



Small scale hydropower design optimization and analysis of hydrologic sensitivity
by David Alan Peterson

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering

Montana State University

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Abstract:

A method by which the hydraulic design of small scale hydropower facilities can be economically optimized and tested for sensitivity to hydrologic prediction has been developed. The method is based on computer modeling of the annual operation of various hydraulic designs for a given flow-duration curve. The optimum design is chosen on the basis of economic rate of return. Economic sensitivity of the optimum design to inaccuracies in hydrologic prediction is analyzed by altering the predicted flow-duration curve by varying degrees and monitoring the project's rate of return.

Three hypothetical project sites representing high, medium, and low head types of development were analyzed using the design method. A flow-duration curve prediction procedure, developed specifically for the geographic region containing the three sites, served as the source of flow data.

The results of the three sensitivity analyses provided both illustration of the method and a basis by which conclusions regarding choice of design from a hydrologic sensitivity and risk mitigation standpoint could be drawn.

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OPTIMIZATION AND ANALYSIS.
OF HYDROLOGIC SENSITIVITY

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APPROVAL

of a thesis submitted by

David Alan Peterson

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ABSTRACT

A method by which the hydraulic design of small scale hydropower facilities can be economically optimized and tested for sensitivity to hydrologic prediction has been developed. The method is based on computer modeling of the annual operation of various hydraulic designs for a given flow-duration curve. The optimum design is chosen on the basis of economic rate of return. Economic sensitivity of the optimum design to inaccuracies in hydrologic prediction is analyzed by altering the predicted flow-duration curve by varying degrees and monitoring the project's rate of return.

Three hypothetical project sites representing high, medium, and low head types of development were analyzed using the design method. A flow-duration curve prediction procedure, developed specifically for the geographic region containing the three sites, served as the source of flow data.

The results of the three sensitivity analyses provided both illustration of the method and a basis by which conclusions regarding choice of design from a hydrologic sensitivity and risk mitigation standpoint could be drawn.

CHAPTER 1

INTRODUCTION

With the passage of the Public Utility Regulatory Policies Act (PURPA) in 1978, potential small hydropower developers began a race to secure permits on the developable streams of the United States that has been deemed by some to be the Gold Rush of the 80's. Until the passing of this act, small scale hydropower (less than 5MW) was seldom considered an economical manner of power production in this country, lending itself useful only in cases of extreme isolation. PURPA, however, stipulated that power companies were required to purchase renewable energy at a price consistent with the price necessary to recover the cost of building new power plants (avoided cost). In addition, the Federal Government provided for an 11 percent tax credit on qualifying alternative energy projects, to be credited in addition to the standard 10 percent investment tax credit. In response to these financial incentives, a new industry has been introduced which is centered around commercial power generation by the private sector.

This type of power generation brings with it some unique problems in terms of engineering analysis and design. In contrast to traditional power developments of past decades, small scale projects are being proposed for locations representing diverse and often highly variable physical and hydrologic conditions - a situation often compounded by a chronic lack of climatic, streamflow and soil test data. In addition, small scale projects are heavily impacted by a variety of state and federal requirements (highly variable from state to state) for permitting and licensing. Negotiation of a power sales agreement with the local utility company likewise adds uncertainty to the ultimate success of proposed projects. These and other factors require that small scale hydroelectric projects be analyzed and designed with a high degree of sensitivity to site specific conditions.

Design

At present there are no design standards for small hydropower facilities, nor is engineering review required for licensing by the Federal Energy Regulatory Commission (F.E.R.C.) Thus any review of project design that occurs is accomplished by the various state and Federal agencies involved in the permitting process. Such agencies include the Montana Department of Fish, Wildlife and Parks, Army Corps of Engineers, Forest Service, Montana Department of Natural Resources and Conservation, and the power company with which the plant will do

business. Aside from staying within the guidelines and constraints set by these governing agencies and others,² the design process is rather arbitrary.

A good comprehensive summary of design and construction procedures is given by Ott⁹ for all of the major components of a small hydropower plant. Specific details on small dams can be found in Design of Small Dams.¹⁴ Valuable input to the design of the powerhouse and pipeline can be obtained from equipment manufacturers. In addition to these sources of information on design, several demonstration projects funded by the Department of Energy (D.O.E.) include blueprints and associated data that can be helpful in selecting a design for a future project.

Design Optimization

Review of the literature associated with design reveals a large void concerning the concept of design optimization. Several sources deal with optimization of design for large hydropower plants at regulated dams with accurate, long-term flow records,^{1,4,6} but none adequately discuss the case of a small run-of-the-river power plant proposed at a previously ungaged, unregulated site. In addition to the problems posed by

² Superscripts refer to references listed in the "References Cited" section of this report.

inadequate flow records, very little information is currently available concerning such things as guidelines for location of diversion and powerhouse structures and sizing of project components to provide an optimum design. Optimum design, in this case, refers to that particular combination of project components which results in the maximum economic rate of return to the developer.

Design Sensitivity

The major problem associated with engineering analysis and design of installations of this type is prediction of a valid flow regime for the site. Annual hydrographs and flow-duration curves represent the foundation for virtually all major design decisions. Because of this, it is very important to assess the degree of economic sensitivity for various types of small hydro projects to variations in the predicted flow regime used in project design.

Statement of Objectives

It is the purpose of this thesis to develop a method by which the hydraulic design of small hydropower facilities can be economically optimized and then tested for sensitivity to variations in hydrologic prediction. Specifically, this method should provide a means by which the pertinent project components(i.e. intake, pipeline(s), turbine, tailrace) can be

chosen so as to provide the optimal economic rate of return for the project. Also, three site examples will be analyzed for sensitivity to inaccuracies of flow-duration curve prediction as a means of illustrating the procedures outlined.

The method and concepts discussed in the following chapters will provide a developer with the most economical design among the alternatives considered for the site in question and give an indication as to the degree of risk associated with implementation of the design.

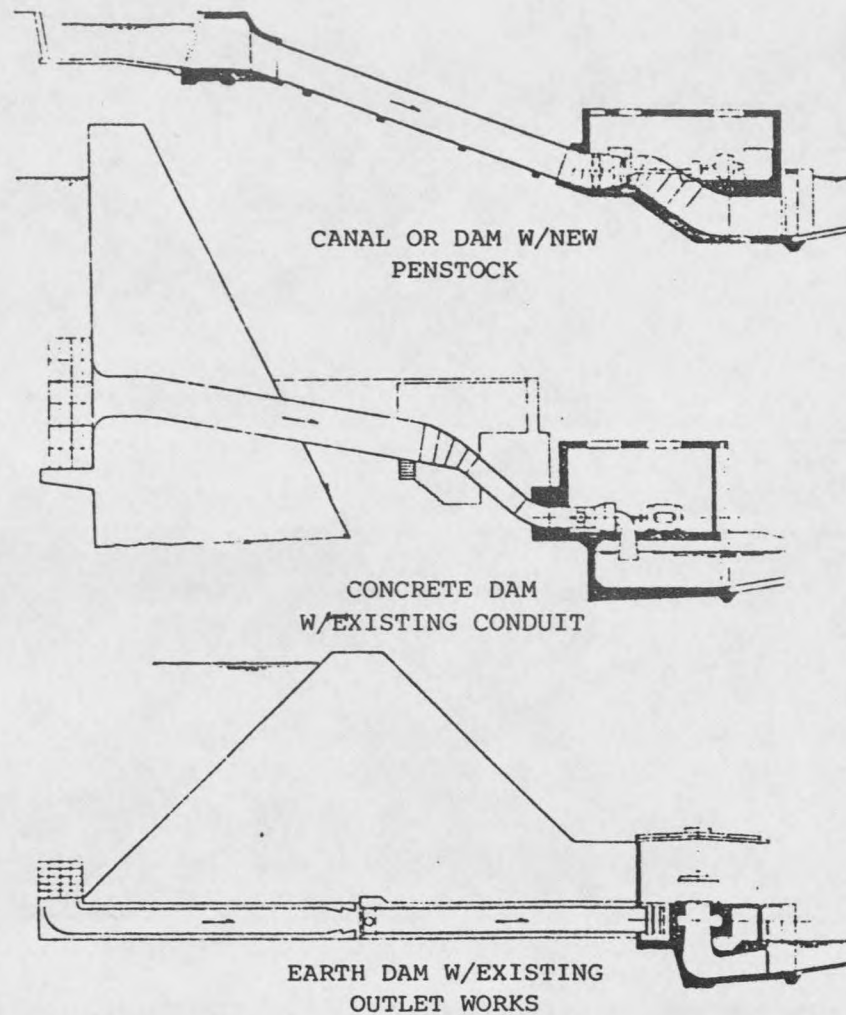
CHAPTER 2

PROJECT LAYOUT

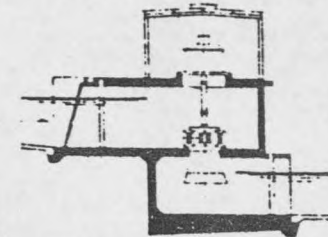
In general, three main types of hydroelectric installations exist: low head, medium head, and high head. In its most general usage, the term head refers to the gross head of a facility, that is, the difference in elevation between the water surfaces at the intake and tailrace. The breakpoint between low and medium head is usually defined as 20 m (66 ft.).⁹ No such clear breakpoint exists between medium and high head sites, but most sources refer to a breakpoint in the vicinity of 122 m (400 ft.).⁹ All three types of projects share the same basic set of components: an intake structure, a conveyance system for efficient delivery of water to the turbine, and a turbine-generator unit for removal of the fluid energy. The form that these three basic components take for each type of plant is discussed below.

Low Head

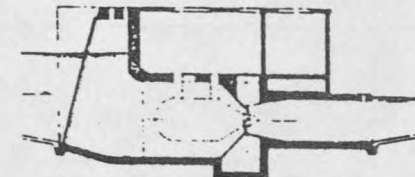
The two main types of low head facilities are canal drop structures and existing small dams. In the case of a canal drop, the intake is formed by damming the upper canal and



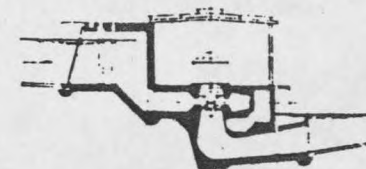
TUBULAR TURBINE



OPEN FLUME TURBINE



BULB TURBINE



PROPELLER TURBINE

POWER PLANTS BUILT AS DAMS

FIGURE 1. TYPICAL LOW-HEAD LAYOUTS
(PERMISSION TO REPRODUCE) 13

diverting water into a pressure conduit, which carries the water downslope a short distance to a powerhouse, then discharges it either into a canal or natural stream (Figure 1). The unique aspects of such a facility center around the frequent lack of environmental constraints such as maintenance of fish habitat, allowance for spring floods, and streambed protection laws. In the case of an existing dam with a low level outlet works intact, a powerhouse can be attached to the outlet works either at the dam or a short distance downstream with minor modifications (Figure 1). An analysis of the safety of the dam and outlet works is required before this type of construction can begin, however, and any weaknesses will have to be rectified before construction can proceed. Such repairs can be costly and often times render the project uneconomical. A third type of low head plant is the open flume type in which a small dam is built to serve as a power plant (Figure 1). This type of plant is best under very low heads where the extent of the required dam structure is small.

Medium and High Head

There is very little difference in the layout of medium and high head small hydropower facilities, so they will be grouped together here. The intake structure of this type of facility is typically a small diversion into a canal or low pressure pipeline. The low pressure conduit or canal carries the water

with a minimum of headloss along a contour to a surge tank. The high pressure penstock carries the water from the surge tank to the powerhouse, and must withstand both static and waterhammer pressures.

The design of the intake structure must take into consideration fish protection both at the intake and below the overflow structure, flood protection, debris protection, and sediment passage. The low pressure conduit or canal must be designed to minimize risk from avalanche, landslide, freeze, sedimentation, linear expansion, and vandalism. The surge tank is located as near to the powerhouse as possible to minimize water hammer transients caused by sudden changes in turbine gate opening. It must be built with its top at least equal in elevation to the water surface at the diversion and its bottom low enough in elevation to maintain submergence of both inlet and outlet during high flow. Any overflow during a surge must be correctly channeled to the main stream. Special consideration in high pressure penstock design must be given to transfer of forces from the penstock to the ground through thrust blocks or burial. In cases of a relatively short distance from diversion to powerhouse, it may be acceptable to run the high pressure pipeline directly from the diversion to the powerhouse without a surge tank. This arrangement is highly susceptible to damage from high surges and unstable transients due to changes in valve setting.

The powerhouse represents the major difference between high and medium head installations for the purposes of this paper. Medium head plants utilize reaction turbines which operate on a pressure difference across the blades, and high head plants use impulse turbines which operate on a change in momentum of a free jet of water. All other aspects of high and medium head sites are the same.

CHAPTER 3

HYDROLOGIC SIMULATION

At the heart of the problem of designing a small hydropower plant at an ungaged location is the lack of information describing the magnitude and time variation of streamflows. Even if stream gaging commences at the conception of a project, data requirements necessary for preliminary design, feasibility analysis, and permitting dictate a need for generation of synthetic flow data. The form that synthetic flow data assumes depends on the availability of methodologies and preference of the engineer performing the study. The two most useful means for expressing flow data for run-of-the-river hydropower installations are the annual hydrograph and the flow-duration curve.

Annual hydrograph synthesis usually involves correlation of the daily streamflows at the site in question with daily streamflows at a nearby gaged basin using either a ratio of drainage areas or area weighted average annual precipitation volumes. The long term "typical" annual hydrograph can be formed by multiplying the daily flows by the ratio of the long

term mean annual flow to the mean annual flow of the year used at the gaged site. One major problem with this method is its short term nature. The year used to generate the annual hydrograph may exhibit non-typical characteristics, such as low spring runoff and high baseflow, or abnormally high spring floods and low baseflow. Long-term simulation under these conditions could possibly yield inaccurate results.

Flow-duration (F-D) curve prediction at the site in question is generally accomplished by a correlation procedure similar to that used to produce a synthetic annual hydrograph, but with F-D curve ordinates substituted for daily flows. Since the gaged flow-duration curves are formed using all historical data, long term variation can be accounted for. In addition, the ease of usage of the finished product for design and economic simulation is attractive to hydropower analysts. For these reasons, the F-D curve was chosen for usage in this thesis.

Methodologies for synthesizing flow-duration curves at ungaged locations have been developed for different geographic regions by various authors.^{3,5}

The flow-duration curve prediction procedure for ungaged mountainous and high plains streams in Montana³ was used to

synthesize flow-duration curves for all three sites investigated in this thesis. The procedure is summarized as follows:

1. Obtain the weighted mean annual basin precipitation by weighting annual precipitation isohyetal values by their areas of influence.
2. Estimate the average annual runoff from the mean annual precipitation obtained in step 1 using Figure 2 and convert average annual runoff to average annual streamflow using the equation:

$$Q_{AA} = (A)(\text{Runoff})(.0737) \quad \text{Where: } Q_{AA} = \text{Average Annual Flow (cfs)}$$

A = Drainage Area
(sq. mi.)

Runoff = Average Annual
Runoff (in/yr.)

.0737 = Units Conversion
Factor

3. Compute the 10% exceedence flow using the equation:

$$Q_{10} = (Q_{AA})(3.056) \quad \text{Where: } Q_{AA} = \text{Average Annual Flow (cfs)}$$

Q_{10} = 10% Exceedence
Flow (cfs)

3.056 = Empirical coefficient based
on existing
streamflow
records.

4. Select a dimensionless flow-duration curve from within the band of Figure 3. The band was formed by the union of the dimensionless F-D curves of selected U.S. Geological Survey (U.S.G.S.) stream gages in Montana. The selected gages were devoid of large springs, diversions, and regulation in their drainage basins. The vertical position of the curve within the band is selected from judgement of the magnitude of the baseflow end of the F-D curve relative to the gages used to form the band. For example, a small, narrow, steep, rocky drainage basin with fast time of concentration and low groundwater storage would most likely plot near the bottom curve (low position), and a large, wide, flat basin with deep soil and a slow concentration time would most likely plot near the top curve (high position).

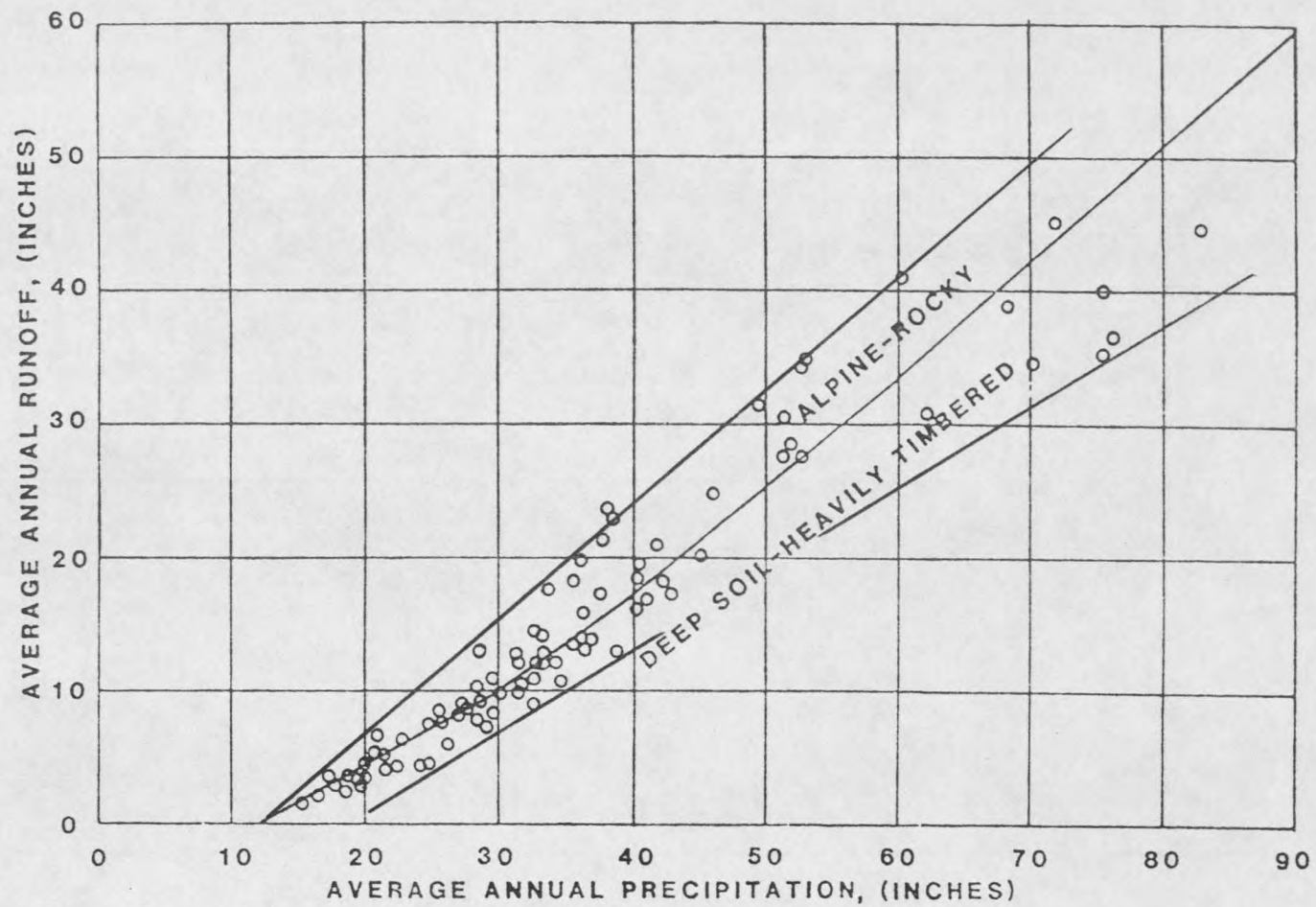


FIGURE 2. PRECIPITATION VS. RUNOFF
(PERMISSION TO REPRODUCE)²

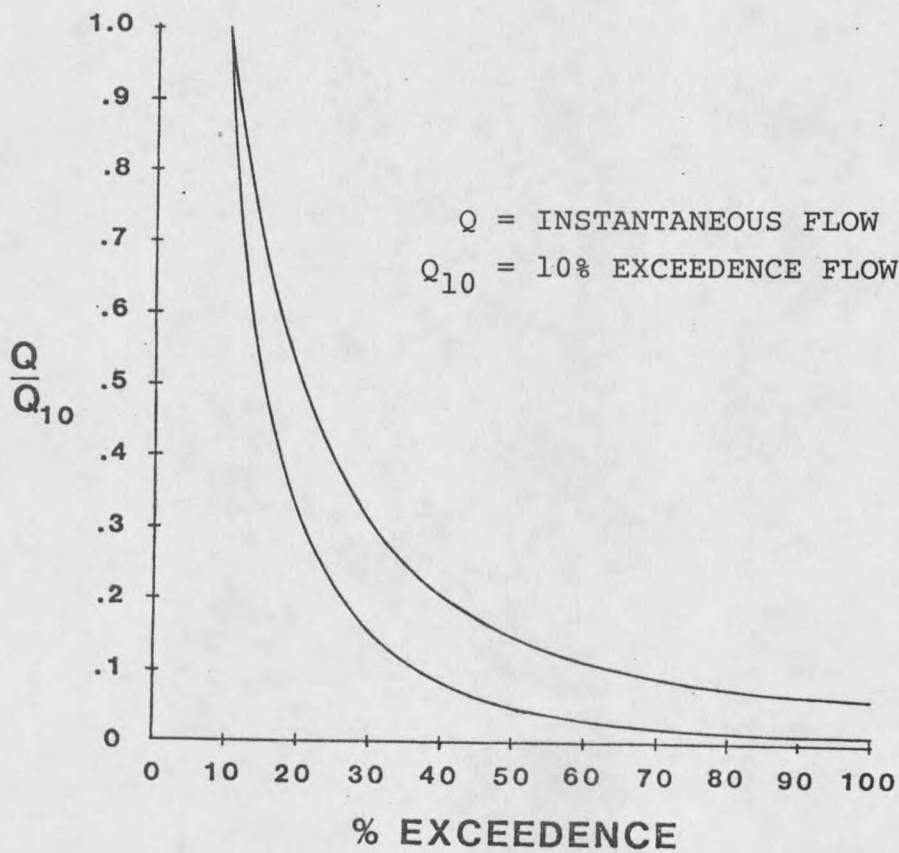


FIGURE 3. DIMENSIONLESS FLOW-DURATION CURVE
BAND - MONTANA STREAMS
(PERMISSION TO REPRODUCE)³

The curve synthesized for the area in question contains a degree of uncertainty because of the difficulty in assessing the hydrologic similarity between the basins used in the prediction. Any flow measurements at the site, when incorporated into the predicted F-D curve, will decrease the amount of risk associated with the synthesized F-D curve. Since long term flow records will probably not be obtained prior to final design of the project, some risk of inaccurate flow forecasts will still be present. It is necessary to identify the sources of uncertainty in the prediction procedure and to assess the consequences of inaccurate flow-duration curve prediction.

CHAPTER 4

HYDRAULICS

Small scale hydropower facility design utilizes the concepts of both open channel and closed conduit flow. The open channel flow concepts apply at the intake and outlet sections of the power plant. In addition, open channel principles apply to the diversion canal when used instead of a low pressure conduit. Closed conduit analysis applies to the penstock, draft tube and turbine. At the intake structure, the water surface elevation is dependent on the combined spillway flow and power plant diversion. In high and medium head systems where a small diversion structure forms the intake, operation of the turbine valving mechanism is such that the water surface elevation in the impoundment is held constant. This provides accurate minimum flow over a weir or other measuring device for maintenance of minimum fish requirements. At flows greater than the turbine maximum, the headwater elevation rises in accordance with the spillway rating curve. The low head system operates in much the same manner except in situations where storage exists and releases do not follow the reservoir inflow pattern.

In these cases the upstream elevation may fall far below the spillway crest. At the outlet of all types of plants, the tailwater elevation varies with the total streamflow, so the total gross head available at any given time depends on the hydraulic design and the stream flow. In cases of high and medium head design, the variation in gross head may be insignificant and hence neglected in hydraulic computations, simplifying computations greatly. The effects of headwater and tailwater elevation changes must be accounted for in the final design of the intake structure and powerhouse so that flood damage, turbine cavitation, and inadequate submergence of the intake are avoided.

The closed conduit portion of the power plant is analyzed using the energy equation written between the two free water surfaces:

$$\Delta z = h_e + V_2^2/(2g) + \Sigma h_{LP} + \Sigma h_{LM}$$

Where: Δz = Gross Head(ft)

h_e = Effective Head
Removed by
Turbine

V_2 = Draft Tube
Exit Velocity
(f/s)

g = Gravitational
Acceleration
(f/s/s)

h_{LP} = Pipe Friction
Losses (ft)

h_{LM} = Minor Losses
(ft)

It should be noted that effective head (h_e), is defined as the gross head minus the sum of all head losses in the system, excluding those in the turbine manufacturer's definition of efficiency. For steady state conditions, the hydraulic grade line exhibits a configuration as illustrated by Figure 4. The efficiency of the turbine is a measure of how well the effective head is removed. The efficiency varies with the flow rate due to the changing incidence angles of the streamlines to the guide vanes, valves, and turbine blades in a reaction turbine, and the variable jet velocity in an impulse turbine. In addition,

varying efficiency is the result of variable head losses through the turbine manufacturer-supplied parts and the variable rotational speed when attached to an induction generator. The head losses accredited to turbine efficiency are all those between the upstream connection to turbine-supplied machinery and either a point just inside the draft tube as specified by the International Electrotechnical Commission (I.E.C.) Code or the equivalent still water surface after exit from the draft tube as specified by the American Society of Mechanical Engineers (A.S.M.E.) Code.¹⁰ Turbines classified by the I.E.C. Code, therefore, will have higher efficiencies than those classified by the A.S.M.E. Code. The efficiency curves for different types of turbines are unique, but vary only slightly among manufacturers. For purposes of preliminary design and analysis, general efficiency curves based on proportions of design flow (at which peak efficiency occurs) can be used (Figure 5).

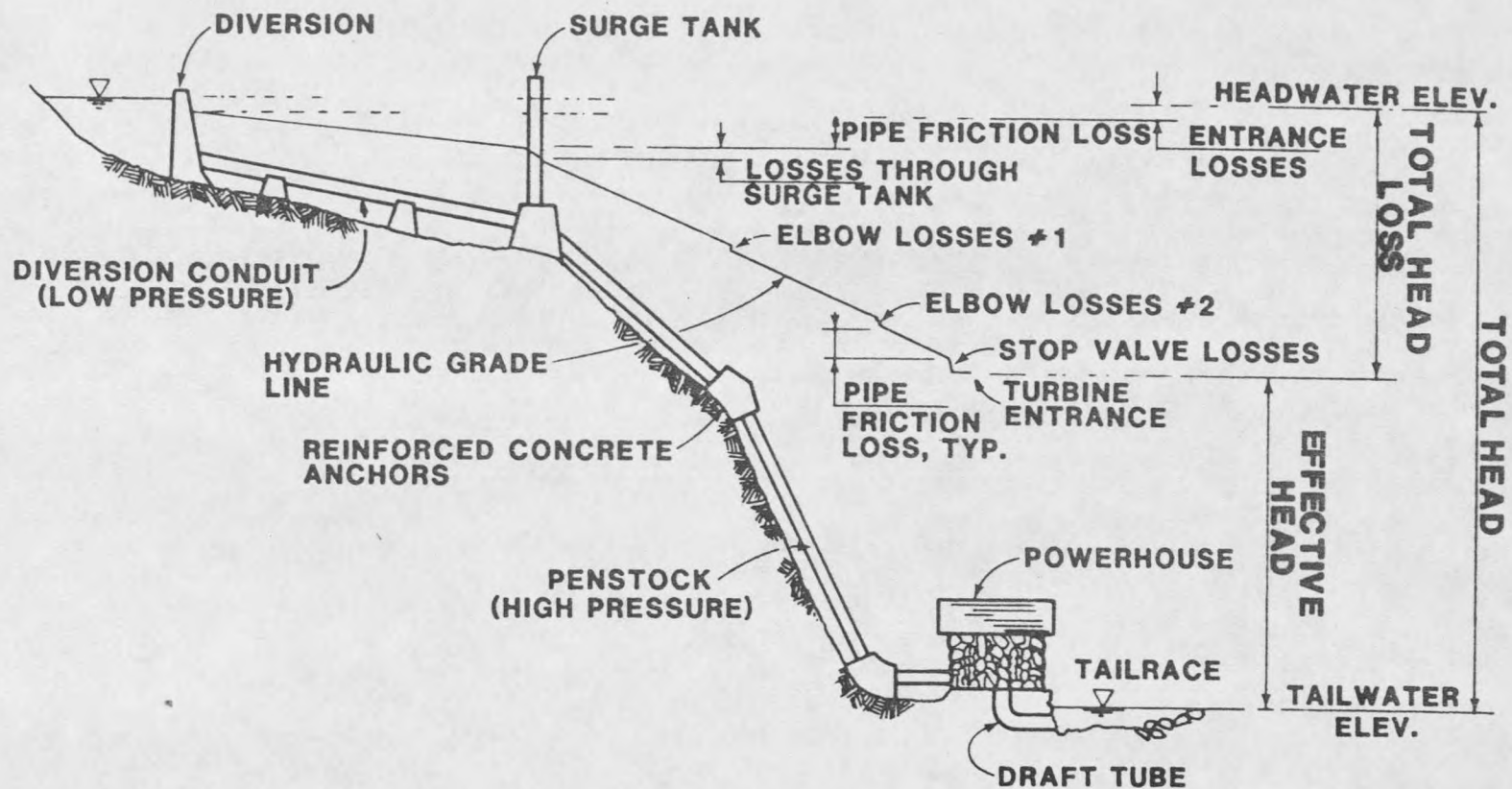


FIGURE 4. EFFECTIVE HEAD DEFINITION 9
(PERMISSION TO REPRODUCE)

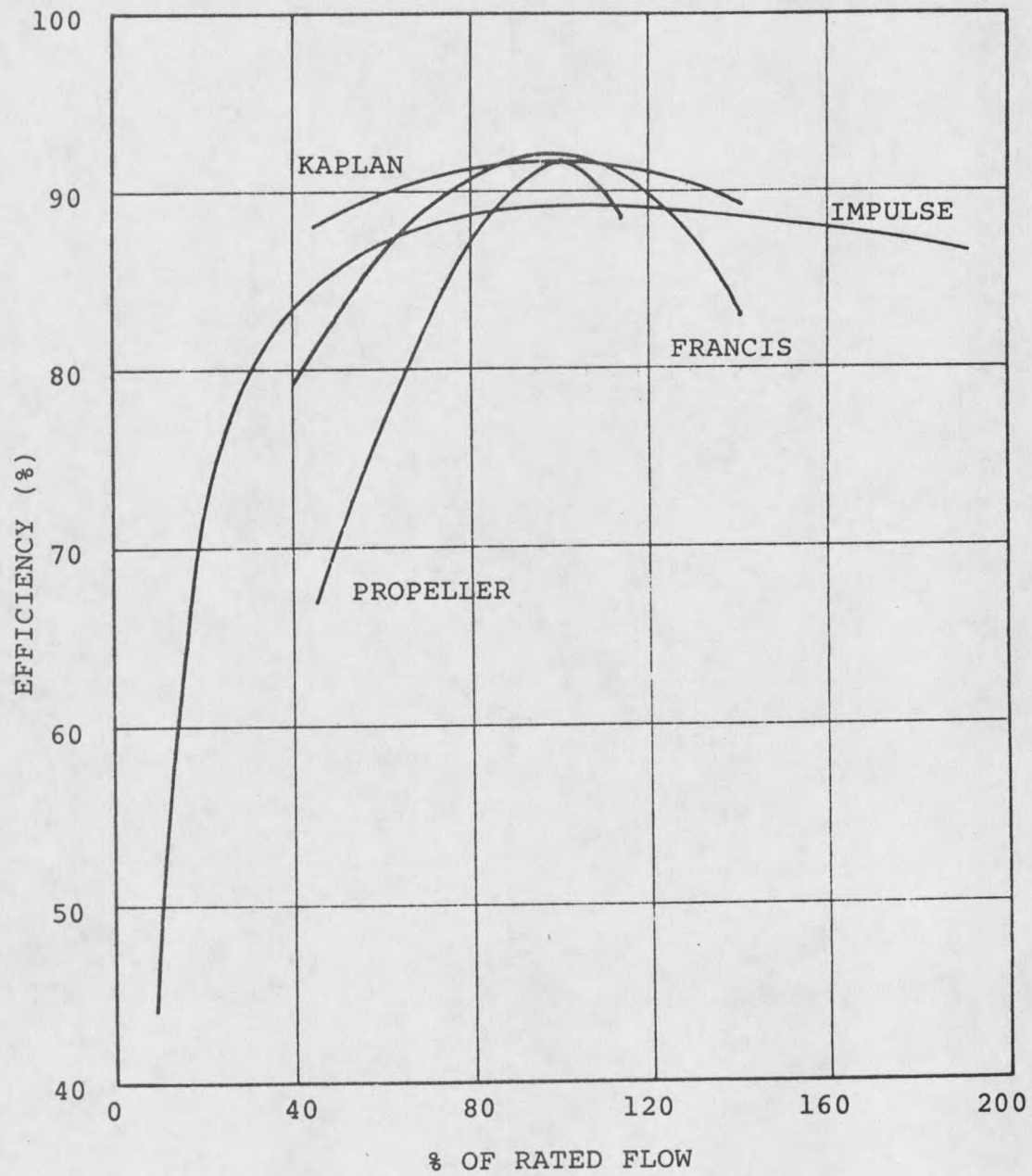


FIGURE 5. GENERAL EFFICIENCY CURVES

The power generated for a given set of conditions is the product of the flow rate through the turbine, effective head, turbine, generator, speed increaser, and transformer efficiencies, and the specific weight of the fluid. Due to the curved nature of the headloss equations and efficiency curves, an increase in flow through the turbine may not always correspond to an increase in power. In fact, for some systems it may not be advantageous to open the gates to full opening (see Site Examples, Chapter 8). The limits of operation of a turbine can be specified either in terms of effective head variation or flow rate variation, and tend to be turbine type-specific, much like efficiency curves. These limits as given by references 1, 2, 4, 6, 7, 9, 12 and 15 are summarized in Table 1, in which Q_D = design flow, h_D = design effective head, Q = flow rate, and h_e = effective head.

