SEVEN YEARS OF BENEFICIAL REUSE OF SAND ON THE OPERABLE UNITS 2-5 LOWER FOX RIVER SEDIMENT REMEDIATION PROJECT

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ABSTRACT

The Lower Fox River sediment remediation project in Wisconsin includes dredging, capping and covering of PCB–impacted sediment at specified locations over a 21.4 kilometer (13.3 mile) stretch of the river comprising Operable Units (OUs) 2-5. One key objective of the sediment processing facility is to minimize waste disposed at the landfill by beneficial reuse of the separated sand and by dewatering the fine (contaminated) fraction of the dredged sediments. This paper will explain how beneficial reuse offsite of recovered sand from the seven years of operation to date (2009-2015) has been successfully implemented; the first such application on a full scale sediment remediation project in the US.

The project team is comprised of Tetra Tech EC, Inc. (Tetra Tech) as general contractor responsible for the engineering design, construction, and operation of the wastewater treatment plant; J.F. Brennan Company as dredging & capping subcontractor; and Stuyvesant Projects Realization Inc. (SPRI) as desanding & dewatering subcontractor. SPRI is one of the US operating companies of Boskalis Environmental. Together with its Dutch sister company, Boskalis Dolman bv, which supports SPRI with engineering and equipment services, these companies have more than 30 years of directly relevant experience in the management of 13.6 million metric tons (15 million short tons) of contaminated sediments/soils in the US, Canada, The Netherlands and other European countries.

Various beneficial reuse opportunities were identified and evaluated, and a major local infrastructure (highway construction) project provided the perfect fit. The process of achieving regulatory approval for beneficial reuse included Tetra Tech's preparation of a "Low Hazard Waste Exemption Request", project logistics, and commercial arrangements. All potential beneficial reuse applications required approval by the state environmental agency, the Wisconsin Department of Natural Resources (WDNR). However, public works projects are favored and do not require public hearings as part of the approval process. This paper presents the sand sampling program parameters, chemical testing criteria, and project-specific allowable contaminant concentrations.

Keywords: Advanced sand separation, infrastructure project, integrated approach, minimizing waste disposal, low hazard waste exemption request.

INTRODUCTION

The Lower Fox River remediation project is designed as a combination remedy to reduce risk to human health and the environment caused by the presence of PCBs in the river sediment. The scope of work includes the remediation of PCB-impacted sediments from a 21.4-kilometer (13.3-mile) stretch of the Lower Fox River between Little Rapids Dam and the mouth of the river at Green Bay. It is a multi-year effort that includes dredging, capping with coarse sand, gravel and quarry stone, sand separation, sediment dewatering, water treatment, transportation and disposal. This project remains one of the largest environmental remediations of its kind in the world.

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Note that the Fox River is unusual in that it flows from south to north and remedial activities are carried out in that sequence from Operable Unit (OU) 2 then OU3, then OU4, and finally OU5 in the bay. Dredging also precedes capping or sand covering. At mile marker #4 lies the heart of the project – the Lower Fox River sediment processing facility. This processing facility is designed to screen out debris, separate sand for potential beneficial reuse, and dewater the remaining fine (contaminated) fraction of the dredged sediments with membrane filter presses.

The primary reasons for separating sand include: 1) avoiding unnecessary transportation & disposal (T&D) cost; 2) producing a product that can possibly be beneficially reused and thereby conserving valuable landfill space; and, 3) preventing additional wear and tear on downstream processing equipment.

For the past seven years of operation (2009-2015) recovered sand from the sediment processing plant has been beneficially reused at several locations within a major local infrastructure (highway construction) project; the first such application on a full scale sediment remediation project in the US. A small amount has also been used beneficially at the landfill for construction projects, such as for building berms.

Project Team

The client is the Lower Fox River Remediation LLC. The regulatory agencies include representatives from the United States Environmental Protection Agency (USEPA) and the Wisconsin Department of Natural Resources (WDNR), along with their consultants, collectively known as the Agencies/Oversight Team (A/OT).

