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December 14, 1988

Mr. Frank Ciavattieri
U.S. Environmental Protection Agency
JFK Building
Waste Management Division (HAN-CAN2)
Boston, MA 02203

Re: New Bedford Harbor

Dear Frank:

Enclosed with this letter, is a submittal which addresses, in draft form only, the key issues raised by you and others at our last meeting and in the various letters between us. As you will note, we believe there are some additional efforts, now underway, which will provide valuable information responsive to the technical questions raised. We hope that you and your team will have an opportunity to read this submittal prior to our meeting later today, as we will be most interested in any comments you may have on current or proposed activities.

I look forward to our meeting this afternoon.

Very truly yours,

Richard J. Hughto

Richard J. Hughto, Ph.D., P.E.
Vice President

RJH/dac/3312H

Enclosure

1. HOT SPOT REMEDIAL ACTION

Discuss how the cap will respond to permanence and reduction in toxicity and volume criteria when no removal or treatment of the "hot spot" is included. EPA has requested that "hot spot" remedial action be addressed with the proposed remedial action alternative of capping. As a starting point, we request that EPA outline on a map their definition of the "hot spot."

The question of the "hot spot" remediation will be addressed more fully in a later submission that will emphasize, in particular, two of the nine Feasibility Study criteria -- permanence of the solution and reduction in toxicity, mobility and volume. Suffice it to note here that the capping remedial alternative was developed with the objective of providing short-term and long-term environmental and health protection.

The proposal is an effective remediation alternative that strives for a solution which will permanently isolate the PCBs from the environment. We believe that the suggested cap, at the thickness and with the construction materials proposed, will physically and chemically isolate the PCBs and prohibit future migration in the environment more effectively than other remedies which the government is presently examining. Cap thickness and construction materials were specifically selected to eliminate diffusive flux of PCBs from the sediments and to eliminate transfer of PCBs to water as a result of bioturbation. This construction and capping material will withstand erosion during a 100-year storm event. Hence, PCBs will not migrate in the environment and be bioavailable as a result of diffusion or uptake mechanisms in benthic infauna.

A number of studies will provide further corroboration of the original conclusions and data that we have presented to you that this remedy will satisfy the nine criteria. At our meeting, we will be providing additional information on the following studies:

- Simulation modeling of the migration of PCBs under current conditions and under those anticipated with cap in place to estimate the diffusive flux of PCBs into the environment after cap placement. This modeling is based on calibration to existing data and addresses mobility and permanence.

- Benthic chamber studies provide physical measurements of PCB diffusion from sediments in the upper estuary, and specifically, in areas of elevated PCB concentrations. These measurements, described further in materials under question 2, address the criteria of mobility and permanence of the cap, as well as providing corroborating measurements for the simulation modeling.

- Thin-layer analyses of sediment cores provide additional information about flux and migration of PCBs, and more precise characterizations of the physical, biological and chemical parameters of upper estuarine sediments.

- Biodegradation studies provide evidence of reduction in toxic congeners and volume of PCB in the environment. Anaerobic degradation of PCBs in New Bedford is being studied in experiments by Dr. James Tiedje of Michigan State University and Dr. Sandra Woods of Oregon State University. Specifically, these studies will provide additional information by identifying PCB dechlorinating organisms and the level of dechlorination in addition to potential limiting factors controlling the rate of degradation.

All of the above studies will provide important information that we expect will be helpful in further demonstrating the appropriateness of a capping remedial alternative for the "hot spot" remediation efforts. In view of the potentially significant environmental and public health consequences of "hot spot" removal, and the emphasis on the cost-effectiveness of remedial alternatives, we are endeavoring to address further the government's concerns regarding "hot spot" removal.

2. CAP THICKNESS

Provide technical backup for the decision to require a 45-cm-thick cap. What is the proposed cap placement method? What is the target cap thickness that will be utilized to ensure that the design thickness will be achieved, as a minimum, throughout the capped area?

Justification for Cap Thickness

The thickness of the cap proposed for the upper estuary must be sufficient to provide an effective barrier to PCB migration from the sediments to the overlying water column. This barrier must be permanent and of sufficient thickness to prevent diffusive flux of PCB through the pore water into the water column. The role of bioturbation and its effect on the cap must also be considered.

The general strategy in specifying cap thickness is to assume that the cap is composed of two layers; one that provides an effective chemical diffusive barrier and the second a bioturbation barrier. The thicknesses of these two layers are then added and a margin of safety employed to determine the total cap thickness. Our technique follows this general approach.

The U.S. Army Corps of Engineers has performed laboratory studies to estimate the thickness of the cap as a chemical diffusive barrier using sediments derived from the upper estuary (Sturgis and Gunnison, 1988). This study investigated three thicknesses (5, 15, and 35 cm) and used a soluble tracer to determine the flux. One verification experiment using PCBs was performed on the 35-cm cap thickness and showed no diffusive flux losses. Based on this laboratory scale experiment, Sturgis and Gunnison (1988) recommended 35 cm as an effective chemical barrier thickness. It should be noted that PCBs are highly particle reactive and the Corps study has potentially significantly overestimated the required cap thickness. It appears from a careful review of the Sturgis and Gunnison work that a cap thickness of 20 cm may be sufficient for the soluble tracers used and, hence, for particle reactive PCBs, the thickness could be significantly less than 20 cm.

