Bay-Dredging
BF 28,10

ASCE National Meeting on
Water Resources Engineering

January 21-25, 1974 Los Angeles, California

$0.75

AMERICAN SOCIETY OF CIVIL ENGINEERS
FOUNDED 1852

EVALUATING DREDGING IMPACTS

John F. Sustar and Thomas H. Wakeman

Meeting Preprint 2139

EVALUATING DREDGING IMPACTS

By John F. Sustar,[1] M. ASCE and Thomas H. Wakeman[2]

Introduction

With the increased recognition of the value of natural systems and the stresses man has placed on both our natural and manmade system "comprehensive planning" now means more than simply including a floral fauna inventory of a project area in the planning process. Active inclusion of the natural system into the planning process requires definition and investigation of effects of proposed manmade systems as th relate to the natural system. A study initiated in April 1972 by the San Francisco District of the U.S. Army Corps of Engineers to determir the environmental impact of dredging operations, was designed based or relating the dredging and disposal operation to the natural system in San Francisco Bay.

Concept of Study

Living in today's world necessitates that, first, we recognize our needs and, second, that we have the capability to implement progr to satisfy those needs. Recognition of our needs appears, at first glance, to be relatively simple. We have certain fundamental needs s as food, water, shelter and an adequate environment in which to grow physically and intellectually. With our rapidly rising living standa we take these needs for granted, placing an increasing stress on not only natural systems, but also on manmade systems. With our improvec standard of living, we have experienced an amelioration in our envirc ment culminating particularly in intellectual growth. This can be se

1/ Civil Engineer, U.S. Army Engineer District, San Francisco.
2/ Biological Oceanographer, U.S. Army Engineer District, San Franc:

in the development of the term "comprehensive planning," especially in the field of water resources planning. "Comprehensive" means the planning for the allocation of a limited resource according to recognized needs and the capability to satisfy those needs. In water resources, the expansion of "comprehensive planning" can be traced with the expansion of Federal legislation, the identification of the needs and the assignment to an agency to implement a program to meet those needs. Planning is relevant only when the resulting plan is meaningful to the beneficiaries. We are now at the stage where we recognize the stresses on both manmade and natural systems and we expand the term beneficiaries to include society as a whole.

The National Environmental Policy Act of 1969 is the present culmination of legislation on "comprehensive planning." However, the requirements of the Act consist merely of identification of man-associated environmental stresses (passive planning) as opposed to the recognition of those stresses as "comprehensive needs" (active planning). This condition exists because we lack basic understanding of the interaction between manmade systems and natural systems. Furthermore, we tend to shy away from the unknown. Our general approach to "comprehensive planning" is limited to inventorying nature. An exception to this is in areas where the engineering factors such as foundations are grossly affected. This approach fails to define the systems (either natural or manmade) and the relationship of the systems to man. Where we recognize the presence of stresses but fail to know the type and degree of stress, the tendency is to develop guidelines for the manmade systems. The question of the relationships and the interactions of man and manmade systems to natural systems still

remains. What constitutes an evaluation of these systems as we associate them with recognized and unrecognized needs?

Navigation projects in San Francisco Bay requiring Federal dredging operations date back to 1874. The average annual amount now dredged by or for the San Francisco District (major project areas shown in Figure 1) is about 7 million cubic yards (5.4 million cubic meters) of which the major quantity of sediments is moved by hopper dredges. The planning process involved in the Federal authorization of the projects relates to the recognized needs of man. As has been stated, recognition of the natural systems in the past has been limited to inventory type studies and studies concerning the engineering concepts of the projects. In the case of a major project, salinity variations were investigated using the San Francisco Bay hydraulic model. However, the planning for the continual maintenance dredging of channels as it relates to man's use of the natural system is not included. Local criteria in the absence of knowledge have been developed not to regulate but to control dredging despite decades of dredging without observed disturbances of the biosphere. Historical observations, even when we did know what to observe, are more effective in defining the environmental impact and enabling evaluation than are baseline inventory studies.

In April 1972, the San Francisco District initiated a $2.4 million study to evaluate dredging impacts as they relate to the continuous maintenance of Federal navigation channels. Dredging, as conducted with aquatic disposal in San Francisco Bay, is a system of artificial sediment movement. Evaluating the dredging impacts in relating the manmade systems and the natural systems can be narrowed to two points: first, defining the sediment balance in the Bay and, second, defining the change in "pollutant" availability by the changes induced by sediment imbalance.

