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Wisconsin Smart Program: Starkweather Creek

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Abstract

Starkweather Creek drains a 23-square-mile urban watershed in the city of Madison, Wisconsin. Urban runoff had resulted in elevated levels of biochemical oxygen demand, mercury, lead, zinc, cadmium, and oil and grease in the sediments and a severely degraded fish and macroinvertebrate habitat. Historically, the creek had received significant amounts of stormwater and industrial waste discharges. Industrial activities in the watershed had included metal fabrication, battery manufacturing, meat packing, and food processing. Starkweather is the second largest tributary and the largest source of mercury to Lake Monona, a principal recreation lake for the Madison area. Downstream transport of sediments and associated pollutants from the Starkweather watershed effects the quality of this important lake, which is under a fish advisory to anglers to restrict consumption of larger walleyes due to elevated mercury levels.

To address contamination in the creek and Lake Monona and to implement the recommendation of the local priority watershed plan, Wisconsin's Sediment Management and Remediation Techniques program selected Starkweather as a sediment remediation demonstration project. A joint U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, county, and city project was developed to 1) reduce nonpoint loading, 2) control the impacts of in-place contaminants, and 3) restore the recreational value and aquatic habitat of the creek. This $1 million program included the dredging of 17,000 yd^3 of contaminated sediments, construction of stormwater detention ponds, development of streambank erosion controls, and aquatic habitat restoration.

Introduction

Starkweather Creek, located on the northeast side of Madison, Wisconsin, is the city's largest urban watershed, draining 23 square miles (Figure 1). The creek discharges to Lake Monona, a principal recreation lake located in the city of Madison. The creek and its watershed have been extensively altered as a result of urbanization. Extensive ditching, channelization, wetland draining and filling, and impervious structure development have shaped the hydrology and water quality of the creek.

Starkweather Creek has been affected by both point and nonpoint pollution over time. The creek drains a heavily industrialized portion of the city where metal fabrication, battery manufacturing, meat packing, and food processing occurred. Urban nonpoint runoff is believed to have contributed significant levels of pollutants in recent years.

Recent monitoring indicated that the creek had elevated levels of sediment oxygen demand, biochemical oxygen demand (BOD), mercury, lead, zinc, cadmium, and oil and grease in the sediments and a severely degraded fish and macroinvertebrate habitat. Concern for the levels of contaminants in the sediments of the creek extended beyond the stream channel and its habitat and also encompassed the downstream impacts of the sediments on Lake Monona.

Lake Monona has a mercury advisory on large walleye due to excessive levels of the metal in the tissues of this fish. Starkweather Creek, identified as the largest source of mercury to the lake, was targeted for remediation to restore the aquatic habitat of the creek and to protect Lake Monona.

Wisconsin Sediment Management and Remediation Techniques Program

In response to the growing awareness of natural resources managers of the continuing impacts of in-place pollutants associated with sediment deposits in the state's waterways, the Wisconsin Department of Natural Resources (DNR) established an interdisciplinary team to develop necessary assessment and remediation tools to restore affected waters of the state. The Wisconsin Sediment Management and Remediation Techniques (SMART) Program has brought together

