Evaluation of Sediment Remediation Conducted at the U.S. Corps of Engineers Marine Maintenance Facility on the Mississippi River at Fountain City, Wisconsin

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Introduction

The U.S. Corps of Engineers St. Paul District (COE) operates a marine equipment maintenance facility (Service Base) at Fountain City, Wisconsin in Pool 5A of the Upper Mississippi River (Figure 1). In the early 1980s, the COE conducted soil cleanup activities at their facility to remove soils containing high levels (10-390 ug/g) of polychlorinated biphenyls (PCBs) at their facility. This contamination stemmed from the use of waste oils containing PCBs as dust suppressants on grounds of the Service Base (Wisconsin Department of Natural Resources, 1981). In 1993, follow-up investigations by the COE in an area omitted during initial remediation work in the 1980s revealed remaining PCB-contaminated soils south of the Marine Way with maximum concentrations exceeding 60 ug/g (Barr Engineering Co., 1994). This study indicated that the PCB contamination was attributed to Aroclor 1260, a PCB mixture containing congeners exhibiting a high degree of chlorination (i.e. hexa-, hepta- and octachlorobiphenlys), (Ballschmiter and Zell, 1980).

The department implemented a study in the fall of 1993 to determine if the Service Base was contributing to significant PCB input to the river based on monitoring caged fish, sediment and semi-permeable devices (SPMDs) deployed upstream and downstream of this facility (Sullivan and Steingraeber, 1995). This study revealed significant differences in the composition of PCBs in the three matrices based on a comparison of upstream to downstream samples. In particular, hexa-, hepta- and octachlorobiphenyls were significantly higher in sediment traps and SPMDs deployed below the Service Base. This response was consistent with the expected local source input of Aroclor 1260. Sediment traps were very useful at demonstrating this response since PCBs are nonpolar and adsorb onto fine organic particulate material (Karickhoff et al. 1979).

In 1995, the COE implemented remediation investigations to define the zone of soil contamination at their facility and to determine the extent sediment contamination adjacent to this site (Figure 2). This study identified a boot-shaped area of soil contamination with PCBs (Aroclor 1260) ranging from about 10 to 65 ug/g. Sediment core samples (0-1 ft and 1-4 ft) indicated substantially lower concentrations with levels ranging from about 1 to 5 ug/g with highest levels detected in the shoreline area adjacent to the site of soil contamination (Braun Intertec Corporation, 1995). The COE collected subsequent sediment samples in Foutain City Bay in February 1996 to better define the spatial and vertical extent of sediment contamination.

The department and the COE reached agreement on a PCB sediment quality cleanup goal of 0.8 ug/g (800 ng/g) in August 1996. This goal was proposed by the Department and was based on meeting a sediment quality objective of 53 ug/g organic carbon which was 10 % of the severe effect level for total PCBs proposed by the Ontario Ministry of the Environment (Persaud et al. 1993). The department recognized that residual PCBs from previous soil remediation efforts would need to be considered in establishing the sediment cleanup goal. The COE proposed a soil cleanup goal of 5 ug/g, which they believed would be consistent with the sediment quality goal considering the roughly 10-fold difference between contaminated soils versus sediment at this site based on pre-remediation monitoring. This soil cleanup goal was one-half the previous soil cleanup goal (i.e. 10 ug/g) for soil remediation work performed at the service base in the early 1980s. The department concurred with this soil goal since it represented an improvement from previous remediation efforts and was consistent with statewide soil remediation efforts.

In the spring of 1999, 2485 cubic yards of contaminated sediment and 680 yards of contaminated soil were excavated and hauled to licensed landfills capable of handling these wastes. Excavated soils were separated into low (<50 ug/g) and high ($\geq$50 ug/g) PCB-contaminated fractions. All dredged sediments and low-level PCB contaminated soils were hauled to the Superior FCR landfill at Buffalo, MN. Approximately 14% of the excavated soils exceeded 50 ug/g and were transported to Wayne Disposal Inc., Belview, MI (World Environmental Inc., 1999 and Baylor, 1999).

The purpose of this report is to summarize the PCB sediment monitoring work that was conducted to assess the impact and effectiveness of soil and sediment remediation efforts at the COE's Service Base. Particular attention was directed to the sediment remediation efforts since they had a more direct bearing on receiving water impacts and there was a need to assess future sediment management activities at this site.

Methods

Monitoring upstream and downstream of the Service Base was conducted during three phases. Pre-remediaton monitoring consisted of sediment trap collections during the fall of 1993 (Sullivan and Steingraeber, 1995) and sediment investigations conducted by the COE or its consultants prior to contaminated sediment dredging in March of 1999. Monitoring during the sediment excavation phase consisted of sediment traps deployed prior to and shortly after the contaminated sediment removal (March 16-26, 1999). Post-remediation monitoring consisted of bed sediment sampling by the COE and department to verify achievement of cleanup goals. In addition, the department deployed upstream and downstream sediment traps to compare to pre-remediation measurements.

The department's utilized clean glass jars (500 ml I-Chem) as a means to trap suspended particulate material. The jars (traps) were placed throughout the water column by attaching the jars to a 1.9 cm o.d. pipe (Sullivan, 1995). Sediments collected from several traps at the monitoring site were composited to form sufficient volume for analysis.

The COE or the department collected bed sediment samples by various means including Ponar (COE) or Van Veen (department) grabs or driven 1 to 4-ft long core samples (COE). Core samples were generally composited into two depth fractions 0-1 ft and about 1-4 ft.

