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Site Selection, Acquisition, and Planning for Aquaculture in Dredged Material Containment Areas

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Prepared for Headquarters, U.S. Army Corps of Engineers

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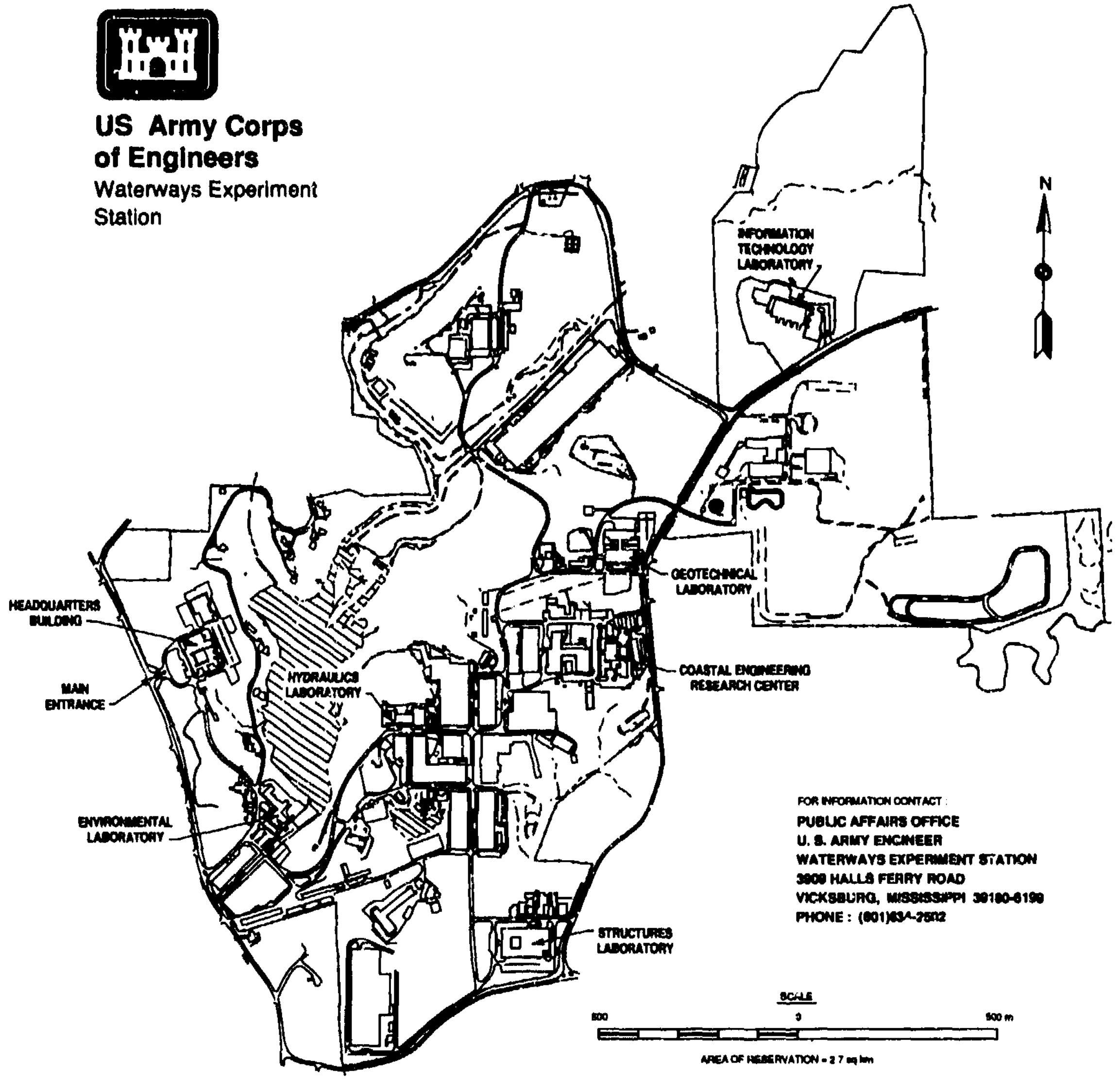

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Contents

Preface

This project was conducted under the Containment Area Aquaculture Program (CAAP) which was sponsored by the Operations, Construction, and Readiness Division, Directorate of Civil Works, Headquarters, U.S. Army Corps of Engineers; and these efforts were in cooperation with the Construction-Operations Division of the U.S. Army Engineer District, Galveston. The CAAP was overseen by a field review committee that included Messrs. Jessie Pfeiffer (CERD-C), John Parez (CECS-OO), David B. Mathis (CECS-PO), Glenn Earhart (CENAB-PD-D), Pat Langan (CESAM-OP-O), I. Braxton Kyzer (CESAC-EN-S), Herbie Maurer (CESWG-CO-M), Carlos Aguillar (CESWD-CO-DN), and Tom Patin (CEWES-EP-D).

CAAP was managed by personnel from the Environmental Laboratory (EL), U.S. Army Engineer Waterways Experiment Station (WES). Mr. Richard E. Coleman was the CAAP Program Manager, and the project was conducted under the supervision of Mr. E. Jack Pullen, Chief, Coastal Ecology Branch, and Dr. C. J. Kirby, Chief, Ecological Research Division. Dr. John Harrison, Director, Environmental Laboratory, provided general supervision. Project management was also provided by Dr. Jurij Homziak, Sea Grant Advisory Service/Cooperative Extension Service, Mississippi State University, and Mr. David Nelson and Mr. John Lunz, WES Ecological Research Division. This report was written by Mr. Jonathan Wilson, Department of Biology, Jackson State University, Jackson, MS, Dr. Homziak, and Mr. Coleman.

The CAAP demonstration facility was designed, built, and operated by personnel from two private aquaculture consulting firms, MariQuest, Inc., Los Angeles, CA, and Cultured Seafood Group, Inc., Laguna Vista, TX. Key personnel from these firms were Mr. Sy Garban, Mr. Durwood M. Dugger, Mr. Scott Kellman, and Ms. Millie Gonzales. Assistance in facility design and construction was provided by Mr. Abel Guerrero and Mr. Art Barrera, Brownsville Area Office, U. S. Army Engineer District, Galveston. Engineering drawings were provided by Mr. Arthur Bennett and Mr. Steve Farmer, U.S. Army Engineer District, Vicksburg.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

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Conversion Factors, SI to Non-SI Units of Measurement

SI units of measurement used in this report can be converted to non-SI units as follows:

Multiply	By	To Obtain
acres	4046.87	square meters
cubic yards	0.7645549	cubic meters
feet	0.3048	meters
miles (U.S. statute)	1.609347	kilometers
pounds per acre	1.123356	kilograms/hectares
pounds (force)	4.448222	newtons

1 Introduction

Background

Pond culture is an efficient and economically successful commercial production method for the cultivation of fish and shellfish world wide (Brown 1983, Huner and Brown 1985). Commercial production of many high-value marine species such as shrimp comes almost entirely from pond culture (e.g. Huner and Brown 1985). In the United States, however, pond culture of marine species has been slow in developing, hindered in part by the lack of access to coastal sites suitable for aquaculture (Glude 1977, National Research Council 1978, Conte and Manus 1980, Joint Subcommittee on Aquaculture 1983). Legal prohibitions (McGlew and Brown 1979, Wypyszinski 1983), competing land uses (Lovell 1979, Conte and Manus 1980), and high real estate costs (Glude 1977, Joint Subcommittee on Aquaculture 1983) effectively limit aquaculture development in many otherwise suitable coastal areas.

One way in which this constraint may be overcome is to utilize dredged material containment areas (DMCA) for aquaculture. The concept of using DMCA's, primarily for periodic dredged material disposal but with culture operations interspersed among disposal events, has been accepted by commercial aquaculture interests and has the support of the U.S. Army Corps of Engineers (USACE) and local port and waterway management interests (see Homziak and Lunz 1983, Lunz and Konikoff 1987a, 1987b). Indeed, the development of such biological multiple uses is the focus of USACE interest (e.g. USACE 1986). Benefits accruing from the application of DMCA aquaculture to the aquaculture industry, land owners, and local communities include: more sites for aquaculturists, more DMCA's for USACE and local sponsors, increased revenue to landowners and improved local economy. These benefits are discussed in detail elsewhere (Homziak and Lunz 1983; Lunz, Nelson, and Tatem 1984; Homziak and Lunz 1987; Lunz and Konikoff 1987a, 1987b; Coleman, Homziak, and Dugger 1990).

The Corps of Engineers has the mission to maintain, improve, and extend the navigable waterways of the United States. It has the regulatory responsibility for the dredging and disposal of over 450 million cubic yards of sediment annually (National Research Council 1985, Schaefer and Schroeder 1988, Engler et al. 1988) from over 400 ports and 25,000 miles of coastal and inland waterways. Pequegnat (1987) estimates that 60 percent of all such dredging takes place in estuarine and coastal areas.

Since the enactment of laws designed to reduce the use of the ocean as a receiving area, disposal of dredged material has shifted in many cases from open water disposal to disposal into diked containment areas (Collier 1984, Hilton 1984, National Research Council 1985). These DMCA's receive approximately 40 percent of dredged material generated from coastal dredging activities (Pequegnat 1987). It should be noted that confined disposal sites, facilities, or areas, diked disposal areas, containment areas, and DMCA's are synonymous; all refer to an engineered structure for containment of dredged material (Headquarters, Department of the Army 1987).

Because over 7,000 acres of new diked disposal areas are estimated to be needed annually (Lunz and Konikoff 1987a, 1987b), both the USACE and port/waterway management bodies have an ongoing interest in acquiring real estate for DMCA construction. One way to accomplish this is through the demonstration of successful multiple uses such as aquaculture (Lunz, Nelson, and Tatem 1984, Homziak and Lunz 1987). Because the focus of USACE and port/waterway management interests in multiple uses of confined disposal areas is on the acquisition of new DMCA sites, this review will be limited to site selection and planning for new DMCA's. Evaluation of existing DMCA's as potential sites for conversion to aquaculture facilities will not be considered except where formerly inactive sites are returned to use. Information on DMCA design, construction, operations and management are available (e.g. Palermo, Montgomery, and Poindexter 1978; Walski and Schroeder 1978; Kyzer 1984; Headquarters, Department of the Army 1987; Averett, Palermo, and Wade 1988; Schaefer and Schroeder 1988) and should be referred to for additional details.

Purpose

This report will serve as a reference document for USACE Districts and Divisions and authorities responsible for port and waterway management and operations. It will guide the planning, selection, and acquisition of sites for multiple-use DMCA's to allow for dredged material disposal and aquaculture. Planning agencies, land owners, prospective aquaculturists, business interests, and others interested in aquaculture as a multiple use of DMCA's may also find this document useful in planning for the development of aquaculture facilities in new DMCA's.

Scope

This report is one of a series of six information transfer documents developed as part of the Containment Area Aquaculture Program (CAAP). This report is limited to site selection, acquisition, and planning for aquaculture operations in new DMCA's. Following an overview of the dredging and disposal process pertinent to DMCA aquaculture planning, important features of DMCA selection, design, construction, and operations are reviewed. Recommended planning considerations for adapting a confined disposal area to aquaculture are discussed during the review of DMCA selection, design, and management. Suitability criteria, analytical methods, and recommended procedures for evaluating DMCA sites for aquaculture are presented as annotated checklists. A brief overview of procedures for leasing or otherwise obtaining access to DMCA sites for aquaculture and a brief review of permit requirements are also included. It is important that the information and guidance presented in this document be used in conjunction with other documents of this series. The other documents in this series are:

a. Legal and Institutional Constraints on Aquaculture in DMCA's.

b. Determination of the Chemical Suitability of a DMCA for Aquaculture.

c. Design and Construction of Aquaculture Facilities in DMCA's.

d. Production and harvest operations of an aquaculture crop in DMCA's.

e. The Economics and Marketing of Aquaculture in DMCA's.

Dredging, Disposal, and DMCA's

Because the basic purpose of the DMCA aquaculture program is to promote the acquisition and retention of sites for the confined disposal of dredged material, aquaculture will remain the secondary or alternative use of any containment site. The primary purpose of a diked containment area is to receive and retain dredged material. For both material disposal and aquaculture to be successful, the containment area must be sited, designed, and constructed with the intended alternative-use needs in mind. Those planning such multiple-use DMCA's must be familiar with current containment area siting, design, and construction requirements to incorporate compatible modifications for aquaculture. In addition, knowledge of dredging operations, especially those that employ DMCA's, is recommended. Informative general references on dredging are Ryan, Calder, and Burney (1984), Barr (1987), and Hutchins and Clar (1983); other useful sources are dredging and disposal related symposia and workshop proceedings (e.g. Montgomery and Leach 1984) and general dredging issue reviews (e.g. National Research Council 1985).

Dredging and disposal operations under the authority of the USACE are conducted according to specific guidelines (Engler et al. 1988). Where disposal into a diked containment area is the selected disposal option (see e.g. Collier 1984, Francingues and Palermo 1984, and Hilton 1984 for selection process), criteria and procedures for the siting, design, construction, and operation of such facilities have been established (e.g. Palermo, Montgomery, and Poindexter 1978; Headquarters, Department of the Army 1987; Schaefer and

Schroeder 1988). It is essential that these guidelines be consulted during the planning and site selection process for a confined disposal site intended for aquaculture as an alternative use.

Bray (1979) provides a detailed technical discussion of dredge types, while Barr (1987) provides a succinct overview of dredging plants. Dredging operations employing hydraulic dredges most often use confined containment areas for material disposal. Hydraulic dredges remove sediment by suction, sometimes first disrupting it with water jets or, more commonly, a rotating cutterhead. The resulting water-sediment slurry (averaging 1,200 g/ℓ or a 4:1 water-to-sediment ratio) is pumped into a containment vessel (hopper dredge or barge) for later pump-out or through a discharge pipe directly into the disposal area. Because of the high production for the size of the plant, the cutterhead suction dredge is the most commonly used dredge in the United States, especially for larger projects (Barr 1987). The use of hopper dredges or barges to temporarily contain and transport dredged material to DMCA's for pumpout is limited because of the high costs associated with the additional handling of the material.

Confined disposal areas receive the hydraulic dredge effluent, the combined mixture of dredged material solids, and overlying water from the dredging site, retaining the solids while allowing the clarified water to be released. Containment areas are designed and operated to meet two objectives: (a) to provide adequate storage capacity for the dredging requirements of the project and (b) to effectively retain solids to meet established effluent suspended sediment guidelines (Palermo, Montgomery, and Poindexter 1978; Palermo 1988). These objectives are interrelated and dictate the design, operation, and management of the containment area.

The characteristics of confined disposal sites are widely variable. Medina (1983) and references in Montgomery and Leach (1984) provide good overviews of DMCA characteristics. While project specific characteristics make each site unique, the main design components of a DMCA are shown in Figure 1. A tract of land is surrounded by dikes to form the containment area. The discharge pipe from a hydraulic dredge is positioned to provide the inflow of dredged sediments and water at one end of the structure. Coarse material (greater than No. 200 sieve, Headquarters, Department of the Army 1987) rapidly falls out of suspension, forming a mound near the inlet pipe. The fine-grained material flows throughout the containment area with most of the solids settling out of suspension. The remaining clarified water is discharged from the containment area over a weir. The elevation of the weir crest controls the depth of water within the DMCA; ponding the water promotes the effective sedimentation of solids.

