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COST ANALYSIS

APPLICATION OF SEDQUAL TO SELECTED PROBLEM AREAS OF THE COMMENCEMENT BAY SUPERFUND SITE

For

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APPLICATION OF SEDQUAL TO SELECTED PROBLEM AREAS OF COMMENCEMENT BAY SUPERFUND SITE (COST ANALYSIS)

INTRODUCTION

A review of comments on the cost estimates made in the Commencement Bay/Nearshore Tideflats feasibility study (FS) resulted in a re-examination of the unit costs, assumptions, and calculation methods used for assessing the costs of sediment remedial actions. In support of the Record of Decision for this site [U.S. Environmental Protection Agency (EPA) in preparation], revised cost estimates are being developed for each problem area and each of four remedial alternatives [nearshore disposal, upland disposal, in-place capping, and onsite confined aquatic disposal (CAD) by overdredging]. This report to the Washington Department of Ecology (Ecology) describes the information and methods used to develop revised cost estimates at the Commencement Bay site.

PTI was requested by the Sediment Management Unit of Ecology to use the Commencement Bay site in an example application of the remedial action cost module of SEDQUAL, a menu-driven sediment quality database (Nielsen 1988) developed under various EPA and Ecology contracts. A detailed analysis of costs at a range of sites in Commencement Bay was not possible within project time constraints and using available information. The principal emphasis of the efforts described here is the development of generally applicable techniques for preparing cost estimates for marine remedial actions. This generalized approach precludes the use of detailed engineering or geotechnical information about the particular sites in question. (Such information would include estimates of side slope stability; optimum dredge-deployment based on the distribution of contamination, bathymetry, and geometry of the site; and other effects on dredging performance.) Investigation of these conditions and their effect on cost must be made during remedial design, but the information may not be available when that feasibility studies are conducted. Whenever possible, these effects should be factored into the generic approach presented here, to attain an estimate that falls within the +30 percent to -50 percent range of accuracy recommended by U.S. EPA (1985) for FS evaluations.

Cost estimates for this report have been made using two approaches. The first is to construct a general-purpose spreadsheet for each type of remedial alternative. Addition of site-specific information, such as volume and area of contamination, area to be mitigated, distance to disposal site, distance to source of capping material, and sample analysis cost allows customized cost estimates to be produced. Other information, such as unit costs for dredging, can also be varied on a site-by-site basis, or generic values can be used. The spreadsheet approach allows the cost analysis for each type of remedial alternative to be customized by the addition of as much detail as is practical and appropriate for that alternative. Although the spreadsheets that resulted are sufficiently general to be used for all Commencement Bay problem areas by changing only the data, their application to other areas may require some modifications. In several respects, the spreadsheets followed a method of calculation similar to that used in the Commencement Bay FS report (Tetra Tech 1988).

The second approach was to use the cost analysis functions built into the SEDQUAL software. This tool provides a more general approach to cost analysis than can be achieved with customized spreadsheets. In addition, the approach to calculation differs substantially in some respects from that used in the spreadsheets. For example, the spreadsheets calculated administrative costs as a fixed percentage of all other costs (as was done in the FS report), whereas the SEDQUAL tool expects administrative costs to be expressed as a fixed cost plus a cost per cubic yard of dredged material. Evaluation of costs using SEDQUAL was intended principally to identify ways of applying the features it provides to produce results comparable to those from the spreadsheets.

MAJOR COST CATEGORIES

Some types of costs are only associated with particular remedial alternatives. Most of these costs are based on the volume to be dredged, but some are assessed differently. Each of the major cost categories is discussed below, focusing on factors that affect the cost estimate, and suitability of the application of generic costs. All of the cost categories applicable to each remedial alternative are also tabulated.

Dredging Operations

The cost of dredging is potentially one of the most significant determinants of total cost, as total cost will vary directly (and in some cases almost linearly) with the volume of contaminated sediment. The simplicity and generality of the calculation (volume times cost per volume), however, are confounded by the difficulty of establishing reliable generic costs.

The actual cost per cubic yard of dredging is affected by many site-specific factors: depth and slope of bottom, type of sediment, type of equipment to be used, number of dredge cuts to be made, distribution of the contaminated sediment, and necessity for a silt curtain or other non-standard gear or techniques. These factors can cause the unit cost of dredging to vary by a factor of 2-3, with a concomitantly great effect on the total cost of the remedial effort. Establishment of a reliable generic unit cost for dredging is therefore difficult. Whenever possible, all available site-specific information should be compiled and a dredge operator or qualified cost analyst should be engaged to make an estimate.

Nearshore Disposal Site

Nearshore disposal involves the removal of contaminated sediments and their isolation in an intertidal or land site accessible by barge. After completion of the dredging and filling, the nearshore site will no longer be under the influence of marine waters; that is, it will be neither intertidal nor subtidal. Two effects of this approach on costs are: 1) marine transportation but no overland transportation costs should be included, and 2) costs for site preparation and closure should be included. Site preparation and closure costs are related in part to the volume of contaminated sediment, and in part to other characteristics of the disposal site such as the depth of fill possible, the amount of diking necessary to enclose the site, the characteristics of the sediment to be used for fill and its structural capability in relation to the intended use of the site after closure, the type and depth of cap required, and the number and depth of monitoring wells. Site acquisition may also have to be included in site preparation costs. Inclusion of all these factors requires specific detail about the disposal site, and is not amenable to the development of generic cost estimates.

In practice, no site preparation or closure costs were included in the estimates for Commencement Bay problem areas. The approach recommended by EPA was to presume that nearshore disposal sites would be available only in conjunction with commercial development, and that the developer would be responsible for site preparation and closure costs (Stoner, M., 1989, personal communication).

Upland Disposal Site

Upland disposal involves the isolation of contaminated sediments in a terrestrial disposal site. Overland transportation costs must therefore be included, but these should not be affected by site-specific considerations. Generic overland transportation costs, expressed as dollars per cubic yard-mile (/cy-mi), are feasible for this cost category.

Depending upon the location of the dredging site, contaminated sediments may or may not be deposited directly into trucks for shipment to the disposal site. A conservative assumption is that barge transportation of dredged sediments will always be necessary; in this case, costs for transfer of sediments from barges to trucks must also be included.

The upland disposal site may be either a previously-established Resource Conservation and Recovery Act (RCRA) site, or a site constructed specifically for one (or several) dredging projects under consideration. In the former case, costs of disposal may be limited to fees payable on a cubic yard basis. Although such fees may vary, this case does allow a simple generic approach to estimating disposal costs: multiplication of dredging volume by the fee per unit volume.

