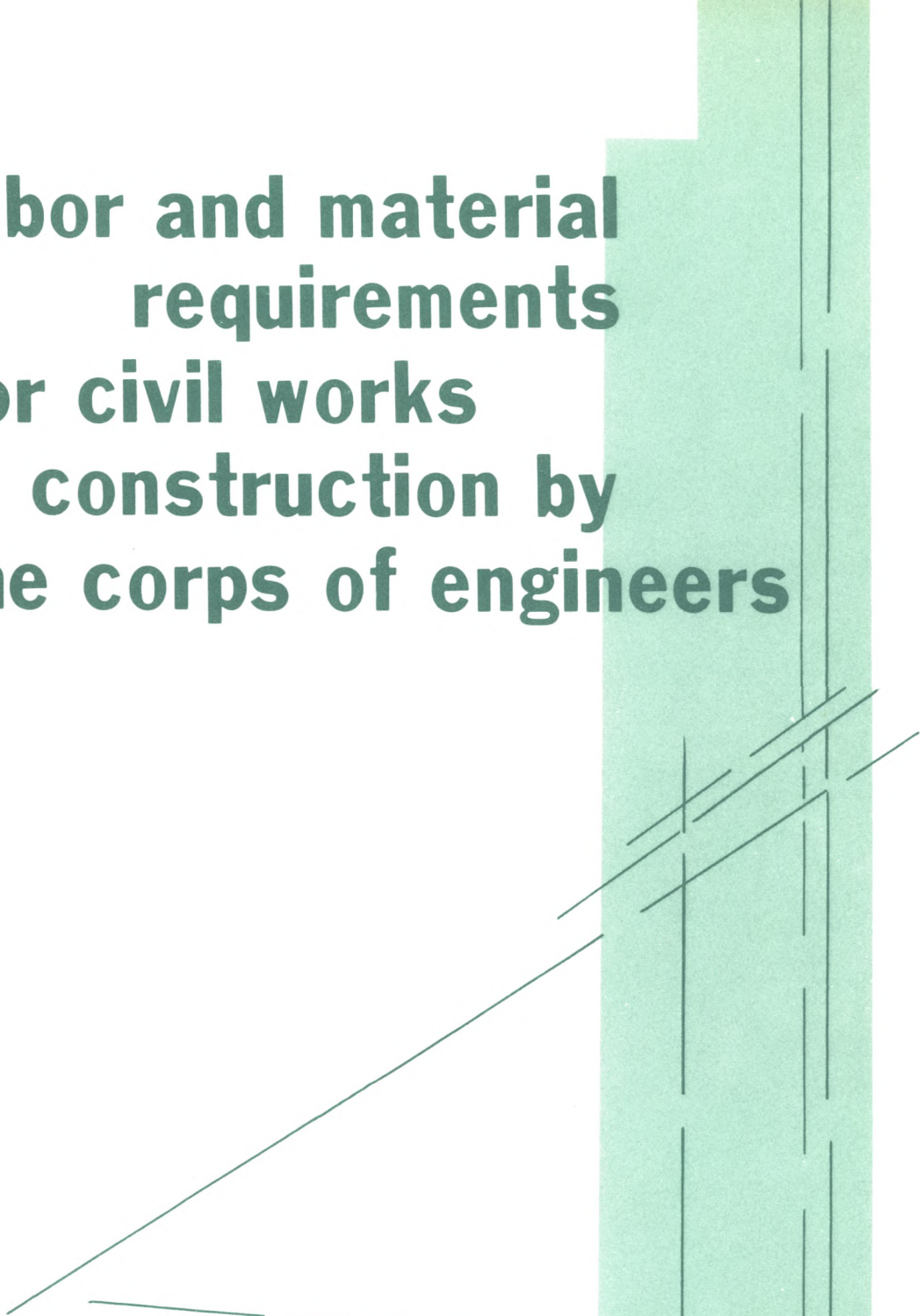
labor and material requirements for civil works construction by the corps of engineers



Bulletin No. 1390

UNITED STATES DEPARTMENT OF LABOR
W. Willard Wirtz, Secretary

BUREAU OF LABOR STATISTICS
Ewan Clague, Commissioner

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Preface

This study of labor requirements for the construction of projects in the civil works program of the Corps of Engineers is one in a series of studies for various types of construction that might be affected by Government action. Previous studies were made for schools, highways, Federal office buildings, and hospitals. Surveys in preparation cover public housing, private residential dwellings, college student housing, and sewage disposal construction.

The studies are being made by the Bureau of Labor Statistics, under the general direction of Leon Greenberg, Assistant Commissioner for Productivity and Technological Developments, and under the immediate supervision of James F. Walker. Roland V. Murray prepared this bulletin and was responsible for compiling the data on on-site labor requirements. Joseph C. Wakefield prepared the data on off-site labor requirements.

The Bureau is grateful to the Office of the Chief of Engineers, Department of the Army, for their generous cooperation in making available the data which were tabulated to determine the labor, material, and equipment usage on the sample projects, and for answering many technical questions.

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LABOR AND MATERIAL REQUIREMENTS FOR CIVIL WORKS CONSTRUCTION BY THE CORPS OF ENGINEERS

Introduction

New construction is a major component of the Nation's output of goods and services and an important source of employment. It creates jobs not only at the project sites, but also in the many manufacturing, trade, and transportation industries which furnish materials and equipment required in the construction processes.

The Bureau of Labor Statistics has undertaken a series of studies to measure these labor requirements for various types of construction. The program of civil works construction under the Corps of Engineers--the construction of facilities such as dams, levees, dikes, and channels to control and develop the Nation's water resources--was chosen for early study because of the size of the program, because it is representative of an important part of heavy construction, and because it is the type of program frequently envisioned when public works construction is under consideration as a means of counteracting cyclical unemployment.

Currently, the new construction program of the Corps of Engineers requires an expenditure of over $ 800 million a year, and the amount has tended to increase. Estimates of expenditures for future years involve forecasts of new project starts, and these in turn depend on budgetary and economic policy, since many such projects are postponable. For this program, however, there is a large reserve of projects which have been authorized by legislation, but not yet funded for actual start. The total Federal cost of these projects is estimated at $ 4.8 billion. Of this amount, about half a billion dollars was accounted for as of June 30, 1963, by projects for which plans were advanced sufficiently for contracts to be let, and plans were in process for projects costing an additional $ 2.6 billion.