Spur dikes (Figure 2) which extend into but not through the disposal area are common in a DMCA. They are often used for breaking up the flow of influent water, preventing channelization, and increasing sedimentation by reducing flow velocity and directing flow to hydraulically inactive "dead areas"

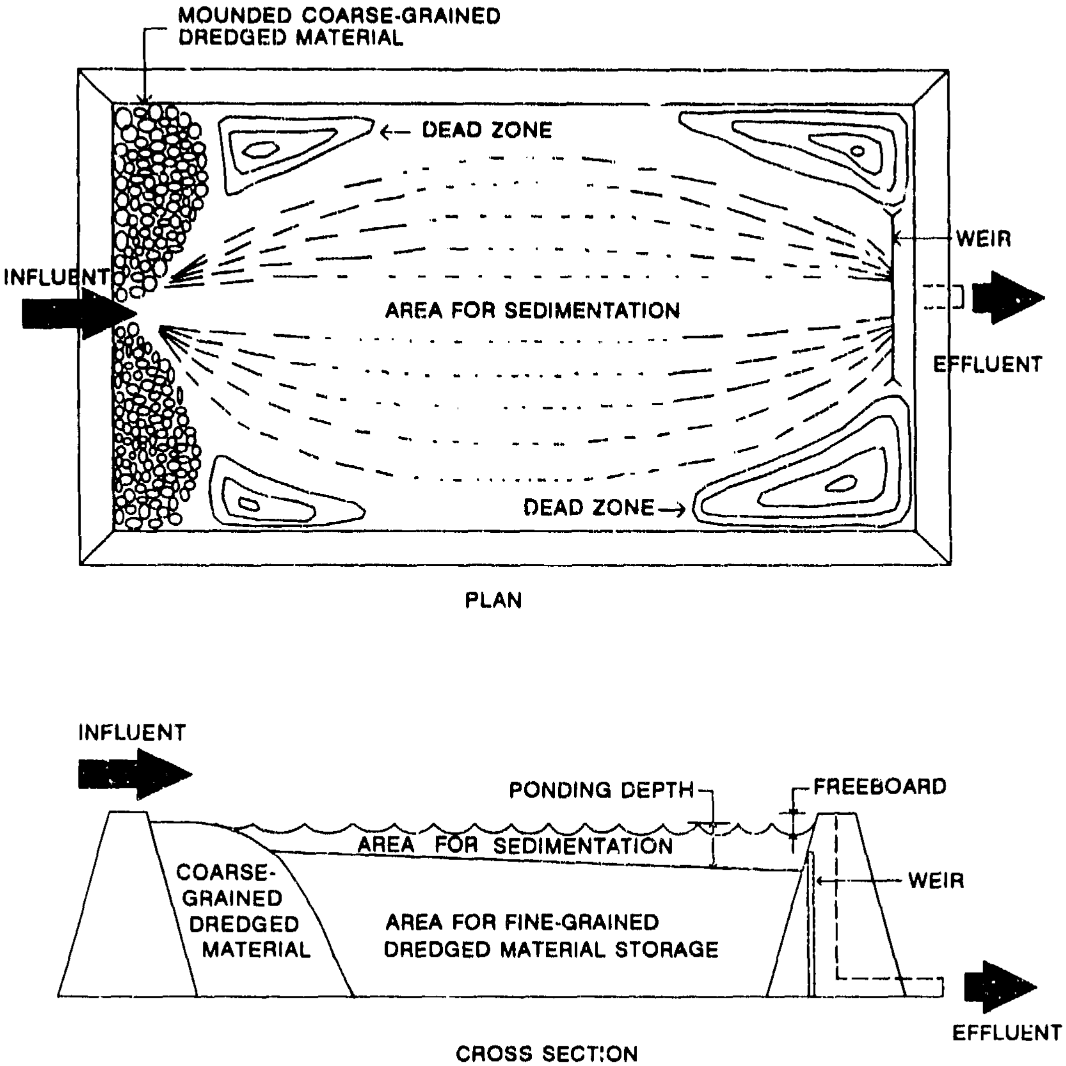

Figure 1. Conceptual diagram of a dredged material containment area (from Headquarters, Department of the Army 1987)

(Walski and Schroeder 1978). Cross dikes with multiple outflows (Figure 2) or multiple weirs (Figure 3), if correctly designed, can accomplish the same role as spur dikes (Headquarters, Department of the Army 1987).

During the disposal operation, the thickness of the deposited material increases with time until the operation is completed. In most cases, DMCA's are used periodically for many years, storing material dredged periodically over the design life of the structure. Long-term storage capacity is thus a major concern in the design and operation of DMCA's. Consolidation of retained material can increase storage capacity and extend the design life of a containment area. Consolidation is the result of dewatering the retained

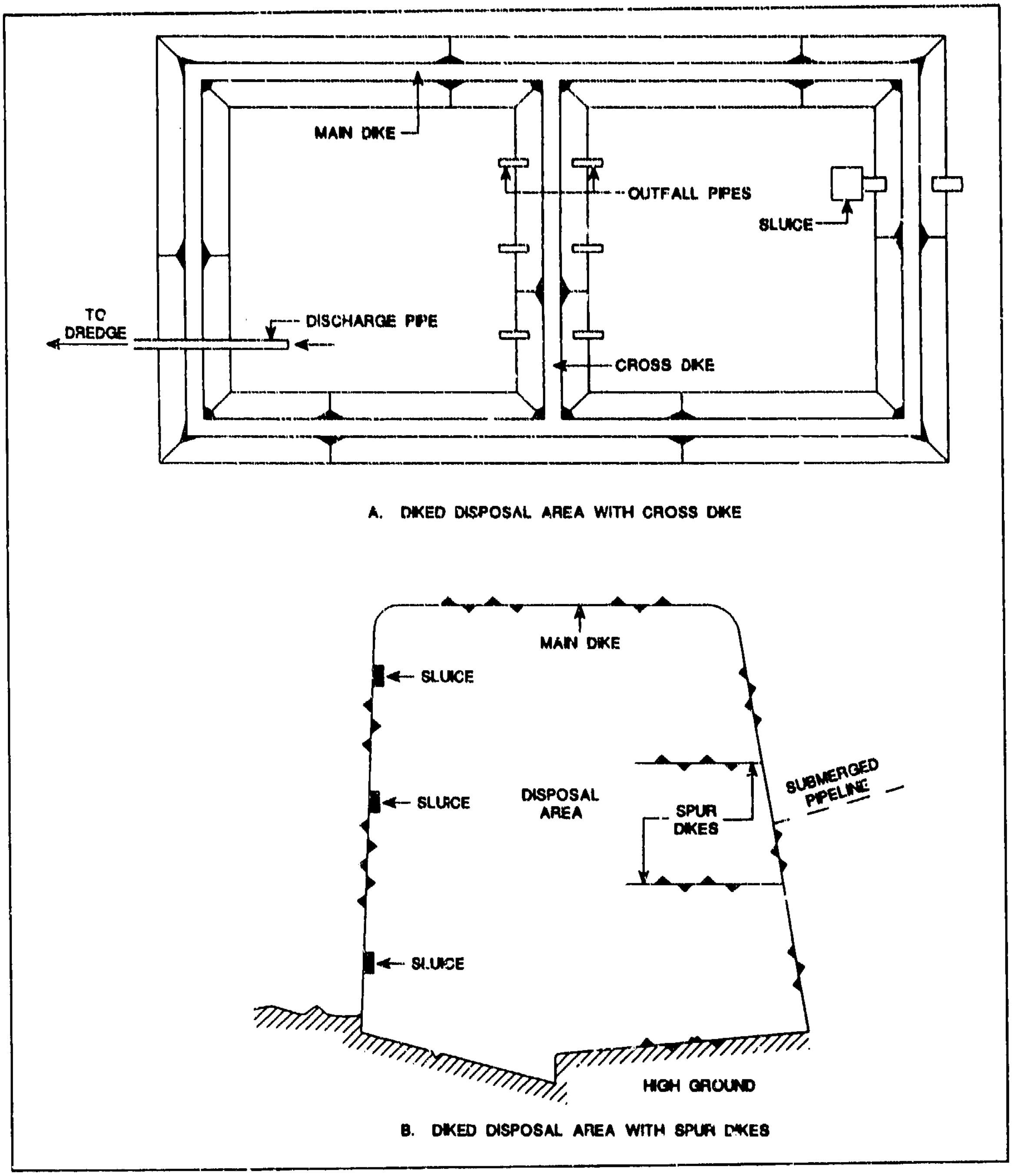

Figure 2. Examples of cross and spur dikes (from Headquarters, Department of the Army 1987)

dredged material. Natural drying and active measures such as trenching assist in dewatering the confined sediments. Once the sediments are properly dewatered and compacted, they can be reflooded without losing compaction. Management strategies that include extended drying periods or require active dewatering also affect the design and operation of a DMCA (Kyzer 1984).

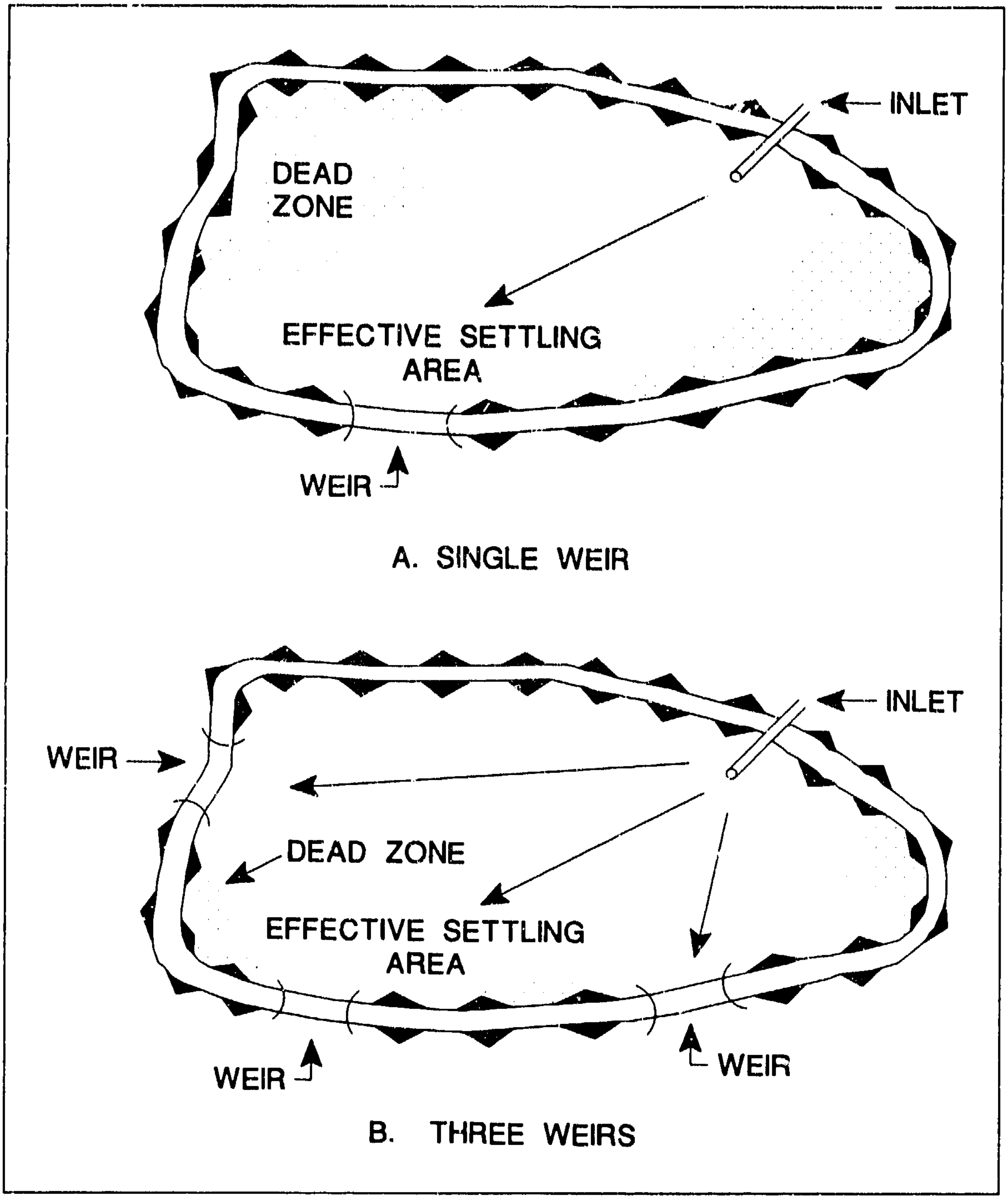

Figure 3. Effect of weir location on short circuiting (from Walski and Schroeder 1978)

2 Site Selection

Overview

Site selection and evaluation for dual use (material disposal and aquaculture) can be viewed as a four-tiered process: feasibility, compatibility, disposal suitability, aquaculture suitability. Concept feasibility must first be determined. The development of DMCA for material disposal and aquaculture can only occur in USACE Districts where DMCA's are planned, where additional DMCA acreage is required, and where district interest in the concept is present. Compatibility of aquaculture with disposal requirements must then be established. Once compatibility is established, the actual on-site selection process can proceed: (a) an evaluation of the site's potential for dredged material disposal, and (b) an evaluation of the DMCA's for aquaculture.

Feasibility Evaluation

Establishing contact and coordinating aquaculture project feasibility evaluation with the responsible local dredging sponsor and USACE District is the first step necessary in the site selection and suitability assessment process. Initial feasibility of a dual-use disposal-aquaculture confined disposal site can be established from information available from the USACE District. Port management plans (e.g. Burke and McDonald 1984, Collier 1984, Hilton 1984) are also excellent sources for initial feasibility evaluation. Information is also available from state dredging programs, local sponsors, and consulting firms working in the areas.

Three factors will determine initial feasibility:

a. There are active dredging projects which use DMCA's for disposal.

b. Additional diked disposal acreage is needed.

c. Interest in developing a dual-use DMCA (disposal and aquaculture) exists with the local sponsor and at the USACE District.

Once feasibility is established, contact should be made with the local dredging project sponsors. Local sponsors have the responsibility of locating and transferring disposal easements for DMCA's to the USACE (Collier 1984; Ryan, Calder, and Burney 1984; Lunz and Konikoff 1987b). Support from both the USACE and the local dredging sponsor is absolutely essential for the successful development of dual-use DMCA's. Both the USACE and dredging sponsors can provide a significant amount of the information required for assessing the feasibility, compatibility, and suitability of a site for dual-use material placement and aquaculture.

Compatibility of Operations

Once project feasibility and necessary agency support have been determined, the next level of site suitability assessment is entered. Detailed information about the dredging project for which confined disposal areas would be built must be assembled from the responsible USACE District, port or waterway management agency, and local sponsor. This information will serve to identify potential sites for DMCA's and establish the compatibility of planned aquaculture activities with project disposal requirements.

At least the following project information will be needed:

a. Project locations which would require additional confined disposal areas along with potential sites for such areas.

b. Project schedules, particularly frequency and duration of dredging.

c. Restrictions, if any, on dredging to specific times of the year.

d. Volume of material to be removed per dredging cycle and capacity for a given diked disposal area.

e. Physico-chemical characteristics of the material to be dredged. This includes the presence (and amounts) of any contaminants of potential concern or a "reason to believe" that contaminants may be present (LaSalle et al. 1991, Tatem 1990).

f. DMCA design specifications.

g. DMCA management strategies.

Dredging project costs are proportional to the length of time a dredge is on the job (Mayer and Stark 1984). Dredging time will vary depending on the choice of equipment; the quantity, character, and location of the material to be dredged; and the location and condition of the disposal areas (Mayer and Stark 1984). Project budgets are sensitive to variations in these factors because they directly affect the time involved in material removal, transport, and disposal. A major budget item in any dredging project is the cost of transporting material from the dredging site to the disposal location (Mayer and Stark 1984, Barr 1987). Sensitivity to this cost effectively limits the suite of possible confined disposal site locations that can serve a hydraulic dredging project to those within economical pumping distances. Therefore, the location of a dredging operation will dictate the choice of diked disposal sites available for an aquaculture venture. Once technically feasible, operationally efficient, and cost-effective sites for a particular dredging operation have been located (Burke and McDonald 1984), then land availability, environmental suitability, and construction costs interact to determine size and location of confined disposal areas (Walski and Carranza 1984).

