Sediment deposition at Charles Mill Lake of Ohio has gradually reduced the effectiveness of reservoir operation over the years. It affects flood control and natural resources preservation including recreation, navigation, and water quality. A survey of the reservoir and channel bed elevations using a global positioning system was conducted by the U.S. Army Corps of Engineers in summer of 1998. The original reservoir and channel bed elevations were digitized at Ohio University. Both surveying and digitizing results were analyzed using a geographic information system (GIS). The accumulation of sediment deposits over the years, associated depths, and their geographic distributions were shown by GIS images. The major sediment deposits are found along the original mainstream of the original riverbed.

Sediment sampling was conducted in summer 1998 for assessing the dredging program. The analysis of sampled sediments was done based on grain sizes, material grading, and soil uniformity using the geographic information system. It is found that there is a minimum percentage of gravel in the composition of sediment deposits, and the settlement of gravels is mainly located at two apparent locations. The uniformity and gradation shown as images provide the geographical distribution of sediment deposits, by which a working program for dredging may be developed in terms of priorities. Two locations in the reservoir are selected for dredging material disposal by forming wetlands.

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INTEGRATING TOXICOLOGY AND BENTHIC ECOLOGY: PUTTING THE "ECO"
BACK INTO ECOTOXICOLOGY

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Assessing sediment toxicity can be done using benthic ecology (reality, but not predictive and
difficult to discern subtle effects) and/or toxicology (least "real" in the laboratory, but can be
predicative and can assess subtle effects). To date toxicology has arguably been
environmental rather than ecological (ecotoxicology). Environmental toxicology tends to
focus on laboratory issues and testing costs, whereas ecological toxicology focuses on
ecological issues and the costs of an incorrect decision. Similarly, benthic ecology needs to
be done better - the primary focus on species diversity and abundance is inappropriate; the
real issue is processes. Ecotoxicology ideally provides an integration of benthic ecology and
toxicology, surpassing their individual limitations. General guidelines for acute and chronic
testing are provided, as are ecotoxicological criteria for species selection (contrasted with
"standard" environmental toxicology criteria). Other issues discussed include: laboratory vs.
field tests and mixed species testing, a detailed example of the need for ecotoxicology is
presented relative to estuarine sediments. Different estuaries and their unique characteristics
are reviewed (overlying and interstitial salinity as a controlling factor, bioavailability
measurements, benthos - "the paradox of brackish water" and seasonal, interstitial-salinity
induced movements up and down-stream). Current sediment toxicity tests, species used, end-
points, problems and resolutions are also reviewed. Most testing has involved single species,
but community level toxicity tests are available. These are best interpreted in combination
with well-designed single species tests. Specific recommendations are provided for ensuring
estuarine sediments are evaluated based on ecotoxicology, not environmental toxicology. An
overall framework based on ecological risk assessment is then proposed for combining
benthic ecology and toxicology to minimize uncertainty and maximize realism. Two
alternatives are possible: extrinsic or intrinsic incorporation of ecology into toxicology (the
latter is preferable). Final recommendations are provide which are not solely scientific (e.g.,
do not separate the disciplines of ecology and toxicology; do not rely on "snapshots in time";
develop and use appropriate tools to measure ecosystem status and indications of stress).
Integrating benthic ecology and toxicology in ecotoxicology represents and important shift
from reductionist to holistic approaches.

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THE USE OF INNOVATIVE SEDIMENT TREATMENT TECHNOLOGIES IN THE GREAT LAKES

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Beginning with the initiation of the Assessment and Remediation of Contaminated Sediments (ARCS) program in 1987, the Great Lakes National Program Office (GLNPO) has been actively involved in the development, testing, and evaluation of assessment and remediation techniques for managing contaminated sediments in the Great Lakes. As part of the 6-year ARCS program, GLNPO was responsible for the study and demonstration of appropriate treatment options for toxic contaminants in bottom sediments. At the conclusion of the ARCS program in 1994, GLNPO continued to provide financial, technical, and field sampling support for contaminated sediment issues throughout the Great Lakes. This presentation discusses results of the ARCS sediment treatment demonstration projects and the status of two innovative sediment treatment projects currently funded under GLNPO's annual grants program.

