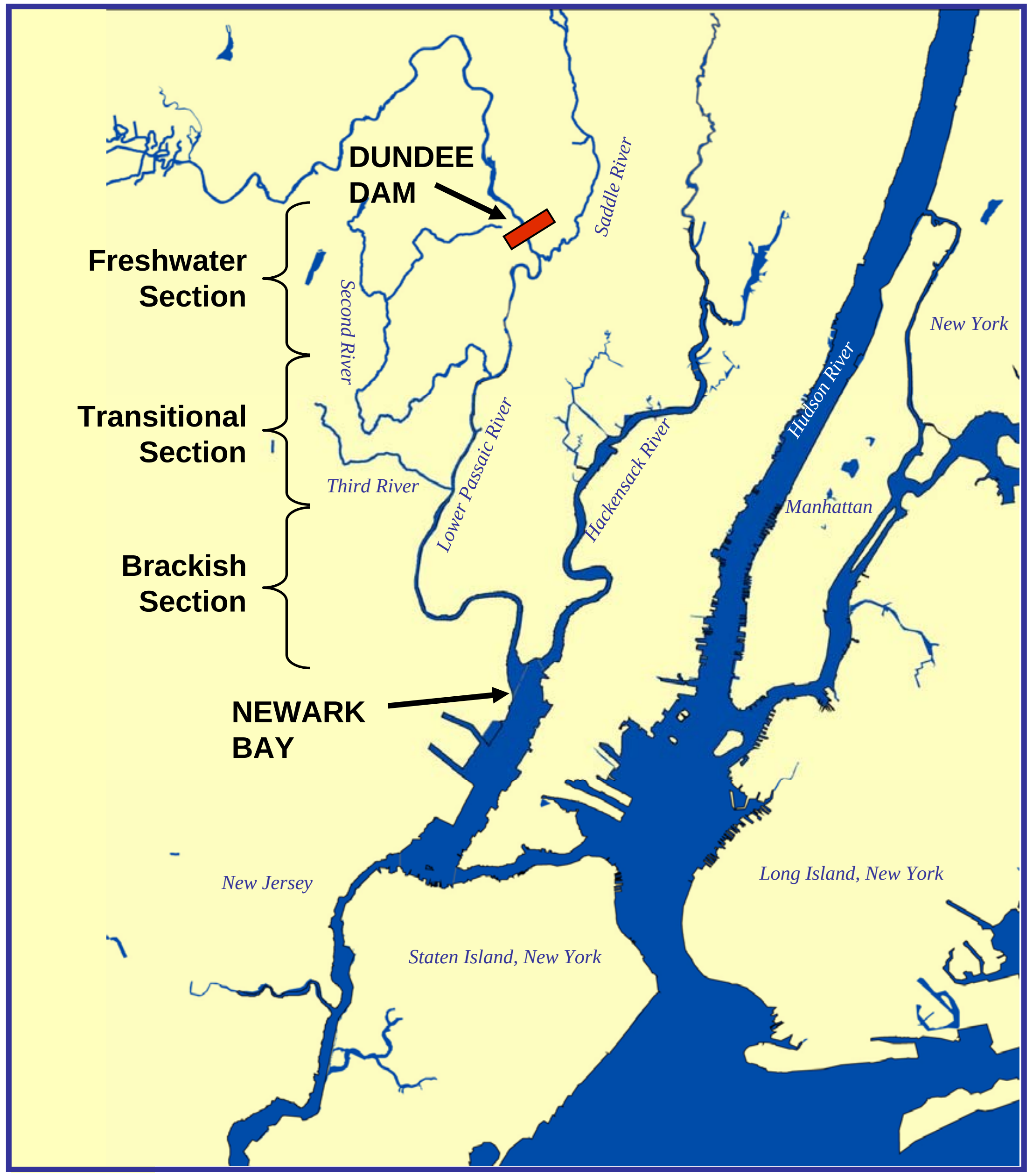
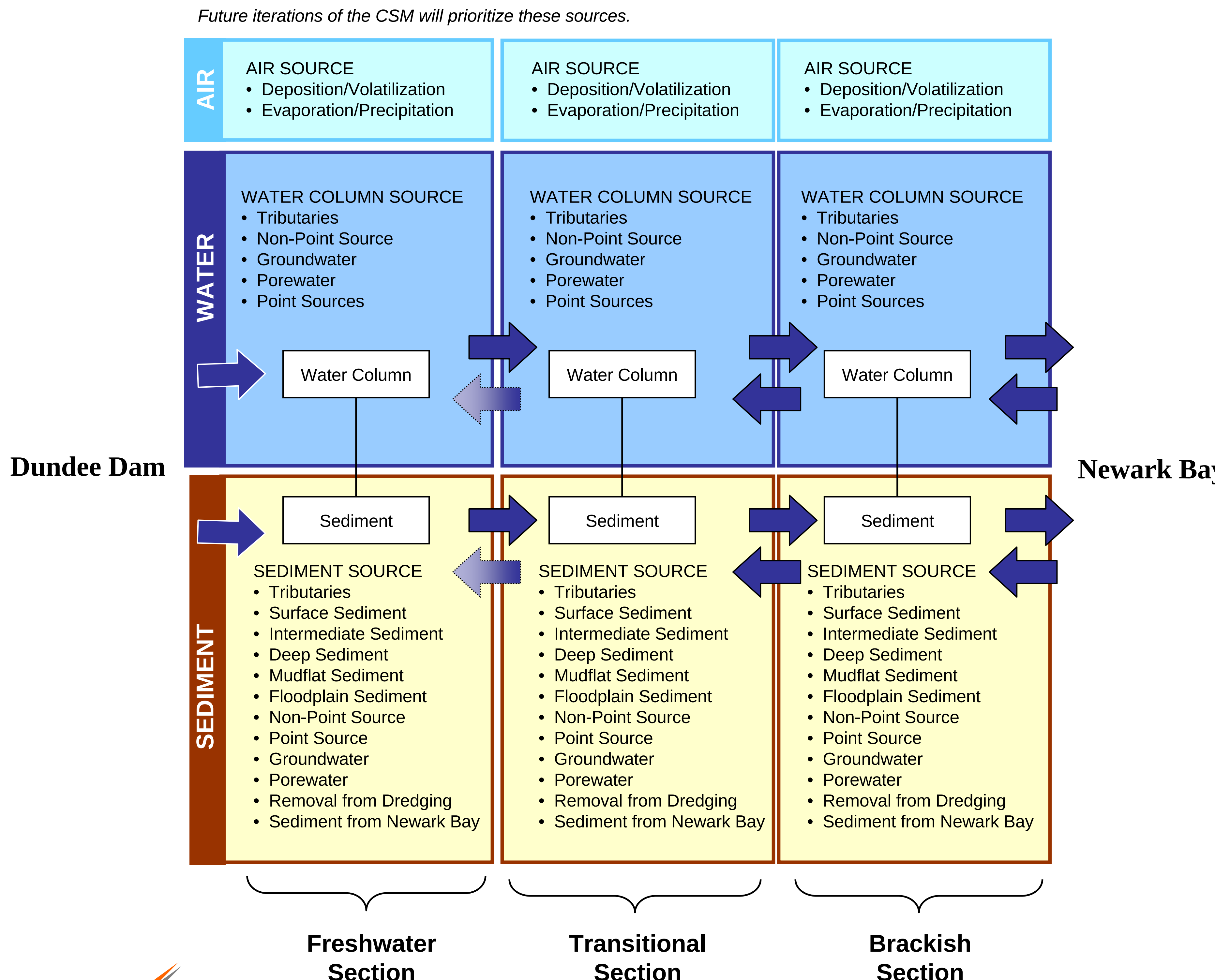
General Sources & Physical Release Mechanisms for Contaminants in Sediment, Water, and Air