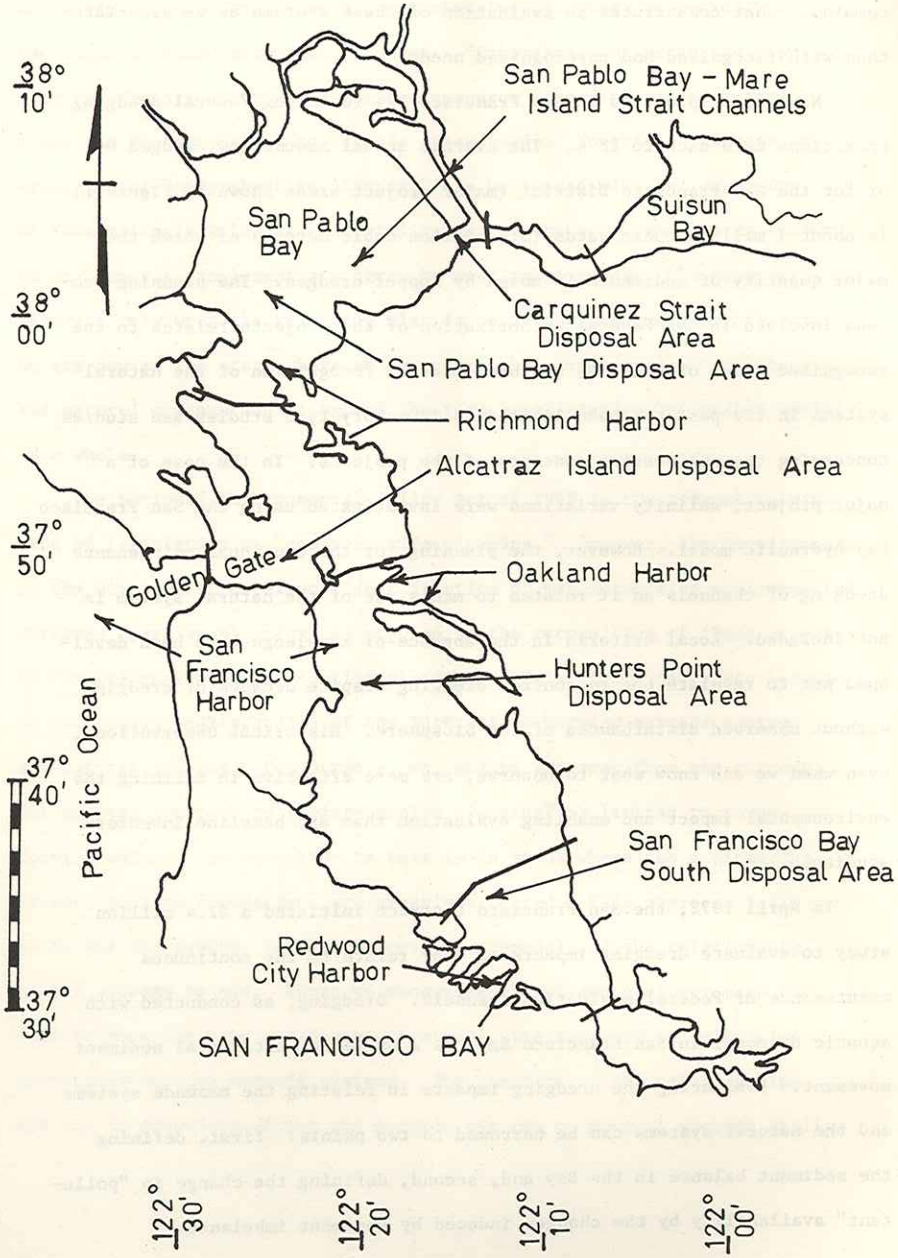


FIGURE 1

Definition of the System

Defining the present maintenance dredging operation in San Francisco Bay includes evaluating:

a. the sediments to be dredged,

b. the mechanism for artificial sediment movement,

c. the physical release of the sediment in the system,

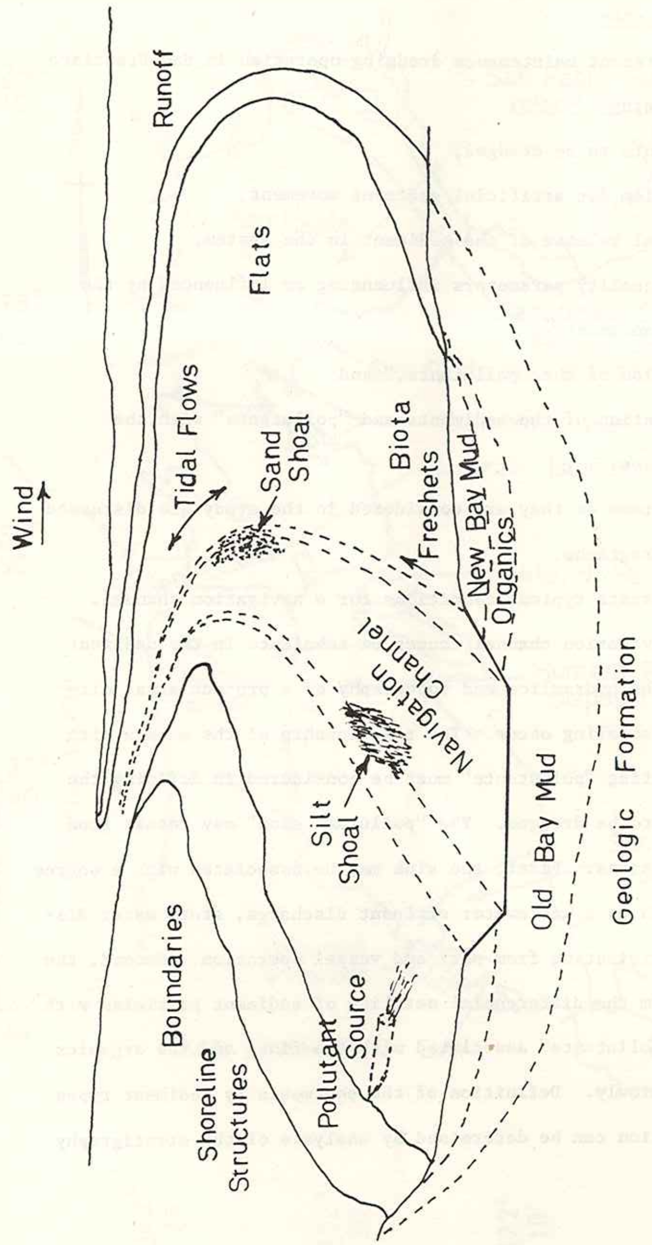
d. the water quality parameters influencing or influenced by the artifical sediment movement,

e. the condition of the "pollutants," and

f. the interaction of the sediments and "pollutants" with the biological communities.

Each of the above items as they are considered in the study are discussed in the following paragraphs.

Figure 2 represents typical conditions for a navigation channel. Development of a navigation channel causes an-imbalance in the sediment hydraulics. With the hydraulics and topography of a project area, different patterns of shoaling occur. The relationship of the shoals with regard to concentrating "pollutants" must be considered in defining the types of sediments to be dredged. The "pollutant sink" may result from two different conditions. First, the sink may be associated with a source of "pollutants" such as a wastewater effluent discharge, storm water discharge or debris originating from port and vessel operation. Second, the sink may result from the differential settling of sediment particles with higher levels of "pollutants" associated with the fines and the organics which settle more slowly. Definition of the sediments by sediment types and areal distribution can be determined by analysis of the stratigraphy



CHANNEL CONDITIONS

FIGURE 2

using seismic profiling; physical factors of sediment circulation including the geography, the tidal hydraulics, wind, etc.; and, finally, relating a coring program which includes analysis by strata. The resulting information provides an interpretation of the "pollutional" characteristics of a project area, and whether or not "hot spots" are present. The information is also valuable in determining dredging methods and operations, with the possibility of reducing maintenance requirements through a better understanding of the system.

The creation of navigation channels interrupts the normal sediment movement causing an artifical disturbance in the sediment hydraulics of the system. The second artificial disturbance of the sediment movement is the actual dredging operation. Two sets of factors are involved in this type of disturbance. The first set involves the dredge's movement through the area with the associated induced energy due to the swash and the minimum clearance necessary between the hull and the sediment-water interface. These factors are present with all major vessel traffic in the channel, making dredging insignificant from the standpoint of sediment resuspension. The second set of factors involve the movement of sediments through the lifting of the sediment to the transport vessel. The factors include the cutting, the lifting and the overflows for maximization of loads. These factors will vary with the type of dredging system being employed. The areas of impact to be considered when knowledge of the types of sediments and the biological community in the project area are available include the possible chemical change of the "pollutants" associated with the sediments and the removal of biological communities.

The third disturbance associated with maintaining artifical channels is the return of the sediments to the system, in terms of both the short-term release pattern and the long-term acclimation of the sediments back into the system. Figure 3 shows the extreme conditions encountered with the release of sediments. The controlling factor for the immediate release pattern is the percent solids. The level of percent solids can be associated with dredging and transport methods. A high percent solids can be associated with clamshell operation and long-haul barge transport. In situ water contents of 55-60 percent as found in San Francisco Bay muds are insufficient to permit dispersion to any great degree in the water column. The cohesive properties of Bay mud cause the sediments to rapidly descend through the water column in large globules, causing minimal turbidity and maximum biological smothering potential. Decreasing the percent solids as occurs during some hopper dredging operations and short-haul transport of sediments permits the dispersion of the sediments in a cloud in the lower portion of the water column. Potential for smothering of benthic communities is decreased; however, the impact of turbidity from the standpoint of the high suspended solid concentrations or the contact area and time of the sediments with the water column must be evaluated. Suspended solids may cause clogging of gills or it may decrease photosynthesis adversely affecting algal populations. Contact area and time may influence the sorption-desorption characteristics of "pollutants" associated with the sediments. The long-term dispersion of sediments influences ultimate acclimation of sediments in the system. The circulation of sediments is of concern because of the sphere of influence of the disposal operation on biological communities and the possibility of modifying disposal operations to reduce maintenance dredging quantities.