This bulletin is based on data for 45 projects constructed under contracts awarded by the Corps of Engineers in its civil works program. Seventeen of these projects were for various types of dredging; these are separately treated throughout the report. The other 28 projects were of the type more commonly visualized as heavy construction--dams, levees, dikes, etc. For convenience, they are referred to as land projects, although barge-mounted equipment and service river craft frequently were used on some types of these projects. The projects were selected as representative of the measures required for flood control and navigation development of the Nation's waterways. (Details of sample selection are given in a later section.) Construction was accomplished during the period from the middle of 1957 to the end of 1960. Most of the work, however, was done in 1959 and 1960.

Basically, the survey covers new construction. However, the distinction between new and repair work on this type of construction is not always sharp, and some work not technically new is included, e.g., some maintenance dredging. Unlike building construction, these projects are complete in themselves, requiring little additional equipping or furnishing for serving their purpose. Such equipment as is required--gate hoists, elevators, stand-by generators--is part of the construction contracts and is, therefore, included in the survey.

The survey was designed primarily to measure the number of man-hours represented by a fixed dollar volume ($1,000) of Corps of Engineers civil works construction. Man-hours, as here defined, cover not only direct on-site construction labor, but also labor required to produce and deliver the materials and equipment used in the construction. On-site man-hours cover supervisory, clerical, and technical personnel as well as the direct construction workers. Off-site data cover a proportional share of the contractor's employment in his home office and other facilities; employment generated by his overhead expenditures; employment in construction materials and equipment manufacture; and finally, employment in all other industries which are affected directly or indirectly by the production and distribution of building materials and equipment, from the raw materials to final manufacture.

Certain types of employment, however, were not covered in the survey. Principally excluded were the employment generated by the project, but not specifically by the construction contract (such as the preparation of plans and specifications, Federal inspection, installations by public utility employees, and other appurtenant work) and employment created by the respending and investing of the wages and profits arising from the construction--the multiplier effect.

General Survey Findings

Construction in 1959-60 of land projects characteristic of much of the Corps of Engineers work created a total of 208 man-hours of employment for each $ 1,000 of construction contract. Of these man-hours, 85 were for on-site employment in the construction industry, and 123 for various off-site activities. For dredging projects, the total was 224 man-hours, with 134 on-site and 90 off-site. The man-hours were allocated as follows:

Industry	Man-hours per $ 1,000 of contract			
	Land projects		Dredging	
	Number	Percent	Number	Percent
Total	208	100	224	100
On-site: Construction	85	41	134	60
Off-site[1]	123	59	90	40
Construction	4	2	10	4
Manufacturing	53	25	47	21
Trade, transportation, and services	47	23	24	11
Mining	13	6	6	3
Other industries	6	3	3	1

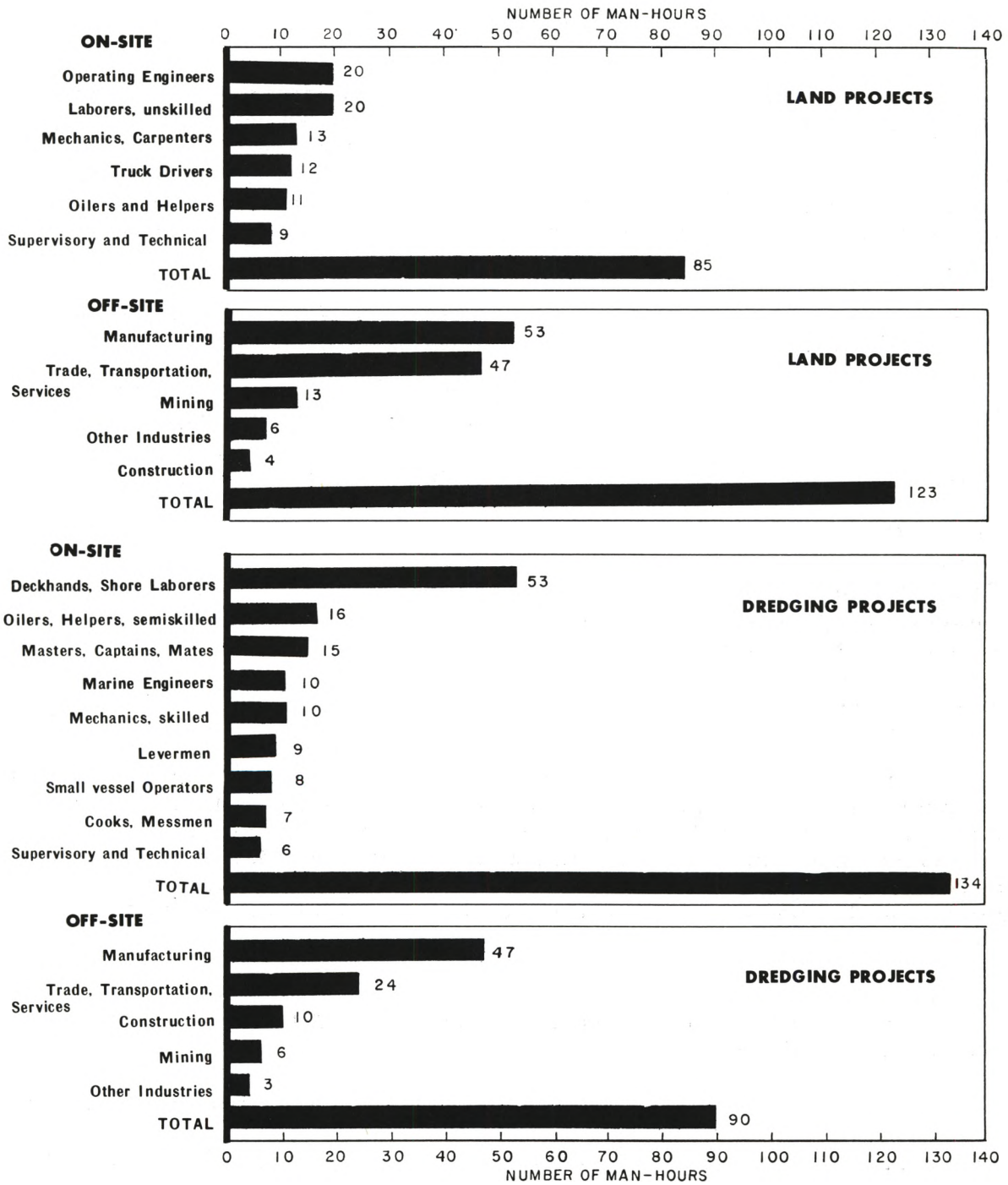
[1] These data for off-site man-hours are not strictly comparable with those published in previous studies in this series, because these figures include man-hour equivalents for items of overhead expense such as insurance, bonds, and rent, hitherto excluded. (Profits and taxes are now the only components of the contract amount not converted to man-hours of employment.) Comparable data for the earlier studies are available on request.

