CHAPTER 8

ESTIMATING POWERHOUSE COSTS

8-1. Introduction. Cost estimates for hydroelectric projects are generally similar to those for other types of projects. However, there are some special considerations, particularly with respect to sources of data. This chapter describes these considerations in the context of the standard cost estimating process. Specific topics addressed include types of estimates, construction costs, investment costs, O&M and replacement costs, transmission costs, and the indexing of costs to current price levels. A sample cost calculation is also included. The methodology and examples cited in this chapter represent a suggested approach. Variations may be appropriate in the case of specific projects. The sample computations shown in Section 8-8 include only powerhouse costs. When making the total estimate for a power project or a multiple-purpose project including power, other cost items would be included as well.

8-2. Types of Cost Estimates.

a. General. Cost estimates are made for all levels of hydropower investigations. Reconnaissance, feasibility, and project design reports each require cost estimates that are consistent with the level of detail presented in the study.

b. Reconnaissance Reports. The purpose of a reconnaissance report is to determine if a project has sufficient promise to warrant more detailed study. The intent of this report is to perform a preliminary economic analysis and appraise the critical issues, rather than to formulate detailed approaches or solutions. Cost information would be obtained from generalized cost curves or from data for similar projects. The report would contain a summary cost estimate for one or more schemes, and drawings would be limited to a cross-section of the powerhouse and a plan showing exterior dimensions of the structure.

c. Feasibility Reports. The purpose of a feasibility study is to determine whether a specific project (or other action) should be recommended for Congressional authorization. At this level of study, the primary objective is to formulate a project and to establish project feasibility. As the study progresses toward selection of the recommended plan, characteristics are defined, and costs for the major electrical and mechanical items, such as turbines and generators, may be obtained directly from the manufacturers. Costs for civil features, such as powerhouse structure, penstock, and intake and outlet works, are similarly refined. In the early stages of project formulation, a large number of alternative plans may be under consideration, and cost estimates may be similar to reconnaissance grade estimates. Once the number of alternatives has been screened down to the best candidates, more detailed cost estimates are prepared. Narrative descriptions of the major elements of the powerhouse are included, together with drawings describing the general location plan, powerhouse plan and section, and a one-line diagram of the electrical system.

d. Design Memoranda. This category includes General Design Memoranda (GDM), Feature Design Memoranda, and the Definite Project Reports (DPR). The DPR is prepared for smaller single-purpose hydro projects and serves as a combination GDM and Feature Design Memorandum. These reports are the last documents written prior to preparation of plans and specifications. At this stage of study, detailed cost estimates are based upon specific design studies for all powerhouse features.

8-3. Construction Costs.

a. Introduction. Powerhouse construction costs are usually defined to include turbines and generators, control systems, communication facilities, ground mats, transformers, high and low voltage switching equipment, buswork, and the service equipment essential for operation of the powerhouse, as well as the powerhouse structure itself. Following is a brief description of the major powerhouse components and the contingency allowances normally used in making powerhouse cost estimates.

b. Major Powerhouse Components.

(1) General. The powerhouse generally includes the items listed in Table 8-1. Intake works, gates, penstocks, and related features are generally not included in powerhouse cost estimates. These items are included in other civil feature cost accounts and will not be discussed here, since they are covered in other engineering manuals such as EM 1110-2-1301, Cost Estimates: Planning and Design Stages.

(2) Powerhouse Structure. This account includes all materials and work needed to construct the actual structure which encloses the powerplant equipment. For an existing structure, this account would include any remodeling or rehabilitation needed to bring the structure up to design specifications. Typical items included in this category

TABLE 8-1
Typical Powerhouse Cost Estimate

Price Level: January, 1981

	FEATURE	COST (DOLLARS)
7.1	POWERHOUSE STRUCTURE	
	a. Excavation	$ 9,240,000
	b. Reinforced concrete	11,070,000
	c. Miscellaneous building items	260,000
	d. Bulkhead, guides & structural steel	1,980,000
	Subtotal	$22,550,000
7.2	TURBINES AND GENERATORS	
	a. Turbines, generators, & governors	$17,130,000
	b. Cooling system	44,000
	Subtotal	$17,174,000
7.3	ACCESSORY ELECTRICAL EQUIPMENT	
	a. Switchgear, breakers & busses	$ 453,000
	b. Station service unit	85,000
	c. Control system	428,000
	d. Miscellaneous electrical systems	597,000
	Subtotal	$ 1,563,000
7.4	AUXILIARY SYSTEMS & EQUIPMENT	
	a. Heating and ventilating	$ 75,000
	b. Station, brake & governor air	50,000
	c. Dewatering & drainage systems	74,000
	d. Bridge crane	425,000
	e. Tailrace, gantry crane	350,000
	f. Miscellaneous mechanical systems	225,000
	Subtotal	$ 1,199,000
7.6	SWITCHYARD	
	a. Power transformer	$ 522,000
	b. High voltage equipment	200,000
	Subtotal	$ 722,000
7.7	SITE PREPARATION & SPECIAL ITEMS	
	a. Mobilization & preparation	$ 1,500,000
	TOTAL	$44,708,000

are excavation and foundation, concrete, structural steel, and architectural features.

(3) Turbine and Generators. This category includes the major equipment and systems needed to convert the available energy in water to electrical energy: the turbines, generators, governors, excitation equipment, and cooling systems.

(4) Accessory Electrical Equipment. These are items that control the generating unit and interconnect the generator with the switchyard. This account includes switchgear, circuit breakers, and station service and control systems.

(5) Auxiliary Systems and Equipment. This account includes supporting systems and equipment and items not included in other powerhouse categories, such as heating and ventilating systems; piping, dewatering, and drainage systems; cranes and hoists; fire protection systems; and machine shop (where appropriate).

(6) Switchyard. This equipment provides the power interface between the power plant and the transmission system. This account consists primarily of the power transformers and related high-voltage equipment.

(7) Site Preparation and Special Items. This account includes those costs associated with contractor setup and other mobilization and preparation items.

c. Contingencies. A contingency allowance is applied to the powerhouse construction cost in order to account for uncertainty in the cost estimate. The magnitude of the contingency allowance varies with the level of study; i.e., a smaller allowance is applied to a GDM estimate than a reconnaissance study estimate. In estimating powerhouse costs, it is sometimes desirable to apply different allowances to different cost components. For example, there is usually more uncertainty associated with foundation and excavation work than with major powerplant equipment such as turbines and generators. Cost estimates prepared by the Hydroelectric Design Centers include contingency allowances which reflect the variation of uncertainty of costs among components. General guidance on contingency allowances is contained in EM 1110-2-1301, and is summarized in Table 8-2.

d. Sources of Powerhouse Cost Data.

(1) General. The principal sources of data on powerhouse costs within the Corps of Engineers are the Hydroelectric Design Centers. For preliminary studies, rough estimates can also be developed using cost data from one of several reference publications.

