SECTION 4
POWERHOUSE AND APPURTENANT FACILITIES SELECTION AND COST GUIDELINES

General

The distinguishing feature between indoor, semi-outdoor, and outdoor hydroelectric plants is basically the type of weather protection afforded the generator and erection area. The main equipment items which may be placed either indoor or outdoors would be the generator, generator breaker, power transformer and crane. Cost data is presented for each turbine configuration.

Indoor Plant. An indoor plant has the erection area and the main equipment items, with the possible exception of the power transformer, within an enclosed building structure. Most small power transformers are air-cooled. Placing the transformer inside a building not only increases the fire hazard but also increases the demands on the cooling system unless an unusually large, well-ventilated area is provided. Consequently, on most contemporary small hydroelectric installation designs, the power transformer is seldom placed indoors, even for an indoor type plant.

With an indoor type plant it is necessary to furnish a bridge-type crane for handling the generator rotor, because portable cranes of the size required are generally not adaptable to indoor plant use. Also, indoor powerhouses can be readily adapted for air-cooling of the generator whereas air-cooling of a generator can be difficult in an outdoor type of plant.

Semi-Outdoor Plant. A semi-outdoor plant has the main generating unit fully enclosed by a building structure. The main lifting equipment, generally a gantry type crane, is located on the powerhouse enclosure roof and the equipment is handled through hatches. Generally the erection area is outdoors. This type of installation is not commonly used and therefore, no costs are presented.

Outdoor Plant. An outdoor plant has a weather-proof housing over the generator with water-cooling coils located within this generator housing. The erection area is outdoors and, accordingly, any major overhaul work requiring dismantling of the generator can only be done during dry weather unless portable shelters are provided. The power transformer is outdoors. Depending on the relative location of the generator with respect to the switchyard, the generator breaker may also be outdoors. If a permanent crane is required, it will probably be of the traveling gantry type. However, portable or mobile cranes can be used to an advantage on outdoor-type small hydroelectric plants.

Location and Setting

The site selected for the hydroelectric installation should be one that maximizes the potential power and minimizes project costs. The maximum power is developed by decreasing the length of water conduit to the turbine while still obtaining the highest vertical fall in the water.

The stream channel conditions downstream of the dam, the accessibility of the site for construction and future maintenance, the foundation conditions and location of the impoundment spillway must all be considered in the site selection. To a lesser degree, the available area for the switchyard enters into the selection of the powerhouse site.

The civil features having the highest cost will be the powerhouse structure, including the excavation, and the waterways (penstock, valves, gates and outlet works). The structure cost is a function of the type of turbine, physical size of the turbine and type of plant (indoor or outdoor). If there is a possibility that more than one type of turbine may have to be considered for economic feasibility, as an example, a Francis turbine or a tube turbine, then estimated project costs may have to be made using each type of turbine. However, a practical approach for a site having a multiple choice of turbines would be to assume one particular type of turbine and, if the site is feasible, the final selection of turbine type can be made during the initial final design period.

The powerhouse civil construction costs may be determined using the cost curves included in this Section. Selection of the turbine best suited to a particular site should be made on the basis of the information presented in Volume V. The curves present the cost as a function of either a principal turbine dimension or the turbine generator nameplate rating. The civil costs are for an outdoor type of plant unless otherwise noted in the following sections describing the turbine and its characteristics. The civil construction costs include the construction of a reinforced concrete powerhouse structure complete with all miscellaneous steel work, and all other civil features required. These cost curve figures, in addition, indicate the area required by the powerhouse structure. This area is used, by following the procedure given in the Excavation Cost Section, in determining the powerhouse excavation costs.

The costs and areas shown in the figures are for single unit powerhouses. For multiple unit installations, these costs should be multiplied by the number of units.

The setting of the actual elevation of the turbine is made based on data given in Volume V. The turbine elevation determines the depth of excavation required for the powerhouse structure.

Structures for Alternate Turbine/Generator Configurations

Tube Turbine. A tube turbine can be efficiently located to become part of the existing outlet works and/or to be adjacent to the existing impoundment. This type is easily adapted to a canal installation. Normally, the generator will be housed within a building. However, it is feasible to have the major erection or overhaul area outdoors. Refer to Volume V for the characteristics of this type turbine. Refer to Figure 4-2 for the civil costs for tube turbine powerhouses. These costs are based on an indoor type plant. Figure 4-1 shows the installation of a tube turbine on a canal drop.

Bulb Turbine and Rim Turbine. The possible configurations for either the bulb or rim turbine are similar to those that are appropriate for the tube turbine. As the turbine and generator for the bulb-type unit are in the water passage, the enclosed structure above the unit is relatively small, unless the erection and maintenance areas are enclosed. Normally, for units less than five MW capacity, these types are not as economical as the tube type, despite the smaller powerhouse. Refer to Volume V for characteristics of this type of turbine. Refer to Figure 4-3 for the civil costs, which are based on an outdoor type plant. Figure 4-4 shows the installation of a bulb turbine.

Fixed and Moveable Blade Propeller Turbine. The propeller turbine can be efficiently located to become part of the existing outlet works and/or to be adjacent to the impoundment. As with tube turbine, propeller turbine installations can be easily adapted to canal drop sites.

A propeller turbine is adaptable to either an indoor or outdoor installation. Refer to Volume V for the characteristics of this type of turbine. Refer to Figure 4-5 for the civil costs, which are based on an outdoor type plant.

Figure 4-1. Tube Turbine Installation, Allis-Chalmers, 420 kW, 16.5 ft. head, 300 cfs, Turnip Power Plant (Courtesy Imperial Irrigation District, Imperial, California).

