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PCB CONTENT IN SHEBOYGAN RIVER SEDIMENTS

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INTRODUCTION

The final report on the "Investigation of Polychlorinated Biphenyls (PCB) in the Sheboygan River System" (Kleinert, et.al., 1978) identified a major PCB source and documented downstream contamination in the mainstream of the Sheboygan River below Sheboygan Falls. One of the several recommendations in this final report directed the Department of Natural Resources to expand the bottom sediment monitoring program for PCBs from Sheboygan Falls to the Sheboygan Harbor.

On August 7, 1978, a bottom sediment sampling survey was conducted in response to this recommendation. The specific objectives of this survey were to identify the location of bottom sediment deposits and to measure the level of PCB contamination in these deposits. Bottom sediment core samples were collected at several river locations and represented a variety of sediment textures.

Background

In 1976, Wisconsin state law (144.50 Wisconsin Statutes) banned the manufacture and purchase of PCBs in the State except for certain exemptions listed in NR 157 of the Wisconsin Administrative Code. With

this reduction in PCB usage, the ultimate source of these compounds to the aquatic food chain became the PCBs accumulated in the environment. Due to their low water solubility, high affinity for adsorption on small particles and strong resistance to breakdown; PCBs have accumulated in receiving water bottom sediments (Flotard, 1978; Choi, et.al., 1976; US EPA, 1978; Neely, 1976).

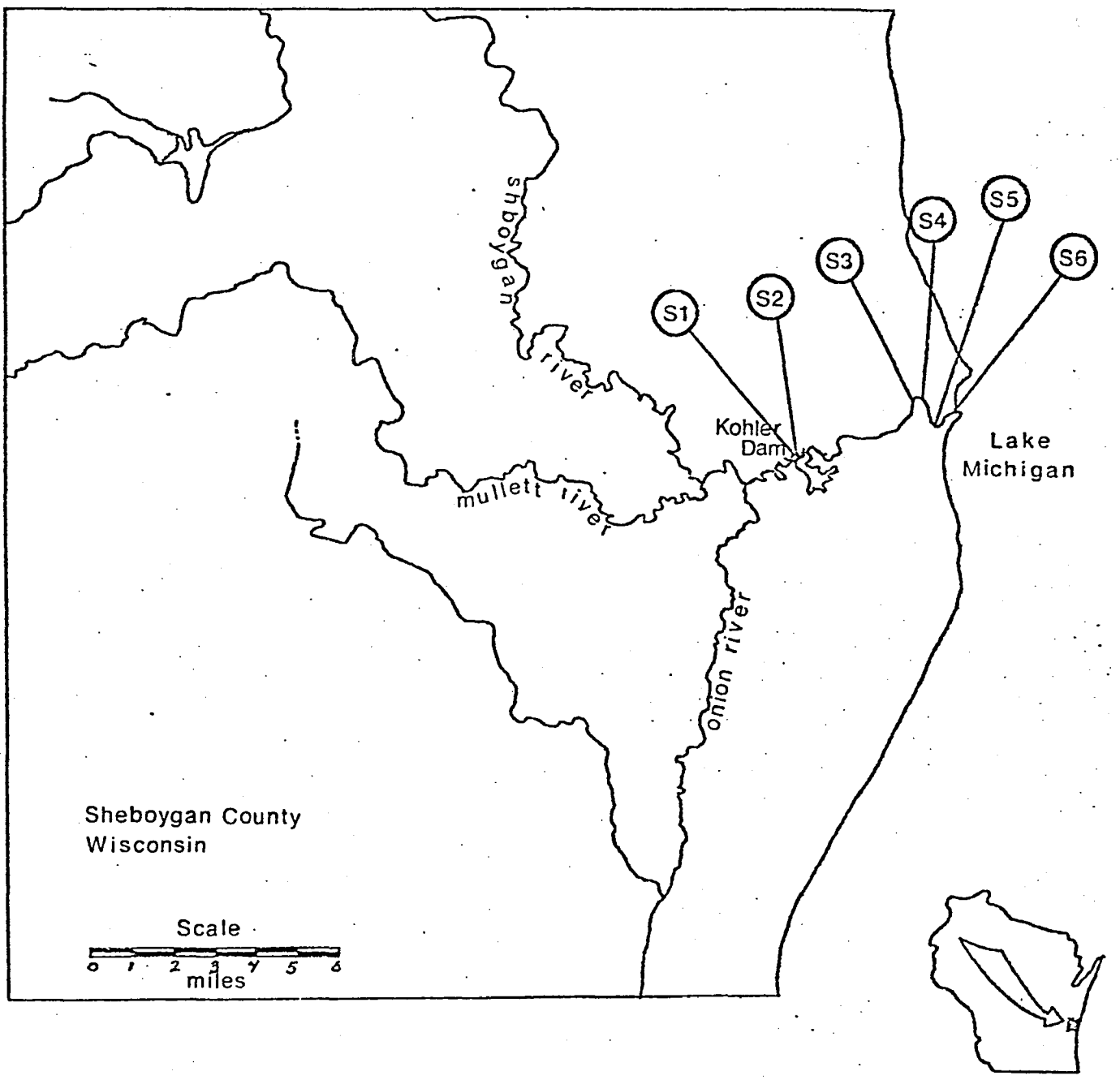
Computer analysis of the Lake Michigan watershed by Neely (1976) concluded that even with the ban on production of PCB compounds and sharp reduction in dispersive uses since 1970, high levels of PCBs in the water column and fish biomass will continue to be a problem for several decades. His model suggested that PCB accumulations in the bottom sediments are now serving as the major PCB source to the water column and to the aquatic food chain.