Table 1. Turbine Head and Flow Limits

Turbine Type	Limits	
	Flow	Effective Head
Impulse	$0.1Q_D \leq Q \leq 1.9Q_D$	$0.3h_D \leq h_e \leq \infty$
Francis	$0.4Q_D \leq Q \leq 1.4Q_D$	$0.65h_D \leq h_e \leq 1.25h_D$
Kaplan	$0.45Q_D \leq Q \leq 1.42Q_D$	$0.5h_D \leq h_e \leq 1.5h_D$
Propeller	$0.45Q_D \leq Q \leq 1.13Q_D$	$0.5h_D \leq h_e \leq 1.5h_D$

The low head limit in Table 1 is the minimum effective head at which it is possible to turn the turbine at the synchronous speed of the generator, and corresponds to the maximum flow condition through the turbine. This limit is only approached in cases where high tailwater decreases gross head appreciably, which forces the gates to open to the maximum in order to keep the turbine at synchronous speed. The high head constraint corresponds to minimum flow through the turbine. This condition is reached when the wicket gates in a reaction turbine cannot cause the flow to spiral enough to avoid cavitation at the backs of the wicket gates and turbine blades. It also occurs when the free jet velocity in an impulse turbine becomes so high as to cause cavitation in the needle valve, the backs of the buckets, and in the bottom of the buckets.

CHAPTER 5

INTERACTION OF HYDROLOGY AND HYDRAULICS- DESIGN

Having described the hydraulics of small hydropower facilities, it remains to apply the annual variation in streamflow to the process of hydraulic design such that economic returns will be maximized. The chief design variables that alter plant operating characteristics are: location and configuration of intake and tailrace; pipe types, lengths, and diameters; number and types of minor loss elements; and the type of turbine. Finding the best combination of these elements for a given flow-duration curve requires an iterative procedure in which the overall project rate of return is used as the means of comparison.

Choosing Intake and Tailrace Locations

The locations of intake and tailrace may be set by legal and institutional constraints such as water rights and land ownership. In the absence of such constraints, however, choice of these locations becomes a major design variable which has a considerable impact on project economics. Where several logical

locations for diversions and powerhouses exist, all combinations should be tried. In this case, logical locations for diversions are at existing structures and points immediately below tributary entrances, preferably near slope breaks at the top of steep sections. Clearly, a trade-off exists between moving the diversion point up the stream to gain more gross head, and reduced drainage area, longer pipeline, change of pipeline route, change in diversion structure requirements, change in in-stream flow requirements, change in road length, and harsher climate. The same type of trade-off exists for locating the powerhouse, with the exception of decreased powerline cost as the powerhouse is moved downstream. Logical locations include slope breaks to more gradual slope, and flat areas where construction costs and high flood levels are minimized. In addition to the tradeoffs mentioned, increasing the gross head by separating the diversion and powerhouse further could introduce the need for a surge tank and more complicated valving procedures to avoid transient surge problems inherent in long pipelines.

Choosing Pipeline Sizes

Once the diversion and powerhouse location options have been chosen, tentative pipeline routes can be noted and lengths measured. In some cases it may be desirable to examine systems with and without surge tanks. Pipe diameters can be chosen as

those near the diameter that produces a velocity of 8 f.p.s. (for water hammer considerations) at a preliminary design flow equal to the flow which is equalled or exceeded 25 percent of the year (25 percent exceedence flow). As will be shown later, this rule of thumb is consistent with the results of this study.

Choosing Turbine Type

The type of turbine required at a site can be found by entering any manufacturer's turbine selection chart such as the one in Figure 6 with the preliminary design flow of the 25 percent exceedence flow and the effective head at that flow. In this case, all combinations of gross head, 25 percent exceedence flow, and the various pipe options should be examined.

Determining the Turbine Design Condition

For each option, a unique turbine design condition of flow and effective head will produce the maximum annual energy output from the plant. The object is to size the turbine to produce power over the widest range of flows and effective heads. This is accomplished by setting the design head, that is, the effective head at which maximum efficiency occurs, equal to the weighted mean effective head.^{4,10} Here, the weighted mean effective head is computed by integrating the effective head duration curve, derived from the F-D curve and the energy equation, over the limits of operation. The design flow, then, will be the flow rate through the turbine corresponding to the design head.

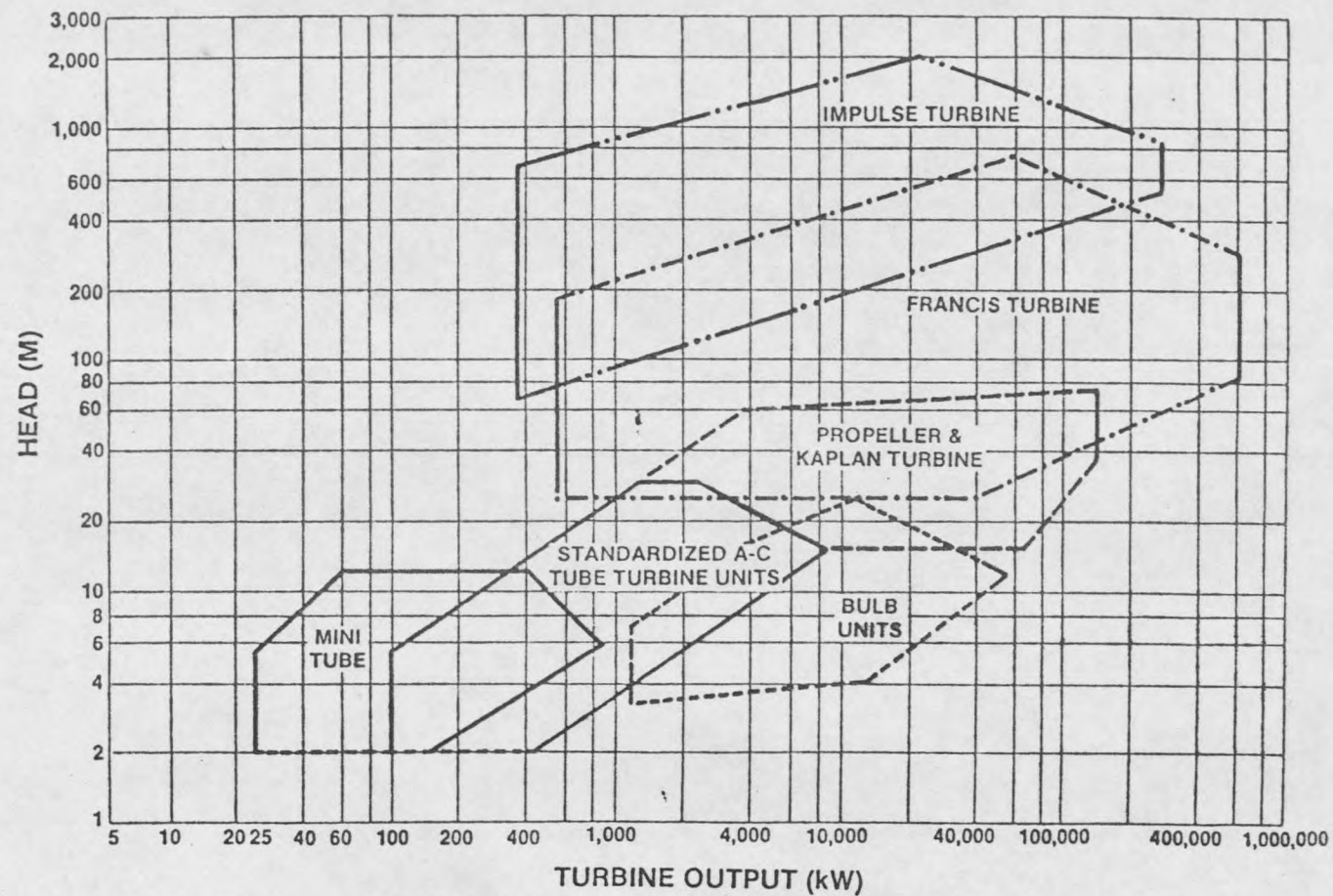


FIGURE 6. TURBINE TYPE SELECTION CHART
(PERMISSION TO REPRODUCE GRANTED BY ALLIS CHALMERS CO.)

CHAPTER 6

ECONOMIC ANALYSIS

Once the design condition has been determined for each alternative, a numerical integration of power over time can be performed from the system equations and flow duration curve over the turbine flow range, to yield average annual energy output, maximum instantaneous power, and capacity factor for each alternative.² Selection of optimum design cannot yet be made on this basis, however, as plant costs will also vary with plant size. In order to determine the relationship between increased output and increased costs, a thorough economic evaluation must be made of each alternative such that objective comparison can be made. This evaluation must include such items as financing, state income and property tax, federal income tax, operation and maintenance costs, project life, inflation, power costs and escalation rates. Final comparison can be made with any economic indicator preferred by the analyst such as benefit/cost ratio or rate of return. This section will discuss the main topics required for an adequate economic analysis. This material should only be considered a basis for forecasting and comparison as the scope of each discussion is limited to general terms.

Estimation of Costs

Paramount to the accuracy of comparison in any economic analysis is the estimation of costs. In order for this to be done adequately, a great deal of time must be spent on preliminary design of all components of each design alternative so that differences in construction requirements can be noted. For example, an increase in the size of hydraulic components for greater maximum power output may, in addition to increasing hydraulic component costs, require a more substantial powerhouse foundation, larger crane structure, larger floor plan, more stringent pipeline burial requirements, and a deeper diversion impoundment for adequate submergence.

As an alternative to this laborious and costly study, it may be preferable to eliminate several alternatives by conducting economic analyses using cost estimation curves such as those published by Ott⁹ and Tudor¹³ (Figures 7-17) for the various major project components. While these curves are not necessarily accurate in an absolute sense, they do show trends that can be valuable for comparison of design alternatives.

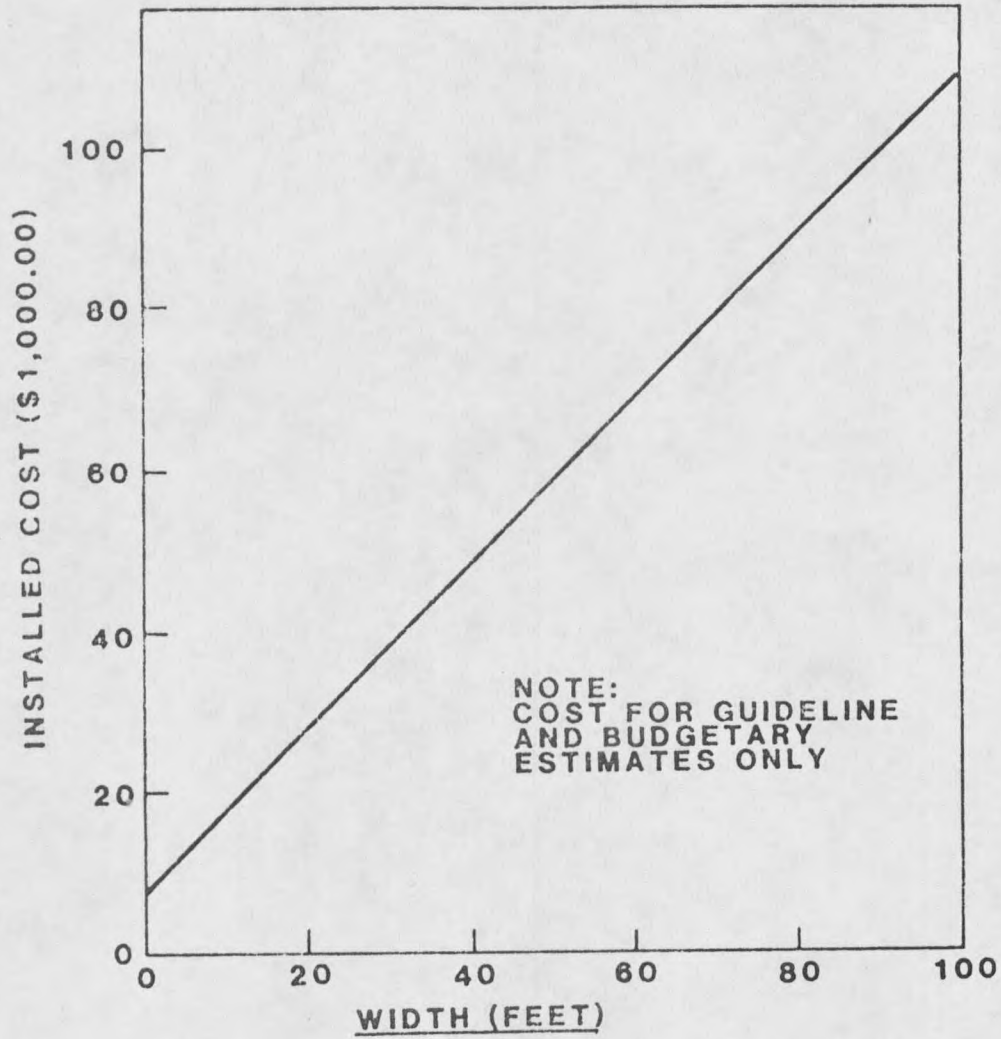


FIGURE 7. DIVERSION STRUCTURE
(INSTALLED COST)
(PERMISSION TO REPRODUCE)⁹

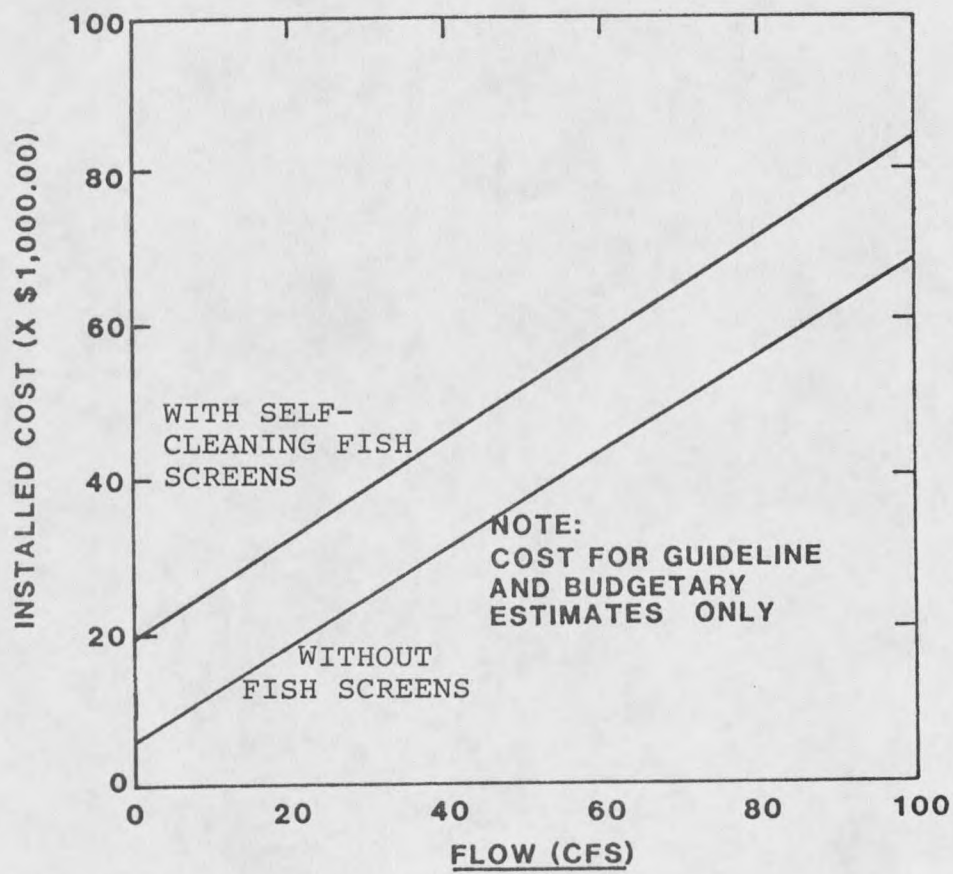


FIGURE 8. INTAKE STRUCTURE
(INSTALLED COST)
(PERMISSION TO REPRODUCE)⁹

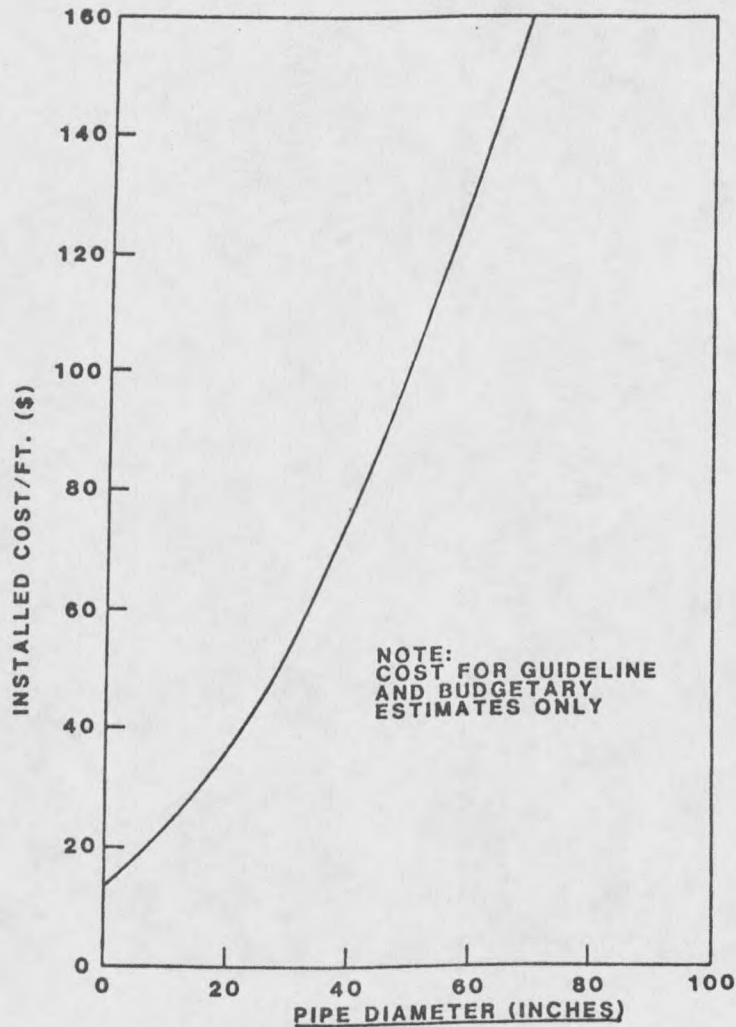


FIGURE 9. LOW-PRESSURE PIPELINE
(INSTALLED COST)
(PERMISSION TO REPRODUCE)⁹

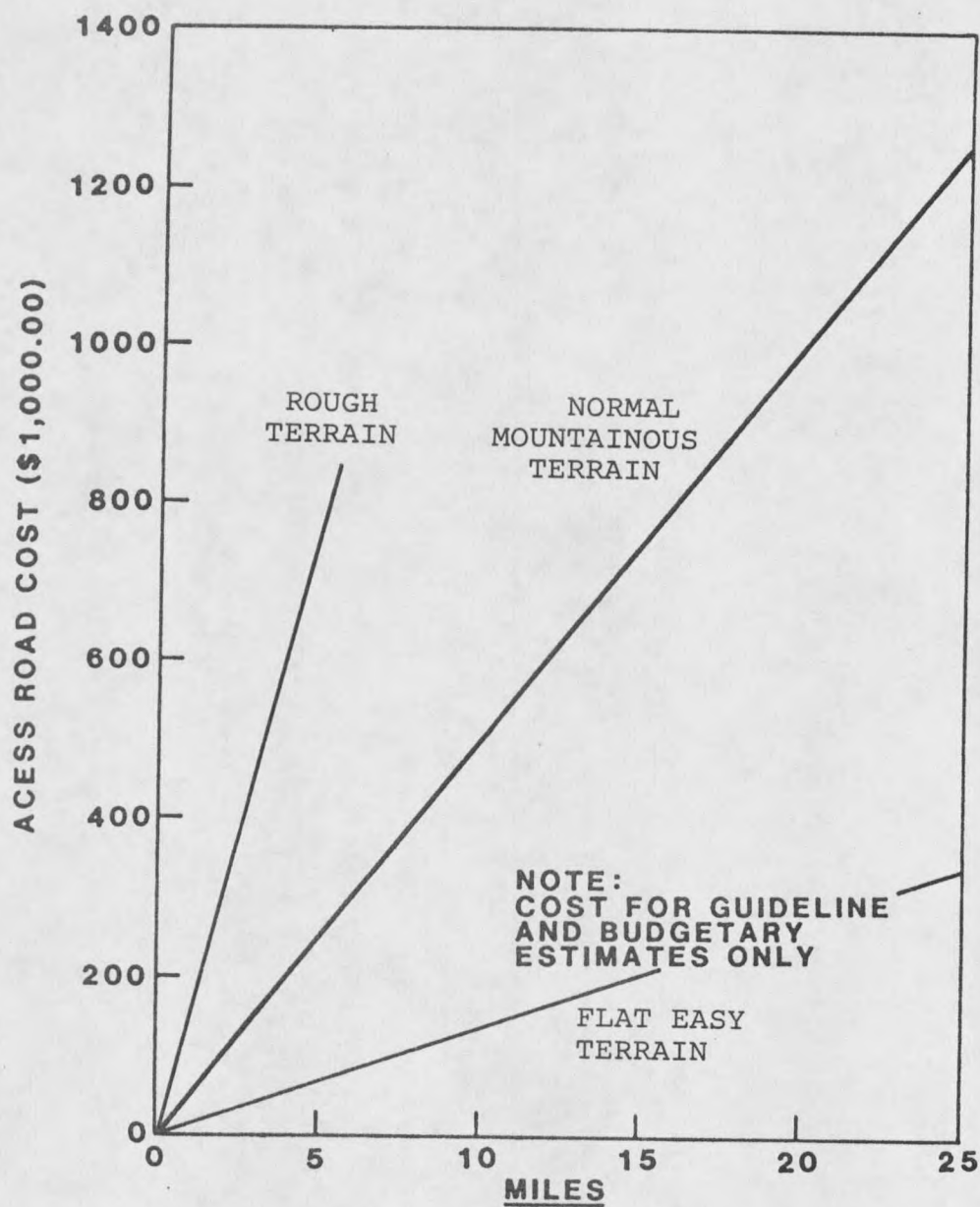


FIGURE 10. ACCESS ROAD (INSTALLED COST),
(PERMISSION TO REPRODUCE)

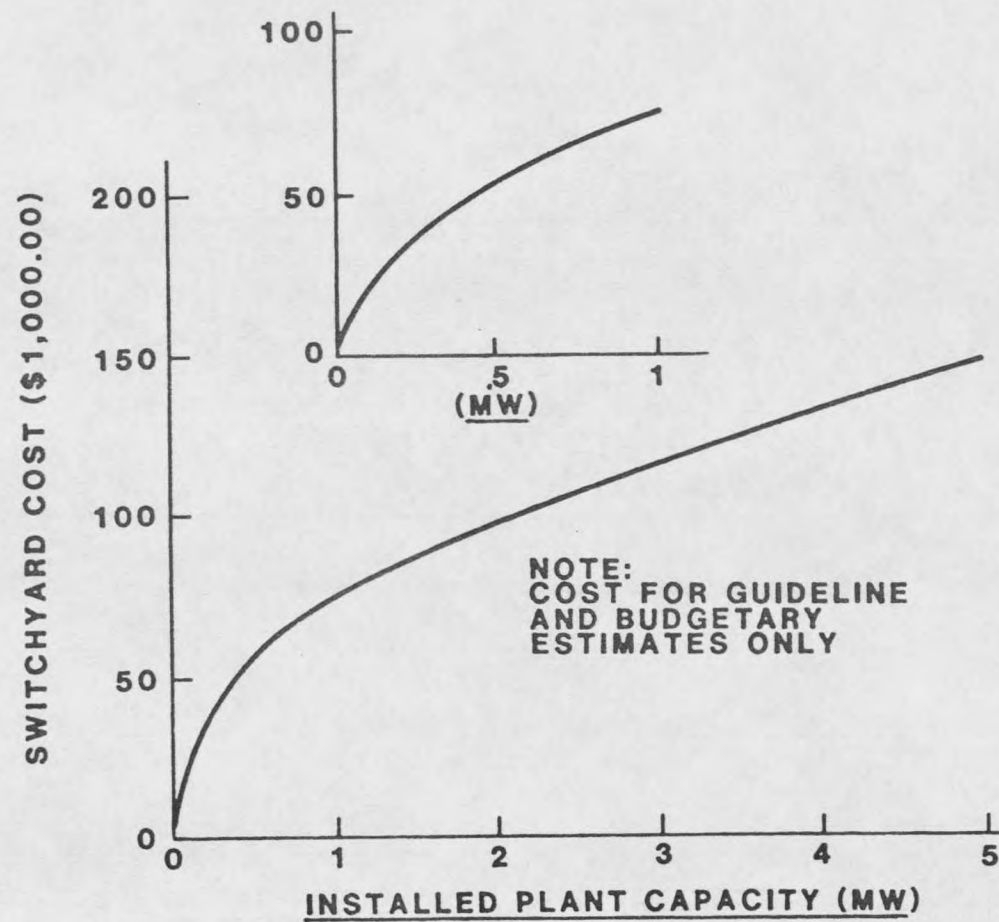


FIGURE 11. SWITCHYARD (INSTALLED COST)₉
(PERMISSION TO REPRODUCE)

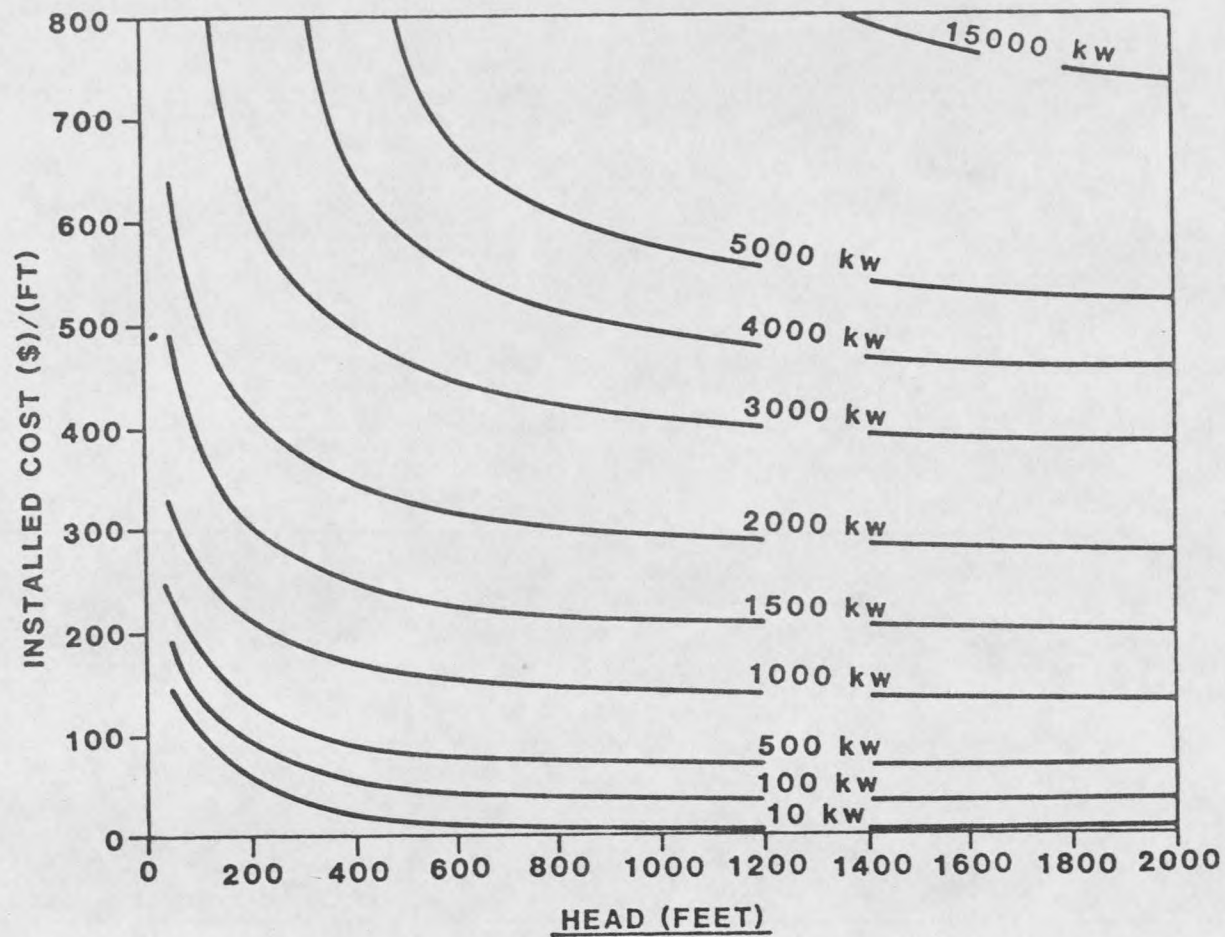


FIGURE 12. HIGH-PRESSURE PENSTOCK (INSTALLED COST)
(PERMISSION TO REPRODUCE) 9

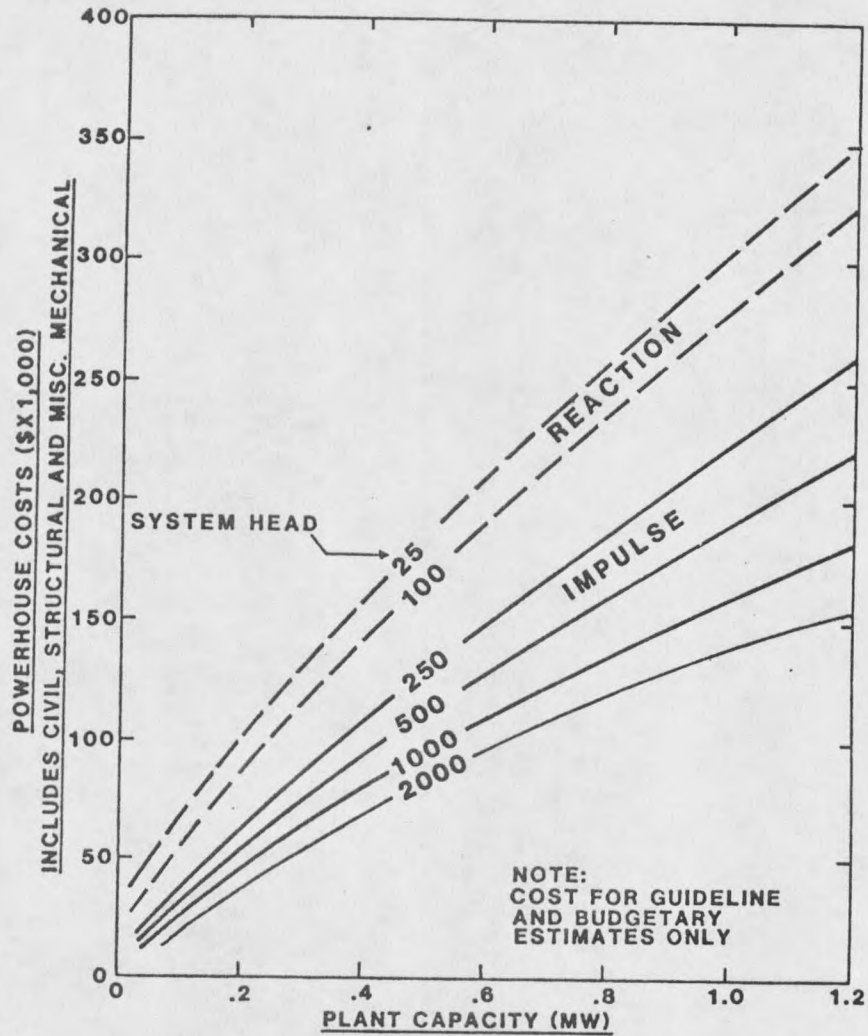


FIGURE 13. POWERHOUSE (INSTALLED COST)₉
(PERMISSION TO REPRODUCE)

