5.0 ASSESSMENT OF CONFINED (DIKED) DISPOSAL

This part of the report describes detailed assessments for alternatives involving confined (diked) disposal facilities (hereinafter referred to as CDFs). In general, disposal of dredged material in CDFs is regulated under the CWA. It is also important to note that the CDF itself must comply with the Guidelines if it is sited in waters of the United States. In addition, there may be other regulatory requirements under NEPA and other applicable laws and regulations on a case-by-case basis.

CDFs differ in their geohydrology, sediment chemistry, carrier water removal, contaminant release rates, and contaminant pathways affected. Therefore, the testing and assessments required will vary somewhat accordingly, although the procedures are based on similar scientific and engineering principles. The framework for assessing confined disposal is illustrated in Flowchart 3-3. The detailed assessments described in this chapter may be performed following a determination of the need for such assessments as described in Chapter 3.

5.1 Determination of Characteristics of Confined Sites

Site specification for CDFs in many ways can be more complex than for open-water sites. Real estate considerations are a major factor in determining the availability of potential sites. Most navigation project authorizations require the local project sponsors to provide the lands, easements, and rights of way for CDFs; some authorizations require the sponsor to provide dikes and site management. CDFs therefore represent a substantial economic investment on the part of the sponsor. In many instances, the sponsors will only provide sites which meet short-term requirements, and additional sites may be required in the future. Another consideration for CDF site specification is the fact that such sites are normally visible to the public and are viewed as a competing interest for land use, especially in coastal areas where there is intense pressure for both development and preservation of lands.

A knowledge of CDF site characteristics is necessary for assessments of potential physical impacts and contaminant impacts. Information on site characteristics needed for assessments includes the following:

- Available area and volumetric storage capacity to contain the material for the required life of the site.
- Real estate considerations.
- Site configuration and access.
- Proximity to sensitive ecological environments.

- Topography to include potential changes in elevation and runoff patterns and adjacent drainage.
- Ability of the dredged material to eventually dry and oxidize.
- Groundwater levels, flow and direction, and potential impact on groundwater discharge and recharge.
- Meteorology and climate.
- Foundation soil properties and stratigraphy.
- Potential groundwater receptors.
- Potential alteration of the existing habitat type.
- Potential for effluent, leachate, and surface runoff impacting adjacent ground and surface water resources.
- Potential for direct uptake and movement of contaminants into food webs.
- Potential for volatilization of contaminants.
- Potential for dust, noise, or odor problems.
- Potential to implement management activities when deemed necessary.
- Potential accessibility of the site by the public.
- Contamination history of proposed site.

Field exploration programs are necessary to assess many of the above considerations in determining the suitability of a site for use as a CDF. Foundation explorations are especially important for dike design and groundwater assessments. Additional information regarding sampling techniques and equipment and development of field exploration programs for CDFs is given in EM 1110-2-5027 (USACE 1987).

5.2 Evaluation of Direct Physical Impacts and Site Capacity

An evaluation of direct physical impacts and initial and long-term CDF site capacity should precede any evaluations of contaminant impacts, since elimination of alternatives based on unacceptable physical impacts or inadequate site capacity could reduce the need for more expensive and involved testing for contaminant effects.

5.2.1 Direct Physical Impacts

Direct physical impacts because of construction of the CDF must be assessed. Such impacts may include alteration of habitat, changes in hydrological conditions (e.g., circulation patterns in surface waters and groundwater recharge), restrictions to navigation, and aesthetic, cultural, and land-use impacts. Guidance on evaluation of such physical impacts in waters of the United States is available (40 CFR 230).

5.2.2 Initial Storage Capacity and Solids Retention

A CDF must be designed and operated to provide adequate initial storage volume and surface area to hold the dredged material solids during an active filling operation and if hydraulically filled, to retain suspended solids such that clarified water is discharged. The required initial storage capacity and surface area is governed by zone, flocculent, and compression-settling processes which occur in a CDF during placement of fine-grained dredged material. Procedures to evaluate the required surface area and volume during active filling operations, to estimate effluent suspended solids concentrations, and to design other features for CDFs are described in engineer manuals (USACE 1983, 1987 and in preparation). Expert systems for evaluation of initial storage capacity and solids retention are described in Hayes and Schroeder (1992).

5.2.3 Long-Term Storage Capacity

In addition to initial capacity during active filling, an evaluation of long-term storage capacity is required if a CDF is intended for use over multiple dredging cycles. The long-term storage capacity of a given site is dependent on the material consolidation and desiccation properties, climate, and operational conditions. Procedures to evaluate long-term storage capacity of CDFs are provided in Engineer Manuals (USACE 1983, 1987 and in preparation). Expert systems for evaluation of long-term consolidation are described in Schroeder et al. (2004).

5.2.4 Need for Management Actions

If the evaluation of direct physical impacts and evaluation of site capacity indicate that the site is adequate, the remaining assessments can be conducted. If the evaluations of direct physical impacts and site capacity indicate unacceptable impacts will result or that site capacity is inadequate, management actions can be considered.

