ERDC TN-DOER-D10
July 2010

Sustainable Confined Disposal Facilities for Long-term Management of Dredged Material

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PURPOSE: Dredged material confined disposal facilities (CDFs) represent a major capital and operating investment for the U.S. Army Corps of Engineers (USACE). As such, they need to be managed in a manner that maximizes the useful life of the facilities, as well as economic, material, and manpower resources. In some areas of the United States, confined disposal capacity for dredged material is finite and dwindling. Limited CDF storage capacity is expected to present major challenges to the Corps' navigation dredging mission in the future. A strategy for prolonging the life of US disposal facilities is critical to preserving the continued ability to dredge and maintain our nation's navigation.

BACKGROUND: As stated in 33CFR 336.1, "The maintenance of a reliable Federal navigation system is essential to the economic well-being and national defense of the country." The primary activity for maintaining the navigation system is dredging to restore navigation depths after shoaling or sediment accumulation occurs. Material dredged from the navigation system must be relocated and used beneficially or placed in a disposal or containment area. The least costly, environmentally acceptable, dredged material disposal alternative that is consistent with sound engineering practices is designated as the Federal standard (33CFR335.7). Three management alternatives for dredged material currently exist: open-water disposal, confined (diked) disposal, and beneficial use (U.S. Environmental Protection Agency (USEPA)/USACE 2004). While open-water disposal is often the preferred alternative on the basis of least cost, it is often not environmentally acceptable to all stakeholders. Beneficial or productive use of the dredged material, such as for habitat creation or restoration, or for beach nourishment, offers environmental advantages by conserving a resource. However, technical, environmental, and economic issues currently limit the volume of dredged material that can be used beneficially. Placement in a confined disposal facility is often the only alternative that is both environmentally and economically acceptable. Furthermore, confined disposal is a necessary component of many beneficial use schemes being implemented or envisioned.

What is a CDF? CDFs are engineered structures (diked impoundments) designed to provide containment for dredged sediments and associated contaminants, as well as control of any water produced on the site (from dredging operations or from precipitation). They may be constructed on land (upland CDFs), adjacent to the shoreline (nearshore CDFs), and in the water (island CDFs). Water discharged from CDFs must meet applicable suspended solids and contaminant criteria standards within a specified mixing zone, and CDFs are designed to accomplish this rudimentary "treatment." CDFs vary in size from a few acres to 2500 acres (e.g., Craney Island CDF). As dictated by project constraints and sediment contaminant levels, the size and design of CDFs may range from simple earthen structures with passive weir systems, to sophisticated disposal facilities with liners, leachate collection systems, and other engineered controls designed to prevent contaminant migration from the site (Palermo and Averett 2000). Since the 1960's, USACE has used CDFs to contain dredged material considered unsuitable for open-water disposal. In the absence of other economical disposal alternatives, CDFs are often used to contain relatively uncontaminated materials as well.

What is meant by sustainability? Sustainability is more than just the latest catch phrase; it represents long-term thinking, big-picture planning, and conservation of resources. USACE environmental operating principles (EOP#1) (USACE 2003) encourage the Corps to "strive to achieve environmental sustainability." Sustainability, as defined by the Brundtland Commission (United Nations 1987), is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." These are, however, conceptual definitions. What practical measures can be used to define sustainability as it applies to CDFs? On a most basic level, "what goes in must come out" (Figure 1). If this could be achieved, CDFs could be infinitely sustainable. However, this appears to be an unreachable target, given that some contaminated sediments require either treatment (which is typically economically infeasible) or permanent containment.

Thus, even if the outgoing material is maximized, and the incoming material is minimized, the life of a CDF is ultimately finite. One cannot simply replace or expand facilities as needed due to factors that are economic, environmental, and social in origin. One can and should, however, improve management practices such that the usable life of all facilities is maximized to the extent practically and economically possible. The goal of sustainability as it applies to CDFs is to manage dredged material disposal in such a manner that: 1) disposal capacity is optimized, 2) dredging operations are not limited by disposal capacity; 3) operations are economically feasible now as well as in the future; and 4) adverse environmental impacts are minimized and benefits maximized.

Why not just replace or expand these facilities as needed?

- Design, permitting and construction of new facilities is costly;
- Suitably located sites are becoming difficult to obtain due to competitive uses and waterfront land value;
- Environmental impacts, particularly in near-shore (wetland) areas, may not be resolvable;
- Local opposition to CDFs can be significant, and
- Availability of adjacent lands may limit lateral expansion and foundation stability may limit vertical expansion.

APPROACH: This document takes a rather broad look at dredging and disposal and the factors relevant to the use and sustainability of CDFs. The objectives of this work effort are to:

- Evaluate the scope and extent of future CDF availability.
- Identify existing tools and resources available to achieve sustainability of CDFs.
- Identify policy, statutory, and regulatory changes necessary to achieve sustainability.
- Identify research gaps that should be addressed to advance the practice of sustainable CDF management and ultimately, dredging sustainability.

As demonstrated by Figure 1, the factors affecting CDF capacity can be conceptualized in simple terms. Ultimately, capacity is a function of:

- CDF size.
- Space occupied by existing material in the CDF (as a function of consolidation behavior and rates).
- Material added annually.
- Material removed.

These factors lead to a basic approach to sustaining capacity, which includes three main categories:

1. Minimize the dredging volume placed into the CDF.
2. Manage the CDF itself to maximize capacity.
3. Maximize recovery/removal of material.

Various tools to conserve CDF capacity are described within these approaches. While the document discusses the big picture of dredging and CDFs, the focus of the recommendations for sustainability is narrowed to that which can practically be implemented by the Corps at CDFs.

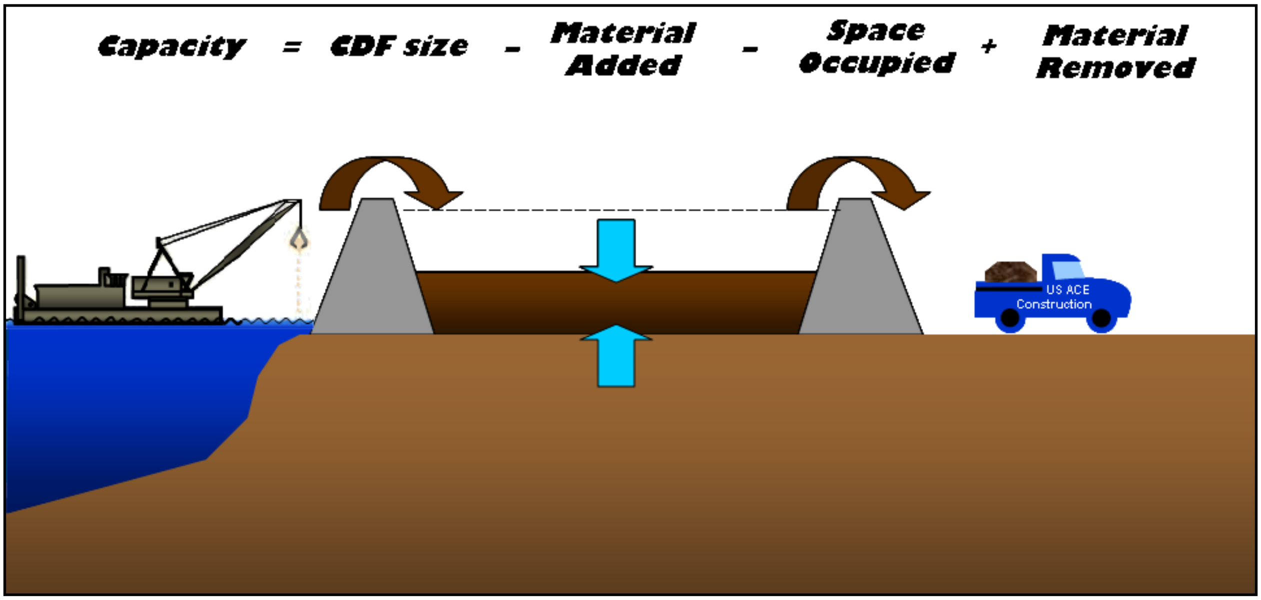

Figure 1. Conceptual approach to CDF sustainability.

