Clean up Options at Rayonier Mill Site
Port Angeles Harbor, Washington

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The Rayonier Mill Site is one of almost 10,000 contaminated sites in the state of Washington. Washington Ecology and the U.S. EPA are the primary agencies responsible for overseeing the cleanup of many of these sites. As a result of these agencies' guidance over sites statewide, it is reasonable to anticipate that there will be some level of continuity and fluidity in the choice of remediation strategies that are selected for each site. Currently, for example, the cleanup of PCB-contaminated sediment at the Duwamish River is further along in the remediation process than at the Rayonier Site. Due to the similarities in driver chemicals and the various media that is contaminated, the remedies selected at the Duwamish may set precedents for the nature of the cleanup at Rayonier. In anticipation of the fall 2009 release of the agency reports for Rayonier, ESC conducted an investigation of issues that either should, or must, influence the specific remediation alternatives that will result in the highest level of cleanup for the Port Angeles Harbor. The subjects discussed below were gathered on the basis of the issues and concerns raised by the public and environmental groups regarding the Feasibility Study released for the Lower Duwamish, current remediation strategies at other sites across the country, and an understanding that global warming will have very real effects on sea-level and storm events in Washington coastal areas. These are all issues ESC foresees needing to be addressed in the Feasibility Study for the Rayonier Mill site.

The Purpose of a Feasibility Study

The Feasibility Study (FS) is a list of methods and technologies that are evaluated to determine if it is appropriate and applicable for this specific site. This two-step method is intended to give a clear, logical, and transparent consideration of how the final selections are made, and prevent a method or technology or cleanup alternative from being selected without justification and a factual basis. If an available and applicable method is dismissed, the FS must provide an explanation. Any FS is intended to present a sufficiently wide range of options clearly showing the different choices and results that are in line with the goals of the community and agencies. In order to accomplish this roadmap, the FS must use proper and appropriate data about the condition of the site (i.e. the Remedial Investigation has to be completed and the extent of contamination known), the data on costs and logistics of technologies has to be correct, and the FS must be designed to provide an accurate and realistic range of cleanup methods, among other features. It must include an option that meets the logical requirements and achieves human health and environmental protection throughout the cleanup process.

Monitored Natural Recovery (MNR)

General Overview

MNR is based on the depositional nature of larger waterways. Over time, sediments from upstream are deposited in contaminated locations, theoretically isolating the pollutants on the stream or river bottom from the water column and wildlife over time (EPA 2005). Once isolated, the pollutants can then begin to degrade. Regulatory officials evaluate on a site-specific basis the amount of time that it takes for the pollutants to break down which depends on a number of variables such as sediment chemistry (% organic carbon, etc.), the constituents and concentrations of the chemical mixture in question, and temperature. Often, the timeframe selected is greater than 20 years. Currently, there are no sites where MNR is in use that have implemented the remedy for the amount of time required to be called successful.

Enhanced natural recovery (ENR) is no more than light capping of contaminated sediments. In EPA's Contaminated Sediment Remediation Guidance for Hazardous Waste Sites, enhanced natural recovery is referred to as "thin-layer placement" and "is not designed to provide long-term isolation of contaminants from benthic organisms." In a 1993 remediation project focused on Pier 53 in Elliott Bay on the Duwamish, three feet of sediment was used to cap the contaminated site. In the shallower areas around the pier it was determined that three feet of sediment would decrease navigational depth and adversely affect the benthic habitat. For these reasons, one foot of sediment was deposited with the idea that small amounts of mixing of clean sediment and contaminated sediment would cause accelerated biodegradation. Of course, sampling afterward showed that the capped area had a lower concentration of chemicals than the surrounding area simply due to burial. However, the cap depth varied across the site as some of the sediment drifted away and the benthic community was obliterated. A benthic community did slowly return to the capped area but it was completely different than the previous set of organisms. The enhanced natural remediation sacrificed an established benthic community to simply cover up contaminated sediments that will eventually resurface in the shallow reaches around the pier due to boat traffic.

Mechanisms of the Breakdown of Persistent Organic Pollutants

The breakdown of toxic compounds is generally defined as any transformation that reduces the toxicity of the pollutant. For most persistent organic pollutants (POPs) such as PCBs and dioxins, this is accomplished through the removal of the chlorine atoms bound to the molecule that give them their toxicity. Unfortunately, this is much easier said than done and a whole industry has been created trying to create new and innovative ways to accomplish this reaction. To date, these efforts have been met with limited success.