Management actions to minimize physical impacts of CDF construction may include site management to reduce effluent solids discharge or dewatering of dredged material between filling operations to extend capacity and reduce the need for a larger site. Management actions are described in paragraph 5.4. If the management actions are determined to be effective, the remaining assessments can then be conducted. If not, then the confined-disposal alternative at the site under consideration should be eliminated.

5.3 Evaluation of Contaminant Pathways of Concern for CDFs

If the initial evaluation of sediment contamination described in paragraph 3.5.3 reveals that contaminants are not of concern for specific pathways, then no additional contaminant testing is required for those pathways. However, if contaminants are of concern, an analysis of appropriate pathways must be conducted that may include possible testing.

5.3.1 Contaminant Pathways for CDFs

The possible migration pathways of contaminants from confined disposal facilities in the upland environment are illustrated in Figure 5-1. These pathways include effluent discharges to surface water during filling operations and subsequent settling and dewatering, rainfall surface runoff, leachate into groundwater, volatilization to the atmosphere, and direct uptake. Direct uptake includes plant uptake and subsequent cycling through food webs and direct uptake by animal populations living in close

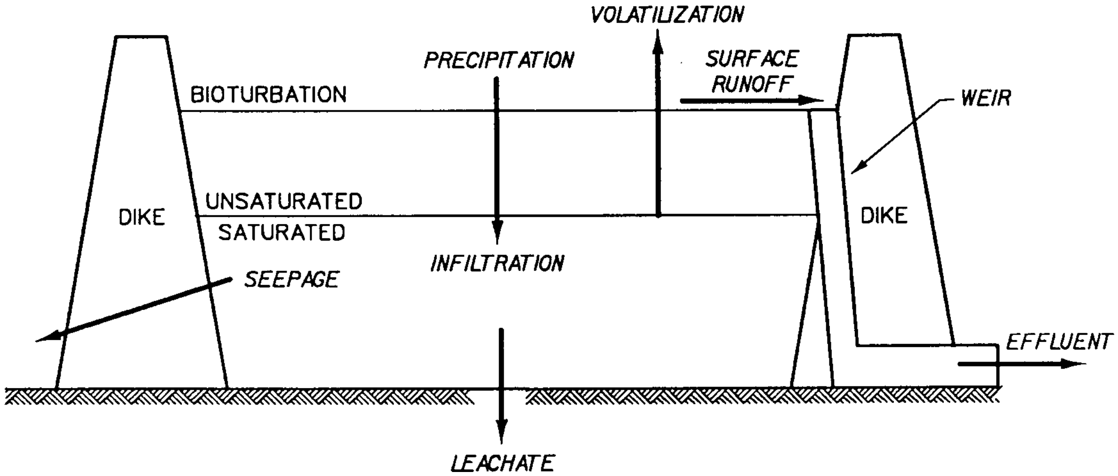

Figure 5-1. Contaminant Pathways for Upland CDFs

association with the dredged material. Effects on surface water quality, groundwater quality, air quality, plants, and animals depend on the characteristics of the dredged material, management and operation of the site during and after filling, and the proximity of the CDF to potential receptors of the contaminants.

Migration pathways affected by nearshore CDFs are illustrated in Figure 5-2 and include all of the pathways previously discussed. Additional considerations for nearshore sites (with one or more sides within the influence of water level fluctuations) are soluble convection through the dike in the partially saturated zone and soluble diffusion from the saturated zone through the dike. Groundwater seepage into or through the site can also be a factor affecting contaminant migration. These additional potential fluxes primarily affect the surface water pathway.

5.3.2 Geochemical Environments for CDFs

When dredged material is placed in an upland environment, physical and/or chemical changes may occur (Francingues et al. 1985). The dredged material initially is dark in color and reduced, with little oxygen. If the material is hydraulically placed in the CDF, the ponded water will usually become oxygenated. This may affect the release of contaminants in effluent discharged during hydraulic filling.

Once disposal operations are completed, and any ponded water has been removed from the surface of the CDF, the exposed dredged material will become oxidized and lighter in color. The dredged material may begin to crack as it dries out. Accumulation of salts will develop on the surface of the dredged material and especially on the edge of the cracks. Rainfall events will tend to dissolve and remove these salt accumulations in surface runoff. Certain metal contaminants may become dissolved in surface runoff.