The following rough breakdown of costs per $ 1,000 is useful in analyzing these allocations:

	Land projects	Dredging
Total	$ 1,000	$ 1,000
Materials and supplies	350	175
Equipment (depreciation)	200	250
On-site wages	250	325
Other (overhead and profit)	200	250

Chart 1

Distribution of man-hours for each $1,000 of civil works construction by the Corps of Engineers



Materials usage in dredging is negligible, the figure shown above representing primarily supplies--the fuel and lubricants required for dredge operation. Dredging costs are higher in the equipment and wages categories. The higher on-site wage cost is particularly significant because it converts into a very large on-site labor requirement owing to lower average hourly earnings in the dredging projects studied ($2.41) than on the land projects ($3.07). These lower earnings result in part from the geographical distribution of dredging jobs and in part from the much larger proportion of unskilled workers employed on them. A less important reason for high on-site labor requirements in dredging is that they include labor required for the subsistence of the production workers--i.e., the labor of cooks, messboys, and quarters janitors. Since dredge crews pay a portion of subsistence cost through payroll deductions, the dredging requirements figures inherently include some of the respending effect otherwise omitted by definition from this series of studies.

Within each of these two overall categories--land and dredging--projects and groups of projects showed rather wide variations in both on-site and off-site man-hours. These are discussed in later sections of the report.

The on-site man-hour data above include an estimate for equipment "mobilization and demobilization" amounting to about 1.5 and 5.0 percent of the total on-site hours for the land and dredging projects, respectively. This component represents the employment of the contractors' forces in marshaling heavy construction equipment to the construction site, including any required disassembly and reassembly as well as transportation. This category of labor is negligible in building construction, but is significant in the types of work under study, where equipment use is heavy, and construction sites often remote and difficult of access. These figures do not include transport of equipment by common carrier, which is reflected in the transportation category. The mobilization requirements are considerably higher for dredging then for other projects because in effect the entire construction work force--the dredge crew--is involved in the plant transfer. In mobilization of plant for other types of work, the workers chiefly involved are those most directly concerned with equipment--truck drivers, equipment operators, and mechanics.

The study of labor requirements provided as by-products several types of information which are also discussed in later sections of this report. These include data on purchased materials and supplies, types of equipment used, and occupations of on-site workers.

Scope and Method of Survey

Nature of the Universe and Selection of the Sample

This study was designed to provide estimates of man-hours required for construction, by the Corps of Engineers, of the facilities described elsewhere in this bulletin for the development and control of the Nation's water resources.

The Corps provided a list of 235 major civil works contracts[1] (those over $ 100,000 in value) under which construction was completed during the calendar year 1960. The contracts were stratified by broad geographical region, general type, and cost class, and a 20-percent sample was taken from each stratum.[2] The resulting 45 sample projects were located in 26 States. They involved a total of 146 prime and subcontracts.

Man-Hour Estimates

Estimates of total man-hour requirements are a combination of data derived by two different procedures. For the on-site activities, where labor input can be identified as relating to a specific project, direct primary data are available. For all other activities, however, such as the manufacture of construction equipment and materials, which are in their nature diffuse and nonspecific with respect to a particular project, an estimating procedure was used. These two methods are described below.

On-Site Man-Hours

With minor exceptions, all construction under contracts awarded by a Federal agency is subject to the Davis-Bacon Act. To check compliance with this law, an administrative regulation requires that each contractor on Federal construction file a copy of his weekly project payroll with the supervising agency. These payrolls are thus a primary source of data on production man-hours worked and wages paid on a project. In the current study, the payroll files for the sample projects were made available for data transcription through the cooperation of the Corps of Engineers and its Division and District offices.

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[1] Excluding 66 contracts for work outside the scope of the study--highways, railroads, buildings, etc.

[2] One large dam project was deliberately selected for its size and complexity to represent a cell of smaller projects, and was given a weight of one-quarter. All measures presented in this report are based on weighted data.

Although these payrolls were the basic source of production worker data, nonproduction workers (e.g., general supervisors, engineers, and clerks) and certain classes of production workers (such as self-employed subcontractors) are not required to be reported on the project payrolls. Moreover, the processing of the payrolls, and of the material described in the following section, developed an occasional question as to completeness or meaning. These questions were resolved, and the supplementary labor data obtained, in telephone interviews or correspondence with the contractors or the Engineers' District offices.

Off-Site Man-Hours

Corps of Engineers regulations, stemming from an act of Congress in 1919, specify that a contract for a construction project may not be awarded if the lowest bid price for the job exceeds a government estimate of its cost by more than 25 percent. The government estimate used as a standard is prepared in considerable detail for each bid item (major subfeature) of the job by an engineer in the District office of the Corps who is familiar with local conditions and practices. In most cases, he has access to a considerable body of experience on similar jobs, since work of the same type tends to recur in a given area.

These estimates, the most common of which is termed "Reasonable Contract Estimate," show not only the estimated quantities and prices of materials and supplies to be used and the wages to be paid, but also judgments as to the type of equipment likely to be used, and estimates of its "rental" cost (the cost of owning and maintaining) and its operating cost (the cost of fuel, lubricants, and minor repairs). These data on materials, supplies, and equipment costs were tabulated for each sample project from the detailed estimates made available by the District offices of the Engineers, and were the basis of the breakdown for all elements of cost with the exception of the on-site labor costs which were derived from the actual construction payrolls as described above. When required by changes in the scope of the work, these estimated costs were adjusted to approximate final costs by use of the ratio of the contractor's original bid to final payment to him for each bid item.

The labor data for plant "mobilization and demobilization" were also based on information in these government estimates. Although this category represents the work of the contractor's own employees in mobilizing heavy construction equipment to the construction site, the work is not required to be reported on the payrolls, and had to be separately estimated. The information available was fragmentary in some cases, and the relative accuracy of the resulting estimates is unknown.

The sources and procedures described above yielded a bill of materials, supplies, and equipment used in construction of the subject projects in terms of purchasers' values. These were transformed into producer's value

on the basis of an updating by the Office of Business Economics, U.S. Department of Commerce, of a previous BLS study. The difference between the two values was taken as the total of all distribution costs between the site of final manufacture and the construction site.

