ABSTRACT

The Fox River Cleanup Project is designed to reduce risk to human health and the environment caused by the presence of PCBs in Fox River sediment.

It is a multi-year cleanup effort that includes dredging, capping with coarse sand, gravel and quarry stone, the separation of clean sand and dewatering of the fine sediments with membrane presses. It is currently one of the largest cleanup projects of its kind in the world, and its unique project approach will remove approximately 3.8 million cubic yards (CY) (2.9 million m³) of PCB contaminated sediments and will place a protective cap or sand cover over 600 acres (243 ha). In addition, billions of gallons of water removed from the river will be treated and returned.

Because of the process used, the volume of the hydraulic dredge slurry is reduced and portions are prepared for beneficial use (e.g., separated sand) or recycled to the river (treated water), the transportation and disposal costs are significantly reduced.

This is particularly important with regard to the hazardous Toxic Substances Control Act (TSCA) dredged material.

INTRODUCTION

The Fox River Cleanup Project aims to remediate PCB-impacted sediments from a 13.3-mile (21.3-km) stretch of the Lower Fox River between Little Rapids Dam and the mouth of the Fox River at Green Bay, Wisconsin (Figure 1). The cleanup project is designed to reduce risk to human health and the environment caused by the presence of PCBs in Fox River sediment. The client is the Lower Fox River Remediation LLC. The regulatory agencies comprise a consortium representing the United States. Environmental Protection Agency (EPA), the Wisconsin Department of Natural Resources and prominent members from private industry, collectively known as the Agencies/Oversight Team (A/OT).

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Figure 1. Location map of Wisconsin and the Lower Fox River where the cleanup project is taking place.
PROJECT APPROACH

The project approach is unique as it is a single stream process where dredged sediments from three hydraulic dredges are directly piped to the land-based processing facility. Dewatering with eight membrane filter presses has been selected as the most economical and efficient means of dewatering the sediment prior to off-site disposal. The design of the sediment desanding and dewatering system required careful balancing of the flow of solids and water through the entire system, from the point of dredging through final production of sand and filter cake and water treatment.

The Lower Fox River OU 2-5 cleanup is being executed as a fast track design-build project, with Tetra Tech EC, Inc. as the prime contractor and Stuyvesant Environmental Contracting Inc., an affiliate of the Dutch based company Boskalis Dolman, and J.F. Brennan as key sub-contractors. Design of the processing facility began in March 2008. Process site clearing and earthwork activities were initiated in July of that year. Mechanical construction was complete by April 2009, followed by several weeks of pre-operational testing and start-up. A six-acre (2.5 ha) building encloses substantially all of the process operations (Figure 2). Deep concrete foundations and floor slabs, the building superstructure and all of the process equipment, piping and electrical systems were erected in about nine months time. Operations on this complex project officially started with dredging and processing on April 28, 2009, ahead of the mandated target of May 1. The first season of dredging, capping and sand covering concluded in mid-November 2009.

In terms of dredging productivity, the ambitious first season goals were exceeded by about 16% with nearly 545,000 CY (417,000 m$^3$) of impacted sediment removed from the river. After the winter shutdown and maintenance period, operations re-started in early April 2010 for the second season of this cleanup project and at the end of the 2010 season more than 720,000 CY (550,000 m$^3$) were removed. Thus about one-third of the total amount of sediment expected to be dredged over the life of the project was accomplished by the end of the second season.

The objective of the Fox River processing facility is to minimise the volume of contaminated sediment for disposal at the landfill by using a three-stage separation approach. The process facility screens, conditions, and dewater the slurry. During this process the volume of the hydraulic dredge slurry is reduced and portions are prepared for beneficial use (e.g., separated sand) or recycle to the river (treated water), significantly reducing transportation and disposal costs. This is particularly important

![Figure 2. Overview of the six-acre (2.5 ha) processing facility and offices.](image)

![Figure 3. The 12-inch hydraulic cutterhead Dredge Mark was first used to remove large amounts of sediments.](image)

![Figure 4. Two smaller 8-inch dredges were then used in shallower areas.](image)
with regard to the hazardous Toxic Substances Control Act (TSCA) dredged material, which must be transported to Michigan with higher disposal costs than the non-TSCA material.

