How to Estimate the Cost of Mechanical Dredging

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Section 1 – Introduction

This technical paper is intended to provide the reader with a general understanding of how to estimate the cost of mechanical dredging. Dredging is, simply, underwater excavation. Mechanical dredging is conducted using a barge-mounted clamshell crane or backhoe, which excavate materials and places them into waiting barges, which are then towed to disposal areas. Other primary types of dredging include pipeline and hopper dredging. Dredging of channels helps maintain the ability of large ships to get to port, thus providing a significant positive economic impact.

Main CSI Division

Division 35 - Waterway and Marine Construction

Main CSI Subdivisions

Subdivision 35 01 40.51 Waterway Dredging

Subdivision 35 01 50.51 Marine Dredging

Subdivision 35 01 50.71 Channel Excavation, Cleaning and Deepening

Subdivision 35 20 23.13 Mechanical Dredging

Reference: US Army Corps of Engineers, Engineering Technical Letter 1110-2-573, 30 Sep 08, Construction Cost Estimating Guide for Civil Works, Appendix D, “Preparation of Dredge Cost Estimates” was used as a basis for portions of this paper.

Brief Description

Mechanical dredges remove material by scooping it from the channel bottom, and placing it onto a waiting barge, also known as a scow. Mechanical dredges work well in consolidated, or hard-packed, materials and can be used to clear rocks and debris. Usually two or more disposal barges are used in conjunction with the mechanical dredge. While one scow is being filled, another is being towed to the disposal site.

It is important for the estimator to thoroughly comprehend the project scope of work and constructability aspects of the project being estimated. The estimator must evaluate the drawings, specifications, and other references to formulate a construction sequence and duration. The quantity take-off is an important part of the estimate and should be based on all available design data. A project narrative should be written to explain the basis for quantity calculations, to clearly show contingency allowances, and to note any factors determined necessary by estimator judgment. These factors should all be considered for the cost estimate to reflect the challenges inherent to working in a marine environment.

Mechanical dredging costs typically include the costs of floating plant: a barge mounted crane or excavator, tugboat, disposal scows, hydrosurvey boat, and the labor to operate the dredging equipment. Costs are computed based on excavation time, transportation time, and disposal time. To determine the unit cost of dredging, divide the gross production cost by the number of pay cubic yards removed.

Sample takeoffs and cost estimates are included in this paper. The estimate is presented from the point of view of an estimator preparing a prime contract bid. It is assumed that the plans and specifications have been prepared to an adequate level by the project's designer. Dredging projects are typically bid as unit priced contracts rather than as lump sum contracts. The contractor applies a unit price to quantities established by the owner or engineer, and extended prices are summed to determine an overall contract amount. During construction, payments are made at the stipulated unit prices as the work proceeds, for the quantities completed.

Estimating software specifically geared towards dredging is often used for preparation of dredge estimates. This paper will present an estimate which uses a manual estimating method.

