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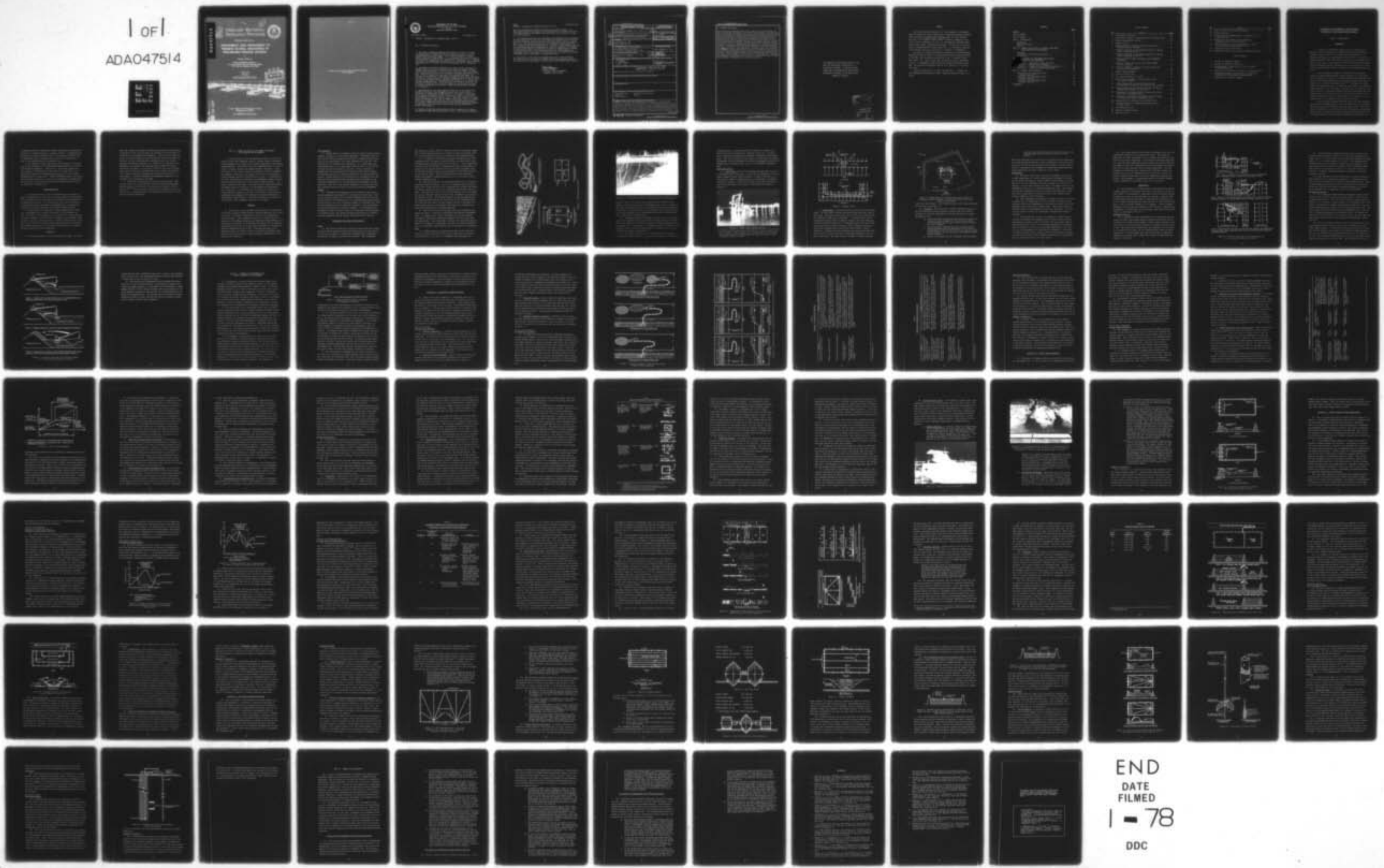

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DREDGED MATERIAL RESEARCH PROGRAM

TECHNICAL REPORT D-77-19

CONTAINMENT AREA MANAGEMENT TO PROMOTE NATURAL DEWATERING OF FINE-GRAINED DREDGED MATERIAL

by

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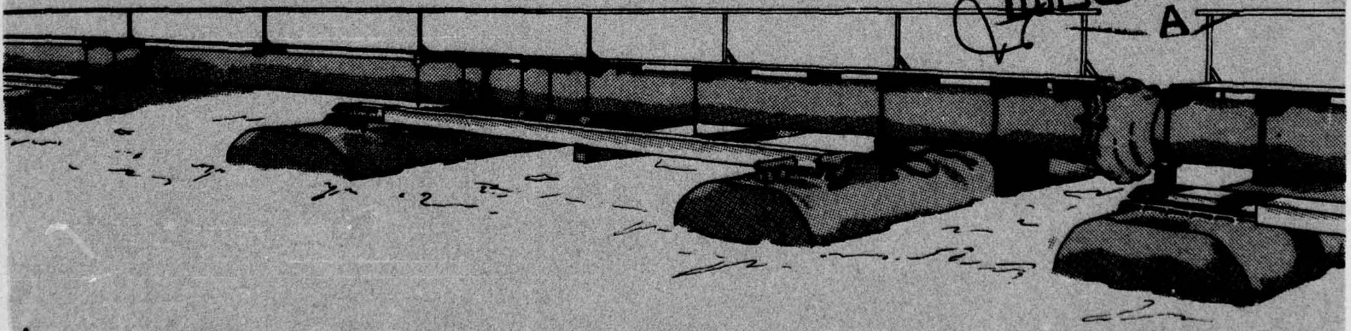

Prepared for Office, Chief of Engineers, U. S. Army
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Under DMRP Work Unit No. 5A13

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UNITED STATES OF AMERICA

DEPARTMENT OF THE ARMY
WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS
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VICKSBURG, MISSISSIPPI 39180

IN REPLY REFER TO: WESYV

31 October 1977

SUBJECT: Transmittal of Technical Report D-77-19

TO: All Report Recipients

1. The report transmitted herewith represents the results of a study of dredged material dewatering concepts evaluated as part of Task 5A (Dredged Material Densification) of the Corps of Engineers' Dredged Material Research Program (DMRP). It is concerned with developing and/or testing promising techniques for dewatering and densifying (i.e., reducing the volume of) dredged material using physical, biological, and/or chemical techniques prior to, during, and/or after placement in the containment area.

2. The rapidly escalating requirements for land for the confinement of dredged material, often in urbanized areas where land values are high, dictated that significant priority be given within the DMRP to determine ways to extend the useful life of existing or proposed containment facilities. While increased life expectancy (and related significant cost savings) can be achieved to some extent by improved site design and operation and to a greater extent by removing dredged material for use elsewhere, the attractive approach being considered under Task 5A is to densify the in-place dredged material. Densification of the material would not only increase site capacity but also would result in an area more attractive for various subsequent uses because of improved engineering properties of the material.

3. The objective of the study reported herein was to investigate and recommend containment area management practices to promote natural dewatering of fine-grained dredged material. The purpose of the study was to provide guidelines for use in the overall design, construction, and management of confined disposal areas. The study consisted of interviews with personnel from Corps of Engineers Districts, visits to dredged material containment areas, and the use of technology being developed by the DMRP. Guidelines developed were based on the engineering judgment of those involved in the study, which did not include laboratory or formal field research.

4. Results of the study indicated that little is being done to dewater fine-grained dredged material confined on land. This was not unexpected

since few economically feasible techniques are generally known. In many instances the local sponsors are responsible for providing facilities for dredged material confinement and the District has no control on long-term site operation.

5. Four general guidelines for containment area management were formulated. The first guideline is concerned with separating sand and gravel from fine material during the disposal operation for later removal from the containment area. The second guideline deals with methods of managing surface water ponded within the containment area. Guideline three presents concepts for optimizing evaporative dewatering by selective scheduling of dredging projects and minimizing the thickness of layers of dredged material within the containment areas. The fourth guideline deals with management of containment areas to facilitate the installation of alternative dewatering techniques such as underdrains or vacuum wellpoints.

6. The results of the study are implementable now by field personnel. The guidelines will be placed in broader context and included as part of the overall Task 5A guidelines on dewatering or densifying dredged material.

JOHN L. CANNON
Colonel, Corps of Engineers
Commander and Director

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This report deals with containment area management to promote natural dewatering of fine-grained dredged material. Interviews with personnel of several Corps of Engineers (CE) Districts and visits to dredged material containment areas showed that little is being done to dewater fine-grained dredged material confined on land. This was not unexpected since few economically feasible techniques were known and in many instances the local sponsors were responsible for providing facilities for dredged material confinement. Based on information

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gained during the preliminary phase of the study and on current research results, four general guidelines for containment area management were formulated. The first guideline is concerned with the separation of sand and gravel from the fine material during the dredging operation; the coarse fraction may have productive use potential or may be useful for constructing drainage blankets to dewater the fine fraction. Surface water management is the subject of the second guideline, which suggests that water be left ponded within the containment area throughout the disposal operation and thereafter removed as quickly as possible to initiate evaporation at the earliest time. Guideline 3 presents concepts for optimizing evapotranspirative dewatering by scheduling dredging before hot, dry weather, by placing dredged material in lifts not greater than 0.3 metre thick, and by using vegetation to transpire water from the dredged material When natural dewatering processes are not effective, such as during the rainy season or during the winter, alternative dewatering techniques may be effective. These alternative methods are the subject of the fourth guideline and include electro-osmosis, vacuum well points, and underdrainage. Containment area management can be planned to facilitate the installation of some of these systems during or immediately after a disposal operation.

PREFACE

This report presents guidelines for the management of containment areas to promote the natural dewatering of fine-grained dredged material. Conducted between December, 1975, and May, 1977, the study was Work Unit 5A13 of the Dredged Material Research Program, conducted for the Office, Chief of Engineers, at the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi. The work unit is part of Task 5A, Dredged Material Densification (Dr. T. A. Haliburton, Manager) of the Disposal Operations Project (C. C. Calhoun, Jr., Manager).

The study was conducted by personnel assigned to the Environmental Engineering Division (EED) of the Environmental Effects Laboratory (EEL) at the WES, under the general supervision of Dr. J. Harrison, Chief, EEL, and Mr. A. J. Green, Chief, EED, and under the direct supervision of Mr. R. L. Montgomery, Chief, Design and Concept Development Branch, EED. The principal investigator was Mr. M. J. Bartos, Jr., who wrote the report.

During the study, COL G. H. Hilt, CE, and COL J. L. Cannon, CE, were Commanders and Directors of WES. Technical Director was Mr. F. R. Brown.

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CONTAINMENT AREA MANAGEMENT TO PROMOTE NATURAL DEWATERING OF FINE-GRAINED DREDGED MATERIAL

PART I: INTRODUCTION

Background

1. In support of waterborne commerce, the U. S. Army Corps of Engineers (CE) is responsible for maintaining more than 40,000 km of navigable waterways and 507 ports and harbors throughout the U. S. Maintenance requires that approximately 230,000,000 m^3 of sediment be dredged annually.[1] While most (140,000,000 m^3) of this material is disposed in open water, a large amount (51,300,000 m^3) must be confined in land-based dredged material containment areas, necessitating the acquisition of approximately 2,850 ha of land for new containment areas each year.[2]

2. Most maintenance dredging is accomplished using hydraulic dredges that pump dredged material slurry (typically 10 to 15 percent solids by weight) for disposal.[1] Dredged material from maintenance projects is often fine-grained and has a high water content after being pumped into a land-based containment area.[1,3] The high water content causes the dredged material to be very soft, with little or no strength. Unless dewatered to the consistency of natural soil, the material is of little value as a construction material, and activities within the containment area are severely restricted. The high water content of the dredged material also causes an unnecessarily large portion of a containment area to be committed to the storage of the water.

3. These and other problems identified by CE Districts related to the disposal of dredged material led to the initiation of the Dredged Material Research Program (DMRP), which was begun in 1973. The objectives of the DMRP are to provide definitive information on the environmental impact of dredging and dredged material disposal operations and to develop technically satisfactory, environmentally compatible, and

economically feasible dredging and disposal alternatives, including consideration of dredged material as a natural resource. A significant improvement in disposal operations could be to increase the service life of containment areas by removing excess water and by removing all or part of the dredged material for productive use.

4. The removal of excess water and a great increase in the potential for the productive use of fine-grained dredged material can both be accomplished by dewatering. Johnson et al. report that reducing the water content of dredged material from twice its liquid limit to its liquid limit reduces the dredged material volume by 36 to 46 percent, depending upon the liquid limit.[4] Further dewatering causes a less spectacular volume reduction, but results in an improvement in dredged material properties to the extent that dewatered dredged material exhibits the properties of natural soil.[3]

Purpose and Scope

5. The general purpose of this investigation was to develop concepts and methodologies to increase the storage capacity of dredged material containment areas and to improve the properties of dredged material by removing excess water. More specifically, the study was conducted to investigate general containment area management as a technique for promoting the natural dewatering of fine-grained dredged material.

6. Current practice is generally to pump dredged material slurry into a containment area, allowing the slurry to flow throughout the area. The effect of the operation on the drying of the dredged material is rarely considered. Many CE Districts recognize that advantage should be taken of natural drying processes to prolong the service lives of the areas. This study was to develop common-sense guidelines for obtaining the maximum natural drying of fine-grained dredged material by gravity drainage, evaporation, and transpiration.

Approach

7. A two-phase approach to the investigation was taken. The first

phase was a survey of available information concerning the land disposal of dredged material, and this phase was followed by the development of guidelines for containment area management. During the first phase personnel of several CE Districts were interviewed, current literature was reviewed, and some dredged material containment areas were visited. Using the information accumulated, the feasibility of containment area management as a technique for enhancing natural dredged material dewatering was evaluated. At that time it was felt that several improvements, many site-specific and applicable only in certain circumstances, could be made in general containment area operations; therefore, the second phase, to develop containment area management guidelines to incorporate these improvements, was begun.

8. During the second phase the guidelines were developed. DMRP research showed that, under favorable conditions and proper management, natural processes were effective for dewatering fine-grained dredged material.[5,6,7] The factors that influence natural dewatering were taken into account to develop guidelines for planning disposal operations conducive to natural dewatering.

PART II: SUMMARY AND ANALYSIS OF CURRENT CONTAINMENT AREA OPERATION AND MAINTENANCE

9. The first phase of this investigation included a survey of CE District offices and containment areas to evaluate current containment area management and its impact on the natural dewatering of fine-grained dredged material. The District survey was supplemented with a review of current literature dealing with dredged material confinement on land. The results of the District survey and literature review are summarized and analyzed in this part of the report to point out the containment-related problems faced by CE Districts and to serve as a background for Part III, which describes containment area management concepts for optimizing the natural dewatering of fine-grained dredged material. The topics discussed in this part of the report include long-range planning, containment layout and operation, and containment area maintenance. This information is not intended to be an exhaustive description of dredged material disposal, but rather is restricted to those aspects of containment area management that influence the natural dewatering of fine-grained dredged material. Additional information is available in the references cited throughout this part of the report.

Planning

10. The District survey indicated that dewatering is generally not considered in planning dredged material disposal operations, due in part to the lack of technical information on which to base comprehensive dewatering plans. Plans generally include not a logical sequence of operations for dredging, disposing, and dewatering dredged material, but instead only an estimate of the dredging requirements for the planning period and the provision of storage capacity adequate for confining the material dredged during that period. Long-range planning is also hampered because the Districts often do not own the containment areas and are not allocated separate funding designated specifically for containment area operations.

Site ownership

11. Dredged material containment areas are owned by local sponsors, dredging contractors, or the Federal government. Containment areas not owned by the Federal government are difficult to manage effectively because of the uncertainty of the future availability of the area. The advisability of containment area improvement (i.e., dewatering, year-round maintenance, etc.) is questionable when the right to use the containment area can be withdrawn at any time. Federal ownership of dredged material containment areas would help justify improved design and operation because the continuous availability of the area would be ensured. Federal control of the availability of containment areas (perhaps most easily achieved through ownership) may be essential to the successful implementation of the containment area management concepts presented in Part III. Where Federal ownership is not practical, easement agreements should be written to allow for year-round management.

Funding

12. Containment area management is also hindered by the lack of funding designated specifically for containment area operations. Funding is generally allocated for a specific dredging project and does not include provision for maintenance of the containment area between dredging operations. This lack of separate funding for containment area operation and maintenance can be partially attributed to the non-ownership of containment areas by the Federal government. The containment area management concepts presented in Part III require year-round maintenance at containment areas, and funding designated specifically for containment area management between disposal operations will be required.

Containment Area Layout and Operation

Shape

13. The District survey and literature review showed that containment areas can be almost any shape from roughly square to long and narrow and that the shape of a particular containment area is generally dictated by the shape of the land area available. Some containment

area shapes are shown in Figure 1; Figure 1a shows an irregularly shaped area in the Sacramento District; and Figure 1b shows two adjacent areas (one roughly square and one long and narrow) in the Savannah District.

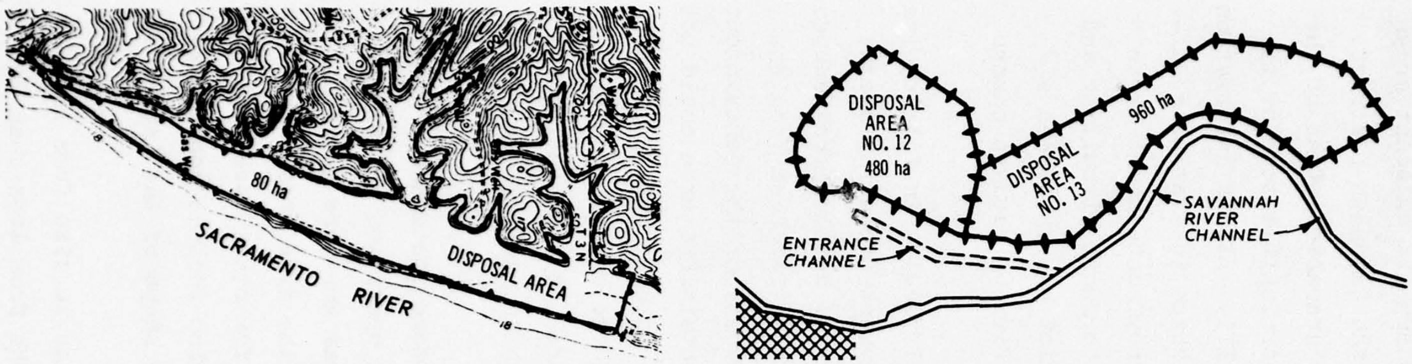
14. In addition to affecting the hydraulic characteristics of the containment area, the shape can also facilitate or inhibit some of the dewatering-related operations described in Part III. Little information on which to base the design of containment area shape is available, although there is general agreement that long, narrow containment areas are desirable because they are less susceptible to short-circuiting and are more easily filled. The San Francisco District has published a report that suggests a length-to-width ratio of five be used to ensure adequate detention time.[8]

15. The Detroit District has experienced difficulty in filling its containment areas completely. One of its containment areas in Toledo Harbor was so long that most of the dredged material settled from suspension before reaching the end of the containment area farthest from the inlet. The result was that the full storage capacity of the containment area was not utilized, because one end of the containment area could not be completely filled. This problem affected the natural dewatering of the dredged material because the unfilled end of the containment area was lower than the outlet, and water unable to drain to the outlet remained ponded within the containment area (Figure 2), preventing the evaporative dewatering of the dredged material.

16. Part III of this report describes how some containment area shapes are useful to facilitate containment area operation and management. For example, long, narrow containment areas are more easily excavated by draglines or clamshells working on the dike crests than are square areas. Other shapes may be suitable for other uses, but the design of the shape of a containment area must also include consideration of its hydraulic characteristics and of the shape of the land area.

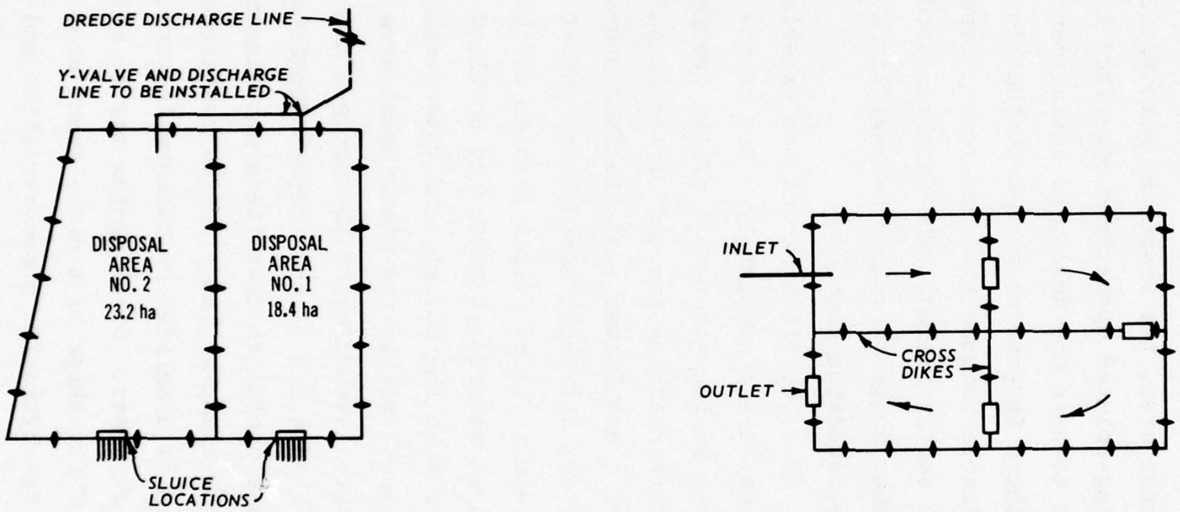
<u>Size</u>

17. Dredged material containment areas range in size from less than 5 ha to more than 1,000 ha and range in depth from less than 2m to more than 10 m. The size of a containment area influences the



a. IRREGULAR SHAPE, SACRAMENTO DISTRICT[9]

b. SQUARE AREA (NO. 12) AND LONG, NARROW AREA (NO. 13); SAVANNAH DISTRICT



c. PARALLEL COMPARTMENTS, MOBILE DISTRICT[9]

d. SERIES COMPARTMENTS CHICAGO DISTRICT

Figure 1. Containment area shapes

Figure 2. Ponded water trapped in dredged material containment area

detention time of the slurry, and therefore affects effluent water quality. The detention time of a containment area is also a function of the dredge production rate and will be different for each size dredge. In addition, the detention time for a containment area decreases during the disposal operation as the containment area fills with dredged material, reducing the effective depth.