A comprehensive review of the benthic bioturbation literature for clean and polluted estuarine environments was performed. The effective depth of bioturbation, based on the maximum expected depth of significant sediment reworking and the depth of the redox potential discontinuity (RPD), is 10 cm for clean estuarine waters and > 3 cm for polluted waters (typical of the upper New Bedford Harbor estuary) (Rhoads, 1974; Rhoads et al., 1977; Rhoads and Germano, 1986).

Employing the Corps estimate of 35 cm for an effective diffusive barrier and 10 cm for bioturbation gives a total cap thickness of 45 cm. This calculation is generally conservative in that the required diffusive barrier thickness is likely overestimated and the bioturbation thickness assumes that the estuary will return to clean conditions.

There are several deficiencies with this estimate for total cap thickness.

1) The Corps experiment used in situ sediments for the cap while the proposed capping alternative calls for capping with clean sand.

2) The Corps experiment has not provided sufficient data to accurately define the minimum acceptable cap thickness for prevention of diffusive flux of PCBs.

3) The bioturbation depth estimates do not account for potential deep-burrowing animals whose burrows may provide a mechanism for PCBs to reach the overlying water column.

We are currently undertaking two studies to address these issues. These are briefly summarized below.

<u>Diffusive Flux Experiment</u>: The experimental laboratory technique presented in Sturgis and Gunnison (1988) will be used to estimate the diffusive barrier thickness. Modifications to this experimental procedure will include:

1) Sandy material, similar to that proposed for the cap, will be used as the capping material.

2) Experiments will be run at 5, 10, 15, 20, 25, and 35-cm cap thickneses with ammonium-nitrogen or orthophosphate-phosphorus as the tracer.

3) Verification experiments using PCBs will then be made at three cap thicknesses. These will be selected based on the soluble tracer experiments and will focus on the region of cap thicknesses where soluble tracer flux is first observed to occur.

4) An additional experiment will be made at the selected cap thickness that includes variations in mixing in the test chamber. This experiment will provide insight into the influence of water column mixing on PCB flux rates.

The data from these laboratory experiments will be summarized to determine the minimum cap thickness necessary as a diffusive barrier to PCB flux.

Cap Thickness for Effective Elimination of Flux Via Bioturbation

The objective of this proposed work is to determine the cap thickness sufficient to isolate contaminated sediment in the Upper Acushnet River Estuary and maintain the integrity of the "chemical seal."

The proposed approach to achieve this objective is outlined below.

1) Perform a detailed review of the various empirical methods which have been used to estimate the effective depth of bioturbation. The review will focus on methodology which has been published in refereed journals or otherwise reviewed by scientists with expertise in this area.

2) Review estimates of the effective depth of bioturbation in New England estuaries for a variety of potential benthic community types, including various successional stages (newly-colonized versus stable, well-developed communities), different sediment types and polluted versus non-polluted environments. Estimates will be made using the various methodologies detailed in Task 1 and will focus on refereed literature.

3) Develop a three-dimensional structural model of the benthos from estimated abundances of functional groups. Bottom-dwelling animals living in the sediment (infauna) construct burrows of varying sizes and depths of penetration into the sediment. These animals will be categorized into functional groups defined by volume and depth of burrow and methods of feeding and burrow irrigation. From abundance of individuals per area of bottom, the percent of bottom bioturbated to various depths may be constructed. A curve will be generated relating the percent of bottom area reworked up to or less than the independent variable of sediment thickness. These curves will be generated for several potential communities which might develop on the cap, as defined by sediment type and pollution level, using previously-reported benthic species abundance surveys. Sufficient benthic surveys appear to be available to perform this type of analysis.

Cap Placement Method/Thickness Control

For the area identified as needing erosive protection (Figure 1, 18 acres), it is proposed to perform all cap placement "in the dry." In this approach, the area would be isolated from the remainder of the estuary by wooden sheet pile