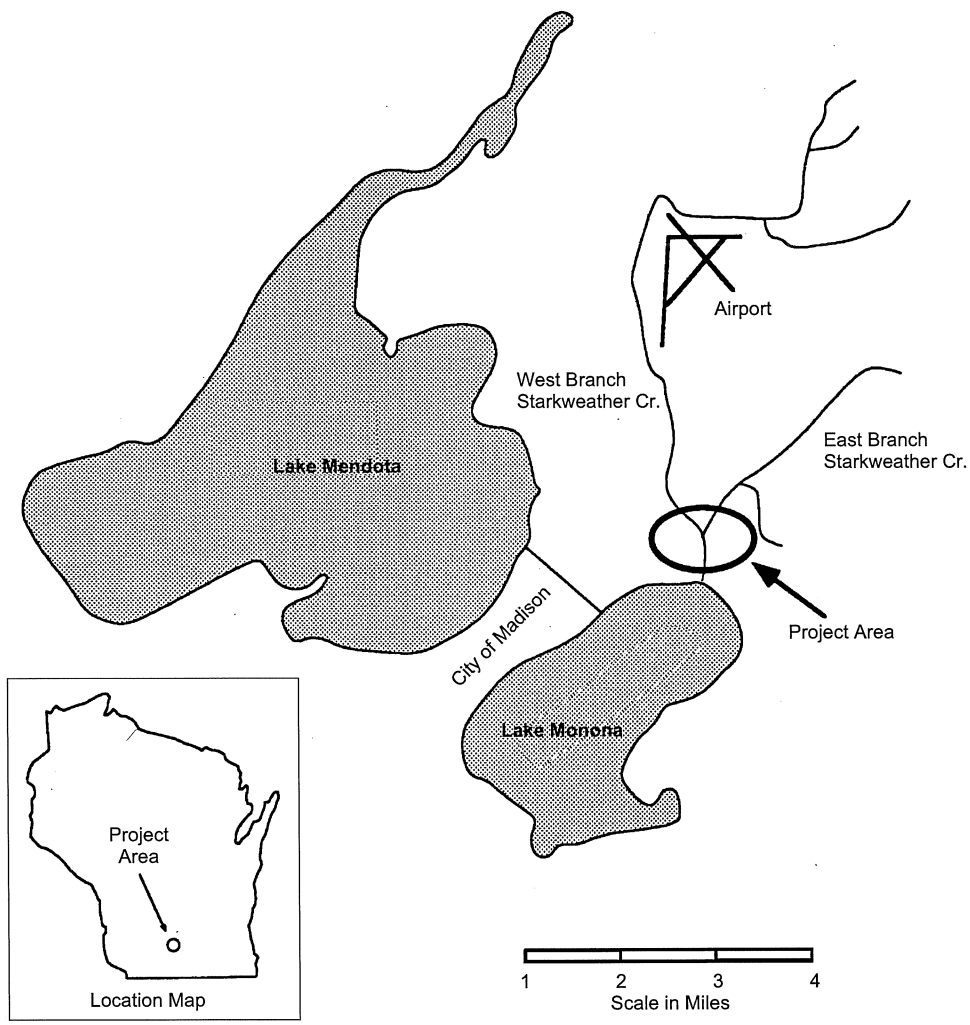

Figure 1. Location map of Starkweather Creek and the restoration project area.

expertise in environmental toxicology, aquatic habitat assessment, hydrographic surveying, sediment mapping, sediment engineering, and remedial technology. The SMART Program has two basic responsibilities: 1) define the extent of sediment contamination and impacts on the waters of the state and 2) guide the remediation of contaminated sediments.

The SMART Program coordinates the state's contaminated sediment activities with various universities and federal programs, such as the U.S. Environmental Protection Agency's Superfund and Great Lakes National Program Office Assessment and Remediation of Contaminated Sediment (ARCS) programs.

Monitoring Data

Starkweather Creek, the first sediment cleanup demonstration of the Wisconsin SMART Program, provided an opportunity to use advance monitoring of the many components of an aquatic system affected by contamination in sediments. Several assessment techniques were used to define the degree of sediment contamination, stream water quality, and aquatic habitat (Table 1). Later sections of this paper address monitoring performed during dredging to assess on- and offsite impacts of the cleanup. Postremediation monitoring will continue for 2 years to document the changes and response of the creek.

Remediation Planning

Starkweather Creek was selected as the first sediment remediation demonstration for the SMART Program based on recommendations from the state's DNR management districts, on the relative small scale of the site, and on ranking of the site with the SMART selection criteria. This criteria included:

- Impaired uses of the water body
- Adequate data for feasibility analysis
- Upstream pollution source controls
- Local support

- Adequate access
- Integration with other state and local programs

The specific project goals and objectives were developed by a project implementation team assembled from representatives of relevant state and local agencies and bureaus who guided the development of the project work plan, schedule, and budget. Individual members were responsible for ensuring that their program's relevant regulations were followed and the work plan was consistent with program policies and goals.