18. Containment areas are currently sized by the use of a bulking factor,[9] an empirical factor that relates the shoal volume of the material to the volume it is expected to occupy after being pumped into the containment area. DMRP research is currently under way to develop a more suitable method for sizing dredged material containment areas to meet effluent water-quality requirements.[10]

19. The impact of the size of a containment area on dewatering the dredged material therein is related to the thickness of the lift of

dredged material; a large surface area is required for placing thin lifts,* which can be dewatered by evaporation (Part III). Sizing is also an important consideration in designing compartmented containment areas. Part III will show that the division of large areas into several compartments can be advantageous for effective management, and each compartment must be carefully sized to act as an individual containment area.

Inlets and outlets

20. Inlet types. The end of the dredge discharge pipe located in a containment area is the inlet. An inlet may be permanent, such as the hopper pumpout facility shown in Figure 3, or may be temporary, as in the case of a length of dredge pipe that is removed when the disposal operation is complete. Inlets can be single or multiple; multiple inlets can be controlled by a Y-valve or uncontrolled as a manifold (Figure 4).

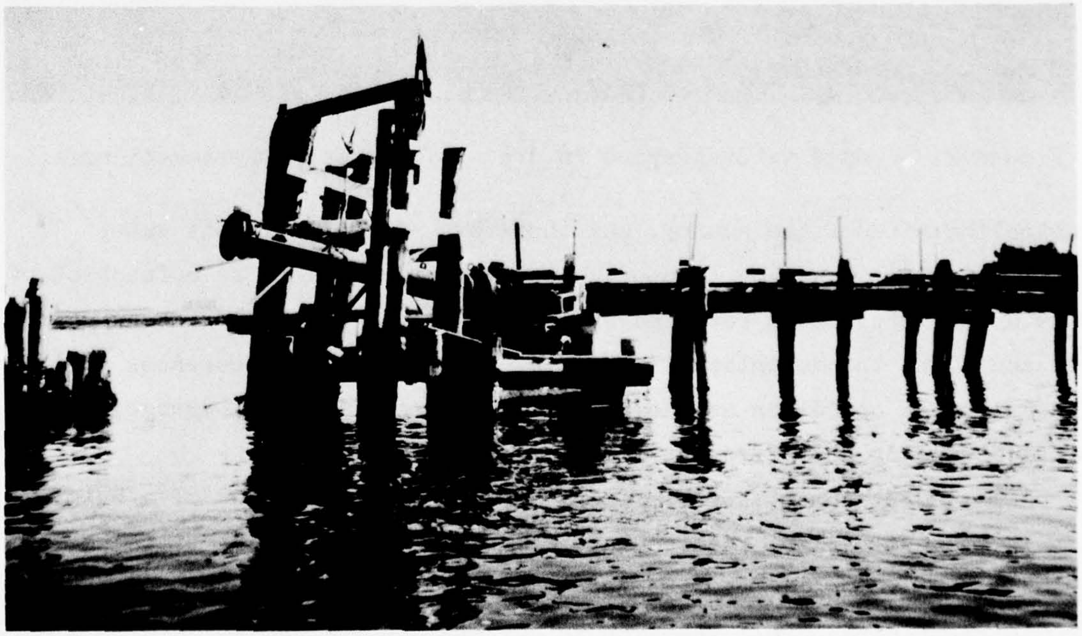


Figure 3. Hopper dredge pumpout facility

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* In this report the term "thin lift" refers to a lift of about 0.3 m. This is based on DMRP research[5] that concluded that for the maximum evaporative dewatering, dredged material should be placed in lifts not greater than 0.3 m thick.

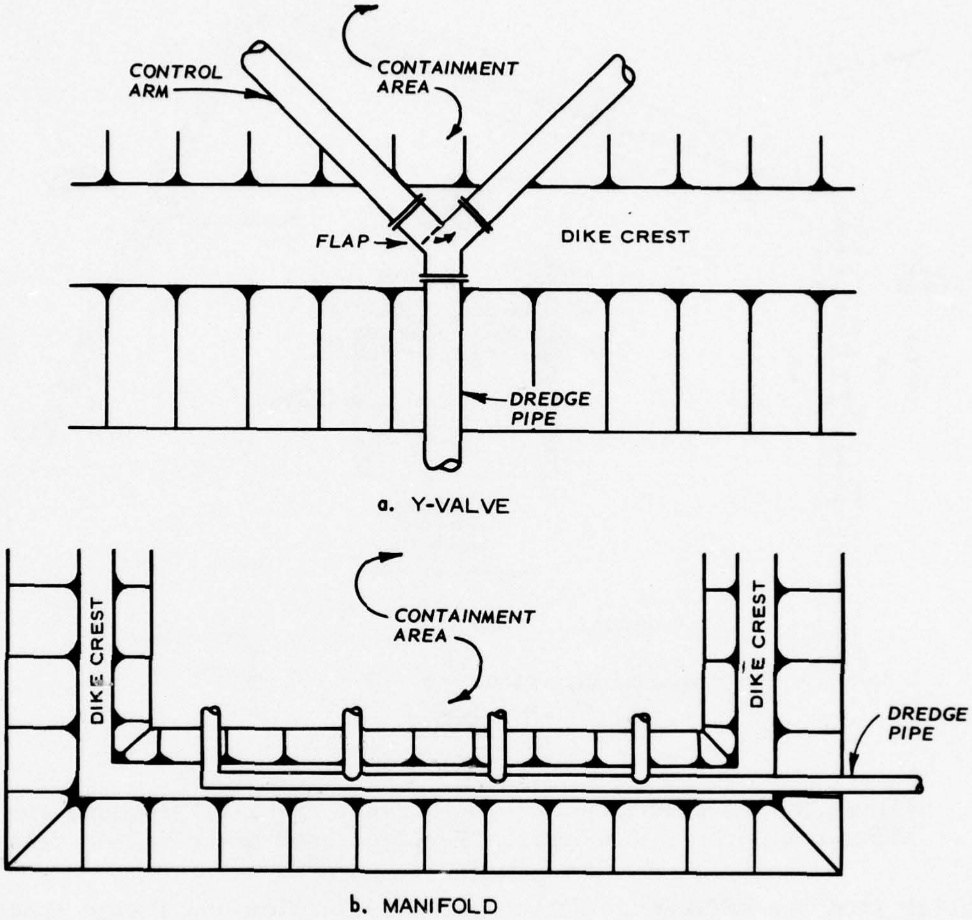


Figure 4. Multiple inlets

21. Outlet types. Drop-type outlets are used at most containment areas. In recent years vertical sand filter drains have been used in some areas. Drop-type outlets allow water to pass over a stop-log weir for discharge through one or more pipes. A drop-type outlet with a corrugated metal pipe riser is shown in Figure 2, and other drop-type outlets are shown in Reference 9. Containment areas in the Great Lakes area are often constructed by diking in water, forming a peninsula; these areas sometimes have vertical sand filter drains as outlets (Figure 5). Effluent from the containment area passes vertically downward through the filter media and is discharged through holes in the side of the drain. This type outlet is designed to remove suspended

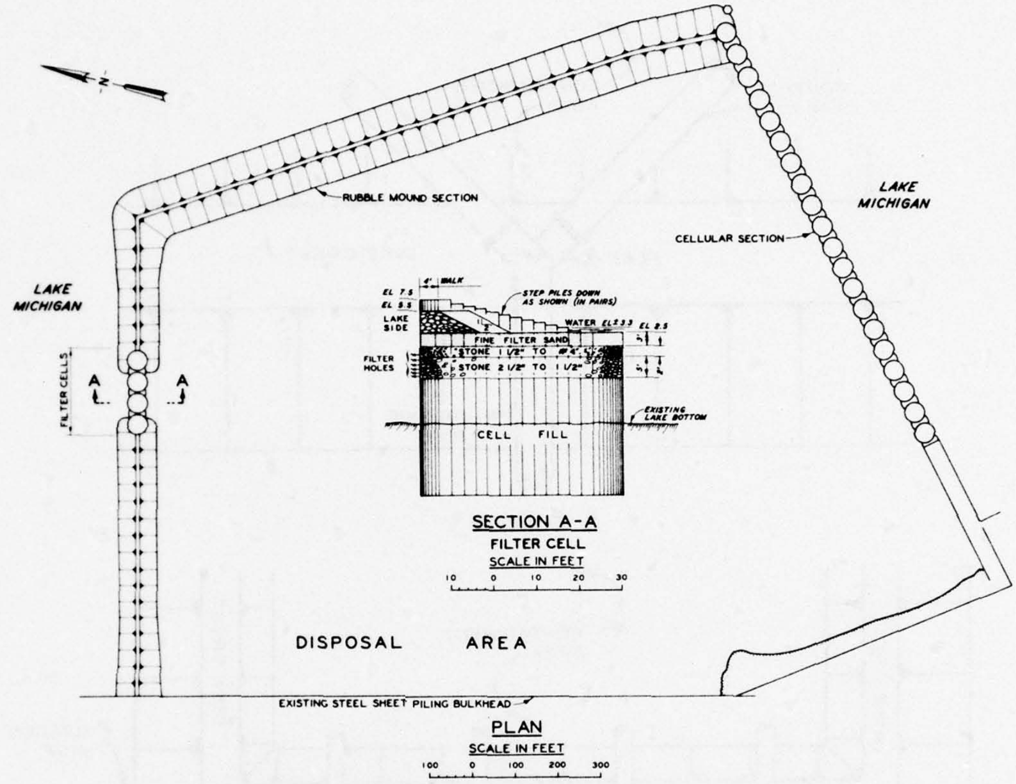


Figure 5. Dredged material containment facility proposed for Milwaukee Harbor, Wisconsin. Vertical sand drain filter cell shown in Section A-A[9]

solids from the effluent. Filter media evaluation and design procedures are reported in Reference 11.

22. Locations. The inspection of several containment areas and the interviews with District personnel revealed that the following rationale for locating containment area inlets and outlets is common throughout the CE:

a. Outlet structures (seldom more than three) are located at low spots on the perimeter of the containment area as near as practical to the body of water to which effluent is to be discharged.

b. After the outlet locations have been specified, inlets (dredge discharge pipe and extension(s)) are located on the perimeter as far from the outlet(s) as possible, while being located as near as possible to the dredge to reduce pumping distance.

c. Inlets are extended into the containment area far enough

> to ensure that the slurry cannot flow along the toe of the dikes and cause erosion that could result in a dike failure.

While this rationale may be effective for reducing short-circuiting and for decreasing pumping distances, other combinations of inlet and outlet locations, such as locating the inlet in the center of the area, may be useful in containment area management for dewatering dredged material. These combinations are given in Part III of this report.

Compartments

23. The use of cross dikes to divide a containment area into two or more compartments is a fairly common practice throughout the Corps. The intention is generally to improve effluent water quality; one procedure is to use the compartments in series, another is to use them in parallel. In the series operation the flow is introduced into the first compartment, which acts as a primary sedimentation basin. The effluent from the first compartment flows into a second (and sometimes a third and fourth) compartment for further settling to meet effluent water-quality standards prior to discharge.

24. When compartments are operated in parallel (Figure 1c), slurry is pumped into one compartment until it is filled. The flow is then directed to the second compartment, so that settling occurs in the first compartment while the second is being filled. After surface water is decanted, slurry is again pumped into the first compartment. The flow is thus alternated between the compartments throughout the disposal operation.

25. The San Francisco District has published a report[8] that describes a containment area management plan to operate several primary compartments in parallel, with the effluent from the primary compartments being drained to one of two secondary compartments (in parallel) that are operated in series with the primary compartments. The objective of this arrangement is to facilitate the placement of thin lifts of dredged material without violating effluent water-quality standards. This and other concepts for the evaporative dewatering of dredged material are described in Part III of this report.

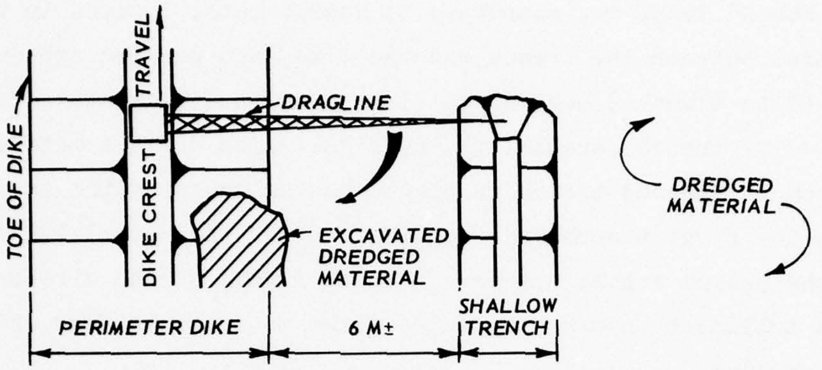
26. The Chicago District once divided a containment area into four compartments (Figure 1d) to be operated in series. The slurry was pumped into the first compartment, and the effluent was allowed to overflow into the second compartment. As the disposal operation progressed, the second and third compartments became filled; and the flow (still being pumped into the first compartment) was passing through all compartments before being discharged into the fourth compartment. From the standpoint of dewatering, this operation was ineffective because the dredged material in all compartments (some of which were filled) constantly contained surface water so that no evaporative dewatering was allowed. The management of compartmented areas for effective dredged material dewatering is discussed in Part III of this report.

Maintenance

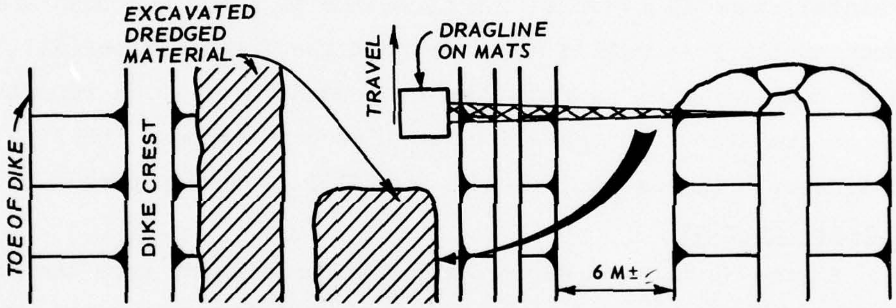
27. The maintenance of dredged material containment areas between disposal operations is generally restricted to dike raising, partly because funding for maintenance is unavailable and partly because District personnel are unsure of what maintenance is required. Except for dike raising between disposal operations, a common practice throughout the CE is to neglect containment areas when they are not being actively used, that is, when no disposal operation is in progress. In the following paragraphs, the dike raising procedures of two Districts, Charleston and Philadelphia, are described; other maintenance, especially surface water removal, is described in Part III.

Charleston District

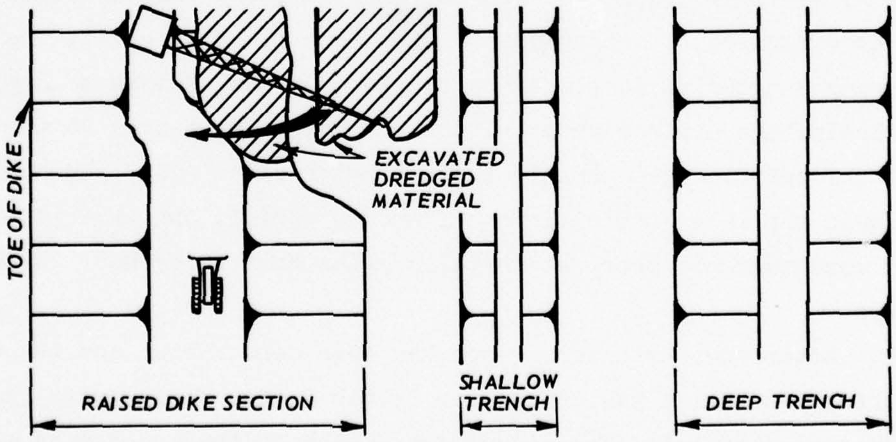
28. At the Daniel Island containment area the Charleston District raises the dikes using dredged material excavated from within the area. A dragline on the dike crest excavates a shallow trench parallel to the dike (Figure 6), and the excavated material is placed on the dike slope to dry. The trench drains surface water and groundwater to the outlets or to breaches in the dikes, and the dredged material begins to dry by evaporation. The area between the trench and the dike is stabilized somewhat as the water table is drawn down slightly by evaporation and seepage to the trench.



STEP 1: SHALLOW TRENCH EXCAVATED PARALLEL TO PERIMETER DIKE; DREDGED MATERIAL PLACED ON DIKE SLOPES TO DRY.



STEP 2: DEEP (2 TO 3 M) TRENCH EXCAVATED PARALLEL TO SHALLOW TRENCH; DREDGED MATERIAL PLACED BETWEEN SHALLOW TRENCH AND DIKE TO DRY.



STEP 3: DRIED DREDGED MATERIAL PLACED ON DIKE, SHAPED, AND COMPACTED BY BULLDOZER. BOTH TRENCHES USED TO DRAIN RAINWATER FROM DREDGED MATERIAL SURFACE.

Figure 6. Perimeter trenching to dry dredged material for raising dikes--Charleston District

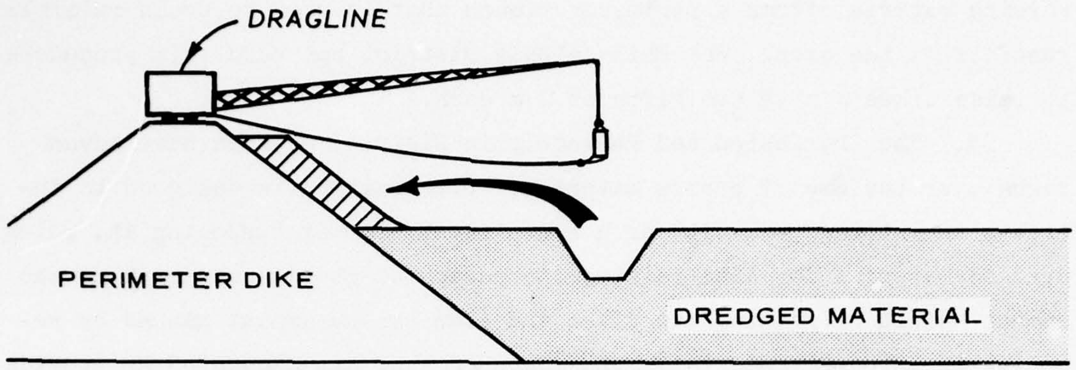
29. A second dragline, supported on double mats, located in the stabilized area between the trench and the dike, and working approximately 2 km (2 to 4 weeks) behind the first dragline, excavates a second, deeper (2 to 3 m) trench parallel to the first. The dredged material excavated from the second trench is placed behind the dragline in the area between the first trench and the dike. After the material excavated from the second trench has dried, it is placed on the dike by a dragline. A bulldozer shapes and compacts the material to form the raised dike section.

30. After the dikes have been raised the two trenches continue to drain rainfall runoff, avoiding the formation of a surface pond that would prevent the evaporation of water from the dredged material. Keeping the dredged material surface free of ponded water is an important maintenance operation that should be continued throughout the life of the containment area, as explained in Part III of this report.

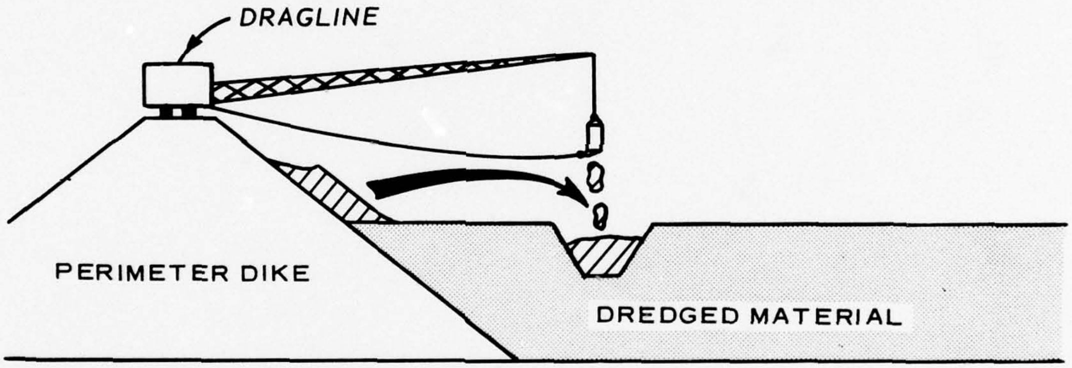
Philadelphia District

31. At the Wilmington Harbor-Edgemoor containment area the Philadelphia District raises the dikes by a method similar to that used by the Charleston District. The first step in the dike raising procedure (Figure 7) is to excavate a trench parallel to the perimeter dike. This trench is excavated by a dragline working from the dike crest; the excavated dredged material is placed on the interior dike slope to dry. The trench drains the surface water within the containment area to the outlets or through breaches made in the perimeter dike. The trench also helps lower the water table; in one 10-month period, the water table was lowered more than one metre at the Wilmington Harbor-Edgemoor containment area.