Section 2 - Types of Methods of Measurements

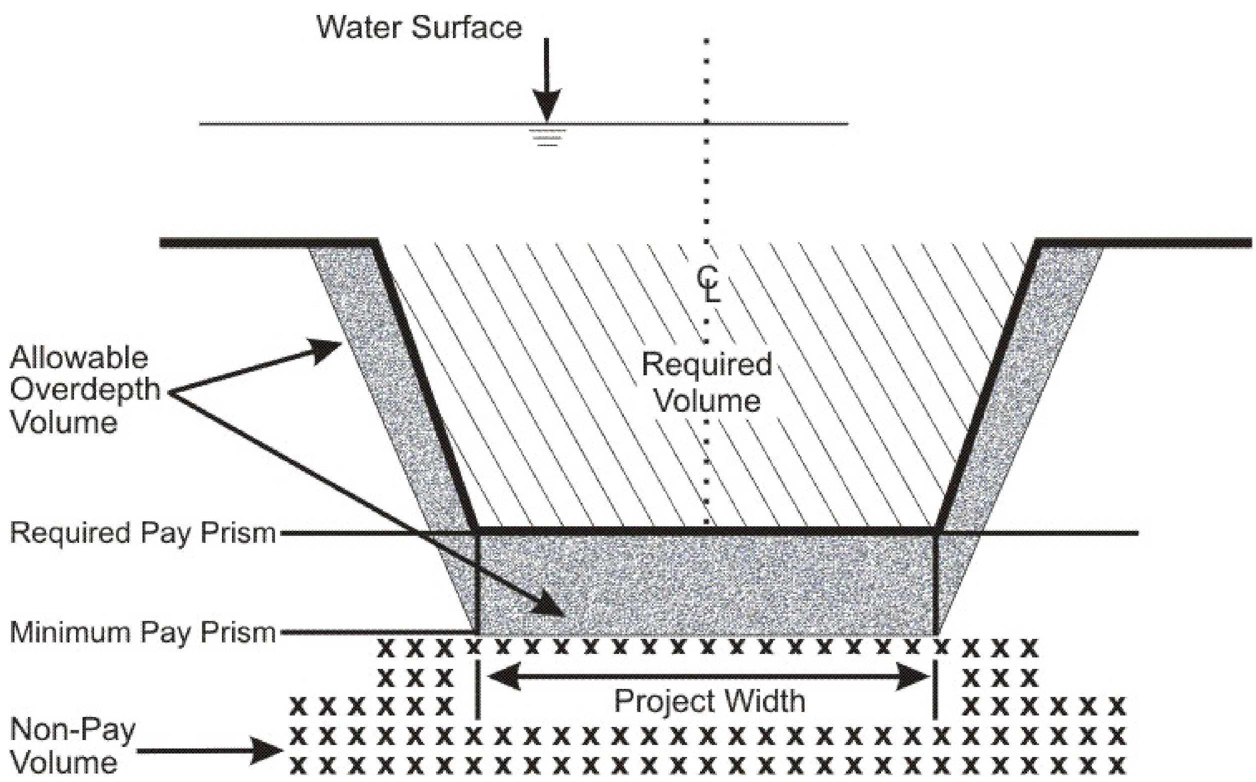
Dredging quantities are often calculated by individuals other than the cost estimator. It is important that the estimator clearly understand the quantity computation, and performs spot checks of accuracy, as appropriate.

Project dimensions include such items as length, width, depth, and channel alignment. Dredging quantities are measured in cubic yards (CY) to be excavated to achieve the desired configuration. Pre-construction quantities, are typically developed from pre-dredge bathymetric survey data (using hydrosurvey boats), and channel design information. Quantities based on these data are determined using volume computation software. Quantities of materials actually dredged are obtained from pre- and post-dredge bathymetric survey data.

For this example, dredging of sand is assumed. This material will not swell significantly. On other projects the estimator should consult the project geotechnical report or consult a geotechnical engineer to help determine the appropriate swell factor, if any. Historical cost data is also a good source for help in determining pertinent material characteristics.

Mechanical dredges are typically only accurate to within plus or minus several inches, resulting in the plans often indicating a pay prism, as shown below. Note there is a "required/minimum pay prism" line, above which no material can remain; an allowable overdepth zone, within which removed material is paid for; and the zone below the overdepth volume, where no payment is made for material removed.

Total dredging quantities are comprised of required volume, overdepth quantity dredged, and incidental non-pay yardage dredged. The cost to dredge the total quantity is divided by the pay yards, to yield the unit price per yard to be paid.



Typical Dredging Pay Prism

(from US Army Corps of Engineers, Engineering Technical Letter 1110-2-573, 30 Sep 08, Construction Cost Estimating Guide for Civil Works, Appendix D)

Section 3 - Project Specific Factors to Consider in Takeoff and Pricing

Small Quantities vs. Large Quantities

Typically jobs involving large quantities will have lower unit costs than obtained on small quantity projects. Large quantities allow the contractor to utilize labor and equipment at optimum productivity. Indirect costs become a lower percentage of the total cost on large quantity projects than on small quantity projects.