Figure 2-2

Conceptual Site Model
Lower Passaic River Restoration Project

Version 2005-08-02





NOTES

Sources and processes shown in Figure 2-2 are applicable to Figure 2-3; however, for simplicity, arrows presented in Figure 2-2 are not duplicated in Figure 2-3. Note that some sources may be less significant or absent in certain river sections; future iteration of the CSM will prioritize these sources.

The color scheme and boxes used in Figure 2-3 reflect different media, including air (light blue box), water (dark blue box), and sediment (brown box), and they represent the sources, mechanisms, and media depicted in Figure 2-1 and Figure 2-2.

LEGEND

- Direction of substantive water flow and sediment transport on the Lower Passaic River
- Direction of potential water flow and sediment transport on the Lower Passaic River

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US Army Corps of Engineers

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Sources in Each River Section

Figure 2-3

Conceptual Site Model
Lower Passaic River Restoration Project

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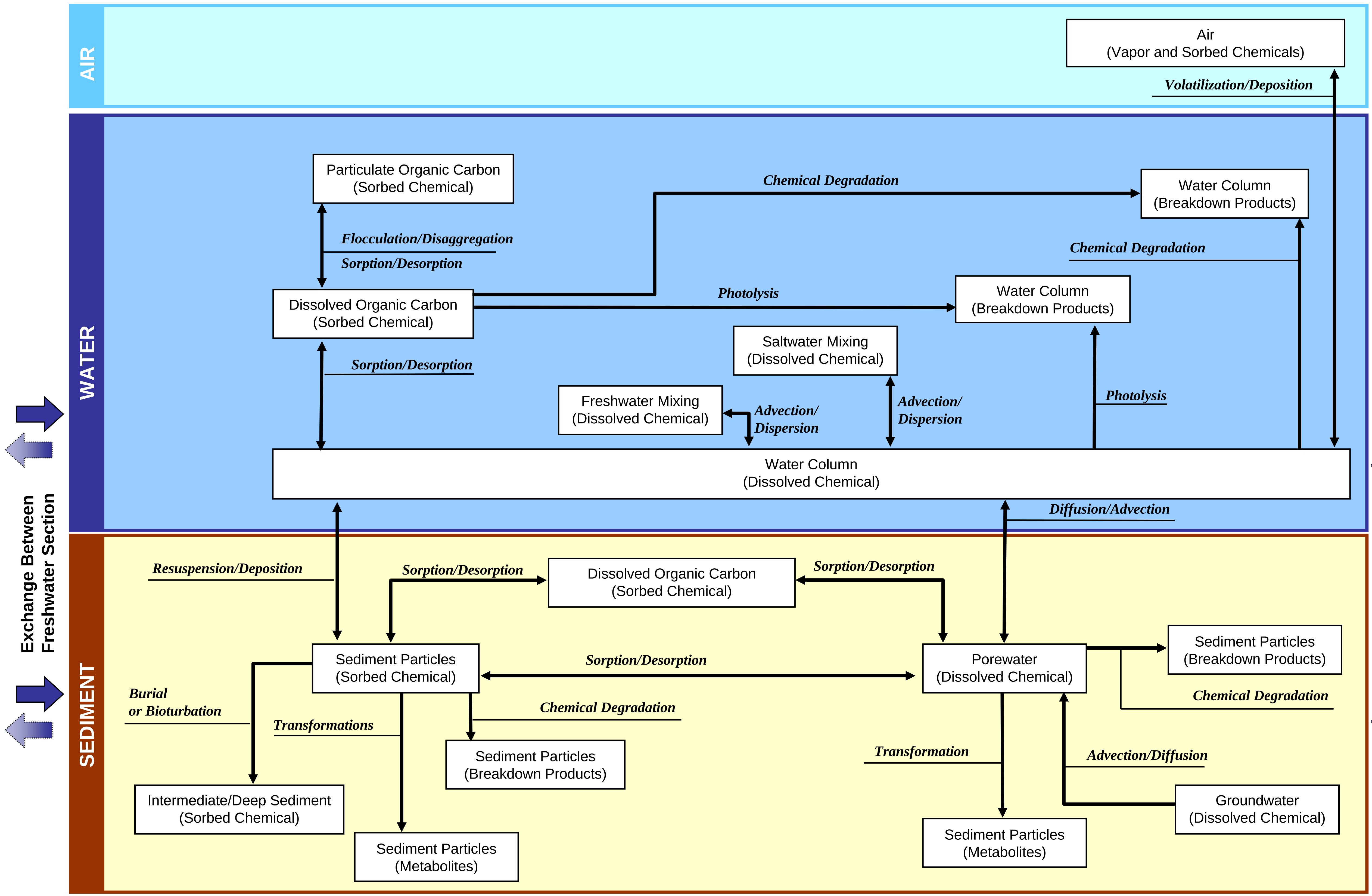