INVENTORY AND SURVEY: A three-pronged effort was conducted to obtain comprehensive information for all Corps districts regarding the amount of material that is being dredged annually, dredging and disposal trends, character of material being dredged, available disposal capacity, and projected life of existing disposal areas. A dredged material management survey was developed and distributed to all Corps districts. The purpose of the scoping-level inventory and survey was to determine if CDF capacity was a problem and, if so, how critical and widespread. The survey was also designed to identify trends and practices that may provide insight into how to handle the problem. The eight questions asked of each district and the responses by USACE division are shown in Table 1. Available Dredged Material Management Plans (DMMPs) for each district, project records, and other reports and publications provided by district personnel were reviewed to obtain information regarding available disposal alternatives and projected lives of their CDFs. Lastly, dredged material volumes were obtained from the national dredging database maintained by the Institute of Water Resources (IWR). This information is used in this technical note to determine sustainability issues and consider technical areas that may benefit from additional research and development.

The IWR (USACE 2008a) maintains records for annual dredged material volumes based on Corps of Engineers contracts. Figure 2 illustrates the trend in total volume dredged and placement or disposal options on a national basis. Total dredged material volume generally declined over the period 2002-2007, and the volume of material employing strictly confined placement accounted for 5 to 10 percent of the total with an average of about 8 percent. Some projects reported upland, mixed, or undefined placement, which may have included additional confined placement. The data in Figure 2 indicate that although the largest fraction of the total dredged material volume continues to be disposed in open water, the open-water fraction is declining. For the 5-year period in Figure 2, open-water disposal options account for 41 to 53 percent; whereas upland and beneficial use alternatives account for 47 to 59 percent. Fifteen of 24 districts included in the survey indicated that CDFs were used mostly for disposal in their districts. Of 20 survey responses, 17 projected shortages of CDF capacity within the next 20 years, with some facing even more critical shortages. The U.S. Army Engineer District, Detroit, (2008) reports that of 23 active CDFs on the Great Lakes, five have less than 5 years capacity remaining, and six have only 5-10 years capacity remaining.

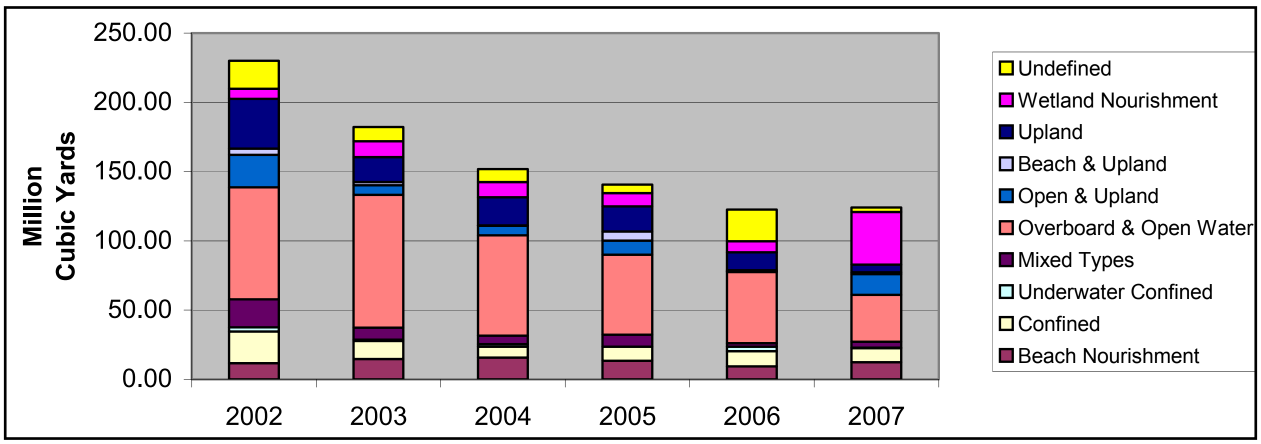

Figure 2. Corps of Engineers annual dredged material placement (IWR 2008).

The Detroit District also reported increased proportions of dredged material going to confined disposal and beach nourishment over time, with no material going to open-water disposal from 2001 forward. Certainly this trend would more rapidly exhaust existing upland disposal capacity. Further, the Detroit District reports critical capacity issues emerging at Milwaukee (mean 360K yd^3/dredging cycle) and Green Bay (mean 360K yd^3/dredging cycle) in Wisconsin and Duluth-Superior Harbor, MN and WI. Cleveland (mean 290K yd^3/dredging cycle) and Lorain Harbors (Buffalo District) were projected to be completely out of capacity by 2008 if fill management plans were not funded. Clearly, diminishing disposal is a critical issue in the Great Lakes Districts and must be addressed.

The volume of sediment dredged in the Great Lakes represents a small proportion of the material dredged annually in the United States, which raises the question, "Is disposal capacity a national problem?" The following were taken from responses to the district survey. Charleston District reports capacity issues in a few areas along the Atlantic Intracoastal Waterway (AIWW) as well as in Middle Winyah Bay (Georgetown Harbor). All CDF capacity for Georgetown will be exhausted at the end of the current maintenance cycle this summer. The New Orleans District reports a severe shortage in capacity for the CDFs along the Calcasieu River. Portland District reports experiencing a shortage of effective upland site capacity and it is anticipated that this shortage will become critical within the next five years. San Francisco District reports the storage issue has become extremely critical for two coastal projects that have dangerous entrance channels. The Galveston District is experiencing some shortage of capacity, which is being addressed by pumping longer distances to the nearest available CDFs, as is Sacramento in some areas. A recent study of New Jersey CDFs (HDR/LMS, Inc. 2007) reported,

> *"Currently, many of the CDFs that were used historically are at or near capacity, and this is the limiting factor for completing dredging projects along many of New Jersey's waterways. The construction of new CDFs is unlikely due to elevated shoreline property values, and environmental regulations restricting construction in wetlands and open waters."*

While the scope and urgency of disposal capacity varies between districts and projects, it does appear to have a national complexion.

Many site-specific issues were reported that limit construction of new CDFs as well as the use of available CDFs. The major issues reported in the survey are summarized in Figure 3, with siting, capacity, and funding emerging as the top three. Conflicts over site use arise when unique habitats have developed on existing sites, or when the sites were designed to transition to another use when filled (i.e., the sites were not intended to be sustainable). The high value of waterfront property may dictate some type of development as the highest and best use of the site, and may also create difficulty in locating sites for new CDFs. Other issues cited as limiting use, expansion, or construction include the following:

- Site designated as habitat following a specified period of disuse.
- Differences in salinity between the dredging site and the disposal site.
- Prohibitive cost to remove clean sediments from CDFs.
- No demand for sediments for beneficial use.
- Environmental legislation protecting marsh areas.
- Wildlife management issues.
- Obtaining regulatory and stakeholder concurrence for construction.
- Planning Guidance Letter (PGL)-47 (USACE 1998) requirements to cost-share diking.
- Lack of steady funding.
- Pressure to release easements on lands with potential for future construction.