Geographic Location

Costs can be impacted by several factors related to the location of the work: plant availability, mobilization and demobilization distances, disposal areas, exposure to wind and waves, and local constraints (such as regulations and permits) that may be placed on the various types of dredge operations.

Seasonal Effect on Work

The season during which the work is conducted can slow production. Winter work can lead to exposure to wind and waves. Cold weather tends to slow construction by inhibiting the efforts of man and machine, because the surfaces of equipment and tools are less stable when covered with water or ice. Visibility and safety are compromised during rainy, foggy or icy days.

Material Type(s) to be Dredged

Information may be obtained from geotechnical investigations, historical data of the specific site or adjoining areas, or similar projects with comparable characteristics. Material type will affect the production rate of the dredge. For instance, rock and boulders can be difficult to remove, while sand and fine-grained materials can leak from the bucket. Contractor experience with various types of materials help determine impacts on dredging production rates.

Section 4 - Overview of Equipment, Labor, Material, Production Rates, Indirect Costs and Approach to Markups

Costs for dredging equipment and labor are usually computed on a monthly basis. Typically, dredging operations are performed round-the-clock, using 2 or 3 shifts. This maximizes usage of the expensive dredging equipment.

Overview of Equipment

General. Mechanical dredges include bucket, clamshell, and dragline dredges. Transportation of the dredged material is usually accomplished using tugs with barges, also known as scows. Mechanical dredges are classified by bucket size. They are an efficient type of dredge for working near bridges, docks, piers, or breakwater structures, or for projects with a long haul distance to the disposal area.

Rental Equipment. Because of the large capital investment involved and the unique expertise required, it is not unusual for dredging contractors to rent some of their equipment, such as additional tugs or scows. For this example, dredging equipment is assumed to be owned by the contractor.

Selection of Equipment. An economical dredge needs to be selected. Dredge type and size depends primarily on availability, job duration, type of material to be dredged, exposure to the elements, disposal area constraints, environmental restrictions, and production requirements.

Equipment Costs. Costs for dredge plant are based on historical data for the contractor's equipment. Costs for owned equipment are comprised of ownership costs and operating costs. Some of the factors used to determine equipment costs include: acquisition costs for specific dredges in the contractor's fleet, year of acquisition, present year, applicable interest rates, depreciation method, plant availability in months per year, current fuel price per gallon, and economic and local factors. The example shown in this paper does not include a detailed calculation of monthly equipment costs.

Overview of Labor

Labor consists of personnel necessary for the operation of the dredge, and attendant plant and equipment. The size and makeup of the labor crew will vary with dredge size and job conditions. This information should be derived from dredge records from previous contracts. Labor costs consist of wages, fringe benefits, taxes, and insurance.

Pay rates for the crew should be based on the existing rates paid by the contractor, which in some cases are prevailing union rates for mechanical dredges, or Davis-Bacon rates for government jobs. Wage rates must equal or be less than the minimum wage rates indicated in the project specifications. Labor rates vary over time, and from region to region. Labor rates must be updated for each estimate to reflect current applicable values for the contractor. Use the contractor’s established rates for taxes and insurance, including state and federal unemployment, workman's compensation, and social security. For each job the estimator must determine if Longshore and Harbor Workers insurance rates apply, in lieu of typical workman’s compensation rates. Add the costs of fringe benefits used by the contractor, including health insurance and vacation time. If applicable, include an allowance for subsistence.

Overview of Production Rates

General. A common approach for estimating production for dredges is to use historical Information for similar type work performed by the same or a similar dredge. For this paper, a production estimate will be developed from scratch, assuming previous records would be used as a check. To determine mechanical dredge production, the estimator must calculate production for both dredge excavation cycle and the hauling cycle. When the haul cycle time is longer than the dredge excavation time, the dredge is sitting idle while waiting on scows. Normally, when this occurs, the number of scows required is increased as necessary to keep the dredge busy, yielding the most efficient operation.