Table 1. A Summary of Starkweather Creek Preremediation Monitoring Data

	Range	Average	Total Weight
Sediment Chemistry			
Mercury	<0.1–3.5	1.1 ppm	40 lb
Lead	33–320	130 ppm	2.4 tons
Chromium	9–31	19 ppm	0.35 tons
Oil and grease	1,500–3,600	2,800 ppm	51 tons
PCBs	<0.14 ppm	<0.14 ppm	
Bulk density	65–106	80 lb/ft^3	18,400 tons
Water Column			
Mercury (total)	1.69–1.70 ng/L		
Mercury (methyl)	0.033–0.050 ng/L		
Lead	<3–10 μg/L		
Chromium	<3–18 μg/L		
Phosphorus–P	0.03–0.37 mg/L		
DO	3.3–14.6 mg/L (37.5–120% saturation)		
COD	10–38 mg/L		
Ammonia–N	0.04–1.8 mg/L		
Fish Tissue			
Freshwater drum (three samples, 10–19 in.)	0.16–0.48 ppm mercury		
Carp (three samples, 18–26 in.)	0.09–0.11 ppm mercury		
Caged Fish Bioaccumulation			
Minnows, 2–wk exposure	0.012–0.018 ppm mercury		
Minnows, 4–wk exposure	0.012–0.016 ppm mercury		
Toxicity Characteristic Leaching Procedure (TCLP)			
Sediment leaching test (three samples)	<1 mg/L lead		
Sediment Mapping			
Surveyed cross sections at 100–ft intervals			
17,000 yd^3 of soft sediment measured			

Following the development of the initial work plan, public informational meetings were held to solicit comments and suggestions. Presentations were also given to neighborhood associations and local environmental groups. Fact sheets outlining the proposed scope of work were distributed at these meetings. These meetings provided the implementation team with feedback on the scope and schedule of the work plan and a sense of the public's priorities regarding the restoration. Most of the public responses were requests for further clarification of the monitoring data, the permitting process, environmental safeguards during remediation, and potential exposure of local residents to contaminants in the sediments. One of the most frequent concerns for local residents was the removal of trees along the creek. The comments provided by the public and interested organizations were, where practical, incorporated into the work plan. For example, the replanting and vegetative restoration aspects of the project were developed in greater detail and the scope of the replanting was increased to address the concerns expressed at the public meetings.

Press releases and direct mailing to interested citizens and residents were used to keep the public involved and informed on the progress of the project.

Work Plan

The Starkweather Implementation Team developed the remediation work plan to achieve the goals of reducing pollutant loading to Lake Monona, restoring the aquatic habitat and fishery, and improving recreational use and access to the creek. The work plan included the following tasks to achieve these goals:

- Dredge 17,000 yd^3 of contaminated sediments.
- Improve the habit for fish and aquatic life through riprapping.
- Regrade and stabilize the eroding creek banks.
- Establish shoreline buffer zones.
- Use vegetative management to improve terrestrial habitat.
- Create public access paths and fishing platforms.
- Enhance public awareness and stewardship.

Dredging was selected as the means to remove the contaminated sediments, eliminate downstream loading of these contaminants, and restore the depth and diversity of the aquatic habitat. Survey cross sections of the creek were established at 100-ft intervals through the project site and were measured for water depth and sediment thickness. These data were used to model the volume and mass of contaminated sediments to be removed from the channel. In addition to removing contaminants from the creek, the enlarged cross-sectional area of the channel would maintain a greater depth of water capable of holding more dissolved oxygen and would provide more cover and structure for aquatic life.

The dredging of the creek channel increased the average depth from 1.5 to 4 ft. The average maximum depth of the channel thalweg was increased from 2 to 7 ft. Figure 2 is a typical cross section of the creek showing the pre- and postproject channel geometry and changes in water depth and streambanks.