The department's sediment samples were analyzed for PCB congeners by the Wisconsin State Laboratory of Hygiene in Madison, Wisconsin. A detailed description of these methods are presented elsewhere (Moody 1997a,b). It should be noted the pre-remediation PCB samples were quantified using a congener standard developed by Mullin (1984), whereas post-remediation samples used a newer standard prepared by Mullin in 1994. This difference could account for some quantitation differences for some congeners, but these were believed to be minor (Sullivan and Steuer, 1999). Total PCBs were estimated by summing all congeners exceeding the limit of detection. Typical detection limits for individual or co-eluting congeners ranged from about 0.2 to 1 ng/g. Congeners reported less that the limits of detection were assumed to be absent (0 ng/g).

Pre-remediation sediment and soil samples analyzed for the COE by Braun Intertec Corporation in 1995 used EPA Method 3540 for extraction and Method 8081 for quantitation (Braun Intertec Corporation, 1995). They reported an Aroclor-based PCB detection limit of 1000 ng/g. The 1996 sediment samples were analyzed by Hazleton Environmental Services using EPA method 8080. This lab reported Aroclor 1260-based detection levels ranging from 32-200 ng/g dependent on the concentrations of PCBs present (Hazleton Environmental Services, 1996). Post-remediation samples were analyzed for the COE by Severn Trent Laboratories and are based on EPA Method 8082 (World Environmental Inc., 1999). PCBs were reported on an Aroclor basis with typical detection limits of about 12 ng/g for sediment samples. Aroclor 1260 was the only form of PCBs detected by these laboratories.

Results and Discussion

Pre- & Post-Remediation Bed Sediment Sampling

In 1995 and 1996, 37 bed sediment samples were collected by the COE (or their consultants) in Fountain City Bay (FCB) immediately adjacent to the PCB soil contamination area at the Service Base. Total PCBs ranged from less than detection to 5300 ng/g with a median concentration of approximately 1000 ng/g. Total organic carbon (TOC) normalized concentrations ranged from less than detection to 929 ug/g

OC with a median of 117 ug/g OC (Figure 3). Highest levels were found in the 1-2 ft depth strata along the shoreline area immediately adjacent to site of soil contamination (Figure 2). It was not possible to compare different sampling strata as a result of unequal sampling although in general, deeper cores (1-4 ft) indicated lowest PCB concentrations (<40 ng/g).

The COE collected eight random sediment samples in the sediment excavation area following the removal of PCB-contaminated sediment. PCBs in these samples were substantially lower than pre-remediation samples and ranged from less than detection to 350 ng/g with a median concentration of approximately 70 ng/g. This sampling indicated that the sediment PCB cleanup goal of 800 ng/g was achieved.

The department collected a post-remediation sediment composite sample (3 Van Veen grabs) on March 26, 1999 in the shoreline area which previously exhibited highest PCB concentrations. This sample had a PCB concentration of 417 ng/g and a TOC-normalized concentration of 80.2 ug/g OC. The TOC-normalized concentration was elevated due a predominance of sandy material and low TOC content (0.5%) in this sample. A second composite sample (5 Van Veen grabs) was collected a few hundred feet downstream of the sediment remediation area on November 10, 2000 to assess off-site movement from the remediation site. This sample reflected the upper 0-10 cm of surficial sediment collected from 5 separate Van Veen Grabs. This sample yielded a total PCB concentration of 33.4 ng/g with a TOC normalized concentration of 0.9 ug/g OC. This sample contained more fines and organic matter (3.8% TOC) typical of backwater or slow-moving, deep-water side channels.

Sediment Trap Sampling

Suspended particulate material was collected using sediment traps deployed several hundred feet upstream and downstream of the sediment remediation site in FCB prior to (Aug-Oct 1993) and after (Sept-Nov 2000) the remediation project (Figure 1). In addition, sediment traps were also deployed downstream of the remediation site in March 1999 during the removal of contaminated sediments to assess the downstream movement of suspended, particulate-bound PCBs during the remediation project.

Suspended sediment collected upstream of the remediation site yielded total PCB concentrations of 31.6 and 16.2 ng/g pre- and post-remediation, respectively. In contrast, PCB levels in suspended matter collected downstream of the project site were 48.1 and 45.6 during these respective periods (Figure 4a). The increase in PCBs observed in downstream sediment traps was found to be statistically significant during pre-remediation monitoring (Sullivan and Steingraeber 1995). Replicate upstream and downstream sampling was not performed during the post-remediation monitoring which prevented a statistical comparison of the recent data. However, it is believed the increase in PCB concentrations observed at the downstream site was again influenced by PCB input from the Service Base. This was especially true of the higher chlorinated congeners, which are discussed below. TOC-normalized PCB concentrations in suspended matter also showed a noted increase below the remediation site during pre- and post-remediation monitoring (Figure 4b) and again likely reflects the local source input.

A relatively high PCB concentration (560 ng/g) was observed at the downstream site during the excavation of contaminated sediment in March 1999. This yielded an estimated whole-water particulate-phase concentration of approximately 12 ng/L based on a maximum total suspended solids concentration of 21 mg/L measured downstream during contaminated sediment excavation. This exceeded similar particulate-phase concentration estimates measured upstream at Lock and Dam 3 in the spring of 1996 by a factor of 4 (Sullivan and Steuer, 1999). The high particulate-phase concentrations measured below the Service Base was most likely due to the mobilization and downstream movement of PCB-contaminated sediment from the remediation site during mechanical dredging of contaminated sediment.

It was difficult to evaluate how the remediation project influenced the suspended sediment quality below the Service Base since loading measurements were not made, and upstream suspended sediment PCB contamination in FCB has decreased over the last several years (Figure 4a). Long-term suspended sediment PCB concentration data for the Mississippi River have been collected by the department (using sediment traps) at Lock and Dam 3 (Red Wing, MN) and Lock and Dam 4 (Alma, WI) since 1987

(Sullivan, 1995) and provide a reference for noting temporal and spatial changes. This evaluation indicated the upstream site in FCB yielded equivalent total and TOC-normalized PCB concentrations as that found at Lock and Dam 4 (Figure 5a and 5b). The downstream site in FCB had total PCB concentrations that were higher than Lock and Dam 4 but lower than Lock and Dam 3 during pre- and post-remediation monitoring. TOC-normalized PCB concentrations at the downstream site in FCB where similar to Lock and Dam 3 in 1993 but were noticeably lower and approached levels observed at Lock and Dam 4 in 1999 (Figure 5b). A relatively low TOC content (1.7%) measured in the pre-remediation sample at the downstream site in 1993 may have influenced this response since it would have contributed to a higher TOC-normalized value at that time. Future sediment trap monitoring at Lock and Dam 4 and downstream of the remediation site would provide additional information to evaluate remediation project and provide an indication of ongoing PCB input from the Service Base.