Construction of a special upland disposal site incurs various costs that are difficult to estimate in a generic way. These costs include site acquisition, site preparation (e.g., construction of roads and buildings, construction of dikes and weirs, placement of liners, installation of leachate collection and treatment systems), site closure (e.g., capping, grading, revegetation, and erosion control), and site monitoring. These costs depend upon the location, areal size, volume, topography, geology, and period of use of the disposal site. To use a generic approach to estimating costs for an upland site, the area of the site must be given. Generic values for land value, lining material, capping material, and number of monitoring wells, all expressed on an areal basis, can then be used to estimate costs. Because costs of lining and capping materials are commonly expressed per cubic yard, it is most practical to require that the depth of lining and cap be supplied. Because the cost of monitoring well construction is a function of well depth, the depth of fill in the upland site must be specified. The number of samples collected during monitoring may also vary with the depth of fill. This limited generic approach neglects the costs of several aspects of site preparation, such as dike and weir construction, that may be necessary.

Capping of Dredging Site

After removal of contaminated sediments, part or all of the dredged area may be capped with clean sediment, either to provide habitat remediation or to isolate residual contamination in underlying sediment. The area of the cap may be unrelated to the volume of contaminated material. For example, cost analyses for Commencement Bay problem areas were based on the presumption that only intertidal areas were to be capped. Capping depths of 3-6 feet are recommended; the actual depth selected will depend on site-specific features, such as the grain-size of the available capping material and current strengths in the area to be capped.

Dredging and transportation costs of clean sediment must also be included in the cost estimate. Generic costs may be even more applicable to dredging of clean sediment than to dredging of contaminated sediment, as the source of clean sediment may conceivably be selected not only on the basis of sediment availability but also on the cost of dredging.

In some cases habitat mitigation may require more than just capping of the problem area. Replanting of eelgrass beds is an example of the extra measures that may be required. The need for, nature of, and costs of such habitat mitigation efforts must be evaluated for each site.

Confined Aquatic Disposal by Overdredging

CAD by overdredging is accomplished by removing contaminated surface sediments, and then removing enough clean sediment from below the contaminated material to create a cavity in which the contaminated material can be buried. The size of the cavity must be equal to the swollen volume of the contaminated sediment plus the depth of the cap to be used over the entire contaminated area. Clean overdredged sediment can be used for capping material.

Because of sediment swelling, there will typically be more overdredged material than needed to form the cap; the excess must be disposed of. The overdredging approach does not itself provide a mechanism for disposing of this excess material. The approach taken with the cost analysis for Commencement Bay (which may serve as a model generic approach) was to presume that the overdredged sediment would meet PSDDA guidelines (because it is presumed to be clean enough for capping), and would therefore be disposed of at the Commencement Bay PSDDA site. Thus, the costs associated with the excess sediment are for marine transportation and disposal, which can both be related to volume.

During the construction of the burial cavity, the contaminated material must be temporarily stored (presumably in barges). The amount of material to be stored will be affected by barge availability, practicality of holding a fleet of barges (e.g., in a busy waterway), and the size of the problem area (i.e., whether it can be completely overdredged at once or whether a cell-by-cell approach must be taken). Holding costs should be directly related to the number of barges involved, which should be related to the volume dredged by a stairstep rather than linear function.

If a cell-by-cell approach must be taken, the configuration of the cells, the potential for slumping, and the need for excess dredging, must be evaluated with respect to their effect on costs. For example, imagine a problem area with contamination extending to 6 feet (e.g., mouth of Hylebos Waterway). Two 4-foot dredging lifts would be required to remove this sediment. Because of sediment swelling and the need for a cap of 3-6 feet, an additional three or four lifts would have to be removed to create a cavity deep enough for disposal. The cavity would then be 20-24 feet deep. Slumping of the sides would result in reduction of the volume, necessitating additional dredging, and may inject contaminated sediment from adjacent cells, complicating the task of separating clean and contaminated sediments. These problems are most severe for long, narrow cells such as would be created by a dredge travelling repeatedly over the same navigation line.

Sample Collection and Analysis

Three kinds of sample collection and analysis must be considered in the cost analysis; these differ depending on the purpose of the sampling:

1. Sampling for remedial design
2. Post-dredging sampling to confirm performance
3. Monitoring of the disposal site.

Sampling plans may vary with the purpose, with the type of remedial alternative, and with the site. For example, the sampling plan may call for core samples with two or more horizons analyzed from each, for cores from which horizons are composited to form a single sample for analysis, or for surface grabs yielding a single sample for analysis. Costs for equipment, sampling effort, and sample analysis differ in each case. The number of samples may be specified on a volume or areal basis, possibly with upper or lower limits established on the total number of samples. Monitoring of nearshore and upland sites will likely involve the construction and maintenance of groundwater wells. Frequency of monitoring may be specified to be twice a year, once a year, every other year, or some other schedule, possibly of gradually decreasing frequency.

Analysis costs depend not only on the total number of samples and the type of samples, but also on the types of compounds to be analyzed for. The chemicals of concern can vary greatly from site to site, depending on the sources of contamination.

Widely applicable generic costs for sampling and analysis therefore would reflect considerable uncertainties.

Cost Categories by Remedial Alternative

In addition to the major cost categories described above, several other categories are included in the complete cost analysis. All of these categories are listed in Table 1, which identifies the categories applicable to each type of remedial action. Note that disposal site acquisition, preparation, and closure are identified as cost categories for nearshore disposal, although no costs were assigned to these categories for application to Commencement Bay problem areas. Similarly, disposal fees are shown as a potential cost for three of the four types of alternatives, although the cost analyses for Commencement Bay only factored in disposal fees for the overdredged sediment deposited at the PSDDA site.