The dredging schedule, including the frequency and duration of the dredging and disposal cycles, is a major consideration in evaluating the compatibility of material disposal and aquaculture in a confined disposal site. The planned frequency of use must allow for sufficient time for crop production between disposal events. The duration of a disposal event which closes the site to alternative uses is also an important consideration in evaluating compatibility. The main advantage of containment area aquaculture over conventional aquaculture is that capital costs for initial construction incurred by an aquaculturist may be reduced by as much as 30 to 50 percent (C-K Associates in preparation). The trade-off is that there may be a loss of up to 20 to 33 percent of production capacity due to disposal activity in a 3- to 5-year disposal cycle. Careful consideration of the effects of periodic closures on aquaculture operations and economics must be made. Alternative production scenarios for the proposed culture species and financial projections based upon these plans are essential to determine how project scheduling will affect the technical and economic viability of aquaculture operations. Careful evaluation of these effects on project operations will establish the suitability of a site for a commercial aquaculture venture.

An additional scheduling concern is the potential restriction of dredging and disposal operations to particular periods. Such seasonal dredging "windows" are often the result of environmental concerns (LaSalle et al. 1991), but restrictions may also be the result of logistic or economic factors. By their nature, seasonal restrictions on dredging are relatively inflexible. As a result, dredging and disposal operations may be forced to overlap a portion of the aquaculture production cycle. Unless an alternative production scheme (e.g. using a different species or production approach) is available, an otherwise suitable site may be unusable.

The physical and chemical characteristics of the material to be deposited in the disposal site are important determinants of the suitability of a DMCA for aquaculture. Of particular importance is the presence of contaminants such as pesticides, heavy metals, and industrial residues in the sediments. It is crucial to determine if the material to be dredged contains such compounds in amounts that warrant concern (Tatem 1983, Lee and Jones 1984, Palermo 1988). Because of the complex nature of this issue, contaminants, contaminant testing procedures, and suitability criteria are treated in a separate report (Tatem 1990).

Physical characteristics of the dredged material will directly influence the design, size, and useful life of a diked disposal area (Headquarters, Department of the Army 1987). The suitability of a DMCA for specific aquaculture ventures will also be determined by these characteristics. Large quantities of fine sediments, for example, may require DMCA's with large areas and volumes, along with internal training dikes and multiple weirs, for effective ponding and material retention. To be compatible, an aquaculture operation must be capable of operating under these conditions. Site features within the DMCA, such as bottom topography and slope, will be altered by subsequent material deposits. The effect and extent of these alterations will be determined by the characteristics of the dredged material. Finally, the height of material deposited during each dredging cycle will be, in part, a function of material characteristics. The height of these "lifts" will determine the life of the DMCA, drying times, and need for active dewatering management.

In general, existing design recommendations and construction specifications for confined disposal areas will be inadequate for an aquaculture facility, although some small-scale facilities may be compatible for both operations. Designs for confined disposal sites focus solely on meeting required levels of suspended solids retention, initial storage capacity, and long-term storage capacity (Headquarters, Department of the Army 1987). Construction methods are least-cost approaches that meet the design specifications. Because confined disposal sites are often refurbished prior to each use for dredged material disposal (Kyzer 1984), least-cost construction specifications for earthworks keep construction costs low.

Even if all other indications suggest that a proposed diked containment site is suitable for aquaculture as an alternative use, a thorough examination of DMCA design recommendations and construction specifications would be prudent. Comparing DMCA design specifications with the design requirements of the proposed aquaculture facility will determine the extent and cost of any required modifications. The feasibility and cost effectiveness of these modifications must be acceptable to both the USACE District and the aquaculture venture. Difficult or costly modifications may preclude the use of a confined disposal area for aquaculture, as would modifications that would not allow the site to be used for material disposal.

Future site conditions, management strategies, and design modifications must also be considered. For example, new construction dredging results in deposits of largely coarse materials, while materials deposited from maintenance dredging are often much finer (Headquarters, Department of the Army 1987; Averett, Palermo, and Wade 1988; Palermo 1988). As a result, containment area design requirements may change over time. A relatively simple containment area design may effectively retain the suspended solids generated by new construction. For fine maintenance material, however, spur dikes (Figure 2) to channel water flow or higher perimeter dikes to allow greater ponding depths may be required for effective retention of suspended solids. In some cases, it may be feasible to remove material by trucks after drying to maintain capacity. Such modifications or actions will enhance the suitability of a site for aquaculture operations.

Site capacity and useable life requirements depend on the consolidation of the dredged material, physical limits of the site foundation soils, and use of active dewatering techniques (discussion follows). After a dredging cycle is completed, loading on the containment area foundation may result in consolidation of compressible foundations soils. This may alter bottom topography, drainage patterns, and other features. Settlement of containing dikes may also occur. Soil foundation conditions and other considerations will also determine maximum dike heights and the required ponding area of a DMCA. Detailed descriptions of foundation evaluations and methods for estimating dike heights, ponding area, and long-term storage capacity are given by Palermo, Montgomery, and Poindexter (1978); Headquarters, Department of the Army (1987); and Schaefer and Schroeder (1988). It is important to consider the long-term effects of foundation loading for a DMCA to effectively assess the utility of a site for aquaculture.

Many USACE Districts actively manage DMCA's to increase their storage capacity and useful life (e.g. Kyzer 1984). This is frequently the case where disposal sites are difficult or costly to acquire. Management strategies employed focus on accelerating or increasing the consolidation of the deposited material within the DMCA by dewatering (Burke and McDonald 1984), by use of underdrains (Kyzer 1984), by raising dike heights, and by removing accumulated material (Headquarters, Department of the Army 1987). Dewatering may be as simple as increasing the drying time between disposal events or as complex as the construction of perimeter and internal trench systems and installation of underdrains to facilitate drainage (Kyzer 1984; Headquarters, Department of the Army 1987) Figure 4 illustrates dewatering sequences where a portion of the dredged material is borrowed to raise dike heights after dewatering. The length of time a containment area may remain unusable for alternative water dependent uses such as aquaculture may be directly affected by these dewatering operations. Long drying times may severely limit the utility of a DMCA for aquaculture even if initial examination of the disposal schedule suggests otherwise. Perimeter trenches, internal trenches and sumps, if required for gains in long-term storage capacity, may also affect planned DMCA aquaculture operations and may require alternative production plans that consider these modifications.

Similarly, methods of raising dike heights and otherwise refurbishing confined disposal areas for future disposal work must be considered when evaluating compatibility. Because such work most often uses material borrowed from adjacent areas (Headquarters, Department of the Army 1987), the plans for such work must be carefully examined. The locations of any borrow areas for dike material, quantities of borrowed material needed, location and dimensions of future dikes, and other factors must be examined for their potential effect on any planned aquaculture operations.

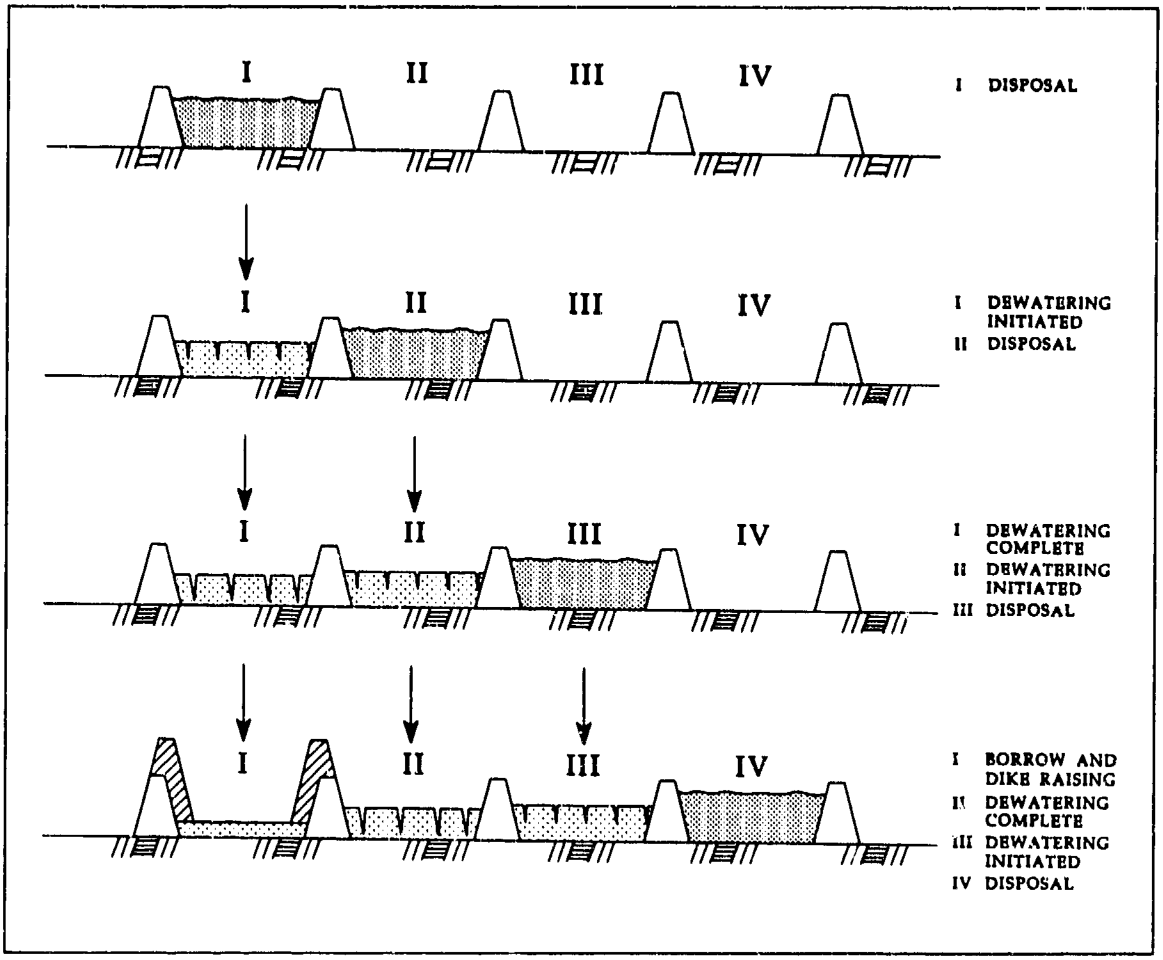

Figure 4. Possible sequential dewatering operations in a hypothetical multiple-cell DMCA (Palermo, Montgomery, and Poindexter 1978)

It is important to consider the overall effect of increased dike heights on aquaculture operations. It is not unusual for dikes to be raised to 40 ft to increase usable life in a disposal area (Burke and McDonald 1984). The effects of such changes in elevation on pumping costs, water control and harvest structure designs, and overall operations must be considered. Because dike-raising methods involve construction within the original perimeter dikes (Figure 5), the area available for material disposal decreases with each incremental increase in dike height (Headquarters, Department of the Army 1987). During subsequent disposal operations, the height of a fixed volume of material placed within the DMCA will increase because less area is available, resulting in increased drying times and/or incorporation of active dewatering techniques (Burke and McDonald 1984). The length of time an aquaculture facility may successfully operate may be determined by such management needs. Development of an aquaculture venture, the objectives of the venture, and production plans may be affected by the long-term management plans for the DMCA.

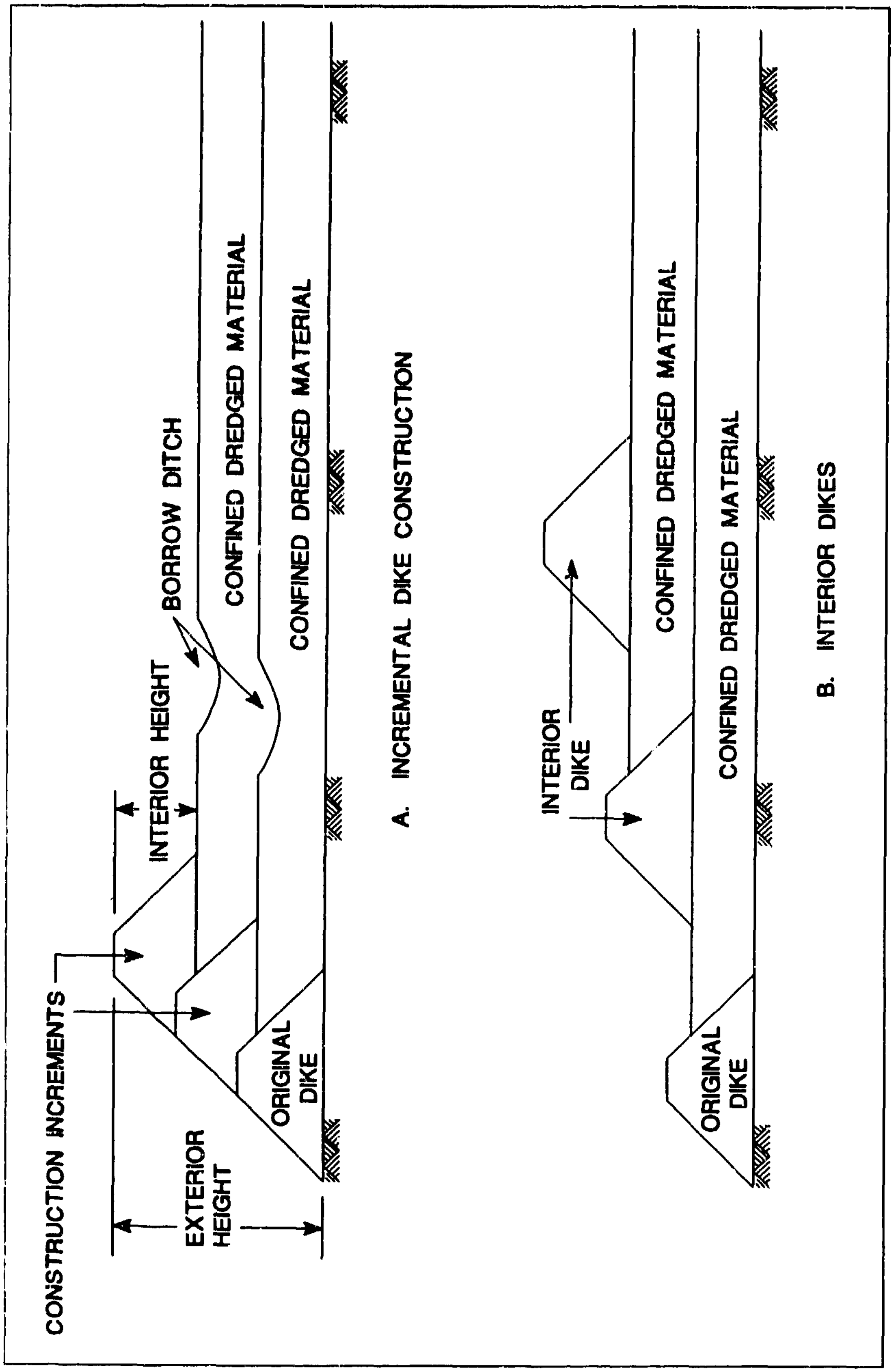

Figure 5. Dike raising methods (Headquarters, Department of the Army 1987)

A time constraint placed upon the use of a site in aquaculture will directly affect an entire suite of decisions. Site development, operations strategy, and crop management for profit maximization will all be affected.

The importance of coordinating feasibility and dual-use compatibility evaluations with the responsible USACE District cannot be overstated. All of the necessary information for an accurate assessment of the prospects of developing a DMCA based aquaculture venture is available from the USACE District. In addition, the potential for modifications of various project specifications to accommodate an aquaculture operation also resides with the USACE District. To develop a successful dual-use DMCA fully compatible with project disposal requirements and commercial aquaculture production will require a coordinated effort among all involved parties, including the local dredging sponsor.

Site Selection

Material disposal suitability

The data collected for the USACE during the confined disposal area site selection, evaluation, and design process is extremely useful in planning and evaluating the site for aquaculture. Project data (volume, flow rates, frequency, etc.) will determine overall site design, while data from the disposal site itself will provide detailed information on the physical characteristics of the planned DMCA. Where a dual-use site is being planned, any additional measurements needed to assess suitability of the site for aquaculture may be integrated with the routine site suitability evaluation process.