PCB Congener Composition - Remediation-Phase Sampling

The congener concentrations and their percent composition of remediation-phase sediment sampling collected in March 1999 are presented in Figure 6. Three sediment matrices were sampled including excavated sediment (dredge spoil), bed sediments (immediately after excavation) and sediment traps (downstream of remediation project). The Dredge spoil sample exhibited the lowest congener concentrations (< 20 ng/g). World Environmental Inc. consultants collected this sample for the department on March 25 from a portion of the stockpiled excavated sediment stored at the Service Base. The mixing of uncontaminated sediment with contaminated sediment during dredging and removal likely resulted in lower PCB concentrations in this sample.

Post-remediation bed sediments and downstream sediment traps yielded very similar congener concentrations with maximum concentrations of about 40-60 ng/g for specific congeners (Figure 6c and 6e). The congener composition indicated a predominance of hexa-, hepta-, and octachlorobiphenyls (congener numbers 141 to 208/196) in all three matrices, which would be expected since they are all closely related and linked to the local PCB contamination (Aroclor 1260) at the Service Base. However, the dredge spoil sample differed from bed and sediment trap samples by the presence of a larger number of lower chlorinated congeners including di-, tri-, ortho-, and pentachlorobiphenyls (congener numbers 8/5 to 77/110), but these were detected at low concentrations (0.2 to 4.4 ng/g). This suggests the dredge spoil sediment was influenced by a different type/source of PCBs other than Aroclor 1260. It is suspected this sample may have been influenced by historical contamination (older sediment) from upstream sources which typically resemble Aroclor mixtures or congeners with lower levels of chlorination (Sullivan 1988 and 1995).

PCB Congener Composition - Post-Remediation Sampling

Post-remediation sampling included a composite of surficial bed sediment (upper 10 cm) collected immediately downstream of the remediation site and sediment traps deployed upstream and downstream of the remediation site during the fall of 2000. In addition, sediment trap data were available for this fall period from deployments made upstream at Lock and Dams 3 and 4 and are included in this report for comparative purposes.

The surficial bed sediment composite sample indicated low congener concentrations (< 4 ng/g) with a major representation from the hexa-, hepta-, and octachlorobiphenyls (Figure 7a and b). In general, the congener composition of the higher chlorinated biphenyls exhibited a similar pattern to the sediment sample collected in the immediate area of the remediation project in March 1999 (Figure 6d). The dominance of congener 180, a dominant heptachlorobiphenyl present in Aroclor 1260 (Ballschmiter and Zell, 1980), may offer a marker for local source contamination from the Service Base. Congener 180 was not present in high amounts in trap samples collected upstream of the Service Base, including those deployed at Lock and Dams 3 and 4 (Figure 7c, and 7e).

Upstream and downstream sediment trap sampling at the Service Base continues to exhibit a difference in congener composition (Figure 7d) indicating local contamination is still influencing suspended sediment PCB levels collected immediately below the Service Base. The fall sample collected downstream in 2000

indicated noticeably higher concentrations of the higher chlorinated congeners below the Service Base. These concentrations were also greater than those observed in sediment trap samples collected from Lock and Dam 4 but were less than those reported for Lock and Dam 3.

Conclusions and Recommendations

The remediation project removed approximately 2500 cubic yards of PCB-contaminated sediment and 700 yards of contaminated soil from areas on or near the U.S. COE Engineers' Service Base located in Pool 5A at Fountain City, Wisconsin. Contaminated sediments and soils were transported to licensed landfills approved for accepting these wastes. Bed sediment sampling indicated the remediation effort met the cleanup goal of 800 ng/g.

Suspended sediment contaminant monitoring was effective for evaluating localized inputs from the Service Base before, during and after the sediment remediation project. Post-remediation monitoring indicate downstream sediment traps continue to exhibit greater PCB concentrations than those measured upstream. This was mainly due to higher chlorinated congeners that reflected the type of PCBs (Aroclor 1260) that were historically deposited at or near the Service Base. Although downstream samples indicated ongoing contributions of PCBs from the Service Base area, the concentrations were within the range of similar measurements made upstream in the Mississippi River at Lock and Dam 4. As a result, no further sediment remediation efforts are recommended. However, periodic sediment trap monitoring for PCB congeners below the Service Base in addition to upstream sampling at Lock and Dam 4 is recommended to gain additional data to assess the remediation effort and to evaluate the relative changes in local source contributions. In order to maintain continuity with past sampling efforts, the Wisconsin State Laboratory of Hygiene should perform these analyses.

Future plans for site modifications at the Service Base (i.e. dredging, soil excavations etc.) will need to be carefully evaluated to ensure PCBs are not re-mobilized or discharged to the river. During these construction projects, consideration should be given to removing or isolating (i.e. encapsulation) the remaining PCB-contaminated soils to reduce the potential for future releases to the river.

Removal of contaminated sediment by mechanical dredging resulted in the downstream transport of PCBs based on sediment trap sampling below the remediation site. Suspended material yielded a relatively high PCB concentration of 570 ng/g, which yielded a whole-water particulate-phase concentration estimate of roughly 12 ng/L. Future dredging of similarly contaminated sediment will need to consider methods for reducing downstream transport of contaminated suspended particulate material.

