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COST ESTIMATING METHODOLOGY FOR ONCE-THROUGH COOLING WATER DISCHARGE MODIFICATIONS

by

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ABSTRACT

This manual presents a methodology for evaluating the engineering and cost implications of constructing or modifying once-through cooling water discharge systems of thermal electric generating plants within the contiguous United States. The procedures presented provide persons not skilled in cost engineering with a means of preparing preliminary cost estimates from conceptual or design drawings. The user should, however, have a technical background and be familiar with once-through cooling water discharge systems.

Principal construction elements of discharge system construction and modification are identified and grouped into categories. Materials and installation methods are discussed for each construction element. Data on labor, materials, equipment, and productivity assumed in unit cost development is provided. A step-by-step procedure is given for: (1) estimation of construction costs; and (2) resolution of construction costs into project and annual costs.

An example is shown using the methodology and comparing result with actual construction costs for modifications to an existing discharge system.

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SECTION I

CONCLUSIONS

This manual enables a person not expertly skilled in cost engineering to prepare a reasonably accurate estimate of the costs for new once-through cooling water discharge systems for thermal electric generating plants and for modifications to existing once-through discharge systems. Table 1 presents four cases of modifications to existing discharge systems and compares actual construction costs and estimates prepared using traditional, more detailed procedures to cost estimates prepared using the methodology in this manual. The results obtained using this manual compare very favorably with the actual construction costs and estimates shown, demonstrating that this manual provides a relatively easy means of preparing a reliable preliminary cost estimate or testing the accuracy of another cost estimate.

Table 1. COMPARISON OF RESULTS[a]

Plant	Estimated Cost, Millions of Dollars: Manual	Estimated Cost, Millions of Dollars: Actual Construction Cost or Estimate	Percentage Difference
Quad Cities	8.9	9.2	4
Nine Mile Point No. 1	6.1	5.7	6
Dresden	.12	.12	-
North Port			
Onshore	6.6	6.6	-
Offshore	14	15	9

[a]See Appendix A for an example of the derivation of the data presented.

SECTION II

INTRODUCTION

GENERAL

This manual presents a methodology for evaluating the engineering and cost implications of constructing or modifying once-through cooling water discharge systems of thermal electric generating plants within the contiguous United States. The procedures presented provide persons not skilled in cost engineering with a means of preparing preliminary cost estimates from conceptual or design drawings. The user should, however, have a technical background and be familiar with once-through cooling water discharge systems.

Principal construction elements of discharge system construction and modification are identified and grouped into categories. Materials and installation methods are discussed for each construction element. Data on labor, materials, equipment, and productivity assumed in unit cost development are provided. A step-by-step procedure is given for:

1. estimation of construction costs and
2. resolution of construction costs into project and annual costs.

An example is shown using the methodology and comparing results with actual construction costs for modifications to an existing system.

DISCHARGE SYSTEMS AND POSSIBLE MODIFICATIONS

Discharge systems

For the purposes of this manual, once-through cooling water discharge systems are classified into two categories: surface discharge and submerged discharge.

The surface discharge category includes two distinct types of outfalls distinguished by geometry and discharge velocity:

1. open channel, characterized by a low velocity discharge from an open channel into the receiving water at or close to the shoreline (see Figure 1); and
2. surface jet, characterized by a high velocity discharge from a conduit at or near the surface of the receiving water (see Figure 1).

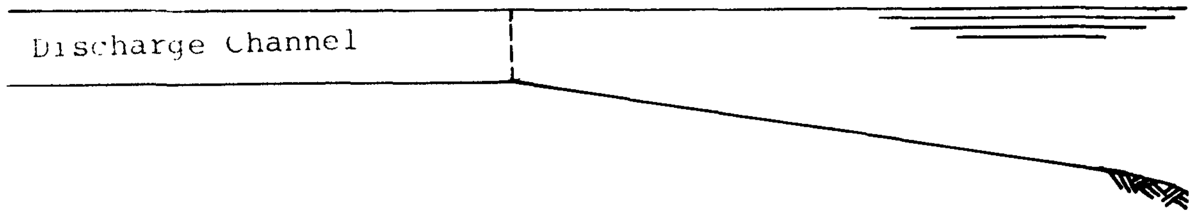
The submerged discharge category also includes two types of outfalls:

1. single port, consisting of the open end of a conduit or other point source discharging beneath the water surface (see Figure 2); and
2. multiport diffuser, consisting of a number of ports or slots arranged along a manifold and discharging at some depth below the water surface (see Figure 2).

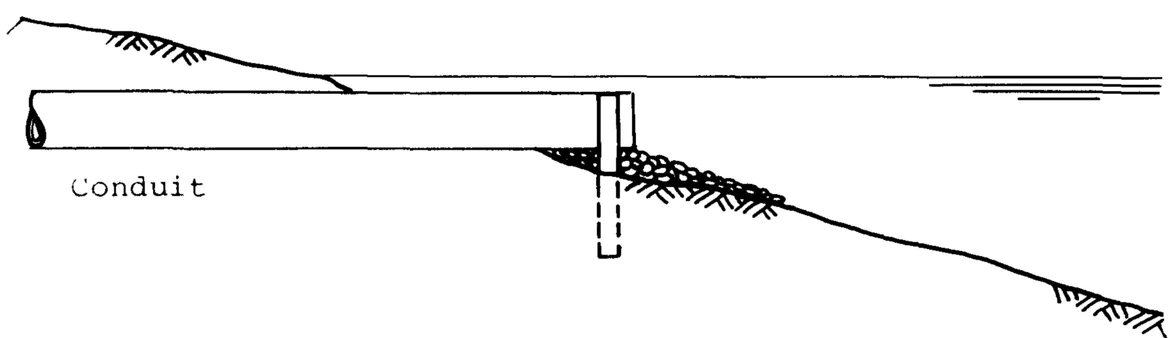
Discharge modifications

The four basic types of once-through cooling water discharge systems and possible modifications thereof are shown in Figure 3 and discussed briefly below:

1. Surface discharge open channel - Possible modifications include:
   a. Surface discharge open channel (improved) - Increase channel width and install a weir to spread and thin the thermal plume.

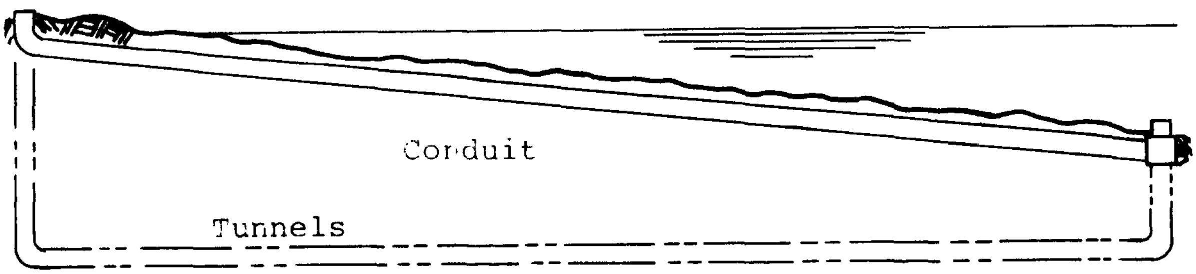


OPEN CHANNEL

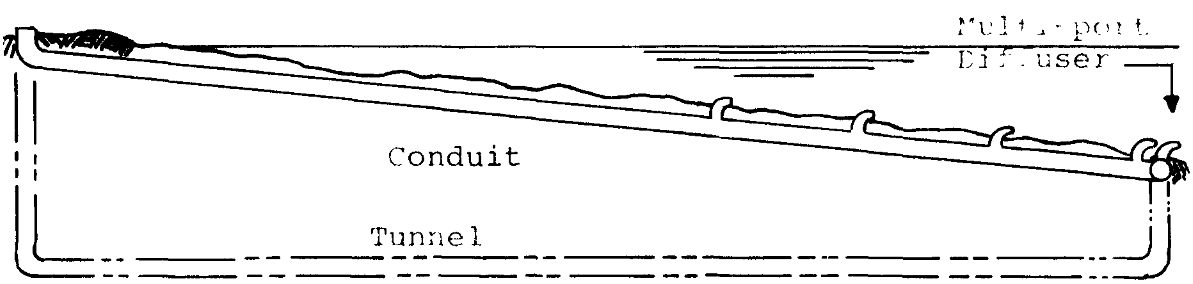


SURFACE JET

Fig. 1 - Surface Discharges



SINGLE PORT DISCHARGE



MULTIPORT DISCHARGE

Fig. 2 - Submerged Discharges

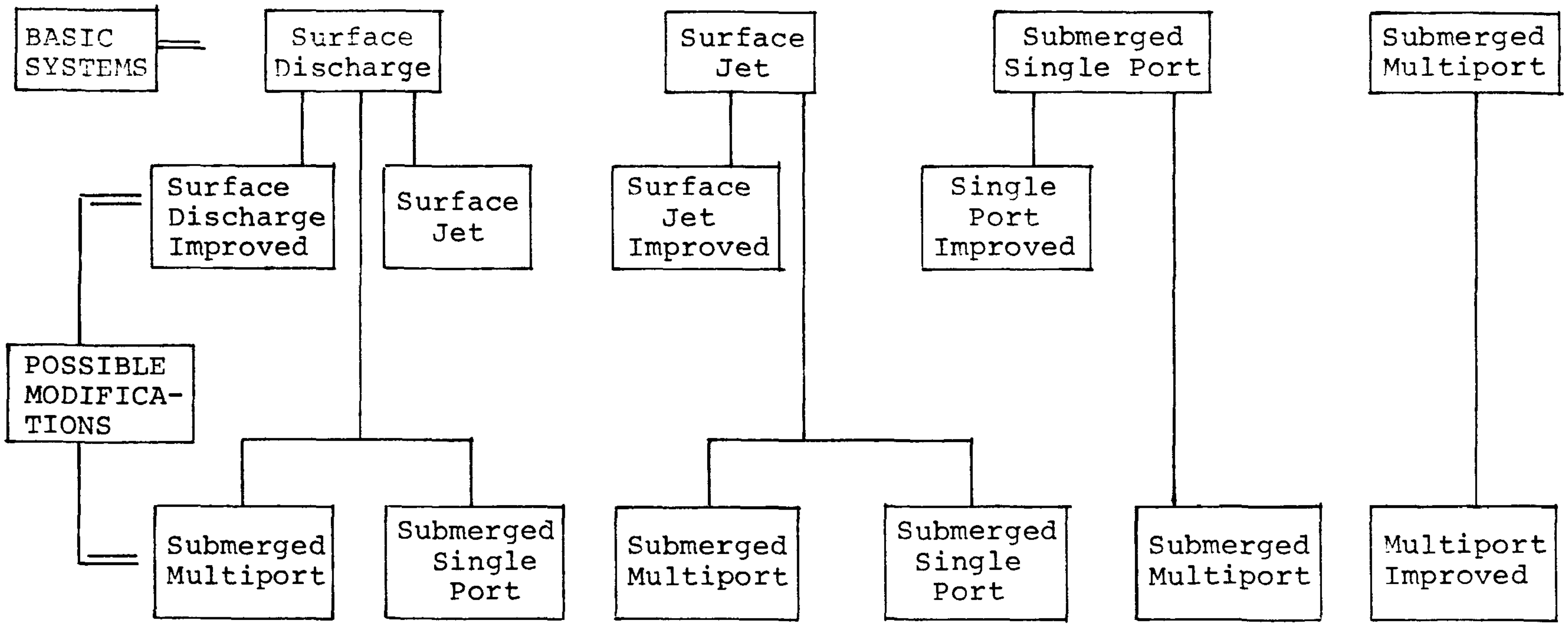


Fig. 3 - Once-Through Basic Discharge Systems and Possible Modifications

b. Surface jet - Close off the open channel, install a conduit with an outfall located near the water surface and shoreline.

c. Submerged single port - Close off the open channel, pump the heated effluent via a conduit or tunnel to a submerged outfall offshore.

d. Submerged multiport - Close the open channel, pump the heated effluent via conduit or tunnel and discharge the water through a submerged multiport diffuser.

2. Surface jet - Possible modifications include:

   a. Surface jet (improved) - Attach a reducer to the end of the conduit to increase discharge velocity at the outfall.

   b. Submerged single port - Extend a conduit or tunnel to a submerged offshore point source outlet.

   c. Submerged multiport - Extend a conduit or tunnel to an offshore submerged location and discharge the heated effluent via a multiport diffuser.

3. Submerged single port - Possible modifications include:

   a. Submerged single port (improved) - Increase the outfall submergence depth by extending the tunnel or conduit into deeper water further from shore.

   b. Submerged multiport - Attach a multiport diffuser at the existing outfall point.

4. Submerged multiport - Possible modifications include changing the diffuser angle of discharge with respect to prevailing currents or changing the discharge angle, spacing, number, and diameter of individual nozzles.

Other types of discharge arrangements are used in once-through cooling water systems, including modified spray ponds and cooling ponds. In these systems, heated water is cooled by evaporation from ponds prior to discharge into the receiving water via one of the systems discussed above. The methodology in this manual can be used to estimate costs for such cooling and spray ponds.

ECONOMIC ANALYSIS - IMPORTANT ENGINEERING AND ECONOMIC CONSIDERATIONS

Engineering considerations

The reader should be aware that the scope of this manual is limited to the discharge system downstream of the condenser. Therefore, engineering considerations for modifications to existing systems assume flow rate and condenser temperature rise to remain unchanged.

Discharge system modifications are generally of three types:

1. changes in outfall geometry;
2. changes in orientation of the discharge relative to predominant ambient currents; or
3. increases in the submergence of the outfall.

Key engineering factors involved in discharge system construction and modification are discussed below.

1. Site preparation - Preconstruction and postconstruction site work includes:
    a. clearing trees and brush from the site;
    b. removal of existing facilities that interfere with construction; and
    c. grading and seeding after construction.
2. Erosion protection - Consideration is given to:
    a. lining the outfall channel to prevent bank erosion due to high discharge velocities;

b. constructing sea walls or bulkheads to protect shorelines from erosion due to waves, tides, or wakes; and

c. providing offshore protection, including riprap at the outfall for scour protection and breakwaters for protection against waves or to prevent recirculation between the discharge and intake.

3. Pumping - Conversion from a gravity system or increasing velocity at the outfall of an existing submerged discharge system increases power requirements which are met by providing a new pump station or by modifying an existing station.

4. Conveyance to discharge point - Site geology and offshore working conditions are primary factors in deciding between a tunnel or conduit to convey cooling water in a submerged discharge system.

5. Outfall configuration - Outfall geometry and orientation and type of diffuser, single port or multiport, are important considerations.

6. Environmental protection - Consideration must be given to control of sediment, dust, turbidity, shock waves, noise, and other pollutants generated as a result of construction. Provisions must be made for disposal of materials such as contaminated sediments excavated from a lake bed and trees cleared from the site. Construction methods and schedules can be adjusted to minimize damage to sensitive ecosystems.

7. Construction methods - Previous experience in the area, site characteristics, and contractor preference will determine construction methods used. Extreme variability in methods exists in the area between the shoreline and one-half mile offshore.

8. Location - Hydrology, geology, and regional and local weather conditions significantly affect the factors listed. For example, productivity in offshore excavation is dependent on weather, bottom conditions, distance to safe harbor, and depth of water.

Economic considerations

Within the discharge system requirements imposed by environmental factors and the limitations of engineering practicability, economic considerations are the ultimate determinant of final design features. Both total project (first) costs and annual costs are evaluated.

Total project costs include engineering and design, lands, construction, supervision and administration, interest during construction, and contingencies. These costs are sensitive to several factors that must be considered, including site specific conditions and construction materials, methods, and management.

Annual costs include amortization of depreciable and nondepreciable capital investments, interest on bonds, taxes, insurance, and operating expenses. The annual cost figure is sensitive to any changes in initial investment costs and interest rates and to increased power requirements resulting from a discharge system modification.

Generally, project costs for a submerged discharge system are higher than for a surface discharge system, primarily because of greater expenses for offshore and tunnel construction and because of the need for more materials at higher unit prices, for example, large diameter conduit. Annual costs are also higher with a submerged discharge system, partly because of the greater initial investment, but also reflecting increased operating costs due to the need for pumping stations.

ORGANIZATION

The manual is comprised of seven main sections, including two appendices:

Section I - Conclusions
Section II - Introduction

A general discussion of the general types of once-through discharge systems and the engineering and economic considerations used in system selection. Possible modifications to existing once-through discharge systems are discussed.

Section III - Approach

A general discussion of procedures, assumptions, and bases for data presented in the methodology. Price levels, contractor markup, unit costs, and categories of construction elements are also discussed.

Section IV - Methodology

A step-by-step procedure for use of the manual, including comments on interpretation of results. Technical and cost data are given for each significant element involved in new construction and system modification.

Section V - References
Section VI - Conversion Tables
Section VII - Appendices

Appendix A - Case Study
An example showing application of procedures in manual to an actual case of discharge system modification. The results obtained using the methodology are compared with actual construction costs.

Appendix B - Unit Cost Data
Background data for unit costs used in this manual.

SECTION III

APPROACH

GENERAL

The basic step-by-step approach for using this manual to cost out new once-through discharge systems or modifications to existing once-through discharge systems is as follows:

Step 1

Select the desired system or modification either on the basis of information in this manual or other considerations.

Step 2

Prepare or otherwise obtain conceptual or detailed drawings of the proposed system or modification. Cost estimate accuracy depends largely on the accuracy and amount of detail in these drawings which, in turn, depend on the study phase and availability of site information. The reader should note that although the information presented in this manual may be useful in system selection, system design is not within the scope of this manual.

Step 3

From the drawings, calculate the quantities specified in the methodology and worksheets provided with this manual.

Detail and accuracy of quantity take-offs should reflect the desired accuracy of the cost estimate, but be consistent with the detail and accuracy of the drawings.

Step 4

Derive project and annual costs for the proposed system or modification by following the procedures recommended in this manual and applying the appropriate cost factors and curves.

The manual is organized into eleven cost categories. Categories 1 - 10 give unit cost data and a procedure for estimating construction costs. Data for adjusting construction costs for region and time and for calculating annual costs are given in Category 11. Definition of the categories and the elements of each category, cost accounts, are given in Section IV.

TECHNICAL DATA

Engineering information on once-through discharge systems, including system components, design features and rules-of-thumb, and construction practices and phases, was compiled from the following sources:

1. Analyses of existing discharge system designs
2. Contacts with engineers in the power utility industry
3. Contacts with capital equipment manufacturers
4. Contacts with civil contractors
5. Company experience.

COST DATA

Unit costs shown in this manual were developed on the basis of December 1974 labor rates in the New York City area and capital equipment and material prices and construction equipment rates in the northeast part of the country. Results are adjusted in Cost Category 11 for price levels in the region and at the date of interest.

Unit costs for construction activities in Cost Categories 1 through 4 and 6 through 9 were developed using the following five-step process:

1. Determine or assume site conditions
2. Select the appropriate labor force and equipment pool
3. Select labor and equipment rates
4. Assume a productivity and calculate the unit cost
5. Add material unit costs where necessary to determine the total unit cost.

Information from several sources was considered during the unit cost analysis:

1. Civil contractors were contacted with regard to unit costs and labor and equipment requirements for specific construction activities
2. Published cost data books were reviewed for construction material costs and labor and equipment rates (see References 1, 2, 3, and 4)
3. Manufacturers were contacted for capital equipment and material costs
4. Power utilities were consulted to determine actual costs of cooling water discharge systems
5. Bid estimates from over 300 contracts in the Engineering News Record were surveyed for civil construction unit cost data to compare with the unit costs developed for use in this manual.

Contractor equipment costs for operation, maintenance, replacement, overhead, and profit were found to agree closely with equipment rental fees compiled by the Associated Equipment Distributors (Reference 1) plus a markup of 10 percent. Therefore, for simplicity, the latter method was used in the development of unit costs for this manual.

It was assumed that capital equipment and materials are provided by the contractor. The unit cost analysis used manufacturer-quoted prices for capital equipment (such as pumps) and some materials (such as conduit). Costs for construction materials (such as riprap) were derived from cost data books and civil contractors. Capital equipment and material prices were marked up 15 percent for contractor overhead and profit.

Labor rates are those recommended in Reference 3 with a markup of 40 percent for overhead and profit.

The unit cost data for Cost Category 5, Tunnels, were developed from Robert S. Mayo and Associates in Reference 5 and the Corps of Engineers in Reference 6.

Mobilization and demobilization costs are not included as part of the unit costs developed for Cost Categories 1 through 9. Instead, they are treated as a separate item (in Cost Category 10) which is consistent with current practice for contract bids.

Some of the data required in Cost Category 11 to estimate annual costs must be obtained from local sources (for example, costs for lands, licenses, royalties, fees, rentals, and leases). Potential local sources for this data are identified. Federal Power Commission annual reports, References 7 and 8, give data for the cost of power and cost of capital. The capital cost resolution procedures were adopted from Capital and Operating Costs of Pollution Control Equipment Modules - Volume 1 - User Guide (Reference 9).

Labor and equipment costs, production rates, and material costs used to develop unit costs for categories 1 through 4 and 6 through 9 are tabulated in Appendix B.

The relationship between quantity and installation unit cost is dependent largely on mobilization and demobilization costs and the size of the equipment required on the job site. Equipment selection, as it relates to job size, is given in Appendix B and mobilization and demobilization costs can be estimated from data in Category 10. Material prices will also vary with the quantity required for the project. Material prices used in this study are averages and may be conservative for very large projects and low for very small projects.

VERIFICATION

To test the validity of the unit cost data and methodology in this manual, cost estimates were prepared for modifications to four existing once-through discharge systems and compared to the actual construction costs or contract bids. The results of the comparison are shown in Table 1.

SECTION IV

METHODOLOGY

COST CATEGORIES

As described briefly in the previous section, the methodology in this manual is based on dividing the construction or modification of a once-through discharge system into eleven cost categories (representing major components and construction phases). The first ten categories reflect major construction phases and design features involved in building and modifying once-through discharge systems. These ten categories are broken down into elemental construction activities and system components. When applying the procedures in this manual to a specific case, quantity take-offs and cost estimates are prepared for each applicable category element. The eleventh cost category includes cost adjustment techniques and procedures to estimate annual costs. The eleven cost categories are as follows:

1. Category 1, Site Preparation - Preparing the site for construction and restoring the site after construction.
2. Category 2, Erosion Protection - Providing shoreline protection, channel lining, and breakwaters constructed of riprap, concrete, and sheet piling.
3. Category 3, Pumps - Modification of existing pump station or installation of new facility.
4. Category 4, Conduits - Materials and installation of various types of conduits.
5. Category 5, Tunnels - Elements of tunneling in consolidated and unconsolidated materials, including excavation, lining, support systems, and dewatering.
6. Category 6, Diffusers - Materials and installation of submerged diffusers.
7. Category 7, Concrete - Material and placement of concrete.

8. Category 8, Fill - Materials, hauling, and placement of earth, gravel, and sand.

9. Category 9, Excavation - Marine and land open-cut excavation; disposal of earth and rock spoil.

10. Category 10, Mobilization - Mobilization and demobilization costs.

11. Category 11, Capital Cost Resolution - Procedures to adjust project costs for region and time; calculation of annual costs, including resolution of project costs and estimation of other annual expenses.

COST ACCOUNTS

Each of the eleven cost categories is broken down into elemental system components and construction activities (called cost accounts). For example, Cost Category 4, Conduits, consists of the cost accounts shown in Table 2.

Cost accounts represent the limit of detail used in this manual for estimating costs. Each cost account is provided with a worksheet giving step-by-step instructions for computing the cost for that particular account. In most cases, the worksheets are similar to that shown in Figure 4, with instructions specifying the design data and quantity take-offs required, the proper unit cost to use or cost graph to refer to, and any cost adjustments that are necessary to compute the final cost for that particular cost account. In some cases, the worksheet instructions direct the reader to use one or more other cost accounts in specified cost categories to compute the cost. Referencing other cost accounts in this manner avoids duplications of cost accounts, such as those involving excavation, which are common to several cost categories.

Table 2. COST ACCOUNTS FOR COST CATEGORY 4

Cost Account Number	Description
401	Precast concrete pipe
402	Cast-in-place box conduit
403.1	Steel conduit
403.2	Steel conduit fittings
404	Corrugated metal pipe
405	Fiberglass pipe
406.1	Onshore excavation of pipe trench
406.2	Onshore pipe laying
406.3	Onshore backfill of pipe trench
406.4	Pipe support systems
406.5	Dewatering
407.1	Offshore excavation of pipe trench
407.2	Offshore pipe laying
407.3	Offshore backfill of pipe trench
407.4	Pipe support systems
407.5	Riprap protection for backfill
407.6	Cofferdam
408	Other
409	Mobilization

Cost accounts and corresponding worksheets and cost graphs are given the same identifying number to avoid any confusion. For example, Cost Account 403.1 uses Worksheet 403.1 and Figure 403.1. Similarly, Cost Account 406.5 uses Worksheet 406.5. However, since this worksheet instructs the reader to use another cost account for the cost computation, a separate figure is not provided for Cost Account 406.5.

Design Data Required

Pipe diameter ____________ m

Wall thickness ____________ cm

With or without stiffeners ____________

Pipe length L = ____________ m

Shop or field fabrication[a] ____________

Base Cost

Enter Figure 403.1, read base unit cost per lineal meter BUC = $ ____________ /m

Base cost = L x BUC BC = $ ____________

Cost Adjustments

Enter Figure 403.1, read design adjustment factors for wall thickness, stiffeners and fabrication

$F_D(1)$ = ____________
$F_D(2)$ = ____________
$F_D(3)$ = ____________

Adjusted Base Cost

Adjusted base cost of materials and fabrication = BC x $F_D(1)$ x $F_D(2)$ x $F_D(3)$ $BC_{403.1}$ = $ ____________

---

[a]For diameters to 3.05 meters, assume shop fabrication.

Fig. 4 - Sample Worksheet - Carbon Steel Pipe, Worksheet 403.1

It is recommended that the reader prepare the cost estimate for a new or modified discharge system by using the cost categories in numerical order. This minimizes the chances for overlooking or, more likely, double-counting certain items. For example, if the reader uses Cost Category 8, Fill, before Cost Category 4, Conduits, he might cost out fill operations involved with conduit installation; and later, when he uses Cost Category 4, he might inadvertently duplicate these same costs.

The reader may find it necessary to use cost accounts more than once. As previously mentioned, this frequently occurs with certain accounts, such as those involving backfill operations, which are common to several construction activities. Multiple use of cost accounts occurs under other circumstances as well, such as changes in conduit diameter or changes in the type of material being tunneled which alter design data input.

STEP-BY-STEP PROCEDURE

The following paragraphs present a step-by-step description of this manual's cost estimating methodology. The procedures described below are those required to complete steps 3 and 4 of the basic approach which were discussed in the previous section. Examples are provided to illustrate the procedures involved; and comments are inserted to aid the reader's understanding and to point out notable exceptions. The general procedures for Cost Categories 1 through 9 are covered in steps 1 through 6 below. It is recommended that the reader complete this entire 6-step sequence for *each cost category before proceeding to the next category* and that the reader handle Cost Categories 1 through 9 in numerical order. Inputs for Categories 10 and 11 are based on results from Categories 1 through 9 and do not follow the general procedures described in steps 1 through 5. Accordingly, the discussion of procedures for Categories 10 and 11 begins with step 6.

Step 1

Survey the cost accounts in the cost category being evaluated, selecting those accounts which apply to the proposed system or modification.

Note that cost accounts in Cost Categories 7 through 9 are used primarily as inputs to accounts in Categories 1 through 6 and generally are not applicable in and by themselves.

For our example, assume that all estimates for Cost Categories 1 through 3 have been completed and that in surveying Cost Category 4, Conduits, Cost Account 403.1 is one of the accounts identified as applicable.

Step 2

For each applicable account, pull out the corresponding worksheet.

Remember that cost accounts and corresponding worksheets and cost graphs have the same identifying number. Worksheet 403.1, which corresponds to Cost Account 403.1, is shown in Figure 4.

Step 3

In the spaces provided on the worksheet, enter the design data required.

The data required, such as volume and type of material excavated, tunnel diameter and length, concrete volume and type of reinforcing, is obtained from the drawings discussed in the previous section in steps 2 and 3 of the basic approach. Some worksheets provide guidelines or rules of thumb to use in cases where the design data required are not readily available.

In our example, we assume all necessary design data are available and are entered as shown in Figure 5.

Design Data Required		
Pipe diameter		3.05 m
Wall thickness		1.27 cm
With or without stiffeners	with	
Pipe length		L = 580 m
Shop or field fabrication[a]	shop	

[a]For diameters to 3.05 meters, assume shop fabrication.

Fig. 5 - Design Data Required for Worksheet 403.1

Step 4

Determine the base cost following the instructions on the worksheet.

In some cases, the worksheet provides the unit cost, which is simply multiplied by the quantity involved to compute the base cost. In other cases, the worksheet references a cost graph from which the base cost is read directly or from which a unit cost is read and then multiplied by the quantity involved to get the base cost.

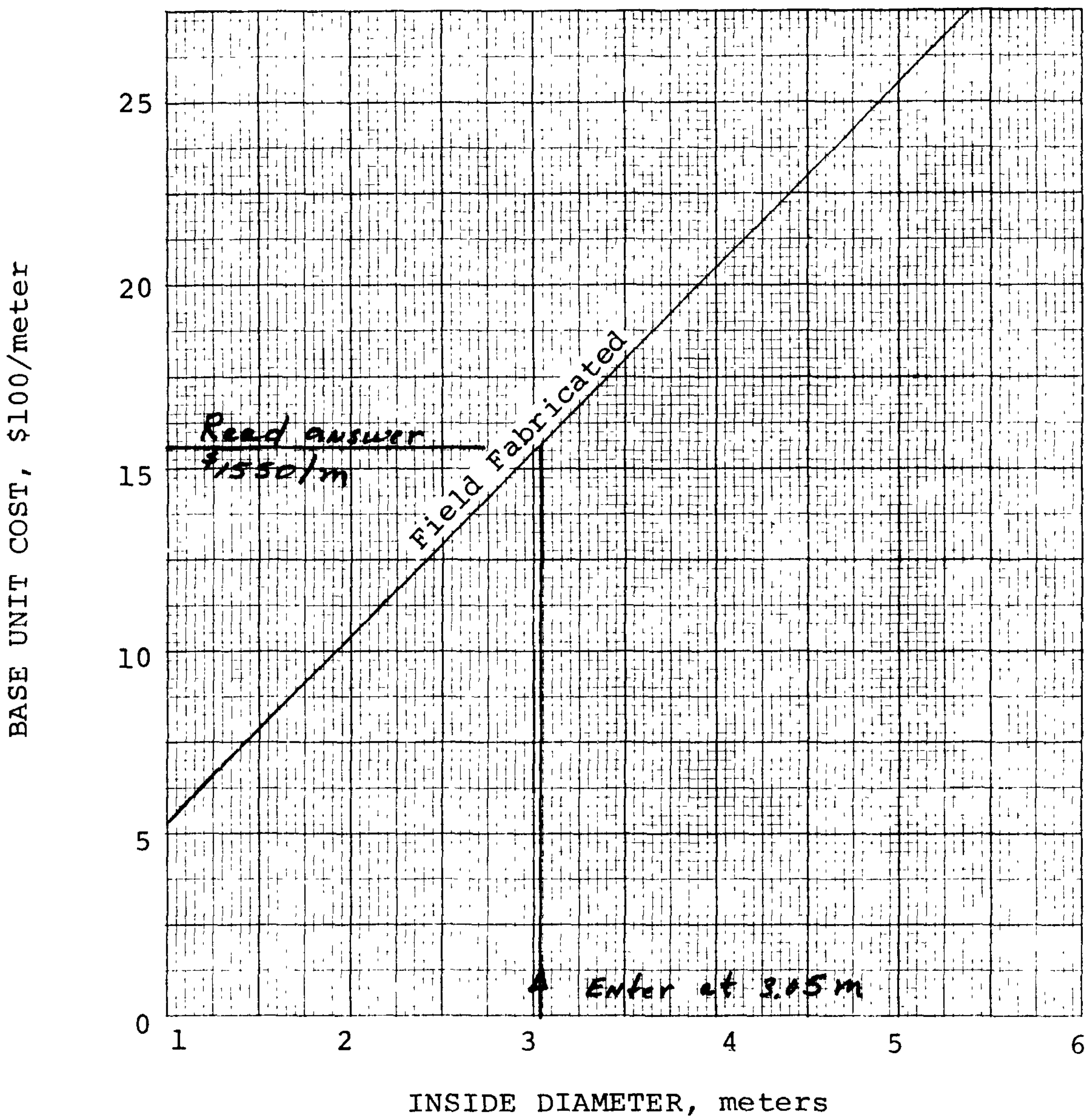
As shown in Figure 6, Worksheet 403.1 references the corresponding Figure 403.1 (shown as Figure 7) from which we read a base unit cost of $1,550/meter for a pipe diameter of 3.05 meters. This base unit cost is multiplied by the length of pipe to get the base cost.

Base Cost	
Enter Figure 403.1, read base unit cost per lineal meter	BUC =$ 1,550 /m
Base cost = L x BUC	BC =$ 899,000

Fig. 6 - Base Cost Computation on Worksheet 403.1

Step 5

Apply design adjustment factors to the base cost to determine the adjusted base cost.



Thickness (cm):	.635	.953	1.27	1.588	1.905	2.22
Factor $F_D(1)$:	.50	.75	1.0	1.25	1.5	1.75

With Stiffeners, $F_D(2)$ = 1.6
Shop Fabrication, $F_D(3)$ = .65

Fig. 7 - Cost Graph Corresponding to Cost Account 403.1 and Worksheet 403.1

Design adjustment factors are provided where variations in parameters, such as component geometry or type of material to be excavated or tunneled, result in significant cost differences. Some cost accounts do not require such adjustments. In these latter cases, the base cost calculated in the step 4 above is the value of interest.

In our example, Worksheet 403.1 (see Figure 8) instructs the reader to obtain design adjustment factors from Figure 403.1 (see Figure 7) and to multiply the base cost by these factors to get the adjusted base cost.

Cost Adjustments	
Enter Figure 403.1, read design adjustment factors for wall thickness, stiffeners, and type of fabrication	$F_D(1)$ = 1.0 $F_D(2)$ = 1.6 $F_D(3)$ = 0.65
Adjusted Base Cost	
Adjusted base cost of materials and fabrication = BC x $F_D(1)$ x $F_D(2)$ x $F_D(3)$	$BC_{403.1}$ =$ 934,960

Fig. 8 - Cost Adjustments on Worksheet 403.1

Step 6

Enter the adjusted base costs (or base cost if no adjustments are required) on the cost category cost summation worksheet and determine total cost for category being evaluated.

Remember that cost accounts in Cost Categories 7 through 9 are primarily used as input to cost accounts in Cost Categories 1 through 6 and generally are not applicable in and by themselves. Consequently, it is unusual to use cost summation worksheets for these three categories. For Cost Categories 1 through 6, the adjusted base costs are entered and summed with the exception of cost accounts for mobilization and demobilization which are entered and totaled on the Cost Category 10 (Mobilization) summary worksheet.

In our example, the adjusted base cost for Account 403.1 is entered on the Category 4 Cost Summation worksheet (see Figure 9) along with all other applicable accounts. These values are summed to get the total cost for this category. The mobilization costs for Category 4 are entered in the Category 10 summary worksheet (see Figure 10) and summed with mobilization and demobilization costs for all other cost categories to derive the total base cost for Category 10.

<u>Step 7</u>

Compute the regional and time adjustment factor and determine the revised total construction cost following the instructions in Category 11.

The total costs for Categories 1 through 10 are entered on Worksheet 1101 (see Figure 11). The sum of these entries is the total construction cost which must be adjusted for the region of the country where the plant is located and the date construction is expected to begin or the price level of interest. The reader notes the regional adjustment factor for the city nearest the plant site and determines

Worksheet 400

Cost Account Number	Description	Base Cost
401	Precast concrete pipe	BC_{401} =$ –
402	Cast-in-place box culvert	BC_{402} =$ –
403	Steel conduit	
403.1	Steel pipe	$BC_{403.1}$=$ 934,960
403.2	Steel fittings	$BC_{403.2}$=$ 76,900
406.2	Onshore pipe laying	$BC_{406.2}$=$ 378,600
406.3	Cushion fill and backfill	$BC_{406.3}$=$ 97,460
406.4	Pipe supports	$BC_{406.4}$=$ 56,320
406.5	Dewatering	$BC_{406.5}$=$ 21,100
408	Other	BC_{408} =$ –
Cost Category 4 Total Cost (Enter Cost in Account 1101)		BC_4 =$1,565,340
409	Mobilization (Enter Cost in Account 1001)	MC_4 =$ 66,000

Fig. 9 - Sample Cost Category, Cost Summation Worksheet

Worksheet 1001

Data Requirements

Cost Category Number	Mobilization Cost
1	MC_1 = $ 28,000
2	MC_2 = $ 30,000
3	MC_3 = $ 40,000
4	MC_4 = $ 66,000
5	MC_5 = $ –
6	MC_6 = $ 59,000
7	MC_7 = $
8	MC_8 = $
9	MC_9 = $
Base Cost	BC_{1001} = $ 223,000

Fig. 10 - Cost Category 10 Summation Worksheet

the Engineering News Record (ENR) Construction Cost Index (CCI) for the price level of interest or for the date construction is expected to begin. For instance, if a cost comparison is desired with an estimate based on price levels prevailing at some past date, the reader can look up the CCI in an issue of the ENR corresponding to that date or refer to Figure 1100 (shown as Figure 12 in this example), a graph of the CCI for the period 1969 to 1974. If construction is to start at some future date, the reader must project the CCI perhaps by extrapolating Figure 1100.

In our example, we assume Minneapolis and January 1976 as the place and start of construction. Figures 11 and 12 show the appropriate entries, CCI extrapolation, and computations to derive the revised total construction cost.

Step 8

Calculate the total project cost following the instructions given in Cost Category 11.

Project costs include all first costs less any cost incurred for a temporary power outage during the switch over to a modified discharge system. Figure 13 shows the computations required on Worksheet 1102 to derive the project costs. If the percentage of total construction costs for engineering and general and administrative items is not known, a value of 10 percent may be assumed. There are no rules-of-thumb for land-related costs. In cases where a discharge system modification is being considered, the utility might already have the necessary lands, easements, and rights-of-way. In cases where a new system is being considered, these items might not have been acquired. In this latter situation, real estate appraisals might be necessary. The contingency factor varies with the detail and accuracy of the data available. For estimates based on detailed and reliable drawings, a contingency of 5 percent might suffice; for a planning-type estimate based on conceptual drawings, a 25-percent contingency is acceptable.

Worksheet 1101

Data Requirements

Regional adjustment factor:

Atlanta -	.79	Kansas City -	.90
Baltimore -	.84	Los Angeles -	.90
Birmingham -	.73	Minneapolis -	.85
Boston -	.90	New Orleans -	.78
Chicago -	.91	New York -	1.00
Cincinnati -	.95	Philadelphia -	.90
Cleveland -	.94	Pittsburgh -	.89
Dallas -	.77	St. Louis -	.89
Denver -	.80	San Francisco -	.94
Detroit -	.93	Seattle -	.85

City nearest to construction area Minneapolis

Regional adjustment factor F_R = 0.85

Date construction is to begin or period of price level being considered January 1976

Engineering News Record Construction Cost Index for above date (20-city avg.) ENRX = 2300

Time adjustment factor = ENRX (   ) ÷ 2097[a] F_T = 1.097

Regional and time adjustment factor = $F_T \times F_R$ F_{RT} = 0.932

---

[a]The Engineering News Record 20-city average for December 12, 1974.

Fig. 11 - Example of Computations for Regional and Time Adjustment of Construction Cost

Worksheet 1101

Data Requirements (Cont'd)

Total costs from Categories 1 through 10:

BC_1 = $ 163,330

BC_2 = $ 185,420

BC_3 = $ 897,700

BC_4 = $ 1,565,340

BC_5 = $ –

BC_6 = $ 678,910

BC_7 = $ –

BC_8 = $ –

BC_9 = $ –

BC_{10} = $ 223,000

Total Cost = Σ (BC_1 through BC_{10}) BC_T = $ 3,713,700

Revised Construction Cost

Total cost = $BC_T \times F_{RT}$ BC_{1101} = $ 3,461,170

Fig. 11 - Example of Computations for Regional and Time Adjustment of Construction Cost

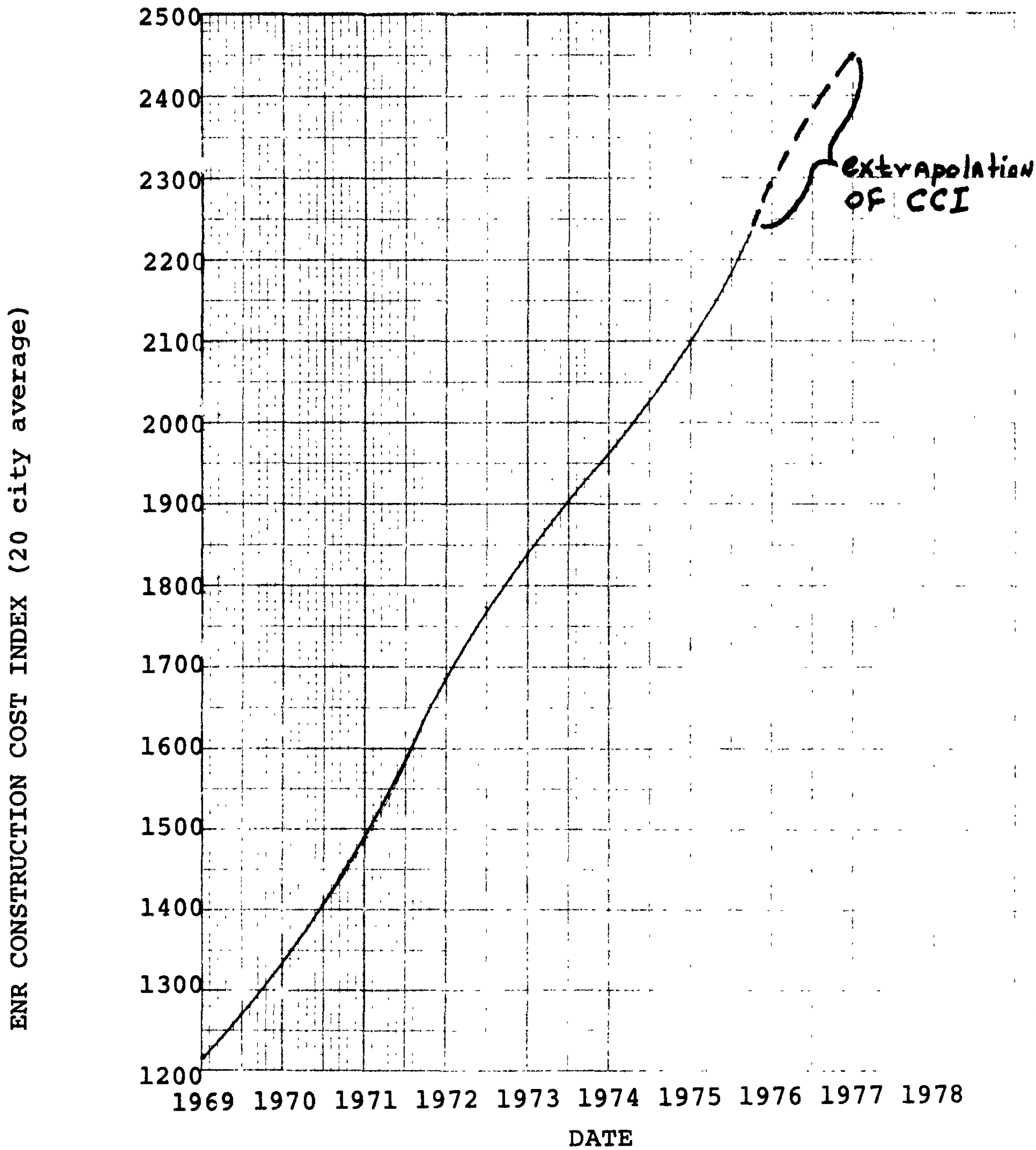


Fig. 1100 - ENR 20-City Construction Cost Index

Fig. 12 - Example of Extrapolating to Future Start of Construction Data

Worksheet 1102

Data Required

Total construction cost	BC_{1101} =	$ 3,461,170
Cost for engineering and general and administrative = $\frac{10\%}{100\%} \times BC_{1101}$[a]	BC_E =	$ 346,117
Cost for lands, easements, and rights-of-way	BC_L =	$ 111,000
Revised cost = $BC_{1101} + BC_E + BC_L$	BC_1 =	$ 3,918,287
Adjustment for contingencies[b] = $(1 + 5\%/100\%) \times BC_1$	BC_2 =	$ 4,114,201
Adjustment for escalation during construction = $BC_2 \times \frac{\text{ENRX (beginning)} + \text{ENRX (end)}}{2 \times \text{ENRX (beginning)}}$	BC_3 =	$ 4,237,627
	$\frac{2300+2450}{2 \times 2300} = 1.03$	
Adjustment for interest during construction[c] = BC_3 x (1 + no.yrs. of construction x annual interest rate/100%) = $BC_3 \times (1 + 1 \times 9\%/100\%)$	BC_4 =	$ 4,619,013
Royalties, licenses, fees, etc.	R =	$ 20,000
Total Project Cost = BC_4 + R	BC_{1102} =	$ 4,639,013

---

[a]Assume 10 percent if detailed information is not available.

[b]With detailed information, use a factor of 5 percent; for a planning estimate use 25 percent.

[c]See account discussion.