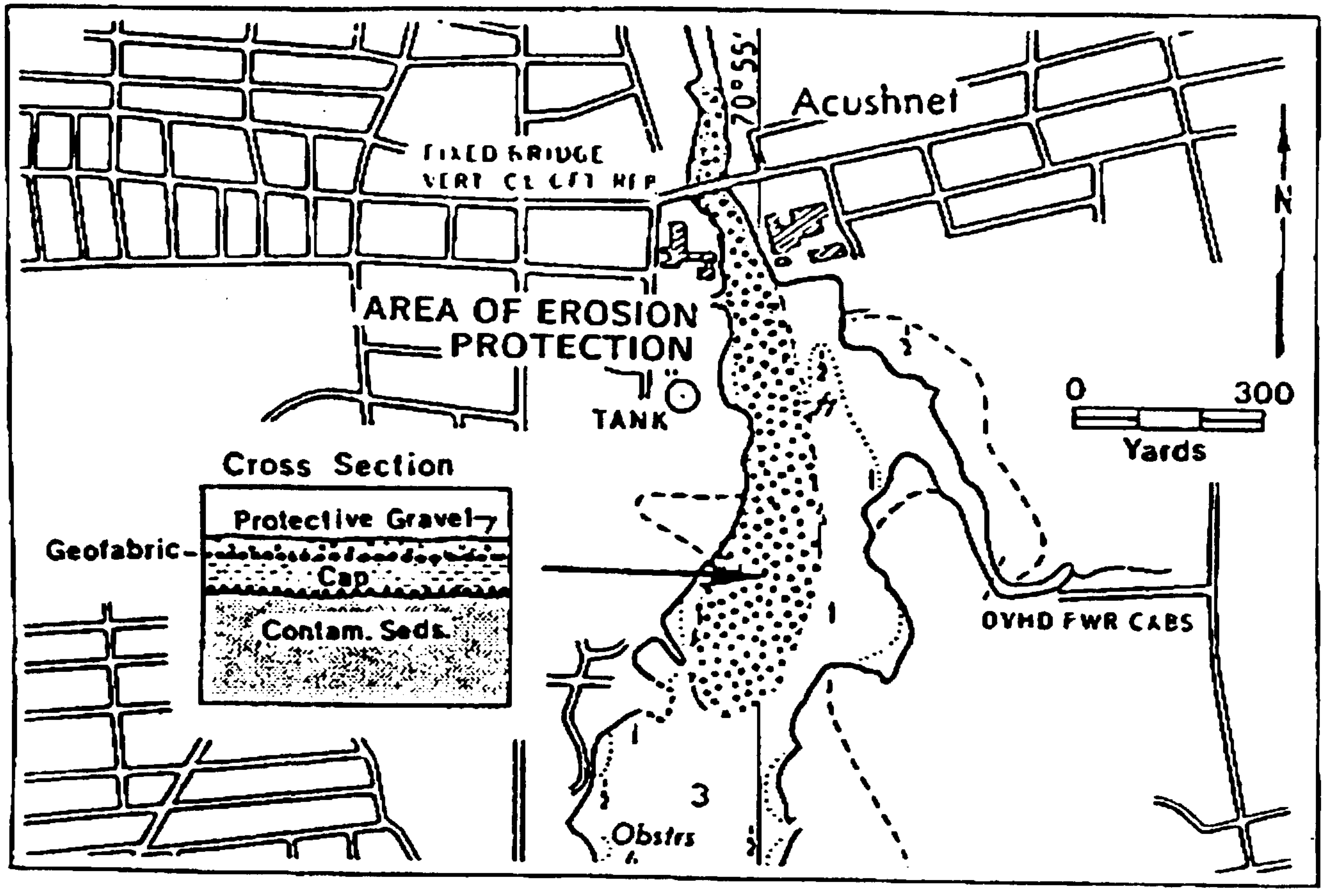

Figure 1. Location of proposed protective gravel cap in the upper estuary.

walls or low earthen cofferdams. Acushnet River flow would be pumped through pipes around the area. After placement of a geofabric over the contaminated sediment, a sand cap would be placed using small construction equipment. The placement would employ the finger pier technique to control mud waves caused by the loading of the soft, weak sediments of the upper estuary. Another layer of geofabric would be placed over the cap and the erosive protection cover (gravel, pea stone, small rock) placed on top.

Cap thickness can be accurately controlled in this area by the use of vertical reference stakes driven into the sediments. This is a well-established, widely used, simple procedure to control placement of the cap. It is anticipated that the sand cap thickness will vary between 45 and 60 cm in this area with the minimum set at 45 cm.

For the remainder of the upper estuary (north of Coggeshall Street Bridge) the cap would be placed by hydraulic means probably using a splash plate or a specifically designed diffuser system that would allow the cap material "to rain" on the sea floor. Capping would proceed from the upper to lower estuary.

Verification of cap thickness could be made by use of a submerged stake field. Stakes would be driven into the existing sediments and marked to denote distance from the sediment-water interface. A diver would measure the cap thickness using the stake. An alternate technique would use an acoustic sub-bottom profiler. This would allow accurate measurements of the cap thickness because of the sharp acoustic impedance gradient between the cap material and the underlying sediments. In this area, the minimum cap thickness, as placed, would be 55 cm with a minimum of 45 cm; since the proposed cap material is sand, placement should be straightforward and no consolidation problems are anticipated.

<u>Physical Permanence of Cap</u>

A concern in the feasibility of the proposed remedial action plan is the impact of storm surge and rainfall-induced runoff on the integrity of the cap, particularly in the upper estuary where sediment PCB concentrations and release rates into the water column are highest. The cap must maintain its integrity and serve as a permanent barrier in order to assure that the PCBs remain immobilized.