As discussed previously, confined disposal sites are designed, operated, and managed to receive and retain hydraulic dredging discharge and to provide long-term storage capacity for dredged material. Guidelines for the design of confined disposal sites, recommended data collection and sampling requirements, descriptions of testing procedures, recommended design criteria, and operational practices and management procedures are described more fully elsewhere (e.g. Palermo, Montgomery, and Poindexter 1978, Walski and Schroeder 1978; Headquarters, Department of the Army 1987; Averett, Palermo, and Wade 1988; Schaefer and Schroeder 1988). They will only be outlined here.

Confined disposal areas must meet four basic requirements (Burke and McDonald 1984). Sites must be technically feasible, operationally efficient, cost-effective, and environmentally sound. Once the proposed confined disposal area site meets these requirements, individual site design can proceed. Confined disposal site design consists of six components (Schaefer and Schroeder 1988):

a. Collection of project data (including disposal site characteristics).

b. Sediment characterization (including contaminants).

c. Design for initial storage.

d. Design for clarification.

e. Design for effluent quality.

f. Weir design.

The first two components, disposal site and project data, and the physical characteristics of the sediments to be dredged determine the design features of the DMCA.

Project data and sediment characteristics

The project data and sediment characterization required for the confined disposal area design and evaluation include the following (Palermo, Montgomery, and Poindexter 1978; Headquarters, Department of the Army 1987; and Schaefer and Schroeder 1988 give details):

a. Estimates of in situ sediment volume.

b. Physical characteristics of the sediment.

(1) In situ sediment concentration, void ratio, or water content.

(2) Specific gravity of solids.

(3) Degree of saturation.

(4) Coarse grained faction (greater than No. 200 sieve).

(5) Settling behavior of the material.

c. Disposal data.

(1) Dredge pipeline diameter/discharge rate.

(2) Dredging schedule and operating hours.

(3) Influent suspended solids concentrations.

(4) Target effluent suspended solids standard.

(5) Maximum required dike height.

(6) Freeboard height.

d. Disposal site data, including estimation of long-term storage capacity.

(1) Foundation conditions.

(2) Groundwater conditions.

(3) Site location and topography.

(4) Soil properties.

(5) Meteorology and climate.

Methods for estimating sediment volume, sampling techniques, and analytical methods for sediment characterization are available in various publications (Headquarters, Department of the Army 1987).

Disposal data for hydraulic pipeline dredges include the type of dredge, size, and number of dredges to be used, average distance to the containment area, depth of dredging, time required for completion, and solids concentration in the discharge (Headquarters, Department of the Army 1987). For hopper dredges and barge pump-outs, slightly different design criteria are used to account for the additional handling. A flowchart for designing a containment area with adequate space and volume for retaining solids through settling and providing storage capacity of dredged solids for a single dredging episode is shown in Figure 6. Details of the processes described in this flowchart are discussed in Averett, Palermo, and Wade (1988).

Investigations of the DMCA site itself focus on data to establish foundation conditions and to estimate long-term storage capacity of the site. These include measurements of depth, thickness, extent, and composition of foundation strata, groundwater conditions, and other factors (Palermo, Montgomery, and Poindexter 1978; Headquarters, Department of the Army 1987; Schaefer and Schroeder 1988). Because new confined disposal sites may be located in old disposal areas or inactive confined disposal sites may be reactivated, samples of the compressible deposited material will be required for consolidation tests.

Water table conditions within the containment area must also be determined for two reasons: to estimate loadings caused by placement of dredged material and to estimate potential groundwater effect (Headquarters, Department of the Army 1987). Because leachates produced during the percolation of water through even uncontaminated dredged material have the potential to adversely affect groundwater quality, careful examination of groundwater resources is required (Headquarters, Department of the Army 1987). These examinations will be conducted by the Headquarters, Department of the Army District prior to selection of a DMCA site, and the information will be available for dual-use planning.

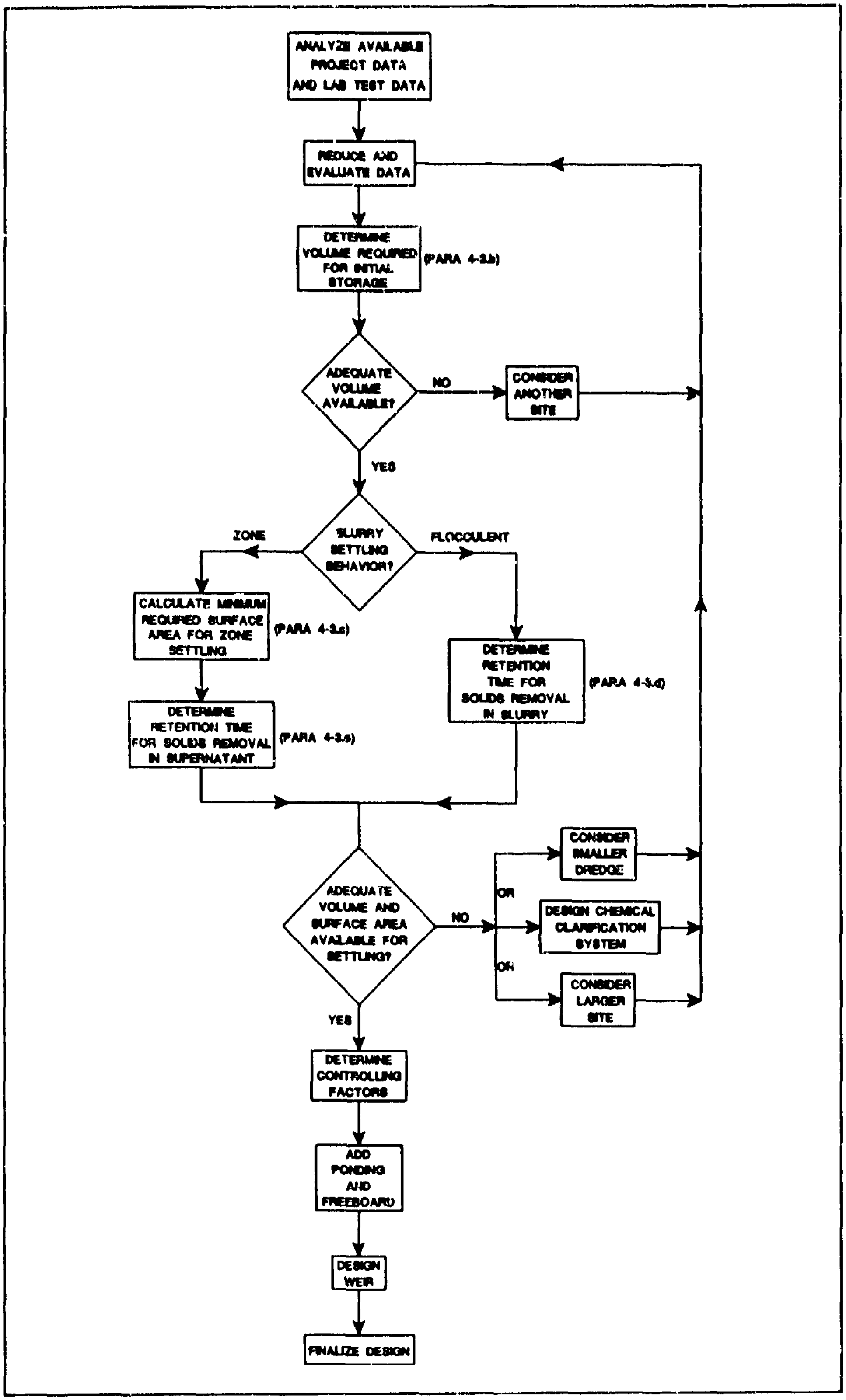

Figure 6. Flowchart of design procedure for settling and initial storage (Averett, Palermo, and Wade 1988)

Site characteristics

Table 1 lists site characteristics that affect groundwater impacts. Site characteristics of particular importance include:

Table 1
Site Characteristics Affecting Groundwater Impacts[1]

Site volume	Depth to bedrock
Site area	Depth to aquicludes
Site configuration	Direction and rate of groundwater flow
Dredging method	Existing land use
Climate (precipitation, temperature wind, evaporation)	Depth of groundwater
Soil texture and permeability	Ecological areas
Soil moisture	Drinking water wells
Topography	Receiving streams (lakes, rivers, etc.)
Drainage	Level of existing contamination
Vegetation	Nearest receptors

[1] Headquarters, Department of the Army (1987).

a. Location. Estimates of parameters needed to calculate potential impacts of a site on groundwater can often be gained from analysis of available regional data.

b. Topography. These descriptions are important in evaluating surface drainage, run-on, and runoff potential of a site.

c. Stratigraphy. This arrangement, based on soil borings to bedrock, is important in determining potential pathways of leachate flow.

d. Groundwater levels. Maps of seasonal water table contours are useful in predicting groundwater flow directions and hydraulic gradients.

e. Groundwater flow. This is derived from information on permeability and porosity of subsurface strata and from data on hydraulic gradients.

f. Meteorology and climate. Water balance for a site can be calculated from measurements of precipitation and evapotranspiration.

g. Soil properties. Measures of pH, cation exchange capacity (CEC), redox potential (Eh), organic carbon content, and soil type are important in evaluating mobility and pathways of leachates.

h. Potential ground and surface water receptors and resources affected. Information on down gradient usage of a water source potentially affected by leachates, including human and environmental resources, will affect site selection.

Preferred strategies to minimize potential groundwater impacts are to locate confined disposal areas at sites with natural clay underlying formations and to avoid aquifer recharge areas.

A summary of the factors guiding site selection for confined disposal areas are presented in Table 2 (U.S. Department of Agriculture, U.S. Soil Conservation Service 1977).

Aquaculture

Preliminary survey. In any large-scale pond aquaculture operation, whether it is in dredged material containment area or not, proper site selection is the single most important decision made. Most aquaculture business failures can be attributed to poor site selection (International Finance Corporation 1987). Selection of a suitable site determines pond construction costs, operating costs, production methods, and other factors strongly influencing the economic viability of the enterprise (Wheaton 1977).

The preliminary survey is intended to evaluate potential DMCA locations for suitability for aquaculture. Those interested in developing a dual-use disposal-aquaculture DMCA, from the dredging sponsor to the landowner, should first determine the overall suitability of the site for aquaculture. The first step is to obtain resource information on the sites. A list of primary sources of basic information is provided in Table 3. Valuable information may be gained from U.S. Geological Service (USGS) topographic maps and other large-scale maps, aerial photographs, hydrological maps, soil surveys, and land use/zoning maps. Much of this material is available from the USACE District and the local dredging sponsor, along with USACE site evaluation, pre- and post-disposal evaluation, and other useful evaluation information. Ideally, the site evaluation for aquaculture should be part of the overall site selection process, reemphasizing the need to coordinate the planning effort with the USACE District.

The preliminary evaluation should consider the following items:

a. Available area for development.

b. Compatibility of site with adjacent land uses.

c. Zoning or legal restrictions on land use.

d. Topography of the area.

Table 2
Summary of Dredged Material Containment Area Site Selection Factors[1]

Factor	Criteria
Land Use	Planned use of the site for dredged material disposal should be compatible with onsite adjacent land use. Dredged material disposal in a residential neighborhood, for example, would not be compatible.
Water Quality/Hydrology/Surface Features	The site should not be a source of water pollution. Site locations on porous soil overlying potable groundwater, in an area subject to flooding, or an area of uncontrolled surface water flow would not be suitable.
Soil Characteristics/Geological Conditions	Site soil characteristics should prevent leachate migration to groundwater sources. The subsoil of a disposal site located over groundwater should be fine-grained, impermeable material, or the site should be lined with similar material to reduce the rate of migration of leachates from the site.
Meteorological Conditions	The site should not be situated in an area of high rainfall and/or extreme wind conditions. Moisture addition to deposited material can result in leaching of contaminants to groundwater and runoff to surface water systems. Wind conditions can make the disposal site a nuisance to surrounding areas and can also result in the transfer of contaminants from the area.
Access	Existing access routes into the site should be of all-weather construction. A site that cannot be readily and economically accessed is of little use. Use of temporary surfaces should be considered first.
Environmental Concerns	The environmental significance or sensitivity of the site and adjacent areas must be evaluated to protect any established habitats. Historical or other significance of the site should also be considered.

(Continued)

[1] Adapted from U.S. Soil Conservation Service (1977).

Table 2 (Concluded)	
Social Factors	Public input should be requested and evaluated when locating a disposal site near a populated area. Both citizen groups and local businesses should be considered.
Institutional Factors	All Federal, State, and local legislation regulating dredged material disposal and land use must be identified for each site.
Economic Factors	Capital and operating costs, environmental protection costs, and transportation costs will affect the selection of a site. Cost comparisons of candidate sites should determine the most feasible.

e. Proximity to services and support systems.

f. General soil type.

g. Accessibility to site; by land, water, or both.

h. Water supply (availability and quality of seawater and/or fresh water).

Other information to be obtained during the preliminary survey are:

a. List of permits required for use of site for dredged material disposal, who holds the permits, agencies responsible for permits (contact and telephone).

b. List of DMCA site owners (with telephone numbers) and landowners along access routes.

c. List of dredging contractors (with address and telephone numbers).

There are several agencies with qualified experts who may assist in the preliminary site evaluation at no charge. Some of these agencies are listed in Table 3. Based on the information obtained from these sources, two or three of the most suitable prospective DMCA sites should be identified.

Secondary survey. A second and more detailed evaluation of the prospective sites should be conducted after the preliminary survey is completed and the choice of species and culture methods is made. In addition to the data gathered in cooperation with the USACE District during the planning phase for the DMCA, the culturist or a qualified representative should visit all the sites to collect site-specific data required to supplement existing data.

Table 3
Primary Sources for Basic Information on Prospective Confined Dredged Material Disposal Sites[1]

For Information Concerning	Contact
Area base maps	· County road department, State Highway Department · City, county, or regional planning department · USGS office or outlets for USGS map sales (such as engineering supply and sporting goods stores)
Site maps	· US Department of Agriculture (USDA), Agricultural Stabilization and Conservation Service (ASCS) · Local office of USGS · State Department of Agriculture · Surveyors and aerial photographers in the area · Local companies
Geology	· USGS reports · State Geological Survey reports · Professional geologist in the area · Geology department of local university
Soils	· USDA, Soil Conservation Service (SCS) · USGS reports of area · Geology or agronomy department of local university · State Agricultural Experiment Station
Hydrology/Water Resources	· Private and public suppliers of water · USGS water supply papers · State or regional water quality protection agencies · USDA-SCS · State or Federal water resources agencies · Local health departments · Geology and environmental science departments at local universities · US Food and Drug Administration (FDA) and the National Shellfish Sanitation Program (NSSP) for water quality standards
Topography	· USGS topographic maps · USDA-ASCS
Vegetation	· County Agricultural Extension Service · Department of agriculture at local university, local arboretum · U.S. Forest Service, Bureau of Land Management, U.S. Army Corps of Engineers · State Wildlife and Fisheries, Forestry, Environmental Departments
Land Use	· City, county, or regional planning agency

(Continued)

[1] Adapted from U.S. Soil Conservation Service (1977).

Table 3 (Concluded)	
Meteorology	· U.S. Weather Service · Nearby airports · U.S. Air Force installations · National Climatic Center · Agricultural Extension Service
Wildlife Use and/or Environmental Concerns	· State and Federal Fish and Wildlife, Environmental, and Forestry Departments · National Marine Fisheries Service · Wildlife, fisheries, and forestry departments at local universities · Archeological departments at universities or state government

Supplementary water, soil, and other samples should be collected, if needed, for additional analysis. During this secondary survey, all of the major site selection criteria for traditional pond aquaculture will be considered (Wheaton 1977, Miget 1985, Texas Aquaculture Association 1988). The type of aquaculture operation being considered will weight the importance of certain factors over others (Wheaton 1977).

