1 Conceptual Site Model

Appendix A

A conceptual site model (CSM) is a basic description of how contaminants enter a system, how they are transported around within the system, and where routes of exposure to organisms and humans occur. As such, it provides an essential framework for assessing risks from contaminants, developing remedial strategies, determining source control requirements, and how to address unacceptable risks.

Some of the key dynamics required to develop a CSM are those that determine contaminant behavior, migration, and fate. These include parameters such as the location and form of contaminant inputs; hydrodynamics and transport factors; degradation rates; contaminant sinks; and mechanisms of exposure and uptake by ecological and human receptors. Because of the complex interplay between the biological and physicochemical compartments of an ecosystem, CSM models, which attempt to address every nuance and answer every scientific question, can become quite complex. On the other hand, a CSM can relay on reasonable assumptions to arrive at more simplified models. More generic results may be associated with broader uncertainties though. Either way, CSMs are a tool to support management decisions, and the issues, constraints, and requirements associated with the management decision ultimately determine the appropriate depth and breadth of the CSM.

Development of the CSM can also help identify key additional data needs. When quantitative CSM models are developed and calibrated (such as the Tidal Anacostia Model/Water quality Analysis Simulation Program, or TAM/WASP model), they can also provide predictive capability that allows evaluation of various remedial options.

The Phase I report introduced and addressed various CSM components for the Anacostia River, which helped guide the identification data gaps for Phase II. This report refines the CSM using available data from Phase II and other sources, and identifies data that are not yet available for incorporation into the CSM. The scope for this CSM, and the focus for most of the fate, transport, and exposure evaluations, is the lower, tidally influenced portion of the river (as opposed to the entire watershed) because it acts as a sink for sediment and contaminants generated within the watershed.

1.1 Overview of Dynamics

Figure 1 represents a generalized diagram of the dynamic processes for an urban river that affect contaminant fate. The primary routes for contaminants to enter any reach of the river are through surface water inputs (in dissolved and/or suspended particulate form), ground water, or through sediment transport into that reach from another portion of the river. There may be several types of surface water inputs: either movement within the river from adjacent reaches (up- or down-stream in the case of the Anacostia) or direct inputs to that reach from outside sources. Inputs from outside the system may include stormwater outfalls, CSOs, wastewater treatment plants, permitted discharge facilities, other non-permitted waste sources (e.g., CERCLIS sites, leaking USTs, landfills), plus tributaries. Tributaries, like stormwater outfalls, can act as collection

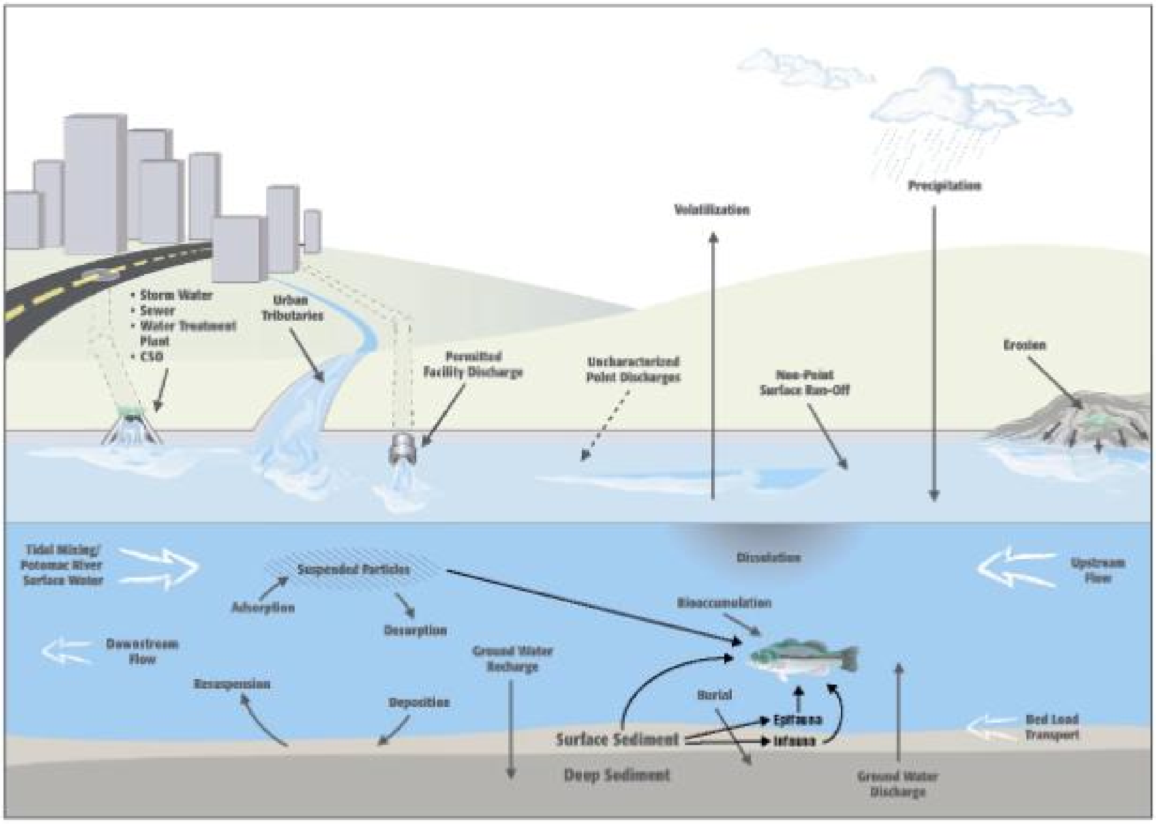

Figure 1: Schematic Representation of the Conceptual Site Model for the Anacostia River showing potential routes for contaminant mobility and fate

systems with single point of entry or discharge into that river reach. Other potential, secondary source routes for contaminants may include groundwater input and aerial deposition.

Once within the system, contaminants are transported in surface water according to specific hydrodynamic processes which include tidal movement; river flow and circulation; and dispersion. Important sediment fate and transport processes in the river are bed load transport or deposition, sediment burial, and resuspension of sediment into the water column.

In the case of the Anacostia, the overall outcome from all these process has been altered on occasion through the dredging activities. The navigation channel of the lower river has not been dredged in over 15 years, but had been maintained by the US Army Corps of Engineers (USACE) previously. The private marina at Bladensburg is reported to have dredged sand deposited from the NE and NW Branches on an annual basis to maintain accessibility. During 2000, the USACE dredged various locations of the upper river to obtain material for wetland creation in Kingman Lake. The hydraulic dredging, as well as the disposal, had obvious, visual impacts to water quality at the time. How these various dredging operations have affecting the distribution and transport of contaminants is not entirely understood, but it is acknowledged that some re-distribution would occur.

Information necessary to complete a contaminant flux or mass balance component of a conceptual model requires locations of potential water and sediment inputs, together with contaminant loadings from each of those source areas, plus the major transport factors. Obtaining information was the subject of some Phase II activities, but still remains incomplete.

Other important processes for contaminant fate and transport may include sorption and desorption onto sediment and particulates, bioturbation of surface sediment, diffusion and advection from sediment porewater into the water column, volatilization, and anaerobic decay. Site-specific information has not been collected for this latter group of processes within the Anacostia River.

Understanding human and ecological exposure pathways is an important component of any CSM. Ultimately, exposure routes to, and uptake by biota (including humans), is of principal concern. Bioaccumulation through the food web is a significant exposure route for many organic contaminants of concern for the Anacostia. The screening level risk assessment indicated that the primary pathway for human exposure is from ingestion of contaminated fish, although other pathways may be present as identified in the Phase I report. The primary ecological receptors at risk within the river are benthic organisms and fish. Benthic organisms may be exposed from direct contact with sediment and water or ingestion of particulates. Fish may be exposed from direct contact with sediment and water plus bioaccumulation of contaminants through the food chain. Site-specific studies describing the food web and bioaccumulation of contaminants (Doelling Brown et al. 2001) have been incorporated into the Phase 1 baseline risk assessment.

1.2 Updated Information for the CSM

This section summarizes information about the key CSM processes, with an emphasis on new data available from the Phase II investigations. In addition to data from field investigations, Phase II activities included updating TAM/WASP mass balance model to estimate fluxes of metals and sediment into the tidally influenced Anacostia River based upon models of hydrodynamic and sediment transport processes presents a list of Phase II field investigations and their status, and identifies which data are being used for development, validation and calibration of the mass balance model.

1.2.1 Contaminant Inputs

The primary sources of contaminants into the tidally influenced Anacostia River is through water or sediment flux into the system from tributaries, groundwater, storm drains, CSOs, direct surface runoff, or facility discharge. Contaminants may also enter the river from atmospheric deposition, but only limited data are available to evaluate this mode of transport and suggest that it is not significant (Velinsky personal communication 2000). Sources of contaminants may include non-point sources such as flushing of widespread surface contamination from impervious surfaces into storm drains after rainfall, and point sources such as outfalls, hazardous waste sites or permitted facility discharges. Total contaminant loads into the tidally influenced Anacostia River can be estimated by measuring both contaminant concentrations and total flows at points of entry into the river. These data can be used to determine if there are some areas with higher mass flux loads than others, which could then be targeted for implementing remedial source control measures or further investigations.

1.2.1.1 Tributaries

The two major tributaries to the Anacostia River are the Northwest and Northeast Branches. Together these streams drain 334 km^2, or 73 % of the area within the Anacostia River watershed. Numerous tributaries feed into each of these branches. Sligo Creek is the primary subwatershed entering the Northwest Branch. The primary tributaries entering the Northeast Branch are Paint Branch, Little Paint Branch, Indian Creek, and Beaverdam.

Lower Beaverdam Creek and Watts Branch are the two next largest tributaries to the tidally influenced portion of the Anacostia River following the NW and NE Branches. Drainage to the remainder of the tidally influenced river is controlled by streams whose final reaches are generally enclosed in storm sewer systems, such as Hickey Run, Pope Branch, Fort Dupont Creek, Stickfoot Creek, etc., by combined storm and sanitary sewers, or storm sewers.

USGS gauging stations are located on the NW and NE Branches. The long-term annual mean daily flows at the NW and NE Branch gauging stations are 1.4 and 2.4 m^3/sec, respectively (ICPRB 1997). There is also a gauging station on Watts Branch, with an average annual mean daily flow of 0.13 m^3/s measured from 1993 to 1999 (USGS 2001).

A monitoring project was conducted in 1995-1996 to sample water at the USGS gauging stations on the NW and NE Branches and estimate the total mass loads of contaminants entering the tidally influenced Anacostia River (ICPRB 1997). Both storm and non-storm flow samples were collected throughout the seasons. Concentrations of metals were generally higher in the NW Branch than in the NE Branch, but since NW flows were lower, total mass loading of metals was similar between watersheds. Overall flow-weighted mean concentrations of total PAHs at both the NW and NE branches were 6.4 and 2.6 mg/L respectively, with 40% higher total loads from the NW Branch. Concentrations of PCBs were measured at 21 and 60 ng/L in the NW and NE Branches, respectively. Total loading of PCBs was substantially (about 5 times) higher in the NE Branch. Among the hexa- through nonachlor congeners, there appeared to be a slight shift to a higher degree of chlorination in particulate and total NW Branch flow-weighted mean concentrations.

Metals and PAHs were primarily associated with the particulate fraction, whereas PCB concentrations were higher in the dissolved than particulate fraction. The data from this study indicate that a significant amount of contaminants enter the tidally influenced Anacostia River from the NW and NE Branches, especially in particulate form, and that the movement of suspended particulate matter from the upper river is likely an important transport mechanism (ICPRB 1997).

The ICPRB calculated representative TSS concentrations for base and storm flows based on available monitoring data (ICPRB 2000). Base and storm flow for the NW Branch were 5 and 310 mg/L, respectively. Base and storm flow for the NE Branch were 7 and 527 mg/L, respectively.

Other tributaries are known to contribute contaminants to the Anacostia. For instance, point sources of hydrocarbons are present in Hickey Run, which has a history of chronic and episodic petroleum hydrocarbon pollution, which then discharges to the Anacostia. As many as 42 potential “hot-spots” have been identified along Hickey Run, most of which are related to transportation activities. An effort is currently being implemented by the District government and the MWCOG to trace the source of the hydrocarbon problem (MWCOG 1997). A preliminary sampling of sediments from subwatersheds by AWTA confirmed the presence of PAHs in Hickey Run.

Stormwater and CSOs

There are no combined sewers discharging into the NW or NE Branches. However, there are approximately 30 storm sewers and 17 combined sewers discharging directly into the tidally influenced Anacostia River (MWCOG 1997). MWCOG estimates that these sewers drain an area of approximately 14 km^2, or approximately three (3) % of the total Anacostia River watershed (MWCOG 1997). Geographical analysis indicates that over half of the CSO drainage area lies within the Anacostia watershed, doubling the figure to six (6) %. ICPRB estimates the area coverage at just over 6 % and the flow contribution at just over 4 % (Schultz 2001). Regardless of the exact coverage or flow, both area extent and flow can be poor indicators of contaminant influence since they do not account for the amount of impervious surface, potential contaminant sources, and so on. Combined sewers discharge into the river even after moderate storm events, with 24-hr precipitation as low as 0.27 inches producing overflow events (TAM/WASP model).

A model constructed by the DC Water and Sewer Authority (WASA) predicted that in 1990 the total volume of water discharged from CSOs and straight storm water sewers was 7,492 million gallons, or an average discharge rate of 1.2 m^3/s. Over 93 % of the CSO flow volume was contributed by the two CSO systems at Main and O Street and Northeast Boundary. More than half of that total flow went through a swirl concentrator at the Northeast Boundary Facility. That facility, however, is not currently at full capacity due to disrepair.