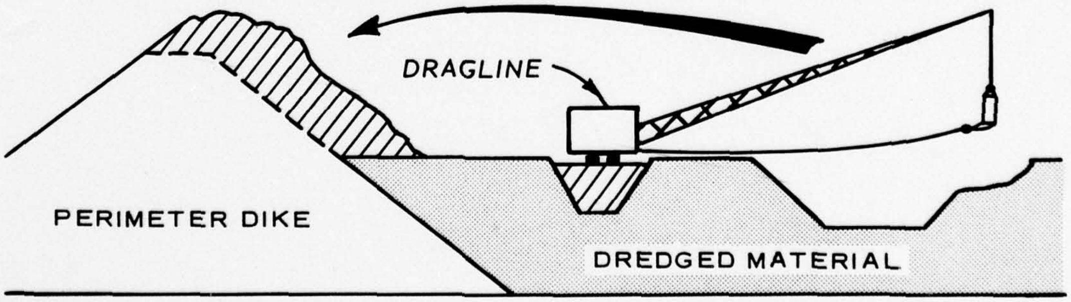
32. After the perimeter trench has been constructed and the excavated dredged material has dried, the trench is backfilled with the dried dredged material. The backfilled trench is then used as a stable base for the dragline, which travels on the backfill around the perimeter of the containment area, excavating material from the interior of the area. This excavated dredged material is placed on the dike, dried, shaped, and compacted to raise the dike. The excavation for the dike



STEP 1: TRENCH EXCAVATED PARALLEL TO PERIMETER DIKE; DREDGED MATERIAL PLACED ON SLOPE TO DRY.



STEP 2: TRENCH BACKFILLED WITH DRIED DREDGED MATERIAL.



STEP 3: DRAGLINE IN BACKFILLED TRENCH RAISES DIKE USING MATERIAL EXCAVATED FROM SECOND PERIMETER TRENCH.

Figure 7. Perimeter trenching to dry dredged material for raising dikes--Philadelphia District

raising material forms a perimeter trench that is used to drain rainfall runoff from the area. The Philadelphia District has used this procedure to raise dikes 4 m in two lifts of 2 m each.

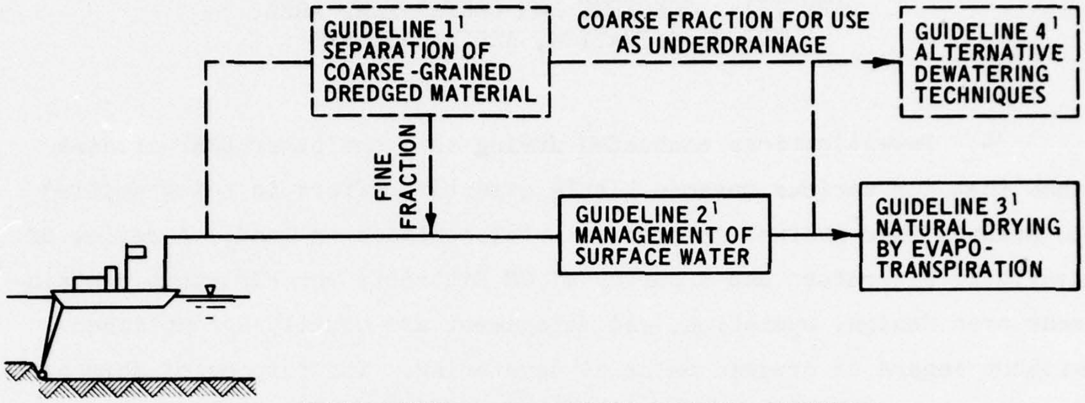
33. The Charleston and Philadelphia District methods have advantages over the use of borrow material. Dike raising is designed to increase the storage capacity of a containment area by deepening it; using dredged material for dike raising increases the storage capacity by the amount gained by raising the dikes and also by the amount gained by removing the dredged material. The trenches that are excavated to provide material with which to raise the dikes are useful for surface drainage and for lowering the water table somewhat.[12]

PART III: CONCEPTS FOR CONTAINMENT AREA DESIGN, OPERATION, AND MANAGEMENT

34. Investigations conducted during this and other DMRP studies show that for various reasons little effective effort is being applied to dewater fine-grained dredged material confined on land. A review of available literature and a survey of CE Districts revealed that containment area design, operation, and management are usually accomplished without regard to dredged material dewatering. The purpose of this part is to present and discuss containment area design, operation, and management concepts that promote dredged material dewatering by the natural processes of gravity drainage, evaporation, and transpiration, and that are adaptable to the incorporation of alternative dewatering techniques.

35. The first phase of this investigation showed that the difficulties experienced by CE Districts trying to operate and manage dredged material containment areas could be attributed in part to institutional factors including the lack of effective long-range planning, the lack of separate funding for containment area operation and maintenance, the inability to provide year-round maintenance at containment areas, and the lack of Federal containment area control. Long-range planning has been hindered by land acquisition difficulties, by the lack of planning information (e.g., containment area sizing method, dewatering technology, etc.), and by the other institutional factors, which have been similarly intensified by their interdependence.

36. The management concepts presented in this part are arranged into specific guidelines for dredged material dewatering (Figure 8). These guidelines present information related to the different phases of dredged material dewatering including separation of the free-draining, coarse-grained fraction and the natural and artificial dewatering of the fine-grained fraction, which is not free-draining. The discussion in this part is oriented toward the dewatering of maintenance dredgings, which are characteristically comprised predominantly of fine-grained particles.[1,3] The objective of each guideline is stated in terms of the intended effect on dredged material dewatering. The advantages,



NOTE: DASHED LINES INDICATE OPTIONAL ACTIVITIES.

Figure 8. Interrelationships among containment area management guidelines

disadvantages, and other considerations of alternative concepts for implementing each guideline are presented for use in making decisions associated with containment area design, operation, and management.

37. The concepts presented in this report are designed specifically for dredged material dewatering, but they must also be environmentally sound. Although not explicitly stated, environmental considerations are of paramount importance in containment area management. The concepts may sometimes appear to conflict with environmental contraints, but sound judgement in designing containment area management plans will result in effective dewatering without compromising environmental objectives. For example, rapid surface drainage after disposal operation is desirable for dewatering, because it allows the initiation of surface drying; but it may not allow time for settlement of all fine particles and may resuspend settled material. By delaying surface drainage until settling is essentially complete and then withdrawing water carefully, excessive suspended solids will not be carried from the containment area. Effluent water-quality requirements will have been met, and the water will have been removed as rapidly as practical.

38. The effectiveness of implementing the concepts presented in this part of the report will be highly dependent upon the ability of the CE to alleviate the difficulties that have historically plagued dredged material containment activities. Long-range planning, separate funding,

effective Federal control, and year-round maintenance of dredged material containment areas will each contribute to the success of effective containment area management. The justification for these measures will be effective long-range management, as opposed to the piecemeal operations that have too often characterized dredged material containment in the past.

Guideline 1: Separation of Sand and Gravel

39. Dredged slurry being pumped into a containment area can include a wide range of particle sizes that can be classified in one of two broad and indistinctly separated categories: coarse-grained (sand and gravel) or fine-grained (silt and clay). Fine-grained dredged material is difficult to dewater, while coarse material is relatively free-draining. The purpose of this guideline is to present information concerning the separation of the coarse-grained material from the fine material and to assess the impact of separation on dredged material dewatering. Natural segregation and artificial separation systems are briefly described, and uses for separated coarse material to dewater fine material are discussed.

Methods for separation of coarse material

40. Natural segregation. As dredged slurry is pumped into a containment area, a mound of coarse material is often formed near the discharge pipe. This material forms a relatively porous deposit consisting of sand, gravel, clay chunks, and miscellaneous trash. In some cases silty material is also deposited in the mound, and in others sandy material is deposited some distance away. The characteristics of the mounded material, that is, the types of material deposited near the dredge pipe, are dependent upon the hydraulics of the system and the settling characteristics of the slurry solids.

41. Selective dredging/feeding. Selective feeding involves placing sand and gravel into a specially designated basin, while fine-grained and mixed coarse and fine dredged material is pumped to a

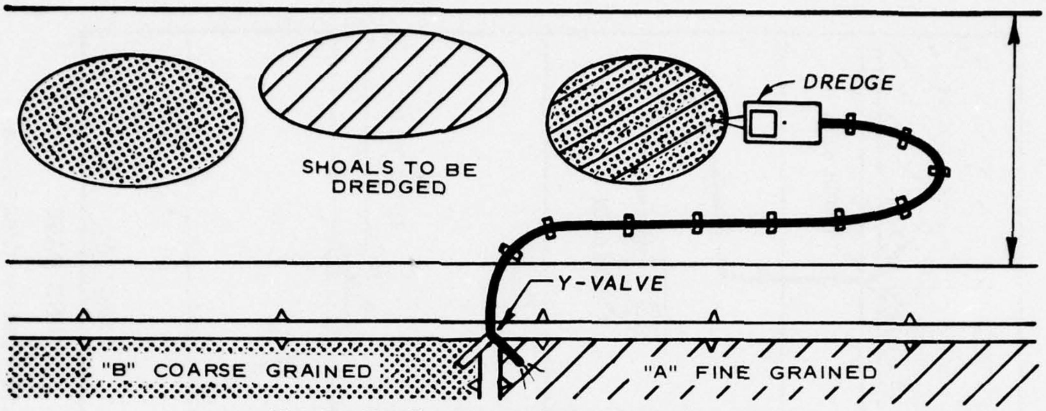
conventional containment area (Figure 9). Selective dredging is a planned operation in which layers of sand and gravel within a shoal are dredged and pumped into a special basin, while the remainder of the shoal is placed into a conventional containment area (Figure 10). Selective dredging and selective feeding differ in regard to the type situation to which each is applicable; selective feeding applies when coarse and fine materials exist in separate shoals, while selective dredging would be used to separate stratified shoals into coarse and fine fractions.

42. Separation basins. Another method for separating coarse material is to use two or more containment areas in series, the first area being hydraulically designed so that only coarse material will settle, while the remainder of the slurry continues into the next area. Reference 13 presents detailed information concerning the design and operation of separation basins. Some concepts for separation basins are summarized in Table 1.

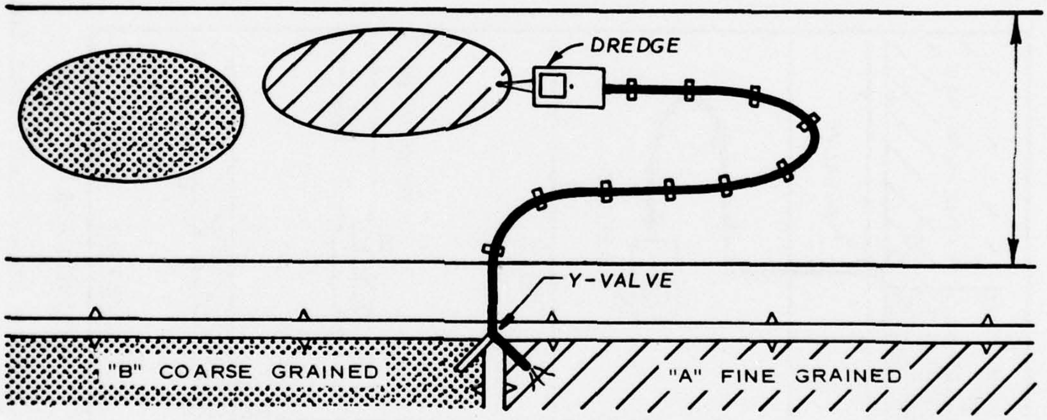
43. Hydraulic separation equipment. Reference 13 also presents detailed information about the use of hydraulic equipment for separation. Hydrocyclones, inclined tube settlers, spiral classifiers, and other pieces of equipment are all discussed, and some concepts are summarized in Table 2.

Use of coarse fraction to dewater fine fraction

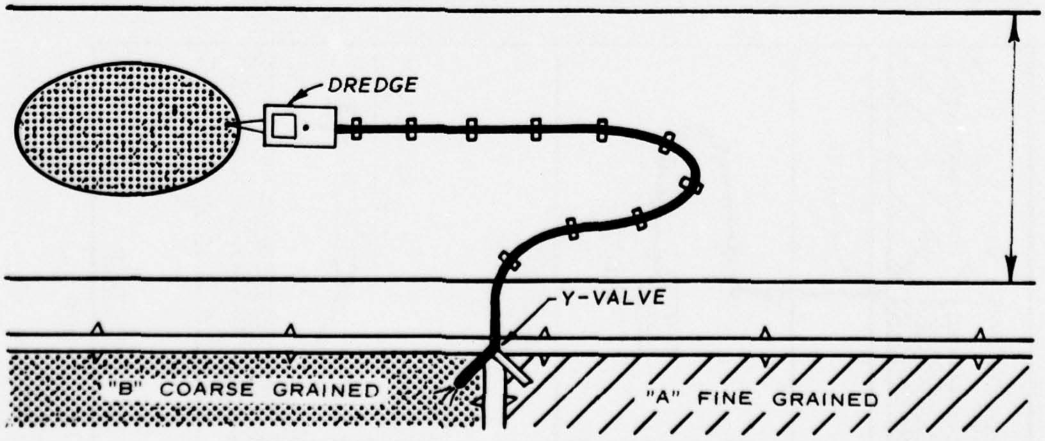
44. If loading and drainage techniques (temporary surcharging, horizontal sand blankets, etc.) can be effectively used to dewater fine-grained dredged material, then the use of sand and gravel separated from the dredged material to construct surcharge, sand drains, etc., should be considered. The use of separated sand and gravel would have two advantages over the use of sand and gravel from other sources. First the use of sand and gravel separated from the dredged material would not increase the total volume of material in the containment area, as using borrow material would. Second, separated sand and gravel may be available at a lower cost than borrow material, especially if enough suitable material becomes separated by natural segregation within the containment area.



MIXED FINE AND COARSE PARTICLES

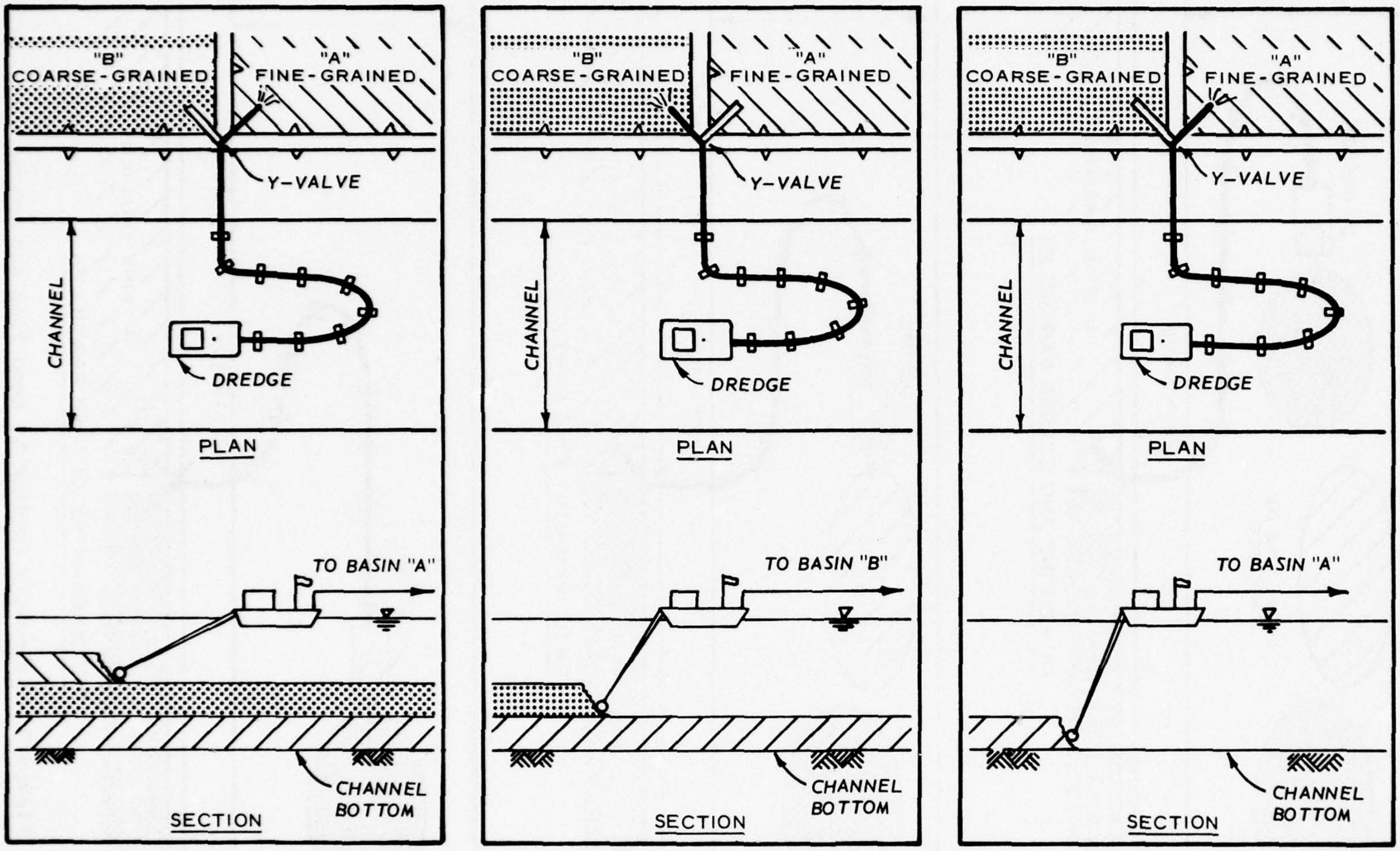


PREDOMINANTLY FINE PARTICLES



PREDOMINANTLY COARSE PARTICLES

Figure 9. Selective feeding to keep fine and coarse dredged material separated



FIRST PASS

SECOND PASS

THIRD PASS

Figure 10. Selective dredging to separate stratified shoal into fine and coarse fractions

Table 1

Concepts for Separation Basins*

Concept	Summary Description
Continuous dragline removal	Uses basins sized for the selective removal of sand and gravel (>74μ) and draglines for the continuous removal of material for conveyance to stockpiles or directly to beneficiation equipment
Multiple separation basins	Uses compartmented basins to separate and store sand and gravel for subsequent removal and processing during the periods between primary dredging operations or for sale in place to commercial firms
Floating separation compartments	A developmental concept in which floating compartments are used to selectively remove and place sand and gravel on the basin bottom to avoid fine-grained material contamination
Continuous removal with secondary dredges	Uses small secondary dredges to continuously remove sand and gravel as concentrated slurries for hydraulic transport to benefaction equipment for processing and stockpiling
Sand and gravel recovery and conventional containment restoration using secondary dredges	Uses small secondary dredges to remove selective deposited sand and gravel following dredging operations or to restore the storage capacity of existing basins and recover sand and gravel

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* From Reference 13.

Table 2

Concepts for Hydraulic Separation*

Concept	Summary Description
Hydraulic scalping and classification at full primary dredge flow to recover materials >74μ	Full primary dredge flow is directed to multiple hydraulic scalping units to separate and classify sand and gravel. Flow distribution is used to equalize flow to units with the number of units set by the settling rate of fine sand (>74μ)
Hydraulic scalping and classification at full primary dredge flow to remove particles @ >149 or >105μ followed by hydrocyclones	Uses a reduced number of hydraulic scalping units to remove sand and gravel down to >149μ or >105μ size followed by hydrocyclones and spiral classifier to recover materials down to >74μ
Hydrocyclone separation at full primary dredge flow	Uses grizzlies for debris removal followed by hydrocyclones to recover sand and gravel in maintenance dredging operations where particle sizes are >500μ. Spiral classifiers are used for benefication of sand and gravel
Hydraulic thickeners with hydraulic scalper and classifiers for the separation and processing of sand and gravel	Uses large cylindrical thickeners with rotating bottom rakes to split the full primary dredge flow with the underflow consisting primarily of sand and gravel processed in fewer hydraulic scalping units than scalpers above
Hydraulic thickeners with hydrocyclones	Uses large cylindrical thickeners with rotating bottom rakes to split primary dredge flow in maintenance dredging operations to reduce the number of hydrocyclones required for sand recovery compared to hydrocyclones above

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* From Reference 13.

Other considerations

45. Other considerations to be made relative to using naturally separated sand and gravel in containment area operations are the control of the area and the location of the coarse material within the area. When the area is not Federally controlled, the sand and gravel may not be available for use because either (1) the owner of the land wants to remove the sand for his own use or (2) the owner may revoke the easement and use the land created by the disposal operation.

46. Another problem is that the material must be hauled and distributed within the area. If the coarse material is to be used as underdrainage for subsequent lifts or for surcharging, then access to the interior of the area is required. This is discussed later in this report. If the material is to be used for dike raising, it must be distributed around the area perimeter. Using inlets located around the perimeter to discharge sand near the dikes would facilitate dike raising; the use of outlets discharging around the perimeter is discussed in a later section.

Summary of Guideline 1

47. Guideline 1 deals with the separation of coarse-grained dredged material and its use to dewater the fine fraction. During a disposal operation coarse-grained dredged material becomes separated from fine material, forming a mound near the discharge pipe. More effective separation can be accomplished by special separation basins, hydraulic separation equipment, etc., although extra cost is incurred. Using the coarse material within the containment area to dewater the fine fraction is advantageous, because no reduction in storage capacity results, and because no purchase cost is involved when coarse material is naturally separated. Coarse-grained dredged material can be used as a temporary surcharge to dewater the fine material or can be used to construct underdrainage for dewatering subsequent lifts.

Guideline 2: Surface Water Management

48. Throughout the dredging operation, ponded water exists within the containment area. As the thickness of the dredged material deposit

increases, the outlet elevation must be raised to provide a sufficient pond depth for settling. Alternatively the outlet can be kept at some constant elevation that will ensure that throughout the disposal operation the pond depth is at least the depth required for settling. After the disposal operation has been completed, the surface water must be removed to expose the dredged material surface to the atmosphere for drying. No dredged material drying can be accomplished until the surface water has been removed; for this reason the removal of surface water is the first step in the dewatering process.

49. This guideline presents a simple concept for managing the surface water in a containment area during and between disposal operations. This concept is designed to suggest a rationale for surface water management that will meet three objectives: (1) provide sufficient pond depth for settling throughout the disposal operation to ensure that effluent water-quality standards are met prior to discharge, (2) provide enough ponded water to support operations that are beneficial to dredged material dewatering, and (3) drain surface water as soon as effluent water-quality standards are met to initiate evaporative dewatering as soon as possible. These objectives are discussed in the following sections.