Other Components of the Cost Analysis

Several miscellaneous factors must be specified to perform a cost analysis. Some of these may have a significant impact. One of the potentially most important of these is the swelling factor for dredged sediment. This factor affects costs by increasing the volume that must be transported and possibly increasing the volume of the disposal site required (depending upon the amount of re-compaction that may be expected). The swelling factor may vary over a wide range: Corlett and Kassebaum (1989) suggest that it may lead to a doubling of sediment volume (although no data are provided), whereas Payonk et al. (1989) found bulk densities in the barge equivalent to those *in situ* after clamshell dredging with an open bucket (for sediments ranging from 60 to 86 percent

TABLE 1. COST CATEGORIES APPLICABLE TO EACH TYPE OF REMEDIAL ACTION

Cost Category	Nearshore	Upland	Capping	Overdredging CAD
Siting and Construction				
Core sampling for remedial design	x	x	x	x
Chemical analysis for remedial design	x	x	x	x
Design/permitting	x	x	x	x
Equipment modifications	x	x		x
Site acquisition	x	x		
Site preparation (dikes, weirs)	x	x		
Site liner	x	x		
Operation				
Equipment mobilization	x	x	x	x
Contaminated sediment dredging	x	x		x
Marine transportation of contaminated sediment	x	x		
Overland transportation of contaminated sediment		x		
Barge unloading to disposal site	x			x
Barge unloading to trucks		x		
CAD site dredging				x
Disposal costs and fees	x	x		x
Capping of upland/disposal site	x	x		
Clean sediment dredging for contaminated site cap	x	x	x	
Clean sediment transportation for contaminated site cap	x	x	x	
Post Closure				
Confirmation sampling	x	x		
Confirmation analysis	x	x		
Well construction	x	x		
Monitoring sampling of disposal site	x	x	x	x
Monitoring sample analysis	x	x	x	x
Administration	x	x	x	x
Contingency	x	x	x	x

silt and clay). Compaction of material may occur after deposition; Thomas and Urso (1989) found that the volume of sediment after deposition in a nearshore impoundment ranged from 80 percent to 140 percent of the volume dredged. Swelling is expected to be greater for sediments of higher silt and clay content, although there does not seem to be sufficient data to establish a consistent relationship. Thus, costs for transportation and disposal site acquisition, preparation, and closing may vary by as much as a factor of 2 depending upon the amount of swelling and compaction to be expected. If insufficient information is available to estimate a site-specific swelling factor, a high factor can be applied to obtain an upper estimate of the actual costs.

For remedial actions that will extend over several years (including monitoring), the present value must be calculated by applying a discount rate to expenditures incurred in future years. Escalation of future prices to account for inflation is not recommended (U.S. EPA 1985). The discount rate used has an effect on total costs, particularly when a large fraction of costs are incurred in future years, as may be the case with intensive monitoring. Although the EPA cites the Office of Management and Budget recommendation of a 10 percent discount rate (U.S. EPA 1985) based on the expected rate of return on private investment, changes in economic conditions may warrant use of a different value.

The dredging equipment used will affect not only the dredging cost per cubic yard, but also the dredging rate. Dredging rate controls the total time taken to complete the project. Even with a single type of dredging equipment (e.g., hydraulic cutterhead or clamshell bucket), rates may vary depending upon the size of equipment (pipeline diameter or bucket volume) and sediment composition (U.S. COE 1985). If variations in rate can lead to completion times that vary by a year or more, then the discount rate adds variation to the total cost of dredging. Extended dredging operations may require different engineering approaches (e.g., division of the problem area into separate cells) that affect costs. When dredging must take place over periods that include bans on dredging activity (e.g., for protection of fishery resources), then the layoff costs (e.g, equipment demobilization and remobilization) must also be included. In some cases it may be feasible to deploy multiple dredges to reduce the total time required, in others (e.g., in constricted waterways) operation of only a single dredge is practical.

UNIT COSTS, OTHER FACTORS, AND SOURCES OF ESTIMATES

Revised cost estimates for the Commencement Bay/Nearshore Tideflats problem areas were prepared using principally the FS (Tetra Tech 1988) as a source for unit costs and other factors (e.g., dredged deployment costs, production rates, sample analysis costs). Information presented by reviewers of the FS report suggested that some unit costs or other factors were questionable or erroneous. In these cases, these estimates were examined and revised in accordance with information presented by the reviewers or available from other sources. Each of the cost categories shown in Table 1 is discussed below, including the value used, the rationale for its selection, and any special features of its application.

Core Sampling for Remedial Design

A collection cost of $1,500 per core is used; this is the figure cited in the FS report (Tetra Tech 1988). The number of cores is presumed to be one per 4,000 cubic yards (cy) of sediment; this rate corresponds to the value used in the FS report and to PSDDA guidance for areas with the highest contamination ranking (PSDDA 1988).

Chemical Analysis for Remedial Design

Sample analysis costs differ with the problem area, according to the costs estimated in the FS report. These costs ranged from $800 to $1,500 per sample. Analysis of three samples from each core is presumed, in accordance with the FS report.

Design/Permitting

The cost assigned to this category is $325,000 (Gershman, Brickner & Bratton 1989). The FS report does not include this cost category. *Confined Disposal of Contaminated Sediments, Documentation of Standards Development* (Parametrix 1989) recommends costs from $810,000 (for CAD) to $1,860,000 (for an upland mixed disposal site).

Equipment Modifications

Equipment modifications for Commencement Bay sites consist of alterations to the clamshell bucket to make it watertight. The cost of $20,000 per clamshell, cited in the FS report, is used. Only one dredge at each problem area is presumed to be practical, hence the cost of one such modification is included for each problem area.

Site Acquisition

Upland disposal is presumed to take place at one of the sites identified in U.S. COE (1985). Land costs in a commercial location are estimated to be $25,000 per acre. The total acreage required is computed as a function of the fill depth at the disposal site and the volume of material to be disposed of (after swelling and compaction).

Site Preparation

Site preparation costs were assessed only for the upland disposal alternative. These were estimated by using values from Table 5-4 of U.S. COE (1985), and applying an annual inflation rate of 5 percent to adjust the 1984 costs to 1989 dollars. The resulting value is $1.30/cy of site capacity. Cost estimates were based on the assumption that all material from the problem area could be disposed of in the upland site, thus this cost is computed as $1.30/cy of contaminated sediment after swelling and compaction.

Site Liner

Liner costs also were assessed only for the upland disposal option. The liner is presumed to be 3 feet of clay over the entire area of the disposal site. The unit cost is based on Table 5-6 of U.S. COE (1985), and inflated from 1982 to 1989 dollars at a rate of 5 percent per year, yielding a value of $22.92/cy of liner. Total cost is computed as the product of site area, liner depth, and the unit cost.

Use of other liner material, inclusion of a membrane, construction of a drainage system, and other modifications of this simple scenario may substantially affect the costs.

Equipment Mobilization

The FS report lumps equipment mobilization with bonding and insurance, and calculates this as a fixed percentage of other costs. The approach used here is to assign a fixed cost to mobilization. The generic unit cost for a clamshell dredge used here is $150,000 per dredge (Parametrix 1989).

