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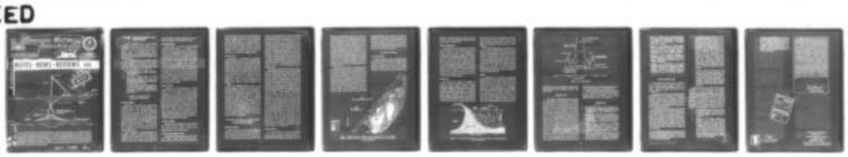

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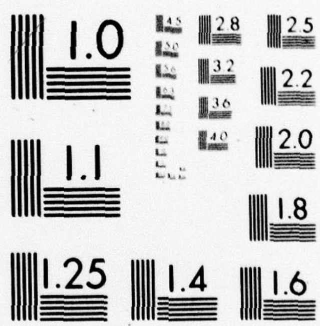

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DREDGED MATERIAL RESEARCH

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U.S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION

Vol D-78-5
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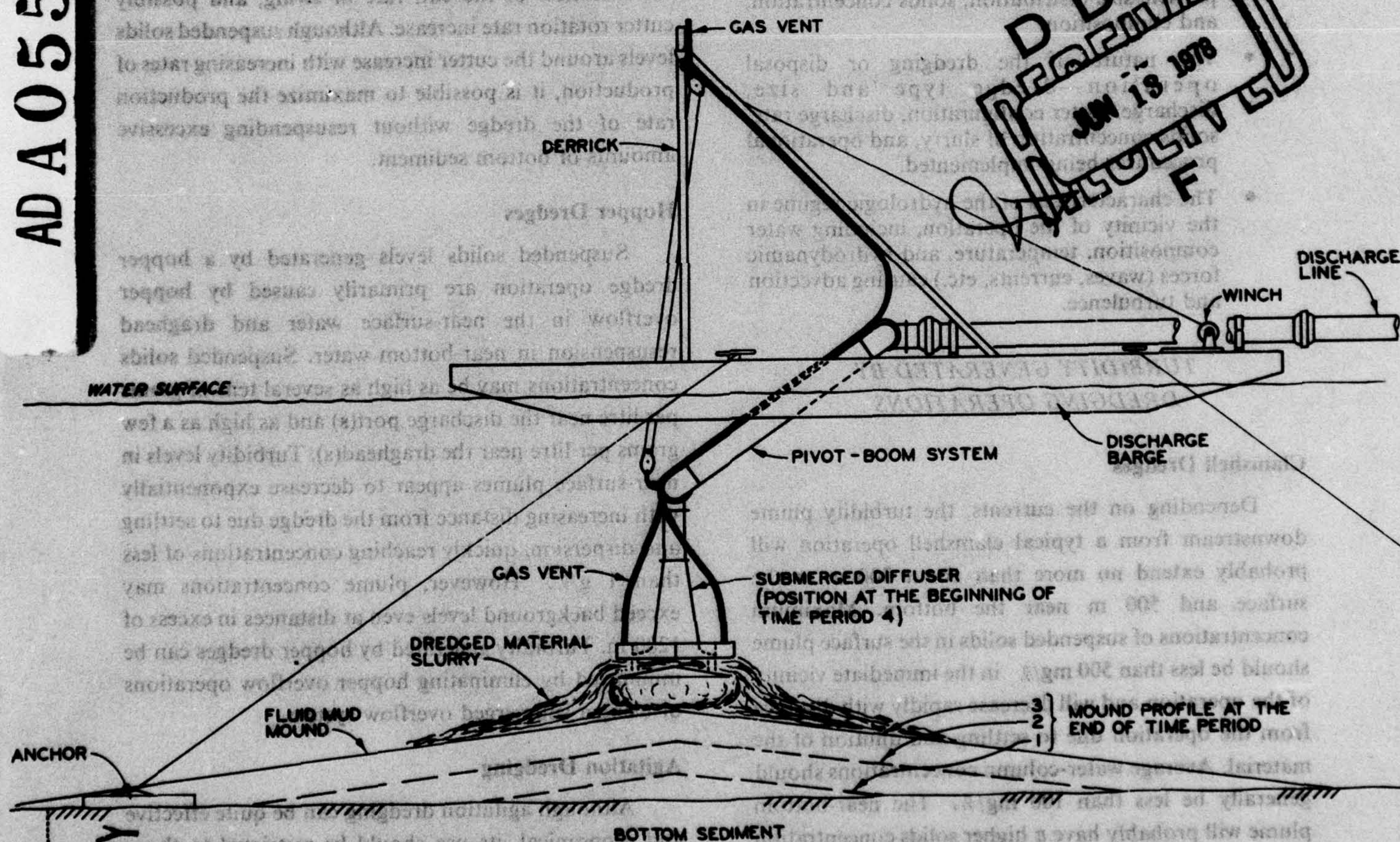
NOTES · NEWS · REVIEWS etc