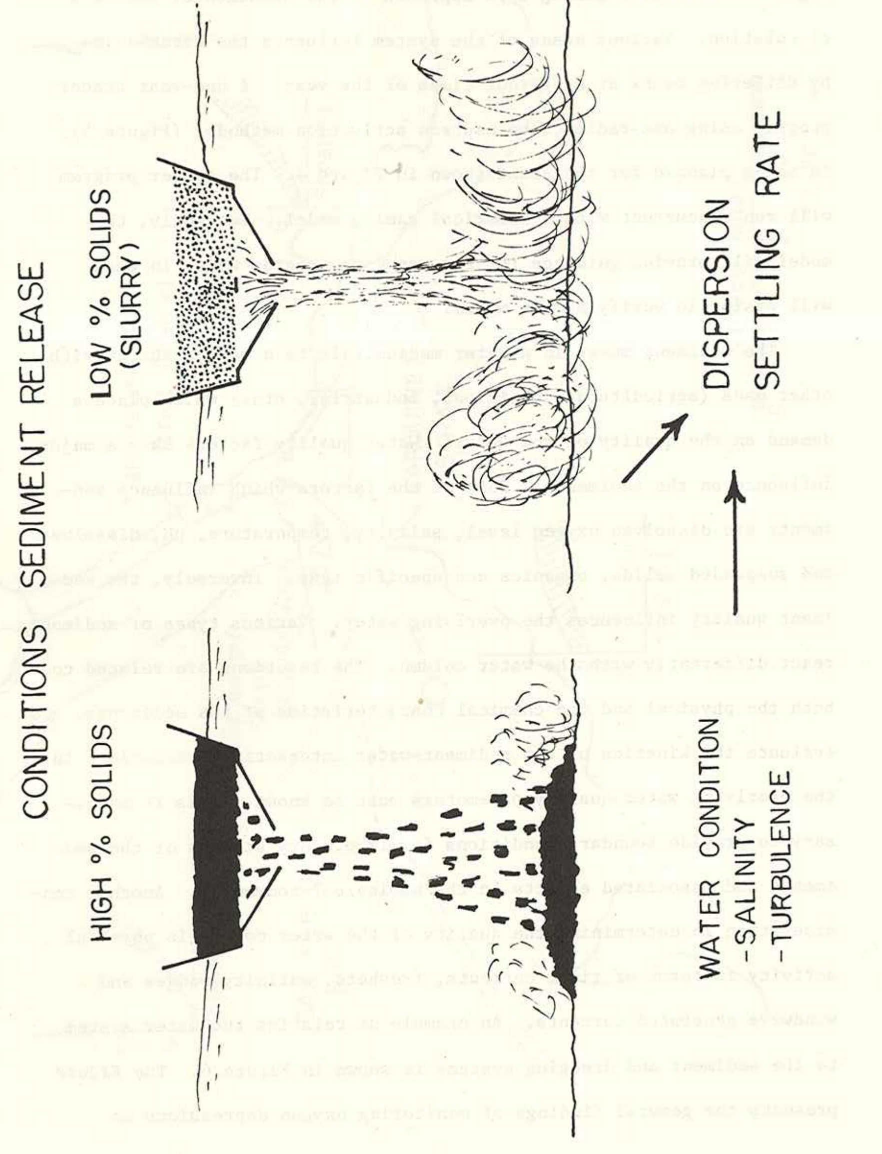


Figure 4 presents a gaming type approach to the question of sediment circulation. Various areas of the system influence the circulation by differing means at different times of the year. A one-year tracer program using non-radioactive neutron activation methods, (Figure 5), is being planned for the areas shown in Figure 4. The tracer program will run concurrent with a numerical gaming model. Hopefully, the model will provide guidance for the sampling program which in turn will assist in verifying the model.

The sediment moves in a water medium. It is a medium shared with other uses (agricultural, municipal, industrial, etc.) which place a demand on the quality of the water. Water quality factors have a major influence on the sediments. Some of the factors which influence sediments are dissolved oxygen level, salinity, temperature, pH, dissolved and suspended solids, organics and specific ions. Inversely, the sediment quality influences the overlying water. Various types of sediments react differently with the water column. The reactions are related to both the physical and the chemical characteristics of the sediments. To evaluate the kinetics of the sediment-water interaction, variations in the overlying water quality parameters must be known. This is necessary to provide boundary conditions for laboratory studies of the sediments and associated effects on the biological community. Another consideration in determining the quality of the water column is physical activity in terms of tidal currents, freshets, salinity wedges and windwave generated currents. An example of relating the water system to the sediment and dredging systems is shown in Figure 6. The Figure presents the general findings of monitoring oxygen depressions in