Effective time (actual time spent on the activity) for both excavation and hauling can be affected by factors such as weather, vessel traffic, repositioning of dredge, and minor operating repairs.

Excavation production rate. Excavation production is the quantity of material removed per unit of time. The dredge excavation production rate consists of digging the material and loading scows. The average excavation yardage per hour is calculated using the following factors:

a. Type of material to be excavated. The estimator must evaluate the type of material predicted for the site. The type of material determines the bucket size and production characteristics. Smaller dredges typically do not dig dense materials.

b. Size of clamshell bucket. Bucket sizes can vary widely, from a fraction of a cubic yard to many cubic yards. An optimum bucket size should be chosen for the job at hand, from the buckets available to the contractor.

c. Bucket fill factor. The bucket fill factor is based on the type of material. For example, mud excavation is more efficient because of its density and tendency to completely fill the bucket. Sand, on the other hand, is less cohesive, and is easily displaced during excavation.

d. Thickness or bank height of material. To be efficient, the clamshell must dig a sufficient depth of material to fill the bucket on each cycle. This factor is related to the height of the bucket, the bucket falling velocity, and other aspects.

e. Bank factor. The bank factor is the ratio of the actual conditions to the optimum bank conditions. For example, if only 4-ft of material is available for a bucket requiring 8-ft, the bank factor would be 0.50.

f. Estimated bucket cycle time. This factor is dependent upon dredge size, operating characteristics, and operator efficiency. A complete cycle is defined as the lowering of the open bucket to the ocean floor, mechanical digging of material, closing the bucket, raising the filled bucket, and positioning the bucket for release into a waiting scow.

g. Effective working time. As stated above, effective time is time spent in actual dredging operations. Often based on historical data, this percentage is multiplied by 730 hours to give a resultant operating time per month. Lost time due to major repairs, vessel alteration, cessation of work, and collisions, is not typically used in dredging time calculations.

h. Site specific multiplier. This is a factor to be used for miscellaneous site specific adjustments, if any. This factor is based on estimator judgment derived from past similar jobs.

i. Cleanup factor. The estimator must account for additional time necessary to perform cleanup dredging to remove minor shoals left inside pay prism, that have been detected by an after-dredge survey. The dredging of these shoals requires additional time that is not very productive.

Hauling production rate. The haul cycle consists of transport time of a scow to the disposal area, and disposal time. This cycle is affected by the size, type, and number of scows available, as well as the size, type, and number of towing vessels available. The material may be unloaded using a bottom dump scow, a pumpout station, or any mechanical means to off-load the material directly into the water or an onshore disposal area.

This cycle is affected by factors such as: time to prepare scow for tow, distance to disposal area, travel speed to the disposal area (scow full), estimated disposal rate for the unloading vessel, time allocated for preparing the unit for the return trip, and travel speed returning from the disposal area (scow empty).

Given these factors, the average cycle time is calculated. An efficiency factor for the probability that this hauling cycle will be maintained is applied. The scow capacity is divided by the hauling cycle time to yield the hauling yardage per hour. This is multiplied by the estimated percentage of usable volume in the scow. Then another factor is applied: the estimated percent of solids for the material in the barge. Estimator judgment and experience are important in accurate determination of these factors.

Overview of Material

Material costs are for dredging work might include weirs and rock used for land disposal operations. For the sample estimate in this paper, in-water disposal is assumed, resulting in no material costs.

Overview of Indirect Cost

Indirect costs are those costs, which cannot be attributed to a single task of construction work. These costs include contractor markups such as overhead, profit, and bond. Overhead costs include job office, engineering, surveying, quality control, testing, safety, insurance, permits, temporary facilities, taxes, and home office (general and administrative) costs. Profit is the return on the contractor’s investment, and is determined by company management. Profit often falls between 5 and 10%. Bond costs are as determined by the contractor’s surety.