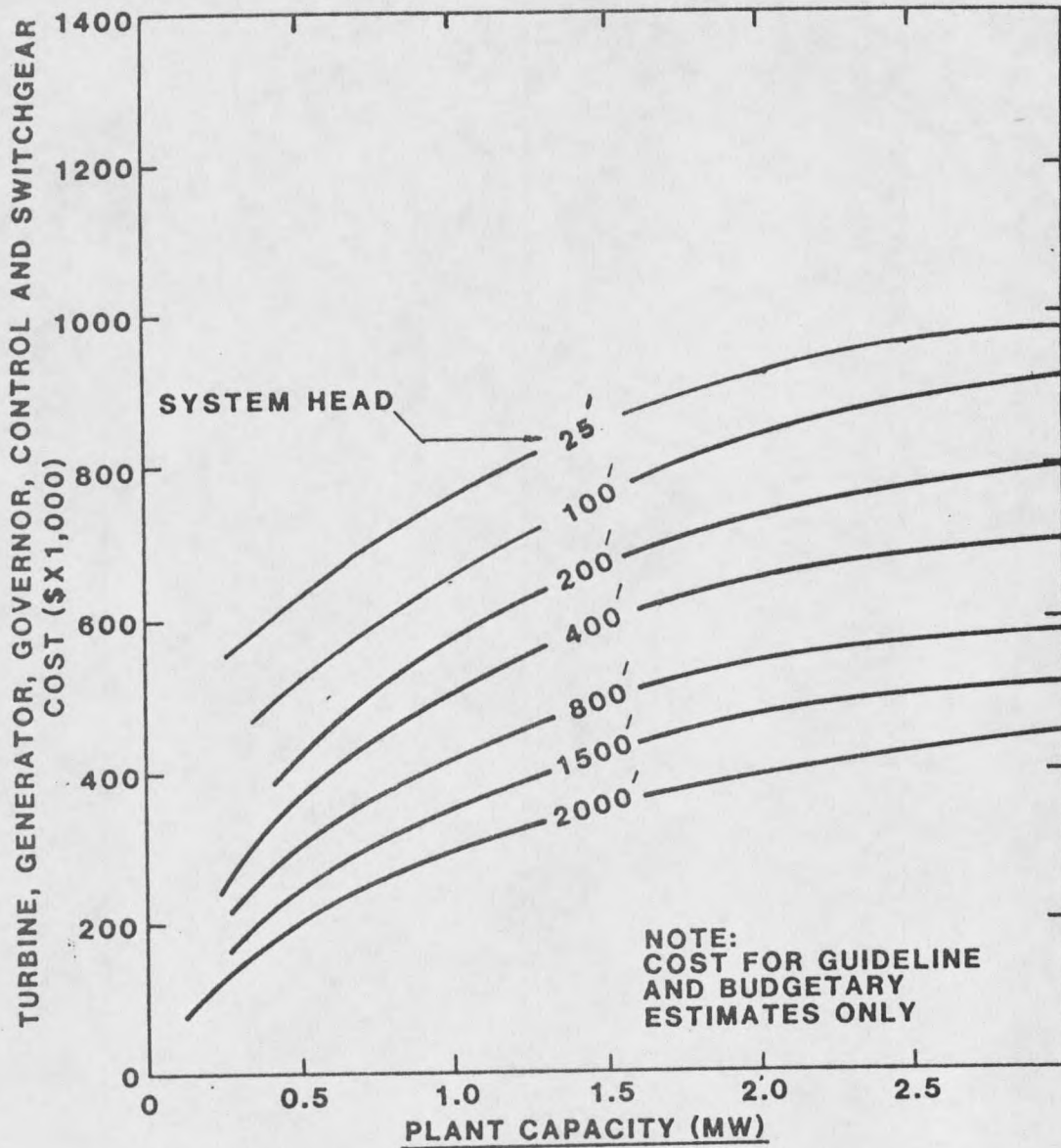


FIGURE 14. TURBINE & MACHINERY
(INSTALLED COST)
(PERMISSION TO REPRODUCE)⁹

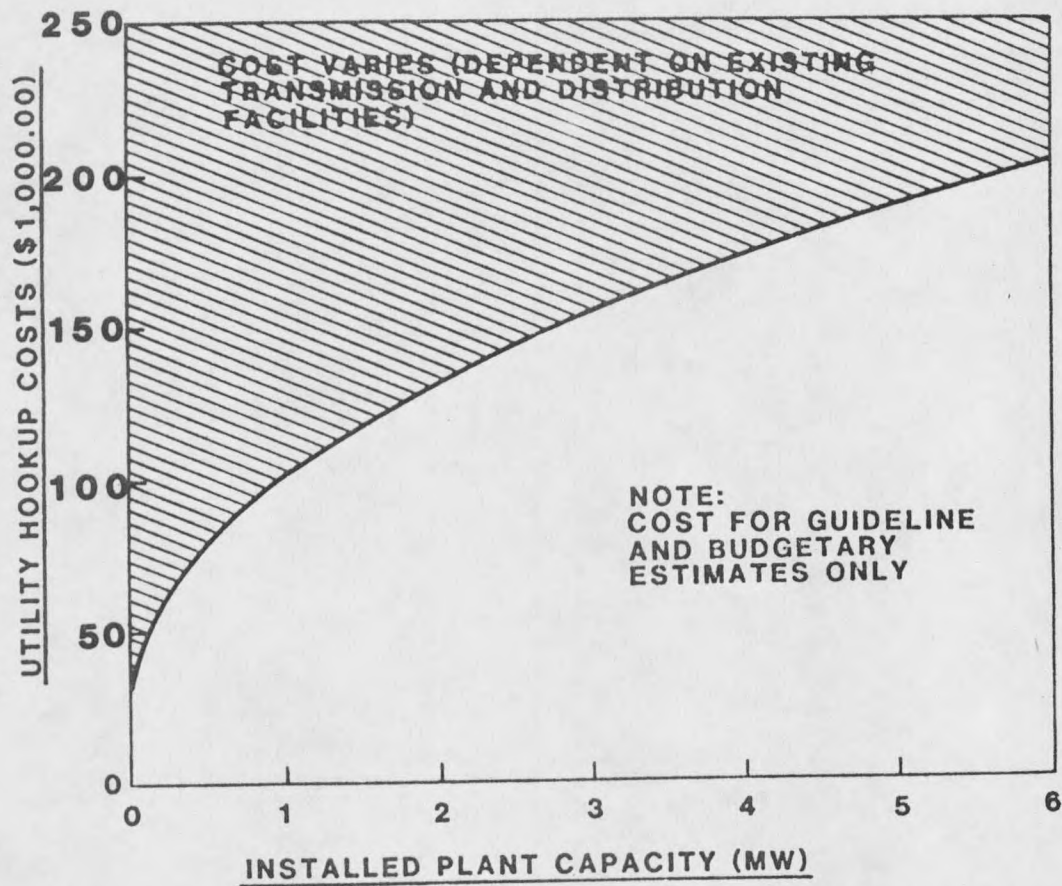


FIGURE 15. UTILITY HOOKUP (INSTALLED COST)₉
(PERMISSION TO REPRODUCE)

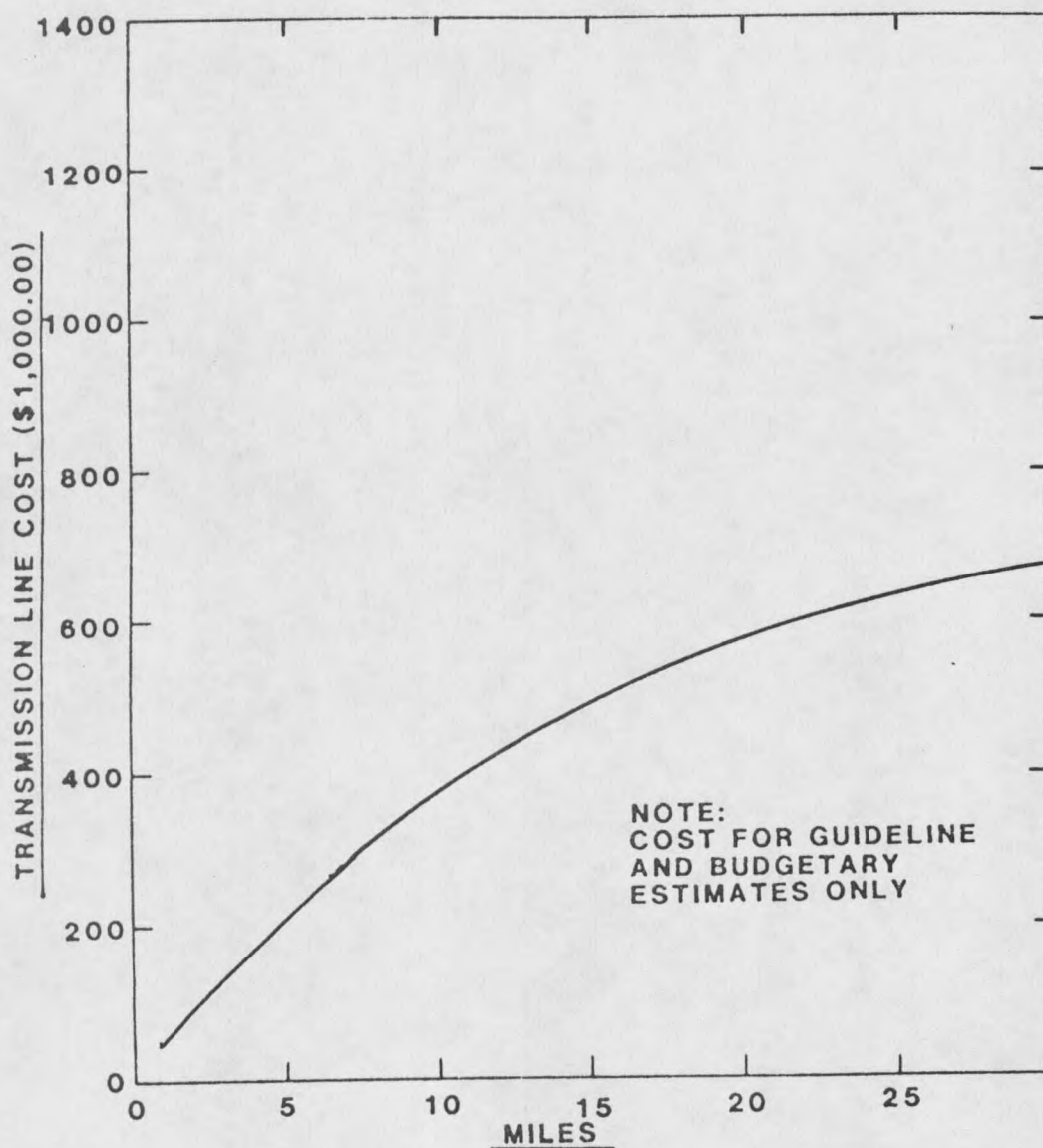


FIGURE 16. TRANSMISSION LINE
(INSTALLED COST)
(PERMISSION TO REPRODUCE)⁹

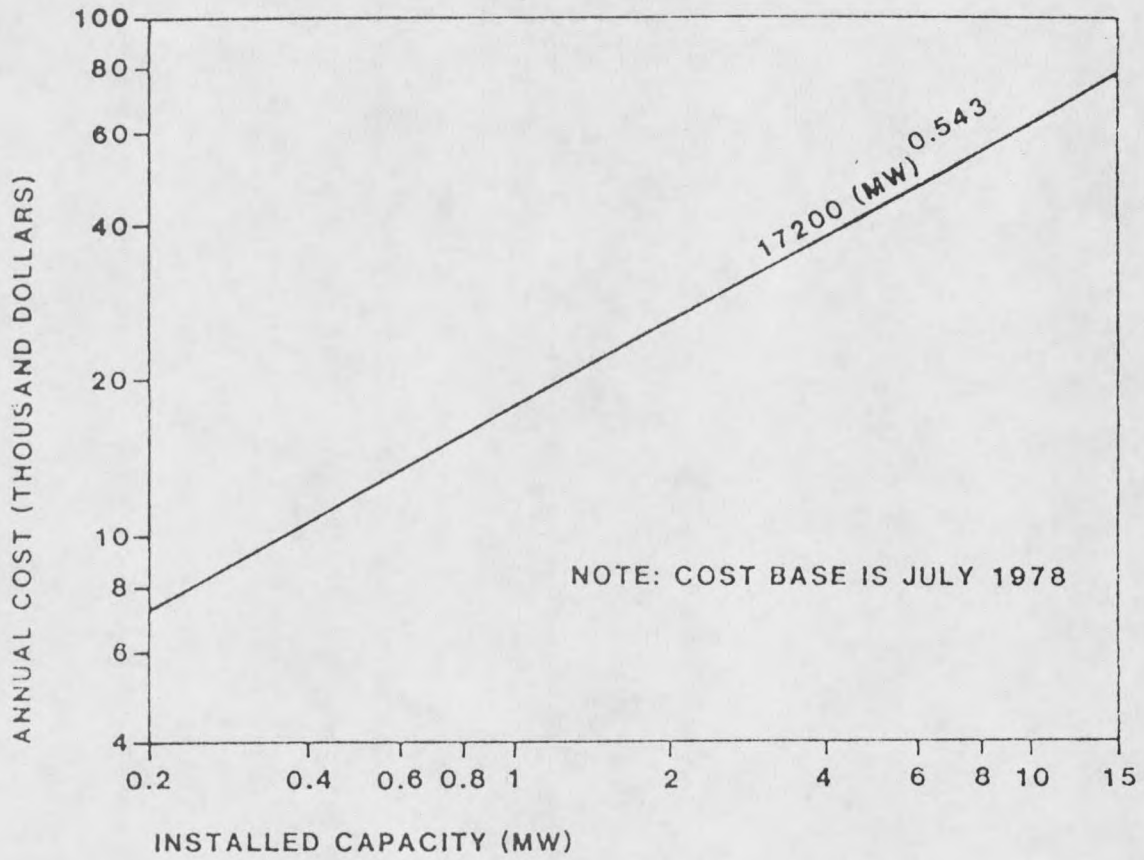


FIGURE 17. OPERATION & MAINTENANCE COST 13
(PERMISSION TO REPRODUCE)

Financing

The financing arrangements on a small hydropower plant can have a tremendous effect on the selection of most economical alternative. The controlling factor in forming a financing scheme is the total amount to be financed. The magnitude of this amount will influence the required collateral, interest rate, downpayment, length of loan, and even the availability of the loan itself. It may be necessary to also consider secondary financing to cover downpayment and negative cash flow costs in the first few years. A preliminary meeting with the lending institution should provide the developer with enough data to make preliminary alternative appraisals possible.

State and Local Taxes

State and local taxes are usually combined and assessed in the form of property tax and income tax. Both types of taxes are defined in publications readily available from state governments and tax consultants. The Montana tax brochure⁸ describes the state income tax as either an individual income tax or corporate license tax. In both cases, the amount of tax is equal to a percentage of the net income. In general, the net income is computed using the same set of deductions from gross income as is allowed under the Federal Internal Revenue Code.

Property taxes are computed by multiplying the taxable value of a given piece of property by the mill levy of the school district with jurisdiction over the property. The taxable value

is a fixed percentage of the assessed value of a piece of property. This percentage depends on the type of property being taxed. For example, a small hydropower plant in Montana has a taxable value of 8.55% of the assessed value of the permanent fixtures (diversion, dam, roads, powerhouse, etc.) plus 11% of the assessed value of the depreciable machinery (intake works, pipelines, turbines, generators, electrical gear, etc.). The assessed value of the various components is a vague concept, but in general can be estimated from the initial costs. Permanent fixtures such as buildings and dams may appreciate in value along with other real estate in the area. Machinery that wears out can be depreciated by straight line depreciation over 20 years to 20% of its initial value after which time the value remains constant at 20% of initial. The assessed value of the machinery in a given year is the value along the depreciation line. The value of the mill levy can vary greatly over the life of a project. A conservative estimate of the variation of the mill levy can be made by assuming an annual increase equal to the prevailing inflation rate.

Federal Income Tax

Small hydropower facilities can be taxed either under individual or corporate tax statutes. The structures of these statutes closely resemble state income taxation codes, in that they compute tax as a percentage of net or taxable income. All legitimate business expenses such as operation and maintenance

costs, interest paid on loans, state income and property taxes, and property depreciation can be deducted from gross income to yield taxable income.

The current corporate tax law¹¹ allows industrial equipment to be depreciated to zero salvage value over five years using the Accelerated Cost Recovery System (ACRS). The amount of depreciation for each year is computed by set percentages of first cost. These percentages are 15, 22, 21, 21, and 21 percent for years one through five, respectively. If it is desired, the industrial assets may be depreciated on a straight-line basis over 5, 12, or 25 years. In general, it is desirable to depreciate an asset as quickly as possible, but occasions do arise where plants operate at losses for several years and in order to recover tax credits it may be necessary to postpone depreciation write-offs.

Once the net income for a given year has been calculated, the corporate or individual tax tables are consulted to find tax due. For corporations, the first \$25,000 is taxed at 16%, the second at 19%, the third at 30%, the fourth at 40%, and any additional net earnings over \$100,000 at 46%. In the event of a negative net income, no tax is due and the loss can be carried back up to three years or forward up to fifteen years to help offset past or future tax liabilities respectively. If several years of net loss years occur, it is wise to "use up" the losses

from the earliest years first, so that none of the write-offs are lost to the fifteen year limit.

Federal Tax Credit

An added incentive for investment in renewable energy resources is the eleven percent tax credit² in addition to the standard ten percent investment tax credit. This percentage applies to the "qualifying" portion of the original cost, which, for the purposes of this paper, can be assumed to be the total cost. Thus, 21% of the initial cost of the plant can be subtracted from the computed tax in qualifying years. The maximum allowable tax credit that can be taken in a given year is the total tax liability, or \$25,000 plus 90% of the tax liability above \$25,000, whichever is less. Any unused credit may be carried back 3 years or forward 15 years.

Power Cost

Revenue from power sales usually consists of two components, the main one resulting from sale of energy, and the secondary one resulting from a capacity and reliability payment. The energy payment is computed by multiplying the total number of kilowatt hours in a given period by the energy rate which is set by the state Public Service Commission. The value of this rate for a given power company is based on the avoided cost of building new power sources, and can be expected to increase with time. In some long-term power sales contracts this escalation rate is specified.

Peak yearly power output, capacity factor, and firm power are also of interest to the power company and are included in the power sales contract in some form. The Montana Power contract² specifies a payment to the small producer proportional to the capacity factor and the maximum instantaneous power over each year. Other companies may specify two different energy rates to reward consistently operating plants; one high rate for "firm" power, or power available at all times during the year, and one lower rate for any excess power. These rates will all escalate along with the energy escalation rate.

In general, small power producers have an advantage over large power producers in that the burden of regulation in the grid system lies with the large power producers. The small power producer can usually sell all the power it is capable of producing, regardless of the electrical demand. The firm power and high capacity factor rewards in the power sales agreement are an encouragement to the small power producer to operate at a relatively constant output.

CHAPTER 7

COMPUTATIONAL PROCEDURE

Selection of the optimum system design and sensitivity analysis of that design involves an extremely lengthy and burdensome set of equations. For this reason, this type of problem is well suited for computer solution. Accordingly, a comprehensive computer program has been developed in this thesis which applies all of the concepts discussed thus far to the design and analysis of small hydropower facilities. An illustration of the computational procedure built into the computer program is given by the flow-chart of Figure 18. The remainder of this chapter is dedicated to explanations of each of the major computational steps in the program.

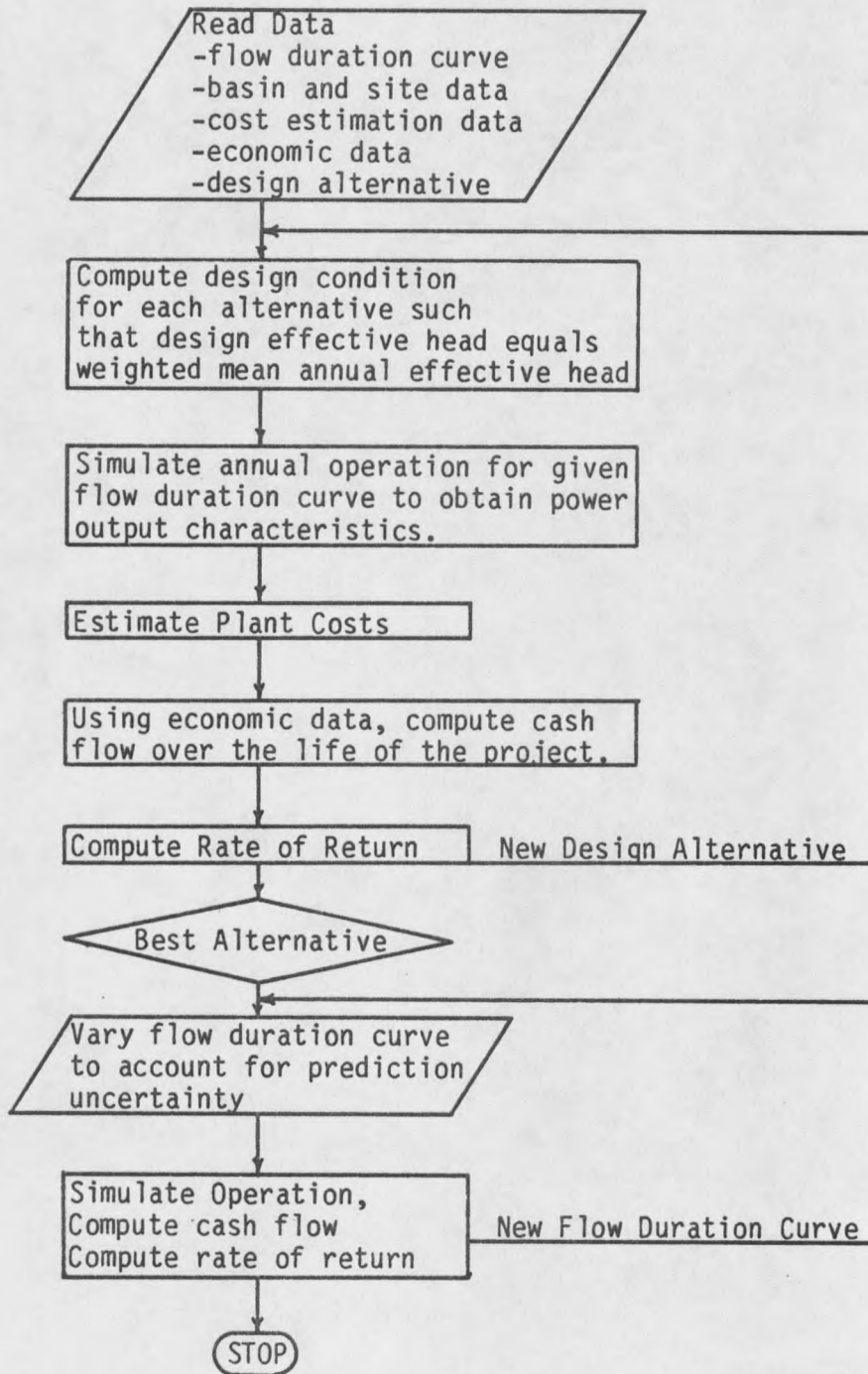


FIGURE 18. MODELING PROCEDURE FLOW CHART

Read Data

The data required for design and analysis of a hydropower plant by the method discussed herein is listed below.

1. Predicted flow duration curve.
2. Range of flow duration curve variation accredited to possible inaccuracy of prediction.
3. Gross head between upstream spillway crest and some tailwater datum.
4. Variation in headwater and tailwater elevations from spillway crest and tailwater datum, respectively with flow rate, if significant.
5. Minimum in-stream flow requirement.
6. General turbine efficiency curve flow head limits of turbine types.
7. Product of efficiencies of all components between turbine and power sales meter.
8. Cost data or cost curves.
9. Economic data
 - a. Mortgage data; interest rate, downpayment, period.
 - b. Tax data; property tax, state income tax, Federal income tax and tax credit.
 - c. Inflation rate
 - d. Project life
 - e. Power cost data.
10. Design, alternative data
 - a. Number of options
 - b. Pipeline layout, including configuration, lengths, diameters, friction coefficients, and minor loss coefficients between free headwater and tailwater surfaces.

- c. Type of turbine
- d. Any added costs above those found from curves associated with design alternative.

Compute Design Condition

The design condition for a particular design option is the combination of flow and effective head used in turbine selection that results in the most efficient use of the system over the expected variation of flows. The optimum design condition can only be found by trial and error. The step by step procedure for solving this problem is as follows:

1. Select trial design flow.
2. Compute design effective head using the trial design flow in the energy equation.
3. Compute the best turbine flow for each of the flow-duration curve ordinates.
 - a. For each finite F-D curve ordinate starting with low exceedence flows, begin computation of best turbine flow by assuming the maximum possible turbine flow (Table 1) is diverted into the turbine. If the F-D curve ordinate is less than this value, assume all of the available streamflow is diverted into the turbine.
 - b. Check the energy equation at this turbine flow to be sure that this flow is within the head limits of the turbine (Table 1). In low head analyses it is necessary to consider gross head changes with streamflow changes when computing effective head. If the effective head lies outside the limits of Table 1, decrease turbine flow until acceptable from an effective head standpoint.

- c. Compute power resulting from assumed turbine flow.
 - d. Decrease turbine flow by an arbitrarily small increment.
 - e. Compute effective head as in (b) and power as in (c).
 - f. Continue decreasing turbine flow down to cutoff flow, noting the turbine flow that produced maximum power for the given streamflow.
 - g. Plot "best" turbine flows versus percent exceedence on the F-D curve to represent the usable flow portion of the F-D curve. Examples of these plots are given in Chapter 8.
4. For each best turbine flow computed in step 3, compute effective head.
 5. Sum the products of the effective heads of step 4 and their respective time weights to give the weighted mean annual effective head.
 6. Compare design effective head (step 2) for the assumed design flow with weighted mean annual effective head (step 3). If they are not equal, adjust design flow and repeat the procedure.

Simulate Annual Operation

Over the portion of the flow-duration curve useful to the turbine (step 3g. in the last section), power is integrated to yield annual energy production. The capacity factor is found by dividing the annual energy production by the value of annual energy that would be produced if the plant were operated at peak power for the entire year.

Estimate Plant Costs

The costs of the major plant components are estimated by entering the cost curves (Figures 7-17) with the design parameters required or by overriding the curves with input values.

Compute Cash Flow

Using the economic factors given, the cash flow over the life of the project is computed.

Debt Service

The annual mortgage payment is found using the standard capital recovery equation:

$$A = P \frac{i (1 + i)^N}{(1 + i)^N - 1}$$

Where: A = annual payment
P = amount financed (total
plant cost - downpayment)
i = interest rate
N = number of years of loan

The interest portion of debt service is tax deductible and is found by multiplying the principal remaining before the loan payment by the interest rate. The new value of principal is found by subtracting the principal portion of loan payment from the previous principal balance.

Depreciation

The 5 year depreciation sequence is found by multiplying the total plant cost by 15%, 22%, and 21% for years 1, 2, and 3 through 5, respectively. This depreciation applies only to state and Federal income tax deductions.

Operation and Maintenance Cost

Once the first year operation and maintenance (O & M) cost is estimated using Figure 17, subsequent annual O & M costs are found by inflating the original cost using the equation:

$$F = P (1+i)^N$$

Where: F= future O & M cost
 P= first year O & M cost
 i= inflation rate
 N= each year in project life

Property Tax

The assessed value of the permanent structures in a power plant is found by appreciating the initial cost of the permanent structures over the project life using the same equation as that used to inflate O & M cost, but with the prevailing property appreciation rate substituted for the inflation rate. The assessed value of the temporary machinery is found by depreciating the machinery along a straight line to 20% of its initial value at 20 years. For later years, the assessed machinery value is a constant 20% of initial. The taxable value of the powerplant in a given year is the sum of 8.55% of the assessed value of the permanent structures and 11% of the

assessed value of the depreciable machinery.¹¹ The value of the mill levy in a given year is found by inflating the initial mill levy by the prevailing inflation rate. Finally, the property tax in a given year is found by multiplying the respective mill levy by the respective taxable value.

State Income Tax

The state tax due in a given year is the product of the tax rate and the taxable income. Taxable income is found by subtracting from gross income all business expenses including loan interest, O & M cost, depreciation, and property tax. If taxable income is less than zero in a given year, the loss can be applied as an expense to revenues up to 3 years back and 15 years forward.

Federal Income Tax

The Federal income tax due in a given year for a corporation is found by multiplying the taxable income greater than \$100,000 by 46%, the taxable income between \$75,000-\$100,000 by 40%, the taxable income between \$50,000-\$75,000 by 30%, the taxable income between \$25,000-\$50,000 by 19%, and the taxable income less than \$25,000 by 16%, and summing the results.¹¹ The taxable income each year is the same as that computed for state income tax with the included deduction of state income tax. As in the case of state tax, net operating losses can be carried back 3 years and forward 15 years.

Tax Credit

In the event that Federal income tax is due in the three years preceding power plant investment or 15 years after, the tax credit of 21% of initial cost can be used to offset the tax. The amount of tax credit that can be taken in any given year is limited to the total tax liability up to \$25,000 or \$25,000 plus 90% of the tax liability above \$25,000. Any tax credit left after 15 years is lost.

Total Cost

Total cost is the sum of the debt service, O & M cost, property tax, state income tax, and Federal income tax in each year.

Gross Revenue

The energy and capacity buyback rates increase each year in the same manner as O & M costs, except the energy cost inflation rate may be different from the prevailing consumer inflation rate. The annual energy, capacity factor, and peak power are assumed to be constant from year to year, so total annual revenue increases with the energy cost escalation rate.

Compute Rate of Return

The rate of return for each alternative is the interest rate that equates the present worth of the costs with the present worth of the revenues. Present worth is computed with the equation:

$$P = F/(1+i)^N$$

Where: P= present worth
F= future cost
i= rate of return
N= future year

or

$$\text{Downpayment} + \sum_{\text{costs}} P = \sum_{\text{revenues}} P$$

Vary Flow-Duration Curve

Applying the above procedure yields a best design alternative that is next tested for sensitivity to flow-duration curve prediction. The flow-duration curve is iterated through the range of foreseeable variations and for each step the annual operation, cash flow, and the rate of return are computed.

CHAPTER 8

PRESENTATION OF EXAMPLES

In order to illustrate the method of hydraulic design and sensitivity analysis discussed thus far, three hypothetical site examples were selected representing the three head classifications of small hydropower facilities. The three sites were selected arbitrarily on streams in Montana with existing U.S.G.S. flow records. All sites chosen had flow records of at least 10 years in length. A further requirement of selection was that each stream be essentially free of diversions, large springs, and regulation. The hydraulic conveyance system of each example site was designed on the basis of a flow-duration curve synthesized by the Montana method.³ The design was then analyzed for sensitivity to possible inaccuracies in utilization of that method. Calculations using the U.S.G.S. gage data served as a final indicator of design sensitivity by displaying the effects of the real case on the chosen hydraulic design.

The locations of the various plant appurtenances in each case were chosen from U.S.G.S. topographic maps from a cost-effectiveness standpoint only. Land ownership or readily obtainable easements were assumed for purposes of example.

Site Example #1 - High Head

The steep, alpine terrain along Flower Creek near Libby, Montana typifies the type of location best suited for a high head hydropower plant. A U.S.G.S. gage (#12-3031) lies just inside the mouth of the canyon, with the major portion of the relief in the drainage above the gage.

Examination of the stream profile reveals several possible locations for the diversion and powerhouse (Figure 19). The two diversion locations chosen for economic comparison lie immediately below the confluences of the 14th and 18th small unnamed creeks above the gage. These locations were selected because moving the diversion upstream of each would result in substantially decreased drainage area and hence flow for the 14th creek diversion, and an insignificant gross head increase for the 18th creek diversion. Three possible locations for the powerhouse were selected. These all lie at the upstream ends of small meadows where further movement down the stream for short distances would not gain enough gross head to justify added pipe costs. In addition, building costs and chances of flood damage would be minimized. The locations tested consist of mile 2.69 above the gage, at the U.S.G.S. gage, and at the upstream end of the small lake below the gage.

In each combination of diversion and powerhouse, the shortest and most effective route for the pipeline is along a contour on the north side of the main channel to a surge tank on

the hillside above the powerhouse, and directly down the hillside with a high pressure penstock to the powerhouse (Figure 20.

Flow-Duration Curves

Using the flow-duration curve prediction procedure for ungaged mountainous and high plains streams in Montana,³ the average annual flow is computed from the weighted mean annual precipitation over the basin, and then the flow-duration curve is drawn by rescaling the chosen dimensionless curve by this value.