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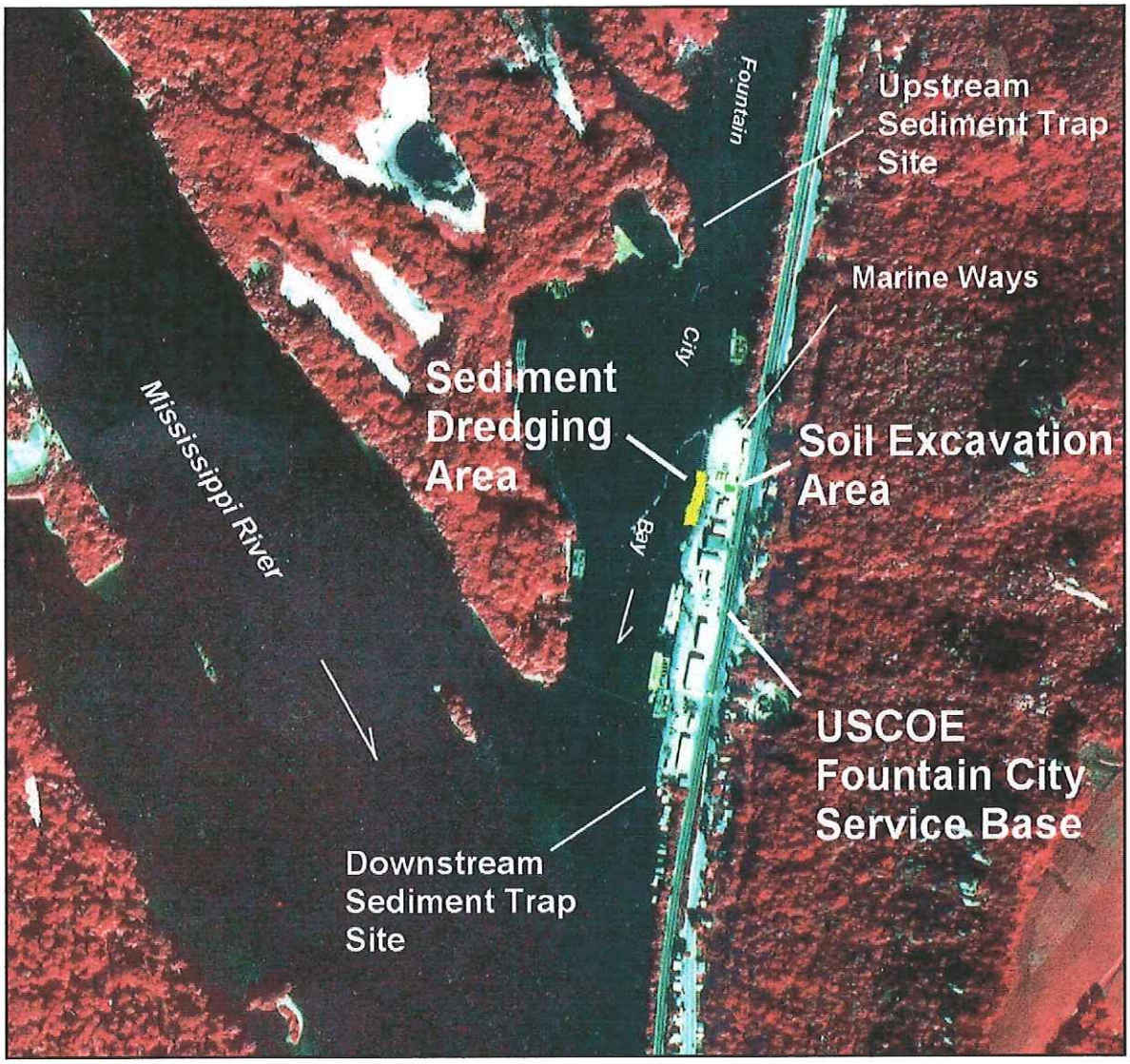


Figure 1. September 16, 1984 color infrared photo of the U.S. Corps of Engineers Marine Maintenance Facility (Service Base) on the Mississippi River in navigation Pool 5A at Fountain City, Wisconsin. The photo illustrates the approximate sites of soil and sediment remediation and sediment trap monitoring.