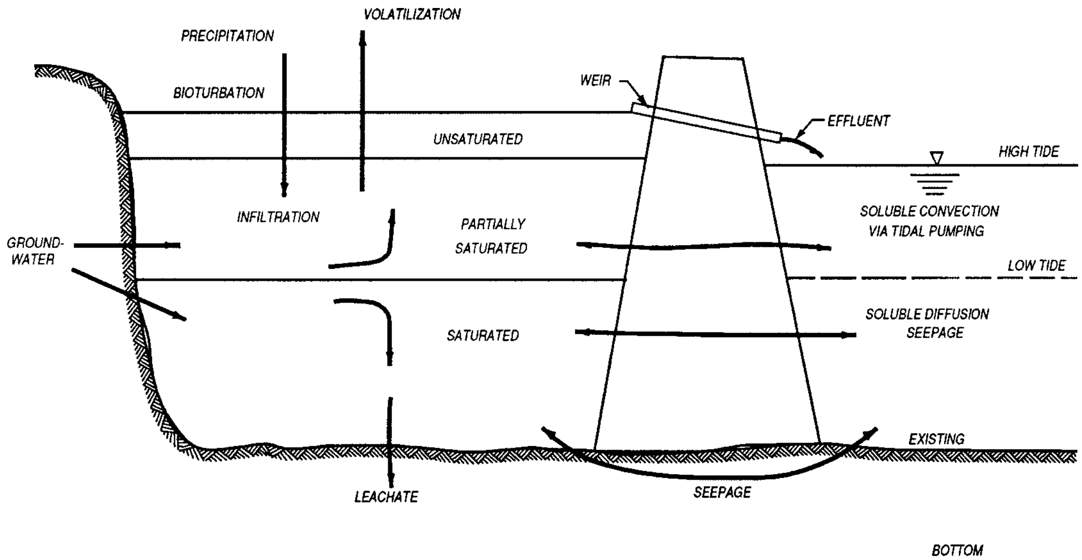

Figure 5-2. Contaminant Pathways for Nearshore CDFs

During the drying process, organic complexes become oxidized and decompose. Sulfide compounds also become oxidized to sulfate salts, and the pH may drop drastically. These chemical transformations can release complex contaminants to surface runoff, soil pore water, and leachate. In addition, plants and animals that colonize the upland site may take up and bioaccumulate these released contaminants.

Volatilization of contaminants depends on the types of contaminants present in the dredged material and the mass transfer rates of the contaminants from sediment to air, water to air, and sediment to water. Release of the dredged material slurry above the water level in the CDF surface will enhance volatilization as the slurry impacts the CDF surface, creating turbulence and releasing dissolved gases. The transfer rate for organics such as polychlorinated biphenyls (PCBs) from water to air is generally slower, but of longer duration, than from sediment to air (Thibodeaux 1989).

CDFs constructed totally or partially in water will usually receive dredged material until the final elevation is above the high-water elevation. Three distinct physicochemical environments may eventually exist at such a site: upland (dry unsaturated layer), intermediate (partially or intermittently saturated layer), and aquatic (totally saturated layer) (Lee et al. 1991).

When material is initially placed in an in-water CDF, it will all be flooded or saturated throughout the vertical profile. The saturated condition is anaerobic and reduced, which favors immobility of contaminants, particularly heavy metals. After the site is filled and dredging ceases, the dredged material above the water level begins to dewater and consolidate through movement of water downward as leachate, upward and out of the site as surface drainage or runoff, and laterally as seepage through the dike. As the material desiccates through evapotranspiration, it becomes aerobic and oxidized, mobilizing some contaminants as described previously. At this point, the surface layer has characteristics similar to that of material in an upland CDF.

The bottom of an in-water CDF below the low-tide or groundwater elevation remains saturated and anaerobic, favoring insolubility and contaminant attraction to particulate matter. After dewatering of the dredged material above the flooded zone ceases and consolidation of the material in the flooded zone reaches its final state, water movement through the flooded material is minimal and the potential for migration of contaminants is low.

The intermediate layer between the saturated and unsaturated layers will be a transition zone and may alternately be saturated and unsaturated as the water surface fluctuates. The depth of this zone and the volume of dredged material affected depend on the difference in tide elevations and on the permeability of the dike and of the dredged material. With low-permeability material, the volume of CDF material impacted by this pumping is very small compared with the in-water CDF's total volume.

5.3.3 Analysis of Pathways for CDFs

Guidance for analysis of contaminant pathways for CDFs is provided in the Upland Testing Manual or UTM (USACE 2003). This manual is a resource document providing detailed testing procedures and approaches for evaluation of potential contaminant migration pathways from diked confined disposal facilities (CDFs). Consideration of pathways for migration of contaminants from the site and potential contaminant impacts is required to determine the need for operational or engineered measures to control contaminant releases. During the 1980s and 1990s, a number of evaluation procedures and laboratory tests were developed for CDF pathway evaluations and serve as the technical basis for procedures in the UTM (Environmental Laboratory 1987, Francingues and Averett 1988, Palermo et al. 1989, Brannon et al. 1990, and Myers 1990).

The UTM uses a tiered approach similar to that long used for evaluation of open water placement of dredged material (USEPA/USACE 1991 and 1998). The pathways of concern for CDFs include effluent discharges to surface water during filling operations, rainfall surface runoff, leachate into groundwater, volatilization to the atmosphere, and direct uptake by plants and animals on site and subsequent cycling through food webs. Additional discussion of the respective CDF pathways including appropriate testing protocols and evaluation procedures are given in the following paragraphs.