Section 5 - Special Risk Considerations

Mechanical dredging can involve many special risks. An important example is harmful effects to protected species, such as fish and mammals that can occur. Any dredging operation will have an impact on the environment, and is governed by numerous environmental regulations. The estimator must account for the cost of environmental controls in the estimate. Turbidity monitoring and control are important examples of environmental costs associated with mechanical dredging. These costs may be difficult to estimate given the wide variation of turbidity requirements, and associated dredging conditions, that could be encountered. Another environmental requirement that may be stipulated is monitoring of endangered species, including affected fish, and mammals. If the dredging negatively impacts these species, expensive measures may be needed to remedy the issue.

Other risks associated with mechanical dredging include: a high potential for storms, leading to high winds and waves; collisions with other vessels or running aground; major equipment breakdowns; encountering unexpected rock layers; and unforeseen safety issues. The estimator must attempt to account for possible extra costs due to these risks, but (if possible) without increasing costs beyond the point where the contractor can win the job.

Section 6 - Ratios and Analysis – Testing the Bid

The dredging environment is unique, and is inherently full of special risks, therefore, it is not possible to develop rules of thumb that apply uniformly to all projects. However, it is always good estimating practice for the estimator to check his estimate for accuracy. When checking the accuracy of a mechanical dredging estimate, the estimator should consider the following:

a. A peer review should be conducted by an estimator experienced in mechanical dredging at the site in using the equipment proposed, if possible.

b. Equipment and methods chosen, and developed unit costs, should be compared to the same factors for previous similar dredging work to provide a sanity check that the estimate is in the correct ballpark.
c. Computed production rates should be checked against historical data for similar equipment at the same or similar site. For example, to estimate the dredging cost for a channel deepening, start with historical production data, then, if warranted lower the production rate, based on geotechnical reports or other data, to account for the undisturbed material never having been dredged before, presumably making it more difficult to remove.
d. An attempt should be made to balance excavation demands with hauling demands. The estimator can examine several scenarios, varying the number of dredges, scows, and tugs, and the size of dredge, to determine the optimum equipment types and sizes.

Section 7 - Other Pertinent Information

Other considerations associated with mechanical dredging can include:

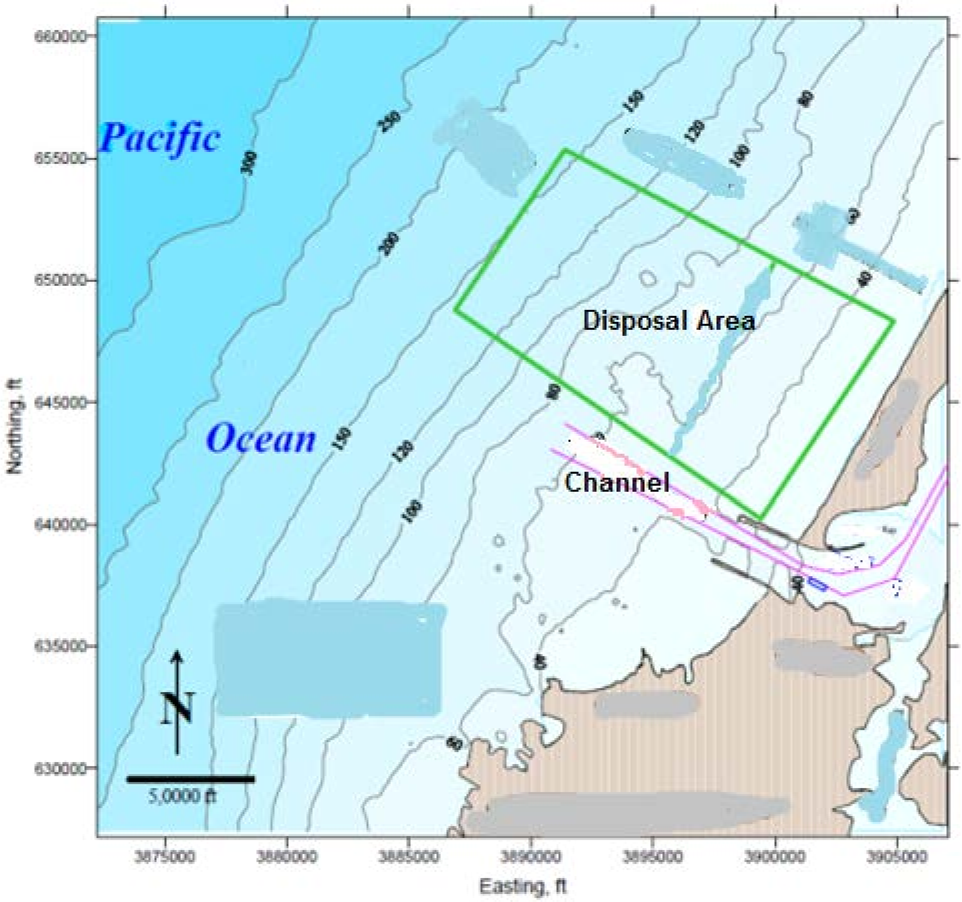
a. Land disposal site costs, such as: clearing and grubbing, dike or weir construction to provide drainage, and management of dredged materials.
b. Drilling and blasting of rock, if necessary.
c. Environmental work periods. Many areas are subject to restricted environmental dredging seasons, potentially causing schedule impacts.
d. Safety considerations. Dredging is conducted in an oftentimes harsh marine environment, making it necessary to provide for extra safety provisions. The costs of required safety training for contractor personnel must be covered.
e. Site restrictions. This may include such items as conflicting waterway usage, vessel traffic, as well as working hours, weather, noise, environmental restraints, and the presence of adjacent dock pilings, underwater cables or pipelines.