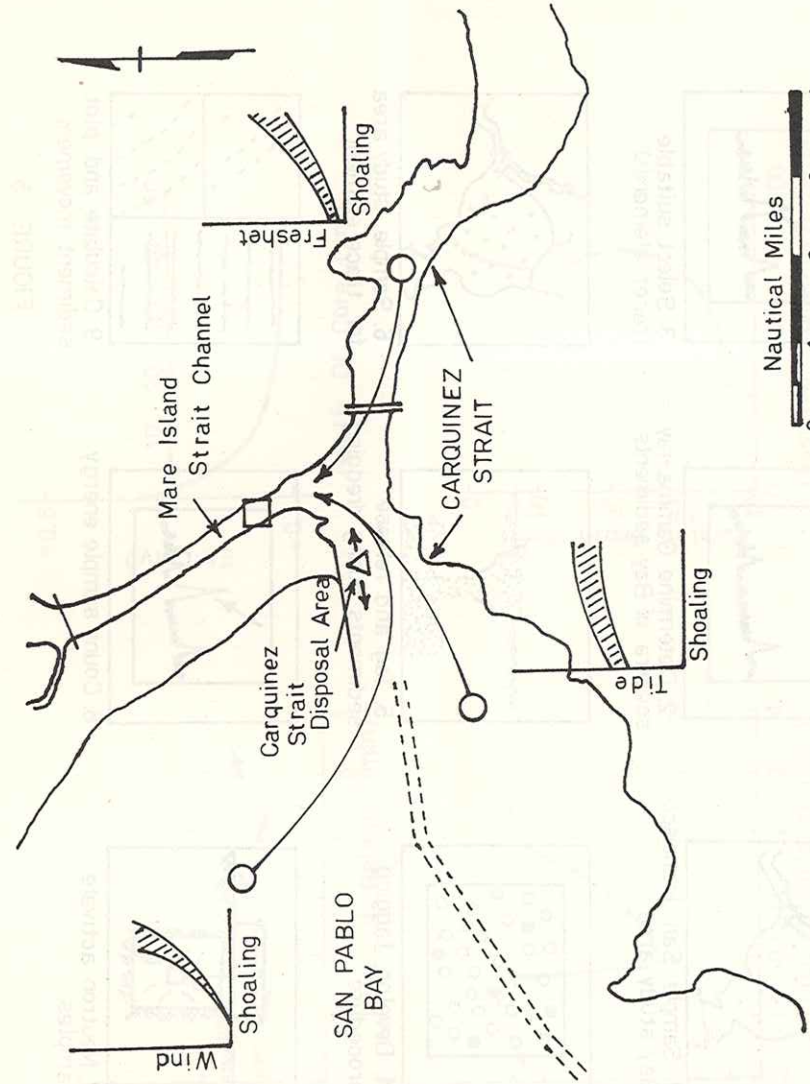


FIGURE 4

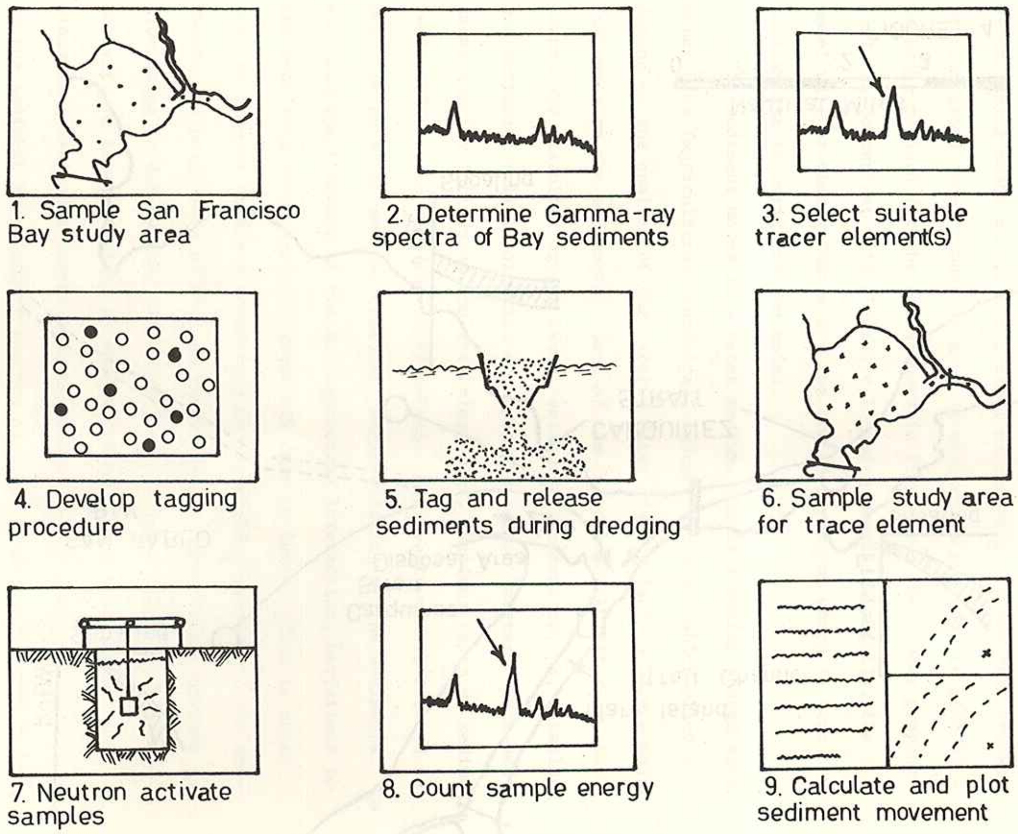


FIGURE 5

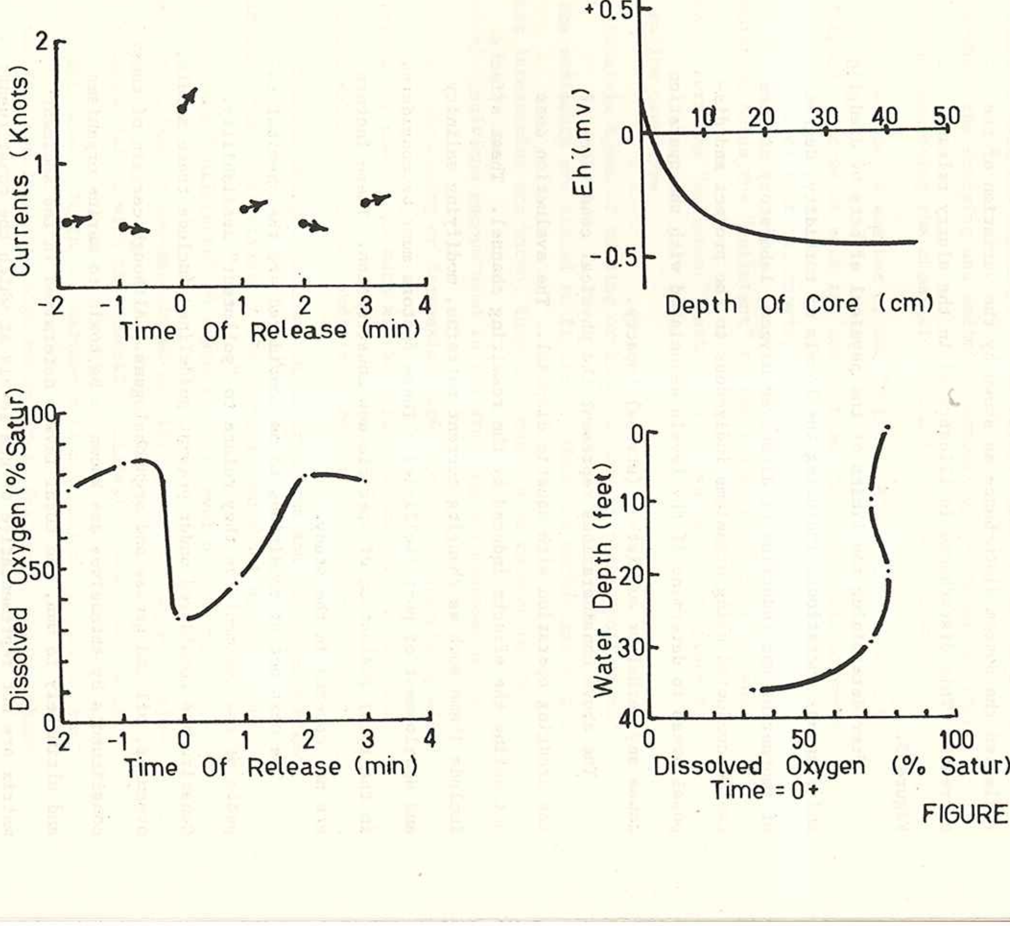


FIGURE 6

Carquinez Strait as associated with the release of dredged sediments. The only depression detected occurred in the lower part of the water column with durations of about two minutes or less. The depression reflected the bottom disturbance as shown by the variation of the currents. This disturbance is illustrated in the slurry release, Figure 3.

After determining the limits of the physical effects of dredging and disposal operations, including the levels of turbidity, degree of smothering and reduction of dissolved oxygen, laboratory studies can be conducted using organisms indigenous to the project and disposal areas to determine if the levels associated with the operation cause any lethal or sub-lethal (stress) impacts.

The above considerations represent the physical conditions of the dredging operation with aquatic disposal. The evaluation does not define the effects induced by the resulting channel. These effects include items such as changing current patterns, modifying salinity and development of port facilities. These factors must be considered in the total evaluation of specific new construction. These factors are not covered in the study.