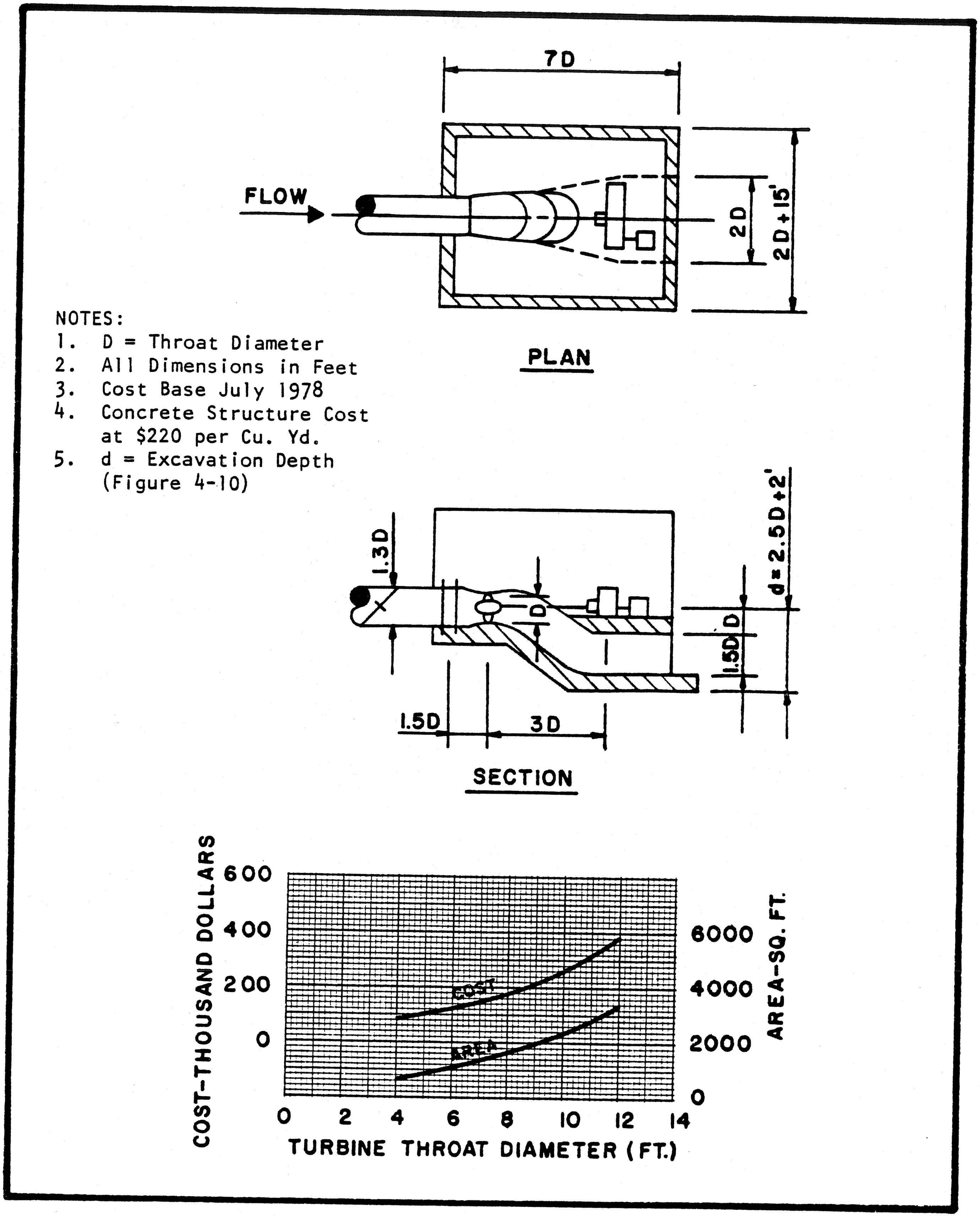


Figure 4-2. Tube Turbine Powerhouse Civil Cost and Area

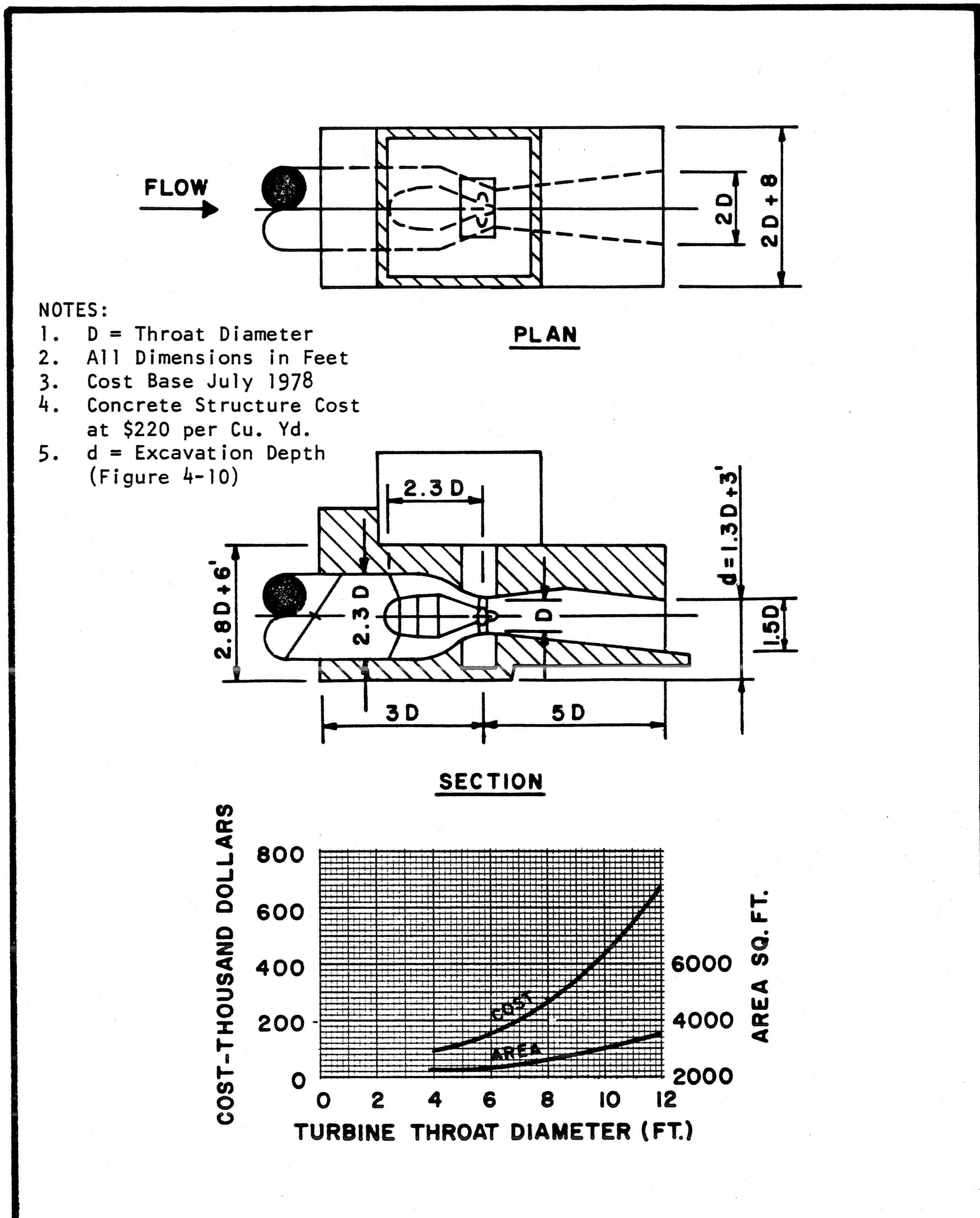


Figure 4-3. Bulb Turbine and Rim Turbine Powerhouse Civil Cost and Area

Francis Turbine. Flow into a Francis turbine is normally conveyed through a penstock. An area must be available downstream from the impoundment to accomodate the larger site requirements of a Francis turbine. This type of turbine can be used either in an indoor or outdoor plant, depending on site conditions. The usual installation is one having a vertical turbine/generator shaft. Refer to Volume V for characteristics of this type of turbine. Refer to Figure 4-6 for the civil costs, which are based on an outdoor type plant.

For very small turbines, those having throat diameters less than 48 inches, there may be a cost advantage in using a Francis type with a horizontal shaft. The arrangement of penstock, discharge and generator can be simpler than those for a vertical shaft unit. Refer to Volume V for the characteristics of this type of machine. Refer to Figure 4-7 for the civil costs which are based on an indoor type plant.

Cross Flow Turbine. The Cross Flow turbine can be used for either a penstock or flume installation. Normally this type of unit is placed indoors. The required erection and maintenance area is minimal. Refer to Volume V for the characteristics of this type of turbine. Refer to Figure 4-8 for the civil costs, which are based on an indoor type plant.

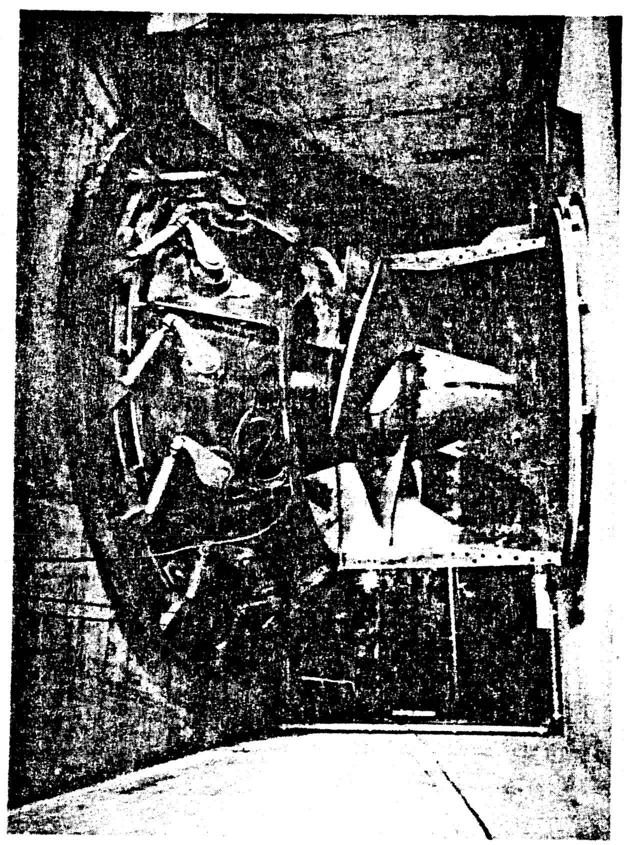


Figure 4-4. Bulb Turbine Kleinmunchen Power Plant, Austria (Courtesy VOEST-ALPINE AG).

Propeller Turbine - Flume Configuration. A propeller turbine may be used in a flume or canal at an existing drop or vertical discontinuity in the flume or canal. This configuration may be used for either an indoor or outdoor type of plant, depending on the site conditions. Penstocks are not used with this type of configuration. Refer to Volume V for characteristics of this configuration. Refer to Figure 4-9 for the civil costs, which are based on an outdoor type plant.

Impulse Turbine. The impulse turbine wheel is limited in its use on low head, small hydroelectric installations. Refer to Volume V. No civil costs are given for impulse turbine installations.

Excavation and Foundation for Powerhouse

Excavation. At small hydroelectric sites, excavation is necessary to correctly set the turbine elevation with respect to the tailwater elevation. The method for determination of the turbine setting elevation is given in Volume V.

The excavation cost may be approximated as a function of the powerhouse area and the maximum depth of excavation. Figure 4-10 shows the relationship of the total cost of excavation to the powerhouse area and the maximum excavation depth. This cost curve for small hydroelectric installations was developed using the following assumptions:

1. Excavation would be done to full depth to a distance of five feet outside the powerhouse perimeter and all side slopes would be on a 45 degree angle.

2. The total volume of excavation would be one-half common excavation and one-half rock excavation.

3. The unit excavation costs assumed were two dollars per cubic yard for common excavation and ten dollars per cubic yard for rock excavation. These can be typical unit costs where the construction haul is normal.

The approximate powerhouse area requirements for each type of turbine are indicated in Figures 4-1, 4-3, and 4-5 to 4-9 inclusive. These figures also show the depth required by the turbine in terms of a turbine parameter. Knowing the turbine size or parameter from Volume V, and the powerhouse area and depth from the above figures, use Figure 4-10 to determine the powerhouse excavation cost.

It is required that the powerhouse structure be placed on sound material in order to develop full resistance to shearing and sliding. Any weathered material and material shattered by blasting must be removed prior to concrete placement. To insure proper foundation conditions, it may be necessary to excavate to a depth greater than that indicated by Figures 4-1, 4-3 and 4-5 to 4-7. Often it is necessary to make a sample boring at a proposed site to determine the below grade foundation conditions. An unusual condition might be cause to select a