**PROJECT TEAM**

The team of contractors on this complex project are part of the Fox River Cleanup Group. Tetra Tech EC, Inc. is the general contractor. There are two primary subcontractors working with Tetra Tech. J.F. Brennan is responsible for the dredging, capping and sand covering scope of this project. Stuyvesant Environmental Contracting Inc. obtained the contract for the sediment desanding and dewatering services. For this project Stuyvesant Environmental Contracting Inc. worked with its Netherlands-based sister company Boskalis Dolman bv. Boskalis Dolman is responsible for the design, engineering and operation of the sediment desanding and dewatering equipment.

**SCOPE OF PROJECT**

The scope of work includes the remediation of PCB-impacted sediments from a 13.3-mile (21.3-km) stretch of the Lower Fox River between Little Rapids Dam and the mouth of the Fox River at Green Bay. Note that the Fox River is unusual in that it flows from south to north and remedial activities are carried out in that sequence. At mile marker #4 lies the heart of the project – the Green Bay processing facility. The remediation is designed as a combined remedy that includes the dredging of 3.8 million CY (2.9 million m³) of sediments and the capping or sand covering of about 600 acres (242 ha).

A J.F. Brennan 12” hydraulic cutterhead dredge is used to remove large amounts of sediments. Two smaller 8” dredges are then used in shallower areas and to complete dredge areas that were initially (production) dredged by the 12” dredge (Figures 3 and 4). The sediments are pumped to the processing facility through HDPE pipelines over a maximum distance of 10 miles (16 km). Booster stations are used at one-mile (1.6-km) intervals to pump the slurry to the processing facility. Monitoring efforts to date have determined that there is minimal re-suspension of contaminated sediment associated with the hydraulic dredging process since this is a suction operation.

Capping is performed in areas with lower levels of PCBs and where dredging would not be effective or economically feasible. Capping is often performed in conjunction with areas that have been dredged, i.e., dredging of the more highly contaminated shallow sediment followed by the installation of an engineered cap over the lower contaminated level deeper sediment left in place. The initial layers of the engineered cap consist of sand and gravel. These layers are placed with a patented broadcast system to reduce mixing and overplacement in terms of area or thickness (Figure 5). The larger armour stone (e.g., quarry spall) is placed mechanically on top of the previous two layers to protect them against erosion or displacement from the effects of propeller action impacts.

**INTEGRATED APPROACH**

The project approach emphasises the “integration” of all of the performing parties. This includes the client, the regulatory agencies,
local stakeholders and the contractors performing various aspects of the work. Local stakeholders include municipalities nearby the project operations and haul route and numerous private and commercial property owners along the river. In a sediment project such as this, communication and cooperation amongst the general contractor, the marine contractor and the sediment-processing contractor are critical in achieving the level of success which has been reached on the Lower Fox River project. The basis for this success, amongst other things, is the mutual understanding of the need for an integrated approach. The team therefore signed a MOU to concretise this approach.

**SITE CHARACTERISATION AND TREATABILITY TESTING**

Sediment sampling (Figure 6) and bench-scale testing were performed in November 2007. The objectives of the testing included the development of a proper characterisation of the sediment properties as well as selection and sizing of the appropriate sediment processing approach and equipment. Perhaps the most critical pieces of equipment that needed to be specified and purchased early, considering delivery lead-time, were the eight large membrane filter presses manufactured in Europe.

Transportation and disposal costs and beneficial reuse options were considered and evaluated during the selection process, while the estimated dredge production rate was critical when sizing the equipment. Particular attention was given to redundancy of equipment items or trains in both the sediment desanding and dewatering process (SDDP) and the water treatment plant (WTP) with regard to ensuring that the rate of dredging would not be impacted. The added expense of designing and installing surplus or redundant processing capacity has proven to be worthwhile.