The hurricane barrier at the entrance to the harbor protects the upper estuary from surges generated by offshore storms (e.g., hurricanes, winter storms, etc.). The Corps operational guidelines indicate that the barrier is to be closed if the sea surface elevation is greater than 1.5 m (U.S. Army Corps of Engineers, 1982). In routine operation, the barrier is closed typically once per month even though the sea elevation is less than 1.5 m, hence the estuary receives more than adequate protection from surges. Storm surges hence pose no problem with respect to cap integrity.

The second area of concern is the markedly increased runoff and flooding associated with extreme rainfall events, such as occur during the 10, 25, 50 or 100-year storm events. In this scenario, the substantial increase in runoff associated with these storms causes the Acushnet River to flood, cross-sectional area velocities to increase, and, if sufficiently high, for capping sediments to resuspend and be transported seaward.

To assess the potential erosion of the cap, an analysis of the impact of flooding conditions for the Acushnet River on upper estuary sediment erodiblity was made. Estimates of the flood flow rate versus storm return period vary considerably depending on author and technique employed (NUS, 1984; U.S. Army Corps, 1987b; FEMA, 1982). The general consensus is that the peak flow rate for the 100-year storm is approximately 38 cubic m/sec. This is roughly 45 times the normal mean flow rate. The peak 100-year flood value is employed in the calculations to follow.

To assess the potential for erodiblity when the proposed cap is in place, an inlet basin hydrodynamic model (Seelig et al., 1984) was applied to the upper estuary and used to simulate the flow and surface elevation field in response to the 100-year storm river flow. Figure 1 shows the hydrodynamic model channel system in the upper estuary. Table 1 shows model predictions for each channel section at the peak flow rate during the 100-year storm event, with and without the 45 cm cap. The cross-sectional areas of the channels are also given for pre and post cap conditions.

With capping included, channel sections 4 through 8 (Figure 1) have velocities that exceed the threshold for cap sediment (fine to medium sand) erosion ($\geq$30 cm/sec). Hence, capping material in this area will be subject to erosion during the storm. It should be noted that a typical storm has a duration of 5-7 hours and hence the period of time that the cap will be subject to erosion is extremely limited.

A combination of a protective cap in the present river channel (Figure 1) and the establishment of cord grass on the intertidal and above mean high water areas will protect the cap from this brief storm-induced erosion event. The size of the protective cap material (gravel) can be selected to provide adequate erosion protection. In areas of higher velocity, the gravel size becomes coarser. In extremely high velocity areas, pea stone, trap rock or even small size rip-rap can be used to provide additional protection.

Table 1. Inlet basin hydrodynamic model predicted flow velocities and associated cross-sectional areas for the channel sections shown in Figure 1. Values are for peak flow rates 100 year storm, with and without a 45 cm cap in the upper estuary.

Channel Number (Figure 4-3)	Average Channel Velocities (cm/sec.)		Channel Cross-Sectional (m^2)	
	Existing	With 45 cm cap.	Existing	With 45 cm cap.
1	10.6	14.7	379.0	273.7
2	10.5	15.8	372.9	246.0
3	14.6	25.1	274.7	160.4
4	17.0	30.7	230.8	125.6
5	20.2	40.3	198.9	99.2
6	22.7	58.1	172.6	60.8
7	24.4	86.6	161.8	41.3
8	36.4	152.1	107.8	17.0

Exact specification of the size of capping material can be made using a Shield's diagram (Figure 2). For additional protection a flow competence curve based on flood geomorphology of river systems can be employed (Figure 3). As an example, Section 8 (Figure 1), which has the highest predicted river flow velocity (1.52 m/sec), requires cap material with a diameter of 9 cm using the flow competence calculation (Figure 3). This corresponds to a trap rock or small size stones.

It is, therefore, proposed to use a fine to medium grade sand in the upper estuary as the primary capping material. In areas subject to erosion during the 100-year storm event, the sand cap will be supplemented by an erosive protection cover comprised of coarser material. The size of the material will be determined by the use of Shield's diagram (Figure 2) or flow competence (Figure 3) curves. For the expected velocity ranges in the area, the cover material will range in size from gravel to trap rock or small size stones.

In summary, resuspension of the cap or the erosive protection cover in the upper estuary will not occur even during the 100-year storm event. Capping will isolate sediment from the environment and the cap integrity will be maintained even under severe weather conditions.

A conceptual design and screening analysis have been performed to specify the major components in the design of an erosive cap for the upper estuary. The next step would be to perform a preliminary engineering design of the erosive cap. Principal items to be addressed include: specification of cap thickness, material (type and size), detailed location of erosive cap and specification of geofabric. Preliminary simulations of the Acushnet River flood flow velocities during the 100-year storm event have been performed using a simplified modeling technique. The NOAA/NWS river flood flow model DAMBRK is presently being applied to predict the flood flow velocities in the river. Preliminary simulations suggest flow velocities similar to those predicted by the simplified model. This work will be continued and will include numerous simulations to determine the effect of cap thickness, river geometry, tidal state/forcing, and flood time history and magnitude on the predicted current fields.