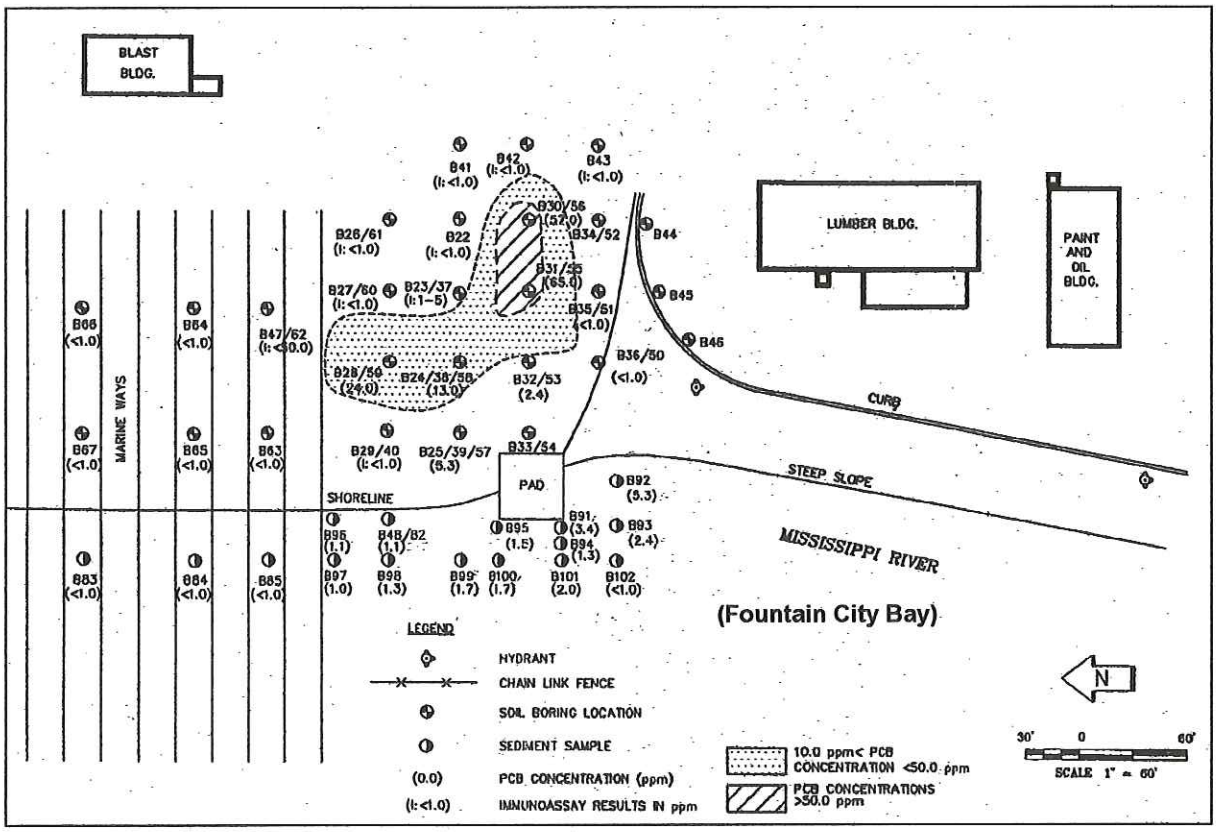


Figure 2. Pre-remediation sediment and soil PCB monitoring results from sampling performed in 1995 at the U.S. Corps of Engineers Service Base located in Pool 5A of the Upper Mississippi River. This is a modification of Figure 4 prepared by Braun Intertec Corporation, 1995.

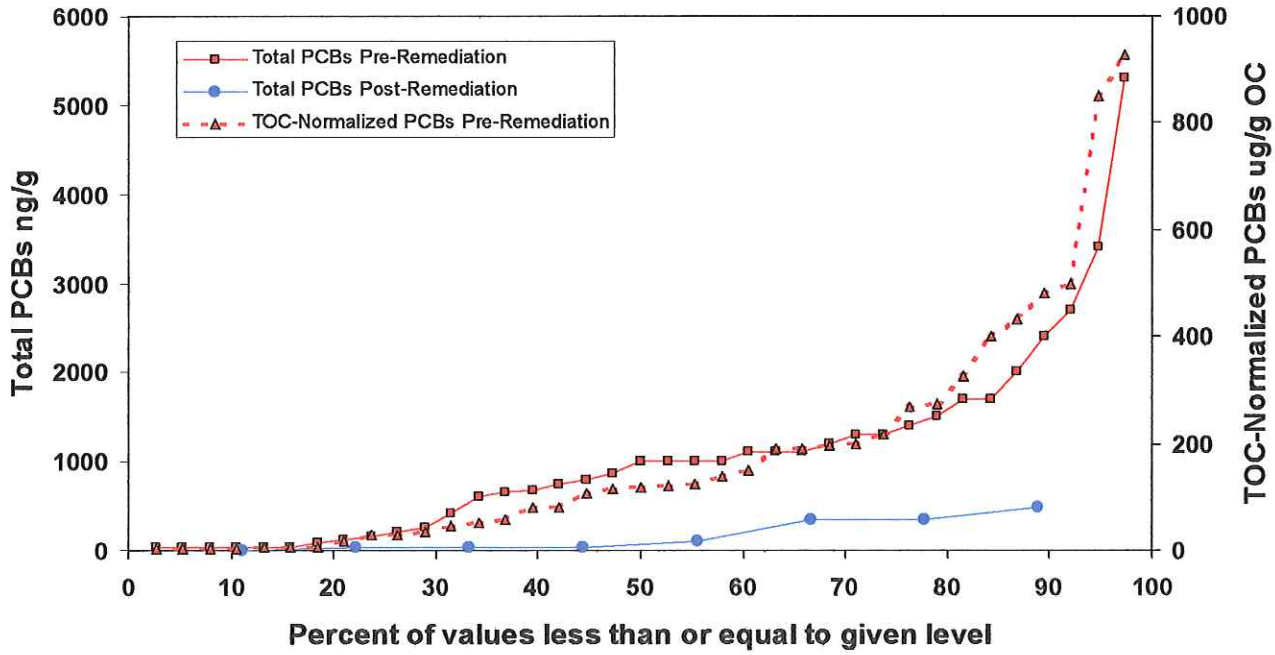


Figure 3. Distributions of total PCB sediment monitoring data based on samples collected by the the U.S. Corps of Engineers at their Service Base at Fountain City, Wisconsin. The data represent samples collected from the sediment remediation area before (1995 and 1996) and after (1999) the sediment remediation project.