Tetra Tech EC, Inc. (Tetra Tech) is the general contractor responsible for the design, construction, and operation of the wastewater treatment plant. Tetra Tech subcontracted J.F. Brennan Company, Inc. for the dredging, capping and sand covering required as part of the remediation; and also subcontracted Boskalis Environmental, which is responsible for the sediment desanding and dewatering plant. Through its US operating company Stuyvesant Projects Realization Inc. (SPRI), engineering and equipment support for SPRI is provided by its Dutch sister company, Boskalis Dolman bv. Both companies are part of Royal Boskalis Westminster N.V., a leading global services provider operating in the dredging, maritime infrastructure and maritime services sectors.

Integrated Approach

The “Integrated Approach” used to perform this sediment remediation project emphasizes the seamless integration of all aspects of the work by each of the performing partners. This includes the client, the A/OT, local stakeholders, and all of the contractors performing the various aspects of the work (e.g., dredging, desanding, dewatering, water treatment, beneficial reuse, and T&D). Local stakeholders include municipalities nearby the project operations and haul route and numerous private and commercial property owners along the river (Feeney et al. 2011).

Communication and cooperation amongst the general contractor, the marine contractor and the sediment processing contractor have proven critical in achieving the level of success on this sediment mega-project. The basis for this success, amongst other things, is the mutual understanding of the need for this collaborative approach, memorialized in a signed Memorandum of Understanding (MOU) among Tetra Tech, SPRI and Brennan. The MOU clearly defines each contractor’s scope and “ownership” of their respective operations, and the agreed upon method to resolving issues in the various interactions among each contractor that focuses on meeting the overall project objectives. Regularly scheduled and frequent MOU meetings, at both the technical/operational and executive levels, facilitate these interactions. This approach has fostered a seamless project execution strategy that achieves end-results faster. Having an MOU among the major contractors ensures a process for smooth collaboration and conflict prevention and resolution. When properly implemented and maintained, this MOU process fosters internal team problem solving and risk sharing instead of adverse impacts resulting from internal disagreement.

PROJECT APPROACH

Early Contractor Involvement & Sediment Testing Program

Our team believes in the added value of early contractor involvement on such remediation projects. While the Lower Fox River project used a fast track design-build approach, we have also provided early contractor input while supporting the remedial design on other sediment projects. The key benefits of early contractor involvement include:

1. Identifying data gaps and how best to fill them to enhance the design of the remedy;

2. Applying the contractor's proven field implementation experience and lessons learned from other projects with similar technical challenges; and,

3. Ensuring the constructability of the remedial alternatives.

One such example of early contractor involvement on all of our team's sediment remediation projects is the sediment sampling and characterization followed by Boskalis Environmental's sediment processing and mechanical dewatering treatability testing program. This testing has repeatedly proven to be of very significant added value for designing the proper and most cost effective approach, as well as during full-scale project execution.

It is important for the test program to simulate the "real world" conditions as closely as possible. Preferably the tests should be performed on the project site. When onsite testing is not possible it is critical to mitigate potential interfering factors that may impact the results such as degradation of sample quality during distant transportation. Note that tests should also be conducted using site/local river water to ensure the actual sediment and water composition (e.g., salinity, pH) that will be encountered during the full-scale remediation.

The necessary components for our sediment processing and mechanical dewatering treatability study include:

1. Review of available sampling information;

2. Sampling plan;

3. Chemical analysis;

4. Geotechnical testing; and,

5. Dewaterability testing.

A description of each component follows and is provided as a general guideline so that others can use this testing approach to benefit their projects.

Review of available sampling information

Start by collecting all available sediment information produced during earlier sampling campaigns. Map the sediment information to get as clear a picture as possible of where different types of sediment are present (e.g., dense, sandy sediment, loose sediment, hot spot material (heavily contaminated), sewer outfall material, etc.).

Sampling plan

Based on the review of available information, configure a sampling plan to verify existing data and ensure collection of all different sediment types, especially those from the various areas where significant quantities are expected to be dredged during the remediation. Preferably, samples will be collected of different types of hot spot material, of the nephloid layer, denser sub-layer material (if any), sewer outfall material, etc. It is important to get sufficient and representative material.