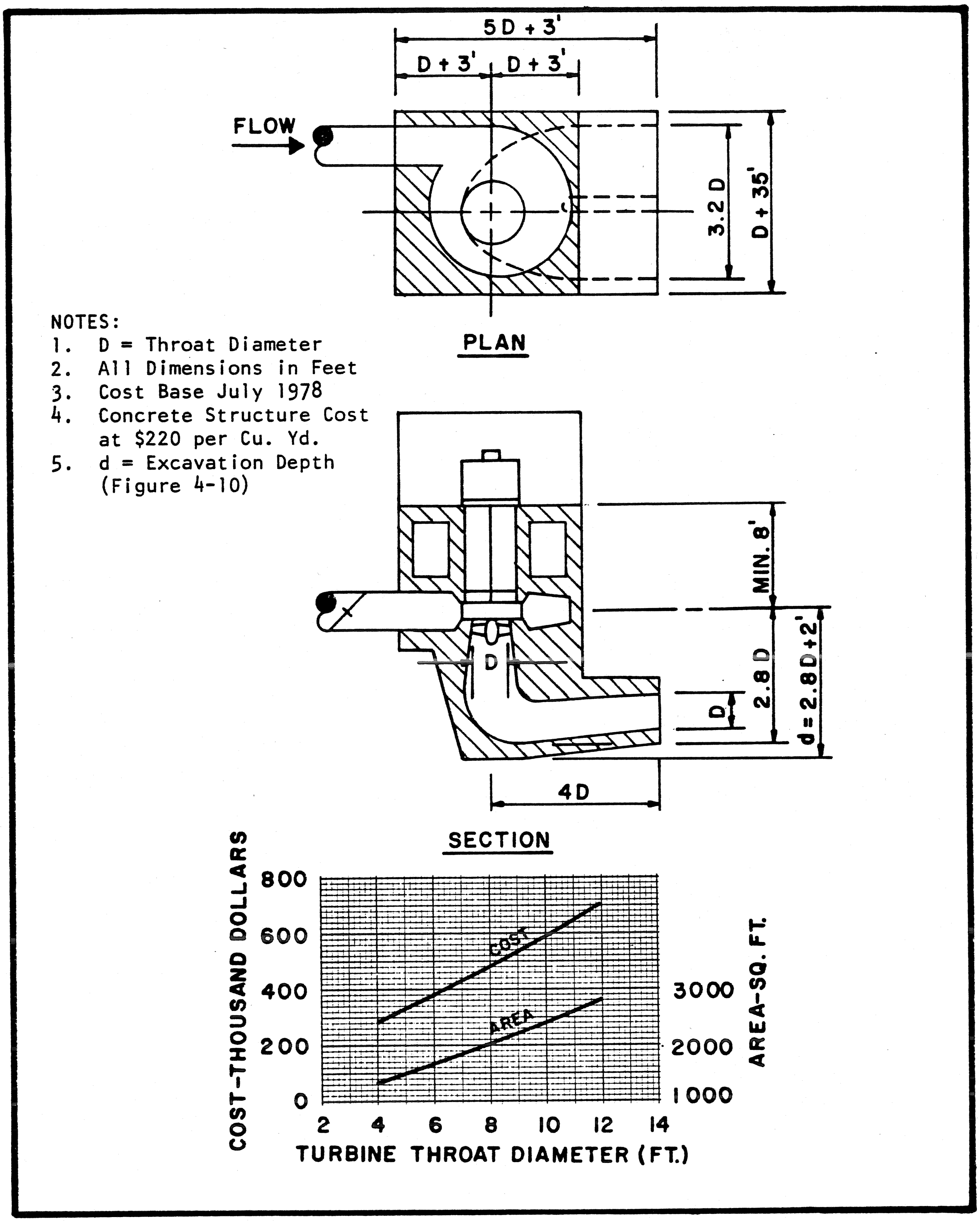


Figure 4-5. Propeller Turbine Powerhouse Civil Cost and Area

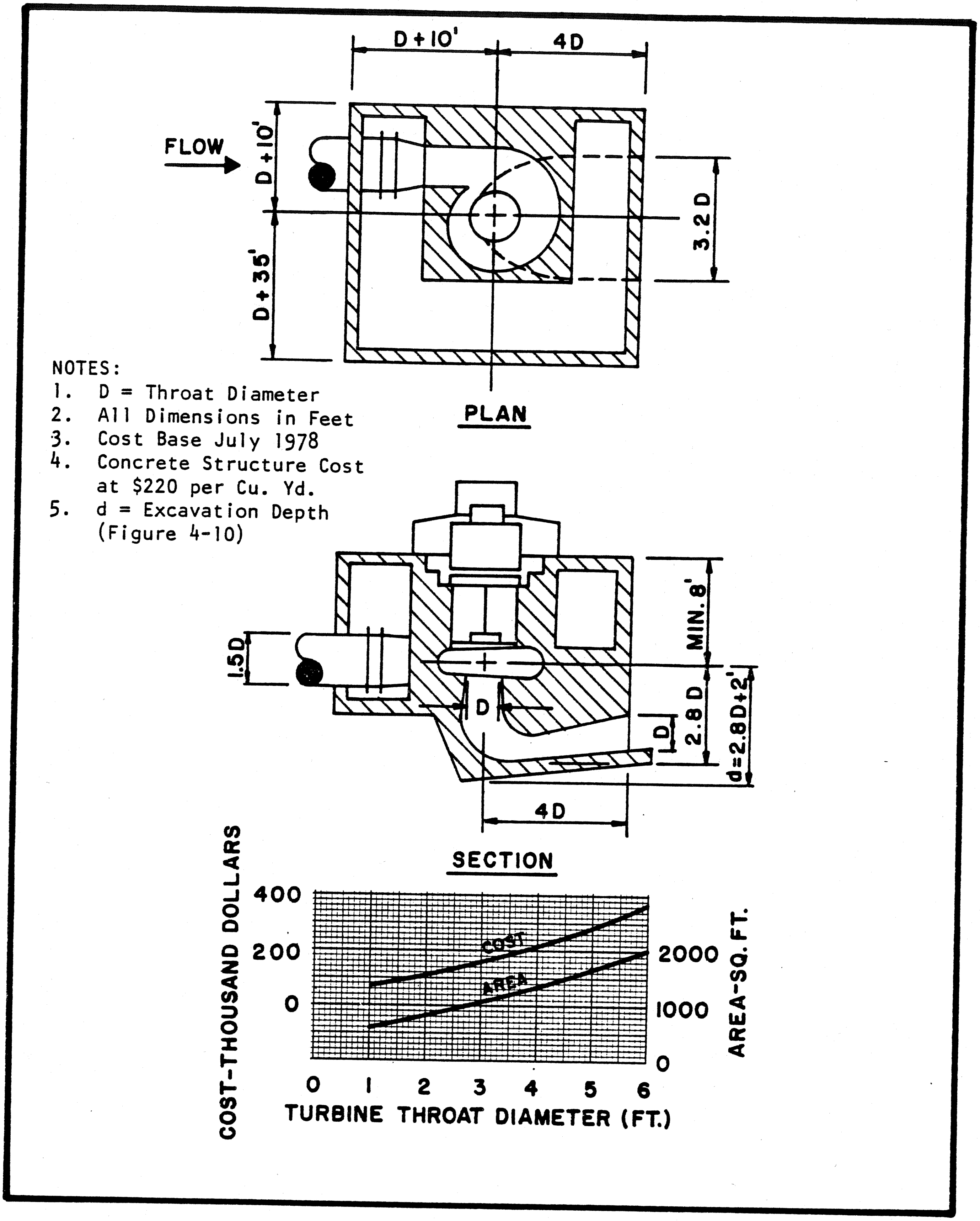


Figure 4-6. Francis Turbine Powerhouse Civil Cost and Area

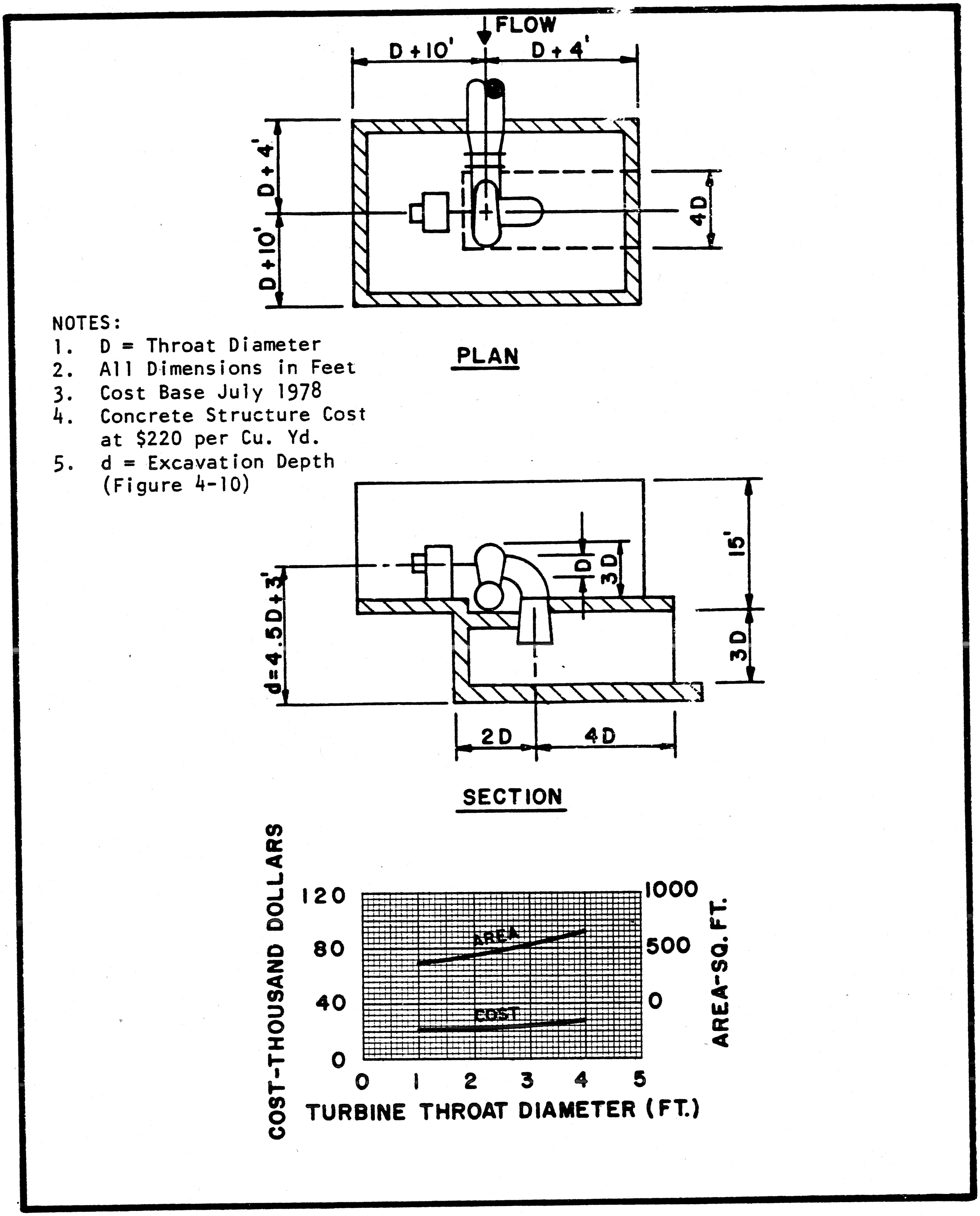


Figure 4-7. Horizontal Francis Turbine Powerhouse Civil Cost and Area

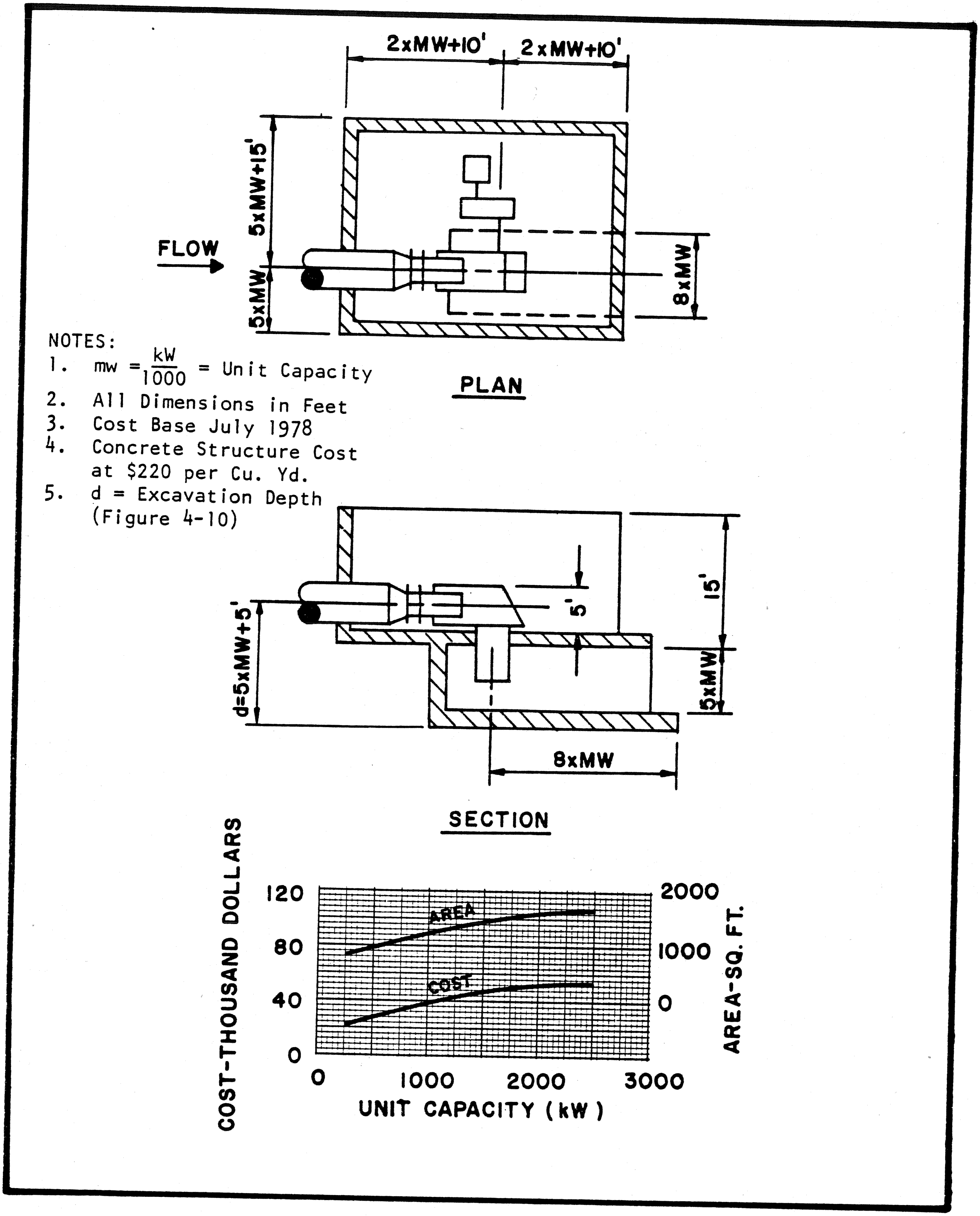


Figure 4-8. Cross Flow Turbine Powerhouse Civil Cost and Area

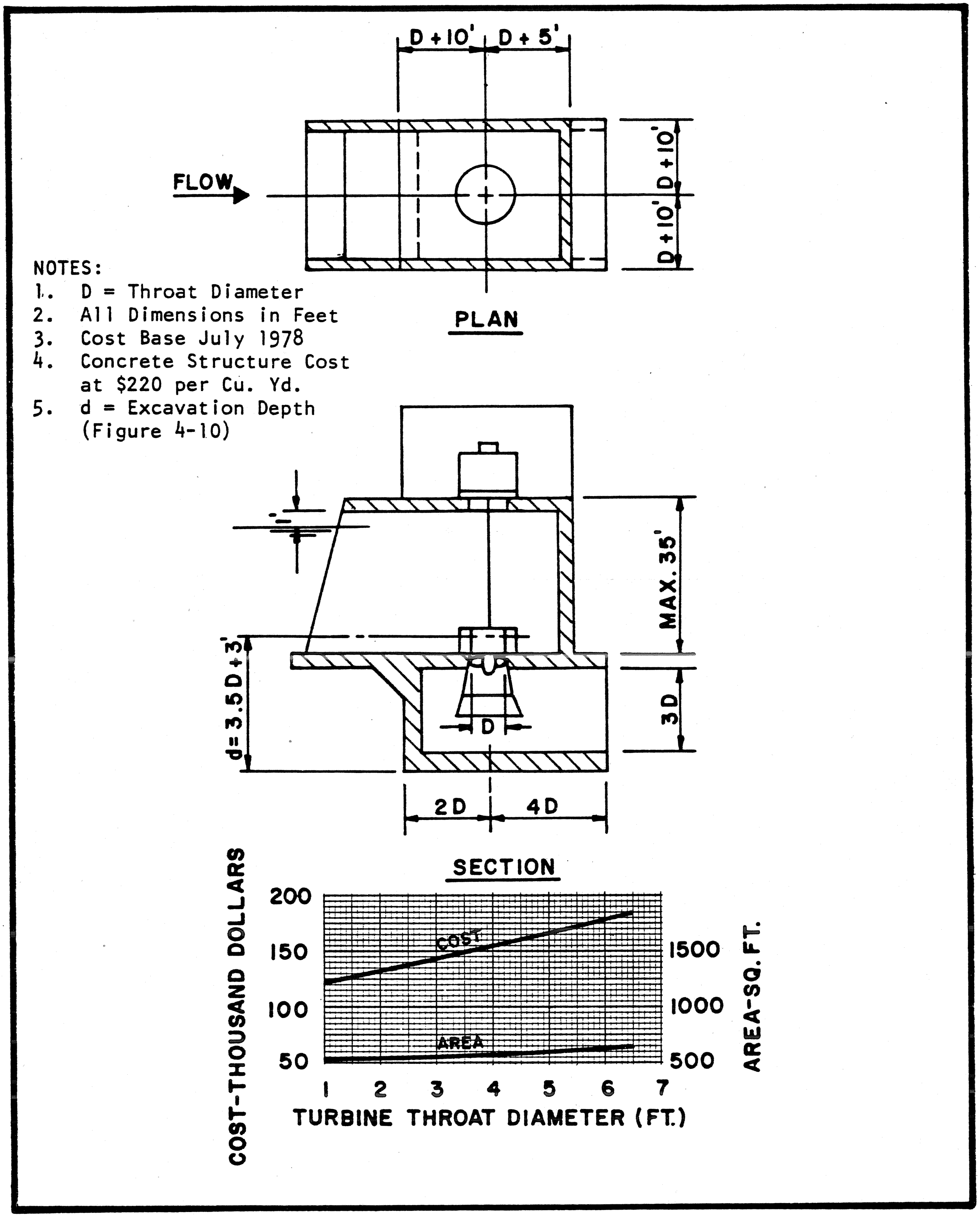