NOTES

Figure 2-4 is intended to depict substantive chemical processes that affect the transport of contaminants. Some chemical processes may be less significant or absent in certain river sections. Future iterations of the CSM will prioritize these processes. For simplicity, physical process shown on Figures 2-2 and 2-3 are not duplicated in this figure. Note that the biological processes are depicted in subsequent figures.

The color scheme and boxes used in Figure 2-4 reflect different media, including air (light blue box), water (dark blue box), and sediment (brown box), and they represent the sources, mechanisms, and media depicted in Figure 2-1 through Figure 2-3.

LEGEND for Figures 2-4 and 2-5

Inventory with chemical state marked in parentheses, where appropriate

Abiotic reactions or pathways connecting associated inventories

Biotic reactions or pathways connecting associated inventories (see Fig. 2-5)

Direction of substantive water flow and sediment transport on the Lower Passaic River

Direction of potential water flow and sediment transport on the Lower Passaic River

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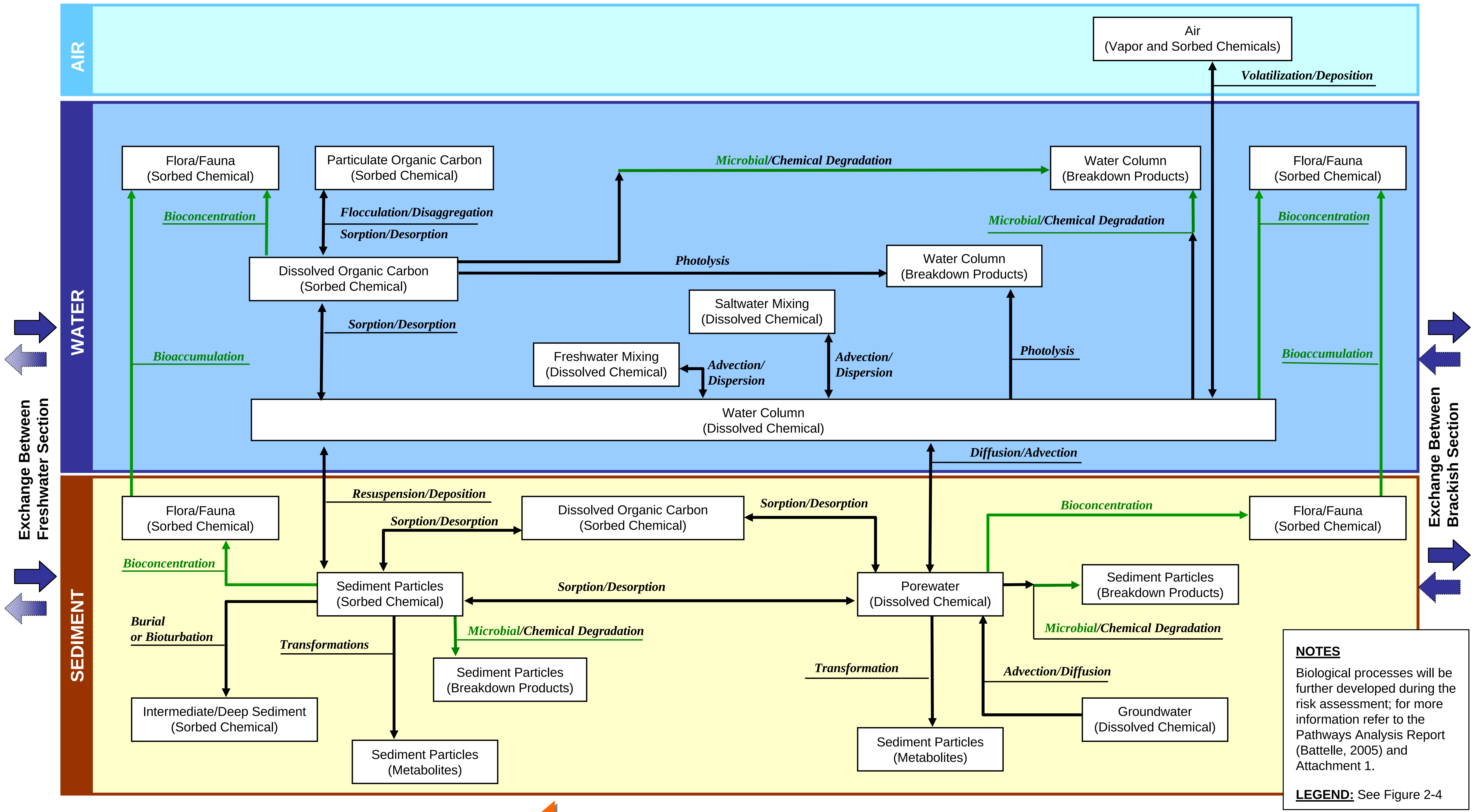
Chemical Fate and Transport Processes in Transitional Section