Volume D-78-5.



The main objectives of Task 6C of the Dredged Material Research Program (DMRP) were to develop the capability for predicting the turbidity in the vicinity of open-water pipeline disposal operations and to evaluate methods for controlling the dispersion of dredged material slurry in the vicinity of dredging and disposal operations. A submerged diffuser system, illustrated above, was developed by the DMRP. The system including the diffuser and discharge barge was designed to minimize the generation of turbidity in the water column and to maximize the mounding of the discharged slurry (the diffuser is raised at intervals as the height of the mound increases). The results and conclusions of Task 6C are described in the following article.

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TASK 6C: TURBIDITY PREDICTION AND CONTROL

Task 6C, conducted as part of the Disposal Operations Project, has been completed and a summarizing document (Synthesis Report) will be available in the near future. This article outlines the general results and conclusions from research conducted within the task over the past five years. More details and specific information will be available in the Synthesis Report.

The nature, degree, and extent of dredged material dispersion (turbidity and fluid mud) around a dredging or disposal operation are controlled by many factors. The relative importance of the different factors (listed below) may vary significantly from site to site.

- The characteristics of dredged material—particle-size distribution, solids concentration, and composition.
- The nature of the dredging or disposal operation—dredge type and size, discharge/cutter configuration, discharge rate, solids concentration of slurry, and operational procedures being implemented.
- The characteristics of the hydrologic regime in the vicinity of the operation, including water composition, temperature, and hydrodynamic forces (waves, currents, etc.) causing advection and turbulence.

TURBIDITY GENERATED BY DREDGING OPERATIONS

Clamshell Dredges

Depending on the currents, the turbidity plume downstream from a typical clamshell operation will probably extend no more than about 300 m at the surface and 500 m near the bottom. Maximum concentrations of suspended solids in the surface plume should be less than 500 mg/ℓ in the immediate vicinity of the operation and will decrease rapidly with distance from the operation due to settling and dilution of the material. Average water-column concentrations should generally be less than 100 mg/ℓ. The near-bottom plume will probably have a higher solids concentration due to resuspension of the bottom material near the clamshell impact point.

A direct comparison of conventional (open) and watertight clamshell operations indicates that watertight buckets generate 30 to 70 percent less turbidity in the water column than conventional buckets. This reduction is probably due primarily to the fact that leakage of dredged material from watertight buckets is reduced by approximately 35 percent.

Cutterhead Dredges

Elevated levels of suspended material around cutterhead dredges appear to be localized to the immediate vicinity of the cutter as it swings back and forth across the dredging site. Within 3 m of the cutter, suspended solids concentrations are highly variable, but may be as high as a few tens of grams per litre; these concentrations decrease exponentially with distance from the cutter to the water surface. Near-bottom suspended solids concentrations may be elevated to levels of a few hundred milligrams per litre at distances of a few hundred metres from the cutter. Turbidity levels generated around the cutter increase exponentially as the thickness of the cut, rate of swing, and possibly cutter rotation rate increase. Although suspended solids levels around the cutter increase with increasing rates of production, it is possible to maximize the production rate of the dredge without resuspending excessive amounts of bottom sediment.