Surface water management during disposal operation

50. The management of surface water during the disposal operation consists of controlling the elevation of the outlet weir throughout the disposal operation to regulate the depth of water ponded within the containment area. While water ponded on the surface of a dredged material deposit prevents it from drying, variation of the depth of ponded water has little direct effect on dewatering. Therefore, surface water management during disposal will have little direct effect on dredged material dewatering as long as ponded water exists to prevent drying.

51. The following concept for managing ponded surface water is applicable to disposal operations in which sufficient dredged slurry is pumped on a continuous basis into a containment area so that a pond deep enough to ensure adequate settling and to serve certain dewatering-related functions will form. DMRP research[10] is currently under way to

determine the pond depth required for adequate settling to meet effluent quality standards.

52. Application of this concept to a large containment area that will not become sufficiently filled during a single disposal operation, or to situations involving intermittent flow, requires some concept modification. Considerations for large containment areas and for intermittent flow are discussed after presentation of the concept.

53. Description of surface water management concept. At the beginning of the disposal operation, the outlet weir is set at a predetermined elevation that will ensure that when the containment area is being filled the ponded water will be deep enough for settling and other functions. As the disposal operation begins, slurry is pumped into the area; no effluent is released until the water level reaches the weir. Once the water level reaches the outlet weir, effluent is released from the area at about the same rate as slurry is pumped into the area. Thereafter, the pond depth decreases as the thickness of the dredged material deposit increases. After completion of the disposal operation and of the activities requiring ponded water, the water is removed as quickly as effluent water-quality standards are met. Figure 11 illustrates the concept.

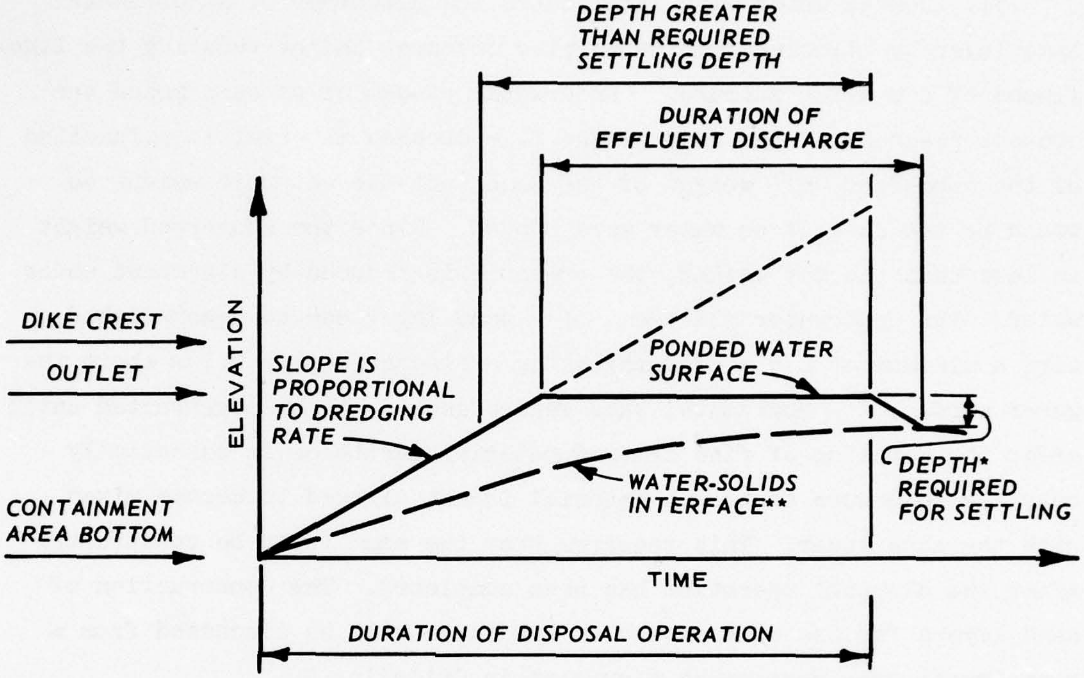
54. Dewatering-related uses of ponded water. Potential dewatering-related uses of ponded water have been suggested by several investigators.[4,5,13,14,15] These uses involve providing access to the interior of the containment area during and immediately following the disposal operation. Table 3 shows a summary of some uses of ponded water that can be of benefit to a dredged material dewatering plan and also indicates when the ponded water is required. The depth of water required is purpose-specific and depends upon the equipment to be used. Determination of the required depth, including factors that limit depth, is discussed in later paragraphs.

55. Floating the pipeline within the containment area can be of benefit to general containment area management and specifically to dredged material dewatering by greatly facilitating the movement of the discharge point without disruption of the dredging operation. Specific

Table 3

The Management of Ponded Water to Aid in Dredged Material Dewatering

Use	Required Depth	Time of Use	Remarks
Installation of dewatering material by workmen in boat or barge	Vessel draft	Indefinite	Installation of well points, electrodes, vertical drains, etc., during disposal operation helps ensure that dewatering systems are operational at earliest possible time
Underwater placement of horizontal sand layer	>0.5 m (Ref 15)	After completion of sedimentation	Underwater placement facilitates movement of pipe and helps prevent bearing failure
Movement of discharge pipe during disposal operation to ensure coverage of entire containment area	Pontoon draft	Throughout entire disposal operation	Floating pipeline. Coverage of entire area ensures minimum lift thickness
Location of discharge in center of containment area	Pontoon draft	Throughout entire disposal operation	Floating pipeline, easily removed after completion of disposal operation



* RESEARCH[10] UNDERWAY TO DETERMINE DEPTH REQUIREMENT

** ASSUMED APPROXIMATELY PARABOLIC (NOT LINEAR) DUE TO COMPRESSION SETTLING

Figure 11. Surface water management

objectives of pipe movement will be presented in subsequent sections of this guideline.

56. Access to the interior of the containment area during the disposal operation is hampered by the soft consistency of the dredged material deposit; but if sufficient water is ponded, then access by boat or small barge is feasible. Access to the interior of the containment area is beneficial to dredged material dewatering because dewatering system material, such as electro-osmosis electrodes, vertical drains, and well points, can be installed during the disposal operation and can be operational immediately after the surface water has been removed. The depth required for this purpose is determined by the draft requirement of the vessel used. Information concerning dewatering systems that can be installed during the disposal operation is presented in Guideline 4.

57. Ponded water also facilitates the placement of a horizontal sand layer by allowing continuous pipe movement and by reducing the likelihood of a bearing failure.[4] Underwater placement of sand means the contact pressure of the sand on the fine dredged material is a function of the submerged unit weight of the sand, not the wet unit weight as would be the case if no water were ponded. Since the submerged weight is less than the wet weight, the pressure is reduced by placement under water. The underwater placement of a sand layer can be accomplished with a minimum of 0.5 m of water using a discharge pipe 0.7 m above the water surface.[15] Horizontal sand layers should not be constructed until after the settling of fine dredged material particles is essentially complete to ensure that such material is not allowed to become mixed with the sand layer. This requires that the sand layer be constructed after the disposal operation has been completed. The construction of sand layers for use as drainage or surcharge will be discussed from a containment area management viewpoint in Guideline 4.

58. Selection of elevation of surface water. The elevation at which the surface water is maintained is determined by the thickness of the dredged material deposit at the end of the disposal operation and by the minimum pond depth requirement. Research is currently under way to develop methods for predicting the final thickness of the dredged material deposit and for determining the minimum depth for settling.[10] Table 3 showed that the depth required for various dewatering-related activities will not be great. A comparison between the depth required for a specific use and the depth required for settling will determine the minimum depth required; it is anticipated that the depth for settling will be adequate for providing access to the area.

59. Considerations for large containment areas. The concept described above for managing ponded surface water is not easily adapted to large containment areas. Large areas do not always become completely covered by dredged material and ponded water until after considerable dredging. To form and maintain a surface water pond to provide access to the interior of the area, the division of the large area into a number of smaller areas may be required. Each smaller area or compartment

can then be managed as a separate containment area.

60. There are several approaches to managing compartmented containment areas. Compartments can be filled one at a time with dredged material, in which case the entire containment area becomes filled horizontally as the compartments are filled. An alternative is to place a thin lift in each compartment, filling the entire containment area incrementally by adding additional thin lifts. A third approach is to use some compartments for confining material being disposed while other compartments are being used to dry material placed during previous disposal operations. Several other alternatives are conceivable; the use of compartmented areas for dredged material dewatering is discussed further in Guideline 3.

61. There are several advantages and disadvantages of dividing large containment areas into compartments. The major disadvantages are the extra cost of constructing cross dikes and the reduction of storage capacity. Dikes must be designed to withstand unbalanced hydrostatic pressures when one compartment is being filled while adjacent compartments are empty,[16] and will probably have a large cross section, which reduces the effective storage capacity of the area. Subsequent dike raising will be less expensive if dredged material is used, because the purchase of borrow material will not be required. Using dredged material to raise dikes also eliminates the storage capacity reduction associated with dike raising using off-site borrow. The excavation of dredged material also increases the capacity of a compartment, reducing the height to which dikes must be raised.

62. The principal advantage of compartments is that surface drainage and dredged material drying can be accomplished in some compartments during a disposal operation, whereas dredged material in large containment areas is constantly inundated during the disposal operation. This is especially important at containment areas where disposal is nearly continuous, with little time for dredged material drying.

63. <u>Consideration for intermittent flow.</u> The ponded water management concept presented above is based on the assumption of a continuous flow of slurry for a relatively long duration followed by an interval of

no disposal, but this is often not the case. The flow during a disposal operation can be intermittent; for example, hopper dredging is characterized by a cyclic disposal operation with intermittent flow.

64. The intervals between pumpouts during a hopper dredging operation provide periods when settling is not disturbed by slurry flow within the containment area, and removal of the clear water may be more advantageous to the overall disposal operation than would uses for ponded water. If settling occurs quickly enough, the clear water should be removed from the containment area prior to pumping in the next load, because the turbulence caused by the slurry flow can resuspend previously settled dredged material. For this operation clarification is accomplished by ponding the water between hopper dredge pumpouts and the clarified effluent is discharged as stated previously. If settling is very slow, then ponding of water for floating pipelines or for access to the interior of the containment area may be advantageous.

Surface water removal

65. Dredged material drying will be greatly enhanced by (1) the removal of surface water after the disposal operation is complete and (2) the rapid removal of rainfall to prevent the re-formation of a surface pond. Surface water remaining within a containment area after the completion of the disposal operation should be removed as soon as effluent water-quality standards can be met. Provision should also be made to ensure rapid rainfall runoff throughout the service life of the containment area.

66. Some of the problems that may hinder the rapid drainage of ponded surface water can be overcome by containment area management. One problem occurs when a large bowl-shaped depression in the interior of the containment area traps a pond of water that cannot drain to the outlet. Another problem is the difficulty in draining isolated ponds caused by an irregular dredged material surface.

67. Depressions. Depressions in the surface of the dredged material in a containment area trap water that cannot drain to outlets located on the perimeter of the containment area. Dredged material containment areas are often constructed on highly compressible foundation

soils.[9] When a dredged material deposit is placed, the foundation soil may consolidate considerably, forming a depression sloping downward from the perimeter toward the center of the containment area. Depressions or low spots can also form when a containment area does not become evenly filled during a disposal operation. Figure 2 shows an example of an unevenly filled containment area; the large pond cannot drain to the outlet.

68. Two alternatives for preventing surface water from becoming trapped in depressions in the interior of containment areas are (a) to prevent the formation of a depression and (b) to provide drainage from the depression to an outlet. The following paragraphs describe containment area management to prevent the formation of large depressions by increasing the thickness of the dredged material in the center of the area or by ensuring that the dredged material is placed evenly throughout the area. Alternatively, the depression could be used to advantage by providing a drainage outlet at the lowest part of the depression.

69. Prevention of depression. If the consolidation of foundation soils is expected to result in a depression in the center of a containment area, then the formation of the depression can be prevented by increasing the thickness of the dredged material in the center. The thickness of the dredged material can be increased by locating the inlet (dredge pipe) in the center of the area. The dredged material mound that builds up at the end of the inlet increases the dredged material thickness in the center of the containment area. If the mound increases the dredged material thickness enough to compensate for the consolidation of the foundation (which will be increased by the increased dredged material thickness), then drainage will be radial from the center outward to the perimeter, where outlets remove the water from the area.

70. While the inlet is usually located on the perimeter of the containment area, several methods of locating the inlet in the center appear feasible. A permanent installation could be made by installing dredge pipe over or through the dike and along the bottom of the containment area prior to disposal. The pipe would extend into the center of the area and an elbow would be provided so that a riser could be

extended above the anticipated level of the surface water. The riser could be fitted with a baffle plate to redirect the slurry flow horizontally and to reduce its velocity.

71. Another method is to extend the pipe, supported above the level of the surface water, into the center of the area. The end of the pipe could be made to rotate under the force of slurry striking an oblique baffle plate; or the direction of the flow could be changed intermittently by changing a flange connection. Changing the direction of flow helps keep the mound uniform and helps ensure that the dredged material flows in all directions, covering the entire containment area.

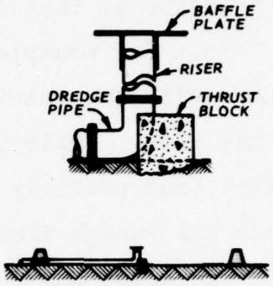
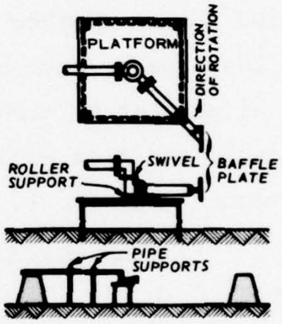
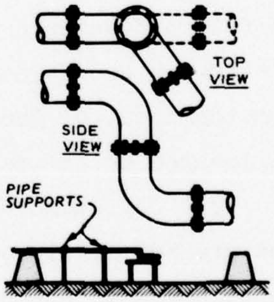
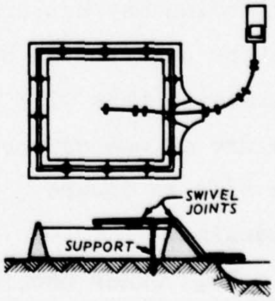
72. A third way to place dredged material in the center of the area is by using a floating pipeline. This pipeline could be anchored in position in the area and moved periodically to form the topography desired. When the disposal operation is completed, the pipe can be removed from the containment area prior to the removal of surface water. This is considered the most flexible and practical method of locating the inlet in the center of the containment area, because the installation does not have to be permanent, and the location can be easily changed. Methods for locating the inlet in the center of the containment area are shown in Table 4.

73. If difficulty in filling a containment area evenly is expected to cause a portion of the containment area to trap a surface pond that cannot drain to the outlet, then measures to place an even layer of dredged material must be implemented. The Detroit District has encountered this problem in several of its containment areas and has resorted to extending the inlet farther into the containment area by using flexible pipe. An alternative is to float the pipe within the containment area. The floating pipeline could be moved as necessary to fill low spots, ensuring that an even layer of dredged material is placed throughout the area.

74. Placing the inlet in the interior of the containment area must be accompanied by careful outlet management to prevent short circuiting. At most containment areas the inlet and outlet are located as far from each other as possible to ensure adequate time for settling. Placing

Table 4

Methods for Locating Inlet in Center of Containment Area

Method	Type of Installation	Operational Feasibility*	Other Considerations	Diagram
Dredge pipe laid along bottom of containment area to center, with vertical riser and baffle	Permanent	Location not variable. Vertical discharge redirected to flow in all horizontal directions	A,B	
Dredge pipe supported above dredged material into center of containment area; end of pipe has oblique baffle	Permanent	Location not variable. Horizontal discharge. Continuous change of flow direction	A,B	
Dredge pipe supported above dredged material into center of containment area. Pipe has flanged elbows and optional baffle at end. May include Y-valve	Permanent	Location not variable. Horizontal discharge. Occasional change of flow direction	A,B, or E,C,D	
Floating pipeline with optional baffle on pipe end	Temporary	Location easily changed. Horizontal discharge. Variability of flow direction dependent on spacing and number of swivel points	A,B, or E	

Note: A - Requires at least one outlet on at least two sides of containment area to avoid short circuiting.
B - Requires large containment area to avoid short circuiting.
C - Requires access to interior of containment area during disposal operation.
D - Requires interruption of flow or use of Y-valve to adjust direction of flow.
E - Requires outlet management to avoid short circuiting.
* Includes possible directions of flow and mobility of inlet.

the inlet in the center reduces the maximum possible distance between inlet and outlet by approximately one-half. To compensate for this, several outlets spaced around the perimeter of the containment area may be required so that slurry is never pumped directly toward an outlet.

75. For example, consider a containment area that is roughly square with the inlet located in the center and an outlet in each corner of the area. While the slurry is being pumped toward one outlet, that outlet (and possibly the two adjacent outlets) should be closed so that water has enough time for settling prior to being removed from the area. When the mound has built up in front of the pipe, the pipe can be directed toward another of the outlets, which is in turn closed. The need to keep one or more outlets closed during the disposal operations could be eliminated by directing the flow vertically upward to a baffle plate, because the flow would be slowed by the baffle plate and would be redirected radially in all horizontal directions.

76. Depression drainage. Prevention of an undrained pond in a depression in the interior of a containment area can also be accomplished by providing an outlet at the low spot in the depression. In this way the natural drainage pattern can be used to advantage. The outlet can be either a drop-type outlet with drainage pipes sloped to remove water from the area; or the outlet can be a trench sloping downward to an outlet located on the perimeter of the containment area.

77. Outlet structures located in the center of the containment area are not likely to be effective measures for several reasons. First, the size and location of a depression are difficult to predict; and the depression may not drain the entire area. Since the outlet structure must be constructed before the disposal operation, the formation of a depression that will drain the entire containment area must be ensured; the use of one or more inlets discharging around the entire perimeter of the dike to ensure a center depression is discussed later in this guideline.

78, Other problems associated with the use of an outlet located in the interior of a containment area involve the pipes required to drain the water from the area. To be effective these pipes must be laid on a slope that will maintain sufficient flow velocity to prevent sedimentation within the pipe. In addition, the pipes would be subject to differential settlements, and pipes not properly bedded may be broken as a result. Another difficulty associated with center outlets is the need to adjust the weir during and after the disposal operation. Access can be afforded to the outlet by boat, bridge, or amphibious craft; but this is more inconvenient than reaching and adjusting weirs located along the containment area perimeter.

79. The use of a center outlet also requires coordination with the inlet(s) to ensure utilization of the entire containment area; inlets should be located around the perimeter of the containment area. Used alternately or simultaneously, the inlets must be controlled such that the dredged material is placed over the entire containment area to ensure that a depression will be formed in the center of the containment area, and not in the spaces between the inlets and the outlet. In addition, the management of inlets located on the perimeter of the containment area must include precautions against mound overlapping, which may trap water between the dike and the mounds.

80. Discharging the outlets alternately is useful for preventing short circuiting. As the area between one inlet and the outlet fills, the slurry may channelize in a more or less direct route from inlet to outlet. When this begins, the flow can be diverted to another inlet. Simultaneous discharge of slurry from several inlets located on the perimeter can also be advantageous, because the lower velocity of the slurry flow results in more pronounced mounding around the edge of the containment area. This mounding in turn increases the slope from inlet to outlet, and drainage will be improved.

81. A more attractive alternative to locating the outlet in the center of the area is to operate the containment area as usual, with the inlet at one end and the outlet at the other. After surface water has been withdrawn through the outlet, only a pond in the depression will remain. This pond can be drained by excavating a trench from the low point of the depression sloping down to the outlet. Water will drain to the low spot of the depression and be conveyed in the trench to the outlet.