For remedial alternatives that include capping of the dredging site, total mobilization costs were based on the assumption that one dredge would be operating in the problem area and another at the source of clean sediment (e.g., the Puyallup River). The mobilization cost of the Puyallup River dredge was apportioned among the problem areas according to the fraction of total area to be capped in each.

Contaminated Sediment Dredging

The unit cost of dredging may vary considerably, as described above, and as shown in the references. For this cost analysis a value of $3.00/cy is used. This is based on a brief review of recent bids for dredging in Puget Sound (Sumeri, A., 1989, personal communication), which averaged approximately $2.50/cy; and the costs estimated by Corlett and Kassebaum (1989), which ranged from $2.50/cy to $12.00/cy.

Marine Transportation of Contaminated Sediment

Transportation of sediment by barge is estimated to cost about $0.30/cy-mi, based on the figure of $0.25/cy-mi cited in U.S. COE (1985), and adjusted for inflation. This is comparable to the cost of $0.25/cy-mi cited in PSDDA (1988). Transportation costs were based on the volume of sediment after swelling.

Overland Transportation of Contaminated Sediment

Overland transportation of contaminated sediment is estimated to cost $0.50/cy-mi, based on the marine transportation cost and the suggestion that trucking costs will exceed barging costs by about $0.20/cy-mi (U.S. COE 1985). Transportation costs were based on the volume of sediment after swelling.

Barge Unloading to Disposal Site

A unit cost of $1.25/cy that was used in the FS report is used for this cost analysis. Unloading costs were based on the volume of the sediment after swelling.

Barge Unloading to Trucks

A unit cost of $2.50/cy is used, based on an estimated cost of $500,000 for 200,000 cy of sediment (Parametrix 1989). Note that PSDDA (1988) has used a cost of $1.50/cy.

CAD Site Dredging

The cost of CAD site dredging is presumed to be equivalent to that for dredging of contaminated sediment (i.e., $3.00/cy). Because of the overdredging approach, however, the sediment removed to create the CAD site will be deeper than the contaminated material. This additional depth may increase the unit cost. For example, Corlett and Kassebaum (1989) estimate that at the head of City Waterway problem area, removal of the first five feet of sediment will cost $2.50/cy, but removal of the underlying three feet will cost $8.00/cy.

The volume of material to be dredged for the CAD site is computed as the swollen and compacted contaminated volume plus the capping depth times the contaminated area. No estimation was attempted of the excess volume that would have to be dredged due to slumping of the excavation.

Disposal Costs and Fees

The fee of $0.40/cy proposed by the Washington Department of Natural Resources (Corlett and Kassebaum 1989) for disposal at PSDDA Phase I disposal sites is used here. It is applied only to the excess volume of clean sediment removed from the CAD site. This sediment is presumed to meet PSDDA guidelines for open-water disposal.

Capping of Upland/Nearshore Disposal Site

The unit cost used is based on a cap of 3 feet of sand and 3 feet of topsoil. In-place costs for these materials are taken from Table 5-6 of U.S. COE (1985), and inflated from 1982 to 1989 costs at a rate of 5 percent per year. The resulting average unit cost is $23.84/cy of capping material. The total volume of capping material is computed by multiplying the upland site area times the depth of cap (2 yards). A similar approach could be taken to estimating capping costs for a nearshore disposal site.

This generic cap may not be suitable for all sites; some may require a greater depth of material, different material (synthetic fabric, asphalt, concrete, or clay), revegetation, or other special measures taken for drainage or erosion control.

Clean Sediment Dredging for Contaminated Site Cap

Dredging of clean sediment is presumed to have a cost equivalent to that of contaminated sediment dredging ($3.00/cy).

Clean Sediment Transportation for Contaminated Site Cap

Transportation of clean sediment is presumed to have a cost equivalent to that of marine transportation of contaminated sediment ($0.30/cy-mi.).

Confirmation Sampling

Confirmation sampling following removal of dredged material is presumed to be carried out by the collection of a grab sample of the sediment surface rather than a core, following the suggestion of the Commencement Bay Group (ENSR Consulting and Engineering 1989). The cost of sample collection is estimated to be $500 per grab, producing one sample per grab. The number of samples is estimated as in the FS report: two samples per acre, with a maximum of 20 samples at a site.

Confirmation Analysis

Samples taken to confirm the success of remedial dredging are presumed to be analyzed for the same contaminants as the samples used to characterize the problem areas. Thus, the analysis cost varies with the problem area as specified in the FS report.

Well Construction

The costs of establishing groundwater monitoring wells at upland and nearshore sites are based on drilling costs of $22.00 per foot, $600 for a screen (Deremer, R., 1989, personal communication), and an estimated $800 for a pump and equipment deployment. These unit costs were applied to an estimated 20 wells (the maximum number of sediment monitoring stations suggested by the FS report) of an average depth of 35 feet (the depth of fill possible at Blair Waterway Slip 1).

Monitoring Sampling of Disposal Site

Sampling of CAD and capping sites is presumed to take place by coring, as specified in the FS report, with a cost of $1,500 per core. Frequency of sampling is two cores per acre, with a maximum of 20 cores. Sampling is presumed to be conducted yearly, and three samples analyzed from each core.

Sampling of groundwater monitoring wells is estimated to cost $120 per well, based on two hours of labor at $30 per hour (including sampling by a safety-certified specialist, document control, quality assurance, data management, and reporting), $30 of other direct costs per well, and a multiplier of 1.5. Frequency of sampling is presumed to be equivalent to that for coring at CAD and capping sites.

Monitoring Sample Analysis

Analysis costs for monitoring samples are presumed to be site-specific, as was assumed for the analysis costs for remedial design sampling and confirmation sampling. The site-specific costs used are those listed in the FS report.

Administration

Administration costs calculated in the FS report were as a percentage of all other costs. A similar approach was taken for the spreadsheet cost analysis. The FS estimate included engineering costs, however, which were included in the design and permitting classification in the revised cost analysis. The factor for administration cost was therefore revised downward from the FS value of 15 percent to 8 percent. The *EPA Remedial Action Costing Procedures Manual* (U.S. EPA 1985) suggests a range of 7-15 percent of capital costs for administration, including design and monitoring. The typical cost suggested by the *Multiuser Confined Disposal Sites Program Study* (Gershman, Brickner, and Bratton 1989) is 6 percent.

Contingency

A contingency cost of 20 percent of all other costs was applied. This is the same proportion used for the FS report.