Hydraulic studies of the creek channel and Lake Monona were performed to assess the local and regional impacts of dredging Starkweather Creek. This work was performed to assess issues related to changes in water surface elevations, channel stability, base level lowering, and potential upstream bed erosion. Starkweather Creek throughout the project area is in the backwater of Lake Monona. The water surface elevation of the creek is the same as the downstream lake. Therefore, the deepening of the creek by dredging would not decrease the water surface elevation or promote upstream bed or bank erosion.

Riprapping was selected for shoreline protection to protect the bank soils from waves and currents and to provide structure for fish and aquatic life. Sheet pile was used in selected areas where the steepness of the shoreline required vertical protection and regrading was not feasible (e.g., near buildings, roadways, and bridges). Vertical shore protection (sheet pile) was avoided in most areas because it presents a less than natural appearance and forms a barrier to aquatic life migration from water to land.

The banks of Starkweather Creek exhibited significant undercutting and failure and were a significant source of sediment to the creek. The failure of the creek banks undermined shoreline trees and vegetation and produced a perpetuating process of landward erosion of

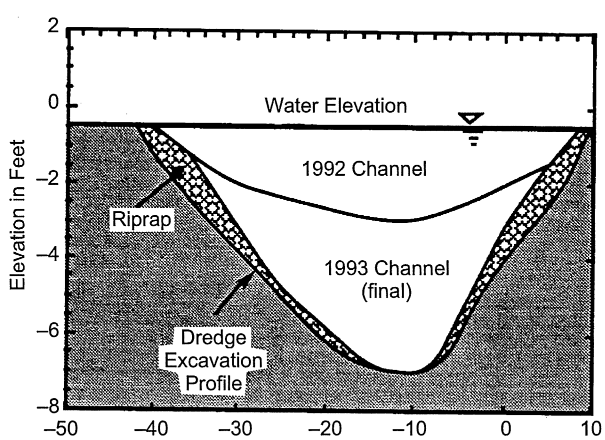

Figure 2. Starkweather Creek example cross section showing the channel profile before and after dredging.

increasingly steep banks. Eventually, the creek would have reached a hydraulic equilibrium by reshaping the channel geometry to a much wider and shallower channel. This process would have eliminated the fishery and small boating uses, however, and would have undermined local structures such as roadways, bridges, and buildings.

The banks of the creek were stabilized by regrading the abovewater slopes from vertical to 3:1 (horizontal:vertical), covering with protective riprap, and finally topping with a 6-in. seed bed planted to native grasses, shrubs, and trees. The near shore areas of the creek banks were planted to provide a vegetative buffer zone to filter pollutants carried by overland flows to the creek.

The terrestrial habitat along Starkweather Creek, although degraded, did provide important food and cover to insects, birds, and animals. Principal goals of the remediation project were to carefully manage all construction activities to minimize disturbances to the existing vegetation, to restore quality terrestrial areas disturbed by the creek restoration construction activities, and to improve the habitat where possible. A vegetation management and restoration plan was developed by the city's landscape architects to identify existing important tree and shrub specimens along the creek that were to be protected during construction work. The management and restoration plan was integrated with the construction plans, and close cooperation between the landscape architects, contractors, the DNR, and city engineering staff was used to resolve conflicting needs for access and mobility of the heavy equipment and the need to preserve desirable species. Trees and shrubs were initially either classified for saving or removal before construction. To reduce disturbance to the site and the costs of revegetation, the landscape architects and construction supervisors performed a final walking tour of the site to identify additional trees and shrubs, initially classified for removal, that could be saved if practical. This process provided the supervising field engineer with the discretion to either modify the construction plans and activities in the field to try to preserve existing vegetation or to permit the construction contractors to remove the specimens to facilitate access and work activities.