Velinsky et al. (1999) collected water samples in the Anacostia River before and after storm events to determine the effects of stormwater runoff on ambient water concentrations of trace metals and PCBs. Concentrations of many trace metals increased after storm events, with the most substantial increases occurring after rainfall greater than 0.6 inches over a 24-hr period. PCBs increased from pre- to post-storm events, but not as consistently as trace elements, nor were the increases as great. It was not possible from this study to determine which storm drain areas or subwatersheds were causing the greatest inputs of contaminants.

A planned Phase II investigation by MWCOG will collect storm water effluent to calculate total loads of contaminants entering the Anacostia River from four locations in the District of Columbia. Base flow samples will be collected on a bi-weekly basis for three months, and storm water samples will be collected at a minimum of three and a maximum of five storms at each station. In addition to the four locations sampled for a comprehensive load assessment, six locations will be monitored once during base flow conditions and for one storm event. During each monitored storm, three samples will be collected at each station, representing the rising limb, peak discharge, and falling limb of the storm hydrograph. It is important to sample the first flush of a storm water event, because the initial pulse of water may contain higher concentrations of contaminants that have accumulated on surface areas during dry periods.

1.2.1.2 Wastewater Treatment Plants, Permitted and Non-permitted Facilities, Other Point Sources

There are 30 municipal and industrial facilities in the Anacostia watershed holding NPDES permits (MWCOG 1997). Specific data on flow or contaminant inputs from these sources were not reviewed by MWCOG. However, pollutant loads from permitted facility discharges were estimated using the waste stream characterizations reported by the facilities. The combined loadings from all the permitted facilities in the area is estimated to account for less than 0.1 % of the annual totals for lead, zinc, and TSS estimated based on land use (MWCOG 1997). There is considerable uncertainty inherent in this approach, and recent modeling efforts and sediment data suggest further characterization is necessary

There are three facilities within the watershed - Beltsville Agricultural Research Center, White Oak Naval Surface Warfare Center, and the Washington Navy Yard- identified as National Priority List sites under CERCLA. Additionally, as of 1996, approximately 50 sites in the Anacostia River watershed had been or were being investigated under CERCLA. Many of those required no further action or were delisted for Brownfield development at that time. These sites include landfills, leaky storage tanks, maintenance facilities, etc. The potential contribution of contaminants from these waste sites to the Anacostia River has not been determined. Other potential sites are currently being investigated as well.

1.2.1.3 Groundwater

Groundwater flow into the river has been previously described in an investigation by the District of Columbia Environmental Health Administration (Logan 1999). This study used a broad-scale, three-dimensional computer model to simulate steady state or transient groundwater flow. The model used available information on water level, geology, topography, local precipitation, streamflow, and discharge. Hydraulic conductivity values were calibrated by the model. The model calculated direct flux of groundwater to the Anacostia River through adjoining wetlands or seepage at approximately 4.0 x 10^6 m^3/yr, compared to groundwater input to tributary stream base flow of 4.8 x 10^6 m^3/yr. These calculations suggest that over half, about 55 %, of the groundwater flux is indirect through tributary base flow and the other 45 % enters through the riverbed or adjoining wetlands. In comparison, average base flows from the NE and NW branches are 1.2 x 10^8 m^3/yr or approximately 93% of the base flow at the mouth of the Anacostia River.

Phase II Seepage Investigation

The Phase II seepage investigation (Chadwick 2001) quantified specific groundwater discharge rates into the Anacostia River at six locations using two types of seepage sampling methods. Discharge rates ranged from 1.4 to 21.3 cm/day, and in general were considered quite low in comparison to values measured in other regions of the U.S. using the same methods. Flux did appear to be related to the local grain size though. Consequently, it should be noted that these rates are highly site-specific and were calculated for only six locations. Discharge rates may be highly variable among locations in the river due to sand lenses and potential fractures in the clay units that may affect hydraulic permeability.

PAH concentrations were also measured in the groundwater samples collected for the Phase II seepage and porewater investigation (Chadwick 2001). The PAH concentrations and discharge rates were used to calculate potential SPAH flux rates into the river at each of the six sites. The highest values for the sum of (S) PAH concentration (270 mg/L) and potential SPAH flux rate (378 ng/cm^2/day) were measured at the Washington Gas site. A site near the National Arboretum was ranked second of the six sites for PAH migration to the river with a SPAH porewater concentration of 2,850 ng/L and potential flux rate of 22.2 ng/cm^2/day.

1.2.1.4 Modeled Inputs

As part of Phase II, a previously developed modeling framework is being updated to model inputs and transport of metals and sediment in the tidally influenced Anacostia River. This TAM/WASP model includes components from the Tidal Anacostia Model (TAM) to represent hydrodynamics and EPA's Water Quality Analysis Simulation Program (WASP) model to represent sediment transport (ICPRB 2000; Schultz, personal communication 2001). Water flows into the river were based on USGS daily inflow data for the NW and NE Branches, and estimated, based on National Airport daily precipitation data, for Lower Beaverdam Creek, Watts Branch, CSOs, separate sewers, and minor tributaries. The average total annual discharge to the tidally influenced Anacostia River for a three-year model run from 1988-90, a time period with typical hydrology, was estimated at 190 x 10^6 m^3 (Schultz personal communication 2001). The relative contributions to the total inflow are as follows: NE and NW Branches – 71%, Lower Beaverdam Creek – 12%, Watts Branch – 3%, minor tributaries and storm sewers in tidally influenced sub-basin – 11%, and District of Columbia CSOs – 3%.

Model results for total loads of metals and TSS are not yet finalized, and modeling of organic contaminants has not yet been initiated. Results from Phase II storm water sampling by MWCOG will provide better data than are currently available for inputs of contaminant loads from storm drains into the tidally influenced Anacostia. Given the large watershed area drained by the NE and NW Branches, those tributaries are likely to contribute the greatest total loads of contaminants and particulate matter. Results from models can be used to determine which subwatersheds are contributing the greatest loads relative to the amount of land drained. Information on relative loading of contaminants and particulates from various sources will help in determining if certain areas should be targeted for source control.

1.2.2 Contaminant Fate and Transport

Once contaminants enter the Anacostia River, their fate and transport in the water column is controlled by the residence time and movement of water in the river (i.e., flushing time and tidal mixing), partitioning of metals and organic compounds to particles, and residence time of suspended particulate matter in the river. Contaminants bound to particles may settle out and deposit on the river bottom. Bottom sediments are subject to resuspension, bed load transport, or burial. This section describes current knowledge of these fate and transport processes in the Anacostia River.

1.2.2.1 Hydrodynamics

Flow in the tidally influenced Anacostia River is heavily influenced by tides and behaves much like a tidally influenced lake, with 3-foot tidal fluctuations (Scatena 1986). In dry-weather conditions, the Anacostia River flow is primarily driven by tidal currents, whereas during storms, the river contains a unidirectional, downstream flow (Scatena 1986). The average tidal prism, or volume of water exchanged during a tidal cycle, was estimated at roughly 20 % of the river volume reported by Scatena (1986), while the average inflow over a comparable 12-hour time period was only one (1) % of the river volume. Mixing and flushing of contaminants within the water column are therefore expected to be heavily influenced by the tides. River flushing values were updated during Phase II and are presented in the following section.

Phase II Hydrodynamic Data

A Phase II investigation by SPAWAR (Katz et al. 2001) characterized the river's bathymetry, tidal mixing, current velocities, and flushing time. The tidally influenced Anacostia River is generally one to two meters deep from Bladensburg to about the 12th Street Bridge, and three to six meters deep from the 12th Street Bridge to the river mouth.

As expected, water flow in the river was found to be dominated by tides. Water levels changed as a standing tidal wave, meaning that water levels rose and fell nearly simultaneously throughout the entire river. Current velocities were primarily directed along the axis of the channel and were relatively homogeneous throughout the water column. Maximum current velocities along the length of the river were 30 cm/s in the vicinity of the Railroad Bridge. In contrast, the maximum flow in the lower river at the South Capitol Street Bridge and in the upper river at the New York Avenue Bridge was only 10 cm/s. These variations in current velocity result from changes in the river's cross-section and from a decrease in the tidal prism volume towards the head of the river. The cross section of the river is greatest near the South Capitol Street Bridge where the lowest maximum velocity was measured.

The net flow at the river mouth was calculated at 4.9 m^3/s during a cross-section survey conducted over one full tidal cycle in July 2000, compared to an average inflow of 3.1 m^3/s at the NE and NW Branches for the same time period. The difference in flow between the two points indication that there was an additional 37 % discharge to the river coming from non-gauged flows, the source of which includes storm water sheet flow, CSOs, or groundwater. The water column was found to be generally well-mixed at the time of sampling, with little horizontal or vertical variation observed in the dissolved oxygen, conductivity, et cetera, although there was evidence of some vertical stratification in the lower river after a storm event.

The flushing time of the river was modeled separately using two types of water exchange mechanisms; tidal prism volume and inflow at the riverhead. The tidal prism model estimated the flushing time of the river to be 23 days, and the river inflow model estimated a flushing time of 28 days. A previous estimate of a 35-day flushing time (Scatena, 1986) was considered to differ because of the estimate of river volume. Another previous estimate calculated by MWCOG of 100 to 110 days under extremely low flow conditions was considered inaccurate, because even under zero flow conditions, tidal flows would effectively flush the river in about 23 days (Katz et al. 2001).

The highest concentrations of TSS measured in surface water (20 to 33 mg/L) by SPAWAR (Katz et al. 2001) in July 2000 were in the middle portion of the river between the top of Kingman Lake and the CSX Railroad bridge. The source of elevated TSS in this area of the river may be related to the highest flow velocities and shallowest depths, causing resuspension of sediment. Velinsky et al. (1999) found similar results during a series of monitoring events with TSS concentrations generally highest in the middle portion of the river near the CSX Railroad Bridge. TSS concentrations varied with tide height in July 2000 (Chadwick 2000). A decrease in TSS concentrations at high tide, slack water suggests that some of the material may be depositing out at these low flow conditions (Katz et al. 2001).

1.2.2.2 Sediment Transport

Sediment Trend Analysis

As part of Phase II, a sediment trend analysis was conducted in the tidally influenced Anacostia River by using data on sediment grain size to determine areas of erosion, stability, and deposition (GeoSea Consulting, Ltd. 2001). The technique to determine the sediment transport regime uses the relative changes in grain size distributions of the bottom sediments. The theory is described in detail by GeoSea Consulting, Ltd. (2001). Four basic sediment environments are most commonly encountered using this methodology. In the Dynamic Equilibrium environment, sediment is being both deposited and transported, and there is a grain-by-grain replacement along the sediment path. In Net Accretion, more grains are deposited along the transport path than are eroded, so the bed is mobile but accreting. In Net Erosion, sediment coarsens and more grains are eroded than deposited. In Total Deposition the bed is accreting sediment and once deposited, there is no further transport.

Sediment varied from gravelly sand in the upstream portions of the river and where tributaries enter the river, to mainly mud in the lower reaches. The trend analysis found that the NW and NE Branches appear to be the predominant sources bringing sediment into the tidally influenced Anacostia, though there are secondary sources which have localized effects as well. As the two major tributaries meet and form the tidally influenced portion of the river, the coarser material settles out and is deposited in a zone of accretion from the confluence of the tributaries to the vicinity of Bladensburg Marina. The current in this part of the river is unable to transport coarser sediments, and under normal conditions, only the fines are transported downstream. Below this area, sediments coarser than muddy sands are found only locally where smaller streams and outfalls enter the river.

The stretch of river from the Bladensburg area to the CSX Railroad Bridge is dominated by Dynamic Equilibrium and occasional Net Erosion. In this zone, finer sediments from upriver move through the system much like a conveyer belt. Although some sediments are diverted into Kingman Lake and Kenilworth Gardens, which is a zone of Total Deposition, most move downriver through this stretch. Between the CSX Railroad and the 12th Street Bridge, the “conveyer-belt” transport zone mixes with a deposition zone, which then becomes a zone of Total Deposition below the 12th Street Bridge. This is also an area where the river widens and the depth increases, allowing the currents to slow and sediment fines to settle.

The lower reaches of the river are completely depositional. About 1.5 km upstream from the mouth of the river, a downstream depositional transport regime is met by an upstream transport regime at the deepest point in the river. The sediments moving upstream are most likely driven by tidal currents and include particulates from the Potomac River. The Potomac River is almost entirely in dynamic equilibrium except at the mouth of the Anacostia where some of the sediment moves into the tide-directed transport regimes of the Anacostia River.

Based on the sediment trend analysis, contaminants should be less likely to be observed in the upper portions of the river where coarser sediments are present because contaminants are more associated with fine sediments. It is also expected that contamination from upstream and localized sources should be dispersed along the mobile transport path in the mid-reaches of the river. Contaminants associated with local sources might be found in hot spots in the lower, depositional parts of the river.

Preliminary calibration of the updated TAM/WASP model for sediment transport indicates that 90 % of sediment stays within the tidal Anacostia, and that the rate of sediment deposition is 1.4 cm/year. This deposition value agrees with several report by Scatenea (1986).

1.2.3 Nature and Extent of Contamination

The presence of, and degree of, contamination of the lower, tidally influenced Anacostia River has been well known for some time. The advisory against the consumption of fish, due to their tissue residues of PCBs and some pesticides, offers evidence to this fact. AWTA's compilation of environmental studies conducted within the last decade, first published in 1999, provided a patchwork, composite picture of what was known about the distribution of contamination. Additionally, this effort brought to light the risk posed by additional classes of contaminants (primarily PAHs) not under the consumption advisory, and also highlighted the major spatial gaps in the characterization of contamination in the river. Although the general nature of contamination was understood, a high-density, systematic survey of the entire river had never been conducted. Thus, the degree of potential contamination of large reaches of the river was unknown.