Table 2. Site #1, Average Annual Flow Computation

For Diversion Immediately Below	Drainage Area ₂ (mi. ²)	Weighted Mean Annual Precip.(in.)	Chosen Annual Runoff (in.)	Avg. Annual Flow(cfs)
Stream Gage #12-3031	11.28	69.8	44.0	36.6
14th Small Creek	6.73	79.8	52.7	26.4
18th Small Creek	3.62	80.0	52.8	14.1

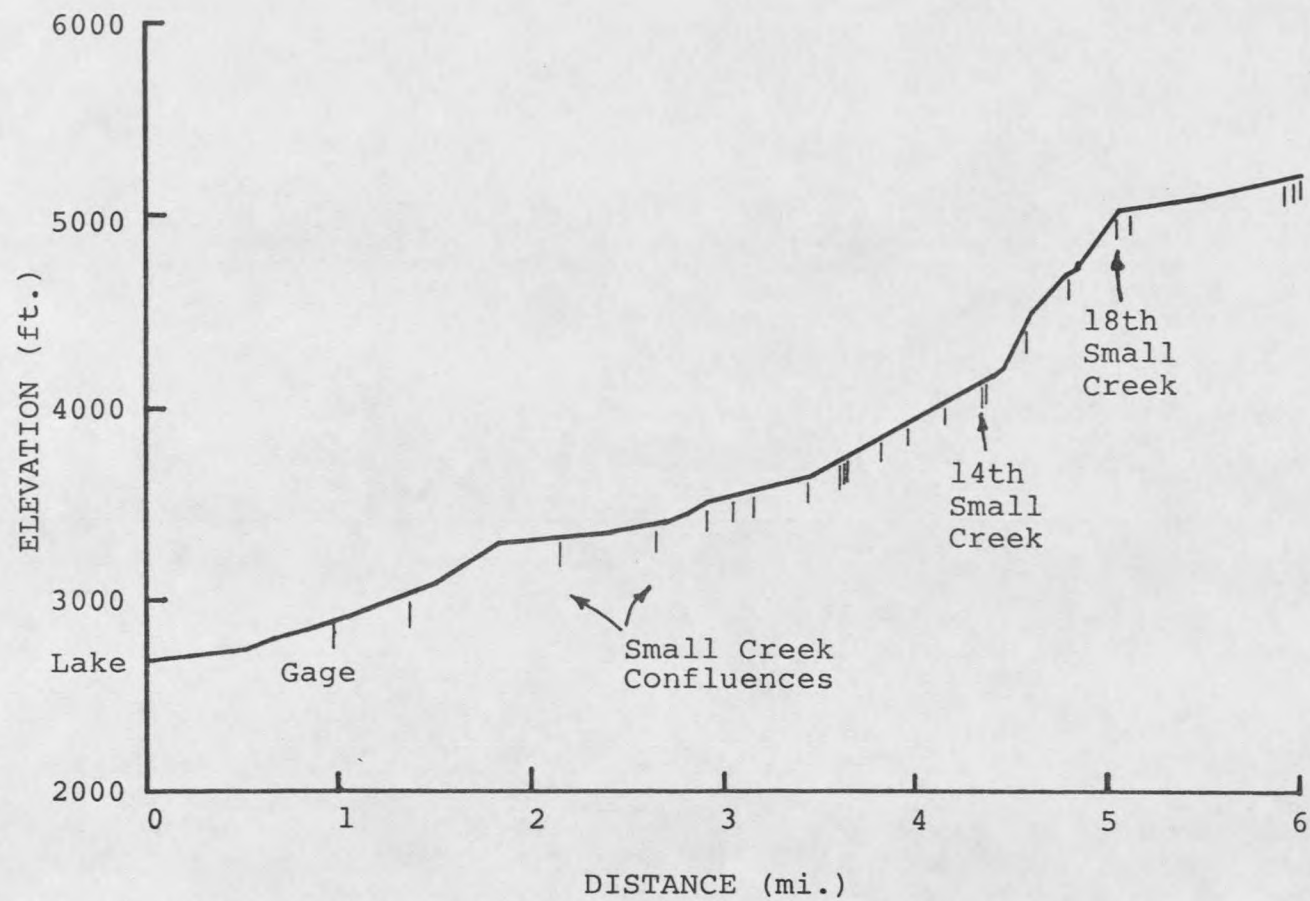


FIGURE 19. FLOWER CREEK PROFILE

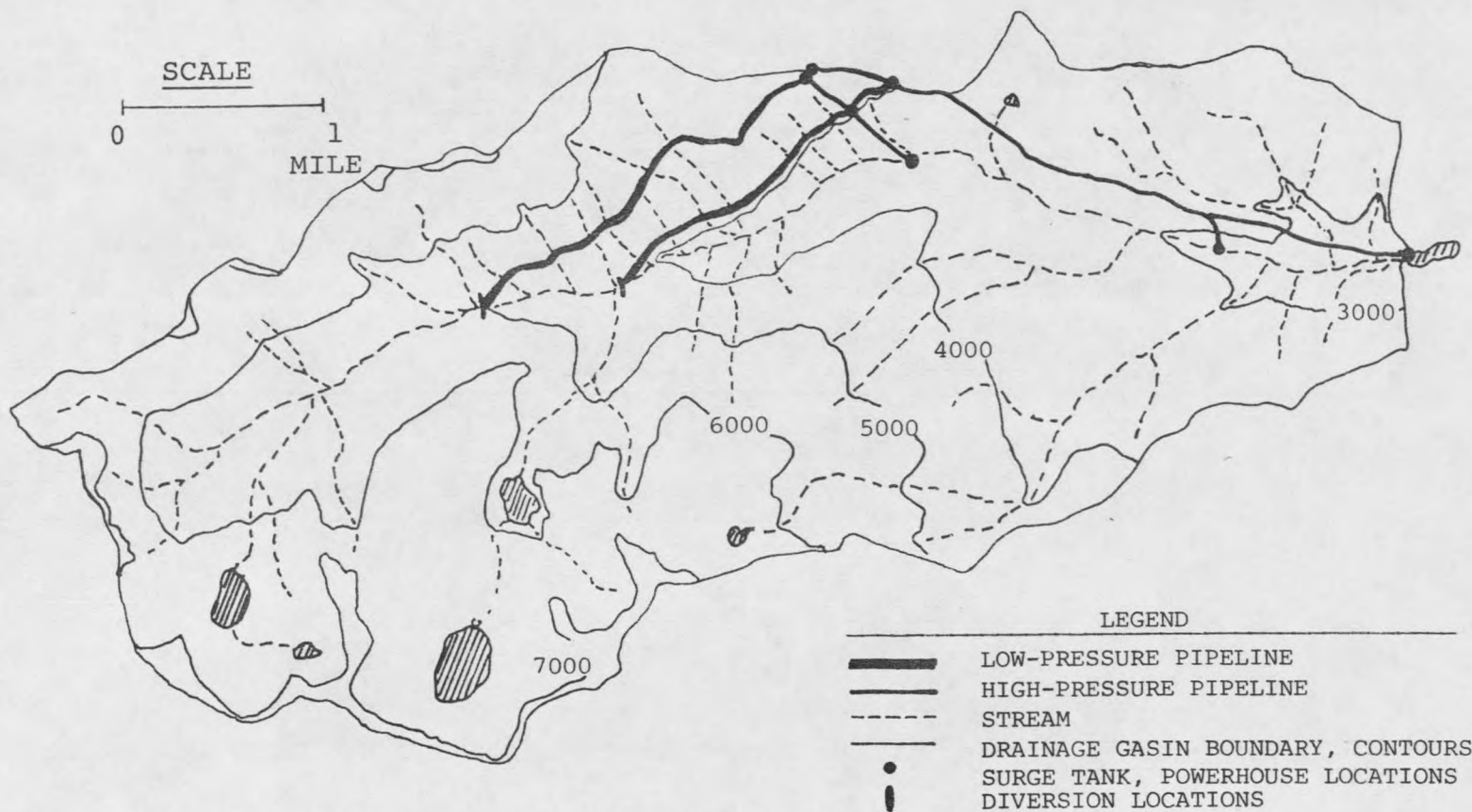


FIGURE 2C. FLOWER CREEK PIPE LOCATION MAP

In Table 2, the value of runoff for each value of precipitation was chosen from Figure 2 as two inches greater than the dividing line between alpine - rocky and deep soil - heavily timbered, solely on judgement formed from map inspection of the drainage area. Using the same judgment, it was felt that the flow-duration curve would have the shape of a curve lying in the center of the dimensionless curve band of Figure 3. This selection of vertical position within the band represents a compromise between the steep, rocky nature of the basin tending to lower the curve within the band, and the presence of numerous lakes in the upper part of the basin tending to raise the curve within the band due to natural regulation. The dimensionless flow-duration curves are scaled by multiplying the ordinates by the 10% exceedence flow, which is found in each case by multiplying the average annual flow by the regression constant 3.056 (noted in Chapter 3). The resulting synthetic flow-duration curves for the two diversion alternatives and the stream gage are given in Table 3.

Table 3. Site #1, Synthetic Flow-Duration Curve Computation

% Exceedence	Dimensionless Coefficient	Synthetic F-D Curve Ordinates(cfs)		
		Stream Gage #12-3031	14th Small Creek	18th Small Creek
10	1.0	112	80.7	43.1
20	.424	47.4	34.2	18.3
30	.229	25.6	18.5	9.9
40	.150	16.8	12.1	6.5
50	.100	11.2	8.1	4.3
60	.074	8.3	6.0	3.2
70	.056	6.3	4.5	2.4
80	.047	5.3	3.8	2.0
90	.039	4.4	3.1	1.7
100	.036	4.0	2.9	1.6

Actual Flow-Duration Curves

The actual flow-duration curves for the three points of interest along Flower Creek were derived from the U.S.G.S. gage #12-3031 data, and are given in Table 4. In this report, "actual F-D curves" are those obtained from measured data. The actual flow-duration curve ordinates for the 18th and 14th small creeks above the gage were assumed to be in direct proportion to the measured F-D curve ordinates at the gage, where the proportion constant was the ratio of the average annual flows as computed by the weighted precipitation method in Table 2.

Table 4. Site #1 Actual Flow-Duration Curve Computation

% Exceedence	Actual Flow-Duration Curve Ordinates (cfs)		
	Stream Gage #12-3032	14th Small Creek	18th Small Creek
10	82	59.1	31.6
20	36	26.0	13.9
30	20	14.4	7.7
40	14	10.1	5.4
50	11	7.9	4.2
60	8.8	6.3	3.4
70	7.5	5.4	2.9
80	6.5	4.7	2.5
90	5.5	4.0	2.1
95	4.9	3.5	1.9
99.9	3.8	2.7	1.5

Minimum In-Stream Flow

Due to the steep cascading nature of the stream bed between the confluences of the 18th and 14th small creeks above the stream gage, it was assumed that no minimum flow requirements for fish would be required in that reach of the stream, however, a minimum wetting flow of 1 cfs was allotted. Below the 14th creek confluence the slope of the stream bed decreases, increasing the probability of a resident fish population. A minimum fish requirement in this reach was assumed to be 3 cfs.

It was assumed that an agreement with the Department of Fish, Wildlife, and Parks could be made that required 1 cfs to be passed through the 18th small creek diversion regardless of the powerhouse location, with the balance of the 3 cfs required below the 14th Creek confluence entering the stream below the diversion naturally. The diversion at the 14th Small creek would have to pass the entire 3 cfs.

Economic Factors

The economic factors in Table 5 were assumed for all alternatives. These factors represent current trends to the extent that realistic results can be expected.

Design Alternatives

Based on the diversion and powerhouse locations chosen for investigation, numerous alternative designs were analyzed. These are summarized in Table 6, with data common to all alternatives given in Table 7.

Table 5. Site #1, Economic Factors

Mortgage Interest Rate	= 14%
Period of Mortgage	= 20 yr.
Down Payment	= 10% of Initial Cost
Property Tax:	
Permanent Property Appreciation Rate	= 2%
Taxable Value of Permanent Property	= 8.55% of Assessed Value
Taxable Value of Depreciable Machinery	= 11% of Assessed Value
Method of Machinery Depreciation	= Straight Line to 20% of initial in 20 yrs.
Initial Mill Levy	= 206.55%
State Income Tax Rate	= 6.75%
Federal Tax Credit	= 21% of Initial cost
Inflation Rate	= 8%
Project Life	= 30 yr.
Initial Energy Cost	= \$.064/kw-hr.
Initial Capacity Cost	= \$7.9294/Contract kw/mo.
Energy Cost Escalation Rate	= 6%

Table 6. Site #1, Design Alternatives

Diversion	Powerhouse	Low Pressure Pipeline				High Pressure Pipeline				Transmission Line Cost
		Diameters (in.)	Type	C _H	Length (ft.)	Diameters (in.)	Type	C _H	Length (ft.)	
18th Creek Elev. = 5000	Mile 2.69 Elev. = 3400	8-30	Fiberglass	140	11360	8-20	Steel	120	3450	\$110,000
	Stream Gage Elev. = 2880	8-30	Fiberglass	140	11360	8-20	Steel	120	11360	70,000
	Lake Elev. = 2680	8-30	Fiberglass	140	11360	8-20	Steel	120	16450	50,000
14th Creek Elev. = 4120	Mile 2.69 Elev. = 3400	20-33	Fiberglass	140	7830	18-30	Steel	120	2040	110,000
	Stream Gage	16-33	Fiberglass	140	11350	14-30	Steel	120	8620	70,000

Table 7. Site #1 Additional Design Data

Access Road Cost (18th Creek Diversion 2.5 mi.)	\$120,000
Access Road Cost (14th Creek Diversion 2 mi.)	100,000
Surge Tank Cost	20,000
Diversion Width	20 ft.
Turbine Type	Impulse
Turbine Limits of Operation	
Cutoff Flow	10% of Design Flow
Wide Open Gate Flow	190% of Design Flow
Minimum Head	30% of Design Net Head
Maximum Head	Unbounded

Results of Alternative Comparison

The computer program outlined earlier was used to optimize the design condition and compute the rate of return for each of the design alternatives listed. The results of that analysis, listed in Table 8, show a predictable parabolic trend in the rate of return along each row and column, with an optimum conjugate pipe diameter clearly defined in most cases. Occasionally the rate of return curve along a row or column has minor humps in it. These are largely attributable to inaccuracies in fitting cost and flow-duration curves, but also are the result of tax credits being utilized in only the larger design options, causing non-uniformities. In order to avoid

Table 8. Site #1, Design Alternative Comparison - Rates of Return (%)

Diversion Site	Powerhouse Site	High Pressure Pipeline Dia. (in.)	Low Pressure Pipeline Dia. (in.)										
			8	10	12	14	16	18	20	24	27	30	33
18th Creek	Mile 2.69	8	11.0	16.9									
		10	11.3	20.0	25.6	27.6	27.1	25.0	23.5				
		12	10.3	19.7	26.9	30.4	30.3	27.3	27.4	26.5			
		14	9.0	18.1	25.9	29.0	29.5	28.6	28.5	29.7	29.1	27.7	
		16	7.6	16.1	23.2	26.4	28.0	27.6	28.8	30.6	30.7	30.0	
		18		14.1	19.9	23.2	25.5	25.7	27.3	29.3	30.9	30.3	
		20		12.2	17.4	20.8	22.7	23.2	25.0	28.4	28.3	28.5	
	Stream Gage	10		13.2	14.0	13.2	12.0						
		12		12.1	14.0	13.8	12.6						
		14		10.1	12.0	12.4	11.4						
		16		7.9	10.1	10.6	9.8						
		18		5.9	8.0	8.6	8.3						
	Lake	20		4.2	6.1	6.8	6.8						
		14				7.6	7.0	6.6					
		16				6.6	5.6	5.0					
		18				5.8	4.4	3.4					
		20				5.4	3.5	2.8					
14th Creek	Mile 2.69	18							18.5	19.3	18.3	17.8	
		20							18.8	20.3	19.6	19.4	18.8
		24							18.3	20.8	20.7	20.6	20.5
		27							17.6	20.3	20.5	20.7	20.4
		30							16.6	19.7	19.6	19.7	19.5
	Stream Gage	14					11.6	11.4	11.0	9.8	9.3	9.3	9.1
		16					11.8	12.0	11.9	10.7	10.5	10.6	10.5
		18					11.4	11.9	12.0	10.9	10.9	11.2	11.2
		20					10.6	11.4	11.5	10.7	10.8	11.2	11.5
		24					8.5	9.3	9.8	9.6	10.0	10.8	11.2
		27							8.3	8.5	9.1	9.8	10.2
		30							6.9	7.4	7.9	8.7	8.9

excess computer expense, Table 8 was only completed to the extent that the best options were found for each set of diversion and powerhouse, or until it was determined that the peak rate of return would not compare with the best options already analyzed.

From the table it can be seen that the combination of 18th Creek diversion and Mile 2.69 powerhouse give the highest rates of return. The major decision remaining is the choice of plant sizing. Since several of the pipe combinations show equally high rates of return, the best chosen design has to depend on other factors, such as financing limits, operation characteristics, and risk of inaccurate flow prediction.

Sensitivity to Flow Prediction

Analysis of hydraulic design sensitivity to hydrologic prediction was conducted on several of the best designs in the hope that conclusions regarding minimum risk designs could be drawn.

The two major sources of error in the Montana flow-duration curve prediction method are: 1) choosing the value of runoff for a given value of mean annual precipitation from Figure 2, and 2) choosing the vertical position of the dimensionless F-D curve within the band in Figure 3. While it is true that other sources of error exist in that prediction method the two listed are the only two tangible enough to predict variation. It was

decided that the economic sensitivity of a hydraulic design to the Montana prediction method would be best expressed by observing the rate of return over all permutations of runoff within the data limits shown in Figure 2, and position within the dimensionless F-D curve band (Figure 3).

The options chosen for sensitivity analysis include: 1) 14 in. low pressure and 12 in. high pressure pipelines, 2) 24 in. low and 16 in. high, 3) 27 in. low and 16 in. high, and 4) 27 in. low and 18 in. high. A copy of the output from Option 1 is given in Appendix A. Changes in the tax structure within the program between the time of alternative comparison runs and sensitivity analysis runs raised the rates of return uniformly. The trends in Table 8 still hold true, but the magnitudes are altered.

Results of Sensitivity Analysis

The designs for Options 1-4 are summarized in Tables 9-12, respectively. Following each of these design tables are the design operation curves and sensitivity plots for each option. In each case the design operation curve (Figure 21) shows the limits of power plant operation for the chosen F-D curve. These limits form an "operation block" of usable area under the F-D curve. The sensitivity plots give the variation in rate of return of the chosen design with changes in the F-D curve prediction. The graph at the top of Figure 22 gives rate of return contours over the two dimensions of uncertainty, namely, vertical position with the band of Figure 3, measured from the

bottom curve (position = 0) to the top curve (position = 9), and the choice of runoff within the boundaries of Figure 2. The graph at the bottom of Figure 22 is a three-dimensional representation of sensitivity of rate of return as a function of runoff and position within the band.

Table 9. Site #1, Option #1, Chosen Design

Diversion:		18th small creek above gage
Powerhouse:		Mile 2.69 above gage
Low Pressure Pipeline:		14 in. Fiberglass, $C_H=140$, Length = 11360 ft.
High Pressure Pipeline:		12 in. Steel, $C_H=120$, Length=3450 ft.
Gross Head	=	1600 ft.
Design Net Head	=	1405.4 ft.
Weighted Avg. Net Head	=	1403.3 ft.
Minimum In-Stream Flow	=	1 cfs
Design Flow	=	7.19 cfs.
Flow at Max. Power	=	12.23 cfs.
Cutoff Flow	=	.72 cfs.
Design Rate of Return [*]	=	37.4%
Actual Rate of Return ^{**}	=	35.2%

* The design rate of return results from using the synthesized F-D curve.

** The actual rate of return results from using the U.S.G.S. measured F-D curve.

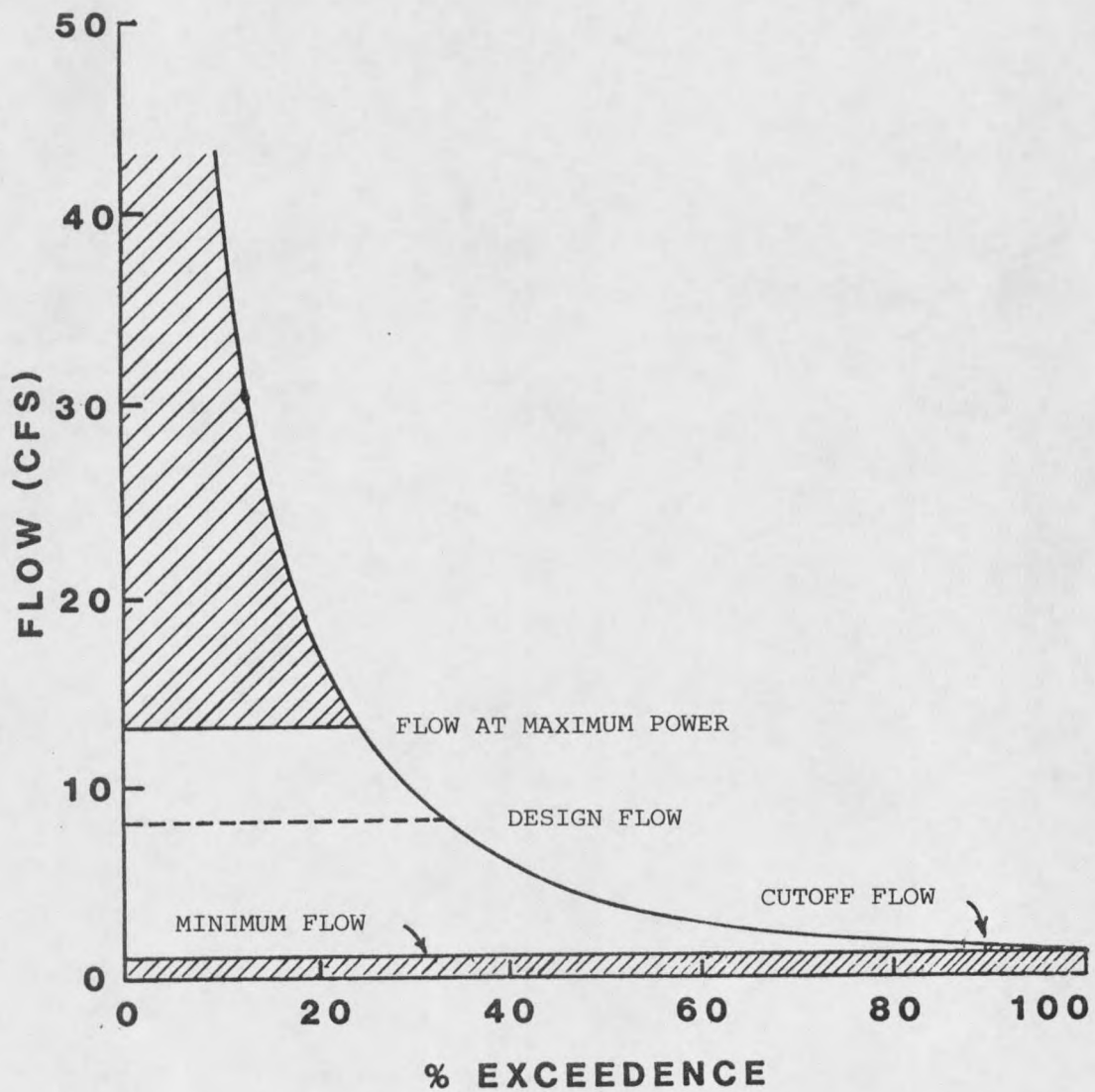


FIGURE 21. SITE #1, OPTION #1, DESIGN OPERATION CURVE

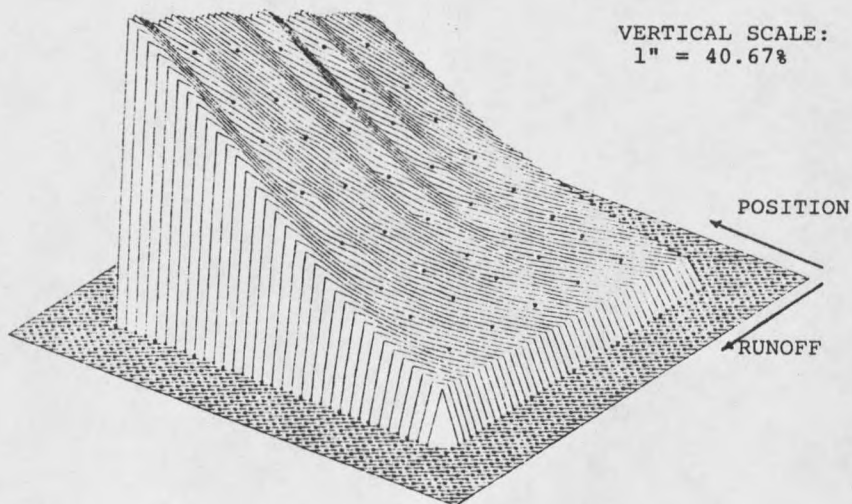
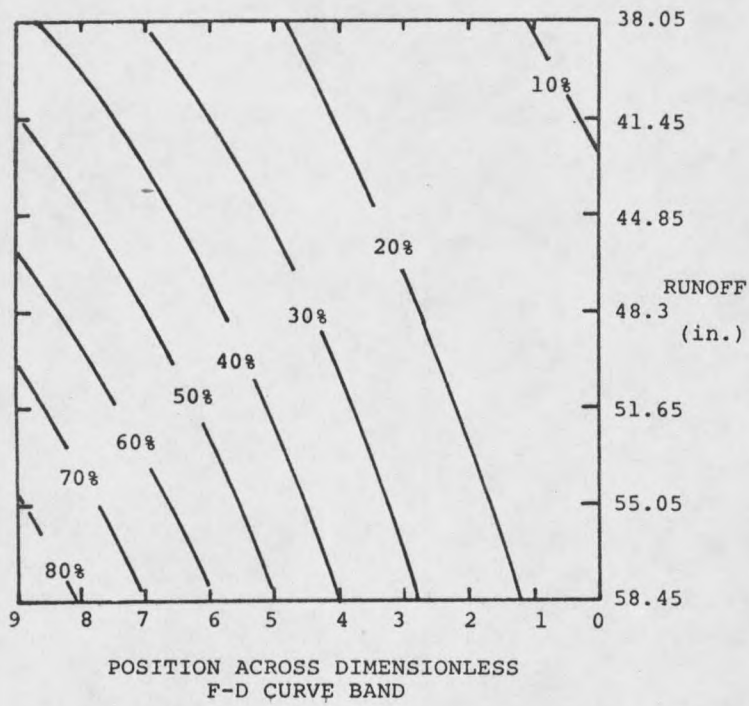


FIGURE 22. SITE #1, OPTION #1, RATE OF RETURN
SENSITIVITY

Table 10. Site #1, Option #2, Chosen Design

Diversion:		18th small creek above gage
Powerhouse:		Mile 2.69 above gage
Low Pressure Pipeline:		24 in. Fiberglass, $C_H = 120$, Length=11360 ft.
High Pressure Pipeline:		16 in. Steel, $C_H = 120$, Length=3450 ft.
Gross Head	=	1600 ft.
Design Net Head	=	1444.6 ft.
Weighted Avg. Net Head	=	1440.6 ft.
Minimum In-Stream Flow	=	1 cfs.
Design Flow	=	17.6 cfs.
Flow at Max. Power	=	33.6 cfs.
Cutoff Flow	=	1.76 cfs.
Design Rate of Return	=	37.8%
Actual Rate of Return	=	26.7%

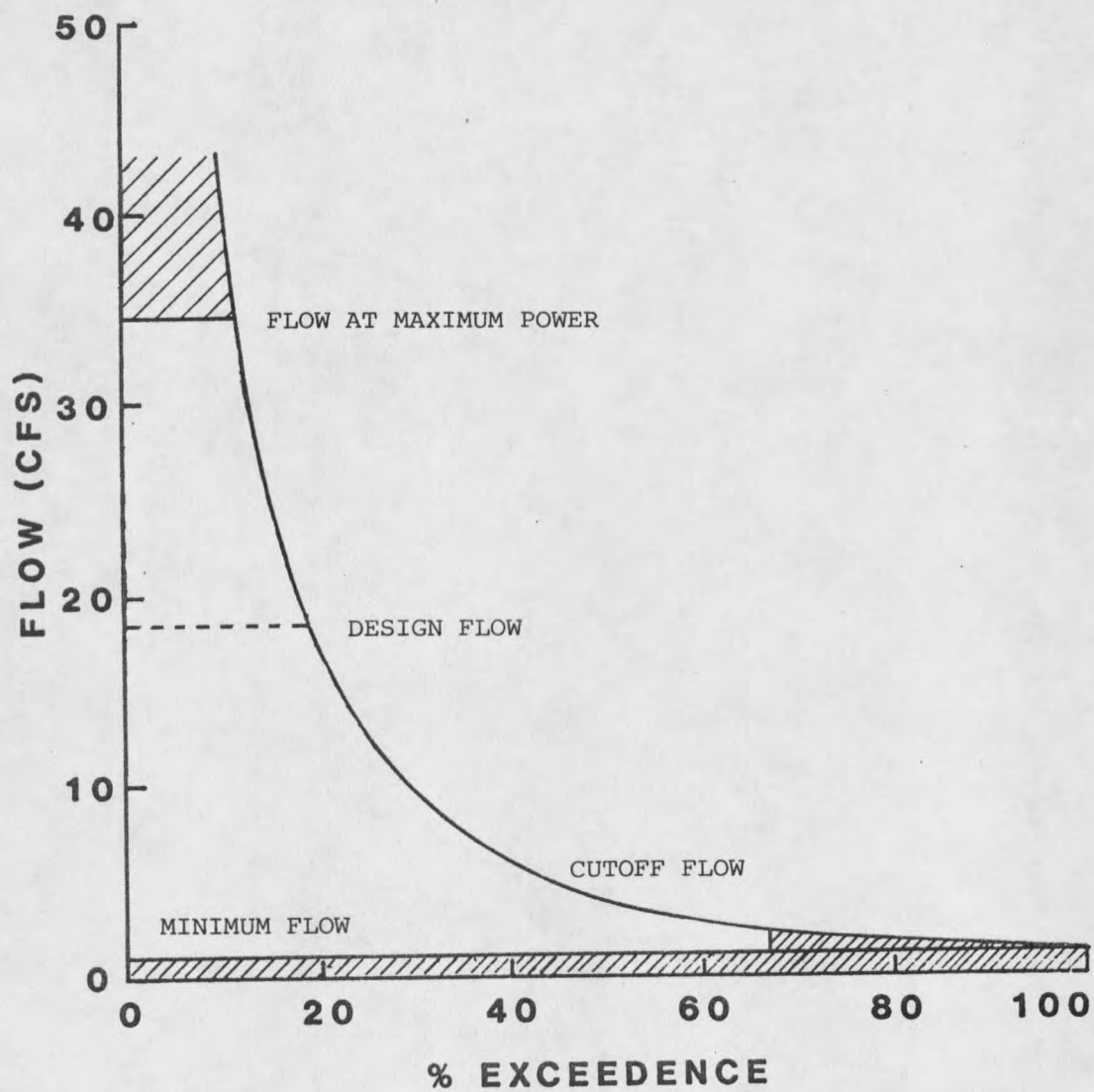


FIGURE 23. SITE #1, OPTION #2, DESIGN OPERATION CURVE

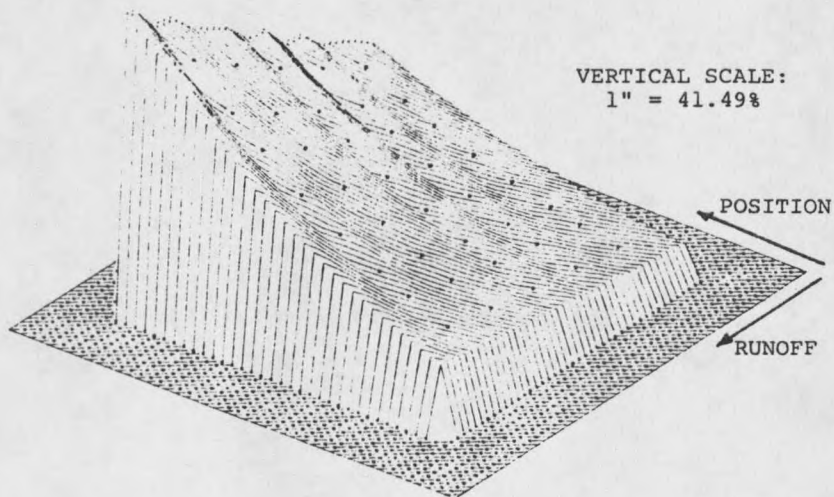
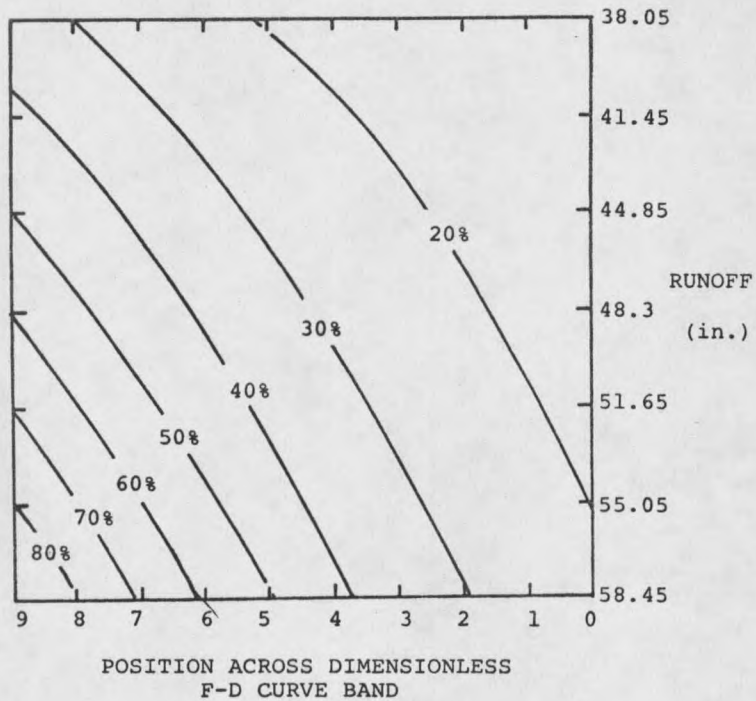


FIGURE 24. SITE #1, OPTION #2, RATE OF RETURN
SENSITIVITY

Table 11. Site #1, Option #3, Chosen Design

Diversion:	18th small creek above gage
Powerhouse:	Mile 2.69 above gage
Low Pressure Pipeline:	27 in. Fiberglass, $C_H = 140$, Length = 11360 ft.
High Pressure Pipeline:	16 in. Steel, $C_H = 120$, Length=3450 ft.
Gross Head	= 1600 ft.
Design Net Head	= 1447.1 ft.
Weighted Avg. Net Head	= 1445.8 ft.
Minimum In-Stream Flow	= 1 cfs.
Design Flow	= 18.6 cfs.
Flow at max. Power	= 35.5 cfs.
Cutoff Flow	= 1.86 cfs.
Design Rate of Return	= 37.8%
Actual Rate of Return	= 26.3%