METHODS AND MATERIALS

Bottom sediment deposits were collected with a 5 foot, 4 inch diameter piston core sampler and Ekman dredge. The river bottom was probed with a steel rod and mapped for general sediment texture. Six sample locations were chosen for core analysis of PCB contamination (Fig. 1). Sample sites represented different river locations and sediment types.

Bottom sediment samples were composited in plastic bags, then stored in individual glass containers with aluminum foil insulated caps. At three downstream sampling sites, core samples were segregated by textural layers and analyzed independently for PCB concentration. All analysis

Fig. 1. Sheboygan River Bottom Sediment Sampling Locations



were conducted by the State Laboratory of Hygiene using the reflex extraction method (AOAC, 1974).

RESULTS AND DISCUSSION

Areas of Sediment Deposition

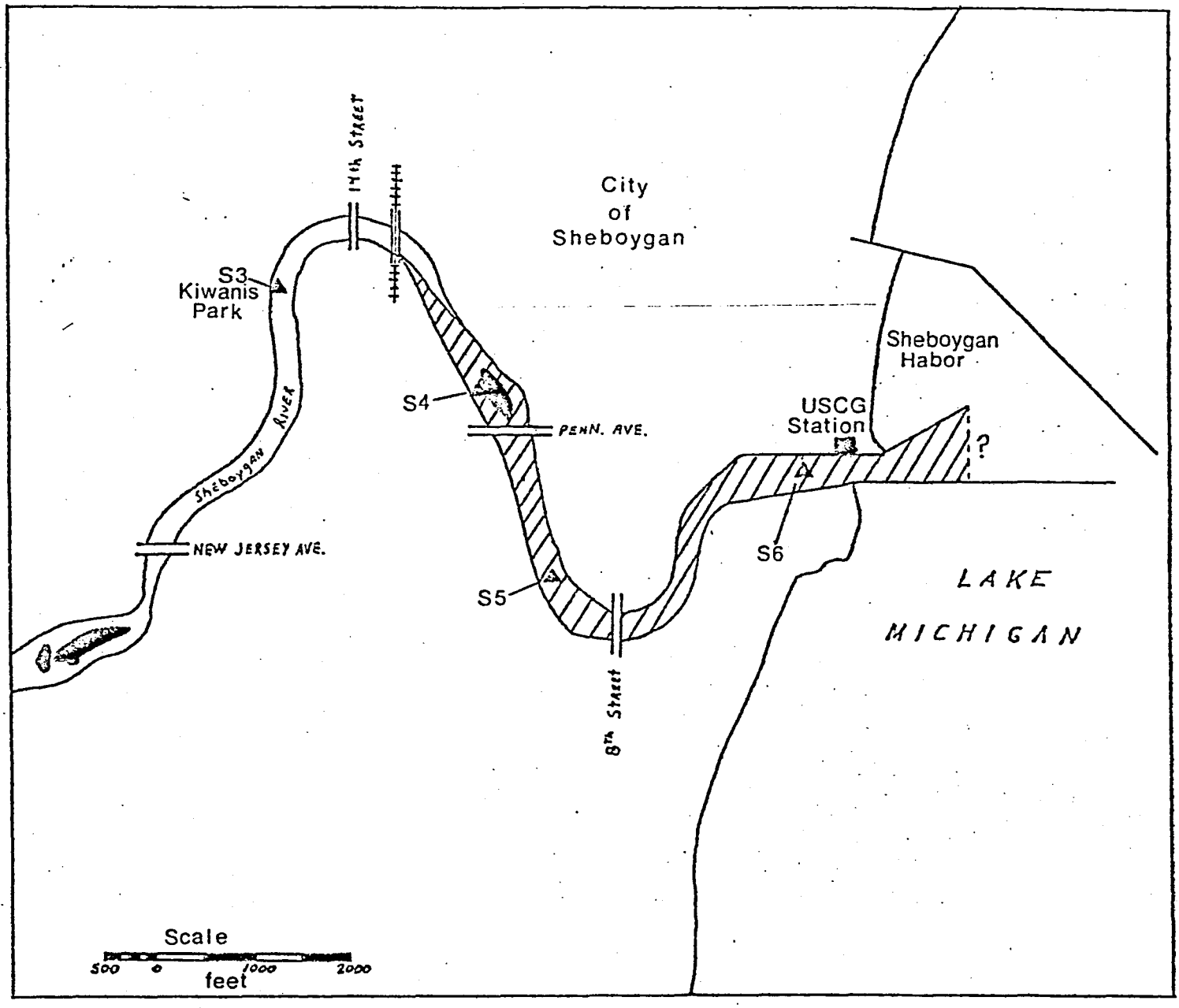
The Sheboygan River bottom from Sheboygan Falls to the City of Sheboygan was generally scoured, with only small areas of sediment deposition ($<100m^3$) above the Kohler Dam and along the stream bank at bends in the river channel. Extensive sediment deposits were located in the main channel of the Sheboygan River from mile 1.5 to the river's mouth (Fig. 2). These deposits consisted of fine grained sands, silts and clay with a high percentage of organic material.

The Kohler Dam impoundment and the lower river area are relatively stagnant bodies of water (<0.5 ft/sec). As the river flows into these areas the velocity of flow decreases; reducing the river's sediment carrying capacity, allowing the sediment load to be deposited. The denser particles of sand settle out first, with the lighter particles of silt and clay progressively settling out downstream. The sedimentation process is not uniform and varies with seasonal and annual changes in river quality and velocity. The sediment deposits in the lower reach of the Sheboygan River from mile 1.5 to the river mouth show a general pattern of decreasing particle size downstream.

Patterns of PCB Contamination

Lab analyses showed PCBs in all of the sediment samples with ten exceeding the EPA threshold concentration ($\geq$10 mg/Kg) for the polluted harbor sediment.

Fig. 2. AREAS of Sediment Deposition Lower Sheboygan River



AREAS of Organic Silt and Clay Deposits

▲ Bottom Sediment Sampling Locations

Island

classification (Bowden, 1977) (Table 1). High concentrations were found at stations S1 and S2, above the Kohler Dam, and at the downstream stations of S4, S5 and S6. In the lower reach of the river (S3 through S6), surface deposits showed increasing PCB concentrations downstream. The upper 10 to 20 centimeters of sediment at stations S3, S4 and S5 had PCB levels of 1.6, 2.7 and 10.5 mg/Kg, respectively. This general pattern of increasing PCB concentrations downstream corresponded closely with the general pattern of decreasing particle size downstream.

Segregated core samples taken in the lower reach of the river (S4 through S6) showed increasing PCB concentrations with increased bottom sediment depth. Levels in the deeper sediments (>20 cm) ranged from 8.4 to 76 mg/Kg, found at a depth of 55 cm at station S5.

The Sheboygan River bottom was dredged in two areas by the US Army Corp of Engineers in 1961 and 1969 (Fig. 3). In the areas dredged, the average rate of sedimentation (estimated by dividing the total depth of accumulated sediment since these areas were last dredged by the number of years since dredging) has been approximately 10 cm/yr (USAE, 1976). This indicated that the upper sediment deposits were a result of recent sedimentation.