There are numerous references to site selection and evaluation for aquaculture. The best guides, however, are associated with handbooks for the cultivation of particular species. For example, pond siting requirements for warm water marine fish are examined by Miget (1985), while requirements for shrimp culture are discussed by Miget (1985) and New and Singholka (1982). Clay and Kovari (1985), Texas Aquaculture Association (1988), Tucker (1985), and Wheaton (1977) discuss site selection in detail for a variety of culture systems for fresh water and marine organisms.

Before the secondary survey is conducted, draft business and management plans, based on the species and culture methods of choice, should be prepared. Recognizing that these will be incomplete without certain data derived from the secondary survey, such plans (at least in outline form) are nevertheless essential to the secondary evaluation process. The business plan is discussed in Part III of this report.

Site evaluation criteria

The following major criteria should be considered when evaluating sites for pond aquaculture in DMCA's (the parameters are *not* listed in order of importance).

a. *Topography.* Important factors to consider are the elevation at the DMCA and the tidal or river levels in the surrounding area. Knowledge of the highest high tide level or river stages (storm levels) will help determine required heights of the perimeter dikes. The site topography will also indicate the amount of grading that may be required to level pond bottoms and facilitate draining. Pond bottom elevations in relation to water supply will determine design of pumping facilities and harvest/water control structures. Topographic information will also determine drainage patterns and potential locations for facilities.

b. *Soil properties.* The following is adapted from Miget (1985). The USDA SCS should be contacted first for available soils information. Each county SCS office has a general soils map which will show the overall soil composition of the proposed site. On the back of the map is a chart evaluating the suitability of the areas covered for pond construction.

More detailed soil composition descriptions are given in the county soil profile books, also available at the SCS office. Soil chemists with the SCS will discuss the suitability of various soils for pond construction as well as visit the site to take core samples and analyze them for clay content.

The following guidelines are suggested for any excavated ponds or for any construction that will require excavation.

- 25-percent clay soil to at least a depth of 3 ft.

- No bedrock or cemented layers within 3 ft of the surface.

- No water table within 3 ft of the surface.

If the site has been farmed recently, a thorough check for pesticides or farm chemical residues should be made, especially around any previous storage or mixing areas.

c. Hydrology. Water supply for the proposed aquaculture facility is an important factor to consider in determining the suitability of a containment area pond site. Water of high quality and available in sufficient quantity during the proposed production season is absolutely necessary. The physical and chemical properties of the water should be determined to make sure that they are favorable for the optimum growth and survival of the species to be cultured. These parameters are best determined from handbooks for the culture of particular species. Temperature and (for mariculture only) salinity profiles of the water body that will supply the pond are necessary data. The aquaculturist or a qualified individual should be responsible for accurately determining water quality. A detailed chemical analyses should include an analysis of nutrients (ammonia, nitrate, nitrite, sulfates), biological oxygen demand (BOD), total solids (suspended and dissolved), and pH and inventory of contaminants, if suspected. For well water, oxygen, hardness, alkalinity, iron, and hydrogen sulfide content should also be determined.

Because salt water from underground sources may differ in composition from seawater, a complete analysis of the ions present should be made.

Biological properties of the water are also very important for a balanced pond ecosystem. Note the color and smell of the water. For brackish water ponds, note the availability of freshwater, saltwater, and groundwater supplies. Surface water sources should be free from pollutants. Industrial sewage and agricultural discharges anywhere in the area should be identified and the potential to threaten water supplies determined. Threats of future pollution should be evaluated. Contact the local health department, state water resource management or fisheries agency, or the local extension service agent for assistance with this evaluation.

If the planned aquaculture venture includes mollusc (clams, oyster) culture in marine or coastal waters, the NSSP classification of the body of water must be determined. Closed waters may not be used for shellfish culture. Anyone considering mollusc culture should be familiar with NSSP closure criteria and the history of past closures for conditionally approved waters. Contact the local U.S. FDA representative or the State Marine Fisheries office for information on NSSP certification.

The USACE site survey, made for the initial DMCA design and planning, will provide most, if not all, of the information needed by the aquaculturist on topography, soil conditions, hydrology, and other important features.

Because of the potential cost of detailed water and soil analyses, these may be postponed until after the site has met all other suitability requirements for aquaculture. Detailed soil and water tests can be run concurrently with the permitting and acquisition process.

d. Meteorological factors. Various meteorological factors should also be considered when selecting a DMCA site for aquaculture. Some of the pertinent factors are:

(1) *Prevailing winds*: Monthly average wind speeds, direction, and maxima. Wind direction and speed may affect pond design and orientation; dike construction specifications and pond management must consider effects of wind/wave erosion.

(2) *Tidal range, river stages (normal cycle and storm effects)*: Include data on hurricane and spring runoff potential. Tidal/ river data: Include tide data on water levels during average, neap, and spring tides; identify daily and monthly tidal cycles. Estuarine and river locations should have information on maximum and minimum (monthly and yearly) river stages and flows. All these factors will influence site design, engineering, and production planning.

(3) *Air and water temperature, humidity, solar radiation, and cloud cover*: Averages on a daily and monthly basis, if available. Air and water temperature means and ranges, and monthly minima and maxima, are particularly important. Dates of average first and last frost dates and records of unseasonably cold weather should be noted. Temperatures are major determinants of the species to be cultured and the management options available for that species' growing season.

(4) *Precipitation/evapotranspiration*: The average (and min./max.) monthly rainfall and evaporation rates; note the wet-dry season cycle. This information will influence dike height, water management, and design characteristics of the site.

(5) *Severe weather data*: Data on seasonality, probability, and historical records of effects of hurricanes, tornados, electrical storms, and wind phenomena (e.g. Santa Ana, scirocco) or other meteorological data should be obtained.

e. *Pollution factors*. This is of particular significance in selecting DMCA sites for aquaculture. All possible sources of pollution, including land, water, and air borne pollutants, industrial wastes, agricultural runoff, and municipal wastes should be examined in conjunction with hydrology. In agricultural areas, particular attention should be paid to farm chemicals used and practices such as crop dusting.

f. *Other factors*. There are a number of other factors that should be considered in selecting a DMCA for pond aquaculture.

(1) Legal considerations, (Robertshaw, Love, and McLaughlin 1993) must be evaluated in the site selection process. Aquaculture is a new enterprise in many areas and regulations governing such activities may not be clear.

(2) Social factors to be evaluated fall into two groups. First, local attitudes toward aquaculture development should be assessed. Local opposition to site development could potentially prevent any activity or construction, and management options may be limited. Second, the social amenities of a location should also be considered. Operations in remote or difficult locations may be difficult to staff, protect from vandalism, and access for harvesting and servicing.

(3) Economic considerations (C-K Associates in preparation) are affected by costs and availability of infrastructure necessary to support aquaculture in a given location. Infrastructure for aquaculture development consists of the goods and services that any business venture requires as inputs. The main categories (Posadas and Homziak 1989) are:

- Project planning
- Transportation
- Utilities
- Communications
- Construction
- Equipment
- Supplies
- Support services
- Other miscellaneous

The cost, quality, and availability of these goods and services may greatly influence the profitability of a given aquaculture venture (Hanson et al. 1988). During the project feasibility analysis, it is crucial to carefully assess the infrastructure needs of the proposed aquaculture operation. Section V, Part D, from Posadas and Homziak (1989), provides a checklist of infrastructure resources required to support aquaculture development.

Final site selection

The results of the secondary survey, based on the factors and criteria discussed, should be compared to the requirements for planned operations. Alternative sites that also meet the selection criteria should be noted. Should acquisition of one site fail, the alternative automatically becomes the site of choice.

3 Project Planning

The core of the planning process is the business plan. A good comprehensive aquaculture business plan contains many elements, including pro forma financial statements, operations descriptions (with species choices), performance assumptions, business organization, market descriptions, and discussion of marketing strategy. A number of excellent publications are available on business plans (e.g. Osgood 1983; Owen, Gardner, and Bunder 1986). Excellent reviews of aquaculture business plan development are presented by Hanson et al. (1988) and Roberts and Harper (1988). Insights on financial planning useful in preparing aquaculture plans are given by Rhodes (1983), Lindbergh and Pryor (1984), and Huguenin and Webber (1981). Good production handbooks (e.g. Chamberlain, Haby, and Miget 1985; Chamberlain, Midget, and Haby 1987), aquaculture investment guides (e.g. International Finance Corporation 1987) and local university extension and sea grant services (e.g. Garling and Helfrich 1982; Else, Paust, and Burns 1987; Keenum and Waldrop 1988) provide excellent guides to financial, production, and management data for successful aquaculture enterprises.

The plan has many uses including objectively evaluating a business idea, presenting the background, abilities, and structure of the business, detailing development and operations plans, and, perhaps most importantly, providing the main vehicle for obtaining financing (Hanson et al. 1988).

The steps in preparing a plan (Hanson et al. 1988) are as follows:

a. Ascertain that the business idea is worth pursuing.

b. Convert the business idea into specific goals.

c. Identify specific products and markets.

d. Design the proposed facility and plan operations.

e. Create alternative scenarios for accomplishing goals.

f. Analyze alternatives under various conditions of production success.

g. Complete plan with proposed alternative and financial projections. Keep the plan on track with a specific goal and a logical plan for achieving it.

Confirming the potential of a business idea in aquaculture requires research. The following sources will be useful (see Hanson et al. 1988): aquaculturists and those in aquaculture related businesses, Government resources (Extension Service, State Natural Resource personnel, fisheries agencies), industry publications, local universities, text books, and aquaculture consultants. The business goals for aquaculture ventures are the same as for any other business and should be clearly stated. Identifying markets and channels for marketing the product are extremely important and often overlooked planning tasks. The importance of marketing and selling in aquaculture should be recognized. More than their traditional agricultural counterparts, aquaculturists may be involved in selling as well as marketing (Roberts and Harper 1988).

For this document, planning the operation will focus primarily on integrating aquaculture operations, as a compatible alternate use of DMCA's, with scheduled material disposal. Species selection, site management strategies, and other operational details are not covered but are left to the individuals or groups intending to operate aquaculture ventures in DMCA's.

Numerous references to the commercial pond cultivation and management of marine and freshwater species are available for use in this phase of the planning process. For species and specific works, see Chamberlain, Haby, and Miget (1985), Chamberlain, Miget, and Haby (1987), and Tucker (1985); and for treatments of groups of similar organisms, see McVey (1983), Dupree and Huner (1984), Stickney (1986), and Texas Aquaculture Association (1988). Journals, such as *Aquaculture Digest, Aquaculture, Aquaculture Magazine, Fish Farming International, Coastal Aquaculture,* publications of aquaculture associations (e.g. American Fisheries Society, Catfish Farmers of America, Striped Bass and Hybrid Striped Bass Producers Association, World Aquaculture Society, and others) and information put out by university extension services, sea grant offices, and commercial newsletters are all useful. A central source for much of this information is the National Aquaculture Library, a division of the National Agricultural Library in Beltsville, MD. Their *Quick Bibliography Reference Series* publications (e.g. Hanfman 1987, Mazzaccaro 1988) are excellent sources of information. Publishers of scientific texts (e.g. Unipub, for F.A.O. publications, Elsevier, CRC Handbooks, Academic Press, Wiley, Fishing News Books, and others) should be contacted for their fisheries and aquaculture offerings. They may also be available at local university libraries or public libraries through inter-library loan programs.

The initial fundamental decisions regard choices of site, species, and production methods. To choose successfully requires a thorough review of information available on the subject and, if available, professional assistance. The production cycle can then be described (Figure 7). The next step is to set the important performance parameters for the proposed operations. Tables 4 and 5, taken from Rhodes and Hollin (1987), provide examples of the most

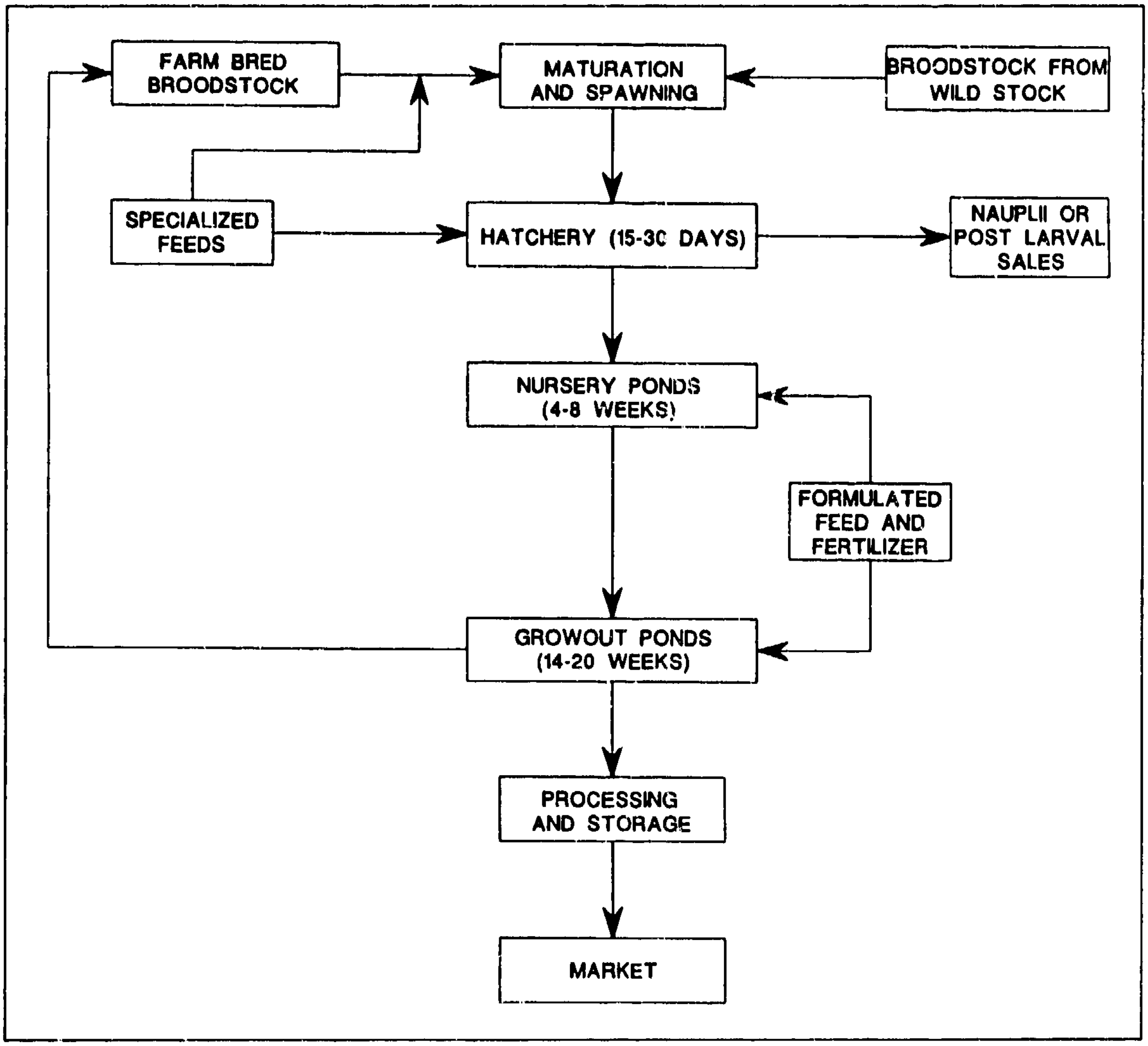

Figure 7. Integrated Shrimp Farm Production Cycle (adapted from International Finance Corporation 1987)

important production assumptions required before proceeding with development for a fish farm. These are the characteristics that will directly influence both capital and operating costs. Refer to specific handbooks (e.g. Chamberlain, Haby, and Miget 1985; Chamberlain, Miget, and Haby 1987; Else, Paust, and Burns 1987; Keenum and Waldrop 1988) for examples of project specific assumptions.