Hopper Dredges

Suspended solids levels generated by a hopper dredge operation are primarily caused by hopper overflow in the near-surface water and draghead resuspension in near-bottom water. Suspended solids concentrations may be as high as several tens of grams per litre near the discharge port(s) and as high as a few grams per litre near the draghead(s). Turbidity levels in near-surface plumes appear to decrease exponentially with increasing distance from the dredge due to settling and dispersion, quickly reaching concentrations of less than 1 g/ℓ. However, plume concentrations may exceed background levels even at distances in excess of 1200 m. Turbidity generated by hopper dredges can be minimized by eliminating hopper overflow operations or using a submerged overflow system.

Agitation Dredging

Although agitation dredging can be quite effective and economical, its use should be restricted to those areas where short-term exposure to high levels of suspended solids will not be detrimental.

Unconventional Dredging Systems

Unconventional dredging systems such as the Mud Cat, Waterless dredge, Delta dredge, pneumatic pumping systems such as the Pneuma, or the Japanese

Clean Up system may provide some advantage over convention dredges on certain types of environmentally sensitive dredging operations. It must be emphasized that most of these systems are not intended for use on typical large-scale maintenance operations. However, they may provide alternative methods for unusual dredging projects (e.g., chemical "hot spots") when the capabilities of a particular system provide some advantage over conventional dredging equipment.

Dredge Selection

According to a comparison of conventional dredges by Wakeman et al.,[1] "The cutterhead dredge seems to have the least effect on water quality during the dredging operation. This is followed by the hopper dredge without overflow. The clamshell dredge and hopper dredge during overflow periods both can produce elevated levels of suspended solids in the water column." Although this may be true under a given set of environmental conditions, the variability between different sites, material types, and dredge sizes and capabilities, as well as operator performance and training, make it difficult to compare different types of dredges.

Since each dredging/disposal project is site specific, a dredge that might be ideal in one situation may not be suitable for another. It is also important to remember that a sophisticated and expensive dredging system will not necessarily eliminate all adverse environmental impacts associated with dredging operations. In addition, it is imperative to concurrently consider all the components of the dredging operation, including excavation, transportation, treatment, and disposal, as a total integrated system and not as separate components. The best dredging system may not be compatible with the best disposal system. In addition, the relative impacts of each component of the system must be objectively evaluated relative to the cost and overall benefits of the operation.

TURBIDITY AND FLUID MUD GENERATED BY OPEN-WATER PIPELINE DISPOSAL OPERATIONS

Fluid Mud Dispersion

During a typical open-water pipeline disposal operation involving channel maintenance material, 95 to 99 percent of the fine-grained dredged material slurry descends rapidly to the bottom of the disposal area where it accumulates under the discharge point in the form of a low gradient fluid mud mound overlying the existing bottom sediment. Initially the fluid mud may flow radially away from the discharge point over the bottom or the surface of an existing mound as a fragmented sheet of low-density fluid mud. The slope of the bottom probably has the greatest influence on the flow characteristics of this low-density fluid mud. Mudflows propagating uphill decelerate very rapidly. However, if fine-grained dredged material slurry is discharged where the bottom slopes are greater than 0.75 degrees, the fluid mud material will flow downslope at velocities of approximately 0.1 to 0.3 m/sec as long as that slope is maintained. The flow characteristics of low-density fluid mud are not significantly affected by low-velocity currents or waves generated by weak to moderate winds.

Except for the surface layer of low-density (flowing or nonflowing) fluid mud, the majority of the mounded material is usually high density (nonflowing) fluid mud. Whereas the recently discharged slurry flows away from the discharge points along the surface of the existing mound as a fragmented sheet of low-density fluid mud, the high-density fluid mud within the mound probably moves away from the discharge point by means of a slow creeping process[2] or sudden failure. The solids concentrations increase very rapidly with depth from approximate levels of a few hundred milligrams per litre to 200 g/ℓ. Below the 200 g/ℓ isopleth, the solids concentration within the fluid mud mound increases at a slower rate with increasing depth; concentrations at the base of the mound may be as high as 500 g/ℓ. If the discharged slurry is widely dispersed, mound slopes will probably range from 1:500 to 1:2000. With a low degree of dispersion, the fluid mud mound will have slopes ranging from 1:100 to 1:500. Typical mound slopes may average about 1:500. Where current velocities are greater than a few centimetres per second, the mound will be skewed in the direction of the predominant current and the mound slopes on the downcurrent side will also be less than those facing the predominant current direction. Depending on the sedimentation/consolidation characteristics of the dredged sediment, consolidation of a fluid mud mound may take from one to several years.[3,4]