Fig. 13 - Computation of Total Project Costs

The adjustment for cost escalation during construction is based on the average CCI for the construction period. If the purpose of the estimate is a cost comparison with another estimate based on a fixed price level, this adjustment is not necessary. However, if a period of construction in the future is specified, this adjustment will require CCI projections. The adjustment for interest during construction is based on the assumption that interest is paid during the entire construction period on the entire amount of capital needed for the project. Costs for royalties, licenses, and other one-time fees are small and may be assumed to be negligible if figures are not readily available.

In our example, as shown in Figure 13, we assume a value of 10 percent for engineering and general and administrative items; $111,000 for lands, easements, and rights-of-way; 5 percent for contingencies; CCI's for a one-year construction period beginning in January 1977 (see Figure 12 for the extrapolation of CCI values); 9 percent for the interest rate; and $20,000 for royalties and other fees.

Step 9

Compute costs due to temporary power outage during switchover to a modified discharge system.

If a plant shutdown is necessary during the switchover, the power is assumed to be purchased from other members of the regional power grid.

In our example, a 750-megawatt plant with a capacity factor of 0.66 is assumed to be shut down for one week (See Figure 14). The unit cost for power is assumed equal to $0.021/kwh(replacement power) minus $0.018/kwh (production expenses) or $0.003/kwh.

Worksheet 1103

Data Required

Period of outage	T = 1	weeks
Power generation losses = [capacity x outage period x capacity factor]	P = 84,000,000	kwh
Unit cost of power = purchase cost - normal production expenses	U = 0.003	\$/kwh

Outage Cost

T x P x U = BC_{1103} = \$ 252,000

Fig. 14 - Computation of Power Outage Costs

Step 10

Compute annual costs by resolving first costs and estimating other annual expenses using the procedures recommended in Cost Category 11.

As shown in Figure 15, annual costs include amortization of the investment using the sinking fund method of depreciation; interest on the bond issue; rental and leasing costs; operating expenses, assuming the only significant operating expenses are those associated with pumping costs; insurance; and property taxes; less tax credits for installation of capital equipment. Rules-of-thumb are provided for estimating several of these items.

In our example, we assume the power plant to be 25 years old at the time of modification, leaving a period of 15 years till the end of the assumed 40-year useful plant life. This establishes the amortization period for the new investment. We assume our sinking fund earns an annual return of 8 percent and use the table of sinking fund factors provided. The salvage value of the new investment 15 years hence is assumed to be $500,000. The computations involved in amortizing the investment are illustrated in Figure 15.

Interest on the investment is calculated assuming the bond issue must finance all first costs, including the cost for a power outage during switchover. Costs for renting or leasing equipment or processes generally may be regarded as negligible.

Pumping costs are the only operating costs assumed to be significant in this analysis. We use the recommended values of 65-percent efficiency and $0.018/kwh. We also assume an average downtime of one month per year in determining the annual operating hours.

Insurance and property taxes on the new investment are calculated using the recommended percentage values. The tax credit computation assumes a straight line depreciation and the income tax rate recommended on the worksheet.

Worksheet 1104

1. Amortization of depreciable capital investment and costs for power outage, royalties, etc.

Useful Life Years	Sinking Fund Factor, Annual Interest Rate	
	8%	12%
3	.30803	.29635
5	.17046	.15741
7	.11207	.09912
10	.06903	.05698
13	.04652	.03568
15	.03683	.02682
18	.02670	.01794
22	.01803	.01081
25	.01368	.00750
28	.01049	.00524
30	.00883	.00414
35	.00580	.00232
40	.00386	.00130

Remaining useful life of the plant $Y =$ 15 yrs

Sinking fund factor (tabulated above) for annual interest rate of 8 % $F =$ 0.03683

Total project (first) cost $BC_{1102} =$ \$ 4,639,013

Salvage value $S =$ \$ 500,000

Land costs $L =$ \$ 111,000

Royalties, fees, licenses, etc. $R =$ \$ 20,000

Depreciable capital investment $BC_{1102} - (S+L+R)$ $D_C =$ \$ 4,008,013

Power outage costs $BC_{1103} =$ \$ 252,000

Fig. 15 - Sample Computation of Annual Costs

The amount amortized is = depreciable capital investment + power outage costs + royalties, fees, etc. $[D_c + BC_{1103} + R]$	D = $ 4,280,013
Annual cost = F x D	C = $ 157,633
2. Amortization of the non-depreciable capital investment (F x S). N_c is a credit (see No. 9 below).	N_c = $ 18,415
3. Interest on the capital investment. Bond interest rate	B = 9 %
Interest payment = B%/100% x $(BC_{1102} + BC_{1103})$	I_p = $ 440,191
4. Rent or lease costs	L_s = $ —
5. Operating costs. Power required in excess of the power required before the addition or modification	
= Theoretical Power ÷ efficiency = 600,000 watts x 100%/65 %	P_e = 923,077 W
Annual operating hours	H = 8,030 hrs
Power costs = H x P_e x $0.018 /kwh[a]	Z = $ 133,421
6. Insurance $(BC_{1102}$ - L - R) x 4 %[b]/100%	I = $ 180,320
7. Property taxes $(BC_{1102}$ - L - R) x 2 %[c]/100%	P_t = $ 90,160
8. Tax credit Income tax rate[d]	I_R = 48 %

Fig. 15 (continued) - Sample Computation of Annual Costs

Worksheet 1104

Methods of depreciation:

a. Straight line depreciation T_1 = $ 128,256

Tax credit =
$D_C \times I_R\%/(100\% \times Y)$
= $4,008,013 x 48%/(100% x 15)

b. Others (refer to tabulation below)

Year	D_R[e] (deprec. rt.)	I_R	D	T_i (annual) increments of depreciation)

$T_1 = \Sigma T_i$ = ________

9. Annual costs = $\Sigma\ (C - N_c + I_p + L_s + Z + I + P_t - T_1)$

BC_{1104} = $ 855,054

---

[a]Assume $.018/kwh

[b]Assume 4 percent

[c]Assume 2 percent

[d]Assume 48 percent

[e]Refer to a depreciation schedule for D_R for other than straight line depreciation

[f]If efficiency is not known, assume a value of 65 percent

Fig. 15 (continued) - Sample Computation of Annual Costs

INTERPRETATION OF RESULTS

Cost data presented in the methodology were developed assuming average conditions. Therefore, the user should not expect results from this manual to be identical with a detailed bid estimate. Also, items not specifically included in this tabulation of data, but which would fall into the "other" cost account of each category might significantly affect the cost. To further complicate the situation, present inflationary trends make estimating for any type of construction rather speculative, necessitating practically a weekly update to achieve accuracy and currency.

Retrofitting involves both marine and land-based construction. Costs for construction along the land-shore interface, i.e., the littoral zone are extremely difficult to accurately predict. Tunneling costs are also very difficult to forecast because of factors such as variable subsurface conditions and seepage rates.

A June 20, 1974, article in the Engineering News Record reported the results of a survey of types of estimates and compared results with actual construction costs. Seventy-six reported an accuracy of +6 to -4 percent using complete quantity take-offs. The sample was primarily for construction on land where construction costs are generally more consistent than for marine work. Therefore, for the types of construction considered in this study, the accuracy to be expected for a detailed estimate should be somewhat less. The user can expect an estimate developed using the methodology in this manual to be in the range of ± 15 percent when detailed site data is provided.

COST CATEGORY 1, SITE PREPARATION

Information on razing existing facilities, clearing and grubbing the site, and site grading is included. Data on hauling materials with a truck are also included. Specific data for each account are given in the following paragraphs.

Riprap removal, Account 101

Key parameters to consider in removing riprap are the size of the stone and where the material is located. The data presented here do not consider offshore relocation. In almost every case, hauling the material from the site is not a viable consideration. However, hauling costs are provided in Account 108.2. It was assumed a crane with a clam shell would be used to excavate the material.

Concrete slab removal, Account 102

The key parameters are slab thickness, reinforcing and access to the slab. Removing a section of a slab used for erosion protection along the shoreline or in a channel are examples of this activity. The maximum slab thickness considered is in the range between 30 and 45 cm. Rates of production vary according to the following conditions:

1. Reinforcing
2. Thickness.

The data are for slabs with relatively easy access. The unit cost was developed assuming a crane rigged with a headache ball is used to break the slab. The same crane is then rigged with a clam bucket for removal and piling or loading the material onto a truck. Reinforcing is cut with an acetylene torch.

Concrete removal (nonslab),
Account 103

The key parameters are the quantity of reinforcing and access to the structure. Blasting is one method to remove the more massive type concrete structures. Plant safety requirements place restrictions on blasting near the plant, and in some cases, it may not be allowed. Cost data were developed for demolition of reinforced and non-reinforced concrete by blasting. Concrete foundations, walls and ground slabs greater than 45 cm thick are samples of the types of structures considered in this account.

Steel sheet piling removal,
Accounts 104.1 and 104.2

The key parameters are the depth of penetration, access to the piling and the condition of the material. The material may be salvaged for scrap or reused depending on the condition of the material. The productivity is related to the depth of penetration. The piling is removed with an extractor rigged on a crane. Data presented do not reflect removing a sheet pile structure requiring considerable labor efforts to ready the piling for extraction.

Clearing and grubbing,
Account 105

Key parameters to consider in the clearing and grubbing operation are the density of the vegetation and the type of disposal. It was assumed that the material would be disposed of on site. Larger materials are sawed and buried. The brush and branches are chipped and used as mulch.

Reseeding, Account 106

The key parameters are the seeding method and the material costs. Cost data reflect minimum site preparation and reseeding of the disturbed areas.

Site grading, Account 107

The key parameters are the area, depth of fill, and cost of imported borrow. Data for dumping and spreading the material are given in Cost Category 8.

Hauling, Accounts 108.1 and 108.2

Key parameters are the haul distance, capacity of the truck, type of road and material hauled. Data reflect hauling rock or earth over a paved road to the disposal area.

Unit costs were developed assuming two 7.6 cubic meter trucks would haul rock or earth 3.22 kilometers (2 miles) to the dump. For hauling materials, more than 3.22 kilometers, costs will increase \$.50/m^3/kilometer; over

3.22 kilometers; for broken concrete and rock and \$.30/ m^3/kilometer for earth. The base unit cost for hauling slabs is based on the rate for hauling broken concrete. In calculating the costs for hauling slabs, it was assumed the slab would increase in volume 25 percent when broken.

Dump operations are included for material disposal.

A suggested round-trip haul distance is included on each worksheet where hauling costs are appropriate. It was assumed the disposal area would be closer (given here as 8 km) than a borrow site or quarry (given here as 18 km). Although, 8 kilometers for hauling materials from the site is within the range of values presented in reference 2, the values suggested here are somewhat arbitrary. Whenever possible, local conditions should be assessed to determine hauling costs.

Mobilization, Account 110

Unit prices do not include mobilization and demobilization (referred to as mobilization) costs. The user adds the mobilization costs for each account that is used in calculating the total Category costs. A discussion of mobilization costs is given in Category 10.

Table 3 presents the correlation between cost account number, worksheet, and figure number. Costs are calculated using the procedure outlined in the introductory remarks to this section and the worksheets in Tables 4 through 15.

Table 3. SITE PREPARATION COST ACCOUNTS

Cost Account Number	Description	Figure Number	Worksheet Number
101	Riprap removal: Costs for excavation and sidecasting material.	--	101
102	Concrete slab removal: Costs include breaking and sidecasting the debris.	102	102
103	Concrete removal (non-slab): Costs include breaking and side-casting the debris.	103	103
104	Steel sheet piling removal.	--	--
104.1	Pulling costs to remove sheet piling and stock-pile on site.	--	104.1
104.2	Salvage credit for sheet piling removed.	--	104.2
105	Clearing and grubbing costs.	105	105
106	Costs for reseeding.	--	106
107	Site grading: Costs for cut and fill operations; hauling, and spreading topsoil. (See Cost Category 8)	--	107
108	Hauling: Costs for hauling materials.	--	--

Table 3 (continued). SITE PREPARATION COST ACCOUNTS

Cost Account Number	Description	Figure Number	Worksheet Number
108.1	Hauling costs for transporting debris from breaking slabs.	108.1	108.1
108.2	Hauling costs for earth, rock, and broken concrete.	108.2	108.2
109	Other.	--	109
110	Mobilization costs.	--	110

Table 4. COST CATEGORY 1 COST SUMMATION

Worksheet 100

Cost Account Number	Description	Base Cost
101	Riprap removal	BC_{101} =$ ________
102	Concrete slab removal	BC_{102} = ________
103	Concrete removal (nonslab)	BC_{103} = ________
104	Sheet pile removal	
104.1	Pulling costs	$BC_{104.1}$ = ________
104.2	Salvage credit	$BSC_{104.2}$ = (-) ________
105	Clearing and grubbing	BC_{105} = ________
106	Reseeding	BC_{106} = ________

Table 4 (continued). COST CATEGORY 1
COST SUMMATION

Worksheet 100

Cost Account Number	Description	Base Cost
107	Site grading	BC_{107} = ________
109	Other	BC_{109} = ________

Cost Category 1 Total Cost (Enter cost in Account 1101) BC_1 =$ ________

110	Mobilization (Enter Cost in Account 1001)	MC_1 =$ ________

Table 5. RIPRAP REMOVAL

Worksheet 101

Design Data Required

Haul distance to disposal site (round trip)[a] ________ km

Volume of riprap V = ________ m^3

Base Cost

Base cost for excavating riprap = $\$5.40/m^3 \times V$ BC(1) = ________

Enter figure 108.2, read base unit cost for rock haul and disposal BUC(2) =$ ________ $/m^3$

Base cost for haul and disposal of riprap = V x BUC(2) BC(2) =$ ________

Total base cost = BC(1) + BC(2) BC_{101} =$ ________

[a]If haul distance is not provided, assume 8-km round trip.

Table 6. CONCRETE SLAB REMOVAL

Worksheet 102

Design Data Required

Haul distance to disposal site (round trip)[a]	________ km
Slab thickness	________ cm
Type of reinforcing (non-reinforced, reinforced)	________
Slab area	A = ________ m^2

Base Cost

Enter Figure 102, read base cost for breaking slabs and sidecasting debris	BC(1) =$ ________
Enter Figure 108.1, read base unit cost for haul and disposal of broken slab	BUC(2)=$ ________ $/m^2$
Base cost for haul and disposal = A x BUC (2)	BC(2) =$ ________
Total base cost = BC(1) + BC(2)	BC_{102} =$ ________

[a]If haul distance is not provided, assume 8-km round trip.

Table 7. CONCRETE REMOVAL (NON-SLAB)

Worksheet 103

Design Data Required

Haul distance to disposal site (round trip)[a]		________ km
Reinforcing (nonreinforced or reinforced)	________	
Volume of concrete	V =	________ m^3

Base Cost

Enter Figure 103, read base cost for breaking concrete and sidecasting debris	BC(1)	=$ ________
Enter Figure 108.2, read base unit cost for haul and disposal of concrete debris	BUC(2)	=$ ________ /m^3
Base cost for haul and disposal of concrete debris	BC(2)	=$ ________
Total base cost = BC(1) + BC(2)	BC_{103}	=$ ________

[a]If haul distance is not provided, assume 8-km round trip.

Table 8. SHEET PILING REMOVAL PULLING COSTS

Worksheet 104.1

Design Data Required

Average depth of penetration D =__________ m

Lineal meters of sheet piling L =__________ m

Base Cost

Penetration area = D x L __________ m^2

Base cost for pulling sheet piling =
A x $20.50/$m^2$ $BC_{104.1}$ =$__________

Table 9. SHEET PILING REMOVAL SALVAGE VALUE

Worksheet 104.2

Design Data Required

Type of steel sheet piling,
weight per unit area W =__________ kg/m^2

Area of steel sheet piling A =__________ m^2

Base Salvage Credit

Base salvage credit = W x A x
$330/kg $BSC_{104.2}$ =$(-)__________

Table 10. CLEARING AND GRUBBING

Worksheet 105

Design Data Required

Type of clearing and grubbing (light, medium or heavy)[a] ________

Area of clearing and grubbing ________ m^2

Base Cost

Enter Figure 105, read base cost

BC_{105} =$ ________

[a]Light - trees to 6-inch diameter.
Medium - trees 6- to 10-inch diameter.
Heavy - trees 10- to 16-inch diameter.

Table 11. RESEEDING

Worksheet 106

Design Data Required

Area of reseeding A = ________ m^2

Base Cost

Base cost = A x \$0.37/m^2 BC_{106} =$ ________

Table 12. SITE GRADING

Worksheet 107

Base Cost

Refer to Cost Category 8 and 9 for appropriate cost accounts and cost estimating procedures.
Base cost = Σ (appropriate base costs). BC_{107} =$ ________

Table 13. HAULING

Worksheets 108.1 & 108.2

Costs for these accounts are incorporated within other cost accounts as appropriate.

Table 14. OTHER

Worksheet 109

Base Cost

Include costs not covered in this Category but that relate to Site Preparation. Data presented in other accounts may be useful in estimating "Other" Costs. BC_{109} =$ ________

Table 15. MOBILIZATION

Worksheet 110

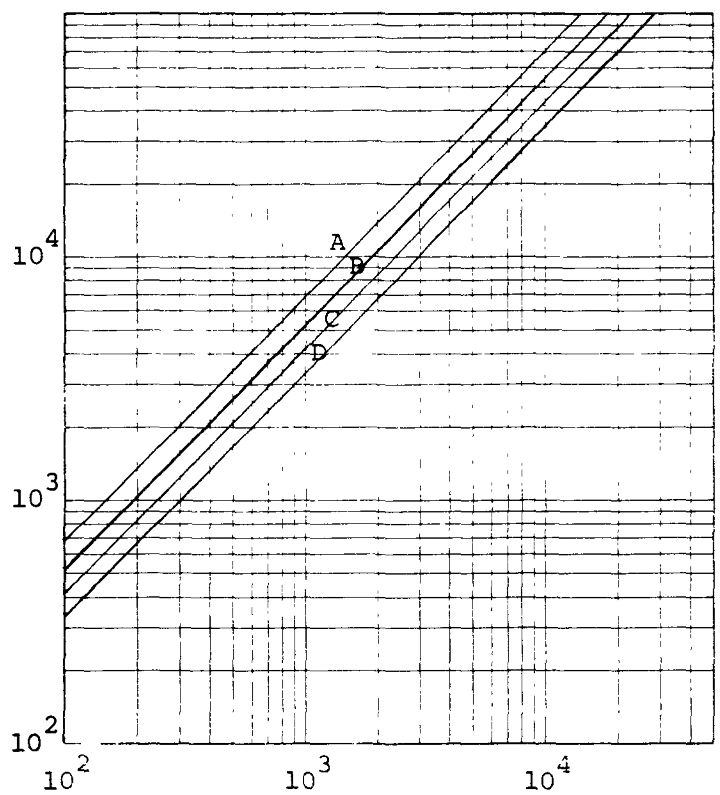
Data Requirement

Cost Account Number	Mobilization Cost	Summation[a]
101	Add $3,300 for any one	
102	of these accounts and	
103	$6,600 if two or more	
104.1	are used	________
105	$ 700	________
106	$ 400	________
107	See Cost Cat. 8	
108[a]	$ 600	________

Mobilization Cost

Mobilization = the total of the summation column (above) MC_1 =$ ________

[a]Add mobilization for hauling if accounts 101, 102, 103 or 106 are used.



Curve	Description
A	Reinforced, 30 to 45 (±) cm
B	Reinforced up to 30 cm
C	Non-reinforced, 30 to 45 cm
D	Non-reinforced, up to 30 cm

Fig. 102 - Removal of Concrete Slabs

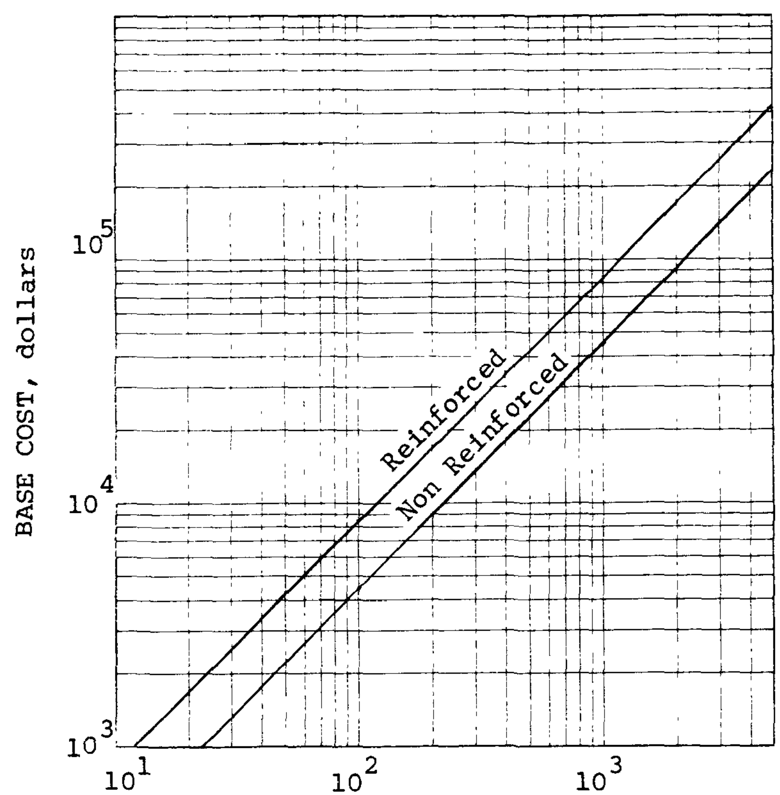


Fig. 103 - Removal of Concrete (Non-Slab)

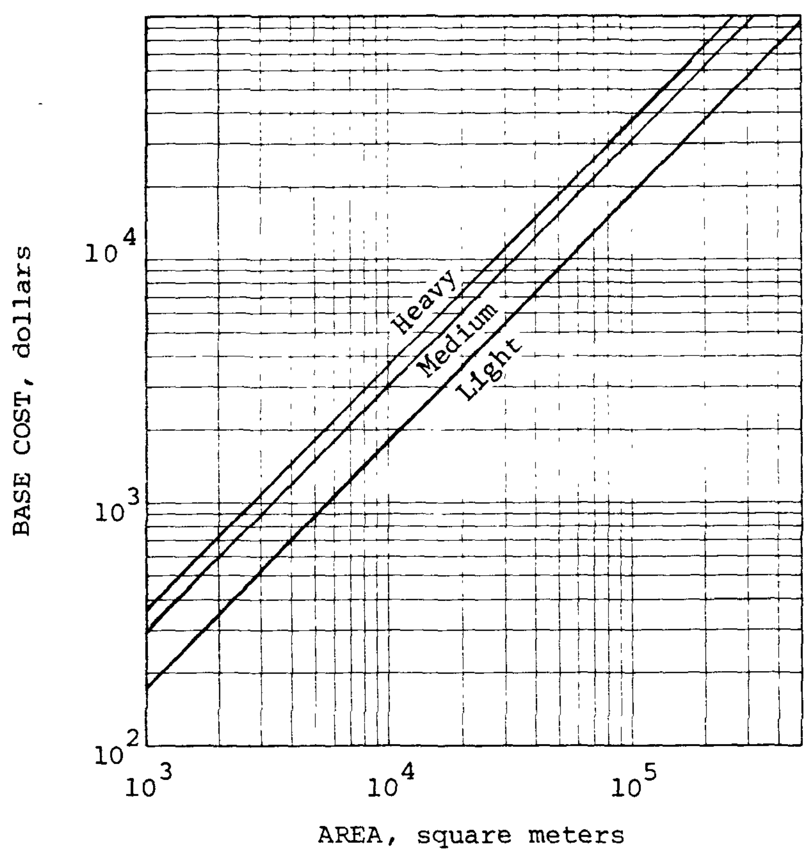


Fig. 105 - Clearing and Grubbing

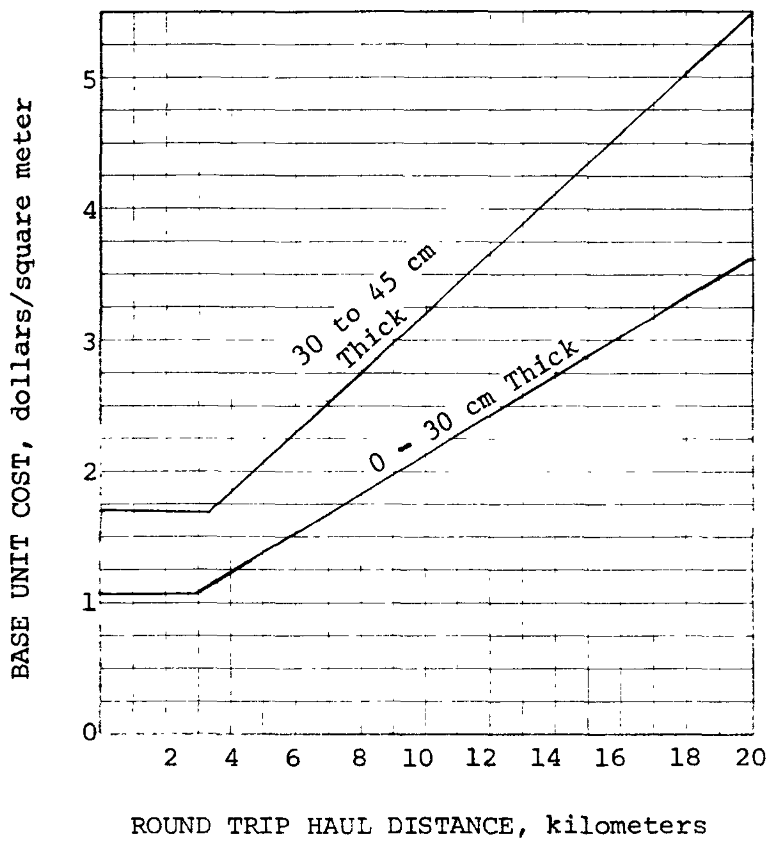
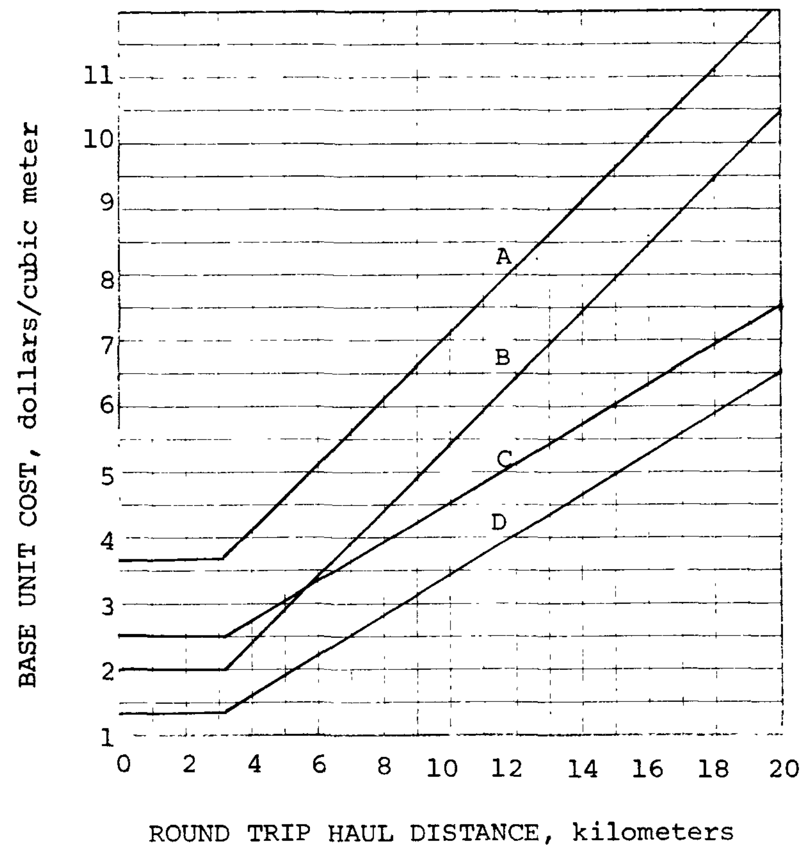


Fig. 108.1 - Hauling Costs for Concrete Slabs



Curve	Description
A	Hauling rock and broken concrete (nonslab) (disposal)
B	Hauling rock w/o disposal
C	Hauling earth with disposal
D	Hauling earth w/o disposal

Fig. 108.2 - Hauling Costs for Earth, Rock, or Broken Concrete

COST CATEGORY 2, EROSION
PROTECTION MEASURES

Data on the materials and installation of riprap, concrete, steel piling and piles are included. The emphasis is on the application of the materials to erosion protection. However, data for steel sheet piling and piles apply to excavation shoring and cofferdams. Specific data for each account are given in the following paragraphs.

Placement of riprap (land-based), Account 201.1

Key parameters are the size and availability of the material. Riprap is used in applications such as channel lining, and sea walls (protection along a lake shore). Riprap can also be used to construct a rubble mound breakwater which is a rock dam extending off shore used to dissipate wave energy. Another application of a breakwater is to separate the discharge plume and intake structure for the plant to prevent recirculation. Riprap protection is placed in layers increasing in particle size from the earth to the outer face. The gradation prevents leaching and erosion of the soil beneath the riprap blanket. The stone sizes are grouped into three types:

1. Filter - A gravel filter used beneath the riprap stone. (Assume thickness is equal to one half the stone size).
2. Riprap stone - Stones less than 1 cubic meter (assume a thickness equal to 0.6 meters).
3. Cover stone - Individual stones of about 10 cubic meters volume.

Local availability will effect the material price and hauling costs for riprap. In many areas inland and along the east coast, riprap must be hauled from distances of hundreds of kilometers. A haul distance of 18 kilometers is given as a basis for estimating the contribution of hauling to riprap costs. However, when possible the user should consult local sources for information.

The smaller stones can be placed by dumping the material from the truck on the slope with a minimum of spreading. The cover stones are usually placed one at a time using a crane and a cable sling.

Placement of riprap (marine), Account 201.2

Key parameters are the size of the stone and availability of the material. The riprap stone may be used to protect the area around the diffuser nozzles. Placing the riprap stone and filter offshore involves:

1. loading the material into scows;
2. towing the scows to the site; and
3. dumping the material.

The cover stones are placed offshore. However, offshore applications of cover stone are often in a rubble mound breakwater. A typical breakwater is constructed using the structure as a peninsula from which to place the stones. For this type application, land-based costs are appropriate. Costs for placing the cover stone offshore are given and were developed by assuming:

1. a crane positioned on land loads the stones onto a flat-top barge;
2. the barge is towed to the offshore site; and
3. a crane barge (a crane mounted on a barge) is used to place the stones.

Steel sheet piling (land), Account 202.1

Key parameters are the type of soil, material costs, the depth of penetration and the bracing required. Steel sheet piling may be used as excavation shoring, for erosion protection, such as a bulkhead in a sea wall, or as channel lining material. The structure may be a single line of piling or two lines connected with braces and empty or filled with some material. Bracing requirements vary at every site. A conservative estimate of bracing requirements, $7/square meter, was given in and adopted from Reference 4. The costs for materials depend on whether the material is new or used. Sheet piling for temporary use such as for excavation shoring may be rented. It was assumed the piling to be left in place is new material. For temporary applications, material costs reflect rental rates. The piling may require trimming and some welding work. However, the cost was neglected. The piling is driven with a pile-driving hammer rigged on a crane boom. Wood piling data are not given because it is not used as often as steel.

Steel sheet piling (marine), Account 202.2

Key parameters are the type of soil, material costs, depth of penetration and the bracing required. Steel sheet piling placed offshore is used for cellular cofferdams and breakwaters. The circular structures can be filled with soil, gravel, or riprap stone. Most of the time only a minimum of bracing and pile supports are required because the interlock strength of the piling carries the net outward earth pressure. If it is desirable to dewater a small area, individual cells may be constructed using circular walers to prevent collapse.

Piles (land), Account 203.1

Key parameters are the type of pile, material, and the depth of penetration. Three materials are used to make piles: concrete, steel, and wood. The piles considered here are foundation piles. One dimension of pile for each material was selected to represent that material. The error introduced should not significantly effect the results.

Piles (marine), Account 203.2

Key parameters are pile materials, depth of penetration, and the type of pile. Piles driven offshore are used as bearing piles for pipe support systems and to support sheet piling driven in the water. A crane barge rigged for driving piles is used to install the piles.

Concrete, Account 204

The key parameters are the application and the volume. Two applications are considered in this account. Concrete slabs are used as a channel lining material and for shore protection. Costs for other concrete slabs and the cushion fill placed between the earth and concrete are given in Category 7. Concrete is also used in the construction of sea wall bulkheads. Slabs are placed between steel piles. The costs for the slabs and piles are given in Cost Category 7 and Cost Category 2.

Mobilization, Account 206

Unit prices do not include the cost for mobilization and demobilization. The user includes costs in accordance with the construction on Worksheet 206. A discussion of mobilization costs is given in Cost Category 10.

Table 16 presents the correlation between cost account number, worksheet and figure number. Costs are calculated using the procedure outlined in the introductory remarks of this section and Worksheets 17 through 26.

Table 16. EROSION PROTECTION COST ACCOUNTS

Cost Account Number	Description	Figure Number	Worksheet Number
201	Riprap: Costs for cover stone, riprap stone, and filter material.	--	--
201.1	Costs for materials and land-based placement of riprap.	201.1	201.1
201.2	Costs for materials and offshore placement of riprap.	201.2	201.2
202	Costs for materials and installation of steel sheet piling.		
202.1	Costs for materials and land-based installation.	202.1	202.1
202.2	Costs for materials and offshore installation.	202.2	202.2

Table 16 (continued). EROSION PROTECTION COST ACCOUNTS

Cost Account Number	Description	Figure Number	Worksheet Number
203	Costs for installation of piles and the material.		
203.1	Piles (land installation).	203.1	203.1
203.2	Piles (marine installation).	203.2	203.2
204	Costs for materials and installation of concrete erosion protective measures.	--	204
205	Other	--	205
206	Mobilization	--	206

Table 17. COST CATEGORY 2 COST SUMMATION

Worksheet 200

Cost Account Number	Description	Base Cost
201	Riprap and filter material and placement	
201.1	Placement by land-based equipment	$BC_{201.1}$=$ ________
201.2	Offshore placement	$BC_{201.2}$= ________
202	Steel sheet piling	
202.1	Placement by land-based equipment	$BC_{202.1}$= ________

Table 17 (continued). COST CATEGORY 2
COST SUMMATION

Worksheet 200

Cost Account Number	Description	Base Cost
202.2	Offshore placement	$BC_{202.2}$=$________
203	Piles	
203.1	Land installation	$BC_{203.1}$=________
203.2	Marine	$BC_{203.2}$=________
204	Concrete	BC_{204} =________
205	Other	BC_{205} =________
Cost Category 2 Total Cost (Enter cost in Account 1101)		BC_2 =$________
206	Mobilization (Enter Cost in Account 1001)	MC_2 =$________

Table 18. PLACEMENT OF
RIPRAP (LAND-BASED)

Worksheet 201.1

Design Data Required

Material[a] ________

Volume of material V = ________ m^3

Haul distance (round trip) from borrow site to construction site[b] H_d = ________ km

[a]Cover stone, riprap stone, or filter stone.

[b]If haul distance is not provided and seems appropriate, assume 18-km round trip (see the discussion for this account).

Table 18 (continued). PLACEMENT OF RIPRAP (LAND-BASED)

Worksheet 201.1

Base Cost

Enter Figure 201.1, read base cost for material and placement	BC(1)	=$ ________
Enter Figure 108.2, read base unit cost for hauling	BUC(2)	=$ ________ /m^3
Base cost for haul = V x BUC(2)	BC(2)	=$ ________
Total base cost = BC(1) + BC(2)	$BC_{201.1}$	=$ ________

Table 19. PLACEMENT OF RIPRAP (MARINE)

Worksheet 201.2

Design Data Required

Material[a]		________
Volume of material	V =	________ m^3
Haul distance (round trip) from borrow site to shoreline staging area[b]		________ km

---

[a]Cover stone, riprap stone, or filter stone.

[b]If haul distance is not provided and seems appropriate, assume 18-km round trip (see discussion for Account 201.1).

Table 19 (continued). PLACEMENT OF RIPRAP (MARINE)

Worksheet 201.2

Base Cost

Enter Figure 201.2, read base cost for material and placement	BC(1)	=$ ________
Enter Figure 108.2, read base unit cost for hauling	BUC(2)	=$ ________ $/m^3$
Base cost for hauling = V x BUC(2)	BC(2)	=$ ________
Total base cost = BC(1) + BC(2)	$BC_{201.2}$	=$ ________

Table 20. STEEL SHEET PILING (LAND)

Worksheet 202.1

Design Data Required

Area of sheet piling	________ m^2
Intended usage (temporary or permanent)	________

Base Cost

Enter Figure 202.1, read base cost

$BC_{202.1}$ =$ ________

Table 21. STEEL SHEET PILING (MARINE)

Worksheet 202.2

Design Data Required

Area of sheet piling ________ m^2

Intended usage
(temporary or permanent) ________

Base Cost

Enter Figure 202.2, read base cost

$BC_{202.2}$ =$________

Table 22. PILES (LAND)

Worksheet 203.1

Design Data Required

Pile material (concrete, steel, or wood)[a] ________

Total length of piles ________m

Base Cost

Enter Figure 203.1, read base cost $BC_{203.1}$=$________

---

[a]Concrete - square 20.3 cm tip and 40.6 cm butt
Steel - 30.5 cm x 30.5 cm H 24kg
Wood - 20.3 cm tip and 35.6 cm butt

Table 23. PILES (MARINE)

Worksheet 203.2

Design Data Required

Pile material (concrete, steel, or wood)[a] __________

Total length of piles __________ m

Base Cost

Enter Figure 203.2, read base cost $BC_{203.2}$ = $ __________

---

[a]Concrete - square 20.3 cm tip and 40.6 cm butt
Steel - 30.5 cm x 30.5 cm H 24kg
Wood - 20.3 cm tip and 35.6 cm butt

Table 24. CONCRETE

Worksheet 204

Base Cost

Concrete slab shore protection and channel lining: Refer to Cost Category 7 for estimating procedure (Cost Account 701).

Bulkhead shore protection: Costs for materials and placement. Vertical concrete slabs are given in Cost Account 701. Costs for H-piles for supporting the concrete slabs are derived from Cost Account 203. BC_{204} = $ __________

Table 25. OTHER

Worksheet 205

Base Cost

Include costs not covered in this category but that relate to erosion protection measures. Data presented in other accounts may be useful in estimating "Other" Costs. BC_{206} = $ ____________

Table 26. MOBILIZATION

Worksheet 206

Data Requirements

Cost Account Number	Mobilization Cost	Summation
201.1 Riprap stone or filter	$3,700	____________
201.1 Cover stone) 202.1) 203.1) 204	$3,300 for one of the accounts (201.1-204) and $6,600 for two or more accounts	____________
Hauling[a]	$600	____________

Mobilization for marine equipment is included in Categories 4 and 6

Mobilization Cost

Mobilization = the total of the summation column (above) MC_2 =$ ____________

[a]If account 201.1 is used and hauling costs are added to the estimate, include the mobilization cost for hauling.