Depending on the level of detail of the available information, the sampling plan might also have to cover exploration of sediment types in (some) parts of the river. In that case, some extra sample material might be collected, to ensure sufficient sample material during evaluation. Unexpected sediment material should be sampled and stored separately for the same reason.

It is important to collect all available information during the sampling, to establish a basis for future work. Important factors include: exact location/position of sample, notes regarding debris encountered; water level; surroundings at sample location, etc.

If there is none or only very little sample information available upfront of the sampling campaign; typically 10 samples per 1.6 kilometers (1.0 mile) of river should be collected in sealable containers (e.g., pails), taking into account as much as possible the different sediment types and particulars in sample locations.

Chemical analysis

Chemical analysis of the sediment samples is necessary to determine the level of contamination in the different sediment types. Parameters to be analyzed typically include PCBs, PAHs, TPH, heavy metals, and others specific to the historical and ongoing sources impacting the river.

Chemical composition data are essential in the overall design of the appropriate sediment processing and wastewater treatment system. For example, in cases where there is a significant amount of oily material these data are critical for designing the correct sequence of unit operations such as oil/water separation, while evaluating if such conditions may interfere with the potential feasibility of beneficial reuse. Chemical concentrations are also necessary for evaluating/designing the chemical compatibility of the materials of construction for all sediment and water processing equipment.

Geotechnical testing

The geotechnical characterization of the sediment is key for evaluating potential sediment processing options. Sandy sediment requires a different approach than loose, fine sediment, and highly organic material will also behave differently than highly mineral inorganic material. For sediment processing, the *in situ* density is important to evaluate the total amount of solids that might need processing. Parameters to test include:

- Density (*in situ*);
- Dry solids (water content);
- Organic content (Loss on ignition);
- Particle Size Distribution (using a method that takes into account the presence of organics) (e.g., Protocol BS 1377 "Methods of test for soil for civil engineering purposes" 1990; British Standard Institute);
- Clay content; and,
- Atterberg limits.

Using the above information, an estimate can be made on the amount of sand and the amount of residue produced from the sediment. Combining all different sediment types and expected volumes per sediment type will result in an estimate of the total amount of sand and fines to be produced during the full-scale remediation.

Dewaterability testing

To evaluate the potential effectiveness of mechanical dewatering, the dewaterability characteristics should be determined per distinct type of sediment. To simulate full-scale processing, the dewaterability testing will include separation of the coarser fraction (debris, gravel and sand). The remaining slurry with fines and organic particles will have to be treated with flocculants and possibly coagulants to enhance thickening and mechanical dewatering. When performing a mechanical dewatering test, filter press capacities and achievable dry solids content can be estimated per sediment type tested. Compatibility between dredging rate and sediment processing capacity is obviously critical such that dredging is never constrained by the capability to process sediment or treat water.

Combining chemical and physical information per sediment type with the information from the dewatering tests as described should result in a first estimate of the mass balance of sand and filter cake expected from the river, and the disposal options and costs for these materials. In addition, the amount of dredged debris should be estimated – something that typically is difficult to analyze from the sediment samples, as the debris is often too large for the sample devices.

Lower Fox River sediment sampling and testing

During the pre-proposal phase for the Lower Fox River project in 2007, we performed an initial site investigation limited to Operable Units 3 and 4 of the river to develop a first insight about the river conditions and to perform basic characterization of the sediments. The results were used to define the team's proposed approach to the remediation, including dredging and processing capacities and potential outlet options for the processed sediments.

After award of the project, initial conclusions were verified by performing an additional site investigation to address the various sediment types. Boskalis Environmental also performed both lab-scale and onsite pilot desanding and dewatering tests to establish the size, number and type of filter presses and most suitable filter cloths. The following equipment was used for these various tests conducted in collaboration with local laboratories, filter press manufacturers, and polymer vendors:

- Jar test equipment at a local lab facility;
- Lab-scale dewatering using bench top plate and frame filter press to simulate mechanical forces on the sediment; and,
- Plate and frame membrane filter press simulator for the onsite pilot dewatering tests.

Our pilot test equipment is shown in Figure 1.