Turbidity Plumes

Less than 5 percent of the material discharged during open-water pipeline disposal operations is dispersed in the water column as a turbidity plume. The levels of suspended solids in the water column above the fluid mud layer generally range from a few tens of milligrams per litre to a few hundred milligrams per litre with concentrations rapidly decreasing with increasing distance downstream from the discharge point and laterally away from the plume centerline due to settling and lateral dispersion of the suspended solids (Figure 1). In addition, depending on the configuration of the pipeline at the discharge point and the water depth in the disposal area, there is often a general trend of increasing solids concentrations with increasing depth. Under tidal conditions, the plume length will usually be only slightly longer than the maximum distance of one tidal excursion; in rivers the plume length is controlled by the strength of the current and the settling properties of the suspended material.

The plume characteristics are controlled mainly by the discharge rate and character of the dredged material slurry, the water depth and hydrodynamic regime, and the discharge configuration. As the current velocity increases, the plume will grow longer. With increasing depth of water in the disposal area, the average level of suspended solids concentrations will tend to increase. In addition, as the diffusion velocity increases for a given current velocity the plume becomes longer and wider, while the solids concentrations in the plume will decrease. Finally, as both the diffusion velocity and particle settling velocity decrease and water depth increases, the length of time required for the plume to dissipate after the disposal operations has ceased will increase. In most cases the visible near-surface plume will disperse within a period of one to two hours;[2,5] however, the subsurface plume may theoretically persist for a few days. A method for predicting the extent and duration of the plume was developed.

CONTROL METHODS

Cutterhead Dredges

Turbidity generation around cutterhead dredges can be minimized by selecting properly designed cutters, removing the cutter if the bottom sediment flows naturally, using water-jet booster systems or ladder-mounted submerged pumps, using a cutter-suction combination, using proper operational techniques, and