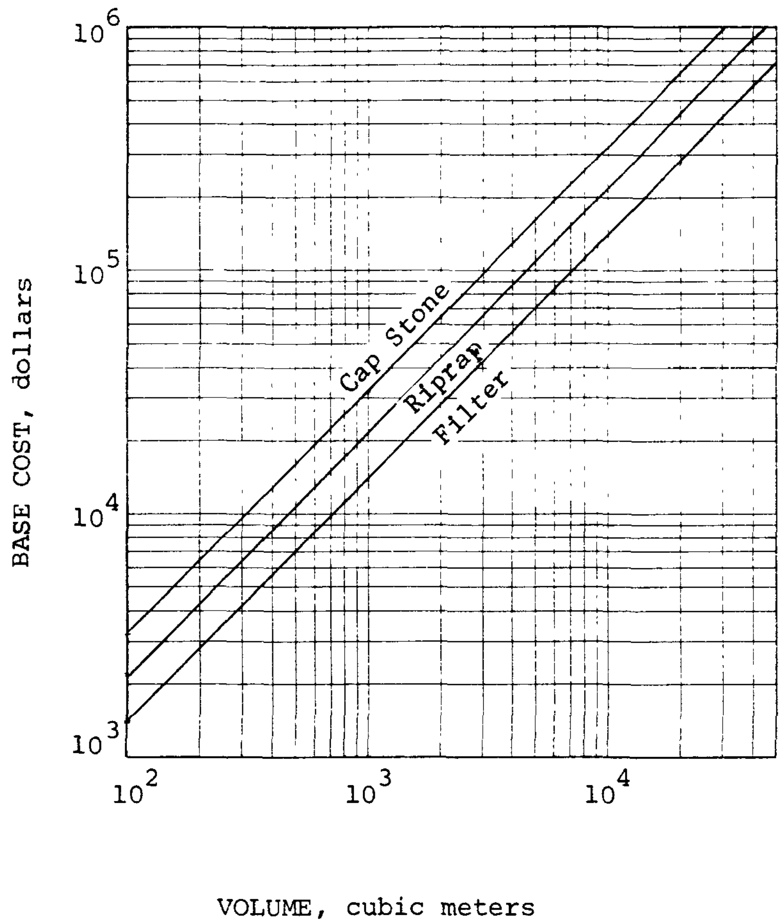


Fig. 201.1 - Costs for Material and Land-Based Placement of Riprap

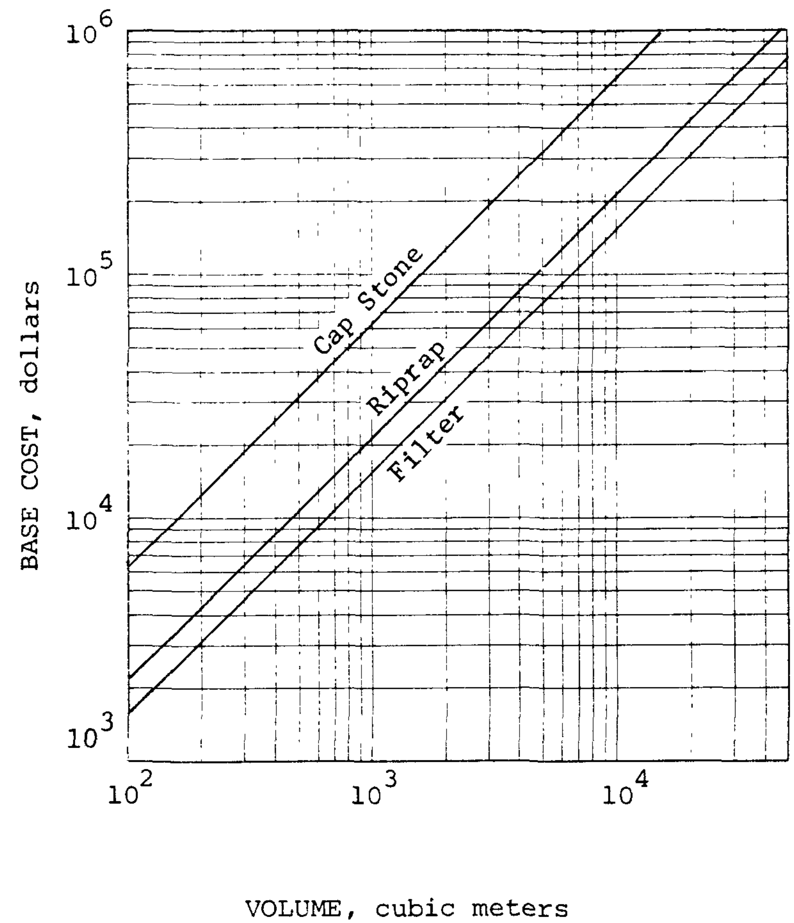


Fig. 201.2 - Costs for Materials and Offshore Placement of Riprap

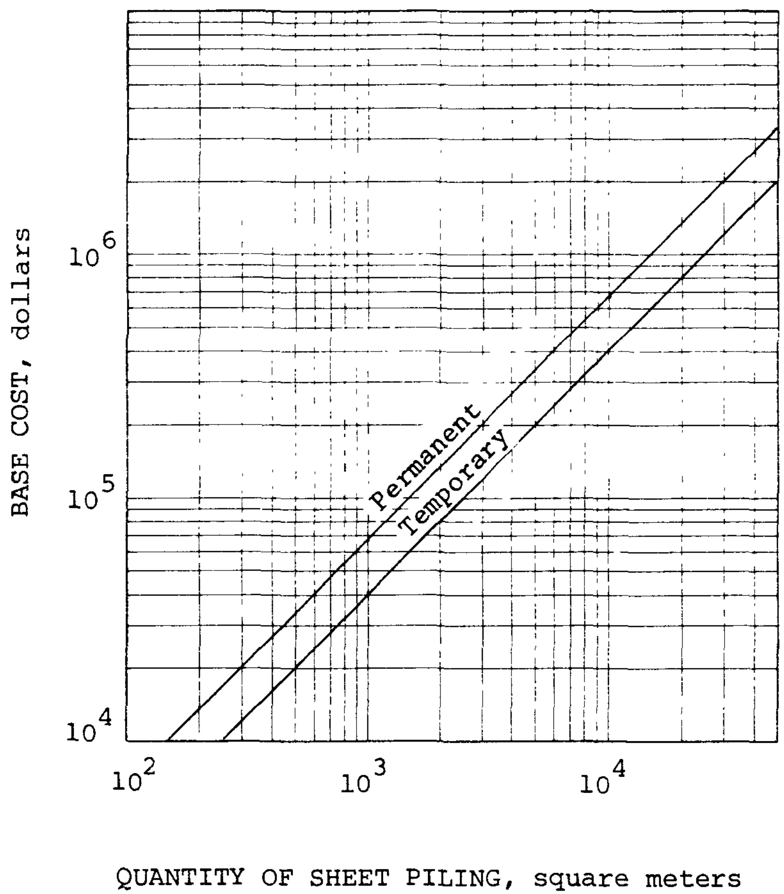


Fig. 202.1 - Costs for Steel Sheet Piling
(Land Installation)

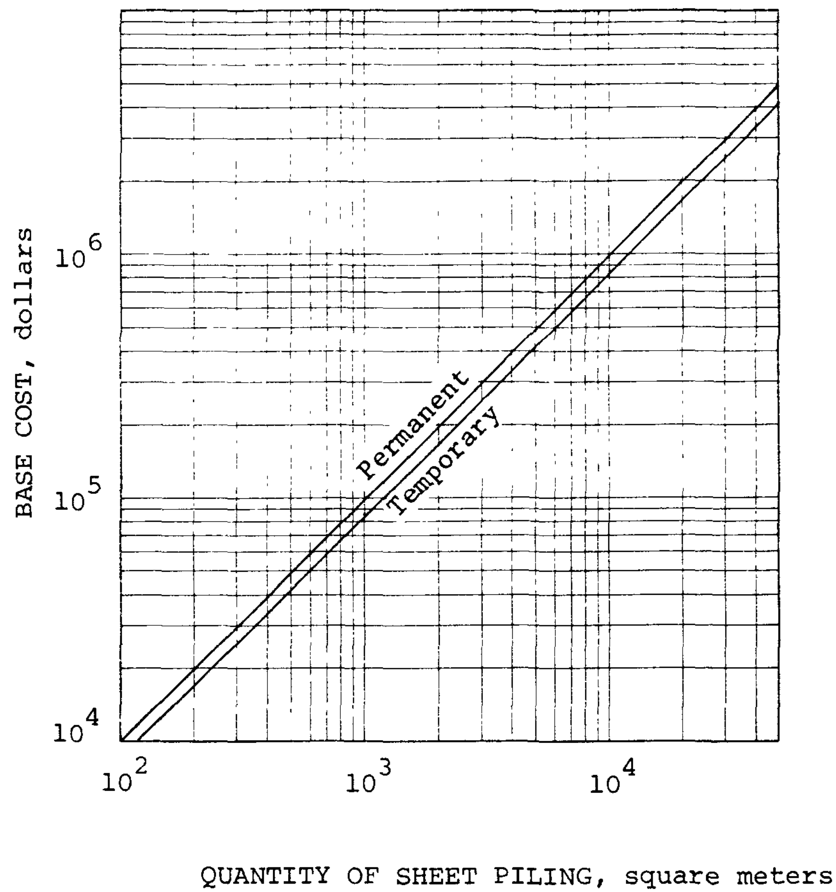


Fig. 202.2 - Costs for Steel Sheet Piling
(Offshore Installation)

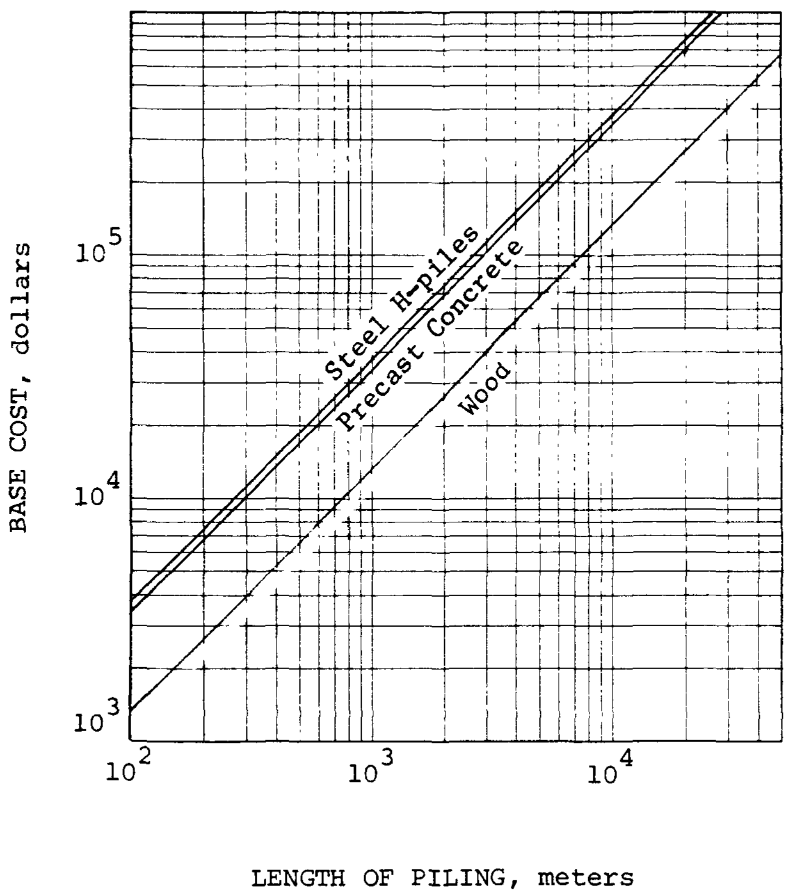


Fig. 203.1 - Costs for Piles
(Land Installation)

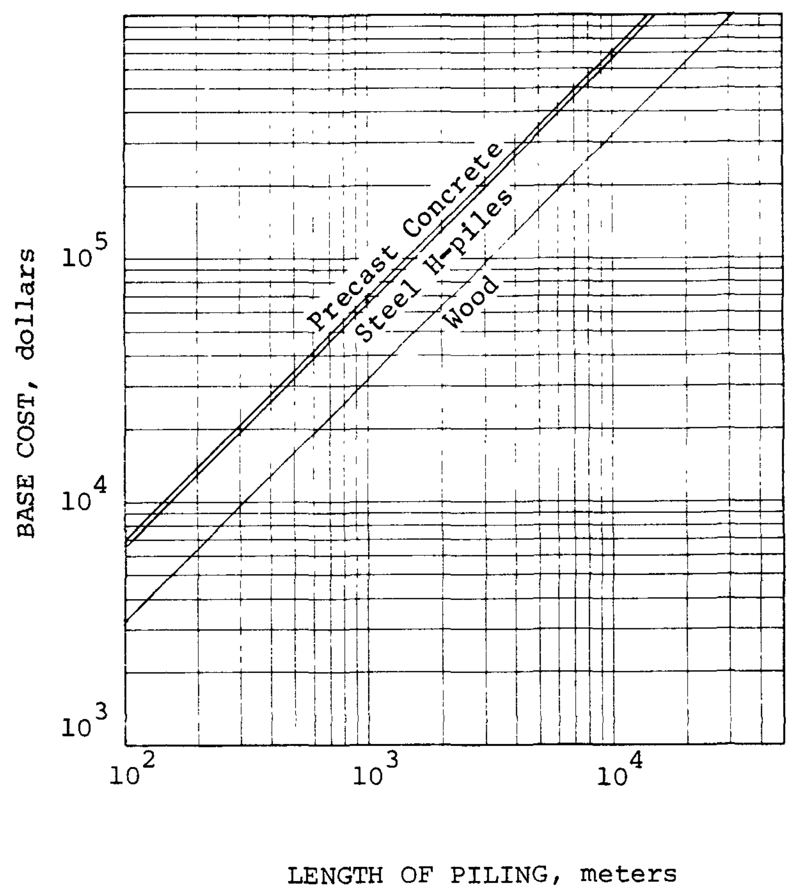


Fig. 203.2 - Costs for Piles
(Offshore Installation)

COST CATEGORY 3, PUMP STATION

Information on modifying an existing pump station or installation of a new facility is given. Typically the existing pump station is located upstream from the condenser. Water enters the cooling system through the intake and is pumped into the condenser and discharged. Installation of a new station will normally be done downstream of the condenser.

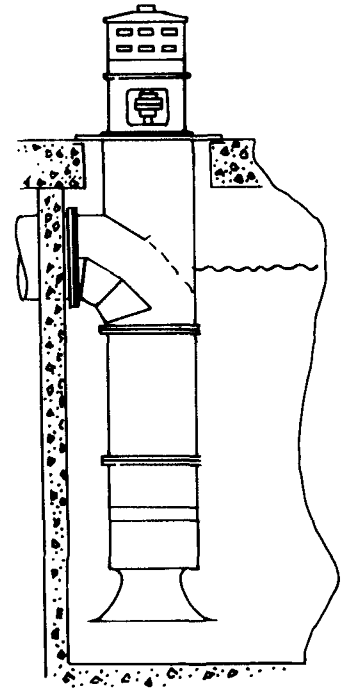
Pumps and motors, Account 301.1

The key parameters are capacity, total head, type of pump, and salinity of the water. Three types of pumps are used for cooling water supply:

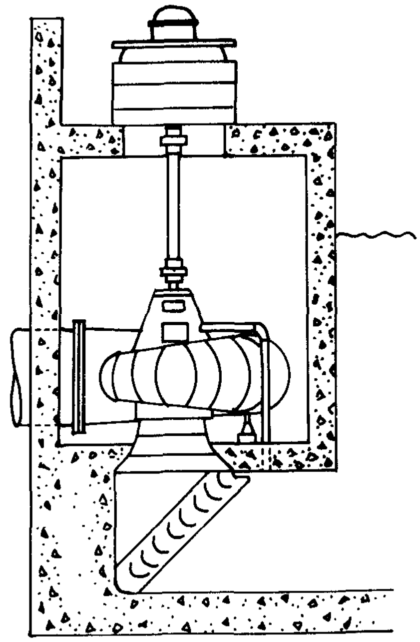
1. The vertical wet pit pump - This type is the least costly from the standpoint of space requirements. The pump is the most common type encountered during the literature review and case studies.
2. The vertical dry pit - A pump with the advantage of being more easily maintained, but it is a bit more expensive in first cost than the vertical wet pit type.
3. Horizontal dry pit - This type requires more space than the others and the motor is subject to water damage because it is located below the water surface elevation.

The types of pumps are sketched in Figure 300.1.

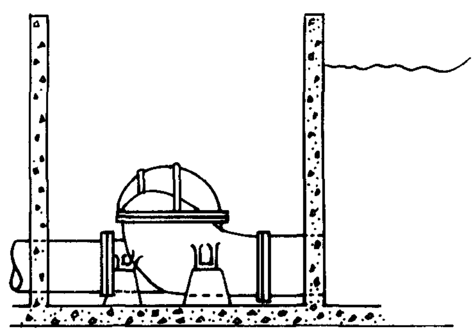
Cost data for the vertical wet pit pump used in fresh water and adjustment factors for the vertical dry pit pumps and salt water pumping are given. Costs for the horizontal dry pit pumps are not included. Material and installation costs are separated as follows:



VERTICAL
WET PIT



VERTICAL
DRY PIT



HORIZONTAL
DRY PIT

Fig. 300.1 - Types of Cooling Water Circulating Pumps

1. Pumps, motors and starter equipment and the cost to bring power from the substation to the motor

2. Equipment and labor costs required to set the pump and motor into place and make them operational - Pump sizes and motor characteristics assumed in developing unit prices are given in Table 27.

Table 27. PUMP AND MOTOR CHARACTERISTICS

Pump Capacity, m^3/sec	Motor	
	Speed, rpm	Voltage, Volts
1.4	880	460
2.8	587	460
8.5	351	4,160
19.8	220	4,160

The pumps and motors are selected based on the cooling water flow rate and the increased head loss associated with the new discharge. A single pump is seldom chosen to meet the pumping requirements for cooling water. A rule of thumb is to have 20 percent in excess of capacity as a reserve. The four sizes given here will not provide the exact combination for every situation. However, interpolation will provide a reasonable cost.

The trash racks and traveling screens of the existing pump station will collect most of the debris that are drawn from the intake. After the water has passed through the condenser, screening requirements are less stringent. Therefore, an account for trash racks and traveling water screens is not included in pump costs. The cost for service water pumps are generally very small compared to the circulating water pumps. Thus, no costs are given.

Installation, Account 301.2

The key parameters are the pump and motor size and the type of installation (new pump station or modifying an existing one). Installation costs reflect using a crane, and common and skilled labor to install the pump and motor. Costs for modifications to an existing station will vary depending on the access to the pumps and motors. In some installations an overhead gantry crane may be provided while for others the equipment will have to be hoisted out using a crane. It is assumed a crane will be used to remove existing equipment, and the installation and removal costs are equal. Thus, the cost for installation of pumps and motors into an existing facility is double that for a new facility unless there is an existing empty bay.

The costs for installation of valves and expansion joints are included in costs for this account.

Valves and expansion joints, Account 301.3

The key parameters are the type of valve and diameter of pipe.

A common type of valve placed between the outlet pipe and the pump is a motor-operated butterfly valve. In many installations an expansion joint is placed between the outlet piping and the pump to protect the pump installation. Cost data for the butterfly valve and expansion joints for diameters to 3.05 meters are given.

Pile foundation, Account 302.1

Pile foundations include the concrete pile cap and the piles. A discussion of concrete is given in Cost Category 7 and the piles in Cost Category 2.

Foundation slab, pit walls and cover slab, Accounts 302.2 and 303.1

A discussion of these types of concrete structures are given in Category 7.

Enclosure, Account 303.2

The key parameters are volume of the building required and the type of construction material.

In warmer climates, a building may not be required and weather-proofing the motor will suffice. Means (Reference 4) provides data on pre-engineered steel buildings. Costs include erection, normal doors, windows, and gutters. Based on the data given in Means and company experience, a value of $10/cubic meters of enclosure was selected.

Foundation excavation,
Account 304

A discussion of structure excavation is given in Cost Category 9. Assume the excavation will have side slopes of at least 2:1 and the outer dimensions are 1 meter beyond the perimeter of the station.

Steel sheet piling, Account 305

A discussion of sheet piling costs is given in Cost Category 2.

Structure backfill, Account 306

A discussion of backfill operations is given in Cost Category 8. Estimate the volume of backfill by subtracting the structure volume from the value used in Account 304 above.

Mobilization, Account 308

Unit prices do not include mobilization and demobilization costs. The user is to add the mobilization cost as indicated on the worksheet provided. A discussion of mobilization cost is given in Cost Category 10.

Table 28 presents the correlation between cost account number, worksheet, and figure number. Costs are calculated using the procedure outline in the introductory remarks to this section and the worksheets in Tables 29 through 42.

Table 28. PUMP STATION COST ACCOUNTS

Cost Account Number	Description	Figure Number	Worksheet Number
301	Mechanical - pumps and motors		
301.1	Costs for pumps and motors	301.1	301.1
301.2	Installation costs	301.2	301.2
301.3	Costs for butterfly valves and expansion joints	301.3	301.3
302	Structural (below grade)	--	302.1
302.1	Pile Foundation: Costs for the piles are given in Cost Category 2. Costs for concrete pile cap are given in Cost Category 7.		
302.2	Costs for the foundation slab and pit walls. (see Cost Category 7)	--	302.2
303	Structural (above grade)		
303.1	Costs for the cover slab. (see Cost Category 7)	--	303.1
303.2	Costs for an enclosure.		303.2
304	Costs for foundation excavation. (see Cost Category 9)	--	304
305	Costs for piling. (see Cost Category 2)	--	305
306	Structure backfill. (see Cost Category 8)	--	306
307	Other	--	307
308	Mobilization	--	308

Table 29. COST CATEGORY 3
COST SUMMATION

Worksheet 300

Cost Account Number	Description	Base Cost
301	Mechanical: Pumps and motors	
301.1	Pumps and motors	$BC_{301.1}$ =$ ________
301.2	Installation	$BC_{301.2}$ =$ ________
301.3	Valves and expansion joints	$BC_{301.3}$ =$ ________
302	Structural below grade	
302.1	Pile foundation	$BC_{302.1}$ =$ ________
302.2	Foundation slab	$BC_{302.2}$ =$ ________
303	Structural above grade	
303.1	Cover slab	$BC_{303.1}$ =$ ________
303.2	Enclosure	$BC_{303.2}$ =$ ________
304	Excavation	BC_{304} =$ ________
305	Piling	BC_{305} =$ ________
306	Backfill	BC_{306} =$ ________
307	Other	BC_{307} =$ ________
Cost Category 3 Total Cost (Enter Cost in Account 1101)		BC_3 =$ ________
308	Mobilization (Enter Cost in Account 1001)	MC_3 =$ ________

Table 30. PUMPS AND MOTORS

Worksheet 301.1

Design Data Required

Individual pump capacity (m^3/sec) Q = ________ (m^3/sec)

Power requirements P = ________ W

Number of pumping units N = ________

Type of pump[a] ________

Fresh or salt water ________

Base Cost

Enter Figure 301.1, read base cost per pumping unit BUC_1 =$ ________

Total base cost =BUC_1 x N BC =$ ________

Cost Adjustment

Enter Figure 301.1, read adjustment factors for type of pump (FD_1) and for fresh or salt water (FD_2)

FD_1 = ________

FD_2 = ________

Adjusted Base Cost

Adjusted base cost = BC x FD_1 x FD_2 $BC_{301.1}$ = ________

---

[a]Vertical dry pit or vertical wet pit.

Table 31. INSTALLATION

Worksheet 301.2

Design Data Required

Pump capacity (m^3/sec) ________

New pump station or modification to existing[a] ________

Number of pumps N = ________

Base Cost

Enter Figure 301.2, read base cost

BC_1 =$ ________

Total cost for installation = BC_1 x N $BC_{301.2}$ =$ ________

---

[a]Costs for modifications to an existing pump station assuming the old unit is removed.

Table 32. EXPANSION JOINTS AND VALVES

Worksheet 301.3

Design Data Required

Pump outlet pipe diameter D = ________ meters

Number of valves N(V) = ________

Number of joints N(J) = ________

Table 32 (continued). EXPANSION JOINTS AND VALVES

Worksheet 301.3

Base Cost

Enter Figure 301.3, read base cost for valves	BC_1 =$ ________
Total cost for valves = $BC_1 \times N(V)$	BC_2 =$ ________
Enter Figure 301.3, read base cost for expansion joints	BC_3 =$ ________
Total costs for expansion joints = $BC_3 \times N(J)$	BC_4 =$ ________
Total base cost = $BC_2 + BC_4$	$BC_{301.3}$ =$ ________

Table 33. PILE FOUNDATION

Worksheet 302.1

Base Cost

Cost for piles (Cost Category 2)	BC_1 =$ ________
Cost for pile caps (Cost Category 7)	BC_2 =$ ________
Total base cost = $BC_1 + BC_2$	$BC_{302.1}$ =$ ________

Table 34. FOUNDATION SLAB AND PIT WALLS

Worksheet 302.2

Base Cost

Cost for foundation slab (Cost Category 7) BC_1 =$ ________

Cost for pit walls BC_2 =$ ________

Total cost = $BC_1 + BC_2$ $BC_{302.2}$ =$ ________

Table 35. COVER SLAB

Worksheet 303.1

Base Cost

Cost for cover slab or deck (Cost Category 7) $BC_{303.1}$ =$ ________

Table 36. ENCLOSURE

Worksheet 303.2

Design Data Required

Volume of building V = ________ m^3

Base Cost

Base cost = 10 x V $BC_{304.2}$ =$ ________

Table 37. FOUNDATION EXCAVATION

Worksheet 304

Base Cost

Cost for excavation (Cost Category 9) BC_{304} =$ ________

Table 38. STEEL SHEET PILING

Worksheet 305

Base Cost

Cost for sheet piling (Cost Category 2) BC_{305} =$ ________

Table 39. STRUCTURE BACKFILL

Worksheet 306

Base Cost

Cost for structure backfill (Cost Category 8) BC_{306} =$ ________

Table 40. OTHER

Worksheet 307

Base Costs

Include costs not covered in this category but that relate to the pump station. Data presented in other accounts may be useful in estimating "Other" costs. BC_{307} =$ ____________

Table 41. MOBILIZATION

Worksheet 308

Mobilization Cost

New pump station - $3,300 MC_3 =$ ____________

The costs for mobilization of the equipment to excavate and backfill are included in Category 4.[a]

---

[a]For a new pump station, one crane could be used to install the pumps and for concrete work. For a modification to an existing station, it was assumed that a crane from some other activity could be used.

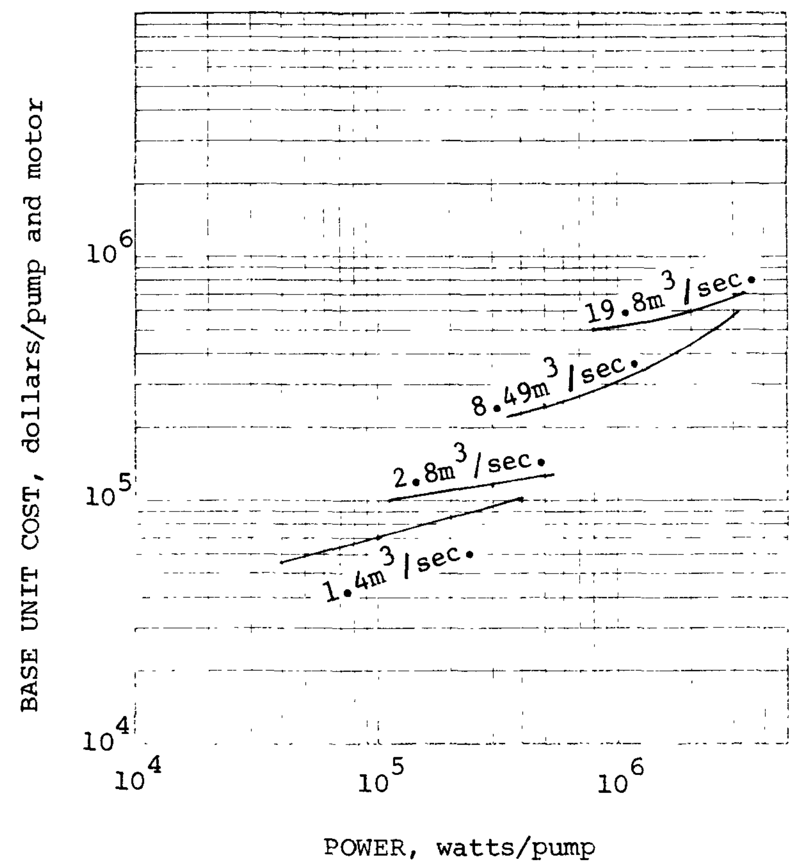


Fig. 301.1 - Pumps and Motors

Pump Type	Adjustment Factor (FD_1)
Vertical wet pit	1.0
Vertical dry pit	1.2

Condition	Adjustment Factor (FD_2)
Fresh	1.0
Salt	2.0

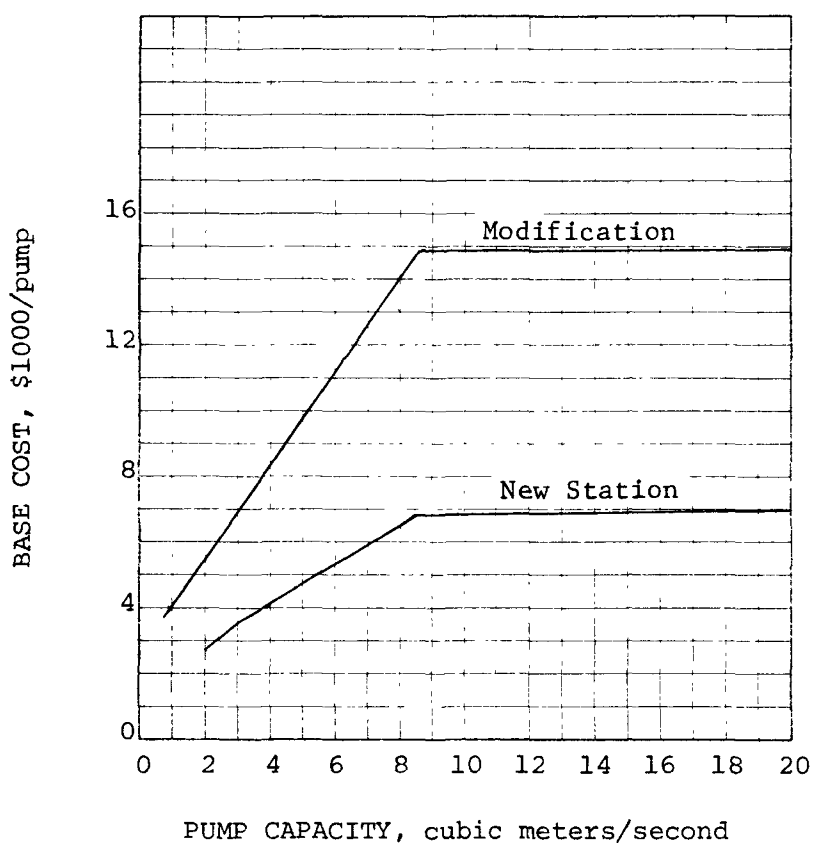


Fig. 301.2 - Pump and Motor Installation

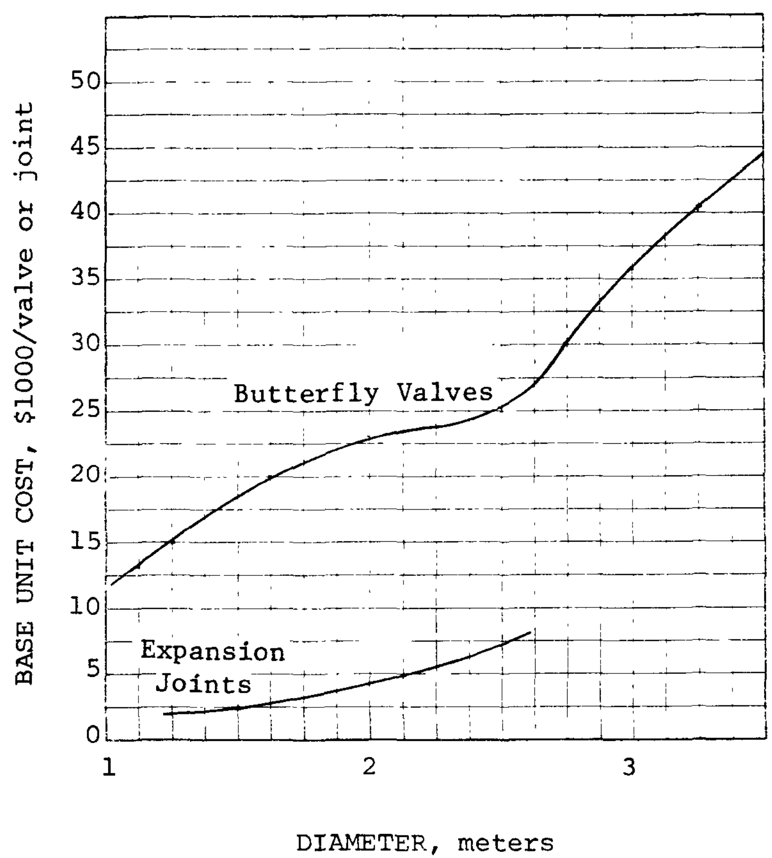


Fig. 301.3 - Costs for Valves and Expansion Joints

COST CATEGORY 4, CONDUITS

Information on the material and installation costs for conduits is given in Cost Category 4. Data given in Accounts 401 through 405 are for materials and Accounts 406 and 407 are for installation. The materials commonly used for conduits are:

1. concrete (precast and cast-in place);
2. steel (corrugated metal and carbon steel); and
3. fiberglass.

No definite guidelines for selection of pipe materials were encountered in the case studies and literature survey. Differences in pipe materials are most evident in offshore pipelines. Precast concrete pipe is the heaviest pipe and requires larger equipment to lay pipe lengths equal to steel and fiberglass pipe. The additional weight of concrete pipe has an advantage in water bodies where the currents may move a lighter pipe. The steel pipe requires a special coating; fiberglass does not, nor does concrete. Each of the pipes have standard fittings (elbows, wyes, etc.) but special carbon steel fittings can be fabricated on site. Cast-in-place concrete and carbon steel pipe are used most often for branching pipes and difficult transitions. The fiberglass pipe is the lightest and has no corrosion problems. More care is required when laying fiberglass pipe to prevent damage during laying. The laying rates for all the conduits are dependent on diameter.

As a rule of thumb, a system velocity between 2.0 and 3.0 meters/second is used for sizing conduits.

Material handling can be an important consideration. If the pipe is shipped to the site by rail, the material may be handled as many as three times before installing the pipe into the trench. Precast pipes are usually laid from a crane barge offshore with two support cranes on land.

Costs for excavation, laying of the pipe, and backfill of the pipe trench are given in separate accounts. However, the three are interrelated in the offshore work, and the rate at which each operation is accomplished will affect the total cost. Equipment selection and productivity used in developing unit prices reflect the interrelationship between excavation, pipe laying, and backfill.

Data on the accounts are given in the following paragraphs.

Precast concrete pipe,
Account 401

Key parameters are the pipe diameter and the application. Material costs are for a prestressed steel cylinder concrete pipe. The pipe costs more for subaqueous use than on land. Prices reflect freight costs F.O.B. railcar to any site approximately 645 kilometers from the point of manufacture and include contractor markup. Unit costs include provision for the cost of fittings. A maximum diameter of 3.97 meters, except in the Northeast, where the maximum is 3.66 meters is used on cost data sheets because shipping restrictions prevent transporting larger diameters. Larger pipe diameters have been cast on the site by the manufacturer, but these are special cases and the costs are not given.

Cast-in-place box conduit,
Account 402

Key parameters are formwork, reinforcing, placement and finishing. A square conduit with a wall thickness equal to 15 percent of the inside diameter is considered. The cost reflects:

1. placing medium (3,000 psi) strength concrete;
2. 71 kilograms of rebar per cubic meter of concrete;
3. formwork costs (which vary with the diameter); and
4. finishing costs.

Adjustment factors for the wall thickness are calculated and shown in the cost data. If this type is used offshore, costs for a cofferdam must be included. Trenching, backfill, cofferdams, and other installation costs are not included.

Steel conduit and fittings,
Account 403.1 and 403.2

Key parameters are the diameter of the pipe and the method of fabrication. For diameters up to approximately 3.05 meters, it was assumed the pipe is shop fabricated (by the manufacturer) and shipped to the site. Larger diameters have been shop fabricated, but it is a special order and costs are not given. Field fabrication for larger diameters is done by field welding rolled steel plates. The pipe can be fabricated in the trench or positioned for offshore laying. If the pipe is fabricated in the trench, no installation costs are added. Field fabrication costs are based to a large extent on data from Reference 12. Shop and field fabrication costs were developed for 1.27 cm steel plate thickness. Design adjustment factors for different plate thicknesses and for using hoop stiffeners are given. Fittings costs are given separately from the pipe. Steel fittings cost more than straight pipe because of the additional welding required.

Corrugated metal pipe,
Account 404

The key parameter is the diameter of the pipe. Up to 3.6 m the pipe is shop fabricated. For diameters greater than 3.6 m the pipe is shipped to the site as galvanized plates. The pipe is bolted together on site, whether in the pipe trench or positioned for offshore laying in completed sections. In either case, installation costs are added.

Fiberglass pipe, Account 405

The key parameter is the diameter of the pipe. Fiberglass pipe is shipped to the site (except in the Northeast) in diameters to 3.97 meters. On occasion, this pipe has been fabricated on site. The costs for field fabricated pipe are given.

Excavation of pipe trench
(land), Account 406.1

A discussion of land excavation is given in Cost Category 9.

Laying pipe on land,
Account 406.2

Key parameters are the pipe material and fabrication. The steel pipes, corrugated metal, and carbon steel can be fabricated in the trench. Installation costs are not added to the material costs for cast-in-place concrete, or carbon steel pipe greater than 3.05 m diameter. For diameters less than 3.05 m, the carbon steel pipe can be shop or field fabricated. Usually, the user can assume the pipe to be shop fabricated and installation costs should be added. Material handling is less of a problem when installation is on land. The pipe can be offloaded into the trench from the truck that hauls the pipe to the site or stockpiled close enough to be handled by the crane used to install the pipe. Therefore, no costs for a yard crane are included in this account. The lengths of pipe used to determine laying rates are:

1. precast concrete (4.9 meters for pipe diameters to 3.66 meters and 3.05 meters for pipe diameters greater than 3.66 meters);
2. corrugated metal (7.3 meters); and
3. fiberglass (14.6 meters).

Onshore backfill, Account 406.3

Discussion of placement and the material used in backfill of the pipe trench is given in Cost Category 8.

Pipe support systems,
Account 406.4

Data for the concrete or piles can be found in the discussion for Cost Category 7.

Dewatering, Account 406.5

The key parameter is the time required to lay the pipe (see also the discussion for Account 904). Pumping costs are given in terms of the dewatering period.

Offshore pipe trench excavation, Account 407.1

A discussion of marine excavation is given in Cost Category 9.

Laying pipe offshore, Account 407.2

Key parameters are the weight of the pipe, length of the pipe section installed, and meteorological conditions. The lighter pipes such as steel and fiberglass pipe can be laid in longer lengths than concrete. In some cases, manufactured lengths are joined on shore. The lengths of pipe sections assumed for developing laying rates are:

1. precast concrete (9.8 meters for pipe diameters) to 3.66 meters and 6.1 meters for pipes 3.66 or longer);
2. corrugated metal (12.2 meters);
3. carbon steel (12.2 meters for pipe diameters to 3.66 meters and 6.1 meters for pipes 3.66 meters or longer); and
4. fiberglass (15.3 meters).

In offshore laying, all the pipes are joined using a bell and spigot joint. Divers bring together the sections using bolts fixed to the outside of the pipe. The depth at which the pipe is laid will affect the costs because of special rigging and diver problems. An adjustment factor for laying pipe in depths greater than 14 meters is included.

Material handling at the site is an important consideration. In some cases, the pipe is off-loaded at the rail head, hauled to a yard and reloaded onto a barge for transport to the site. Alternatively, the pipe can be transported to the site on a barge loaded at a port near the manufacturer's permanent or temporary plant. Cost data are given for ground transport to the site (the first case).

Two support cranes on shore are considered in addition to a flat top and crane barge used in laying the pipe.

In some areas, water currents will cause siltation of the trench to the extent of limiting the length of pipe that can be laid. An example is laying a pipeline in the surf zone of a lake or ocean. A discussion of estimating costs for laying pipe in the surf zone and river is given in Account 408.

Offshore backfill, Account 407.3

A discussion of backfilling the pipe trench including the cushion fill and common earth is included in Cost Category 8.

Pipe support systems, Account 407.4

Key parameters are the foundation (earth or rock) and the weight of the pipe. If in the area where the pipe is laid, the soil bearing capacity is poor, a concrete cradle supported by piles may be required. Data to estimate the cost for the piles and concrete are included in Cost Category 2 and Cost Category 7, respectively. The lighter pipes may require concrete anchors placed to restrict movement. Data for tremie concrete are given in Category 7.

Riprap protection, Account 407.5

Riprap protection may be required to protect the backfill from erosion. A discussion of offshore placement of rip-rap is given in Category 2.

Cofferdam, Account 407.6

In some instances, offshore work cannot be done by divers. A cofferdam is constructed and the area dewatered. An example of the possible use for cofferdam is extending a single port discharge further offshore. If the existing outfall were encased in concrete, the area might be de-watered to permit attaching the additional pipe.

Other, Account 408

Installation of the pipe in the river or the surf zone is more costly than for conventional offshore laying methods. The contractor may over-excavate the trench to allow for siltation. However, over-excavation may not be a viable alternative in some cases and the laying of pipe may involve:

1. building a trestle constructed of steel H-pile bents with steel beam stringers and wooden planks (The trestle extends from the shore to where littoral currents no longer influence the pipe laying operation);
2. positioning a crane on the trestle for driving sheet piling to keep the currents from filling the trench with silt (The crane can be used to excavate the trench, lay the pipe and backfill the trench);
3. placing concrete around top of the pipe to prevent erosion of the backfill.

Costs for this type of operation are difficult to assess because the length of the zone is not well defined. Also this is a method of construction and probably will not be delineated on the available drawings. A rule of thumb for estimating the cost for building the trestle is to assume $1,500/meter. Other costs such as shoring and pipe laying can be estimated using the procedures outlined in the manual. Because the crane is working from the trestle, costs for land-based operations may be appropriate. To estimate the length to which the special construction method applies, assume a water depth between 2 and 3 meters divides the surf zone and conventional laying methods.

Mobilization, Account 409

The cost for mobilization and demobilization is not included in the unit price. The costs for mobilizing equipment to excavate the pipe trench, lay the pipe and backfill the trench are given. A discussion of mobilization is given in Category 10.

Table 42 presents the correlation between cost account number, worksheet, and figure number. Costs are calculated using the procedure outlined in the introductory remarks to this section and the worksheets in Tables 43 through 62.

Table 42. CONDUIT COST ACCOUNTS

Cost Account Number	Description	Figure Number	Worksheet Number
401	Precast concrete pipe costs for materials for diameters to 4 meters.	401	401
402	Cast-in-place box conduit costs for in-place casting of square concrete conduits.	402	402
403	Steel conduit and fittings costs for materials and fabrication for diameters to 6 meters.		
403.1	Pipe costs	403.1	403.1
403.2	Cost of fittings, including elbows, reducers and tees.	403.2	403.2
404	Corrugated metal pipe material and fabrication costs for diameters to 6 meters. Installation costs are not included.	404	404
405	Fiberglass pipe. Costs for material and fabrication for diameters to 6 meters. Installation costs are not included.	405	405
406	Cost for land installation of pipe.		
406.1	Costs for onshore excavation of pipe trench (see Cost Category 9).	--	406.1

Table 42 (continued). CONDUIT COST ACCOUNTS

Cost Account Number	Description	Figure Number	Worksheet Number
406.2	Costs for laying pipe onshore.	406.2	406.2
406.3	Costs for cushion fill and trench backfill (see Cost Category 8).	--	406.3
406.4	Costs for pipe supports, including concrete thrust blocks, encasement, cradles, and piles.	--	406.4
406.5	Cost for dewatering the pipe trench.	406.5	406.5
407	Cost for marine installation of pipe:		
407.1	Offshore excavation costs for pipe trench (see Cost Category 9).	--	407.1
407.2	Costs for laying pipe off-shore.	407.2	407.2
407.3	Costs for fill cushion and trench backfill (see Cost Category 8).	--	407.3
407.4	Costs for pipe supports, including concrete thrust blocks, encasement, cradles, and piles.	--	407.4
407.5	Costs for riprap protection for pipe trench.	--	407.5
407.6	Costs for materials and construction of coffer-dams used in pipe in-stallation.	--	407.6
408	Other	--	408
409	Mobilization	--	409

Table 43. COST CATEGORY 4 COST SUMMATION

Worksheet 400

Cost Account Number	Description	Base Cost
401	Precast concrete pipe	BC_{401} =$ ________
402	Cast-in-place box culvert	BC_{402} = ________
403	Steel conduit	
403.1	Steel pipe	$BC_{403.1}$= ________
403.2	Steel fittings	$BC_{403.2}$= ________
404	Corrugated metal pipe	BC_{404} = ________
405	Fiberglass pipe	BC_{405} = ________
406	Land installation of pipe	
406.1	Onshore excavation	$BC_{406.1}$= ________
406.2	Onshore pipe laying	$BC_{406.2}$= ________
406.3	Cushion fill and backfill	$BC_{406.3}$= ________
406.4	Pipe supports	$BC_{406.4}$= ________
406.5	Dewatering	$BC_{406.5}$= ________
407	Marine installation of pipe	
407.1	Offshore excavation	$BC_{407.1}$= ________
407.2	Offshore pipe laying	$BC_{407.2}$= ________
407.3	Cushion fill and backfill	$BC_{407.3}$= ________

Table 43 (continued). COST CATEGORY 4
COST SUMMATION

Worksheet 400

Cost Account Number	Description	Base Cost
407.4	Pipe supports	$BC_{407.4}$= ________
407.5	Riprap protection	$BC_{407.5}$= ________
407.6	Cofferdams	$BC_{407.6}$= ________
408	Other	BC_{408} = ________
Cost Category 4 Total Cost (Enter Cost in Account 1101)		BC_4 =$ ________
409	Mobilization (Enter Cost in Account 1001)	MC_4 =$ ________

Table 44. PRECAST CONCRETE PIPE

Worksheet 401

Design Data Required

Pipe diameter ________ m

Pipe length L = ________ m

Land or marine installation ________

Base Cost

Enter Figure 401, read base unit cost per lineal meter. BUC =$ ________

Base cost = L x BUC BC_{401} =$ ________

Table 45. CAST-IN-PLACE BOX CONDUIT

Worksheet 402

Design Data Required

Width or height of square conduit		________ m
Wall thickness		________ cm
Length of pipe	L =	________ m

Base Cost

Enter Figure 402, read base unit cost per lineal meter	BUC	=$ ________
Base cost = L x BUC	BC	=$ ________

Cost Adjustments

Enter Figure 402, read design adjustment factor for wall thickness	F_D	= ________

Adjusted Base Cost

Base cost of materials and fabrication = BC x F_D	BC_{402}	=$ ________

Table 46. STEEL CONDUIT

Worksheet 403.1

Design Data Required

Pipe diameter	________	m
Wall thickness	________	cm
With or without stiffeners	________	
Pipe length	L = ________	m
Shop or field fabrication[a]	________	

Base Cost

Enter Figure 403.1, read base unit cost per lineal meter	BUC =$ ________	/m
Base cost = L x BUC	BC =$ ________	

Cost Adjustments

Enter Figure 403.1, read design adjustment factors for wall thickness, stiffeners and fabrication	$F_D(1)$= ________ $F_D(2)$= ________ $F_D(3)$= ________

Adjusted Base Cost

Adjusted base cost of materials and fabrication = BC x $F_D(1)$ x $F_D(2)$ x $F_D(3)$	$BC_{403.1}$=$ ________

[a]For diameters to 3.05 meters, assume shop fabrication.

Table 47. STEEL PIPE FITTINGS

Worksheet 403.2

Design Data Required

Type (elbow, reducer, tee, connection)	________	
Diameter (if a fitting diameter varies, use largest diameter)	________	m
Angle (for reducer or connection)	________	o
Number	N = ________	
Wall thickness	________	cm
With or without stiffeners	________	

Base Cost

Enter Figure 403.2, read base unit cost per fitting	BUC =$ ________	
Base cost = N x BUC	BC =$ ________	

Cost Adjustments

Enter Figure 403.1, read design adjustment factors for wall thickness and stiffeners and fabrication	$F_D(1)$= ________ $F_D(2)$= ________ $F_D(3)$= ________

Adjusted Base Cost

Adjusted base cost of materials and fabrication for particular type of fitting = BC x $F_D(1)$ x $F_D(2)$ x $F_D(3)$	$BC_{403.2}$=$ ________

Table 48. CORRUGATED METAL PIPE

Worksheet 404

Design Data Required

Pipe diameter		________ m
Pipe length	L =	________ m

Base Cost

Enter Figure 404, read base unit cost per lineal meter	BUC	=$ ________
Base cost = L x BUC	BC_{404}	=$ ________

Table 49. FIBERGLASS PIPE

Worksheet 405

Design Data Required

Pipe diameter		________ m
Pipe length	L =	________ m

Base Cost

Enter Figure 405, read base unit cost per lineal meter	BUC	=$ ________
Base cost = L x BUC	BC_{405}	=$ ________

Table 50. ONSHORE PIPE TRENCH EXCAVATION

Worksheet 406.1

Base Cost

Refer to Cost Accounts 901 or 902 for cost estimating procedure $BC_{406.1}$=$ ________

Table 51. LAYING PIPE ON LAND

Worksheet 406.2

Design Data Required

Length of pipe	L = ________	m
Diameter of pipe	D = ________	m
Material	________	

Base Cost

Enter Figure 406.2, read base unit cost per lineal meter BUC =$ ________

Base cost = L x BUC $BC_{406.2}$ =$ ________

Table 52. ONSHORE BACKFILL

Worksheet 406.3

Base Cost

Refer to Cost Category 8 for appropriate cost accounts and estimating procedures $BC_{406.3}$ =$ ________

Table 53. PIPE SUPPORT SYSTEMS

Worksheet 406.4

Base Cost

Refer to Cost Category 7 for concrete costs and 2 for piling costs $BC_{406.4}$ =$ ____________

Table 54. DEWATERING

Worksheet 406.5

Design Data Required

Length of pipes	L =	____________
Pipe material[a]	____________	
Diameter		____________ m

Base Cost

Enter Figure 406.5, read base unit cost for Dewatering BUC =$ ____________

Base cost = BUC x L $BC_{406.5}$ =$ ____________

---

[a]Steel,
Concrete, or
Fiberglass Pipe

Table 55. OFFSHORE PIPE TRENCH EXCAVATION

Worksheet 407.1

Base Cost

Refer to Cost Accounts 901 or 902 for cost estimating procedure $BC_{407.1}$=$ ____________

Table 56. LAYING OFFSHORE PIPE

Worksheet 407.2

Design Data Required

Length of pipe L = ____________ m

Diameter D = ____________ m

Pipe material ____________

Depth of water ____________ m

Base Cost

Enter Figure 407.2, read base unit cost per lineal meter BUC =$____________/m

Base cost = L x BUC BC =$____________

Cost Adjustment

Enter Figure 407.2, read adjustment factor for water depth F_D = ____________

Adjusted Base Cost

Adjusted base cost for laying pipe offshore = BC x FD $BC_{407.2}$=$____________

Table 57. OFFSHORE BACKFILL

Worksheet 407.3

Base Cost

Refer to Cost Category 8 for appropriate cost accounts and cost estimating procedure $BC_{407.3}$=$____________

Table 58. PIPE SUPPORT SYSTEMS

Worksheet 407.4

Base Cost

Refer to Cost Categories 7 and 2 for appropriate cost accounts and estimating procedures $BC_{407.4}$=$________

Table 59. RIPRAP PROTECTION

Worksheet 407.5

Base Cost

Refer to Cost Account 201.2 for estimating procedure $BC_{407.5}$=$________

Table 60. COFFERDAMS

Worksheet 407.6

Base Cost

Refer to Cost Category 2 for appropriate cost accounts and estimating procedures $BC_{407.6}$=$________

Table 61. OTHER

Worksheet 408

Base Cost

Include costs not covered in this category but that relate to conduits. Data presented in other accounts may be useful in estimating "Other" costs.