The ARCS program researched over 250 treatment technologies, most of which had not been previously demonstrated on contaminated sediments. Nine (9) of these technologies were selected for bench-scale testing, including: solidification/stabilization, particle separation, bioremediation, base catalyzed decomposition, basic extractive sludge treatment (BEST) process, low temperature thermal desorption, wet air oxidation, thermal reduction (Ecologic process), and In-situ stabilization. Based on these results, GLNPO sponsored pilot-scale demonstrations of the BEST solvent extraction and the low temperature thermal desorption processes. Reports discussing the results of bench- and pilot-scale demonstrations are available through the USEPA's Great Lakes National Program Office in Chicago, Illinois. While the processes proved to be effective at removing PCBs, PAHs, and other volatile and semivolatile compounds from the sediments, cost estimates for full-scale operations indicated that these treatment would be expensive, $250-$535 per cubic yard of material.

With tens of millions of cubic yards of contaminated sediment within the Great Lakes basin potentially requiring remediation and/or treatment the cost of treatment could run into the billions of dollars. Additionally, space in landfills and confined disposal facilities (CDF) is running running low. GLNPO and its Great Lakes partners are interested supporting the development of cost effective alternatives to landfills and CDFs. To reach this end, GLNPO is supporting feasibility scale testing of two innovative sediment treatment technologies that combine contaminated sediment treatment with the production of a marketable final product, the Glass Aggregate Feasibility Study, and the Cement-Lock pilot-scale demonstration.

The glass aggregate feasibility study uses a thermal treatment technology that is currently being used to treat paper mill sludge to produce a glass aggregate fill material. The Cement Lock process also uses a thermal treatment process to produce a blended cement product. By recovering a portion of the treatment costs through sale of the final product unit costs for each process are estimated at $60-$100 per cubic yard. Both demonstrations are scheduled to begin in calendar year 2001.

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INNOVATIVE EROSION CONTROL INVOLVING THE BENEFICIAL USE OF DREDGED MATERIAL, INDIGENOUS VEGETATION AND LANDSCAPING ALONG THE LAKE ERIE SHORELINE

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Current conventional methods used to retard shoreline erosion include the installation of breakwaters, groins, and jetties. Sand replenishment is often used in conjunction with these methods when shorelines are being extended or restored. These techniques, though often functional, are costly and can detract from the natural environment.

The purpose of this abstract is to describe an innovative erosion protection project at Presque Isle State Park. This low cost, innovative demonstration project minimized erosion in the lesser energy zone of Misery Bay in Presque Isle State Park by utilizing native plants, bioengineering, and non-conventional erosion practices. The project, funded with a matching grant from the Great Lakes Commission, was completed in the spring of 1999 and early indications are that it has the potential of serving as a model for other lesser energy zones of bays and inlets along the Great Lakes.

Presque Isle State Park, located along the shores of Lake Erie in Pennsylvania, is a 3,200-acre migrating sand spit that juts 7 miles into the lake. The park is a major recreational landmark for approximately 4 million visitors each year. Presque Isle beaches provide park visitors with the only surf swimming in the state. The park, a National Natural Designated Landmark, is particularly environmentally sensitive with its constantly evolving shoreline and the presence of numerous plants recognized as being of exceptional value. Additionally, the Audubon Society rates Presque Isle as one of the top birding areas in the northeast.

Protection of the spit has been an ongoing process since 1828. Along the Lake Erie shoreline, a series of conventional erosion control techniques such as groins, bulkheads, seawalls and beach nourishment have been used with varying success. Between 1989 and 1992, many of the previous structures were removed and 55 offshore rubble mound breakwaters were constructed. Since completion of the breakwater construction, shoreline maintenance has been limited to an annual beach nourishment program.

Along the southern shoreline of the peninsula within Presque Isle Bay, Misery Bay, Marina Lake, and Thompson Bay, erosion of a much lesser degree has historically been remedied with riprap along the shoreline. This practice has proven successful in many recreational use areas of the park, but adjacent to Presque Isle's ecological reservation area, this remedy was not appropriate to match the park's designated management prescriptions.