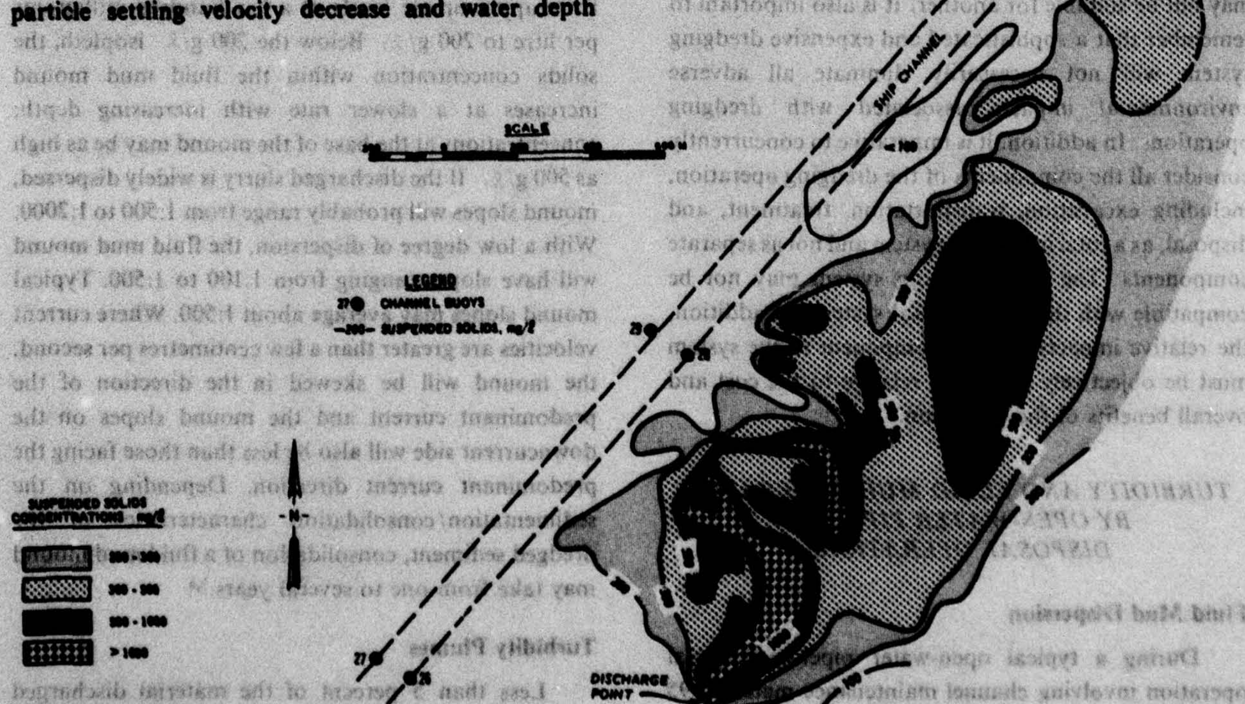

Figure 1. Middepth (0.9-m) turbidity plume generated by a 71-cm (28-in.) pipeline disposal operation in the Atchafalaya Bay. Current flow was generally toward the northeast

perhaps by installing production meters and other automatic controls, modifying the dredge to include a spud carriage or Wagger system.

Pipeline Configurations

The configuration of the pipeline at the discharge point appears to be the only parameter that can be varied to effectively control the characteristics of dredged material dispersion. Pipeline configurations that minimize water column turbidity tend to produce fluid mud mounds with steep side slopes, maximum thickness, and minimal areal coverage. Conversely, those configurations that generate maximum levels of water column turbidity usually minimize the mounding tendency of the fluid mud. A simple open-ended pipeline discharging slurry parallel to and above the water surface produces a maximum amount of dispersion. Dispersion is minimized by discharging the material vertically below the water surface.

Silt Curtains

One method for physically controlling the dispersion of near-surface turbid water in the vicinity of open-water pipeline disposal operations, effluent discharges from upland containment areas, and possibly clamshell dredging operations in quiescent environments involves placing a silt curtain or turbidity barrier either downcurrent from or around the operation (Figure 2). More information on silt curtains, including specific guidelines for their selection and use, has been given previously in an earlier bulletin (October 1977). Silt curtains are *not* recommended for operations in the open ocean, in areas frequently exposed to high winds and large breaking waves, or around hopper dredges where frequent curtain movement would be necessary.

Under relatively quiescent current conditions (i.e., 5 cm/sec or less), turbidity levels in the water column outside the curtain can be as high as 80 to 90 percent lower than the levels inside or upstream of the curtain. However, the effectiveness of silt curtains can be significantly reduced in high energy regimes where high currents cause silt curtains to flare. A current velocity of approximately 1 knot appears to be a practical limiting condition for silt curtain use. Whereas properly deployed and maintained silt curtains can effectively control the flow of turbid water, they are not designed to contain or control fluid mud.

Diffuser

An alternative to silt curtains is a submerged diffuser system (Figure 3) developed by the DMRP. The diffuser minimizes water column turbidity by radially discharging the slurry parallel to and just above the bottom at a velocity of about 0.5 m/sec. Although the diffuser has not been field tested, it has excellent potential for minimizing turbidity in the water column and maximizing the mounding tendency of the discharged dredged material. This will minimize the areal coverage of the fluid mud mound, but will not eliminate the relatively significant impact of the fluid mud on the benthic organisms covered by the mound.

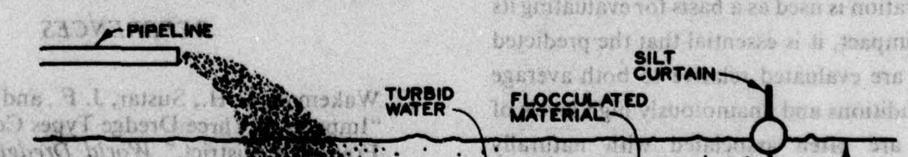

Figure 2. Processes affecting the performance of silt curtains in controlling dredged material dispersion