The model results will then be used in conjunction with Shield's diagrams and flow competence curves to specify the erosive cap material (type and size) and thickness. A detailed specification of the geofabric will also be made.

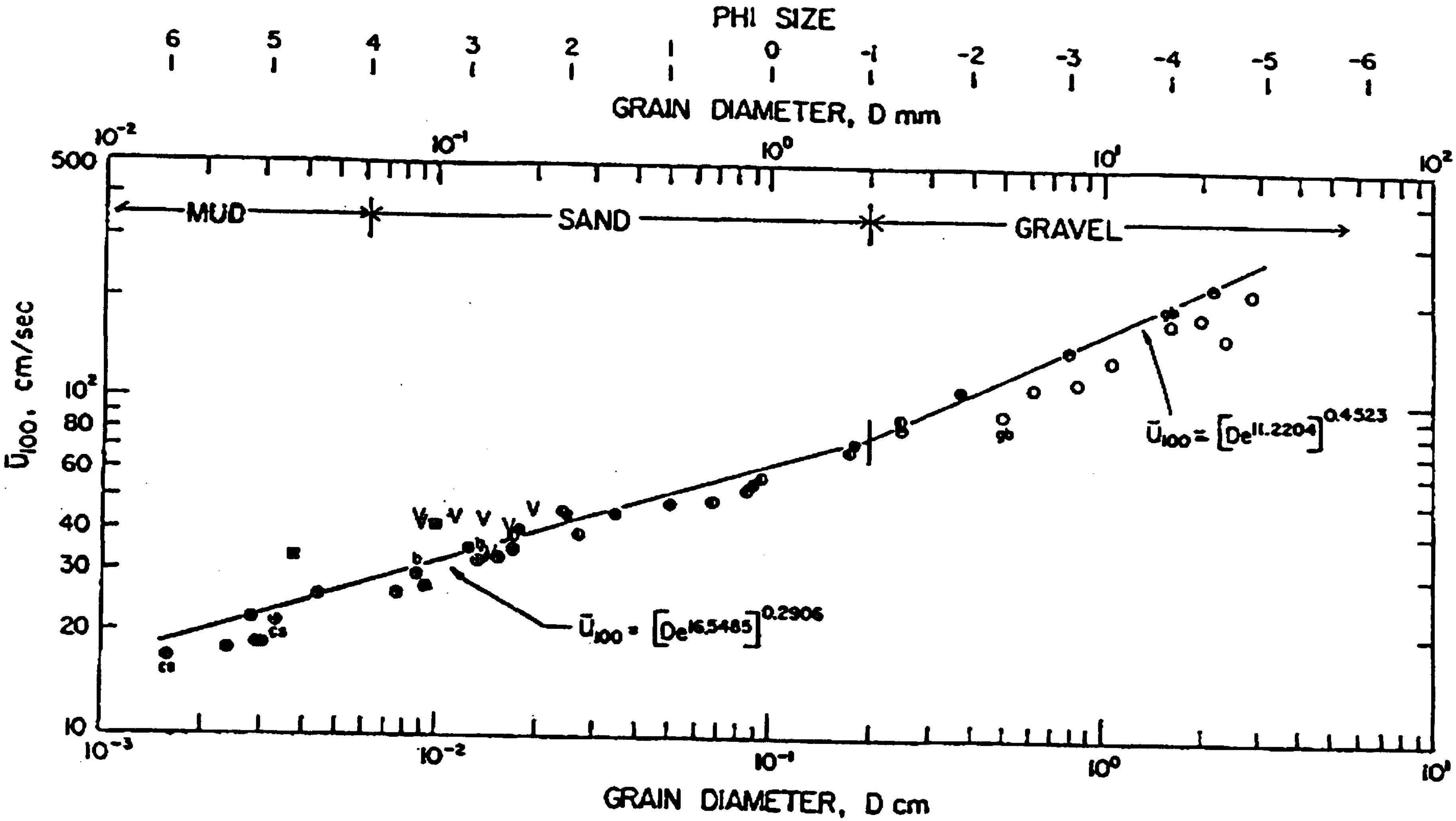

Figure 2. Shield's diagram sediment erosion threshold for velocity versus sediment grain diameter.