The lower PCB concentrations in the upper sediments may be related to recent cutbacks in PCB usage and discharge. The higher levels experienced in the deeper sediments most likely represented deposits from a time when PCB usage and discharge was higher than present. Higher PCB concentrations

Table 1. Results of August 7, 1978 Sediment Sampling
Sheboygan River, Wisconsin

Sample Site (Subsample)	Location	River Mile	Depth of Core	Depth Core Subsample	PCB Conc. (mg/Kg)	Sediment Texture
	SHEBOYGAN RIVER		(cm)	(cm)		
S1	150 yards above Kohler Dam	9.25	30	Composite	42	Silt and organic
S2	75 yards above Kohler Dam	9.25	45	Composite	46*	Silt and organic
S3	Kiwanis Park, Sheboygan	2.08	8	Composite	1.6	Sand and silt
S4	West of Island, upstream of Penn Ave.	1.26	78			
(a)				0-20	2.7	Silt and sand
(b)				20-40	8.4	Clay
(c)				40-55	12*	Coarse sand and silt
(d)				55-60	76*	Silt and clay with organic material
(e)				65-78	76*	Clay and silt with organic material
S5	800 feet upstream of 8th Street bridge	0.70	45			
(a)				0-10	10.5	Clay and silt
(b)				10-35	10	Silt and Sand
(c)				35-45	65	Clay and silt
S6	550 feet upstream from USCG station	0.20	152			
(a)				0-76	15	Clay and silt
(b)				76-152	35	Clay and silt

*± 10 percent.