Thousands of core samples were taken over the stretch of the river to map levels of PCBs, in terms of depth and area, and to determine the sediment characteristics in the river. This extensive chemical characterisation of the river bottom is needed to perform geostatistical modelling of the 1 ppm cleanup level and produce a neatline profile. The GPS based computer controls on the hydraulic dredges can then remove target sediments along the neatline much more precisely than would be accomplished by typical mechanical dredging, saving project operational costs and preserving landfill space.

Figure 6. Vessel at work during pre-investigation of sediment.

Figure 7. Mobilisation of membrane press parts to the site.

Figure 8. Installation of the membrane presses.
The neatline design and hydraulic dredging combination is significantly more efficient in removing a higher proportion of the sediment above 1 ppm while leaving in place a greater degree of non-target material less than 1 ppm that would have been removed by a mechanical dredge implementing a typical dredge prism design.

A detailed analysis of available sediment data was performed to design an appropriate sediment desanding and dewatering system that would be able to accommodate the range of anticipated dredge production rates and the overall project schedule. Based on this analysis, a system of eight large membrane filter presses with a total maximum filter cake production of 14 CY (10.7 m³) per hour was selected. The membrane filter presses dewater the filter cake at a pressure of 225 psig, achieving a typical solids percentage of nearly 55%.

Pilot-scale testing was performed at the Fox River OU 2-5 sediment processing site in June 2008. The objectives of the pilot testing were to evaluate the performance of polymers and filter cloth materials that could be utilized for the dewatering operation, and to evaluate the quality of the filter cake produced by each filter cloth. The pilot testing at the site was performed using scaled-down versions of key process components, including a scalping screen, slurry tank, hydrocyclone separator, pre-thickener tank, polymer dosing system, and filter press.

For each pilot test performed using a different filter cloth, representative sediment samples were obtained from the Fox River and slurried with river water to feed the pilot plant. Each filter cloth was tested by running at least 55 gallons (208 liters) of slurried sediment through the process, producing filter cake, and obtaining filtrate samples for total suspended solids (TSS) analysis.

The filter cloth materials evaluated included woven polypropylene filters. The filtration efficiency of each material was evaluated based on the TSS present in the filtrate from the pilot filter press. The quality of the filter cake produced was evaluated by performing a suite of analytical and geotechnical tests, including total PCBs, grain size, density, percent solids, and shear strength. As a result of the pilot testing, it was determined that a combination of coagulant and polymer would provide optimal results in terms of filter cake properties and filtrate quality and acceptable cycle times for the equipment.

**PROCESSING PLANT**

The SDDP and WTP are installed within a 250,000 square foot (23,225 m²) building that was erected for the purpose of this project. The building also has a large area for indoor storage and handling of the filter cake and houses administrative office space for project staff. Boskalis Dolman designed, mobilised and constructed the SDDP within a short 8-month period to meet the overall project schedule (Figures 7 and 8).
Tetra Tech procured and constructed the filter cake storage and handling systems and the WTP during the same time period (Figure 9). In order to ensure a safe working environment within the building and minimise operator exposure to airborne PCBs, the interior volume of the building is exchanged eight times per day. The air drawn from the building is treated using many vapor phase filters containing activated carbon so that PCBs will not be discharged to the surrounding environment.

Sediment hydraulically dredged by the three dredges is pumped directly to the sediment desanding and dewatering facility (SDDP) (Figure 10). The SDDP is designed to accommodate a maximum flow of 6,000 gallons per minute (GPM) (22,690 liters per minute) with approximately 5 to 10% solids.

The dredge pipeline routes the sediments on a vibrating screen (Figure 11) that removes oversized particles larger than 6 mm. Particles smaller than 6 mm pass through the scalping screen and are pumped to a slurry thickener system that separates the sand size fraction from the finer sediment using cyclonic action provided by several hydrocyclones (Figure 12).