The next set of conditions to be considered are the chemical aspects of the sediments as they relate to "pollutant" availability. Constituents considered under present guidelines include trace metals, organics, oil and grease and organohalogens. Although certain of these constituents by themselves are known to be toxic to marine organisms and ultimately to man, the total levels determined in the sediment matrix are not representative of the levels at which the constituents

are actually available for uptake by organisms. The chemical aspects of the sediments are outlined in Figure 7. Several physical aspects are included with the chemical. These several aspects are the conditions which the dredging and sediment disposal operation may affect, conditions modifying the chemical equilibrium of the sediments.

The question of whether or not "pollutants" are available must be defined in terms of both the sediment and the biological communities encountered; that is, knowing what types of bonding or chemical association holds the "pollutant" to the sediment particle and what state or form the "pollutant" must be to be available for uptake by the marine organisms.

Possible types of bonding or associations of these "pollutants" in the sediments are listed in Figure 7. Once the mechanisms of pollutant interaction are known, they then need to be related to the physical conditions encountered in the dredging and disposal operation, i.e., increasing or decreasing water content or associated with different Bay conditions such as the artificial movement to an area of higher salinity. These conditions are listed in Figure 7 under State of Slurry, Dredged Sediment in Water Column and Deposited Dredged Sediments. The interactions of the chemical and physical conditions will place the "pollutants" in suspension (a level of bonding with mineral particles or non-associated metallic particle), aqueous solution (disassociation with the mineral particles) or associated with organic molecules. Burial of sediments is not considered because the disposal is accomplished in high energy areas (naturally scoured channels) and massive recirculation of sediments occurs with tidal and wind-wave currents due to the shallowness of the Bay. The "pollutants"

CONDITION OF POLLUTANTS

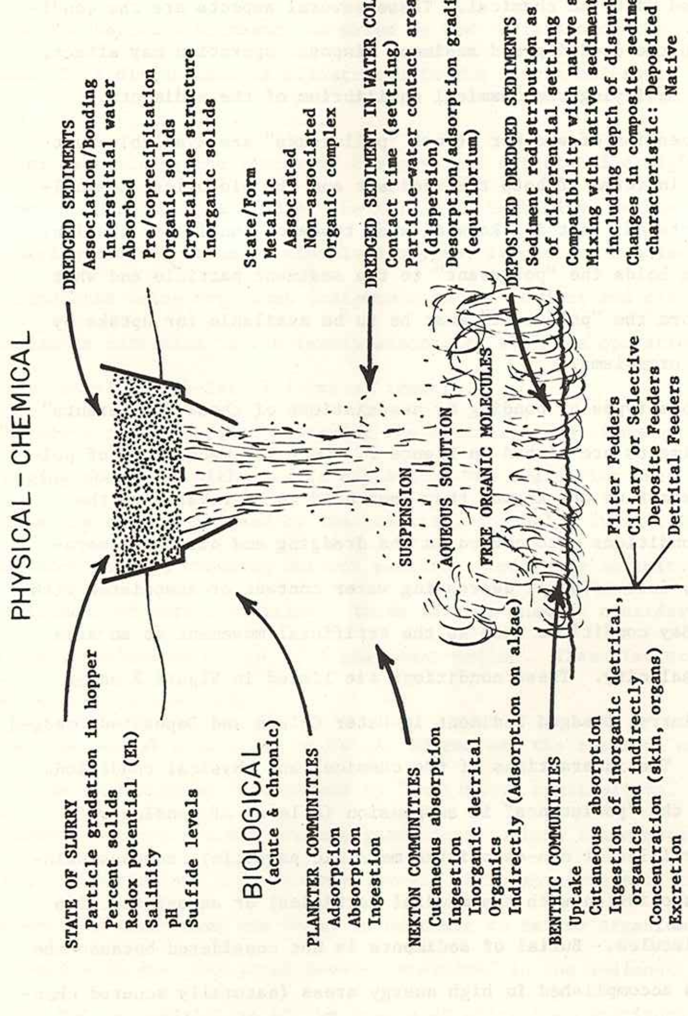


FIGURE 7

in suspension, solution or associated with organic molecules then provide the basis for relating "polluted" sediments with the biological communities within the sphere of influence of the disturbed or dispersed sediments.

Relating impact to the natural system (the biological community, food chains and eventually to man) requires knowledge of the mode of uptake, the ability of organisms to concentrate "pollutants" causing lethal or sub-lethal effects either to themselves or to higher organisms in the food chain. Uptake may occur directly or indirectly as listed in Figure 7. Quantification of uptake with toxicant levels can not be defined. Some of the factors which hinder quantification include the "classification" of types of organisms, the variation in natural and artifical conditions encountered, depression of digestive and other organ systems due to sediment, water column and community conditions, chemical cycles, and synergistic-antagonistic effects of the "pollutants" themselves.