The project area was scheduled for replanting in the early spring of 1993. In addition to native and park grasses, 1,400 trees and shrubs were to be planted, including white ash, basswood, oak species, and maples. Planting would be located and spaced to provide optimal habitat areas along the shore of varying species, heights, and distribution.

Public access was provided to allow pedestrians to walk the site without disturbing the wildlife areas or trampling the banks of the creek. Landscape architects designed walkways to connect the project site with existing city parks and natural areas. Access to the creek was provided by low-lying shore areas and fishing/canoe access platforms constructed into higher creek banks near the water line.

Public awareness and stewardship was encouraged from the start to involve local groups throughout the project from early project design through final restoration. Regular press releases, media interviews, talks to neighborhood groups, direct mailings on project activities, aquatic education tours, fishing-for-kids clinic, and a volunteer planting event were used to keep people involved in and informed about the restoration.

Permits and Regulatory Review

The environmental restoration of Starkweather Creek included construction activities that were under the administrative and regulatory jurisdiction of several programs and agencies. Guidance from members of the implementation team representing the state's Water Regulation and Zoning, Solid Waste, and Environmental Assessment Bureaus were incorporated in the development of the project work plan and construction plans. City personnel guided the planning for compliance with local ordinances and coordination with local utilities. Permits were necessary for dredging and shoreline excavation and filling. In addition, regulatory review and approval was requested for the management of sediments dredged from the creek. Related regulations requiring compliance were historical and archeological site assessment, floodplain zoning regulations, and state environmental assessment guidelines. The city of Madison was the applicant for the construction work. Because many portions of the creek shoreline in the work area are privately owned, the permit required that either all riparian landowners individually apply for permits or that they assign the city to act as their agent for the permit application. A form letter was sent to the riparian landowners requesting their approval for the city to apply for the permit in their behalf. All riparian landowners in the project area approved, and copies of the signoff letters were then submitted to the U.S. Army Corps of Engineers and DNR.

Construction

Following completion of the construction plans, sealed bids were requested from qualified, interested contractors. The lowest of five bids was accepted. Speedway Sand and Gravel, Inc., of Madison, Wisconsin, was awarded the contract with a bid 17 percent lower than the highest bid.

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Retention Site

The sediment retention and dewatering facility, 6 miles southeast of the project area, was built in January 1992. The site covered 2.8 acres and was built on county-owned land at the local municipal landfill. The sediment retention facility was designed to dewater the sediments and contain the sediment and carriage water. The facility is square in plan view with 7-ft berms built of local clay soils. The bottom was unlined but consisted of several feet of clay. Local monitoring wells provide data on potential leachate from the facility. A concrete drop inlet spillway was built into the facility to allow excess water to be pumped to a sanitary sewer if necessary.

The retention site was built to contain 17,000 yd of sediment with a 25-percent bulking factor and to provide a minimum of 1.5 ft of freeboard to contain direct precipitation and provide a margin of safety.

Dewatered sediments from the facility are available for use as cover on the landfill.

Site Preparation

A double silt curtain of geotextile fabric was placed across the creek at the downstream end of the project in mid-November 1992. The silt curtains were intended to trap debris in the streamflow generated by construction activities. In addition, the porous fabric was intended to trap sediments resuspended by the dredging. The curtains were held in place at the top by a half-inch steel cable tied to trees on the bank and weighted at the bottom by a heavy logging chain.

Utility representatives identified and marked all pipelines, cables, and utility facilities along the creek in the project area.

Site clearing and grading for heavy equipment access followed the installation of the silt curtains. Access roads and trees to be left undisturbed were clearly identified to minimize site disturbances and the cost of restoring vegetation.

Dredging

Dredging began on the upstream end of the west branch of Starkweather Creek on November 19, 1992. Dredging was performed with a backhoe. Construction activities were staged through the project area such that approximately 100 yd of streambed was dredged, the banks were shaped to a stable slope, and then the site was riprapped. The goal of this sequence was to minimize the size of the project area opened by construction. In addition, because the project is in a residential neighborhood, keeping the principal work confined to a limited area at one time minimized noise and dust in the area.