TABLE 8-2
Contingency Allowances

Basis of Estimate	Contingency Allowances for Projects with Construction Cost of: More Than $10,000,000	Less Than $10,000,000
Survey and review	20%	25%
Phase I GDM	20%	25%
Phase II GDM	15%	20%
Completed plans and specs	10%	10%
Awarded contracts	5%	5%
Completed contracts	0%	0%

(2) Hydroelectric Design Centers. ER 10-1-41 and ETL 1110-2-272 require that all cost estimates for project studies beyond the feasibility stage be prepared or reviewed by one of the Hydroelectric Design Centers (see Section 1-7). These offices are also equipped to make reconnaissance and feasibility grade cost estimates, and Districts not having in-house capability are encouraged to consult the Centers for these estimates as well. The Centers utilize historical information, detailed cost curves, manufacturers' data, and design studies when making these estimates.

(3) Cost Estimating Reports. Three reports contain information which may be useful in making preliminary powerhouse cost estimates:

- Hydropower Cost Estimating Manual, prepared by North Pacific Division for the National Hydroelectric Power Resources Study, dated May, 1979 and revised July, 1981 (41).

- Feasibility Studies For Small Scale Hydropower Additions: A Guide Manual, prepared by the Hydrologic Engineering Center for the Department of Energy, dated July, 1979 (39).

- Reconnaissance Evaluation of Small, Low-Head Hydroelectric Installations, prepared by Tudor Engineering Company for the Bureau of Reclamation, dated July, 1980 (36).

The data contained in these reports was developed primarily from statistical studies of historical cost data and is presented in the form of curves and equations. The Hydropower Cost Estimating Manual, which is due to be updated in CY 1985, presents data on all sizes of powerplants, while the latter two reports deal primarily with small hydro projects. The data from these reports is not all-inclusive, and the user must index cost data to current price levels. It must be emphasized that these estimates are very general and are appropriate only for preliminary studies.

8-4. Investment Cost.

a. General. Investment cost is the total cost required to bring a project on-line and includes indirect costs such as engineering and design, supervision and administration, and interest during construction. The following paragraphs describe each of these items and the adjustments that must sometimes be applied to construction cost estimates in order to account for inflation during construction. More specific guidance on each of these elements is contained in EM 1110-2-1301.

b. Construction Costs. This is the total cost required to build the project, including both the structure and equipment (see Section 8-3).

c. Project Engineering and Design (E&D) Costs. The magnitude of these costs is influenced by many factors, including the type, size, and geographical location of the project. In the early stages of study, E&D costs are usually treated as a percentage of the construction cost, and the value used varies somewhat from District to District. A sampling of recent hydropower studies showed that most values fall in the 6 to 10 percent range, with 8 percent being most common. For very large projects, a value of less than 6 percent might be justified. As a project moves into the design memorandum stages, project-specific E&D costs are often computed.

d. Supervision and Administration (S&A) Costs. S&A costs include field office and inspection costs, construction management costs, and a percentage of the District's general overhead costs. These items are treated similarly to E&D costs. A percentage of construction costs is generally used in the pre-authorization studies, and project-specific cost estimates are often developed for design memoranda. A sampling of recent studies showed that S&A costs generally fall in the 5 to 7 percent range.

e. Interest During Construction.

(1) Interest during construction (IDC) accounts for the cost of capital during the construction period. ER 1105-2-40, which provides general guidance on the computation of IDC, states that it must be based on compound interest.

(2) IDC computations are based on the projected power on-line date. IDC is compounded on all expenditures preceding that date, and all expenditures incurred after that date are discounted from their expected expenditure date to the power on-line date. For very preliminary studies, a uniform distribution of costs over the period of construction can be assumed. However, for most reconnaissance and all feasibility studies, a year-by-year distribution of costs should be used.

(3) Figure 8-1 shows a typical distribution of costs for powerhouses (including the cost of procuring turbines and generators). Table 8-3 is based upon Figure 8-1 and shows the typical annual construction cost distribution for projects with construction periods ranging from 1 to 6 years. Interest during construction is applied to the total project cost (construction cost plus E&D and S&A), using the applicable Federal interest rate.

(4) IDC must be readjusted following completion of the cost allocation to reflect the power repayment interest rate of the Department of Energy. This is in accordance with the interagency agreement of 1 September 1983.

f. Investment Cost. The investment cost is the sum of the total project cost and interest during construction.

g. Inflation During Construction. A hydropower project is usually constructed over a period of several years. During this time, the price of the items necessary to build the project may escalate due to inflation. Contractors making bid estimates on projects are aware of these effects and increase their bid estimates accordingly. If the construction cost estimates are based upon past contractor bid prices, these inflated cost estimates must be adjusted to a base year for proper economic analysis. The inflation adjustment would be applied to the construction cost, thus providing an adjusted (inflation-free) construction cost for use in the economic analysis. If the cost estimates are based upon spot prices for work to be done or materials to be delivered immediately, the estimates need not be adjusted for inflation. Section 8-8d illustrates how an inflation adjustment could be made.

8-5. Annual Costs.

a. General. Benefits and costs must be reduced to the same time basis for valid economic comparison, and the preferred time basis is the equivalent annual value. Both the annual benefits and annual costs must be adjusted to the same base price level. The annual cost consists of the amortized investment cost plus yearly operation, maintenance, and interim replacement costs. For pumped-storage projects, pumping costs would be included as well.

b. Interest and Amortization. Amortization of investment cost is the process of spreading the project's cost over its economic life to determine an equivalent annual cost. This requires the computation