5.3.4 Effluent Discharge

The effluent from a CDF may contain both dissolved and particulate-associated contaminants. A large portion of the total contaminant concentration is tightly bound to the particulates. Effluent from a CDF is considered a dredged material discharge under

Section 404 of the CWA and is also subject to water quality certification under Section 401 State/Tribal water quality standards.

Prediction of effluent quality may be made using partitioning analysis (Estes, Schroeder, and Bailey in preparation), or the effluent elutriate test procedure (Palermo 1985; Palermo and Thackston 1988, USEPA/USACE 1998, USACE 2003). Partitioning analysis provides an estimate of effluent concentrations that will result for measured sediment and carrier water concentrations. This can be helpful in narrowing the constituents of concern to those that appear to be present at concentrations that may be environmentally problematic. The modified elutriate test simulates the geochemical and physical processes occurring during confined disposal. This test provides additional information on dissolved and particulate contaminant concentrations. The column settling test (USACE 1987) and expert system SETTLE (Hayes and Schroeder 1992) used for CDF design provide an estimate of the effluent solids concentrations. Results of both elutriate and settling tests can be used to predict a total concentration of contaminants in the effluent. The predicted effluent quality, with allowance for any mixing zone, can be compared directly with water quality standards. Computerized programs are also available to compare predicted effluent concentrations with water quality criteria (Palermo and Schroeder 1991).

Where water quality standards are unavailable or are predicted to be exceeded, risk assessment may be necessary to further evaluate the environmental impacts associated with the effluent discharge. Guidance regarding effluent toxicity bioassays and ecological and human health risk assessment in aquatic environments can be found in Brandon, Schroeder, and Lee (1997a) and Cura et al. (2001), respectively. The modified elutriate test can be used to develop the water medium for bioassays if a biological approach to evaluation of effluent quality is needed. These bioassays are conducted in a manner similar to those for open-water disposal. The quality of a reference water (usually the receiving water) should be considered in test interpretation.

If impacts of effluent contaminant concentrations are unacceptable, appropriate controls should be considered. Control measures available for effluent discharge include improved settling design or reduced flow to the containment area, chemical clarification or filtration to remove particulate contaminants, and removal of dissolved contaminants by more sophisticated treatment processes.

5.3.5 Surface Runoff

Immediately after material placement in a CDF and after ponding water is decanted, the settled material may experience surface runoff. Rainfall during this initial period will likely be erosive, and runoff will contain elevated solids concentrations. Geochemically speaking, the contaminant release is controlled by anaerobic conditions. Once the surface is allowed to dry, the runoff will contain a lesser concentration of solids, but the release is now controlled by aerobic conditions, and release of some dissolved contaminants may be elevated. Runoff water quality requirements may be a condition of the water quality certification or considered as part of the NEPA process.

As for effluent, partitioning analysis may be used to provide an initial estimate of runoff concentrations, and this can be done for both oxidized and unoxidized conditions (Price, Schroeder, and Estes in preparation). There also is now available a simplified test procedure for prediction of runoff quality (SLRP) (Price, Skogerboe and Lee 1998 and USACE 2003). A soil lysimeter testing protocol (Lee and Skogerboe 1983 and USACE 2003) has also been used to predict surface runoff quality with good results. The lysimeter is equipped with a rainfall simulator and can be used in the laboratory or transported to the field site. The soil lysimeter is a more expensive and elaborate testing protocol, requiring large volumes of sediment and approximately 8 months for test completion.

Computerized programs are available to compare predicted runoff concentrations with water quality criteria (Schroeder, Gibson, and Dardeau 1995). If runoff concentrations exceed water quality standards, appropriate controls may include placement of a surface cover or cap on the site, maintenance of ponded water conditions (although this may conflict with other management goals), vegetation to stabilize the surface, treatments such as liming to raise pH, or treatment of the runoff as for effluent (Lee and Skogerboe 1987). Risk assessment may be used to evaluate the environmental effects associated with runoff and determine the need for controls where standards are predicted to be exceeded, or standards are not available (Cura, Wickwire and McArlde in preparation). Procedures for evaluation of runoff toxicity bioassay tests can also be found in Brandon, Schroeder, and Lee (1997b).

5.3.6 Leachate

Subsurface drainage from upland CDFs may reach adjacent aquifers or may enter surface waters. Fine-grained dredged material tends to form its own disposal-area liner as particles settle with percolation of water, but some time may be required for sufficient consolidation to occur. Particulate transport in leachate is also minimal. Constituents present in leachate are primarily found in the dissolved fraction.

Evaluation of the leachate quality from a CDF must include a prediction of which contaminants may be released in leachate and the relative degree of release or mass of contaminants (Schroeder 2000). Pore water analysis may provide a good preliminary estimate of leachate quality. Partitioning analysis may also be used to estimate concentrations of constituents in leachate, based on measured sediment concentrations (Myers, Schroeder and Estes in preparation (a)). Experimental procedures have been developed for prediction of leachate quality from dredged material (Myers and Brannon 1991; Brannon, Myers and Tardy 1994; Myers, Brannon and Tardy 1996, USACE 2003). These procedures are based on theoretical analysis and laboratory batch testing and column testing, but have not been routinely applied due to the time required to perform these tests and the associated cost.