GRAIN THRESHOLD AND FLOW COMPETENCE

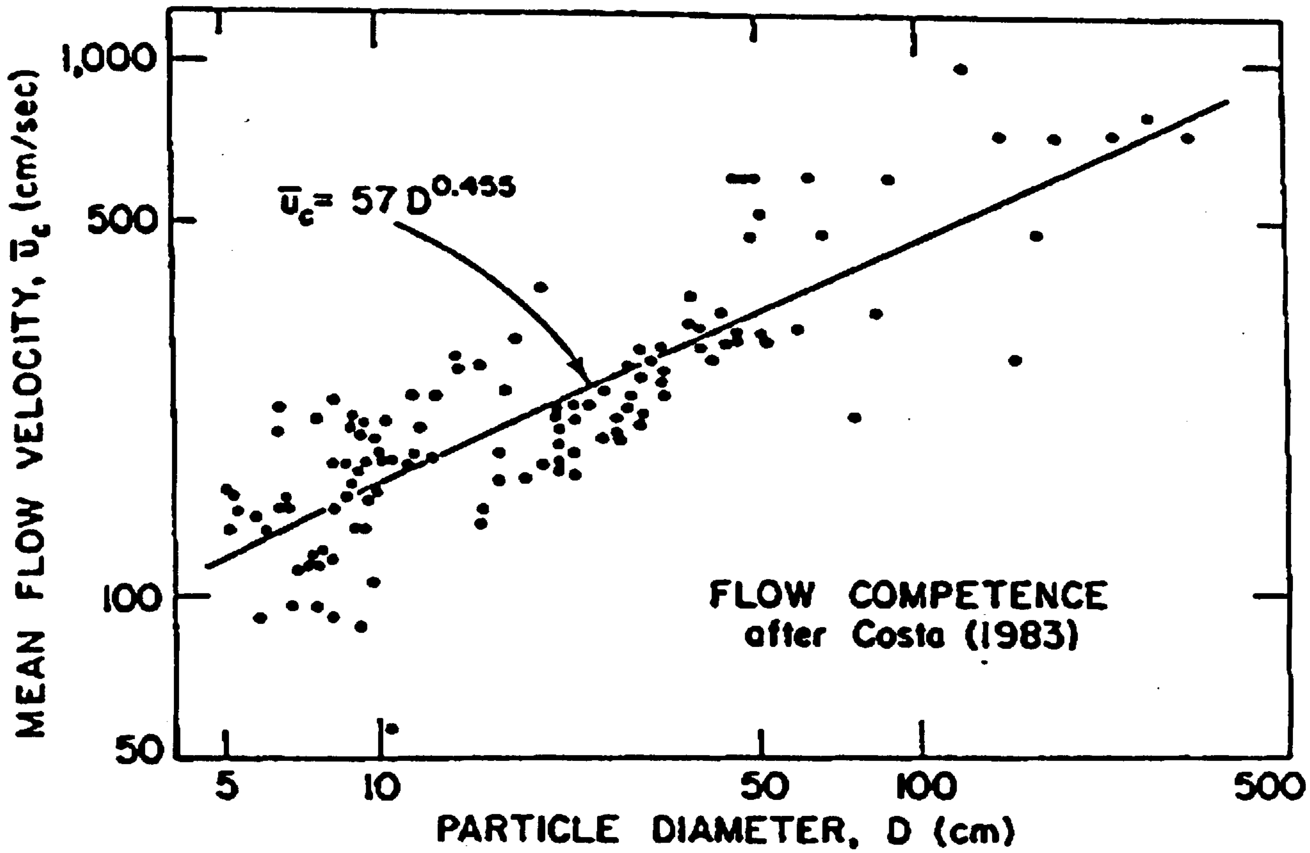

Figure 3. Flow competence curve based on data from flooded rivers.

3. IMPACTS OF CAPPING ON WETLANDS

What impacts will the cap placement have on the wetlands and potential flooding in the remedial action area?

The primary impact of the cap is to change the geomorphology of the area, making the upper estuary shallower. The cap (45 cm) will increase the areal extent of the maximum probable spring high water (MPSHW) to mean seal level (MSL) depth zone by 30 acres and the intertidal mud flats area [MSL to mean spring low water (MSLW)] by 25 acres. The subtidal area, currently 175 acres, will decrease by 73 acres to 102 acres. The protective erosion cap area will occupy 18 acres, 6 acres below MSLW and 12 acres between MSL-MSLW.

Capping is not proposed in the existing salt marsh and hence no changes in the wetland will occur in this area. The newly created area (30 acres) in the MPSHW to MSL depth zone will be planted with cord grass (spartina alterniflora).

The net result of the capping operation is to increase the area of salt marsh from 53 to 83 acres or a net increase of 30 acres. As shown in Figure 1, the newly created marsh is concentrated in the northeastern-most portion of the upper estuary and in a small cove on the west side of the river near the present location of the CDF and CAD pilot dredging projects (U.S. Army Corps, 1987).

Impact on Flooding

The proposed capping operation will not change the surface area of the upper estuary above mean sea level. The water storage capacity of the area remains the same as under present (uncapped) conditions. The cap placement hence has no impact on potential flooding in the area. This analysis is in agreement with the U.S. Army Corps of Engineers (1987) study on the hydrology of floods in New Bedford Harbor.

4. DAM OPERATION

How will the dam be operated and what impacts will that operation have on wetlands in the area?

It is proposed to place a temporary sheet pile dam across the Coggeshall Street Bridge channel. The dam will have a moveable gate that could be opened and closed as required. The gate cross-sectional area (60 square m) will allow the same exchange of water between the upper and lower estuary when the gate is open as exists without the dam. The primary purpose of the dam, with gate, is to allow water level and circulation control to aid in construction operations and cap placement in the upper estuary.