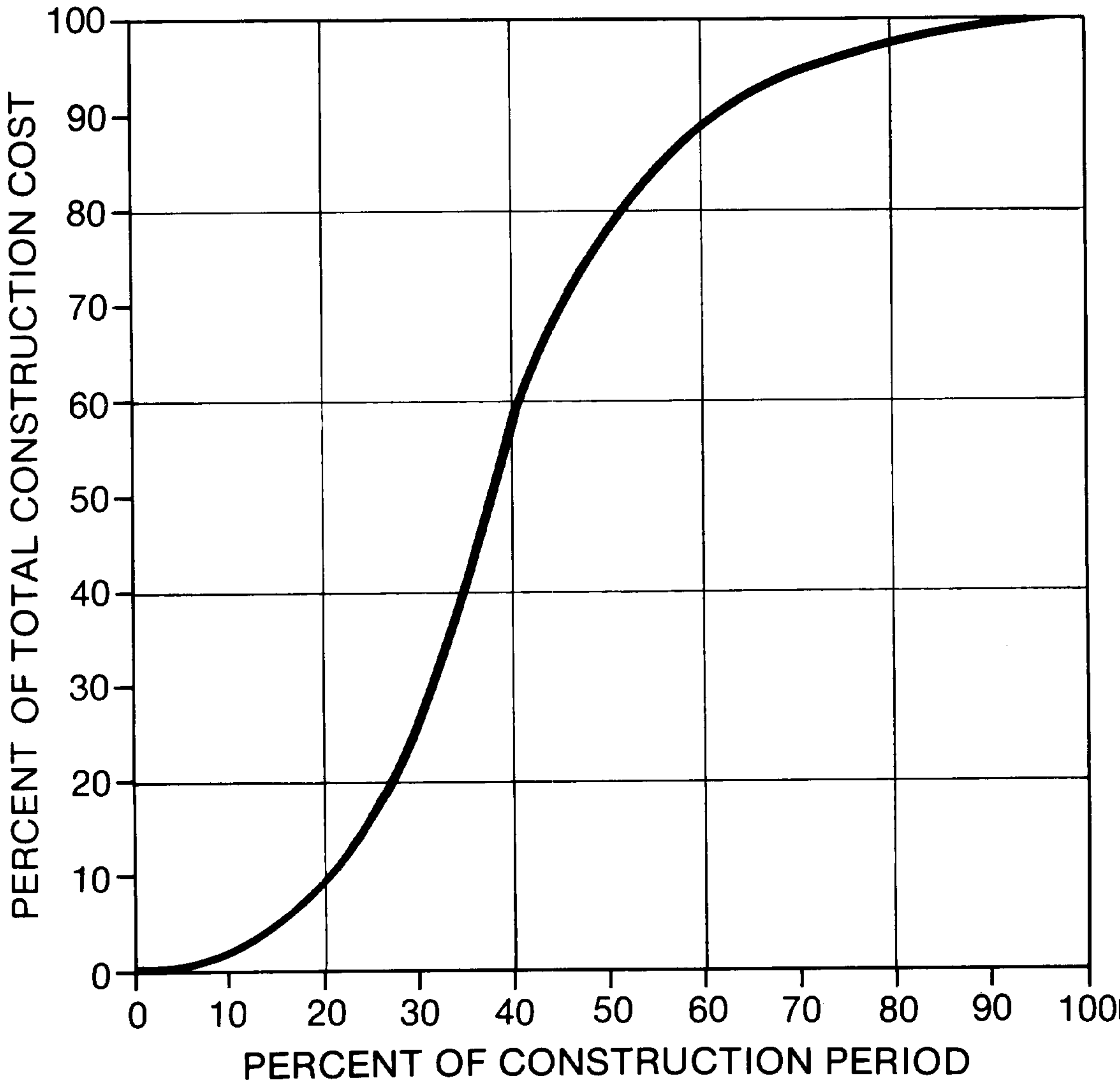

Figure 8-1. Distribution of powerhouse construction costs over construction period

TABLE 8-3
Powerhouse Construction Cost Distribution
by Year for Various Construction Periods

Construction period	Percentage of total project costs expended during year: 1	2	3	4	5	6
1 Year	100	-	-	-	-	-
2 Years	77	23	-	-	-	-
3 Years	37	56	7	-	-	-
4 Years	16	62	18	4	-	-
5 Years	9	49	30	9	3	-
6 Years	6	31	40	15	6	2

of an amortization factor based upon the annual interest rate and economic life. The applicable interest rate is recomputed each year, and field offices are advised annually by HQ, USACE of these changes. The interest rate for a given project must be adjusted annually through the planning process, but once construction funds are appropriated, the project interest rate is fixed. The same interest rate is used for interest during construction calculations. Section 9-3c gives guidance on the economic life to be used in estimating annual costs for hydropower projects.

c. Operation and Maintenance.

(1) Operation and Maintenance (O&M) costs represent the average annual costs of maintaining the project at full operating efficiency throughout project life. This includes salaries of operating personnel; the cost of labor, plant, and supplies for ordinary maintenance and repairs; and applicable supervisory and overhead costs. Many Corps projects are multiple purpose installations that provide benefits and services other than power production. Some of the costs of operating multiple purpose projects are joint costs, which must be apportioned among all project functions, including hydropower. These joint O&M costs are allocated to project purposes on the same basis that joint construction costs are allocated, but the

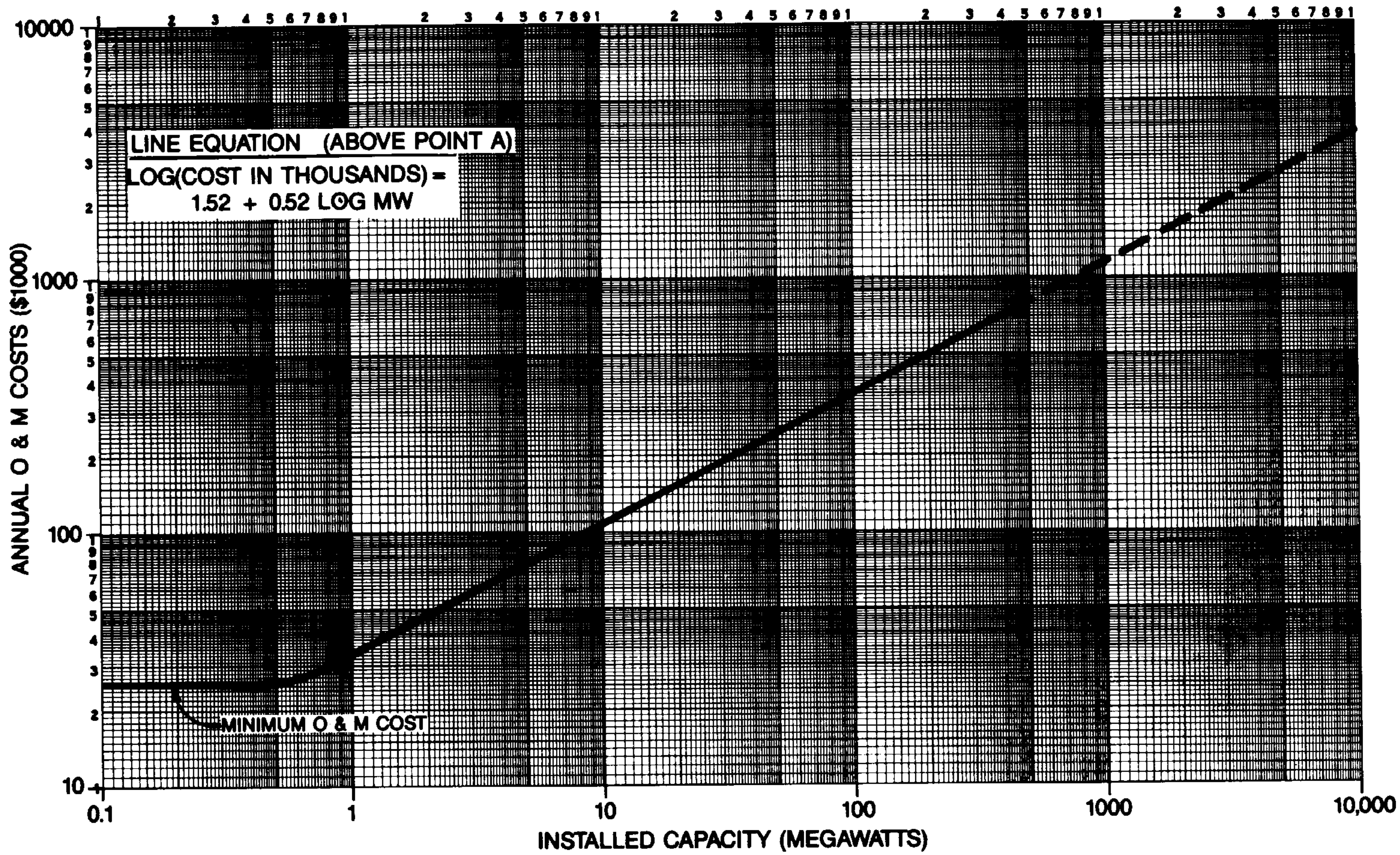

Figure 8-2. Annual operation and maintenance costs for remotely operated power plants (1983 prices)