Dredging, bank shaping, and stabilization proceeded in a downstream direction on the west branch to the confluence with the east branch. When the west branch was finished, work moved to the upstream end of the east branch. Approximately 12 dump trucks were used to haul the dredged sediments to the retention facility. Trucks were loaded on average every 5 minutes. To prevent leakage from the trucks, the tailgates were fitted

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with neoprene seals, and chain binders were used to provide a backup to the tailgate lock. No sediment spills occurred during hauling. Dredging was completed on January 27, 1993. Bank shaping and stabilization work finished 2 weeks later.

Nearly 14,000 tons of riprap and 3,400 tons of crushed stone were used on the project. Bank shaping involved 3,200 yd^3 of soil.

Dredge Monitoring

Monitoring during dredging and other construction work was performed to track the impact of these activities on the creek and Lake Monona. Visual observations were made daily of the degree of turbidity changes caused by construction. Best management practices related to the work on site were used to minimize the instream and offsite impacts. Water sampling for chemical analyses was performed on a weekly basis at upstream reference sites, downstream of the dredging, and above and below the silt curtains. Creek water samples were analyzed for metals (arsenic, cadmium, calcium, copper, chromium, iron, lead, magnesium, nickel, zinc), nutrients (ammonia, nitrate and nitrite, total Kjeldahl nitrogen, total phosphorus), and general water quality parameters (suspended solids, chemical oxygen demand, BOD, conductivity, pH, alkalinity, hardness, temperature, dissolved oxygen).

Monitoring results indicate that there was no significant difference between the water quality parameters at the upstream reference sites and at the downstream end of the project on the dates of sampling. Figure 3 is a plot of selected water quality parameters measured on December 3, 1992, during the dredging activities. On this date, dredging was performed approximately 300 yd downstream of the upstream reference sampling site on the west branch. Sampling was also performed at the first bridge downstream of the dredging site. Other data shown in Figure 3 were obtained on the same date at a reference site on the east branch above the project and at two locations on the downstream end at the silt curtains. In can be seen in this figure that data from the dredging site show significantly higher values than at other sampling sites. The concentrations from the downstream end of the project (at the silt curtains), however, are equivalent to the undisturbed reference sites for most parameters, indicating that the resuspension of sediment and pollutants from the dredging had minimum offsite impacts. Lead and zinc values did exhibit an increase at the downstream site samples (Figure 3) compared with the upstream reference sites; however, the values at the downstream sites were within the