AWTA supported two major surveys of the entire river with its Phase II efforts in 2000. One survey was designed primarily to evaluate the possibility of migration of pollutants from specific potential sources to the river by applying field screening analytical techniques to quantitate contaminants in over 100 sediment samples and by analysis of the water column. The second survey used traditional laboratory analysis to assess over 120 samples distributed throughout all of the river reaches on a more uniform basis. This latter study, because of its broader and more uniform distribution, will provide the majority of the basis for the following characterization of contamination of the river.

The primary contaminants of concern (CoCs) evaluated are actually two classes of chemicals- PCBs and PAHs. Three trace metals are also included as secondary CoCs. The selection of these CoCs is consistent with what has been observed previously and with the results of screening risk assessments. Several different approaches to evaluating results have been applied to observations from Phase II studies. These include: a purely statistical presentation of the raw concentrations data (i.e., deviations from mean values);

· a statistical presentation of organic data normalized to the amount of fine-grained material present in samples (because organic contaminants are most highly associated with this fraction of the sediment);

· a statistical presentation of trace metal data;

· a statistical presentation of trace metal data normalized to the amount of aluminum and iron present in samples (these elements are indicative of how much basal or crustal rock is present in the sample); and,

· a comparative evaluation of concentrations relative to published benchmarks for aquatic ecological risk.

Concordance and convergence of observations from disparate lines of study were also examined to heighten confidence in conclusions drawn. These assessments include comparisons with results from previous surveys of the river too.

Although results of chemical analyses of sediment samples indicate that the Anacostia is far from pristine, they also tend to suggest that substantial contamination of the river is primarily oriented to areas of the lower half of the river (below Kingman Lake), in the river reaches where sediment is being deposited, plus in some other, isolated locales of the river. The sedimentary record of contamination, as a temporal integrator of inputs, helps to identify and prioritize apparent loading sources within the river.

The following sections will describe the general findings and patterns for primary and secondary CoCs.

1.2.3.1 PCBs

PCBs are a class of chlorinated organic chemicals which were produced in the U.S. from 1929 to 1977 and used in a wide range of applications (electrical transformers and capacitors, hydraulic systems, heat transfer systems, and carbonless copy paper, among others), owing to a rare combination of properties, including high dielectric constant (good insulator), low flammability, high heat capacity, low chemical reactivity, and long term resistance to degradation. The majority of PCBs were used in dielectric fluids for use in transformers. Although PCBs' primary use was associated with electrical equipment (transformers, wiring, et cetera), some of the largest direct releases to the environment have come from the use of PCB hydraulic fluids (e.g., in metal casting machines). Many hydraulic systems were designed to leak slowly to provide lubrication, thereby releasing PCBs. Other processes such as combustion or incineration of materials containing PCBs, inadvertent generation during certain production processes, plus releases from environmental sinks of past PCB contamination or storage and disposal facilities were also significant sources. These releases have led to wide-spread contamination of the environment by PCBs . The manufacture of PCBs has been banned since 1977.

Phase II studies indicate that concentrations of PCBs in sediments below benchmark values associated with a low probability of observing adverse biological effects (freshwater TELs) are essentially observed only in the Potomac River (see Figure 2) the entire Anacostia is above these threshold concentrations. However, within the Anacostia, there are variations in the levels of PCBs and extreme concentrations appear to occur in certain locations, such as in the vicinity of the O Street Pumping station CSO and across to Poplar Point; upstream of the Stickfoot sewer outfall on Poplar Point; upstream from the CSX rail road bridge; near the northern boundary of the PEPCO Benning Road power generating station; and, to a lesser degree, downstream from the Benning Road Bridge. .

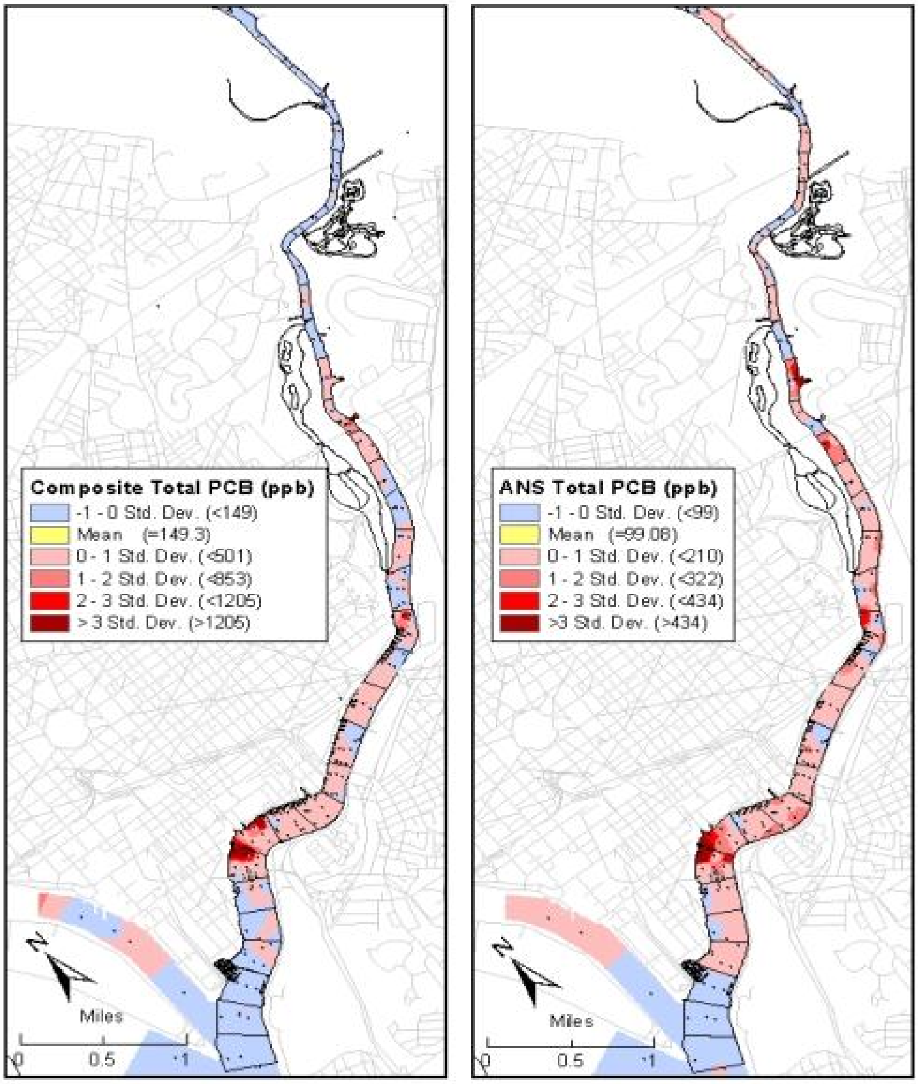

Figure 2: Interpolated concentrations of PCBs based on composite and on Phase II data analysis by ANS.

When PCB concentrations are normalized to the fine-grained content of the sediments to better indicate enrichment on that sediment fraction, a slightly different pattern emerges. The "hot-spot" upstream of the Stickfoot sewer outfall shifts downstream to just off the outfall. This is an area where a berm or sand bar of coarser-grained, sandier material has formed at the river's edge in front of the outfall. Since coarser, sandier sediments tend to adsorb less organic contaminants, bulk chemical analyses of coarse material may be misleading. Also, the composition of low weight to higher weight, more chlorinated PCBs indicates further distinctions from the surroundings. These shifts tend to suggest that effluents from Stickfoot sewer may be the source.

When PCB content is normalized to fine-grained fraction and when the proportional makeup of the total PCBs is examined, yet another area emerges as being enriched and potentially indicative of inputs to the river system – the lower half of the Bladensburg Marina reach. Normalization to Total Organic Carbon provides similar results as that for fine-grain for both this area and the Stickfoot sewer area.

When the nature , or the composition, of the total PCB mixture is examined, a distinct shift in the relative composition of PCBs is observed throughout the river: PCBs in the upper portion of the river are comprised proportionately more by lower weight, less highly chlorinated PCBs, while those in the lower reaches characteristically have a greater proportion of higher weight PCBs. The shift appears to occur in an area just above the 11th Street Bridge, which is co-incident with a shift to more fine-grained sediment. The occurrence of predominance by higher weight, less chlorinated PCBs does not appear to potentially reflect the intrusion of Potomac River water and particulates into the Anacostia River: sediments from the head of Washington Channel at the Tidal Basin down to Fort McNair are even more strongly skewed toward heavier PCBs, yet a Sediment Transport Analysis (STA) indicates that Potomac River influence does not extend this far up the channel. There is one additional river reach, from lower Bladensburg Marina to Fort Lincoln, where sediment PCBs also appear to be predominated by heavier PCBs. Because there are variations in the pattern of high weight to low weight PCBs within areas dominated by fine-grained sediments, this overall trend through the entire river does not appear to be entirely an artifact of grain size partitioning.

1.2.3.2 PAHs

PAHs are a class of aromatic hydrocarbons composed of various numbers of benzene rings. They are quite ubiquitous in the environment and essentially are always found as various mixtures of individual compounds. There are several different sources including crude oil, all types of refined petroleum products, as a waste or by-product of combustion, and some even occur naturally.

Phase II results for PAH concentrations in sediment (See Figure 3) reaffirm their ubiquitous nature in urban settings. Only two samples of sandy material (near Bladensberg) had PAH levels that did not exceed benchmark values associated with a low probability of observing adverse biological effects. Evaluation of the bulk concentration data, or of the concentrations normalized to either fine-grained fraction or TOC, all provide reasonably similar indications: there are essentially four locales, all in the lower reaches of the river, whose sediments contained elevated concentrations of PAHs relative to other locations within the river. These include the vicinity of the O Street Pumping station CSO; around the Stickfoot sewer outfall on Poplar Point; upstream from the CSX Railroad bridge to the NW boundary swirl facility's outfall; and, near Washington Gas & Light. With the exception of the Stickfoot sewer area, sediment in the other three locales all contained PAHs above levels associated with a high probability of observing adverse effects, and, the entire river system has concentrations above those associated with reproductive impairment and cancerous conditions in some bottom fish. Normalization to fine-grained content did highlight one additional area, an outfall location near the Frederick Douglass bridge, as having relatively higher PAH levels.

Evaluation of the composition of individual PAHs in the mixtures observed (see Figure ##) provides a slightly different spatial pattern than that displayed by bulk concentrations. For instance, samples from the Potomac River and Washington Channel all had similar, low bulk concentrations of tPAHs. However, the Potomac samples were made up of predominantly lower-weight PAHs (LW-PAHs) while those in the Washington Channel were dominated by higher-weight compounds (HW-PAHs). The area in the vicinity of the O Street Pumping station CSO and the outfall near the Frederick Douglass Bridge were both dominated by LW-PAHs, as was the area downstream of Hickey run to Benning Road Bridge plus around the NW Boundary swirl facility outfall. Conversely, the upper reaches of the river down to Hickey Run and the reach from Washington Gas & Light past the Navy Yard were both dominated by HW-PAHs. The examination of differences in source characteristics – LW-PAHs are typical of petroleum sources while HW-PAHs reflect combustion by-products- can also provide some insight into the source types of the PAHs observed.

The different composition of PAHs as well as the shifts in PCBs both suggest a variety of individual sources or inputs into the river system at various points along the river reaches.

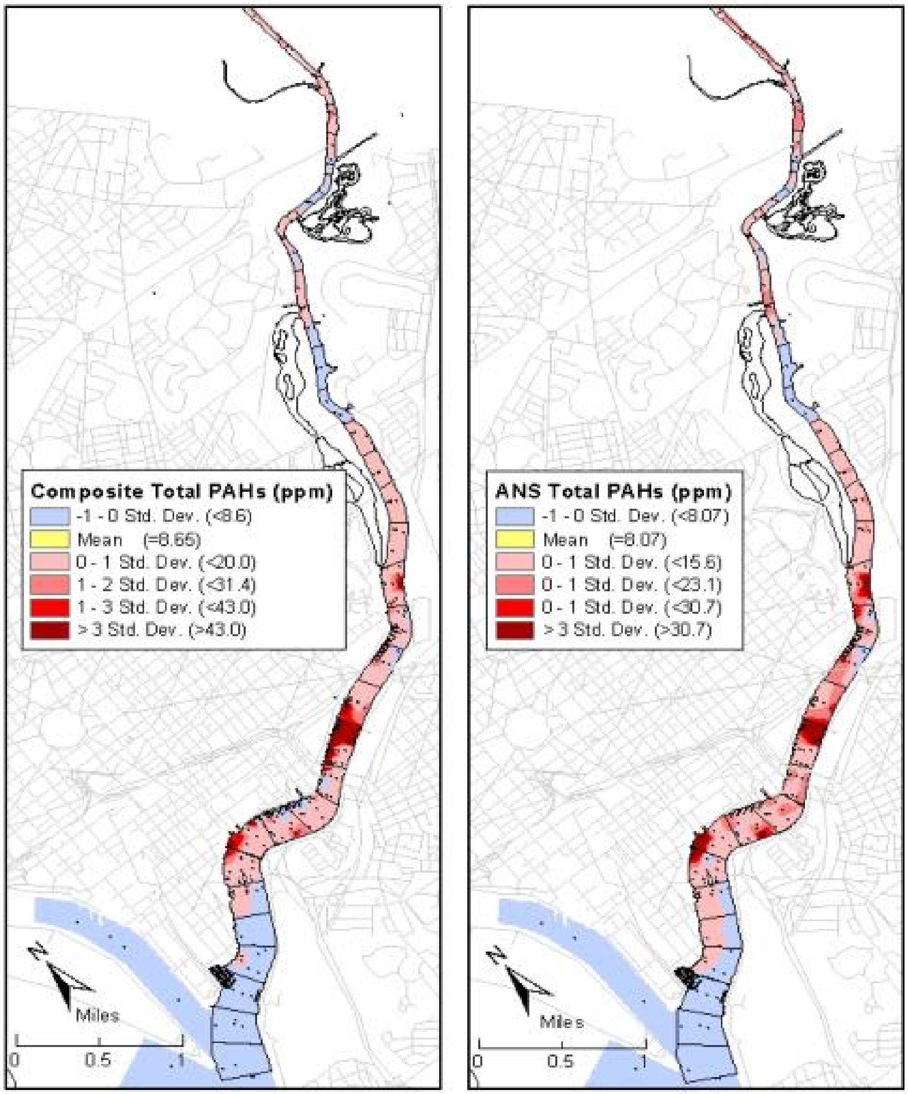

Figure 3: Interpolated concentrations of PAHs based on composite data and on Phase II data analysis by ANS.