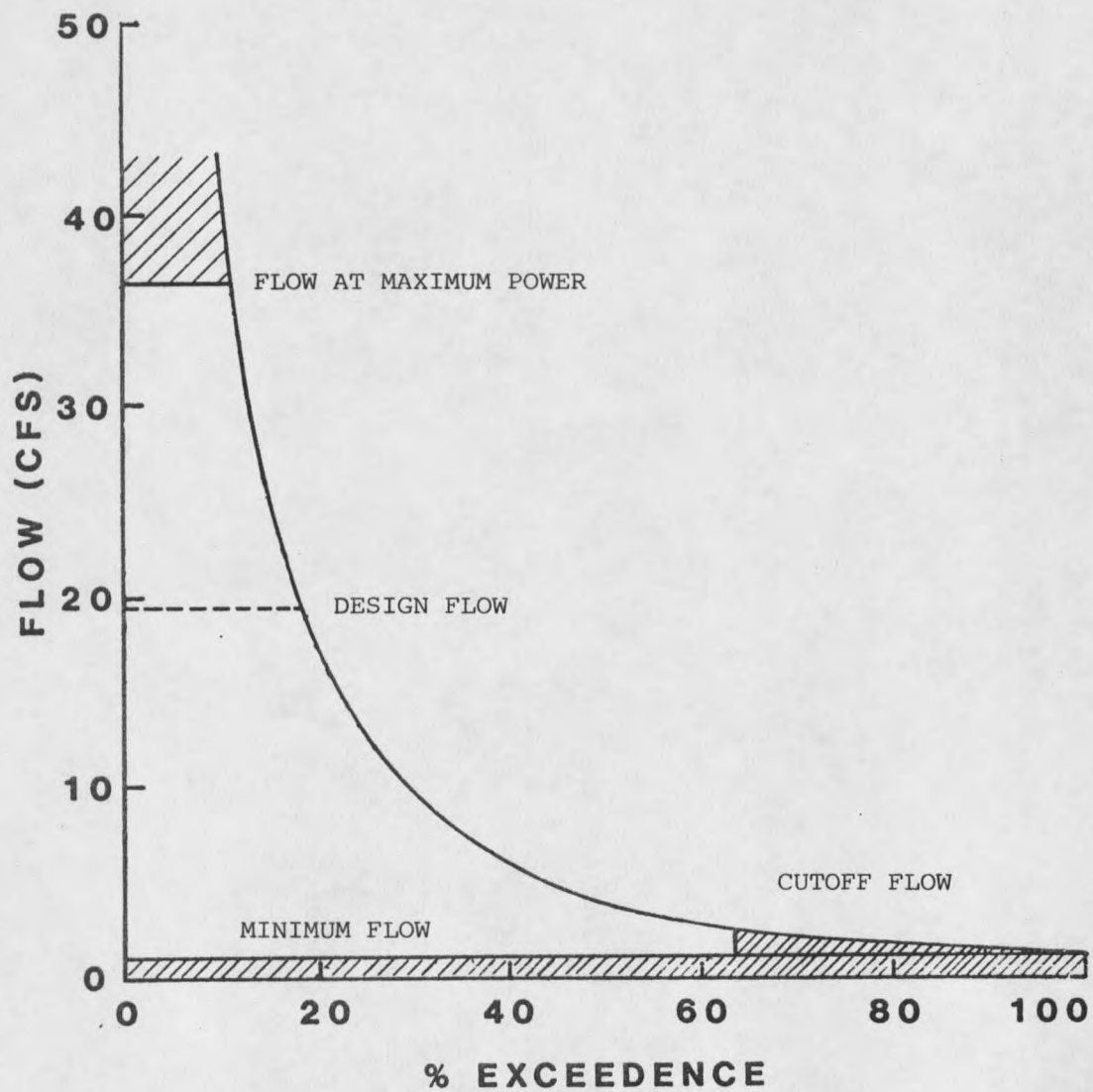


FIGURE 25. SITE #1, OPTION #3, DESIGN OPERATION CURVE

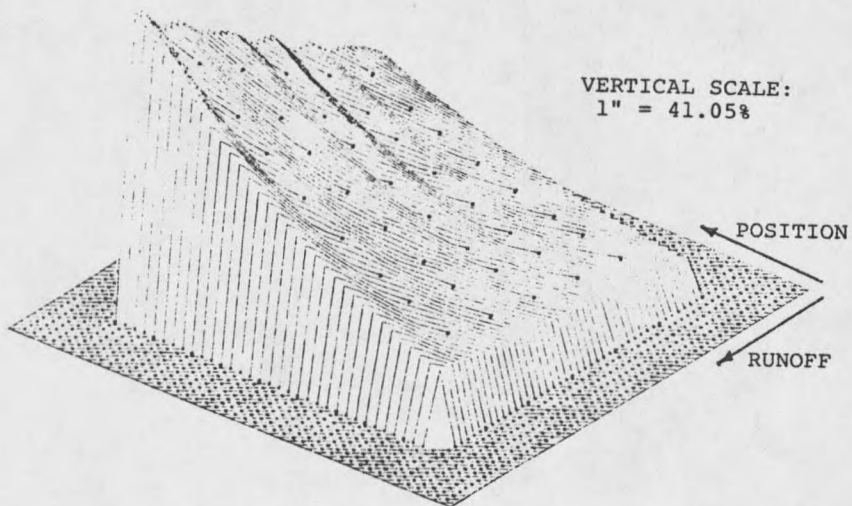
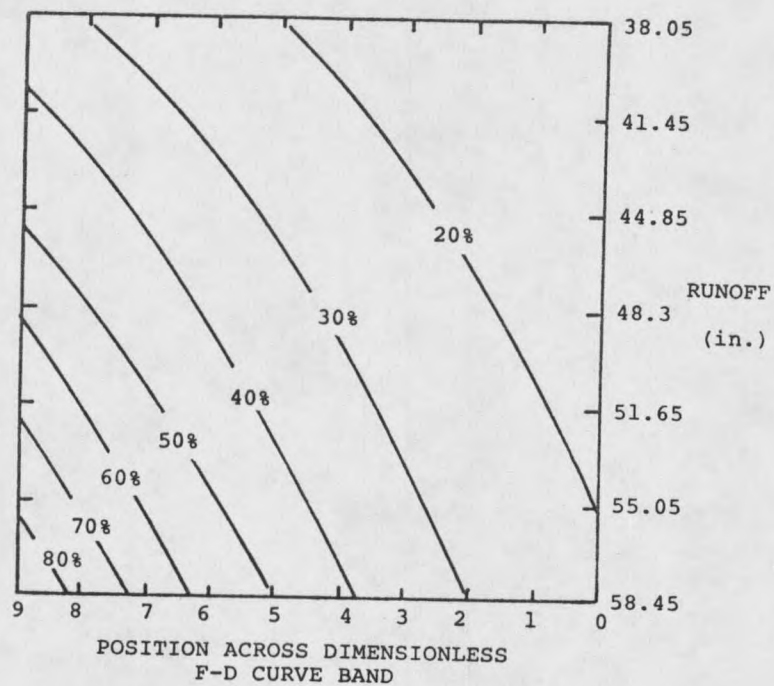


FIGURE 26. SITE #1, OPTION #3, RATE OF RETURN SENSITIVITY

Table 12. Site #1, Option #4, Chosen Design

Diversion:	18th small creek above gage
Powerhouse:	Mile 2.69 above gage
Low Pressure Pipeline:	27 in. Fiberglass, $C_H = 140$ Length = 11360 ft.
High Pressure Pipelines:	18 in. Steel, $C_H = 120$, Length=3450 ft.
Gross Head	= 1600 ft.
Design Net Head	= 1464.6 ft.
Weighted Avg. Net Head	= 1463.9 ft.
Minimum In-Stream Flow	= 1 cfs.
Design Flow	= 22.3 cfs.
Flow at Max. Power	= 45.1 cfs.
Cutoff Flow	= 2.23 cfs.
Design Rate of Return	= 38.1%
Actual Rate of Return	= 23.2%

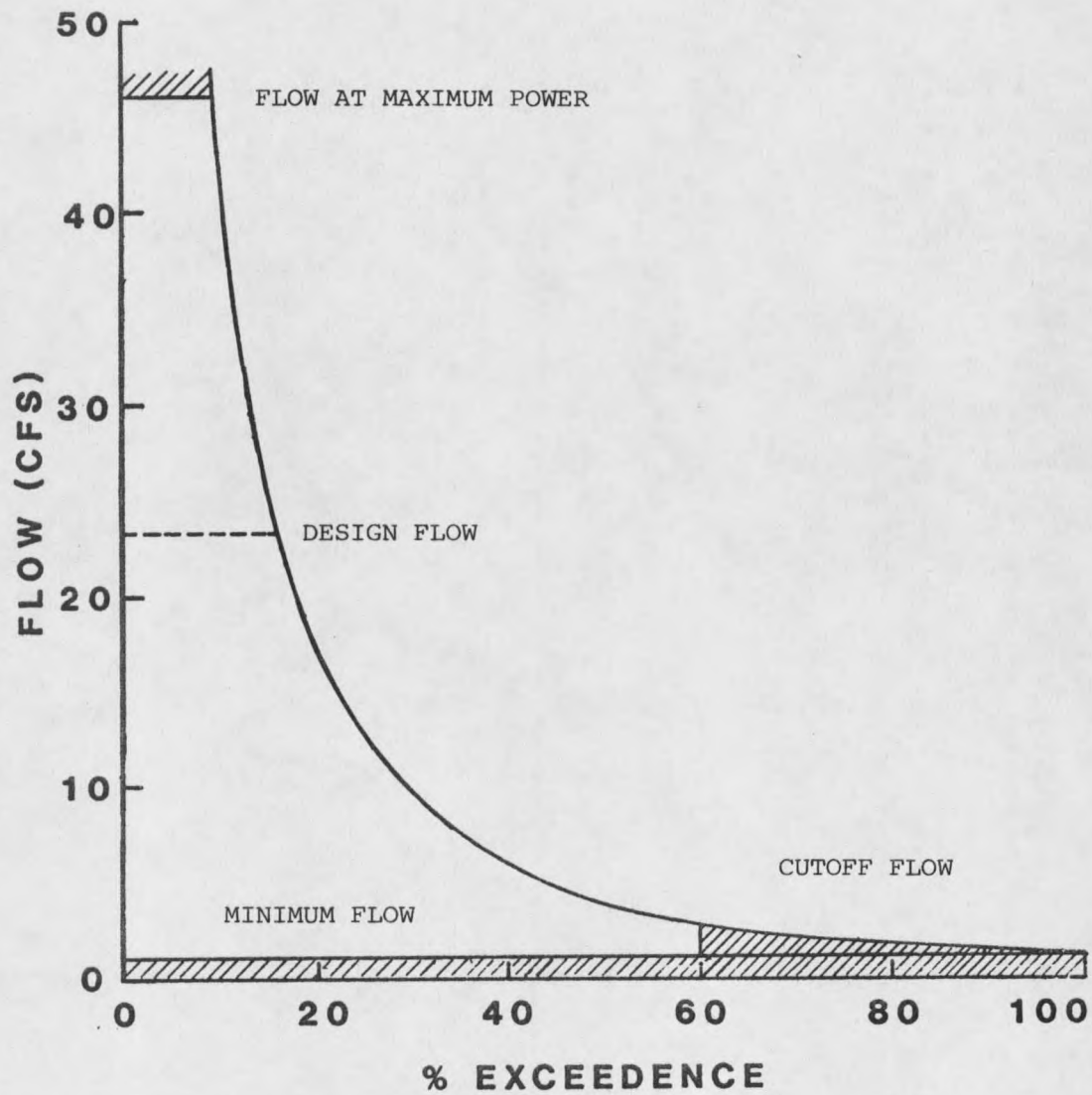


FIGURE 27. SITE #1, OPTION #4, DESIGN OPERATION CURVE

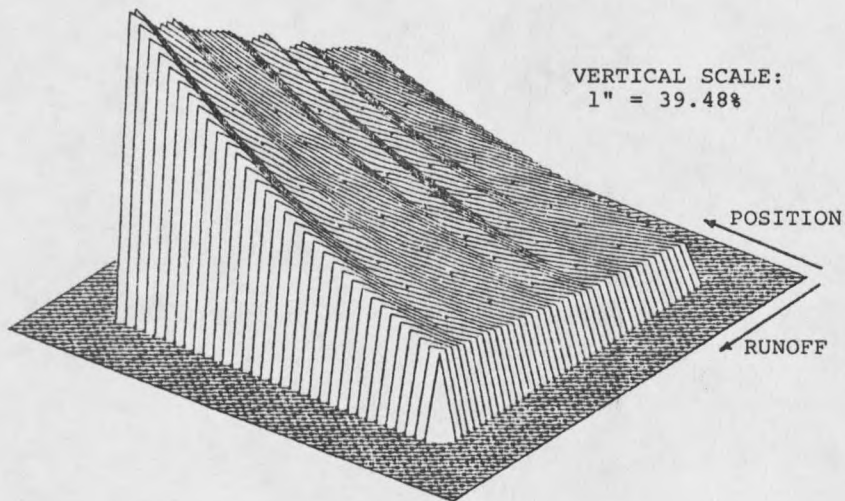
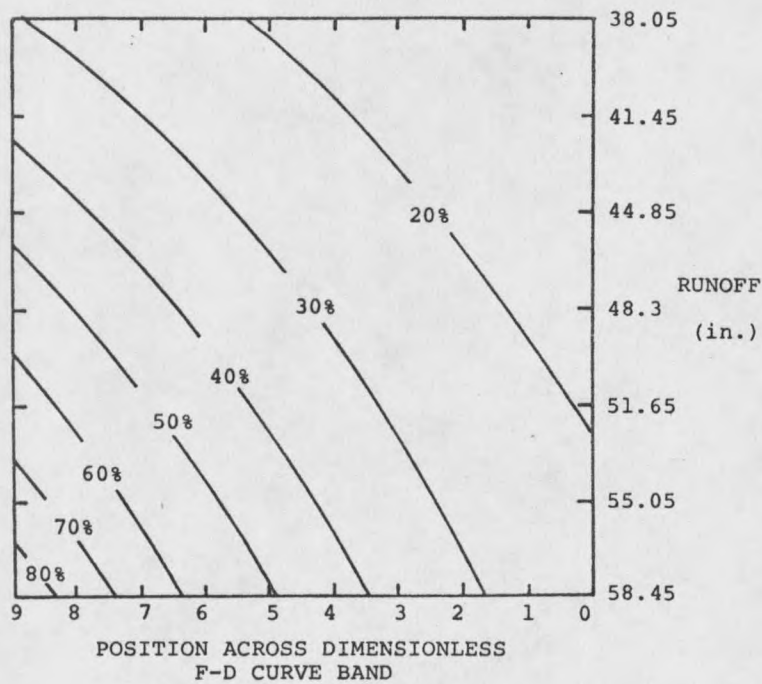


FIGURE 28. SITE #1, OPTION #4, RATE OF RETURN SENSITIVITY

Discussion of Results

Examination of the sensitivity results of the four design options yields some interesting characteristics.

1. The larger the design size the greater the sensitivity to runoff.
2. The smaller the design size - the greater the sensitivity to position.
3. The smaller the design size - the greater the overall variation in rate of return and hence the greater the overall sensitivity to prediction.
4. The smaller the design size - the greater the rate of return with the actual flow-duration curve.

The first two observations are easily explained. Designs based on low exceedence flows only operate during a short time of the year, and do not generate income during low flow periods. These designs, therefore, rely heavily on a flow duration curve synthesis method's ability to accurately predict high flows. For the Montana method, this task involves the prediction of runoff volume from precipitation. In addition, added uncertainty lies in the relationship assumed between the average annual and ten percent exceedence flows. Smaller designs, conversely, rely heavily on low flows for the bulk of their energy production. While accuracy of runoff prediction is important for these types of designs, the selected position is the greatest influence on low flow magnitudes.

The third observation stems from the fact that large designs cover the high flow end of the flow-duration curve (Figure 27). As the dimensionless prediction procedure is permuted from the lowest to the highest curve, the proportionate increase in the useable area under the curve for the Option #4 design, at 1.9, is less than the smaller Option #1's increase of 2.3 (Figure 29). Thus the overall change in rate of return for the larger design is less than for the smaller design.

The fourth observation is the result of the actual flow duration curve exhibiting only a slightly higher actual runoff volume, while displaying a much higher position than that predicted. These conditions favor the position-sensitive smaller design.

Site Example #2 - Medium Head

The combination of a large drainage area in mountainous terrain with gradual slope are typical of the medium head power plant. Twin Creek near Hungry Horse, Montana, was used to simulate these conditions. U.S.G.S. gage #12-3600, near the confluence of Twin Creek with the South Fork of the Flathead River, was used for actual flow-duration curve formulation at diversion sites above it.

Two diversion sites and five powerhouses were chosen for investigation. The diversions were chosen immediately below the confluences of Nanny Creek and South Creek, due to the significant sizes of their subdrainages (Figure 30). The five

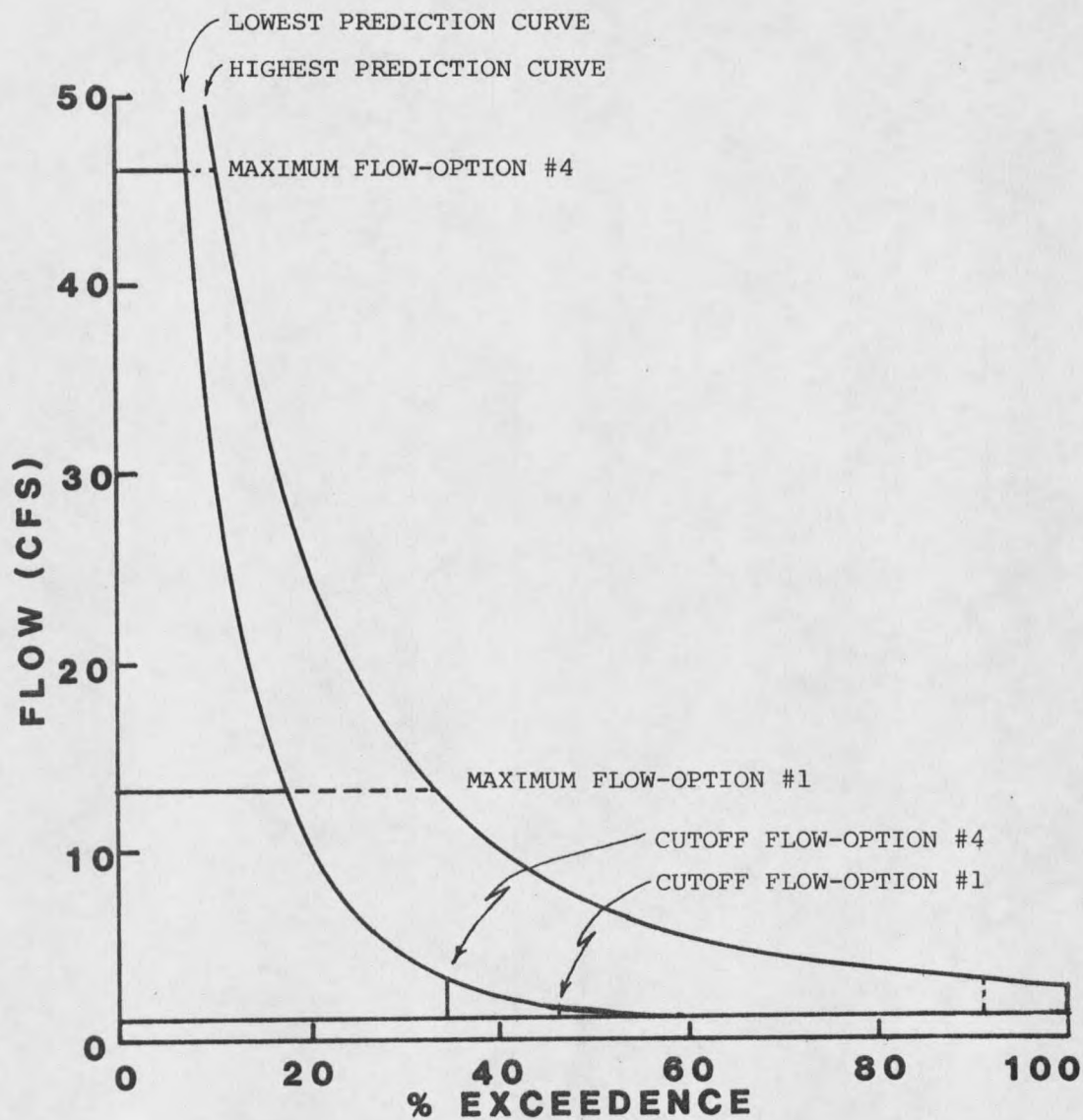


FIGURE 29. OPERATION CURVES FOR SITE #1, OPTIONS 1 AND 4 FOR EXTREME HIGHEST AND LOWEST PREDICTED F-D CURVES

powerhouse sites were chosen on the basis of slope break, flat building pad, flood mitigation, ease of pipeline route, and ease of road building. These sites include mile 4 above the gage, slope break at mile 3.63, Flat Creek confluence, mile 2.5, and at the gage.

A surge tank is required for stability of plant operation in cases of long penstocks. For the purposes of this report, it was assumed that any pipeline over 10,000 feet long would require a surge tank. In those cases the low pressure pipeline was routed along a contour to the surge tank, with a high pressure penstock continuing directly to the powerhouse. Otherwise, it was assumed that a single low-pressure pipeline would be routed parallel to the stream.

Flow-Duration Curves

The value of runoff corresponding to the mean basin precipitation for Twin Creek was chosen to lie on the dividing line between Alpine - Rocky and Deep Soil - Heavily Timbered (Figure 2), due to the presence of low peaks and high percentage forest cover. The chosen position within the dimensionless F-D curve band was one-third up, due to the combination of heavy forest and fine soils tending to hold water for high base flows and the close proximity of all points in the basin to a stream resulting in rapid time of concentration. Tables 13 - 15 show the synthetic and actual flow-duration curves formed by the procedures outlined in example 1.

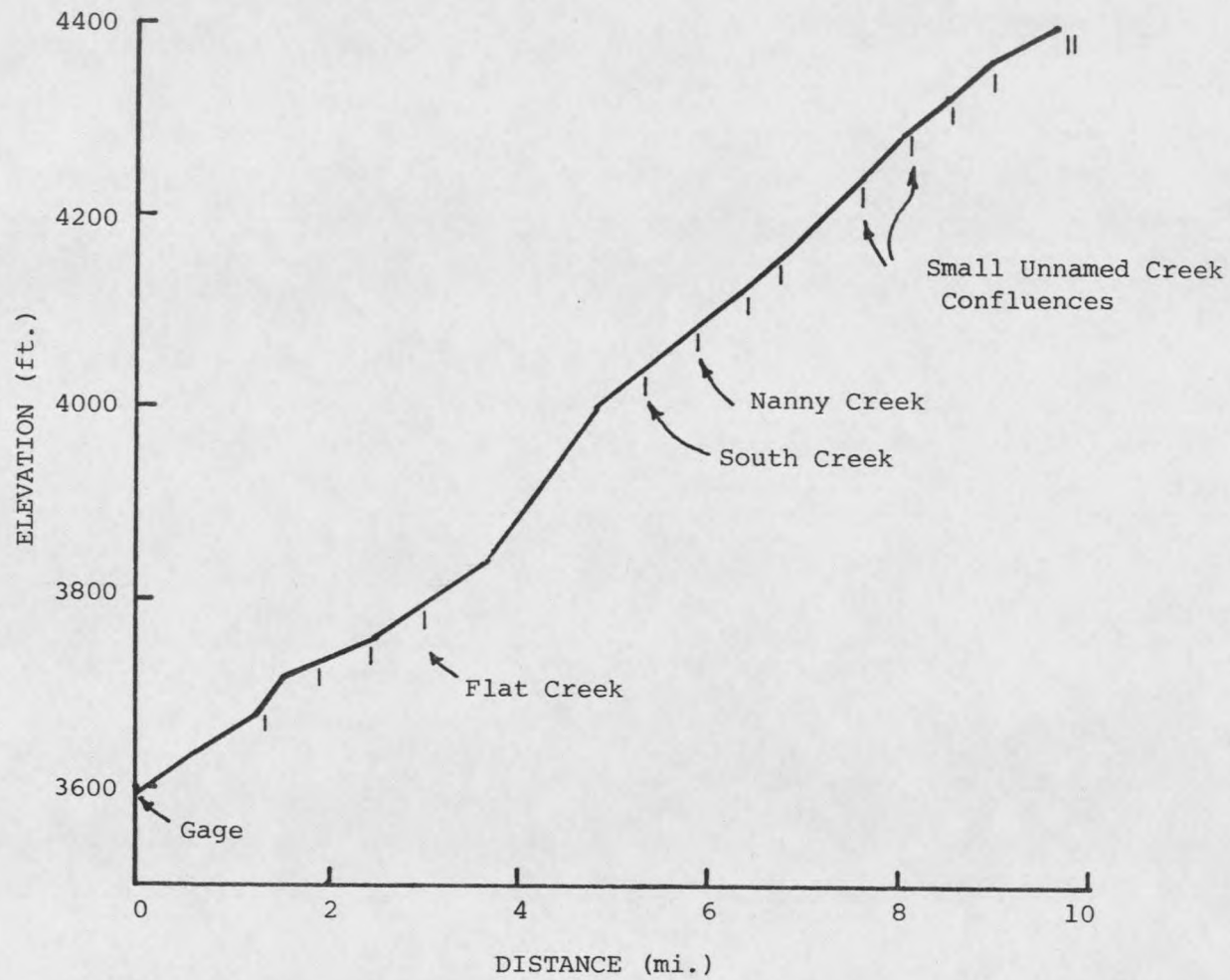


FIGURE 30. TWIN CREEK PROFILE

Table 13. Site #2 Average Annual Flow Computation

For Diversion Immediately Below	Drainage Area ₂ (mi. ²)	Weighted Mean Annual PPT. (in.)	Chosen Runoff (in.)	Average Annual Flow (cfs)
Stream Gage #12-3600	47.0	53.2	27.9	96.7
South Creek	38.2	56.3	30.4	85.4
Nanny Creek	32.9	57.5	31.4	76.1

Table 14. Site #2, Synthetic Flow Duration Curve, Computation

% Exceedence	Dimensionless Coefficient	Synthetic F-D Curve Ordinates (cfs)		
		Stream Gage 12-3600	South Creek	Nanny Creek
10	1.0	296	261	233
20	.390	115	102	90.7
30	.201	59.4	52.5	46.7
40	.128	37.8	33.5	29.8
50	.083	24.5	21.8	19.3
60	.060	17.7	15.6	14.0
70	.044	13.0	11.5	10.2
80	.036	10.6	9.4	8.4
90	.029	8.6	7.7	6.7
100	.027	8.0	7.0	6.3

Table 15. Site #2, Actual Flow-Duration Curve Computation

% Exceedence	<u>Actual Flow-Duration Curve Ordinates (cfs)</u>		
	Stream Gage 12-3600	South Creek	Nanny Creek
10	411	363	323
20	168	148	132
30	68	60	54
40	43	38	34
50	33	29	26
60	26	23	20
70	20	18	16
80	16	14	13
90	12	11	9.4
95	9.6	8.5	7.6
99.9	4.8	4.2	3.8

Minimum In-Stream Flow

The gradual slope of Twin Creek is an indicator of the likelihood of a resident and migrating fish population. It was assumed for this report that a minimum flow of 10 cfs was specified for both diversion sites by the Montana Department of Fish, Wildlife, and Parks. In addition, it was assumed that special fish screens were required at diversions (Figure 8).

Economic Factors

The economic factors used in all design alternatives are given in Table 16.

Table 16. Site #2 Economic Factors

Mortgage Interest Rate	= 10%
Period of Mortgage	= 30 yr.
Down Payment	= 15% of Initial Cost
Property Tax Data	
Permanent Property Appreciation Rate	= 2%
Taxable Value of Permanent property	= 8.55% of Assessed Value
Taxable Value of Depreciable Machinery	= 11% of Assessed Value
Method of Depreciation	= Straight line to 20% of Initial in 20 years
Initial Mill Levy	= 211.696
State Income Tax Rate	= 6.75%
Federal Tax Credit	= 21%
Inflation Rate	= 8%
Project Life	= 50 yr.
Initial Energy Cost	= \$.064/kw-hr.
Initial Capacity Cost	= \$7.9294/contract kw/mo.
Energy Cost Escalation Rate	= 6%

Design Alternatives

The design alternatives tested are given in Table 17, with additional data common to all alternatives in Table 18.

Table 17. Site #2, Design Alternatives

Diversion	Powerhouse	Low Pressure Pipeline					High Pressure Pipeline					Transmission Line Cost
		Diameters (in.)	Type	C _H	Length (ft.)	Surge Tank Cost	Diameters (in.)	Type	C _H	Length (ft.)	Diversion Width	
South Creek Elev.=4040	Mile 4 Elev.=3880	27- 72	Fiberglass	140	6860	\$ 0	-	-	-	-	22.5- 60	\$165,000
	Mile 3.63 Elev.=3840	27- 72	Fiberglass	140	8650	0	-	-	-	-	22.5- 60	\$155,000
	Flat Creek Elev.=3795	27- 72	Fiberglass	140	10400	\$20,000	27- 72	Fiberglass	140	1000	22.5- 60	\$130,000
	Mile 2.5 Elev.=3760	27- 72	Fiberglass	140	12100	\$20,000	27- 72	Fiberglass	140	1500	22.5- 60	\$115,000
	Stream Gage Elev.=3585	27- 54	Fiberglass	140	24100	\$20,000	20- 54	Steel	120	1300	22.5- 45	-0-
Wanny Creek Elev.=4080	Mile 3.63 Elev.=3840	27- 72	Fiberglass	140	10450	\$20,000	27- 72	Fiberglass	140	1000	22.5- 60	\$155,000
	Mile 2.5 Elev.=3760	27- 72	Fiberglass	140	14900	\$20,000	27- 72	Steel	120	1500	22.5- 60	\$115,000

Table 18. Site #2, Additional Alternative Data

Access Road Cost (South Creek Diversion 5.3 mi)	\$260,000
Access Road Cost (Nanny Creek Diversion 5.83 mi)	\$286,000
Turbine Type	Reaction (Francis)
Turbine Limits of Operation	
Cutoff Flow	40% of Design Flow
Wide Open Gate Flow	140% of Design Flow
Minimum Head	65% of Design Net Head
Maximum Head	125% of Design Net Head

Results of Alternative Comparison

The diversion and powerhouse locations were first screened by using equal diameters for high and low pressure pipelines. It soon became evident that the South Creek diversion site was the most economical choice, so only two powerhouse locations were tested with the Nanny Creek diversion before it was dropped. The South Creek diversion - stream gage powerhouse combination produced the highest rates of return on the equal diameter runs, as shown in Table 19, eliminating all other powerhouse options. The best combination of high and low pressure pipeline diameters for the chosen diversion powerhouse option was found next (Table 20), and unlike Site Example #1, was a single option.

Table 19. Site #2 Design Alternative Comparison Rates of Return (%)

Diversion	Powerhouse	Low and High Pressure Pipeline Diameter (in.)									
		27	30	33	36	42	48	54	60	66	72
South Cr.	Mile 4	0	0	3.9	5.2	6.3	5.9	6.3	6.5	6.4	6.0
	Mile 3.63	0	3.7	7.0	8.0	9.0	8.4	8.8	9.0	8.7	8.1
	Flat Cr.	3.0	5.6	8.0	9.7	11.1	10.2	10.4	10.	10.4	9.8
	Mile 2.5	4.5	6.7	8.9	10.9	12.3	11.3	11.6	11.8	11.2	10.6
	Stream Gage	7.9	9.4	11.2	13.5	14.4	13.0	12.1			
Nanny Cr.	Mile 3.63	0	0	2.6	4.6	5.8	5.3	5.8	6.0	5.7	5.3
	Mile 2.5	4.5	6.6	8.9	10.1	10.5	10.4	11.0	11.0	10.0	9.4

As in Site Example #1, Tables 19 and 20 exhibit parabolic behavior of the rate of return across rows and down columns, with small minor imperfections caused by inaccurate curve fits and tax credit phenomena. The optimum design from Table 13 is clearly defined as a 42-inch low pressure 42-inch high pressure pipeline combination from a rate of return basis.

Table 20. Site #2 South Creek Diversion - Stream Gage Power-house; Pipeline Option Comparison, Rates of Return (%)

High Pressure

Pipeline Low Pressure Pipeline Dia. (in.)

Dia.(in.) 27 30 33 36 42 48 54

20	7.5	8.0	8.4	8.5			
24	7.9	8.8	10.0	10.8	11.9	11.3	10.2
27	7.9	9.1	10.6	13.1	13.1	12.6	11.3
30	7.9	9.4	10.8	13.3	13.7	13.4	11.4
33	8.0	9.5	11.2	13.4	14.2	13.3	11.7
36	7.8	9.4	11.1	13.5	14.3	13.0	11.8
42			11.2	13.4	14.4	12.9	12.0
48			11.0	13.2	14.3	13.0	12.1
54			10.7	12.9	14.0	12.8	12.1

Sensitivity To Flow Prediction

The single, best design was next tested for sensitivity to inaccuracies of F-D curve prediction, as described for Site Example #1. As with Site Example #1, minor changes were made in the computer program to reflect the true property tax structure

between the time alternative comparison runs and sensitivity runs were made. Those changes had no effect on the choice of best alternative.

In addition to the property tax changes, minor losses at the intake, surge tank, valves, and tailrace were added in the final sensitivity run. These changes were made in attempt to more realistically simulate the system.

Results of Sensitivity Analysis

The design, summarized in Table 21, with the predicted operation curve of Figure 31, was found to have the sensitivity plots of Figure 32.