Also the costs for the surf zone are to be added in this account. BC_{408} =$ ____________

Table 62. MOBILIZATION

Worksheet 409

Data Requirement

Description	Mobilization Cost	Summation
For offshore installation of a conduit add $96,000[a]	$96,000	________
For land installation of the conduit add	$ 6,600	________
For hauling fill	$ 600	________

Mobilization Cost

Mobilization = the total of the summation column (above) MC_4 =$ ________

[a]The mobilization costs are inclusive of accounts 407.1 through 407.6.

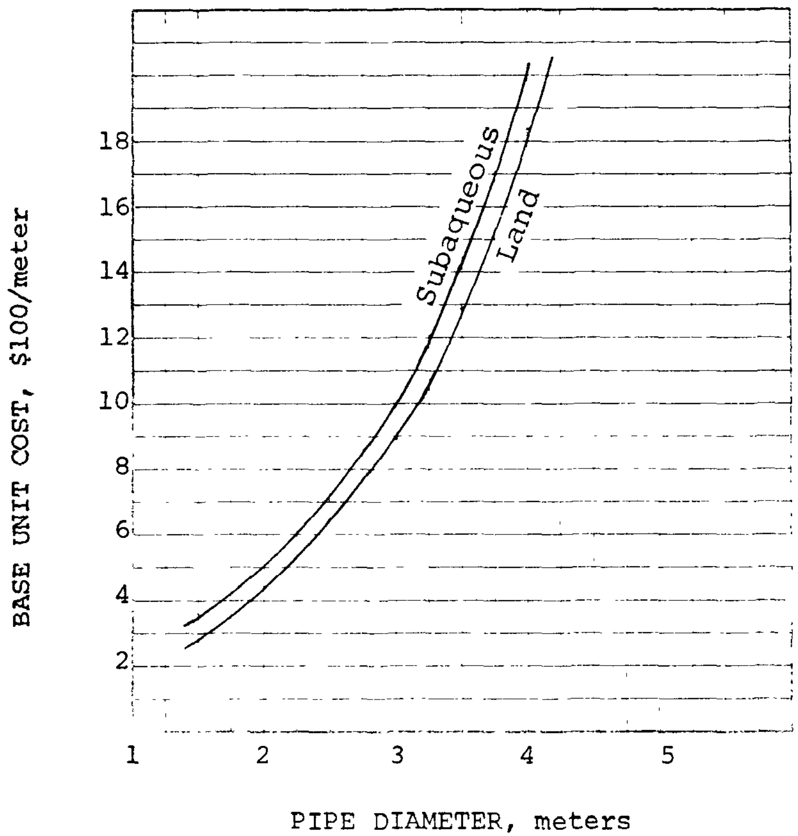
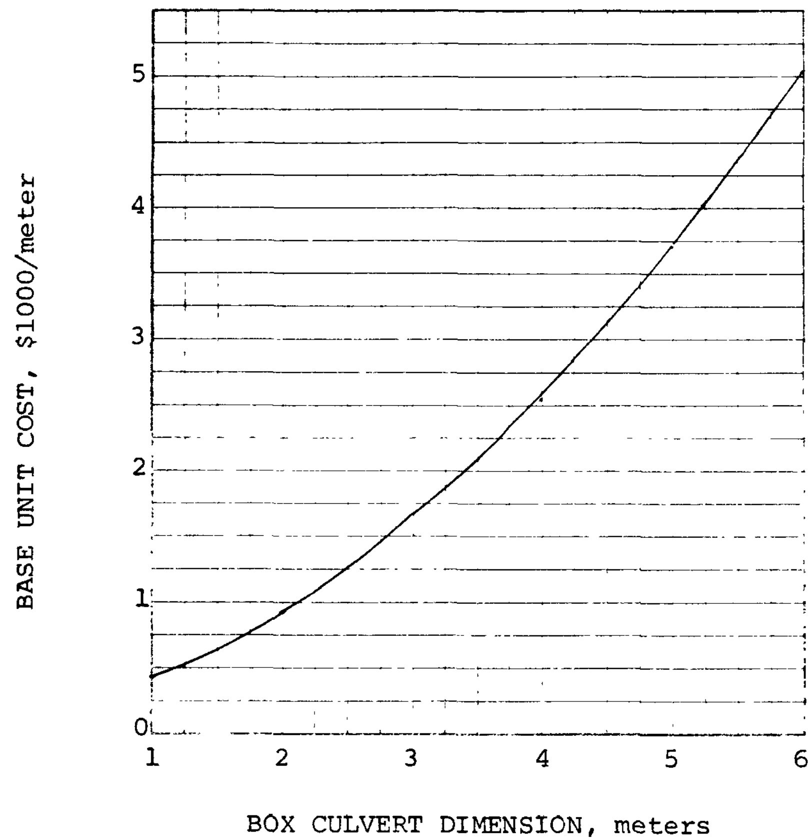


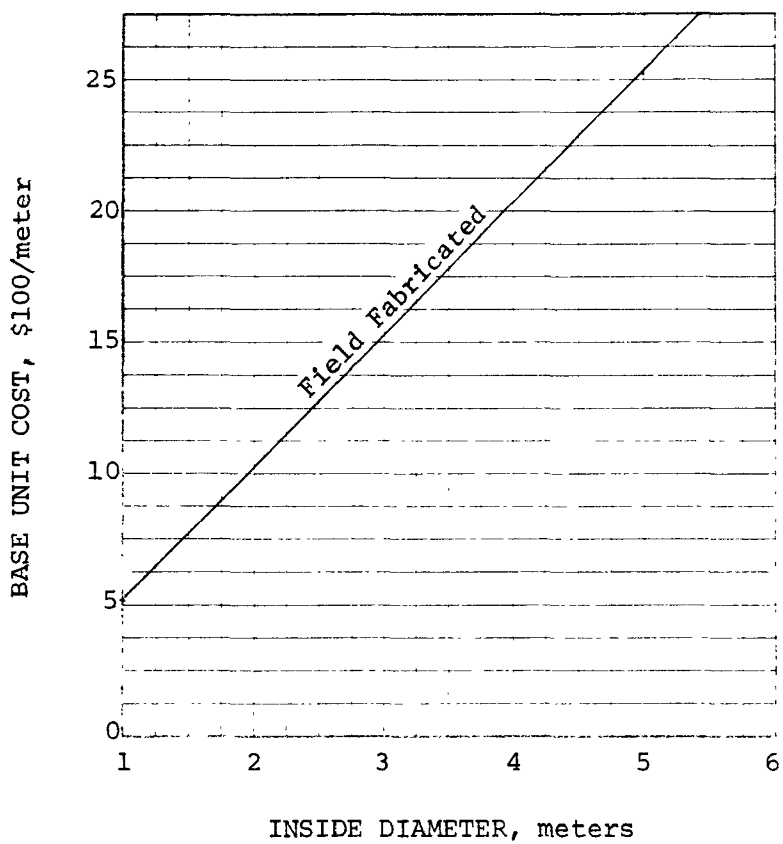
Fig. 401 - Costs for Precast Concrete Pipe



Factors for Variation in Wall Thickness:

Diameter (Meters)	Wall Thickness (cm) 15	30	45	60	75	90
1	1.00	--	--	--	--	--
2	0.73	1.00	1.28	1.60	--	--
3	0.60	0.79	1.00	1.22	1.46	--
4	--	0.66	0.83	1.00	1.19	1.38
5	--	--	0.70	0.85	1.00	1.16
6	--	--	--	0.74	0.87	1.00

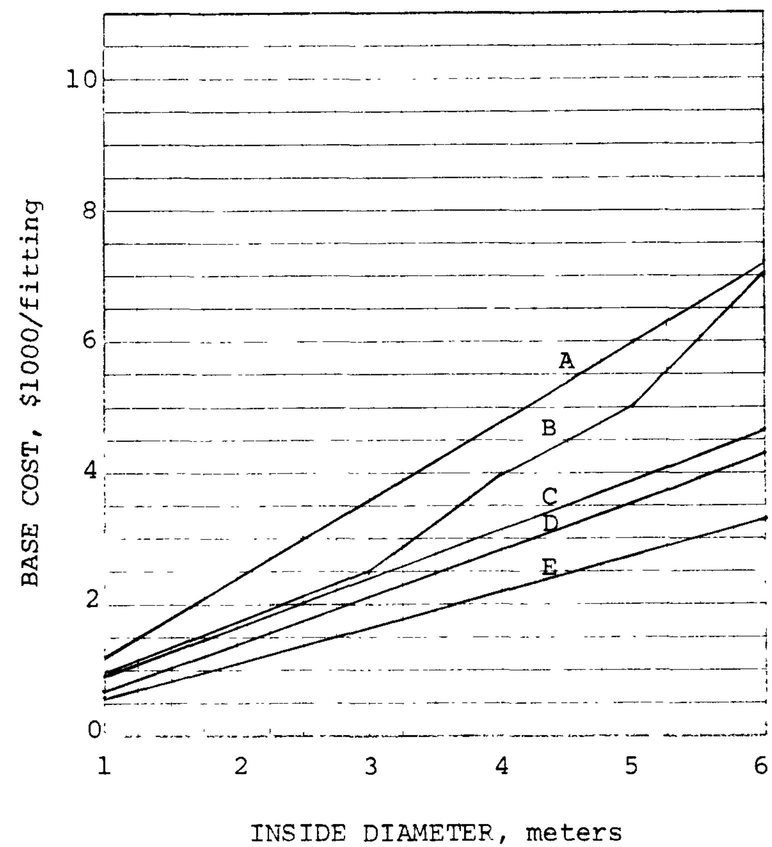
Fig. 402 - Cost for Cast-In-Place Box Conduit



Thickness (cm):	.635	.953	1.27	1.588	1.905	2.22
Factor FD (1):	.50	.75	1.0	1.25	1.5	1.75

With Stiffeners, FD(2) = 1.6
Shop Fabrication, FD(3) = .65

Fig. 403.1 - Cost for Carbon Steel Pipe



Curve	
A	90° Elbow (mitered)
B	Reducer (plotted for larger diam.)
C	45° Connection
D	Tee Connection
E	45° Elbow (mitered)

Fig. 403.2 - Cost for Elbows, Reducers, and Connections

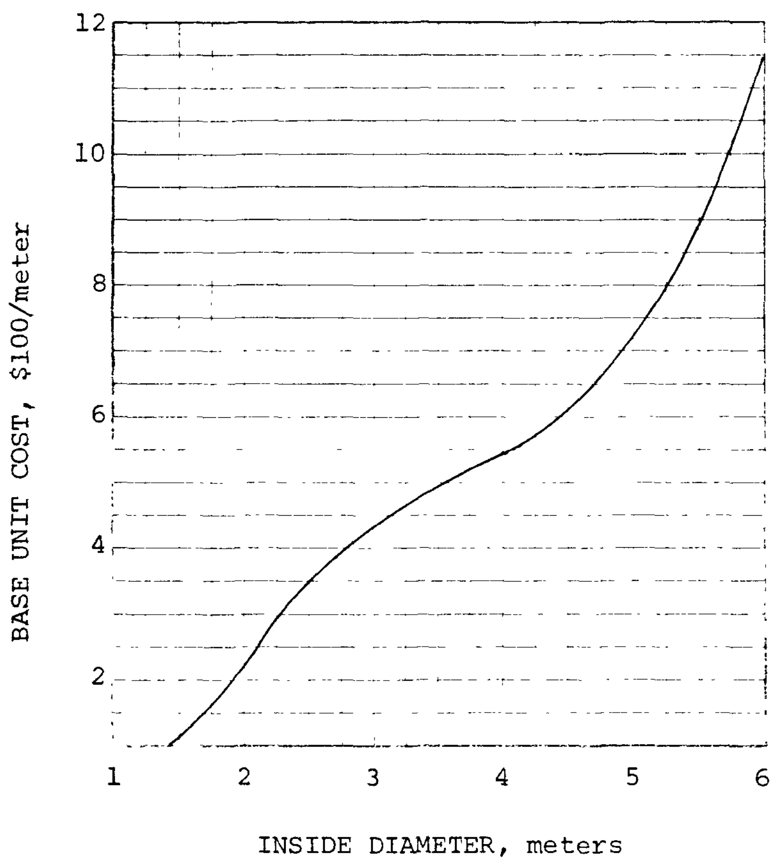


Fig. 404 - Costs for Corrugated Steel Pipe

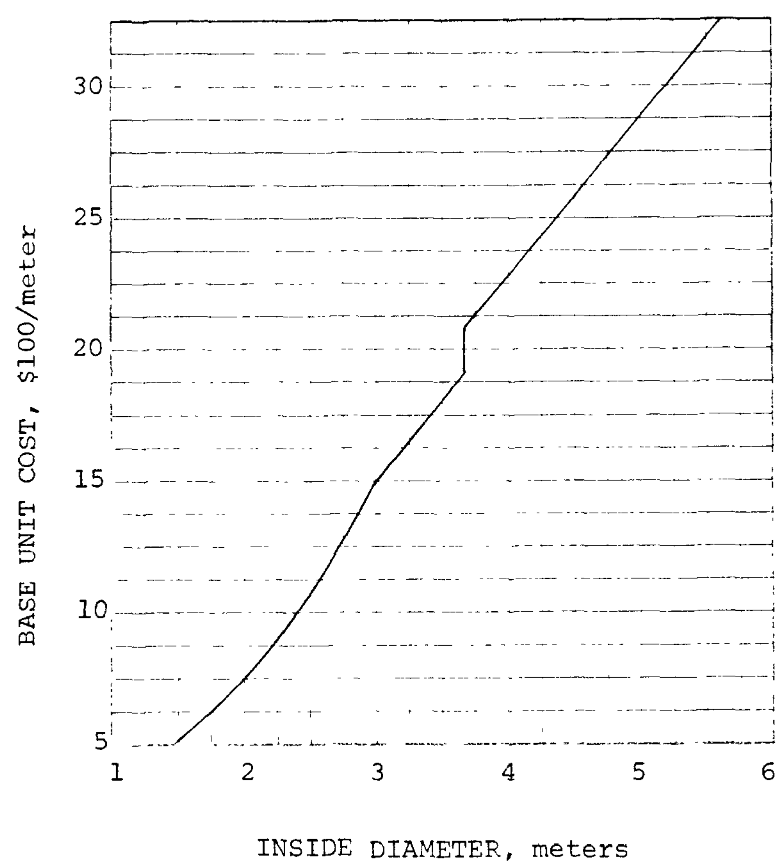
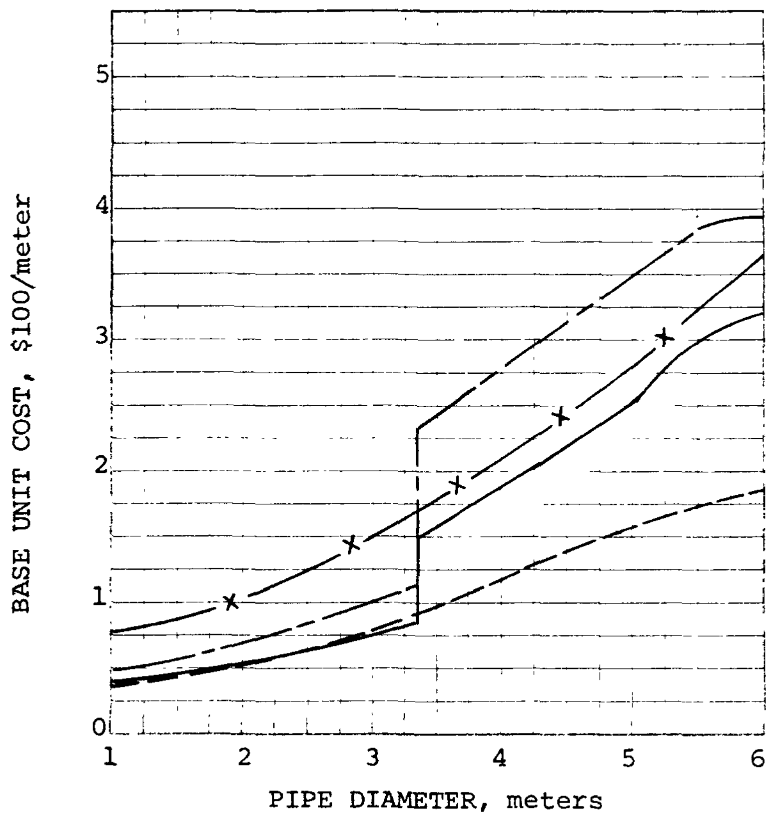
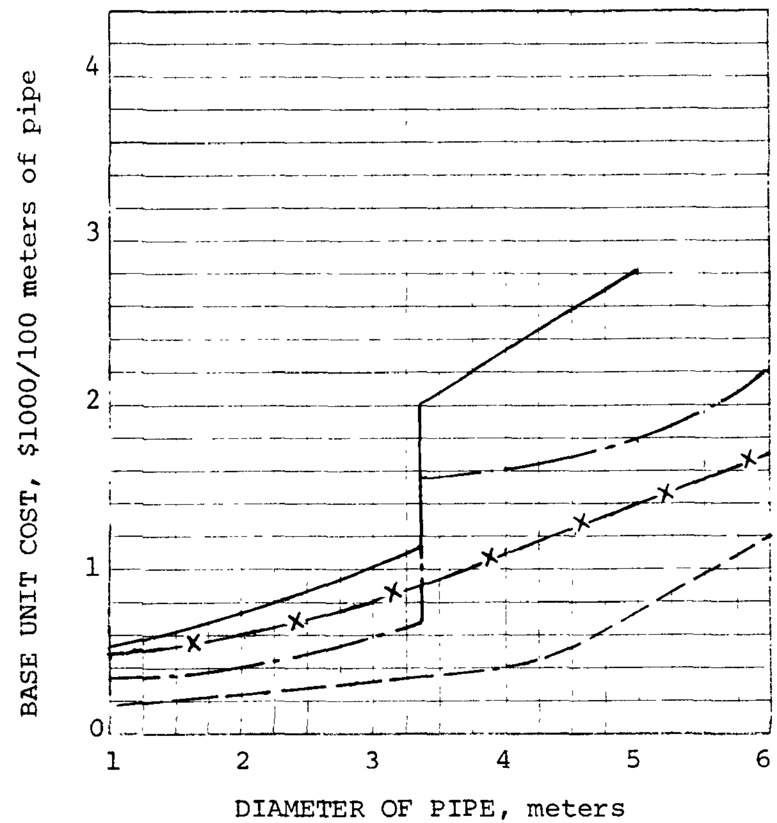


Fig. 405 - Cost for Fiberglass Pipe



——— Precast Concrete Pipe
- - - - Fiberglass Pipe
— - — Corrugated Metal Pipe
x - x Carbon Steel (for shop fabrication only)

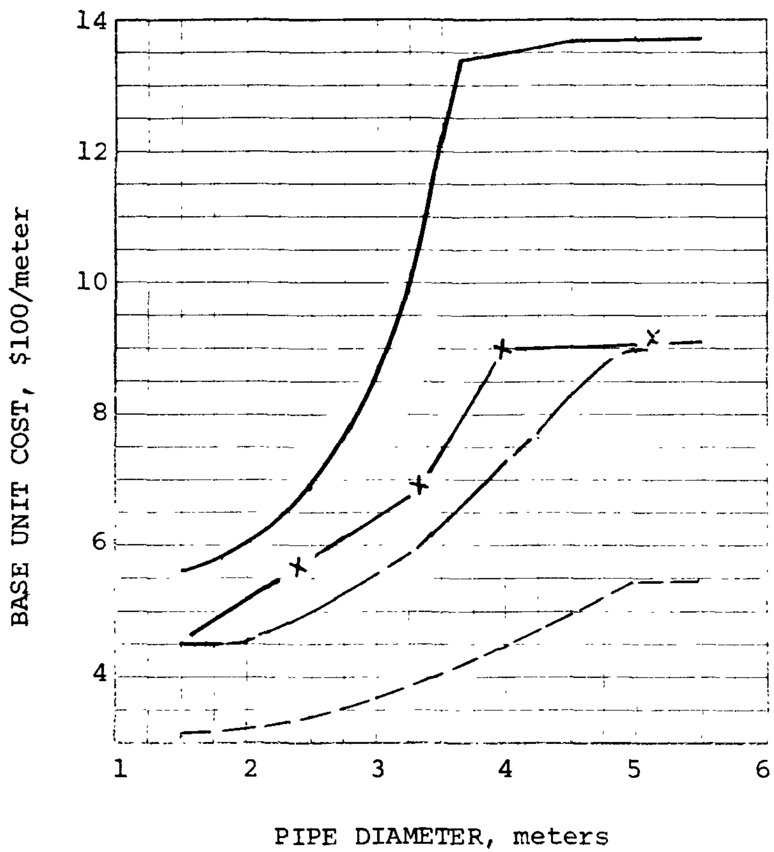
Fig. 406.2 - Costs for Pipe Installation (Land)



——— Precast Concrete Pipe
- - - - Fiberglass Pipe
— - — Corrugated Metal Pipe
x - x Carbon Steel Pipe (Shop Fabricated)

Note: For field fabricated carbon steel pipe, use Adjustment Factor of 1.53

Fig. 406.5 - Dewatering Costs for Pipe Installation



——— Precast Concrete Pipe
----- Fiberglass Pipe
—·—·— Corrugated Metal Pipe
x - x Carbon Steel

Water Depth	Adjustment Factor
Less than 14 m	1.0
Greater than 14 m	1.2

Fig. 407.2 - Costs for Pipe Installation (Marine)

COST CATEGORY 5, TUNNELING

Data is provided for excavation, lining, support systems, and dewatering. A lay classification of rock characteristics is adopted to simplify the discussion. The correlation between rock types, quality designation, and classification is given in Table 63.

Table 63. ROCK TYPES

Rock Description	RQD[a]	Classification
Hard and intact; hard stratified or schistose	> 95	Excellent
Massive, moderately jointed; moderately blocky and seamy	75-95	Good
Very blocky and seamy	50-75	Fair
Shattered and/or unconsolidated	25-50	Poor
Unconsolidated or completely crushed; gravel or sand	< 25	Very poor

[a]Rock Quality Designation: A modified core recovery technique based indirectly on the number of fractures and amount of softening or alteration in the rock mass as observed in cores from a 3-inch drill hole.

The system of using lay classifications is useful in the discussion but often the descriptions overlap and do not exactly fit all cases. However, the discrepancies do not adversely affect the estimating accuracy.

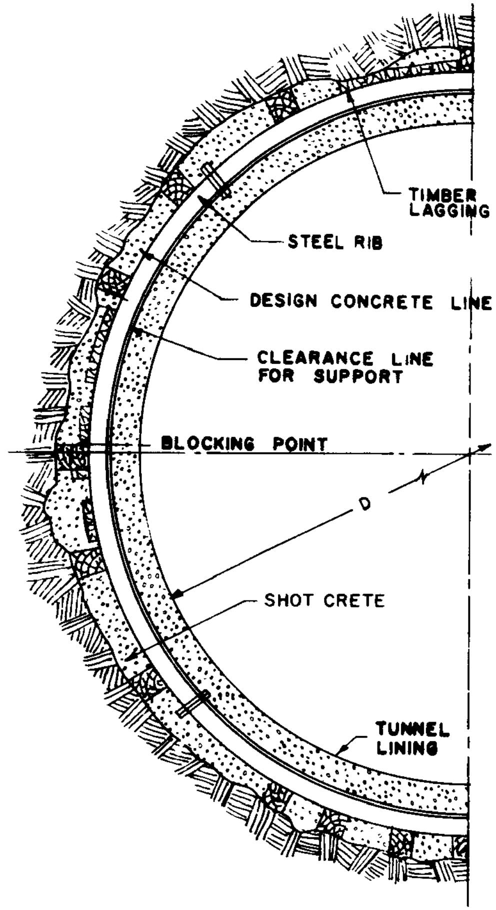
Rock quality affects excavation and the type of rock support system. In addition, costs are dependent on the type of heading; wet or dry. A wet heading is defined as having more than 0.4 cubic meters/minute of water flowing into the tunnel. If adequate information is available on conditions expected along the proposed tunnel alignment, the tunnel should be divided into reaches of generally similar characteristics and the construction cost estimated for each reach individually.

When the design information is limited, the user should assume the best condition encountered will be classified as fair. Four support systems are used alone or in combination depending on site conditions:

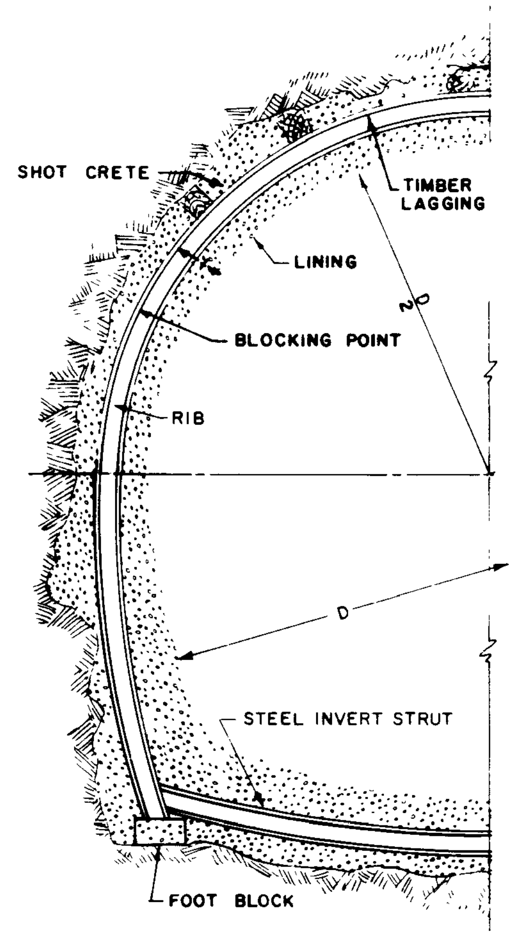
1. Rock bolts - Bolts used to tie rock closest to excavation back into undisturbed strata.
2. Shotcrete - Mixture of sand and cement pneumatically applied to roof and walls of tunnel. In this study, costs include grouting for rock bolts. For poor rock conditions, shotcrete is usually combined with other support alternatives (see Figure 500.1).
3. Horseshoe ribs - As rock conditions become poorer, continuous roof support is required. A common support system consists of a series of horseshoe-shaped ribs made from steel wide-flange beams and separated by timber lagging (see Figure 500.1).
4. Circular ribs - In poor quality rock, circular steel ribs support the circumference of the tunnel excavation (see Figure 500.1).

Types of support and relative sizes and dimensions associated with the lay rock classifications are given in Table 64 (see Reference 5).

Unless specifically noted, each support system is used independently. Thus when the user seeks the cost for a support system, he should select the type given in his design plans and use that cost alone (except where noted in Table 64).



Circular Rib



[illegible]

Fig. [illegible] [illegible]ural Supports

The design velocity for tunnels is approximately 2 to 3 meters/second. Data for the accounts of Cost Category 5 are given in the following paragraphs.

Tunnel excavation, Account 501

Key parameters are the geological condition of the tunnel area, the size of the tunnel and the type of heading (wet or dry). Data are given for circular tunnels with a diameter of 3 to 8 meters. For other shapes, assume an equivalent diameter, or the height dimension of the tunnel.

Excavation costs vary substantially with the type of rock and with the size of tunnel. Data presented in "Tunneling-The State of the Art", by R. S. Mayo and Associates (Reference 5) were used as the source for excavation costs.

Costs were estimated for each of the following rock conditions:

1. Dry headings in:
    a. stratified or schistose rock (excellent);
    b. massive moderately jointed rock (good);
    c. moderately blocky and seamy rock (good);
    d. very blocky and seamy rock (fair); and
    e. completely crushed or unconsolidated sediments (very poor).
2. Wet headings in:
    a. competent rock (excellent to poor); and
    b. crushed rock or unconsolidated sediments very poor).

Tunnels may be excavated using a boring machine or by conventional means. The data given here are based on conventional mining techniques. For cooling water tunnels, shaft headings are required and costs must be included for shaft excavation and hoisting equipment. It was assumed for all excavation costs that tunnel spoil would be disposed of in the immediate vicinity (within one kilometer). For operations in which a disposal area is not located nearby, the hauling costs should be added to the excavation costs (refer to Category 1 for hauling costs).

Rock bolts, Account 502.1

Key parameters are the rock bolt spacing and the penetration length. Rock bolts are installed by drilling a hole into the rock, placing the bolt and grouting the bolt into place (optional). The spacing is increased as the rock conditions improve. The bolts are placed into the crown of the tunnel bore. Refer to Table 64 for examples of rock bolt spacings and the interrelationship of tunnel support systems.

Shotcrete, Account 502.2

Key parameters are thickness and the percent of the tunnel crown covered. Shotcrete is a structural measure used during construction of the tunnel and is in addition to lining (Account 503). Shotcrete can be used alone as rock support or in combination with other systems. For poor or very poor rock, shotcrete is usually used in combinations with other support systems (refer to Table 64).

Table 64. ROCK SUPPORT CRITERIA

Rock Quality	Rock Bolts Recommended[a]	Shotcrete Recommended[a]	Steel Sets Recommended[a]
Excellent (RQD > 90)	--	0 to 5 to 8 cm Thickness	0 to occasional
Good (75<RQD<90)	1.5 - 1.8 m on center pattern	5 - 8 cm	1.5 to 1.8 m centers
Fair (50<RQD<75)	1 x 1m to 1.5x1.5m	10 cm	1.2 to 1.5 m centers
Poor (25<RQD<50)	.6x.6m to 1.2x1.2m	15 cm or more, Combine w/bolts	4' - .6x.6m to 1.2x1.2 centers
Very Poor (RQD<25)	1 x 1m	15 cm or more on whole section. Combine with medium to heavy sets.	Heavy circular sets on .6m centers
Very Poor (Squeezing or Swelling)	.6x.6m to 1x1m	15cm or more, Combine with heavy sets	Very heavy circular sets - .6m centers

[a] Recommendations from Corps of Engineers' Manual on Tunnels and Shafts (1973) (Reference 6).

Structural steel supports,
Accounts 502.3, 502.4 and 502.5

Key parameters are the tunnel diameter spacing and size of the members. Mayo (Reference 5) gives the support spacing based on the comparison between rock loading and tunnel dimensions. The size of the members is based on the data given in Reference 13. Timber lagging is used between the steel sets to contain loose rocks and separate the sets.

Concrete tunnel lining,
Account 503

The key parameter is the lining thickness. An allowance should be made for over-excavation of the tunnel and grouting to fill voids between the lining. A factor of 1.2 times "neat line dimensions" is recommended. The tunnel lining does provide structural support. However, the primary function is to reduce hydraulic friction loss. All tunnels are not lined but usually omitting the lining is reserved for tunnels in excellent rock that were excavated using a boring machine.

Tunnel dewatering, Account 504

The key parameter is the inflow rate. Pump and pipe sizes are assumed for given inflow rates. The rental and labor costs were calculated and related to the inflow.

Shafts, Account 505

For cooling water tunnels, shaft headings are required and costs must be included for shaft excavation hoisting equipment and additional structural support. Costs for shaft headings are calculated by multiplying the total horizontal tunnel costs times 2 (Reference 5). If a shaft is to be excavated offshore, it will probably be to connect some type of diffuser. The costs for the shafts are given here and the costs for cofferdams and other installation charges are included in Cost Category 6.

Mobilization is not given an account number. Mobilization costs are estimated to be 5 percent of the construction costs. The calculation is done on summary worksheet number 500.

To estimate the cost for tunnel excavation and support systems, the outside diameter is used. Whereas, selection of the tunnel for hydraulic criteria is based on inside dimension. The relationship between inside and outside diameter for different rock quality designations is given in Figure 500.4 (placed with the cost graphs).

Table 65 presents the correlation between cost account number, worksheet, and figure number. Costs are calculated using the procedure outlined in the introductory remarks to this section and the worksheets in Tables 66 through 77.

Table 65. TUNNEL COST ACCOUNTS

Cost Account Number	Description	Figure Number	Worksheet Number
501	Costs for excavating tunnels. Hauling costs are not included.		
501.1	Costs for dry tunneling.	501.1	501.1
501.2	Costs for wet tunneling.	501.2	501.2
502	Costs for support systems are given for tunnel outside diameters from 3 to 8 meters.		
502.1	Costs for rock bolt support.	502.1	502.1
502.2	Costs for shotcrete support.	502.2	502.2
502.3	Costs for horseshoe rib support.	502.3	502.3
502.4	Costs for circular rib support.	502.4	502.4
502.5	Costs for timber lagging used between the ribs to support loose stones.	502.5	502.5
503	Costs for concrete lining for tunnel diameters from 3 to 9 meters.	503	503
504	Costs for tunnel dewatering.	504	504
505	Shafts: Costs for vertical shafts are approximately twice those for tunneling horizontally.	--	505
506	Other	--	506

Table 66. COST CATEGORY 5
COST SUMMATION

Worksheet 500

Cost Account Number	Description	Base Cost
501	Excavation	
501.1	Dry tunneling excavation	$BC_{501.1}$=$
501.2	Wet tunneling excavation	$BC_{501.2}$=$
502	Tunnel support systems	
502.1	Rock bolts	$BC_{502.1}$=$
502.2	Shotcrete	$BC_{502.2}$=$
502.3	Horseshoe ribs	$BC_{502.3}$=$
502.4	Circular ribs	$BC_{502.4}$=$
502.5	Timber Lagging	$BC_{502.5}$=$
503	Tunnel lining	BC_{503} =$
504	Tunnel dewatering	BC_{504} =$
505	Shafts	BC_{505} =$
506	Other	BC_{506} =$
Total Cost Category 5 Adjusted Cost (Enter cost in Account 1101)		BC_5 =$
Mobilization BC_5 x 0.05		MC_5 =$

Table 67. TUNNELING EXCAVATION, DRY

Worksheet 501.1

Design Data Required

Tunnel outside diameter[a]		________ m
Rock classification (see Table 63)		________
Tunnel length	L =	________ m

Base Cost

Enter Figure 501.1, read base unit cost per lineal meter	BUC	=$ ________
Base cost = L x BUC	$BC_{501.1}$	=$ ________

Table 68. TUNNELING EXCAVATION, WET

Worksheet 501.2

Design Data Required

Tunnel outside diameter[a]		________ m
Rock classification (see Table 63)		________
Tunnel or vertical shaft length	L =	________ m

Base Cost

Enter Figure 501.2, read base unit cost per lineal meter	BUC	=$ ________
Base cost = L x BUC	$BC_{501.2}$	=$ ________

---

[a]Figure 500.4 gives the relationship between inside and outside diameter.

Table 69. ROCK BOLTS

Worksheet 502.1

Design Data Required

Tunnel outside diameter	________ m
Rock classification (see Table 63)	________
Tunnel length	L = ________ m

Base Cost

Enter Figure 502.1, read base unit cost per lineal meter	BUC =$ ________
Base cost = L x BUC	$BC_{502.1}$ =$ ________

Table 70. SHOTCRETE

Worksheet 502.2

Design Data Required

Tunnel outside diameter	________ m
Rock classification	________
Tunnel length	L = ________ m

Base Cost

Enter Figure 502.2, read base unit cost per lineal meter	BUC =$ ________
Base cost = L x BUC	$BC_{502.2}$ =$ ________

Table 71. HORSESHOE RIB SUPPORT

Worksheet 502.3

Design Data Required

Tunnel outside diameter	________ m
Rock classification[a]	________
Tunnel length	L = ________ m

Base Cost

Enter Figure 502.3, estimate base unit cost for given rock classification zone	BUC =$ ________
Base cost = L x BUC	$BC_{502.3}$ =$ ________

---

[a]Good, fair or poor. For poor or very poor rock, recommend using the costs for circular ribs (see Worksheet 502.4). Rock classifications are given in Table 63.

Table 72. CIRCULAR RIB SUPPORT

Worksheet 502.4

Design Data Required

Tunnel outside diameter	________ m
Rock classification[a]	________
Tunnel length	L = ________ m

---

[a]Poor or very poor classification (see Table 63).

Table 72 (continued). CIRCULAR RIB SUPPORT

Worksheet 502.4

Base Cost

Enter Figure 502.4, estimate base unit cost for given rock classification zone — BUC =$ ________

Base cost = L x BUC — $BC_{502.4}$ =$ ________

Table 73. TIMBER LAGGING

Worksheet 502.5

Design Data Required

Tunnel outside diameter ________ m

Rock classification[a] ________

Tunnel length — L = ________ m

Base Cost

Enter Figure 502.5, read base unit cost per lineal meter — BUC =$ ________

Base cost = L x BUC — $BC_{502.5}$ =$ ________

---

[a]Good, fair, poor, or poor with wet heading (see Tables 63 and 64).

Table 74. CONCRETE TUNNEL LINING

Worksheet 503

Design Data Required

Tunnel outside diameter	________ m
Rock classification[a]	________
Tunnel length	L = ________ m

Base Cost

Enter Figure 503, read base unit cost per lineal meter	BUC =$ ________
Base cost = L x BUC	BC_{503} =$ ________

---

[a]Excellent, good to fair, poor (see Table 64).

Table 75. TUNNEL DEWATERING

Worksheet 504

Design Data Required

Seepage classification[a]	________
Length of wet heading	L = ________ m

Base Cost

Enter Figure 504, read base cost for wet heading lengths	BC_{504} =$ ________

---

[a]Three seepage rates are given: light, moderate, and heavy. Unless data is available, assume a moderate flow rate for wet headings.

Table 76. SHAFTS

Worksheet 505

Data Required

Base cost for:

Account 501	BC_{501} =$ ________
Account 502	BC_{502} =$ ________
Account 503	BC_{503} =$ ________
Total	BC_H =$ ________

Base Cost

Base cost = BC_H x 2	BC_{505} =$ ________

Table 77. OTHER

Worksheet 506

Base Cost

Include costs not covered in this category but that relate to tunneling. Data presented in other accounts may be useful in estimating "Other" costs.	BC_{506} =$ ________

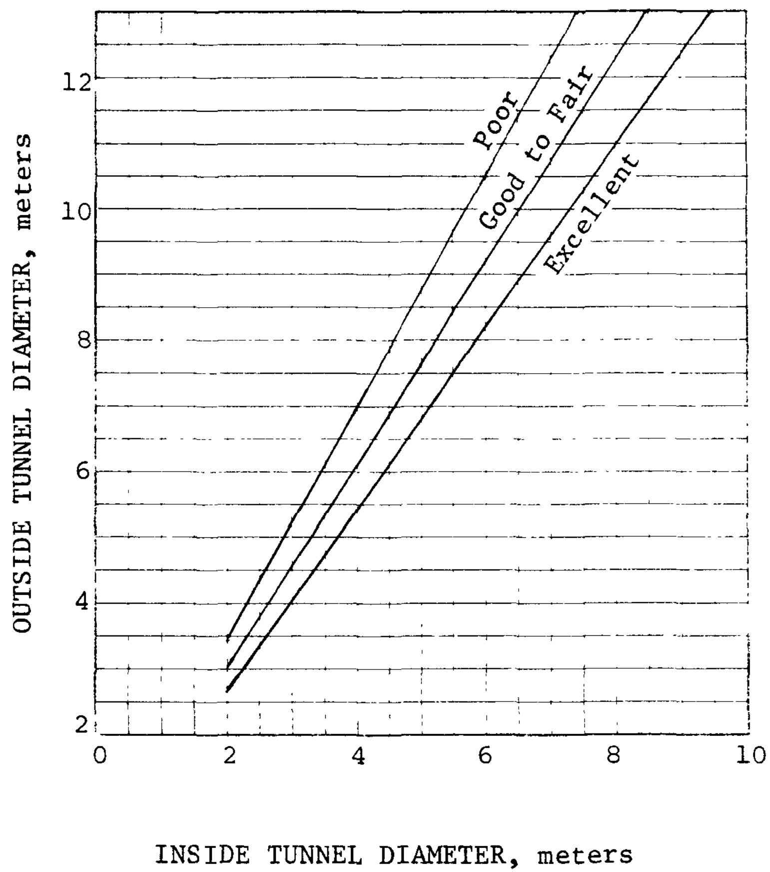


Fig. 500.4 - Diameter Relationships

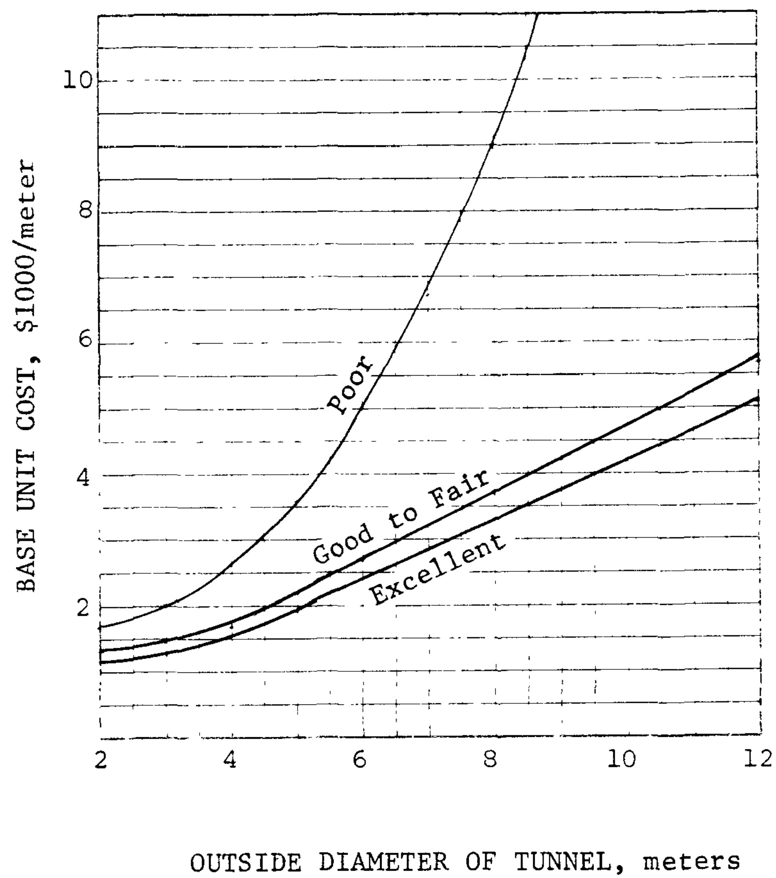
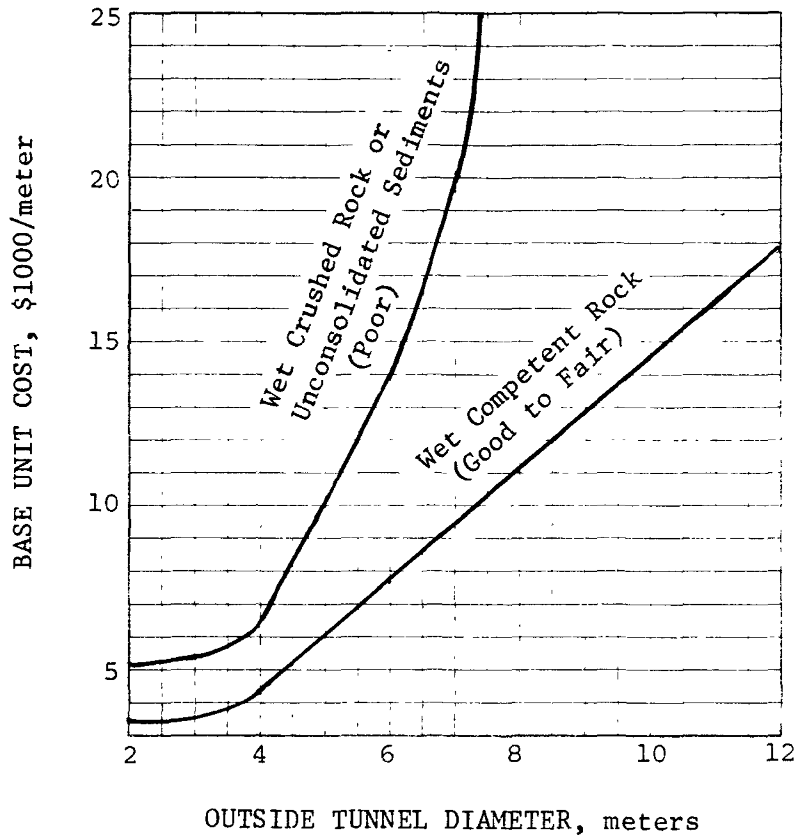


Fig. 501.1 - Tunnel Excavation Costs for Dry Headings



NOTE: Dewatering costs should be added to total cost determined from above base unit costs.