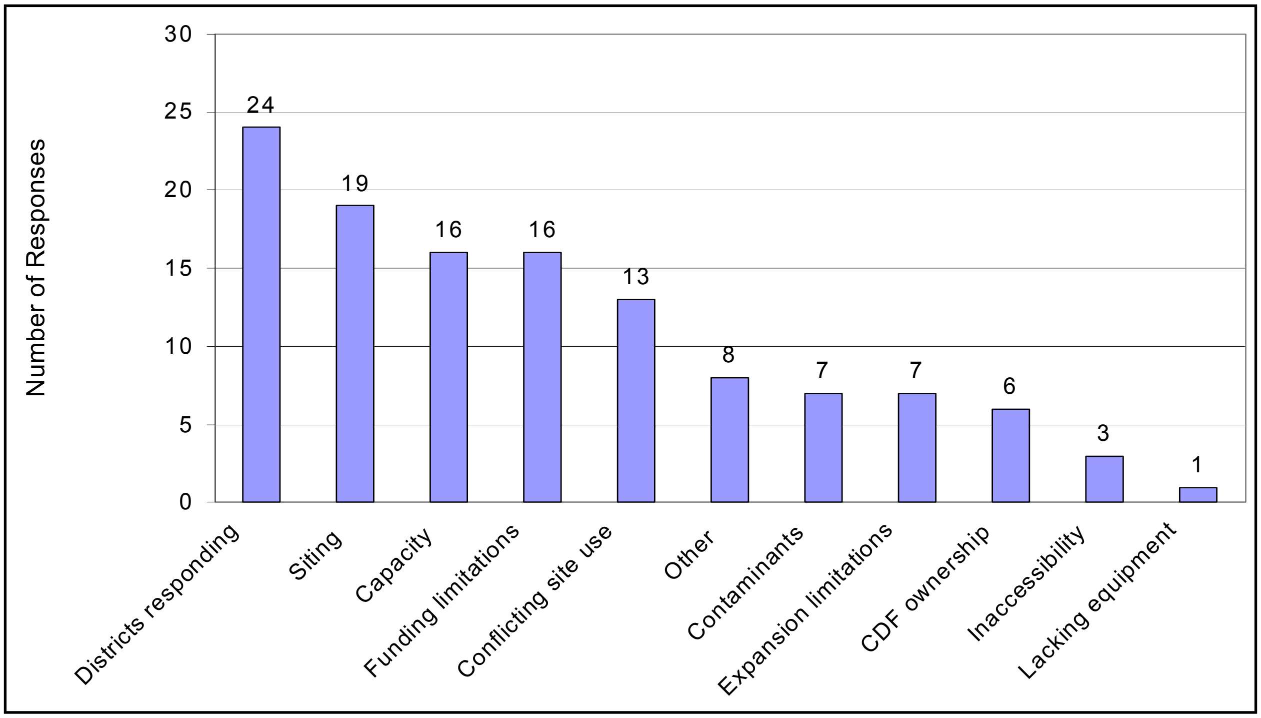

Figure 3. Issues limiting effective use of CDFs (survey responses).

Overall, the scoping effort identified some of the current trends and issues faced by the districts and showed a need to implement some strategy toward sustaining disposal capacity.

MINIMIZATION: As shown in the major approaches to sustainability, one obvious way to extend the life of CDFs is to reduce the volume of dredged material placed in them. The major approaches to reducing dredging volumes designated for CDF disposal are:

- Minimizing the volume of material that requires dredging.
- Optimizing the dredging process.
- Alternative placement of dredged material.

Basically, this means dredge less, dredge more efficiently, and place material somewhere other than CDFs when possible. Table 1 summarizes strategies and technologies to be considered in minimizing the volume of material going to a CDF.

Minimization Guidance. The concepts for minimizing the volume of dredged material bound for CDFs should be considered during the planning phase. During the development of a DMMP, a “triage” for dredged material placement should be applied. Long-term cost analysis should be employed to evaluate the use of various minimization and dredging techniques and placement options. Essentially each planning phase should begin with an in-depth look at the most modern tools and techniques available, their long-term impacts on capacity and economics, and benefits to be derived from the application of Regional Sediment Management (RSM) principles.

Table 1
Minimization of Dredged Material Placed in a CDF

Strategy	Approach	Methods/Technologies
Minimize volume of material that requires dredging		
Erosion control	Reduce sediment transport from watershed to waterway	Best management practices for land use as promoted by the U.S. Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS)
Reduce shoaling in navigation channel	Keep sediment moving through area	Flow training structures (subarea dikes, submerged sills)
		Flow augmentation (channel training/ realignment, channel diversion, scour/propeller jets)
		Facility relocation
	Keep sediment from entering area	Permanent barriers (dikes, sills)
		Harbor entrance modification (eddy reduction, gates, curtains, pneumatic barriers)
		Sediment basins or traps
State of the art dredging processes		
Optimize dredging	Evaluate benefit of advanced maintenance dredging	Hydrodynamic modeling to assess benefits, adjust cuts, and optimize dredging time intervals
	Dredge more efficiently	Silent inspector, acoustic monitoring, etc.
		Evaluate impacts of over-depth dredging[1]
		Contract performance specifications
	Minimize unnecessary dredging of fluid-mud in channel	Establish nautical bottom
Re-locate sediment in waterway	Fluidize sediment	Water injection dredging
		Silt wing excavator
Place dredged material in alternative (optimal) locations		
Alternative placement	Use CDFs only when other alternatives are not available	Open-water placement
		Nearshore/beach placement
		Beneficial uses
	Redo DMMP using replacement cost economics	Utilize multiple disposal alternatives for the same project
Regional sediment management (RSM)	Restore natural sediment sources, sinks, and pathways that have been altered by engineering actions or anthropogenic activities	Holistic approach to sediment management with many partners and stakeholders
		Use dredged sediments within the regional watershed system to restore/enhance natural conditions (beneficial use)

[1] There is disagreement among experts on the net long-term effect of this practice, and whether an actual reduction of total dredging volume is achieved, or simply a deferral of dredging volume

CDF MANAGEMENT: The goal of sustainability can be accomplished in part by optimal design and management of CDFs. Good CDF management practices will increase the longevity of the CDF (pseudo-sustainability). However, as long as some sediment requires permanent disposal due to contamination, no simple management strategy will sustain CDFs indefinitely. In practice, at least until treatment becomes a technically and economically viable option, the useful life attainable will be a function of the fraction of incoming dredged material that lends itself to beneficial use. For many projects, there are some materials that will require permanent disposal somewhere, if not in a CDF, then in a permitted landfill. At this writing, the best available management practice is to remove from the CDF as much material as possible, after necessary dewatering and classification, and utilize these materials beneficially.

Maximizing CDF Capacity. Developing new CDF capacity is not considered a sustainable practice, economically or logistically. Coastal property suitable for development is in scarce supply with high competing demand for residential, industrial and commercial uses, which makes it largely unaffordable for dredged material confinement. This, and stakeholder concerns regarding aesthetics and contaminants, make siting new CDFs very difficult. Sustaining capacity therefore must be focused on "using what you've got" in the most efficient manner possible.

CDFs are typically constructed with engineered earthen dikes, and expanding facility capacity by raising the dikes is quite common. However, logistical, structural, and economic considerations must be taken into account in order to maximize the achievable benefit. Logistically, the existing and proposed geometry of the site and the dike will influence feasibility of expansion. The higher the dike, the more area the dike itself consumes, so there may be a point of diminishing return. The use of permanently stored and dewatered dredged material for dike construction can increase the life of a CDF, but this material is not always suitable. For all types of facilities, dike heights and geometric configuration are ultimately dictated by containment capacity requirements, availability and engineering properties of construction materials, site restrictions (proximity of structures), and wave and foundation conditions. Given their proximity to the shoreline, many CDFs are constructed on poor foundation soils that limit the maximum constructible dike height and potential for CDF expansion. Construction methods have been developed to address this concern, and some may be feasible given sufficient area and manageable cost. When the foundation soils are very soft, various geometric sections may be used to provide stability (USACE 1987), such as a floating section, with very flat slopes, and often a berm. Other options include preloading or staged construction, lightweight fill material, foundation displacement, excavation and replacement, geosynthetic reinforcement (Fowler 1989), sand-filled geosynthetic containers, sheet pile cofferdams and vertical sheet pile retaining wall structures and soil-cement mixing.

Managing to Minimize In-CDF Volume. When sediments are removed from the water body, the volume increases due to entrainment of water during the dredging process. The volume initially disposed in the CDF is therefore much larger than the in situ volume. The degree of bulking varies with dredging method. A bulking factor of 1.1 is typical for mechanical dredging, and 1.5 is typical of hydraulic dredging after initial compression settling and dewatering have occurred. Over time, the material will consolidate. Mechanically dredged material will consolidate relatively rapidly after disposal, to about 90 percent of in situ volume. Hydraulically dredged material takes longer due to the higher initial water content.

Engineering methods to enhance dewatering will both reduce the period required for dewatering and increase the consolidation of the material, thus reducing the volume occupied. A variety of dewatering enhancements exist and have been implemented at various locations, including wick drains, underdrains, trenching, and thin layer placement. (Trenching may be done in the foundation materials during construction, around the interior of the dike, and in the surface of materials placed in the CDF after construction.) Less common but viable dewatering methods also include geobags, phyto-dewatering, vacuum dewatering, and electro-osmosis.