Within this section of the park, parallel to the shoreline, is a 9.6-mile multi-purpose trail, a section of which had exhibited substantial erosion to within 15 feet of the multipurpose trail in the area known as Misery Bay. In addition, a 300-foot sand bar had developed at the Perry Monument, also located within the Misery Bay area. Rather than use costly conventional erosion protection methods for this environmentally sensitive area, the project incorporated a
combination of riprap as well as indigenous plants, bioengineering, and innovative landscape architecture to abate the shoreline erosion.

Approximately 1,200 cubic yards of sand from the sand bar was dredged and then placed at a staging area so it could naturally dewater. Riprap (12-24 inches in diameter) was placed 25-30 feet from the multipurpose trail shoreline creating a "toe slope". The dewatered sand from the Perry Monument sand bar was then placed behind and over this riprap, creating a higher dune line and providing a buffer of 25-30 feet between the water and the trail. Additionally, the project area is adjacent to the park's ecological reservation area that is home to several species of turtles; therefore, placement of the sand over the riprap created a gently sloping back beach area for turtle migration and egg hatching.

Next, to enhance the "natural" appearance of the shoreline, randomly spaced downed trees and stumps from the park (10-36 inches in diameter), minus the limbs, were used both as timber groins and breakwaters. To function as groins, the tree root bases were anchored behind the riprap in the fill, and the trunks extended out past the riprap and into the water. After the fill had been placed, it was covered with geotextile made of coconut fiber in order to protect the shore zone area from erosion and to aid in vegetative rooting. Subsequently, indigenous vegetation that included willow, red osier dogwood, silky dogwood, and buttonbush was planted via the placement of wattles. These wattles were placed end to end, parallel to the shoreline approximately at the average high water mark for the length of the project. This construction of the off-shore "toe slope", timber groins, breakwaters, and the dune line, combined with the planting of native vegetation, greatly reduced erosion and provided protection for the heavily used multipurpose trail.

The completed project has resulted in several additional acres of stabilized vegetation and has decreased soil and subsequent nutrient runoff from entering Lake Erie. Through the years, conventional erosion protection techniques at Presque Isle have been both costly and inappropriate for natural area management. Conversely, this economical project with a total cost of $33,000 provided a natural and aesthetic alternative to conventional shoreline erosion protection. While remaining within standard bureaucratic financial constraints, the project affords a valuable example to other parks and recreational facilities along the Great Lakes faced with the challenge of minimizing erosion and maintaining a natural appearance.

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Coastal ecosystems providing vital natural services to society have been severely damaged by development. In addition, the ecosystem functions of large areas of America's remaining natural wetlands have been degraded by subsidence due to groundwater, oil and gas withdrawals, and persistent sea level rise (Delaney et al. 2000). Greatest wetland losses in the United States have been in coastal California and the northern Gulf of Mexico (Turner 1997; Zedler et al. 1997).

Hundreds of cubic kilometers of sediment are dredged each year for commercial and recreational purposes and discharged into the nation's oceans, estuaries, rivers and lakes, or to land-based disposal facilities. Dredged material containment facilities are nearing capacity or are already full; and opening new containment sites creates numerous social and economic conflicts. Dredged materials are invaluable resources for stabilizing or restoring America's wetlands and beaches; and methods of wetland restoration using uncontaminated dredged materials are either straightforward, or, are in development. While development may have altered the hydrology of wetland ecosystems and reduced vegetative cover, the hydric soils built through geological time remain. In these cases, wetlands can be restored by simply adding uncontaminated dredged materials on top of subsiding wetlands to increase their elevation so that marsh vegetation can be established. Testing and evaluating the contaminant status of dredged material are the first steps to exclude contaminated materials unsuitable for environmental use. Thirty-three case studies from the US Army Corps of Engineers/EPA web site on the beneficial uses of dredge materials were summarized (Table 1). In comparison with the enormous quantities of materials available, the majority of projects were small (less than 100 acres); used sand and silts; used riprap for protection in low to moderate energy environments; and lacked long-term monitoring and research. Costs of projects ranged from $1.00 to $11.25 per cubic yard, with a mode of $1.50.