1.2.3.3 Metals

A variety of interpolated contours for trace metals is presented in Figures 4, 5, and 6 for copper, lead, and mercury. These metals all display similar general distribution patterns in that concentrations are higher in the lower portion of the river, mean values are above ecological thresholds associated with low probability of adverse impact (TELs), concentrations in the lower river a re generally above thresholds associated with high probability of adverse impacts (PELs), and have one consistent “hot-spot” at the O street pump station area. The pattern of each element does present certain unique characteristics too though. For instance, the extent of contamination by lead is more prevalent than the others. Both lead and copper both have apparent “hot-spots” in the vicinity of CSO #017 between the 12th Street and Pennsylvania Avenue bridges. Copper also is elevated in the cove north of the Benning Road PEPCO plant. Mercury in the vicinity of the mouth at both the upper and lower entrances to Kingman Lake is elevated relative to the surrounding reaches.

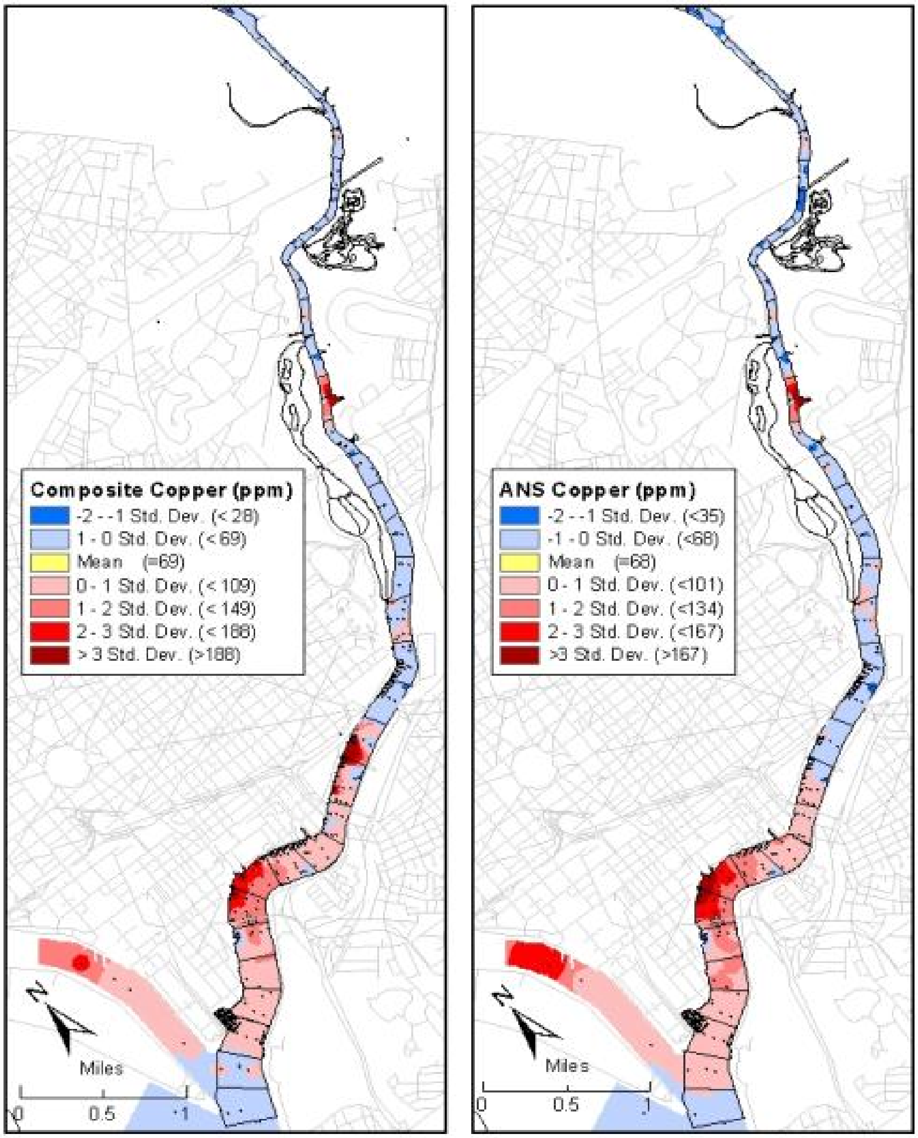

Figure 4: Interpolated concentrations of Copper based on composite data and on Phase II data analysis by ANS

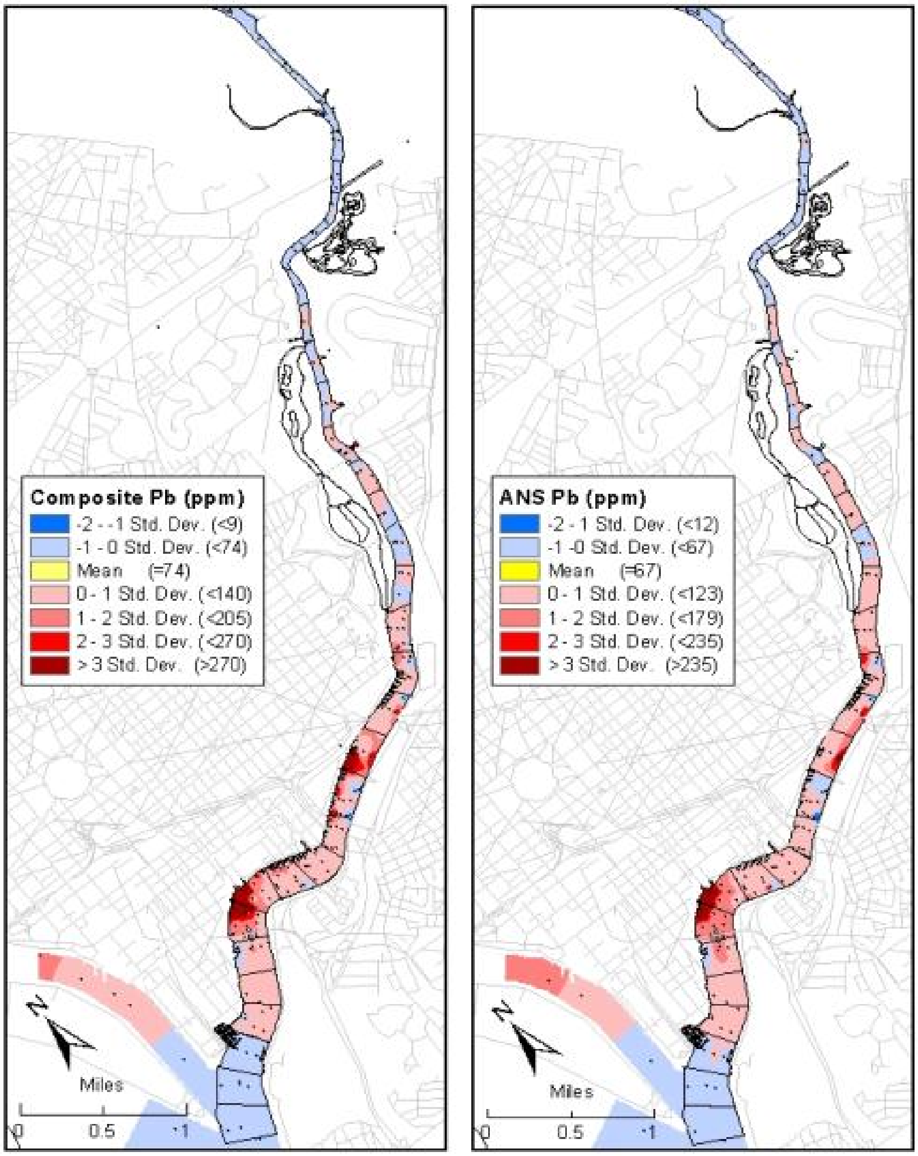

Figure 5: Interpolated concentrations of Lead based on composite data and on Phase II data analysis by ANS

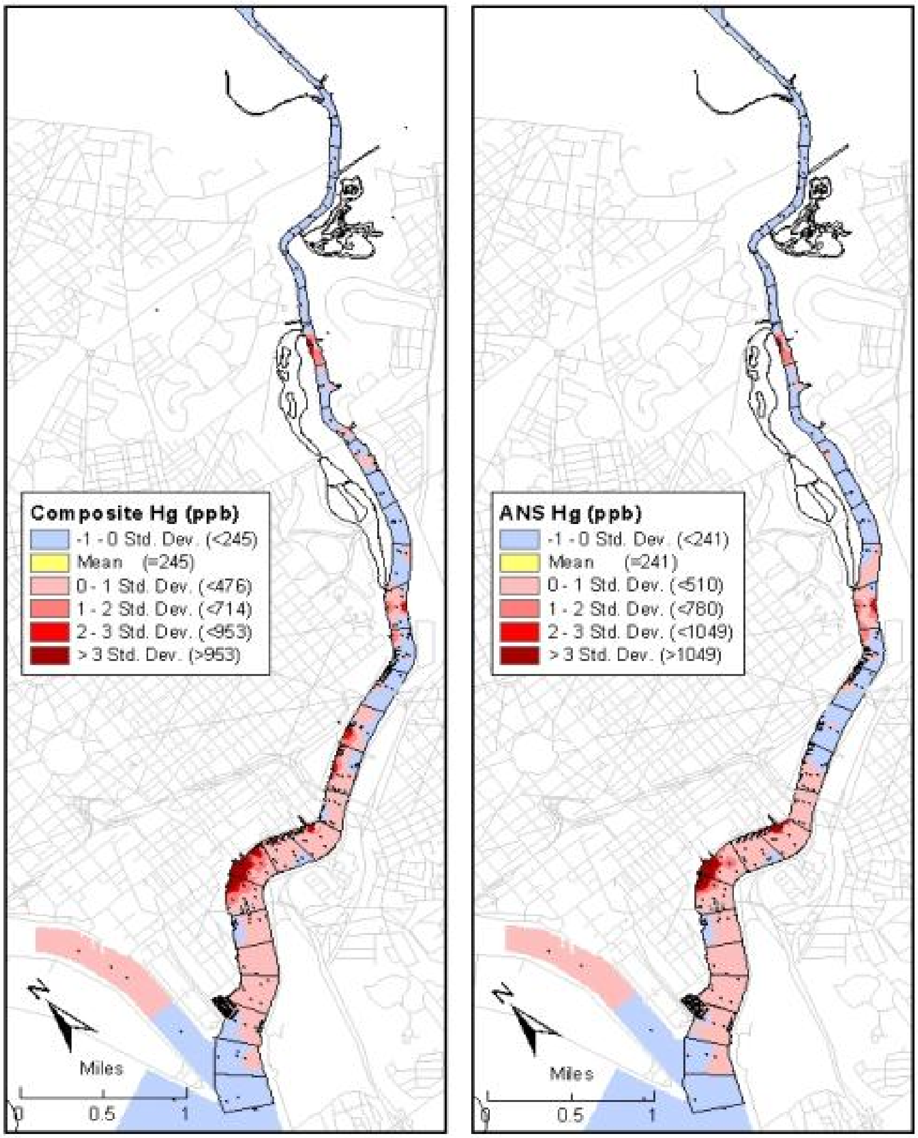

Figure 6: Interpolated concentrations of Mercury based on composite data and on Phase II data analysis by ANS

1.2.4 Human Health Exposure and Effects

Screening for Human Health Risk was conducted during Phase I by comparing maximum concentrations in sediment, surface water, and fish tissue to risk-based concentrations (RBCs). Exposure pathways for sediment were based on direct contact, and exposure pathways for surface water and fish tissue were based on ingestion. Results of the screening assessment identified 39 contaminants of potential concern (COPCs) in fish tissue. The primary chemical classes identified in fish tissue were dioxins/furans, pesticides, PCBs and trace elements (arsenic, cadmium, lead, and mercury). COPCs in sediment were arsenic, PCBs, and four PAH compounds. Arsenic, PCBs, heptachlor, DDE, and DDT were identified as COPCs in surface water.