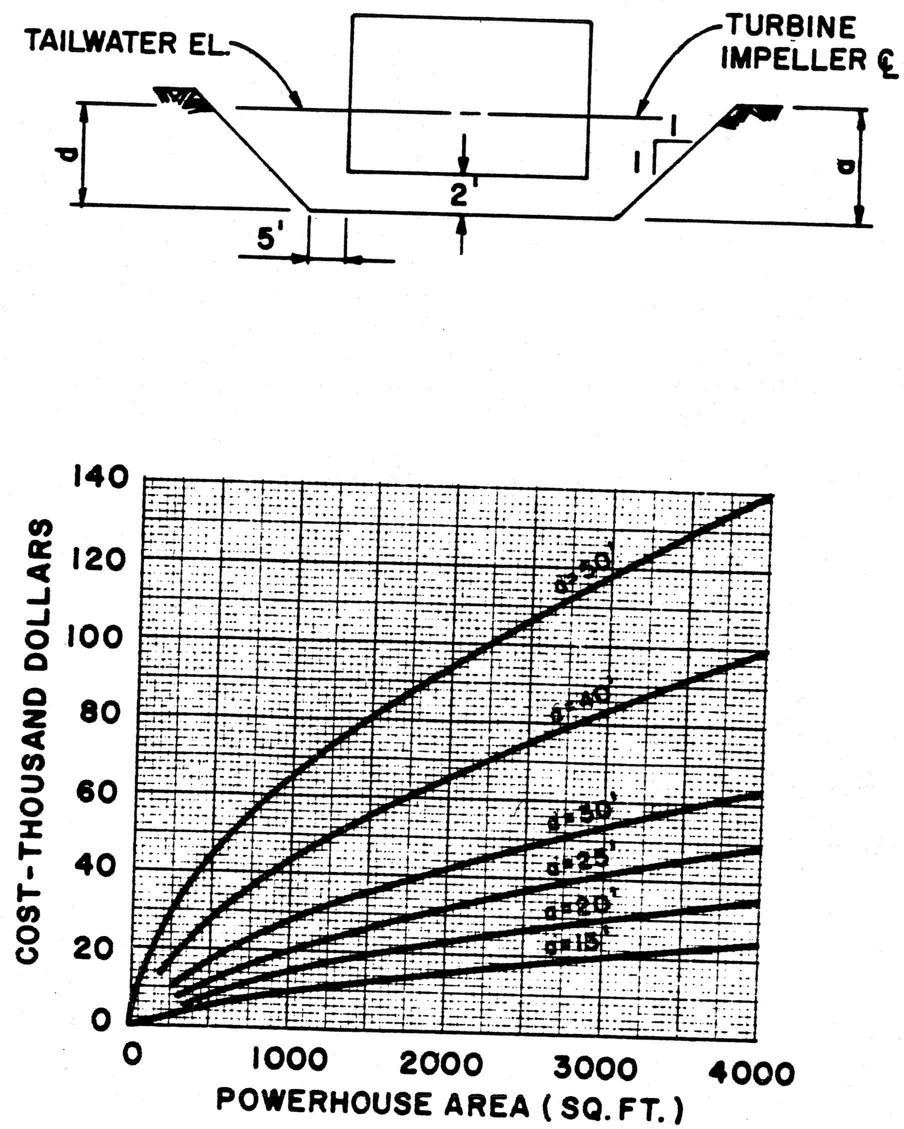


Figure 4-9. Flume Type Installation Powerhouse Civil Cost and Area



NOTES:

1. Cost Base July 1978
2. Excavation Costs: 50% common at $2 per Cu. Yd. and 50% rock at $10 per Cu. Yd.
3. The absolute value of "a", depth of excavation, is generally more than the value of "d" shown in Figures 4-1 to 4-7, as the original ground elevation is usually higher than the design tailwater elevation.