Figure 1. Plate and frame membrane filter press simulator for onsite pilot testing

Several important findings resulted from the pilot testing. There were relatively large differences in sediment dewatering characteristics. The selected polymer was effective for all the samples tested (which represented a large stretch of the river), however dosages varied significantly. The fine material organic matter content was proven to be an especially important parameter defining sediment dewaterability and filter cake dry solids content. We determined that a coagulant was needed in addition to the polymer to achieve the best dewatering performance.

We also determined that the ASTM 422D method for particle size distribution was not the appropriate test method. Using the ASTM method results in larger amounts of sand being reported due to the presence of organic material and clay balls. In contrast, the British Protocol BS 1377-9 ("Methods of test for soil for civil engineering purposes" 1990; British Standard Institute) appeared to be more accurate, presenting lower (i.e., conservative) amounts of sand. Therefore, in collaboration with the general contractor and the client's representative, a Technical Memorandum - Standard Operating Procedures (SOPs) for Grain Size Analysis, which included a combination of both methods, was developed and approved for the Lower Fox River dewatered sediments (Tetra Tech EC, Stuyvesant Dredging Inc. and AECOM 2009).

ATTAINING REGULATORY APPROVAL

While evaluating the sediment characteristics in the testing program described above is critical to determine the suitability for potential beneficial reuse, the reuse concept can only be implemented if the project team is able to collaborate with the regulatory agencies and other stakeholders. Fortunately, on the Lower Fox River project such collaboration exists and it all began with following the regulatory procedures while establishing trust amongst all parties.

The 2007 Record of Decision (ROD) Amendment for the Lower Fox River and Green Bay Site (USEPA 2007) contemplated the beneficial reuse of sand processed at the Site as follows:

"Sediment de-sanding. In general, PCBs tend to adhere to smaller sediment particles (such as silt or some clays) rather than to larger-sized sediment particles (such as sand and gravel). For that reason, the sand fraction of sediment that is removed from the River may be recovered, washed or otherwise treated, and beneficially reused. Thus, under the Amended Remedy, relatively uncontaminated sand and/or gravel may be recovered from dredged sediments, if USEPA and WDNR have approved specific beneficial uses of such sand and/or gravel. The PCB concentration of the recovered sand would generally need to be less than 0.25 ppm before it could be beneficially reused, although USEPA and WDNR may approve an alternate concentration threshold for particular uses. Some examples of potential beneficial uses would be use as partial fill for staging areas, road fill, or daily cover for a landfill. It is estimated that approximately 172,025 cubic meters (225,000 cubic yards) of segregated sand and/or gravel material may be available for potential beneficial reuse under the Amended Remedy."

On July 2, 2010, Tetra Tech prepared and submitted to WDNR the project's first Low Hazard Exemption Request. The overall procedure for obtaining WDNR approval requires that each request must be for a specific offsite project or projects. Details that need to be provided for each project include proposed location, use, tons shipped, schedule, analytical and geotechnical data. Tetra Tech addressed WDNR's comments on the request, conducted a public hearing to address questions from the local community and then on October 18, 2010 WDNR issued Tetra Tech a "Conditional Grant of Low Hazard Exemption for the Beneficial Reuse of Separate Sand" from dredging non-TSCA sediment from the Lower Fox River remediation project. In accordance with this conditional grant, our team began shipping sand from the project in 2011. Later in 2012 WDNR modified the original exemption to extend the expiration date, expand the uses of the material, and relax notification requirements.

Following demonstration of concept with sand separated from dredging non-TSCA sediment, Tetra Tech obtained approval to beneficially reuse sand separated from dredging *in situ* TSCA sediment, subject to complying with the same analytical parameters. In 2013 USEPA confirmed that based on input from their Region 5 TSCA program, they had no objection to the proposed beneficial reuses described by our team provided that the PCB concentration of the sand is less than 1 mg/kg, however the WDNR amended the PCB limit to coincide with that for sand separated from dredging non-TSCA sediment, a maximum 0.49 mg/kg PCB concentration. In response to Tetra Tech's request to allow reuse of sand from dredging of *in situ* TSCA designated material, USEPA further clarified that their 2013 approval includes all sand material generated by the Fox River remediation regardless of *in situ* TSCA or non-TSCA designation.