The results of the screening risk assessment identified several gaps in the available database, limiting its usefulness in supporting a baseline risk assessment. These data gaps were related primarily to the lack of adequate sediment and surface water data throughout the river to adequately characterize contamination both spatially and temporally. Data collected in Phase II to characterize the nature and extent of contamination, as discussed in Section 1.2.3, addresses these data gaps in the baseline risk assessment. In addition, the fish tissue database used for Phase I will be updated with more recent data. More definitive estimates of the number of fish eaten by anglers is still needed for a revised human health assessment. Until the human health baseline risk assessment is completed, there is no additional information to update the conceptual model for human exposure and effects. Based on the Phase I results, the primary exposure pathway is likely to be ingestion of fish tissue. However, the extent of risk from this exposure pathway should be quantified, and additional possible exposure scenarios from direct contact with sediment and surface water need to be addressed.Ecological Exposure and Effects

As presented in the Phase I report, the screening-level ecological risk assessment indicated that a risk may be posed to benthic invertebrates from exposure to metals, PAHs, PCBs, and several pesticides in sediment based on a comparison to Threshold Effects Level (TEL) and Probable Effects Level (PEL) sediment quality guidelines. Elevated concentrations of PAHs in sediment may pose a threat to bottom-feeding fish based on comparison to a sediment quality threshold of 2 mg/kg. The screening level Ecological Risk Assessment (ERA) also found that PCBs, pesticides, and lead were present in fish tissue at concentrations that may adversely affect fish. Risk to birds and mammals from metals, PAHs, and PCBs was determined to be much less substantial than risk to benthic organisms and fish. Figure 7 presents a conceptual model of food web exposure of benthic organisms and fish to contaminated sediment from both direct exposure and from bioaccumulation through the food chain. Although the screening level risk assessment confirmed ecological risk was likely, there were many gaps, especially spatial ones, in the assessment.

Several investigations were proposed for Phase II to further define the risk posed to aquatic organisms from contaminants of concern in Anacostia River sediment and surface water. Those additional components, which will be presented in a more in-depth ERA, include benthic community analyses, sediment bioassays, tumor prevalence in bullhead, fish toxicity testing, and bioaccumulation testing. Preliminary results of these investigations are presented in the following sections. In addition, evaluation of potential risk to fish in the Anacostia River from bioaccumulation of PCBs conducted by Doelling-Brown et al. (2000) is discussed.

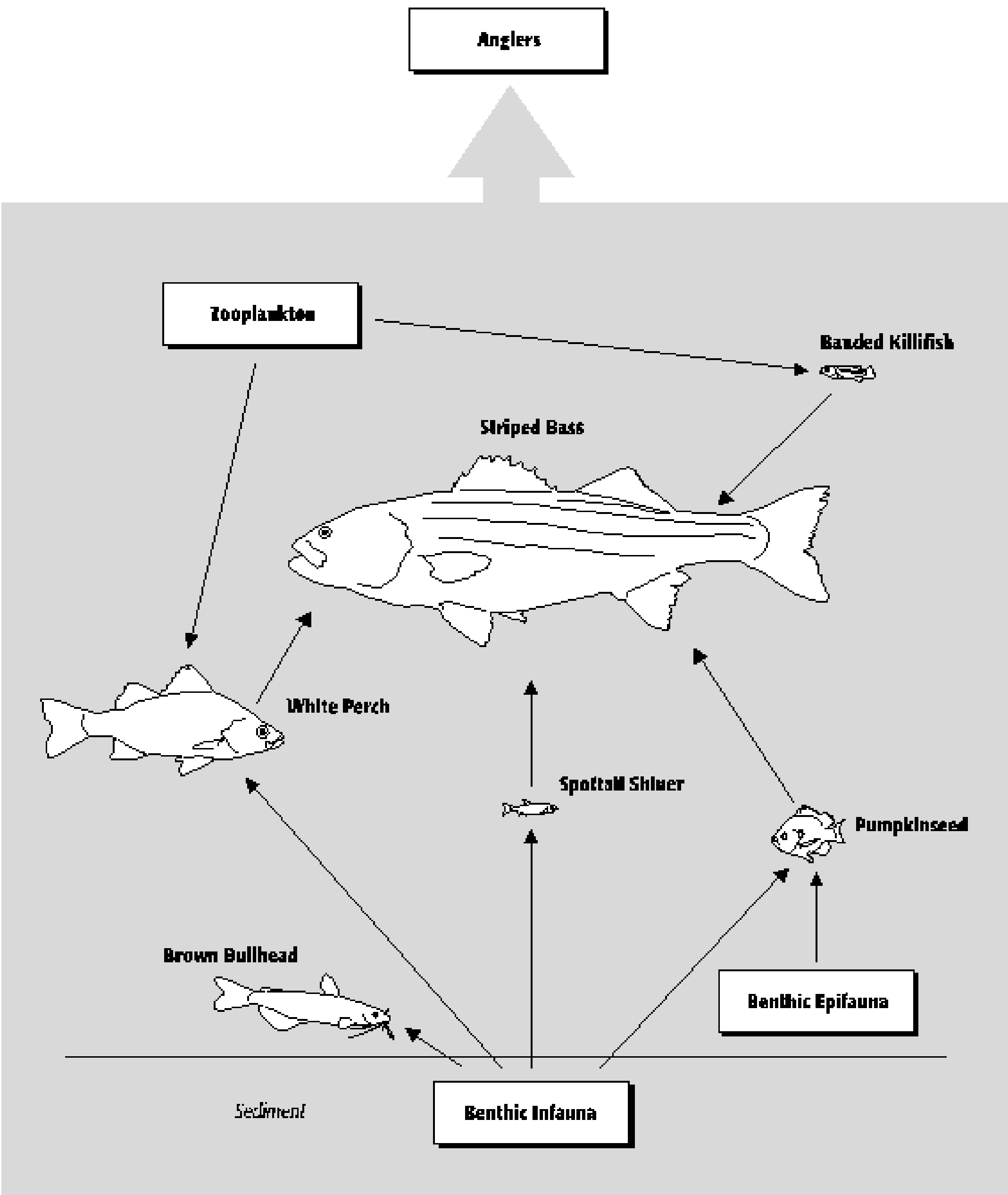

Figure 7: Conceptual model of the Anacostia River food web.

1.2.4.1 Benthic community analyses and bioassays

Samples of sediment were collected from several stations throughout the river for benthic community analysis. Although organisms in the samples are still being enumerated, general observations during processing of the samples confirms that the benthic community is essentially depauparate with low diversity and abundance and is dominated by pollution tolerant worms.

These same samples were also subjected to laboratory testing of toxicity using short-term bioassays in which two different invertebrates (*Hyalella azteca* and *Chironomus tentans*) were exposed to the bulk sediment samples. This bioassessment indicated chronic impacts to growth of both species in samples from the O Street outfall area. Subsequent re-testing of sediment from this area using fractionation techniques suggest that toxicity is due primarily to organic contaminants (McGee 2001 pers comm.).

1.2.4.2 Effects of PAHs on Brown Bullhead

Widespread contamination of the Anacostia sediment by PAH compounds was first identified as a contamination issue in the Phase I report. PAHs are known to be tumor inducers, and there was a demonstrated prevalence of tumors among Anacostia fish, particularly brown bullhead. Such tumors have been linked to contaminated sediment in other studies. For instance, Baumann et al (1996) found that liver tumor prevalence above 9 % and skin tumor prevalence above 20 % were indicative of contaminant exposure. Brown bullheads could be used as appropriate sentinel species because their home range is limited. Sakaris et al (2002) reported that the home range of bullheads in the Anacostia is on the order of 2 km or less. Despite preliminary indications, a more thorough connection between observed effects and exposure to PAHs was desired. To further demonstrate effects on Anacostia fish from exposure to sediment PAHs and to update a 1996 sampling which found a 55 % prevalence of liver tumors (Pinkney et al.2000), brown bullhead were collected by US Fish &Wildlife Service (US F&WS). This follow up survey was conducted to compare incidence rates in brown bullhead from several areas of the river, to statistically analyze relationships between tumors and sediment contamination, and to also evaluate the relationship between age, DNA alterations, and tumors.

The results from one survey of 2000/01, conducted with fish from near the mouth of Kenilworth Marsh, near the CSX rail road bridge, and near the O Street outfall complex found nearly identical tumor rates in adults as in 1996 samples. Liver tumor prevalence increased from 56% near Kenilworth to 68% off O Street, compared to 3 % found in fish collected from a reference site in the Tuckahoe River (Pinkney et al. 2002). These rates approach those observed in some of the most contaminated areas of the Great Lakes. Results from juvenile fish (age 1-2) indicate that they also have elevated prevalence rates of liver tumors (10 to 17%). Their levels of DNA adducts are also comparable to that of older fish. Both young and old fish also have substantial levels of PAH metabolites in their bile.

These results indicate that bullheads are receiving significant PAH exposure; the exposure to PAHs has been long-term enough, even amongst juveniles, to exert genotoxic impacts by damaging DNA; and that these fish develop liver and skin tumors, as early as their first or second year, that as adults is on par with some of the most contaminated sites in the country.

1.2.4.3 Toxicity of Water to Larval Fish

A number of broad restoration efforts throughout the Anacostia watershed include specific projects to restore runs of migratory fish. For instance, restocking and removal of barriers are planned for certain areas. The success of these efforts, as well as the general reproductive health of the resident fish community within the river, is dependent on conditions being amenable to the survival of sensitive, early life stages of fish. To begin to address the question of survival of larval fish, one Phase II investigation was conducted to determine if surface water in the Anacostia River is toxic to larvae or juvenile fish, and whether there is a difference in toxicity under high flow or base flow conditions (Pinkney et al. 2002b). Limited water samples were collected from four locations during four separate events; two during high flow and two during base flow. Two types of laboratory toxicity tests were conducted with these field-collected samples: a 7-day larval fathead minnow test with survival, growth, and biomass endpoints and a 96-hour larval American shad test with a survival endpoint. Water samples were analyzed for metals, PAHs, PCBs, and pesticides. To date, both types of toxicity tests for two high flow events and one base flow event have been completed.

The American shad tests have been unsuccessful due to poor survival of the shad in the lab. Preliminary results for fathead minnow tests showed no effects on any endpoints for one of the base flow tests and one of the high flow tests. However, the second high flow test showed 50 to 60 % survival at two locations (Bladensburg and Kenilworth Marsh) compared to 90 to 100 % survival at the control and two remaining locations (CSX Railroad Bridge and James Creek). Biomass was lowest at the Bladensburg and Kenilworth Marsh locations. Chemistry data will be available in mid-August 2001, at which time the larval response data will be compared with water concentrations of contaminants.

1.2.4.4 Bioaccumulation Investigations

A bioaccumulation investigation to evaluate bioavailability of contaminants in the Anacostia River was conducted as part of Phase II. Clams were deployed for four weeks and semi-permeable membrane devices (SPMDs) for eight weeks in the NE and NW Branches, and at seven other locations in the tidally influenced Anacostia. After the deployment period, clams and SPMDs were analyzed for PCBs, PAHs, and pesticides. Clams were also analyzed for metals.

The screening level ecological risk assessment presented literature effects concentrations for PCBs accumulated in fish tissue and compared these effects to concentrations found in fish from the Anacostia River. Exceedances were indicated in various areas of the river and for both brown bullhead and largemouth bass.

Doelling Brown et al. have also conducted several investigations related to PCB effects in Anacostia fish. One study investigated the potential for impairment of reproductive success in white perch due to PCB bioaccumulation (Doelling Brown et al. 2000). They compared PCB concentrations in the spawning population of white perch to a literature-based comparable whole body concentration of 0.4 ppm in rainbow trout associated with low egg survival (U.S. EPA 1980, as cited in Eisler 1986) and found that the whole body tissue levels of Anacostia white perch exceeded this benchmark (Doelling Brown et al. 2000). Four of five white perch samples from Kenilworth Marsh and all five samples from the Navy Yard area collected in 1998 and 1999 had concentrations exceeding 0.4 ppm. Literature data indicate toxic effects at egg concentrations ranging from 0.1 to 1.9 ppm (Monod 1985; Niimi 1983). PCB residues can be estimated for Anacostia white perch using results from Niimi (1983) showing an average of 29 % of maternal body burden transferred to eggs in a Great Lakes species with similar lipid content to white perch. Using this factor, PCB residues in white perch eggs were estimated at approximately 0.2 ppm (Doelling Brown et al. 2000), indicating a potential for effects in the Anacostia River.

Doelling Brown et al also measured concentrations of PCBs in multiple age classes of three additional species in the Anacostia River in 1998 and 1999 (2000). The results showed that for several species of fish (white perch, pumpkinseed, brown bullhead, and spottail shiner), there was a decline in PCB body burden associated with the first spawn. This decline is apparently due to lipid mobilization during spawning, which transfers a portion of the PCB body burden to the egg mass. PCB congener analysis of tissues indicated that low molecular weight PCB congeners were preferentially depleted, as shown by a consistent pattern of enrichment of high molecular weight PCBs in post-spawn fish. This observation has significant implications for the design of any fish monitoring program.

Doelling Brown also applied models to simulate the bioaccumulation of PCBs in fish (2001) in the food chain (see Figure x) using a model developed by Gobas (1993). PCBs in fish tissue were modeled based on measured dissolved phase concentrations, concentrations in diet, gill uptake and elimination constants, egestion constant, metabolic transformation constant, and growth rate. The results showed that predictions of fish body burdens are close to measured concentrations when prey concentrations are known. The majority of the body burden was attributed to dietary sources. The model is currently being refined with data from abiotic compartments and lower trophic organisms to establish a good predictor for prey concentrations. The model is also being expanded to predict PCB uptake into biota using partitioning from sediment organic carbon into organism lipid (Brown 2001 personal communication). It is possible that once a sediment component of the model is developed, it could be used to back-calculate maximum sediment concentrations that must be met to maintain PCB body burdens at concentrations below risk-based values. These data could then be used to derive management goals for sediment PCB concentrations.

1.3 Summary of Updated CSM

While much has been added recently, the conceptual site model is still under development and much of the data collected under Phase II are in preliminary phases of analysis and have not yet been fully incorporated into a detailed model. Data are currently being collected on contaminant loadings from outfalls, an important component of the model, which will partially address the requirements for accurate loading estimates. TAM/WASP modeling of contaminant inputs to the tidally influenced Anacostia River, along with hydrodynamic and sediment transport modeling, is still undergoing development, validation, and calibration. The human and ecological risk assessments have not yet been completed. Although data gaps remain, this document provides a summary of knowledge to date suitable for the purposes of drafting a preliminary management plan.