Other Factors

Two factors were used to estimate the effect of sediment swelling and compaction. The swelling factor determines the increase in sediment volume after dredging and deposition in a barge; and the compaction factor determines the decrease in volume after confinement and compaction of the sediment. The swelling factor used for the revised cost estimate is 0.75, meaning that sediment would increase in volume by 75 percent upon dredging (Church 1981). As noted previously, this factor may be highly variable, so a value at the upper range of reported swelling factors was chosen. The compaction factor was chosen so that the net volume change from the original sediment in place would be an increase of 20 percent; the value of this factor is therefore selected to be 0.69 (i.e., 1.20/1.75).

The discount rate used for this revised cost calculation is 7 percent, which is a slightly lower estimated rate than the current rate of return on 2-year Certificates of Deposit.

The production rate for dredging was presumed to be 200 cy/hour, as shown in Table 5-2 of U.S. COE (1985) for a 5-cy clamshell dredge.

A dredging lift depth of four feet, typical of clamshell dredges (PSDDA 1988) is used for this calculation. The actual volume dredged is calculated based on the number of dredging lifts that would completely remove the contaminated sediment. Thus, contamination to a depth of 2 feet would require one dredging lift (with overdredging of 100 percent), whereas contamination to a depth of 5 feet would require two dredging lifts (with overdredging of 60 percent).

COST ESTIMATES USING SPREADSHEETS

The cost categories and unit costs described above were assembled into four computerized (Lotus 1-2-3™) spreadsheets, one for each type of remedial alternative. Each spreadsheet is capable of estimating costs for multiple problem areas; this analysis requires only the entry of appropriate site-specific information such as contaminated area and depth. Further customization of the spreadsheets for particular sites can be carried out by modifying appropriate unit costs and other factors. An example spreadsheet is shown in Table 2, which illustrates the computation of upland disposal costs for the head of City Waterway problem area.

The spreadsheet shown in Table 2 is divided into five distinct (but related) tables. On the right-hand side of the first page is a table containing site-specific information for each problem area. On the left-hand side of the first page is a table titled "Input variables" that specifies other factors that can be modified to customize the calculation. Below this is a table titled "Calculated variables" which contains a variety of values calculated on the basis of the information in the first two tables. Most of these values are used in later calculations, some are presented simply to illustrate conditions in the problem area.

On the second page of Table 2 is a table titled "QUANTITIES". All of the cost categories applicable to the remedial alternative are identified in this table, and the unit cost for each is included. The units in which costs are expressed are also displayed to make interpretation easier. These unit costs may be modified to customize the cost estimate. The main body of the table contains estimates of the quantity of each cost item that will be expended in each year. Each of these cells in the spreadsheet contains a formula expressing the relationships described previously. For example, contaminated sediment dredging in the first year is computed as the minimum of the volume to be dredged and the maximum total volume dredged per year (see "Calculated variables"). For following years, the cubic yards dredged are computed as the minimum of the remaining volume and the maximum yearly volume. Costs for offloading, transport, and capping are apportioned between years in proportion to the fraction of total contaminated volume dredged in each year.

At the bottom of the second page of Table 2, and extending onto the third page, is the "COSTS" table. Each row in this table corresponds exactly to one row in the "QUANTITIES" table. Each cell in the table is simply the product of the unit cost and the quantity for the corresponding item and year.

At the bottom of Table 2, contingency and administration factors are applied on a year-by-year basis, and then the present value of each year's expenditures is calculated. The last line in Table 2 sums the present value across all years to produce a total cost for the remedial alternative.

Spreadsheets for other alternatives function identically to the one shown in Table 2. The only differences were the actual items entered in the "QUANTITIES" and "COSTS" tables.

COST ESTIMATES USING SEDQUAL

The cost analysis tool included in SEDQUAL follows a simpler approach than can be achieved with spreadsheets, and therefore is not as adaptable to special circumstances. SEDQUAL's approach to cost calculation involves the use of separate cost categories, each of which has associated a fixed

TABLE 2. SPREADSHEET FOR ESTIMATING COSTS OF UPLAND DISPOSAL

REMEDIAL ACTION COSTS
For Upland Disposal

Site code: 6
Site: Head of City

Assumptions:

----

1) An upland site of capacity equal to the dredging volume is used.

******************** Input variables ************************

Depth of dredging lift:	4 ft
Swell factor for dredged sediment:	0.75 (fractional increase in size)
Compaction factor for deposited sed.	0.69 (change after deposition and compact
Dredging rate:	200 cy/hr
Discount rate:	7.00 percent
Number of dredges in operation:	1
Distance to upland site:	3 mi
Depth of fill at upland site:	12 ft
Depth of habitat mitigation cap:	5 ft

****

Site Code	Site	Vol.	Area	Dist. to disp site (mi.)	Inter-tidal area	Dist. to Puyallup R. (mi.)	Sample Anal. Cost ($)
1	Head of Hylebos	217000	217000	4	7000	6	1500
2	Mouth of Hylebos	230000	115000	2	0	4	1000
3	Sitcum	66000	66000	1	0	3	1200
4	St. Paul	174000	87000	2	2000	3	800
5	Middle	57000	114000	2	1000	3	900
6	Head of City	426000	171000	3	13000	4	1500
7	Wheeler-Osgood	11000	22000	3	9000	4	1200
8	Mouth of City	0	0	2	0	3	800
	Comm. Bay total	1181000	792000				

******************* Calculated variables ********************

Volume of contaminated sediment:	426000 cubic yards (cy)
Distance to disposal site:	3 mi
Area of contamination:	171000 square yards
Depth of contaminated sediment:	7.47 ft
Number of dredging lifts:	2
Volume to be dredged (1):	456000 cy
Volume to be dredged (swollen):	798000 cy
Swelled/compacted contam. sed't vol:	550620 cy
Upland site area:	137655 square yards
Volume dredged per dredge per yr.:	400000 cy
Total volume dredged per year:	400000

****

TABLE 2. (Continued)