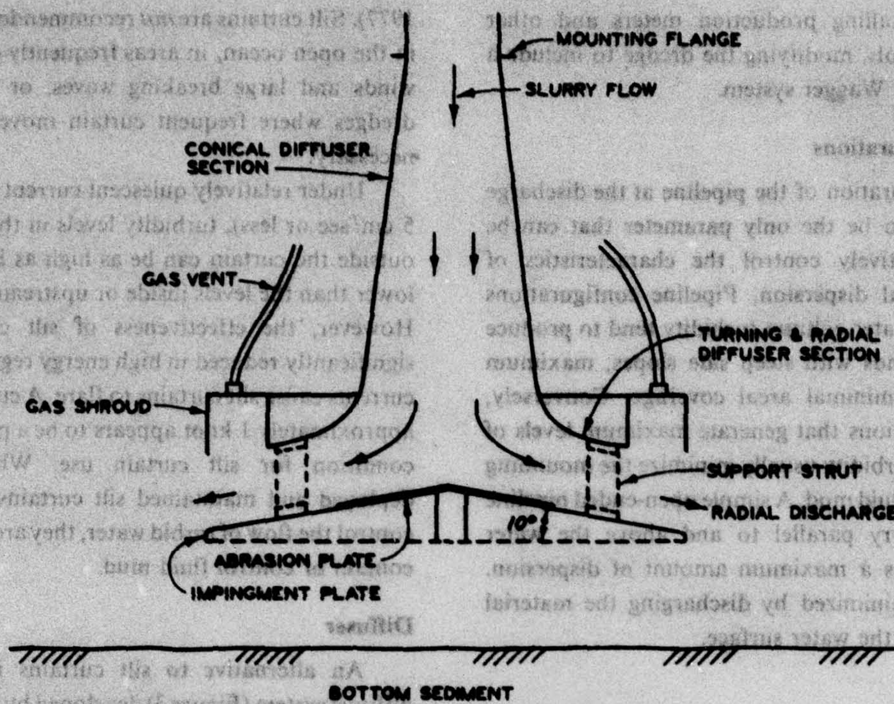

Figure 3. Submerged diffuser

The diffuser may also have application within in-water confined disposal areas to minimize turbidity in the water column.

A PERSPECTIVE

If the amount of turbidity generated by a dredging or disposal operation is used as a basis for evaluating its environmental impact, it is essential that the predicted turbidity levels are evaluated relative to both average background conditions and anamolously high levels of turbidity that are often associated with naturally occurring storms, high wave conditions, and/or floods, as well as activities of man. Fortunately, the traditional fears of water-quality degradation resulting from the resuspension of dredged material during dredging and disposal operations are for the most part unfounded; there are no well-defined plumes of dissolved metals or nutrients at levels significantly greater than background concentrations.[6,7,8] Whereas the impact associated with water-column turbidity around dredging and disposal operations appears to be insignificant in most situations, the impact associated with the dispersal and deposition of fluid mud dredged material appears to have a relatively significant short-term impact on the benthic organisms within open-water disposal areas. It is therefore necessary to evaluate the potential impact of each proposed operation on a site-specific basis.

Task 6C has been conducted under the direction of Dr. W. D. Barnard, who is also author of the task synthesis report. The Manager of the Disposal Operations Project is Mr. C. C. Calhoun, Jr.

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NEW LITERATURE

U. S. Environmental Protection Agency, *Evaluation of the Problem Posed by In-Place Pollutants in Baltimore Harbor and Recommendation of Corrective Action*, Report No. EPA 440/5-77-015B, 1977, Washington, D. C.

This study: (1) describes the in-place pollutants within Baltimore Harbor, (2) analyzes the pollutants for their effect upon the environment, (3) investigates potential corrective actions for feasibility and cost, (4) examines the effectiveness and permanence of potential corrective actions, (5) derives conclusions and makes recommendations, and (6) recommends the course of action which is most realistic given the conditions of the Harbor's requirements and use.

Following a comprehensive review of prior related work, a field program was developed and carried out to confirm and extend the results of earlier investigators. In the field program, core borings were taken from twenty sites. Each core was divided into sections to test the levels of concentrations of selected pollutants to depths of 10 feet below the sediment/water interface. The individual samples were analyzed for nine heavy metals, total hydrocarbons by hexane extract, PCB's, and interstitial water metals. In addition, elutriate tests were made, and surface sediments from nine of the twenty sites were used in a bioassay of two finfish and one clam species.