Figure 2-4

Conceptual Site Model
Lower Passaic River Restoration Project

Version 2005-08-02



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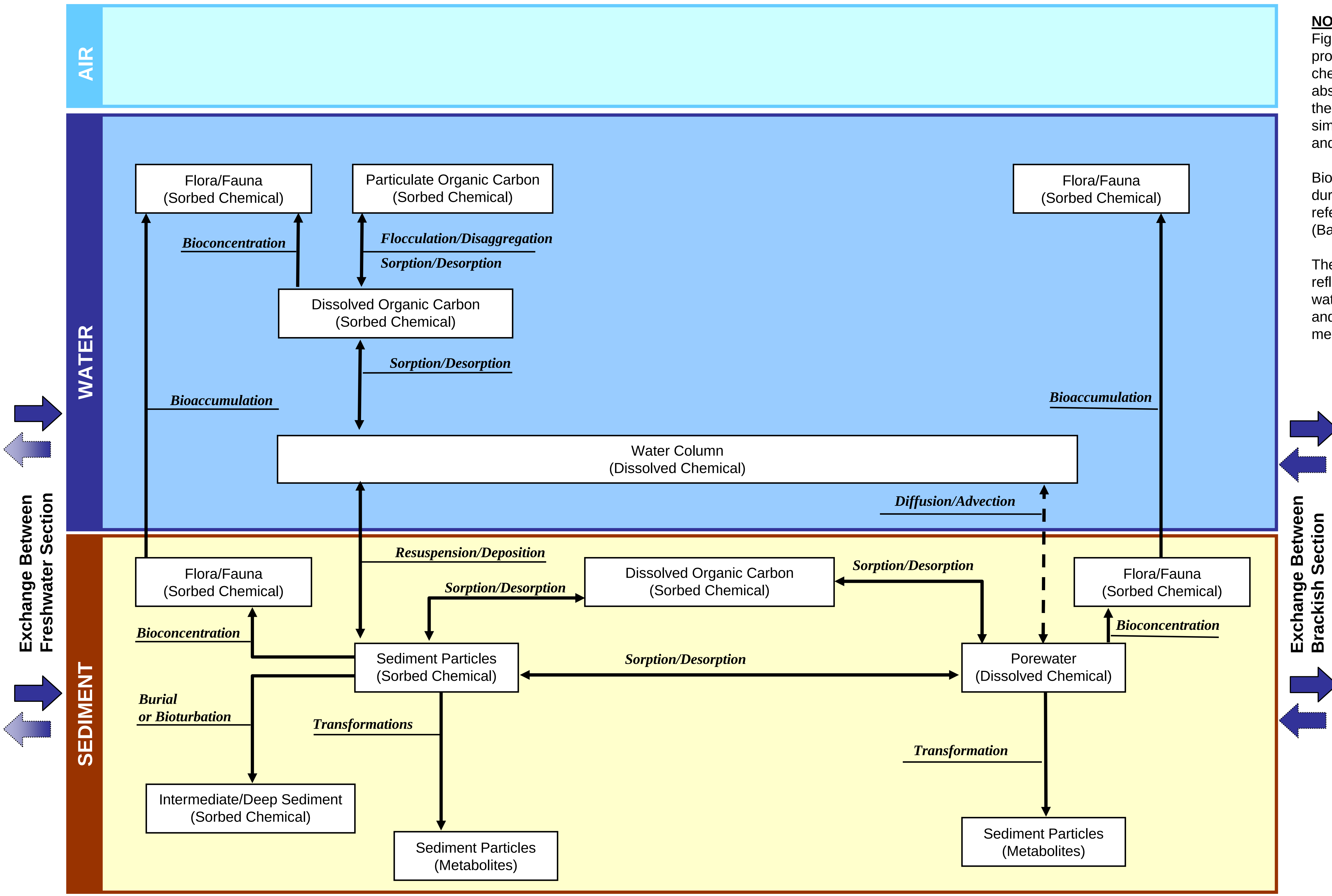
Chemical and Biological Fate and Transport Processes in Transitional Section

Figure 2-5

Conceptual Site Model
Lower Passaic River Restoration Project

Version 2005-08-02



NOTES

Figure 2-6 is intended to depict substantive processes that affect the transport of DDT. Some chemical processes may be less significant or absent in certain river sections. Future iterations of the CSM will prioritize these processes. For simplicity, physical process shown on Figures 2-2 and 2-3 are not duplicated in this figure.

Biological processes will be further developed during the risk assessment; for more information refer to the Pathways Analysis Report (Battelle, 2005) and Attachment 1.

The color scheme and boxes used in Figure 2-6 reflect different media, including air (light blue box), water (dark blue box), and sediment (brown box), and they represent the sources, mechanisms, and media depicted in Figure 2-1 through Figure 2-5

LEGEND

Inventory with chemical state marked in parentheses, where appropriate

Reactions or pathways connecting appropriate DDT inventories (bi-directional arrows are marked with two reactions or pathways separated by a slash mark)

Potential reactions or pathways that connect appropriate DDT inventories (bi-directional arrows are marked with two reactions or pathways separated by a slash mark)

Direction of substantive water flow and sediment transport on the Lower Passaic River

Direction of potential water flow and sediment transport on the Lower Passaic River

MALCOLM PIRNIE

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Human Health and
Ecological Evaluations

Chemical and Biological Fate and Transport Processes for DDT in Transitional Section

Figure 2-6

Conceptual Site Model
Lower Passaic River Restoration Project

Version 2005-08-02

Attachment 1

Battelle, 2005. “Pathways Analysis Report.” Prepared by Battelle under contract to Malcolm Pirnie, Inc. (White Plains, NY) for the USEPA Region 2 and USACE-New York District. May 2005.