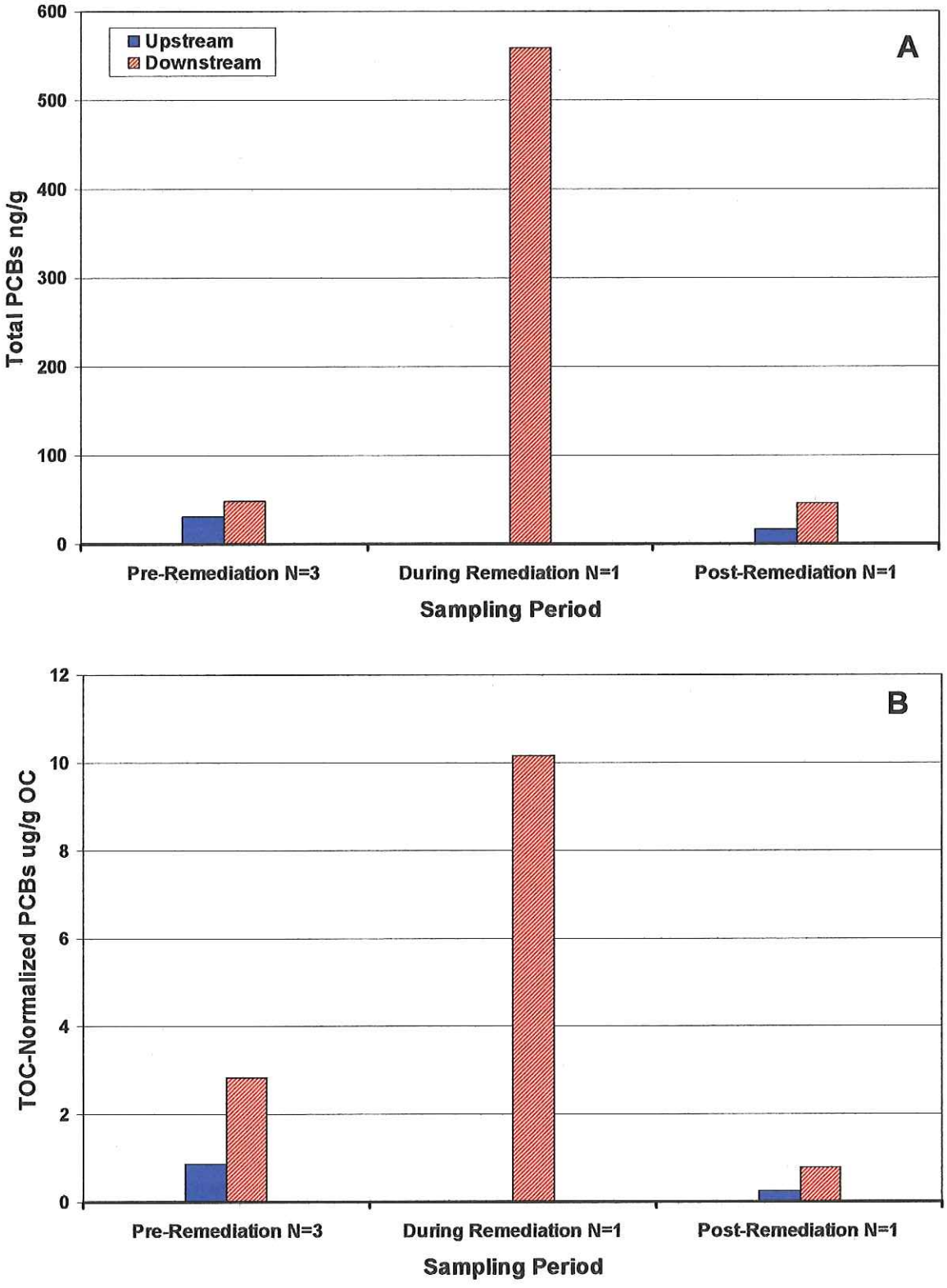
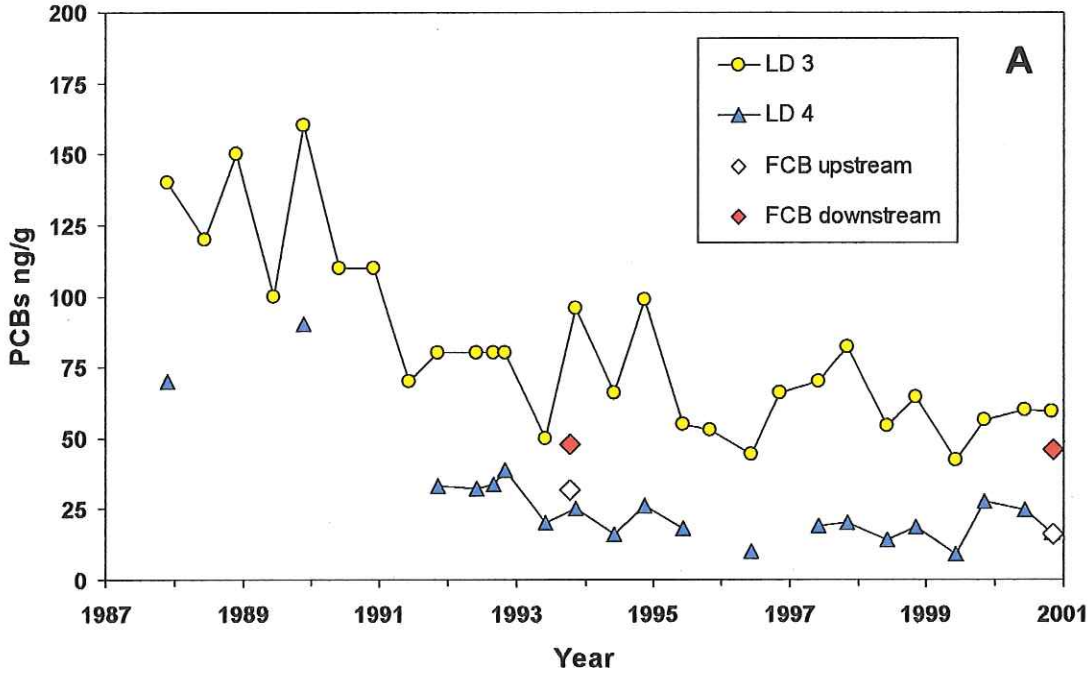


Figure 4. **A.** Total PCB concentrations in suspended sediment collected by the Wisconsin DNR using sediment traps deployed upstream and downstream of the U.S. Corps of Engineers Service Base at Fountain City, Wisconsin prior to (Fall 1993), during (March 1999) and after (fall 2000) the sediment remediation project. **B.** Total PCBs expressed at total organic carbon-normalized concentrations.