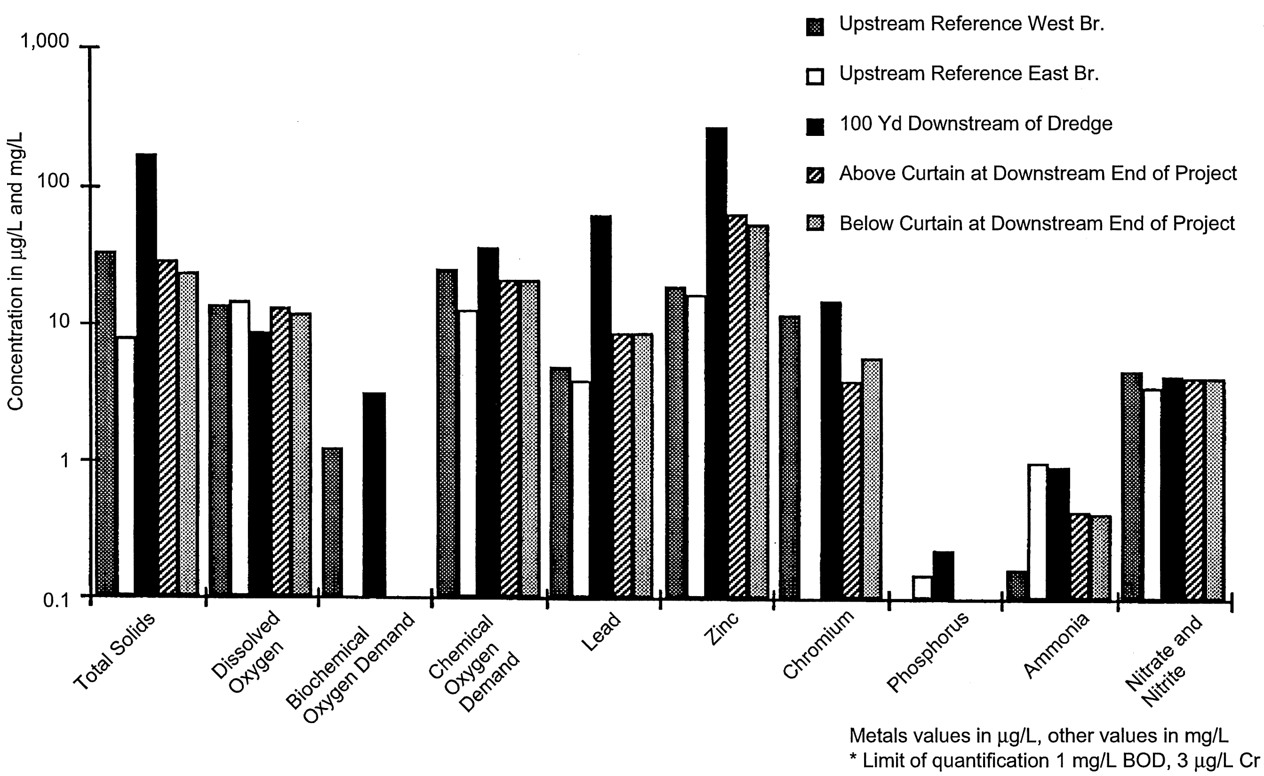

Figure 3. Selected water quality monitoring data, Starkweather Creek, December 3, 1992.

range of values measured over time at the undisturbed reference sites. Lead and zinc concentrations in water at the downstream end of the project were well below State Water Quality Criteria NR105 for acute and chronic toxicity in all water samples.

The silt curtains had little effect on the water quality of the stream—nearly all parameters were at the same levels above and below the curtains. Sediments and associated contaminants resuspended by the dredging work settled fairly quickly in the creek channel, and downstream loading to Lake Monona remained at background levels during the construction work. This project deployed the silt curtains normal to the streamflow (i.e., across the width of the channel) in an attempt to trap debris generated by the construction activity and to control resuspended sediments. The curtains were effective in trapping floating debris; however, they were not always effective in filtering solids from the streamflow. Figure 3 shows a slight drop in solids concentration across the silt curtain; however, the difference in concentration is fairly low and was not seen in most water sampling days. Field observations of the performance of the curtains showed that during all but the lowest base flow, the curtains would "billow out" to the downstream, allowing the streamflow to pass beneath the curtains.

Postremediation Monitoring

Routine water quality sampling will continue on a monthly basis for a least a year following the completion of construction work. Additional monitoring intended to document the restored conditions of the creek include fish shocking surveys, caged fish bioaccumulation, sediment bioassay, sediment chemistry, qualitative habitat assessment, and macroinvertebrate sampling (sediment and artificial substrate). These additional activities will be performed over the next 2 years to assess the success or failure of the restoration work, help to refine further work at other aquatic restoration projects, and guide the development of standard procedures for sediment assessment work.

Summary and Conclusion

Contaminated sediments can be managed to restore lost beneficial uses of a degraded waterway. The environmental restoration of Starkweather Creek has demonstrated that the knowledge and skills of various environmental programs can be successfully coordinated to accurately assess the degree of contamination, identify necessary sediment removal and disposal techniques, develop and implement a cross-program work plan, and carefully monitor the site disturbance and final restoration.

Some important aspects of this project that were critical to its successful implementation were cross-program coordination and communication, public communications and feedback, construction field supervision, and a significant investment in environmental monitoring to guide the development of the work plan and document the results of the restoration.

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