While active dewatering will reduce material volume over the short term, given sufficient time, the same volume reduction may be achieved with passive dewatering and optimum weir design and management. Active dewatering will therefore make capacity available faster, but true gains in capacity will only be realized if the active dewatering results in consolidation beyond that which would occur naturally over time. Total volume reduction achievable will be a function of the compressibility of the material. Coarse-grained material may not change volume significantly with incremental reductions in water content, for example. Dewatering may be impeded in island and nearshore CDFs by surrounding water levels and infiltration into the CDF through the berms. Typically there is a permanently saturated layer of material in most CDFs, due to infiltration of rainfall coupled with the low permeability of fine-grained materials after consolidation.

The degree of CDF management varies from district to district. Of districts responding to the CDF User Survey, 16 of 24 reported that dewatering operations were performed, with methods such as weir construction and management and trenching employed. Many reported using dredged materials for berm construction. Five districts noted that physical separation was used, and nine indicated material recovery was used.

Management to Facilitate Reclamation. Most CDFs are currently designed and managed as permanent storage facilities. However, only a portion of all dredged material brought to a CDF may really require permanent disposal. In order to implement sustainable practices, the Corps could change the way CDFs are designed and managed or retrofit existing CDFs to transition them into rehandling facilities. CDFs would provide temporary storage and processing with planned removal for beneficial use. The CDF would be divided into a section for permanent storage, a section to dewater and process reusable material, and a section for stockpiling materials prior to placement in a beneficial use capacity. This approach has the most potential for capacity recovery where obstacles to beneficial use can be overcome.

In order to recover material from a CDF, not only must a viable beneficial use application be available, but the material must meet the physical and chemical requirements necessary for the intended use, and both the CDF and targeted material within the CDF must be accessible.

As high levels of contaminants are not tolerated for most beneficial uses, compartmentalization of the CDF may be necessary to segregate the clean material from the contaminated. Compartmentalization may also be used to keep different types of materials separate (e.g. coarse versus fine-grained materials), or even various processing streams resulting from rehandling of the material. If material does not naturally meet beneficial use requirements, management or processing options are available that may be used to create a useful product.

Physical separation can be achieved passively during disposal, or mechanically, either during or following disposal. Neither option is a 100-percent efficient process, and the efficiency of separation required to meet grain size distribution specifications for beneficial use will impact the method used.

Passive separation can be achieved by considering the settling properties of the sediment and subdividing the interior of the CDF into cells with aspect ratios optimized to attain the desired separation, or by incorporating a sluice at the inlet of the CDF to wash the fines from the coarse material. Coarse-grained material separated in this manner will dewater rapidly and can be excavated and stockpiled for reuse, assuming the material is relatively uncontaminated. The energy of the incoming slurry may be capitalized upon by separating materials at the time of disposal, minimizing future rehandling. Mechanically dredged materials will require re-slurrying for fluidized separation methods, though simple screening may be feasible once the material has dried. For mechanical separation processes requiring a fluidized material, re-slurrying may give greater control of slurry solids and process flow rate, important to these types of processes.

CDFs where active material recovery is taking place, such as the Bayport facility in Green Bay, WI, were designed with multiple cells allowing gross separation of material from different dredging projects. Rotation of disposal through the cells provides inactive periods in each cell, which facilitates passive dewatering (and would also facilitate trenching and other active dewatering methods). The CDF is not subdivided at the Duluth CDF, but passive separation is achieved with a rudimentary sluicing process during disposal.

Mechanical separation typically involves a series of screening steps to remove large debris (grizzly) and trash (scalping screen), followed by separation of sand and fines. Screening may be done on dry or slurried material, though dry screening may be difficult and separation relatively inefficient due to agglomeration of fine materials. Sand can also be separated from fines using a hydroseparator or a hydrocyclone, both of which exploit differences in size and density of the particles. In some operations, combinations of these pieces of equipment are used to improve the efficiency of the separation. Processing constraints should be evaluated on a site-specific basis in order to determine the best approach for a specific material and location. A hydroseparator, such as a sand screw with sump, is potentially a high capacity, low-tech separation method that could be economically employed during disposal of hydraulically dredged sediments. Hydrocyclones are simple devices as well, but may be more subject to wear in processing granular materials and require pumps between the dredge and the cyclone to control throughput. These factors may make them more expensive, and more technically challenging to operate than a hydroseparator. A number of references discuss basic soil separation concepts and equipment, relative advantages and disadvantages, as well as assessment of volume reduction potential (Olin-Estes et al. 1999, 2001, 2002a, 2002b). However, efficiency of these processes in dredged material separation has not been well documented.

Mechanical separation is generally used only in conjunction with environmental dredging projects where the sediments must be mechanically dewatered, and separation is a necessary pretreatment. Although there has been recent interest in separation as a means for recovering CDF capacity, the cost generally discourages its use. Unless the cost to replace the CDF capacity is factored into the cost benefit analysis (which may not be the case since the CDF represents a sunk (past) cost), mechanical separation is unlikely to ever represent the least-cost alternative (Olin-Estes et al. 2002b). Also, in many cases, recovery of the sand fraction, which is the most straightforward process, typically addresses only a small portion of the total volume of dredged material in many cases. Further, staging areas may be needed for processing of the material and temporary storage and rehandling of debris for off-site disposal. A blending facility of some type may be needed to amend the material to improve its properties or facilitate biodegradation of contaminants, and an area for composting may also be desirable. Thus, separation processes themselves compete for area with the CDF.

Other processes include desalination, a relatively new concept in dredged material management. Feasibility of effectively reducing salinity passively is currently being researched (Bailey et al., in preparation). Passive flushing of the material would require a multiple cell configuration and, perhaps, underdrain systems. Alternatively, dewatering equipment such as filter presses may be incorporated to facilitate desalination (Olin-Estes et al. 2002b).

BENEFICIAL USE: Removal of dredged material from CDFs for beneficial use probably has potential for the greatest impact on sustaining CDF capacity. Given the historic use of CDFs to contain any material for which open-water disposal was not an option, CDFs potentially contain a great deal of material having intrinsic value for beneficial use. By recovering capacity in conjunction with achieving economic or environmental benefit, beneficial use embodies the Corps environmental operating principles of synergistic solutions. However, despite the availability of material and the attractiveness of the concept, there are a number of obstacles and limitations to overcome for beneficial use to become standard operating practice. Limitations, as well as positive trends toward beneficial use, reported in the initial survey of Corps districts are summarized in Table 2. Because beneficial use of dredged material offers the greatest potential to conserve or reclaim CDF capacity, a second survey of district experiences was conducted in 2008. The districts were asked to estimate dredged material quantities in CDFs that were available and accessible for beneficial use and to comment on volumes suitable for various uses. Five districts responded, indicating in three of the five cases that available volumes ranged from 100,000 to 200,000,000 yd^3. Qualitative information received from these districts is summarized in Table 3.

A number of recent publications focus on challenges and opportunities for beneficial use. USEPA/USACE (2007a) “Identifying, Planning, and Financing Beneficial Use Projects Using Dredged Material: Beneficial Use Planning Manual” discusses the following categories of beneficial uses:

1. ***Habitat Restoration and Development:*** Using dredged material to build and restore wildlife habitat, especially wetlands or other water-based habitat (e.g., nesting islands and offshore reefs).

2. ***Beach Nourishment:*** Using dredged material (primarily sandy material) to restore beaches subject to erosion.

3. ***Parks and Recreation:*** Using dredged material as the foundation for parks and recreational facilities; for example, waterside parks providing such amenities as swimming, picnicking, camping, and/or boating.