82. Isolated shallow ponds. As the removal of surface water nears completion, the rate of runoff decreases due to the lack of head. This same problem exists after a rainfall that results in the buildup of isolated shallow ponds of water in the containment area. In addition to the lack of head, runoff is also retarded by the surface roughness and mild or horizontal slopes characteristic of dredged material deposits. Surface water runoff may be further hindered by vegetation. Surface trenching and inlet-outlet management appear to have potential for improving the surface drainage characteristics of dredged material deposits.

a. Surface trenching. An effective method for draining shallow and isolated ponds of surface water from dredged material containment areas has been demonstrated in Riverine Utility Craft (RUC) field trials. The RUC (Figure 12), an amphibious vehicle developed for use by the U. S. Navy, is capable of draining surface water by making two drainage ditches with its helical screws as the vehicle moves across the surface of the dredged material

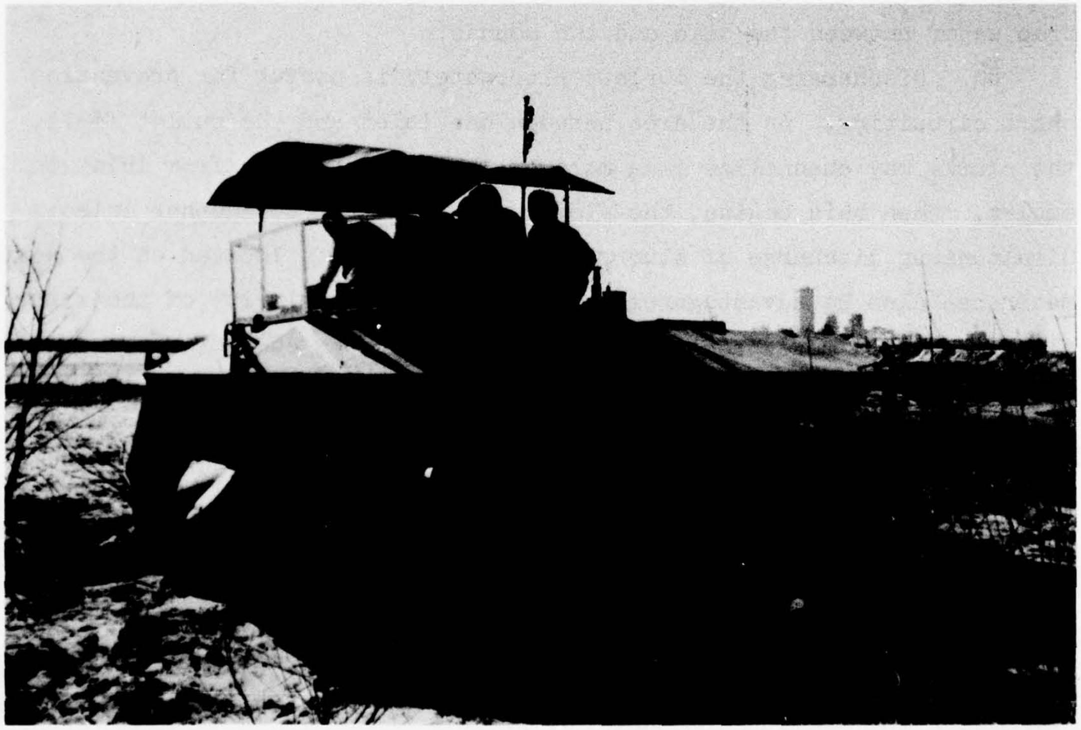


Figure 12. Riverine Utility Craft (RUC)[17]

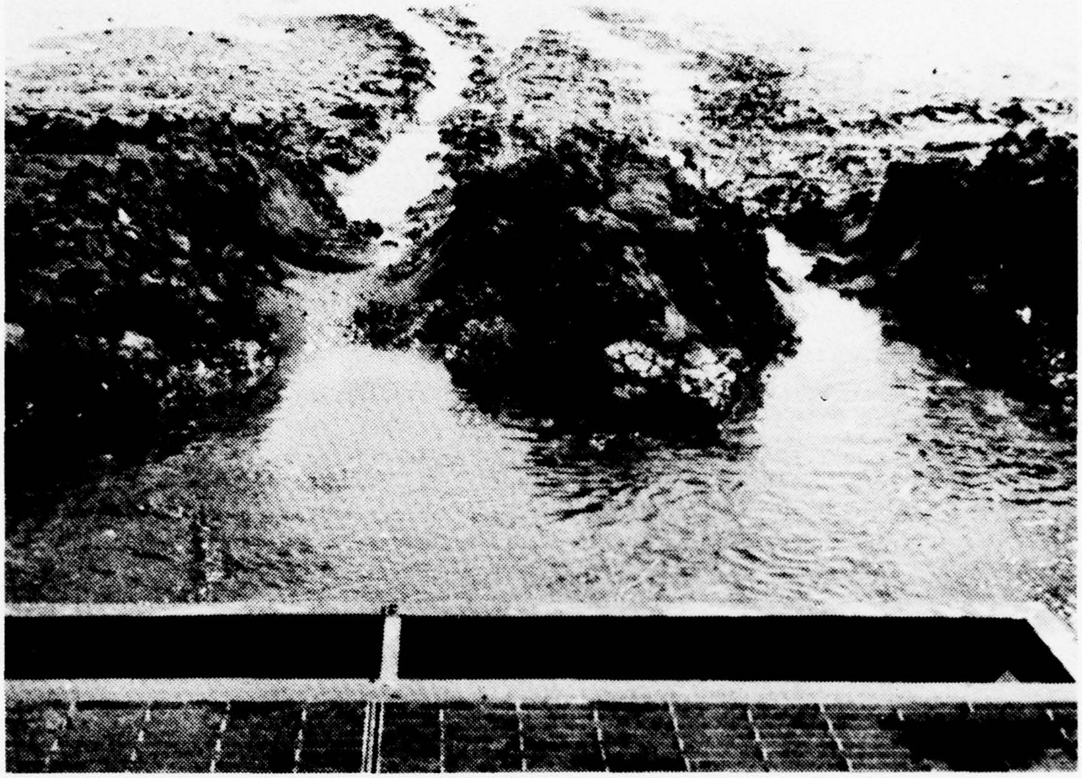


Figure 13. The trenching ability of the RUC in exceptionally soft soil and the effectiveness of the trenches in collecting water are illustrated in this view taken directly behind the vehicle[17]

(Figure 13). During a 2-1/2 day field trial in the Mobile District, a RUC was used to drain surface water from a 96-ha containment area.[17] Further information concerning the use of the RUC for dredged material dewatering is presented in Guideline 4. Other approaches to trenching, using different types of equipment, are effective for draining surface water and are discussed in Guideline 4; but the RUC seems to be the most effective method for obtaining rapid surface drainage, when no crust or a crust less than 15 cm thick exists.

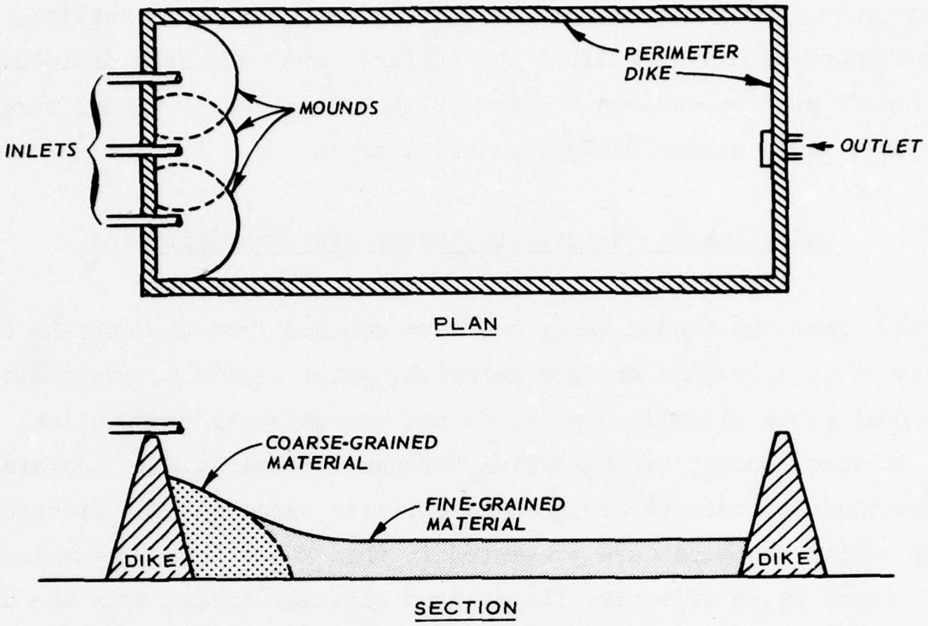
b. Inlet-outlet management. The removal of a shallow depth of water can be somewhat expedited by managing inlets and outlets during the disposal operation to place a dredged material deposit whose surface slopes continually and as steeply as practical toward the outlets. The slope should be steep enough to overcome the effects of surface roughness on runoff, but not so steep that the dredged material is eroded. The following inlet-outlet management concept is designed to provide a slope from one end of a containment area to another. Concepts for sloping the dredged material from the perimeter to the center and vice versa have been presented previously.

(1) Figure 14 shows a containment area with an outlet in one end and an inlet zone in the opposite end. Inlets are located at various points in the inlet zone, discharging either simultaneously (multiple inlets) or alternately (single movable inlet or multiple inlets discharging singly). A common practice is to use a single inlet, changing its location between disposal operations as necessary to keep mounding from blocking the flow of slurry. The result of this practice is the buildup of several mounds, one near each discharge location. By careful management of the discharge locations, a continuous line of mounds can be constructed, as shown in Figure 14a. When the line of mounds is complete, the dredged material will slope down toward the outlet. By grading the mound area between disposal operations, the process can be repeated by extending the pipe over the mound area and constructing a new line of mounds, as shown in Figure 14b. Water trapped between mounds must be removed.

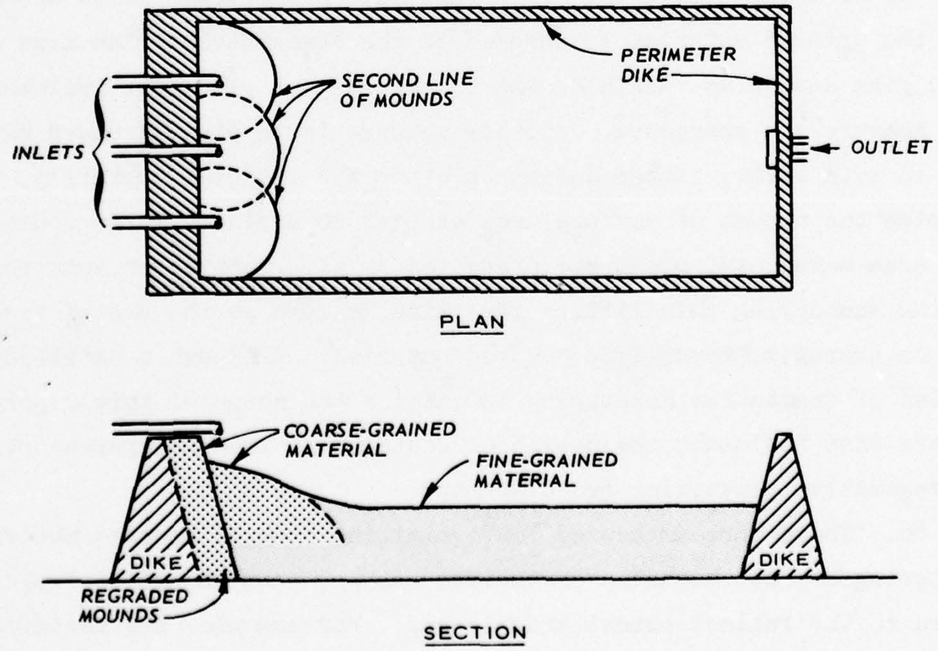
(2) The use of several inlets discharging simultaneously from the same dredge pipe serves to divide the flow, reducing the velocity. The reduced velocity in turn induces the settlement of smaller particles near the inlets, so that mounding may be somewhat increased. The increased mounding may cause a steeper slope near the inlets, but the slope away from the inlet will be correspondingly flatter. Increased mounding may also cause a problem by building up to a height at which the line of mounds blocks the flow of slurry; but this is easily remedied by extending the pipe, using the line of mounds to support the pipes. As in the case of alternating inlets, the water trapped between mounds must be removed.

Summary of Guideline 2

83. Guideline 2 is concerned with surface water management during and between disposal operations. During disposal operations surface water should remain ponded to a depth that will provide adequate detention time to meet effluent water-quality standards. The water ponded for this purpose provides a means of access to the interior of the containment area during disposal for installing dewatering system material or for floating pipelines. Upon completion of disposal operations the



a. FIRST LINE OF MOUNDS



b. SECOND LINE OF MOUNDS

Figure 14. Inlet-outlet management to provide smooth slope from inlet to outlet

surface water should be drained as quickly as possible to initiate dredged material drying. After the surface water has been drained, rainfall runoff must be ensured to prevent the formation of ponded surface water that would hinder dredged material drying.

Guideline 3: Natural Drying by Evapotranspiration

84. Once the ponded water has been drained from the surface of a deposit of fine-grained dredged material, water begins to evaporate from the deposit when climatic conditions are conducive to evaporation. Water is also removed by vegetation through transpiration. Containment area management concepts designed to optimize these natural dredged material drying processes are presented in this guideline. The concepts are designed to be effective for dredged material drying from the time the surface water is removed until climatic conditions are no longer conducive to natural dewatering.

85. In this guideline three measures to optimize the natural dewatering of dredged material are described. One measure is to ensure that the dredged material is exposed to the atmosphere for as much of the drying season as possible, and two management plans for implementing this measure are presented. Another measure is to place dredged material in thin lifts, either during or after the disposal operation, to maximize the amount of surface area exposed to drying. Three containment area management plans are presented as alternative concepts for placing and drying thin lifts. The third measure is the use of vegetation to transpire water from dredged material. Although a detailed discussion of vegetative dewatering is outside the scope of this report, factors that influence the design of containment area management plans for vegetative dewatering are discussed.

86. These three measures for optimizing natural dredged material dewatering are not mutually exclusive; rather, each should be implemented to the fullest extent practicable. For example, the maximization of the amount of time the dredged material is exposed to drying conditions is a natural complement to placing and drying thin lifts. The

contribution that each measure can make to the optimization of dredged material drying should be fully utilized.

Concepts for maximizing exposure of dredged material to atmosphere during drying conditions

87. Three factors that contribute to maximizing the exposure time of a dredged material deposit to the atmosphere are: (1) surface drainage, (2) arrangement of the dredging schedule to accomplish maximum dredging before hot, dry weather, and (3) arrangement of the containment area utilization schedule to maximize the dredged material surface area left undisturbed throughout the drying season. The first factor has been discussed in Guideline 2. The second factor may sometimes be somewhat idealistic and impractical, because other important factors influence the dredging schedule; but in cases where practical, the scheduling of winter/rainy season dredging can result in increased drying time for the dredged material during the hot, dry season. The scheduling of dredging to enhance dewatering is somewhat beyond the scope of containment area management, but Districts should review their dredging schedules in an attempt to schedule as much dredging as possible during unfavorable drying conditions, paying special attention to dredging projects that utilize containment areas that are used only once per year or less frequently.

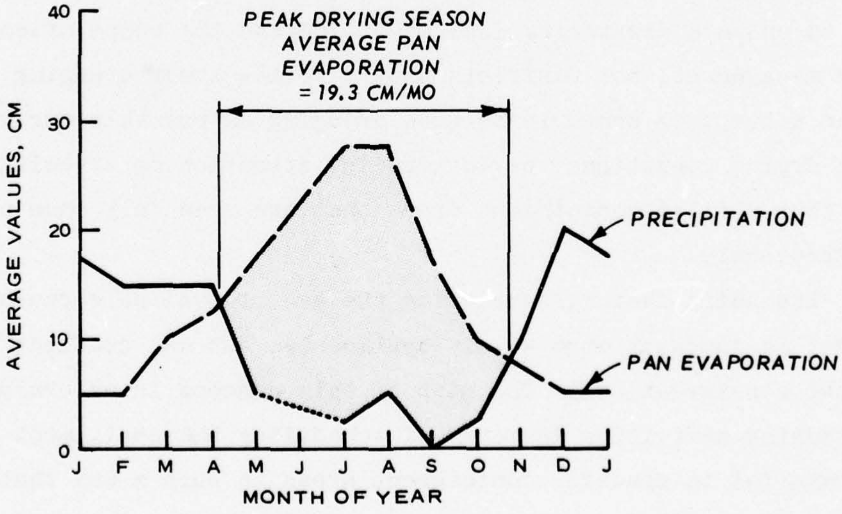
88. The third factor, scheduling the use of available containment facilities, is somewhat more widely applicable, but may conflict with operational considerations. The gist of this concept is an evaluation of all dredging activities in terms of scheduling the assignment of dredged material to specific containment areas in such a way that some of the dredged material is allowed to dry during the entire drying season.

89. Economic practice is to place dredged material into the containment area nearest the dredging site, thus minimizing pumping costs; but in some cases large volumes of dredged material must be disposed into several containment areas located within a relatively small geographic area or into a large compartmented area. Under these

circumstances it may be possible to select certain of the available containment areas or compartments for use during the dry season, while the remaining areas would be inactive. The dredged material in the inactive areas would be undisturbed during the entire drying season, during which time dewatering could be accomplished by evapotranspiration, some alternate dewatering technique (Guideline 4), or a comprehensive plan incorporating some combination of dewatering techniques.

Evaporation of water from
fine-grained dredged material

90. Extensive laboratory and field studies of the evaporation of water from fine-grained dredged material are reported in Reference 5, which includes maps showing monthly average pan evaporation and net evaporation rates throughout the U. S. Using these maps, Figures 15 and 16 were prepared, showing average pan evaporation and precipitation for the San Francisco, California, and Mobile, Alabama, areas, respectively.



NOTE: DATA FROM REFERENCE 5.
POSITIVE NET EVAPORATION IN SHADED AREA.
JUNE PRECIPITATION NOT KNOWN.

Figure 15. Average evaporation and precipitation data for San Francisco, California, area between 1931 and 1960

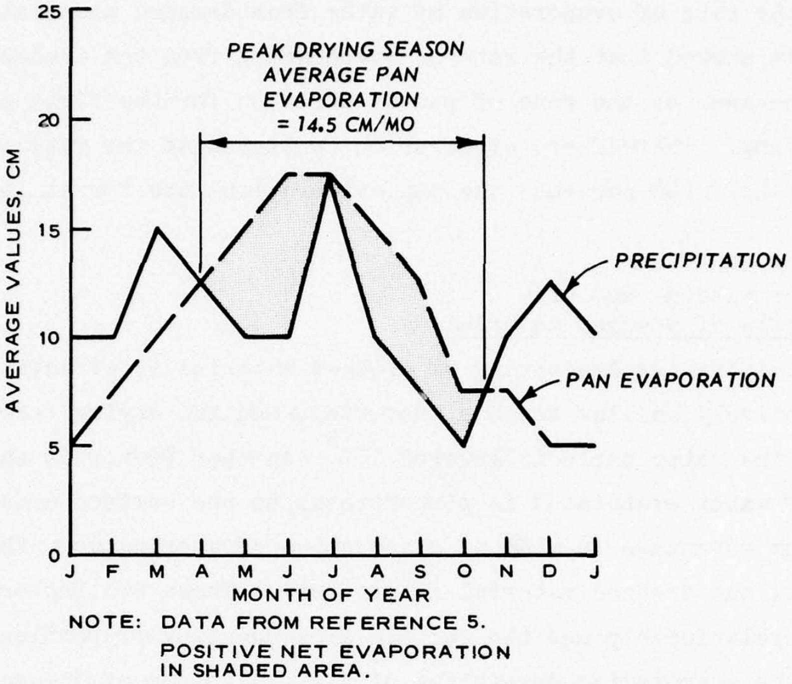


Figure 16. Average evaporation and precipitation data for Mobile, Alabama, area between 1931 and 1960

91. Figures such as these are useful for estimating the length of the drying season and for estimating the effectiveness of evaporative dewatering. The drying season shown in each of these two figures is that period of time during which evaporation equals or exceeds precipitation. The actual drying season is probably somewhat longer, because if a substantial amount of rainfall does not infiltrate the dredged material, then net evaporation will result even though precipitation is greater than evaporation.

92. Figures 15 and 16 show that the San Francisco area is much more suitable for evaporative dewatering than is Mobile. Unless rainfall infiltration is very slight evaporation is not likely to be a very effective method for dewatering dredged material in the Mobile area. Improved surface drainage would minimize infiltration and only a small fraction of the precipitation would require evaporation.

93. Using large samples of four different types of fine-grained dredged material, field evaporation experiments were conducted to

determine the rate of evaporation of water from dredged material.[5] The test results showed that the rate of evaporation from the dredged material was the same as the rate of pan evaporation for the first eight days of drying. Thereafter, evaporation continued at the rate of approximately one-half (48 percent) the pan evaporation rate for at least 90 days.

Concepts for placing and drying thin lifts of dredged material

94. Evaporative dewatering of dredged material is effective for only a relatively shallow depth of material, and the drying rate decreases as the water table is lowered.[5,14] Another factor is that the quantity of water evaporated is proportional to the surface area, so that maximum advantage is made of evaporative dewatering when the surface area of the dredged material is greatest. These two factors, the depth-rate relationship and the surface area-quantity proportionality, show that the evaporative dewatering of a given volume of dredged material will be more effective if the dredged material is placed as a thin lift than if it were placed as a thick lift. Table 5 shows the recommended maximum lift thicknesses suggested by various investigators. There is little evidence that any of these is an optimum thickness for drying, and thicknesses are intended for different purposes.

95. One approach to placing dredged material in thin lifts is to obtain sufficient land area to ensure adequate storage capacity without the need for thick lifts. Implementation will require careful long-range planning to ensure that the large land area is used effectively for dredged material dewatering, rather than simply being a containment area whose service life is longer than that of a smaller area. The acquisition of large land areas will be more worthwhile when advantage is made of the area by placing and drying dredged material in thin lifts. Government control of large areas is advantageous to ensure their availability throughout their service life.

96. Another method is to dredge large quantities for a short time, forming a thick lift, which is then rehandled and dried incrementally in thin lifts elsewhere. This procedure will require careful planning

Table 5

Recommended Maximum Lift Thickness for Evaporative Dewatering of Fine-Grained Dredged Material

Reference	Recommended Maximum Thickness, m	Basis for Recommendation	Remarks
4	1.0	Literature review and extensive expertise in soil dewatering	
5	0.3	Laboratory and field dredged material evaporation experiments	Considered most practical thickness for undisturbed (no trenching, etc.) evaporative dewatering
6	1.0	Extensive European experience with the "ripening" of dredged material deposits	Requires two-year drying period to be effective. "Ripening" process reviewed in Guideline 4
8	0.3	No rationale stated; thickness used for example calculations	Tentative disposal scheme using several "primary" settling ponds and two "secondary" ponds. Scheme is based on lab testing of sediment but is untested in field
14	0.1	Theoretical analysis of overconsolidation by desiccation	This thickness is considered impractical

to ensure that material is dried before being covered by another lift. Government control of the area to ensure freedom of rehandling activities will be advantageous and perhaps necessary in some cases. Funding designated specifically for the rehandling and drying activities will be required to ensure completion of the entire process.

97. A third concept is to arrange the dredging schedule such that material is dredged in small amounts over a long term, rather than in large amounts in a relatively short time. This concept requires long-range planning so that dredging requirements can be satisfied. Government control of containment areas will be helpful so that negotiations to acquire containment areas will not disrupt the dredging schedule.

98. Use of large land area. Simple geometry shows that the way to reduce the vertical thickness of a dredged material deposit is to increase its horizontal area. Instead of the present practice of acquiring land and constructing containment areas incrementally over a long period of time, bulk acquisition and construction would permit the placement of thin lifts. Several Districts have attempted, with varying degrees of success to acquire large tracts of land to provide long-term storage capacity; but the intention was not to facilitate the placement of thin lifts. Those Districts that utilize large containment areas have generally not managed these areas for effective evaporative dewatering; and those Districts that have not been successful in developing long-term containment capability have generally failed because of land acquisition problems, which are described in Reference 9.