Fox River sediment typically contains at least 25% sand, which is separated from the sediment bearing the PCBs and can be beneficially reused (Figure 13). Coarse and fine sand separation units then separate sand in the ranges of 150 microns to 6 mm and 63 microns to 150 microns. Sand separation is performed by using hydrocyclones of various sizes. Separated sand is polished in upstream classifiers. The fines (silt and clay) removed during desanding operations are pumped to the dewatering process equipment, which includes pre-thickener tanks, sludge holding tanks, and membrane plate and frame filter presses. The filter presses designed for the Fox River are sized to process approximately 14 CY (10.7 m³) of solids per hour per press, with a compression factor of 1.3 and a cycle time of 75 minutes. The number of presses needed was calculated based on the anticipated range of flow rates through the dewatering system, an assumed uptime for the presses ranging from 75 to 100%, a range of 20 to 40% sand removal, and the hourly production rate for each press (Figures 14 and 15). It was determined that eight presses would be needed; however, space has been allocated and foundations installed for two additional presses.

The end product is a filter cake which is initially stored within the building. From there the cake is loaded in trucks and transported to a landfill for final disposal. For non-TSCA materials the filter cake is disposed of nearby the processing plant at approximately 30 miles (48 km) distance. The TSCA material is trucked to a disposal site in the state Michigan at a distance of 465 miles (744 km), which takes approximately 7.5 to 8 hours to drive with a truck (Figures 16 and 17).

Process water is re-used in the operation. Surplus water from the SDDP is treated and 

Figure 11. The vibrating screen receiving sediments from dredgers. Figure 12. Hydrocyclones for sand separation. Figure 13. Separated sand for beneficial use.
analysed before being discharged to the river or re-used in the processing facility. Some of the treated water is used for dust control purposes on the large sand storage piles outdoors. The water treatment plant consists of three treatment trains each capable of handling 3,000 GPM (11,345 liters per minute). Treatment includes sand filtration, carbon filtration and bag filtration. After treatment the water is returned to the river under regulations set by the State of Wisconsin. These include treatment goals or goal ranges for PCBs, TSS, pH, mercury, ammonia and biochemical oxygen demand (BOD). The treated water is returned to the river through a multi-port diffuser, which was modelled to assure acceptable dilution characteristics based on the expected flow rate range and concentration goal for ammonia in the effluent.

**EVALUATION FOR THE 2009 SEASON**

The following narrative summarises the project performance versus the 2009 objectives:

**Objective No. 1:**
Complete installation of the SDDP and WTP process systems equipment, piping, instrumentation and all other ancillary equipment and building systems to enable full-scale remediation and processing operations to begin by the target date of May 1, 2009.
- Installation of the SDDP and WTP process systems equipment, piping and instrumentation and all other ancillary equipment and building systems was completed by approximately April 1.
- Following pre-operational testing, the SDDP and WTP and all related ancillary equipment and building systems were ready for start-up.

**Objective No. 2:**
Complete building electrical, mechanical and HVAC systems installation and interior construction finishing activities.
- The building electrical, mechanical and HVAC systems installation and interior construction finishing activities were completed by approximately March 1.
- Project management activities moved to the administrative section of the building on about March 11.

**Objective No. 3:**
Complete start-up and testing of all SDDP and WTP equipment.
- Pre-operational testing – pressure testing, electrical check-outs, instrumentation inspections – occurred from about April 1 through April 24.
- Start-up and operational testing of the SDDP and WTP systems occurred from about April 28 through May 8 while dredging was conducted for about 12 hours per day.

**Objective No. 4:**
Perform site development activities at the OU3 secondary staging area.
- The 17-acre (6.8 ha) secondary staging area, located at Brown County Land Parcel ED-50-1 (near 2646 Old Plank Road), De Pere, Wisconsin, was leased from Irvin and Viola Peeters on May 5.
- Site development activities at the OU3 Staging Area began on June 1 and were completed on approximately June 26. The OU3 Staging Area began being used as an auxiliary location for staging cover sand and aggregate on about July 28.