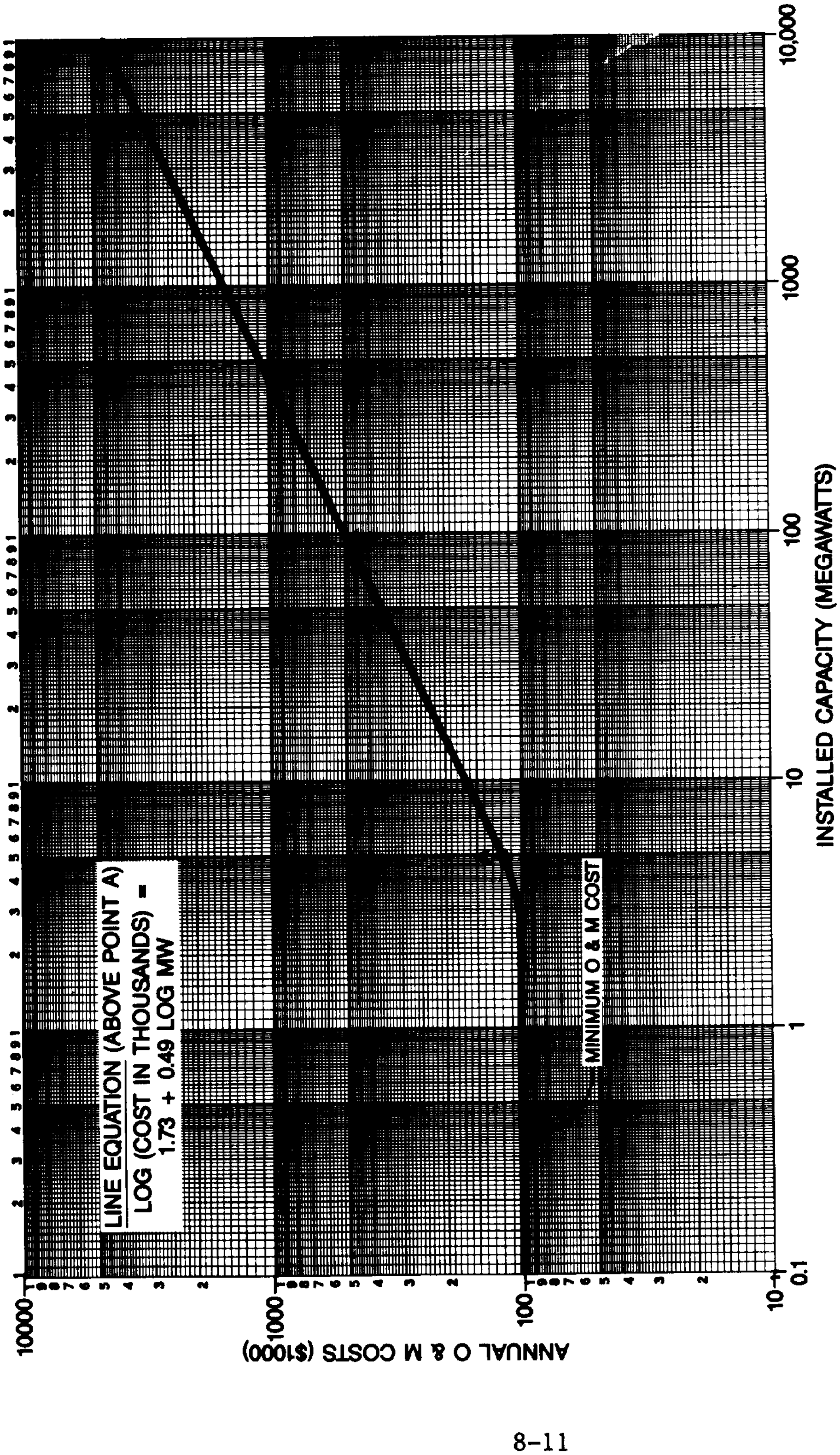

Figure 8-3. Annual operation and maintenance costs for locally operated power plants (1983 prices)

distribution percentages are not usually identical (refer to ER 1105-2-40 and EP 1105-2-45, which are part of the Planning Guidance Notebook).

(2) O&M costs are usually a function of installed capacity and type of operation. The operation of power projects is divided into two general categories: local and remote. Projects that are operated locally have operators on-station. Typical projects of this type are older power projects and new power projects where the location or the complexity of operation requires a manned station. Remote operation is performed by automated equipment, with operating instructions transmitted being from a centralized source. The complexity of the control equipment depends on plant size and location. When two or more plants are located in one area, it is often possible to operate them all from one location. In these cases, it is also common to perform maintenance at all projects with a single crew.

(3) Figures 8-2 and 8-3 show annual O&M costs as a function of project size for remote and local plant operation, respectively. These curves are based on historical O&M costs for a large number of projects throughout the country, adjusted to 1983 price levels. As Figures 8-2 and 8-3 show, total O&M costs generally decrease with plant size down to a fixed minimum level, which is necessary to cover minimum personnel and supply costs. These minimum levels are estimated to be $25,000 per year for remotely controlled projects and $100,000 per year for locally controlled projects (assuming that part of operator costs can be allocated to non-power project functions). The figures show a straight line relationship on the log-log grid. Equations for these lines are also shown on the figures, for convenience in preparing the O&M cost estimates. The curves are generalized and therefore do not reflect special conditions that can be unique to some projects. If better information is available, such as historical data from a similar project, it should be used in lieu of data from the curves. In design memoranda and other advanced studies, project-specific O&M costs based on expected staffing requirements and other costs should be developed.

d. Replacement Costs.

(1) Certain major components of a powerhouse require replacement before the end of the project life. Examples are generator windings, turbine runners, thrust bearings, pumps, air compressors, communications equipment, generator, voltage regulation and excitation equipment, and certain types of transformers. The replacement cost for a facility is the estimated future cost of such replacements, converted to an equivalent average annual value over the entire project life. ER 37-2-10, Accounting and Reporting Civil Works

Activities, provides guidance on the procedure to be used and lists the estimated service life for most of these components.

(2) The detailed procedure described in ER 37-2-10 should be used for post-authorization (design memoranda and beyond) cost estimates, and may also be used in the feasibility report. For pre-authorization studies, replacement costs can also be estimated from the construction cost estimate using an approximate procedure based on composite service lives. Detailed cost estimates were examined for a number of powerhouses of different types, and estimates were made of the percentage of each cost account that represents equipment that would require replacement at least once during project life. Service lives were then assigned to each piece of equipment requiring replacement, based on the data shown in ER 37-2-10, and composite service lives were developed for each cost account. In developing these composite service lives, the service life for each component (the generator windings, for example) was weighted by the cost of that component. Table 8-4 lists the percentages of each cost account that requires interim replacement and the corresponding composite service lives for both medium to large and small (smaller than 10 MW) hydro plants.

(3) The annual replacement cost for each cost account is estimated by (a) computing the portion of the construction cost (including contingencies) that requires replacement during the life of the project (using the percentages listed in Table 8-4), then (b) computing the present worth of that cost based on its composite service life and the project interest rate, and finally (c) amortizing the present worth amount over the composite service life. This procedure results in the determination of the amount required to be deposited annually in a sinking fund, earning interest at the project interest rate, in order to accumulate an amount equal to the estimated replacement cost. This analysis, of course, ignores future increases in replacement costs resulting from general inflation. Table 8-5 shows an example based on the construction costs from Tables 8-1 and 8-9. Note that replacement costs were not computed for the mobilization expenses. Also, to simplify the table, the present worth factor and annuity factor were combined into a single sinking fund factor.