f. Small, disadvantaged, or minority owned businesses. Many owners required the prime contractor to meet established goals for participation by these businesses, which the estimator should consider in preparing the bid.

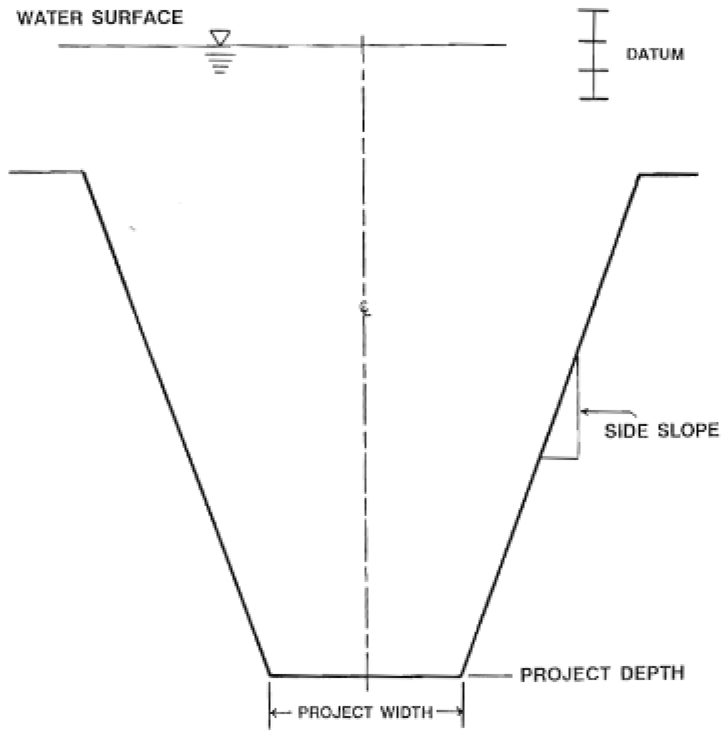
g. Hydrographic surveys (Hydrosurveys). Hydrosurveys are made prior to dredging to determine existing depths within the project area, and after dredging to determine the depths that were attained as a result of the dredging operation. Hydrosurvey boats are usually technologically advanced, often using the global positioning system, lasers, single and multi-beam sonar techniques to accomplish required surveying.

The Sample Estimate provided in this paper does not cover the above items, for simplicity.