**Objective No. 5:**
Complete installation of fused pipelines and booster pump stations to support OU2 and OU3 dredging activities.
- Booster stations 1 through 9 and the necessary dredge pipeline were installed in time to begin dredging operations in OU2 on June 8.
- Dredge piping and booster station no. 9 were removed on June 26 based on completion of dredging activities in OU2.
- Additional dredge pipeline and booster station no. 8 were removed on August 27 based on completion of dredging activities south of Area D9.
- Additional dredge pipeline and booster station no. 7 were removed on September 15 based on completion of dredging activities south of Area D11/12.
- Additional dredge pipeline and booster station no. 6 were removed on October 28 based on completion of dredging activities south of Area D16.

**Objective No. 6:**
Begin dredging and processing operations by May 1, 2009.
- Dredging and processing operations began on April 28. Initially work was performed for approximately 12 hours per day.
- On May 11 24-hour dredging and processing operations began.
Objective No. 7:
Complete dredging adjacent to the processing facility, to the degree necessary, to allow for installation of the sheet pile bulkhead wall, including removal of approximately 10,000 CY (7650 m³) of TSCA material.
- Dredging at the processing facility, designated as D58, began on April 28 and was completed on June 27, 2009. Sufficient PCB-impacted sediment and debris were removed to allow for installation of the sheet pile bulkhead wall.
- Approximately 51,235.5 CY (39,172 m³) of non-TSCA material were removed from D58 in 2009.
- Approximately 7,403 CY (5,660 m³) of TSCA material were removed from D58 in 2009.

Objective No. 8:
Begin installation of the sheet pile bulkhead wall and back fill to elevation 577 feet (176 metres) followed by installation of the wick drains and gravel drainage layer.

As discussed with the A/OT, installation of the sheet pile bulkhead wall was postponed until the 2010 operations season because of an unexpectedly low yield of sand from the dredged material. There is no impact to project progress as a result of this change to the original objective.

Objective No. 9:
Remove, process and dispose of approximately 468,900 CY (358,568 m³) of target TSCA and non-TSCA material from the river.
- Dredging began on April 28 and continued until the morning of November 14.
- During this time, a total of 544,535 in situ CY (416,326 m³) of target sediment was removed from the river.

Objective No. 10:
Installation of sand cover, as the primary remedy, and armoured caps was not scheduled to begin until 2010.
- Placement of sand cover as a primary remedy began in OU2 on August 17.
- Installation of armor stone began in OU2 on August 31.

Objective No. 11:
Comply with all ARARs (Applicable or Relevant and Appropriate Requirement) identified for work in OU2-5 of the Fox River.
- The list of ARARs that pertain to the Lower Fox River OU2-5 work is included in Section 1.3 of the 2009 Phase 2B Remedial Action Work Plan. They include Federal chemical-specific, Federal action/location specific, State chemical-specific and State action/location-specific standards. For construction and remedial action work performed in 2009, the Tetra Tech team has complied with all of these ARARs.

CONCLUSIONS

The first operations season exceeded the 2009 targets for dredging and processing. In addition, despite the extremely aggressive construction period and nearly two years of operations, with more than 750,000 hours worked, there have been no lost time incidents on the project.

This extremely important project is being used as a model by various agencies and other companies as an example of how to clean up rivers with similar conditions. Remediation work in 2010 continued very well with more than 720,000 CY (550,800 m³) of sediment removed from the river. Last year’s total was exceeded in mid-September.

The 2010 amount is above the 550,000 to 700,000 CY (420,500 to 535,200 m³) range that was planned for this year before the season began.

At the end of 2010, therefore, approximately 1,265,000 CY (967,162 m³) of PCB contaminated sediment will have been removed from the Fox River, representing about 33% of the total estimated before the remedial action began.