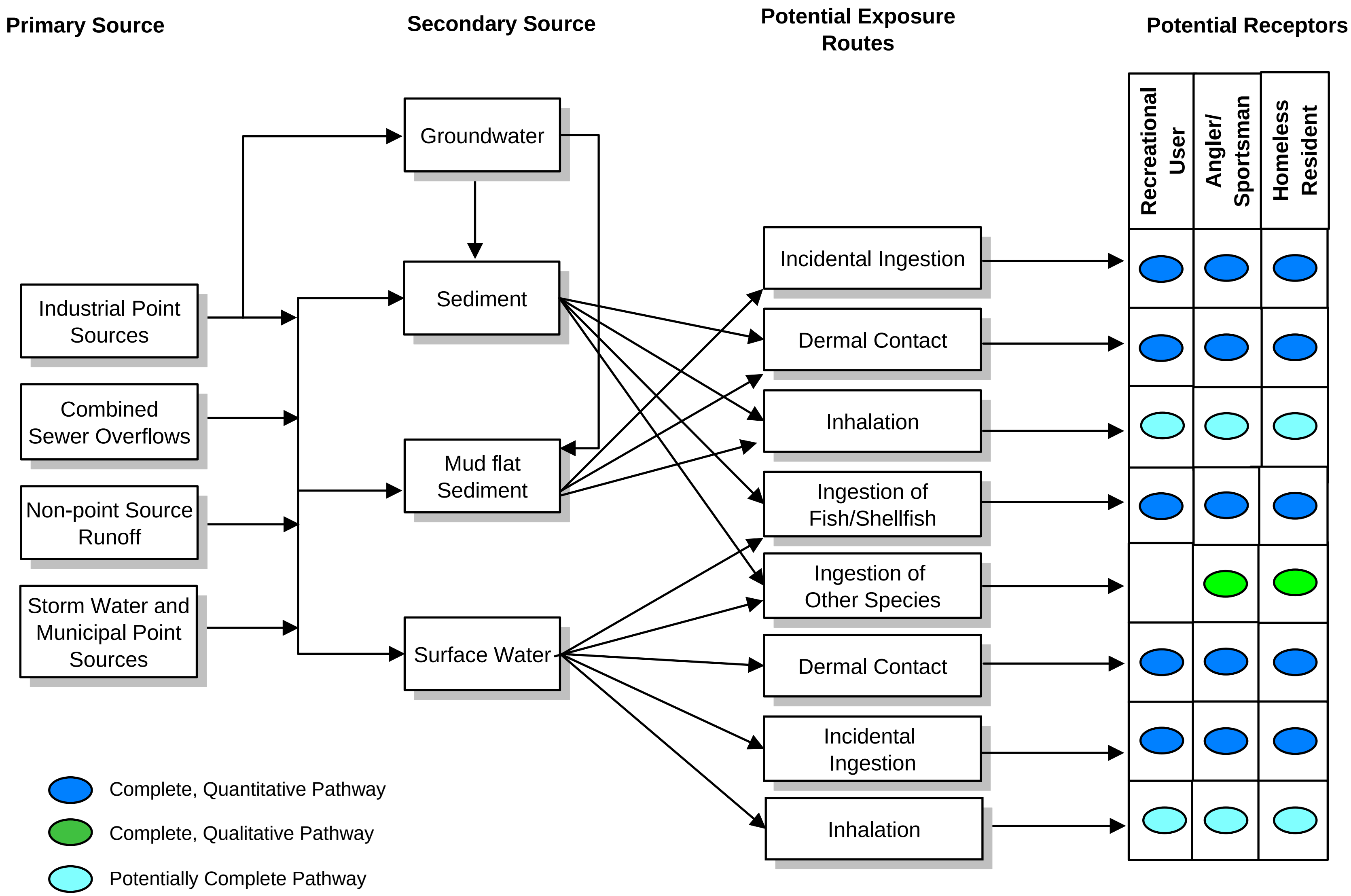

Figure 5. Human Health Conceptual Site Model.