NOTE: The DMRP regrets it cannot be a distributing agent for the new items of literature listed in this bulletin. All items presented are available at the time of listing from the publishing or issuing agency and requests for copies should be addressed to them. In many instances, only limited copies are available and the use of Interlibrary Loan or related services is encouraged.

- The analytical techniques used to determine the existence and degree of pollution, such as the bulk sediment analyses, the elutriate tests, interstitial water metal analyses, PCB concentration analyses, and the bioassay did not correlate one with another to indicate pollutants or toxic elements consistently or predictably. The two analytical techniques that did correlate were the bioassay and the sediment analyses for heavy metal, hexane extract, and PCB concentrations. The elutriate test showed that the entire Harbor is classified as polluted, the elutriate being greater than 1.5 times the overlying filtered water metal concentration. Neither the elutriate test nor the interstitial water metal concentration analyses indicated consistent zones of intensity or correlated with the areas known to contain very high levels of toxic materials.
- The biota within the Harbor are being stressed by the in-place pollutants. The benthic organisms suffer the greatest amount of damage, intensity varying according to location within the highly, moderately, low, or slightly toxic zones. The pelagic species are damaged to a much lesser extent. The cause of damage, whether from in-place pollutants or from those presently being discharged, is unknown.

In-place pollutants are a direct result of waste discharges that are incorporated into the sediments. Although the exact quantities and chemical composition of the present discharges are not known, NPDES permit authorizations indicate that significant quantities of heavy metals and total suspended solids are being added to the Harbor each day. The last total inventory of heavy metals and toxic chemicals, published in 1973, showed a daily Harbor influx of 86 tons. Until the goals of P. L. 92-500 are achieved and discharges of toxic materials are greatly reduced or eliminated, any action such as removal of the in-place pollutants would result in but a temporary solution.

- Of the potential corrective actions, "leaving the pollutants in place" is recommended as the preferred choice, at least until the influx of pollutant loads is greatly reduced or eliminated.
- Removal of the in-place pollutants by dredging may be an effective and feasible action to be taken in the future, after the discharge of pollutants has been eliminated. Dredging should be contemplated only after an appropriate amount of time has passed after the elimination of incoming pollutants; natural recovery to the biota of the Harbor may be possible and may well take place through blanketing of the in-place pollutants with clean sediment and natural loss of heavy metals to the water column.

- **Placement in a diked disposal area such as the Hart-Miller Island disposal site is feasible and is acceptable under Maryland State law. Costs to dredge and place 79 million cubic yards are estimated at 74 million dollars. To construct a diked disposal site for that quantity of material would cost 54.5 million dollars—a total estimated expenditure of 128.5 million dollars.**

This bulletin is published in accordance with AR 310-2. It has been prepared and distributed as one of the information dissemination functions of the Environmental Laboratory of the Waterways Experiment Station. It is principally intended to be a forum whereby information pertaining to and resulting from the Corps of Engineers' nationwide Dredged Material Research Program (DMRP) could be rapidly and widely disseminated to Corps District and Division offices as well as other Federal agencies, State agencies, universities, research institutes, corporations, and individuals. Although the DMRP was completed in March 1978, all research results have not yet been disseminated to this wide audience. Hence it is being continued until such time as all significant DMRP results and data are summarized. It will be issued on an irregular basis as dictated by the quantity and importance of information available and compiled for publication. Contributions of notes, news, reviews, or any other type of information are solicited from all sources and will be considered for publication as long as they are relevant to the theme of providing definitive information on the environmental impact of dredging and dredged material disposal operations and the development of technically satisfactory, environmentally compatible, and economically feasible dredging and disposal alternatives, including consideration of dredged material as a manageable resource. Special emphasis is placed on materials relating to the application of research results or technology to specific project needs. Communications are welcomed and should be addressed to the Environmental Laboratory, ATTN: R. T. Saucier, U. S. Army Engineer Waterways Experiment Station, P. O. Box 631, Vicksburg, Miss. 39180, or call AC 601, 636-3111, Ext. 3233 (FTS 542-3233).

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