The Clean Water Action Plan and the Coastal Wetlands Protection, Planning, and Restoration Act establish the groundwork to increase the area of restored wetlands in the USA. Disposal of uncontaminated dredge materials into the Nation's waters and landfills creates a needless waste of America's ecological, economic, engineering and scientific wealth. Three assessments by National Research Council (NRC) have stated that the restoration of coastal wetland and beach ecosystems is a national priority (NRC 1992, 1994a,b). NRC (1994b) recommended that, "Federal science agencies should encourage rapid advancement of the science and engineering of ecosystem restoration and rehabilitation". More collaborative, interdisciplinary studies need to be funded within long-term monitoring programs to fully evaluate the key ecological engineering aspects for use of using uncontaminated dredge materials for environmental purposes. One noteworthy collaborative program is the "Beneficial Use of Dredged Materials Monitoring Program", a collaboration between the US Army Corps of Engineers New Orleans District and the Coastal Research Laboratory, Department of Geology and Geophysics, University of New Orleans.

Increased use of dredged materials in coastal areas will make disposal of uncontaminated dredged materials unnecessary. It should be the policy of the United States government and its agencies to use every available uncontaminated cubic yard of dredge materials for beneficial environmental purposes.
References

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Table 1. Wetland restoration and erosion control projects.