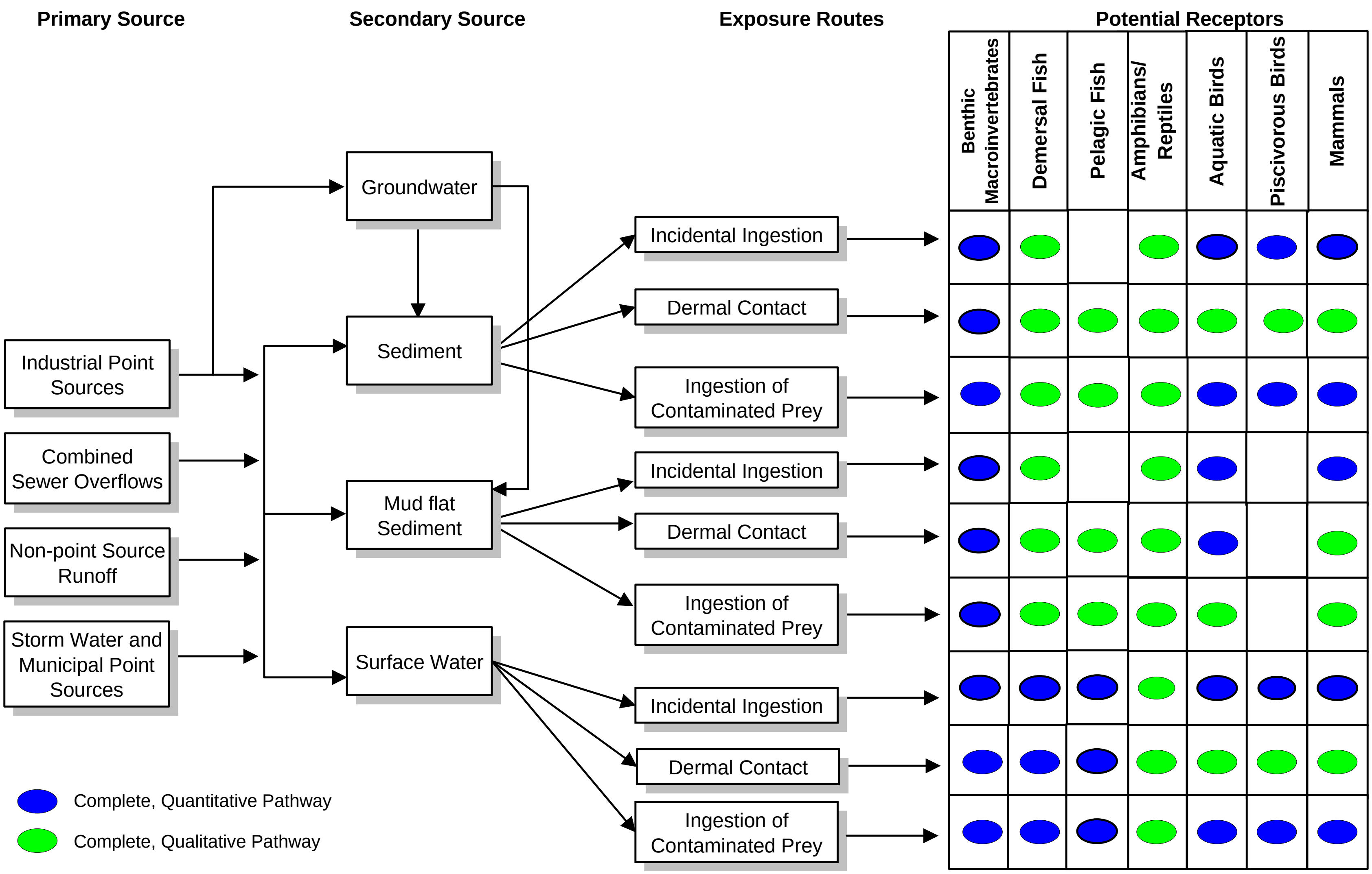

Figure 6. Ecological Conceptual Site Model.