The experimental testing procedures only give data on leachate quality. Estimates of leachate quantity must be made by considering site-specific characteristics and groundwater hydrology. Computerized procedures such as the USEPA Hydrologic

Evaluation of Landfill Performance model (Schroeder et al. 1984) have also been used to estimate water balance (budget) for dredged material CDFs (Palermo et al. 1989; Francingues and Averett 1988). Additional procedures and computer estimating tools are also available to estimate attenuation of contaminants in the subsurface (Schroeder and Aziz 2003; Aziz and Schroeder 1999a; Aziz and Schroeder 1999b; Schroeder et al. 1994a; Schroeder et al. 1994b; Schroeder et al. 2004). Source terms for partitioning analysis and attenuation calculations can be found in Streile et al. (1996).

If leachate concentrations exceed applicable criteria, or criteria are not available and effects cannot be shown to be acceptable using risk assessment (USEPA 1998; Cura, Wickwire and McArlde in preparation), controls for leachate must be considered. These may include proper site specification to minimize potential movement of water into aquifers, dewatering to reduce leachate generation, chemical modifications to retard or immobilize contaminants, physical barriers such as clay and synthetic liners, capping/vegetating the surface to reduce leachate production, or collection and treatment of the leachate.

5.3.7 Plant and Animal Uptake

Some contaminants can be bioaccumulated in plant tissue and become further available to the food chain. There are few reference values available specifically for assessing the potential for adverse plant or animal uptake from dredged material. Criteria established for sewage sludge are sometimes used, but apply to a limited number of metals, and are based on conservative assumptions that are not directly applicable to a disposal area. A computerized screening program has been developed which compares measured sediment concentrations to available reference values. The Diethylenetriamine-pentaacetic acid (DTPA) extract test has also been utilized to provide a simplified assessment of the potential for plant and animal uptake (Lee et al. 1978; Folsom, Lee, and Bates 1981; Lee, Folsom, and Engler 1982; Lee, Folsom, and Bates 1983; U.S. Army Engineer Waterways Experiment Station 1987, USACE 2003). A computerized program, the Plant Uptake Program (PUP) uses the results of the DTPA extraction procedure to predict bioaccumulation of metals from freshwater dredged material by freshwater plants and compare the results to a background or reference sediment or soil (Folsom and Houck 1990).

If the contaminants are identified in the dredged material at levels, which cause a concern, a more extensive evaluation may be performed based on a plant or animal bioassay. Appropriate plant or animal species are grown in either a flooded or dry soil condition using the appropriate experimental procedure and laboratory or field test apparatus (Folsom and Lee 1985; Simmers, Rhett, and Lee 1986; American Society for Testing and Materials (ASTM) 1997; USACE 2003). Contaminant uptake is then measured by chemical analysis of the biomass (tissue). Growth, phytotoxicity, and bioaccumulation of contaminants are monitored during the growth period in the case of the plant bioassay. An index species is also grown to serve as a mechanism to extrapolate the results to allow use of other databases, such as metals uptake by agricultural food crops. This indexing procedure provides information upon which a decision can be made regarding potential for human health effects and for beneficial uses of the site or dredged material. Levels of contaminants in the biomass are compared with Federal criteria for food or forage. Risk assessment may also be performed to evaluate the potential effects of plant and animal uptake on sensitive species subject to primary or secondary exposure (Cura, Wickwire, and McArlde in preparation).

From the test results, appropriate management strategies can be formulated regarding where to place dredged material to minimize plant or animal uptake or how to control and manage the species on the site so that desirable species that do not take up and accumulate contaminants are allowed to colonize the site, while undesirable species are removed or eliminated.

5.3.8 Volatilization to Air

Contaminant transport from in situ sediment to air is a relatively slow process, because most contaminants must first be released to the water phase prior to reaching the air. Potential for volatilization should be evaluated in accordance with regulatory requirements of the Clean Air Act. Thibodeaux (1989) discusses volatilization of organic chemicals during dredging and disposal and identifies four locales where volatilization may occur:

- Dredged material exposed directly to air.
- Dredging site or other water area where suspended solids are elevated.
- Ponded CDF with a quiescent, low-suspended solids concentration.
- Dredged material covered with vegetation.

In cases where highly contaminated sediments are disposed, airborne emissions must be considered to protect workers and others who could inhale contaminants released through this pathway.

Rate equations based on chemical vapor equilibrium concepts and transport phenomena fundamentals have been used to predict chemical flux (Thibodeaux 1989; Semmler 1990). Computerized programs have been developed utilizing these rate equations for the evaluation of volatile emissions from dredged material (Myers, Schroeder and Estes in preparation (b)). Since the original publication of this document, considerable effort has also been directed to testing procedures for direct measurement of volatile emissions (Price et al. 1997; Price et al. 1998; Price et al. 1999, USACE 2003).