Fig. 501.2 - Tunnel Excavation Costs for Wet Headings

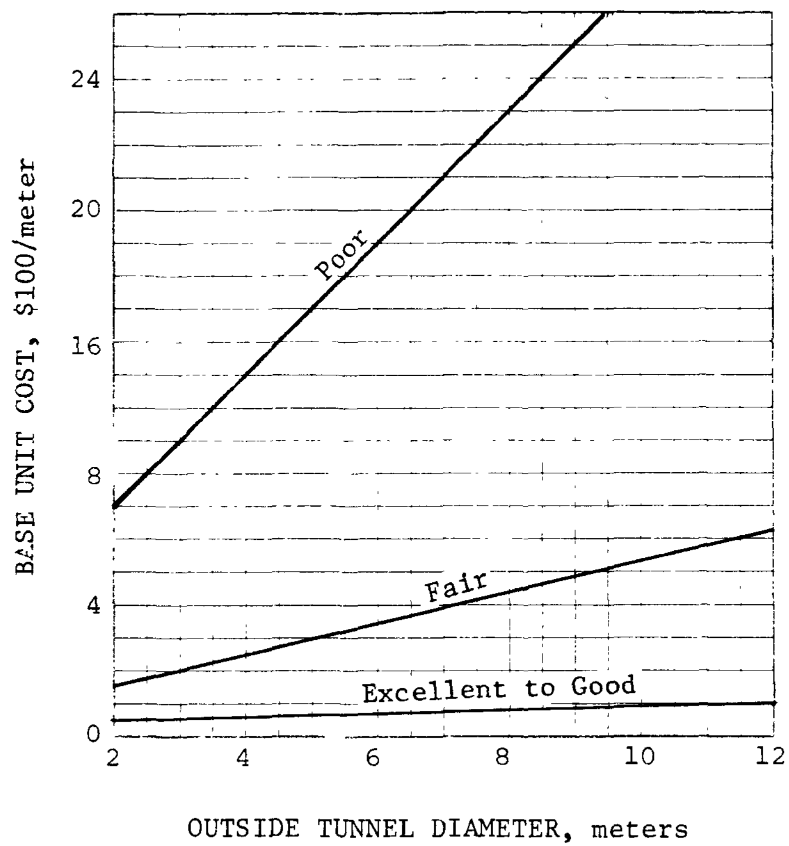
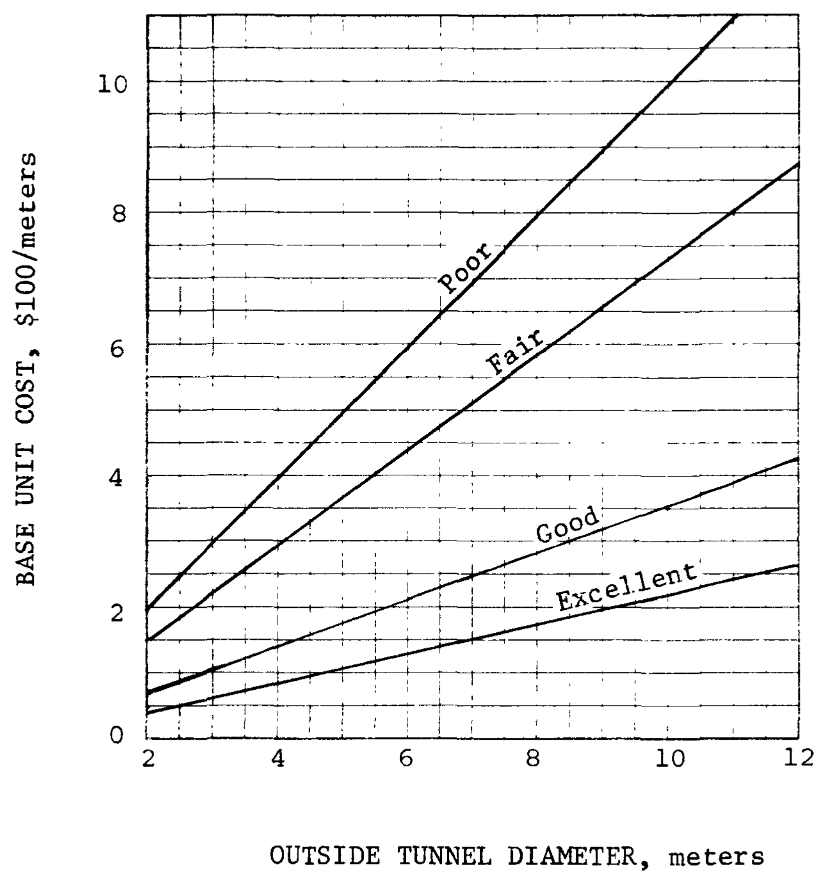


Fig. 502.1 - Costs for Rock Bolt Supports



NOTE: For poor rock conditions, shotcrete support methods are usually combined with one of the other support alternatives.

Fig. 502.2 - Costs for Shotcrete Support

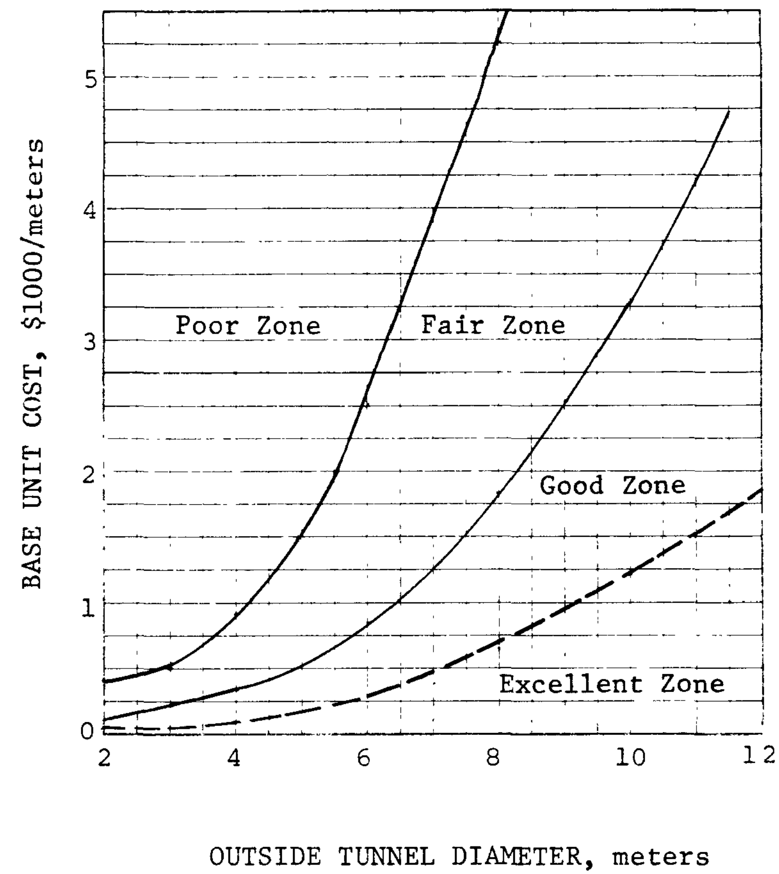


Fig. 502.3 - Cost for Continuous Horseshoe Rib Supports

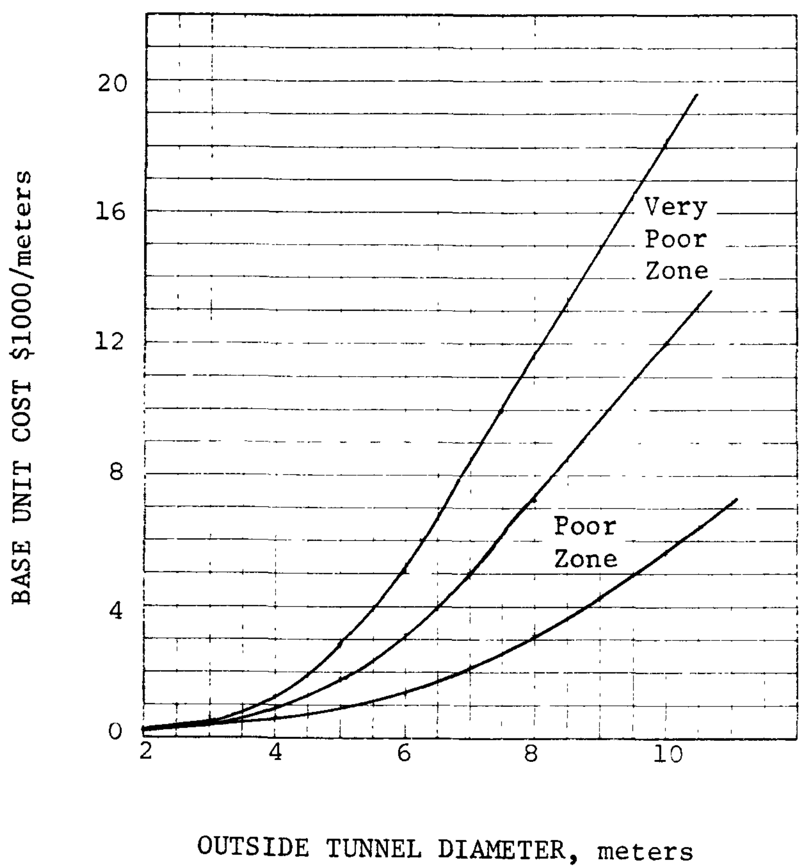


Fig. 502.4 - Cost for Circular Rib Supports

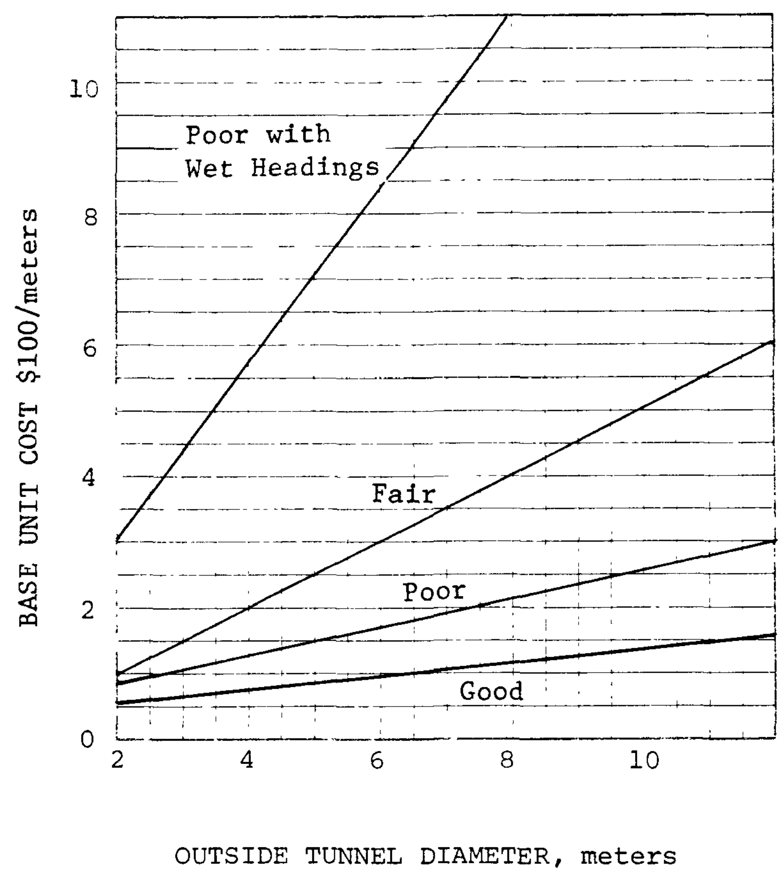


Fig. 502.5 - Costs for Timber Lagging

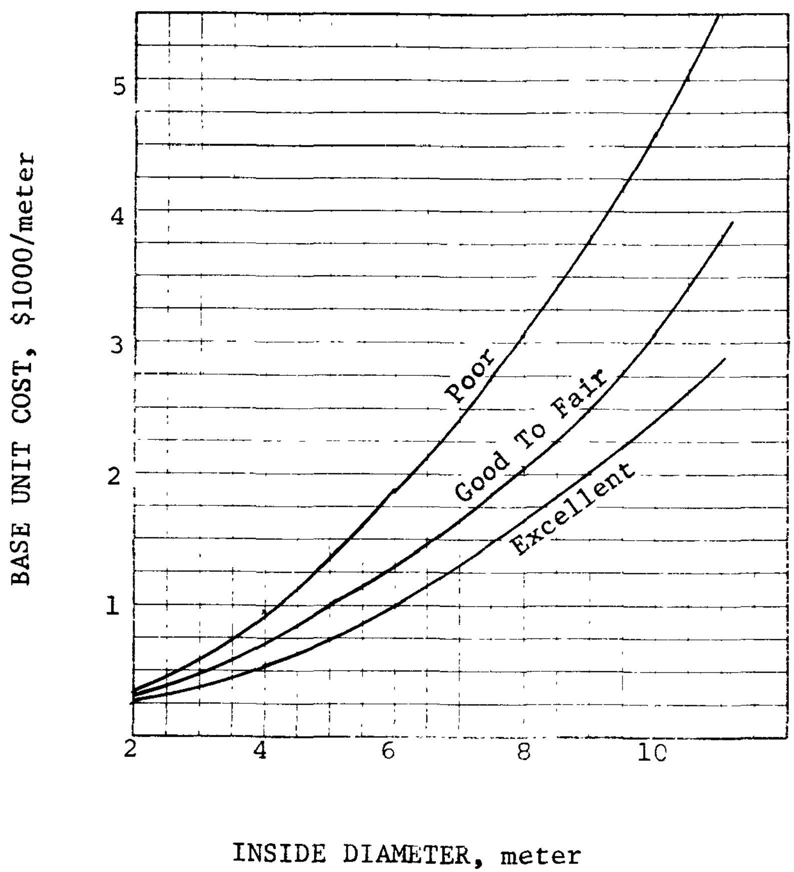


Fig. 503 - Costs for Tunnel Lining

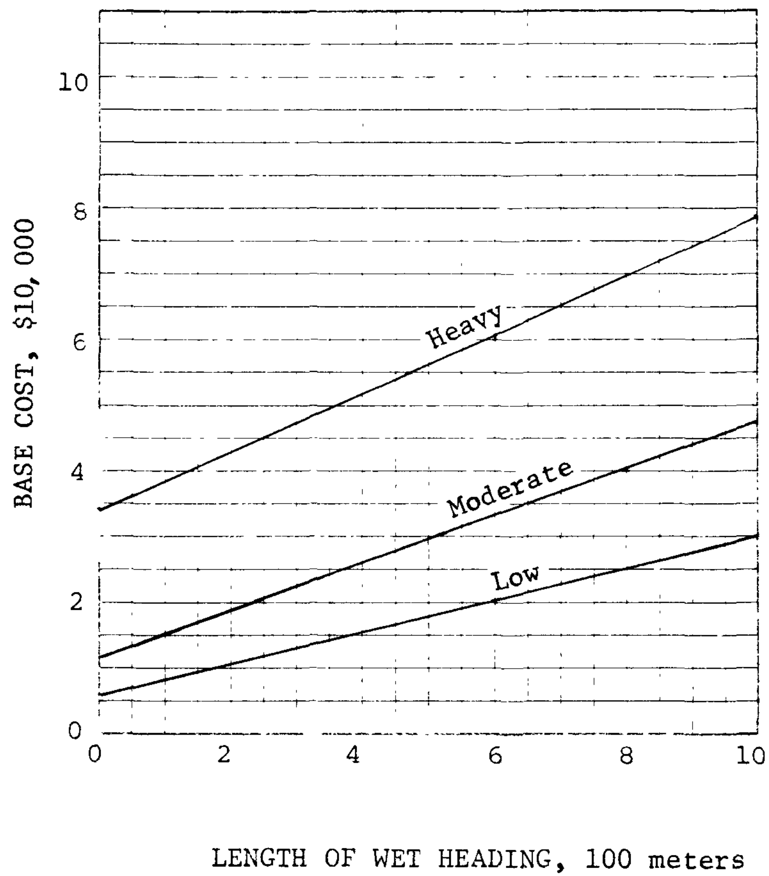


Fig. 504— Costs for Tunnel Dewatering

COST CATEGORY 6, DIFFUSER

Information on materials and installation of diffusers is provided. Three types of diffusers considered are as follows:

1. Single port - A single port discharge is a simple type of diffuser. The outfall is usually the open end of a conduit with a concrete structure for protection or to divert the flow vertically. Costs for a single port discharge are given separately from the other diffusers in Account 604.

2. Conduit diffuser - The term "conduit diffuser" describes a series of nozzles or slots arranged along a conduit manifold. The conduit diffuser is set in a pipe trench on the lake bed and can be connected to the discharge pipe or a tunnel (see Figure 600.1).

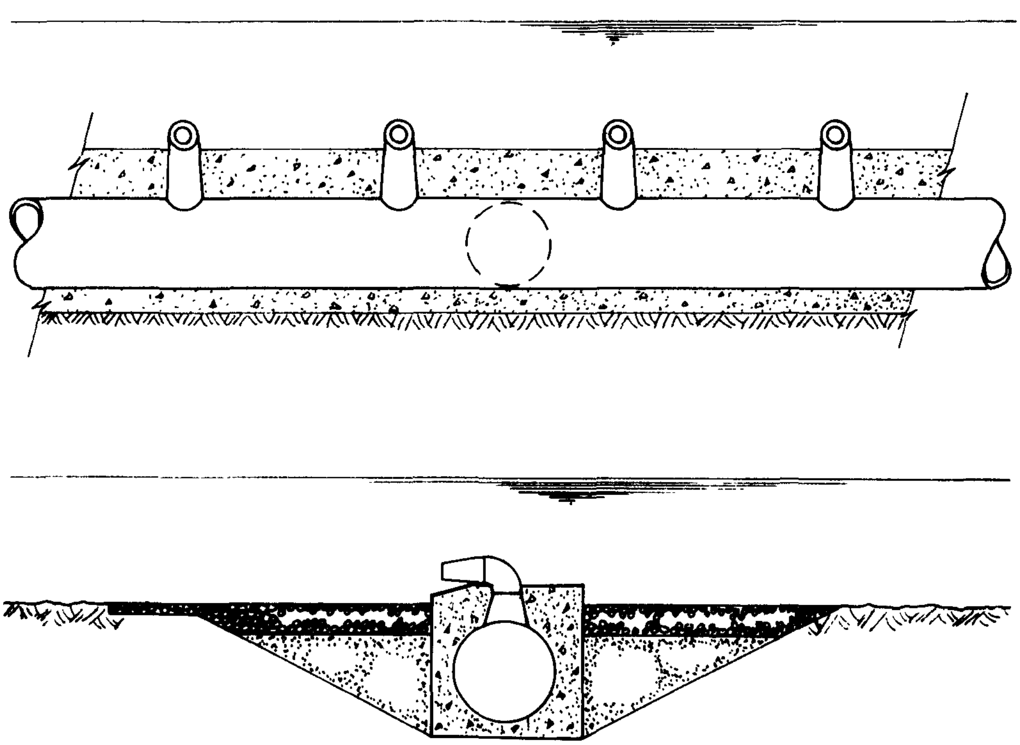


Fig. 600.1 - Conduit Diffuser

3. Tunnel diffuser - The term "tunnel diffuser" refers to a series of nozzles individually grouted into a tunnel (See Figure 600.2).

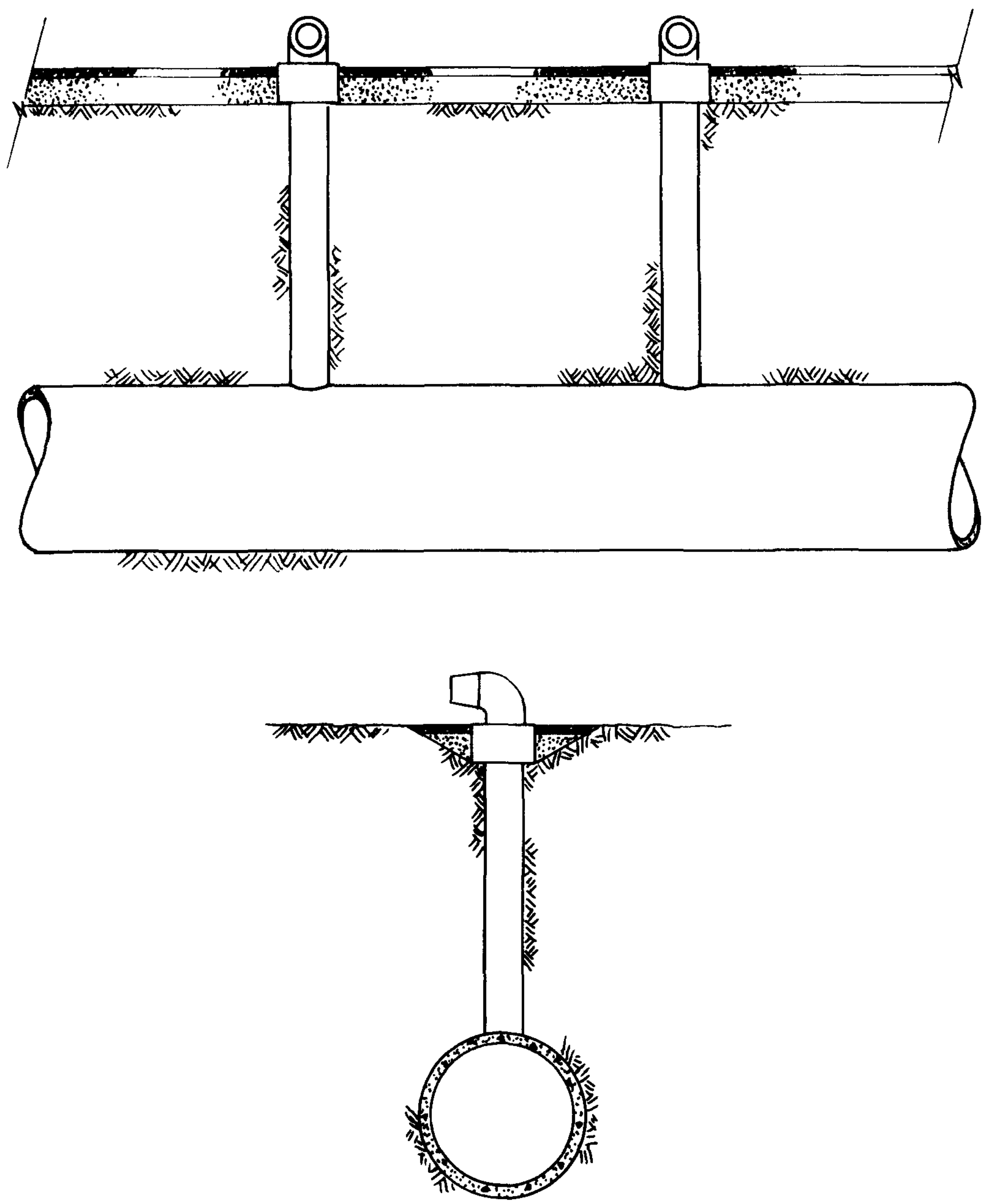


Fig. 600.2 - Tunnel Diffuser

The diffuser can be an extension of the conduit or tunnel, and can be perpendicular to the conveyance pipe or any angle in between.

The estimate for a conduit diffuser is the sum of the individual costs for nozzles (601), the manifold (602.1 to 602.3) and installation of the diffuser as a unit (603.1). In addition, Accounts 603.2 to 603.7 may apply. The procedure for estimating the cost of a tunnel diffuser is the same as for a conduit diffuser except installation costs are for the nozzles only (603.2).

Data for the individual accounts are presented in the following paragraphs.

Steel nozzles, Account 601

Key parameters are the construction material and the nozzle diameter. Cost data are provided for shop fabrication of steel nozzles from 1.27 cm steel plate. Precast concrete pipe prices include an allowance for pipe sections with the nozzles attached as part of the manufacturing process. Therefore, separate costs for concrete nozzles are not given. The costs for cutting the hole for the nozzles, or for slots, into the steel pipe and welding nozzles to the pipe can be neglected. The costs for steel nozzles are used for the tunnel manifold application.

Manifolds, Accounts 602.1 to 602.3

If the manifold is a conduit, the pipe and fitting costs given in Cost Category 4 can be used. One example of fitting costs is for reducers which are considered because the conduit diameter may decrease as the distance from the end of the conduit increases. Decreasing the manifold diameter is done to maintain uniform discharge and to prevent siltation in the outer ends of the manifold. If the manifold is a tunnel-type, use the cost data given in Category 5.

Installation of conduit diffuser, Account 603.1

The slots will be cut or the nozzles attached to the conduit on land. Costs for installing this type of manifold can be assumed to be equal to conduit installation costs. Refer to Cost Category 4 for information. If the diffuser is at an angle to the conduit, costs for a concrete anchor block at the junction should be included in the estimate (see Cost Category 7). A vertical shaft from a tunnel can be raised to the lake bed and a conduit manifold installed. This method may require a cofferdam (see Category 2) during excavation and connecting the manifold to the tunnel shaft. Connection of a conduit manifold to the end of the pipe can be done underwater as part of the laying operation.

Installation of nozzles into a tunnel diffuser, Account 603.2

Key parameters are the method of installation, the number of nozzles, and the depth of rock penetrated by the nozzle riser. Two methods that are used to install nozzles into a tunnel are to:

1. first mine the tunnel manifold, then drill the hole and grout in the nozzle (placing the nozzle after the tunnel is mined requires tunnel de-watering, capping the hole from the inside, drilling the nozzle hole, and grouting the nozzle into place); or
2. drill holes into the rock bottom and grout the nozzle into the desired location prior to mining the tunnel (The nozzle is capped to prevent water from entering when the tunnel excavation reaches the nozzle).

Costs for using a large drill mounted on a barge to drill the nozzle holes prior to mining the tunnel, method No. 2 above, are given in this account. Grouting costs can be neglected because the hole is only drilled 3 to 5 cm larger than the nozzle riser diameter.

Cofferdams, Account 603.3

A cofferdam may be used when connecting a conduit manifold to the end of the tunnel. Other applications of cofferdams can be included in this account. See Cost Category 2 for the discussion on cofferdams.

Trench excavation, Account 603.4

A discussion of offshore trench excavation is given in Cost Category 9.

Diffuser support systems, Account 603.5

A discussion of piles and concrete is included in Cost Categories 2 and 7, respectively.

Riprap protection, Account 603.6

To prevent bed scour caused by the jets, riprap is placed in the area around the diffuser. Information required to estimate the cost for material and placement of the riprap is given in Category 2.

Trench backfill, Account 603.7

The data required to estimate the costs for backfilling the pipe trench are included in Cost Category 8.

Single Port, Account 604

The single port outfall usually includes a concrete structure. The costs for concrete are included in Cost Category 7.

Mobilization, Account 606

The costs for mobilization and demobilization are not included in the unit prices. If the diffuser is a tunnel manifold, the cost for towing the drill to the site is given as the mobilization cost. The costs for mobilizing the drill are not included. If the diffuser is a conduit manifold, the mobilization costs given in Category 4 are sufficient. A discussion of mobilization is given in Cost Category 10.

Table 78 presents the correlation between cost account number, worksheet, and figure number. Costs are calculated using the procedure outlined in the introductory remarks to this section and the worksheets in Tables 79 through 93.

Table 78. DIFFUSER COST ACCOUNTS

Cost Account Number	Description	Figure Number	Worksheet Number
601	Costs are provided for fabrication of steel nozzles.	601	601
602	Manifolds (material and fabrication as appropriate)		
602.1	Costs for steel manifolds (see Cost Account 403)	--	602.1
602.2	Costs for concrete manifolds (see Cost Accounts 401 and 402)	--	602.2

Table 78 (continued). DIFFUSER COST ACCOUNTS

Cost Account Number	Description	Figure Number	Worksheet Number
602.3	Costs for fittings, such as tees and reducers, for steel pipe manifolds are provided in Cost Account 403.2. For concrete manifolds, fitting costs are included in straight pipe costs.	--	602.3
603	Installation costs		
603.1	Conduit manifold (see Cost Category 4)	--	603.1
603.2	Costs for installing individual nozzles into a tunnel	603.2	603.2
603.3	Costs for cofferdams (see Cost Category 2)	--	603.3
603.4	Excavation costs (Cost Category 9)	--	603.4
603.5	Costs for support systems (see Cost Category 2 & 7)	--	603.5
603.6	Costs for riprap protection (see Cost Category 2)	--	603.6
603.7	Costs for backfill (see Cost Category 9)	--	603.7
604	Single Port	--	604
605	Other	--	605
606	Mobilization	--	606

Table 79. COST CATEGORY 6
COST SUMMATION

Worksheet 600

Cost Account Number	Description		Base Cost
601	Nozzles	BC_{601}	=$
602	Manifolds		
602.1	Concrete manifold	$BC_{602.1}$	=$
602.2	Steel manifold	$BC_{602.2}$	=$
602.3	Steel fittings	$BC_{602.3}$	=$
603	Installation		
603.1	Conduit manifold	$BC_{603.1}$	=$
603.2	Nozzles	$BC_{603.2}$	=$
603.3	Cofferdams	$BC_{603.3}$	=$
603.4	Excavation	$BC_{603.4}$	=$
603.5	Diffuser Support	$BC_{603.5}$	=$
603.6	Scour protection	$BC_{603.6}$	=$
603.7	Backfill	$BC_{603.7}$	=$
604	Single Port	BC_{604}	=$
605	Other	BC_{605}	=$
Cost Category 6, Total Cost (Enter cost in Acct. 1101)		BC_6	=$
606	Mobilization (Enter Cost in Acct. 1001)	MC_6	=$

Table 80. STEEL NOZZLES

Worksheet 601

Design Data Required

Nozzle inside diameter	________ m
Riser length [a]	________ m
Number of nozzles	N = ________

Base Cost

Enter Figure 601, read base unit cost per nozzle	BUC =$ ________
Base cost = N x BUC	BC =$ ________

Cost Adjustments

Enter Figure 601, read design adjustment factor for the riser length(f)	F_D = ________

Adjusted Base Cost

Adjusted cost = BC x F_D	BC_{601} =$ ________

---

[a] The riser length "f" is the distance from the (horizontal) nozzle centerline to the top of the manifold minus 1.5 times the nozzle diameter.

Table 81. CONCRETE MANIFOLD

Worksheet 602.1

Base Cost

Select Cost Account 401 for precast concrete pipe or Cost Account 402 for cast-in-place conduit, whichever is appropriate.

Base cost = BC_{401} or BC_{402} $BC_{602.1}$ =$ ________

Table 82. STEEL MANIFOLD

Worksheet 602.2

Base Cost

Refer to Cost Account 403, Steel Conduit. Base cost = BC_{403} $BC_{602.2}$ =$ ________

Table 83. STEEL MANIFOLD FITTINGS

Worksheet 602.3

Base Cost

Refer to Cost Account 403.2

Base cost = $BC_{403.2}$ $BC_{602.3}$ =$ ________

Table 84. INSTALLATION OF CONDUIT DIFFUSER

Worksheet 603.1

Base Cost

Select cost account 406.2 for dry installation within an offshore cofferdam or 407.2 for underwater installation.

Base cost = $BC_{406.2}$ or $BC_{407.2}$ $BC_{603.1}$ =$ ________

Table 85. INSTALLATION OF NOZZLES INTO A TUNNEL DIFFUSER

Worksheet 603.2

Design Data Required

Number of nozzles N = ________

Length of the riser L = ________ m

Base Cost

Enter Figure 603.2, read base cost

Base cost = $BC_{603.2}$=$ ________

Table 86. COFFERDAMS

Worksheet 603.3

Base Cost

Refer to Cost Account 202.2

Base cost = $BC_{202.2}$ $BC_{603.2}$ =$ ________

Table 87. TRENCH EXCAVATION

Worksheet 603.4

Base Cost

Refer to Cost Category 9 and select the cost from either Cost Account 901 or 902

Base cost = BC_{901} or BC_{902} $BC_{603.4}$ =$ ________

Table 88. DIFFUSER SUPPORT SYSTEMS

Worksheet 603.5

Base Cost

Refer to Cost Category 7

Base cost = the base cost from the appropriate account in Cost Category 7 $BC_{603.5}$ =$ ________

Table 89. RIPRAP PROTECTION

Worksheet 603.6

Base Cost

Refer to Cost Account 201.2

Base cost = $BC_{201.2}$ $BC_{603.6}$ =$ ________

Table 90. TRENCH BACKFILL

Worksheet 603.7

Base Cost

Base cost = base cost from the appropriate accounts in Cost Category 8. $BC_{603.7}$ =$ ______________

Table 91. SINGLE PORT

Worksheet 604

Base Cost

Refer to Cost Category 7 for estimating procedure BC_{604} =$ ______________

Table 92. OTHER

Worksheet 605

Base Cost

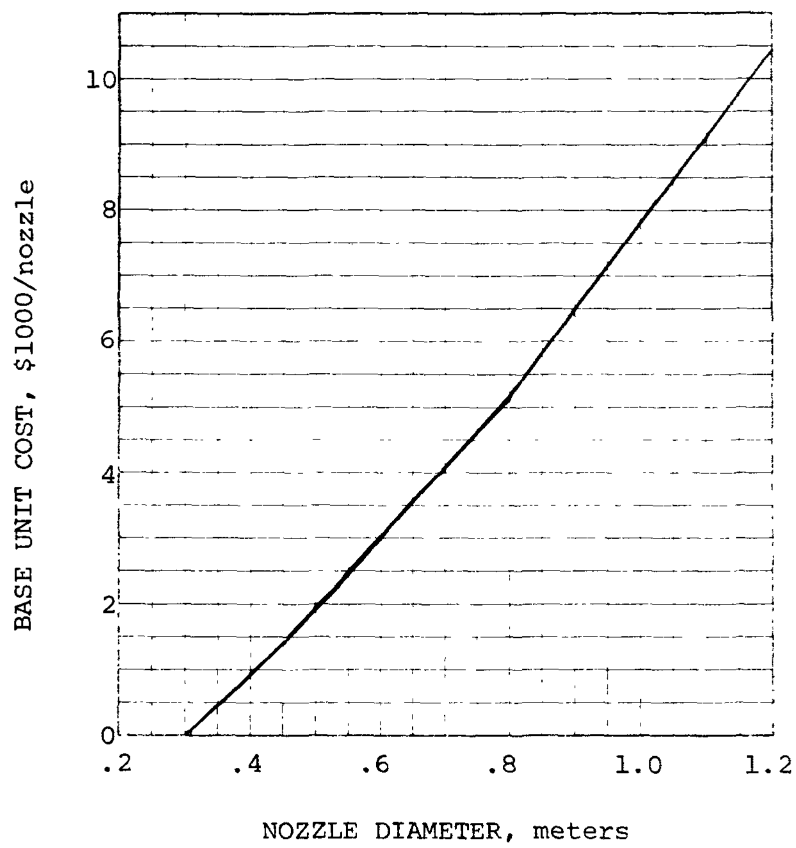
Include costs not covered in this category but that relate to the diffuser. Data presented in other accounts may be useful in estimating "Other" costs. BC_{605} =$ ______________

Table 93. MOBILIZATION

Worksheet 606

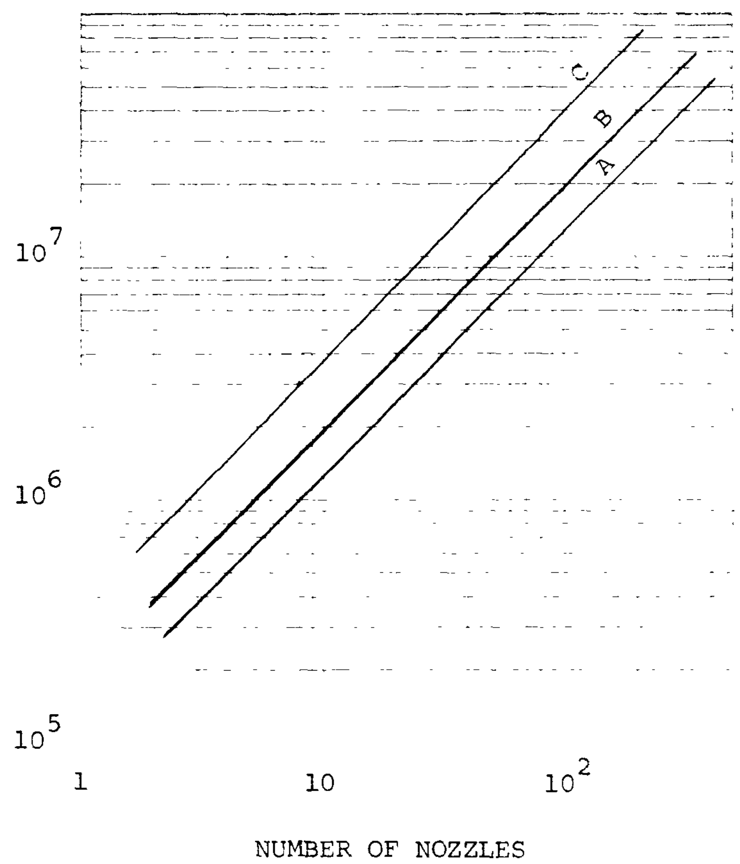
Mobilization Cost

Mobilization = $30,000 if the diffuser is a tunnel diffuser. If the total length of offshore pipe is the manifold for a conduit diffuser, add $96,000. (Caution: do not duplicate costs in Account 408.) MC_6 =$ ______________



Dimension f (m)	Adjustment Factors F_D — Nozzle Diameters (m): .458	.61	.915	1.065
1.0	1.00	0.90	0.84	0.84
2.0	1.32	1.10	1.00	1.00
5.0	2.34	1.80	1.50	1.45
10.0	3.98	3.02	2.33	2.22
20.0	7.30	5.41	4.00	3.75
30.0	10.62	7.80	5.67	5.27

Fig. 601 - Costs for Steel Nozzles



Curve	Riser Lengths, f
A	0 to 6 meters
B	6 to 15 meters
C	Greater than 15

Fig. 603.2 - Installing Individual Nozzles Into a Tunnel Manifold

COST CATEGORY 7, CONCRETE

Information on material and placement costs for concrete are given in this category. Data for each of the accounts are given in the following paragraphs.

Structural concrete, Accounts 701.1 and 701.2

The key parameters are concrete material and placement costs, reinforcing quantity, the area of formwork, and finishing costs. The data presented in References 2 and 4 suggest grouping structural members with similar values for the key parameters. For example, concrete costs for a wall or suspended slab will be more expensive than a pipe cradle or encasing a pipe in concrete without formwork. Therefore, three general groups of structural members were selected. The groups are:

1. suspended slabs, beams and walls;
2. spread footings, grade slabs, and pile caps; and
3. concrete structures with no reinforcing steel and little or no formwork requirements.

The deck and walls for a pump station or other box type structure would fit into Group 1. Channel lining or the floor of the pump station and the pile caps used for a structure foundation would fit into Group 2. Concrete cradles cast on site are an example of Group 3.

Material costs for concrete can vary according to special admixture requirements and strength. Costs given are for medium strength (3000 psi) concrete without special admixtures. The cost differential between low strength (2,500 psi) and high strength (5,000 psi) concrete is $7/cubic meter. It was not considered in presentation of the costs.

Concrete for the type of structures considered here can be placed with a crane and concrete bucket. The crane can also be used in formwork and placing the steel.

Reinforcing is separated in the accounting because this is common practice for presenting estimates. The costs for rebar reinforcing are given. A rule of thumb for mesh reinforcing is: It costs about twice as much as rebar reinforcing installed.

Concrete (marine), Account 702

The key parameters are the thickness of the structure and waste. Tremie concrete may be used for pipe support, partial encasement of a pipe to give the conduit added weight, or thrust blocks for nozzles and the manifold. The concrete is transported to the offshore site and placed using a flexible hose extending down to within the formwork for the structure being placed. Because the concrete is being placed underwater, the top layer of the structure will be destroyed by the mixing of concrete and water. Therefore, an allowance for waste should be included in the quantity measured from the neat lines on a drawing. A waste allowance of 20 percent is appropriate. The unit cost was developed using the costs for:

1. a flat-top barge and a tug boat to tow concrete trucks to the site;
2. two cranes mounted on barges, one to swing a hopper between the concrete trucks and the flexible hose and the other to support the flexible hose; and

3. costs for labor and a diver are also included.

Grouting, Account 703

The key parameter is the rock conditions. Data are for foundation grouting or forming a grout curtain to cut off a water bearing strata. Grouting quantities can be measured in terms of the take.

The term "take" is defined as the ratio of the volume of material that is pumped into a hole(s) to the drilled hole volume. The unit costs for grout will vary inversely to the take. Costs given are for a badly fractured rock. The take is assumed to be double the hole volume for a 1.22 cm diameter hole. Estimating take is difficult even with detailed site data. In many cases, grouting is bid in terms of cost per bag of cement and quantity of sand. Although the data given will provide some measure of the cost, the user should recognize the limitations. Costs for chemical additives are not included.

Cushion fill, Account 704

The gravel base placed beneath a grade slab is similar to the gravel filter used beneath riprap. Data for cushion fill are obtained from Cost Account 201.1 (Filter material).

Mobilization, Account 706

Unit prices do not include mobilization and demobilization costs. Costs for mobilizing equipment should be added only if a large concrete structure, other than the pump station, is included in the modification. Otherwise, mobilization costs given in Category 3 will suffice. A discussion of mobilization is given in Cost Category 10.

Table 94 presents the correlation between cost account number, worksheet, and figure number. Costs are calculated using the procedure outline in the introductory remarks to this section and the worksheets in Tables 95 through 102.

Table 94. CONCRETE COST ACCOUNTS

Cost Account Number	Description	Figure Number	Worksheet Number
701	Cast-in-place structural concrete costs for material and placement of concrete and reinforcing steel		
701.1	Concrete placement	701.1	701.1
701.2	Reinforcing steel	701.2	701.2
702	Cast-in-place concrete (marine)	--	702
703	Costs for grouting	--	703
704	Cushion fill (see Cost Account 201.1)	--	704
705	Other	--	705
706	Mobilization	--	706

Table 95. COST CATEGORY 7
COST SUMMATION

Worksheet 700

Cost Account Number	Description	Base Cost
701	Structural concrete	
701.1	Concrete placement[a]	$BC_{701.1}$ =$ ______
701.2	Reinforcing steel[a]	$BC_{701.2}$ =$ ______
702	Concrete (marine)[a]	BC_{702} =$ ______
703	Grouting	BC_{703} =$ ______
704	Cushion fill	BC_{704} =$ ______
705	Other	BC_{705} =$ ______
Cost Category 7 Total Cost (Enter cost in Account 1101)		BC_7 =$ ______
706	Mobilization (Enter cost in Acct. 1001)	MC_7 =$ ______

[a]The user is cautioned that most of the time the costs for these accounts are used in other categories. Do not enter here if they are used in another category.

Table 96. CAST-IN-PLACE
STRUCTURAL CONCRETE, CONCRETE PLACEMENT

Worksheet 701.1

Design Data Required

Category of structure[a] ____________

Volume of concrete __________ m^3

Base Cost

Enter Figure 701.1, read base cost $BC_{701.1}$ =$__________

---

[a]1. Suspended slabs, beams, walls.
2. Spread footings, grade slabs, and pile caps.
3. Structures with little or no reinforcing.

Table 97. CAST-IN-PLACE STRUCTURAL
CONCRETE, REINFORCING STEEL

Worksheet 701.2

Design Data Required

Category of structure[a] ____________

Weight of reinforcing steel[b] __________kg

Base Cost

Enter Figure 701.2 read base cost $BC_{701.2}$ =$__________

---

[a]1. Suspended slabs, beams, and walls.
2. Spread footings, grade slabs, and pile caps.
3. Structures with little or no reinforcing.

[b]If weight of reinforcing steel is not available, assume values shown in the following table:

Table 97 (continued). CAST-IN-PLACE STRUCTURAL CONCRETE, REINFORCING STEEL

Worksheet 701.2

Category	Weight of Reinforcing to assume, kg/m^3 of conc.
1	89
2	71
3	0-20

Table 98. CAST-IN-PLACE CONCRETE (MARINE)

Worksheet 702

Design Data Required

Volume of concrete[a] $V = \_\_\_\_\_\_ m^3$

Base Cost

Base cost = V x $86.30/m^3$ BC_{702} =$ ______

[a]Unless detailed data is available, add 20 percent to design volume of concrete for waste during underwater placement.