Several major contaminants, including PCBs, arsenic, dioxins, other metals, do not breakdown into less toxic breakdown products and are not degraded by microbial activity to any measurable extent. The persistence of these contaminants that are drivers in the cleanup limits the range of possibilities on how the contaminated sediments are treated in cleanup. According to the EPA's *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites*, "When dealing with mixed contaminants at a site, the project manager should not focus unduly on one contaminant without understanding the effects of natural processes on the other contaminants, *including breakdown products*. Understanding the interactions between effects and prioritizing the significance of these effects to the MNR remedy should be part of a natural process analysis" (emphasis added).

POPs, as their name implies, are incredibly long-lived in the environment. They resist biological breakdown by bacteria and other microbes, and were often created and used because of their stability and lack of reactivity with other compounds. Many are also quite resistant to thermal breakdown, with some congeners of dioxins requiring temperatures in excess of 700°C (1,292°F) for decomposition (Rice et al 2003). When POPs enter aquatic systems such as streams and rivers, they become even more stable and difficult to break down.

The two most effective processes for the natural degradation of POPs like dioxins and PCBs are exposure to sunlight and decomposition by some anaerobic bacteria. Anaerobic (no oxygen) metabolism by microbes has been shown to have a limited ability to dechlorinate toxic POPs (Adriaens 1995, Ballerstedt 1997, Barkovskii 1996, Bedard 2007). Unfortunately, when the compounds are bound to sediments this ability is greatly reduced (Albrecht et al 1999). The US EPA has acknowledged these limitations in their assessment of monitored natural recovery, *Monitored Natural Attenuation: USEPA Research Program - An EPA Science Advisory Board Review*.

Light does not have the opportunity to act on PCBs during MNR since the principle behind the approach requires that contaminated sediments be buried and isolated from the environment over time. However, when the sediments are isolated in this fashion it prevents sunlight from reaching and breaking down contaminants. Therefore, once POPs are bound to sediment and subsequently buried, they are effectively isolated from any natural processes that work to break them down.

The Interplay of Water and Sediments in Aquatic Systems

Even though POPs bind tightly with sediments and are not soluble in water, they are not completely immobile in aquatic systems even once they are buried beneath layers of sediment. Many aquatic environments, particularly streams and rivers, are quite dynamic. Conditions vary significantly over both temporal and spatial scales, and can have significant effects on sediments within the water body. These changes are critical in understanding the spatial distribution and concentrations of POPs within these systems. Furthermore, because biota seek out the organic fraction of sediments that contains the highest levels of organic POPs, biological activity is likely to mobilize POPs into the food web.

Conditions change substantially the further one goes upstream in a river system. Large rivers are mostly depositional, murky with sediments that have runoff from its watershed. This turbidity acts to substantially limit the penetration of light into the river, and prevents submerged plant communities from becoming established. As one goes upstream, erosion becomes more significant than deposition (Paul and Meyer 2001). Flash flooding becomes more common because streambeds are smaller and have a reduced capacity to accept runoff. There are significant and regular interactions between the floodplain and the stream in these smaller systems. Scouring of the streambed is common in these streams, particularly in highly developed areas accepting large amounts of sediments. These low order streams are much more dynamic than large rivers, and conditions change constantly.

This is not to say that large rivers are static. Large flooding events can move significant amounts of sediment downstream and bring large debris into the river that can cause significant scouring of the riverbed. One flood in the Colorado River increased the stream bed by nearly five feet (Leopold 1962). In colder climates, ice can also disturb the bottom of even large rivers. In the lower Fox River in Wisconsin, ice scours as much as four feet deep have been recorded (WDNR 2006). The creation of frazil ice, or ice crystals that are formed within the water column in turbulent waters at very cold temperatures, can also cause significant scouring of sediments.

Rivers and watersheds are the primary pathways of sediment transport in most areas. Events both large and small have the potential to disturb streambed sediments. Most of these events happen with enough frequency that it is not so much a matter of *if* but *when* they will occur.