Figure 4-10. Powerhouse Excavation Costs deeper depth curve on Figure 4-10 than that indicated by the turbine parameter. However, it is not necessary for a reconnaissance evaluation to assess this possibility. A feasibility evaluation will have to evaluate the requirements of using a deeper depth curve.

Some sites may require the construction of a cofferdam to protect the construction site. This protection may be either in the form of sheet piling or a dike and rip-rap. Construction dewatering and care and handling of the stream facilities normally will be required for the excavated area. As these costs are unique to the site and soil conditions, the costs for flood protection and dewatering facilities are not included in Figure 4-10. An evaluation should be made on a site specific basis for the costs for these items. Protection of the construction site could total ten percent of the total civil features cost.

Foundation and Stability. The cost of the powerhouse foundation should be considered. It is difficult to accurately estimate the extent and cost of required foundation work without some detailed soil information. On the basis that the reconnaissance assessment will be made without the benefit of a soils report, some allowance should be made in the total estimated cost for possible additional foundation work. This additional work would primarily include cut-off walls and drain systems.

For foundation assessments, there are three basic types of power plant sites, each with different foundation requirements and associated costs. The first type of site has the power plant in, or as a part of, an existing structure. With this type of site, there would be little or no foundation work required, and therefore no additional foundation costs. The second type of site has the power plant as a part of a new water retaining structure or dam. With this installation, there is a head difference across the structure which presents the potential for subsurface flows below the structure, causing uplift and a possible overturning moment. The additional cost for added excavation or structural work can be substantial, and would vary considerably with the specific site conditions. A nominal cost of $100,000 (Table 4-1) may be assumed for this case. The third type of installation has the power plant separate from the dam, with the water conveyed to it through an enclosed conveyance, so that water pressures are not a problem. Although there will be some foundation costs for this type of installation, depending on the soil types and the site topography, the cost would normally be much less than for the previous case. A nominal cost of $20,000 (Table 4-1) may be assumed.

TABLE 4-1
Foundation Costs
(Cost Base July 1978)

Type of Site	Cost
Addition to Existing Structure	$ 0
New Structure Below Impoundment	$ 20,000
New Structure Acting as Impoundment	$100,000

Figure 4-11 shows various methods of stabilizing the powerhouse structure. There must be enough mass in the powerhouse structure and its contents that will prohibit the structure from floating if there is a hydraulic uplift. If sufficient mass is not available then lips are provided at the base of the structure which effectively allows an earth mass to be added to the powerhouse mass weight for overcoming floatation. Adequate drainage around the powerhouse subgrade will decrease the hydraulic uplift. However, provisions may have to be provided to offset the tendency of the tail water to produce a hydraulic uplift. Full penstock pressure against the closed turbine valve or wicket gates will produce a hydraulic thrust which produces an overturning moment on the powerhouse structure. The overturning moment must be resisted by either deadweight mass, anchors, increasing the size of the powerhouse base or any combination of these features. The hydraulic thrust has to be resisted by either a shear key or anchor bolts.

Tailrace Improvements and Costs. The main function of the tailrace is to maintain a minimum tailwater elevation below the power plant and to keep the draft tube submerged. All turbines, with the exception of the impulse turbine, require that the tailwater be maintained above a minimum elevation to minimize the effects of cavitation. It is also important to keep the draft tube submerged, even when there is no flow in the downstream channel or tailrace, in order to improve the turbine start up conditions. This is normally accomplished by excavating the channel immediately downstream of the power plant to maintain a pool of sufficient depth to keep the draft tube covered, and by including a control structure, such as a weir, to maintain the pool at a minimum elevation. Also, a section of new channel might be necessary to connect the new installation with the existing stream channel.

The major portion of the tailrace cost is in the cost for the required excavation, with some additional cost for concrete channel lining, a concrete sill or weir, and riprap. The amount of excavation required depends on the elevation of the turbine spiral case and the length, width and depth of the channel required to return the plant discharge to the existing stream channel. The cost for the tailrace is predominately proportional to the tailrace length, but there is also a fixed cost to cover the excavation immediately downstream of the draft tube. The tailrace cost may be estimated as $15,000 plus $200 per linear foot. (Table 4-2)

Switchyards. Economic studies are usually required to determine the location of the power transformer, circuit breaker and other items of electrical equipment specified in Volume V which may be placed in the

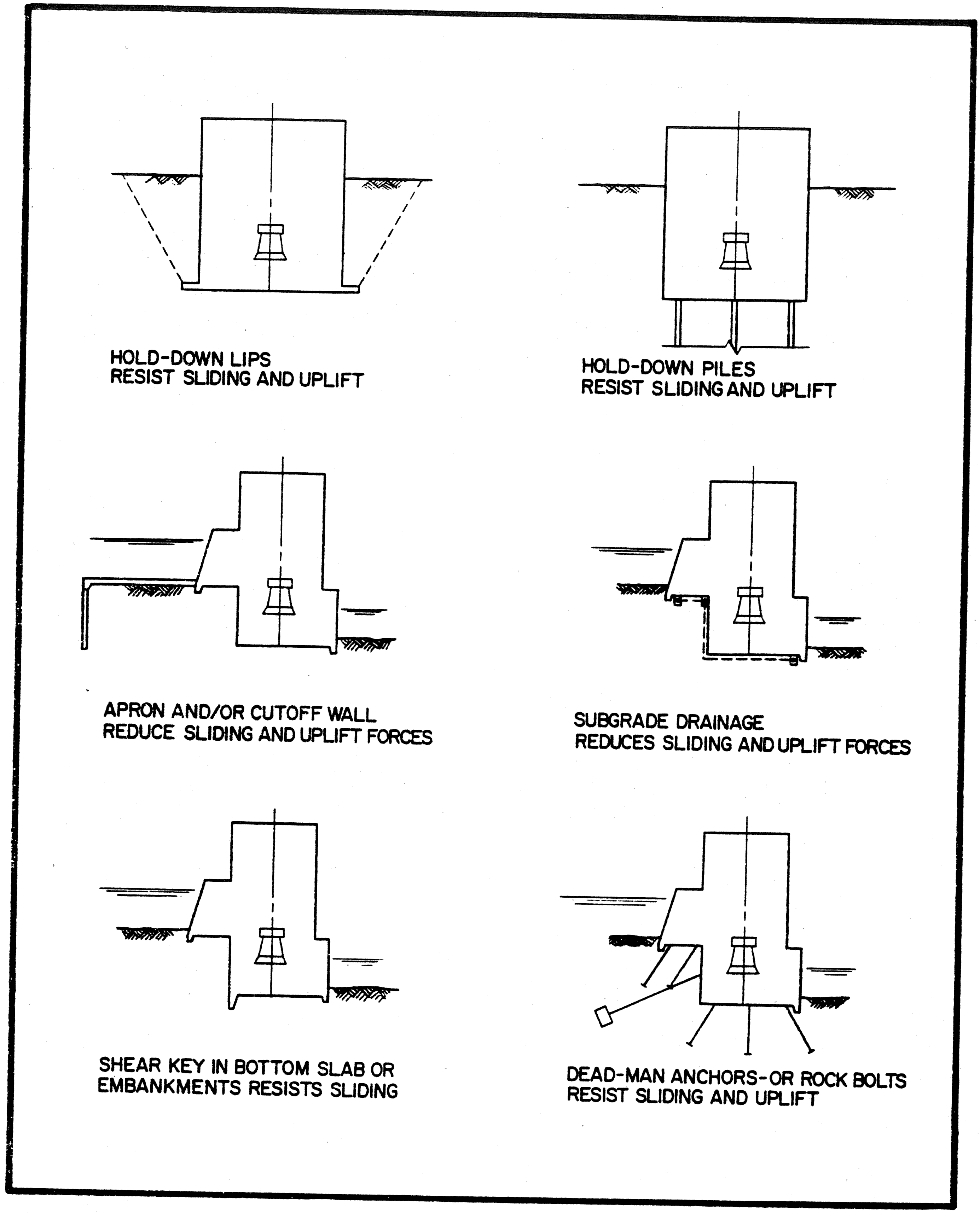


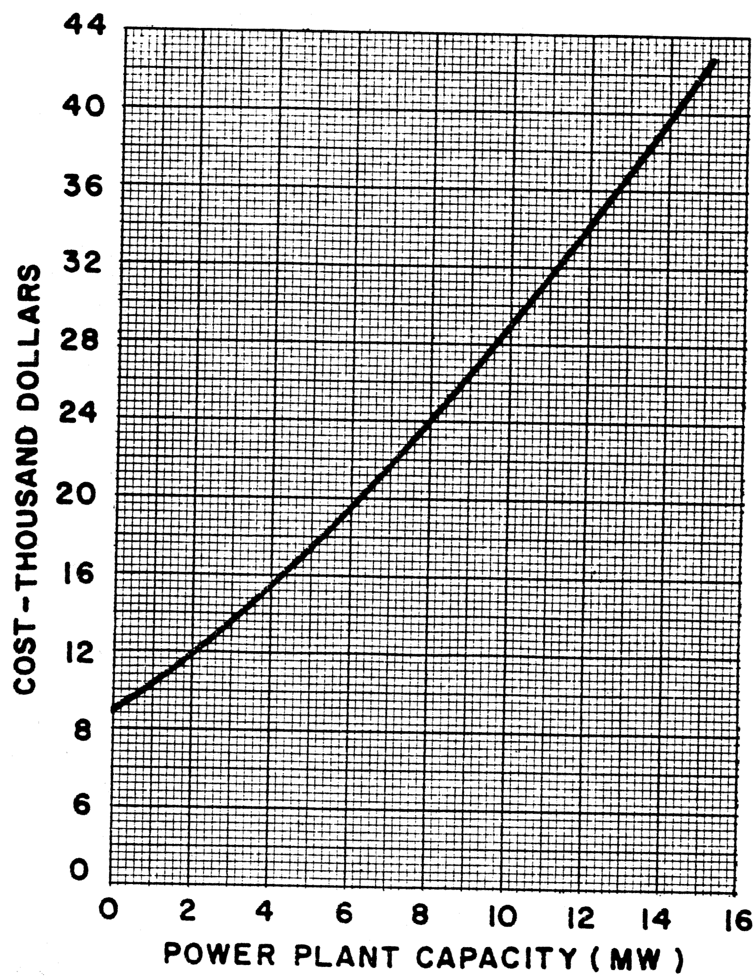
Figure 4-11. Methods for Obtaining Stability Against Sliding, Uplift and Overturning

TABLE 4-2
Tailrace Cost
(Cost base July 1978)

Fixed Cost	$15,000
Proportional Cost	$200 per linear foot

switchyard, and to determine the method of routing the electrical power conductors from the generator to the initial point of the transmission line for connecting to the power grid. Normally, for small hydroelectric installations, the power transformer is located within the switchyard. Accordingly, the switchyard should be placed as close as practical to the generator to minimize the electrical losses and length of the generator conductors. Further, the switchyard site must be above the flood elevation and placed where any possible water spray will not effect the high voltage equipment. Using the generator rating from Volume V, the switchyard civil costs may be determined by the use of Figure 4-12.