Table 2
District Survey Responses on Beneficial Use

Progress
• Ten districts reported that dredged material is currently being used beneficially • Twelve additional districts reported dredged material being used beneficially on a limited basis • Some state agencies gaining interest in reuse, e.g., California and Ohio • Beneficial use becoming a priority for long-term management strategy in Sacramento District • Mobile District has full-time project manager dedicated to finding beneficial use for dredged material • Seattle District encourages beneficial use, tests dredged material for beneficial uses, and supports an inter-agency forum seeking beneficial use opportunities • New York District investigating feasibility of public processing facility in a centralized location where dredged material could be brought, processed, and distributed • Commercial and interagency partnerships evolving in a number of districts
Obstacles
• Seventeen districts identified cost as an obstacle to beneficial use of dredged material • Seventeen districts reported inadequate markets for dredged material or dredged material products • Eight districts reported excessive time and effort required to wade through the regulations and deviate from current procedures • Cost-sharing issues • Inability to meet State standards • Difficulty in accessing and transporting the dredged material • Uncertainty in sampling and characterizing the dredged material (physical, chemical, risks, etc.) due to wide variations in physical and chemical characteristics • Perception of public that dredged material is associated with sludge or other waste material and that it carries environmental or public health risk • Limited beneficial uses for fine-grained silts and clays (which have greater contamination potential) • Inconsistent criteria and regulation for evaluating exposure pathways and risk of beneficially using dredged material • Cost analysis of projects often based on short-term rather than life cycle cost—CDF replacement costs often not considered • Section 204 (WRDA 1992[1]) funding limited and cumbersome to work through • Economic analysis of beneficial uses not well defined making comparison to disposal alternatives difficult • Landowner issues • Limited markets for dredged material due to availability of competing materials • Corps of Engineers not doing enough to engage community and sell beneficial use of dredged material as a resource • Material cannot be given away without first advertising to determine “no value”
[1] Water Resources Development Act 1992, Public Law 102–580, 106 Stat. 4797, 33 U.S.C. 2201 *et seq*.

4. ***Agriculture, Forestry, Horticulture, and Aquaculture:*** Using dredged material to replace eroded topsoil, elevate the soil surface, or improve the physical and chemical characteristics of soils.

5. ***Strip-Mine Reclamation and Solid Waste Management:*** Using dredged material to reclaim strip mines, to cap solid waste landfills, or to protect landfills.

6. ***Construction/Industrial Development:*** Using dredged material to support commercial or industrial activities (including brownfields redevelopment), primarily near waterways; for example, expanding or raising the height of the land base, or providing bank stabilization. In addition, dredged material may be used as construction material.

Table 3 **Qualitative Comments from 2008 Survey of Potentially Recoverably Dredged Material in Corps Districts**
• Additional material testing is needed to ascertain characteristics acceptable for beneficial use • State regulators issue strict requirements on material quality for reused material • Acceptable dredged material for beneficial use not all in one location in CDF(s) • Beach quality sand a priority beneficial use • Urban areas have great potential for beneficial use • Brownfield reclamation promising as a beneficial use • Topsoil and fertilizer potentially promising beneficial uses • Accessibility of dredged material suitable for beneficial use varies site to site • Fine-grained materials offer greater challenge for beneficial use • Simpler and more expeditious policies and procedures allowing for cost sharing beneficial uses needed (guidelines for pre-approval of beneficial use projects suggested) • Sediments becoming cleaner, offering opportunities for open-water disposal

7. ***Multiple-Purpose Activities:*** Using dredged material to meet a series of needs simultaneously, such as habitat development, recreation, and beach nourishment, which might all be supported by a single beneficial use project.

A companion to the Planning Manual is USEPA/USACE (2007b), which explains the role of the Federal Standard in implementing beneficial uses of dredged material from navigation projects. Brandon and Price (2007) compiled current guidance and best practices for evaluating dredged material for beneficial uses. The Great Lakes Beneficial Use Task Force (Great Lakes Commission 2001) offers findings and recommendations regarding beneficial use of dredged material which encourages reuse and recycling of dredged material as an alternative to CDF or open-water disposal.

COST AND FUNDING LIMITATIONS: Cost is ultimately the deciding factor between alternatives that are otherwise environmentally acceptable and technically feasible for federal dredging projects. A number of issues were identified in the district survey pertaining to the ways in which cost, cost sharing, and funding mechanisms impact their ability to implement sustainable dredging and disposal practices. The major issues are summarized below.

Shortage of Funding/ Inconsistent Funding. Shortage of consistent funding was cited by several districts as limiting maintenance operations such as ditching and dewatering at CDFs, as well as CDF construction and expansion. Long-term programming is reportedly difficult due to "back and forth" changes in the source of CDF construction funds (construction general vs. operation and maintenance). Other issues reported include administrative refusal to fund diking in the absence of an approved DMMP, and Policy Guidance Letter (PGL)-47 (USACE 1998) requirements to share diking costs. Sponsors are frustrated when they fund their portion of a multi-year coordinated plan and the Corps provides only a fraction of what was budgeted.

Authorities for Additional Cost. Most beneficial use carries with it some additional cost over that of CDF disposal, particularly if the cost of replacing the storage used is not factored into the analysis (customary practice was not verified, but the understanding is that sunk costs are not considered in a federal cost/benefit analysis). Whether a real or a perceived limitation, the Federal Standard is often cited as an obstacle to consideration of value-engineered alternatives.

More than one district indicated that for beneficial reuse to be the preferred plan in a DMMP, it would have to be the least-cost alternative. Cost sharing may have an impact in least-cost alternative determinations.

Cost Sharing/Funding for Beneficial Use. The complexity of cost sharing programs such as Section 204, WRDA 1992, was also cited as problematic. The Section 204 program is reportedly under-funded and it can take over five years to work through the process. Most potential users have more immediate needs. In other cases, the limitation is that the sponsors do not have the cost-sharing ability required. Reportedly “there is very little funding in the General Investigation (GI) program, Continuing Authorities Program (CAP) or RSM Demonstration program to support beneficial use applications,” so there would appear to be funding issues on both sides. Several districts report having RSM teams in place but being unable to implement their program due to lack of funding in the RSM program. Other districts report that the dredging program is marginally funded and they are unable to divert funds to RSM (this may be a greater issue for smaller districts). Lack of local funding to employ sediment control measures where needed was also cited.

Transportation Cost. The remote location of some CDFs makes transporting material from the site for beneficial use cost-prohibitive. Some districts cited this as one of the principal obstacles to reuse in their district. Rehandling and, in some cases, treatment are also required, the cost of which was also cited as an obstacle to beneficial use.

Value Engineering. Despite the focus on cost minimization, customary methods of cost estimating for federal projects sometimes neglect sunk costs, such as the construction cost of an existing CDF. Off-site disposal alternatives, including beneficial use alternatives, are therefore typically at a disadvantage in the comparison to on-site disposal (at existing facilities). The fallacy with this approach is that it does not consider the future replacement cost of the disposal facility and therefore represents a false, short-term economy. In the interest of sustainability, alternatives must be compared on an equivalent footing, taking into account true life-cycle costs. This should be addressed during periodic revisions to existing DMMPs and during development of DMMPs for new projects, each of which will be governed by different recommended planning periods (50 years for economic justification of new construction and 20 years for existing projects).

Cost-saving Opportunities. Potential opportunities to minimize costs associated with disposal of dredged material at CDFs take advantage of economies of scale and impacts of deferred costs. Unit cost of storage can be reduced through construction of larger facilities, and present value comparisons will usually be more favorable for facilities with replacement costs pushed out further into the future. These savings may be offset, however, by increased costs to pump greater distances (more booster pumps and pipelines) and longer cycle times.

POLICY AND AUTHORIZATIONS: Issues related to CDF capacity and siting have long been recognized. The WRDA 76 act directed the Corps to use management practices to extend the life of disposal areas, minimizing the need for new sites. Under 33CFR337.9, District Commanders (DC) are required to explore management techniques. WRDA requirements have gradually made local sponsors responsible for a greater share of the cost for navigation projects. (WRDA 96 increased non-Federal cost share from 25 to 35 percent for new flood control projects.) However, many projects were scaled back as a result of the cost-sharing component and inability of local sponsors to share costs. Further, in shifting greater responsibility to the local sponsors, the Federal government also relinquished some control over the management and disposition of dredged material and dredged material disposal sites. One of the issues brought out in the district survey was that of motivating sponsors to extend disposal facility life. In a number of cases, existing disposal sites were lost to development, or donated to nature groups.