The operation of the dam and its impact on the wetlands are described below for both dry and wet capping.

<u>Dry Capping</u>

Following Garbisch's (1988) recommendation, capping in the dry should be done during the dormant season (November - March) to minimize the impact on the existing salt marsh if dam closure is necessary. He suggests a biweekly opening of the dam to restore tidal circulation and water level fluctuations. A gate open period of 2 to 3 days is sufficient to restore the salinity and tidal circulation in the upper estuary to normal conditions. This rapid response is due to the large tidal prism in the upper estuary compared to the mean low water volume.

In practice, it appears that most of the dry capping can be done without use of the dam at all. The only time the dam would need to be used is to control circulation in the final stages of closure of the coffer or sheet pile wall dams to be placed north and south of the erosive protection area. Several two week periods will likely be sufficient to complete this task.

When the capping operation is underway, the temporary (sheet pile or earthen coffer) dams will prevent water from entering the area to be capped and hence the gate in the Coggeshall Street Bridge channel can remain open and the tidal circulation in the upper estuary generally unimpeded. Little impact on the wetland is anticipated.

<u>Wet Capping</u>

Garbisch (1988) recommends that the wet capping phase be done in the growing season (May - September), again to minimize the impact on the existing salt marsh. He suggests a weekly to biweekly opening of the dam to restore tidal circulation and water level fluctuations to the upper estuary. Again, a 2 to 3-day gate open period is suggested.

From a construction point of view, given the low currents in most of the area and the use of sand as a capping material (rapid settling rates) capping in the wet can generally proceed without closing the gate. When capping the shallowest portions of the area and in high current areas (i.e., near the Coggeshall Street Bridge channel), the gate closure would be used to control water level and circulation, respectively, the former providing access to shallow water areas and the latter to minimize current effects on cap placement. In these two instances, the schedule should follow Garbisch's recommendations.

5. COST ESTIMATE AND CONSTRUCTION SCHEDULE

Provide more detail on the construction schedule and cost estimate; it seems optimistic.

The cost estimating method applied at this conceptual stage of the analysis for the remedial action alternative proposal is consistent with the estimating method commonly used for engineering estimating on construction projects. We began by laying out the concept, defining the engineering and construction elements, consulting with contractors, and using the team's engineers' experience to estimate unit costs for various components of the construction project. We compiled the data to develop costs estimates for individual elements of the proposed project and added engineering and contingency fees. The remedial action proposal that has been submitted to the EPA is obviously in the conceptual stage and the cost estimating method applied is consistent with that level of development of the alternative. The cost estimate presented does not include post-closure monitoring or a five-year review of the site at this conceptual stage. As the concept is further refined for inclusion in the Feasibility Study, these elements will be included.

At this time, we are performing additional work and engineering analyses in two specific areas, which will result in refinement of the cost estimate:

1. Identification of specific cap material source locations
2. Additional conceptual engineering of cap material movement and placement procedures.

Based on the results of these analyses, the cost estimates will be further refined. We assume that at the end of these analyses we will have identified specific potential cap material source locations and methods for movement of material to the cap site and for placement of the materials. At that time we believe we will have a better understanding of what the costs may be, in a preliminary sense, for a specific scenario of construction.

The engineering cost estimating procedure that we have undertaken is common to that used for engineering feasibility analyses for construction projects and is not unique to the Superfund process. We have gone from the development of a concept for a project and further refined the concept into basic engineering elements. We have discussed the project with the governing regulatory agencies, further refined the concept and initiated the development of a feasibility analysis for the concept prior to entering into a detailed design. During this process, cost estimates are constantly refined as an engineer better defines the project elements that will have an impact on the ultimate cost and construction. The costs are preliminary at this stage as the engineering is conceptual and much refinement is needed before a more firm cost estimate can be developed.

In all engineering feasibility analyses good cost estimates are not available until a preliminary or the final design is completed. This is particularly true in hazardous waste remedial action design, as the technologies being analyzed and designed are often not commonly applied in the field and routinely have special conditions not commonly encountered.

The major cost items and our cost estimates at this time are as follows:

Activity	Cost ($ million)
Mobilization/demobilization	$0.75
Capital equipment	0.75
Dam construction and removal	2.50
Cap material	8.00
Cap placement (sand)	8.00
Placement of geotextile and gravel	3.50
Management and quality control	3.50
Revegetation	1.50
	$28.5 million

A construction schedule was estimated based on discussions with contractors potentially qualified to install the cap. As with the cost estimating procedure, as we better define potential techniques for placement of the cap and specific sources of cap material, we will be much better prepared to develop a more detailed construction schedule. In addition, as a part of this submission, we are addressing the operation of the proposed dam and how the water level will be controlled within the upper harbor during construction, as it relates to raising the water level in the wetlands and the environmental impact of the water level control. These considerations will be taken into consideration during the development and refinement of the construction schedule. At this time, however, we believe that the project can be constructed within two years.