Most of the total flow of water to the tidally influenced Anacostia River (approximately 71% as modeled by TAM/WASP) enters from the NE and NW Branches. Lower Beaverdam Creek is estimated to contribute 12% of the total flow, and minor tributaries and storm sewers add another 11%. Watts Branch and District of Columbia CSOs each contribute 3%. Groundwater flow in general appears to be a much less substantial input than surface water flows. Seep studies suggest the possibility that groundwater may represent a contaminant pathway in very localized situations where both a substantial plume of contamination exists, and it is adjacent to higher permeable locations of the river. A major source of TSS loading to the tidally influenced river is from the NE and NW Branches, because of the large area drained by these tributaries. Metals, PAHs, and to a lesser degree, PCBs were associated with the suspended particulate matter in the NE and NW Branches indicating that movement of suspended sediment from these tributaries may be an important source and transport mechanism for contaminants into the tidally influenced river. Finer grained material and the pollutants associated with these particulates appears to travel through the river system to be deposited in the lower reaches of the river where depths and the channel width both increase and current velocity decreases. Superimposed over this general pattern is the influence from localized inputs, such as outfalls.

Sediment trend analysis shows that the mid-section of the river acts much like a conveyer belt, transporting sediment to lower, depositional portions of the river located below the 12th Street Bridge. Contaminants associated with fine sediments are less likely to be found in the upper portion of the tidally influenced river because they are expected to be transported to the lower portion and deposited there. Based on sediment transport patterns, contamination from outfalls in the lower, depositional portion of the river is not expected to be transported a substantial distance, so may be found in localized “hot-spots” near the source.

The effects of localized inputs are superimposed upon this concept of the river as a giant conveyor belt. CSOs and storm drains contribute substantial amounts of TSS and sediment to the tidally influenced Anacostia River at least in their immediate vicinity, as evidenced by the sand berms built up in front of many.. Monitoring of specific CSO outfalls and storm drains for contaminants of concern, particularly for organic contaminants, has been limited. Data currently being collected by MWCOG will help fill this data gap and will provide estimates of total loads of contaminants to the tidally influenced river from four specific outfall locations. What is apparent from the existing river data is that many of these outfalls act as discharge points to the river for PAHs and PCBs. Changes in patterns in the makeup of both pollutants coincide with each other at some outfalls and also distinguish these discharge points from the surrounding locale at others. Some of these pattern shifts are also consistent with the nature of the source material (for instance, street runoff versus coal tar).

Characterization of contamination indicates that PAHs are widespread throughout the river, with localized hotpots. Conversely, PCBs appear primarily to occur in localized hotpots. The composition of each mixture of contaminants presents unique patterns, suggesting that each has its own unique set of sources and inputs. Regardless, certain locales, such as the O street outfall, consistently present elevated levels of all contaminants.

The primary pathway for human exposure to contaminants in the Anacostia River is likely to be ingestion of fish who themselves have been exposed through bioaccumulation in the food chain. The baseline risk assessment will provide more detailed information on this pathway, as well as exposure via direct contact with sediment and surface water. The screening level ecological risk assessment indicated that risk may be posed to benthic organisms from direct contact with sediment. Fish may be at risk from direct contact with surface water and sediment, and from bioaccumulation of contaminants. In addition, a risk may be posed to piscivorous birds and mammals from dietary exposure to contaminants in fish and invertebrate tissue. The primary contaminants of ecological concern are PCBs, PAHs, trace elements and pesticides. The baseline ecological risk assessment will quantify risks that have been identified on a preliminary basis and will present targeted sediment concentrations for protection aquatic organisms.

1.4 Computerized TAM/WASP Sediment Transport Model

In order to help scientists and managers understand how chemical contaminants enter the river and how chemicals move about and disperse within the river, a computer model, the TAM/WASP Toxics Screening Level Model, has being developed and is being refined to simulate the daily input, movement and transformations of chemicals in the tidal portion of the Anacostia. The TAM/WASP sediment transport model simulates advection and dispersion of suspended sediment, settling and deposition of suspended sediment onto the riverbed, and erosion of bed sediment.

The model can make predictions about the changes over time of concentrations of chemicals of concern in the river water and the river bed sediments. One intended use of the model is to examine the impact of potential changes that might occur or actions that might be taken to reduce the presence of toxic chemicals in the river. For instance, if the amount of PAHs flowing into the river could be reduced by 60%, what improvement would likely be observed in the river bed sediments after three years time? Or, if a PCB “hot spot” were removed from the river bed, what would be the effect on the surrounding sediments over time? By estimating the impacts of changes such as these, the computer model will assist managers in evaluating the efficacy of potential watershed management or sediment remediation scenarios.

It is important to keep in mind that computer simulation models can only provide estimates of what has occurred in the river and what is likely to occur, and that these estimates may be poor if the underlying data used to develop the model is inadequate. Because the Anacostia River has been the subject of many fine studies over the years, many components of the TAM/WASP model are based on comprehensive and detailed data sets. However, it must be noted that one important component of the Toxic Screening Level Model is subject to a high degree of uncertainty due to lack of adequate data. That component is the load estimation component, based on available storm water monitoring data, and described in more detail below. Our current estimates of the chemical loads to the tidal river, that is, the quantities of chemicals entering every day from the numerous tributaries and sewer outfalls, are based on measurements of chemical concentrations of a limited number of samples taken at only a few locations over short time periods. This lack of data clearly limits the model’s ability to represent where and in what quantities chemicals are entering the river. This data gap is primarily due to the lack of understanding, until recently that discharges with very low concentrations of certain chemicals, such as PCBs or PAHs, may in some situations have a significant impact on the river. Therefore, in order to provide data which can be used to quantify chemical loads to a river such as the Anacostia, storm water monitoring studies must begin using highly sensitive laboratory analysis techniques to measure chemical concentrations in waters entering the river. The steps currently being taken by AWTA to address this data gap, and the additional steps necessary to reduce our uncertainty concerning where and in what quantities chemicals are entering the river, are included in the discussion below.

1.4.1 Model Overview

A previously developed modeling framework, TAM/WASP (Mandel and Schultz, 2000; Schultz, 2001), is being updated to serve as a screening level model to simulate the loading, fate and transport of sediment and toxic contaminants in the tidal Anacostia River. TAM/WASP is a one-dimensional (1-D) model, that is, it simulates processes in the river by idealizing the river as a long channel where conditions may vary along the length of the channel but where conditions are assumed to be uniform throughout any channel transect (i.e. from left bank to right bank). Along its length, the main channel is divided into 35 model segments, as depicted in Figure 8. Approximating the river as a one-dimensional system is reasonable given the results of the summer 2000 SPAWAR study, which concluded that throughout a channel transect, the water in the river was generally well-mixed, and current velocities were relatively homogenous and primarily directed along the axis of the channel (Katz et al., 2001). The TAM/WASP model currently can be configured to simulate conditions in the river for any time interval between January 1, 1985 and July 31, 2000, or any hypothetical future time interval.

The TAM/WASP Toxics Screening Level Model includes three primary components:

- A hydrodynamic component, based on the Tidal Anacostia Model (TAM), originally developed at MWCOG in the 1980's and recently upgraded by ICPRB. This component simulates the changes in water level and water flow velocities throughout the river due to the influence of tides and due to the various flow inputs entering the river

- A load estimation component, constructed by ICPRB using Microsoft ACCESS. Water containing sediment and chemicals flows into the river every day from a variety of sources, including the upstream tributaries (the NE and NW Branches), the tidal basin tributaries (Lower Beaverdam Creek, Watts Branch and others), the combined sewer system overflows (CSOs), the separate storm sewer system, and ground water. The ICPRB load estimate component estimates daily water flows into the river based on USGS gage data for the NW and NE Branches, HSPF data from Watts Branch, and National Airport daily precipitation data for flows from other sources. It also estimates daily sediment and chemical loads into the river.

- A water quality component, based on the EPA's Water Quality Analysis Simulation Program (WASP5) for sediments and toxic contaminants. This component simulates the physical and chemical processes that transport and transform chemical contaminants that have entered the river. The WASP sediment/toxics transport module has been enhanced by ICPRB to more realistically simulate sediment erosion and deposition processes based on hydrodynamic conditions.

1.4.1.1 Hydrodynamic Simulation

The simulation of hydrodynamics in the river is based on a description of the river's geometry, obtained from aerial photos and bathymetry data, on information concerning local tides, obtained from NOAA hourly tidal height data collected at a station in the Washington Ship channel, and on estimates of how much water flows into the river on a given day, determined from USGS daily flow data for the NW and NE Branch tributaries and National Airport hourly precipitation data. Using this information, the model is able to simulate water levels and flow velocities along

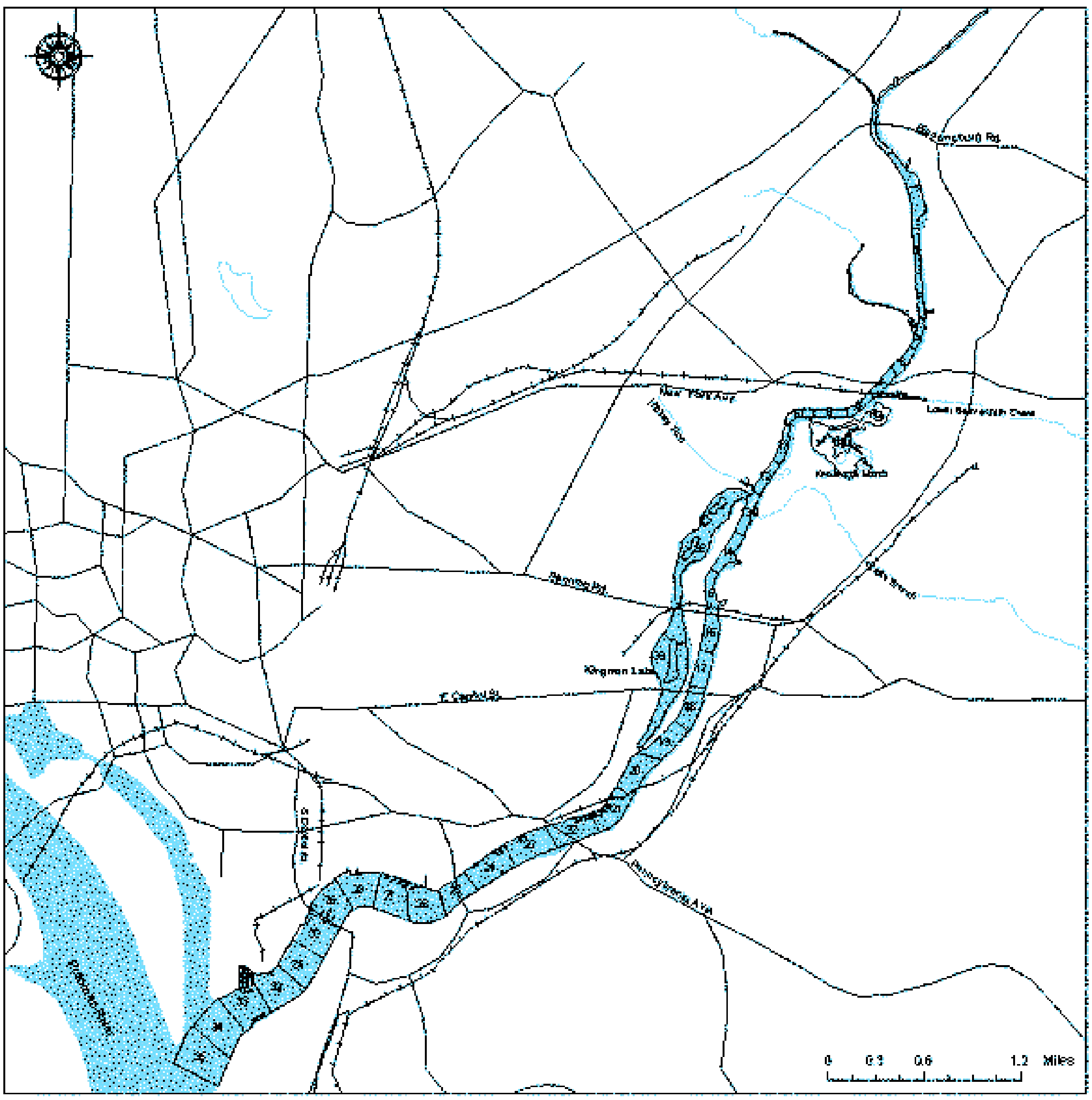

Figure 8: Segmentation of TAM/WASP Model Version 2

the length of the tidal river. That is, the model can predict water levels and flow velocities for each of the 35 model segments at each model time step (where a model time step of 1/200th of a day is typically used).

According to the description of the Anacostia River's geometry incorporated in the model, the total volume of the tidal river at mean tide is approximately 10,000,000 m^3, and the total surface area is approximately 3,300,000 m^2. The average total annual discharge to the tidal river for a three-year model run from 1988-90, a time period with average high/low yearly rainfall, was estimated to be 190,000,000 m^3. The relative contributions to the total inflow according to model estimates are given in Table 1.

Table 1 Estimated Average Annual Flow Input Summary[1]

Drainage Area Type	**Area (acres)**	**Area (%)**	**Average Annual Flow (1000 m^3)**	**Average Annual Flow (%)**
Upstream Drainage Area: NE and NW Branches	77,800	72.0%	136,183	70.3%
Tidal Drainage Area: Watts Branch	2,470	2.2%	4,987	2.6%
Tidal Drainage Area: Lower Beaverdam	10,466	9.3%	23,390	12.1%
Tidal Drainage Area: Separate Storm Sewers and Minor Tributaries	10,501	10.0%	20,951	10.8%
Tidal Drainage Area: CSOs	6,946	6.4%	8,129	4.2%
Total Watershed	108,183	100.0%	193,640	100.0%

[1] From Schultz, 2001.