The Water Resources and Development Act of 2007 (WRDA 2007), Section 2005 amends Section 217 of WRDA 1996 regarding dredged material management. Important facets of this bill relating to CDF sustainability and beneficial use are as follows (USACE 2008b):

- Broadened definition of dredged material management measures--extends Federal participation in dredged material management facilities beyond disposal facilities and can include processing, treatment, and contaminant reduction.
- Non-Federal interests can perform acquisition, design, construct, manage, or operate a cost-shared dredged material processing, treatment, contaminant reduction, or disposal facility.
- Dredged material processing, treatment, contamination reduction, or disposal facilities may manage dredged material from multiple Federal projects in the region with combined cost-sharing among the multiple projects.
- The Corps of Engineers can pay the Federal share of dredged material disposal or placement capacity for Federal projects at dredged material processing, treatment, contaminant reduction, or disposal facilities.
- A non-Federal cost-sharing sponsor may receive credit for funds provided for dredged material processing, treatment, contaminant reduction, or disposal facilities.
- The Act does not change the Federal Standard to dredge in the most cost-effective way consistent with economic, engineering, and environmental criteria.
- If a dredged material processing, treatment, contaminant reduction, or disposal facility is not the Federal Standard, but beneficially uses dredged material for structural or non-structural flood control, hurricane and storm damage reduction, or environmental protection and restoration, it can be considered for Federal participation under the beneficial use authorities of Section 204 of the WRDA 92, as amended by Section 207 of WRDA 97 and Section 2037 of WRDA 2007.

Several of these points do not represent a change in policy, but serve to clarify legislative policy already in place.

STRATEGY: Results of the CDF User Survey demonstrate that dredged material management and CDF practices vary among Corps offices. Some of these differences may be attributable to differences in the types of projects, sediment quality, stakeholder preferences, and logistical constraints. However, other differences may occur due to recent advances in technology, practice, or interpretation of policy that are not widely disseminated between district offices. The following recommendations are made to share knowledge and ensure utilization of available technical assistance:

- Hold a Corps-only workshop on sustainable Dredged Material Management and CDFs. Include discussions of survey results as well as:
    - Marketing needs/strategies for dredged material reuse
    - Managing and designing CDFs to facilitate beneficial use
    - Using dredged material management plans to forge the federal standard for beneficial use and regional sediment management
    - Developing a national approach to renewing capacity of existing CDFs through agreements with local interests
    - Potential research needs
    - Establishing need and availability of data for CDF life-cycle optimization analysis
    - Authorizations and policy - real versus perceived obstacles
    - Availability of technical resources – Dredging Operations Technical Support (DOTS), ERDC – DMMP and placement activity reviews

- Based on this workshop, document existing practice and methods that can be applied nationwide. Create "how to" technical notes. Post this information on a CDF User website. Refine existing research and development plans with input from district personnel.

A number of things could be done in the near term to facilitate sustainable management and support dredged material reuse.

Develop Positive Market for Dredged Sediment. Each region needs to examine the vehicles in place to highlight use of dredged sediments of all types, for regional sediment management and beneficial use. Good examples are the Great Lakes Commission web site (*http://glc.org/rsm/index.html*) where available materials in the Great Lakes region are listed, and the regional framework for the Great Lakes (Great Lakes Commission 2004). Beneficial use case studies can be found on the ERDC website at *http://el.erdc.usace.army.mil/dots/budm/budm.cfm*.

Optimization and CDF Life-Cycle Assessment. Assess impact and benefit of management practices on CDF life cycle through evaluation of field data, modeling, and bench scale testing. For a variety of sediments, assess impact on storage requirements and CDF life cycle of different rates of placement, lift depth, and active and passive dewatering practices. Correlate cost/benefit in terms of extended life and anticipated replacement cost. Compare results for different economic periods (10, 20, 50, 100 years). Develop guidance on selection of management practices with the greatest economic and life cycle benefit for site-specific conditions.

Establish a National Beneficial Use Team. This team would function in a manner similar to the Great Lakes Beneficial Use Task Force (Great Lakes Commission 2001), charged with ensuring that the most recent advances in beneficial use, criteria, and market development are widely disseminated. The team would continue to advance the practice of beneficial use through consistent, targeted efforts to address limitations and obstacles, engaging individuals with direct experience in beneficial use.

User Fees. Corps policy states that the Corps CAN impose user fees for other users, but this is not consistently done. Establish a consistent policy of user fees based on CDF management and replacement costs.

Quantitative Assessment of Real Potential for CDF Sustainability. The central purpose of this document was to develop a strategy for sustainable management of CDFs that could be broadly applied throughout the Corps, and to identify critical research needs that must be addressed to support sustainability. The work completed to date under this effort has been largely qualitative in nature. In order to justify allocation of significant resources to resolution of identified issues, a more quantitative assessment of the real potential for sustainability is needed.

Proposed Template for Providing a Definitive Path Forward On a District-by-District Basis
• **Step 1 – What is the Real Capacity Recovery Potential?** Assess the actual volume recovery potential accounting for the total volume in storage, volume that is accessible, the volume that could be used beneficially, and the value of the capacity determined to be recoverable. • **Step 2 – Determine Site-specific Issues.** Perform a cost benefit evaluation considering the value of recovered capacity (CDF replacement cost) and the cost to recover the material. The value of the recovered capacity would then be weighed against the cost to recover it. Once it has been determined that economic benefit can be derived by recovering capacity, focused efforts must be directed to identifying and overcoming the obstacles specific to the district and facilities involved. • **Step 3 – Forge Site-specific Solutions to Develop a Comprehensive Long-Term Plan for Sustainability. Engage the Corps, Public, State, etc. to identify issues and develop a plan for recovery of existing material.** Incorporate sustainability modifications and operational procedures into the DMMP, and design the CDF and supporting technologies to capture, manage, and market the material for the specific CDF/harbor/sediment type. • **Step 4 – Funding Recruitment, Permitting, Formal Agreements in Place.** Develop a plan for future dredged material management. Long-term commitments, including contracts and funding stream, will be needed to realize a viable project. • **Step 5 – Implementation.** • **Step 6 – Review, Evaluation, and Adaptive Management.**

RECOMMENDED RESEARCH AREAS: A number of potential research areas were identified as a result of this work effort. These are summarized in the following Statements of Need, listed in priority order.

1. **Establish Risk-Based Criteria.** Beneficial use is currently restricted by the lack of a sound, consistent, risk-based criteria and assessment protocols accepted by all State and regulatory agencies. Because beneficial use of dredged material appears to have the greatest potential for recovering and sustaining storage capacity in existing CDFs, lack of universally accepted criteria is a pivotal obstacle to sustainability. Establishment of risk-based criteria for beneficial use of dredged material was therefore identified as the number 1 research need.

The development of Federally-endorsed, risk-based criteria or methodology for criteria development, and subsequent adoption by the States, is envisioned to have multiple benefits:

- Criteria would provide an urgently needed, streamlined, uniform decision process regarding beneficial use applications.

- Scientifically defensible criteria would instill confidence among state regulators as well as the environmentally conscientious public.

- Project planners could establish in advance what uses would be acceptable for material to be dredged.

- Assurance of dredged material acceptability and reliability would
  - Facilitate the establishment of permanent markets for material.
  - Facilitate coordination between dredging and beneficial use placements, potentially eliminating intermediate steps.

- Coordination between dredging and beneficial use placements will be facilitated, potentially eliminating intermediate steps.

Potentially the most successful approach would be to develop tiered criteria for dredged material based on intended use and anticipated exposure levels. All would be similar to the Preliminary Remediation Goal (PRG) or Ecological Soil Screening Level (Eco-SSL) approaches, producing conservative screening-level criteria for several tiers, but also providing an established protocol utilizing an accepted “formula” or expert system, utilizing site-specific information that would yield adequately protective criteria without the need to resort to a full-blown risk assessment. Ideally, a set of look-up criteria could be developed for beneficial use applications where no direct exposure is expected.

2. **CDF Characterization.** Removal of DM from CDFs for beneficial use offers the best potential for sustaining existing CDF capacity, while embodying the Corps’ environmental operating principles of synergistic solutions. There is no precedent, however, for characterizing a CDF prior to excavation in order to assess material suitability for beneficial use or to estimate recoverable capacity. Moreover, field sampling, particularly coring, and chemical characterization are very expensive. A strategy for targeted sampling, compositing, and analysis is needed for these uniquely stratified materials. Uncertainty associated with material characterization must be addressed in order to ensure a high degree of confidence in the utility, environmental acceptability, and marketability of the materials recovered, and to adequately assess volume reduction potential. Optimization of the overall effort is necessary to maximize the utility of the data obtained such that these objectives are met at a minimum possible cost.