(4) For reconnaissance studies where a detailed powerhouse cost breakdown is not available, the annual replacement costs can be approximated as 0.2 percent of the powerhouse cost estimate.

e. Pumping Costs.

(1) The cost of pumping energy is a part of the annual operating costs for both off-stream and integral pumped-storage projects. Estimates of the average annual pumping energy requirement can be

TABLE 8-4
Representative Composite Service Lives for Powerhouse Equipment Requiring Replacement During Project Life

	Med. to Large Plants 1/		Small Plants 2/	
	Percent 3/ Requiring Replacement	Composite Serv. Life (years)	Percent 3/ Requiring Replacement	Composite Serv. Life (years)
7.1 Powerhouse structure	1	38	-	0
7.2 Turbines, generators, and governors	24	38	18	39
7.3 Accessory electrical equipment	50	34	80	38
7.4 Auxiliary systems and equipment	7	24	20	35
7.5 Tailrace	-	-	0	-
7.6 Switchyard	43	36	53	38

1/ Plants larger than 10 megawatts installed capacity
2/ Plants of 10 megawatts installed capacity or smaller
3/ Percentage of total account cost which requires replacement at least once during project life.

obtained from sequential routing studies or from power system production cost studies. For integral (pump-back) projects, routing studies can be used to define the periods when streamflows are such that pumping is required to firm up capacity. Hourly production cost studies can be used to determine when pumped-storage operation is economical for both pump-back and off-stream projects, and they can also be used to estimate the average annual pumping requirement. The POWRSYM model (see Section 6-9f) is particularly well-suited to analysis of pumped-storage projects, and FERC, North Pacific Division, and Omaha District have used the model for studies of this type.

(2) To estimate pumping costs, the unit cost of pumping energy must also be determined. This value can be obtained from production cost models such as POWRSYM. The value should reflect the same base fuel costs, price levels, and real fuel cost assumptions as the power values used for estimating energy benefits. Pumping energy values are normally obtained from FERC and are generally requested at the same time as the power values (see Section 9-5k). Section 7-5h(2) provides

TABLE 8-5
Computation of Powerhouse Replacement Costs (Approximate Method)

	Cost Account	Cost of 1/ Replacements ($1000's)	Composite Serv. Life (years) 2/	Sinking Fund Factor 3/	Annuity
7.1	Powerhouse structure	$321	38	0.004401	$1,400
7.2	Turbines, generators, and governors	5,524	38	0.004401	24,300
7.3	Accessory electrical equipment	1,055	34	0.006137	6,500
7.4	Auxiliary systems and equipment	113	24	0.014720	1,700
7.5	Tailrace	4/	-	-	-
7.6	Switchyard	408	36	0.005193	2,100
				TOTAL	$36,000
				Rounded	$40,000

1/ Construction Cost (from Table 8-9) multiplied by Percent Requiring Replacement (from Table 8-4). For example, for cost account 7.1, Cost of Replacements = ($32,070,000)x(1%) = $321,000.
2/ From Table 8-4
3/ Based upon 8-1/8% interest rate and period equal to composite service life.
4/ In this example, tailrace costs are included in powerhouse costs.

additional information on estimating pumping energy requirements, and Section 9-10d describes how to treat the cost of pumping energy in the net benefit analysis.

8-6. Transmission Costs.

a. Transmission costs consist of the cost of the transmission line and substation equipment needed to transfer generated power to the regional transmission grid. Transmission costs vary depending on the location of the proposed project relative to the existing system and on the size of the project. For some projects, transmission requirements may be minor, because existing transmission facilities are nearby. In other cases, transmission costs can be a significant part of project costs, due to a remote site location, difficult topography, or right-of-way constraints.

b. For some projects, it is possible to clearly identify the increment of transmission facilities required for a proposed hydro project, but often the analysis is more complex. For example, the transmission facilities carrying the project's output to the load center(s) may also be used by other generating projects or may be required for system stability or reliability. In these instances, a portion of the transmission costs should be allocated to these other users. In cases where modification or replacement of existing transmission lines would be required, it is necessary to estimate transmission facility costs both with and without the proposed hydro project. The difference between these costs is the economic cost of transmission chargeable to the project.

c. In most cases, the responsibility for transmission facilities rests with entities other than the Corps of Engineers. In the western and south-central states, the regional Federal Power Marketing Administrations (PMA's) generally construct the required transmission facilities (see Section 3-12a and Figure 3-2). In other cases, utilities wheel the power to the load centers under contracts, administered in most cases by the PMA's. Thus, the primary source of information on transmission costs would usually be the PMA, and a request for transmission costs would be sent to the PMA once the project location and generating capacity are defined. The transmission costs should be based on the same interest rate and price level as the project costs and should include contingencies, IDC, operation and maintenance costs, and replacement costs where applicable. The transmission costs would be converted to an equivalent average annual cost in the same manner as for hydro project costs (see Section 8-5).

d. In the Pacific Northwest, the complexity of the regional transmission system is such that it is frequently difficult to isolate the transmission costs associated with given hydro projects. In these cases, the PMA (Bonneville Power Administration) has estimated average per kilowatt transmission costs. These costs are incorporated by FERC in the project capacity values, which then become "at-hydro site" capacity values rather than "at-market" values (see Section 9-5g). This approach should be applied only to projects where site-specific transmission costs cannot be identified.

8-7. Updating Cost Estimates.

a. General. Once a cost estimate has been made, it is frequently necessary to update the estimate to reflect current price levels and interest rates. Following is a discussion of cost indices available for updating powerhouse costs and procedures to be used for updating O&M and replacement costs.

b. Construction Cost Indexes.

(1) The Engineering News Record (ENR) Construction Cost Index and the Bureau of Reclamation (USBR) Construction Cost Trends are the two sources of information most often used to update hydro project construction cost prices.

(2) The ENR Construction Cost Index is a weighted aggregate cost index intended to reflect general cost trends in the construction industry as a whole. The index is derived from the costs of labor, steel, cement, and lumber, and is computed for twenty major U.S. cities. A twenty-city average is also computed. Separate indices are also developed for skilled labor, common labor, and building materials. The 20-city average indices are published weekly in Engineering News Record, and the regional indices are published quarterly. The first quarterly cost round-up for each year also includes a tabulation of historical indices. Many Corps offices rely heavily on ENR indices for updating construction costs.