Simulation results of the TAM/WASP hydrodynamic model are generally consistent with data taken during AWTA's Phase II investigation. Predicted water surface levels at each model segment closely match the water level at the nearby NOAA tidal gage station. Model-predicted flow velocities for the three-year time period, 1988 - 1990, are generally less than 0.5 m/sec, and at no time during the years, 1988 through 1990, did the model predict a flow velocity greater than 0.85 m/sec. Predicted flow velocities compare reasonably well with measured flow velocities, including data taken for AWTA in the summer of 2000 by the Navy's SPAWAR group. Model predictions of median flow velocity at each model transect (where transect n is the boundary between model segment (n-1) and model segment n), computed from a cumulative distribution of model-predicted flow velocities at model transects for each time step of the 1988-1990 run, are shown in Figure 9. From this graph it is evident that flow velocities in the tidal river are greatest mid-river, with the highest median velocities occurring in the two stretches of the river represented by model segments 11 through 14 and segments 18 and 19.

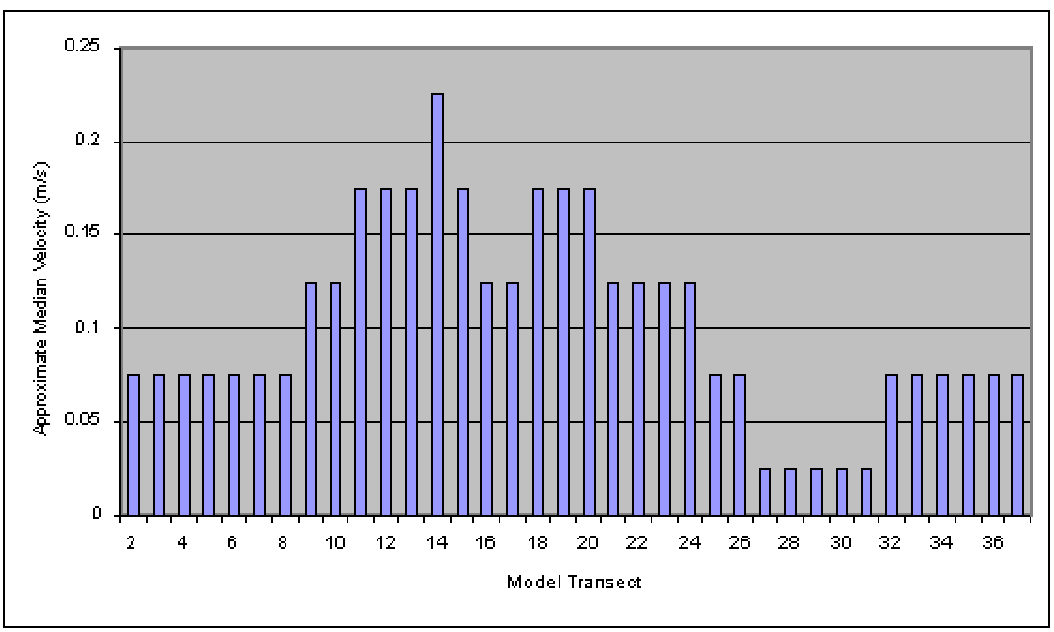

Figure 9: Medians of Model-Predicted Flow Velocities at Model Transects

1.4.1.2 Flow and Load Estimation

Water containing sediment and chemicals flows into the Anacostia River every day from the various tributaries and the separate storm sewer and combined sewer system outfalls. In total, the model makes estimates of flows and loads into the tidal portion of the river for each of more than 30 sub-watershed areas, including the Northeast and Northwest Branch sub-watersheds in Maryland, CSO and separate storm sewer sub-watersheds in the District of Columbia, and a number of small tidal tributary sub-watersheds. The daily volume of water flowing in from NW and NE Branch tributaries are estimated based on USGS gage station data. Daily volumes of flow from other sub-sheds are estimated based on National Airport precipitation data. As is evident from Table 1, approximately 70% of the water flowing into the tidal river comes from the Northeast Branch and the Northwest Branch sub-sheds. Thus, these upstream tributaries are potentially important sources of contaminants to the tidal portion of the river.

Water flowing into the river carries with it sediments and trace amounts of toxic chemicals. To estimate sediment and chemical loads, that is, the quantities of sediments and chemicals entering the river each day, data from storm water monitoring and other monitoring studies are used. These studies measure the concentrations of sediment and toxic chemicals in water discharging into the river from tributaries and sewer outfalls. Data from several studies are available for the Anacostia watershed. The most important data source to date for toxic chemicals is a storm water monitoring study conducted by ICPRB in 1995-96 for the DC DOH at the Northeast and Northwest Branch tributaries (Gruessner et al., 1997). In this study, water samples were collected during four storm events and on five additional non-storm days, low-detection analytical methods were used for concentrations of selected metals, PCBs, PAHs, chlordane, and a variety of other organic chemicals. This data allows us to make rough estimates of the chemical loads coming from the upstream portions of the basin. Other past, ongoing, or upcoming storm water or monthly monitoring studies of the Anacostia watershed which include at least some toxic chemicals are listed in Table 2.

Table 2 Storm Water Monitoring Studies Providing Data for Chemical Load Estimates

Monitoring Study	**Metals Data**	**Low Detection Limit Organics Data**
ICPRB/DC DOH NE/NW Branches Study [1]	yes	yes
WASA LTCP Studies [2]	yes	no
COG Study [3]	yes	no
Spring 2002 COG/AWTA monitoring [4]	yes	yes
DC MS4 Program [5]	yes	not at present time

[1] Gruessner et al., 1997.

[2] DC WASA, 2000.

[3] Shepp et al., 2000.

[4] T.J. Murphy et al., work in progress.

[5] D.C. Part 2B Storm Water Permit Storm Water Sampling Data, as appearing in DC WASA, 2000.

Unfortunately, as is evident from Table 2, at this time no data are available to estimate loads of organic chemicals from the watershed apart from the NE/NW Branches study data. Because different types of human activities have occurred at different places in the watershed, it is likely, at least for some chemicals, that the concentrations of chemicals carried by storm water runoff can vary greatly from one sub-watershed to another. Therefore, in order to understand the spatial distribution of chemical contaminants in the Anacostia sediments, and to evaluate the relative importance of various contaminant sources, it is necessary to have tributary and outfall monitoring data from a reasonable number of locations. AWTA has begun to address this data gap in its Phase II effort by sponsoring a study by MWCOG to collect baseflow and storm water monitoring data at several tidal sub-basin discharge points including Lower Beaverdam Creek, Hickey Run, and the O Street Sewage Pump Station outfall.

An additional problem in estimating toxic chemical loads to the river is the small number of sample points available, or anticipated to be available, at any given location. Because of the high cost of analyzing water samples for toxic chemicals using the very sensitive methods required for load estimates, studies typically collect samples for only a handful of storm events. Table 3 shows the results of a statistical analysis of data collected for the ICPRB/DC DOH Northwest and Northeast Branches study, in which four storm samples and five non-storm samples were analyzed for organic contaminants using very low detection limits. This table shows the estimated mean storm and baseflow (non-storm flow) concentrations of total PCBs, total PAHs, zinc, lead, and copper, which are used in the TAM/WASP model to compute corresponding loads to the river from the Northeast and Northwest Branch sub-sheds. The table also shows estimates of an 80% two-tailed confidence interval around each of the estimated means. Computations were done using the assumption that concentrations have a lognormal distribution, using the methods given in Gilbert (1987).

Table 3 Summary of Analysis of Upstream Tributaries Toxic Chemical Concentrations

Data (TPAH - Total PAHs TPCBs - Total PCBs BF - Baseflow samples SF - Stormflow samples)	Number of Samples	Range	Estimated Mean - (Lognormal)	Estimated Lower Limit for 80% Confidence Interval - (Lognormal)	Estimated Upper Limit for 80% Confidence Interval - (Lognormal)
TPAHs (ng/L) - NE BF	6	64 - 900	190	120	660
TPAHs (ng/L) - NE SF	4	960 - 4722	2900	1900	8900
TPAHs (ng/L) - NW BF	6	84 - 1814	350	200	1800
TPAHs (ng/L) - NW SF	4	1268 - 9113	7100	4200	65,000
TPCBs (ng/L) - NE BF	6	2.7 - 4.8	4.0	3.6	4.7
TPCBs (ng/L) - NE SF	4	12.8 - 20.9	16.8	14.5	20.4
TPCBs (ng/L) - NW BF	6	2.6 - 6.2	3.5	3.0	4.5
TPCBs (ng/L) - NW SF	4	2.1 - 30.7	11.0	6.1	187.2
Total Zn (:g/L) - NE BF	10	0.8 - 21.9	7.8	5.2	14.9
Total Zn (:g/L) - NE SF	4	31 - 125	77	53	169
Total Zn (:g/L) - NW BF	10	3.2 - 15.4	6.8	5.6	9.4
Total Zn (:g/L) - NW SF	4	37 - 210	91	59	286
Total Pb (:g/L) - NE BF	10	0.2 - 1.5	0.5	0.4	0.7
Total Pb (:g/L) - NE SF	4	3 - 76	49	24	1392
Total Pb (:g/L) - NW BF	10	0.1 - 5.0	0.6	0.4	1.8
Total Pb (:g/L) - NW SF	4	4 - 282	103	45	44,000
Total Cu (:g/L) - NE BF	10	0.4 - 9.1	3.2	2.3	6.0
Total Cu (:g/L) - NE SF	4	11 - 48	25	17	55
Total Cu (:g/L) - NW BF	10	1.0 - 21.7	3.6	2.5	7.2
Total Cu (:g/L) - NW SF	4	4 - 80	43	21	481

Though the individual uncertainty estimates themselves are highly unreliable due to the small number of sample points available, results appearing in Table 4 imply that annual load estimates based on data from a handful of samples may sometimes be a factor of two or three or even a hundred times smaller than actual loads, or may in other cases be a factor of two times larger than actual loads. These results emphasize the need in the Anacostia for storm water monitoring studies with larger numbers of sample points per sampling location. Without a substantial amount of additional data, our understanding of where and in what quantities toxic chemicals are entering the Anacostia will be limited.

1.4.1.3 Contaminant Fate and Transport

Once toxic contaminants have entered the Anacostia River, their fate and transport is governed by processes including the movement of water within the river, the net rate of outflow into the Potomac River, the extent of adsorption of chemicals to sediment particles, and the ability of bacteria present in the river to break down certain chemicals. Contaminants bound to sediment particles may settle out and deposit on the river bottom surface. Bottom sediments are subject to resuspension, transport along the sediment bed, or burial. The TAM/WASP Toxics Screening Level Model water quality component is able to simulate these processes and others which may affect the concentrations of toxic contaminants which are measured in the river water or bed sediments. The water quality component is based on the EPA's WASP-TOXI model, enhanced by ICPRB to more realistically simulate the settling and resuspension of sediments. This model was used in 2001 to simulate sediment loading, fate, and transport in the tidal river to assist the District of Columbia and the EPA in development of the TMDL for suspended solids in the Anacostia. Model calibration results for suspended solids were consistent with available water column monitoring data for TSS (total suspended solids) and with bed sediment grain size composition data. In Figure 10, model-predicted concentrations of fine-grained material (frac1: < 30 :m), medium-grained material (frac2: > 30 :m and < 120 :m) and coarse-grained material (frac3: >120 :m) are compared with corresponding data collected in Phase II by GeoSea Consulting Ltd.(2001). Draft TAM/WASP model runs for metals have also been completed, and are discussed below. Only very preliminary results for organic chemicals are currently available, due to the absence of any storm water monitoring data for the tidal portion of the basin.

The TAM/WASP Toxics Screening Level Model currently consists of four sub-models:

- Sub-Model 1: Metals (zinc, lead, and copper)
- Sub-Model 2: PCBs (three groupings)
- Sub-Model 3: PAHs (three groupings)
- Sub-Model 4: chlordane

Because WASP can only model three chemicals at a time, PCB congeners have been combined into three groups: 1 and 2 chlorinated homologs; 3, 4, and 5 chlorinated homologs; and 6 to 10 chlorinated homologs. Likewise, the 16 PAHs considered by the model have been combined into three groups: 2 and 3 rings; 4 rings; and 5 and 6 rings.

Model predictions of Anacostia River metals concentrations are in fairly good agreement with available data. A comparison of draft model results for the last day of a six-year[1] run with bed sediment concentrations data in Figure 10, 11, 12 and 13. Model-predicted zinc and copper concentrations match the general pattern and magnitude of measured concentrations reasonably well. Model-predicted lead concentrations follow to some extent the spatial pattern observed in the river, though predicted concentrations are roughly two times higher than measured concentrations. However, as discussed in Section 1.4.1.2, actual upstream loads may in many cases be a factor of two or three greater or a factor of two smaller than the loads estimated using the small amount of available upstream data. It should also be noted, referring to Table 3, that the estimated range of uncertainty in upstream storm concentrations of lead was considerably higher than for copper or zinc. Model test runs for lead using reduced upstream storm loads show that lead results are within a reasonable range of load uncertainty.