3. **Testing Protocols for Beneficial Use.** While much is known about contaminant pathways associated with confined disposal of dredged material, less work has been done documenting contaminant migration from dredged material placed in environments that may be geochemically dissimilar. Further, while bioavailability is not typically a significant concern for material disposed in a CDF because exposures are expected to be limited and infrequent, the same may not be true for material used beneficially outside the confines of a CDF. The potential availability and mobility of contaminants in upland, wetland, and aquatic environments must be assessed in dredged material testing simulating potential exposure pathways and conditions specific to each environment. Conservative, economical, and representative testing protocols similar to those available for dredged material disposal are needed.

4. **Benefits Analysis Tool for DMMP.** To maximize sustainability of dredged material disposal, the available dredged material management alternatives should be evaluated on the basis of life cycle cost, taking into account the value of existing disposal capacity and the cost to replace it. In this way, the true cost benefit of beneficial use can be measured and sustainable management decisions made. In this case, life cycle analysis requires the integration of technical expertise in multiple fields, together with traditional economic analysis. As a result, the process is not transparent. Tools are needed to assist the project manager in comparing multiple disposal and beneficial use alternatives, modeling the cost in terms of capacity depletion or recovery (sustainability), revenue (if any, including cost-sharing), and environmental benefit over time. It is envisioned that a protocol integrating these considerations into a simple software tool, such as an enhanced version of the ADDAMS D2M2 module, could be incorporated into DMMPs to optimize long-term dredging and disposal decisions.

5. **Dredged Material Processing for Reuse.** While some dredged material can readily be used in an as-dredged state, some beneficial uses will require processing to meet material specifications for a particular use. Some processing requirements may include separation to achieve either a clean fraction, or a specific grain size/gradation; blending to incorporate organic matter or other materials; dewatering to allow transport or further processing; washing or leaching to reduce the salt content to support vegetation; or even treatment to remove or stabilize contaminants. It has long been considered that processing is too expensive, but as the cost to replace lost capacity increases, processing material to gain capacity is becoming more justifiable. However, CDFs deal with large volumes of often-heterogeneous materials, frequently in locations isolated from municipal resources, and require economical and scalable processes. While recent research efforts have identified energy-intensive systems capable of relatively high treatment efficiency for management of contaminated sediments, these are probably not good candidates for treatment of typical navigation dredged material. Passive systems that are not sufficiently efficient for industrial applications, however, may be good candidates for sediment processing at CDFs where the energy of the incoming dredged material slurry, time between dredging cycles, and the expanse of the CDF can be exploited to achieve separation, desalination, and dewatering. Operating costs, efficiency, water, energy and staging area requirements need to be evaluated in order to quantify the benefits associated with sediment processing for capacity recovery.

6. **Retro-Fitting for Sustainability.** CDFs are currently designed as permanent storage facilities. However, for the value of beneficial use to be fully realized, confined disposal facilities need to transition to dredged material rehandling stations, configured for eventual removal of material from the CDF. While new CDFs could be built as state-of-the-art facilities, this may not be logistically or economically feasible in all locations. Existing facilities will need to be retrofitted to incorporate the various processes associated with rehandling and material recovery. Compartmentalization to separate materials based on contamination, material types, and processing status will be needed. Retro-fitting design will require analysis of the incoming volumes of different materials, estimation of the storage volumes required for processing or dewatering, and a logical plan for managing materials in the various compartments. Staging and processing areas will be needed, as well as areas for loading the products for removal. Operations to recover and process existing material in the CDF will be required as well as operations to accept and handle incoming dredged material.

7. **CDF Construction.** Given their proximity to the shoreline, many CDFs are constructed on low-strength foundation soils, which limit the maximum constructible dike height and potential for CDF expansion. The "foundation" must have adequate shear strength to resist the imposed dike load, or failure will occur. Guidance is needed for designing or building on foundations with shear strengths less than 200 lb/ft^2. Affordable alternatives for strengthening foundations also need to be investigated to allow expansion by raising existing dikes. Specifically, research is needed to determine the effectiveness, limitations, and cost of various alternatives for strengthening soils.

8. **Implementing Sustainability Strategies.** Some concepts for sustaining dredged material disposal capacity have been suggested. However, guidance is needed to implement these strategies. Disseminating information is key. This can best be accomplished through establishing working groups, as well as web sites where information can be shared. Case studies could be made public to share information regarding successful and innovative remedies to technical, logistical, and policy obstacles. As there appear to be significant differences in understanding regarding what can legally be done in this regard, a roadmap providing transparency to Corps policies is urgently needed. In addition, a collaborative evaluation of Corps policies needs to be initiated across all levels of the operational structure, to identify policy changes that need to be made to facilitate sustainable practices.

SUMMARY: Approaches to sustaining dredged material capacity have been presented. Some of these can be applied immediately, whereas others will require longer term modifications to Corps practices and even policy. Most reflect a multifaceted approach to achieving incremental gains in CDF life cycles, employing synergistic solutions and taking advantage of regional sediment management or beneficial use efforts. Achieving sustainability will require out-of-the-box thinking to find innovative solutions, and these will vary regionally and temporally. There is no method to creativity. "Sustainability thinking" will require staying attuned to possibilities as they present themselves and being prepared to integrate them into the dredged material management plan. Acknowledging that CDF capacity is not infinite, and that there is a need to seek out sustainable alternatives, is perhaps the most important step to achieving dredging and disposal practices that can be sustained well into the future.

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Bailey, S. E., T. J. Estes, P. R. Schroeder, T. E. Myers, J. D. Rosati, T. L. Welp, L. T. Lee, W. V. Gwin, and D. E. Averett. 2009. *Sustainable confined disposal facilities for long-term management of dredged material.* DOER Technical Notes Collection. ERDC TN-DOER-D10. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

REFERENCES:

Bailey, S. E., D. Acevedo, and P. R. Schroeder. In preparation. *Passive desalination of fine-grained dredged material in confined disposal facilities*. DOER Technical Notes Collection. Vicksburg, MS: U.S. Army Engineer Research and Development Center. *http://www.wes.army.mil/el/dots/doer.*

Brandon, D. L., and R. A. Price. 2007. *Summary of available guidance and best practices for determining the suitability of dredged material for beneficial uses*. ERDC/EL TR-07-27. Vicksburg, MS: U.S. Army Engineer Research and Development Center. *http://el.erdc.usace.army.mil/elpubs/pdf/trel07-27.pdf.*

Fowler, J. 1989. *Geotextile reinforced embankments on soft foundations*. Miscellaneous Paper GL-89-30. Vicksburg, MS: U.S. Army Engineer Waterways Experiment Station.

Great Lakes Commission. 2001. *Beneficial uses of Great Lakes dredged materials: A report of the Great Lakes beneficial use task force.* Ann Arbor, MI: Great Lakes Commission.

Great Lakes Commission. 2004. *Upland beneficial use of dredged material testing and evaluation annotated bibliography.* Ann Arbor, MI: Great Lakes Commission.

HDR/LMS, Inc. 2007. *Characterization of dredged material stored in New Jersey confined disposal facilities*. Trenton, NJ: New Jersey Department of Transportation, Office of Maritime Resources.

Olin-Estes, T. J., S. E. Bailey, M. A. Mann, C. C. Lutes, C. A. Seward, and C. F. Singer. 1999. *Physical separation (soil washing) equipment for volume reduction of contaminated soils and sediments.* EPA-905-R-99-006. Assessment and Remediation of Contaminated Sediments Program. Chicago, IL: Great Lakes National Program Office.

Olin-Estes, T. J., and M. R. Palermo. 2001. Recovery of dredged material for beneficial use: The future role of physical separation processes. *Journal of Hazardous Materials* 85(2001): 39-51.