Over the past 7 operating seasons, separated sand from our project has been shipped to various reuse locations including two Wisconsin landfills (for reuse, i.e., not as waste) and several construction sites managed by the Wisconsin Department of Transportation (WisDOT). Public works such as infrastructure projects are preferred for such beneficial reuse opportunities, and do not require public hearings as part of the approval process. For each reuse project, commercial arrangements were made between our client, the trucking company and the receiving party. Tetra Tech implemented tracking and reporting of sand shipments from the Lower Fox River site to the approved reuse sites and annually provides reports to WDNR on amounts shipped and the test results for the sand.

According to the WDNR approval the following test frequency is required for the separated sand to be reused:

- One sample per 765 cubic meters (1,000 cubic yard [cy]) for the first 7,650 cubic meters (10,000 cy), beginning each dredge season;

- Then one sample per 7,650 cubic meters (10,000 cy) thereafter.

Table 1 presents the Maximum Allowable Contaminant Concentrations provided by WDNR as part of their conditional approval. The concentrations shown pertain to sand that is not capped in place, and are therefore conservative if applied to sand that will be capped. Note that the target limit of 0.49 mg/kg was established by WDNR as an alternate concentration threshold based on the particular uses. Therefore, separated sand from all sediment is eligible as beneficial reuse material (BRM) provided it meets the WDNR requirements specified in Table 1.

Table 1. Chemical and Geotechnical Characterization Criteria for Separated Sand Beneficial Reuse Projects

Chemical Parameters	**Maximum Allowable Contaminant Concentrations (mg/kg, unless otherwise noted[1])**
PCB, Total	0.49
Total 2,3,7,8 TCDD	0.19 (ug/kg)
Total 2,3,7,8 TCDF	0.19 (ug/kg)
DDT (and its metabolites DDD & DDE)	1.0
Arsenic	8.0
Barium	500
Cadmium	7.8
Chromium	14.5
Copper	150
Cyanide	100
Iron	20,000
Lead	50
Manganese	1,100
Mercury	4.7
Nickel	250
Selenium	63
Zinc	1,500
Geotechnical Properties	
Total Organic Carbon	Max. 5% by weight
Grain Size analysis, percent moisture/solids content, permeability	Information purposes only

1. The 95 percent upper confidence limit of the arithmetic mean shall be used to determine the maximum allowable contaminant concentration. Arithmetic mean shall be based on a running statistical analysis for sand dredged each calendar year. Method detection limits shall be used for any reported non-detects in performing statistical analyses.

Table 2 provides a summary of the average PCB concentrations in the separated sand fractions per operating season.

Table 2. Average PCB concentration in sand for beneficial reuse

Average PCB Concentration (mg/kg) vs. target of 0.49 mg/kg	2009	2010	2011	2012	2013	2014	2015
Fine sand (63 µm to 150 µm)	**0.266**	**0.184**	**0.137**	**0.101**	**0.088**	**0.085**	**0.198**
Coarse sand (150 µm to 6 mm)	**0.353**	**0.113**	**0.075**	**0.079**	**0.053**	**0.063**	**0.191**
Running average (combined fractions)	**0.280**	**0.148**	**0.100**	**0.091**	**0.075**	**0.075**	**0.196**

Note: these numbers represent test results from all produced sand during each specific operational season, dredged from both TSCA and non-TSCA designated areas. The running average is not the result over the entire 7 years.

It is of interest to note that approximately 90% of all sand separated from dredged sediment during the 7 years of project operations has been beneficially reused.

IMPLEMENTATION ON FULL-SCALE PROJECT

Sediment Processing Facility

The objective of the sediment processing facility is to minimize the volume of contaminated sediment for disposal at the landfill by using a three-stage advanced sand separation approach. The process facility screens, conditions, and dewaters the dredge 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 with regard to the higher levels of PCBs in the Toxic Substances Control Act (TSCA) dredged material, which has a higher disposal cost than the non-TSCA material and often higher transportation cost due to a greater distance to the closest TSCA licensed landfill.