TAM/WASP Screening Level Model results for metals will be finalized after receipt of the upcoming MWCOG storm water monitoring data, which will be used to update load estimates for tidal basin sub-sheds. However, with the exception of the Lower Beaverdam Creek sub-shed, metals load estimates are unlikely to change substantially, since a reasonable amount of storm water monitoring data is already available for metals. According to the Draft TAM/WASP Screening Level Model estimates, total zinc, lead, and copper loads to the tidal portion of the river can be broken down as follows:

Table 4 Draft Model Estimates of Metals Loads to the Tidal Portion of the Anacostia

	Upstream Tributaries	**Separate Sewer System and Minor Tributaries**	**CSOs**	**Lower Beaverdam Creek**	**Watts Branch**
Zinc	20,800	6,500	3,700	15,600	1,600
Lead	5,500	400	500	1,900	100
Copper	2,700	700	400	700	200

[1]

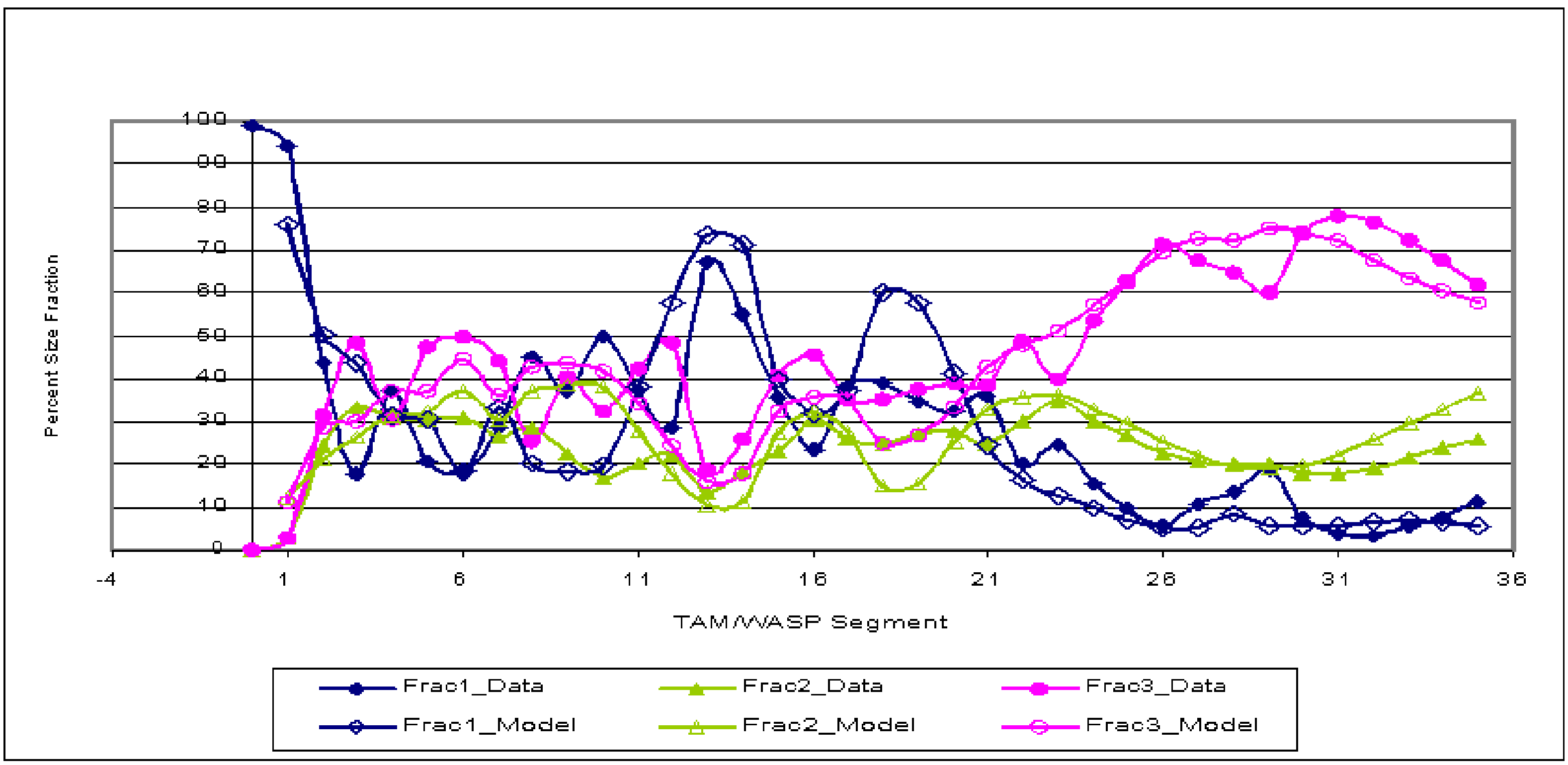

Figure 10: Comparison of Model-Predicted Versus Measured Sediment Bed Grain Size Composition

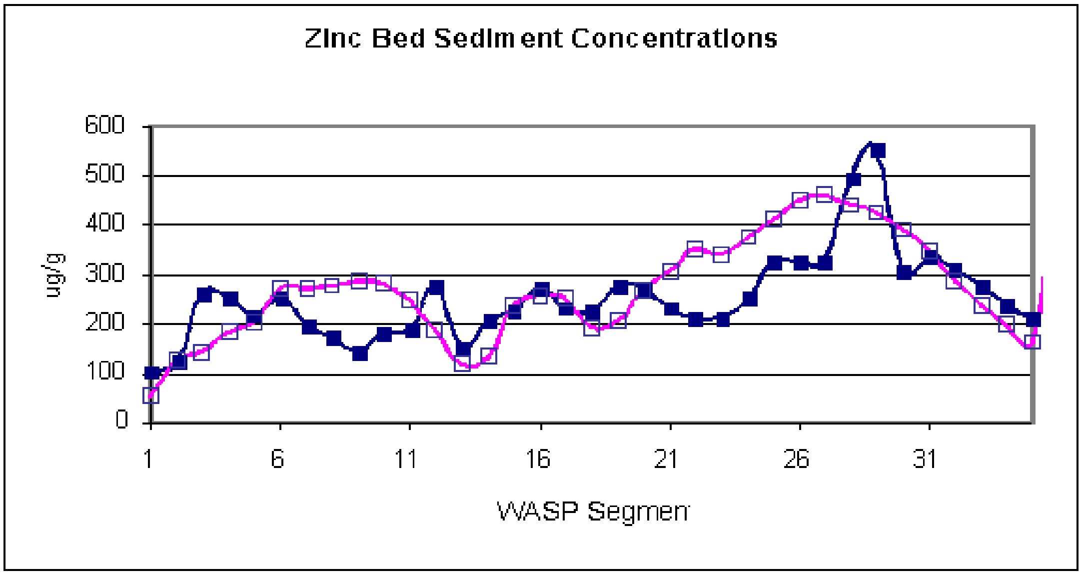

Figure 11 Comparison of Model-Predicted Versus Measured Zinc Concentrations in Sediment Bed

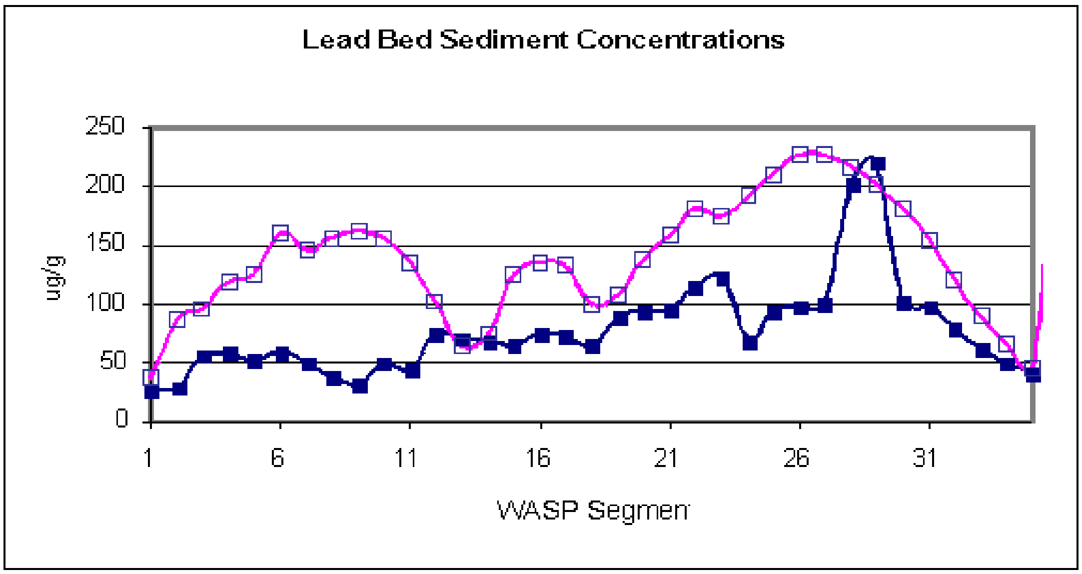

Figure 12 Comparison of Model-Predicted Versus Measured Lead Concentrations in Sediment Bed

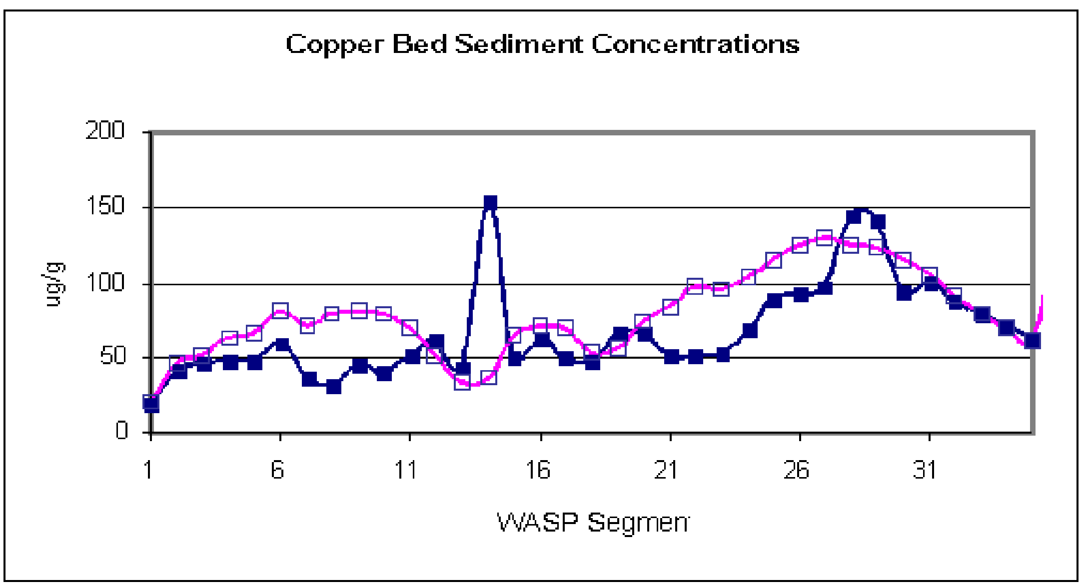

Figure 13 Comparison of Model-Predicted Versus Measured Copper Concentrations in Sediment Bed

Preliminary model runs for PCBs, PAHs and chlordane have also been made. Since the only data currently available to estimate loads for these chemicals is the upstream tributary data discussed above, it was assumed in these preliminary runs that storm and non-storm concentrations from all subsheds throughout the watershed are identical to measured upstream concentrations. Results of preliminary model runs for PCBs and PAHs are poor, with predicted sediment bed concentrations much too low. These results indicate that tidal sub-shed concentrations of these chemicals are much higher than upstream tributary concentrations, and/or that actual upstream tributary concentrations are on average much higher than the estimates computed from the very limited amount of available data. Hopefully, the storm water monitoring data collected in the spring of 2002 by MWCOG will shed light on this problem. However, it is most certainly the case that the relative contributions of loads of organic chemicals to the tidal Anacostia will not be well understood until funding is found for further storm water monitoring studies, using adequately low detection limits.

1.4.1.4 Summary of Preliminary Modeling Results

Though modeling results will be incomplete until data from the upcoming AWTA/COG storm water monitoring study is available, preliminary modeling results, based on incomplete data, allow us to draw several conclusions. First, results of the draft metals model, which takes advantage of the fact that a reasonable amount of historical data is available to characterize metals inputs into the river, indicate that the 1D TAM/WASP Screening Level model is capable of successfully simulating chemical concentrations in both the river bed sediment and water column. Simulated metals concentrations follow the general trends observed in the river, though the model is not able to reproduce many of the localized sediment “hot spot” areas. Second, it is clear from results of the preliminary models for PCBs and PAHs that because of our lack of data concerning inputs of organic chemicals from the river’s storm sewers, CSOs, tributaries, and groundwater, the model is currently not completely representing major sources of these chemicals to the river. The model is seriously underestimating concentrations of these chemicals throughout the tidal river bed sediments.   Finally, even for the input sources best understood in the Anacostia basin, the upstream tributaries, statistical analyses of uncertainty indicate that because of the small sample size of the data set, input load estimates may be in error by a factor of two or three, potentially leading to significant errors in model predictions.

Preliminary modeling results are therefore promising, but point to the need for additional storm water monitoring data at additional locations in the District of Columbia. Data should be collected at outfalls located near bed sediment hot spots in order to increase the likelihood that significant sources to the river are characterized and to give the model the ability to represent better the observed spatial patterns of contaminant concentrations in the bed sediment. Additional data is also needed for the upstream tributaries to reduce statistical uncertainties. Data sets should contain a minimum of six (6) data points per location per model parameter to be estimated, allowing the reasonable estimation of a mean concentration, and allowing a sign test to be used to compare concentrations at two different locations.   Preferably, data sets should contain a minimum of twelve (12) data points per location per model parameter to be estimated, allowing a reasonable estimation of the mean and the variance of concentration at a given location.

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[1] A six year run is 2 model runs for 1988 to 1990 were the output from the first run is input for the second run. This is necessary because the system may not reach equilibrium for three to six years.