========================= QUANTITIES ================================

Item	Unit price	Unit	Quantities by year 0	1	2	3	4	5	6	7	8	9	10
SITING AND CONSTRUCTION													
Clamshell modification	20000	/dredge	1										
Core sampling (2)	1500	/core	107										
Chemical analysis	4500	/core	107										
Design/permitting (3)	325000	/each	1										
Upland site acquisition	25000	/acre	28										
Upland site prep. (4)	1.30	/cy	550620										
Upland site liner (5)	22.92	/cy liner	137655										
OPERATION													
Equipment mobil. (6)	150000	/dredge	1.40625										
Cont. sed. dredging (7)	3.00	/cy	400000	56000	0	0	0	0	0	0	0	0	0
Offloading to trucks (8)	2.50	/cy	700000	98000	0	0	0	0	0	0	0	0	0
Transp. to disp. site (9)	0.50	/cy-mi	2100000	294000	0	0	0	0	0	0	0	0	0
Capping (10)	23.84	/cy cap	241500	33810	0	0	0	0	0	0	0	0	0
Clean sediment dredging	3.00	/cy	15740	2204	0	0	0	0	0	0	0	0	0
Clean sediment transport	0.30	/cy-mi	110180	15428	0	0	0	0	0	0	0	0	0
POST CLOSURE													
Confirmation sampling (10	500	/grab	20										
Confirmation analysis (10	1500	/grab	20										
Well construction (11)	2200	/well	14										
Well sampling (12)	120	/well		14	14	14	14	14	14	14	14	14	14
Chemical analysis	4500	/well		14	14	14	14	14	14	14	14	14	14

========================= COSTS ===================================

Item	Dollars by year 0	1	2	3	4	5	6	7	8	9	10
SITING AND CONSTRUCTION											

TABLE 2. (Continued)

EXAMPLE.PRN

Clamshell modification	20000	0	0	0	0	0	0	0	0	0	0
Core sampling	160500	0	0	0	0	0	0	0	0	0	0
Chemical analysis	481500	0	0	0	0	0	0	0	0	0	0
Design/permitting	325000	0	0	0	0	0	0	0	0	0	0
Upland site acquisition	700000	0	0	0	0	0	0	0	0	0	0
Upland site prep.	715806	0	0	0	0	0	0	0	0	0	0
Upland site liner	3155052.	0	0	0	0	0	0	0	0	0	0
OPERATION											
Equipment mobil.	210937.5										
Cont. sed. dredging	1200000	168000	0	0	0	0	0	0	0	0	0
Offloading to trucks	1750000	245000	0	0	0	0	0	0	0	0	0
Transp. to disp. site	1050000	147000	0	0	0	0	0	0	0	0	0
Capping	5757360	806030.4	0	0	0	0	0	0	0	0	0
Clean sediment dredging	47220	6612	0	0	0	0	0	0	0	0	0
Clean sediment transport	33054	4628.4	0	0	0	0	0	0	0	0	0
POST CLOSURE											
Confirmation sampling	10000	0	0	0	0	0	0	0	0	0	0
Confirmation analysis	30000	0	0	0	0	0	0	0	0	0	0
Well construction	30800	0	0	0	0	0	0	0	0	0	0
Well sampling	0	1680	1680	1680	1680	1680	1680	1680	1680	1680	1680
Chemical analysis	0	63000	63000	63000	63000	63000	63000	63000	63000	63000	63000

SUBTOTAL	15677230	1441950.	64680	64680	64680	64680	64680	64680	64680	64680	64680
CONTINGENCY (20%)	3135446.	288390.1	12936	12936	12936	12936	12936	12936	12936	12936	12936
SUBTOTAL WITH CONTINGENCY	18812676	1730340.	77616	77616	77616	77616	77616	77616	77616	77616	77616
ADMINISTRATION (8%)	1505014.	138427.2	6209.28	6209.28	6209.28	6209.28	6209.28	6209.28	6209.28	6209.28	6209.28
TOTAL	20317690	1868768.	83825.28	83825.28	83825.28	83825.28	83825.28	83825.28	83825.28	83825.28	83825.28
PRESENT VALUE FACTOR	1	0.934579	0.873438	0.816297	0.762895	0.712986	0.666342	0.622749	0.582009	0.543933	0.508349
PRESENT VALUE	20317690	1746512.	73216.24	68426.39	63949.90	59766.26	55856.32	52202.17	48787.07	45595.39	42612.52

TOTAL 10-YEAR COST	22574614										

cost and a unit cost. For example, the cost of dredging would be represented by assigning equipment mobilization costs to the fixed fraction and the per-cubic-yard cost to the unit fraction. This approach constrains unit costs to be expressed in terms either of the volume of contaminated material or the distance from dredging to disposal sites. Some unit costs for the alternatives investigated were most appropriately expressed on some other basis, such as upland disposal site capping costs, which are expressed in terms of the area of the disposal site. The cost categories initially defined in SEDQUAL, in addition, combined several of the categories that were costed separately in the spreadsheet, and did not allow others to be adequately expressed.

Use of SEDQUAL to perform cost analyses comparable to those carried out with spreadsheets therefore involved two activities: modifying SEDQUAL's cost categories and calculation to take account of some additional factors, and making decisions about how each cost item in the spreadsheet should be expressed in terms of SEDQUAL's fixed and unit costs.

Modifications to SEDQUAL

The principal enhancement made to the SEDQUAL cost module was the addition of two cost categories for the dredging and transportation of capping material. In addition, a new type of remedial alternative, capping, was added to the list of those supported. The cost categories of dredging and transportation of capping material were also added to the "DISPOSAL2" type of remedial alternative. Previously this remedial alternative had been described as "Removal, treatment, and disposal"; this description was modified to say "removal, treatment or capping, and disposal."

Enhancements were also made to allow a sediment swelling factor to be applied to the computation of transportation costs, and to allow a contingency factor to be applied. Additional changes would be required to enable SEDQUAL to perform the calculation in exactly the same manner as the spreadsheet. In particular, the SEDQUAL tool does not calculate yearly costs and net present value. Also, although the capability has been added to calculate overall capping costs, it is not possible without further modification to separately evaluate costs for capping of the problem area and capping of a separate disposal site. Situations such as this require the user to pre-calculate some quantities and supply them to SEDQUAL as fixed costs. Elaboration of the simple calculation approach used by SEDQUAL and addition of some more cost categories could reduce the need for users to perform some calculations in exchange for the requirement that users enter more information into SEDQUAL.

Cost Assignments

Use of SEDQUAL is illustrated in the following sections for upland disposal and the head of City Waterway problem area. These are the same conditions used for the spreadsheet shown in Table 2. The emphasis of this example is on the assignment of costs for the cost categories described previously to those provided by SEDQUAL. The most appropriate type of remedial alternative supported by SEDQUAL for entering upland disposal costs is the one identified as "DISPOSAL2". The SEDQUAL cost categories provided for this type of remedial alternative are shown in Table 3. Although none of these cost categories are specifically identified with upland disposal, the costs associated with this disposal option can be established using the "TRANSPORT2", "SITEPREP", "DISPOSAL", "MITIGATE2", and "MISC" cost categories. The values actually associated with each cost category are described in the following paragraphs.