The project approach presents certain technical challenges since it is comprised of a single stream process where dredged sediments from multiple (typically three) hydraulic dredges are directly piped to the land-based processing facility. Dewatering with eight membrane filter presses was selected as the most cost-effective 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 separated sand and filter cake along with the associated water treatment. It is critical that the sediment desanding and dewatering system not constrain the rate at which sediment is normally dredged.

An approximate flow of 20,800 to 22,700 liters per minute (5,500 – 6,000 gallons per minute) enters the processing plant by two separate lines, 24 hours a day, 5 days per week. One line is directly connected to the 25.4-centimeter (10-inch) dredge and the other line is connected to the two/three 20.3-centimeter (8-inch) dredges; the feed lines from the 20.3 centimeters (8 inches) are merged before entering the plant. Typical dry solids content pumped to the processing facility is about 5%-10% by weight; this number changes depending on the dredge cut (layer thickness) and the sediment characteristics.

The start of the desanding process is the scalping screen that separates the fine debris entrained with the dredge slurry from the incoming flow. Both incoming dredge flows enter into a feedbox before running over the 6-mm (1/4") shaker screen. In this feedbox the flows are blended and therewith spikes in dredge flow concentrations are minimized. The scalping/shaker screen has a flat screening surface enhanced by a shaking motion that prevents clogging while maximizing throughput. The screened slurry is then collected in a slurry tank, situated under the shaker screen, and then pumped to the hydrocyclones of the desanding unit. The fine screenings (scalping material) drop onto a conveyor belt and are conveyed into a roll-off box outside the process building. In the roll-off, the scalping material (majority is organic material) can drain so the amount of water transported to the final reuse or disposal destination is minimized (cost aspect).

The slurry is pumped from the slurry bunker underneath the shaker screen to the two-way sand separation unit. The sand separation at the Lower Fox River Project separates sand at two cut-points, 150µm (0.005906 inch) and 63 µm (.00248 inch) (Sieve mesh No.100 and No. 230). This approach was implemented based on our extensive experience, the aim for beneficially reusing the sand, and the history of the contaminants. PCBs typically adhere to organic particles, which are highly present in the sediments (ranging12-20% by weight). Introducing an extra cut point in the sand separation (150µm [0.005906 inch]) was designed to further enhance our separation capability using upflow technology, thereby increasing the possibility to meet the reuse criteria. With an additional processing step for the 63µm separation, this portion of the sand will likely also be suitable for reuse. The sand separation unit uses hydrocyclones to separate the fraction greater than 150µm (0.005906 inch) into a separate stream that falls onto a dewatering shaker screen and is dewatered to a condition where it can be stockpiled. The sand solids content is approximately 80% coming from the screen. The dewatered sand drops onto the storage pad where it will be sampled and chemically tested. The 63µm sand separation also uses hydrocyclones for separation; however the underflow of the cyclones slides into the additional (advanced) processing step. In this step the 63µm (.00248 inch) sand will create a higher quality sand product since organic particles will be taken out. The 63µm sand falls onto a dewatering shaker screen and is dewatered so it can be stockpiled. The sand solids content is approximately 80% coming from the screen. The dewatered sand drops onto the storage pad where it will be sampled and chemically tested. After both sand flows are tested and approved they are blended together and stockpiled in an onsite storage area awaiting transportation to the reuse site.

Our advanced sand separation unit in the Lower Fox River processing facility, along with the typical resulting product from the additional processing step is shown in Figure 2.

Figure 2. Advanced sand separation unit and typical resulting product from additional processing step

The approved sand stockpile outside of the sediment processing building is shown in Figure 3. To mitigate the potential impacts of strong winds blowing away the sand, the stockpiles were initially covered with a liner. The liner cover was later replaced by spraying a polymer emulsion bonding agent over the stockpiles (i.e., DirtGlue®).