Project output and revenues for financial analysis are determined from the key performance characteristics described in Table 4. These performance characteristics are needed to evaluate the profitability of a project. They are critical because they also influence capital development (start-up) and operations costs (International Finance Corporation 1987, Rhodes and Hollin 1987). The planning process also involves constructing detailed cash flows for

Table 4
Example of Performance Characteristics for a Hypothetical Red Drum Semi-Intensive Farm in South Carolina (from Rhodes and Hollin 1987)

Yearling Ponds:	
Stocking Density, fingerlings per acre:	5,882
Duration of Yearling Cycle, months:	9
Projected Survival Rate:	8
Size of Yearling Ponds, acres:	5.0
Number of Yearling Ponds:	6.0
Total Yearling Pond Acreage:	30.0
Projected Yield, number of fish/acre:	5,000
Growout Ponds:	
Stocking Density, yearlings per acre:	1,250
Duration of Growout Cycle, months:	10
Projected Survival Rate:	95.0%
Size of Growout Ponds, acres:	20.0
Number of Growout Ponds:	6.0
Total Growout Pond Acreage:	120.0
Average Harvest Weight, lb:	3
Projected Yield, lb per acre:	3,563
Other Characteristics:	
Feed Conversion Ration (FCR)[1]: (Pounds of Feed: Pounds of Live Red Drum)	2.5
Average Paddlewheel HP/Growout acre:	1.0
Average Paddlewheel HP/Yearling acre:	2.0

[1] The FCR is projected to decline 0.1 per year after year 1 until it reaches 2.0 in year 6.

analysis under various production assumptions. Financial and economic analyses are treated in more detail in a separate publication of this series (C-K Associates in preparation).

There are four critical factors to consider in planning an aquaculture venture prior to any detailed financial analyses: site selection, management, availability of technology, and seedstock and project design (International Finance Corporation 1987, Rhodes and Hollin 1987).

Table 5
Major Financial Assumptions for a Hypothetical Semi-Intensive Red Drum Farm in South Carolina (from Rhodes and Hollin 1987)

Depreciation Treatment: Modified Accelerated Cost Recovery System (MACR) (No IRS Section 179 deduction was used)
Income Tax Rate: Federal: Corporate rate effective after July 1, 1987 State: 6% of Net Income (Note: Alternative minimum taxes, net operating losses, and other tax treatments affecting corporate income taxes were not considered in this analysis.)
Type of Capital (Debt to Equity Ratio): 100% Equity
Inflation Rate: 3% compounded annually after Year 1
Land Cost: Leasing at $75 per acre per year.

The importance of site selection cannot be overemphasized. The leader of the aquaculture venture may choose to rely on outside sources for assistance but must be well enough informed to take full responsibility for final decisions (Garling and Helfrich 1982). In DMCA aquaculture, the wealth of information gathered during the siting and design of the confined disposal area will provide a sound basis for selecting a site on physical characteristics. Exhaustive research (see Hanson et al. 1988 for examples) will allow the planner to factor in other important, but less easily quantifiable, site selection factors such as location, infrastructure availability, local support or opposition, and others.

Several other factors must also be considered during the planning process. The success of any organization is dependent upon the technical and management personnel employed (Rhodes 1983). Locating and recruiting key personnel should be given high priority.

Availability of technology to support a particular production plan is also critical. Aquaculture production methods, even if proven on an experimental level, may depend on new technology to make them commercially feasible (see Huguenin and Webber 1981, Lindbergh and Pryor 1984, Roberts and Harper 1988). The seasonality of seed production, composition of feed, ease of breeding, and many other technology dependent factors will affect project plans. Do not base plans on yet-to-be developed commercial level processes or products (see Lindbergh and Pryor 1984 for succinct advice), and beware of the difficulties inherent in scaling up experimental or pilot systems to commercial levels (Huguenin and Webber 1981).

A schematic production cycle (Figure 7, from International Finance Corporation 1987) is useful in identifying all of the necessary stages that must be evaluated in assessing the technical feasibility of a project. Personnel requirements, support equipment, infrastructure needs, and other production features can be matched to production cycle needs.

There are limits constraining the planning process which must be appreciated. Because commercial production techniques for many species are rapidly changing, current knowledge may soon be obsolete (C-K Associates in preparation). For species new to cultivation, such as striped bass and hybrids (Kerby 1986) and redfish, growout techniques, hatchery technology, broodstock acquisition, feed formulations, and market information and strategies have not been adequately tested in commercial production. Many of the physical production parameters are interrelated. Harvest weight, for example (Keenum and Waldrop 1988), is a function of growth, itself the product of several interrelated functions, including biological potential, stocking density, grow-out days, water quality, and feed conversion. The quantitative relations between these factors and the influence of others is not well known, especially at commercial scales of operations. These precautions and limitations should be kept in mind when planning a DMCA or any other aquaculture venture.

Planning for a DMCA-based aquaculture facility should adhere closely to the business plan format recommended for any business. Compared to other aquaculture ventures, DMCA-based aquaculture planning will emphasize how production operations, performance assumptions, management, and financial aspects are affected by integrating aquaculture operations with disposal activities. Particularly important are cost liabilities, benefits in capital expenditures, and the financial effects of disposal interruptions on production costs. The planning process should begin as soon as possible.

The production methods and operational plans should guide the site selection and feasibility evaluation process. Preliminary selection of species, market analysis, and outlines of possible management and production scenarios may be developed somewhat independently of site. These concepts will then be refined during the various steps of preliminary and secondary site assessment and feasibility analysis.

4 Site Acquisition and Permitting

Acquisition

Acquisition and retention of disposal sites is a primary concern of USACE Districts (Homziak and Lunz 1983; Coleman, Homziak, and Dugger 1990). The availability of disposal easements has been severely limited in recent years due to environmental constraints and increasing land values. The USACE is primarily interested in aquaculture in DMCA's to increase site acquisition and retention for dredging. The prospective aquaculturist may work with the USACE, the dredging sponsor, and the landowner to obtain aquaculture leases for new confined disposal areas. For existing but inactive DMCA's, existing easement agreements must be amended, requiring prospective aquaculturists to reach separate agreements with the property owner, local dredging sponsor and the USACE (Lunz, Nelson, and Tatem 1984). Such amendments may warrant extensive legal involvement and an attorney should be consulted and retained if necessary by the prospective farmer until all easements are settled and acquisition of the containment area site for aquaculture is complete. The legal considerations of DMCA aquaculture, including site leases, easements, and other concerns will be covered in depth in a separate report in this series (Robertshaw, Love, and McLaughlin in preparation).

The prospective aquaculturist may either purchase the DMCA or, more probably, negotiate a long-term lease for the property. Property should not be purchased or leased, even if it is fully suitable, until it is reasonably certain that all required permits for both material disposal and aquaculture can be obtained.

Permitting

The acquisition of permits is a critical step in establishing aquaculture operations in a confined disposal area. Even after the property has been acquired, culture operation cannot begin until permits from all the appropriate regulating agencies are in place. Since many of the permits required by an aquaculture operation are also needed for DMCA construction and operation, coordinating the aquaculture and disposal permit efforts will save both time and effort for the aquaculturist. The report on legal and institutional constraints on DMCA aquaculture (Robertshaw, Love, and McLaughlin 1993) treats the subject of Federal and State permits thoroughly and provides recommendations on coordinating aquaculture and disposal permits. As stated previously, close coordination with the USACE District will be crucial in this process.

Local regulations, including zoning and land use restrictions, and their potential effects on DMCA aquaculture activities, are numerous. It is recommended that local sources of this information (e.g. county or state economic development agencies, planning bodies) be developed during the primary and secondary site evaluation phases described in Chapter 3.

Barr (1987), Engler et al. (1988), and McLaughlin, Howorth, and Hunt (1989) provide reviews of the regulatory framework guiding dredging, and disposal of dredged material. While the discussion of state regulations by Barr (1987) and McLaughlin, Howorth, and Hunt (1989) is limited, the approach, discussion of Federal requirements, and suggested actions make these references useful for anyone involved in DMCA aquaculture. Engler et al. (1988) review disposal guidelines in relation to Federal standards. The USACE District with responsibility over the project will have detailed information on permit requirements and will have experience in obtaining the permits needed for site construction and dredged material disposal.

Generally, the following agencies have a role in the Federal permit and regulatory process for confined disposal area site construction, material disposal, and effluent water quality control.

a. State Coastal Zone Management Agency: reviews activities requiring Federal permits for consistency with state regulations.

b. U.S. Army Corps of Engineers, Section 10, Section 103, Section 404 permits: required for any construction activity seaward of mean high water. A State Water Quality Certificate is also required to satisfy Section 401, Federal Water Pollution Control Act, before any USACE permit is issued.

c. U.S. Environmental Protection Agency: acts chiefly in an advisory role but can assert significant regulatory authority under Federal Water Pollution Control Act, National Environmental Policy Act of 1969, and Marine Protection, Research and Sanctuaries Act of 1972. EPA coreviews USACE Section 404 permit applications.

d. U.S. Fish and Wildlife Service: no permit required; a major participant in Federal permit reviews, predominantly advisory capacity. Responsible for the assessment of impacts on fish and wildlife in all land and water related development projects using requiring Federal permits. Operates under a variety of authorizations.

e. National Marine Fisheries Service: no permit required; advisory capacity; uses a broad spectrum of regulatory authority to ensure that all coastal zone development activities give full consideration to fisheries impacts.

f. National Park Service: advisory capacity for projects on park lands.

g. U.S. Coast Guard: has authority and responsibility for construction permits for projects in navigable waters.

Barr (1987), McLaughlin, Howorth, and Hunt (1989), and Robertshaw, Love, and McLaughlin (in preparation) discuss the permits, authorization, filing procedures, and other details for permit applications and reviews with these agencies. State and local DMCA permit regulations vary greatly. State agencies responsible for fisheries, wildlife, environmental protection, and water quality generally play a role in permitting a confined disposal area. The local USACE District is the best source of information on these permits.

Aquaculture permits are covered by the same Federal regulations that govern construction, environmental protection, and water pollution in the coastal zone, essentially the same agencies that regulate DMCA construction and operation. The National Research Council (1978), the Aspen Institute (1980), Wypyszinski (1983), and South Carolina Joint Legislative Committee on Aquaculture (1989) discuss Federal regulations pertaining to aquaculture. Also, Harrison (1983) discusses laws governing the acquisition, maintenance, and operation of dredged material disposal while Theberge (1983) gives a synopsis of legal aspects of containment site mariculture.

State regulations governing aquaculture vary greatly. Younger, Moseley, and Shiner (1987) review a number of coastal state regulations pertaining to pond culture of marine fish. Because regulations for individual states are presented in such a variety of publications (e.g. McGlew and Brown 1979; Stickney and Davis 1981; South Carolina Sea Grant Consortium 1982; Florida Aquaculture Review Council 1985; Younger 1985; California Interagency Committee on Aquaculture Development 1988; Landkamer, Gross, and Kapuscinski 1988; McLaughlin, Howorth, and Hunt 1989; South Carolina Joint Legislative Committee on Aquaculture 1989), a synthesis of state regulations potentially affecting DMCA aquaculture is presented in a separate report of this series (Robertshaw, Love, and McLaughlin in preparation).

Local regulations, those below the state level, may also affect DMCA aquaculture development. Contacts with economic development interests, planning agencies, or marine advisory and extension services early in the planning process will allow these regulations to be adequately addressed. See McLaughlin, Howorth, and Hunt (1989) for an example of local regulations.

A brief synopsis of the permitting process and recommended procedures to follow are presented below, adapted largely from Younger, Moseley, and

Shiner (1987). Information from Dugger and Roegge (1983), Barr (1987), and Younger (1985) is also included.

Regulations governing aquaculture were enacted for legitimate purposes of water quality and wetlands protection, public health service, and others. Because these laws were enacted largely before the recent growth in aquaculture, they often do not consider the unique circumstances and requirements of the industry. Permits and the associated review and approval processes are an unavoidable requirement for any operation. To successfully begin an aquaculture venture, the permit process must be considered thoroughly and planned with the same care and effort put into any other aspect of the operation.

The first step is to identify the permitting and review agencies involved. The local USACE District office cooperating on the project and the local marine advisory or agricultural extension service agents are invaluable resources. When the permitting and reviewing agencies are known: request information and copies of the applications from the various agencies identified; allow plenty of time for permit approval; ask how long the process is expected to take; review the applications and meet informally with agency representatives to fully understand requirements and procedures; prepare useful maps, plans, drawings, etc. to accompany required documents; interact frequently with the permitting and reviewing agencies to promptly identify inadequacies in the application materials. Again, do not commit irrevocably to a site before you are reasonably certain that all the necessary permits can be obtained. Be sure to start early, be thorough, and accurate in completing applications and be cooperative with the agencies.

In completing the applications, plan ahead and allow for excess requirements to accommodate emergencies or expansion. Plan to avoid additional permit requests in the future. Plan with the USACE District and the local dredging sponsor to have the permits required for DMCA construction and operation modified to include aquaculture operations requirements. This is a critical step. The local dredging sponsor may already hold certain permits for future DMCA sites that are not yet developed. The permits required for construction and use of a confined disposal area (required by State and Federal agencies), including those affecting water rights or use (State), water discharge (State, Federal), construction in wetlands jurisdictions (State, Federal), coastal zone development (State, Federal), or affecting wildlife, fisheries, or the environment (State, Federal) will also be required by the aquaculture facility. If at all possible, arrange to have the permits required for planned DMCA aquaculture venture included in the overall DMCA and dredging permit requests.

5 Checklists for Determining Potential of Using Existing Containment Areas for Aquaculture

Purpose and Scope of the Checklists

These checklists provide the prospective aquaculturist, the USACE, Federal, State, and local regulating agencies, and other interested parties with a summary and quick reference of all the results obtained during feasibility and compatibility analysis, site selection, planning, and acquisition. The checklists cover the possible factors that must be considered in site selection and evaluation of containment areas for pond aquaculture.

Four parts are listed:

a. Part A is the preliminary survey and collection of background information.

b. Part B is the secondary survey of all the candidate DMCA's selected in Part A, the preliminary survey with a summary of activities and factors that must be considered.

c. Part C outlines the requirements for site acquisition, preparation, and operation of the selected DMCA.

d. Part D outlines the suggested infrastructure needs to be investigated for aquaculture development.

Part A: Preliminary Survey and Background Information - Identification and Compatibility of Planned Containment Areas for Aquaculture[1]

Background work

a. Determine feasibility of dual use DMCA's. Contact the USACE and solicit their cooperation. Contact project sponsor to establish support.

b. Determine project locations that require additional DMCA's.

c. Identify and secure all relevant documents and maps, and identify information resources.

(1) Large scale base maps.

(2) Topographic maps.

(3) Aerial photographs.

(4) USACE documents.

(5) Port management plans.

- Post disposal evaluation report.
- Environmental reports and assessments.
- Project documents, including previous projects in area.
- Construction and project specifications and invitations for bids.

(6) Contacts and information sources

- Permit and review agencies.
- Site owners and landowners along access routes.
- Dredging contractors.
- Local economic development assistance groups.
- Other aquaculture operations in local area.

---

[1] These are minimum suggested requirements to be investigated. Additional items, particularly those of a site-specific or project-specific nature, may frequently be required.

Part A (Continued) (see text for details)

d. Review culture techniques and biology of the target species.

e. Develop preliminary production and business plans.

a. Locate all candidate sites in area.

b. Determine dredging schedule, season, lengths of time site will be used for disposal.

c. Determine access, power supply lines, other basic services to site.

d. Determine characteristics and volume of material to be deposited at site.

(1) Estimates of in situ sediment volume.

(2) In situ sediment concentration, void ratio, or water content.

(3) Specific gravity of material.

(4) Degree of saturation.

(5) Coarse grained fraction (> No. 200 sieve).

(6) Settling behavior of the material.

(7) Contaminant status (present, reason to believe, absent).

e. Evaluate current soil characteristics at site.

(1) Soil classification (SCS).

(2) Soil particle size and shape.

(3) Permeability/porosity of soil.

(4) Percent clay content.