Costs shown in Figure 4-12 include a normal amount of grading and fencing costs. If the switchyard site is sufficiently remote from the powerhouse structure, and where more than a normal amount of grading may be required, the extra grading costs can be determined by applying the parameters of Table 2-2 and Figure 2-1. Except for extremely unusual site conditions, any of these increases will not be significant project costs and need not be considered.



NOTE: Cost Base July 1978

Figure 4-12. Switchyard Civil Costs

SECTION 5
SPECIAL NEEDS FOR POWER ADDITIONS TO DAMS

General

It may be found that, to use an existing impoundment for developing hydroelectric power, the project will not be feasible unless existing civil features are utilized with a minimum of modification costs. Unusual design elements can often be used to simplify this utilization. With the inclusion of an unusual design element, a marginal project may become feasible. The resulting design, however, would not be one that would have been followed if the original impoundment had included a hydroelectric plant.

This Section will describe some innovative designs to stimulate thought of possible solutions to the foregoing problem.

Innovative Design Possibilities

The following items describe several unusual designs that may be considered:

1. Concrete gravity section dams are often constructed in narrow canyons with no apparent location for a powerhouse. Normally, an outlet works through the dam exists which can be easily connected to a turbine. To avoid a large excavation in the canyon well, a powerhouse can be constructed at the downstream toe of the dam by extending the spillway lip downstream. The extension of the spillway floor would form the roof on the proposed powerplant. Access to the powerplant could be developed along one side of the spillway.

2. Low concrete gravity dams with spillway gates are often constructed in congested areas with no space on either abutment for a powerhouse. A powerplant could possibly be constructed by the conversion of several of the spillway bays into a powerplant. The modifications would include the extension downstream of the spillway piers and construction of a back wall with a large gate to form a forebay for the powerplant. The turbine and draft tube would be placed in the extended spillway. The generator would be placed on a deck level with the top of the spillway piers. The turbine-generator shaft would be encased in a hollow pier between the apron and generator floor. The gates in the downstream wall of the powerhouse would be opened only to allow the spillway to pass flood flows.

3. An old abandoned powerhouse may now have historical importance. As modern turbine generator units have a smaller overall size than earlier units of the same rating, a new powerplant can often be constructed inside the existing structure. The original facade of the structure can be left intact. Demolition costs will be saved and environmental problems may be avoided.

4. Often, more than one conduit penetrates an existing dam. However, the conduit diameters are sometimes small and limit the generation of power. By joining two of the existing conduits together, a larger turbine/ generator can be installed which would produce enough generation capacity to make the project feasible.

5. The effective head on the turbine can be increased with a decrease in the tail water elevation. This can be accomplished by excavating the tail race to a lower depth and joining the tail race of the powerplant to the existing stream farther downstream from the dam.

6. Use can sometimes be made of inflatable rubber or fabric bags, placed on the spillway crest to raise the reservoir water level which increases the head on the turbine. The increased head increases the power output of the powerplant. The storage capacity of the reservoir is also increased which could result in an increase in energy production for the unit. At a predetermined increase in elevation the inflated bags would automatically deflate and the capacity of the spillway would not be changed. Costs are given in this Section for a similar design which uses bascule gates to increase the effective head on the turbine.

Spillway Modification

Frequently, the feasibility of a particular hydroelectric site can be enhanced by increasing the available head. The most practical method for raising the water surface elevation at an existing dam is to add bascule gates to the spillway crest to allow a higher water surface elevation. The bascule gates offer several advantages over other types for this application. Because the bascule gates rotate about their base and can be controlled from one end, they don't require a superstructure or intermediate supports. This results in a lower cost than other types of gates. With the gate in the lowered position (fully open), the face of the gate is almost flush with the spillway crest, so there is little change in the original discharge rating for the spillway. The bascule gates can be automatically controlled to maintain a predetermined water surface elevation within close tolerances. For gates up to 10 feet high, the cost for the gate and the complete operating mechanism is about $5,000 per foot of length (Table 5-1).

The function of the spillway is to protect a dam from being overtopped during a design flood. In adding bascule gates, or any similar device, to the spillway crest it is mandatory that the device allow the spillway crest to have its normally rated capacity.

TABLE 5-1
Bascule Gate Costs
(Cost Base July 1978)

Cost Item	Cost
Bascule Gate (maximum 10 foot height)	$5,000 per linear foot

Site Planning and Facilities Arrangements

The location and arrangement of the powerhouse and related facilities can pose a problem when adapting a hydroelectric facility to an existing dam. The facilities which are normally included in each site are the access road, parking area, switchyard, maintenance building, and powerhouse. The greatest restrictions on the locating of facilities are caused by natural obstacles such as cliffs, canyons, and the stream channel. In situations where the site is confined, space can be saved by such methods as placing the switchyard on top of the powerhouse or on a platform over the tailrace or by combining the maintenance building and switchyard with the powerhouse. In a very narrow canyon, where access roads would be too expensive or impossible to build, it might be necessary to provide access to the powerhouse with elevators, cranes, or cableways.

SECTION 6

SUMMARY AND FEASIBILITY STUDY COST GUIDELINES

General

This section describes the method of updating the civil features costs, as presented in this volume, from the July 1978 base to the date required for either the reconnaissance or feasibility study. Two indices are presented. The first, which is for escalation, is the United States Bureau of Reclamation index of project component costs. The second is a correction for site location and reflects the variation of construction costs within the continental United States. The first index is given on Figure 6-1 and the second is given on Figure 6-2.

The method for obtaining indirect costs, which include engineering, construction management, and the operation and maintenance and insurance is also provided in this section. The method and the percentage presented is the same as used in Volume V.

Escalation

The United States Bureau of Reclamation publishes on a quarterly basis the cost indices for thirty-four construction items that are common to irrigation and hydro projects. These are published in *Engineering News Record* (1977-1978) and are applicable to the eighteen western states. Four of these indices, which are considered the most significant, are included on Figure 6-1 for the last six years. By future indices, as they are published, the four curves in Figure 6-1 may be extended beyond July 1978 and extrapolated, if necessary, to the date required for the feasibility assessment. The construction item for which an escalated cost is required must be considered to be represented by one of the four classifications in Figure 6-1.

The escalated construction cost is obtained by determining the index number on the extended curve for the required date. The ratio of the July 1978 index to the index for the date used in the feasibility assessment is the multiplier by which the July 1978 base cost is multiplied to obtain the escalated cost.

Regional Cost Correction

A regional cost adjustment is made on the final cost after all the individual costs have been escalated. Figure 6-2 shows the regional cost variation. The cost base used in the preceding Sections represent a regional cost value of one. If the construction site is in a region having a cost value other than one, as shown by the Figure 6-2, then this different regional value is used as a multiplier to correct the total escalated cost for any regional cost difference.

Manpower Allocation for Studies

Personnel required to perform the analysis described must have civil engineering experience in hydroelectric plant design and project engineering. The studies should be directed by a Senior Civil Engineer having broad experience in this field. The majority of the study will be prepared by a Civil Engineer with less experience. The remainder of the work, including layout drawings and quantity takeoffs, will be done by a Designer. A total of ten man-days of effort should be allocated to prepare the feasibility study and cost estimate. A reconnaissance study and cost estimate will require about five man-days of effort. The allocation of time will be approximately ten percent for the Senior Civil Engineer, sixty percent for the Civil Engineer and thirty percent for the Designer. The civil engineering cost of this study is two percent of the total civil features cost.

Contingency

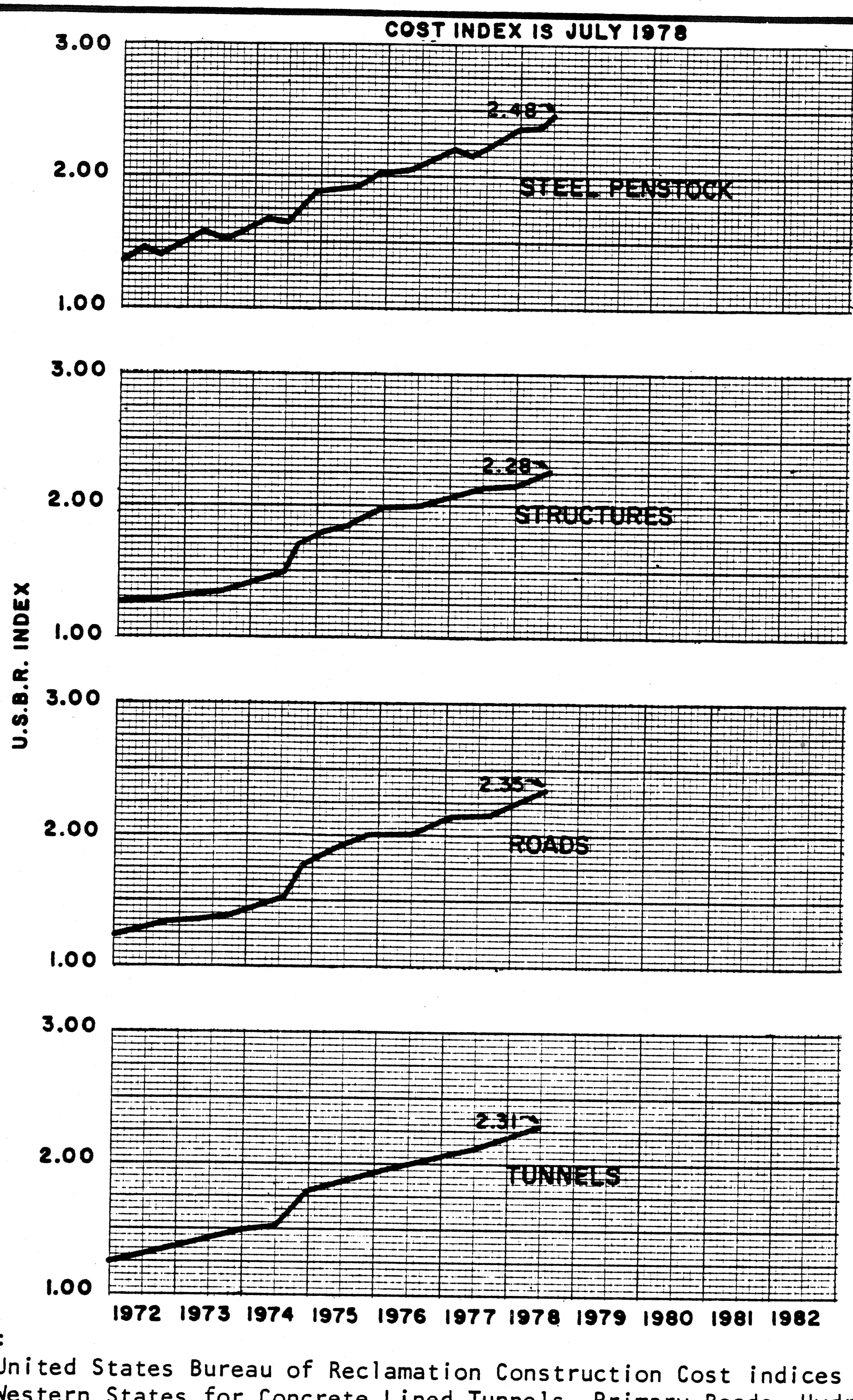
A contingency allowance is added to the escalated and regionally corrected construction costs to cover unknown and omitted items which would normally be included in a more detailed cost estimate. Contingencies also include an allowance for possible cost increases due to unforeseen conditions. Contingencies are normally estimated as 20 percent of the construction cost.