Section 8 - Sample Plan and Section Views



Sample Dredging and Disposal Plan



NAVIGATION PROJECT DIMENSIONS

Typical Dredging Section – Work Completed

Section 9 - Sample Take-off and Pricing Sheets

For this sample mechanical dredging estimate, the following assumptions are made:

a. Use a clamshell type of mechanical dredge, as opposed to a barge-mounted backhoe.

b. The material being excavated is sand.

c. Material will be dredged from the channel shown on the Sample Dredging and Disposal Plan, and deposited in the disposal area shown. Assume channel length is 5,000 feet.

d. The channel will be excavated as shown on the generic Navigation Project Dimensions cross-section, above. The assumed depth of excavation required is 5 feet, with an average channel width of 600 feet.

e. The quantity used in the estimate is the amount computed from the established channel dimensions, and does not separately account for overdepth volume or non-pay yardage.

f. In-water disposal is assumed, rather than land disposal.

g. Mobilization and demobilization costs are not included.

h. Costs for costs for surveys and environmental monitoring are not covered.

Quantity Takeoff		
Assume:		
Channel length to be dredged	5000	feet
Average cross section be dredged:		
Average depth of dredging	5	feet
Channel width	600	feet
Cross-sectional area	3000	square feet
Volume to be dredged	**555,556**	CY
Assume loose sand will be dredged, swell will be negligible.		

Equipment:			
Item		Monthly Cost	
Clamshell Dredge, 16 CY		$ 80,000	
Work Tug		$ 10,000	
Crew Boat		$ 8,000	
Survey Boat		$ 12,000	
Fuel/Water Barge		$ 2,000	
Towing Vessel, 3,000 HP		$ 100,000	
Scows, bottom dump, 2000 CY		$ 50,000	2 @ $25k each
	Total Monthly Equipment Cost	**$ 262,000**	

Labor:							
Assume dredge works round the clock. Assume one of each crew member listed below							
will be working at all times.							
Hours per month = 24 hr per day x 365 day per yr / 12 mon/yr = 730 hours per month							
Labor Taxes and Insurance							
Social Security Tax	7.65%						
Workman's Compensation	38.00%						
State Unemployment Comp.	3.35%						
Federal Unemployment Comp.	1.00%						
Total	50.00%						
	Hourly	Fringe		Taxes and		Hour per	Monthly
Position	Rate	Benefits	Subtotal	Insurance	Hourly Cost	Month	Cost
Operator (Dredge)	$30.00	$10.00	$40.00	$20.00	$60.00	730	$43,800.00
Engineer (Dredge)	$29.00	$10.00	$39.00	$19.50	$58.50	730	$42,705.00
Mate (Dredge)	$28.00	$10.00	$38.00	$19.00	$57.00	730	$41,610.00
Deckhand (Dredge)	$20.00	$10.00	$30.00	$15.00	$45.00	730	$32,850.00
Tug Master (Tow Tug)	$30.00	$10.00	$40.00	$20.00	$60.00	730	$43,800.00
Deckhand (Tow Tug)	$20.00	$10.00	$30.00	$15.00	$45.00	730	$32,850.00
					Total Monthly Labor Cost		**$ 237,615.00**
Total Monthly Cost, Equipment and Labor:	$ 262,000	+	$ 237,615.00	=	**$ 499,615.00**	**per month**	
Materials:							
Assume materials costs are negligible for this project.							

Production Rate:			
Bucket size	16	CY	
Soil type	Sand		
Cycle time	45	second	
Buckets per minute	1.33		
Buckets per hour	80		
Bucket fill factor	0.7	from historical data	
Average depth of cut	5	feet	
Optimum depth of cut	6	feet	
Bank factor	0.83	average depth of cut divided by optimum depth of cut	
Cleanup factor	0.9	assume 10% additional time	
Effective working time	0.8	job efficiency, historical	
Bulking (swell) factor	1.0	for sand	
Production rate, hourly	537.6	CY/hour (from above factors)	
Hours per month	730	hr/month	
Production rate, monthly	**392,448**	**CY/month**	