(5) History of contamination (agricultural, industrial).

f. Evaluate hydrological properties of source water (monthly means, ranges, monthly and annual minima and maxima).

(1) Temperature.

(2) Salinity.

Part A (Continued)

(3) Tidal range (average and maximum).

(4) Solutes.

(5) Nutrients.

(6) Dissolved gases.

(7) Contaminants, agricultural runoff, sewage, wastewater.

(8) National Shellfish Sanitation Program (NSSP) classification (surface marine water sources).

Disposal operations data evaluation

a. Frequency of disposal operations.

b. Duration of site closure.

c. Season(s) or months of year dredging scheduled (include regulated restrictions).

d. Discharge rate, net volume retained.

e. How long will site be used?

f. New work/maintenance work. If new work, repeat evaluation of dredged materials and site design for maintenance work conditions.

g. Compatibility of site for disposal of dredged material and aquaculture based on dredging operations schedule.

Disposal site data evaluation

a. Foundation conditions of base strata.

(1) Depth.

(2) Thickness.

(3) Extent.

(4) Composition.

Part A (Continued)

Disposal site data evaluation (Continued)

b. Groundwater conditions.

(1) Depth.

(2) Hydraulic gradients.

(3) Down gradient use.

c. Site location and topography.

d. Proposed disposal area design.

(1) Dike dimensions.

(2) Weirs (number and placement).

(3) Spur dikes.

(4) Intended ponding depth.

(5) Height per lift of material.

(6) Intended storage capacity of site.

(7) Other features.

e. Soil properties (for new disposal site; repeat for material after disposal).

(1) Soil type.

(2) pH.

(3) Eh.

(4) Organic carbon.

(5) Cation exchange capacity.

(6) Engineering data.

f. Site-specific meteorology and climate.

(1) Water budget (rainfall, evapotranspiration).

(2) Wind data (direction, average speed, maxima).

Part A (Continued)

(3) Tidal data (cycle, maximum and minimum heights).

g. Site-specific management plans.

(1) Proposed future site refurbishing plans.

(2) Dewatering.

(3) Future dike elevation methods.

(4) Borrow area placement.

(5) Other management requirements.

Candidate site data form

Candidate Sites							
			Location				
Candidate No. (Example)	Site Name	Map Reference Code	Municipality	County	State	Area (acres)	Estimated Capacity (million cu yd)
1	Cove	A49	Shrimptown	Wilson	TX	125	30.8
2							
etc.							

Part B: Secondary Survey - Detailed Site-Specific Data Collection

Because the disposal of dredged material takes precedence over aquaculture, the USACE requirements for new DMCA must first be met before accommodating those for aquaculture. However, there are enough overlaps in the requirements for site selection for DMCA's and conventional aquaculture to allow both the USACE and the aquaculturist to work together successfully. The checklist that follows is a modification of Checklist B of the USDA SCS (1977). Much of the information is available from the USACE site survey.

Candidate Site No. ______________________________

Site Name ______________________________

Location ______________________________

Map Reference Code ______________________________

Determine Relevant Land Use Information and Institutional Constraints for This Site:

	Onsite	Adjacent Property or Vicinity
a. Property owner(s)	______	______
	______	______
(1) Address	______	______
	______	______
(2) Telephone No.	______	______
	______	______
	______	______
	______	______
	______	______
	______	______
	______	______
	______	______
	______	______
b. Land use		
(1) Previous		
· Recent past	______	______
	______	______
· Archaeological & historical significance	______	______
	______	______
	______	______
(2) Present	______	______
	______	______

Note: One set of this form (Part B) should be completed for each candidate disposal site.

Part B (Continued)

	Onsite	Adjacent Property or Vicinity
(3) Projected		
· Without dredged material disposal area	____	____
	____	____
· With dredged material disposal area	____	____
	____	____
· Long-term (after termination of disposal operations)	____	____
	____	____
	____	____

c. What existing improvements would require relocation?

	Onsite	Adjacent Property or Vicinity
(1) Utilities	____	____
(2) Pipelines	____	____
(3) Roads	____	____
(4) Residences	____	____
(5) Other structures	____	____

d. Could site used as dredged material disposal area conform to:

(1) Area (county/municipal) land use plan? yes ____ no ____

(2) Zoning regulations? yes ____ no ____

If not, are variances or special permits available? yes ____ no ____

(3) Pollution control requirements?

· Federal yes ____ no ____

Part B (Continued)

- State yes ____ no ____
- Local yes ____ no ____

e. Anticipated land trade-off requirements ______________________________
____

f. Comments ____
____

g. Based on land use information and legal constraints, site use for disposal of dredged and aquaculture material would likely be:

(1) Feasible ____

(2) Uncertain ____

(3) Not feasible ____

Characterize Physical and Chemical Features of This Site

a. Soils (initial site conditions and post disposal conditions)

(1) Soil type/classification ______________________________
____

(2) Soil profile (Soil Conservation Service) ______________________
____
____
____

(3) Suitability for pond construction ______________________
____

(4) Particle size, shape (mean size, sorting, size frequency distribution, clay content) ______________________________
____
____

(5) Percolation rate ______________________________

(6) Compression ______________________________

(7) Angle of repose ______________________________

Part B (Continued)

(8) Fertility ____
____

(9) Bacterial population ______________________________________
____

(10) Soil color ____

(11) Presence of calcium carbonate, iron sulfides, other features________
____
____

(12) pH, Eh ____

(13) Presence of contaminants __________________________________
____
____

(14) Other pertinent information _________________________________
____
____
____

b. Subsurface hydrology

(1) Existence of aquifer beneath site? yes ____ no ____

(2) What kind?

- Artesian ____
- Unconfined ____

(3) Estimated range of depths to aquifer ______________________

(4) Provide available subsurface waterquality data

<u>Primary Factors:</u>

Ammonia	____ppm	Nitrite	____
Nitrate	____ppm	Sulfates	____ppm
Total Dissolved Solids (TDS)	____ppm	Total Dissolved Gas (TDG)	____%

Part B (Continued)

Total Suspended Solids	____ppm	Turbility	____
Biochemical Oxygen Demand	____	Chemical Oxygen Demand	____
Ph	____	Specific Conductors	____

<u>Secondary Factors:</u>

Aluminum	____ppm	Fluoride	____ppm
Ammonia (Undissociated)	____ppm	Hardness	____
Bicarbonate	____ppm	Hydrogen Sulfide	____ppm
Cadmium	____ppm	Iron	____ppm
Calcium	____ppm	Lead	____ppm
Carbonate	____ppm	Magnesium	____ppm
Chloride	____ppm	Manganese	____ppm
Chromium	____ppm	Mercury	____ppm
Color	____units	Silica	____ppm
Copper	____ppm	Sodium	____ppm
Fecal-Coliform	____mpn/100 ml.		

<u>Water Quality Standards:</u>

Agency: ______________________________

Phone: ______________________________

a. Temperature of Water Source ____Centigrade/Fahrenheit

Part B (Continued)

b. Flow Rate

Total Flow Rate ____gpm

Artesian Flow Rate (if available) ____gpm

c. NSSP classification (if applicable)

<u>Well Data:</u>

Pump Model ______________________________

Pump Capacity ______________________________

Casing Size ____________________inches

Water Depth ____________________feet

Pumped Flow Rate ________________gpm

Deepwater Temperature __________Centigrade/Fahrenheit

Surface Water Temperature _______Centigrade/Fahrenheit

(5) Is nearby fresh water used for:

- Drinking yes ____no ____
- Irrigation yes ____no ____
- Industrial cooling yes ____no ____
- Agricultural drainage yes ____no ____

(6) Direction of groundwater flow ____________________

(7) Fluctuations in groundwater depth (seasonal and long-term trends) ____________________

(8) Distance to nearest wells using aquifer:

- Upstream of site ___________

Part B (Continued)

- Downstream of site ________
- Site location related
  to cone of depression ______

(9) Site location:

- Discharge area yes ___no ___
- Recharge area yes ___no ___

c. Geologic conditions

(1) Any outcrops visible on site? yes ___no ___

(2) Dominant geologic features on site: (i.e. hill, sink, depressions, etc.)

____

____

(3) Slope of site: <1° ___ 5° ___ 10° ___ >15° ___

(4) Onsite landslide or slumpage potential ________________

____

____

(5) Subsurface geology: Description of subsurface formations, depth to bedrock, etc. ________________

____

____

(6) Seismic data (if available)

- Presence of onsite fault ________________
- Location of fault ________________
- Date and magnitude of fault activity, if any ________________

____

d. Topography

(1) Is candidate site subject to: periodic flooding, hurricanes,
and storm surges yes ___no ___

If so, what frequency (e.g. 50-year, 10-year, 5-year, etc.)

Part B (Continued)

(2) Is candidate site subject to:

- Ponding, after rainfall yes ____no ____

e. Surface waters (note if temporary).

(1) Are there onsite:

- Springs yes ____no ____
- Streams yes ____no ____
- Ponds yes ____no ____
- Lake yes ____no ____
- Estuary yes ____no ____
- Marine waters yes ____no ____
- Man-made (irrigation ditches, ship canals, etc.) yes ____no ____

(2) Distance to nearby surface waters

- Upstream ____________________
- Downstream __________________

(3) Uses of these waters and watershed characteristics.

- Upstream ____
- Downstream ____

(4) Provide available surface water quality data

<u>Primary Factors:</u>

Ammonia	____ppm	Nitrite	____
Nitrate	____ppm	Sulfates	____ppm

Part B (Continued)

Total Dissolved Solids (TDS)	____ppm	Total Dissolved Gas (TDG)	____%
Total Suspended Solids	____ppm	Turbidity	____
Biochemical Oxygen Demand	____	Chemical Oxygen Demand	____
Ph	____	Specific Conductors	____

Secondary Factors:

Aluminum	____ppm	Fluoride	____ppm
Ammonia (Undis-sociated)	____ppm	Hardness	____
Bicarbonate	____ppm	Hydrogen Sulfide	____ppm
Cadmium	____ppm	Iron	____ppm
Calcium	____ppm	Lead	____ppm
Carbonate	____ppm	Magnesium	____ppm
Chloride	____ppm	Manganese	____ppm
Chromium	____ppm	Mercury	____ppm
Color	____units	Silica	____ppm
Copper	____ppm	Sodium	____ppm
Fecal-Coliform	____mpn/100 ml		

Water Quality Standards:

Source: ____________________

Phone ____________________

Part B (Continued)

<u>Water Temperature/Quantity Data</u>

- Temperature of Water Source (average monthly and range) ____Centigrade/Fahrenheit

  Deepwater Temperature ____Centigrade/Fahrenheit

  Surface Water Temperature ____Centigrade/Fahrenheit

  - Flow Rate (moving water)

    Total Flow Rate __________gpm

    Water Depth __________feet

    Potential Pumped Flow Rate __________gpm

  - Total Water Area of Source __________acres

  - Sketch of Area:

Biological factors

- Photosynthetic activity
- Degree of eutrophication

f. Vegetation

(1) Description of onsite vegetation ______________________________

____

(2) Description of surrounding vegetation __________________________

____

(3) Wetland plants present? ___________________________________

(4) Adjacent agricultural activities _______________________________

g. Fauna

(1) Description of on-site fauna _________________________________

____

Part B (Continued)

(2) Description of surrounding fauna (habitats) ____________________

____

h. Climatological data (use monthly average data from past records)

(1) Evaporation rate (inches per month/year) ____________________

(2) Transpiration rate (inches per month/year)[1] ____________________

(3) Rainfall (inches per month/year) ____________________

(4) Snow (inches per month/year) ____________________

(5) Temperature mean and range (monthly and annual maximum - minimum) ____________________

(6) Prevailing monthly wind direction and velocity ____________________

(7) Solar radiation (BTU/hour/square foot) ____________________

(8) Humidity (percent, monthly average, minimum, maximum) ________

(9) Cloud cover (percent, monthly average) ____________________

i. Comments (hurricane, waterspout, frost dates, etc.) ____________________

____

j. Noncompatible activities on adjacent sites, (crop dusting, industrial uses, oil/gas extraction, etc.) ____________________

____

k. Based on the physical features, site use for disposal of dredged material and aquaculture would likely be:

(1) Feasible ________

(2) Uncertain ________

(3) Not feasible ________

[1] Estimated on basis of types of vegetation.

Part B (Continued)

Describe Technical Considerations for This Site

a. Site accessibility

(1) Identify existing access (sketch on area map)

- Paved roads: identify (e.g. US30) ________ width ___________
  % grade ______ bearing capacity ______ restrictions _________

- Unpaved roads: identify _________ width _________
  % grade ______ bearing capacity ______ restrictions _________
  surface characteristics (all weather, etc.) ________________

- Rail: identify _________

- Canal: identify ________ width _________
  depth _________ navigable months ________________

- River: identify ________ width _________
  depth _________ navigable months ________________

b. Suitability of soils for construction of DMCA/fish pond

(1) Are acceptable soils available? (yes or no)

____

From / For	Onsite Borrow Area	Borrow Area on Nearby Property	Dredged Material
· Construction of earth berms	______	__________	_______
· Impermeable site liners	______	__________	_______
· Cover material	______	__________	_______
· Construction of access roads	______	__________	_______

Part B (Continued)

- Under-drainage for leachate collection ______ __________ ________

(2) Bearing strength of site subbase is sufficient to support:

- Desired slopes of excavations and landscape modifications. yes ____ no ____
- Weight of dredged material without excessive settlement. yes ____ no ____

Comments ____
____
____
____

d. Based on technical considerations, site use for disposal of dredged material and aquaculture would likely be:

(1) Feasible __________

(2) Uncertain _________

(3) Not feasible ______

Assess Potential Negative Environmental and Social Impacts of Fish Culture at the Selected DMCA Site

Instructions: For each of the numbered factors, indicate whether the anticipated magnitude of impact is severe, moderate, or less severe. Then, based upon the expected impacts for each set of factors, indicate an overall anticipated magnitude of impact for the lettered environmental characteristic (e.g. groundwater quality, surface water quality, flooding, etc.)

	Anticipated Magnitude of Impact		
Impact	Severe	Moderate	Less Severe
a. Groundwater quality	( )	( )	( )

Part B (Continued)

	Anticipated Magnitude of Impact		
	Severe	Moderate	Less Severe
Factors			
(1) Leachate production & potential migration to groundwater	____	____	____
(2) Water table fluctuations which can result from extraction	____	____	____
Impact			
b. Surface water quality	( )	( )	( )
Factors			
· Surface erosion and runoff from disposal site to surface water	____	____	____
· Nutrient enrichment of surface water from discharge	____	____	____
Impact			
c. Flooding	( )	( )	( )
(1) Decreased flow area in site drainage basin	____	____	____
d. Air quality	( )	( )	( )
(1) Dust generation due to:	____	____	____
· Site preparation	____	____	____
· Disposal activities	____	____	____

Part B (Continued)

	Anticipated Magnitude of Impact		
	Severe	Moderate	Less Severe
· Extended dry periods	____	____	____
· Prevailing winds	____	____	____
Impact			
e. Wildlife habitat and ecosystem alterations	( )	( )	( )
Factors			
(1) Effects on animal breeding habitat or foraging areas	____	____	____
(2) Physical blockage of travel routes (barrier creation)	____	____	____
(3) Food chain alterations	____	____	____
(4) Introduction or attraction of foreign species (by transport and disposal of seeds, spores, organisms, etc.)	____	____	____
(5) Effects on ________ preserves, etc.	____	____	____
Impact			
f. Attraction of vectors (insects or rodents) due to creation of favorable breeding or forage areas	( )	( )	( )

Part B (Continued)

	Anticipated Magnitude of Impact		
	Severe	Moderate	Less Severe
Factors			
(1) Improper surface drainage resulting in ponding of water	_____	_____	_____
(2) Desiccation cracks or other areas with stagnant water	_____	_____	_____
(3) Feed storage and handling (rodents)	_____	_____	_____
Impact			
g. Economics in area	( )	( )	( )
Factors			
(1) Property devaluation	_____	_____	_____
(2) Tax rate alteration	_____	_____	_____
· Property tax increase	_____	_____	_____
· Property tax decrease	_____	_____	_____
(3) Property damage	_____	_____	_____
Impact			
h. Alteration of land use in area	( )	( )	( )

Part B (Continued)

Factors	Anticipated Magnitude of Impact: Severe	Moderate	Less Severe
(1) Potential aesthetic degradation due to presence of site and disposal activities	_____	_____	_____
(2) Limitation on future site uses due to type of material deposited	_____	_____	_____
(3) Limits on use of adjacent sites	_____	_____	_____

i. Comments ____
____
____
____

j. Based on environmental and social impacts, site use for disposal of dredged material and aquaculture would be:

(1) Feasible _____

(2) Uncertain _____

(3) Not feasible _____

Assess Public Attitudes Toward this Site

a. Identify appropriate or affected public. Based on past activities in the area and knowledge of similar projects, indicate in the following form which parties can be expected to express interest in the selection of the candidate site for (1) dredged material disposal and (2) aquaculture.