Alternative Systems

In any discussion of maintenance dredging, questions regarding alternative disposal methods arise. Alternatives to the present system of aquatic disposal mean the introduction of other systems with new considerations of resource allocation. The question of maintaining sediment balance within San Francisco Bay may be a moot point since the concern is for the filling of the Bay and an estimated one and one-half billion cubic yards of sediment resides in the Bay from the days of hydraulic mining.

The three alternative systems to be considered for San Francisco Bay include land, ocean and sub-tidal ponds utilized for salt production. Of these three systems, land presents the most dramatic conflict of sediment compatibility with the natural system as is illustrated in Figure 8. The challenge of considering this alternative rests in reducing the conflict, the problems of stability and sterility. The ocean poses the question of acclimation of the natural system, regardless of how vast, to receive the sediments. The argument may be made that the ocean nearshore already receives a sediment load from the Bay and the 100-fathom line (slope of continental shelf) may already be biologically submarginal. The arguments in favor of this alternative still does not explain what happens when fine sediments are released into the system. The third alternative system of forming tidal areas in diked ponds to establish vascular vegetation is the most compatible system, tending to restore a natural system. Marsh systems are recognized as needed for a naturally healthy estuarine system.

Conclusion

Water resources planning has developed beyond the stage of single-purpose planning. One aspect of comprehensive or matrix planning is the isolation of the natural system and then the introduction of other purpose modifications as they relate to the natural system. The evaluation ignores the needs which generate the primary purposes of planning. The evaluation should define the systems and the functions within the system. The functions become the study elements or tasks and the impact is defined by the interrelation of functions.

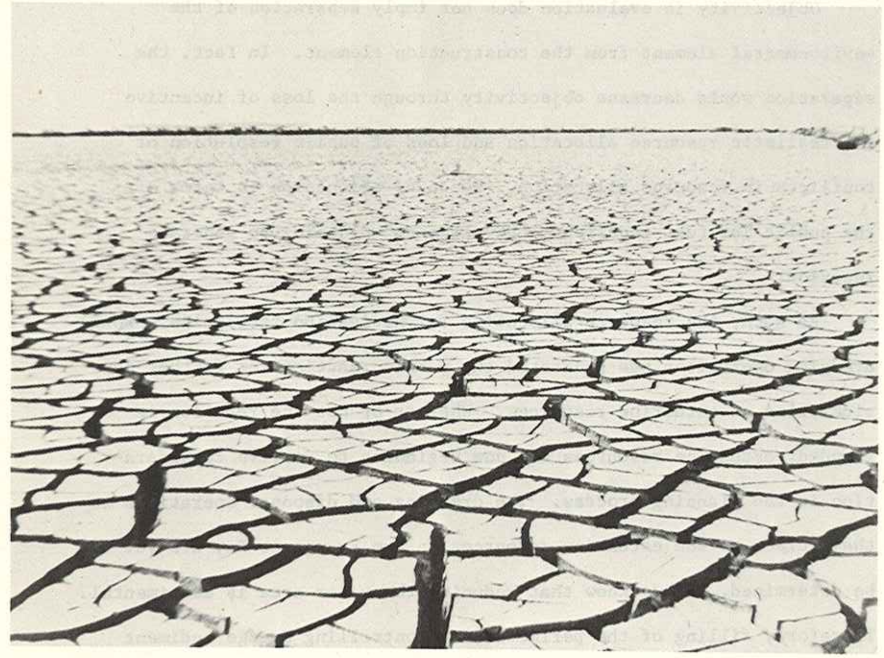


FIGURE 8 LANDFILL

Objectivity in evaluation does not imply separation of the environmental element from the construction element. In fact, the separation would decrease objectivity through the loss of incentive for realistic resource allocation and loss of public resolution of conflicts in resource allocation. Resource allocation in terms of the public interest requires a "development" planning to generate reaction.

As such, the resource allocation for navigation facilities through dredging operations has generated the public reaction for further consideration of estuarine resources. Whether or not the reaction is founded, estuarine resources are now beginning to receive consideration in the planning process. The dredging and disposal operations as they relate to the estuarine resources in San Francisco Bay are yet to be determined. We do know that reducing the water area is detrimental. Therefore, filling of the perimeter and controlling dredge sediment disposal to high energy areas in the Bay are regulated. As adverse impacts on the estuarine system due to dredging and disposal operations are identified, additional guidelines or criteria should be developed to either control or eliminate the identified adverse impacts. The guidelines or criteria should then serve as the planning tool for evaluating the benefits achieved through variations of resource allocations.

Acknowledgement

The material in this paper is based on information developed during the Corps of Engineers investigation of dredge material disposal in San Francisco Bay and Estuary. Publication of this paper has been approved by the Corps of Engineers, but any views, interpretations or conclusions are those of the writers only.