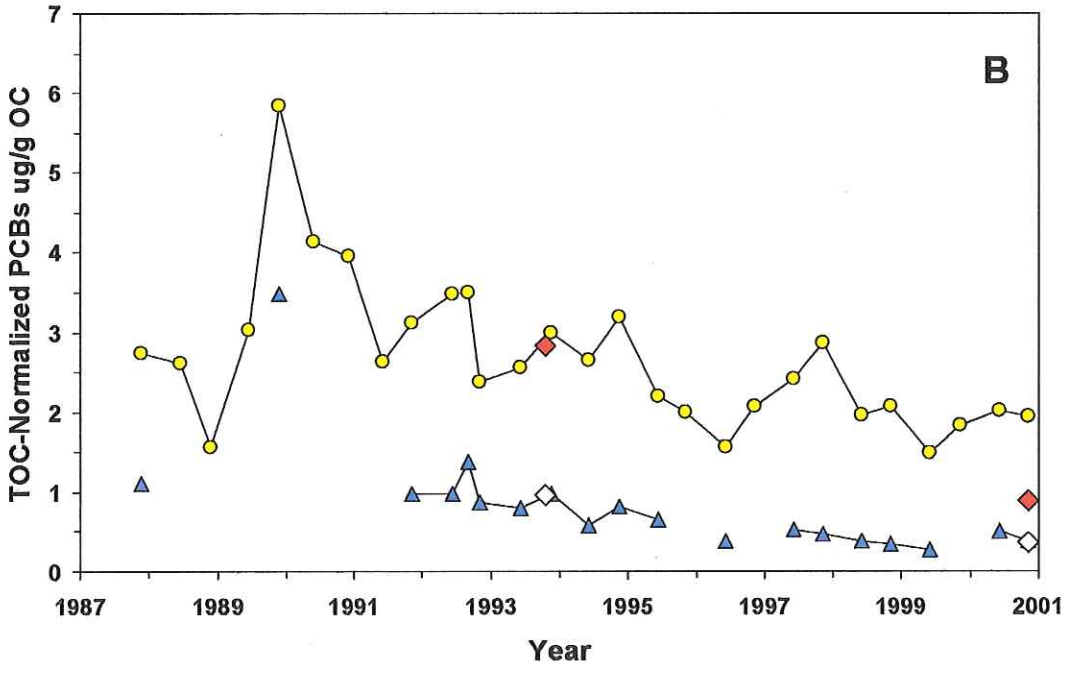


Figure 5. **A**. Long-term total PCB concentrations in sediment trap samples deployed by the Wisconsin DNR in the Mississippi River at Lock and Dams 3 and 4 and pre- (fall 1993) and post-(fall 2000) remediation sediment trap monitoring conducted near the U.S. Corps of Engineers Service Base in Fountain City Bay (FCB). **B**. Total organic carbon-normalized concentrations.