Emission rates are primarily dependent on the chemical concentration at the source, the surface area of the source, and the degree to which the dredged material is in direct contact with the air. The magnitude of release from exposed dredged material is initially higher than for ponded conditions. This is of limited duration however. Volatilization from ponded areas occurs at a lower rate, but is continuous, and may result in a higher mass flux over time.

Effects associated with volatilization of contaminants are evaluated based on estimated exposure to selected receptors, and appropriate inhalation reference doses (Myers, Schroeder and Estes in preparation (b)). Risk assessment may also be employed in assessing the effects associated with exposure (Cura, Wickwire, and McArlde in preparation).

5.3.9 Particulate Transport

Airborne transport of particulates from the surface of a CDF is also potentially of concern. Exposure to contaminants may occur through inhalation of fine particles or from direct contact with or ingestion of particles re-deposited in areas off-site. Tools to quantify particulate transport are not well developed. Qualitative analysis of expected surface conditions may identify periods when particulate transport will be of concern; primarily when the material surface is dry, net precipitation is low, and prevailing winds are sufficient to effect transport. Vegetation or surface covers may provide effective control of particulate transport, although implementation may be logistically difficult due to the size of the areas involved and the limited weight bearing capacity of the material while it is still consolidating.

5.3.10 Need for Contaminant Controls

If the analysis of contaminant pathways and associated testing indicates that the standards or Guidelines, as appropriate, are met, the CDF alternative is environmentally acceptable from the standpoint of contaminant effects for that pathway. If the applicable standards or Guidelines are not met, contaminant control measures can be considered to reduce impacts to acceptable levels.

Control measures to minimize contaminant impacts may include operational modification, treatment, site controls (e.g., liners or covers), and other site management actions. These control measures are described in paragraph 5.4. If the control measures are determined to be effective, then the alternative is environmentally acceptable from the standpoint of contaminants. If there are no effective control measures for one or more pathways, then disposal at the CDF under consideration should be eliminated.

5.4 Evaluation of Management Actions and Contaminant Control Measures for CDFs

In cases where evaluations of direct physical impacts, site capacity, or contaminant pathways indicate impacts will be unacceptable when conventional CDF disposal techniques are used, management actions and contaminant control measures may be considered. It should be noted that a CDF is neither a conventional wastewater treatment facility nor a conventional solids-handling facility. The dredged materials placed in CDFs typically contain 10 to 50 percent solids; therefore, an effective CDF must incorporate features of both wastewater treatment and solids-handling facilities in a combination that is unlike either (Averett et al. 1990).

Descriptions of the commonly used management actions and contaminant controls are given in the following paragraphs. Additional guidance on selection of management actions and contaminant controls for CDFs is available (USACE 1983, 1987 and in preparation; Francingues et al. 1985; Cullinane et al. 1986; Averett et al. 1990). These references contain testing procedures and criteria needed for evaluating and selecting appropriate contaminant control measures for CDFs, and should be consulted for additional detailed discussions of the attributes of the various technologies.

Management actions may include managing or modifying the proposed placement operation, modification of the CDF design or geometry, treatment of effluent, runoff, or leachate discharges, and physical management such as covers, liners, or barrier systems (USACE 2003). Recent references relevant to application of management actions at CDFs include USEPA (1994); National Research Council (1997); Permanent International Association of Navigation Congresses (PIANC) (1996 and 2003); Palermo and Averett (2000).

5.4.1 Management Actions for Physical Impacts and Storage Capacity

A number of management techniques have been developed and used that can eliminate or minimize adverse direct physical impacts resulting from construction of CDFs. These include:

- Management of the CDF for dewatering the dredged material, thereby reducing the volume of material and reducing the need for larger or additional sites (USACE 1987).
- Treatment of effluent to remove additional solids and reduce turbidity of the discharge (USACE 1987).
- Implementation of Disposal Area Reuse Management involving removal of material from the CDF for some beneficial use, thereby restoring the capacity of the CDF (USACE 1987; Lee 1999; Olin-Estes and Palermo 2000a; Olin-Estes and Palermo 2000b; Olin-Estes 2000; Lee 2000; Spaine et al. 2001; Lee 2001; Olin-Estes et al. 2002b).
- Mitigation to include creation of alternative habitat and designated resource management onsite.
- Modification of site through landscaping and screening to improve site aesthetics and features to protect cultural resources.

5.4.2 Treatment of Liquid Streams

The objective of liquid streams controls is to remove residual contaminants from the liquids produced as discharges from a CDF operation such as:

- Effluent discharges from active filling operations.
- Surface runoff.
- Leachate.
- Water produced from dewatering or treatment processes.