<table>
<thead>
<tr>
<th>Environmental Dredging Projects Size</th>
<th>Size (acre)</th>
<th>Substrate</th>
<th>Energy Levels</th>
<th>Physical Protection</th>
<th>Cost (yd3)</th>
<th>Monitoring/Research Programs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Donlin Island, CA</td>
<td>35</td>
<td>silt,sand</td>
<td>low</td>
<td>none</td>
<td>1.5</td>
<td>long term by UCD &amp; ACE</td>
</tr>
<tr>
<td>Mobile, AL</td>
<td>33</td>
<td>sand, silt, shell</td>
<td>moderate</td>
<td>none</td>
<td>NA</td>
<td>short term within project</td>
</tr>
<tr>
<td>Slaughter Creek, MD</td>
<td>4</td>
<td>sand, silt</td>
<td>moderate</td>
<td>none</td>
<td>1.5</td>
<td>NMFS &amp;ACE pre, during &amp; post mon</td>
</tr>
<tr>
<td>Texas City, TX</td>
<td>4</td>
<td>silt, sand</td>
<td>moderate</td>
<td>breakwater</td>
<td>1.25</td>
<td>ACE</td>
</tr>
<tr>
<td>Atchafalaya Riv. LA</td>
<td>15</td>
<td>silt</td>
<td>low</td>
<td>none</td>
<td>2.00</td>
<td></td>
</tr>
<tr>
<td>Atlantic Intracoastal Waterway</td>
<td>100</td>
<td>sand, silt</td>
<td>low</td>
<td>none or riprap</td>
<td>1.00</td>
<td>DMRP; USFWS/Univ. post mon</td>
</tr>
<tr>
<td>Barren Island, MD</td>
<td>100</td>
<td>Sand</td>
<td>low to moderate</td>
<td>geotextile tubes; near shoreline</td>
<td>NA</td>
<td>ACE</td>
</tr>
<tr>
<td>Columbia River Islands OR, WA</td>
<td>NA</td>
<td>sand</td>
<td>moderate</td>
<td>none</td>
<td>NA</td>
<td>during project only</td>
</tr>
<tr>
<td>Core Sound Islands NC</td>
<td>15</td>
<td>sand</td>
<td>high</td>
<td>40ft2 nylon saddlebags</td>
<td>1.5</td>
<td>UNCW; NCSU:ACE post mon</td>
</tr>
<tr>
<td>Craney Island,</td>
<td>15</td>
<td>sand</td>
<td>high</td>
<td>riprap dike</td>
<td>NA</td>
<td>None</td>
</tr>
<tr>
<td>Location</td>
<td>Population</td>
<td>Sediment</td>
<td>Water Level</td>
<td>Protection</td>
<td>Monitoring</td>
<td></td>
</tr>
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<td>--------------------------------</td>
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<td>-------------</td>
<td>------------</td>
<td>------------</td>
<td></td>
</tr>
<tr>
<td>Folly Island, SC</td>
<td>20</td>
<td>silt, sand</td>
<td>low</td>
<td>none</td>
<td>2.28</td>
<td></td>
</tr>
<tr>
<td>Galliard Island, AL</td>
<td>35</td>
<td>silt, sand</td>
<td>moderate</td>
<td>riprap dike</td>
<td>1.25</td>
<td></td>
</tr>
<tr>
<td>Great Lakes Islands, MI, MN</td>
<td>.5-100</td>
<td>sand, cobble</td>
<td>moderate</td>
<td>riprap or none</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Gulf Coast Intra-coastal Waterway, FL, AL, TX</td>
<td>.5-100</td>
<td>sand, silt</td>
<td>low</td>
<td>riprap, dikes, or none</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Hart Miller Island, MD</td>
<td>1100</td>
<td>silt, sand</td>
<td>high</td>
<td>riprap</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Hillsborough Gay, FL</td>
<td>400-500</td>
<td>sand</td>
<td>high</td>
<td>limited riprap</td>
<td>11.25</td>
<td></td>
</tr>
<tr>
<td>Muzzi Marsh</td>
<td>50</td>
<td>sand, silt</td>
<td>high, variable</td>
<td>none</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>Point Mouillee, MI</td>
<td>4600</td>
<td>sand, silt</td>
<td>high, variable</td>
<td>riprap dike and side dike</td>
<td>9.43</td>
<td></td>
</tr>
<tr>
<td>Pacific Coast islands, WA, OR, CA</td>
<td>2-200</td>
<td>sand, cobble volcanic</td>
<td>high</td>
<td>none</td>
<td>&lt;1.00</td>
<td></td>
</tr>
<tr>
<td>Queen Bess Island, CA</td>
<td>8</td>
<td>silt, sand</td>
<td>low</td>
<td>none</td>
<td>70, 156/acre</td>
<td></td>
</tr>
<tr>
<td>TN-Tombigbee Waterway, AL, MS</td>
<td>14000</td>
<td>silt, sand</td>
<td>low</td>
<td>none</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Times Beach, NY</td>
<td>25</td>
<td>silt, sand</td>
<td>low</td>
<td>CDF dike</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Warm Springs, CA</td>
<td>100</td>
<td>silt</td>
<td>high</td>
<td>dikes, culverts</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Weaver Bottoms, MN</td>
<td>5000</td>
<td>sand</td>
<td>moderate</td>
<td>none</td>
<td>NA</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: ACE=Army Corps of Engineers; UCD=University of California Davis; UNCW=University of North Carolina Wilmington; NCSU=North Carolina State University; USFWS=US Fish and Wildlife Service; DNR=Department of Natural Resources; MSU=Mississippi State University; and DMRP=Dredged Material Research Program
USE OF PHOSPHORUS TO STABILIZE HEAVY METALS IN CONTAMINATED SEDIMENTS

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Key words: phosphorus, contaminated sediments, lead, cadmium, zinc, stabilization, leaching

Heavy metals are a prevalent and tenacious contaminant in many sediments and dredged materials. The management of these sediments requires innovations that will provide affordable technologies to coastal decision-makers. Phosphorus has been used for decades to stabilize heavy metal-contaminated wastes in industrial and terrestrial environments, but the application of this technology to contaminated sediments is relatively new.

In a laboratory scale project, three heavy metal contaminated sediments from Providence Harbor, Rhode Island, Newtown Creek, New York, and Cochecho River, New Hampshire were treated with 10% phosphorus and lime. The source of phosphorus is a calcium apatite mineral mined in Florida. Results of the treatment were analyzed using pH dependent leaching experiments, geochemical modeling, X-ray powder diffraction analysis, and X-ray photoelectron spectroscopy. The treatment successfully reduced the solubilities of lead by 77%, cadmium by 54%, and zinc by 46%. Spectroscopic analysis indicated the presence of severalapatite minerals that had incorporated heavy metals into their structures. The use of phosphorus is shown to be an effective technology for reducing the solubility of heavy metals in contaminated sediments through the formation of insoluble metal phosphate minerals.