(3) The USBR cost indices (see Table 8-6) are tailored more specifically to water resource projects and are more detailed. Separate indices are developed for various project components, including "Power Plant, Hydro". For example, the USBR powerhouse cost index is based on a mixture of labor, material, and equipment costs typical of a powerhouse. The individual components included in that index are periodically updated using the published index that applies to each component, and they are weighted according to each component's share of the total powerhouse cost. The Bureau of Reclamation's Construction Cost Trends are published quarterly by the Bureau's Division of Construction, located at the Engineering and Research Center, P.O. Box 25007, Denver, CO 80225. They are also included in Engineering News Record's quarterly cost round-ups. The USBR indices are particularly appropriate for indexing powerhouse costs, because they reflect the cost of major equipment (such as turbines and generators) in addition to labor and construction materials, and they are based on a mix of labor and materials that is characteristic of powerhouse construction.

c. Updating O&M Costs. Operation and maintenance costs consist of a mix of labor and materials costs. The materials cost represents supplies, tools, equipment, and minor replacement parts. Separate indices should be used for updating each, and in most cases indexing can be done with the annual price level adjustments developed by field offices for updating budgetary submittals. Where detailed O&M cost estimates have been made, segregating the labor and materials comp-

TABLE 8-6.
Example of USBR Construction Cost Trend Indices

BUREAU OF RECLAMATION CONSTRUCTION COST TRENDS
(BASE 1977 = 100 FOR INDEXING FIELD COSTS ONLY)

	1980				1981				1982				1983			
	JAN	APR	JUL	OCT	JAN	APR	JUL	OCT	JAN	APR	JUL	OCT	JAN	APR	JUL	OCT
CONSTRUCTION INDEXES																
EARTH DAMS	123	127	132	134	137	140	143	144	146	144	145	142	141	140	139	139
DAM STRUCTURE	119	122	124	127	132	135	137	138	141	139	140	135	135	134	132	131
SPILLWAY	128	134	140	143	143	147	149	150	151	148	149	147	146	146	144	144
OUTLET WORKS	128	132	139	141	141	145	148	150	151	150	151	151	151	151	152	152
CONCRETE DAMS	128	133	139	142	142	146	150	151	153	153	154	153	153	153	153	153
DIVERSION DAMS	125	128	133	136	137	140	144	147	149	150	152	152	151	151	152	153
PUMPING PLANTS	124	127	131	134	136	139	143	146	148	150	151	152	151	151	152	153
STRUCTURES AND IMPROVEMENTS	126	129	133	136	138	140	143	145	147	149	150	149	148	147	147	148
EQUIPMENT	122	124	129	133	135	138	143	147	150	151	154	156	156	157	158	160
PUMPS AND PRIME MOVERS	123	125	131	133	137	141	145	149	152	154	156	157	157	157	158	160
ACCESSORY ELECT + MISC. EQUIP.	121	123	128	131	132	134	139	144	146	148	151	153	155	155	158	160
POWERPLANTS	122	126	132	135	138	141	145	149	151	152	154	155	155	155	156	157
STRUCTURES AND IMPROVEMENTS	125	129	133	135	138	140	143	145	147	149	150	149	148	147	148	148
EQUIPMENT	120	125	132	136	138	142	147	151	152	154	157	157	158	158	159	160
TURBINES AND GENERATORS	120	125	133	137	139	144	148	152	154	156	158	159	160	160	161	162
ACCESSORY ELECT + MISC. EQUIP.	121	123	127	130	132	134	139	143	145	146	149	150	151	151	153	155
STEEL PIPELINES	124	127	130	135	137	139	145	149	152	154	158	158	158	158	161	161
CONCRETE PIPELINES	125	130	135	138	141	143	146	148	150	151	153	154	154	153	154	156
CANALS	123	127	130	134	137	139	142	144	147	147	148	146	144	144	144	144
CANAL EARTHWORK	122	125	128	133	138	141	143	146	147	146	147	144	143	143	143	143
CANAL STRUCTURES	125	129	132	135	137	139	142	144	146	149	150	149	148	147	147	148
TUNNELS	125	128	132	136	138	140	144	149	151	154	157	158	158	158	160	161
LATERALS AND DRAINS	122	126	129	133	135	137	140	142	145	146	146	144	143	142	141	142
LATERAL EARTHWORK	120	123	126	130	133	135	139	142	144	143	144	142	141	139	139	140
LATERAL STRUCTURES	123	127	130	134	136	138	140	142	145	147	148	146	145	144	143	144
DISTRIBUTION PIPELINES	124	129	133	136	139	141	144	147	148	149	152	152	152	152	153	154
SWITCHYARDS AND SUBSTATIONS	123	127	132	134	135	138	141	145	146	148	151	152	152	152	153	154
WOOD POLE TRANSMISSION LINES	129	132	133	134	136	138	141	142	142	141	142	141	141	141	144	146
POLES AND FIXTURES	132	132	132	132	130	131	132	133	132	130	130	130	129	129	133	136
OVERHEAD CONDUCTORS AND DEVICES	125	131	134	138	142	146	151	153	155	155	156	157	157	156	158	159
STEEL TOWER TRANSMISSION LINES	126	130	135	138	140	144	148	152	154	157	161	162	162	162	163	163
PRIMARY ROADS	131	137	142	144	146	148	150	151	152	153	154	154	153	152	153	154
SECONDARY ROADS	137	145	152	154	160	160	160	159	162	164	162	162	160	160	161	160
BRIDGES	126	129	134	137	140	141	144	147	150	153	155	155	154	153	154	154
GENERAL PROPERTY	127	127	131	133	133	136	139	143	144	144	147	148	149	149	152	155
LAND INDEXES																
ARIZONA	123	128	130	132	134	136	136	139	143	145	146	146	146	146	137	133
CALIFORNIA	158	165	169	173	176	206	209	214	218	219	223	227	228	229	225	225
COLORADO	149	153	157	160	162	166	167	172	174	176	176	176	176	176	164	161
IDAHO	135	138	141	143	144	145	146	149	152	153	154	155	156	156	144	140
KANSAS	129	132	134	136	138	138	138	139	141	142	142	142	142	142	130	126
MONTANA	135	142	145	148	150	150	150	152	154	155	158	160	161	162	150	146
NEBRASKA	133	137	139	143	145	149	150	153	155	157	156	155	154	153	135	129
NEVADA	126	129	131	132	133	137	139	141	142	144	145	145	145	146	137	133
NEW MEXICO	122	124	128	130	133	132	133	136	142	144	144	144	144	144	136	133
NORTH DAKOTA	124	134	138	141	142	145	147	149	151	153	153	154	154	154	145	142
OKLAHOMA	134	140	144	147	149	156	156	160	163	165	166	167	167	168	159	156
OREGON	121	121	125	129	131	140	141	143	144	147	147	148	148	149	141	138
SOUTH DAKOTA	141	147	151	155	157	157	157	159	163	165	160	160	160	160	145	140
TEXAS	136	142	145	149	150	157	158	161	165	167	174	180	185	187	198	191
UTAH	123	126	128	130	131	135	135	137	140	142	142	142	142	142	133	130
WASHINGTON	124	125	126	128	129	148	149	151	152	154	154	155	155	156	154	152
WYOMING	126	128	130	131	132	136	136	138	141	142	142	143	143	144	136	133
OTHER INDICATORS																
COMPOSITE TREND	124	128	132	135	137	140	144	146	148	149	152	152	151	151	152	153
MACHINERY AND EQUIPMENT (BLS)	129	133	136	140	143	148	152	154	158	160	162	162	163	164	165	166
FEDERAL SALARY	119	119	119	129	129	129	129	136	136	136	136	141	141	141	141	141

TABLE 8-7
Indices for Adjustment of Materials Cost Component to
Reflect Interest Rate (Base Interest Rate = 2-1/2 percent)