Table 21. Site #2, Chosen Design

Diversion:		South Creek Confluence
Powerhouse:		Stream Gage
Low Pressure Pipeline:		42 in. Fiberglass, $C_H = 140$, Length = 24,100 ft.
High Pressure Pipeline:		42 in. Steel, $C_H = 120$, Length = 1,300 ft.
Gross Head	=	455 ft.
Design Net Head	=	366.4 ft.
Weighted Avg. Net Head	=	365.2 ft.
Minimum In-Stream Flow	=	10 cfs.
Design Flow	=	75.2 cfs.
Flow at Max. Power	=	91.8 cfs.
Cutoff Flow	=	30.1 cfs.
Design Rate of Return	=	16.4%
Actual Rate of Return	=	18.9%

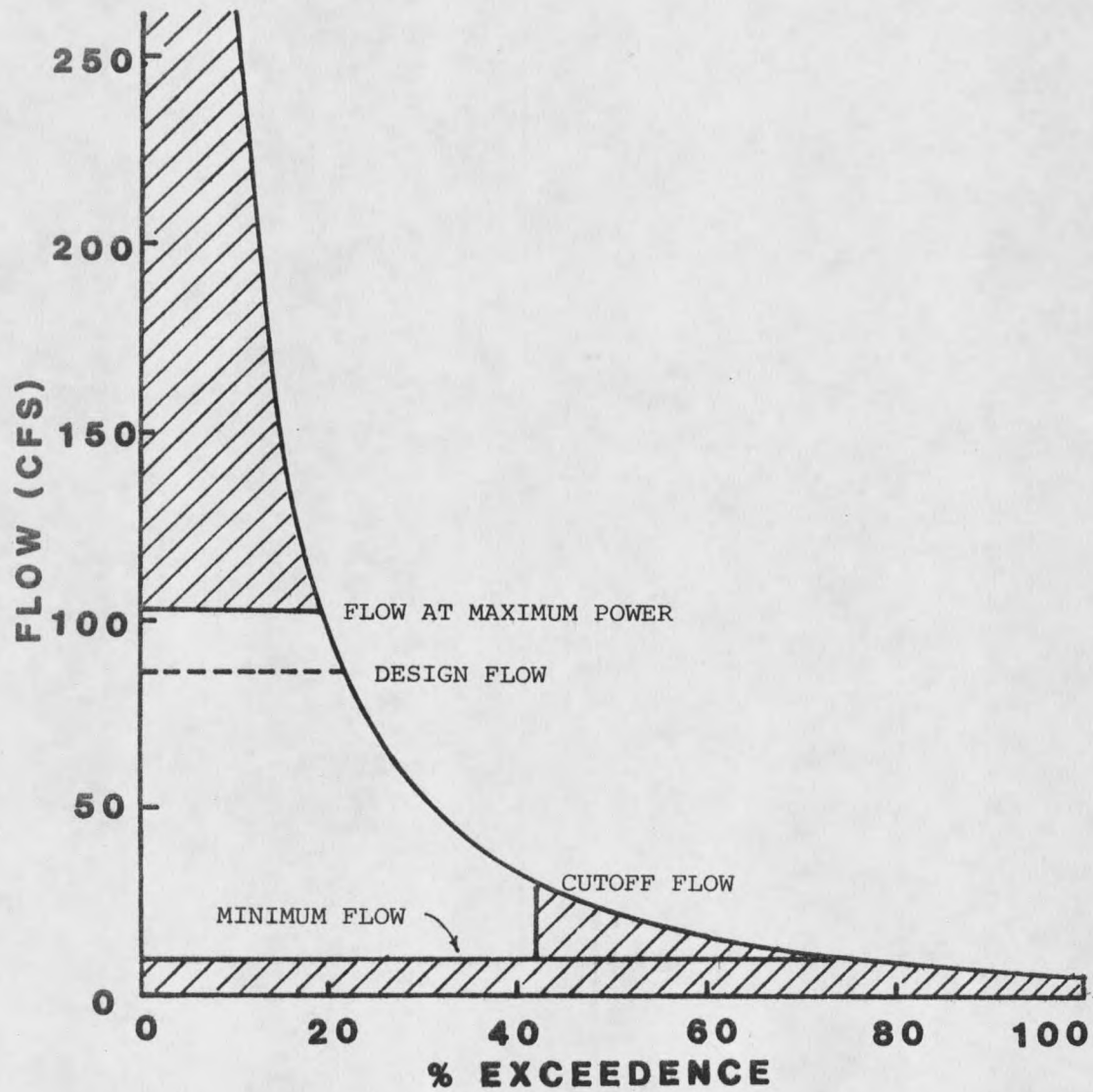


FIGURE 31. SITE #2, DESIGN OPERATION CURVE

-100-

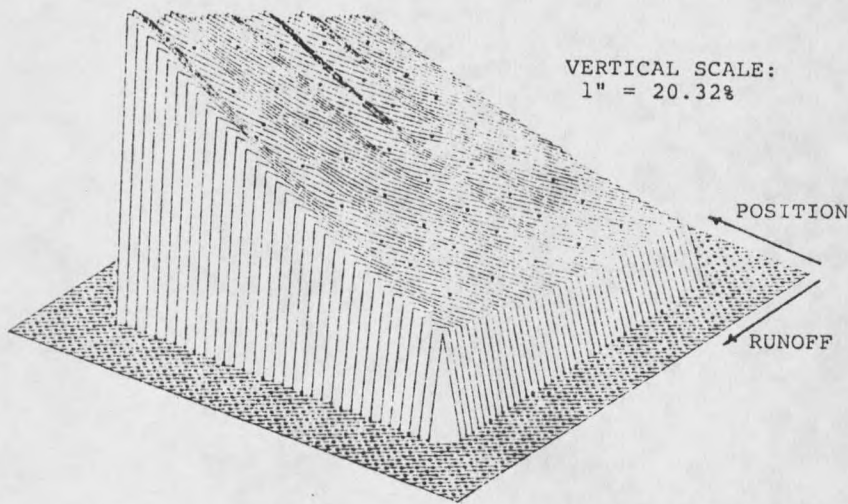
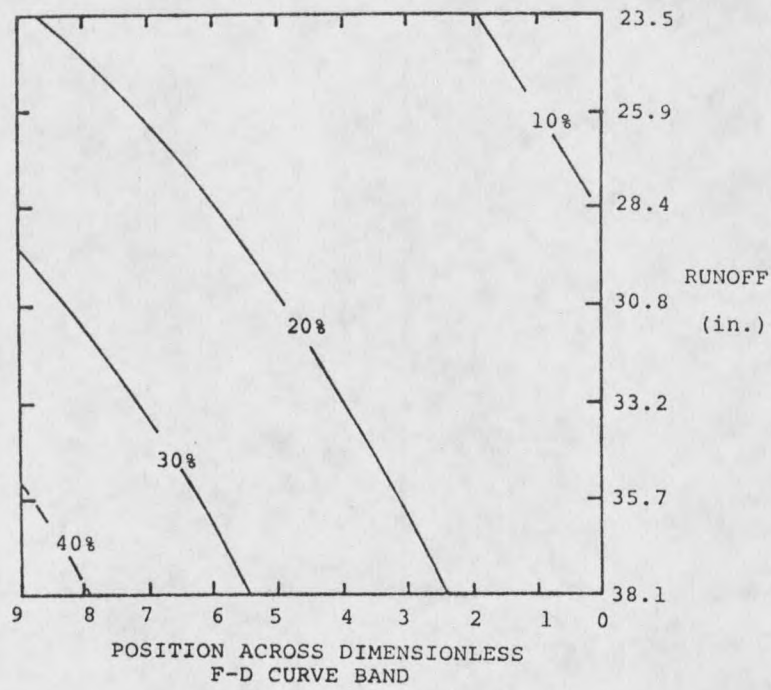


FIGURE 32. SITE #2, RATE OF RETURN SENSITIVITY

Discussion of Results

Review of the sensitivity plot for the medium head example reveals a few interesting characteristics:

1. The chosen design is more sensitive to position than runoff.
2. The overall surface is flatter than those for Example #1.

The first observation indicates a design which depends primarily on the low flow period of the year. The increased sensitivity to position is attributable to the high cutoff flow associated with reaction turbines, which, for this design, is located at a point where the low flow leg is beginning to flatten out. Any small change in position will shift the cutoff exceedence a great deal, providing a significant change in annual energy production.

The flatness of the sensitivity surface is due to the narrow operating range of the reaction turbine. This narrow range has the effect of restricting the ability of the powerplant to effectively absorb changes in the flow-duration curve.

Site Example #3 - Low Head

Flat topography and a large drainage basin make Belt Creek near Monarch, Montana suitable for a low head hydropower facility. For the purposes of this report, a 48 foot high run-of-the river dam was assumed to be in place at the same

location as the existing U.S.G.S. gage #6-0905. It was also assumed that the spillway and low level outlet works were in good enough condition to allow development to be limited to attaching a powerhouse to the low level outlet.

It was necessary to obtain the spillway and tailwater rating curves, because any head changes will be significant. The tailwater rating curve was assumed to be the same as the stage-discharge relationship existing at the gage, which is given in Table 22. The spillway was assumed to be designed to pass the U.S.G.S.'s value of the 100 yr. flood, equal to 6700 cfs, at a depth of 7 feet. Thus, for a spillway crest of 40 feet above the base, and a U. S. Army Corps of Engineers Waterway Experiment Station standard spillway shape, a crest width of 90 feet was selected. The spillway rating curve is then defined by:

$$H_s = .019662Q_s^{2/3}$$

Where: H_s = water depth over
spillway ft.

Q_s = flow rate over
spillway cfs.

Further assumptions regarding the existing dam structure are given as they are needed.

Table 22. Site #3 Tailwater Rating Curve

Elevation Above Datum* (ft.)	Tailwater Flow Rate (cfs)
.1	27.1
.2	32.6
.3	38.8
.4	46.0
.5	54.0
.6	63.0
.8	84.5
1.0	115
1.2	152
1.4	194
1.6	242
1.8	295
2.0	355
2.4	505
2.8	694
3.2	921
3.4	1050

*Datum is assumed to be 40 ft. below spillway crest.

Flow-Duration Curves

Even though the actual U.S.G.S. flow data was used to provide a hypothetical dam design, the hydropower design was selected on the basis of predicted data.

The synthetic flow-duration curve for Belt Creek was formed by assuming a runoff roughly midway between the Alpine - Deep Soil line and the lower data boundary (Figure 2) and a position of 3/4 of the way up the dimensionless F-D band (Figure 3). The choice of runoff was made to account for the loss of water to deep percolation expected in that location. The relatively high F-D curve position was chosen to account for the large groundwater storage and slow time of concentration expected in the wide, flat, and deep soiled drainage basin of Belt Creek. Tables 24 gives the synthetic and actual F-D curves resulting.

Table 23. Site #3 Average Annual Flow Computation

Location on stream	Drainage Area ₂ (mi. ²)	Weighted Mean Annual PPT. (in.)	Chosen Runoff (in.)	Average Annual Flow(cfs)
Stream Gage #6-0905	368	24.2	5.5	149

Table 24. Site #3, Flow-Duration Curves at Gage

% Exceedence	Dimensionless Coefficient	Synthetic F-D Ordinates (cfs)	Actual F-D Ordinates (cfs)
10	1	456	529
20	.474	216	218
30	.269	123	116
40	.183	83.2	77
50	.125	57.0	59
60	.094	43.0	47
70	.074	33.7	38
80	.064	29.0	30
90	.054	24.4	21
100	.049	22.2	2.9

Minimum In-Stream Flow

Since no water is being diverted from the stream, it was assumed that all of the water was available for power generation.

Economic Factors

The economic factors used are given in Table 25.

Table 25. Site #3 Economic Factors

Mortgage Interest Rate	= 12%
Period of Mortgage	= 30 yr.
Down Payment	= 10% of initial cost
Property Tax Data	
Permanent Property Appreciation Rate	= 2%
Taxable Value of Permanent Property	= 8.55% of Assessed Value
Taxable Value of Depreciable machinery	= 11% of Assessed Value
Method of Depreciation	= Straight line to 20% of initial
Initial Mill Levy	= 237.24
State Income Tax Rate	= 6.75%
Federal Tax Credit	= 21%
Inflation Rate	= 8%
Project Life	= 40 yr.
Initial Energy Cost	= \$.064/kw. hr.
Initial Capacity Cost	= \$7.9294/Contract kw/mo.
Energy Cost Escalation Rate	= 6%

Design Alternative

Due to the low slope of the terrain at the outlet, moving the powerhouse downstream of the dam would not be profitable. The only alternative considered, then, was that of affixing the powerhouse to the outlet works at the dam.

The existing low level outlet was assumed to have been designed to release the actual 25% exceedence flow at 10 fps. The dam was assumed to have 3:1 slopes with a 20 foot top width. The low level outlet, assumed horizontal 8 feet up from the base, was therefore assumed to have the characteristics:

Dia. = 54 in.

Type: Steel

C_H = 120

Length = 260 ft.

The inlet was assumed to be well rounded, with a dewatering gate valve and trashrack in place. The trashrack was assumed to be round, with a velocity of 2 fps. through it at the design flow and a minor loss coefficient of .41.^{9,10}

From the Allis-Chalmers sizing chart for tube turbines (Figures 33,34), the size of the tailrace of a standard turbine for a design flow of 165 cfs (the synthetic 25% exceedence flow) and a design head of 38 feet was found to be 2 meters by 1.5 meters. The turbine itself was assumed to be a fixed blade propeller type with adjustable wicket gates for flow control.

The hydraulic design is summarized in Table 26 and 27.

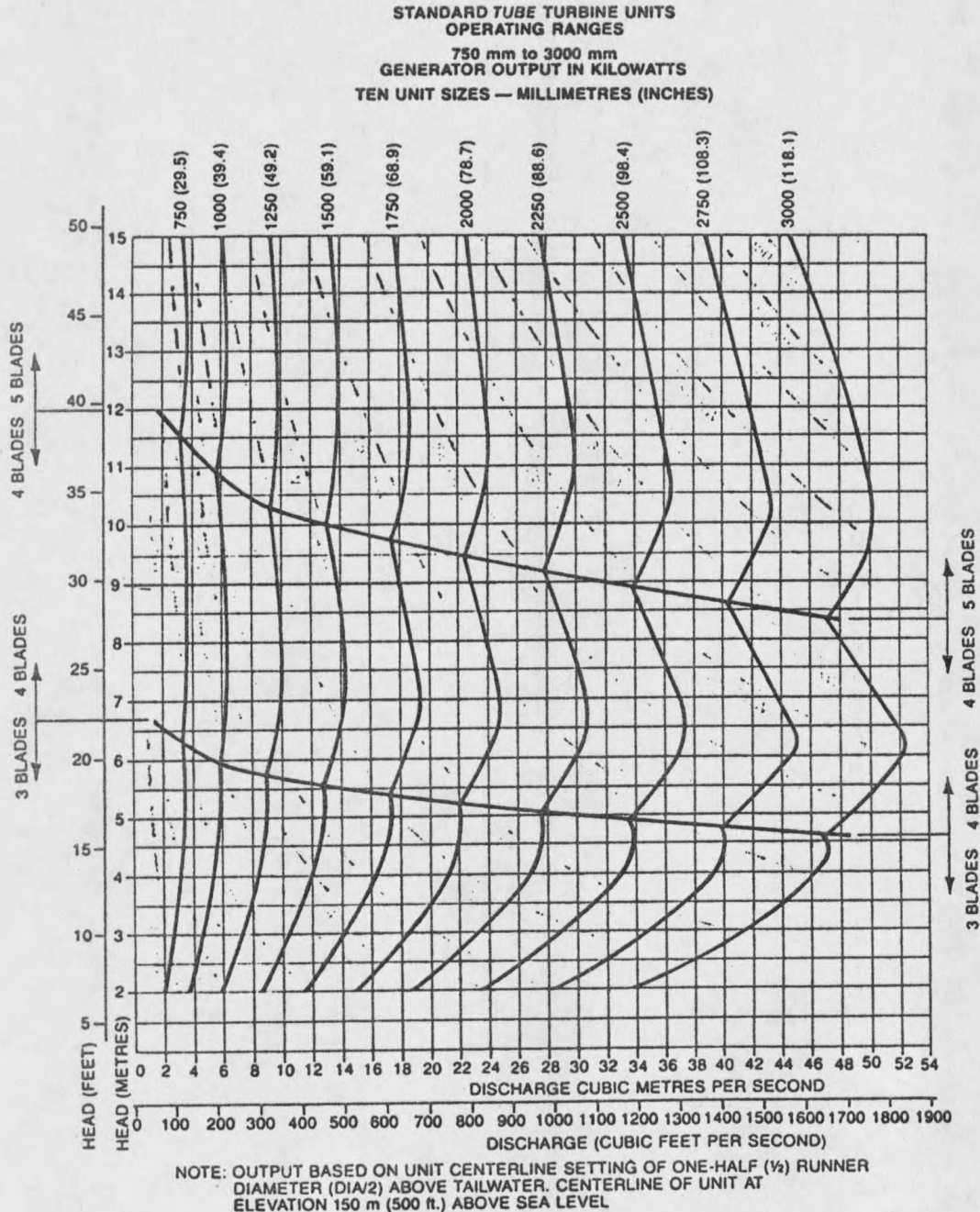
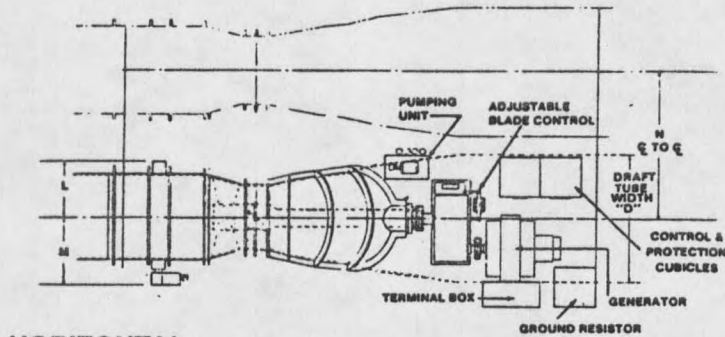
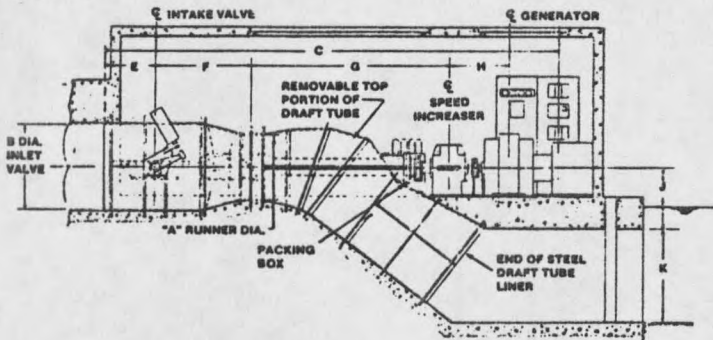


FIGURE 33. ALLIS-CHALMERS TUBE TURBINE SIZING CHART
(PERMISSION TO REPRODUCE GIVEN BY ALLIS-CHALMERS CORPORATION)



HORIZONTAL UNITS



BASIC DIMENSIONS

A = Runner Diameter in millimeters (inches) = 1.00

All Other Dimensions Are In Proportion From Runner Diameter

A	750 (29.5)	1000 (39.4)	1250 (49.2)	1500 (59.6)	1750 (68.9)	2000 (78.7)	2250 (88.6)	2500 (98.4)	2750 (108.3)	3000 (118.1)
B	1.43	1.37	1.34	1.32	1.31	1.30	1.29	1.28	1.27	1.22
C	8.6	7.9	7.3	7.2	6.9	6.7	6.6	6.6	6.5	6.5
D	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
E	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.6	0.6
F	1.8	1.6	1.5	1.5	1.5	1.4	1.4	1.4	1.4	1.4
G	3.8	3.6	3.5	3.5	3.4	3.4	3.3	3.3	3.3	3.3
H	1.5	1.3	1.1	1.1	1.0	0.9	0.9	0.9	0.8	0.8
J	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
K	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
L	0.9	0.9	0.9	0.9	0.8	0.8	0.8	0.8	0.8	0.7
M	1.3	1.3	1.3	1.2	1.2	1.2	1.2	1.2	1.2	1.2
N	3.0	2.7	2.6	2.5	2.4	2.4	2.3	2.3	2.3	2.2

NOTE: Dimensions are approximate and may vary for specific applications.

FIGURE 34. ALLIS-CHALMERS TUBE TURBINE DIMENSIONS
(PERMISSION TO REPRODUCE GIVEN BY ALLIS-CHALMERS CORPORATION)

Table 26. Site #3, Design Data Constants

Item	Loss Coefficient	Diameter or Equivalent Diameter(in.)	Length (ft.)
Intake (well rounded)	.1	54	-
Trashrack	.41	123	-
Gate Valve (wide open)	.2	54	-
Low Pressure Pipeline	120	54	260
Wicket Gates	In Efficiency	-	-
Exit Losses	1.0	78	-

Table 27. Site #3 Additional Design Data

Access Road Cost	\$ 0
Transmission Line Cost	\$ 0
Turbine Type	Reaction (Propeller)
Cutoff Flow	45% of Design Flow
Wide Open Gate Flow	113% of Design Flow
Minimum Head	50% of Design Net Head
Maximum Head	150% of Design Net Head

Results of Operation Simulation and Sensitivity Analysis

The variable gross head on the low head site example produced some interesting operation results, particularly the

instantaneous power production at high flows. The computer output for this example, printed in Appendix B, shows the output power changing in response to the varying gross head. For this particular design, the tailwater elevation changes faster than the spillway elevation at flows less than 800 cfs (about 6% exceedence). The power output decreases from 0-6% exceedence, then increases from 6-24%; all while the powerhouse flow remains constant at the "flow at maximum power". These trends are entirely site specific and could just as easily have had changing powerhouse flows and continuously decreasing gross head over the same flow duration curve domain, and are found by optimizing the operation at each streamflow to produce maximum power.

The operation and sensitivity plots are shown in Figures 35 and 36.

Discussion of Results

The sensitivity of the low head example design exhibited higher sensitivity to runoff than position, indicating a high flow design with narrow flow limits. The high rates of return at the peak of the sensitivity plot are due to the low original runoff selection, combined with the effect of the gross head raising above 800 cfs, causing higher outputs for high stream flows.

Table 28. Site #3 Design Conditions

Gross Head	=	Variable
Design Net Head	=	37.48 ft.
Weighted Avg. Net Head	=	37.54 ft.
Minimum In-Stream Flow	=	0 cfs.
Design Flow	=	132.05 cfs.
Flow at Max. Power	=	146.58 cfs
Cutoff Flow	=	59.42 cfs
Design Rate of Return	=	13.9%
Actual Rate of Return	=	13.2%

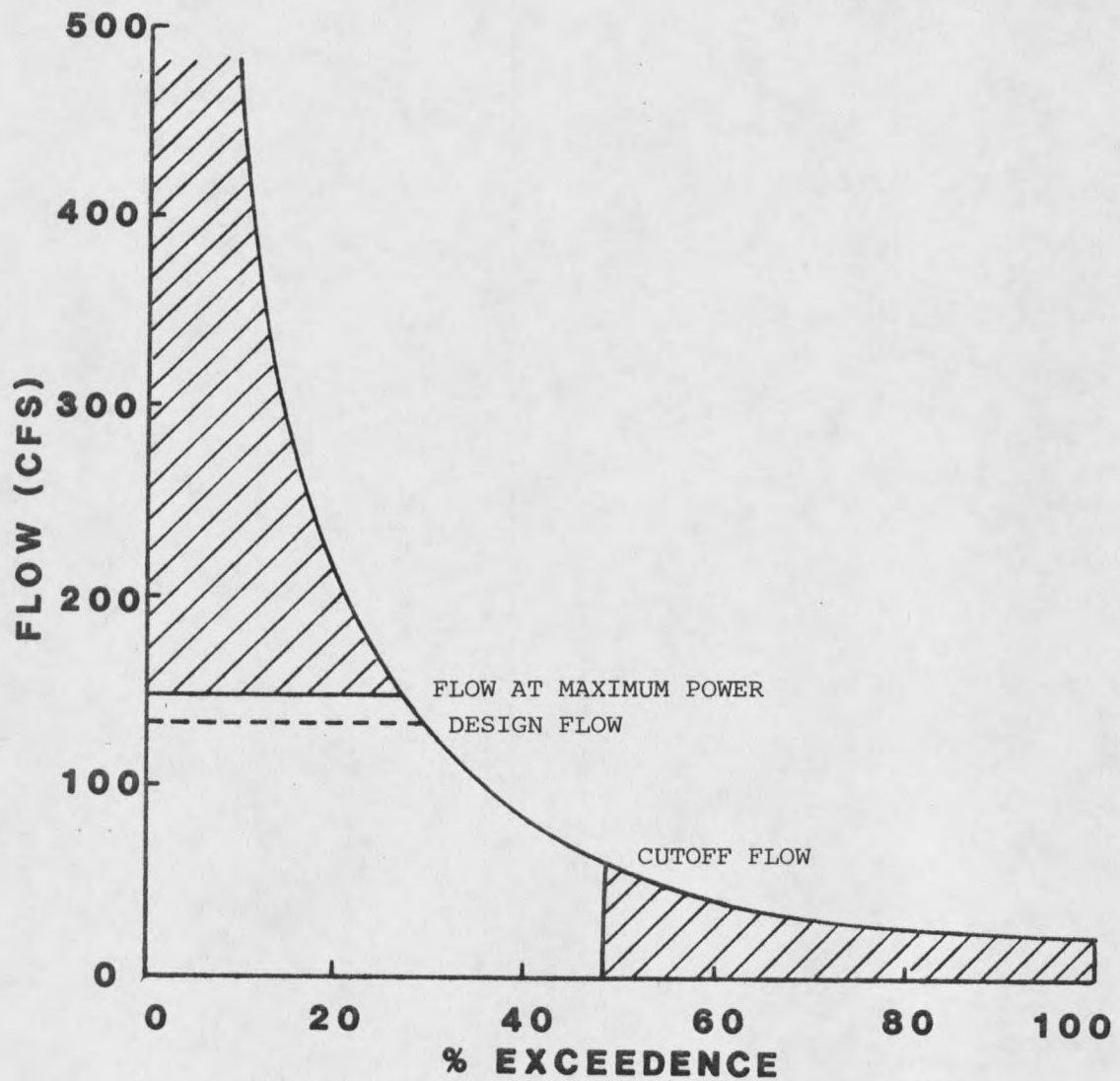


FIGURE 35. SITE #3, DESIGN OPERATION CURVE

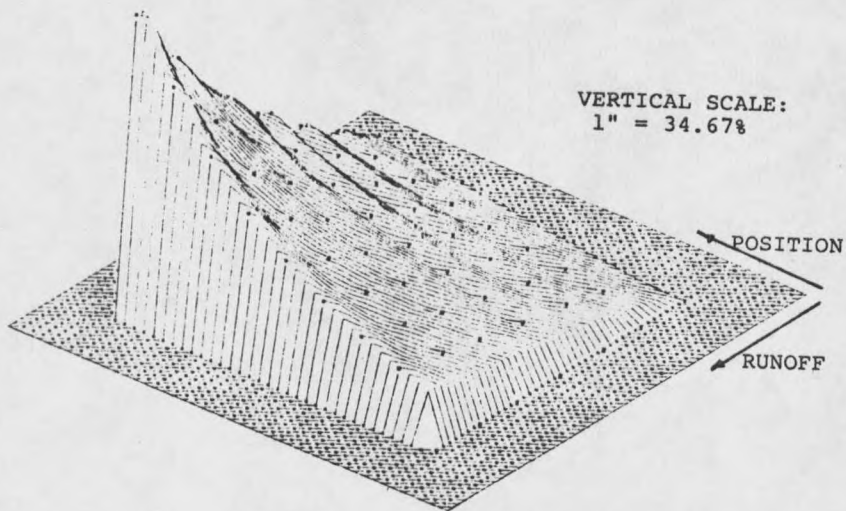
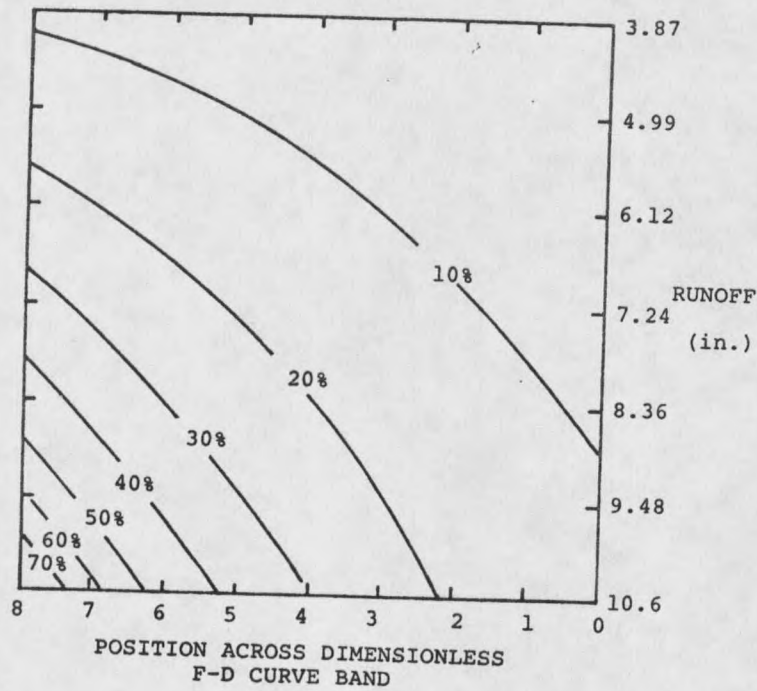


FIGURE 36. SITE #3, RATE OF RETURN SENSITIVITY

CHAPTER 9

CONCLUSIONS

A method by which the economically optimum hydraulic design of small scale hydropower facilities can be found and tested for sensitivity to hydrologic prediction has been developed. This method provides small hydropower developers with a tool to make accurate assessment of the capabilities of given sites along with the degrees of risk associated with the implementation of chosen designs.

Three example sites were analyzed to demonstrate the method. In addition to the summaries of those examples written within the body of this report, two sample computer outputs have been included for illustration in Appendices A and B.

Based on the results of the sensitivity analyses of the three site examples, several conclusions were drawn:

1. Where several design options gave equally high rates of return, the larger capacity designs were less sensitive to variations in the predicted flow-duration (F-D) curve.

2. The larger design options used in this study were found to be more sensitive to runoff prediction from mean basin precipitation (Figure 2) than the position chosen within the dimensionless flow-duration curve band (Figure 3).
3. Smaller options were found to be more sensitive to choice of position within the flow-duration curve band than runoff prediction.
4. Impulse turbine designs were found to be more sensitive to variations in flow-duration curves than reaction turbines.
5. Smaller designs, although more sensitive to flow prediction than larger designs, carry less overall economic risk.

The first four conclusions are a product of the placement of the operation block under the flow duration curve. In this case, "operation block" refers to the block of useable area under the flow-duration curve confined by the turbine flow and head limits. As the block extends out into the low flow leg, the influence of the F-D curve position choice increases. As the block extends upward to accommodate high flows over short periods of time, the design becomes more and more dependent on the accuracy of predicting the 10% exceedence flow, and hence runoff from precipitation. Impulse turbines are able to operate

over a wider range of flows than reaction turbines, so they have a larger operation block which extends in both directions. Any change in runoff or position will therefore have a greater effect on an impulse turbine than on a reaction turbine.

The final conclusion is the most important. It would appear from the data that since smaller designs are more sensitive overall to inaccuracies in flow-duration curve prediction, a higher degree of economic risk would be associated. If sensitivity to flow prediction were the only source of risk, the inference would be correct. In reality, other elements of risk must be added into the risk of the larger design, such as higher investment, greater yearly variation of high flows, greater down time, inconsistent cash flow, difficulty of obtaining a power sales contract due to the low capacity factor, and greater risk in the event of breakdown. In addition, the risk associated with implementation of small capacity designs can be easily lowered by adjusting the predicted flow-duration curve to correspond with spot measurements taken during low flow periods. The high flows on the modified flow-duration curve will then carry the greatest uncertainty.