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APPENDIX A

APPENDIX A

RESTRICTIONS ON THE PROPOSED CAPPING OPERATIONS IN NEW BEDFORD HARBOR TO MAINTAIN THE VIABILITY OF EXISTING SALT MARSH

Salt marsh plant species tolerate, but do not require salt for optimum development and propagation. In fact, freshwater culture of salt marsh species is the most practical approach for nursery propagation (Garbisch, unpublished results). The tolerance of salt marsh plants to soil salinities is limited and salinities in excess of 50 ppt are toxic to most species. Consequently, in order to maintain the viability of existing salt marsh during the capping operations, soil salt concentrations must be maintained well below the toxic 50 ppt level, particularly during the growing season.

Wetland plant species survive anoxic root environments through various adaptive and avoidance mechanisms, the most significant of which appears to be an avoidance mechanism in which the plant develops an oxygen transport path from aboveground to belowground parts. This produces an oxidized rhizosphere which allows aerobic root respiration as well as oxidation of sulfide toxins and supplies oxygen to mycorrhizal symbionts (Mendelssohn and Burdick 1988).

Spartina alterniflora (cordgrass) is a salt marsh plant species that utilizes this avoidance mechanism to survive anoxic root environments during the growing season (Mendelssohn and Burdick 1988). However, during the dormant season when this oxygen transport mechanism is no longer functioning, this species will not survive continually waterlogged and flooded soils (Garbisch, unpublished results). Apparently, root/rhizome respiration during the dormant period is significant and the species has no adaptive mechanism to survive anoxic soils. Consequently, in order to maintain the viability of existing salt marsh during the capping operations, continually waterlogged or flooded soils must be avoided, particularly during the dormant season.

Two approaches to capping have been considered: dry capping and wet capping. During the dry capping operations, tidal water is excluded from the capping area by constructing a temporary dam. Freshwater inflows to the area are pumped out. In wet capping, the weir level in the dam under the Coggeshall St. Bridge is set at a level to retain a sufficient height of water over the areas to be capped in order to complete the capping operations. It would appear that the dry and wet capping operations would be best conducted during the dormant (November-March) and growing (May-September) seasons, respectively, in order to maintain the viability of the existing salt marsh.

Dry Capping

Dry capping should not be conducted during the growing season. The problem is not so much desiccation as it is salt toxicity. With soil salt concentrations of about 25 ppt, soil water has to evaporate/evapotranspirate by only one-half before the soil salt concentrations become toxic to cordgrass and the high marsh plant species. Irrigation by saltwater does not appear to be a solution. To be effective and not aggravate the salt buildup problem, such irrigation would have to be continuous so as to maintain saturated soils with soil salt concentrations between 25 and 40 ppt. Such continuous irrigation of the salt marsh would likely interfere with the dry capping operations.

Dry capping should be accomplished during the late fall and winter (November-March) for the following reasons. Dormant salt marsh plants are not as sensitive to high soil salt concentrations as are the growing plants. There is no evapotranspiration during the dormant season and evaporation rates are greatly reduced because of low temperatures. Also, precipitation normally is greater during the dormant than during the growing season. The low and high marsh plant species are hardy and not subject to freeze kill.

The dry capping operations during the late fall and winter probably should be shut down on a biweekly schedule in order to reintroduce unrestricted tidal water to the estuary for several days before resumption of the capping operations.

Wet Capping

It is unknown for how long cordgrass and the high marsh plant species can tolerate waterlogged and flooded soils during the dormant season before suffocating. During the overwintering of nursery plants of these species, continuous flooding over the tops of the pots by 2-3" of water for two weeks has led to a total loss of the plants. When this degree of flooding is maintained during the entire growing season, excellent plant development results (Garbisch, unpublished results).

Wet capping probably could be accomplished successfully at any time of year if the plant tolerances to flooding during the dormant season were better understood. The advantages to wet capping during the dormant season is that the depth of water over the vegetated areas should not be a critical element. However, as details regarding plant tolerances to prolonged flooding during the dormant season are unknown, wet capping should be conducted during the growing season.

In wet capping during the growing season (May-September), it is important that all salt marsh species emerge sufficiently from the water to effectively transport oxygen below ground. In the nursery production of cordgrass, having at least one-half the height of the plant emerge from the water is sufficient (Garbisch, unpublished results).

If the lowest elevation cordgrass is about 4 feet tall and found at approximately Mean Sea Level, the highest the weir on the dam should be set would be at Mean High Water. This would lead to a flooding of the lowest elevation cordgrass by 1.85 feet of water during times when the tide is at MHW or below. Setting the weir above MHW would jeopardize the short high marsh herbaceous species (Spartina patens and Distichlis spicata) as well as the lower elevation cordgrass.

Wet capping operations probably should be shut down on a weekly or at least biweekly schedule. Unrestricted tidal water should be reintroduced to the capping area for several days before resumption of the capping operations.