TABLE 3. COST CATEGORIES FOR SEDQUAL's "DISPOSAL 2" TYPE OF REMEDIAL ACTION

Cost Category	Description
ADMIN	Administrative oversight costs
CAPDREDGE	Dredging of clean capping material
CAPTRANSP	Marine transportation of cap material
DISPOSAL	Disposal cost
DREDGING	Cost of dredging operations
MISC	Miscellaneous costs
MITIGATE1	Habitat mitigation at the cleanup site
MITIGATE2	Habitat mitigation at the disposal site
PERMIT	Cost of permit application process
SITEPREP	Disposal site preparation
TESTING	Cost of chemical or biological testing
TRANSPORT1	Marine transportation cost
TRANSPORT2	Overland transportation cost
TREATMENT	Detoxification or other treatment action

ADMIN—SEDQUAL expects administrative expenses to be expressed as a fixed cost and a unit cost varying with the volume of sediment. There is no way to directly translate the approach used in the FS report and the spreadsheet (a percentage of other costs) to these terms. Instead, the spreadsheet was used to identify the total administrative cost for each Commencement Bay problem area, and these costs regressed against problem area volume. The result is a regression line with a slope of $3.90/cy and an intercept of $176,761. These were used as the unit and fixed costs required by SEDQUAL. The r-value for this line is 0.98, indicating a very good fit. Regressions for other remedial alternatives also had high r-values, but very different slopes and intercepts. These administrative costs should therefore be applied only to upland disposal sites.

CAPDREDGE—The fixed cost for dredging of cap material is that for mobilization of the dredge used to excavate clean sediment. This fixed cost is calculated to be $60,938 using the FS report's mobilization cost of $150,000 per clamshell dredge, and the approach taken in the spreadsheet of allocating the cost to each problem area in proportion to its fraction of intertidal area to be capped (for head of City Waterway this is 13000/32000 or 0.41). The unit cost is just as in the spreadsheet or $3.00/cy.

CAPTRANSP—No minimum or fixed cost is associated with the marine transportation of clean capping material. The unit cost is identical to that used for the spreadsheet or $0.30/cy-mi.

DISPOSAL—If the upland site were a RCRA facility and fees or unloading cost were incurred, then they could be recorded in this cost category. Because of the simple assumptions made about upland disposal in the absence of any actual site to be used for Commencement Bay problem areas, there are no costs that need to be directly assigned to this cost category.

DREDGING—The fixed cost associated with the dredging of contaminated sediment is that of mobilization of a single dredge, or $150,000. The unit cost is identical to that used for the spreadsheet or $3.00/cy.

MISC—This cost category was used to record the cost of unloading contaminated sediment to trucks. There is no fixed cost associated with this action; the unit cost is $2.50/cy of contaminated sediment.

MITIGATE1—This cost category could be used to identify any costs of habitat mitigation at the cleanup site in addition to capping. As no other costs are envisioned for the example calculation, both fixed and unit costs for this category are zero.

MITIGATE2—This category was used to record the costs of capping of the upland site, the only type of mitigation activity presumed to take place. A difficulty arises because the capping cost is most appropriately expressed in terms of the area of the disposal site, but SEDQUAL presumes that the unit cost for this category is expressed in terms of volume of contaminated sediment. One possible solution is to express the disposal site area as a function of contaminated volume; this may be done if the depth of fill at the disposal site is fixed but the total area is not. (The spreadsheet takes this approach.) Another solution is to regard the area of the disposal site as fixed and vary the depth to accommodate different volumes of sediment. Cost of capping would then be expressed as a fixed cost rather than a unit cost.

To facilitate comparison of results with the spreadsheet, the former approach was taken. The spreadsheet presumes the fill depth at the upland site to be 12 feet, or 4 yards. The disposal site area was then related to the (swollen and compacted) sediment volume by a factor of four. The depth of the cap is presumed to be 2 yards over the entire area, therefore the cost per cubic yard of cap is related to the contaminated volume by a factor of 4/2 or 2. The result must be further adjusted for the net change in sediment volume expected as a result of swelling and compaction. This net change is presumed to be a net increase by 20 percent. The unit cost for upland capping is therefore 1.2 × $23.84/2 or $14.30.

PERMIT—This cost category was used to record the cost of design and permitting. The fixed cost for this activity is presumed to be $325,000. There is no associated unit cost.

SITEPREP—This cost category was used to record the costs of site acquisition, site preparation, and placement of the liner. The first and last of these are expressed in terms of the area of the upland site, so, in concordance with the approach taken with upland capping costs, they must be converted into terms that can be expressed in relation to the volume of contaminated sediment.

Site acquisition cost is presumed to be $25,000 per acre or $5.17 per square yard (/sy). The area of the upland site is related to the volume of (swollen and compacted) contaminated material by a factor of 1.2/4. Therefore the fraction of the unit cost due to site acquisition is $1.55 (i.e., $5.17 × 1.2/4).

Upland site preparation is already expressed in terms of cubic yards of contaminated material, so the value of $1.30/cy does not need to be modified.

The upland site liner is presumed to be one yard in depth, therefore the cost of $22.92/cy is equivalent to $22.92/sy of disposal site. Once again, the factor relating disposal site area to contaminated volume is 1.2/4, so the fraction of the unit cost due to liner placement is $6.88 (i.e., $22.92 × 1.2/4).

After the costs of site acquisition, site preparation, and liner placement are all expressed in terms of cubic yards of contaminated sediment, they can be summed to generate the final unit cost for this category: $9.73.

TESTING—SEDQUAL provides a single category for testing costs, in which the costs for remedial design sampling, confirmation sampling, and disposal site monitoring must be recorded. As with the costs for upland site preparation and capping, these costs can be transformed (with some assumptions) to a form expressed in terms of cubic yards of dredged material. Remedial design sampling is related to contaminated volume, disposal site monitoring is related to disposal site area, and confirmation sampling is related to contaminated area. To convert the costs of confirmation sampling to terms of contaminated volume, a relationship between volume and area must be assumed. Such an assumption limits the applicability of this cost category to other problem areas. In addition, unit costs cannot be expressed in such a way as to incorporate the rule of a maximum of 20 monitoring stations regardless of area.