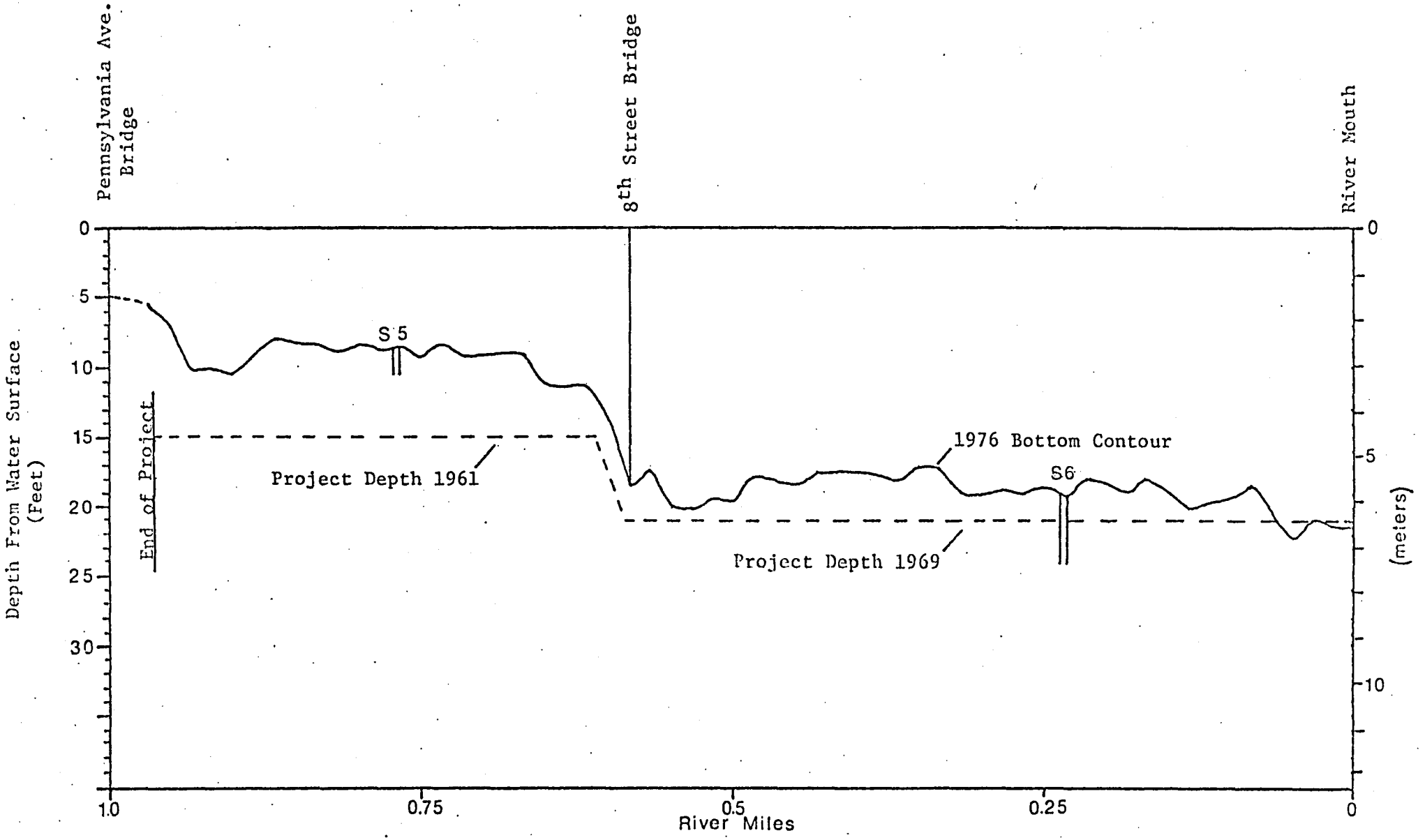


Fig. 3 USAE Channel Maintenance Project Area and 1976 Depth Contour

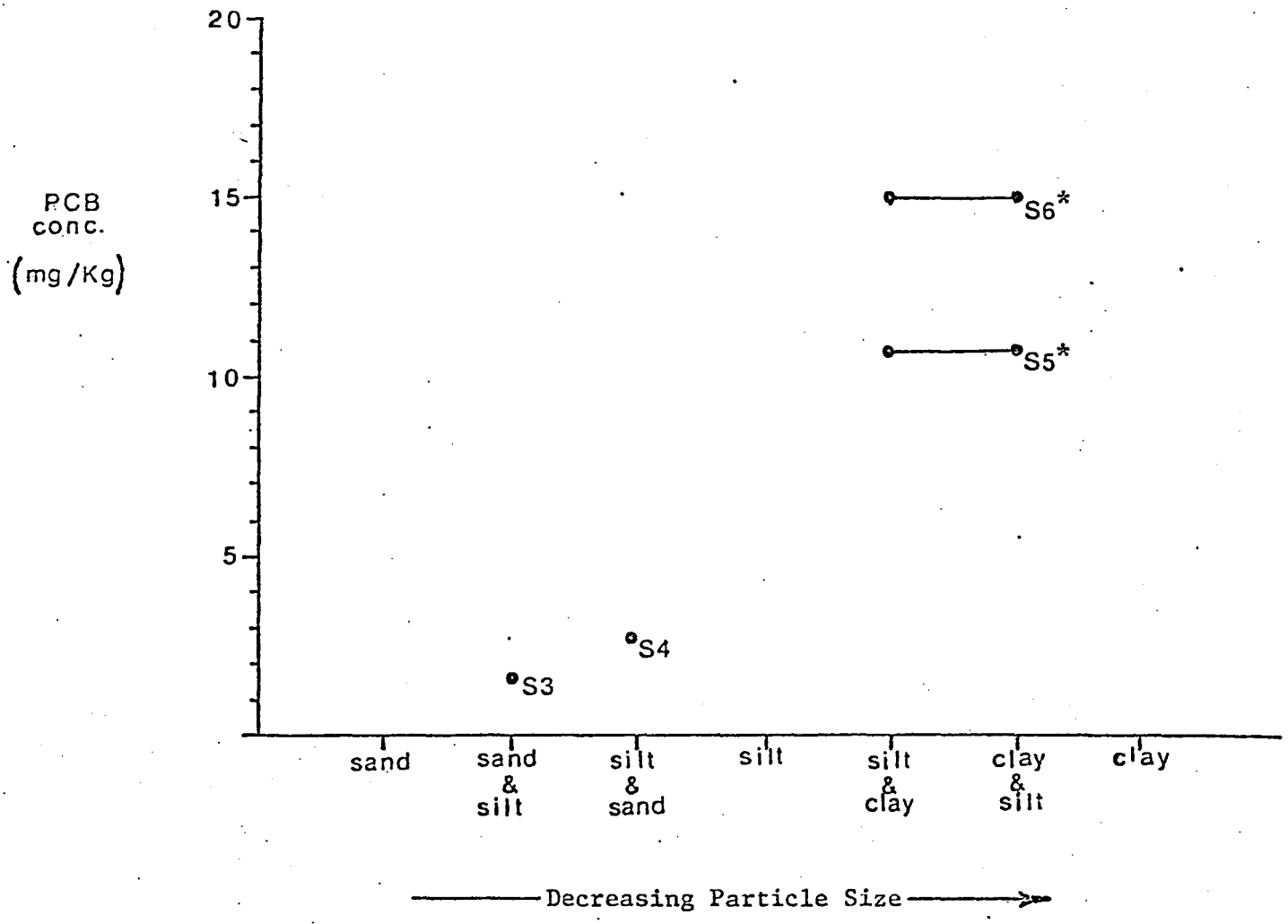
found in the deeper sediments at station S6(b) (Fig. 3) indicated contamination of the bottom sediments with PCBs was occurring before this area was dredged in 1969.