99. Until land acquisition difficulties are alleviated, the use of large areas to place and dry thin lifts of dredged material will be restricted. Some help in alleviating this problem may be possible if the use of large areas can be shown to be of benefit to dredged material dewatering. If placing thin lifts can be shown to be a necessary or desirable part of an overall dewatering plan, and if this dewatering plan can be justified by the resulting increases in storage capacity and improvements in dredged material properties, then local sponsors may be more successful in providing land for dredged material containment areas.

100. Once a District has large areas for dredged material

confinement, operation and management plans for the effective use of the areas will be required to ensure that thin lifts are placed and that each lift is allowed to dry before the next lift is placed. One approach is the use of compartmented containment areas, as described in Guideline 2.

101. Large containment areas, especially those used nearly continuously, are difficult to manage for effective natural drying of dredged material. However, dividing of a large containment area into several compartments can facilitate management because each compartment can be managed separately. The practice of continuous disposal and surface water decantation does not allow sufficient time for natural drying. A compartmented area, on the other hand, can be managed so that some compartments are being filled while the dredged material in others is being dewatered.

102. One District has proposed a technique for the design and operation of a large area in which to place and dry thin lifts of dredged material. While this is only a tentative scheme, it serves as a useful example, and may be of value as a rationale for designing similar operations in other Districts. The scheme (Figure 17) consists of providing a number of primary basins to be used sequentially as containment areas, and a pair of secondary basins, to be used for clarifying the effluent from the primary basins. Each primary basin is sized to contain a thin lift of dredged material, and enough basins are provided so that each primary basin is allowed sufficient drying time before another lift is placed inside.

103. Effluent from the primary basins would be very turbid, because water would be drained rapidly to expedite drying. Effluent clarification would be accomplished in the secondary basins, which would be sized to ensure that appropriate effluent water-quality standards were met prior to discharge. Maintenance of the secondary basins would be simplified by operating them in parallel, using one for clarification while placing the sediment from the other into one of the primary basins.

104. Figure 18 shows a similar management procedure for placing

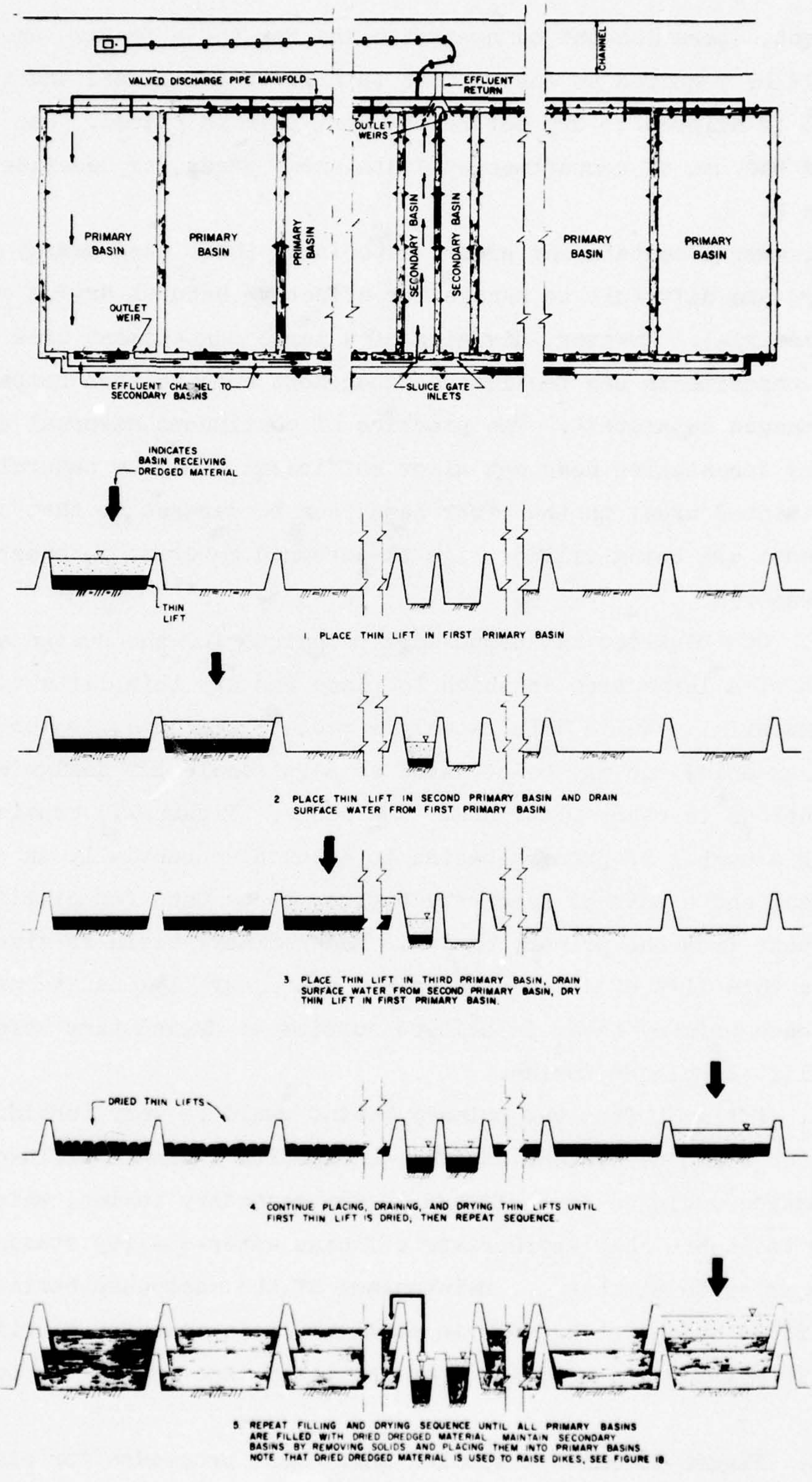
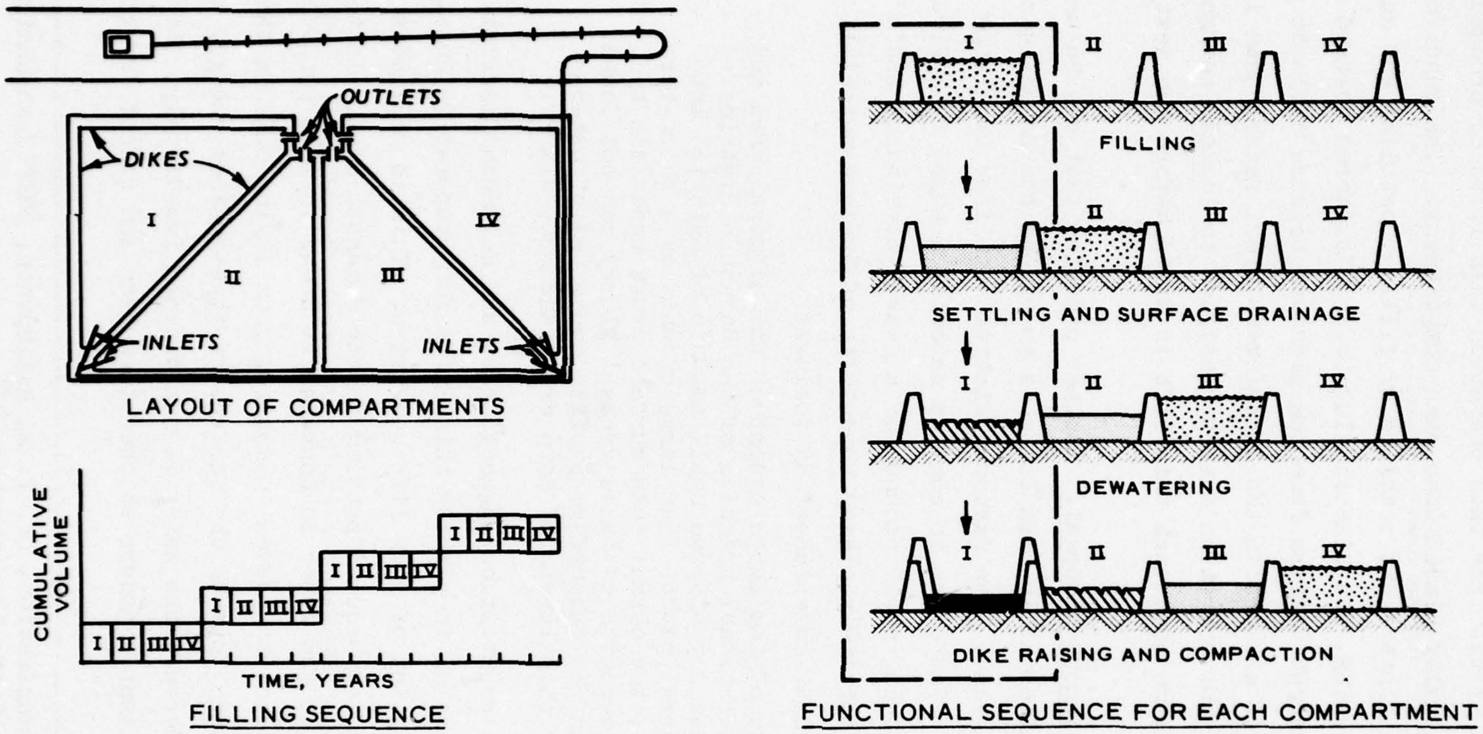


Figure 17. Compartmented containment area for placing and drying thin lifts of dredged material



LAYOUT OF COMPARTMENTS

FILLING SEQUENCE

FUNCTIONAL SEQUENCE FOR EACH COMPARTMENT

Figure 18. Alternative compartmented containment area for placing and drying thin lifts of dredged material

and drying thin lifts. For this operation thin lifts of dredged material are sequentially placed into each compartment. The functional sequence for each compartment consists of filling, settling and surface drainage, dewatering, and dike raising (using dewatered dredged material). This concept differs from the previous because effluent water-quality standards are met in the containment area, rather than in a special basin. The operation must be designed to include enough compartments to ensure that each thin lift is dried before the next lift is placed.

105. Continuous disposal. Another practice that can be used to place dredged material in thin lifts is to extend the dredging season over the entire year. The Savannah District utilizes two large containment areas, Figure 1b, to confine material dredged from Savannah Harbor. By dredging small amounts on a nearly continuous basis the District has effectively placed thin lifts of dredged material, described by one DMRP researcher* as follows:

> Because of the large extent of the disposal area and the operational practice of the Savannah District to continuously dispose small amounts of material into this area (rather than large amounts on a short-term basis), the normal thin surface crust underlain by thick deposits of 'axle grease' slurry was not found. Instead the subsurface profile consisted of alternating thin layers of hard crust and soft slurry.

106. This description suggests that the Savannah District was only partially successful in placing thin lifts for evaporative dewatering, since only a portion of each lift was dried. This is misleading, however, because of a mosquito problem in the Savannah area. In the Savannah District the water in containment areas is left ponded between disposal operations to prevent mosquitos from laying eggs in the desiccation cracks that form on the surface of fine-grained dredged material upon drying. Because the water is not drained immediately, the lift does not have sufficient exposure to the atmosphere and cannot dry completely.

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* Personal communication, Dr. T. A. Haliburton, DMRP Geotechnical Engineering Consultant, 13 September 1976.

107. Like any concept for placing dredged material in thin lifts, a large containment area is required. One of the keys to the success of this concept is in the availability of sufficient land area. The two areas shown in Figure 1b are very large, 480 and 960 ha. Table 6 shows the quantities of material dredged and placed into these areas between FY 70 and FY 73. These volumes represent the volume of material dredged, not the volume the material occupies in the containment area. The volume of material immediately after sedimentation inside the containment is usually larger than the volume dredged.[9] This table shows that a large volume of dredged material was placed in thin lifts; therefore this concept appears feasible.

108. Rehandling. Another concept for placing and drying thin lifts is to transfer dredged material from one containment area or compartment to another in increments. This concept is intended for situations in which sufficient land area is not available or in which continuous dredging is not feasible to implement one of the previous concepts. This concept requires two containment areas: one with sufficient storage capacity to contain all the material to be dredged during one dredging season, and one large enough to store the material from the first, after the material has been dewatered and compacted. The reclamation of a filled containment area could also be accomplished by this method, which is described below.

109. The first step of this procedure (Figure 19) is to confine the material in the first area in the conventional manner. Ideally, the dredging is accomplished during the cold/wet season so the material will be exposed during the hot/dry season. After completion of the disposal operation, surface water is removed (Guideline 2), unless the material is to be removed by a small secondary dredge. At or before the beginning of the dry season, a thin lift of material is taken from the storage area and placed into the drying area, which is located adjacent to the storage area if possible. While the thin lift is drying, the surface layer of the dredged material in the storage area is also drying.

110. When the thin lift in the drying area is sufficiently dry, the dry material in the storage area is removed and placed onto the thin

Table 6

Savannah Harbor Pipeline Dredging*

Fiscal Year	Volume Dredged, m^3	Dredge Size, m	Average Pumping Distance, m
73	4.28×10^6	0.61	880
	8.10×10^5	0.46	610
72	4.25×10^6	0.61	1310
71	4.36×10^6	0.61	1370
	3.37×10^6	0.56, 0.61	850
70	3.56×10^6	0.61	1460

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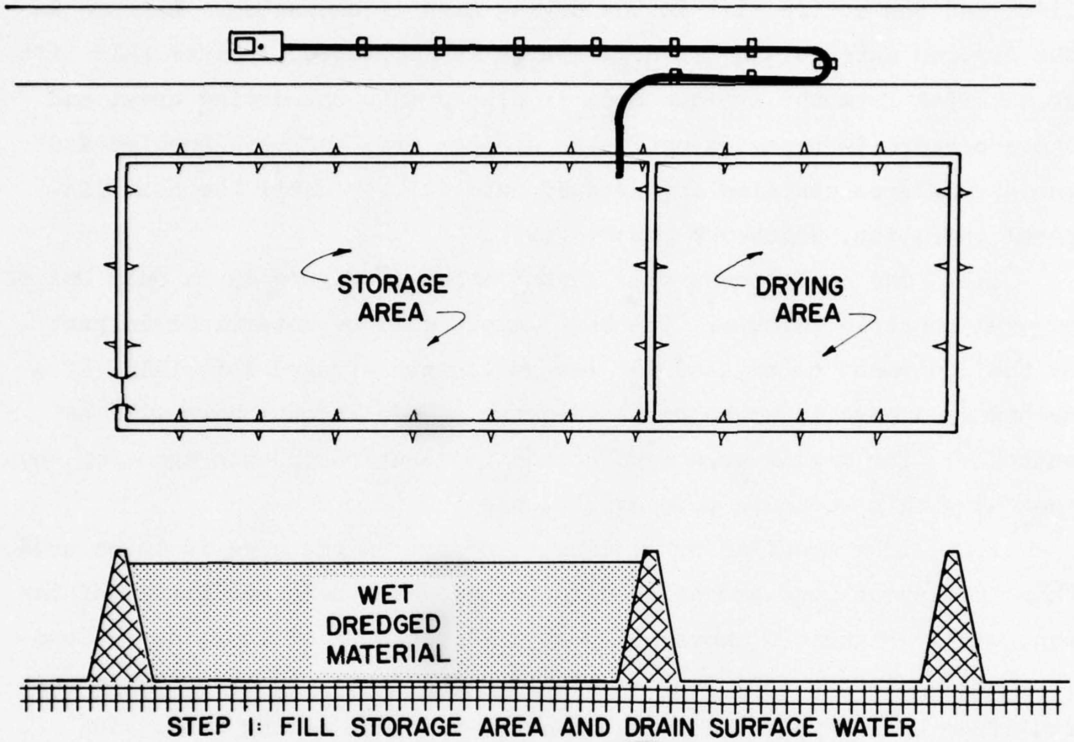
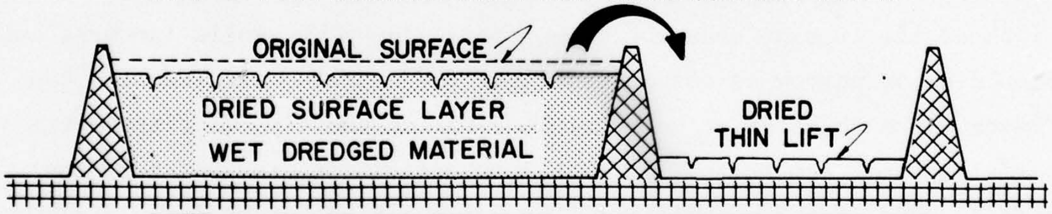
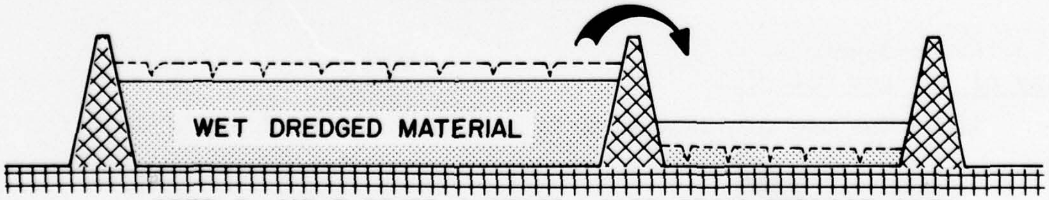
* From Reference 18.



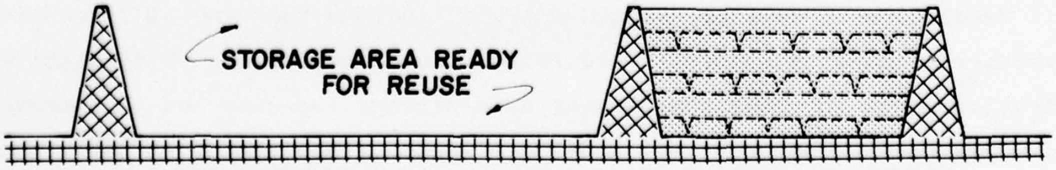
STEP 1: FILL STORAGE AREA AND DRAIN SURFACE WATER



STEP 2: PLACE AND DRY THIN LIFTS IN DRYING AREA AND DRY SURFACE LAYER IN STORAGE AREA



STEP 3: MOVE DRIED SURFACE LAYER FROM STORAGE AREA INTO DRYING AREA AND COMPACT ENTIRE DRYING AREA LIFT



REPEAT STEPS 2 AND 3 UNTIL STORAGE AREA IS EMPTY

Figure 19. Dredged material rehandling to place thin lifts

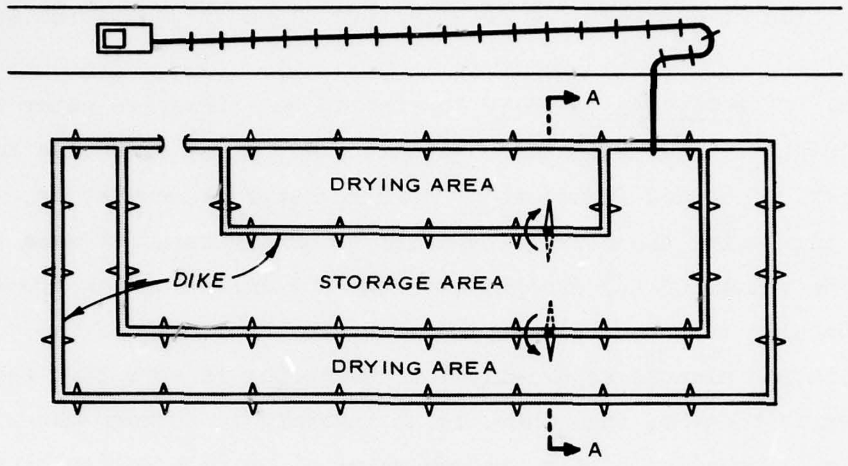
lift; and the entire lift in the drying area is compacted. As soon as the dredged material in the drying area is compacted, another thin lift of material from the storage area is placed into the drying area; and the procedure is repeated until the storage area has been emptied and the drying area contains dry dredged material, or until the next disposal operation, whichever occurs first.

111. The containment area layout shown in Figure 19 is only one of several possible layouts. The best layout will be determined in part by the equipment to be used for rehandling the dredged material. If a secondary dredge is to be used, then the simple layout shown will be suitable. The drying area need not be adjacent to the storage area, but must be within economic pumping distance.

112. If a dragline or clamshell located on the dike is to be used, then the layout must be designed to accommodate the capabilities of the equipment. Figure 20 shows a layout that consists of long, narrow compartments. As the equipment moves along the dikes, it excavates material from the storage area and places it into the drying area. The width of the storage area would be determined by hydraulic factors, but should be as narrow as possible so that the dragline or clamshell can "reach" as much material as possible. During the time that the wet material is weak enough to flow back into excavations the width of the storage area is not so critical, because the fine material would always be within reach of the excavation equipment.

Vegetative dewatering of dredged material

113. The use of vegetation to dewater dredged material deposits is currently being investigated under the DMRP (work units 2C10 and 5A18); and the role of containment area management in vegetative dewatering is quite uncertain. Considerations that will affect the use of vegetation to dewater dredged material include the type of vegetation, whether planted or naturally occurring; the effectiveness of vegetative dewatering to increase containment area storage capacity and to improve dredged material properties; and the effects of vegetation on subsequent disposal operations.