Long-Term Effectiveness

There is little information on the long-term effectiveness of MNR. Preliminary data indicate that these techniques may not be as effective as predicted. One example is the James River in Richmond, VA. Illegal dumping of the pesticide Kepone contaminated the river and resulted in a ban on fishing in 1975. The pesticide is incredibly toxic and also stable in the environment in ways similar to PCBs and dioxins. The ban was replaced in 1988 with a fish consumption advisory which remains in place to this day. Fish tissue concentrations, sampled in the James River, indicate that chemical concentrations of Kepone have fallen over time. More importantly, however, the most recent data available from Virginia DEQ indicates that samples of fish tissue concentrations continue to exceed the limit of 0.03 ppm. Figure 1 displays the decline in Kepone concentrations in white perch and striped bass from 1976 to 2002, sampled from various zones within the James River estuary. Though concentrations have decreased, white perch and bass tissues have continued to be sampled at concentrations higher than the level set by the Virginia Department of Health as protective of human health. Data from 2004 indicates that fish tissue samples in striped bass were still as high as 0.09, three times the DOH limit, and samples in white perch were as high as 0.07 (Virginia DEQ). Despite the overall decline, data indicates that the James River fish populations have had 28 years to prove that natural recovery is effectively cleaning up the river. In those 28 years, fish tissues are still coming back higher than Virginia's Department of Health deems protective of human consumption. After three decades, monitored natural recovery has not successfully caused a decrease in chemical concentration below the levels acceptable for human health.

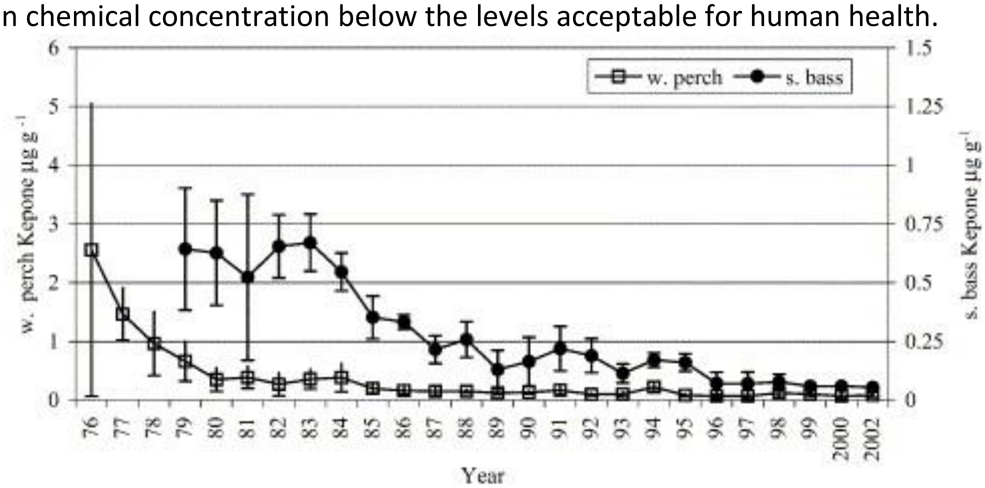

Figure 1. Average Kepone concentrations in white perch and striped bass from zones D–A (Hopewell to the mouth of the James River) (Luellen et. al 2006)

The possibility that Port Angeles could result in the same prolonged contamination should not be surprising given the extreme persistence in the environment of many of these compounds. The same processes that isolate contaminated sediments from aquatic organisms also serve to prevent or inhibit natural recovery mechanisms. Considering that many POPs have the potential to remain in sediment for over 100 years, it is almost a statistical certainty that a significant scouring event (such as a 100 year flood event) will occur during the timeframe required for MNR to run its course. These events redistribute the essentially un-degraded POPs and make them readily accessible to aquatic organisms such as fish where they can enter and accumulate in the food chain. The long-term effectiveness of MNR is countered by many of the same natural processes that it wishes to exploit. In most cases MNR is not a desirable remedial option, particularly if the objective is to reduce fish tissue concentrations below levels that require consumption advisories.

To date, there have been no studies concluding with certainty that natural recovery is an effective means of remediation. The problem with MNR is that there is no evidence that it works to either a) cover the sediments with a sufficient layer of clean sediment, or b) isolate the contamination to the point where the chemicals do not move into the aquatic food web. These two processes are related but not at all the same. The first process is the physical burial of sediments with freshly deposited sediment. The second process is preventing movement of contaminants into the food web. This second process may also be considered the absence of biological activity that brings contaminants up to the surface from below. Burial can be predicted (more or less) from some models and measured information on sedimentation. Isolation is not so easily predicted and there is not a "model" to help predict it. Ultimately, MNR should not be considered a reliable option in the FS for Port Angeles.