Part B (Continued)

Public Attitude Toward Site

Group	Name	Address	Telephone No.	Anticipated Interest, neg./ positive/null
(1) Local & neighborhood residents				
(2) Schools				
(3) Business interests				
(4) Recreation groups				
(5) Conserva-tionists				
(6) Active social/ political groups				

Part B (Continued)

Anticipated Group	Name	Address	Telephone No.	Interest, neg./positive/null
(7) Other site users or affected persons	______	______	______	______
	______	______	______	______
	______	______	______	______
	______	______	______	______
(8) Other civic groups	______	______	______	______
	______	______	______	______
	______	______	______	______
	______	______	______	______

b. Identify methods suitable for educating and involving the affected public

(1) Public meetings yes ____ no ____

(2) Official hearings yes ____ no ____

(3) Public educational programs yes ____ no ____

(4) News media coverage yes ____ no ____

(5) Presentations at special-interest group meetings yes ____ no ____

(6) Other ______________________ yes ____ no ____

____

c. Indicate expected or perceived causes for public concern resulting from use of the candidate site for disposal of dredged material and aquaculture

Part B (Continued)

(1) Groundwater contamination due to predator control using pesticide	yes ____	no ____
(2) Surface water contamination	yes ____	no ____
(3) Area flooding	yes ____	no ____
(4) Vectors & public health hazards	yes ____	no ____
(5) Wildlife habitat & ecosystem alterations	yes ____	no ____
(6) Air quality degradation	yes ____	no ____
(7) Dust	yes ____	no ____
(8) Odors	yes ____	no ____
(9) Noise	yes ____	no ____
(10) Traffic increases	yes ____	no ____
(11) Safety hazards	yes ____	no ____
(12) Property damage	yes ____	no ____
(13) Property devaluation	yes ____	no ____
(14) Tax-rate alterations	yes ____	no ____
(15) Aesthetic degradation	yes ____	no ____
(16) Future land use changes	yes ____	no ____
(17) Others (e.g. political) ____________ ____________	yes ____	no ____

d. Evaluate potential effects of public involvement

Part B (Continued)

(1) Will public involvement in approving a disposal site for aquaculture cause:

- Project delays yes ____ no ____
- Increased project costs yes ____ no ____
- Project rejection yes ____ no ____

e. Comments____
____
____
____

f. Based on public attitudes, site use for disposal of dredged material and aquaculture would likely be:

(1) Feasible ____

(2) Uncertain ____

(3) Not feasible ____

Part C: Requirements for Site Acquisition, Preparation, and Operation of DMCA Aquaculture

There are several steps involved in the final phase of site acquisition and preparation for DMCA aquaculture. Before site acquisition, the site must be approved for both disposal and aquaculture by the various regulatory agencies (i.e. federal, state, and local) outlined in earlier sections of this report. The method of acquiring the site must be determined according to sponsor policy, availability of the site, and owner agreement(s). In this section of the checklist, the various steps necessary for meeting regulatory agency requirements, proper site acquisition, implementation, and operating a DMCA for aquaculture are outlined.

Coordinate with and Obtain Approval of Jurisdictional Government Agencies (Robertshaw, Love, and McLaughlin 1993) for detailed permit acquisition procedures).

Agency	Approval Required	Contact Person Name, Tel. No.	Date Solicited	Date Obtained
a. Federal (not all agencies listed will have jurisdiction or concern for all disposal sites)	______	______	______	______
(1) Environmental Protection Agency (Washington, DC and Regional Office)	______	______	______	______
(2) Department of Interior (Fish & Wildlife,[1] National Park Service, Bureau of Reclamation, Bureau of Land Management)	______	______	______	______
(3) Department of Housing and Urban Development	______	______	______	______
(4) Department of Transportation	______	______	______	______
(5) Department of Health, Education, and Welfare	______	______	______	______

[1] Apply here for exotic species permit.

Part C (Continued)

Agency	Approval Required	Contact Person Name, Tel. No.	Date Solicited	Date Obtained
(6) Department of Agriculture (Soil Conservation Service)	______	______	______	______
(7) Department of Commerce National Marine Fisheries Service	______	______	______	______
(8) Other ______	______	______	______	______
______	______	______	______	______
______	______	______	______	______
b. Regional				
(1) Port Authorities	______	______	______	______
(2) Coastal Zone Management Commission	______	______	______	______
(3) River Basin Planning Commission	______	______	______	______
(4) Land Use Management Group	______	______	______	______
(5) Council of governments or regional associations	______	______	______	______
(6) National Marine Fisheries Service	______	______	______	______
(7) Other ______	______	______	______	______
______	______	______	______	______

Part C (Continued)

Agency	Approval Required	Contact Person Name, Tel. No.	Date Solicited	Date Obtained
c. State(s)				
(1) Department of Natural Resources, Department of Environmental Protection, or equivalent				
(2) Water Quality Control Board/ Commission				
(3) Department of Solid Waste Management or equivalent				
(4) Department of Historic and Cultural Affairs or equivalent				
(5) Department of Education				
(6) Department of Community Affairs or equivalent				
(7) Department of Agriculture				
(8) Bureau of Mines				
(9) Department of Transportation				

Part C (Continued)

Agency	Approval Required	Contact Person Name, Tel. No.	Date Solicited	Date Obtained
(10) Other ______	______	______	______	______
______	______	______	______	______

d. Local (county, township, municipality)

(1) Planning Department	______	______	______	______
(2) Public Works (highways, solid waste, water pollution control)	______	______	______	______
(3) Other ______	______	______	______	______
______	______	______	______	______
______	______	______	______	______

e. Comments ______________________________

____

____

Acquire Site

a. Determine method of site acquisition

(1) Purchase ______________

(2) Perpetual Easement ______________

(3) Temporary Easement ______________

(4) Lease ______________

(5) Other ______________

b. Develop agreements with site owner(s)/sponsor(s)

(1) Owner understands intended site use. yes ____ no ____

Part C (Continued)

(2) Provisions have been made for site access. yes ____ no ____

(3) Length of easement or lease (if site not purchased). Negotiate longest possible lease

(4) Conditions for termination of agreement: ______________________________

____

(5) Identify parties responsible for:

- Site operation and maintenance ______________________________

  ____

- Postdisposal clean up ______________________________

- Postdisposal environmental monitoring ______________________________

- Correcting environmental problems that may arise During and/or after aquaculture operations ______________________________

  ____

c. Comments ____

____

____

____

____

Determine Requirements for Site Preparation for Aquaculture

	Required	Not Required
a. Access road construction	____	____
b. Removal of vegetation and rocks	____	____
c. Grading and leveling	____	____
d. Drainage diversion	____	____
e. Dredged material containment structure design and construction	____	____
f. Groundwater protection	____	____

Part C (Continued)

	Required	Not Required
g. Base soil preparation	______	______
h. Building construction	______	______
i. Utilities installation	______	______
j. Utilities relocation	______	______
k. Building relocation	______	______
l. Road relocation	______	______
m. Dike renovation/construction	______	______
n. Access control	______	______
o. Water control devices	______	______
p. Other ______________________	______	______
______________________________	______	______
______________________________	______	______

q. Comments ____
____
____
____
____

Plan for Disposal Site Closing and Future Site Use

a. Requirements for site closing

(1) Final cover material	yes ____	no ____
(2) Removal of berms	yes ____	no ____
(3) Dismantle equipment	yes ____	no ____
(4) Removal of structures	yes ____	no ____
(5) Grading	yes ____	no ____

Part C (Continued)

	Required	Not Required
(6) Erosion control	yes ___	no ___
(7) Landscaping	yes ___	no ___
(8) Other ______________ ______________	yes ___	no ___

b. Continued site monitoring and environmental control program ______________________________
____

c. Future site use plans ______________________________
____
____

d. Emergency plans for natural disaster, e.g. hurricanes, floods, etc.
____

e. Comments ______________________________
____

Part D: Infrastructure Assessment (adapted from Posadas and Homziak 1989)

Items to be Assessed

a. Project planning

b. Transportation

c. Utilities

d. Communications

e. Construction

f. Equipment

g. Supplies

h. Support Services

i. Other

Assessment Details, Existing Services (Description of services, address, telephone number, contact person to be provided)

a. Planning

(1) Economic development assistance - state, county power company assistance to manufacturing and agricultural enterprise start ups, tax incentive programs

(2) Financial planning - private sector lending institutions, public sector assistance

(3) Legal planning - permit agencies, zoning regulations, agricultural/manufacturing legal advice tax collection agencies

(4) Aquaculture planning - production plans, development assistance for specific projects

(5) Real estate - agents, legal advice

(6) Architectural planning and plant design

Part D (Continued)

b. Transportation

(1) Roads - maps and use designations, load limits on bridges, height and weight restrictions on use

(2) Transport services

- Air - air fields, commercial and private carriers, air freight services (especially live product, wet product, frozen)
- Rail - delivery points, schedules for bulk deliveries
- Truck - freight lines, charter services, specialized freight (e.g. live haul, reefer), parcel service

c. Utilities

(1) Water - municipal service guide, rates, capacities

(2) Electric - power companies and cooperatives, rates, use categories, other devices and costs (e.g. running power to new site)

(3) Sewerage and waste disposal - service, capacity, regulations, landfills, costs

d. Communications

(1) Telephone - local and long distance service companies and rates, other services (e.g. planning)

(2) Courier - package/letter express, postal services, FAX availability

e. Construction

(1) Engineering

- Water testing and hydrological services
- Soil testing
- Environmental impact assessment
- Waste water assessment
- Climatological data analysis

Part D (Continued)

- Pond siting and design
- Construction planning and management
- Industrial architects

(2) Surveyors

(3) Construction contractors

- Well drilling
- General Construction Contractor.
  - Earth moving and road construction (including black-top and gravel).
  - Concrete work and block masonry
  - Agricultural grading, leveling, and ditching
  - Landing clearing (timber cutting, stumping, bush hogging)
  - Industrial plumbing and water heating
  - Industrial electrical and lighting services
  - Construction carpentry and roofing
  - Painting
  - Fences, security, and alarm systems
  - Metal fabricators (welding, cutting)
- Marine construction (piers, bulkheads, docks)
- Modular/prefabricated buildings suppliers and contractors (greenhouses, metal industrial building, etc.)
- Commercial materials suppliers (contractors supplies of lumber, hardware, plumbing and electric, block/brick, paint/epoxy, industrial sealants, marine supplies)
- Septic tank

Part D (Continued)

- Industrial landscape and erosion control

f. Equipment

(1) Rolling Stock

- Auto and truck sales/lease
- ATV, motorcycle sales
- Farm equipment sales/lease
- Heavy construction equipment lease

(2) Boats, motors, other marine equipment and electronics

(3) Water supplies

- Pumps (well, fish pumps, large-volume irrigation)
- Water treatment (drinking water)

(4) Electric generators

(5) Aeration (oxygen injection, paddle wheels, etc.)

(6) Farm equipment (tanks, feed bins, augers, fuel storage, etc.)

(7) Safety equipment (fire extinguishers, smoke detectors, marine safety, etc.)

(8) Specialized aquaculture equipment and furnishings (meters, test kits, feed blowers, filter systems, etc.)

(9) Office equipment

- Furnishings
- Electric (copiers, computers, etc.), sales or lease

(10) Fisheries processing machinery (sorting, washing, packaging, etc.)

(11) Feed mill equipment

(12) Refrigeration (coolers, freezers)

Part D (Continued)

(13) Harvest equipment (nets, seines, etc.)

g. Supplies

(1) Fuel (bulk delivery)

- gasoline
- diesel
- propane, other fuel gases

(2) Rolling stock and boat consumables and supplies

(3) Feed

- Manufactured feeds
- Feed components

(4) Seed stock

(5) Agricultural chemicals

- Fertilizers
- Herbicides, pesticides
- Specialized aquaculture chemicals

(6) Industrial gases (especially oxygen)

(7) Laboratory supplies

(8) General supplies (office and farm)

(9) Preservation and processing supplies

(10) Ice

h. Services

(1) Service contracts for all major equipment and machinery

(2) Contract harvesting services

(3) Contract processing and cold storage facilities

Part D (Continued)

(4) Contract hauling services (fresh product)

(5) Technical support

- Disease diagnosis
- Export assistance
- Water, soil, and other testing services
- Extension services

(6) Local seafood brokers, dealers, and markets

(7) Security services

(8) Labor

- Technical staff pool
- Secretarial staff
- Other (bookkeeping, audit, tax preparation, etc.)

i. Miscellaneous

(1) Aquaculture producers and trade organizations

(2) Universities with aquaculture courses or faculty

(3) Libraries with scientific holdings

(4) Other local aquaculture enterprises (planned and operating)

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13. ABSTRACT *(Maximum 200 words)*

High land and construction costs hinder development of pond-based aquaculture in the United States. A partnership with the U.S. Army Corps of Engineers (USACE) may reduce these constraints. The dredged material containment areas (DMCA) operated by the Corps are structurally similar to aquaculture ponds and typically are used by the USACE only once every 3 to 10 years. With the Corps and navigational interests contributing to dike construction and land acquisition, the costs of aquaculture may be reduced while providing the Corps with the additional disposal areas needed to maintain our nation's waterways. The Containment Area Aquaculture Program was established to investigate the feasibility of DMCA aquaculture from biological, economic, engineering, and legal perspectives. The technical feasibility of DMCA aquaculture was demonstrated in 42- and 47-ha DMCA's near Brownsville, TX. Pumps, filters, and drainage structures were added to these DMCA's to accommodate aquaculture operations and a 1.6-ha nursery pond was constructed. During a 3-year period, four crops of penaeid shrimp were raised. Production rates averaged 670 kg/ha of whole shrimp (range: 338 to 1,143 kg/ha) with 51 percent survival (range: 23 to 74 percent). Total production for the four crops was 116,088 kg of whole shrimp (71,878 kg tails) which was sold for over $475,000. This report gives a general overview of site selection considerations when

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colocating a DMCA and an aquaculture facility. Checklists are given to provide aquaculturists, USACE personnel, regulatory agencies, and others with a summary and quick reference to important factors in choosing a site.

Site selection is the most important decision made in any large-scale pond aquaculture operation, regardless of whether the operation will be in a DMCA. Establishment and operation of a DMCA aquaculture facility will typically require close cooperation between the aquaculturist, local dredging sponsor, and USACE district. A general screening of potential sites can be made by examining dredging records to determine if dredging needs coincide with areas feasible for aquaculture operations. In doing this assessment, future site conditions, management strategies, and design modifications should be anticipated to the extent practicable. Other factors to consider include: area available for development, compatibility with adjacent land uses, zoning or legal restrictions, topography, general soil types, and proximity to service and support systems. After this preliminary survey is completed and species and culture methods are chosen, a more detailed evaluation that focuses upon aquaculture operations should be conducted. In general, the typical design criteria for DMCA's (most notably the water control structures and bottom slope) must be modified to accommodate an aquaculture operation: therefore, effort should be spent detailing the modifications needed and their cost.