Figure 3. Approved sand stockpile outside of sediment processing building

Production and Lessons Learned

To date, an estimated 319,000 metric tons (352,000 short tons) of sand have been separated. Approximately 90% of the total tonnage of separated sand or 286,000 metric tons (315,000 short tons), has been hauled offsite and beneficially reused at several project locations including the ongoing WisDOT major highway expansion project near Green Bay. Of the portion not sent offsite for beneficial reuse (about 33,500 metric tons [37,000 short tons]), a significant volume was used onsite for grading purposes or disposed. The remainder was disposed at an offsite landfill due to not meeting the BRM criteria (Table 1).

Over the past 7 seasons on the Lower Fox River project we have observed a wide variety in the composition of the sediments. The sand content in the sediments range from 10% – 80% (all on weight/weight basis), with an average of 24%, where the amount of fines varied from 35% - 95% with an average of 74%. The remaining 2% represents the fraction larger than 6 mm (scalping material) which showed a fluctuation between 0% - 15%.

Separated sand produced during one season was hauled to the approved WisDOT project located at 2059 Shawano Avenue near the US Highway 41/State Highway 29 Interchange; an aerial photo is presented in Figure 4.

Figure 4. Aerial photo of US Highway 41/State Highway 29 Interchange showing WisDOT construction using approved sand from Lower Fox River project

WisDOT manages the stockpiles of sand delivered from the Lower Fox River remediation project inside proper erosion controls. The sand is incorporated into the road base construction as shown in Figure 5.

Figure 5. Approved sand from the Lower Fox River remediation project being incorporated into the road base construction at the approved WisDOT project

We also learned that sand separated from dredging *in situ* TSCA sediment is as likely to be qualified as BRM as sand from dredging non-TSCA sediment, based on the effectiveness of our advanced sand separation unit.

CONCLUSIONS

The Lower Fox River project remains one of the largest environmental remediations of its kind in the world. For the past seven years of operation (2009-2015) approximately 286,000 metric tons (315,000 short tons) of the total 319,000 metric tons (352,000 short tons) of recovered sand from the sediment processing plant has been successfully reused at several locations within a major local infrastructure (WisDOT highway construction) project; the first such application on a full scale sediment remediation project in the US. A small amount has also been used beneficially at the landfill for construction projects, such as for building berms.

A combination of several critical factors has led to the project success achieved to date on beneficial reuse:

- Experienced project team using the integrated approach;
- Early contractor involvement including comprehensive sediment testing program upfront;
- Collaboration with regulatory agencies and other stakeholders;
- Support of the local community;
- Operation of advanced sand separation unit; and,
- Identification of suitable local reuse sites.

Achieving the required approvals to ship separated sand from the Lower Fox River remediation project to the approved WisDOT reuse sites resulted in a “Win-Win” for these 2 major projects. The LLC (client) saved substantial cost by not having to transport the sand for landfill disposal and WisDot benefitted from getting local sand for reuse at no cost instead of purchasing from commercial sources.

Performing a thorough evaluation of sediment characteristics upfront proved to be a worthwhile investment on this project since it confirmed the potential for beneficial reuse of separated sand which was then incorporated into the design. While such a testing program is a critical first step towards beneficial reuse, the reuse concept can only be implemented if the project team is able to collaborate with the regulatory agencies and other stakeholders. Fortunately, on the Lower Fox River project such collaboration exists and it all began with following the regulatory procedures while establishing trust amongst all parties.

Our team has described the overall process and procedures we followed as a general guideline so that others in the sediment remediation field can use such a testing approach to benefit their projects, where applicable. Successful implementation of these concepts will result in significant cost savings for the clients along with implementing a more sustainable solution by reusing the sand as a valuable resource instead of disposal as a waste.

REFERENCES

Feeney, R., Lammers, B., Smith, G. (2011). “Cleanup of the Lower Fox River, Wisconsin Operable Units 2-5.” *Terra et Aqua*, Number 122, March 2011.

Tetra Tech CES, Stuyvesant Dredging, Inc. and AECOM. (2009) *Technical Memorandum – Standard Operating Procedures (SOPs) for Grain Size Analysis*. October 2009.

USEPA (2007). “Record of Decision Amendment, Operable Unit 2 (Deposit DD), Operable Unit 3, Operable Unit 4, and Operable Unit 5 (River Mouth), Lower Fox River and Green Bay Superfund Site.” June 2007.

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