Table 99. GROUTING

Worksheet 703

Design Data Required

Volume of drilled holes $V = \_\_\_\_\_\_ m^3$

Base Cost

Base cost = 2V x $231.90/m^3$ BC_{703} =$ ______

Table 100. CUSHION FILL

Worksheet 704

Base Cost

Refer to Cost Account 201.1 for cost estimating procedure BC_{704} =$ ________

Table 101. OTHER

Worksheet 705

Base Cost

Include costs not covered in this category but that relate to concrete. Data presented in other accounts may be useful in estimating "Other" costs. BC_{705} =$ ________

Table 102. MOBILIZATION

Worksheet 706

Mobilization Cost

For a large structure other than the pump station, add $3,300 MC_7 =$ ________

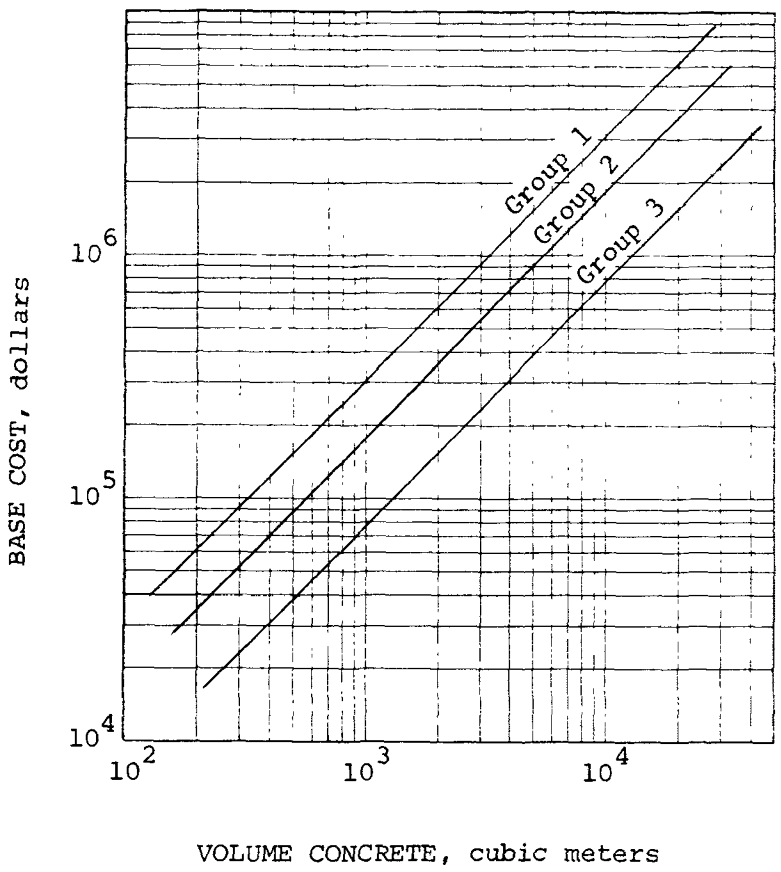


Fig. 701.1 - Costs for Structural Concrete, Concrete Placement

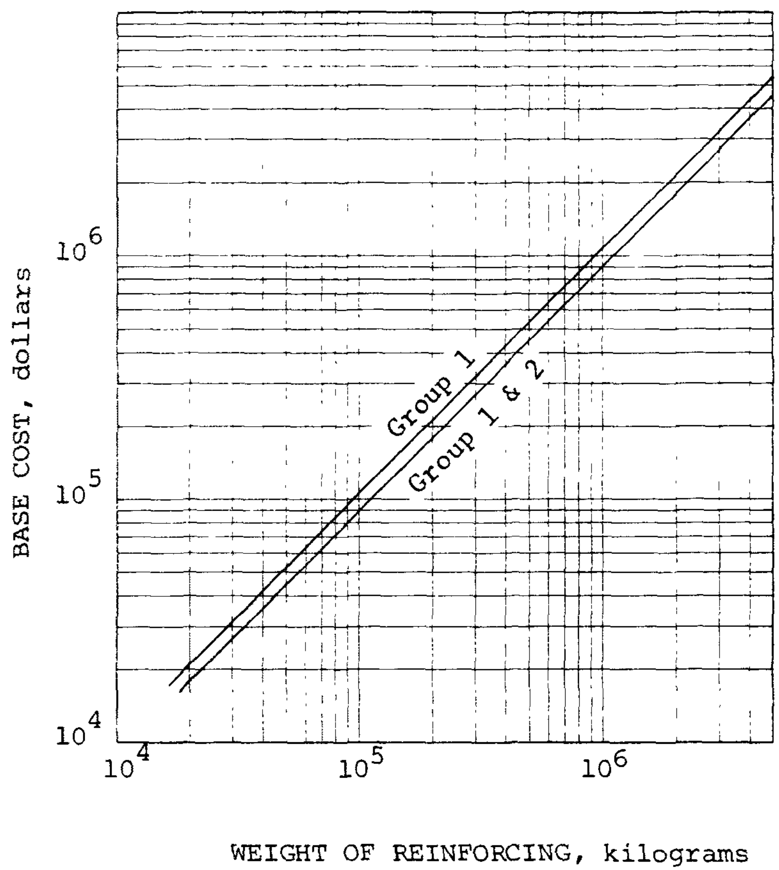


Fig. 701.2 - Costs for Structural Concrete, Reinforcing Steel

COST CATEGORY 8, FILL

Data on the costs of material and placement of fill are Given in this category.

Data for the accounts of Cost Category 8 are given in the following paragraphs.

Material and hauling costs, Account 801

The key parameters are the cost of the material and the haul distance. A discussion of hauling costs is given in Cost Category 1. The types of fill considered in this account are unclassified earth, sand, gravel (either bank run or graded) and topsoil. Costs for stone fill such as riprap are included in Cost Category 2. Costs for operating the borrow are included in the material costs.

Placement of fill (land), Account 802.1

Key parameters are the working area, methods of compaction, and extent of compaction. Placement of material can be classified into three groups. The groups are as follows:

Group 1 - The costs for a grader to spread fill that has been dumped from a truck are given. Compaction costs are not included. Spreading topsoil or filling swales are examples of activities included in this group.

Group 2 - Placement and compaction of fill around structures. Costs for placement of the material with a loader and using hand tampers to compact the fill are given. Placing fill around conduits and the pump stations are examples of this group.

Group 3 - Placement and compaction of fill in an open area. Costs were developed assuming that a vibrating roller is used for compacting granular material and a sheepsfoot roller for compacting earth material. When the area immediately around the pipe has been compacted by hand, any additional compaction requirements can be met using machine compaction.

Placement of fill (marine), Account 802.2

The key parameter is the type of placement. Backfill of the pipe trench or placing cushion fill in the pipe trench can be done by loading the material into scows, towing the scows offshore and releasing the material into the trench from the scow. If the fill is to be used in a cell cofferdam, costs for off-loading the material using a crane mounted on a barge are given. Costs for backfill using material that was side cast are included.

Mobilization, Account 804

Unit prices do not include mobilization and demobilization costs. Mobilization costs for the equipment used to backfill the pipe trench and pump station are given in Cost Category 4 and Category 3, respectively. Therefore, mobilization costs for dumping and spreading fill will generally be the only costs added from this account. A discussion of mobilization is given in Category 10.

Table 103 presents the correlation between cost account number, worksheet, and figure number. Costs are calculated using the procedure outline in the introductory remarks to this section and the worksheets in Tables 104 through 109.

Table 103. FILL COST ACCOUNTS

Cost Account Number	Description	Figure Number	Worksheet Number
801	Material and hauling costs	801	801
802	Placement of fill		
802.1	Cost placement and compaction of fill on land	802.1	802.1
802.2	Placement of fill offshore (marine)	802.2	802.2
803	Other	--	803
804	Mobilization	--	804

Table 104. COST CATEGORY 8 COST SUMMATION

Worksheet 800

Cost Account Number	Description	Base Cost
801	Material and hauling costs[a]	BC_{801} =$________
802	Placement of fill	
802.1	Placement of fill (land)	$BC_{802.1}$=$________

[a]The user is cautioned that most of the time the costs for these accounts are used in other categories. Do not enter here if they are used in another category.

Table 104 (continued). COST CATEGORY 8 COST SUMMATION

Worksheet 800

Cost Account Number	Description	Base Cost
802.2	Placement of fill (marine)	$BC_{802.2}$ = $______
803	Other	BC_{803} = $______
Cost Category 8 Total Cost (Enter cost in Acct. 1101)		BC_8 = $______
804	Mobilization (Enter cost in Acct. 1001)	MC_8 = $______

Table 105. MATERIAL AND HAULING COSTS

Worksheet 801

Design Data Required

Type of fill material ________

Haul distance (round trip)[a] from the borrow site ______ km

Volume of fill V = ______ m^3

[a]If haul distance is not known, assume an 18-km haul.

Table 105 (continued). MATERIAL AND HAULING COSTS

Worksheet 801

Base Cost

Enter figure 108.2, read base unit cost for hauling.	BUC = $__________/$m^3$
Base cost for hauling = BUC x V	BC_1 = $__________
Enter Figure 801, read base cost	BC_2 = $__________

Cost Adjustment

Enter Figure 801, read adjustment factor for material	F_D = __________

Adjusted Base Cost

Adjusted base cost = $(BC_2 \times F_D) + BC_1$	BC_{801} = $__________

Table 106. PLACEMENT OF FILL (LAND)

Worksheet 802.1

Design Data Required

Nature of the placement operation[a] group number	__________
Volume of fill	V = __________ m^3

[a]Group 1 - Dump and spread fill
Group 2 - Hand compaction of fill
Group 3 - Machine compaction

Table 106 (continued). PLACEMENT OF FILL (LAND)

Worksheet 802.1

Base Cost

Enter Figure 802.1, read base cost $BC_{802.1}$=$ ____________

Table 107. PLACEMENT OF FILL (MARINE)

Worksheet 802.2

Design Data Required

Nature of the placement operation[a] ____________

Volume of fill V = ____________ m^3

Base Cost

Enter Figure 802.2, read base cost $BC_{802.2}$=$ ____________

---

[a]Backfill of a pipe trench; placing fill into a cofferdam or backfill using excavated material side cast along the trench.

Table 108. OTHER

Worksheet 803

Base Cost

Include costs not covered in this category but that related to Fill. Data presented in other accounts may be useful in estimating "Other" costs. BC_{803}=$__________

Table 109. MOBILIZATION

Worksheet 804

Data Requirements

		Summation
802.1	Mobilization costs for Group 1 of the land placement of fill is $1,700	__________
[a]The costs for Group 2 is $900		__________
The costs for Group 3 is $800		__________

Mobilization Cost

Mobilization = the total of the summation column. Usually only Group 1 of account 802.1 will be considered (see the discussion for this account). MC_8 =$__________

---

[a]Use the costs for group 2 and 3 only if there is a large structure other than the pumping station that requires backfill.

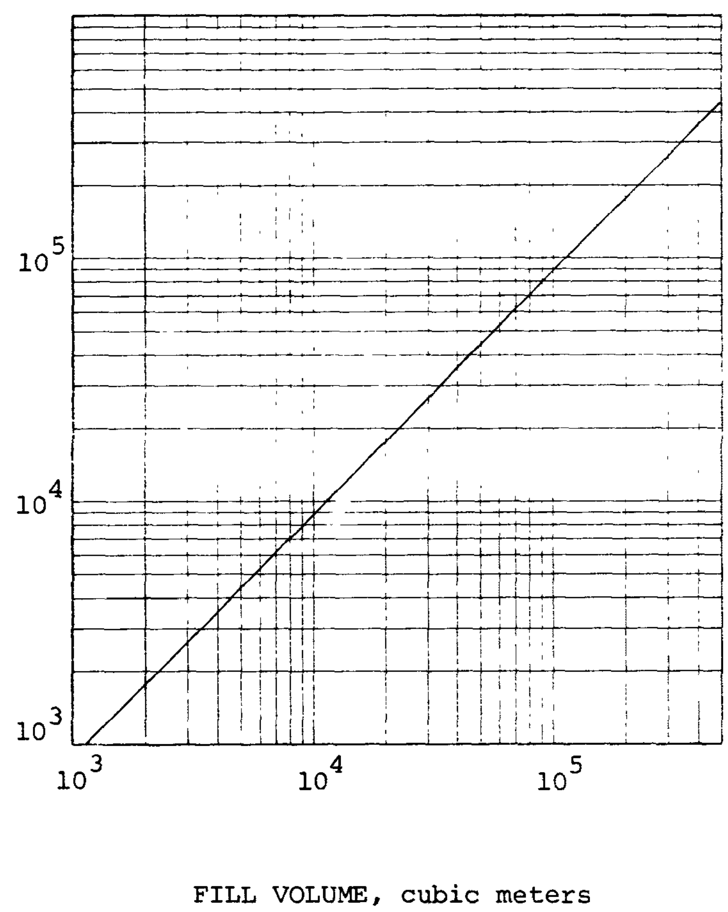


Fig. 801 - Cost for Fill Material

Fill Material	Adjustment Factor, F_D
Unclassified Earth	1.00
Bank Run Gravel or Sand	3.63
Graded Gravel or Sand	4.33
Topsoil & Loam	4.70

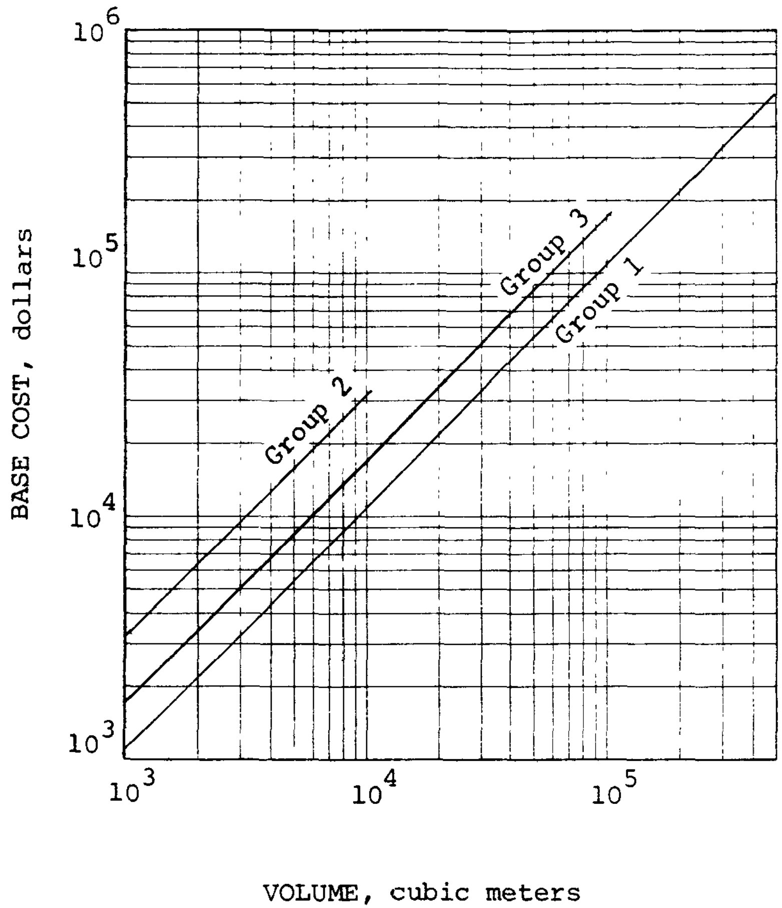


Fig. 802.1 - Cost for Placement of Fill (Land)

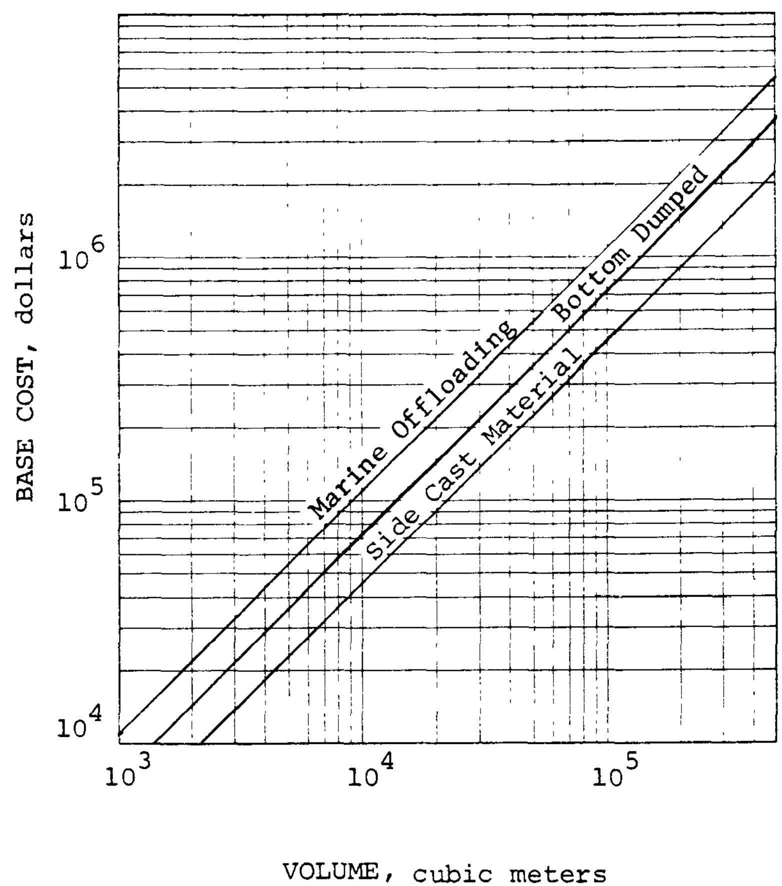


Fig. 802.2 - Cost for Placement of Fill (Marine)

COST CATEGORY 9, EXCAVATION

Data are given for land and marine open cut excavation. Tunnel excavation is not included in this category.

Data for each account are given in the following paragraphs.

Earth excavation (land), Account 901.1

Key parameters considered are volume of excavation and the physical size of the excavation.

The volume of excavation and the physical size of the trench or foundation will affect the choice of equipment. For the relatively small excavation volumes encountered in this type of construction, the size of the excavation has the greater influence on equipment costs.

Land-based earth excavation, therefore, is grouped according to size of the excavation. The volume of excavation is implied in the choice of equipment. The groups are:

1. Structures and trench excavation for small buildings, for additions to existing buildings and for smaller pipes - Production rates are low, yet the labor and equipment costs are relatively high. Unit costs were developed for using a hydraulic backhoe to excavate the material.
2. Structure excavation for larger structures such as a pumping station - The size of the equipment used and the associated costs do increase. However, the production rates improve. Unit costs include the cost for a crane rigged with a clam or dragline.
3. When pipe diameters approach the size that require a trench width equal to that of a scraper, less costly excavation methods can be used - The costs for using a scraper to excavate the material was used in unit cost development.

Water problems and the necessity for shoring add to the cost of excavation, see Accounts 903 and 904 and may reduce productivity. The cost data given in this account were developed assuming the area enclosed in shoring can be dewatered and is large enough not to hamper production significantly.

Earth excavation (marine),
Account 901.2

Key parameters are the volume of excavation, type of material, the method of disposal, and production rates. It is assumed the equipment production time will be 16 days per month, and the work periods will be 24 hours per day for a six-day week. The production for days spent actually excavating material will vary according to weather delays, maintenance requirements, and the distance to a protected harbor. The working season affects annual production time. In the northern climate, the work season is 7 to 8 months compared to 12 months in the south. All these variables affect the costs making an "average" unit cost difficult to assess.

The information presented for this type of excavation is related to the consistency of the material and method of disposal. Materials are classifed into three groups and a type of excavation equipment assumed for each. The groups and equipment are:

1. A hard material (a till or weathered rock) - It was assumed excavation is done with a barge-mounted backhoe (dipper dredge) with spuds that secure it to the bottom for leverage.
2. A firm cohesive material - Excavation of this type of material will be done using a barge-mounted clamshell dredge. (Sand is an example of firm material).
3. Soft material (unconsolidated silt) - Excavation of this material will also be done with a clamshell dredge. Production rates will improve over (2) above.

The minimum bottom width that can be dug with the dipper dredge is 7 to 8 meters. The clam can excavate a 3-meter wide trench. When this equipment works in shallow water the trench will be excavated to 30 meters wide.

Offshore excavation relates exclusively to digging the pipe trench. The materials excavated from the trench can be side cast along the trench or disposed of on shore in designated areas. On-shore disposal requires the addition of scows and tug boats to the equipment pool for transporting the spoil to shore. The haul distance offshore then becomes a factor. It is assumed the distance to the shore offloading point is within a kilometer of the excavation area. Costs for maintenance of the disposal area are left to the user. Data presented in this manual will be useful.

Rock excavation (land),
Account 902.1

Key parameters are the dimensions of the trench and disposal of the material. A narrow deep trench will require more control holes per unit volume of rock, and cleanup costs are more because of the equipment size limits. Differences in unit prices for a narrow and wide trench are reflected in the productivity assumed. An arbitrary division between a narrow and wide trench is 5 meters. The trench in many cases will be over-excavated to allow .8 meters of sand for pipe bedding. The user should include an allowance for this in the estimate. Costs for a rock drill and a crane with clam to remove the rock from the trench are used in developing unit costs for this account.

Powder costs are included as a lump sum of $3/cubic meter.

Rock excavation (marine),
Account 902.2

Key parameters are the volume, the disposal of the materials, and production rates. A production time of 16 days per month and a work period of 6 days per week is assumed. For some of the work, a period of 24 hours per day is assumed. The same limitations on production exist for this account as for account 901.2.

The methodology assumed for excavation of rock offshore is to:

1. blast the rock;
2. load the blasted material with a dipper dredge into a scow;
3. tow the material to shore; and
4. transfer material from the scows to trucks or to a stockpile for disposal.

Powder costs are added as a lump sum of $3/per cubic meter. The trench is often over-excavated to minimize clean-up work and to allow for placing a sand bedding for the pipe. Assume over-excavation to be 1 meter.

Shoring, Account 903

A discussion of sheet piling used for excavation shoring is given in Cost Category 2.

Excavation Dewatering,
Account 904

Key parameters are the initial and the sustained dewatering requirements. The procedure used here is to:

1. assume an inflow rate;
2. develop the costs for pumping on a per week basis;
3. equate the excavation time and the pumping time;
4. divide the production rate into the total volume of excavation; the quotient is the pumping time (production rates used are the same as those used in developing the unit costs).

Therefore, given the inflow, the volume of excavation and the group number, (see Account 901.1) sustained dewatering costs can be estimated. Initial dewatering costs are not given.

Mobilization, Account 905

Unit prices do not include the cost for mobilizing and de-mobilizing equipment. Mobilization costs were added for marine and land installation in Category 4. A discussion of mobilization costs is given in Cost Category 10.

Table 110 presents the correlation between cost account number, worksheet, and figure number. Costs are calculated using the procedure outline in the introductory remarks to this section and the worksheets in Tables 111 through 119.

Table 110. EXCAVATION COST ACCOUNTS

Cost Account Number	Description	Figure Number	Worksheet Number
901	Earth excavation	--	--
901.1	Earth excavation (land): Costs for earth excavation of channels, foundations, and pipe trenches	901.1	901.1
901.2	Earth excavation (marine): Costs for excavation of a pipe trench for three general types of material and for alternative disposal methods	901.2	901.2
902	Rock excavation	--	--
902.1	Rock excavation (land): Costs for onshore rock excavation	--	902.1
902.2	Rock excavation (marine): Costs for excavation of pipe trench offshore in rock material	--	902.2
903	Shoring: Shoring costs for foundation and trench excavation using steel sheet piling (see Category 2)	--	903
904	Dewatering: The cost of dewatering for foundation and trench excavation	904	904
905	Other	--	905
906	Mobilization	--	906

Table 111. COST CATEGORY 9
COST SUMMATION

Worksheet 900

Cost Account Number	Description	Base Cost
901	Earth excavation	
901.1	Earth excavation (land)[a]	$BC_{901.1}$ =$ ______
901.2	Earth excavation (marine)[a]	$BC_{901.2}$ =$ ______
902	Rock excavation	
902.1	Rock excavation (land)[a]	$BC_{902.1}$ =$ ______
902.2	Rock excavation (marine)[a]	$BC_{902.2}$ =$ ______
903	Shoring for excavation[a]	BC_{903} =$ ______
904	Dewatering during excavation[a]	BC_{904} =$ ______
905	Other	BC_{905} =$ ______
Cost Category 9 Total Cost (Enter cost in Account 1101)		BC_9 =$ ______
906	Mobilization (Enter cost in Acct. 1001)	MC_9 =$ ______

[a]The user is cautioned that most of the time the costs for these accounts are used in other categories. Do not enter here if they are used in another category.

Table 112. EARTH EXCAVATION (LAND)

Worksheet 901.1

Design Data Required

Type of excavation[a]		________
Volume of excavation	V =	________ m^3
Haul distance (round trip) from excavation site to disposal site[b]		________ km

Base Cost

Enter Figure 901.1, read base cost for excavation	BC(1)	=$ ________
Enter Figure 108.2, read base unit cost for hauling	BUC(2)	=$ ________
Base cost for hauling = V x BUC(2)	BC(2)	=$ ________
Total base cost = BC(1) + BC(2)	$BC_{901.1}$	=$ ________

---

[a]1. Trench or small foundation
2. Large foundation
3. Channel or large trench

[b]If haul distance is not given and hauling is known to be a factor assume 8-km round trip.

Table 113. EARTH EXCAVATION (MARINE)

Worksheet 901.2

Design Data Required

Type of excavation (soft, firm, hard)[a]	________
Volume of excavation	V = ________ m^3
Disposal method[b]	________
Haul distance (round trip)[c]	________ km

Base Cost

Enter Figure 901.2, read base cost for excavation	BC(1)=$ ________
Enter Figure 108.2, read base unit cost for haul	BUC(2)=$ ________
Base cost for hauling = V x BUC(2)	BC(2)=$ ________

Cost Adjustment

Enter Figure 901.2, read design adjustment factor for disposal method	F_D= ________

Adjusted Base Cost

Adjusted cost = ((BC(1) x F_D) + BC(2))	$BC_{901.2}$=$ ________

---

[a]Soft - Sand or unconsolidated silt.
Firm - Clay or other cohesive material.
Hard - Till or soft, weathered rock.

[b]Side cast or hauled to shore

[c]From the shoreline to a land disposal area. If this haul distance is unknown, assume an 8-km round trip.

Table 114. ROCK EXCAVATION (LAND)

Worksheet 902.1

Design Data Required

Volume of excavation V = ____________ m^3

Haul distance (round trip) from excavation site to disposal site[a] ____________ km

Bottom width of the trench ____________ m

Base Cost

Enter Fig. 902.1, read base cost for excavation BC(1) =$____________

Enter Figure 108.2, read base unit cost for hauling BUC(2)=$____________

Base cost for hauling = V x BUC(2) BC(2) =$____________

Total base cost = BC(1) + BC(2) $BC_{902.1}$=$____________

[a]If haul distance is not given and hauling is known to be a factor, assume 8-km round trip.

Table 115. ROCK EXCAVATION (MARINE)

Worksheet 902.2

Design Data Required

Volume at excavation	V =	____________ m^3
Haul distance (round-trip)[a] from shoreline to disposal area		____________ km

Base Cost

Base cost for offshore rock excavation = $55.40/$m^3$ x V	BC(1) =	$____________
Enter Figure 108.2, read base unit cost for rock haul and disposal	BUC(2) =	$____________
Base cost for haul and disposal of waste rock V x BUC(2)	BC(2) =	$____________
Total base cost = BC(1) + BC(2)	$BC_{902.2}$ =	$____________

---

[a]If haul distance is not given and hauling is known to be a factor assume 8-km round-trip.

Table 116. SHORING

Worksheet 903

Base Cost

Reder to Cost Category 2 for cost estimating Procedures. Base cost = Σ (appropriate base costs from Account 202). BC_{903} = $______

Table 117. EXCAVATION DEWATERING

Worksheet 904

Design Data Required

Volume of excavation V = ______ m^3

Type of excavation group[a] ______

Base Cost

Enter Figure 904, read base cost BC_{904} = $______

---

[a]Group 1 - Trench or small foundation
Group 2 - Large foundation
Group 3 - Channel or large trench

Table 118. OTHER

Worksheet 905

Base Cost

Include costs not covered in this category but that relate to excavation. Data presented in other accounts may be useful in estimating "Other" costs. BC_{905} = ________

Table 119. MOBILIZATION

Worksheet 906

Data Requirement

Cost Account Number	Mobilization Costs	Summation
901.1[a] (Group No.)		
1	$1,000	________
2	$3,300	________
3	$1,500	________
902.1[a]	$4,000	________

Mobilization Cost

Mobilization = the total of the summation column (above) MC_9 = $ ________

---

[a]These costs are included only if there is excavation other than for a pump station or a pipe trench.

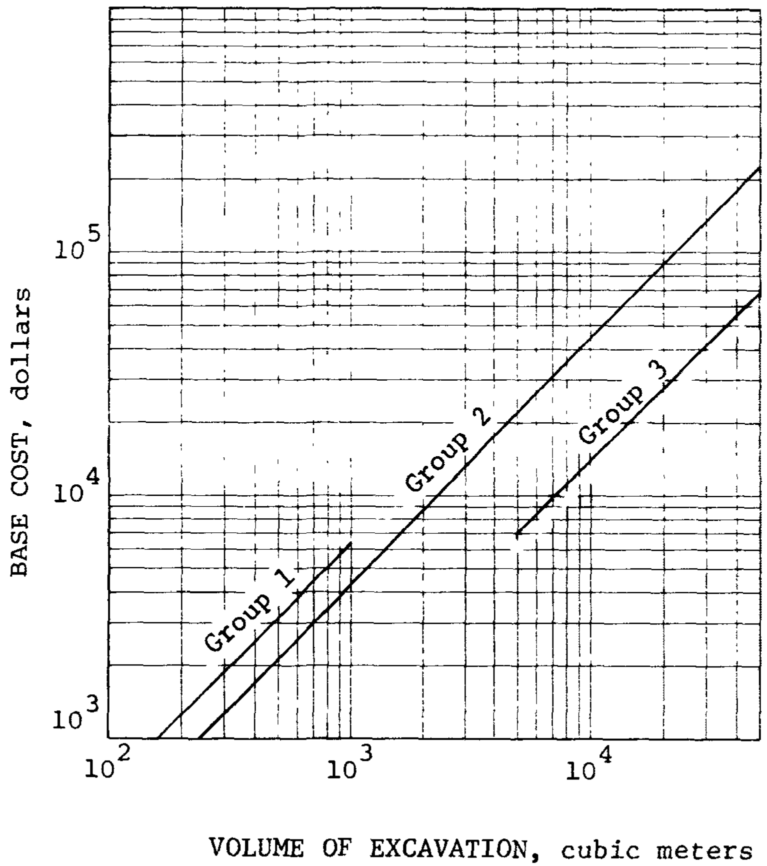
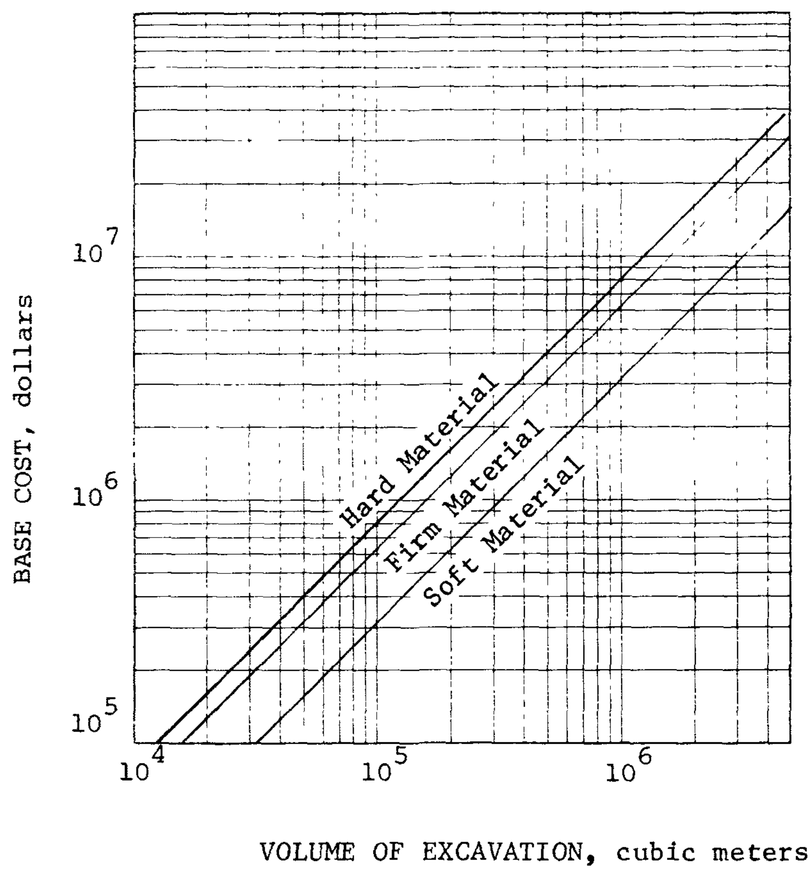


Fig. 901.1 - Costs for Earth Excavation (Land)



Description	Adjustment Factor for Onshore Disposal F_D
Hard Material	1.07
Firm Material	1.09
Soft Material	1.09

Fig. 901.2 - Costs for Earth Excavation (Marine)

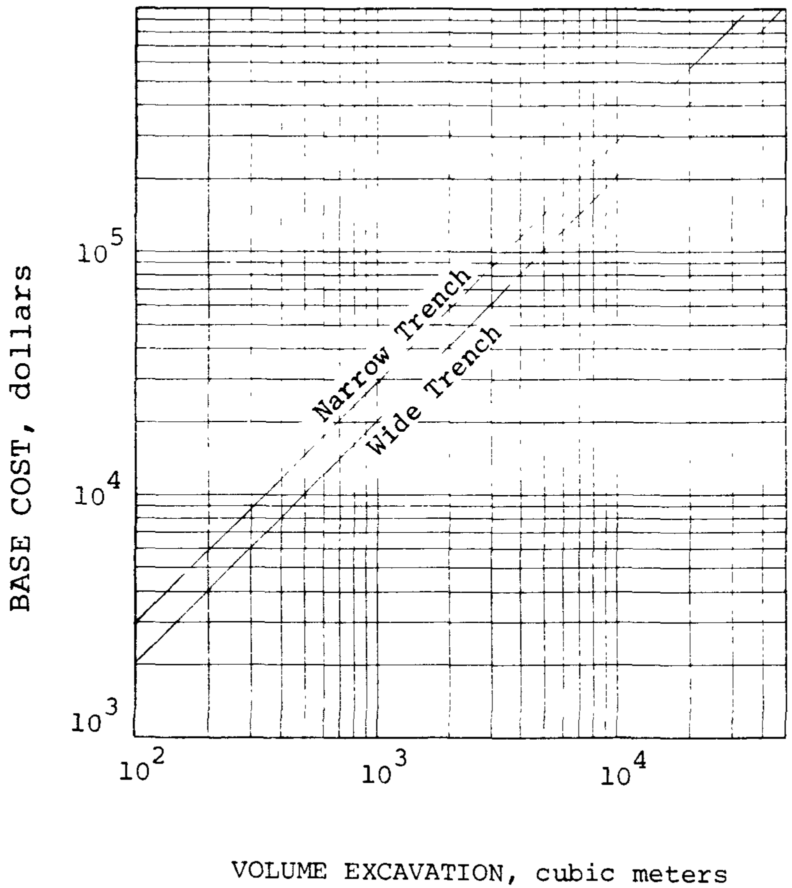


Fig. 902.1 - Costs for Rock Excavation (Land)

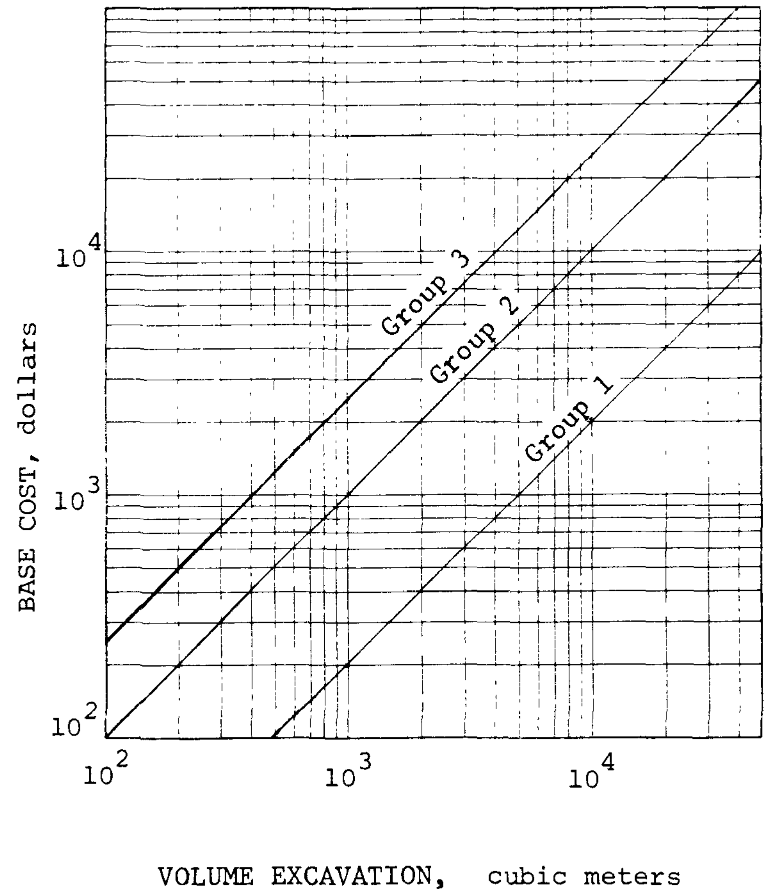


Fig. 904 - Costs for Excavation Dewatering

COST CATEGORY 10, MOBILIZATION

Information on the costs for mobilization and demobilization of equipment used in construction of the facilities is given. The costs for field offices, mobilization of supervisory people, etc., is included in overhead costs. The key parameters affecting mobilization are the location of the site relative to equipment location and whether the contractor uses his equipment or rents the equipment. Obviously, if the job is in the immediate area of the equipment, the cost for mobilization will be minimal. Also, the contractor may choose to rent the equipment from a local firm, thus effectively eliminating the cost for mobilization. It is not possible to predict the location of equipment nor whether or not the contractor will rent or use his own equipment. Therefore, it is assumed the equipment will have to be towed (marine) or shipped to the site.

Data for estimating mobilization costs are given for all the categories except tunnels. Equipment for tunneling is specialized, and there is very little published data available to base an estimate for mobilization. Therefore, mobilization costs for tunnels are given as a percentage of the total costs for that category. Data from contracts listed in the Engineering News Record were used to develop a reasonable percentage to apply to tunneling costs for mobilization. Analysis of 50 contracts given by Engineering News Record revealed that approximately 5 percent of the total construction cost is included in mobilization and demobilization.

No trend with regard to total construction cost was found. For costs ranging from 0 to 1 million, 1 million to 10 million, and 10 million to 100 million, the percentages for mobilization and demobilization were 4.0, 4.9, and 5.0, respectively.

The mobilization data are grouped into two accounts. The first account included data for all categories except tunneling. The second account relates to tunneling only.

Mobilization, Account 1001

Land Based -

The key parameters are equipment location, type, and weight. Mobilization costs may include:

1. shipping costs expended in getting the equipment to the construction site (rail freight plus the cost to off-load and truck the equipment to the site is on weight basis), and
2. the labor, supplies, and equipment required to prepare the equipment for operation (Equipment shipped by rail is partially disassembled. Crane booms are taken off and the tracks are removed from a crawler tractor, for example. In addition, most of the lubricants are removed).

Demobilization costs include preparation of the equipment for shipping and hauling it to the railroad loading area. The data given for mobilization include trucking and equipment preparation costs. The mobilization costs given represent the assumed upper limit of costs; beyond which the contractor would rent local equipment.

Marine -

The key parameters are the location of the equipment relative to the job site and the number of pieces of equipment.

The equipment is towed to the site with tug boats. To develop the mobilization costs, the towing time required and the number of equipment items requiring towing must be considered. The construction is grouped into categories based on the type of conveyance to the offshore discharge.

1. Tunnel - If a tunnel is used, the offshore requirements will be equipment for the activities of Cost Category 2 and Category 6. The rental rate for one tug boat for two weeks is assumed.

2. Conduit - If a conduit is used, the offshore requirements increase. The rental rate for three tug boats for two weeks is assumed; one for excavation, one for the lay barge, and one for backfill of the trench.

Mobilization for tunneling,
Account 1002

Mobilization for tunneling work includes electrical, ventilation, and other equipment. Insufficient published data was located to prepare an estimate for mobilizing tunneling equipment. Therefore, based on the Engineering News Record data, a markup of 5 percent is suggested.

Table 120 presents the correlation between cost accounts and worksheets. Costs are calculated using the introductory remarks to this section and the worksheets in Tables 121-123.

Table 120. MOBILIZATION COST ACCOUNTS

Cost Account Number	Description	Figure Number	Worksheet Number
1001	Mobilization	--	1001
1002	Other	--	1002

Table 121. COST CATEGORY 10
COST SUMMATION

Worksheet 1000

Cost Account Number	Description	Base Cost
1001	Mobilization	BC_{1001} = $ ________
1002	Other	BC_{1002} = $ ________

Cost Category 10 Total Cost (Enter cost in Acct. 1101) BC_{10} = $ ________

Table 122. MOBILIZATION

Worksheet 1001

Data Requirements

Cost Category Number	Mobilization Cost
1	MC_1 = $ ________
2	MC_2 = $ ________
3	MC_3 = $ ________
4	MC_4 = $ ________
5	MC_5 = $ ________
6	MC_6 = $ ________
7	MC_7 = $ ________
8	MC_8 = $ ________
9	MC_9 = $ ________

Base Cost

Total BC_{1001} = $ ________

Table 123. OTHER

Worksheet 1002

Base Cost

Include costs not covered in this category but that relate to mobilization. Data presented in other accounts may be useful in estimating "Other" costs. BC_{1002} = $ ____________

COST CATEGORY 11, CAPITAL
COST RESOLUTION

The information provided in this category gives the user the capability to:

1. adjust the unit price for regional and time variations;
2. determine project costs; and
3. resolve the capital costs into annual costs.

Most of the data that are used to develop project and annual costs are in the form of percentages applied to the construction costs or added cost items such as land or leasing costs. The values for some cost burdens cannot be included in the manual. An approximate value is given for the factors or a source for the data is identified. Whenever possible, local data sources should be used. Data for the accounts of this category are given below.

Time and regional adjustment
factor, Account 1101

The key parameters are cost escalation, regional price differences and the initial price levels. The prices are for the New York City area in December 1974. The regional adjustment factors were derived using the average of the adjustments given in References 2, 3, and 4. Regional adjustment factors are tabulated on the worksheet provided for this account.

Data provided in the Engineering News Record (ENR) were chosen to reflect price escalation because it is readily available, the indexes are revised weekly, and the data are considered good indicators of price trends in the construction industry. Two indexes are presented in the ENR that reflect the cost trends in construction wages and material: the Building Cost Index and the Construction Cost Index. The Building Cost Index is based on material costs and skilled labor. Common labor is substituted for skilled labor in the Construction Cost Index. The authors of Engineering News Record suggest the Construction Cost Index should be used when the costs for common labor are a large percentage of the total cost. That description for common labor hours applies to the type of work considered here. Therefore, the 20-cities average Construction Cost Index was adopted. The December 1974 value of the ENR Construction Cost Index, 2097, is given in the worksheet for this account. Use Figure 1100 to project beyond December 1974. Data are provided from 1969 to 1974, projection beyond December 1974 is left to the user.

Total project costs,
Account 1102

The key parameters are the percentages and values selected and the order in which they are applied. Project costs include, in addition to the construction costs, burdens to the owner for:

1. engineering and general and administrative costs (Engineering costs include design costs, model studies, and construction supervision. General and administrative costs include payrolls, records, and construction management. A value of 10 percent is considered representative for this cost markup);
2. land costs (Costs for easements, rights-of-way, and purchase of land required to accommodate the discharge system or its modification must be considered. Local county officials and real estate salesmen are sources for data);
3. contingency (The value of contingency should reflect the type of input data used. If the quantities were taken from detailed drawings, a contingency

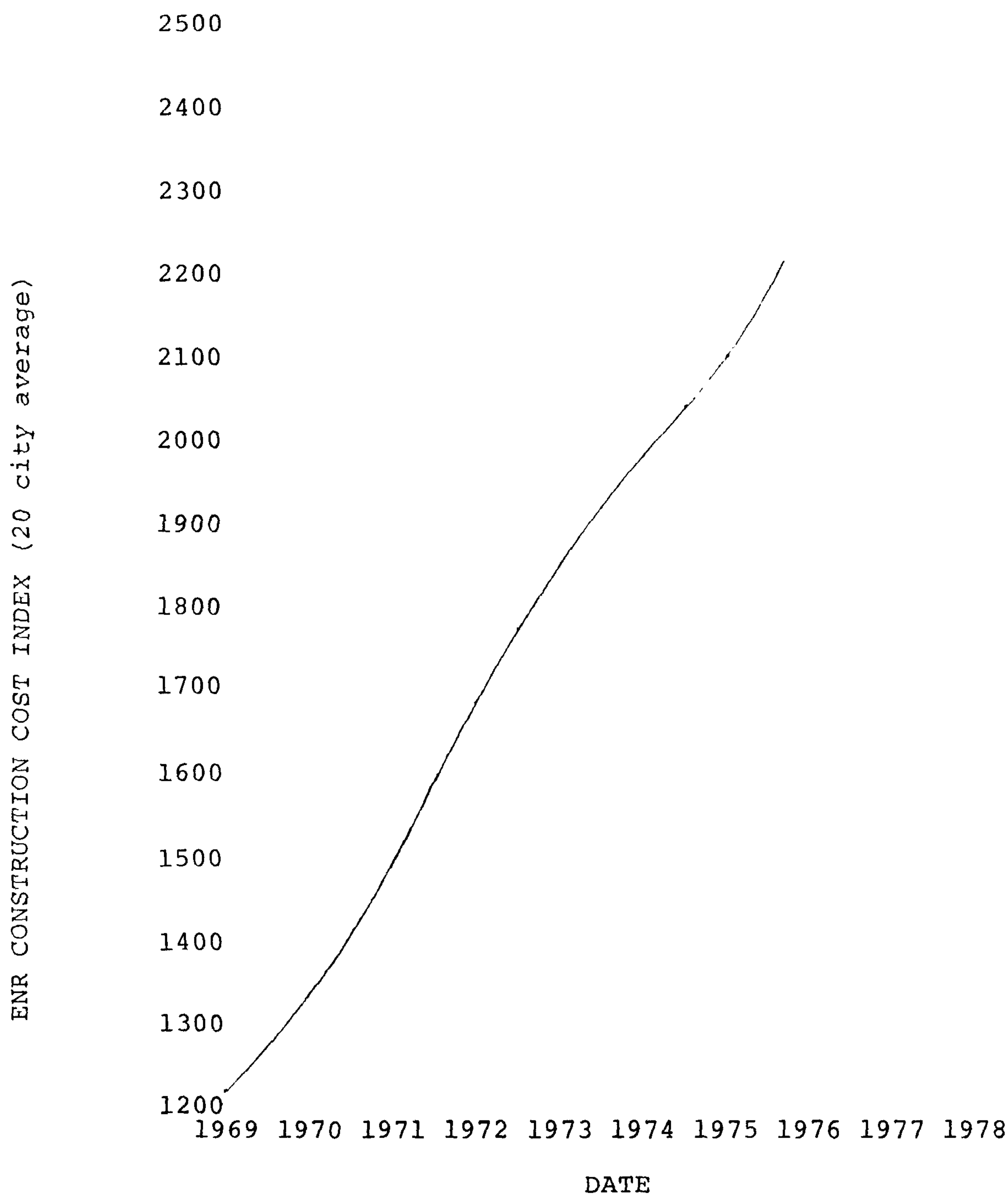


Fig. 1100 - ENR 20-City Construction Cost Index

of 5 percent may be appropriate. A contingency of 25 percent may be more appropriate for a planning type estimate);

4. escalation during construction (Construction costs are calculated in base year dollars. Because of inflation, the prices will rise over the construction period. The procedure used to calculate escalation is to assume a cash flow and apply escalation to the costs in each year. In most cases, the construction period for this type of work will be less than three years. Values of the construction cost index for the period from 1969 to December 1974 are plotted in Figure 1100. Dividing the project average ENR Index for the construction period by its base year value provides an adjustment factor for escalation. Projection beyond December 1974 is left to the user);

5. interest during construction (The cost for interest on the capital required at the time of construction. The interest rate depends on the capital structure of the utility. The user should contact a stock broker to determine the interest rate on bonds for the utility considered); and

6. royalties, licenses, fees, etc. (One-time costs for licenses and miscellaneous fees should be considered. State and Federal agencies can provide the data for estimating license costs. If no data are available, because this item is small, it may be assumed as zero).