Contaminants in these streams will present a wide array of concentrations depending on their source, and individual sources are often highly variable in concentrations and flows. Most of the contaminants for these streams (with the exception of leachate) are associated with the suspended solids and will be removed by effective suspended solids removal. Another characteristic of these streams is their variety of contaminants, both organic and inorganic, as well as potentially toxic contaminants. These characteristics may require more than one treatment process. Commonly used wastewater treatment processes are available to achieve effluent limits for most contaminants. However, application of treatment processes for dredged material effluent has been generally limited to removal of suspended solids and contaminants associated with these particulates.

Liquid treatment technologies can be classified as metals removal processes, organic treatment processes, and suspended solids removal processes. Many of these processes concentrate contaminants into another phase, which may require special treatment or disposal. This discussion focuses on suspended solids, toxic organics, and heavy metals. Conventional contaminants, such as nutrients, ammonia, oxygen-demanding materials, and oil and grease, may also be a concern for dredged material effluents. Most of the processes for dissolved organics removal are suitable for these contaminants.

5.4.2.1 Suspended Solids Removal

Suspended solids removal is the most important liquid streams technology because it offers the greatest benefits in improving effluent quality not only by reducing turbidity but also by removing particulate-associated contaminants. Suspended solids removal processes differ from dewatering processes because for this application the solids concentration is much lower than for a dredged material slurry. Settling mechanisms for these streams are characterized by flocculent settling rather than zone or compression settling. For CDF liquid streams, the solids remaining will be clay or colloidal size material that may require flocculants to promote further settling in clarifiers or sedimentation ponds. Chemical clarification using organic polyelectrolytes is a proven technology for CDF effluents (Schroeder 1983). Filtration, permeable dikes, sand-filled weirs, and wetlands have also been used on occasion for CDF demonstrations or pilot evaluations. More detailed guidance on suspended solids removal processes as applied to CDFs is available (USACE 1987; Cullinane et al. 1986).

5.4.2.2 Metals Removal

Metals removal processes that may be considered for application at CDFs are similar to those commonly used for industrial applications. Flocculation is effective for removal of metals associated with particulate matter. Polymers and inorganic flocculants have been demonstrated to be effective for removal of suspended solids from dredging effluents, but removal of dissolved heavy metals has not been evaluated in field applications. Ion exchange and precipitation are probably two of the more efficient metals removal processes, but they must generally be designed for specific metals and often require major investments in operational control for efficient operation. Natural ion-exchange media, such as zeolites, may be effective but have not been demonstrated in this application. Use of man-made wetlands for retention of heavy metals and other contaminants from effluents could represent a viable option for certain sites and contaminants (Fennessy and Mitsch 1989). Less likely choices include biological ion exchange, electrocoagulation, and ultrafiltration. More detailed guidance on metals treatment processes as applied to CDFs is available (Cullinane et al. 1986; Averett et al. 1990).

5.4.2.3 Organics Treatment

The applicability and effectiveness of options for treatment of dissolved organic contaminants are mostly dependent on the concentration and flow of the liquid stream. Mechanical biological wastewater treatment processes are typically not considered because it is doubtful that sufficient organic matter would be available to support biological growth and because operation of biological systems under the conditions of fluctuating flows and temperatures would be difficult. Biological processes such as nitrification, nutrient catabolism, and photosynthesis are important degradation mechanisms for nutrients, oxygen-demanding materials, and other organics in CDFs. The principal process for dissolved refractory organic contaminants that has been applied to dredged material effluent is carbon adsorption, which was applied to a PCB spill on the Duwamish Waterway in the 1970s (Blazevich et al. 1977). Air and steam stripping could be used for volatile contaminants, but these are generally not a problem for contaminants originating in most dredged sediments. Ultraviolet light (UV) and chemical oxidation processes offer destruction of organic contaminants and are being extensively investigated in the field for a wide range of contaminants. Created wetlands also offer potential for retention and degradation of organics. The more effective organic treatment process options are:

- Carbon adsorption.
- Chemical oxidation using ozone.
- UV/hydrogen peroxide.
- UV/ozone.
- Oil separation.
- Resin adsorption.
- Steam stripping.
- Created wetlands.

More detailed guidance on organics treatment processes as applied to CDFs is available (Cullinane et al. 1986; Averett et al. 1990; USACE 1983 and USACE in preparation).

5.4.3 Site Controls

Site controls (e.g., surface covers and liners) can be effective control measures applied at a CDF to prevent migration of contaminants from the dredged material (Cullinane et al. 1986; Averett et al. 1990). The implementability and effectiveness of these controls is highly specific to the CDF location and the dredged material characteristics.

Use of site controls such as liners, slurry walls, groundwater pumping, and subsurface drainage are limited in most nearshore, in-water CDFs. Graded stone dikes with sand or steel sheet pile cutoffs have been used or proposed at upland CDFs and a few in-water CDFs to control leachate migration. The low permeability of fine-grained sediments following compaction can reduce the need for liners in many cases, but it can also limit the effectiveness and implementability of groundwater pumping and subsurface drainage controls.