Engineering, Construction Management and Other Costs

Once the escalated and regionally corrected construction cost has been determined, it is necessary to estimate the engineering, construction management and administration costs, sometimes referred to as development or indirect costs. These costs include expenditures for feasibility study, license and permit applications, preliminary and final design, construction management, and administration. A multiplier of 20 percent should be applied to the total final construction cost, including contingencies, to estimate these development costs.

For a more detailed breakdown of these development costs the following percentages, applied to the final construction costs plus contingencies, may be used:

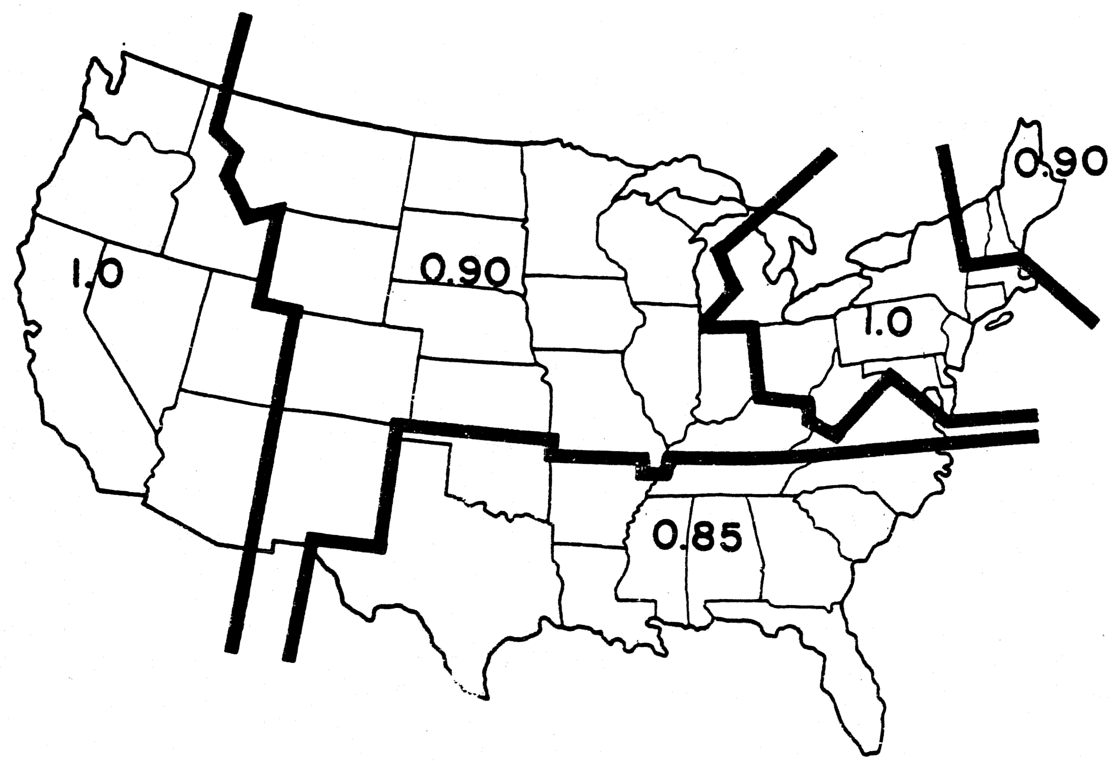
Feasibility Study	2%
License and Permit Applications	2%
Preliminary Design	3%
Final Design	6.5%
Construction Management	5.5%
Administration	1%



NOTE:

1. United States Bureau of Reclamation Construction Cost indices for the 18 Western States for Concrete Lined Tunnels, Primary Roads, Hydroelectric Power Plant Structures (Rein. Conc. Structures and Improv.), and Steel Penstocks.

Figure 6-1. Historical Cost Indices



NOTE: San Francisco, California Base = 1.0, July 1978

Figure 6-2. Construction Cost Variation in the United States

The above percentage are for the civil feature costs only, hence the multipliers should be applied only to the costs of this volume. Not included in the above development costs are interest during construction, legal fees and financing fees. These omitted costs will be covered in Volume II which describes economic and financial considerations.

Operation and Maintenance Costs

General. Operation and maintenance costs for small hydroelectric plants are difficult to forecast accurately. The costs are directly related to the site and the owner's capability to perform the operation and maintenance function. The amounts which are suggested to be used in this report are based on those published by the U.S. Bureau of Reclamation and are updated to reflect recent experience.

Operation and maintenance costs as described herein, include the items listed below.

Insurance. The government is basically a self-insurer, however, for a commercial installation, coverage is required for fire and storm damage, vandalism, property damage and public liability.

Routine Maintenance and Operation. An amount must be budgeted to cover the costs of manpower, wages, services, equipment and parts utilized in the normal operation and maintenance of the hydroelectric plant.

General Expenses. The final portion of operation and maintenance costs are made up of those expenditures for administration fees and other miscellaneous costs required during project operation.

Operation and Maintenance Cost. The cost of operation and maintenance expenses can be estimated by multiplying the investment cost for the powerplant, including contingencies and development costs, by 1.2 percent. The resulting amount will be the estimated cost for operation and maintenance of the hydroelectric plant for the first year of operation. The operation and maintenance costs will increase with time, corresponding to inflationary trends. The current annual increase for operation and maintenance costs is taken to be 6-1/2 percent.

There are two final comments to be observed in determining the operation and maintenance costs of hydroelectric plant facilities. First, the total annual costs for operation and maintenance (from Volume V and VI) should never be estimated below a certain minimum amount, approximately $20,000 in 1978 dollars. Second, the multiplier given previously, 1.2 percent, should be used only if the owner can integrate the operation of the small hydropower facility with other related operations. If the operating entity will operate and maintain only the small hydroelectric facility under consideration, a multiplier of 2 to 4 percent should be used to determine annual O&M costs.

Cost Summary Sheet

Completing the Cost Summary Sheet, shown as Exhibit I, provides a method for determining the civil cost to be used in the feasibility assessment estimate. The account numbers used in Exhibit I are those designated by the Federal Energy Regulatory Commission for hydroelectric development. Although provision has been made for a civil costs contingency item, it is normal to include this with the other contingencies as an overall project cost. Refer to Volume II.

REFERENCES

Bier, P.J., *Welded Steel Penstocks design and construction, Engineering Monographs, No. 3,* United States Department of Interior, Bureau of Reclamation, 1966.

Davis, Calvin Victor, and Sorensen, Kenneth E., *Handbook of Applied Hydraulics,* Third Edition, 1969, McGraw-Hill Book Company, Section 22, Pg. 22-66 & 22-67, Hydraulic Design Factors; Section 27, Water Hammer Pg. 27-1; Section 28, Surge Tanks Pg. 28-1.

Engineering News-Record, McGraw-Hill's Construction Weekly, McGraw-Hill Inc., McGraw-Hill Building, 1221 Avenue of the Americas, New York, N.Y. 10020; December 22, 1977 Page 101; March 23, 1978 page 97; June 22, 1978 page 109; September 21, 1978 page 121.

EXHIBIT I
COST SUMMARY SHEET

PROJECT ____________________ PLANT CAPACITY __________ MW

JOB NO. ____________________ AVG. ANNUAL ENERGY __________ MWh

DATE __________ BY __________

FERC ACCT. NO.	DESCRIPTION	COST*	ESCALATION FACTOR	ESCALATED COST	TOTAL	
331	STRUCTURES & IMPROVEMENTS					
	SITE					
.11	DRAINAGE SYSTEM					
.12	EROSION CONTROL					
.13	FINAL GRADING					
.14	ACCESS ROAD					
.15	PARKING & MISC. SITE FEATURES					
.16	ENVIRONMENTAL CONSTRUCTION CONTROLS					
.17						
.18						
	POWERHOUSE					
.21	STRUCTURAL					
.22	EXCAVATION					
.23	FOUNDATION					
.24	SWITCHYARD					
.25						
.26						
	TOTAL, ACCOUNT 331					
	* COST BASE JULY 1978					

FERC Acct. No.	Description	Cost*	Escalation Factor	Escalated Cost	Total	
332	RESERVOIRS, DAMS & WATERWAYS					
.01	Penstock					
.02	Valves					
.03	Bifurcation & Slide Gates					
.04	Tailrace					
.05						
.06						
	Total, Account 332					
	TOTAL CIVIL COSTS					
	Contingencies					
	Regional Correction Factor					
	CORRECTED CIVIL COSTS					
	Engineering, Construction Management and Other Costs					
	GRAND TOTAL					
	* Cost Base, July 1978					

GLOSSARY

Abbreviations

alternating current	ac	head in feet	H
barrel (42 gallons)	bbl	Hertz	Hz
benefit-cost ratio	B/C	horsepower	hp
British thermal units	Btu	kilovolt	kV
cents	¢	kilovolt-ampere	kVA
cubic feet	ft^3	kilowatt	kW
cubic feet per second	cfs	kilowatt-hours	kWh
cubic yard	cu yd	megavolt ampere	MVA
direct current	dc	megawatt	MW
dollars	$	megawatt-hours	MWh
efficiency in percent	E	percent	%
feet	ft	pound	lb
flow in cfs	Q	pounds per square inch	psi
gigawatt	GW	revolutions per minute	r/min
gravitational constant	g	square yards	sq yd

ALTERNATING CURRENT (ac)—an electric current that reverses its direction of flow periodically as contrasted to direct current.