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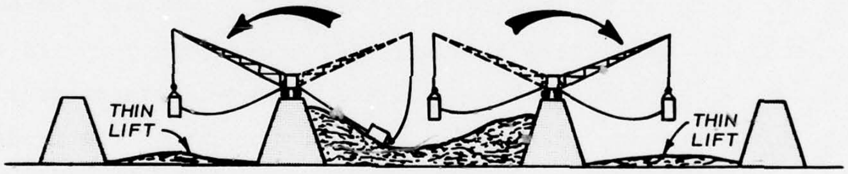


SECTION A - A

Figure 20. Alternative layout for rehandling dredged material in thin lifts

114. Type of vegetation. An important consideration concerning the mangement of vegetative dewatering is the type of vegetation to be used. Information concerning the type(s) of vegetation available that will be effective in dewatering dredged material must be obtained so that the vegetation can be managed properly. The effectiveness of a certain type of vegetation is determined not only by the rate at which it can transpire water, but also by the depth of root penetration, especially for dewatering thick lifts of dredged material. The choice of the desired type of vegetation establishes the need, or lack thereof, of planting the vegetation. Vegetation that establishes itself naturally within the containment area requires no effort; but if the naturally occurring types are not very effective for transpiration, then the

transplanting or seeding of more effective types of vegetation may be worthwhile.

115. Effectiveness. While vegetation can transpire water from dredged material, establishing vegetation may not be effective for accomplishing the intended functions of dredged material dewatering, which include increasing the storage capacity of the containment area by reducing the volume of the dredged material and improving the properties of the dredged material by reducing its water content. If the volume of the vegetation planted especially for dewatering is more than that of the water it removes, then there is no increase in storage capacity. Similarly, if shading of the dredged material or restriction of air movement by vegetation causes such a reduction in the evaporative dewatering rate that the overall evapotranspirative dewatering rate is less than the evaporative dewatering rate would be without the additional vegetation, then the additional vegetative dewatering is ineffective. A third potential adverse effect of vegetative dewatering is the possibility that the increase in organic content of the dredged material, caused by the decomposition of the vegetation, could result in the degradation of the properties of the dredged material. Even in cases where vegetation is not effective for dredged material dewatering, some benefit may be obtained if a widespread root mat is developed. Such a root mat may help stabilize the soft dredged material enough to permit access on the dredged material by low-ground-pressure vehicles. By using data relevant to specific types of vegetation, these factors can be evaluated so that an effective plan of vegetative dewatering can be developed.

116. Effects of vegetation on subsequent disposal operations. There are conflicting reports on the effects of vegetation on subsequent disposal operations. One District reports that the vegetation in their containment areas restricts the flow of dredged slurry over the area and that paths through the vegetation must sometimes be cut. Another District reports that the vegetation causes little restriction to the flow of dredged slurry, because the plants are bent over by the slurry flow and straighten up after the disposal operation is complete. In both

cases the plant in question is Phragmites communis, whose dewatering capability is being evaluated at a field demonstration as part of the DMRP (work unit 2C10). Districts will have to rely on their own judgement and experience in evaluating the effects of vegetation on disposal operations.

Summary of Guideline 3

117. There are three complementary measures for optimizing the natural dewatering of fine-grained dredged material, and the effectiveness of natural dewatering depends on the success in implementing these measures. One measure is to maximize the amount of time the dredged material surface is exposed to the atmosphere during the drying season; this is accomplished by ensuring the rapid removal of surface water and by the judicious scheduling of dredging and containment area use. Another measure is to place dredged material in thin lifts that can dry before being covered by subsequent lifts. This requires the use of large containment areas or an operation to remove a thick lift incrementally, and then placing and drying several thin lifts. The third measure is to use vegetation to transpire water from the dredged material; DMRP research is currently in progress to evaluate vegetative dewatering.

Guideline 4: Alternative Dewatering Methods

118. While the purpose of this study was to evaluate general containment area management as a technique to promote the dewatering of fine-grained dredged material by the natural processes of evaporation, transpiration, and drainage, alternate dewatering methods should be considered during the design of a containment area management plan for dredged material dewatering. Because of a variety of factors, including land acquisition difficulties, short drying seasons, operational difficulties, and time constraints, natural drying will not always be an effective means to dewater dredged material. A number of dewatering techniques are being investigated under the DMRP and elsewhere, and these methods are summarized briefly in this guideline to demonstrate how they may supplement or replace natural drying (Guideline 3) in a containment area management plan.

Surface trenching

119. A detailed discussion of dredged material dewatering by trenching is beyond the scope of this report. In the following paragraphs a brief listing of the different types of trenching that have been investigated is presented, and the use of the completed trenches to drain subsequent lifts of dredged material is described.

120. Trenching programs. There are several approaches to trenching, including the excavation of numerous shallow trenches, a single trench extending from outlet across the containment area, or one or more perimeter trenches. Each type of trenching program has advantages and disadvantages and is best accomplished by certain types of equipment. Shallow trenches can be formed quickly by amphibious equipment such as the RUC or the Amphirol (Dutch). Single trenches can be excavated by marsh draglines after the formation of a surface crust or by small dredges before surface water is removed. Perimeter trenches can be excavated by draglines working from the crest of perimeter dikes. The purpose of the trenches is to remove surface water from the site so total rather than wet evaporation rates may be taken advantage of. The trenches are not intended to draw the water table down from gravity subdrainage.

121. Intensive surface trenching with amphibious equipment. Two similar approaches to surface trenching have been proven in the field to be effective for dredged material dewatering. One technique is to construct numerous shallow trenches to the outlets by using a RUC. The other technique, developed by the Dutch, involves a process in which shallow trenches are formed by an Amphirol and progressively deepened by equipment towed behind the Amphirol.

122. After most surface water has been removed from the containment area, the RUC can be used to create shallow trenches draining to the outlets. After the groundwater table has lowered slightly, the RUC is used to deepen the trenches. During field trials held in August and September, 1975, repeated passes by the RUC created trenches 0.6 m deep through a 0.45-m-thick surface crust; and based on these field trials, it is felt that trenching with the RUC can promote the formation of a

surface crust approximately one metre thick, sufficient to support conventional equipment with which to deepen the trenches further if desired.[17]

123. The RUC has demonstrated great potential for use in dewatering dredged material, and an investigation has been conducted to determine the best procedure for surface trenching.[12] Of particular importance are the determination of the depth to which trenches can be effectively excavated by the RUC and the time interval between operations. The following procedure is presented to show the type of program that will be used for surface trenching with the RUC:

- a. Use the RUC to excavate a system of shallow trenches extending radially outward from each outlet across the entire containment area (Figure 21). Trenches should not cross because the RUC blocks trenches it crosses. This step should be done before the surface water has been completely removed from the area, because the RUC trenches will help drain the surface water more quickly (Guideline 2).

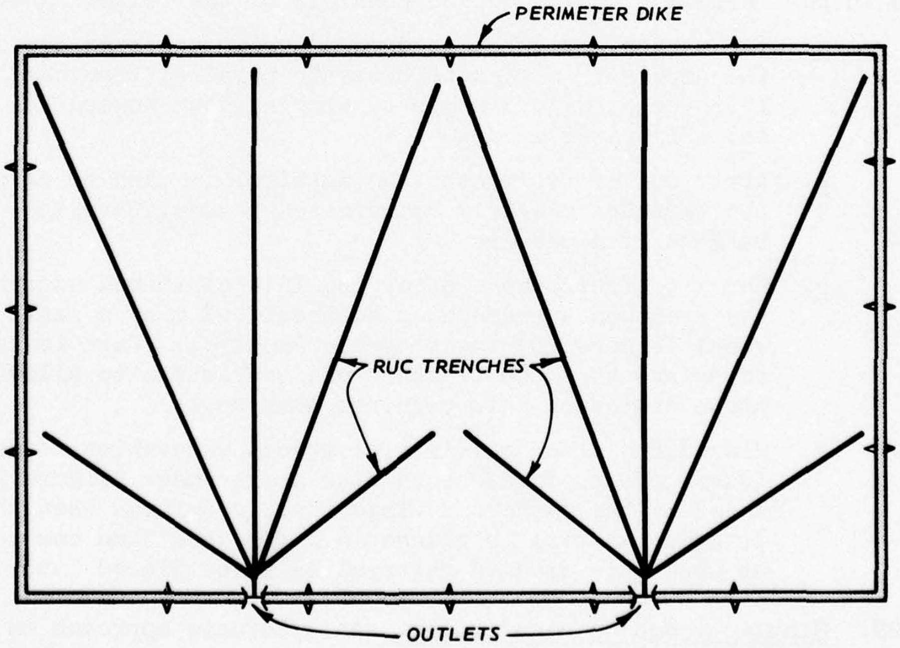


Figure 21. RUC trenching pattern. Note that trenches do not cross each other, because the RUC blocks trenches it crosses

b. Use the RUC to keep the trenches open and draining to the outlets. If necessary, the RUC can be used to excavate a sump near each outlet to facilitate drainage.

c. After the groundwater table has been lowered, deepen the trenches. This deepening may involve the use of implements towed behind the RUC if implements are shown to be more effective than the RUC alone. The time interval between steps a and c and the depth to which the trenches should be deepened must be determined by field test.

d. Use the RUC and/or hand work to maintain the trench system.

e. Repeat steps c and d until RUC trenching is no longer effective. Further trenching may be possible by conventional equipment if sufficient crust has developed, or some crust removal may be desired.

124. The Dutch have reported a method for dredged material dewatering by progressive trenching using an Amphirol and towed disc wheels.[6] The Amphirol, which is similar to but smaller than the RUC, is used first alone to excavate shallow trenches. The dewatering process, described in more detail in Reference 6, consists of the following steps:

a. Two months after the dredged material has been deposited, the Amphirol is used to excavate parallel trenches, 5 to 10 cm deep, 2 to 3 m apart, sloping down toward the outlet (Figure 22).

b. After one or two months the Amphirol is used to deepen the trenches slightly by repeated passes, carrying ballast if necessary.

c. Three to four months after the initial trench excavation, the trenches are deepened to about 0.3 m by a small disc wheel (Figure 23) towed by the Amphirol. Care is taken to ensure that the trenches are continuous to allow complete drainage; this requires hand work.

d. Six months after the initial trench excavation, every fourth trench is deepened by a large wheel (Figure 24) towed by the Amphirol. This step is omitted when the dredged material is placed in lifts less than one metre or when more dredged material is to be placed later.

125. Single trench to each outlet. An alternate approach to the excavation of many trenches is the excavation of single, progressively deepened, large trenches, one extending from each outlet across the entire containment area (Figure 25). The details and design procedure

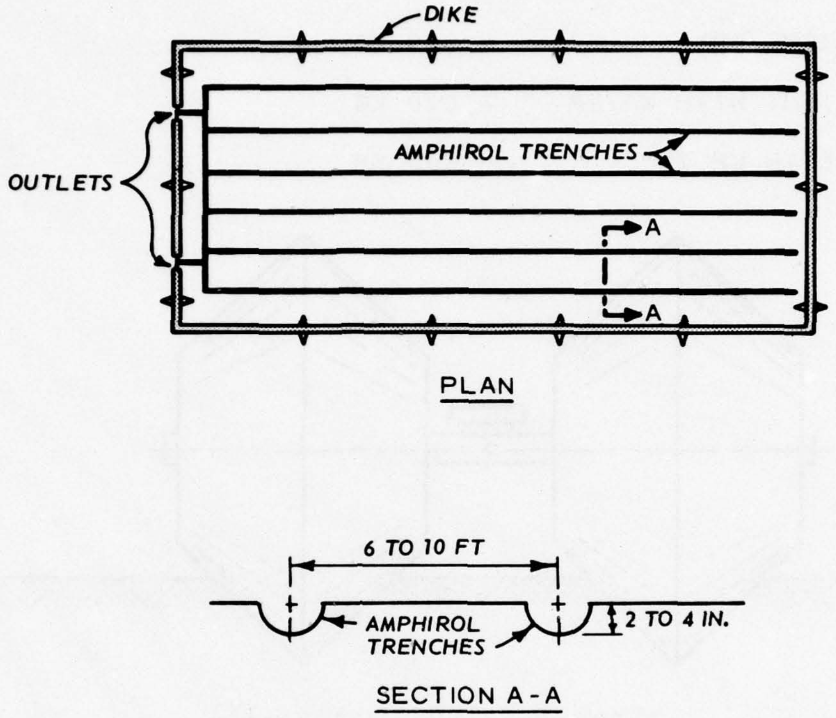


Figure 22. Amphirol trenching pattern

for this plan are found in Reference 5, and the plan consists of the following steps:

a. Excavate shallow trenches, one extending from each outlet across the containment area, using a small dredge. Remove surface water. Ensure drainage to the trenches by pumping the material dredged from the trenches to the centerline of the space between the trenches, filling the depressions and grading the area smoothly toward the trenches.

b. Allow the groundwater table to lower and a surface crust to develop.

c. Deepen the trenches using a marsh dragline when sufficient crust has developed.

d. Repeat steps b and c until the trenches fully penetrate the dredged material.

126. Perimeter trenching. The dike raising methods used by the Philadelphia and Charleston Districts (see Part II) involve the excavation of one or two trenches near and parallel to the perimeter dikes.

DISCUS WHEEL	Ø 2,300 MM
TOTAL WEIGHT DRY	4,000 KG
TOTAL WEIGHT WITH WATER	7,000 KG
TRENCH DEPTH UP TO	400 MM

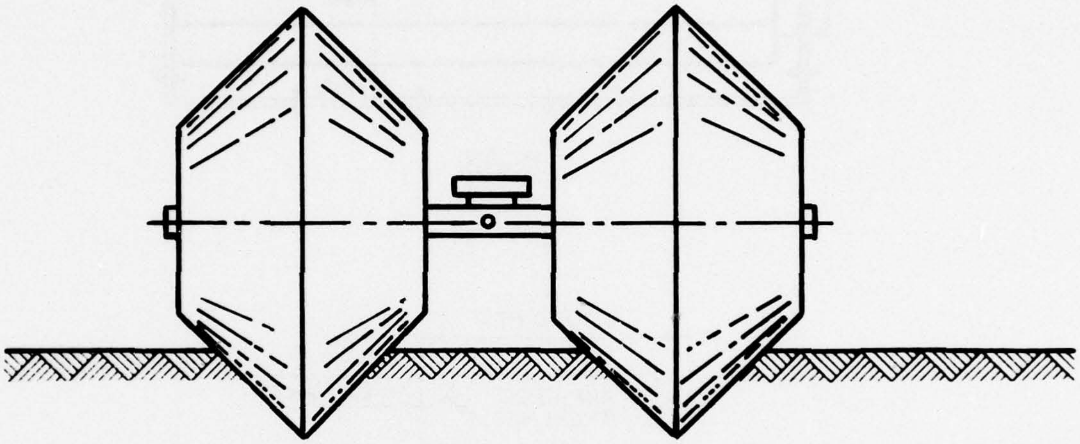


Figure 23. Small disc wheel[6]

DISCUS WHEEL	Ø 3,500 MM
STABILIZING WHEEL	Ø 2,300 MM
TOTAL WEIGHT DRY	9,000 KG
TOTAL WEIGHT WITH WATER	12,000 KG
TRENCH DEPTH UP TO	1,000 MM*

* ADJUSTABLE WITH THE STABILIZING WHEELS

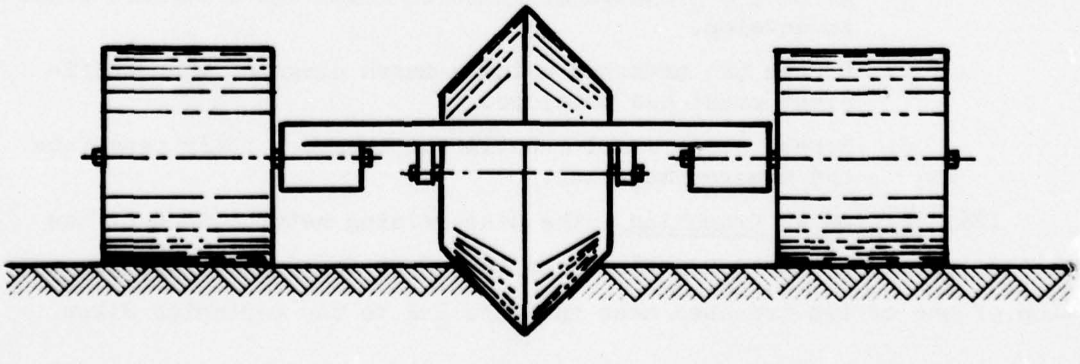


Figure 24. Large disc wheel with stabilizing wheels

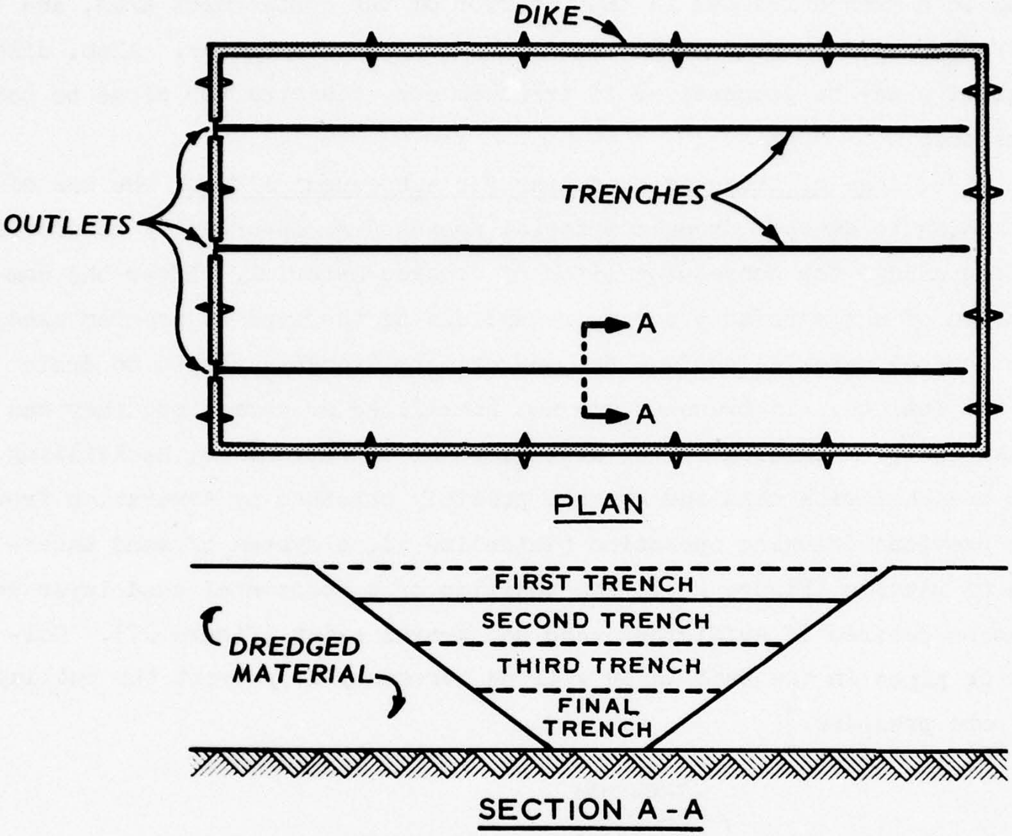


Figure 25. Surface trenching

These trenches are used as a source of borrow with which to raise the dikes and are also used to drain the area. The Philadelphia District reports a 1.2-m lowering of the groundwater tables by drainage to the perimeter trench[7] and, therefore, the storage capacity of the containment area is increased by not only the raised dike but also the dredged material consolidation.

127. Perimeter trenches can be used effectively for dredged material dewatering by ensuring that they are kept open and draining to the outlets. An advantage of perimeter trenches over trenches in the interior of the area is that perimeter trenches can be excavated easily by conventional earth-moving equipment located on the dike crest. A disadvantage of perimeter trenching is that the drainage path from the center of the containment area is longer to a trench at the perimeter

than to a trench located in the interior of the containment area, and this may preclude groundwater table lowering in the center. Also, dike stability may be jeopardized if trenches are excavated too close to the dike toe.

128. Use of trenches as drains for subsequent lifts. The use of trenching to dewater dredged material presents an opportunity to provide underdrainage for subsequent lifts of dredged material. After the completion of a trenching program, regardless of the type of program used, the dredged material surface has one or more trenches sloped to drain to the outlets. If trenches are not backfilled or dammed up, they can cause short circuiting in the next disposal operation. By backfilling the trenches with sand and gravel, possibly obtained by separation from the previous dredging operation (Guideline 1), a system of sand underdrains results (Figure 26). The addition of a horizontal sand layer may also be desired if sufficient sand and gravel exist (Figure 27). Collector pipes in the sand layer will be necessary to prevent the buildup of pore pressure.[4]

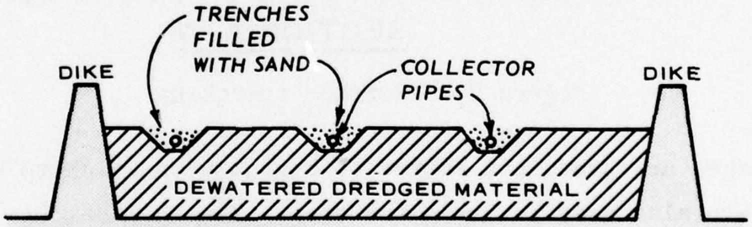


Figure 26. Trenches used for underdrainage of subsequent lift of dredged material. Dredged material must be strong enough to support hauling equipment

129. The construction of sand drains in a containment area whose dredged material has been dewatered by trenching is shown in Figure 28. After the area has been filled and the surface water has been drained, the trenching program is begun. Trenches are progressively deepened as the area is dewatered. When trenches are complete and enough crust has formed to support earth-moving equipment, sand and gravel are excavated from the mound of coarse material and are placed (with collector pipes)

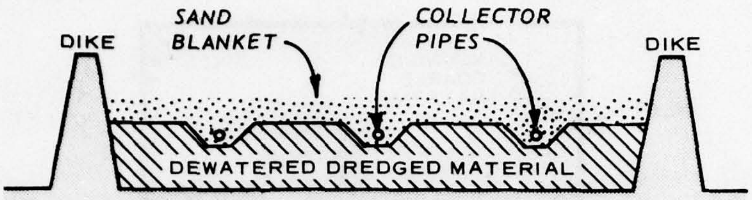


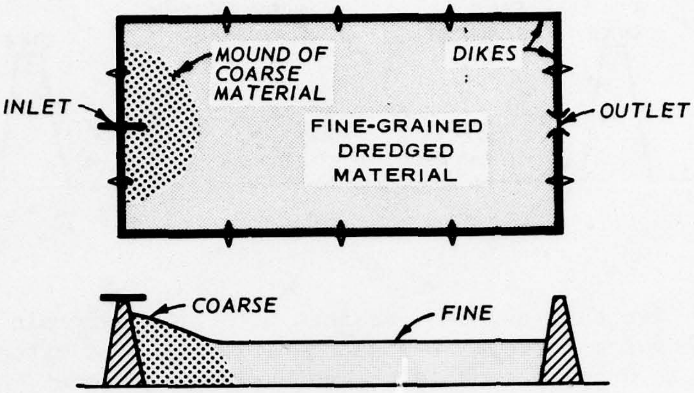
Figure 27. Trenches and sand blanket used to underdrain subsequent lift of dredged material. Dredged material must be strong enough to support sand layer and hauling equipment

into the trenches. Encapsulating the sand and gravel with filter cloth will help prevent erosion of the sand and gravel by the incoming slurry and will help prevent clogging of the sand and gravel by fine dredged material. Encapsulation would require that the trenches be lined with filter cloth prior to being backfilled with sand and gravel. If sufficient coarse material is available, a sand blanket is placed over the area prior to the next lift of dredged material.