A cover can be highly effective in reducing leachate generation by avoiding rainfall infiltration, isolation from bioturbation and uptake by plants and animals, minimizing volatilization of contaminants from the surface, and eliminating detachment and transport of contaminants by rainfall and runoff. A layer of clean material can achieve the last three benefits mentioned. However, prevention of infiltration requires a barrier of very low permeability, such as a flexible membrane or a compacted clay layer, both of which are not easily or reliably implemented for CDFs. Other leachate control measures include groundwater pumping, liners, subsurface drainage, sheet pile walls, slurry walls, and surface drainage. Liners have not been used extensively for contaminated dredged material sites because of the inherent low permeability of fine-grained dredged material, the retention of contaminants on solids, and the difficulty and expense of construction of a reliable liner system for wet dredged material, particularly for in-water or nearshore sites. Leachate collection techniques, such as groundwater pumping and subsurface drainage, have been evaluated in a limited number of situations, but these techniques appear to have limited feasibility for in-water sites. Sheet pile walls and slurry walls can be used to provide barriers to leachate and seepage movement from a CDF. To be effective, the barrier should tie to a geologic formation with very low permeability. Sheet pile walls are not leakproof and deteriorate over time; therefore, they should not be considered as a primary containment measure. More detailed guidance on site controls for CDFs is available (Cullinane et al. 1986; Averett et al. 1990; USACE 1983 and USACE in preparation).

5.4.4 Treatment of Dredged Material Solids

Treatment of the dredged material might be considered if this would facilitate beneficial use of the material, or provide a cost effective alternative to treatment of the various discharges from a CDF. A variety of treatment processes have been proposed for dredged material solids (i.e., the mass of dredged material following placement within a CDF) or dredged material slurries. These processes fall under one of the following categories: bioremediation (use of bacteria, fungi, or enzymes to break down organic contaminants), chemical treatment (e.g., oxidation, reduction, chelation, hydrolysis, detoxification, nucleophilic substitution, and thionation processes), extraction (removal of contaminants by dissolution in fluid), thermal (e.g., incineration), immobilization (processes which limit the mobility of contaminants) and volume reduction (physical separation of contaminated fractions).

Some of these treatment processes have been applied in pilot-scale demonstrations, and some have been applied full scale (Myers and Bowman 1999; Myers, Bowman, and Myers 2003; Olin-Estes et al. 2002a; USACE Los Angeles District 2002; USEPA 1999; Tetra Tech and Averett 1994). Recent work on phytoremediation of lead contaminated sediments can be found in Lee and Price (2003). Potential for biotreatement or phytoremediation of contaminated sediments is discussed in the following references (Price and Lee 1999; Fredrickson et al.1999; Price, Lee and Simmers 1999; Myers and Williford 2000).

The cost of treatment alternatives relative to the cost of conventional disposal is a major constraint on their potential use. The potential for implementation of immobilization processes is better than other treatment processes, because they are not as sensitive to process-control conditions, and they are relatively cost effective techniques for reducing contaminant mobility. The opportunity for applying these processes in situ in a CDF is also an advantage.

The environmental pathway most affected by immobilization processes is transport of contaminants as leachate to the groundwater or surface water. Most of the immobilization processes fall into the category of solidification/stabilization (S/S). Objectives of S/S are generally to improve the handling and physical characteristics of the material, decrease the surface area of the sediment mass across which transfer or loss of contaminants can occur, and/or limit the solubility of contaminants by pH adjustment or sorption phenomena. Effectiveness of S/S processes is usually evaluated in terms of reduction of leaching potential. Reductions are process and contaminant specific, with immobilization of some contaminants accompanied by increased mobility of other contaminants.

5.4.5 Site Operations

Site operations can be used as a control measure for CDFs to reduce the exposure of material through the surface water, volatilization, and groundwater pathways. Operational controls may include management of the site pond during and after disposal operations. Mobilization of contaminants from dredged material depends on the oxidation state of the solids. Most metals are much less mobile when maintained in an anaerobic reduced condition. On the other hand, aerobic sediments generally improve conditions for biodegradation of organic contaminants. Maintaining ponded water on the site may decrease the rate at which volatilization occurs (though not necessarily the overall mass flux) but produces a hydraulic gradient that increases the potential for movement of leachate through the site. Whether to cultivate or inhibit plant and animal propagation is also an issue. Management of the site both during filling and after disposal requires a comprehensive understanding of the migration pathways and the effects various contaminant controls have on the overall mass balance and rate of contaminant releases. The decision to apply certain management options requires trade-offs for the site and contaminant-specific conditions for the project.

5.5 Retention of Environmentally Acceptable Confined Alternatives

Once appropriate confined-disposal tests and assessments are complete, a determination of environmental acceptability can be made. This determination must ensure that all applicable standards or criteria are met. If control measures were considered, a determination of the effectiveness of the control measures in meeting the standards or criteria must be made. If all standards or criteria are met, the confined-disposal alternative can be considered environmentally acceptable. At this point, other factors can be considered in the selection of an alternative as described in paragraph 3.6 and Chapter 7.