ANADROMOUS FISH—fish, such as salmon, which ascend rivers from the sea at certain seasons to spawn.

AVERAGE LOAD—the hypothetical constant load over a specified time period that would produce the same energy as the actual load would produce for the same period.

BENEFIT-COST RATIO (B/C)—the ratio of the present value of the benefit stream to the present value of the project cost stream computed for comparable price level assumptions.

BENEFITS (ECONOMIC)—the increase in economic value produced by the hydropower addition project, typically represented as a time stream of value produced by the generation of hydroelectric power. In small hydro projects this is often limited for analysis purposes to the stream of costs that would be representative of the least costly alternative source of equivalent power.

BRITISH THERMAL UNIT (Btu)—the quantity of heat energy required to raise the temperature of 1 pound of water 1 degree Fahrenheit, at sea level.

BUS—an electrical conductor which serves as a common connection for two or more electrical circuits. A bus may be in the form of rigid bars, either circular or rectangular in cross section, or in form of stranded-conductor overhead cables held under tension.

BUSBAR—an electrical conductor in the form of rigid bars, located in switchyard or power plants, serving as a common connection for two or more electrical circuits.

CAPACITOR—a dielectric device which momentarily absorbs and stores electrical energy.

CAPACITY—the maximum power output or load for which a turbine-generator, station, or system is rated.

CAPACITY VALUE—that part of the market value of electric power which is assigned to dependable capacity.

CAPITAL RECOVERY FACTOR—a mathematics of finance value used to convert a lump sum amount to an equivalent uniform annual stream of values.

CIRCUIT BREAKER—a switch that automatically opens an electric circuit carrying power when an abnormal condition occurs.

COSTS (ECONOMIC)—the stream of value required to produce the hydro electric power. In small hydro projects this is often limited to the management and construction cost required to develop the power plant, and the administration, operations, maintenance and replacement costs required to continue the power plant in service.

COST OF SERVICE—cost of producing electric energy at the point of ownership transfer.

CRITICAL STREAMFLOW—the amount of streamflow available for hydroelectric power generation during the most adverse streamflow period.

CRITICAL DRAWDOWN PERIOD—the time period between maximum pool drawdown and the previous occurrence of full pool.

DEMAND—see LOAD.

DEBT SERVICE—principle and interest payments on the debt used to finance the project.

DEPENDABLE CAPACITY—the load carrying ability of a hydropower plant under adverse hydrologic conditions for the time interval and period specified of a particular system load.

DIRECT CURRENT (dc)—electricity that flows continuously in one direction as contrasted with alternating current.

ENERGY—the capacity for performing work. The electrical energy term generally used is kilowatt-hours and represents power (kilowatts) operating for some time period (hours).

ENERGY VALUE—that part of the market value of electric power which is assigned to energy generated.

ELECTRIC RATE SCHEDULE—a statement of the terms and conditions governing the sale of electric service to a particular class of customers.

FEASIBILITY STUDY—an investigation performed to formulate a hydropower project and definitively assess its desirability for implementation.

FEDERAL ENERGY REGULATORY COMMISSION (FERC)—an agency in the Department of Energy which licenses non-Federal hydropower projects and regulates interstate transfer of electric energy. Formerly the Federal Power Commission (FPC).

FIRM ENERGY—the energy generation ability of a hydropower plant under adverse hydrologic conditions for the time interval and period specified of a particular system load.

FORCE MAJEURE—an event or effect that cannot be reasonably anticipated or controlled.

FORCED OUTAGE—the shutting down of a generating unit for emergency reasons.

FORCED OUTAGE RATE—the percent of scheduled generating time a unit is unable to generate because of forced outages due to mechanical, electrical or another failure.

FOSSIL FUELS—refers to coal, oil, and natural gas.

GENERATOR—a machine which converts mechanical energy into electric energy.

GIGAWATT (GW)—one million kilowatts.

GRAVITATIONAL CONSTANT (g)—the rate of acceleration of gravity, approximately 32.2 feet per second per second.

HEAD, GROSS (H)—the difference in elevation between the headwater surface above and the tailwater surface below a hydroelectric power plant, under specified conditions.

HERTZ (Hz)—cycles per second.

HYDROELECTRIC PLANT or HYDROPOWER PLANT—an electric power plant in which the turbine-generators are driven by falling water.

INSTALLED CAPACITY—the total of the capacities shown on the nameplates of the generating units in a hydropower plant.

INTERCONNECTION—a transmission line joining two or more power systems through which power produced by one can be used by the other.

KILOVOLT (kV)—one thousand volts.

KILOWATT (kW)—one thousand watts.

KILOWATT-HOUR (kWh)—the amount of electrical energy involved with a one kilowatt demand over a period of one hour. It is equivalent to 3,413 Btu of heat energy.

LOAD—the amount of power needed to be delivered at a given point on an electric system.

LOAD CURVE—a curve showing power (kilowatts) supplied, plotted against time of occurrence, and illustrating the varying magnitude of the load during the period covered.

LOAD FACTOR—the ratio of the average load during a designated period to the peak or maximum load occurring in that period.

LOW HEAD HYDROPOWER—hydropower that operates with a head of 20 meters (66 feet) or less.

(AT) MARKET VALUE—the value of power at the load center as measured by the cost of producing and delivering equivalent alternative power to the market.

MEGAWATT (MW)—one thousand kilowatts.

MEGAWATT-HOURS (MWh)—one thousand kilowatt-hours.

MINIMUM REVENUE REQUIREMENT—funds required to pay all costs incurred by a project.

MULTIPURPOSE RIVER BASIN PROGRAM—programs for the development of rivers with dams and related structures which serve more than one purpose, such as - hydroelectric power, irrigation, water supply, water quality control, and fish and wildlife enhancement.

NUCLEAR ENERGY—energy produced largely in the form of heat during nuclear reactions, which, with conventional generating equipment can be transfered into electric energy.

NUCLEAR POWER—power released from the heat of nuclear reactions, which is converted to electric power by a turbine-generator unit.

OUTAGE—the period in which a generating unit, transmission line, or other facility, is out of service.

(IN) PARALLEL—several units whose AC frequencies are exactly equal, operating in synchronism as part of the same electric system.

PEAKING CAPACITY—that part of a system's capacity which is operated during the hours of highest power demand.

PEAK LOAD—the maximum load in a stated period of time.

PLANT FACTOR—ratio of the average load to the installed capacity of the plant, expressed as an annual percentage.

PONDAGE—the amount of water stored behind a hydroelectric dam of relatively small storage capacity used for daily or weekly regulation of the flow of a river.

POWER (ELECTRIC)—the rate of generation or use of electric energy, usually measured in kilowatts.

POWER FACTOR—the percentage ratio of the amount of power, measured in kilowatts, used by a consuming electric facility to the apparent power measured in kilovolt-amperes.

POWER POOL—two or more electric systems which are interconnected and coordinated to a greater or lesser degree to supply, in the most economical manner, electric power for their combined loads.

PREFERENCE CUSTOMERS—publicly-owned systems and nonprofit cooperatives which by law have preference over investor-owned systems for the purchase of power from Federal projects.

PROJECT SPONSOR—the entity controlling the small hydro site and promoting construction of the facility.

PUMPED STORAGE—an arrangement whereby electric power is generated during peak load periods by using water previously pumped into a storage reservoir during off-peak periods.

RATE OF RETURN ON INVESTMENT—the interest rate at which the present worth of annual benefits equals the present worth of annual costs.

RECONNAISSANCE STUDY—a preliminary feasibility study designed to ascertain whether a feasibility study is warranted.

SECONDARY ENERGY—all hydroelectric energy other than FIRM ENERGY.

SERVICE OUTAGE—the shut-down of a generating unit, transmission line or other facility for inspection, maintenance, or repair.

SMALL HYDROPOWER—hydropower installations that are 15,000 KW (15 MW) or less in capacity.

SPINNING RESERVE—generating units operating at no load or at partial load with excess capacity readily available to support additional load.

STEAM-ELECTRIC PLANT—a plant in which the prime movers (turbines) connected to the generators are driven by steam.

SURPLUS POWER—generating capacity which is not needed on the system at the time it is available.

SYSTEM, ELECTRIC—the physically connected generation, transmission, distribution, and other facilities operated as an integral unit under one control, management or operating supervision.

THERMAL PLANT—a generating plant which uses heat to produce electricity. Such plants may burn coal, gas, oil, or use nuclear energy to produce thermal energy.

THERMAL POLLUTION—rise in temperature of water such as that resulting from heat released by a thermal plant to the cooling water when the effects on other uses of the water are detrimental.

TRANSFORMER—an electromagnetic device for changing the voltage of alternating current electricity.

TRANSMISSION—the act or process of transporting electric energy in bulk.

TURBINE—the part of a generating unit which is spun by the force of water or steam to drive an electric generator. The turbine usually consists of a series of curved vanes or blades on a central spindle.

TURBINE-GENERATOR—a rotary-type unit consisting of a turbine and an electric generator. (See TURBINE & GENERATOR)

VERTICALLY INTEGRATED SYSTEM—refers to power systems which combine generation, transmission, and distribution functions.

VOLTAGE OF A CIRCUIT—the electric potential difference between conductors or conductors to ground, usually expressed in volts or kilovolts.

WATT—the rate of energy transfer equivalent to one ampere under a pressure of one volt at unity power factor.

WHEELING—transportation of electricity by a utility over its lines for another utility; also includes the receipt from and delivery to another system of like amounts but not necessarily the same energy.