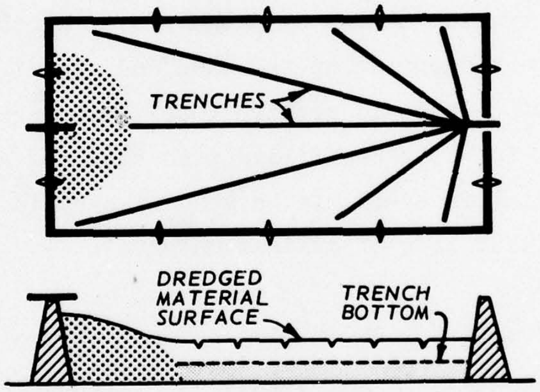
Gravity drainage

130. Dredged material dewatering by conventional underdrainage and vertical drains has been investigated,[4,7,14] and field studies have been initiated under the DMRP (work unit 5A15). Until field data have been evaluated, the effectiveness of drainage systems is unknown, but some considerations for the use of drainage and its relationship to containment area management are presented below.

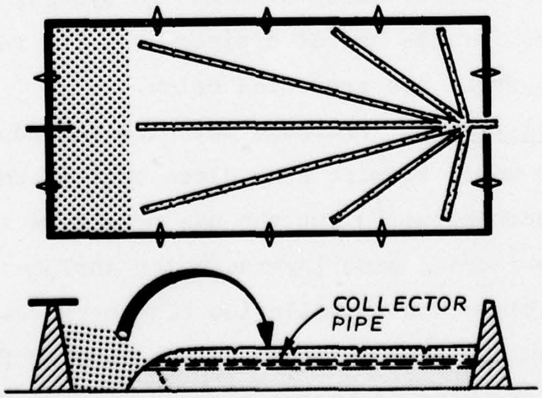
131. Vertical drains. Drainage path length reduction by the use of vertical drains would require such close spacing that their use is not likely to be economical,[14] but the use of widely spaced vertical drains to drain horizontal sand layers to the surface or to collector pipes may be feasible. The installation of a perforated pipe wrapped in filter cloth could be accomplished by men working from a boat, although the filter cloth could become clogged with fine dredged material when the drain is inserted. An expedient method for workmen in a boat to install vertical drains is shown in Figure 29. This method was developed by the Mobile District for installing drains in soft dredged



CONTAINMENT AREA FILLED, SURFACE DRAINED

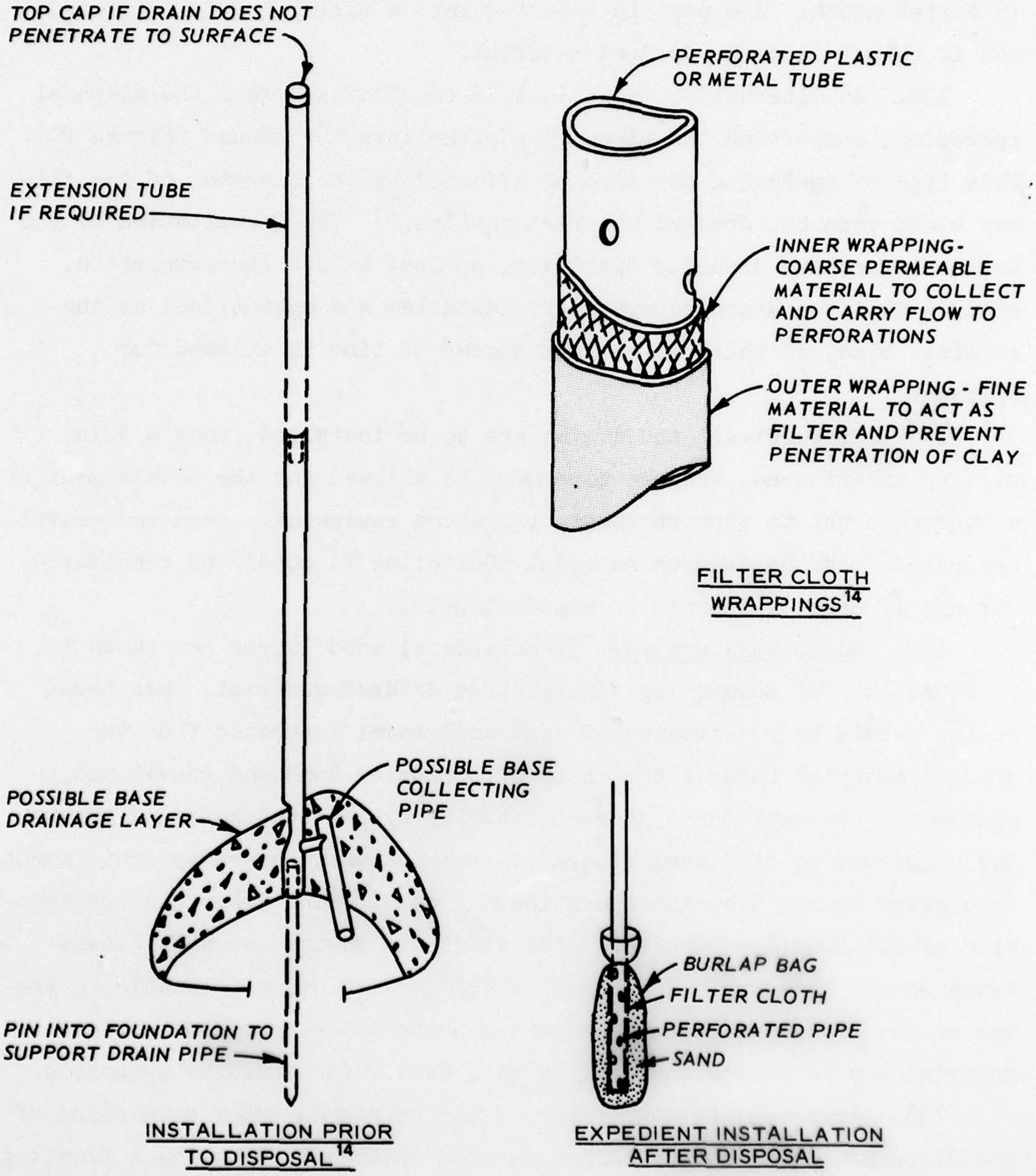


DREDGED MATERIAL DEWATERED BY TRENCHING



TRENCHES BACKFILLED WITH SAND AND GRAVEL

Figure 28. Trenches backfilled with sand and gravel to underdrain subsequent dredged material lift



INSTALLATION PRIOR TO DISPOSAL[14]

FILTER CLOTH WRAPPINGS[14]

EXPEDIENT INSTALLATION AFTER DISPOSAL

Figure 29. Installation of vertical drains

material when the crust would support men but not the equipment required for installing casings, etc. Drains consist of perforated pipes wrapped in filter cloth. The pipe is inserted into a burlap bag full of sand and is thrust into the dredged material.

132. An alternative is to install the drains before the disposal operation, supporting the pipes by a stake into the ground (Figure 29). This type of operation may also be affected by the clogging of the filter cloth when the dredged material settles.[14] The installation of the drains before the dredging operation, or just before its completion, ensures that the drainage system is installed and operational at the earliest time, so that the maximum amount of time is allowed for drainage.

133. If vertical sand drains are to be installed, then a delay will be experienced, because time must be allowed for the development of a surface crust to support the installation equipment. Sand and gravel separated from the dredged material (Guideline 1) should be considered for use if sand drains are to be constructed.

134. Horizontal drains. If horizontal sand layers are shown to be effective for dewatering fine-grained dredged material, then these drains should be constructed of sand and gravel separated from the dredged material to save the costs of procuring sand and gravel and to reduce the consumption of storage capacity by imported sand and gravel. The construction of a sand blanket in the bottom of an empty containment area prior to the disposal operation is not difficult, but the construction of intermediate layers is more difficult due to the soft consistency of the fine-grained dredged material. Equipment is unable to travel on the dredged material, and the bearing capacity of the dredged material may be so low that only a thin sand layer could be supported.

135. Intermediate sand layers could be placed after completion of the disposal operation but before surface drainage. By using a floating pipeline movable over the entire area, a small dredge could pump sand and gravel over the fresh deposit of dredged material. The water in the area would reduce the effective stress, so that a bearing failure could be averted. Careful management of the operation would be required to

ensure that the sand was spread evenly over the area and that the dredged material did not become resuspended and mix with the sand.

Surcharging

136. A surcharge or preload placed onto the surface of a dredged material deposit increases the effective stress. If drainage is provided, the dredged material overconsolidates under the surcharge. Several investigations into dredged material dewatering by surcharging have been made,[4,7,14] but are not reviewed here, because surcharging is not greatly influenced by containment area management, except that the use of coarse material separated from the dredged material could be used for the surcharge.

Vacuum well points and electro-osmosis

137. Dredged material dewatering by vacuum well points[4] and electro-osmosis (work unit 5A04) have been investigated under the DMRP, and field tests (work units 5A09 and 5A17) are currently under way. The management of ponded surface water (Guideline 2) presents a method of installing the well points and electrodes for these dewatering systems. Well points and electrodes could be installed in the same manner as vertical drains, by men working in boats. Well points, either for a vacuum well point installation or for the cathodes in an electro-osmosis system (Figure 30), could be installed by wrapping the perforated tips in burlap bags filled with sand and thrusting them into the dredged material (Figure 27). Anodes for electro-osmosis could be inserted into the dredged material in the same fashion.

138. After the well points and risers are installed, men working in boats could connect the header pipes and make the vacuum connections. For electro-osmosis the header pipes could be installed and electrical connections made. After surface water removal, the vacuum would be applied to the well points, or the power turned on to create the electrical gradient between the anodes and cathodes in an electro-osmosis system. By performing the installations before the surface water is removed, the time delay for crust development to provide access to the

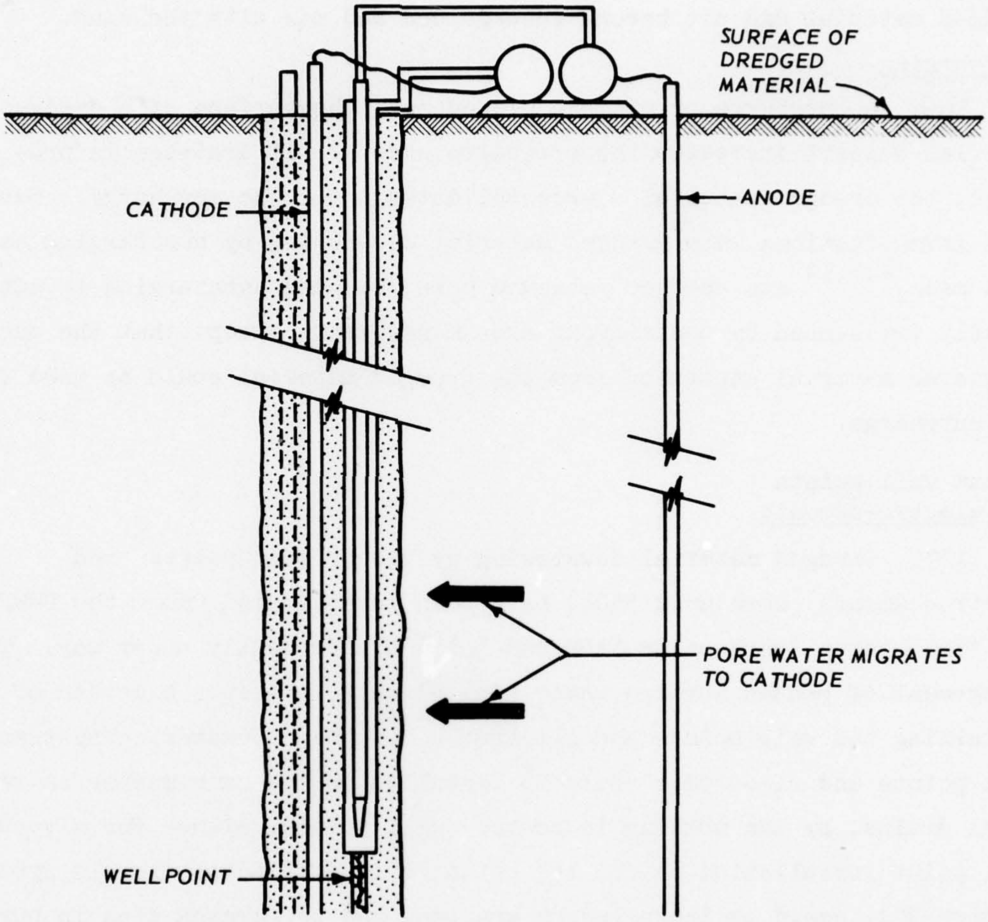


Figure 30. Schematic of typical electro-osmotic dewatering system[13]

site is not required; and the dredged material dewatering can begin immediately.

Summary of Guideline 4

139. Several alternative methods for dewatering fine-grained dredged material are being evaluated under the DMRP, and some of the techniques can be enhanced somewhat by containment area management. Surface trenches that result in the formation of a crust strong enough to support earth-moving equipment should be filled with sand and gravel to form underdrains for the next lift. Vertical drains should be installed by men working in boats near the completion of the disposal

operation so that the dewatering system can be operational at the earliest possible time. Horizontal sand layers can be placed on soft dredged material before the surface water is drained. The water permits the use of a floating pipeline for placing the sand by a small dredge and also reduces the effective stress of the sand layer.

PART IV: SUMMARY AND CONCLUSIONS

140. A survey of dredged material containment area operation and maintenance showed that little attention is paid to dredged material dewatering. This has resulted in the most part from lack of technical information, funding constraints, and the lack of control on a long-term basis of the disposal site. Dredged slurry is pumped into a containment area without regard to the effect of the operation on natural dewatering processes, and maintenance is limited to dike raising to increase the storage capacity of the containment area immediately prior to subsequent disposal operations. Natural dewatering of fine-grained dredged material can be enhanced by common-sense containment area management including year-round maintenance, as summarized below.

141. The guidelines presented in Part III, rearranged as guidelines for containment area management before, during, and after dredged material disposal operations, are summarized in this part. There is no distinct division between the time after one disposal operation and the time before the next. In this part, containment area management before a disposal operation includes those activities initiated well after the completion of a disposal operation and completed immediately prior to the initiation of the next disposal. Conversely, containment area management after a disposal operation includes those activities initiated soon after the completion of a disposal operation; these activities may or may not continue throughout the entire time interval between disposal operations.

Containment Area Management Before Disposal Operation

142. Activities that should be accomplished before a dredged material disposal operation begins are dependent upon the condition of the dredged material (if any) present in the containment area and upon the method (s) to be used to dewater the subsequent lift. The following dewatering-related functions should be considered when formulating containment area management plans.

a. The advantages and disadvantages of the separation of coarse material should be considered. If uses for sand either to dewater the dredged material or for other productive uses have been identified, then the coarse-grained dredged material should be used as the source of sand and gravel.

b. If the containment area has never been used or if the dredged material has dried enough to support construction equipment, then underdrainage (sand blankets, collector pipes, etc.) may be installed. Likewise, the installation of material for other dewatering schemes may be feasible. Properly supported, electro-osmosis electrodes, well points, and other vertical drains could be installed before the disposal operation.

c. The relocation of the inlet(s) and/or the outlet(s) may be desirable in some cases. By moving the inlet periodically, the mound that forms near the inlet can be manipulated to form topography that will be conducive to rapid surface drainage and rainfall runoff. Outlets are generally installed permanently, but when the inlet location is changed the installation of one or more additional outlets may be necessary to prevent short circuiting.

d. Immediately before a disposal operation, vegetation within the containment area should be investigated. Although vegetation is beneficial because it helps dewater dredged material by transpiration and may improve the effluent quality by filtering, very dense vegetation may severely reduce the storage capacity of the containment area and may restrict the flow of dredged slurry throughout the area. If harvesting the vegetation is required, it should be delayed until immediately before the disposal operation to obtain the maximum amount of transpiration.

e. If dikes must be raised to provide adequate storage capacity for the next lift of dredged material, the use of the dried dredged material within the containment will be beneficial. In addition to eliminating the costs associated with the acquisition of borrow, additional storage capacity is generated by removing the dredged material from within the area. If a trenching program similar to that of either the Philadelphia or the Charleston District is used to dry dredged material for dike raising, trench drainage can be beneficial by lowering the groundwater table and by providing surface drainage.

Containment Area Management During Disposal Operation

143. During a disposal operation effluent water quality is a more

important consideration than dredged material dewatering. Certain activities can be helpful for dredged material dewatering, however; and most are related to using surface water for access to the area. Each of the considerations listed below is secondary in importance to environmental considerations; dewatering-related containment area management must not have an adverse effect on effluent water quality or have any other adverse environmental impact.

a. A disposal operation can be managed so that the dredged material will have surface topography conducive to surface drainage and rapid rainfall runoff. Inlets located around the perimeter can be operated to form topography that will cause water to drain to the center of the area, where it can be collected and drained from the area. Alternatively, an inlet can be located in the center of the containment area so that a mound in the center is formed, and surface water will drain radially away from the center to outlets on the perimeter.

b. Instead of forming topography that slopes either toward or away from the center, placing dredged material evenly throughout the containment area may be desirable. This could be accomplished using a floating pipeline that could be moved during the disposal operation. A uniform thickness of dredged material would not prevent the formation of a depression caused by foundation settlement, but the even surface would be less likely to develop isolated ponds than would an irregular surface.

c. The ponded water can also be used to support a boat or barge from which workmen could install dewatering systems near the end of a disposal operation. The dewatering systems could be in place by the time the surface water is removed, thereby avoiding the time delay for a crust to form to permit access within the area.

d. If some of the shoals to be dredged are comprised primarily of sand and gravel, these shoals can be selectively dredged and pumped to specially designated containment areas for temporary storage. The potential for the productive use of sand and gravel is very high, and the coarse material requires no special dewatering. This sand and gravel could be stored for later use as underdrainage or surcharge to dewater fine-grained dredged material.

e. At large containment areas, dredged material should be placed in thin lifts to maximize the evaporation of water from the dredged material. Large containment areas exist in several Districts but are often not managed properly to obtain their maximum benefit for natural dewatering. By ensuring that the dredged slurry is evenly spread throughout the entire containment area (perhaps by using a floating pipeline) the thickness of the dredged material will be minimized. To obtain the maximum natural dewatering, surface water must be removed as quickly as possible. In some cases, the use of compartments can be beneficial, because thin lifts can be placed in some compartments while the surface water is being removed from others. In this way, some of the dredged material is exposed to the atmosphere for evaporation while the disposal operation continues.

Containment Area Management After Disposal Operation

144. Containment area management immediately following the completion of a disposal operation can have the most beneficial impact on the natural dewatering of fine-grained dredged material. Optimum natural dredged material dewatering is ensured by the exposure of the largest possible dredged material surface area to the most favorable evaporative drying conditions for the longest time. The following measures are designed to promote dredged material dewatering by natural processes, supplemented by alternative techniques as necessary.

- a. The single most important phase of containment area management after the disposal operation is to drain the surface water immediately and then to ensure rapid rainfall runoff. Ponded water should be drained from the containment area as quickly as effluent water-quality standards can be met to initiate the evaporation of water from the dredged material, and no subsequent ponded water buildup due to rainfall should be allowed. Keeping the surface of the dredged material free of ponded water ensures that evaporation can continue throughout the drying season.
- b. A very effective method for dewatering dredged material containment areas is to provide trenches for the removal of surface water. Demonstrations have shown that the RUC is very effective for providing surface drainage, and that surface drainage in turn leads to the rapid formation of a thick crust of dried dredged material.
- c. If the dredged material has been placed in a thick lift during the disposal operation evaporative dewatering will be restricted by the low (as compared to a thin lift) surface area of the dredged material. An increase in surface area, and consequently in evaporative water loss,

can be accomplished by excavating some of the dredged material from the thick lift and placing it in a thin lift in an adjacent area. In this way water can evaporate from both lifts. When the thin lift has dried, another thin lift of wet material can be placed and the process repeated.

d. In some cases evaporative dewatering can be supplemented with transpiration by encouraging the growth of vegetation within the containment area. Vegetation must be carefully managed to ensure that the overall dewatering rate is not decreased by the presence of the vegetation, that the storage capacity of the containment area is not reduced by the volume of the vegetation, that the organic content of decaying vegetation does not result in an unacceptable deterioration of the engineering properties of the dredged material, and that the vegetation does not have an adverse effect on subsequent disposal operations.

e. Natural processes are not always dependable for dewatering dredged material; they are greatly influenced by climate and are relatively slow. When natural dewatering is not acceptable for one reason or another, then alternative dewatering techniques must be used. Under the DMRP several such techniques have been investigated, and field demonstrations have been conducted.[17]

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In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

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