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BENEFICIAL USES OF DREDGED MATERIAL: PART OF THE SOLUTION TO RESTORATION OF LOUISIANA'S COASTAL WETLANDS

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Key words: dredged material, beneficial use, wetland restoration, Louisiana land loss

The USACE, New Orleans District annually removes 70,000,000 to 90,000,000 cubic yards of shoal material from discontinuous reaches of 10 Federal navigational channels in coastal Louisiana. Since 1974, whenever feasible, the dredged material from routine maintenance has been used beneficially to create, restore, nourish, and protect coastal wetland habitats. Hydraulic cutterhead pipeline dredges place the dredged material into shallow, open water areas adjacent to the navigational channels in a manner conducive to wetlands development.

In the mid-1980s when the magnitude of coastal wetland loss in Louisiana became apparent, the State of Louisiana looked to the District as a partner in the effort to thwart this catastrophic land loss. The state saw the dredged material from the District's maintenance dredging program as a valuable resource to be used to create and restore coastal wetland habitats. Approximately 7000 acres of wetlands have been created and/or restored through the beneficial use of dredged material since 1985.

The State contends that a significant portion of Louisiana's coastal wetlands could be restored annually if all of the dredged material from the District's maintenance dredging program were used in a beneficial manner. However, in addition to the Corps of Engineers' policy relative to a "Federal Standard", a number of other factors limit the amount of coastal wetlands restoration that can be accomplished using dredged material from maintenance of Federal navigational channels. Among these factors are: 1) logistics; 2) chemical and physical characteristics of the dredged material; 3) channel dynamics; and 4) lands, easements, rights-of-way, relocations and disposal areas. Changes in the Corps' policy would not remove all limitations imposed by these factors; therefore, beneficial uses of dredged material from the District's maintenance dredging program will remain only part of the solution to restoration of Louisiana's coastal wetlands.

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REVIEW OF COMPARATIVE RISK ASSESSMENT METHODS AND THEIR APPLICABILITY TO DREDGED MATERIAL MANAGEMENT DECISIONS

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The purpose of this paper is to review the status of comparative risk assessment within the context of environmental decision-making, to evaluate its potential application as a decision-making framework for selecting alternative technologies for dredged material management, and to make recommendations for implementing such a framework. We provide the various definitions of comparative risk assessment, review the relevant literature concerning its application, or more often, suggested application, in policy development, regulatory prioritization, technology selection, and chemical hazard comparisons. We summarize the various methods and critiques of comparative risk assessment, and suggest its potential application in helping to select among various technology options for dredged material management.

This review demonstrates that comparative risk assessment has not found a successful universally applied methodology or approach. Rather, the literature largely offers comparisons of specific chemicals based on current risk assessment approaches, descriptions of specific applications that are variations on an EPA theme for setting policy agendas, or critiques of methodology with the hope that it may find an application.

One of the most important points from this review for the United States Army Corps of Engineers (USACE) is that comparative risk assessment, however conducted, is an inherently subjective, value-laden process. There is some objection to this lack of total scientific objectivity (referred to as the "hard version" of comparative risk assessment). However, the "hard versions" provide little help in suggesting a method that surmounts the psychology of choice in any decision making scheme. The application of comparative risk assessment in the decision making process at dredged material management facilities will have to an element of value and professional judgement in the process.

The literature suggests that the best way to incorporate this subjectivity and still maintain a defensible comparative framework is to develop a method that carefully selects the basis for comparisons and is inclusive of various perspectives. The method must be logically consistent and allow for uncertainty by comparing risks on the basis of more than one set of criteria, more than one set of categories, and more than one set of experts. It should incorporate a probabilistic approach where necessary and possible, based on management goals. The general opinion is that iteration within the comparative risk framework lends some sense of the range of outcomes to an inherently subjective analysis.

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