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REFERENCES CITED

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APPENDICES

APPENDIX A

Site #1, Option #1, Computer Output

```

1 * HYDROPOWER DESIGN AND SENSITIVITY- FLOWER CREEK NEAR LIBBY, MT, HIGH HEAD
2 *
3 *
4 *
5 *
6 * PREDICTED FLOW-DURATION CURVE AFTER MINIMUM FLOWS
7 * -----
8 * -----
9 *
10 *
11 * % EXCEEDENCE      Q (CFS)
12 * -----
13 *
14 *      10.      42.11
15 *      20.      17.23
16 *      30.      8.88
17 *      40.      5.51
18 *      50.      3.41
19 *      60.      2.13
20 *      70.      1.39
21 *      80.      1.01
22 *      90.      .78
23 *     100.      .51
24 *
25 *
26 *
27 * MINIMUM FLOW= 1.CFS
28 *
29 *
30 *
31 *
32 *
33 *
34 *
35 * -----
36 * DESIGN OPTION= 1
37 * -----
38 *
39 *
40 * TURBINE TYPE= IMPULSE
111 *
112 * PIPE # 1.    CONVEYANCE= 2.7268326    DIAMETER= 14.000"    CH=140.
113 * PIPE # 2.    CONVEYANCE= 2.3333596    DIAMETER= 12.000"    CH=120.
114 *

```

	Q (CFS)	NOZZLE		HL (FT)	HN (FT)	EFF	P (KW)	TIME	E (MWHR)
		AREA (SQ FT)	FT)						
117 *									
118 *									
119 *									
120 *	12.232	.04638	520.03	1079.97	.814	910.50	.24399	1946.028	
121 *	12.160	.04599	514.39	1085.61	.815	910.23	.00080	6.372	
122 *	12.088	.04560	508.78	1091.22	.815	909.87	.00090	7.167	
123 *	12.016	.04521	503.20	1096.80	.815	909.43	.00080	6.367	
124 *	11.944	.04483	497.64	1102.36	.816	908.91	.00090	7.159	
125 *	11.872	.04445	492.11	1107.89	.816	908.30	.00090	7.154	
126 *	11.801	.04407	486.62	1113.38	.816	907.61	.00090	7.149	
127 *	11.729	.04369	481.14	1118.86	.816	906.84	.00090	7.143	
128 *	11.657	.04332	475.70	1124.30	.817	905.98	.00090	7.136	
129 *	11.585	.04295	470.29	1129.71	.817	905.05	.00090	7.129	
130 *	11.513	.04258	464.90	1135.10	.817	904.03	.00090	7.121	
131 *	11.441	.04222	459.55	1140.45	.818	902.93	.00100	7.903	
132 *	11.369	.04185	454.22	1145.78	.818	901.76	.00100	7.893	
133 *	11.297	.04149	448.92	1151.08	.818	900.50	.00090	7.093	
134 *	11.225	.04114	443.65	1156.35	.818	899.17	.00100	7.870	
135 *	11.153	.04078	438.41	1161.59	.819	897.75	.00100	7.858	
136 *	11.082	.04043	433.19	1166.81	.819	896.26	.00100	7.845	
137 *	11.010	.04007	428.01	1171.99	.819	894.69	.00110	8.615	
138 *	10.938	.03973	422.85	1177.15	.819	893.04	.00100	7.817	
139 *	10.866	.03938	417.72	1182.28	.820	891.32	.00110	8.582	
140 *	10.794	.03903	412.63	1187.37	.820	889.52	.00110	8.565	
141 *	10.722	.03869	407.56	1192.44	.820	887.64	.00110	8.547	
142 *	10.650	.03835	402.51	1197.49	.821	885.69	.00110	8.528	
143 *	10.578	.03801	397.50	1202.50	.821	883.66	.00110	8.508	
144 *	10.506	.03768	392.52	1207.48	.821	881.56	.00120	9.261	
145 *	10.435	.03734	387.56	1212.44	.821	879.38	.00110	8.467	
146 *	10.363	.03701	382.64	1217.36	.821	877.13	.00120	9.214	
147 *	10.291	.03668	377.74	1222.26	.822	874.80	.00120	9.190	
148 *	10.219	.03635	372.87	1227.13	.822	872.40	.00120	9.164	
149 *	10.147	.03602	368.03	1231.97	.822	869.93	.00130	9.900	
150 *	10.075	.03570	363.23	1236.77	.822	867.38	.00130	9.871	
151 *	10.003	.03538	358.44	1241.56	.823	864.77	.00130	9.842	
152 *	9.931	.03505	353.69	1246.31	.823	862.07	.00130	9.811	
153 *	9.859	.03474	348.97	1251.03	.823	859.31	.00130	9.780	
154 *	9.787	.03442	344.28	1255.72	.823	856.48	.00140	10.498	
155 *	9.716	.03410	339.61	1260.39	.824	853.57	.00140	10.462	
156 *	9.644	.03379	334.98	1265.02	.824	850.60	.00140	10.426	
157 *	9.572	.03347	330.37	1269.63	.824	847.55	.00150	11.131	
158 *	9.500	.03316	325.80	1274.20	.824	844.43	.00140	10.350	
159 *	9.428	.03285	321.25	1278.75	.824	841.24	.00150	11.048	
160 *	9.356	.03255	316.73	1283.27	.825	837.98	.00160	11.739	
161 *	9.284	.03224	312.25	1287.75	.825	834.65	.00160	11.692	
162 *	9.212	.03193	307.79	1292.21	.825	831.25	.00160	11.645	
163 *	9.140	.03163	303.36	1296.64	.825	827.79	.00160	11.596	

164	*	9.069	.03133	298.96	1301.04	.825	824.25	.00170	12.269
165	*	8.997	.03103	294.59	1305.41	.826	820.64	.00170	12.215
166	*	8.925	.03073	290.25	1309.75	.826	816.67	.00180	12.876
167	*	8.853	.03043	285.94	1314.06	.826	813.22	.00180	12.817
168	*	8.781	.03014	281.66	1318.34	.826	809.41	.00180	12.757
169	*	8.709	.02984	277.41	1322.59	.826	805.53	.00190	13.401
170	*	8.637	.02955	273.18	1326.82	.826	801.58	.00200	14.038
171	*	8.565	.02926	268.99	1331.01	.827	797.56	.00190	13.269
172	*	8.493	.02896	264.83	1335.17	.827	793.48	.00210	14.591
173	*	8.421	.02868	260.70	1339.30	.827	789.33	.00200	13.823
174	*	8.350	.02839	256.59	1343.41	.827	785.11	.00210	14.437
175	*	8.278	.02810	252.52	1347.48	.827	780.83	.00220	15.043
176	*	8.206	.02781	248.48	1351.52	.827	776.47	.00220	14.959
177	*	8.134	.02753	244.47	1355.53	.827	772.06	.00220	14.874
178	*	8.062	.02725	240.48	1359.52	.827	767.57	.00230	15.460
179	*	7.990	.02696	236.53	1363.47	.828	763.02	.00240	16.036
180	*	7.918	.02668	232.61	1367.39	.828	758.40	.00230	15.275
181	*	7.846	.02640	228.72	1371.28	.828	753.72	.00240	15.841
182	*	7.774	.02612	224.86	1375.14	.828	748.97	.00250	16.397
183	*	7.703	.02585	221.02	1378.98	.828	744.16	.00240	15.640
184	*	7.631	.02557	217.22	1382.78	.828	739.28	.00250	16.185
185	*	7.559	.02530	213.45	1386.55	.828	734.34	.00250	16.077
186	*	7.487	.02502	209.71	1390.29	.828	729.33	.00250	15.967
187	*	7.415	.02475	206.00	1394.00	.828	724.26	.00250	15.856
188	*	7.343	.02448	202.32	1397.68	.828	719.13	.00250	15.744
189	*	7.271	.02420	198.67	1401.33	.828	713.93	.00250	15.630
190	*	7.199	.02393	195.05	1404.95	.828	708.67	.00250	15.515
191	*	7.127	.02366	191.46	1408.54	.828	703.34	.00240	14.782
192	*	7.055	.02340	187.91	1412.09	.828	697.95	.00240	14.669
193	*	6.984	.02313	184.38	1415.62	.828	692.50	.00240	14.554
194	*	6.912	.02286	180.88	1419.12	.828	686.99	.00240	14.438
195	*	6.840	.02260	177.42	1422.58	.827	681.42	.00230	13.724
196	*	6.768	.02233	173.98	1426.02	.827	675.78	.00230	13.611
197	*	6.696	.02207	170.58	1429.42	.827	670.03	.00230	13.496
198	*	6.624	.02181	167.21	1432.79	.827	664.33	.00220	12.798
199	*	6.552	.02155	163.86	1436.14	.827	658.51	.00210	12.109
200	*	6.480	.02128	160.55	1439.45	.827	652.63	.00210	12.001
201	*	6.408	.02102	157.27	1442.73	.826	646.69	.00210	11.892
202	*	6.337	.02076	154.03	1445.97	.826	640.69	.00200	11.220
203	*	6.265	.02051	150.81	1449.19	.826	634.64	.00200	11.114
204	*	6.193	.02025	147.62	1452.38	.826	628.52	.00190	10.457
205	*	6.121	.01999	144.47	1455.53	.825	622.35	.00190	10.354
206	*	6.049	.01974	141.34	1458.66	.825	616.12	.00180	9.711
207	*	5.977	.01948	138.25	1461.75	.825	609.83	.00180	9.611
208	*	5.905	.01923	135.19	1464.81	.824	603.49	.00180	9.512
209	*	5.833	.01897	132.16	1467.84	.824	597.09	.00170	8.888
210	*	5.761	.01872	129.16	1470.84	.824	590.64	.00170	8.792

211	*	5.689	.01847	126.20	1473.80	.823	534.13	.00170	8.695
212	*	5.618	.01822	123.26	1476.74	.823	577.57	.00160	8.091
213	*	5.546	.01797	121.36	1479.64	.822	570.95	.00150	7.498
214	*	5.474	.01772	117.49	1482.51	.822	564.28	.00070	3.456
215	*	5.402	.01747	114.65	1485.35	.821	557.56	.00130	6.345
216	*	5.330	.01722	111.84	1488.16	.820	550.79	.00290	13.988
217	*	5.258	.01697	109.07	1490.93	.820	543.97	.00300	14.292
218	*	5.186	.01672	106.33	1493.67	.819	537.09	.00310	14.582
219	*	5.114	.01647	103.62	1496.38	.818	530.17	.00300	13.929
220	*	5.042	.01623	100.94	1499.06	.813	523.20	.00310	14.204
221	*	4.971	.01598	98.29	1501.71	.817	516.13	.00320	14.466
222	*	4.899	.01574	95.63	1504.32	.816	509.12	.00320	14.263
223	*	4.827	.01549	93.10	1506.90	.815	502.01	.00320	14.069
224	*	4.755	.01525	90.55	1509.45	.815	494.85	.00330	14.302
225	*	4.683	.01501	88.03	1511.97	.814	487.65	.00330	14.094
226	*	4.611	.01476	85.55	1514.45	.813	480.41	.00330	13.884
227	*	4.539	.01452	83.09	1516.91	.812	473.13	.00340	14.088
228	*	4.467	.01428	80.68	1519.32	.811	465.80	.00350	14.278
229	*	4.395	.01404	78.29	1521.71	.810	458.44	.00350	14.053
230	*	4.323	.01380	75.94	1524.06	.809	451.04	.00350	13.826
231	*	4.252	.01356	73.62	1526.38	.808	443.59	.00360	13.986
232	*	4.180	.01332	71.33	1528.67	.806	436.12	.00370	14.132
233	*	4.108	.01308	69.08	1530.92	.805	428.60	.00370	13.889
234	*	4.036	.01284	66.86	1533.14	.804	421.06	.00380	14.013
235	*	3.964	.01261	64.67	1535.33	.803	413.48	.00380	13.761
236	*	3.892	.01237	62.52	1537.48	.801	405.87	.00390	13.863
237	*	3.820	.01213	60.40	1539.60	.800	398.23	.00390	13.602
238	*	3.748	.01190	58.31	1541.69	.799	390.56	.00410	14.025
239	*	3.676	.01166	56.26	1543.74	.797	382.86	.00410	13.748
240	*	3.605	.01142	54.24	1545.76	.795	375.14	.00420	13.799
241	*	3.533	.01119	52.26	1547.74	.794	367.39	.00420	13.515
242	*	3.461	.01095	50.31	1549.69	.792	359.62	.00440	13.859
243	*	3.389	.01072	48.39	1551.61	.791	351.83	.00440	13.559
244	*	3.317	.01049	46.51	1553.49	.789	344.02	.00450	13.559
245	*	3.245	.01025	44.66	1555.34	.787	336.19	.00460	13.545
246	*	3.173	.01002	42.83	1557.15	.785	328.34	.00480	13.804
247	*	3.101	.00979	41.07	1558.93	.783	320.48	.00480	13.474
248	*	3.029	.00956	39.33	1560.67	.781	312.61	.00490	13.416
249	*	2.957	.00932	37.62	1562.38	.779	304.73	.00510	13.612
250	*	2.886	.00909	35.94	1564.06	.777	296.84	.00520	13.520
251	*	2.814	.00886	34.30	1565.70	.775	288.94	.00530	13.413
252	*	2.742	.00863	32.70	1567.30	.773	281.03	.00550	13.538
253	*	2.670	.00840	31.13	1568.87	.770	273.12	.00560	13.397
254	*	2.598	.00817	29.60	1570.40	.768	265.21	.00580	13.473
255	*	2.526	.00794	28.10	1571.90	.764	256.65	.00590	13.263
256	*	2.454	.00771	26.64	1573.36	.761	248.77	.00620	13.509
257	*	2.382	.00748	25.21	1574.79	.758	240.82	.00630	13.289

258 *	2.310	.00725	23.82	1576.18	.755	232.80	.00660	13.458
259 *	2.239	.00702	22.47	1577.53	.752	224.68	.00680	13.382
260 *	2.167	.00679	21.15	1578.85	.748	216.47	.00710	13.462
261 *	2.095	.00657	19.87	1580.13	.743	208.15	.00730	13.310
262 *	2.023	.00634	18.63	1581.37	.738	199.73	.00770	13.471
263 *	1.951	.00611	17.42	1582.58	.732	191.20	.00800	13.398
264 *	1.879	.00588	16.25	1583.75	.725	182.57	.00840	13.433
265 *	1.807	.00566	15.12	1584.88	.717	173.84	.00890	13.552
266 *	1.735	.00543	14.03	1585.97	.708	165.02	.00940	13.588
267 *	1.663	.00520	12.97	1587.03	.699	156.13	.00990	13.539
268 *	1.591	.00498	11.95	1588.05	.688	147.17	.01050	13.536
269 *	1.520	.00475	10.97	1589.03	.676	138.17	.01130	13.676
270 *	1.448	.00452	10.03	1589.97	.663	129.14	.01230	13.914
271 *	1.376	.00430	9.13	1590.87	.648	120.11	.01320	13.888
272 *	1.304	.00407	8.27	1591.73	.632	111.11	.01460	14.209
273 *	1.232	.00385	7.44	1592.56	.615	102.15	.01610	14.407
274 *	1.160	.00362	6.66	1593.34	.596	93.28	.01810	14.790
275 *	1.088	.00340	5.92	1594.08	.576	84.53	.02050	15.180
276 *	1.016	.00317	5.21	1594.79	.554	75.94	.02370	15.766
277 *	.944	.00295	4.55	1595.45	.530	67.54	.02750	16.271
278 *	.873	.00272	3.93	1596.07	.504	59.39	.03130	16.284
279 *	.801	.00250	3.35	1596.65	.476	51.52	.03370	15.209
280 *	.729	.00227	2.82	1597.18	.447	43.99	.03300	12.716
281 *								
282 *								
283 *								
284 *	FOR DESIGN OPTION #	:						
285 *	-----							
286 *								
287 *								
288 *								
289 *	RATED FLOW=		7.19	CFS				
290 *	FLOW AT MAXIMUM POWER=		12.23	CFS				
291 *	CUTOFF FLOW=		.72	CFS				
292 *	RATED HEAD=		1405.44	FT				
293 *	WEIGHTED AVG. NET HEAD=		1403.25	FT				
294 *	MINIMUM HEAD=		421.63	FT				
295 *	MAXIMUM HEAD=		7027.19	FT				
296 *								
297 *								
298 *								
299 *	AVG. ANN. ENERGY=		3900.769	MWH				
300 *	MAX. POWER=		910.50	KW				
301 *	CAPACITY FACTOR=		.4891					

304 * ECONOMIC ANALYSIS

305 * -----

306 *

307 * COSTS

308 * -----

309 *	DIVERSION STRUCTURE=	28000.
310 *	HIGH PRESSURE PENSTOCK=	388014.
311 *	POWERHOUSE CIVIL COST=	139411.
312 *	INTAKE COST=	10457.
313 *	LOW PRESSURE PIPELINE=	304253.
314 *	SWITCHYARD=	76424.
315 *	TURBINE, GENERATOR, CONTROLS, SWITCHGEAR=	347312.
316 *	UTILITY HOOKUP=	98106.
317 *	EXTRA COST=	250000.
318 *	-----	-----
319 *	TOTAL COST=	1641977.

320 *

321 *

322 *

323 * ECONOMIC FACTORS

324 * -----

325 *	O&M COST IN 1ST YEAR=	16346.2	
326 *	DOWN PAYMENT=	.100	(FRACTION OF FIRST COST)
327 *	MORTGAGE INTEREST RATE=	.140	
328 *	PERIOD OF MORTGAGE=	20.0	
329 *	PROPERTY APPRECIATION RATE=	.020	
330 *	TAXABLE VALUE (PERMANENT)=	.0355	
331 *	TAXABLE VALUE (MACHINERY)=	.11	
332 *	MACHINERY DEPRECIATION LIFE=	20 YEARS, TO 20% MINIMUM	
333 *	INITIAL MILL LEVY=	.2066	
334 *	INVESTMENT TAX CREDIT=	.210	(FRACTION OF FIRST COST)
335 *	STATE INCOME TAX RATE=	.0675	
336 *	INFLATION RATE=	.080	
337 *	PROJECT LIFE=	30	
338 *	INITIAL POWER COST=	.064000	(\$/KWH)
339 *	INITIAL CAPACITY COST=	7.92940	(\$/ANNUAL CONTRACT KW/MO.)
340 *	RATE OF POWER COST INCREASE=	.060	
341 *	5 YEAR ACRS DEPRECIATION		

CASH FLOW

YEAR	DEPT SERVICE	INTST	DEPR.	O&M COST	PROP. TAX	STATE INC TAX	TAXABLE INCOME	TAX CREDIT	FED. INC TAX	TOTAL COST	ENERGY RATE	CAPACITY RATE	TOTAL REVENUE
1	223124.	206889.	246297.	16346.	342229.	0.	-211740.	344815.	0.	273699.	.06400	7.9294	292020.
2	223124.	204616.	361235.	17654.	35928.	0.	-521631.	344815.	0.	276705.	.06784	8.4052	309541.
3	223124.	202025.	344815.	19066.	37683.	0.	-797107.	344815.	0.	279873.	.07191	8.9095	328114.
4	223124.	199071.	344815.	20591.	39492.	0.	-1053276.	344815.	0.	283208.	.07623	9.4440	347801.
5	223124.	195704.	344815.	22239.	41355.	0.	-1288720.	344815.	0.	286717.	.08080	10.0107	368669.
6	223124.	191865.	0.	24018.	43267.	0.	-157081.	344815.	0.	290409.	.08565	10.6113	390789.
7	223124.	187469.	0.	25939.	45226.	0.	-1001499.	344815.	0.	294289.	.09079	11.6480	414236.
8	223124.	182500.	0.	28014.	47227.	0.	-820149.	344815.	0.	298365.	.09623	11.9229	439090.
9	223124.	176812.	0.	30256.	49265.	0.	-611046.	344815.	0.	302644.	.10201	12.6383	465436.
10	223124.	170329.	0.	32676.	51333.	0.	-372022.	344815.	0.	307133.	.10813	13.3966	493362.
11	223124.	162937.	0.	35290.	53425.	0.	-100712.	344815.	0.	311839.	.11461	14.2003	522964.
12	223124.	154511.	0.	38113.	55532.	13869.	-191604.	280766.	4339.	334977.	.12149	15.0524	554341.
13	223124.	144906.	0.	41162.	57643.	23213.	320679.	163280.	10276.	355418.	.12878	15.9555	587602.
14	223124.	133955.	0.	44455.	59746.	25967.	358734.	30039.	12027.	365320.	.13651	16.9128	622858.
15	223124.	121471.	0.	48012.	61828.	28952.	399966.	0.	134195.	496111.	.14470	17.9276	660229.
16	223124.	107240.	0.	51853.	63874.	32189.	444688.	0.	184806.	555846.	.15338	19.0035	699843.
17	223124.	91016.	0.	56001.	65864.	35704.	493248.	0.	207144.	588838.	.16258	20.1435	741834.
18	223124.	72521.	0.	60481.	67779.	39525.	546037.	0.	231427.	622337.	.17234	21.3521	786344.
19	223124.	51437.	0.	65320.	69596.	43684.	603488.	0.	257855.	659978.	.18268	22.6332	833525.
20	223124.	27401.	0.	70545.	71287.	48215.	666087.	0.	286650.	699822.	.19364	23.9912	883536.
21	0.	0.	0.	76189.	78012.	52808.	729539.	0.	315838.	522847.	.20526	25.4307	936548.
22	0.	0.	0.	82284.	85377.	55693.	769387.	0.	334168.	557522.	.21757	26.9565	992741.
23	0.	0.	0.	88867.	93447.	58724.	811268.	0.	353433.	594471.	.23063	28.5739	1052305.
24	0.	0.	0.	95976.	102287.	61910.	855271.	0.	373675.	633847.	.24446	30.2883	1118444.
25	0.	0.	0.	103654.	111974.	65255.	901487.	0.	394934.	675817.	.25913	32.1256	1182370.
26	0.	0.	0.	111946.	122588.	68763.	950011.	0.	417255.	720557.	.27468	34.0320	1253313.
27	0.	0.	0.	120902.	134220.	72454.	1000935.	0.	440680.	768256.	.29116	36.0739	1328511.
28	0.	0.	0.	130574.	146938.	76321.	1054359.	0.	465255.	819118.	.30863	38.2383	1408222.
29	0.	0.	0.	141020.	160940.	80376.	1110380.	0.	491025.	873360.	.32715	40.5326	1492715.
30	0.	0.	0.	152302.	176254.	84626.	1169096.	0.	518034.	931216.	.34678	42.9646	1582278.

UNUSED TAX CREDIT AFTER 15YR CARRYOVER= 0.

RATE OF RETURN= .3740

403	*	POSITION	RUNOFF(IN)	ENERGY	PMAX	CF	ROR	UNUSED CREDIT
404	*							
405	*	0.	38.050	2332.356	910.50	.2937	.0330	344815.
406	*	1.	38.050	2541.197	910.50	.3186	.1010	344815.
407	*	2.	38.050	2708.020	910.50	.3395	.1210	344815.
408	*	3.	38.050	2882.128	910.50	.3614	.1440	344815.
409	*	4.	38.050	3064.547	910.50	.3842	.1720	344815.
410	*	5.	38.050	3258.422	910.50	.4085	.2090	266009.
411	*	6.	38.050	3471.702	910.50	.4353	.2570	137750.
412	*	7.	38.050	3705.100	910.50	.4645	.3180	0.
413	*	8.	38.050	3935.930	910.50	.4935	.3850	0.
414	*	9.	38.050	4137.340	910.50	.5137	.4500	0.
415	*	0.	41.450	2487.274	910.50	.3118	.0950	344815.
416	*	1.	41.450	2659.435	910.50	.3334	.1150	344815.
417	*	2.	41.450	2839.638	910.50	.3560	.1390	344815.
418	*	3.	41.450	3028.036	910.50	.3796	.1660	344815.
419	*	4.	41.450	3227.153	910.50	.4046	.2020	287043.
420	*	5.	41.450	3443.605	910.50	.4317	.2500	156711.
421	*	6.	41.450	3686.580	910.50	.4622	.3130	8538.
422	*	7.	41.450	3934.646	910.50	.4933	.3840	0.
423	*	8.	41.450	4151.461	910.50	.5205	.4550	0.
424	*	9.	41.450	4372.622	910.50	.5482	.5320	0.
425	*	0.	44.850	2587.691	910.50	.3244	.1060	344815.
426	*	1.	44.850	2772.343	910.50	.3476	.1290	344815.
427	*	2.	44.850	2965.521	910.50	.3718	.1570	344815.
428	*	3.	44.850	3168.305	910.50	.3972	.1910	326236.
429	*	4.	44.850	3385.445	910.50	.4245	.2370	195836.
430	*	5.	44.850	3623.694	910.50	.4550	.2970	47477.
431	*	6.	44.850	3892.988	910.50	.4831	.3720	0.
432	*	7.	44.850	4135.578	910.50	.5135	.4490	0.
433	*	8.	44.850	4362.154	910.50	.5469	.5280	0.
434	*	9.	44.850	4578.493	910.50	.5740	.6080	0.
435	*	0.	48.250	2633.966	910.50	.3355	.1180	344815.
436	*	1.	48.250	2830.453	910.50	.3611	.1440	344815.
437	*	2.	48.250	3036.216	910.50	.3869	.1760	344815.
438	*	3.	48.250	3303.713	910.50	.4142	.2180	235541.
439	*	4.	48.250	3541.296	910.50	.4440	.2740	100357.
440	*	5.	48.250	3812.062	910.50	.4779	.3480	0.
441	*	6.	48.250	4088.192	910.50	.5126	.4330	0.
442	*	7.	48.250	4324.782	910.50	.5422	.5150	0.
443	*	8.	48.250	4557.960	910.50	.5717	.6010	0.
444	*	9.	48.250	4784.154	910.50	.5998	.6380	0.
445	*	0.	51.650	2776.340	910.50	.3431	.1300	344815.
446	*	1.	51.650	2934.126	910.50	.3741	.1600	344815.

447 *	2.	51.650	3202.315	910.50	.4015	.1970	303752.
448 *	3.	51.650	3435.113	910.50	.4307	.2480	162421.
449 *	4.	51.650	3696.307	910.50	.4634	.3150	1995.
450 *	5.	51.650	3937.832	910.50	.5000	.4010	0.
451 *	6.	51.650	4257.369	910.50	.5340	.4920	0.
452 *	7.	51.650	4502.634	910.50	.5645	.5300	0.
453 *	8.	51.650	4745.742	910.50	.5950	.6730	0.
454 *	9.	51.650	4977.137	910.50	.6240	.7640	0.
455 *	0.	55.050	2864.889	910.50	.3592	.1420	344315.
456 *	1.	55.050	3033.643	910.50	.3366	.1750	344315.
457 *	2.	55.050	3314.076	910.50	.4155	.2210	231190.
458 *	3.	55.050	3563.377	910.50	.4463	.2800	90091.
459 *	4.	55.050	3350.555	910.50	.4828	.3590	0.
460 *	5.	55.050	4155.037	910.50	.5210	.4560	0.
461 *	6.	55.050	4420.275	910.50	.5542	.5490	0.
462 *	7.	55.050	4634.081	910.50	.5873	.6490	0.
463 *	8.	55.050	4920.218	910.50	.6167	.7420	0.
464 *	9.	55.050	5139.356	910.50	.6444	.8300	0.
465 *	0.	53.450	2242.943	910.50	.3679	.1540	344315.
466 *	1.	53.450	3177.248	910.50	.3936	.1730	319193.
467 *	2.	53.450	3422.032	910.50	.4290	.2450	171223.
468 *	3.	53.450	3639.615	910.50	.4626	.3130	6496.
469 *	4.	53.450	4100.475	910.50	.5016	.4050	0.
470 *	5.	53.450	4277.701	910.50	.5371	.5060	0.
471 *	6.	53.450	4533.615	910.50	.5747	.6100	0.
472 *	7.	53.450	4842.554	910.50	.6071	.7110	0.
473 *	8.	53.450	5034.221	910.50	.6374	.8080	0.
474 *	9.	53.450	5307.710	910.50	.6657	.9010	0.
475 *	MEASURED CURVE:		3327.473	910.50	.4779	.3520	0.

APPENDIX B

Site #3, Computer Output

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1 * HYDROPOWER DESIGN AND SENSITIVITY- BELT CREEK NEAR MONARCH, MT, LOW HEAD
2 *
3 *
4 *
5 *
6 * PREDICTED FLOW-DURATION CURVE AFTER MINIMUM FLOWS
7 * -----
8 * -----
9 *
10 *
11 * % EXCEEDENCE      Q(CFS)
12 * -----
13 *
14 *      10.      455.57
15 *      20.      216.34
16 *      30.      123.18
17 *      40.      83.95
18 *      50.      58.13
19 *      60.      42.51
20 *      70.      33.45
21 *      80.      23.59
22 *      90.      25.53
23 *     100.      21.95
24 *
25 *
26 *
27 * MINIMUM FLOW= 0.CFS
28 *
29 *
30 *
31 *
32 *
33 *
34 *
35 * -----
36 * DESIGN OPTION= 1
37 * -----
38 *
39 *
40 * TURBINE TYPE= REACTION
41 *
42 *
43 * PIPE # 1.   CONVEYANCE= .0001159   DIAMETER= 54.000" ~ CH=120.

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	QSTREAM	QTURB	GROSS HEAD	TAILWATER ELEV	HL	HN	EFF	P	TIME	ENERGY
	(CFS)	(CFS)	(FT)	(FT)	(FT)	(FT)		(KW)		(MWH)
47 *										
48 *										
49 *										
50 *	1356.93	146.575	38.47	3.76	1.89	36.58	.778	353.14	.00100	3.093
51 *	1347.82	146.575	38.47	3.75	1.89	36.58	.778	353.13	.00100	3.093
52 *	1338.71	146.575	38.47	3.74	1.89	36.58	.778	353.12	.00100	3.093
53 *	1329.60	146.575	38.47	3.73	1.89	36.58	.778	353.11	.00100	3.093
54 *	1320.50	146.575	38.47	3.72	1.89	36.58	.778	353.10	.00100	3.093
55 *	1311.39	146.575	38.47	3.71	1.89	36.58	.778	353.09	.00100	3.093
56 *	1302.28	146.575	38.47	3.70	1.89	36.57	.778	353.08	.00100	3.093
57 *	1293.18	146.575	38.47	3.69	1.89	36.57	.778	353.07	.00100	3.093
58 *	1284.07	146.575	38.46	3.68	1.89	36.57	.778	353.05	.00100	3.093
59 *	1274.96	146.575	38.46	3.67	1.89	36.57	.778	353.04	.00100	3.093
60 *	1265.86	146.575	38.46	3.66	1.89	36.57	.778	353.03	.00100	3.093
61 *	1256.75	146.575	38.46	3.65	1.89	36.57	.778	353.01	.00100	3.092
62 *	1247.64	146.575	38.46	3.64	1.89	36.57	.778	353.00	.00100	3.092
63 *	1238.54	146.575	38.46	3.63	1.89	36.56	.778	352.98	.00100	3.092
64 *	1229.43	146.575	38.46	3.62	1.89	36.56	.778	352.97	.00100	3.092
65 *	1220.32	146.575	38.45	3.61	1.89	36.56	.778	352.95	.00100	3.092
66 *	1211.21	146.575	38.45	3.60	1.89	36.56	.778	352.93	.00100	3.092
67 *	1202.11	146.575	38.45	3.59	1.89	36.56	.778	352.92	.00100	3.092
68 *	1193.00	146.575	38.45	3.58	1.89	36.56	.778	352.90	.00100	3.091
69 *	1183.89	146.575	38.45	3.57	1.89	36.55	.778	352.88	.00100	3.091
70 *	1174.79	146.575	38.44	3.56	1.89	36.55	.778	352.86	.00100	3.091
71 *	1165.68	146.575	38.44	3.55	1.89	36.55	.778	352.84	.00100	3.091
72 *	1156.57	146.575	38.44	3.54	1.89	36.55	.778	352.82	.00100	3.091
73 *	1147.47	146.575	38.44	3.53	1.89	36.55	.778	352.81	.00100	3.091
74 *	1138.36	146.575	38.44	3.52	1.89	36.54	.778	352.79	.00100	3.090
75 *	1129.25	146.575	38.43	3.51	1.89	36.54	.778	352.77	.00100	3.090
76 *	1120.15	146.575	38.43	3.50	1.89	36.54	.778	352.75	.00100	3.090
77 *	1111.04	146.575	38.43	3.49	1.89	36.54	.778	352.73	.00100	3.090
78 *	1101.93	146.575	38.43	3.48	1.89	36.54	.778	352.71	.00100	3.090
79 *	1092.82	146.575	38.43	3.47	1.89	36.53	.778	352.69	.00100	3.090
80 *	1083.72	146.575	38.42	3.46	1.89	36.53	.778	352.67	.00100	3.089
81 *	1074.61	146.575	38.42	3.45	1.89	36.53	.778	352.65	.00100	3.089
82 *	1065.50	146.575	38.42	3.44	1.89	36.53	.778	352.63	.00100	3.089
83 *	1056.40	146.575	38.42	3.43	1.89	36.53	.778	352.61	.00100	3.089
84 *	1047.29	146.575	38.42	3.42	1.89	36.52	.778	352.59	.00100	3.089
85 *	1038.18	146.575	38.41	3.41	1.89	36.52	.778	352.57	.00100	3.089
86 *	1029.08	146.575	38.41	3.40	1.89	36.52	.778	352.55	.00100	3.088
87 *	1019.97	146.575	38.41	3.39	1.89	36.52	.778	352.54	.00100	3.088
88 *	1010.86	146.575	38.41	3.38	1.89	36.52	.778	352.52	.00100	3.088
89 *	1001.76	146.575	38.41	3.36	1.89	36.52	.778	352.50	.00100	3.088
90 *	992.65	146.575	38.41	3.35	1.89	36.51	.778	352.48	.00100	3.088
91 *	983.54	146.575	38.40	3.34	1.89	36.51	.778	352.47	.00100	3.088
92 *	974.44	146.575	38.40	3.33	1.89	36.51	.778	352.45	.00100	3.087
93 *	965.33	146.575	38.40	3.32	1.89	36.51	.778	352.43	.00100	3.087