In general, the producers' values of the bill of materials were converted to man-hour requirements for their production by the use of employment-to-output ratios developed from the 1960 Survey of Manufactures. For the final stage of manufacture, and for the final distribution phases, the application of these ratios is direct and relatively uncomplicated. However, prior to this stage, there occurred a complex of interacting processes involving all sectors of the economy, including the extraction of basic materials. A study of these interindustry relationships was the basis for establishing the indirect contribution of each sector of the economy to the bill of materials.[3] The employment-to-output ratios for each sector were applied to the sum of these contributions to estimate secondary labor requirements.

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[3] W. Duane Evans and Marvin Hoffenberg. "The Interindustry Relations Study for 1947," The Review of Economics and Statistics (Cambridge, Mass., Harvard University Press), Vol. 34, May 1952. For details of the application of this study in the labor requirements program, see previous studies in the series, especially "Labor and Material Requirements: Highway Construction, 1958 and 1961." Reprint No. 2413 from Monthly Labor Review, April 1963.

Project Characteristics

As previously mentioned, the 45 projects studied were typical of the work completed in a single year (1960) by the Corps of Engineers in furtherance of its chief civil function[4] of providing facilities for the control, development, and utilization of the Nation's water resources. These facilities are divided into two major programs, according to their objective: Flood control, and river and harbor development to provide navigable waterways. Some measures provided in the flood control program are levees, flood walls, and flood channels; in the river and harbor program are channel excavation, harbor dredging, and jetties. Some measures may serve either program if they tend to provide a flow of water in a river neither so heavy as to cause flooding nor so light as to impede navigation.

Despite this apparent diversity of types of construction, most of the work consists essentially of changing the earth's topography--in moving earth and stone from one place to another. This has become one of the most highly mechanized of the construction operations, a fact which has an important bearing on much of the statistical material later presented. The fabrication of intricate structures requiring much specialized hand crafting is not an important segment of the work, although many small jobs of this type may be required on a large project.

Seven broad categories of projects were represented in this study. The number of projects and their cost (unweighted) were as follows:

Type	Number of projects	Construction contract cost (000)
Total	45	$ 43,163
Dredging	17	10,092
Levees	7	2,370
Dams	4	16,579
Pile dikes	5	1,544
Bank stabilization	5	1,756
Local flood protection	3	6,645
Miscellaneous other	4	4,177

A brief description of each of these categories follows.

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[4] The basic task of the Corps is the construction and maintenance of military facilities; these are in no way involved in this report.

Three major types of dredging are employed in creating and improving the navigable waterways of the country. The most common is the hydraulic type in which a dredge, equipped with a cutterhead, pumps relatively soft material through a pipeline to a disposal area, usually, though not always, on a shore area. Contracts covering 12 projects of this type of dredging, totaling $ 7,136,000, are represented in this study. The second type is that in which soft or broken hard material is loaded by a clamshell or dipper bucket into scows and hauled away for dumping in a disposal area, usually in deep water. This study included five such projects totaling $ 2,956,000; 2 of these 5 projects were primarily for rock removal, and involved extensive drilling and blasting.

The third major type of dredging is not represented in this study because it is not done by private contract, in the United States. This is the so-called hopper dredging in which a large seagoing dredge pumps material into its hopper for subsequent dumping at sea. In this country, only the Federal Government owns hopper dredges, which are used primarily on ocean bars and similar exposed locations.

Levees are the simple flood control structures of heaped and compacted earth. In one of the study's sample cases, the earth fill was obtained hydraulically by pumping from the adjacent river in an operation similar to the pipeline dredging described above. In this and one other case, slopes were protected from erosion by stone facing.

Included in the category of dams and reservoirs are two earth fill dams, one of large and one of moderate size; a rock fill dam; and a reservoir clearing project. (A concrete dam of modest size is a feature of one of the "local flood protection" projects and is included in that category.) The sample does not include any of the multipurpose dam and reservoir projects, costing in the tens of millions of dollars and involving elaborate hydroelectric power installations.

Pile dike structures consist of two rows of timber piles in clumps, with rock dumped between and around them. They usually extend outward from the banks of a river in a downstream direction. Their function is to slow the river current so as to deposit silt and thus confine the channel and build up the bank. All of the sample projects are located on the Arkansas and Missouri Rivers.

Bank stabilization projects reflect three different types of installations designed to prevent the erosion of the banks of rivers: Riprap and other stone placed on the banks above and below the water level; the asphalt paving of the banks above the water level; and the lumber "mattresses" installed on the banks above or below water. The latter are lattices of boards weighted in place with stone.

Local protection projects, in general, embrace a variety of facilities designed to protect a specific area, usually urban, from flood damage. The sample projects are for the benefit of three such areas, and embrace flood walls; a concrete-lined flood channel; a concrete dam; an earth dike; a pumping plant; and river channel improvement. Flood walls, as opposed to levees, are the flood water barriers often preferred in urban areas, where space is restricted and land costly.

The four projects in the miscellaneous group were, in order of size: Two rubble-stone jetties; a concrete seawall; a bayou channel clearing and snagging operation; and a pressure relief system. The last was a system of wells designed to relieve upward ground water pressure on a dam outlet structure.

On-Site Man-Hour and Wage Requirements

Substantial differences were found in on-site man-hours and wages as a percent of cost, as shown in the following tabulation.

Type of project	On-site man-hours per $1,000 of cost	On-site wages as a percent of cost
Dredging	134	32
Land projects	85	26
Levees	101	31
Dams	96	29
Pile dikes	87	24
Bank stabilization	60	12
Local flood protection	80	27
Miscellaneous other	71	22

Significant differences in on-site labor requirements among types reflect a number of factors, including the relationship of other costs, particularly the cost of purchased materials, to labor costs; the degree to which certain materials requirements, such as for stone and concrete, are met by production at the site; the degree of mechanization of operations; the wage distribution and skill composition of the work force; and the subsistence services, if any, supplied.

The effects of several of these factors are evident in the high on-site labor requirements for dredging as compared with the low requirements for bank stabilization. The high requirements for dredging arise from the relative importance of labor costs, in the virtual absence of materials requirements; from the provision of food and other subsistence items to the dredge crews; and from the nonmechanized nature of much of the shore work. The low requirements for bank stabilization, on the other hand, reflect in large part a relatively high cost for the purchase and transportation of materials, especially rock and lumber, which required a minimum of rehandling at the site.

The range of on-site labor requirements within the above types is substantial, suggesting that these averages are applicable only to broad programs. A common cause of significant variation between similar types of work is the extent to which the contractor produces certain needed materials as part of his on-site operations. Some of these materials include concrete, rock (crushed or broken), sand and gravel, and wood stakes. Even though the materials may be produced at some distance from the actual job site, the operations are considered as "on-site" if they have no commercial purpose, but supply only the specific job needs.