Power outage costs,
Account 1103

The key parameters are the time, the plant capacity factor and the unit cost of equivalent or replacement power. It was assumed the utility can purchase the power. Outage costs do not imply cost for interim power generation equipment. In many cases the actual conversion from the old to new system will not cause an interruption in power generation. Extended plant downtime may be avoided by construction of a temporary discharge system. Construction costs for a temporary discharge can be estimated using the data in Categories 1 through 10 and should be included in the total construction costs. The annual maintenance period may be an appropriate time to complete the conversion. However, there will be cases where interruption of power is unavoidable. The power outage period is a value that the user must supply.

The unit cost for power during the outage period is equal to the cost to purchase the replacement power from another utility minus normal production expenses. The region, the utility and the regional power grid demand at the time of outage will all affect the unit power costs. The user should contact the utility for specific data, including an appropriate plant capacity factor.

Annual Costs, Account 1104

Annual costs are useful in comparing systems because the costs are resolved to a common base. The remaining useful life of the plant and the life discharge system should be assumed to be equal. The date the thermal electric plant became operational can be found in Reference 7, which lists data for all the plants in the United States. Assume the initial plant life is 40 years in calculating the remaining useful life. Annual costs include those listed below:

1. Amortization of the depreciable capital investment, royalties, licenses, fees, etc., and power outage costs

   Depreciable capital investment represents the amount of the original value (or worth) that will decrease with time. The depreciable capital is calculated by subtracting the land costs and salvage value from the total project costs. Costs for royalties, licenses, fees, etc. and power outages are one-time charges that are neither depreciable nor exactly non-depreciable. Amortization of these one-time charges is lumped with the depreciable investment. Annual costs for the items considered here are calculated by establishing a sinking fund payment. At the end of the useful life of the facility, the sum of the payments plus interest will equal the original investment. Sinking fund factors for interest rates of 8 and 12 percent are given in the worksheet for this account.

2. Amortization of the non-depreciable capital investment
   It is assumed land costs are recoverable at any time. Therefore, the non-depreciable investment is the salvage value of the facility. The annual costs for depreciation are calculated using the sinking fund factors given for amoritzation of the depreciable capital investment. Salvage value is a credit and is included as a negative fixed charge. The pumps will have some salvage value, but the costs to remove the pumps at the end of the useful life may exceed the credit. Therefore, the salvage credit can be assumed to be negligible in most cases.

3. Interest on the capital investment
   If the initial investment is financed by a bond issue the interest payments on the bond issue are included in the annual costs. Interest rates on bonds will vary with the area and the capital structure of the utility. The interest rate value for utility bonds can be obtained from a local stock broker.

4. Rent or lease costs
   The costs for renting or leasing equipment or processes. Generally this type of cost is not important for the systems considered.

5. Operation costs
   Additional operating costs attributed to the discharge modification. Only the differential cost for pumping is included in this item.

6. Insurance
   Insurance rates will be based on the utility's total system and will depend on the type of insurance. A value of 4 percent is considered appropriate to apply to the total project cost.

7. Property taxes
   Property taxes can be determined from county agencies in the area. The property taxes may be assumed at 2 percent of the total project costs.

8. Tax credit
   The tax credit for installation of capital equipment is included here. A tax credit is based on:

   a. the income tax rate (assume 48 percent is applied to the depreciable capital);

   b. depreciation rate (The depreciation rate varies according to useful life. Tables of depreciation rates are readily available);

   c. depreciable capital (The total project costs less the land costs and salvage value of the facility equals the depreciable capital); and

   d. depreciation schedules (Straight-line double declining, sum of digits, etc. are some schedules used. Depreciation schedules are readily available. Therefore, no values are given).

The differential cost for maintenance of the pumps is considered negligible.

Table 124 presents the correlation between cost account number, worksheet, and figure number. Costs are calculated using the procedure outlined in the introductory remarks to this section and the worksheets in Table 125 through 129.

Table 124. CAPITAL COST RESOLUTION ACCOUNTS

Cost Account Number	Description	Figure Number	Worksheet Number
1101	Time and regional adjustment factor	--	1101
1102	Project costs	--	1102
1103	Power outage costs	--	1103
1104	Annual costs	--	1104

Table 125. COST CATEGORY 11 COST SUMMATION

Cost Account Number	Description	Base Cost
1101	Construction costs	BC_{1101} =$ ________
1102	Project costs	BC_{1102} =$ ________
1103	Power outage costs	BC_{1103} =$ ________
1104	Annual costs	BC_{1104} =$ ________

Table 126 (continued). TIME AND REGIONAL ADJUSTMENT FACTOR

Worksheet 1101

Data Requirements

Regional adjustment factor:

Atlanta -	.79	Kansas City -	.90
Baltimore -	.84	Los Angeles -	.90
Birmingham -	.73	Minneapolis -	.85
Boston -	.90	New Orleans -	.78
Chicago -	.91	New York -	1.00
Cincinnati -	.95	Philadelphia -	.90
Cleveland -	.94	Pittsburgh -	.89
Dallas -	.77	St. Louis -	.89
Denver -	.80	San Francisco -	.94
Detroit -	.93	Seattle -	.85

City nearest to construction area ______________

Regional adjustment factor F_R = ______________

Date construction is to begin or period of price level being considered ______________

Engineering News Record Construction Cost Index for above date (20-city average) ENRX = ______________

Time adjustment factor = ENRX (   ) ÷ 2097[a] F_T = ______________

Regional and time adjustment factor = $F_T \times F_R$ F_{RT} = ______________

[a]The Engineering News Record 20-city average for December 12, 1974

Table 126. TIME AND REGIONAL ADJUSTMENT FACTOR

Worksheet 1101

Data Requirements (cont'd)

Total costs from Categories 1 through 10:

BC_1 = $ __________

BC_2 = $ __________

BC_3 = $ __________

BC_4 = $ __________

BC_5 = $ __________

BC_6 = $ __________

BC_7 = $ __________

BC_8 = $ __________

BC_9 = $ __________

BC_{10} = $ __________

Total Cost = Σ (BC_1 through BC_{10}) BC_T = $ __________

Revised Construction Cost

Total cost = $BC_T \times F_{RT}$ BC_{1101} = $ __________

Table 127. PROJECT COSTS

Worksheet 1102

Data Required

Total construction cost	BC_{1101} =	$ ______
Cost for engineering and general and administrative $\frac{\_\_\_\%}{100\%} \times BC_{1101}$ [a]	BC_E =	$ ______
Costs for lands, easements, and rights-of-way	BC_L =	$ ______
Revised cost = $BC_{1101} + BC_E + BC_L$	BC_1 =	$ ______
Adjustment for contingencies = $BC_1 \times (1 + \_\_\%/100\%)$ [b]	BC_2 =	$ ______
Adjustment for escalation during construction = $BC_2 \times \frac{\text{ENRX (beginning)} + \text{ENRX (end)}}{2 \times \text{ENRX (beginning)}}$	BC_3 =	$ ______
Adjustment for interest during construction[c] = BC_3 x (1 + no.yrs. of construction x annual interest rate/100%) = $BC_3 \times (1 + \_\_ \times \_\_\%/100\%)$	BC_4 =	$ ______
Royalties, licenses, fees, etc.	R =	$ ______
Total Project Cost = BC_4 + R	BC_{1102} =	$ ______

[a]Assume 10 percent.

[b]With detailed information, use a factor of 5 percent; for a planning estimate, use 25 percent.

[c]See account discussion.

Table 128. POWER OUTAGE COSTS

Worksheet 1103

Data Required

Period of outage	T = ________	weeks
Power generation losses = [capacity x outage period x capacity factor]	P = ________	kwh
Unit cost of power = Purchase cost - normal production expenses	U = ________	$/kwh

Outage Cost

T x P x U = BC_{1103} = $________

Table 129. ANNUAL COSTS

Worksheet 1104

1. Amortization of depreciable capital investment and costs for power outage, royalties, etc.

Useful Life Years	Sinking Fund Factor, Annual Interest Rate 8%	12%
3	.30803	.29635
5	.17046	.15741
7	.11207	.09912
10	.06903	.05698
13	.04652	.03568
15	.03683	.02682
18	.02670	.01794
22	.01803	.01081
25	.01368	.00750
28	.01049	.00524
30	.00883	.00414
35	.00580	.00232
40	.00386	.00130

Table 129 (continued). ANNUAL COSTS

Worksheet 1104

Remaining useful life of the plant	Y =	______ yrs.
Sinking fund factor (tabulated above) for annual interest rate of ___%	F =	______
Total project (first) cost	BC_{1102} =	$ ______
Salvage value	S =	$ ______
Land costs	L =	$ ______
Royalties, fees, licenses, etc.	R =	$ ______
Depreciable capital investment = $BC_{1102} - (S+L+R)$	D_c =	$ ______
Power outage costs	BC_{1103} =	$ ______
The amount amortized is = depreciable capital investment + power outage costs + royalties, fees, etc. or $D_c + BC_{1103} + R$	D =	$ ______
Annual cost = F x D	C =	$ ______
2. Amortization of the non-depreciable capital investment (F x S). N_c is a credit (see No. 9 below).	N_c =	$ ______
3. Interest on the capital investment. Bond interest rate	B =	______ %
Interest payment = B%/100% x $(BC_{1102} + BC_{1103})$	I_p =	$ ______
4. Rent or lease costs	L_s =	$ ______

Table 129 (continued). ANNUAL COSTS

Worksheet 1104

5. Operating costs. Electric power in excess of the power required before the addition or modification

= Theoretical Power ÷ efficiency P_e = ____________W

= ____________watts x 100%/___%

Annual operating hours H = ____________hrs.

Power costs = H x P_e x ___/kwh[a] Z = $____________

6. Insurance (BC_{1102} - L - R) x ___%[b]/100% I = $____________

7. Property taxes (BC_{1102} - L - R) x ____%[c]/100% P_t = $____________

8. Tax credit

Income tax rate[d] I_R = ____________%

Methods of depreciation:

a. Straight line depreciation
Tax credit = D_C x I_R%/(100% x Y) T_1 = $____________
= $____ x ____%/(100% x Y)

b. Others (refer to the following tabulation)

---

[a] Assume $.018/kwh
[b] Assume 4 percent
[c] Assume 2 percent
[d] Assume 48 percent

Table 129 (continued). ANNUAL COSTS

Worksheet 1104

Year	D_R[e] (deprec. rt.)	I_R	D_C	T_i (annual increments of depreciation)

$T_1 = \Sigma\ T_i =$ ______

9. Annual costs = $\Sigma\ (C - N_c + I_p + L_s + Z + I + P_t - T_1)$

$EC_{1104} = \$$ ______

[e]Refer to a depreciation schedule for D_R for other than straight line depreciation

SECTION V

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SECTION VI

CONVERSION FACTORS

Data for converting from English to the International System of Units is given below:

One acre	=	4047 square meters
One cubic foot	=	0.0283 cubic meters
One cubic yard	=	0.7646 cubic meters
One foot	=	.3048 meters
One foot per second	=	18.29 meters per minute
One gallon	=	3.785 x 10^{-3} power
One gallon per minute	=	.0630 liters per second
One horse power	=	745.7 watts
One inch	=	2.54 centimeters
One mile	=	1.6093 kilometers
One pound	=	0.4536 kilometers
One pound per square inch	=	703.1 kilograms per square meter
One square foot	=	.0929 square meters
One square yard	=	0.8361 square meters
One ton (short)	=	907.2 kilograms
One yard	=	0.9144 meters

SECTION VII

APPENDICES

APPENDIX A

CASE STUDY

GENERAL

An example is included here to illustrate the application of the procedures in the manual to an actual case of once-through cooling water discharge system modifications. A project description and step-by-step procedure for estimating the costs are given. The results using the methodology in the manual are compared with the actual construction costs.

The cost data for this project and the others listed in Table 1, not included here, are not part of the information used to develop the unit costs for the manual.

The basis for comparison of the costs is as follows:

1. Manual - Construction costs are December 1974 level and are adjusted for the project location. A contingency of 5 percent is added (the data were considered as detailed information).
2. Plant data - Actual construction costs for the modifications to the once-through cooling water discharge were furnished by the utility owner. The costs are escalated from the mid-point of the construction period to December 1974.

PROJECT DESCRIPTION

Project: Quad Cities - Station Units 1 and 2
Commonwealth Edison Company
Chicago, Illinois

Quad-Cities Station is a nuclear fueled steam electric generating plant located about 34 kilometers north of Moline, Illinois on the Illinois shore of the Mississippi River, (Pool 14). The plant consists of two-809 mWe boiling water reactors which withdraw 65 cubic meters per second from the Mississippi River for condenser cooling. The plant has an open cycle condenser cooling system which discharges heated cooling water into the river.

The original shoreline "side-jet" discharge system consisted of a concrete lined channel with sheet pile slot jet emptying into the Mississippi River. This was used as an interim system to meet the scheduled start-up date. In 1972, the interim discharge system was modified to a multiport diffuser type consisting of two underwater carbon steel diffuser pipes with nozzles discharging water perpendicular to the shoreline. The discharge arrangement is shown in Figure 1201.

All quantities and related information used in the cost development were determined from drawings provided by Commonwealth Edison Company.

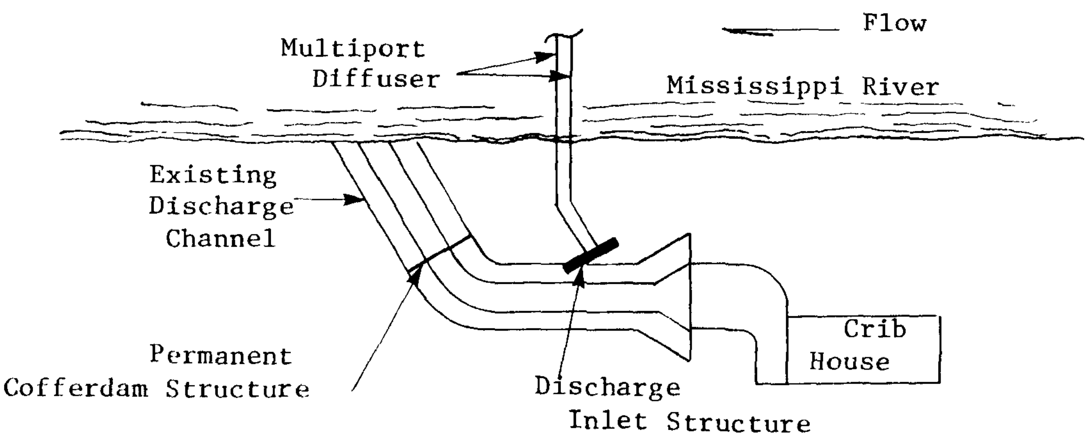

Fig. 1201 - Discharge Arrangement at Quad Cities

ESTIMATE

The following estimate includes costs for:

1. construction of a cofferdam across the discharge channel;
2. removal of riprap from the existing channel bank and excavation of a new channel to divert the flow into the inlet structure;
3. construction of a concrete and steel sheet pile inlet structure; and
4. installation of carbon steel pipe on land and a multiport diffuser offshore. (Nozzles are arranged along the conduit from near the shore to the offshore end of the pipe.)

The inlet structure is constructed by first driving piling to form a rectangular area, excavating the material from within the rectangle, installing the pipes and concrete structure and finally backfilling with sand to the original ground level.

Cost Category 1

Account 101, Riprap removal (Worksheet 101) -

The riprap removed from the channel is assumed to be stockpiled on site and used for lining the new channel section. Therefore, hauling costs are not included.

Table 5. RIPRAP REMOVAL

Worksheet 101

Design Data Required

Haul distance to disposal site (round trip)[a]	N.A. km
Volume of riprap	V = 300 m^3

Base Cost

Base cost for excavating riprap = \$5.40/m^3 x V	BC(1) = 1620
Enter figure 108.2, read base unit cost for rock haul and disposal	BUC(2)=\$ N.A. /m^3
Base cost for haul and disposal of riprap = V x BUC(2)	BC(2) =\$ N.A.
Total base cost = BC(1) + BC(2)	BC_{101} =\$ 1620

[a]If haul distance is not provided, assume 8-km round trip.

Accounts 102, 103, 104.1, 104.2, and 105 do not apply

Account 106, Reseeding (Worksheet 106) -

Table 11. RESEEDING

Worksheet 106

Design Data Required

Area of reseeding A = 5400 m^2

Base Cost

Base cost = A x \$0.37/m^2 BC_{106} =\$ 2,000

Account 107, Site Grading
(Worksheets 802.1, 901.1 and 107) -

A cut and fill operation is assumed. Material and hauling costs are not included because earth excavated from the pipe trench and from within the sheet piling enclosure can be used to balance cut and fill. Costs are calculated on Worksheets 802.1 and 901.1, then transferred to Worksheet 107.

Table 108. PLACEMENT OF FILL (LAND)

Worksheet 802.1

Design Data Required

Nature of the placement operation[a] group number 1

Volume of fill V = 3970 m^3

[a]Group 1 - Dump and spread fill
Group 2 - Hand compaction of fill
Group 3 - Machine compaction

Base Cost

Enter Figure 802.1, read base cost — $BC_{802.1}$ =$ 5,000

Transfer to Account 107

Table 114. EARTH EXCAVATION (LAND)

Worksheet 901.1

Design Data Required

Type of excavation[a]		3	
Volume of excavation	V =	1760	m^3
Haul distance (round trip) from excavation site to disposal site[b]		—	km

Base Cost

Enter Figure 901.1, read base cost for excavation	BC(1)	=$	2500
Enter Figure 108.2, read base unit cost for hauling	BUC(2)	=$	—
Base cost for hauling = V x BUC(2)	BC(2)	=$	—
Total base cost = BC(1) + BC(2)	$BC_{901.1}$	=$	2,500

Transfer to Account 107

[a] 1. Trench or small foundation
2. Large foundation
3. Channel or large trench

[b] If haul distance is not given and hauling is known to be a factor, assume 8-km round trip.

Table 12. SITE GRADING

Worksheet 107

Base Cost

Refer to Cost Category 8 and 9 for appropriate cost accounts and cost estimate procedures.
Base cost = Σ (appropriate base costs).

$5,000
+ 2,500

BC_{107} =$ 7,500

Accounts 108 and 109 do not apply

Account 110 Mobilization (Worksheet 110) -

Table 15. MOBILIZATION

Worksheet 110

Data Requirement

Cost Account Number	Mobilization Cost	Summation[a]
101	Add $3,300 for any one	
102	of these accounts and	
103	$6,600 if two or more	
104.1	are used	3,300
105	$700	—
106	$400	400
107	See Cost Cat. 8	3200
108[a]	$600	

Mobilization Cost

Mobilization = the total of the summation column (above) MC_1 = 6900

---

[a]Add mobilization for hauling if accounts 101, 102, 103 or 106 are used.

The costs from each account are entered on cost summary sheet for Category 1.

Table 4. COST CATEGORY 1 COST SUMMATION

Worksheet 100

Cost Account Number	Description	Base Cost
101	Riprap removal	BC_{101} = 1,620
102	Concrete slab removal	BC_{102} = N.A.
103	Concrete removal (nonslab)	BC_{103} = N.A.
104	Sheet pile removal	
104.1	Pulling costs	$BC_{104.1}$ = N.A.
104.2	Salvage credit	$BSC_{104.2}$ = (-) N.A.
105	Clearing and grubbing	BC_{105} = N.A.
106	Reseeding	BC_{106} = 2,000
107	Site grading	BC_{107} = 7,500

109	Other	BC_{109}	= N.A.
Cost Category 1 Total Cost (Enter cost in Account 1101)		BC_1	=$ 11,120
110	Mobilization (Enter Cost in Account 1001)	MC_1	=$ 6900

Cost Category 2

Account 201.1, Placement of riprap (land-based) (Worksheet 201.1) -

A total of 835 m^3 of riprap is needed to line the new channel to the inlet structure. Costs for material and hauling are not included for the riprap stockpiled from removal operations (Account 101). The costs for placement and material and hauling of riprap are included for the remaining 535 cubic meters of riprap.

Table 18. PLACEMENT OF RIPRAP (LAND-BASED)

Worksheet 201.1 (Sheet #1)

Design Data Required

Material[a] Riprap Stone

Volume of material $V =$ 535 m^3

Haul distance (round trip) from borrow site to construction site[b] $H_d =$ 18 km

Base Cost

Enter Figure 201.1, read base cost for material and placement	BC(1)	=$ 12,000
Enter Figure 108.2, read base unit cost for hauling	BUC(2)	=$ 9.40 /m^3
Base cost for haul = V x BUC(2)	BC(2)	=$ 5030
Total base cost = BC(1) + BC(2)	$BC_{201.1}$	=$ 17,030

[a]Cover stone, riprap stone, or filter stone.

[b]If haul distance is not provided and seems appropriate, assume 18-km round trip (see the discussion for this account).

Table 18. PLACEMENT OF RIPRAP (LAND-BASED)

Worksheet 201.1 (Sht. #2)

Design Data Required

Material[a]		(Excavated material) → Riprap Stone
Volume of material	V =	300 m^3
Haul distance (round trip) from borrow site to construction site[b]	H_d =	— km

Base Cost

Enter Figure 201.1, read base cost for material and placement	BC(1)	=$ 1,810*
		*Does not include material and hauling
Enter Figure 108.2, read base unit cost for hauling	BUC(2)	=$ — /m^3
Base cost for haul = V x BUC(2)	BC(2)	=$ —
Total base cost = BC(1) + BC(2)	$BC_{201.1}$	=$ 1,810

Total $BC_{201.1}$ $17,030 + $1,810 = $18,840

[a]Cover stone, riprap stone, or filter stone.

[b]If haul distance is not provided and seems appropriate, assume 18-km round trip (see discussion for this account).

Account 201.2 does not apply

Account 202.1, Steel sheet piling (land) -

Refer to Worksheet for costs of the piling used in the inlet structure.

Table 20. STEEL SHEET PILING (LAND)

Worksheet 202.1

Design Data Required

Area of sheet piling	2530 m^2
Intended usage (temporary or permanent)	Permanent

Base Cost

Enter Figure 202.1, read base cost $BC_{202.1}$ =$ 165,000

Accounts 203, 204, and 205 do not apply.

Account 206 Mobilization (Worksheet 206) -

Table 26. MOBILIZATION

Worksheet 206

Data Requirements

Cost Account Number	Mobilization Cost	Summation
201.1 Riprap stone or filter	$3,700	3,700
201.1 Cover stone) 202.1) 203.1) 204	$3,300 for one of the accounts (201.1-204) and $6,600 for two or more accounts	3,300
Hauling[a]	$600	600

Mobilization for marine equipment is included in Categories 4 and 6

Mobilization Cost

Mobilization = the total of the summation column (above) MC_2 = 7,600

[a]If account 201.1 is used and hauling costs are added to the estimate, include the mobilization cost for hauling.

Costs for each account are entered on the summary worksheet for Category 2.

Table 17. COST CATEGORY 2 COST SUMMATION

Worksheet 200

Cost Account Number	Description	Base Cost
201	Riprap and filter material and placement	
201.1	Placement by land-based equipment	$BC_{201.1}$ =$ 18,840
201.2	Offshore placement	$BC_{201.2}$ =$ N.A.
202	Steel sheet piling	
202.1	Placement by land-based equipment	$BC_{202.1}$ =$ 165,000
202.2	Offshore placement	$BC_{202.2}$ =$ N.A.
203	Piles	
203.1	Land installation	$BC_{203.1}$ =$ N.A.
203.2	Marine	$BC_{203.2}$ =$ N.A.
204	Concrete	BC_{204} =$ N.A.
205	Other	BC_{205} =$ —
Cost Category 2 Total Cost (Enter cost in Account 1101)		BC_2 =$ 183,840
206	Mobilization (Enter Cost in Account 1001)	MC_2 =$ 7,600

Cost Category 3 does not apply.

Cost Category 4

Accounts 401 and 402 do not apply.

Account 403.1, Steel pipe (Worksheet 403.1) -

Information supplied by Commonwealth Edison indicates that the pipe was shop fabricated and shipped to site. Pipe costs are for onshore piping only. The conduit offshore is used as a manifold for the diffuser. Therefore, costs are given in Category 6.

Table 46. STEEL CONDUIT

Worksheet 403.1

Design Data Required

Pipe diameter	4.88 m
Wall thickness	2.54 cm
With or without stiffeners	without
Pipe length	L = 75 m
Shop or field fabrication[a]	shop (Indicated by owner)

Base Cost

Enter Figure 403.1, read base unit cost per lineal meter	BUC	=$ 2,450
Base cost = L x BUC	BC	=$ 183,750

Cost Adjustments

Enter Figure 403.1, read design adjustment factors for wall thickness, stiffeners and fabrication	$F_D(1)$	= 2.0
	$F_D(2)$	= N.A.
	$F_D(3)$	= 0.65

Adjusted Base Cost

Adjusted base cost of materials and fabrication = BC x $F_D(1)$ x $F_D(2)$ x $F_D(3)$	$BC_{403.1}$	=$ 238,875

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[a]For diameters to 3.05 meters, assume shop fabrication.

Account 403.2, Carbon Steel pipe fittings (Worksheet 403.2) -

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Table 47. STEEL PIPE FITTINGS

Worksheet 403.2

Design Data Required

Type (elbow, reducer, tee, connection)	45° elbow
Diameter (if a fitting diameter varies, use largest diameter)	4.88 m

Angle (for reducer or connection)		— °
Number	N =	2
Wall thickness		2.54 cm
With or without stiffeners		without

Base Cost

Enter Figure 403.2, read base unit cost per fitting	BUC	=$ 2700
Base cost = N x BUC	BC	=$ 5,400

Cost Adjustments

Enter Figure 403.1, read design adjustment factors for wall thickness and stiffeners and fabrication	$F_D(1)$	= 2.0
	$F_D(2)$	= N.A.
	$F_D(3)$	= 0.65

Adjusted Base Cost

Adjusted base cost of materials and fabrication for particular type of fitting = BC x $F_D(1)$ x $F_D(2)$ x $F_D(3)$	$BC_{403.2}$	=$ 7,020

Accounts 404 and 405 are not applicable.

Account 406.1, Onshore pipe trench excavation (Worksheets 901.1 and 406.1) -

The pipe trench is large and excavation can be done with a minimal amount of dewatering. Costs for excavation are calculated on Worksheet 901.1 and transferred to 406.1.

Table 112. EARTH EXCAVATION (LAND)

Worksheet 901.1

Design Data Required

Type of excavation[a]		2
Volume of excavation	V =	20,650 m^3
Haul distance (round trip) from excavation site to disposal site[b]		8 km

Base Cost

Enter Figure 901.1, read base cost for excavation	BC(1)	=$ 88,000
Enter Figure 108.2, read base cost for hauling	BUC(2)	=$ 3.90
Base cost for hauling = V x BUC(2) 1800 m^3 (surplus) X $3.90 =	BC(2)	=$ 7,020
Total base cost = BC(1) + BC(2)	$BC_{901.1}$	=$ 95,020

Transfer to Account 406.1

[a]1. Trench or small foundation
2. Large foundation
3. Channel or large trench

[b]If haul distance is not given and hauling is known to be a factor assume 8-km round trip.

Table 50. ONSHORE PIPE TRENCH EXCAVATION

Worksheet 406.1

Base Cost

Refer to Cost Accounts 901 or 902 for cost estimating procedure — $BC_{406.1}$ =$ 95,020

Account 406.2, Onshore pipe laying (Worksheet 406.2) -

Table 51. LAYING PIPE ON LAND

Worksheet 406.2

Design Data Required

Length of pipe	L =	75 m
Diameter of pipe	D =	4.88 m
Material		Carbon Steel

Base Cost

Enter Figure 406.2, read base unit cost per lineal meter	BUC	=$ 275
Base cost = L x BUC	$BC_{406.2}$	=$ 20,625

Account 406.3, Onshore fill
(Worksheets 802.1 and 406.3) -

The material used for backfill is that excavated from the pipe trench. Hand compaction is assumed for 25 percent of backfill placed. The remaining fill is machine compacted.

Table 106. PLACEMENT OF FILL (LAND)

Worksheet 802.1

Design Data Required

Nature of the placement operation group number[a]	2
Volume of fill	V = 4700 m^3

Base Cost

Enter Figure 802.1, read base cost	$BC_{802.1}$ =$ 15,500

Transfer to Account 406.3

[a]Group 1 - Dump and spread fill
Group 2 - Hand compaction of fill
Group 3 - Machine compaction

Table 106. PLACEMENT OF FILL (LAND)

Worksheet 802.1

Design Data Required

Nature of the placement operation group number[a]	3
Volume of fill	V = 14,130 m^3

Base Cost

Enter Figure 802.1, read base cost	$BC_{802.1}$ =$ 25,000

Transfer to account 406.3

[a]Group 1 - Dump and spread fill
Group 2 - Hand compaction of fill
Group 3 - Machine compaction

Table 52. ONSHORE BACKFILL

Worksheet 406.3

Base Cost

$15,500
$25,000

Refer to Cost Category 8 for appropriate cost accounts and estimating procedures	$BC_{406.3}$ =$ 40,500

Acounts 406.4, 406.5 and 407.1 Through 407.6 do not apply

The offshore conduit is used as a manifold for the diffuser. Therefore, costs for offshore pipe is included in Category 6. (If a pipe were used to convey the water to a diffuser, costs for the pipe would be included here.)

Account 409, Mobilization (Worksheet 409) -

Table 62. MOBILIZATION

Worksheet 409

Data Requirement

Description	Mobilization Cost	Summation
For offshore installation of a conduit add $96,000[a]	$96,000	—
For land installation of the conduit add	$ 6,600	6,600
For hauling fill	$ 600	600

Mobilization Cost

Mobilization = the total of the summation column (above) MC_4 =$ 7,200

[a]The mobilization costs are inclusive of accounts 407.1 through 407.6.

Enter costs from each account onto the summary worksheet for Category 4.

Table 43. COST CATEGORY 4
COST SUMMATION

Worksheet 400

Cost Account Number	Description	Base Cost
401	Precast concrete pipe	BC_{401} =$ N.A.
402	Cast-in-place box culvert	BC_{402} =$ N.A.
403	Steel conduit	
403.1	Steel pipe	$BC_{403.1}$ =$ 238,875
403.2	Steel fittings	$BC_{403.2}$ =$ 7020
404	Corrugated metal pipe	BC_{404} =$ N.A.
405	Fiberglass pipe	BC_{405} =$ N.A.
406	Land installation of pipe	
406.1	Onshore excavation	$BC_{406.1}$ =$ 95,020
406.2	Onshore pipe laying	$BC_{406.2}$ =$ 20,625
406.3	Cushion fill and backfill	$BC_{406.3}$ =$ 40,500
406.4	Pipe supports	$BC_{406.4}$ =$ N.A.
406.5	Dewatering	$BC_{406.5}$ =$ N.A.

407	Marine Installation of pipe	
407.1	Offshore excavation	$BC_{407.1}$ =$ N.A.
407.2	Offshore pipe laying	$BC_{407.2}$ =$ N.A.
407.3	Cushion fill and backfill	$BC_{407.3}$ =$ N.A.
407.4	Pipe supports	$BC_{407.4}$ =$ N.A.
407.5	Riprap protection	$BC_{407.5}$ =$ N.A.
407.6	Cofferdams	$BC_{407.6}$ =$ N.A.
408	Other	BC_{408} =$ N.A.
Cost Category 4 Total Cost (Enter Cost in Account 1101)		BC_4 =$ 402,040
409	Mobilization (Enter Cost in Account 1001)	MC_4 =$ 7,200

Cost Category 5 does not apply.

Cost Category 6

Account 601, Nozzles (Worksheet 601) -

It is assumed that all nozzles are shop fabricated from 1.27 cm thick carbon steel plate, and the nozzles are welded to the manifold pipe before offshore placement.

Two types of nozzles, conventional and stub, are used for the diffuser system. The stub nozzle is the riser, (dimention "f") without an elbow to divert the flow. To determine stub nozzle costs, adjustment factors for two conventional nozzles of the same diameter are read from Figure 601. If the difference in "f" values used to select the adjustment factors is equal to the stub nozzle height, a second adjustment factor is derived (FD_2). Multiply this factor times the value read from graph in figure 601.

Table 80. STEEL NOZZLES

Worksheet 601

Design Data Required

Nozzle inside diameter		0.61 m
Riser length[a]		0.61 m
Number of nozzles	N =	10

Base Cost

Enter Figure 601, read base unit cost per nozzle	BUC	=$ 3,100
Base cost = N x BUC	BC	=$ 31,000

Cost Adjustments

Enter Figure 601, read design adjustment factor for the riser length (f)	F_D	= 0.80

Adjusted Base Cost

Adjusted cost = BC x F_D	BC_{601}	=$ 24,800

[a]The riser length "f" is the distance from the (horizontal) nozzle centerline to the top of the manifold minus 1.5 times the nozzle diameter.

Table 80. STEEL NOZZLES

Worksheet 601

Design Data Required

Nozzle inside diameter		0.91	m
Riser length[a]		0.61	m
Number of nozzles	N =	40	

Base Cost

Enter Figure 601, read base unit cost per nozzle	BUC	=$ 6,600	
Base cost = N x BUC	BC	=$ 264,000	

Cost Adjustments

Enter Figure 601, read design adjustment factor for the riser length (f)	F_D	= 0.76	

Adjusted Base Cost

Adjusted cost = BC x F_D	BC_{601}	=$ 200,640	

[a]The riser length "f" is the distance from the (horizontal) nozzle centerline to the top of the manifold minus 1.5 times the nozzle diameter.

Table 80. STEEL NOZZLES

Worksheet 601 (Stub Nozzles)

Design Data Required

Nozzle inside diameter		1.22 m
Riser length[a]		0.61 m
Number of nozzles	N =	4

Base Cost

Enter Figure 601, read base unit cost per nozzle	BUC	= $ 10,500
Base cost = N x BUC	BC	= $ 42,000

Cost Adjustments

Enter Figure 601, read design adjustment factor for the riser length (f)	F_D	= 0.09

Adjusted Base Cost

Adjusted cost = BC x F_D	BC_{601}	= $ 3780

[a]The riser length "f" is the distance from the (horizontal) nozzle centerline to the top of the manifold minus 1.5 times the nozzle diameter.

Table 80. STEEL NOZZLES

Worksheet 601 (Stub Nozzles)

Design Data Required

Nozzle inside diameter		0.91 m
Riser length[a]		0.61 m
Number of nozzles	N =	40

Base Cost

Enter Figure 601, read base unit cost per nozzle	BUC	=$ 6,600
Base cost = N x BUC	BC	=$ 264,000

Cost Adjustments

Enter Figure 601, read design adjustment factor for the riser length (f)	F_D	= 0.09

Adjusted Base Cost

Adjusted cost = BC x F_D	BC_{601}	=$ 23,760

[a]The riser length "f" is the distance from the (horizontal) nozzle centerline to the top of the manifold minus 1.5 times the nozzle diameter.

Table 80. STEEL NOZZLES

Worksheet 601 (Stub Nozzles)

Design Data Required

Nozzle inside diameter		0.61 m
Riser length[a]		0.61 m
Number of nozzles	N =	28

Base Cost

Enter Figure 601, read base unit cost per nozzle	BUC	= $ 3,100
Base cost = N x BUC	BC	= $ 86,800

Cost Adjustments

Enter Figure 601, read design adjustment factor for the riser length (f)	F_D	= 0.13

Adjusted Base Cost

Adjusted cost = BC x F_D	BC_{601}	= $ 11,290

[a]The riser length "f" is the distance from the (horizontal) nozzle centerline to the top of the manifold minus 1.5 times the nozzle diameter.

Total for Account 601:
$24,800 + $200,640 + 3780 + $23,760
+ $11,290 = $264,270

Account 602.1 does not apply.

Account 602.2, Steel manifolds (Worksheets 403.1 and 602.2) -

Costs for installation of conduit offshore is calculated on Worksheet 403.1 and transferred to Worksheet 602.2.

Table 46. STEEL CONDUIT

Worksheet 403.1

Design Data Required

Pipe diameter		4.88 m
Wall thickness		2.54 cm
With or without stiffeners		without
Pipe length	L =	1100 m
Shop or field fabrication[a]		Shop

Base Cost

Enter Figure 403.1, read base unit cost per lineal meter	BUC	=$ 2450 /m^3
Base cost = L x BUC	BC	=$ 2,695,000

Cost Adjustments

Enter Figure 403.1, read design adjustment factors for wall thickness, stiffeners and fabrication	$F_D(1)$	= 2.0
	$F_D(2)$	= N.A.
	$F_D(3)$	= 0.65

Adjusted Base Cost

Adjusted base cost of materials and fabrication = BC x $F_D(1)$ x $F_D(2)$ x $F_D(3)$ $BC_{403.1}$ =$ 3,503,500

Transfer to Account 602.2

[a]For diameters to 3.05 meters, assume shop fabrication.

Table 82. STEEL MANIFOLD

Worksheet 602.2

Base Cost

Refer to Cost Account 403, Steel conduit. Base cost = BC_{403} $BC_{602.1}$ =$ 3,503,500

Account 603.1, Installation of conduit diffuser (Worksheets 407.2 and 603.1) -

Table 56. LAYING OFFSHORE PIPE

Worksheet 407.2

Design Data Required

Length of pipe L = 1100 m

Diameter D = 4.88 m

Pipe material Carbon Steel

Depth of water less than 14 m

Base Cost

Enter Figure 407.2, read base unit cost per lineal meter	BUC	=$ 890
Base cost = L x BUC	BC	=$ 979,000

Cost Adjustment

Enter Figure 407.2, read adjustment factor for water depth	F_D	= 1

Adjusted Base Cost

Adjusted base cost for laying pipe offshore = BC x F_D	$BC_{407.2}$	=$ 979,000

Transfer to Account 603.1

Table 84. INSTALLATION OF CONDUIT DIFFUSER

Worksheet 603.1

Base Cost

Select cost Account 406.2 for dry installation within an offshore cofferdam or 407.2 for underwater installation.

Base cost = $BC_{406.2}$ or $BC_{407.2}$	$BC_{603.1}$	=$ 979,000

Account 603.2 and 603.3 do not apply.

Account 603.4, Trench excavation
(Worksheets 901.2 and 902.2 and 603.4) -

Table 113. EARTH EXCAVATION (MARINE)

Worksheet 901.2

Design Data Required

Type of excavation (soft, firm, hard)[a]		Firm
Volume of excavation	V =	135,400 m^3
Disposal method[b]		Hauled to Shore
Haul distance (round trip)[c]		8 km

Base Cost

Enter Figure 901.2, read base cost for excavation	BC(1)	=$ 830,000
Enter Figure 108.2, read base unit cost for haul	BUC(2)	=$ 3.90
Base cost for hauling = V x BUC(2)	BC(2)	=$ 528,060

Cost Adjustment

Enter Figure 901.2, read design adjustment factor for disposal method	F_D	= 1.09

Adjusted Base Cost

Adjusted cost = (BC(1) x F_D) + BC(2)) $BC_{901.2}$ =$ 1,432,760

Transfer to Account 603.4

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[a] Soft - Sand or unconsolidated silt.
Firm - Clay or other cohesive material.
Hard - Till or soft, weathered rock.

[b] Side cast or hauled to shore.

[c] From the shoreline to a land disposal area. If this haul distance is unknown, assume an 8-km round trip.

Table 115. ROCK EXCAVATION (MARINE)

Worksheet 902.2

Design Data Required

Volume at excavation	V =	400 m^3
Haul distance (round trip)[a] from shoreline to disposal area		8 km

Base Cost

Base cost for offshore rock excavation = $55.40/$m^3$ x V	BC(1)	=$ 22,160
Enter Figure 108.2, read base unit cost for rock haul and disposal (curve A)	BUC(2)	=$ 6.10
Base cost for haul and disposal of waste rock V x BUC(2)	BC(2)	=$ 2440
Total base cost = BC(1)+BC(2)	$BC_{902.2}$	=$ 24,600

Transfer to account 603.4

---

[a] If haul distance is not given and hauling is known to be a factor, assume 8-km round-trip.

Table 87. TRENCH EXCAVATION

Worksheet 603.4

Base Cost

Refer to Cost Category 9 and select the cost from either Cost Account 901.1 or 901.2 — $ 1,432,760 / $24,600

Base cost = $BC_{901.1}$ or $BC_{901.2}$ — $BC_{603.4}$ = $ 1,457,360

Accounts 603.5 and 603.6 do not apply.

Account 603.7, Trench backfill (Worksheets 801, 802.2 and 603.7) -

Table 105. MATERIAL AND HAULING COSTS

Worksheet 801

Design Data Required

Type of fill material — Unclassified

Haul distance (round trip)[a] from the borrow site — 18 km

Volume of fill — V = 135,400 m^3

Base Cost

Enter figure 108.2, read base unit cost for hauling — BUC =$ 5.90

Base cost for hauling = BUC x V — BC_1 =$ 798,860

Enter Figure 801, read base cost — BC_2 =$ 110,000

Cost Adjustment

Enter Figure 801, read adjustment factor for material — F_D = 1

Adjusted Base Cost

Adjusted base cost = $(BC_2 \times F_D) + BC_1$ — BC_{801} =$ 908,860

Transfer to account 603.7

[a] If haul distance is not known, assume an 18-km haul.

Table 105. MATERIAL AND HAULING COSTS

Worksheet 801

Design Data Required

Type of fill material — Stone Fill

Haul distance (round trip)[a] from the borrow site — 18 km

Volume of fill — V = 13,900 m^3

Base Cost

Enter Figure 108.1, read base unit cost for hauling — BUC =$ 5.90

Base cost for hauling = BUC x V — BC_1 =$ 82,010

Enter Figure 801, read base cost — BC_2 =$ 11,500

Cost Adjustment

Enter Figure 801, read adjustment factor for material — F_D = 3.63

Adjusted Base Cost

Adjusted base cost = $(BC_2 \times F_D) + BC_1$ — BC_{801} =$ 123,755

Transfer to Account 603.7

[a] If haul distance is not known, assume an 18-km haul.

Table 107. PLACEMENT OF FILL (MARINE)

Worksheet 802.2

Design Data Required

Nature of the placement operation[a] — Back fill Pipe trench

Volume of fill — V = 149,300 m^3

Base Cost

Enter Figure 802.2, read base cost $BC_{802.2}$ =$ 1,050,000

Transfer to account 603.7

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[a]Backfill of a pipe trench; placing fill into a cofferdam or backfill using excavated material side cast along the trench.

Table 90. TRENCH BACKFILL

Worksheet 603.7

$908,860
$123,755
1,050,000

Base Cost

Base cost = base cost from the appropriate accounts in Cost Category 8. $BC_{603.7}$ =$ 2,082,615

Accounts 604 and 605 do not apply.

Account 606, Mobilization (Worksheet 605) -

Table 93. MOBILIZATION

Worksheet 606

Mobilization Cost

Mobilization = $30,000 if the diffuser is a tunnel diffuser. If the total length of offshore pipe is the manifold for a conduit diffuser, add $96,000. (Caution: do not duplicate costs in Account 408.) MC_6 =$ 96,000

Enter costs for each account onto the summary worksheet for Category 6.

Table 79. COST CATEGORY 6 COST SUMMATION

Worksheet 600

Cost Account Number	Description	Base Cost
601	Nozzles	BC_{601} =$ 264,270
602	Manifolds	
602.1	Concrete manifolds	$BC_{602.1}$ =$ 3,503,500
602.2	Steel manifolds	$BC_{602.2}$ =$ N.A.
602.3	Steel fittings	$BC_{602.3}$ =$ N.A.
603	Installation	
603.1	Conduit manifold	$BC_{603.1}$ =$ 979,000
603.2	Nozzles	$BC_{603.2}$ =$ N.A.

603.3	Cofferdams	$BC_{603.3}$	=$ N.A.
603.4	Excavation	$BC_{603.4}$	=$ N.A.
603.5	Diffuser Support	$BC_{603.5}$	=$ N.A.
603.6	Scour protection	$BC_{603.6}$	=$ N.A.
603.7	Backfill	$BC_{603.7}$	=$ 2,082,615
604	Single Port	BC_{604}	=$ N.A.
605	Other	BC_{605}	=$ N.A.
Cost Category 6, Total Cost (Enter cost in Account 1101)		BC_6	=$ 8,286,745
606	Mobilization (Enter cost in Account 1001)	MC_6	=$ 96,000

Cost Category 7

Account 701.1 Cast-in-place concrete (Worksheet 701.1) -

Concrete is used in the construction of the inlet structure for encasement of the pipes (structure category 3) and a reinforced concrete wall (structure category 1).