Given the difficulty of expressing testing costs as a unit cost related to contaminated sediment volume, the alternative of expressing them as a fixed cost is reasonable. This approach also restricts the applicability of this set of costs (i.e., makes it specific to a single problem area), but allows much better expression of the costs for that problem area. Calculation of the number of cores, grabs, and groundwater samples must be carried out by hand, just as it is done in the spreadsheet. The number of years of monitoring should be considered when calculating the total number of samples. The total number of samples must then be multiplied by the sample analysis cost (which is presumed to be the same for all types of samples). Groundwater well construction costs must also be added in. The result is a single fixed cost for all sampling of $1,370,800.

TRANSPORT1—Marine transportation cost is not included in this cost estimate.

TRANSPORT2—Overland transport has no fixed cost component, but is represented by a unit cost of $0.50/cy-mi.

TREATMENT—If dewatering, precipitation, or other treatments were applied to the contaminated sediment before shipment to the upland site, they could be recorded here. No treatment costs were included in this cost estimate.

Calculation of Total Cost

After fixed and unit costs are selected and entered into SEDQUAL, they are automatically saved so that they can be applied to different problem areas or different sediment volumes. Each set of saved costs is given a name by the user to distinguish it from all others. To carry out a cost calculation, it is necessary to indicate which set of costs are to be used, followed by entry of site-specific information. Using this set of costs, SEDQUAL will prompt for the following site-specific information:

- Volume of contaminated sediment—rather than entering the contaminated volume itself, the volume value should be adjusted so that it is equivalent to a whole number of dredging lifts over the problem area. For the head of City Waterway, this corresponds to two 4-foot lifts over an area of 171,000 sy or a volume of 456,000 cy.
- Overland transportation distance—a distance of 3 miles is presumed.
- Marine transportation distance—no marine transportation is included in this cost estimate.
- Swelling factor—the value of 0.75 is presumed to be appropriate. SEDQUAL does not apply a compaction factor.
- Capping area—the intertidal area at the head of City Waterway is to be capped; this area is 13,000 sy.
- Depth of the cap—a depth of 5 feet is presumed.

- Distance to the source of capping material—the distance to the Puyallup River is approximately 4 miles from the head of City Waterway.

- Contingency factor—a value of 0.20 is used.

All of these numbers can be found in the spreadsheet example (Table 2), in the summary of site specific data, in the summary of input variables, or (for the volume of sediment to be dredged) in the summary of calculated variables.

The total cost calculated by SEDQUAL is shown in Table 4. It is within five percent of the total cost calculated with the customized spreadsheet. The differences are the result of modifications in the way that administrative, site preparation, and capping costs were expressed.

Despite the good agreement, the SEDQUAL cost module could be improved by allowing some unit costs to be expressed in user-selected terms other than volume of contaminated sediment. This would eliminate the need for the site-specific assumptions and calculations that were used to derive the costs, and allow those costs to be more reliably applied to different problem areas.

SUMMARY AND RECOMMENDATIONS

The most important categories of costs applicable to four different types of remedial alternatives have been listed, and the factors affecting actual costs have been discussed. Many categories of costs are strongly influenced by site-specific factors; these may cause some costs to vary by a factor of two or more. These factors introduce uncertainty in the resulting cost estimates that likely exceeds the +30 percent to -50 percent range of accuracy recommended by U.S. EPA (1985) for FS evaluations.

In each category of costs, values have been selected for application to Commencement Bay Nearshore/Tideflats problem areas, specifically to upland disposal of contaminated sediment at the head of City Waterway. These values were used to perform cost analyses by two different methods: customized spreadsheets and SEDQUAL software. Total costs that agreed within 5 percent were achieved with the two approaches.

Because of the many factors influencing cost items such as disposal site acquisition and preparation, sampling, and the dredging operation itself, the costs used here cannot be recommended as generic or widely applicable costs. Cost estimates for sediment remedial action should be based, whenever possible, on detailed site-specific information. Some of the most important information needed in addition to the volume and area of the contaminated site is:

- Water depth at the contaminated site

- Sediment composition at the contaminated site

- Depth of excavation

- Type of dredging equipment to be employed

TABLE 4. COST OF REMEDIAL ACTION CALCULATELD BY THE SEDQUAL COST ANALYSIS SOFTWARE

Cost Categories	Costs for UPLCITY[a,b,c,d]
ADMIN	$1,838,161
CAPDREDGE	98,081
CAPTRANSP	26,000
DISPOSAL	
DREDGING	1,428,000
MISC	1,065,000
MITIGATE1	
MITIGATE2	6,091,800
PERMIT	325,000
SITEPREP	4,144,980
TESTING	1,359,600
TRANSPORT1	
TRANSPORT2	1,118,250
TREATMENT	
CONTINGENCY	3,498,974
TOTAL	**$20,993,846**

[a] UPLCITY - Upland disposal for head of City waterway.

[b] Volume - 426,000 cubic yards.

[c] Swelling factor - 0.75.

[d] Contingency factor - 0.20.

- Distance to the disposal site
- Disposal site requirements, including acquisition, preparation, lining, and closure.

The first four of these categories affect the cost of dredging, either directly or through the influence of variations in sediment swelling. The last two categories can vary greatly from one remedial action site to another without regard to the relative volumes of the sites.

Adequate generic costs can be developed and applied only if practical and reliable relationships can be developed between each category of cost and the factors that affect the category. The result would not strictly be generic costs, but generic cost formulas or tables. For example, the sediment swelling factor might (with sufficient data) be found to vary consistently with sediment composition and dredging equipment. Similarly, if a reliable empirical relationship could be found between the dredging cost and sediment type, depth, and slope, excavation depth, and equipment, it could be used to develop generic cost tables. Although these factors are typically included by contractors when preparing cost estimates, reliable estimates appear to require considerable additional detail, and cannot be reliably simplified and generalized (Tarkoy 1989).

The applicability of generic cost estimates, using the broadly defined cost categories identified here, can best be demonstrated by examination of the actual costs incurred in past or future dredging projects. These costs should be partitioned into the appropriate cost categories. After sufficient data have been collected to allow statistically supportable conclusions, the actual costs should be examined in relation to the few site characteristics that may be known at the time of a FS (e.g., contaminated volume and area, percent fines in the sediment, distance to and size of the disposal site). If empirical but statistically significant relationships are observed (e.g., by multiple regression), then they can be used as the basis for establishing generic costs or generic cost formulas.

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