An example of the influence of this factor is noted in the pile dike category. On three closely comparable jobs in this group, the large amount of broken stone required was purchased in one case, and produced "on-site" from nearby sources in the other two. The latter jobs had man-hour requirements of 101 and 89 per $ 1,000 of contract amount, as compared with 52 on the former.

The range of on-site labor requirements among the dredging projects was extreme and the apparent reasons deserve special comment.

On a physical unit basis, a wide range in requirements for dredging as a whole would be expected because of differences in the type of materials to be removed and methods to be employed. Thus, in the present study, man-hours per 1,000 cubic yards averaged 40 for hydraulic dredging, 143 for bucket and scow dredging in soft material, and 572 for ledge rock removal where blasting was required. Moreover, even within one of these broad types, labor requirements per physical unit may vary substantially because of distance from disposal area, amount and kind of shore work, if any, and other site conditions.

These factors, however, cannot explain wide variations in man-hour requirements per $ 1,000 of contract amount, since these known conditions would for the most part be reflected in that contract amount. Discussions with individuals familiar with the industry have indicated that the apparent range in labor requirements arises from two factors (neither of which was the subject of direct examination in the current study), profit margins, and depreciation allowances on the individual sample projects. Profit margins tend to be extremely erratic in the dredging industry because of competitive conditions existing at the time of bidding, and because of the virtual impossibility of predicting either the materials or other conditions to be encountered under water, or the weather which may prevail. In addition, nominal profit margins are affected by the amount of depreciation writeoff, the practices for which vary widely from company to company. Therefore, $ 1,000 of contract amount may represent widely different elements on different jobs, with labor costs a relatively large or small portion of it. To illustrate, a contract concluded at a thin profit margin, with depreciation charges relatively small (possibly because the contractor considered his dredge fully depreciated), which encounters difficulty at the job site, would probably show a large labor cost percentage.

Distribution of On-Site Man-Hours

Land projects. The distribution by principal occupation of man-hours worked on construction of the land projects shows a pattern strongly oriented to mechanized earthmoving. (See table 1.) The operation, repair, and maintenance and servicing of heavy equipment, represented respectively by "operating engineers," "mechanics and welders," and "oilers and greasers" accounted for over a third of total man-hours. In addition, "truckdrivers," who were principally engaged in heavy earth and rock hauling both on and off highways, accounted for 14 percent.

Table 1. Corps of Engineers Civil Works: On-site man-hours, by occupation, land projects

Occupation	On-site man-hours	
	Man-hours per $ 1,000 of contract	Percent of total man-hours
All occupations	84.7	100.0
Superintendents, general foremen	5.9	6.9
Field office personnel	1.5	1.8
Civil engineers and other technical	1.2	1.4
Operating engineers	20.4	24.1
Equipment mechanics and welders	4.0	4.8
Carpenters	5.4	6.4
Reinforcing, structural, and ornamental iron workers	2.6	3.1
Cement finishers	1.0	1.1
Other building trades	.2	.2
Truckdrivers	11.8	14.0
Oilers and greasers	6.5	7.7
Hand tool operators	1.7	2.0
Helpers and tenders	.8	.9
Powdermen and blasters	.5	.6
Labor foremen	.7	.8
Laborers	18.7	22.1
Deck hands	.8	.9
Watchmen, flagmen	.4	.5
All other	.6	.7

Data on the type of equipment operated were available for over three-quarters of the man-hours of operating engineers, as follows:

Type of equipment	Percent of classifiable operators' man-hours
Total	100
Bulldozer	33
Dragline	10
Shovel	8
Crane	8
Scraper	10
Grader	6
Drilling machines	5
Compressors and pumps	4
Tractors (attachments, if any, not specified)	3
Miscellaneous marine equipment	4
All other	9

Operators of bulldozers accounted for a third of all equipment operators' man-hours. Operators of draglines, shovels, and cranes, together accounted for slightly more than a fourth of all operators' time. These three machines are usually considered as a group because of their basic similarity.

Skilled trades not directly associated with heavy equipment operations were principally those required in concrete construction--carpenters, reinforcing iron workers, and cement finishers. Less skilled occupations not previously mentioned were predominately those involved in rock dynamiting--drillers (tabulated in "hand tool operators"), chuck tenders (in "helpers and tenders"), and "powdermen and blasters."

Dredging. Dredging operations required a large proportion of employment in occupations usually associated with maritime rather than with construction activities (table 2). These occupations include, among others, ship master, marine engineer, and deckhand.

Table 2. Corps of Engineers Civil Works: On-site man-hours, by occupation, dredging projects

Occupation	On-site man-hours	
	Man-hours per $ 1,000 of contract	Percent of total man-hours
All occupations	133.9	100.0
Superintendents, general foremen	3.0	2.2
Site office personnel	1.3	1.0
Civil engineers and other technical	2.0	1.5
Masters, captains, and mates	15.0	11.2
Marine engineers	9.9	7.4
Small vessel operators	8.0	6.0
Levermen	8.6	6.4
Welders, mechanics, and "handymen"	6.2	4.6
Drillers (drillboat)	1.4	1.1
Blasters	.7	.6
Heavy shore equipment operators	1.5	1.1
Stewards, cooks and messmen	6.7	5.0
Oilers	8.0	6.0
Firemen	3.1	2.3
Helpers and tenders	2.3	1.7
Truckdrivers	.4	.3
Labor foremen	2.3	1.7
Deckhands, scowmen	32.2	24.0
Shoremen, pipeline laborers	21.0	15.7
Other	.3	.2

The largest percentage of skilled workers' hours were those of the dredge and tug officers--the deck contingent of masters, captains, and mates, and the chief engineer and his assistants in the engine room. Dredge captains perform general supervisory duties on some projects; this accounts in part for the smaller proportion of hours for "superintendents, general foremen" in dredging than in land jobs. Hours worked by employees in command of smaller craft are shown separately in the category "small vessel

operators." These small vessels are of a size not requiring licensed marine personnel; they are utilized to supply and service the dredge, to transport personnel, and to move and service the discharge pipelines, etc.

The category "levermen" covers the employees most directly concerned with the actual dredging operations. These workers manipulate the controls which activate the dredging mechanism, whether it be a cutterhead on a hydraulic dredge, or the boom and bucket of a clamshell dredge. These are the key men in the dredging operations, to whom other workers are supportive.