Percent	0	1/8	1/4	3/8	1/2	5/8	3/4	7/8
2	-	-	-	-	1.000	0.936	0.886	0.842
3	0.800	0.760	0.722	0.688	0.656	0.626	0.599	0.574
4	0.550	0.526	0.503	0.481	0.460	0.440	0.421	0.404
5	0.388	0.372	0.357	0.343	0.329	0.316	0.303	0.291
6	0.279	0.267	0.255	0.243	0.232	0.221	0.211	0.203
7	0.194	0.186	0.177	0.169	0.161	0.153	0.146	0.139
8	0.132	0.126	0.120	0.115	0.110	0.104	0.099	0.093
9	0.088	0.083	0.079	0.076	0.073	0.070	0.067	0.064
10	0.061	0.058	0.055	0.053	0.051	0.048	0.045	0.043
11	0.041	0.038	0.036	0.034	0.032	0.031	0.030	0.028
12	0.026	0.025	0.024	0.023	0.022	0.021	0.020	0.019
13	0.019	0.018	0.018	0.017	0.017	0.016	0.016	0.015
14	0.014	0.013	0.013	0.012	0.011	0.011	0.010	0.010
15	0.009							

onents is a straightforward process. Where a breakdown is not available, powerhouse O&M costs can be roughly apportioned 80 percent to labor and 20 percent to materials.

d. Updating Replacement Costs. Replacement costs are essentially 100 percent materials costs and should be updated using an index which is representative of the mechanical and electrical equipment which would require replacement. In many cases, price level adjustments developed by field offices for updating budgetary submittals can be used. An alternative is the USBR index for "equipment," which is a sub-category under "Power Plants, Hydro" (see Table 8-6). Because replacement costs represent a sinking fund, they must be adjusted for changes in project interest rate. The most precise approach is to recompute the replacement cost as shown on Table 8-5, using updated construction costs and sinking fund factors. An alternative is to use the indices from Table 8-7. For example, in order to adjust the materials cost from a 7 percent project interest rate to 8 percent, an adjustment factor of (0.132/0.194) = 0.680 would be used.

TABLE 8-8
Adjustment of Costs for Price Level

Cost Account	Jan 1981 Costs	Oct 83 Index/ Jan 81 Index	Oct 1983 Costs
7.1 Powerhouse	$22,550,000	(157/138)	$25,655,000
7.2 Turbines & generators	17,174,000	(162/139)	20,016,000
7.3 Accessory electrical equip.	1,563,000	(155/132)	1,835,000
7.4 Auxiliary systems & equip.	1,199,000	(155/132)	1,408,000
7.6 Switchyard	722,000	(154/135)	824,000
7.7 Site prep. & special items	1,500,000	(155/133)	1,748,000

8-8. Example Powerhouse Cost Analysis.

a. Introduction. In order to illustrate the concepts presented in this chapter, an example calculation of annual costs for a power project is presented. This example includes only powerhouse costs.

Given:
- cost estimate breakdown presented in Table 8-1.
- USBR Construction Cost Trends presented in Table 8-6.
- project life: 100 years.
- Federal interest rate: 8-1/8%.
- price level: October 1983
- construction period: 4 years.

b. Price Level Adjustment. The costs presented in Table 8-1 are in January 1981 dollars and must be adjusted to represent October 1983 price levels. This is done by applying the USBR indices from Table 8-6 to each of the powerplant features (see Table 8-8).

c. Contingencies. The next step is to adjust for contingencies, so that the above figures will represent construction costs. Turbine and generator costs and other equipment costs can generally be estimated with greater precision than other costs. In this example, a 15 percent contingency allowance has been assumed for these items, and 25 percent is assumed for the remaining accounts (see Table 8-9).

d. Inflation Adjustment.

(1) It is assumed that the cost estimate shown in Figure 8-1 was developed from bid prices for similar projects. Since bid prices

TABLE 8-9
Contingency Adjustment

Cost Account	Oct 1983 Cost	Contingency Allowance	Construction Cost
7.1 Powerhouse	$25,655,000	25%	$32,070,000
7.2 Turbines & generators	20,016,000	15%	23,020,000
7.3 Accessory electrical equip.	1,835,000	15%	2,110,000
7.4 Auxilary systems & equip.	1,408,000	15%	1,620,000
7.6 Switchyard	824,000	15%	950,000
7.7 Site prep. & special items	1,748,000	25%	2,180,000
TOTAL			$61,950,000

incorporate the contractor's estimate of inflation over the construction period, the cost estimate must be adjusted to remove the estimated inflation during construction. It is further assumed that these estimates were taken from a project that had an identical construction payout schedule.

(2) For this example, it is assumed that the average inflation rate per year during this construction period was determined to be 6%. Powerhouse costs accounts 7.2 and 7.3 (turbines, generators, and electrical equipment) are not adjusted for inflation during construction because these cost estimates are based upon point in time delivery. Therefore, only the remaining features will be adjusted for inflation during construction effects. The cost to be adjusted would then be:

$61,950,000 - ($23,020,000 + 2,110,000) = $36,820,000

(3) Since these construction costs are paid out over a series of years, inflation effects will vary for each year. The procedure to adjust for these effects consists of converting each year's payment to inflation-free costs. This is done by discounting each year's payment from the midpoint of that year to the start of construction by using the inflation rate as the discounting factor (see Table 8-10).

(4) The costs shown on line F of Table 8-10 represent the expected real cost distribution for features 7.1, 7.4, 7.6, and 7.7. To obtain total costs, the costs of features 7.2 and 7.3 must be added to this distribution, as shown in Table 8-11.

TABLE 8-10
Adjustments for Inflation During Construction

Total project cost to be adjusted: $36,820,000 (from Section 8-8d(2)).

	Year 1	Year 2	Year 3	Year 4
A. Yearly percentage (Table 8-3)	15.7	61.7	18.6	4.0
B. Yearly cost 1/	$5,780,000	22,720,000	6,850,000	1,470,000
C. Years from start of construction (n)	0.5	1.5	2.5	3.5
D. Interest rate (i), %	6.0	6.0	6.0	6.0
E. $(1+i)^n$	1.030	1.091	1.157	1.226
F. (B)/(E)	$5,610,000	20,820,000	5,920,000	1,200,000

1/ ($36,820,000)x(A)

TABLE 8-11
Adjusted Construction Costs

Cost of features 7.2 and 7.3; $23,020,000 + $2,110,000 = $25,130,000

	Year 1	Year 2	Year 3	Year 4
A. Yearly percentage	15.7	61.7	18.6	4.0
B. Yearly cost of accts. 7.2 and 7.3 1/	$3,950,000	15,510,000	4,670,000	1,000,000
C. Yearly cost of accts. 7.1,7.4,7.6,7.7 2/	$5,610,000	20,820,000	5,920,000	1,200,000
D. Total cost for year (B)+(C)	$9,560,000	36,330,000	10,590,000	2,200,000

E. Total powerplant cost = $58,680,000

1/ ($25,130,000)x(A)
2/ From line F of Table 8-10

TABLE 8-12
E&D and S&A Costs

	Year 1	Year 2	Year 3	Year 4
A. Construction expenditure	$9,560,000	36,330,000	10,590,000	2,200,000
B. E&D, (A)x(0.08)	760,000	2,910,000	850,000	180,000
C. S&A, (A)x(0.06)	570,000	2,180,000	640,000	130,000
D. Adjusted expenditure (A)x(B) - rounded	$10,890,000	41,420,000	12,080,000	2,510,000

Total adjusted expenditure = $66,900,000

e. Engineering and Design & Supervision and Administration (E&D and S&A). These costs are calculated by applying flat percentages to the construction costs from line D of Table 8-11 (see Table 8-12). Values of 8 percent for E&D and 6 percent for S&A are assumed (see Sections 8-4c and 8-4d).

f. Interest During Construction. In order to obtain total investment cost, including interest during construction, each expenditure is brought to the project on-line date by discounting with the Federal interest rate. These values are then summed to establish total investment cost. Table 8-13 shows these calculations.

g. Annual Cost.