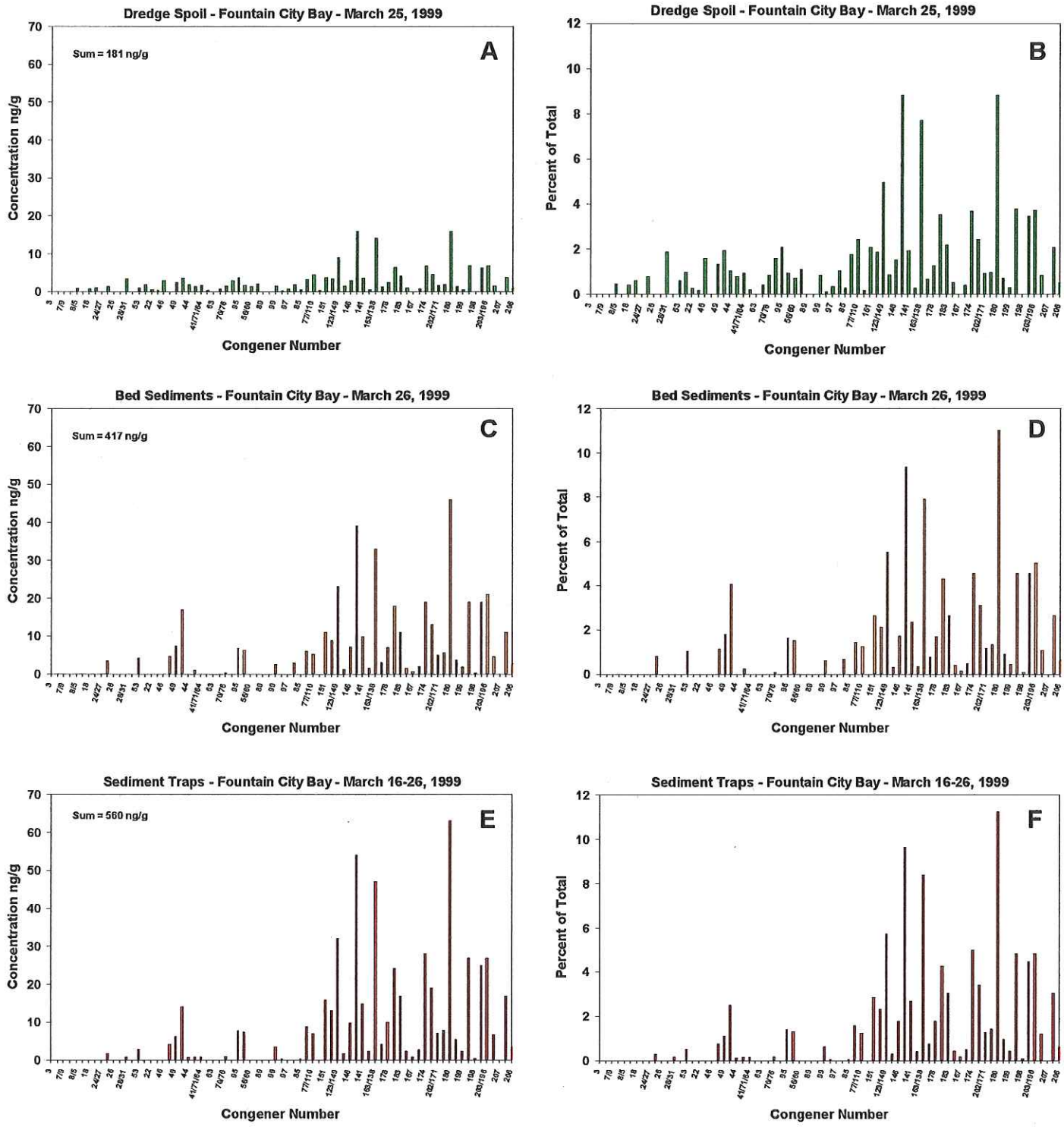


Figure 6. Polychlorinated biphenyl congener concentrations in dredge spoil (**A**), bed sediments (**B**) and sediment traps (**E**) collected at the U.S. Corps of Engineers Service Base in Fountain City Bay (FCB) during or immediately after the sediment remediation project in March 1999. Sediment traps were deployed downstream of the sediment remediation site. Polychlorinated biphenyl congener compositions (% of Total PCBs) in these samples are reflected in the adjacent graph (**B**, **D** and **E**).

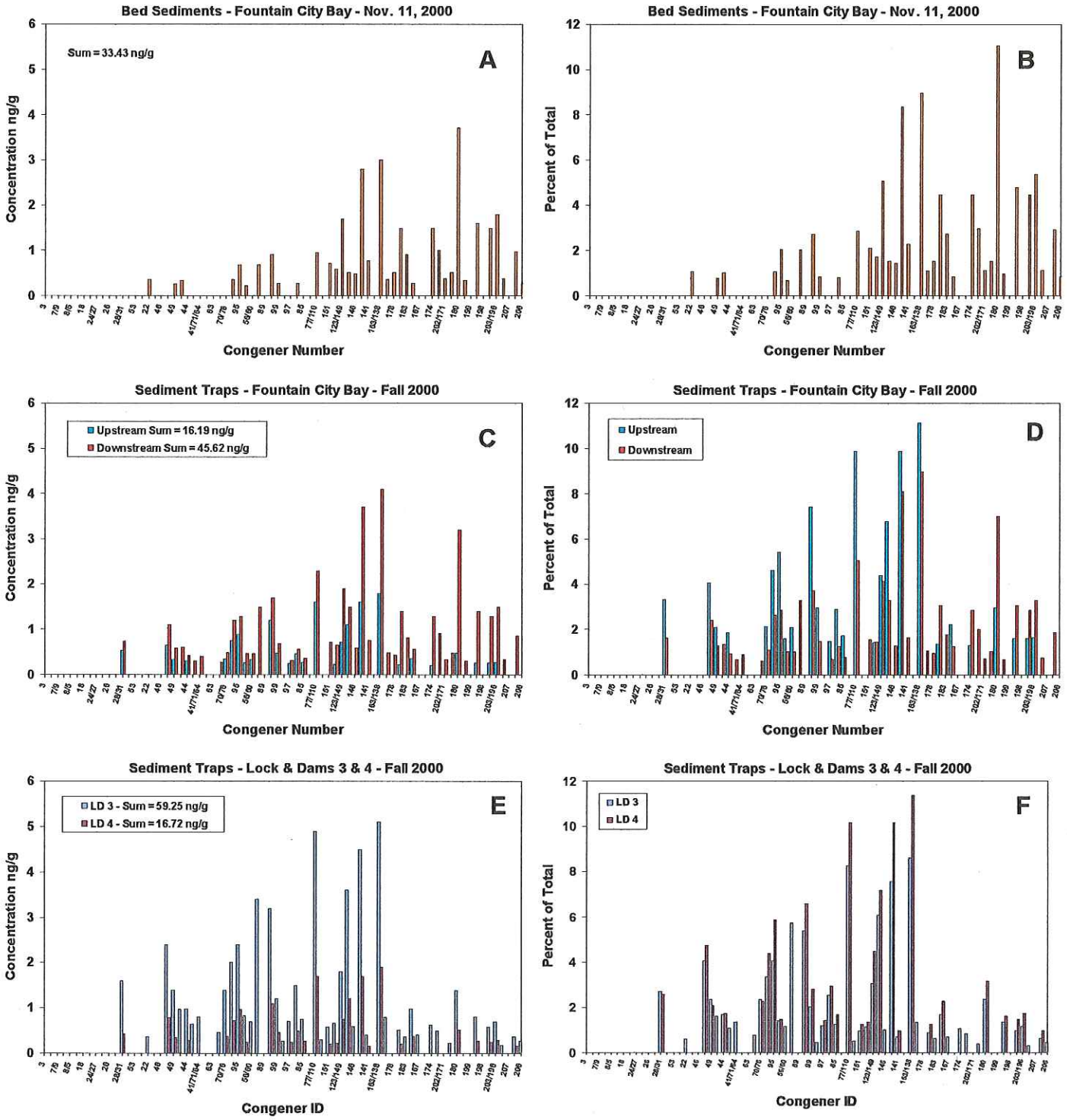


Figure 7. (A) Polychlorinated biphenyl (PCB) congener concentrations and percent composition (B) in bed sediments collected downstream of the sediment remediation site in Fountain City Bay in November 2000. (C) PCB congener concentrations and percent composition (D) in sediment traps deployed upstream and downstream of the U.S. Corps of Engineers' Service Base at Fountain City, Wisconsin in the fall of 2000. (E) PCB congener concentrations and percent composition (F) in sediment traps deployed at Lock and Dams 3 and 4 during the fall of 2000.