Dredging

General Overview

Environmental dredging, as defined by the EPA's Contaminated Sediment Remediation Guidance for Hazardous Waste Sites, "is intended to remove sediment contaminated above certain levels while minimizing the spread of contaminants to the surrounding environment during dredging." It is the most frequent cleanup method used at Superfund sites. It utilizes mechanical (buckets) and hydraulic (pumping) methods of sediment removal. Each method has requirements for sediment removal efficiency and proper disposal.

A hydraulic dredge is a suction dredge that "vacuums" up the sediment, and operates in softer sediment. Some types of hydraulic dredge are equipped with a "cutter head" that can dig into compacted sediments, and these dredges are usually referred to as "cutter head" dredges. A hydraulic dredge can also be fitted with a smaller horizontal auger dredge to be used in even shallower areas. Hydraulic dredges operate in soft sediment and have the advantage of removing large amounts with less disturbance and resuspension of sediments. The equipment consists of a small barge containing the hydraulic dredge and a tube that siphons the sediments out to a settling pond. The process is nimble and can be readily used in shallower waters, along banks and near piers. Hydraulic dredging is being used along several river miles of the Hudson River outside of the deeper navigation channel.

The latest in clamshell buckets for sediment removal comes from Cable Arm Inc. which has engineered an environmental clamshell that has features that reduce the impacts of environmental dredging. A venting system allows water to move through the clamshell as it is lowered to the sediment surface, decreasing water displacement and minimizing resuspension. As it is raised, water stays within the bucket until it reaches the surface where excess water is drained, reducing dewatering costs. The environmental clamshell also features level cutting to ensure complete sediment removal and overlapping sides with rubber seals that keep sediments in the bucket until unloaded. The clamshells are GPS-guided and have a lower overall weight because they do not need counterweights. In shallower areas where the water depth may not support the weight of a scow for containment of sediment after dredging, hydraulic transport may be used to pipe the dredged material to a dewatering site. These features make environmental clamshell buckets ideal for environmental dredging in most any riverine system. Cable Arm Inc. environmental clamshell buckets have been used in New Bedford, Yankee Rowe, Calumet, Saginaw, Searsport, and the St. Lawrence River. The cleanup of the Hudson River is also utilizing environmental clamshell buckets.

Addressing Issues with Dredging

Dredging is the most permanent and reliable remediation method. There are some issues that arise with dredging that can easily be remedied and should be addressed in the Port Angeles FS. These include turbidity causing resedimentation of contaminated sediments and the presence of debris. During the dredging process, silt barriers can be used in the area of dredging to cut down on turbidity and to prevent the movement of contaminated sediments further downstream, even on a tidal river. Given site specific conditions, they are effective in currents less than 3-5 knots when installed properly. Also, starting upstream and continually working downstream will help prevent recontamination of a previously cleaned area of the river. Clean up of the lower Passaic River in New Jersey included continual monitoring of water temperature, river velocity, currents, tides, salinity, suspended solids and sediment particle size both upstream and downstream of the dredging site. Environmental clamshell buckets in conjunction with silt curtains and monitoring of water quality conditions can ensure a productive, clean, and cost effective method for contaminated sediment removal.

The presence of debris has been cited as impedance to dredging at other contaminated sites because excess debris, large rocks, etc. would clog or jam the dredge. Though the Hudson River is freshwater and brackish, these characteristics do not affect debris loading. In the Hudson River, dredging in the upper reaches occurs despite the presence of debris. According to the Engineering Performance Standards for the Hudson River, a report prepared for the Army Corps of Engineers:

> “To minimize delays in dredging related to the presence of boulders and debris, visual surveys conducted by divers, ground penetrating radar, and side scan sonar surveys are frequently used to determine where these adverse dredging conditions exist and to plan in advance for coping with them. Hydraulic excavators mounted on workboats and equipped with grapples or other material

> handling devices are generally used to remove sunken logs, appliances, and other debris, while heavy growths of weeds can be removed with weed harvesters. Boulders and cobbles can be moved to areas outside of the navigation channel that have already been dredged by a workboat operating in close coordination with the dredge, but a loss of production inevitably occurs under these conditions. Environmental buckets mounted on hydraulic excavator booms and equipped with hydraulic pistons to close the bucket can minimize the problem of debris for mechanical dredges but may have secondary problems of maintenance and repair that can impact overall production."

Thus, considerable amounts of debris do not automatically preclude the option of dredging. The problem with debris may be solved with screens over the intake for the dredge, used to prevent debris from damaging the equipment. Since these issues can be easily remedied, they should be addressed in the feasibility study but not used as a reason to preclude dredging as a remedy for Port Angeles.