(1) General. In order to calculate annual cost, the project's investment cost is amortized over its economic life and added to annual operation, maintenance, and replacement costs.

(2) Interest and Amortization. Interest and amortization is calculated by multiplying the investment cost by an amortization factor, which in this example is based upon a Federal interest rate of 8-1/8% and a project economic life of 100 years.

Interest and Amortization = $80,870,000 x 0.08129 = $6,570,000

(3) Operation and Maintenance. These costs are determined from Figure 8-2 for a remotely controlled site of 25 MW installed capacity.

O&M Cost = $180,000.

TABLE 8-13
Computation of Investment Cost

	Year 1	Year 2	Year 3	Year 4
A. Yearly expenditure (from Table 8-12)	$10,890,000	41,420,000	12,080,000	2,510,000
B. Years to on-line date (n)	3.5	2.5	1.5	0.5
C. $(1+i)^n$ 1/	1.314	1.216	1.124	1.040
D. Yearly investment cost, (A)x(C)	$14,310,000	50,370,000	13,580,000	2,610,000

Total IDC = $80,870,000 - 66,900,000 = $13,970,000

1/ (1+i) @ 8-1/8 % = 1.08125

Although the O&M cost from Figure 8-2 is in 1983 dollars, assume for purposes of illustration that it is in 1981 dollars and must be adjusted to reflect October 1983 costs. It is assumed that this cost consists of 80% material and 20% labor.

TABLE 8-14
Adjustment of O&M for Price Level

	Labor	Materials
A. O&M cost (Jan 1981) = $180,000		
B. Percentage breakdown	80%	20%
C. Cost breakdown (A)x(B)	$144,000	$36,000
D. USBR cost index (Oct 1983/Jan 1981)	141/129 1/	166/143 2/
E. Adjusted cost (C)x(D)	$160,000	$40,000

Total adjusted O&M cost (Oct 1983) = $160,000 + $40,000 = $200,000

1/ Federal salary index
2/ Machinery & equipment index

(4) Replacement Costs. Replacement costs are estimated as described in Table 8-5. This value is already based on an 8-1/8 percent interest rate and a 1983 price level so it requires no further adjustment. Annual replacement costs are $40,000.

(5) Total Annual Costs. This project's annual cost is the sum of the amortized investment cost, operation and maintenance costs, and interim replacement costs. Table 8-15 summarizes total annual costs.

TABLE 8-15
Summary of Project Costs

	Source	Cost
Construction cost	Table 8-11	$58,680,000
Engineering and design costs	Table 8-12	4,700,000
Supervision and administration costs	Table 8-12	3,520,000
Interest during construction	Table 8-13	13,970,000
Total investment cost	Table 8-13	$80,870,000
Annual interest & amortization	Para. 8-8g(2)	6,570,000
Annual O&M costs	Table 8-14	200,000
Annual replacement costs	Table 8-5	40,000
Total annual cost		$6,810,000

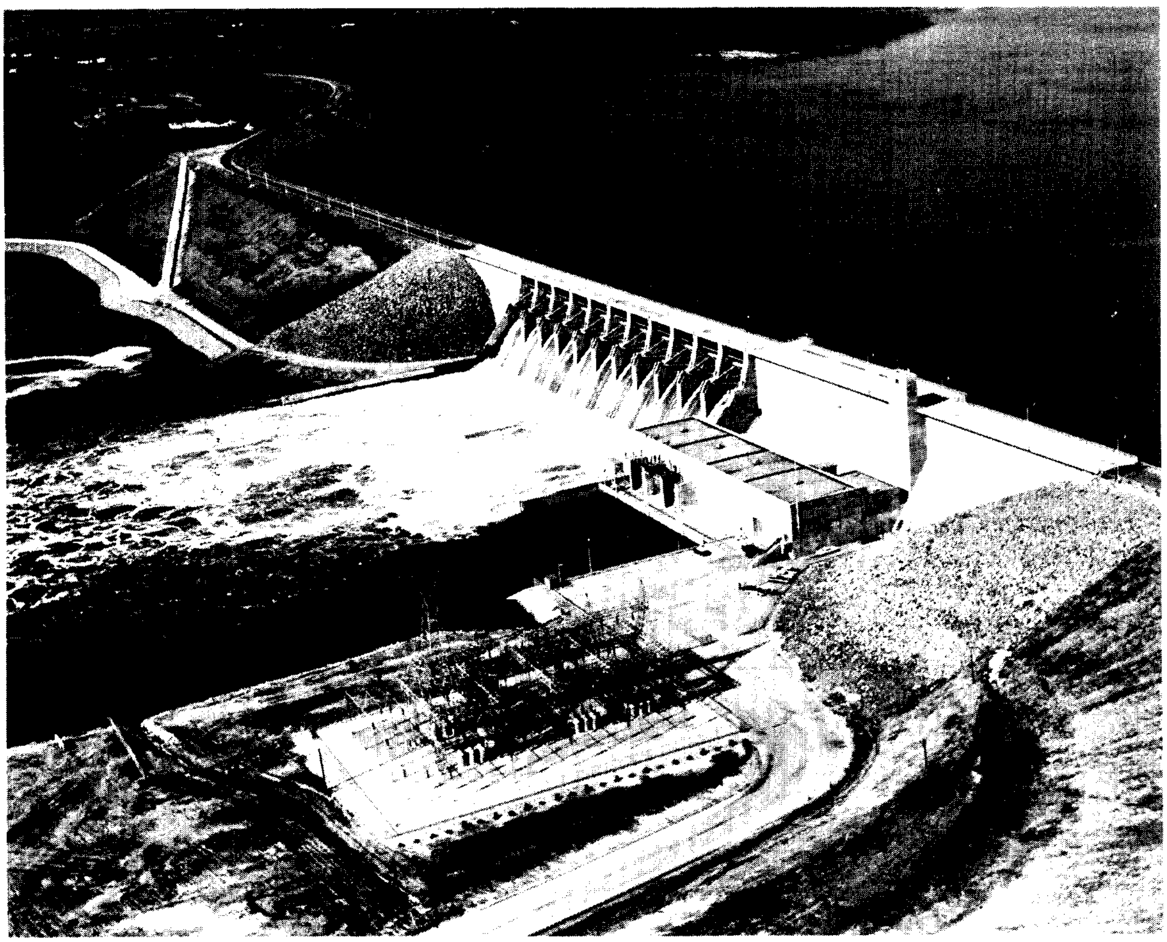

Figure 8-4. Eufaula Dam and Lake (Tulsa District)