PCB Relationship to Particle Size

The fraction of very fine silt and clay ($\leq$8 um) and the amount of humic substances are important factors in controlling the adsorption capacity of chlorinated hydrocarbons in bottom sediments (Choi, et.al., 1976). Fine silts and clay in sediments are closely associated with humic substances and exist in the form of organoclay complexes. It is suggested that these complexes tie up chlorinated hydrocarbons in bottom sediments.

In the lower Sheboygan River the finer grained sediments, composed of primarily silt, clay and organic material, revealed higher concentrations of PCBs than those experienced in sand and silt substrates deposited in the same time period. In the most recently deposited sediments, PCB concentrations in sand-silt substrates ranged from 1.6 to 2.7 mg/Kg while concentrations in the finer grained deposits of silt-clay downstream ranged from 10.5 to 15 mg/Kg (Fig. 4), and deposits rich in organic substances exhibited the highest PCB concentrations. This suggested that the major reservoirs of PCB material are located in those areas of organic silt and clay deposits and explained the general trend of increasing concentrations of PCBs downstream from station S3 through S6.

Fig. 4. Relationship of PCB Concentration to Sediment Particle Size



*Particle size is based on field observations making distinction between the two categories very difficult.

CONCLUSIONS

The Sheboygan River bottom from Sheboygan Falls to the City of Sheboygan is generally scoured with only small depositional areas above the Kohler Dam and along the stream bank at various bends in the river channel. Extensive bottom sediment deposits of fine sand, silt, clay and organic material are located in the lower reach of the Sheboygan River from mile 1.5 to the river mouth. The average rate of deposition in this area calculates to approximately 10 cm/yr. The sediment deposits show general trends of decreasing particle density downstream.

The bottom sediment deposits above the Kohler Dam and in the lower sections of the Sheboygan River contain moderate to high concentrations of PCBs. PCB concentrations in the bottom sediments range from 1.6 to 76 mg/Kg, with ten of the thirteen samples collected exceeding the US EPA classification for polluted harbor sediments. These PCB accumulations in the bottom sediments are now serving as a major PCB source to the water column and to the aquatic food chain of the lower Sheboygan River.

The pattern of PCB concentrations in the bottom sediments of the lower Sheboygan River was influenced by the time of deposition and the substrate's composition. The more recently deposited, upper bottom sediments contained lower PCB concentrations than the deeper, previously deposited substrates apparently reflective of recent cutbacks in PCB usage and discharge in the watershed. The larger substrate particles of upstream, sand-silt deposits exhibited lower PCB concentrations than the downstream, fine silt-clay deposits and the organic deposits. The PCB concentrations

in the bottom sediments of the lower Sheboygan River generally increased with substrate depth in response to higher ambient PCB water column concentrations at the time of deposition and with distance downstream due to progressive settling of finer particles and organic matter with greater PCB adsorption capacity.

IMPLICATIONS

Since the upper, more recently deposited bottom sediments are lower in PCB concentrations than the underlying sediments, partial dredging would expose the water column to a substrate higher in PCB. The reexposed lower bottom sediments would then pose a stronger threat of contamination to Sheboygan River fish and other aquatic life and their consumers. Therefore, if dredging were necessary (either because of socioeconomic or environmental reasons), a total dredging of all bottom sediments may be environmentally warranted. The dredged spoils would have to be disposed of in a properly licensed landfill to accommodate PCB laden waste material.

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