Technologies for Dredged material

New technologies handling the contaminated sediments once they have been dredged have created the opportunity to turn waste into a usable resource. BioGenesis Enterprises, Inc. in 2006 unveiled a new technology that strips away contaminants from dredged sediment and leaves behind clean, quality top soil. This technology was used in a Woodbridge, New Jersey facility to treat more than 4500 cubic yards of contaminated sediment from the lower Passaic River. In addition to sediment washing technology, Endesco Clean Harbors has patented a technology that heats the sediment and blends it with cement. This process is being used to treat sediment stored on the Raritan River at Bayshore Recycling in New Jersey.

Phytoremediation

Phytoremediation is being used around the country to remediate contaminated sediments and should be included in the Port Angeles FS. Phytoremediation, or the utilization of plants, fungus, and algae to effectively control, break down or remove contaminants, can be used to remediate contaminants found at low to medium levels and has been used at numerous Superfund sites and in combination with other remediation strategies. Phytoremediation is effective for shallow soil depths, groundwater, and marine sediment, depending on the plants selected. The EPA notes that studies of vegetated soils are better able to degrade, remove, and mineralize PCBs, PAHs, pesticides, and many other contaminants, than non-vegetated soils. According to the Air Force Center for Engineering and the Environment, phytoremediation is a good treatment for nickel, copper, and zinc. Both nickel and zinc are driver chemicals at Rayonier. Based on the Low Impact Development Manual (2005), certain plants can absorb or immobilize metal pollutants while other plants can metabolize or accumulate organic and nutrient contaminants. Plants can indirectly accelerate degradation of contaminants as well by increasing microbial activity in the soil. Native plants show the most promise in the process of phytoremediation and reduce the chances of overgrowth that could occur by using non native, or invasive, species. The advantage in the long term is that phytoremediation provides a root structure that prevents transport of contaminated sediments from the uplands to Ennis creek or elsewhere in the watershed. Native trees and grasses planted around Ennis Creek that are capable of phytoremediation may act as long term source control. For example, the native plant *Streptanthus polygaloides* can “hyperaccumulate” nickel at levels beyond what is necessary for normal growth (Jhee 2006). Washington state is currently using hybrid poplars to treat volatile organic compounds and the Washington Department of Transportation has collaborated with scientists to utilize mushrooms to successfully remediate contaminated soils along stretches of state highway. With phytoremediation already in use – successfully - by state agencies, Washington Ecology should thoroughly examine phytoremediation as a feasible alternative in the Rayonier FS.

Climate Change

Weather events predicted to result from global warming include changes in major storm events and associated precipitation. It is expected that increasingly frequent storm events will affect the majority of coastal states in the United States, and Washington is no exception. The U.S. government’s report on climate change, released June 16, 2009, states that, “sea-level rise will increase erosion of the Northwest coast and cause the loss of beaches and significant coastal land areas. Among the most vulnerable parts of the coast is the heavily populated south Puget Sound region, which includes the cities of Olympia, Tacoma, and Seattle, Washington.” In addition to sea-level rise, a 2007 report from Environment America analyzed data from the National Climatic Data Center, the Department of Commerce, and the National Oceanic and Atmospheric Administration, among others, and determined that the percent of extreme precipitation frequency has increased thirty percent (30%) from 1948-2006. A direct result of increased precipitation is increased likelihood of flooding. Increased precipitation and flooding can overload storm drains and create sewage overflows, both of which will amplify land-based pollution outfall to the river. Also, flooding events can increase the velocity of the river’s flow as well as the amount of debris transported through the watershed. These two factors create a high probability of sediment disruption and scour. The FS must consider global warming and its implications for the Port Angeles area.

Sources Cited

Adriaens, P, QZ Fu, and D Grbicgalic. 1995. Bioavailability and transformation of highly chlorinated dibenzo-p-dioxins in anaerobic soils and sediments. Environmental Science and Technology. 29:2252.

Air Force Center for Engineering and the Environment. Phytoremediation. <http://www.afcee.af.mil/resources/technologytransfer/programsandinitiatives/phytoremediation/index.asp> (Accessed 29 June 2009).

Albrecht, ID, AL Barkovskii, and P Adriaens. 1999. Production and dechlorination of2,3,7,8-tetrachlorodibenzo-pdioxin in historically-contaminated estuarine sediments. Environmental Science and Technology. 33: 737.