Table 96. CAST-IN-PLACE
STRUCTURAL CONCRETE, CONCRETE PLACEMENT

Worksheet 701.1

Design Data Required

Category of structure[a] 1

Volume of concrete V = 160 m^3

Base Cost

Enter Figure 701.1, read base cost $BC_{701.1}$ =$ 48,000

[a]1. Suspended slabs, beams, walls
2. Spread footings, grade slabs, and pile caps.
3. Structures with little or no reinforcing.

Table 96. CAST-IN-PLACE
STRUCTURAL CONCRETE, CONCRETE PLACEMENT

Worksheet 701.1

Design Data Required

Category of structure[a] 3

Volume of concrete V = 1,000 m^3

Base Cost

Enter Figure 701.1, read base cost — $BC_{701.1}$ =$ 78,000

---

[a]1. Suspended slabs, beams, walls.
2. Spread footings, grade slabs, and pile caps.
3. Structures with little or no reinforcing.

Account 701.2, Reinforcing (Worksheet 701.2) -

The unit weights of reinforcing assumed are 89 kg/m^3 and 10 kg/m^3 for structure categories 1 and 3, respectively.

Table 97. CAST-IN-PLACE STRUCTURAL CONCRETE, REINFORCING STEEL

Worksheet 701.2

Design Data Required

Category of structure[a] — 1

Weight of reinforcing steel[b] — 14,300 kg

Base Cost

Enter Figure 701.2 read base cost — $BC_{701.2}$ =$ 15,000

---

[a]1. Suspended slabs, beams, and walls.
2. Spread footings, grade slabs, and pile caps.
3. Structures with little or no reinforcing.

[b]If weight of reinforcing steel is not available, assume values shown in the following table:

Category	Weight of Reinforcing to assume, kg/m^3 of conc.
1	89
2	71
3	0-20

Table 97. CAST-IN-PLACE STRUCTURAL CONCRETE, REINFORCING STEEL

Worksheet 701.2

Design Data Required

Category of structure[a] 3

Weight of reinforcing steel[b] 10,000 kg

Base Cost

Enter Figure 701.2 read base cost $BC_{701.2}$ =$ 9,000

[a]1. Suspended slabs, beams, and walls.
2. Spread footings, grade slabs, and pile caps.
3. Structures with little or no reinforcing.

[b]If weight of reinforcing steel is not available, assume values shown in the following table:

Category	Weight of Reinforcing to assume, kg/m^3 of conc.
1	89
2	71
3	0-20

Accounts 702, 703, 704, and 705 do not apply.

Account 706, Mobilization (Worksheet 707) -

Refer to worksheet.

Table 102. MOBILIZATION

Worksheet 706

Mobilization Cost

For a large structure other than the pump station, add \$3,300 MC_7 =\$ 3,300

Enter the charts from each account onto the summary worksheet for Category 7.

Table 95. COST CATEGORY 7 COST SUMMATION

Worksheet 700

Cost Account Number	Description	Base Cost
701	Structural concrete	
701.1	Concrete placement[a]	$BC_{701.1}$ =\$ 126,000
701.2	Reinforcing steel[a]	$BC_{701.2}$ =\$ 24,000
702	Concrete (marine)[a]	BC_{702} =\$ N.A.
703	Grouting	BC_{703} =\$ N.A.

704	Cushion fill	BC_{704}	=$ N.A.
705	Other	BC_{705}	=$ N.A.

Cost Category 7 Total Cost (Enter cost in Account 1101)	BC_7	=$ 150,000

706	Mobilization (Enter cost in Account 1001)	MC_7	=$ 3,300

[a]The user is cautioned that most of the time the costs for these accounts are used in other categories. Do not enter here if they are used in another category.

Cost Category 8

Account 801, Material and hauling costs (Worksheet 801) -

Sand fill is placed within the steel sheet piling enclosure. Costs are given here and in Account 802.1.

Table 105. MATERIAL AND HAULING COSTS

Worksheet 801

Design Data Required

Type of fill material Sand Fill

Haul distance (round trip)[a] from the borrow site 8 km

Volume of fill V = 8,000 m^3

Base Cost

Enter Figure 108.1, read base unit cost for hauling	BUC	=$ 5.90
Base cost for hauling = BUC x V	BC_1	=$ 47,200
Enter Figure 801, read base cost	BC_2	=$ 6,700

Cost Adjustment

Enter Figure 801, read adjustment factor for material	F_D	= 3.63

Adjusted Base Cost

Adjusted base cost = $(BC_2 \times F_D) + BC_1$	BC_{801}	=$ 71,520

---

[a]If haul distance is not known, assume an 18-km haul.

Account 802.1, Backfill (land) Worksheet 802.1) -

It is assumed the sand is hand compacted.

Table 106. PLACEMENT OF FILL (LAND)

Worksheet 802.1

Design Data Required

Nature of the placement operation[a] group number	2
Volume of fill	V = 980 m^3

Base Cost

Enter Figure 802.1, read base cost $BC_{802.1}$ =$ 3,300

---

[a]Group 1 - Dump and spread fill
Group 2 - Hand compaction of fill
Group 3 - Machine compaction

Table 106. PLACEMENT OF FILL (LAND)

Worksheet 802.1

Design Data Required

Nature of the placement operation[a] group number 3

Volume of fill V = 7,260 m^3

Base Cost

Enter Figure 802.1, read base cost $BC_{802.1}$ =$ 13,000

---

[a]Group 1 - Dump and spread fill
Group 2 - Hand compaction of fill
Group 3 - Machine compaction

Accounts 802.2 and 803 do not apply.

Account 804, Mobilization (Worksheet 804) -

Table 109. MOBILIZATION

Worksheet 804

Data Requirements

		Summation
802.1	Mobilization costs for Group 1 of the land placement of fill is $1,700	–
The costs for Group 2 is $900[a]		900
The costs for Group 3 is $800[a]		800

Mobilization Cost

Mobilization = the total of the summation column. Usually only Group 1 of Account 802.1 will be considered (see the discussion for this account). MC_8 =$ 1700

[a]Use the costs for groups 2 and 3 only if there is a large structure other than the pumping station that requires backfill.

Enter the costs from each account onto the summary worksheet for Category 8.

Table 104. COST CATEGORY 8 COST SUMMATION

Worksheet 800

Cost Account Number	Description	Base Cost
801	Material and hauling costs[a]	BC_{801} =$ 71,520
802	Placement of fill[a]	

802.1	Placement of fill (land)[a]	$BC_{802.1}$	=$ 16,300
802.2	Placement of fill (marine)[a]	$BC_{802.2}$	=$ N.A.
803	Other	BC_{803}	=$ N.A.
Cost Category 8 Total Cost (Enter cost in Account 1101)		BC_8	=$ 87,820
804	Mobilization (Enter cost in Account 1001)	MC_8	=$ 1,700

[a]The user is cautioned that most of the time the costs for these accounts are used in other categories. Do not enter here if they are used in another category.

Cost Category 9

Account 901.1, Earth excavation (Worksheet 901.1) -

It is assumed excavation of material from within the sheet pile inlet structure is comparable to excavation of a large foundation. Excavated material is used for on-site back-fill. Therefore, hauling costs do not apply.

Table 112. EARTH EXCAVATION (LAND)

Worksheet 901.1 (Sheet #1)

Design Data Required

Type of excavation[a]		2
Volume of excavation	V =	7880 m^3
Haul distance (round trip) from excavation site to disposal site[b]		— km

Base Cost

Enter Figure 901.1, read base cost for excavation	BC(1)	=$ 35,000
Enter Figure 108.2, read base unit cost for hauling	BUC(2)	=$ —
Base cost for hauling = V x BUC(2)	BC(2)	=$ —
Total base cost = BC(1) + BC(2)	$BC_{901.1}$	=$ 35,000

[a]1. Trench or small foundation
2. Large foundation
3. Channel or large trench

[b]If haul distance is not given and hauling is known to be a factor, assume 8-km round trip.

Table 112. EARTH EXCAVATION (LAND)

Worksheet 901.1 (Sheet #2)

Design Data Required

Type of excavation[a]		3
Volume of excavation	V =	6880 m^3
Haul distance (round trip) from excavation site to disposal site[b]		— km

Base Cost

Enter Figure 901.1, read base cost for excavation	BC(1)	=$ 9800
Enter Figure 108.2, read base unit cost for hauling	BUC(2)	=$ —
Base cost for hauling = V x BUC(2)	BC(2)	=$ —
Total base cost = BC(1) + BC(2)	$BC_{901.1}$	=$ 9800

[a]1. Trench or small foundation
2. Large foundation
3. Channel or large trench

[b]If haul distance is not given and hauling is known to be a factor, assume 8-km round trip.

Account 901.2, Earth excavation (marine) -

All costs for earth excavation (marine) are included in Account 406.1.

Accounts 902.1 - 903 do not apply.

Account 904, Dewatering during excavation -

Seepage is assumed to be minimal and dewatering costs are neglected.

Account 907 does not apply.

Account 908, Mobilization (Worksheet 908) -

Mobilization costs for group 3 are shown on the worksheet.

Table 119. MOBILIZATION

Worksheet 906

Data Requirement

Cost Account Number		Mobilization Costs	Summation
901.1[a]	(Group No.)		
	1	$1,000	—
	2	$3,300	—
	3	$1,500	1,500
902.1[a]		$4,000	—

Mobilization Cost

Mobilization = the total of the summation column (above) MC_9 =$ 1,500

[a]These costs are included only if there is excavation other than for a pump station or a pipe trench.

Enter the costs from each account onto the summary worksheet for Category 9.

Table 111. COST OF CATEGORY 9 COST SUMMATION

Worksheet 900

Cost Account Number	Description	Base Cost
901	Earth excavation	
901.1	Earth excavation (land)[a]	$BC_{901.1}$ =$ 44,800
901.2	Earth excavation (marine)[a]	$BC_{901.2}$ =$ N.A.
902	Rock excavation	
902.1	Rock excavation (land)[a]	$BC_{902.1}$ =$ N.A.
902.2	Rock excavation (marine)[a]	$BC_{902.2}$ =$ N.A.
903	Shoring for excavation[a]	BC_{903} =$ N.A.
904	Dewatering during excavation[a]	BC_{904} =$ N.A.
905	Other	BC_{905} =$ N.A.
Cost Category 9 Total Cost (Enter cost in Account 1101)		BC_9 =$ 44,800
906	Mobilization (Enter cost in Account 1001)	MC_9 =$ 1,500

[a]The user is cautioned that most of the time the costs for these accounts are used in other categories. Do not enter here if they are used in another category.

Cost Category 10

Table 122. MOBILIZATION

Worksheet 1001

Data Requirements

Cost Category Number	Mobilization Cost
1	MC_1 =$ 6,900
2	MC_2 =$ 7,600
3	MC_3 =$ —
4	MC_4 =$ 7,200
5	MC_5 =$ —
6	MC_6 =$ 96,000
7	MC_7 =$ 3,300
8	MC_8 =$ 1,700
9	MC_9 =$ 1,500

Base Cost

Total BC_{1001} =$ 124,200

Table 122. COST CATEGORY 10
COST SUMMATION

Worksheet 1000

Cost Account Number	Description	Base Cost
1001	Mobilization	BC_{1001} =$ 124,200
1002	Other	BC_{1002} =$ N.A.

Cost Category 10 Total Cost
(Enter cost in Account 1101) BC_{10} =$ 124,200

Time and Regional Adjustment
(Worksheet 1101) -

The construction site is located near Chicago. All costs were based on a 1.00 adjustment factor for time. (A comparison is made by updating the actual costs for the project to December 1974 level.)

Table 127. TIME AND
REGIONAL ADJUSTMENT FACTOR

Worksheet 1101

Data Requirements

Regional adjustment factor:

Atlanta -	.79	Kansas City -	.90
Baltimore -	.84	Los Angeles -	.90

Birmingham -	.73	Minneapolis -	.85
Boston -	.90	New Orleans -	.78
Chicago -	.91	New York -	1.00
Cincinnati -	.95	Philadelphia -	.90
Cleveland -	.94	Pittsburgh -	.89
Dallas -	.77	St. Louis -	.89
Denver -	.80	San Francisco -	.94
Detroit -	.93	Seattle -	.85

City nearest to construction area ___Chicago___

Regional adjustment factor F_R = ___0.91___

Date construction is to begin or period of price level being considered ___Dec. 1974___

Engineering News Record Construction Cost Index for above date (20-city average) ENRX = ___2097___

Time adjustment factor = ENRX (   ) ÷ 2097[a] F_T = ___1.00___

Regional and time adjustment factor = $F_T \times F_R$ F_{RT} = ___0.91___

Total costs from Categories 1 through 10:

BC_1 = $ 11,120

BC_2 = $ 183,840

BC_3 = $ —

BC_4 = $ 402,040

BC_5 = $ —

BC_6 = $ 8,286,745

BC_7 = $ 150,000

BC_8 = $ 87,820

BC_9 = $ 44,800

BC_{10} = $ 124,200

Total Cost = Σ (BC_1 through BC_{10}) BC_T = $ 9,290,565

Revised Construction Cost

Total cost = $BC_T \times F_{RT}$ BC_{1101} = $ 8,454,414

Contingency 5% 422,721

Total =$ 8,877,135

Round to $ 8,877,000

---

[a]The Engineering News Record 20-city average for December 12, 1974.

Comparison to actual costs - Commonwealth Edison indicated that the total construction costs added up to the amount of $7,748,000 (excluding the costs of engineering and model studies).

According to information obtained from the owner, most of the construction was carried out during the 1972 fiscal year. For purposes of comparison, the above amount must be adjusted to 1974 price levels.

Assuming June 1972 as a base for actual construction, the ENR index corresponding to this date equals 1761. The ENR for December 1974 equals 2097.

The adjustment factor for the actual cost is:

$$F_T = \frac{2097}{1761} = 1.19$$

Adjustment of the actual construction cost gives a total amount = $7,748,000 x 1.19 = $9,220,120, rounded to $9,220,000.

A comparison of the actual cost in terms of 1974 prices and the estimated cost using the manual indicates a variation of $43,000 or approximately 3.7 percent of the actual cost.

APPENDIX B

BACKGROUND UNIT COST DATA

GENERAL

This appendix gives the user a detailed description of the components of unit cost development. Cost levels, data sources and provision for contractor overhead are as given in Section III, Approach.

It is assumed time for one shift in excess of 8 hours per day or 40 hours per week is charged at double the normal labor rates. Installation costs for land based operations are based on 5-8 hour days per week. A 4-week month is used as the base time period when the work includes marine operations. Work periods, days per week and hours per day, vary depending on the type of marine operation. Marine work periods are given in a footnote below the appropriate table. Labor and equipment costs are not separated for offshore operations.

Rates for the equipment operator and foreman are based on the type of equipment on the job site. The cost of an equipment operator for a bulldozer, for example, is less than for a crane operator. Also, a foreman that oversees an operation with a bulldozer is assumed to receive less than a foreman in charge of work requiring a crane.

The data presented here include the following:

1. Identification of a representative labor force (number and type of workers) and equipment pool (size and number of pieces of equipment) for the activity considered
2. Labor and equipment costs

3. Production rates
4. Installation costs
5. Where appropriate, material costs which are added to installation costs to obtain the total unit cost.

The unit cost background information is grouped according to the cost categories used in the methodology. However, the system of cross referencing between categories is not adopted. Unit cost data are given only for the accounts where the figures are located or calculations are done. For example, to locate the background information on unit costs for pipe trench excavation, the user must go to Cost Category 9 and not Category 4.

The data are tabulated as follows:

1. Labor force and equipment pool - The information pertinent to items (1) and (2) above is given in table(s) for each account.
2. Unit cost data - The unit cost for labor and equipment, equal to the total of labor and equipment costs divided by the production rate, is presented in the second table(s). In addition, where materials are a part of the total unit cost, material costs are given.

The format of the tables is modified for some of the accounts of cost categories 4 and 7 to improve the clarity of presentation.

Data for Cost Category 5 and accounts that have only material costs are not included.

COST CATEGORY 1

Riprap removal, Account 101

Table B-1. LABOR FORCE AND EQUIPMENT POOL, ACCOUNT 101

Labor	Cost, \$/week	Equipment	Cost, \$/week
Equipment Operator	861	Crane (5.44 x 10 kg)[a]	1,100
Oiler	726	Clam Bucket ($2.3m^3$)	167
Laborer	654		
Foreman	934		
TOTAL	3,175	TOTAL	1,267

[a]The capacity of equipment is given within parentheses.

Costs, productivity, and the unit cost for Account 101 are listed below:

1. Labor and Equipment — \$4442/week
2. Productivity — $820m^3$/week
3. Unit Cost — \$5.40/m^3

Concrete slab removal, Account 102

Table B-2. LABOR FORCE AND EQUIPMENT POOL, ACCOUNT 102

Labor	Cost, $/week	Equipment	Cost, $/week
Foreman	934		
Equipment Operator	861	Crane (5.44×10^4 kg)	1,100
Oiler	726	Clam (2.3 m^3)	167
2 Laborers	1,308	Headache ball	60
TOTAL	3,829	TOTAL	1,327

Table B-3. UNIT COST DATA, ACCOUNT 102

	Reinforced		Non-Reinforced	
Description	Thickness, to 30 cm	30-45 cm	Thickness, to 30 cm	30-45 cm
Labor and Equipment, $/week	5,156	5,156	5,156	5,156
Productivity, m^2/week	1,000	750	1,500	1,225
Installation unit cost, $/$m^2$	5.20	6.90	3.40	4.20

Concrete removal, Account 103

Table B-4. LABOR FORCE AND EQUIPMENT POOL, ACCOUNT 103

Labor	Cost, \$/week	Equipment	Cost, \$/week
Foreman	934	Crane (5.44×10^4kg)	1,100
2 Equipment Operators	1,722	Clam Bucket ($2.3m^3$)	167
Driller	825	Track Drill (14 cm)	344
Blaster	800		
4 Laborers	2,616	Air compressor (25.5 m^3/min.)	350
2 Oilers	1,452		
TOTAL	8,349	TOTAL	1,961

Table B-5. UNIT COST DATA, ACCOUNT 103

Description	Reinforced	Non-Reinforced
Labor and Equipment, \$/week	10,310	10,310
Productivity, m^3/week	125	250
Installation Unit Cost, \$/m^3	82.50	41.20
Material, powder, etc., \$/m^3	3	3
TOTAL UNIT COST, \$/m^3	85.50	44.20

Sheet piling removal, Account 104

Table B-6. LABOR FORCE AND EQUIPMENT POOL, ACCOUNT 104

Labor	Cost, $/week	Equipment	Cost, $/week
Foreman	934	Crane (5.44×10^4 kg)	1,100
4 Pile Drivers	3,300	Extractor	190
Equipment Operator	861	Leads	30
2 Oilers	1,452	Compressor (25.5 m^3/min.)	350
TOTAL	6,547	TOTAL	1,670

Costs, productivity, and the unit cost for Account 104 are listed below:

1.	Labor and Equipment	$8,217
2.	Productivity	400 m^2/weeks
3.	Unit cost	$20.50/$m^2$
4.	Salvage credit	$330/kg

Clearing and grubbing, Account 105

Table B-7. LABOR FORCE AND EQUIPMENT POOL, ACCOUNT 105 (LIGHT CLEARING)

Labor	Cost, $/week	Equipment	Cost, $/week
3 Laborers	1,962	Dozer (67,113 W)	586
Equipment Operator	825		
Oiler	726		
Foreman	898		
TOTAL	4,411	TOTAL	586

Table B-8. LABOR FORCE AND EQUIPMENT POOL, ACCOUNT 105 (MEDIUM TO HEAVY CLEARING)

Labor	Cost, $/week	Equipment	Cost, $/week
3 Laborers	1,962	Chipping Machine	200
2 Equipment Operators	1,650	Dozer (67,113 W)	586
1 Oiler	726		
Foreman	898		
TOTAL	5,236	TOTAL	786

Table B-9. UNIT COST DATA, ACCOUNT 105

Description	Vegetation Density		
	Light	Medium	Heavy
Labor and Equipment, $/week	4,997	6,022	6,022
Productivity, m^2/week	28,400	20,400	16,200
Unit Cost, $/$m^2$	.18	.30	.37

Reseeding, Account 106

Table B-10. LABOR FORCE AND EQUIPMENT POOL, ACCOUNT 106

Labor	Cost, $/week	Equipment	Cost, $/week
2 Laborers	1,308	Truck (3.8m^3)	104
Teamster	649	York Rake	250
TOTAL	1,957	TOTAL	354

Costs, productivity, and the unit costs for Account 106 are listed below:

1. Labor and Equipment — $2,311/week
2. Productivity — 13,500 m^2/week
3. Installation Unit Cost — $0.17/$m^2$
4. Material - seed fertilizer & limestone — $0.20/$m^2$
5. TOTAL UNIT COST — $0.37/$m^2$

Hauling, Account 108

Table B-11. LABOR FORCE AND EQUIPMENT POOL, ACCOUNT 108

Labor	Cost, $/week	Equipment	Cost, $/week
2 Drivers	1,298	2 Trucks	550
1 Laborer	654	Dozer (67,113 W)	586[a]
Equipment Operator	825[a]		
Oiler	726[a]		
TOTAL	1,952	TOTAL	550

[a]Additional costs for operation of the disposal area.

Table B-12. UNIT COST DATA, ACCOUNT 108

Description	Earth		Rock[a]	
	Haul	Disposal	Haul	Disposal
Labor and Equipment, $/week	2,502	4,639	2,502	4,639
Productivity, m^3/week	1,850	1,850	1,250	1,250
Unit Cost, $/$m^3$	1.35	2.50	2.00	3.70

[a]For slabs it is assumed the in-place volume increases 25 percent; productivity is assumed to be 4,200 m^2/week for slabs 0-30 cm thick and 2780 m^2/week for slabs 30-45 cm thick.

COST CATEGORY 2

Placement of riprap (land-based),
Account 201.1 (Sheet 1 of 2)

Table B-13. LABOR FORCE AND EQUIPMENT POOL, ACCOUNT 201.1 (RIPRAP, STONE AND FILTER)

Labor	Cost, $/week	Equipment	Cost, $/week
Foreman	934	Hydraulic Backhoe (1.9 m^3)	1,750
Equipment Operator	825		
2 Laborers	1,308		
1 Oiler	726		
TOTAL	3,793	TOTAL	1,750

Table B-14. LABOR FORCE AND EQUIPMENT POOL, ACCOUNT 201.1 (COVER STONE)

Labor	Cost, $/week	Equipment	Cost, $/week
Foreman	934	Crane (5.4×10^4 kg)	1,100
3 Laborers	1,962		
Oiler	726	Leads	30
Equipment Operator	861		
TOTAL	4,483	TOTAL	1,130

Table B-15. UNIT COST DATA, ACCOUNT 201.1

Description	Riprap Stone	Filter	Cover Stone
Labor and Equipment, $/m^3$	5,543	5,543	5,613
Productivity, m^3/week	925	925	300
Installation Unit Cost, $/m^3$	6.00	6.00	18.70
Material, $/m^3$	16.00	9.50	13.00
TOTAL UNIT COST, $/m^3$	22.00	15.50	31.70

Background data for Placement of Riprap (marine), Account 201.2

Table B-16. LABOR FORCE AND EQUIPMENT POOL, ACCOUNT 201.2 (RIPRAP STONE AND FILTER)

Labor	Cost, $/month	Equipment	Cost, $/month
Equipment Operator	4,322	Crane (5.4×10^4kg)	4,400
		Tug Boat[a]	60,000
Oiler	4,066	2 Scows[a]	6,000
2 Laborers	7,325	Clam ($2.3m^3$)	664
Foreman	5,230		
TOTAL	21,443	TOTAL	71,064

[a]Equipment is fully manned 6 days/week, 8 hours/day.

Table B-17. LABOR FORCE AND EQUIPMENT POOL, ACCOUNT 201.2 (COVER STONE)

Labor	Cost, $/month	Equipment	Cost, $/month
Equipment Operator	4,822	Crane (5.4×10^4 kg)	4,400
		Crane Barge[a]	60,000
Foreman	5,230	Flat Top Barge[a]	5,000
Oiler	4,066	Tug Boat[a]	60,000
4 Laborers	14,650		
TOTAL	28,768	TOTAL	129,400

[a]Equipment is fully manned 6 days/week, 8 hours/day.

Table B-18. UNIT COST DATA, ACCOUNT 201.2

Description	Riprap Stone	Filter	Cover Stone
Labor and Equipment $/month	92,507	92,507	158,168
Productivity, m^3/month	12,500	12,500	3,000
Installation Unit Cost, $/$m^3$	7.40	7.40	52.70
Material, $/$m^3$	16.00	9.50	13.00
TOTAL UNIT COST, $/$m^3$	23.40	16.90	65.70

Steel sheet piling (land), Account 202.1

Table B-19. LABOR FORCE AND EQUIPMENT POOL, ACCOUNT 202.1

Labor	Cost, $/week	Equipment	Cost, $/week
Foreman	934	Crane (5.4 x 10^4 kg)	1,100
2 Equipment Operators	1,686	Hammer (Diesel)	300
		Leads & Misc.	150
2 Oilers	1,452		
		Air Compressor ($25\ m^3$/min.)	350
4 Pile Drivers	3,300		
TOTAL	7,372	TOTAL	1,900

Table B-20. UNIT COST DATA, ACCOUNT 202.1

Description	Application	
	Permanent	Temporary
Labor and Equipment, $/week	9,272	9,272
Productivity, m^2/week	500	300
Installation Unit Cost, $/$m^2$	18.55	30.90
Material, $/$m^2$	50.00	10.00
TOTAL UNIT COST, $/$m^2$	68.55	40.90

Steel sheet piling (marine),
Account 202.2

Table B-21. LABOR FORCE AND EQUIPMENT POOL, ACCOUNT 202.2

Labor	Cost, $/month	Equipment	Cost, $/month
4 Pile Drivers	18,480	Crane Barge[a]	60,000
Foreman	5,230	Air Compressor ($25\ m^3/min.$)	1,400
2 Laborers	7,325	Hammer (Diesel)	1,200
Equipment Operator	4,822	Leads & Misc.	600
Oiler	4,066	Tug Boat[a]	60,000
		Flat Top Barge[a]	5,000
TOTAL	39,923	TOTAL	128,200

[a]Equipment is fully manned, 6 days/week, 8 hours/day.

Table B-22. UNIT COST DATA, ACCOUNT 202.2

Description	Permanent	Temporary
Labor and Equipment, $/month	168,123	168,123
Productivity, m^2/month	3,300	2,200
Installation Unit Cost, $/$m^2$	51	76.40
Material, $/$m^2$	50	10
TOTAL UNIT COST, $/$m^2$	101	86.40

Piles (land), Account 203.1

Table B-23. LABOR FORCE AND EQUIPMENT POOL, ACCOUNT 203.1

Labor	Cost, $/week	Equipment	Cost, $/week
Foreman	934	Crane (5.4 x 10^4kg)	1,100
2 Equipment Operators	1,686	Hammer (Diesel)	300
		Leads & Misc.	150
2 Oilers	1,452	Air Compressor (25 m^3/min.)	350
4 Pile Drivers	3,300		
TOTAL	7,372	TOTAL	1,900

Table B-24. UNIT COST DATA, ACCOUNT 203.1

Description	Materials		
	Wood	Concrete	Steel
Labor and Equipment, $/week	9,272	9,272	9,272
Productivity, m/week	1,500	750	1,050
Installation Unit Cost, $/m	6.18	12.36	8.83
Material, $/m	7.50	22.00	30.00
TOTAL UNIT COST, $/m	13.68	34.36	38.83

Piles (marine), Account 203.2

Table B-25. LABOR FORCE AND EQUIPMENT POOL, ACCOUNT 203.2

Labor	Cost, $/month	Equipment	Cost, $/month
4 Pile Drivers	18,480	Crane Barge[a] (5.44 x 10^4kg)	60,000

Table B-25 (continued). LABOR FORCE AND EQUIPMENT POOL, ACCOUNT 203.2

Labor	Cost, $/month	Equipment	Cost, $/month
Foreman	5,230		
2 Laborers	7,325	Air Compressor ($25\ m^3/min.$)	1,400
1 Equipment Operator	4,822	Hammer (Diesel)	1,200
1 Oiler	4,066	Tug Boat[a]	60,000
		Flat Top Barge[a]	5,000
TOTAL	39,923	TOTAL	128,200

[a]Equipment is fully manned 6 days/week, 8 hours/day.

Table B-26. UNIT COST DATA, ACCOUNT 203.2

Description	Materials		
	Wood	Concrete	Steel
Labor and Equipment, $/month	168,123	168,123	168,123
Productivity, m/month	6,500	3,500	4,500
Installation Unit Cost, $/m	25.85	48.00	37.35
Material, $/m	7.50	22.00	30.00
TOTAL COST, $/m	33.35	70.00	67.35

COST CATEGORY 3

Installation, Account 301.2

Table B-27. LABOR FORCE AND EQUIPMENT POOL, ACCOUNT 301.2

Labor	Cost, $/week	Equipment	Cost, $/week
Equipment Operator	861	Crane (5.4×10^4 kg)	1,100
2 Millwrights	882	Leads	30
1 Pipe fitter	1,017		
2 Laborers	1,308		
Foreman	934		
Oiler	726		
TOTAL	5,728	TOTAL	1,130

Table B-28. UNIT COST DATA, ACCOUNT 301.2

Description	PUMP SIZE (m^3/sec) 1.4	2.8	8.49	19.8
Labor and Equipment, $/week	6,858	6,858	6,858	6,858
Productivity, Pumps/week	3	2	1	1
Installation Cost, $/pump	2,286	3,429	6,858	6,858

COST CATEGORY 4

Cast-in-place box conduit, Account 402

Table B-29. UNIT COST DATA, ACCOUNT 402

Description	Unit Cost
Formwork	$\$40.90/m^2$
Concrete Placement	$83.20/m^3$
Steel Reinforcing	$55.40/m^3$
Finish Work	$5.00/m^2$

Steel conduit and fittings, Account 403

Table B-30. UNIT COST DATA, ACCOUNT 403

Description	Cost, $/kg of Steel
Field Fabricated Pipe	1.60[a]
Shop Fabricated Pipe	1.00

[a]Material, labor and equipment for erection and welding are reflected in the unit cost.

Laying pipe on land, Account 406.2

Table B-31. LABOR FORCE AND EQUIPMENT POOL, ACCOUNT 406.2

Labor	Cost, $/day	Equipment	Cost, $/day
Equipment Operator	172	Crane (5.4×10^4 kg)	220
Oiler	145		

Table B-32. UNIT COST DATA, ACCOUNT 406.2

(Unit Cost, \$/meter)[a]

Diam., meters	Precast Concrete	Corrugated Steel Pipe[b]	Fiberglass Pipe	Carbon Steel Pipe
1.52	48	56	44	90
1.83	52	62	51	104
2.44	62	79	64	125
3.05	77	99	79	157
3.66	164	263	108	--
4.27	197	295	128	--
4.88	247	328	154	--
5.49	--	394	180	--
6.10	--	394	--	--

[a]Joint sealing costs and/or connecting costs are included in installation prices.

[b]If the diameter exceeds 3.66 meters, installation costs for multiplate pipe are based on installation costs quoted by manufacturers.

Laying pipe offshore, Account 407.2

Table B-33. LABOR FORCE AND EQUIPMENT POOL, ACCOUNT 407.2

Labor	Cost, \$/month	Equipment	Cost, \$/month
Foreman	5,232	2 Cranes (on land) (5.4×10^4 kg)	8,800
2 Equipment Operators	9,644	Flat Top Barge[a]	5,000
2 Oilers	8,131	Lay Barge[a]	60,000
5 Laborers	18,312	Tugboat[a]	
6 Divers	23,500		60,000
TOTAL	64,819	TOTAL	133,800

[a]Equipment is fully manned 6 days/week, 8 hours/day.

Table B-34. MONTHLY OUTPUT DATA, ACCOUNT 407.2

Diam. meters	Precast Concrete	Corrugated Steel Pipe	Figerglass Pipe	Carbon Steel Pipe
1.52	351	439	640	439
1.83	351	439	640	365
2.44	293	365	550	365
3.05	234	365	550	292
3.66	146	292	457	292
3.96	146	292	457	220
4.88	146	220	365	220
5.49	--	220	365	220
6.10	--	220	--	--

Laying pipe offshore, Account 407.2

Table B-35. UNIT COST DATA, ACCOUNT 407.2

(unit cost, (\$/m))[a]

Diam., meters	Precast Concrete	Corrugated Steel Pipe	Fiberglass Pipe	Carbon Steel Pipe
1.52	566	452	310	452
1.83	566	452	310	544
2.44	678	544	361	544
3.05	849	544	361	680
3.66	1,360	680	435	680
3.96	1,360	680	435	903
4.88	1,360	903	544	903
5.49	--	903	544	903
6.10	--	903	--	--

[a]For water depths greater than 14 meters, it was assumed production was curtailed by 20 percent. The data presented in Table B-36 are for water depths less than 14 m. An adjustment factor is given in Figure 407.2.

Background data Sheet for dewatering, Account 406.5

Table B-36.[a] PUMPING EQUIPMENT AND LABOR COST, ACCOUNT 406.5

Labor	Cost, $/week	Pump Capacity, m^3/min.	Cost $/week
1 Oiler	726	.252	72
		.630	86
		1.260	110
		2.520	175
		5.670	289
		7.875	408

[a]The unit cost for dewatering, per meter of pipe installed, is calculated by dividing the assumed laying rate for each pipe material into the pumping costs (not shown).

COST CATEGORY 6

Installation of nozzles into a tunnel diffuser, Account 602.3

Table B-37. LABOR FORCE AND EQUIPMENT POOL, ACCOUNT 602.3

Labor	Cost, $/month	Equipment	Cost, $/month
Foreman	9,714	Platform	70,000
Master Mechanic	8,580	Derrick	25,000
3 Equipment Operators	26,860	Big Bore Drilling Rig w/Drill Wt. & Boring Unit	75,000
2 Oilers	15,100	2 Compressor Units (25 m^3/min.)	2,800
2 Pile Drivers	17,160	Flat Top Barge[a]	5,000
4 Laborers	27,206	Cherry Picker	1,500
2 Divers	14,560	Crane (5.4 x 10^4kg)	4,400
Tenant	8,580	Concrete Pump (1 wk/month	500
		Tug Boat[a]	60,000
TOTAL	127,760	TOTAL	244,200

[a]Equipment is fully manned 6 days/week, 12 hours/day.

Table B-38. UNIT COST DATA, ACCOUNT 602.3

Description	0-6m Depth	6m to 15m Depth	Over 15m Depth
Labor and Equipment, $/month	371,960	371,960	371,960
Productivity, nozzle/month	3	2	1
Installation Unit Cost, $/nozzle	123,990	185,980	371,960
Rounded Unit Cost $/nozzle	124,000	186,000	372,000

COST CATEGORY 7

Structural concrete,
Accounts 701.1 and 701.2

Table B-39. COST FOR COMPONENTS OF STRUCTURAL CONCRETE, ACCOUNTS 701.1 AND 701.2

Component	Group Number 1	2	3
Placement, $\$/m^3$	63	63	63
Formwork, $\$/m^3$	166	97	15
Finishing, $\$/m^3$	76	20	--
Sub-Total for Concrete Work, $\$/m^3$	305	180	78
Reinforcing, $/kg	1.06	.90	.90

Concrete marine, Account 702

Table B-40. LABOR FORCE AND EQUIPMENT POOL, ACCOUNT 702

Labor	Cost, $/month	Equipment	Cost, $/month
4 Laborers	14,650	Crane Barge w/two cranes	60,000
Foreman	5,230		
		Tug Boat[a]	60,000
		Hopper, truck	500
		Flat Top Barge[a]	5,000
TOTAL	19,880	TOTAL	125,500

[a]Equipment if fully manned 6 days/week, 8 hours/day.

Costs, productivity, and the unit cost for Account 702 are listed below:

1. Labor and Equipment $145,380/month
2. Productivity 4,000 m^3/month
3. Installation Unit Cost $36.30/$m^3$
4. Material $50/$m^3$
5. TOTAL UNIT COST $86.30/$m^3$

Grouting, Account 703

Table B-41. LABOR FORCE AND EQUIPMENT POOL, ACCOUNT 703

Labor	Cost, $/week	Equipment	Cost, $/week
Foreman	898	Air Compressor (25 m^3/min.)	350
Driller	825		
4 Laborers	2,616	Track Drill (14 cm)	344
Equipment Operator	825	Concrete pump	500
Oiler	726		
TOTAL	5,890	TOTAL	1,194

Costs, productivity, and the unit cost for Account 703 are listed below:

1. Labor and Equipment $7,084/week
2. Productivity 40 m^3/week
3. Installation Unit Cost $177.10/$m^3$
4. Material Cost (1:1 cement grout mix) $54.80/$m^3$
5. TOTAL UNIT COST $231.90/$m^3$

COST CATEGORY 8

Placement of fill (land), Account 802.1

Table B-42. LABOR FORCE AND EQUIPMENT POOL, ACCOUNT 802.1 (GROUP 1)

Labor	Cost, $/week	Equipment	Cost, $/week
Equipment Operator	825	Grader	300
Laborer	654		
Foreman	898		
Oiler	726		
TOTAL	3,103	TOTAL	300

Table B-43. LABOR FORCE AND EQUIPMENT POOL, ACCOUNT 802.1 (GROUP 2)

Labor	Cost, $/week	Equipment	Cost, $/week
Foreman	898	4 Hand Compactors	352
Equipment Operator	825	Industrial tractor with loader and backhoe	516
Oiler	726		
4 Laborers	2,616		
TOTAL	5,065	TOTAL	868

Table B-44. LABOR FORCE AND EQUIPMENT POOL, ACCOUNT 802.1 (GROUP 3)

Labor	Cost, $/week	Equipment	Cost, $/week
Foreman	898	Dozer (67,113 W)	586
2 Equipment Operators	1,650	Vibratory Roller[a] (towed)	480
Oiler	726		
TOTAL	3,274	TOTAL	1,066

[a]Add $163 for a self-propelled sheepsfoot roller used for compaction of earth.

Table B-45. UNIT COST DATA, ACCOUNT 802.1

Description	(Group Number) 1	2	3 Earth[a]	3 Gran.[b]
Labor and Equipment, $/week	3,403	5,933	4,503	4,340
Productivity, m^3/week	3,000	1,800	2,500	2,500
UNIT COST, $/$m^3$	1.13	3.30	1.80	1.74

[a]Self propelled sheepsfoot roller.

[b]Vibrating roller (towed).

Placement of fill (marine), Account 802.2

Table B-46. LABOR FORCE AND EQUIPMENT POOL, ACCOUNT 802.2

Labor	Cost, $/month	Equipment	Cost, $/month
Foreman	5,230	Crane (5.4×10^4 kg)	4,400
Equipment Operator	4,822	Tug Boat[a]	60,000
		2 Scows[a]	6,000
Oiler	4,066	Clam ($2.3 m^3$)	668
2 Laborers	7,325	Crane Barge[b]	60,000
TOTAL	21,443	TOTAL	71,068

[a]Equipment is fully manned 6 days/week, 8 hours/day.

[b]Crane barge for filling offshore cofferdam.

Table B-47. UNIT COST DATA, ACCOUNT 802.2

Description	Placement[a]	
	Dumped	Offloaded
Labor and Equipment, $/month	92,511	152,511
Productivity, m^3/month	12,800	13,600
UNIT COST, $/$m^3$[a]	7.20	11.20

[a]Unit cost for backfill with side cast material is assumed to equal 75 percent of excavation costs for a firm material or $4.62/$m^3$.

COST CATEGORY 9

Earth excavation (land), Account 901.1

Table B-48. LABOR FORCE AND EQUIPMENT POOL, ACCOUNT 901.1 (GROUP 1)

Labor	Cost, $/week	Equipment	Cost, $/week
Equipment Operator	825	Hydraulic Backhoe (.76 m^3)	753
Foreman	898		
Laborer	654		
TOTAL	2,377	TOTAL	753

Table B-49. LABOR FORCE AND EQUIPMENT POOL, ACCOUNT 901.1 (GROUP 2)

Labor	Cost, $/week	Equipment	Cost, $/week
Foreman	934	Crane (5.44 x 10^4kg)	1,100
Equipment Operator	861	Clam (2.3 m^3)	167
Oiler	726		
Laborer	654		
TOTAL	3,175	TOTAL	1,267

Table B-50. LABOR FORCE AND EQUIPMENT POOL, ACCOUNT 901.1 (GROUP 3)

Labor	Cost, $/week	Equipment	Cost, $/week
Foreman	934	2 Scrapers ($15.2\ m^3$)	4,414
2 Equipment Operators	1,650	Push Dozer (223,710 W)	990
2 Oilers	1,452		
Laborer	654		
TOTAL	4,690	TOTAL	5,404

Table B-51. UNIT COST DATA, ACCOUNT 901.1

Description	Group Numbers 1	2	3
Labor and Equipment, $/week	3,130	4,442	10,094
Productivity, m^3/week	500	1,000	7,500
UNIT COST, $/$m^3$	6.26	4.44	1.35

Earth excavation (marine), Account 901.2

Table B-52. LABOR FORCE AND EQUIPMENT POOL, ACCOUNT 901.2 (HARD MATERIAL)

Labor	Cost, $/month	Equipment	Cost, $/month
Foreman	15,691	Tug Boat[a]	100,000
		Crew Boat[a]	13,000
		Dipper Dredge[a]	270,000
TOTAL	15,691	TOTAL	383,000

[a]Equipment is fully manned 24 hours/day, 6 days/week.

Table B-53. LABOR FORCE AND EQUIPMENT POOL, ACCOUNT 901.2 (FIRM OR SOFT MATERIAL)

Labor	Cost, $/month	Equipment	Cost, $/month
Foreman	15,691	Clamshell Dredge[a]	180,000
		Tug Boat[a]	100,000
		Crew Boat[a]	13,000
TOTAL	15,691	TOTAL	293,000

[a]Equipment is fully manned 24 hours/day, 6 days/week.

Table B-54. LABOR FORCE AND EQUIPMENT POOL, ACCOUNT 901.2 (DISPOSAL)

Labor	Cost, $/month	Equipment	Cost, $/month
Equipment Operator	14,465	Crane (5.44 x 10^4kg)	4,400
		3 Scows (1500 m^3)[a]	15,000
Oiler	12,197		
Laborer	10,987		
TOTAL	37,649	TOTAL	19,400

[a]Equipment is fully manned 24 hours/day, 6 days/week. The scows are towed to shore using the tug boats listed in tables B-53 and B-54.

Table B-55. UNIT COST DATA, ACCOUNT 901.2 (SIDE CAST)

Description	Hard Material	Firm Material	Soft Material
Labor and Equipment, $/month	398,691	308,691	308,691
Productivity, m^3/month	50,000	50,000	100,000
UNIT COST, $/month	7.97	6.17	3.09

Table B-56. UNIT PRICE DATA, ACCOUNT 902 (ONSHORE DISPOSAL)

Description	Hard Material	Firm Material	Soft Material
Labor and Equipment $/month	455,740	365,740	365,740
Productivity, m^3/month	50,000	50,000	100,000
UNIT COST, $/month	9.11	7.31	3.66

Rock excavation (land), Account 902.1

Table B-57. LABOR FORCE AND EQUIPMENT POOL, ACCOUNT 902.1

Labor	Cost, $/week	Equipment	Cost, $/week
Foreman	934	Crane (5.4 x 10^4kg)	1,100
2 Equipment Operators	1,686	Clam Bucket ($2.3m^3$ rigged)	167
Driller	825	Track Drill (14 cm)	344
Blaster	800	Air compressor (25.5 m^3/min.)	350
4 Laborers	2,616		
2 Oilers	1,452		
TOTAL	8,313	TOTAL	1,961

Table B-58. UNIT COST DATA, ACCOUNT 902.1

Description	Wide Trench > (75 meters)	Narrow Trench < (25 meters)
Labor and Equipment, \$/week	10,274	10,274
Productivity, m^3/week	575	400
Unit Cost, \$/m^3	17.86	25.70
Material (powder), \$/m^3	3.00	3.00
TOTAL UNIT COST, \$/m^3	20.86	28.70

Rock excavation (marine), Account 902.2

Table B-59. LABOR FORCE AND EQUIPMENT POOL, ACCOUNT 902.2

Labor	Cost, \$/month	Equipment	Cost, \$/month
Foreman	15,691	Drill Boat[a]	225,000
Equipment Operator	14,465	Powder Scow[a]	3,000
		Tug Boat[a]	60,000
Oiler	12,197	Dipper Dredge[a]	270,000
Laborer	10,987	Crewboat[a]	13,000
		Crane (5.44×10^4 kg)	4,400
TOTAL	53,340	TOTAL	575,400

[a]Equipment is fully manned 24 hours/day, 6 days/week.

Costs, productivity, and the unit cost for Account 902.2 are listed below:

1.	Labor and Equipment	\$628,740/month
2.	Productivity	\$12,000 m^3/month
3.	Installed Unit Cost	\$52.40/m^3
4.	Material (powder)	\$3.00/m^3
5.	TOTAL UNIT COST	\$55.40/m^3

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16. ABSTRACT

The manual presents a methodology for evaluating the engineering and cost implications of constructing or modifying once-through cooling water discharge systems of thermal electric generating plants. The procedures presented provide persons not skilled in cost engineering with a means of preparing preliminary cost estimates from conceptual or design drawings. The user should, however, have a technical background and be familiar with once-through cooling water discharge systems.

Principal construction elements of discharge system construction and modification are identified and grouped into categories. Materials and installation methods are discussed for each construction element. Data on labor, materials, equipment, and productivity assumed in unit cost development is provided. A step-by-step procedure is given for: (1) estimation of construction costs; and (2) resolution of construction costs into project and annual costs.

An example is shown using the methodology and comparing result with actual construction costs for modifications to an existing discharge system.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
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