Determine No. of Scows Required			
Scow Quantity			
Size of scow	2,000	CY	
Useable capacity, percent	90%		
Useable volume	1,800	CY	
Slurry density	80%		
Average volume hauled	1,440	CY	
Cycle time per scow trip			
Prepare scow for tow	15	min	
Distance to disposal area	10	miles	
Average hauling speed, loaded scow	7	mph	
Haul to disposal area	86	min	
Dump load	5	min	
Distance back to dredge	10	miles	
Average hauling speed, empty scow scow	8	mph	
Trip back to dredge	75	min	
Disengage tow rigging, tie up scow	10	min	
Average cycle time	191	min/round trip	
Average cycle time	3.18	hr/round trip	
Production per scow, hourly	453	CY/hr	
Hours per month	730	hr/mon	
Production per scow, monthly	330,715	CY/mon	
No. of scows required	1.19	Divide dredge production by scow production	
No. of scows required, rounded up	**2**	**Scows required to keep dredge busy**	

Dredging Time, Direct Cost, Indirect Costs, Total Cost, Unit cost			
Time to complete dredging	1.42	months	quantity divided by dredging production rate
Direct cost for dredging	**$ 709,453.30**	time multiplied by monthly cost	
Overhead, percent	15%		
Overhead, cost	$ 106,418.00		
Running subtotal	$ 815,871.30		
Profit, percent	10%		
Profit, cost	$ 81,587.13		
Running subtotal	$ 897,458.42		
Bond, percent	1%		
Bond, cost	$ 8,974.58		
Total dredging cost	**$ 906,433.01**	not including mob/demob and "other" cost items	
Unit cost for dredging	**$ 1.63**	**per CY**	

Section 10 - Copy of Topic Approval Letter from ASPE Certification Board

American Society of Professional Estimators CERTIFICATION

Mailing & Administrative Office:
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Summary Certification Cycle/Topic Acceptance Form

August 15, 2012

Candidate Number: *0712017* Chapter Number: *54* Region: *NW*

Workshop Completed by: **September 30, 2012** Selected workshop format: **Online**

Technical Paper Topic: HTETCO Mechanical Dredging

Technical Paper Due Date: **December 15, 2012.**
Late papers are subject to penalty of score as stated in the "Technical Paper" booklet.

Testing: **Schedule test dates during the month of March, 2013. If submitting Q&P in lieu of DST, The complete set of questions and problem will be due by March 31, 2013.**
Provide the Society Business Office with proctor information and schedule test dates 15 business days prior to testing.

Certification Discipline: 1.4 General Construction

Contact Email Address: patricktjones@hotmail.com

Online Workshop link: **http://cei2.com/SCRIPT/805/scripts/serve_home**

Online Workshop User ID: **CB43** Online Workshop Password: **812cp**

I agree to the selected topic and will prepare my technical paper according to the format stated for the ASPE Certification Program.

I will meet the deadlines for the completion of the workshop, submittal of my technical paper, and testing. If I do not meet these deadlines, I understand that this certification cycle will terminate and I will need to submit a new application.

I have read the above information and by signing below agree to meet the requirements of the ASPE Certification Program and adhere to the guidelines of the program.

Signature: Patrick J. Jones **Date:** 9/24/12

Please retain a copy of this form for your records and technical paper. ***Return this form to the Society Business Office***
Fax: 615-316-9800 or email tanya@aspenational.org

Section 11 - Terminology-Glossary

Pay prism – cross-section that depicts required excavation, an overdepth zone, a non-pay line, the channel width, and channel slopes.

Required volume – quantity between existing ground line and “required” excavation line.

Overdepth volume – pay quantity dredged below “required” excavation line and above the “non-pay” line.

Non-pay volume – quantity dredged below the non-pay line

Hydrosurvey – survey of the channel bottom conducted pre- and post-dredging operations.

Effective working time – time during dredging operations when material is being removed from the channel.

Lost time – downtime during which there are no dredging operations. Lost time can be due to major repairs, collisions, lack of required crew, and other factors.