A substantial number of skilled worker hours were accounted for by the welders, mechanics and "handymen" group--the group responsible for the maintenance and repair of the dredge, its machinery, and pipelines. The term "handyman" is not a catchall designation in the dredging operation, but the name for a specific repair occupation.

Other skilled worker hours were accounted for chiefly by the drillers and blasters, who were engaged in loosening ledge rock on the two jobs which required rock removal, and by the operators of heavy equipment ashore. This latter equipment included primarily draglines and bulldozers for building dikes and spillways to confine and drain the spoil area, and level the fill.

A significant proportion of hours were worked by the stewards, cooks, and messmen who prepare and serve the meals provided the dredge workers, at about a dollar or two a day. In a division of man-hours for dredging operations between production and nonproduction categories, these hours should be included in the latter. Among production workers of intermediate skills, marine oilers and firemen, and drillers' helpers predominated.

The largest percentage of man-hours--over half--of workers in the unskilled category were worked by the deckhands and scowmen--the laborers on the dredges and attendant floating plant. However, over a third of the hours in this category were worked by the shore laborers. These are the workers who install and shift the discharge pipeline, maintain the confining levees, and do other tasks in the disposal area. The shore crews can vary greatly in size depending on the length of pipeline, the requirements of the fill, etc.

Apprentices. Employment of apprentices is relatively negligible in the type of projects under study, if only those who participate in formal, registered apprenticeship programs are included. In the present study, apprenticeship man-hours accounted for less than 1 percent of the total man-hours worked on the land projects; and for none of the hours worked on dredging.

The skills of most of the higher paid workers on the land jobs under study were acquired by informal on-the-job training, as with heavy equipment operation and repair, where formal apprenticeship programs are just

evolving.[5] On the dredging jobs, the maritime skills are acquired through the work and study programs leading to progressively higher grade marine licenses.

The few formal apprentices in the subject study were those in the traditional programs of the building trades, particularly in carpentry and ironworking.

Overtime. Overtime hours (i.e., those hours paid for at premium rates) have a considerable effect on the total wage cost of the type of projects covered in this study.[6] Overtime hours constituted 15 percent of the total number of man-hours worked on the land contracts, and 25 percent of the man-hours worked on the dredging projects. For individual projects, overtime ranged from 1 to 34 percent on land jobs, and from 17 to 34 percent on dredging jobs.

The reasons for the extensive overtime inhere in the nature of the work under study. Modern earthmoving and allied operations are heavily mechanized and the economical operation of the costly equipment requires that it be used intensively. These operations, moreover, are performed almost entirely in the open and thus subject to interruption by bad weather, high water, etc. It is therefore advantageous to make the best use of favorable conditions.

For these reasons, scheduled hours of work tend to be much longer in these heavy construction projects than in building construction. Ten-hour days for 6 days a week are common in land operations during ideal conditions, and 7-day weeks are not infrequent. In dredging, hours tend to be even longer, since dredges usually operate continuously once they commence work at the site. Although in the dredging projects surveyed, provisions were occasionally made for staggering shifts so that workers had at least 1 day off a week, 7-day weeks were equally common, and scheduled hours as high as 84 a week were noted.

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[5] National apprenticeship standards for heavy equipment operating engineers and mechanics were not established until 1963 (by the Associated General Contractors, the National Constructors Association, and the International Union of Operating Engineers).

[6] If all time worked on the sample projects had been paid for at straight-time rates only, without overtime premiums, the percent of total contract cost paid in on-site wages would have been reduced from 26 to 24 on the land projects, and from 32 to 29 on the dredging projects. Average hourly earnings would have been reduced from $3.07 to $2.86 on land projects, and from $2.41 to $2.14 on dredging projects.

Construction Time

Land jobs covered in the study required an average of about 48 weeks to complete; construction time on individual projects ranged from 9 to 129 weeks. Corresponding figures for the dredging projects were an average of 29 weeks and a range of 8 to 68 weeks. These figures cover the total elapsed period from the start of operations at the site until substantial completion of the contract. They do not cover the period of mobilization and demobilization--the marshaling of equipment to the construction site--nor callbacks for remedial work after substantial completion. On the other hand, they do include periods during the course of the construction when, for various reasons, no work was performed.

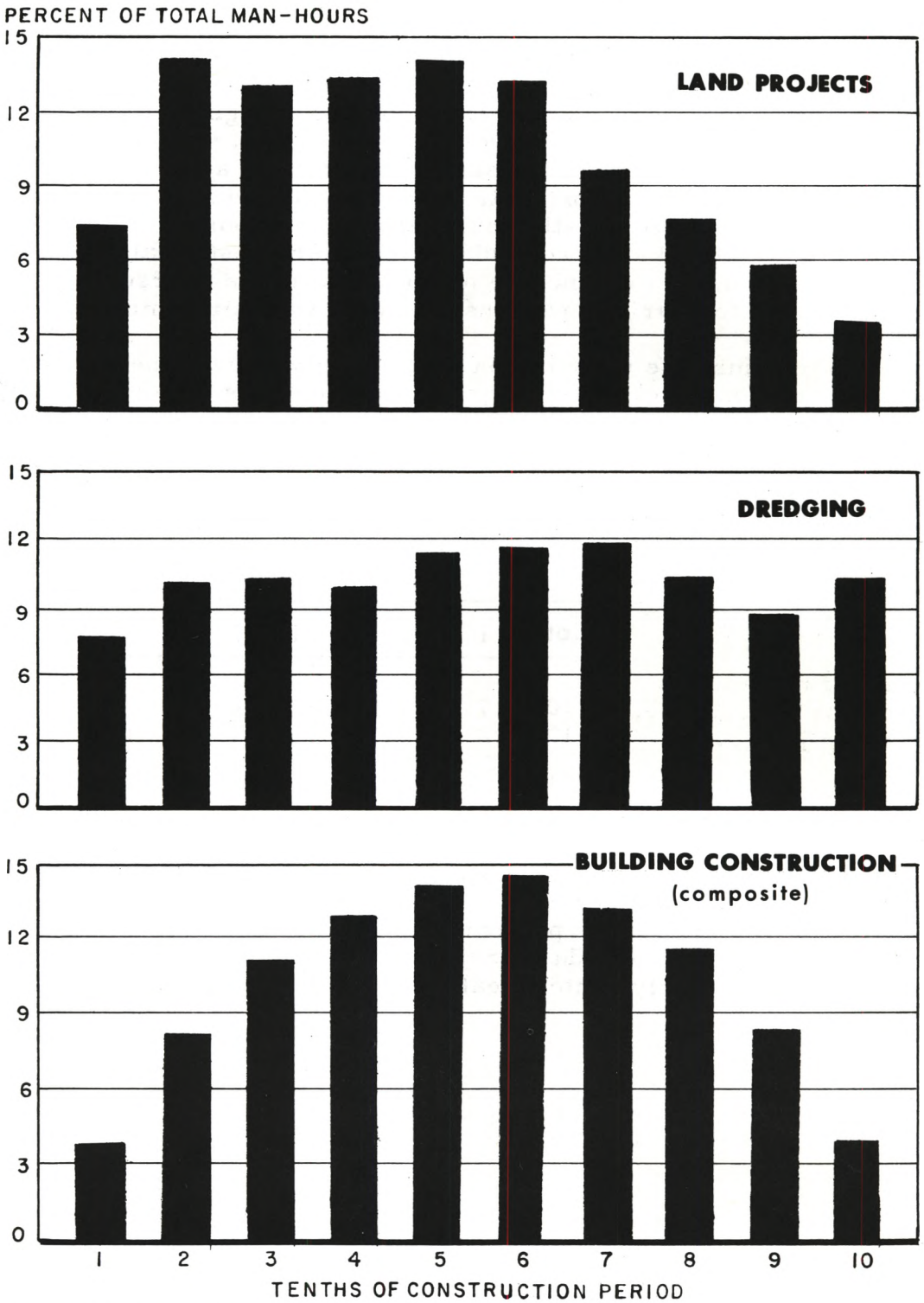
To measure the distribution of employment over the period of construction, the construction time for each project was divided into 10 equal intervals, and data were tabulated on the number of man-hours worked in each interval. This permitted the combination of man-hours for projects of various sizes in order to obtain typical employment patterns. The results for the two major groups of projects are as follows:

	Tenths of construction period									
	Total	1	2	3	4	5	6	7	8	9	10
Percent of man-hours											
Land jobs	100	7	14	13	13	14	13	9	8	6	3
Dredging jobs	100	8	10	10	10	11	11	11	10	9	10

Neither group shows the tendency noticed in the construction of buildings for employment to build up steadily to a peak in the fifth or sixth interval and then to decline. The dredging group, in particular, shows the uniform distribution which might be expected of a relatively uncomplicated type of work. Both of these patterns, however, conceal very erratic distributions of work on individual projects, caused most frequently by weather conditions, particularly winter weather in the north and high water in the south.

Chart 2.

Percent of total on-site man-hours worked in each tenth of construction period, Corps of Engineers land projects and dredging, compared with building construction



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Off-Site Employment

For each man-hour of work performed at the site of construction of these projects, an additional 1.4 man-hours of work for land operations, or 0.7 for dredging, were required to produce and distribute the necessary construction materials, supplies, and equipment used at the site. Off-site employment is generated in many places, but may be classified in the broad industry divisions shown under "off-site" in the tabulation on page 3 and discussed below.

Construction industry. Employment in the contractors' home offices, shops and yards (possibly including, for dredging companies, the lay-up and repair shipyards), and warehouses required about 4 man-hours per $ 1,000 of contract amount on land projects, and about 10 man-hours on dredging projects. An exact study of this employment was not attempted since it was not possible to separate the requirements for a specific project from the other projects in a contractor's program; the man-hours were, therefore, estimated as in previous studies.

Manufacturing. Manufacture of the materials, supplies, and construction equipment used in the projects studied required a total of 53 man-hours per $ 1,000 in the land projects and 47 in dredging. These man-hours covered requirements for the manufacture of all materials, supplies, and equipment (including both construction equipment depreciated in the construction process, and the equipment built into the projects). These requirements are low relative to those in building construction, because fewer highly fabricated materials are used, and certain of the most common of the commodities consumed, such as cement and petroleum products, require a low labor input.

Trade, transportation, and services. The man-hour requirements for these activities were, respectively, 47 and 24 per $ 1,000 for land operations and dredging. They represent employment in the industries involved in the distribution of materials, supplies, and equipment, and in miscellaneous service industries. Included are wholesale and retail trade, warehousing, all types of common carriers, and provision of such services as financing and insurance. These requirements are high for the land operations as compared with dredging, and as compared with building construction, because of the relatively high cost of transporting the heavy, bulky, and comparatively unfabricated materials such as stone, sand and gravel, cement, and petroleum products which are important in heavy engineering projects.

Mining. Requirements in the mining industry for the civil works contracts studied were 13 man-hours per $ 1,000 for the land projects and 6 for dredging. In the latter, as in most construction, virtually all of these hours represent the extraction of basic minerals and crude oil subsequently processed into materials, equipment, and supplies used at the site. For the

land operations, however, more than half of the mining requirements reflect the stone, sand, and gravel purchased for use directly at the site. (Production of materials by the contractor as part of his construction operations is included with on-site requirements.)

Other industries. Requirements in all other industries were 6 man-hours per $1,000 for land operations and 3 for dredging. These were mainly in agricultural and forest activities.

Purchased Materials and Supplies

Land Projects

Materials and supplies purchased for the land projects accounted for 35 percent of the total cost of these contracts. This percentage does not include charges for equipment depreciation, which are elsewhere treated, but does cover supplies used in the operation of the equipment. Supplies in general (i.e., all those commodities which are not physically incorporated into the structures, but which are consumed in the construction process) accounted for a much larger portion of purchases--about a third--in these projects than in building construction. On the other hand, purchased materials do not represent the total value of materials incorporated in the structures, since a substantial quantity of materials were produced at the site by the contractors' work force. Although the supplies and equipment which were required for these contractor-produced materials are represented in this and the following sections, the labor required is covered in the sections for on-site man-hours.

The dollars-and-cents cost of the major purchased items of materials and supplies per $ 1,000 of contract amount is shown in table 3. These costs may be readily converted to percentages by shifting the decimal point one place to the left. Thus, the $ 350 cost of total purchased materials and supplies per $ 1,000 of contract equals 35 percent of contract cost.

Most of the dollar cost of the purchased materials and supplies is in items of a relatively low degree of fabrication. The largest single category, for example, is broken and crushed stone, which accounted for over 7 percent of contract amount. Broken stone predominated in this category; it was extensively used in the protection of river banks against erosion, either by itself merely dumped in place, or used to weight a lumber "mattress." This purchased stone by no means represented the total use of stone as a material--it was produced on site as the fill for a jetty system, and in another case, rock removed in a major spillway excavation was the fill in portions of the related dam.