Olin-Estes, T., S. Bailey, D. Bowman, and D. Brandon. 2002a. *Soil separation mobile treatment plant demonstration, Bayport confined disposal facility, Green Bay, Wisconsin*. Technical Report ERDC/EL-02-38. Vicksburg, MS: U.S. Army Engineer Research and Development Center. *http://el.erdc.usace.army.mil/elpubs/pdf/trel02-38.pdf.*

Olin-Estes, T. J., S. E. Bailey, S. A. Heisey, and K. D Hofseth. 2002b. *Planning level cost-benefit analysis for physical separation at confined disposal facilities.* DOER Technical Notes Collection. ERDC TN-DOER-C27. Vicksburg, MS: U.S. Army Engineer Research and Development Center. *http://www.wes.army.mil/el/dots/doer.*

Palermo, M. R., and D. E. Averett. 2000. *Confined disposal facility (CDF) containment measures: A summary of field experience.* DOER Technical Notes Collection. ERDC TN-DOER-C18. Vicksburg, MS: U.S. Army Engineer Research and Development Center. *http://el.erdc.usace.army.mil/elpubs/pdf/doerc18.pdf*.

United Nations. 1987. *Report of the World Commission on Environment and Development: Our common future (Brundtland Report).* Transmitted to the General Assembly as an Annex to document A/42/427 - Development and International Co-operation: Environment. Gro Harlem Brundtland, Chairman. New York, NY: United Nations. *http://www.un-documents.net/wced-ocf.htm*

U.S. Army Corps of Engineers (USACE). 1987. *Confined disposal of dredged material*. Engineer Manual 1110-2-5027. Washington, DC: U.S. Army Corps of Engineers. *http://www.usace.army.mil/publications/eng-manuals/em1110-2-5027*

U.S. Army Corps of Engineers (USACE). 1998. *Policy guidance letter (PGL) no. 47, cost sharing for dredged material disposal facilities and dredged material disposal facility partnerships*. CECW-O/CECW-A/CECW-P Memorandum, April 3, 1998. Washington, DC: U.S. Army Corps of Engineers. *http://www.usace.army.mil/cw/cecw-p/pgls/pgl47.pdf*

U.S. Army Corps of Engineers (USACE). 2003. *Policy for implementation and integrated application of the U.S. Army Corps of Engineers (USACE) environmental operating principles (EOP) and doctrine*. Engineer Regulation 200-1-5. Washington, DC: U.S. Army Corps of Engineers. *http://www.usace.army.mil/publications/eng-regs/er200-1-5/entire.pdf*

U.S. Environmental Protection Agency (USEPA)/U.S. Army Corps of Engineers (USACE). 2004. *Evaluating environmental effects of dredged material management alternatives - a technical framework.* EPA842-B-92-008, Washington, DC: U.S. Environmental Protection Agency and U.S. Army Corps of Engineers. *http://el.erdc.usace.army.mil/dots/guidance.html*

U.S. Environmental Protection Agency (USEPA)/U.S. Army Corps of Engineers (USACE). 2007a. *Identifying, planning, and financing beneficial use projects using dredged material: Beneficial use planning manual*. EPA842-B-07-001. Washington, DC: Oceans and Coastal Protection Division, Office of Wetlands, Oceans, and Watersheds, and Office of Water, U.S. Environmental Protection Agency. *http://el.erdc.usace.army.mil/dots/budm/pdf/PlanningManual.pdf*

U.S. Environmental Protection Agency (EPA)/U.S. Army Corps of Engineers (USACE). 2007b. *The role of the federal standard in the beneficial use of dredged material from U.S. Army Corps of Engineers new and maintenance navigation projects: beneficial uses of dredged material*. EPA842-B-07-002. Washington, DC: Oceans and Coastal Protection Division, Office of Wetlands, Oceans, and Watersheds, and Office of Water, U.S. Environmental Protection Agency. *http://el.erdc.usace.army.mil/dots/budm/pdf/ RoleFederal.pdf*

U.S. Army Engineer District, Detroit. 2008. *Active confined disposal facilities on the Great Lakes*. Detroit, MI: U.S. Army Engineer District. *http://www.lre.usace.army.mil/_kd/go.cfm?destination=Page&Pge_ID=2184*

U.S. Army Corps of Engineers (USACE). 2008a. *Dredging information system: Dollars, number of contracts and cubic yards by type of material disposal and fiscal year*. Alexandria, VA: Institute for Water Resources, Navigation Data Center. *http://www.ndc.iwr.usace.army.mil/dredge/drgdisp.htm*

U.S. Army Corps of Engineers (USACE). 2008b. *Identification and use of disposal areas.* 33CFR 337.9.

U.S. Army Corps of Engineers (USACE). 2008c. *Implementation guidance for dredged material disposal—section 2005 of the Water Resources Development Act of 2007 (WRDA 2007).* CECW-P Memorandum. August 11, 2008. Washington, DC: U.S. Army Corps of Engineers. *http://www.usace.army.mil/cw/cecw-p/leg_manage/wrda/wrda2007/sec_2005.pdf*

Table 1. Summary of District Responses to CDF Sustainability Survey

Survey Question	Survey Answers	No. of District Responses								
		LRD	MVD	NWD	NAD	POD	SAD	SPD	SWD	Total
Number of districts responding per Division		3	4	3	4	1	5	3	1	**24**
To what extent are CDFs used for dredged material disposal?	Never	0	1	1	1	0	0	0	0	**3**
	Occasionally	1	0	1	1	1	0	2	0	**6**
	Mostly	2	3	1	2	0	5	0	1	**14**
	Exclusively	0	0	0	0	0	0	1	0	**1**
Is your district facing problems that hamper effective usage of CDFs?	Capacity shortage	3	4	1	2	0	3	2	1	**16**
	Difficulty siting new disposal areas	3	3	1	3	1	4	3	1	**19**
	Inability to raise dikes or expand	2	0	0	1	0	2	1	1	**7**
	Shortage of funding	3	3	1	1	1	5	1	1	**16**
	CDFs are inaccessible	0	0	1	0	0	2	0	0	**3**
	Lack of equipment	1	0	0	0	0	0	0	0	**1**
	Contaminants	3	1	0	0	1	1	1	0	**7**
	Problems with ownership	1	1	1	0	1	2	0	0	**6**
	Conflicting use of CDF site	3	2	1	1	1	3	2	0	**13**
	Other	2	0	1	2	0	2	1	0	**8**
How critical is the issue of CDF storage capacity at your district?	Unlimited	0	0	1	0	1	1	0	0	**3**
	Shortage in <10 years	3	1	0	0	0	4	2	1	**11**
	Shortage in 10-20 years	0	1	1	2	0	1	0	0	**5**
	Out of capacity	0	1	0	0	0	0	0	0	**1**
How extensively has beneficial use been investigated?	Currently used	0	2	1	3	0	4	0	0	**10**
	Used on limited basis	3	1	2	1	1	1	2	1	**12**
	Investigated but not used	1	0	0	0	0	0	1	0	**2**
	Not investigated	0	2	0	0	0	0	0	0	**2**
What do you see as obstacles to beneficial use of dredged material?	Corps policies	1	0	0	0	0	4	0	1	**6**
	Inadequate market	2	3	1	3	1	5	1	1	**17**
	Cost	3	2	2	4	1	2	2	1	**17**
	Inability to meet State standards	2	1	1	1	0	2	0	0	**7**
	CDF materials not easy to access	1	2	1	1	0	5	0	0	**10**
	Uncertainty in characterization	2	0	0	0	0	0	1	0	**3**
	Current regulations or procedures	1	0	2	2	0	3	0	0	**8**
	Other	2	1	0	2	0	1	2	0	**8**
What CDF management techniques are currently employed in your district?	Dewatering	1	2	2	2	0	5	3	1	**16**
	Material recovery	1	1	0	2	0	4	1	0	**9**
	Physical separation	1	0	0	1	0	2	1	0	**5**
Do you feel improvements in CDF management could be made to effectively sustain CDF capacity?	Yes	2	1	0	1	1	3	1	1	**10**
	Somewhat	2	1	1	2	0	1	1	0	**8**
	No	0	1	1	0	0	0	1	0	**3**
Is Regional Sediment Management being employed in your district?	Yes	2	0	3	2	1	2	1	1	**12**
	No	1	3	0	1	0	2	2	0	**9**
	What is RSM?	1	1	0	0	0	1	0	0	**3**