Ballerstedt, H, A Krauss and U Lechner. 1997. Reductive chlorination of 1,2,3,4 tetrachlorodibenzo-p-dioxin and its products by anaerobic mixed cultures from Saale River sediment. Environmental Science and Technology. 31:1749.

Barkovskii, AL and P Adriaens. 1996. Microbial dechlorination of historically present and freshly spiked chlorinated dioxins and diversity of dioxin dechlorinating populations. Applied Environmental Microbiology. 62: 4556.

Bedard, DL, KM Ritalahti and FE Löffler. 2007. *Dehalococcoides* in a sedimentfree, mixed culture metabolically dechlorinate the commercial polychlorinated biphenyl mixture Aroclor 1260. Applied Environmental Microbiology.

Cable Arm Inc. Environmental Dredging Solutions. <http://www.cablearm.com> (Accessed 27 May 2009)

Dredge America. Hydraulic dredging: Least invasive and most cost effective. <http://www.dredgeamerica.com/dredge-america-in-action-video-3.html> (Accessed 28 May 2009).

Dredging Operations and Environmental Research Program. September 2005. Silt Curtains as a Dredging Project Management Practice. <http://el.erdc.usace.army.mil/elpubs/pdf/doere21.pdf> (Accessed 4 June 2009).

Elliot Bay/Duwamish Restoration Program. November 1993. Pier 53-55 Sediment Cap and Enhanced Natural Recovery Area Remediation Project. <http://your.kingcounty.gov/dnrp/library/1993/mr7359/frontmatter.pdf> (Accessed 28 May 2009).

GE Hudson River Dredging Project. Pace of Hudson River dredging quickens. <http://www.hudsondredging.com/leadstory/> (Accessed 27 May 2009).

Granit Environmental. Type III Silt Barrier. <http://www.erosionpollution.com/Type-III-Silt-Barrier.html> (Accessed 4 June 2009).

Karl, Thomas R., Jerry M. Melillo, and Thomas C. Peterson (Eds.). 2009. Global Climate Change Impacts in the United States. Cambridge University Press, 2009.

Leopold, LB. 1962. Rivers. American Science. 50: 511-37.

Luellen, Drew R., George G. Vadas and Michael A. Unger. 1 April 2006. Kepone in James River fish: 1976–2002. Science of the Total Environment. 358:1-3. 286-297.

Madsen, Travis and Emily Figdor. 2007. When It Rains, It Pours: Global Warming and the Rising Frequency of Extreme Participation in the United States. Environment America Research and Policy Center.

Malcolm Pirnie, Inc and TAMS Consultants, Inc. 2004. Hudson River PCBs Superfund Site, Engineering Performance Standards: Technical Basis and Implementation of the Productivity Standard. Prepared for US Army Corps of Engineers. Volume 4 of 5.

Mears, M. Technology turns contaminated sediment into useful product. USEPA Press Release, Region 2. March 24, 2006.

Nichols, Maynard. 1990. Sedimentologic fate and cycling of Kepone in an estuarine system: Example from the James River estuary. Science of the Total Environment. 97-98: 407-440.

Paul, MJ and JL Meyer. 2001. Streams in the Urban Landscape. Annual Review of Ecology and Systematics. 32: 333-365.

Rice, C.P, P.W. O'Keefe, and T.J. Kubiak. 2003. "Sources, Pathways, and Effects of PCBs, Dioxins, and Dibenzofurans." Handbook of Ecotoxicology: Second Edition. Ed. D.J. Hoffman, B.A. Rattner, G.A. Burton Jr., and J. Cairns Jr. Lewis Publishers, New York, NY. Pg. 501-573.

US EPA. 2005e. Contaminated Sediment Remediation Guidance for Hazardous Waste Sites. OWSER. EPA-540-R-05-012. Washington, DC.

US EPA. April 2004. Hudson River PCBs Superfund Site. Engineering Performance Standards. Volume 4: Technical basis and implementation of the productivity standard. <http://www.epa.gov/hudson/eng_perf/FP4001.pdf> (Accessed 4 June 2009).

Wilde, C. Clean it, reuse it. Dredging and Port Construction: Dredged Sediment Management. February 2006. <http://www.biogenesis.com/mediasite/attachments/048_Clean%20It%20Reuse%20It-Dredging%20&%20Port%20Construction.pdf>

Wisconsin Department of Natural Resources. 2006. Basis of Design Report: Lower Fox River and Green Bay Site. Prepared by Shaw Environmental Inc.