Half of the fabricated metal products group is represented by the reinforcing steel used in concrete construction. Such construction accounts for many of the materials listed in the table, including sand and gravel (concrete aggregate), cement, ready-mixed concrete, lumber (form building), chemical products (hardeners, curing compounds), and rubber products (waterstops).

Fuel (gasoline and diesel oil) and lubricants required for the operation of construction equipment, including trucks, constituted about 95 percent of the petroleum products used. Asphalt and other bituminous materials used in paving roads and river banks made up virtually all of the remainder.

Table 3. Corps of Engineers Civil Works: Materials and supplies, land and dredging projects

Type of material or supply	Amount per $ 1,000 of contract
Land projects, total	$ 350.50
Stone, sand, and gravel	94.70
Broken and crushed stone	71.20
Sand and gravel	23.50
Fabricated metal products	76.20
Reinforcing steel	37.90
Gates, water control (flood, spillway, etc.)	15.10
Small tools	6.60
Structural steel	4.60
Pipe	4.00
Fencing	2.40
Railing	1.60
Other fabricated metal products	4.00
Petroleum products	68.60
Fuel and lubricants (equipment)	64.70
Bituminous paving materials	3.70
Other petroleum products	.20
Cement, concrete and related products	49.30
Cement	31.70
Ready-mixed concrete	9.40
Concrete products	7.50
Miscellaneous clay, cement, and glass products	.70
Wood products	22.50
Rough and dressed lumber and timber	10.90
Piling, treated	7.00
Piling, untreated	3.60
Other wood products	1.00
Chemical products	21.00
Explosives	19.50
Other chemical products	1.50

Table 3. Corps of Engineers Civil Works: Materials and supplies, land and dredging projects--Continued

Type of material or supply	Amount per $ 1,000 of contract
Rubber products	$ 9.00
Tires and tubes (equipment)	7.20
Other rubber products	1.80
All other products	9.20
Machinery	3.20
Miscellaneous primary metal products	2.60
Miscellaneous electrical equipment and supplies	1.30
Other and unspecified	2.10
Dredging projects, total	173.20
Petroleum products	118.50
Rope (wire and hemp)	20.20
Dynamite and caps	16.60
Small tools	6.30
Drill bits	5.90
Other	5.70

The distribution of products in the cement, concrete, and related products category reflects characteristics of the type of construction under study. In programs of building construction, the value of purchased ready-mixed concrete greatly exceeds that of cement. The reverse is true in the civil works projects studied, because the size and remote location of many of the projects makes the on-site production of concrete advantageous. The third most important item in this general category--concrete products--represents concrete piling.

The wood products purchases, which accounted for about 2 percent of the contract amount, included a very minor amount of fabricated products. Ninety-five percent of the category was about equally divided between lumber and piling. The lumber and timber was used partly as a supply, in concrete form work and shoring, and partly as material, in bank protection "mattress" construction.

Chemical products which, except for paints, are a negligible factor in most construction costs were significant in the program under study because of the use of explosives--dynamite and blasting caps. These are required to fragment rock in excavation and quarrying operations. Similarly, rubber products, not usually significant in construction, accounted for about 1 percent of the contract amount, principally because of the tires and tubes required for the operation of trucks and some other wheeled equipment.

Dredging Projects

Virtually no materials are required for dredging jobs. At least 98 percent of purchases for the projects studied was for supplies, particularly for petroleum products--the fuel and lubricants required for operating the dredges and their attendant plant. Most of the remaining purchases were for the dynamite and caps used in loosening ledge rock, and for rope. The purchase of food and other subsistence items is not included in these figures. A loss on commissary service is expected in dredge operation, the nominal deductions for meals being less than the costs of providing them; this loss is reflected in overhead expenses.

Equipment Depreciation

In contrast to building construction, the cost of owning and operating construction equipment in the type of projects under study is substantial. Operating costs have been largely reflected in other sections of the report; e.g., the operators' wages in the on-site wage section, and the cost of fuel and lubricants in the petroleum products category of the materials and supplies list above. This section is concerned with the cost of owning equipment.

The principal such cost is depreciation, reflecting equipment wear and obsolescence. The exact amount of depreciation attributable to a specific project is extremely difficult to determine; at best, it is usually an estimate calculated from some type of formula. In the present study, depreciation charges were derived from the contract cost estimates developed by the Corps of Engineers, as described in the section on Scope and Method. The estimates do not relate to the specific items of equipment actually used in the construction of the projects, but they have the advantage of uniformity in approach. This probably would not have been the case had the estimates been obtained from the contractors, whose accounting procedures vary considerably. Therefore, the figures given in this section cannot be considered more than a rough approximation of the cost of depreciation of equipment.

For all projects other than dredging, the depreciation costs for contractor-owned equipment were estimated to be $192 for each $1,000 of contract amount. This figure includes an estimate for the value of the repair parts required for the field repair and major overhaul of the equipment, but does not include other costs of ownership such as insurance, taxes, and interest on investment, nor the cost of equipment used in services purchased by the contractor. These latter are included in overhead expenses.

A distribution of these costs indicates that trucks accounted for about one-third of total equipment costs, and that the bulldozer-tractor and shovel-dragline-crane groups each accounted for about a fifth.

Type of equipment, land projects	Estimated amount of depreciation expense per $1,000 of contract
Total	$192
Trucks	68
Bulldozers	31
Tractors	8
Shovels	18
Draglines	10
Cranes	11
All other	46

On dredging projects, the equipment depreciation was estimated at $249 for each $1,000 of contract. This higher level, as compared with the land projects, reflects in part the fact that virtually no expenditures for materials are required for dredging projects. About half of this total may be attributed to the dredge itself, and about a fifth each to the dredge's attendant floating plant--the tugs, launches, barges, and scows which service the dredge--and the pipe, pontoons, and fittings which make up the discharge pipeline. Shore equipment, primarily draglines and dozers, accounted for most of the remainder.

Type of equipment, dredging projects	Estimated amount of depreciation expense per $1,000 of contract
Total	$249
Dredges	128
Attendant floating plant	48
Pipeline	52
All other	21

It should again be emphasized that these costs may not be the same as the actual depreciation provisions made by the contractors for the projects studied. These costs were summarized from estimates by Corps of Engineers District officials based on assumptions as to type, age, and other data about the plant available for each of the sample projects. In practice, contracts may be awarded on bids which contain little or no provision for depreciation, either because the contractor considered his equipment "fully written off" or because he had special reasons for seeking the contract. The figures, therefore, are hardly more than an indication of the magnitude of the equipment depreciation element in this type of work.

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