94	*	956.22	146.575	38.40	3.31	1.89	36.51	.778	352.42	.00100	3.087
95	*	947.11	146.575	38.40	3.30	1.89	36.51	.778	352.40	.00100	3.087
96	*	938.01	146.575	38.40	3.29	1.89	36.50	.778	352.39	.00100	3.087
97	*	923.90	146.575	38.39	3.28	1.89	36.50	.778	352.38	.00100	3.087
98	*	912.79	146.575	38.39	3.26	1.89	36.50	.778	352.36	.00100	3.087
99	*	910.69	146.575	38.39	3.25	1.89	36.50	.778	352.35	.00100	3.087
100	*	901.58	146.575	38.39	3.24	1.89	36.50	.778	352.34	.00100	3.087
101	*	892.47	146.575	38.39	3.23	1.89	36.50	.778	352.33	.00100	3.086
102	*	883.37	146.575	38.39	3.22	1.89	36.50	.778	352.32	.00100	3.086
103	*	874.26	146.575	38.39	3.20	1.89	36.50	.778	352.32	.00100	3.086
104	*	865.15	146.575	38.39	3.19	1.89	36.50	.778	352.31	.00100	3.086
105	*	856.05	146.575	38.39	3.18	1.89	36.49	.778	352.30	.00100	3.086
106	*	846.94	146.575	38.39	3.16	1.89	36.49	.778	352.30	.00100	3.086
107	*	837.83	146.575	38.39	3.15	1.89	36.49	.778	352.29	.00100	3.086
108	*	828.72	146.575	38.39	3.14	1.89	36.49	.778	352.29	.00100	3.086
109	*	819.62	146.575	38.39	3.12	1.89	36.49	.778	352.29	.00100	3.086
110	*	810.51	146.575	38.39	3.11	1.89	36.49	.778	352.29	.00100	3.086
111	*	801.40	146.575	38.39	3.10	1.89	36.49	.778	352.29	.00100	3.086
112	*	792.30	146.575	38.39	3.08	1.89	36.49	.778	352.30	.00100	3.086
113	*	783.19	146.575	38.39	3.07	1.89	36.49	.778	352.30	.00100	3.086
114	*	774.08	146.575	38.39	3.05	1.89	36.50	.778	352.31	.00100	3.086
115	*	764.98	146.575	38.39	3.04	1.89	36.50	.778	352.32	.00100	3.086
116	*	755.87	146.575	38.39	3.02	1.89	36.50	.778	352.32	.00100	3.086
117	*	746.76	146.575	38.39	3.01	1.89	36.50	.778	352.34	.00100	3.086
118	*	737.66	146.575	38.39	2.99	1.89	36.50	.778	352.35	.00100	3.087
119	*	728.55	146.575	38.39	2.98	1.89	36.50	.778	352.36	.00100	3.087
120	*	719.44	146.575	38.39	2.96	1.89	36.50	.778	352.38	.00100	3.087
121	*	710.33	146.575	38.40	2.95	1.89	36.50	.778	352.40	.00100	3.087
122	*	701.23	146.575	38.40	2.93	1.89	36.51	.778	352.42	.00100	3.087
123	*	692.12	146.575	38.40	2.91	1.89	36.51	.778	352.44	.00100	3.087
124	*	683.01	146.575	38.40	2.89	1.89	36.51	.778	352.47	.00100	3.088
125	*	673.91	146.575	38.41	2.88	1.89	36.51	.778	352.49	.00100	3.088
126	*	664.80	146.575	38.41	2.86	1.89	36.52	.778	352.52	.00100	3.088
127	*	655.69	146.575	38.41	2.84	1.89	36.52	.778	352.55	.00100	3.088
128	*	646.59	146.575	38.42	2.82	1.89	36.52	.778	352.59	.00100	3.089
129	*	637.48	146.575	38.42	2.80	1.89	36.53	.778	352.62	.00100	3.089
130	*	628.37	146.575	38.42	2.78	1.89	36.53	.778	352.66	.00100	3.089
131	*	619.27	146.575	38.43	2.77	1.89	36.54	.778	352.70	.00100	3.090
132	*	610.16	146.575	38.43	2.75	1.89	36.54	.778	352.75	.00100	3.090
133	*	601.05	146.575	38.44	2.73	1.89	36.55	.778	352.79	.00100	3.091
134	*	591.95	146.575	38.44	2.70	1.89	36.55	.778	352.84	.00100	3.091
135	*	582.84	146.575	38.45	2.68	1.89	36.56	.778	352.89	.00100	3.092
136	*	573.73	146.575	38.45	2.66	1.89	36.56	.778	352.95	.00100	3.092
137	*	564.62	146.575	38.46	2.64	1.89	36.57	.778	353.00	.00100	3.092
138	*	555.52	146.575	38.47	2.62	1.89	36.57	.778	353.06	.00100	3.093

139	*	546.41	146.575	38.47	2.60	1.89	36.58	.778	353.13	.00100	3.093
140	*	537.30	146.575	38.48	2.57	1.89	36.59	.778	353.19	.00100	3.094
141	*	528.20	146.575	38.49	2.55	1.89	36.59	.778	353.26	.00100	3.095
142	*	519.09	146.575	38.49	2.52	1.89	36.60	.778	353.33	.00100	3.095
143	*	509.93	146.575	38.50	2.50	1.89	36.61	.778	353.41	.00100	3.096
144	*	500.83	146.575	38.51	2.48	1.89	36.62	.778	353.48	.00100	3.097
145	*	491.77	146.575	38.52	2.45	1.89	36.63	.778	353.56	.00100	3.097
146	*	482.66	146.575	38.53	2.42	1.89	36.63	.778	353.65	.00100	3.098
147	*	473.56	146.575	38.53	2.40	1.89	36.64	.778	353.73	.00100	3.099
148	*	464.45	146.575	38.54	2.37	1.89	36.65	.778	353.82	.00100	3.100
149	*	454.02	146.575	38.56	2.34	1.89	36.66	.778	353.93	.00140	4.238
150	*	452.70	146.575	38.56	2.34	1.89	36.66	.778	353.95	.00040	1.238
151	*	451.38	146.575	38.56	2.33	1.89	36.67	.778	353.96	.00040	1.238
152	*	450.06	146.575	38.56	2.33	1.89	36.67	.778	353.97	.00040	1.238
153	*	443.74	146.575	38.56	2.32	1.89	36.67	.778	353.99	.00040	1.238
154	*	447.42	146.575	38.56	2.32	1.89	36.67	.778	354.00	.00040	1.238
155	*	446.10	146.575	38.56	2.32	1.89	36.67	.778	354.02	.00030	1.238
156	*	444.78	146.575	38.57	2.31	1.89	36.67	.778	354.03	.00040	1.238
157	*	443.46	146.575	38.57	2.31	1.89	36.68	.778	354.05	.00040	1.238
158	*	442.14	146.575	38.57	2.30	1.89	36.68	.778	354.06	.00040	1.238
159	*	440.82	146.575	38.57	2.30	1.89	36.68	.778	354.08	.00040	1.238
160	*	439.50	146.575	38.57	2.30	1.89	36.68	.778	354.09	.00040	1.238
161	*	438.17	146.575	38.57	2.29	1.89	36.68	.778	354.10	.00040	1.238
162	*	436.85	146.575	38.57	2.29	1.89	36.68	.778	354.12	.00040	1.238
163	*	435.53	146.575	38.58	2.28	1.89	36.68	.778	354.13	.00040	1.238
164	*	434.21	146.575	38.58	2.28	1.89	36.69	.778	354.15	.00040	1.238
165	*	432.89	146.575	38.58	2.27	1.89	36.69	.778	354.16	.00040	1.238
166	*	431.57	146.575	38.58	2.27	1.89	36.69	.778	354.18	.00040	1.238
167	*	430.25	146.575	38.58	2.27	1.89	36.69	.778	354.19	.00040	1.238
168	*	428.93	146.575	38.58	2.26	1.89	36.69	.778	354.21	.00050	1.549
169	*	427.61	146.575	38.59	2.26	1.89	36.69	.778	354.22	.00040	1.239
170	*	426.29	146.575	38.59	2.25	1.89	36.70	.778	354.24	.00040	1.239
171	*	424.97	146.575	38.59	2.25	1.89	36.70	.778	354.26	.00040	1.239
172	*	423.65	146.575	38.59	2.25	1.89	36.70	.778	354.27	.00040	1.239
173	*	422.33	146.575	38.59	2.24	1.89	36.70	.778	354.29	.00040	1.239
174	*	421.01	146.575	38.59	2.24	1.89	36.70	.778	354.30	.00040	1.239
175	*	419.69	146.575	38.60	2.23	1.89	36.70	.778	354.32	.00040	1.239
176	*	418.37	146.575	38.60	2.23	1.89	36.70	.778	354.33	.00050	1.549
177	*	417.05	146.575	38.60	2.22	1.89	36.71	.778	354.35	.00040	1.239
178	*	415.73	146.575	38.60	2.22	1.89	36.71	.778	354.37	.00040	1.239
179	*	414.41	146.575	38.60	2.22	1.89	36.71	.778	354.38	.00040	1.239
180	*	413.08	146.575	38.60	2.21	1.89	36.71	.778	354.40	.00040	1.239
181	*	411.76	146.575	38.61	2.21	1.89	36.71	.778	354.41	.00050	1.550
182	*	410.44	146.575	38.61	2.20	1.89	36.71	.778	354.43	.00040	1.239
183	*	409.12	146.575	38.61	2.20	1.89	36.72	.778	354.45	.00040	1.239
184	*	407.80	146.575	38.61	2.19	1.89	36.72	.778	354.46	.00040	1.239

185	*	406.48	146.575	33.61	2.19	1.89	36.72	.778	354.48	.00050	1.550
186	*	405.16	146.575	33.61	2.18	1.89	36.72	.778	354.49	.00040	1.240
187	*	403.84	146.575	33.62	2.18	1.89	36.72	.778	354.51	.00040	1.240
188	*	402.52	146.575	33.62	2.18	1.89	36.73	.778	354.53	.00050	1.550
189	*	401.20	146.575	33.62	2.17	1.89	36.73	.778	354.54	.00040	1.240
190	*	399.88	146.575	33.62	2.17	1.89	36.73	.778	354.56	.00040	1.240
191	*	398.56	146.575	33.62	2.16	1.89	36.73	.778	354.58	.00050	1.550
192	*	397.24	146.575	33.62	2.16	1.89	36.73	.778	354.60	.00040	1.240
193	*	395.92	146.575	33.63	2.15	1.89	36.73	.778	354.61	.00040	1.240
194	*	394.60	146.575	33.63	2.15	1.89	36.74	.778	354.63	.00050	1.551
195	*	393.28	146.575	33.63	2.14	1.89	36.74	.778	354.65	.00040	1.240
196	*	391.96	146.575	33.63	2.14	1.89	36.74	.778	354.66	.00050	1.551
197	*	390.64	146.575	33.63	2.14	1.89	36.74	.778	354.68	.00040	1.240
198	*	389.32	146.575	33.63	2.13	1.89	36.74	.778	354.70	.00050	1.551
199	*	387.99	146.575	33.64	2.13	1.89	36.74	.778	354.72	.00040	1.240
200	*	386.67	146.575	33.64	2.12	1.89	36.75	.778	354.73	.00050	1.551
201	*	385.35	146.575	33.64	2.12	1.89	36.75	.778	354.75	.00040	1.240
202	*	384.03	146.575	33.64	2.11	1.89	36.75	.778	354.77	.00050	1.551
203	*	382.71	146.575	33.64	2.11	1.89	36.75	.778	354.79	.00040	1.241
204	*	381.39	146.575	33.65	2.10	1.89	36.75	.778	354.80	.00050	1.551
205	*	380.07	146.575	33.65	2.10	1.89	36.76	.778	354.82	.00040	1.241
206	*	378.75	146.575	33.65	2.09	1.89	36.76	.778	354.84	.00050	1.552
207	*	377.43	146.575	33.65	2.09	1.89	36.76	.778	354.86	.00050	1.552
208	*	376.11	146.575	33.65	2.08	1.89	36.76	.778	354.88	.00040	1.241
209	*	374.79	146.575	33.65	2.08	1.89	36.76	.778	354.89	.00050	1.552
210	*	373.47	146.575	33.66	2.07	1.89	36.76	.778	354.91	.00050	1.552
211	*	372.15	146.575	33.66	2.07	1.89	36.77	.778	354.93	.00040	1.241
212	*	370.83	146.575	33.66	2.07	1.89	36.77	.778	354.95	.00050	1.552
213	*	369.51	146.575	33.66	2.06	1.89	36.77	.778	354.97	.00050	1.552
214	*	368.19	146.575	33.66	2.06	1.89	36.77	.778	354.98	.00040	1.241
215	*	366.87	146.575	33.67	2.05	1.89	36.77	.778	355.00	.00050	1.552
216	*	365.55	146.575	33.67	2.05	1.89	36.78	.778	355.02	.00050	1.552
217	*	364.23	146.575	33.67	2.04	1.89	36.78	.778	355.04	.00050	1.552
218	*	362.90	146.575	33.67	2.04	1.89	36.78	.778	355.06	.00040	1.242
219	*	361.58	146.575	33.67	2.03	1.89	36.78	.778	355.08	.00050	1.553
220	*	360.26	146.575	33.68	2.03	1.89	36.78	.778	355.10	.00050	1.553
221	*	358.94	146.575	33.68	2.02	1.89	36.79	.778	355.12	.00050	1.553
222	*	357.62	146.575	33.68	2.02	1.89	36.79	.778	355.13	.00050	1.553
223	*	356.30	146.575	33.68	2.01	1.89	36.79	.778	355.15	.00050	1.553
224	*	354.98	146.575	33.68	2.01	1.89	36.79	.778	355.17	.00040	1.242
225	*	353.66	146.575	33.69	2.00	1.89	36.79	.778	355.19	.00050	1.553
226	*	352.34	146.575	33.69	2.00	1.89	36.80	.778	355.21	.00050	1.553
227	*	351.02	146.575	33.69	1.99	1.89	36.80	.778	355.23	.00050	1.553
228	*	349.70	146.575	33.69	1.99	1.89	36.80	.778	355.25	.00050	1.553
229	*	348.38	146.575	33.69	1.98	1.89	36.80	.778	355.27	.00050	1.553
230	*	347.06	146.575	33.70	1.98	1.89	36.80	.778	355.29	.00050	1.554

231	*	345.74	146.575	38.70	1.97	1.89	36.81	.778	355.31	.00050	1.554
232	*	344.42	146.575	38.70	1.97	1.89	36.81	.778	355.33	.00050	1.554
233	*	343.10	146.575	38.70	1.96	1.89	36.81	.778	355.35	.00050	1.554
234	*	341.78	146.575	38.70	1.96	1.89	36.81	.778	355.37	.00060	1.865
235	*	340.46	146.575	38.71	1.95	1.89	36.81	.778	355.39	.00050	1.554
236	*	339.14	146.575	38.71	1.95	1.89	36.82	.778	355.41	.00050	1.554
237	*	337.81	146.575	38.71	1.94	1.89	36.82	.778	355.43	.00050	1.554
238	*	336.49	146.575	38.71	1.94	1.89	36.82	.778	355.45	.00050	1.554
239	*	335.17	146.575	38.71	1.93	1.89	36.82	.778	355.47	.00050	1.554
240	*	333.85	146.575	38.72	1.93	1.89	36.82	.778	355.49	.00060	1.866
241	*	332.53	146.575	38.72	1.92	1.89	36.83	.778	355.51	.00050	1.555
242	*	331.21	146.575	38.72	1.92	1.89	36.83	.778	355.53	.00050	1.555
243	*	329.89	146.575	38.72	1.91	1.89	36.83	.778	355.55	.00050	1.555
244	*	328.57	146.575	38.72	1.91	1.89	36.83	.778	355.57	.00060	1.866
245	*	327.25	146.575	38.73	1.90	1.89	36.84	.778	355.59	.00050	1.555
246	*	325.93	146.575	38.73	1.90	1.89	36.84	.778	355.61	.00050	1.555
247	*	324.61	146.575	38.73	1.89	1.89	36.84	.778	355.63	.00060	1.867
248	*	323.29	146.575	38.73	1.89	1.89	36.84	.778	355.65	.00050	1.555
249	*	321.97	146.575	38.74	1.88	1.89	36.84	.778	355.67	.00050	1.555
250	*	320.65	146.575	38.74	1.88	1.89	36.85	.778	355.69	.00060	1.867
251	*	319.33	146.575	38.74	1.87	1.89	36.85	.778	355.71	.00050	1.555
252	*	318.01	146.575	38.74	1.86	1.89	36.85	.778	355.74	.00060	1.867
253	*	316.69	146.575	38.74	1.86	1.89	36.85	.778	355.76	.00050	1.556
254	*	315.37	146.575	38.75	1.85	1.89	36.85	.778	355.78	.00060	1.867
255	*	314.05	146.575	38.75	1.85	1.89	36.86	.778	355.80	.00050	1.556
256	*	312.72	146.575	38.75	1.84	1.89	36.86	.778	355.82	.00060	1.868
257	*	311.40	146.575	38.75	1.84	1.89	36.86	.778	355.84	.00060	1.868
258	*	310.08	146.575	38.76	1.83	1.89	36.86	.778	355.86	.00050	1.556
259	*	308.76	146.575	38.76	1.83	1.89	36.87	.778	355.88	.00060	1.868
260	*	307.44	146.575	38.76	1.82	1.89	36.87	.778	355.90	.00060	1.868
261	*	306.12	146.575	38.76	1.82	1.89	36.87	.778	355.93	.00050	1.556
262	*	304.80	146.575	38.76	1.81	1.89	36.87	.778	355.95	.00060	1.868
263	*	303.48	146.575	38.77	1.81	1.89	36.87	.778	355.97	.00060	1.868
264	*	302.16	146.575	38.77	1.80	1.89	36.88	.778	355.99	.00060	1.868
265	*	300.84	146.575	38.77	1.79	1.89	36.88	.778	356.01	.00060	1.869
266	*	299.52	146.575	38.77	1.79	1.89	36.88	.778	356.03	.00050	1.557
267	*	298.20	146.575	38.78	1.73	1.89	36.88	.778	356.06	.00060	1.869
268	*	296.88	146.575	38.78	1.78	1.89	36.89	.778	356.08	.00060	1.869
269	*	295.56	146.575	38.78	1.77	1.89	36.89	.778	356.10	.00060	1.869
270	*	294.24	146.575	38.78	1.77	1.89	36.89	.778	356.12	.00060	1.869
271	*	292.92	146.575	38.78	1.76	1.89	36.89	.778	356.14	.00060	1.869
272	*	291.60	146.575	38.79	1.76	1.89	36.90	.778	356.16	.00060	1.869
273	*	290.28	146.575	38.79	1.75	1.89	36.90	.778	356.19	.00060	1.869
274	*	288.96	146.575	38.79	1.75	1.89	36.90	.778	356.21	.00060	1.870
275	*	287.63	146.575	38.79	1.74	1.89	36.90	.778	356.23	.00060	1.870
276	*	286.31	146.575	38.80	1.73	1.89	36.90	.778	356.25	.00070	2.182
277	*	284.99	146.575	38.80	1.73	1.89	36.91	.778	356.27	.00060	1.870
278	*	283.67	146.575	38.80	1.72	1.89	36.91	.778	356.30	.00060	1.870

279	*	282.35	146.575	38.90	1.72	1.89	36.91	.778	356.32	.00060	1.870
280	*	281.03	146.575	38.90	1.71	1.89	36.91	.778	356.34	.00070	2.182
281	*	279.71	146.575	38.91	1.71	1.89	36.92	.778	356.36	.00060	1.870
282	*	278.39	146.575	38.91	1.70	1.89	36.92	.778	356.39	.00060	1.871
283	*	277.07	146.575	38.91	1.69	1.89	36.92	.778	356.41	.00070	2.183
284	*	275.75	146.575	38.91	1.69	1.89	36.92	.778	356.43	.00060	1.871
285	*	274.43	146.575	38.92	1.68	1.89	36.92	.778	356.45	.00070	2.183
286	*	273.11	146.575	38.92	1.68	1.89	36.93	.778	356.48	.00060	1.871
287	*	271.79	146.575	38.92	1.67	1.89	36.93	.778	356.50	.00070	2.183
288	*	270.47	146.575	38.92	1.67	1.89	36.93	.778	356.52	.00060	1.871
289	*	269.15	146.575	38.93	1.66	1.89	36.93	.778	356.54	.00070	2.184
290	*	267.83	146.575	38.93	1.65	1.89	36.94	.778	356.57	.00070	2.184
291	*	266.51	146.575	38.93	1.65	1.89	36.94	.778	356.59	.00060	1.872
292	*	265.19	146.575	38.93	1.64	1.89	36.94	.778	356.61	.00070	2.184
293	*	263.87	146.575	38.94	1.64	1.89	36.94	.778	356.63	.00070	2.184
294	*	262.54	146.575	38.94	1.63	1.89	36.95	.778	356.66	.00070	2.184
295	*	261.22	146.575	38.94	1.62	1.89	36.95	.778	356.68	.00060	1.872
296	*	259.90	146.575	38.94	1.62	1.89	36.95	.778	356.70	.00070	2.185
297	*	258.58	146.575	38.94	1.61	1.89	36.95	.778	356.73	.00070	2.185
298	*	257.26	146.575	38.95	1.61	1.89	36.95	.778	356.75	.00070	2.185
299	*	255.94	146.575	38.95	1.60	1.89	36.96	.778	356.77	.00070	2.185
300	*	254.62	146.575	38.95	1.59	1.89	36.96	.778	356.79	.00070	2.185
301	*	253.30	146.575	38.95	1.59	1.89	36.96	.778	356.82	.00070	2.185
302	*	251.98	146.575	38.96	1.58	1.89	36.96	.778	356.84	.00080	2.498
303	*	250.66	146.575	38.96	1.58	1.89	36.97	.778	356.86	.00070	2.186
304	*	249.34	146.575	38.96	1.57	1.89	36.97	.778	356.88	.00070	2.186
305	*	248.02	146.575	38.96	1.56	1.89	36.97	.778	356.91	.00070	2.186
306	*	246.70	146.575	38.97	1.56	1.89	36.97	.778	356.93	.00080	2.499
307	*	245.38	146.575	38.97	1.55	1.89	36.98	.778	356.95	.00070	2.186
308	*	244.06	146.575	38.97	1.55	1.89	36.98	.778	356.98	.00070	2.186
309	*	242.74	146.575	38.97	1.54	1.89	36.98	.778	357.00	.00080	2.499
310	*	241.42	146.575	38.98	1.53	1.89	36.98	.778	357.02	.00080	2.499
311	*	240.10	146.575	38.98	1.53	1.89	36.99	.778	357.04	.00070	2.187
312	*	238.78	146.575	38.98	1.52	1.89	36.99	.778	357.07	.00080	2.500
313	*	237.46	146.575	38.98	1.52	1.89	36.99	.778	357.09	.00080	2.500
314	*	236.13	146.575	38.98	1.51	1.89	36.99	.778	357.11	.00070	2.187
315	*	234.81	146.575	38.99	1.50	1.89	37.00	.778	357.13	.00080	2.500
316	*	233.49	146.575	38.99	1.50	1.89	37.00	.778	357.16	.00080	2.500
317	*	232.17	146.575	38.99	1.49	1.89	37.00	.778	357.18	.00080	2.501
318	*	230.85	146.575	38.99	1.48	1.89	37.00	.778	357.20	.00080	2.501
319	*	229.53	146.575	38.90	1.48	1.89	37.00	.778	357.23	.00080	2.501
320	*	228.21	146.575	38.90	1.47	1.89	37.01	.778	357.25	.00080	2.501
321	*	226.89	146.575	38.90	1.46	1.89	37.01	.778	357.27	.00080	2.501
322	*	225.57	146.575	38.90	1.46	1.89	37.01	.778	357.29	.00090	2.814
323	*	224.25	146.575	38.91	1.45	1.89	37.01	.778	357.31	.00080	2.501
324	*	222.93	146.575	38.91	1.45	1.89	37.02	.778	357.34	.00080	2.502
325	*	221.61	146.575	38.91	1.44	1.89	37.02	.778	357.36	.00090	2.815

326 *	220.29	146.575	38.91	1.43	1.89	37.02	.778	357.38	.00080	2.502
327 *	218.97	146.575	38.91	1.43	1.89	37.02	.778	357.40	.00090	2.815
328 *	217.65	146.575	38.92	1.42	1.89	37.03	.778	357.43	.00080	2.502
329 *	216.33	146.575	38.92	1.41	1.89	37.03	.778	357.45	.00090	2.815
330 *	215.01	146.575	38.92	1.41	1.89	37.03	.778	357.47	.00090	2.816
331 *	213.69	146.575	38.92	1.40	1.89	37.03	.778	357.49	.00090	2.816
332 *	212.37	146.575	38.93	1.39	1.89	37.03	.778	357.51	.00090	2.816
333 *	211.05	146.575	38.93	1.39	1.89	37.04	.778	357.53	.00090	2.816
334 *	209.72	146.575	38.93	1.38	1.89	37.04	.778	357.55	.00090	2.816
335 *	208.40	146.575	38.93	1.37	1.89	37.04	.778	357.58	.00090	2.817
336 *	207.08	146.575	38.93	1.37	1.89	37.04	.778	357.60	.00090	2.817
337 *	205.76	146.575	38.94	1.36	1.89	37.05	.778	357.62	.00100	3.130
338 *	204.44	146.575	38.94	1.36	1.89	37.05	.778	357.64	.00090	2.817
339 *	203.12	146.575	38.94	1.35	1.89	37.05	.778	357.66	.00100	3.130
340 *	201.80	146.575	38.94	1.34	1.89	37.05	.778	357.68	.00090	2.817
341 *	200.48	146.575	38.95	1.34	1.89	37.05	.778	357.70	.00100	3.131
342 *	199.16	146.575	38.95	1.33	1.89	37.06	.778	357.72	.00100	3.131
343 *	197.84	146.575	38.95	1.32	1.89	37.06	.778	357.74	.00100	3.131
344 *	196.52	146.575	38.95	1.32	1.89	37.06	.778	357.76	.00100	3.131
345 *	195.20	146.575	38.95	1.31	1.89	37.06	.778	357.78	.00100	3.132
346 *	193.88	146.575	38.96	1.30	1.89	37.06	.778	357.80	.00100	3.132
347 *	192.56	146.575	38.96	1.29	1.89	37.07	.778	357.82	.00110	3.445
348 *	191.24	146.575	38.96	1.29	1.89	37.07	.778	357.83	.00100	3.132
349 *	189.92	146.575	38.96	1.28	1.89	37.07	.778	357.85	.00110	3.446
350 *	188.60	146.575	38.96	1.27	1.89	37.07	.778	357.87	.00100	3.132
351 *	187.28	146.575	38.97	1.27	1.89	37.07	.778	357.89	.00110	3.446
352 *	185.96	146.575	38.97	1.26	1.89	37.07	.778	357.91	.00110	3.446
353 *	184.64	146.575	38.97	1.25	1.89	37.08	.778	357.92	.00110	3.446
354 *	183.31	146.575	38.97	1.25	1.89	37.08	.778	357.94	.00110	3.446
355 *	181.99	146.575	38.97	1.24	1.89	37.08	.778	357.95	.00110	3.447
356 *	180.67	146.575	38.97	1.23	1.89	37.08	.778	357.97	.00120	3.760
357 *	179.35	146.575	38.98	1.23	1.89	37.08	.778	357.98	.00120	3.761
358 *	178.03	146.575	38.98	1.22	1.89	37.08	.778	358.00	.00110	3.447
359 *	176.71	146.575	38.98	1.21	1.89	37.09	.778	358.01	.00120	3.761
360 *	175.39	146.575	38.98	1.21	1.89	37.09	.778	358.03	.00120	3.761
361 *	174.07	146.575	38.98	1.20	1.89	37.09	.778	358.04	.00120	3.761
362 *	172.75	146.575	38.98	1.19	1.89	37.09	.778	358.05	.00130	4.075
363 *	171.43	146.575	38.98	1.18	1.89	37.09	.778	358.06	.00120	3.761
364 *	170.11	146.575	38.98	1.18	1.89	37.09	.778	358.07	.00130	4.075
365 *	168.79	146.575	38.99	1.17	1.89	37.09	.778	358.08	.00130	4.075
366 *	167.47	146.575	38.99	1.16	1.89	37.09	.778	358.09	.00130	4.075
367 *	166.15	146.575	38.99	1.16	1.89	37.09	.778	358.10	.00130	4.075
368 *	164.83	146.575	38.99	1.15	1.89	37.10	.778	358.10	.00130	4.075
369 *	163.51	146.575	38.99	1.14	1.89	37.10	.778	358.11	.00140	4.389
370 *	162.19	146.575	38.99	1.13	1.89	37.10	.778	358.11	.00140	4.389
371 *	160.87	146.575	38.99	1.13	1.89	37.10	.778	358.11	.00140	4.389
372 *	159.55	146.575	38.99	1.12	1.89	37.10	.778	358.11	.00140	4.389

373	*	153.23	146.575	33.99	1.11	1.89	37.10	.778	358.11	.00150	4.703
374	*	156.90	146.575	33.99	1.11	1.89	37.10	.778	358.10	.00140	4.389
375	*	155.58	146.575	33.99	1.10	1.89	37.09	.778	358.10	.00150	4.703
376	*	154.26	146.575	33.99	1.09	1.89	37.09	.778	358.08	.00160	5.016
377	*	152.94	146.575	33.98	1.08	1.89	37.09	.778	358.07	.00150	4.702
378	*	151.62	146.575	33.98	1.08	1.89	37.09	.778	358.04	.00160	5.016
379	*	150.30	146.575	33.98	1.07	1.89	37.09	.778	358.01	.00160	5.015
380	*	148.98	146.575	33.97	1.06	1.89	37.08	.778	357.97	.00160	5.015
381	*	147.66	146.575	33.97	1.05	1.89	37.07	.778	357.90	.00170	5.327
382	*	146.34	145.255	33.97	1.05	1.86	37.11	.784	357.64	.00170	5.323
383	*	145.02	143.934	33.98	1.04	1.83	37.15	.789	357.00	.00170	5.314
384	*	143.70	142.614	33.99	1.03	1.80	37.19	.793	356.00	.00180	5.611
385	*	142.38	141.293	39.00	1.03	1.75	37.23	.797	354.67	.00180	5.590
386	*	141.06	139.973	39.00	1.02	1.73	37.27	.800	353.04	.00190	5.873
387	*	139.74	138.652	39.01	1.01	1.70	37.31	.802	351.11	.00180	5.534
388	*	138.42	137.332	39.02	1.00	1.67	37.35	.804	348.93	.00200	6.111
389	*	137.10	136.011	39.03	1.00	1.64	37.39	.805	346.49	.00190	5.765
390	*	135.78	134.691	39.03	.99	1.61	37.42	.806	343.34	.00200	6.022
391	*	134.46	133.370	39.04	.98	1.53	37.46	.806	340.97	.00210	6.270
392	*	133.14	132.050	39.05	.97	1.55	37.50	.806	337.91	.00210	6.214
393	*	131.82	130.729	39.06	.96	1.52	37.53	.806	334.68	.00220	6.448
394	*	130.49	129.409	39.06	.96	1.49	37.57	.805	331.29	.00220	6.382
395	*	129.17	128.088	39.07	.95	1.46	37.61	.804	327.76	.00230	6.601
396	*	127.85	126.768	39.08	.94	1.43	37.64	.802	324.10	.00230	6.528
397	*	126.53	125.447	39.09	.93	1.41	37.68	.801	320.33	.00240	6.732
398	*	125.21	124.127	39.09	.93	1.38	37.72	.799	316.45	.00240	6.651
399	*	123.89	122.806	39.10	.92	1.35	37.75	.796	312.49	.00260	7.115
400	*	122.57	121.486	39.11	.91	1.32	37.79	.794	308.44	.00260	7.023
401	*	121.25	120.165	39.12	.90	1.30	37.82	.791	304.32	.00260	6.929
402	*	119.93	118.845	39.13	.90	1.27	37.86	.788	300.15	.00280	7.360
403	*	118.61	117.524	39.13	.89	1.24	37.89	.785	295.93	.00280	7.256
404	*	117.29	116.204	39.14	.88	1.22	37.93	.782	291.66	.00290	7.407
405	*	115.97	114.883	39.15	.87	1.19	37.96	.779	287.36	.00300	7.550
406	*	114.65	113.563	39.16	.86	1.16	37.99	.775	283.04	.00300	7.436
407	*	113.33	112.242	39.16	.86	1.14	38.03	.771	278.69	.00320	7.810
408	*	112.01	110.922	39.17	.85	1.11	38.06	.768	274.34	.00320	7.688
409	*	110.69	109.601	39.18	.84	1.09	38.09	.764	269.97	.00340	8.039
410	*	109.37	108.281	39.19	.83	1.06	38.13	.760	265.60	.00330	7.676
411	*	108.05	106.960	39.20	.83	1.04	38.16	.756	261.23	.00350	8.008
412	*	106.73	105.640	39.20	.82	1.01	38.19	.752	256.87	.00360	8.099
413	*	105.41	104.319	39.21	.81	.99	38.22	.748	252.52	.00360	7.962
414	*	104.09	102.999	39.22	.80	.97	38.25	.744	248.18	.00360	7.825
415	*	102.76	101.678	39.23	.79	.94	38.29	.740	243.85	.00380	8.116
416	*	101.44	100.358	39.24	.79	.92	38.32	.736	239.54	.00370	7.762
417	*	100.12	99.037	39.24	.78	.90	38.35	.732	235.24	.00380	7.829
418	*	98.80	97.717	39.25	.77	.87	38.38	.728	230.97	.00370	7.484
419	*	97.48	96.396	39.26	.76	.85	38.41	.723	226.71	.00380	7.545

420 *	96.16	95.076	39.27	.75	.33	33.44	.719	222.48	.00370	7.209
421 *	94.84	93.755	39.28	.74	.81	38.47	.715	218.27	.00370	7.073
422 *	93.52	92.435	39.28	.74	.79	33.50	.711	214.07	.00370	6.937
423 *	92.20	91.114	39.29	.73	.76	33.53	.706	209.90	.00360	6.618
424 *	90.83	89.794	39.30	.72	.74	38.56	.702	205.75	.00350	6.307
425 *	89.56	88.473	39.31	.71	.72	38.59	.698	201.62	.00350	6.180
426 *	88.24	87.153	39.32	.70	.70	38.61	.693	197.51	.00340	5.881
427 *	86.92	85.832	39.33	.70	.68	33.64	.689	193.41	.00330	5.590
428 *	85.60	84.512	39.33	.69	.66	33.67	.684	189.33	.00320	5.306
429 *	84.28	83.191	39.34	.68	.64	33.70	.680	185.26	.00310	5.030
430 *	82.96	81.371	39.35	.67	.62	38.73	.675	181.21	.00080	1.269
431 *	81.64	80.550	39.36	.66	.60	38.75	.671	177.16	.00360	5.586
432 *	80.32	79.230	39.37	.65	.59	33.78	.666	173.13	.00450	6.823
433 *	79.00	77.909	39.38	.65	.57	38.81	.661	169.10	.00460	6.813
434 *	77.67	76.589	39.38	.64	.55	33.83	.656	165.08	.00470	6.795
435 *	76.35	75.268	39.39	.63	.53	33.86	.651	161.05	.00480	6.771
436 *	75.03	73.948	39.40	.62	.51	38.89	.645	157.03	.00490	6.739
437 *	73.71	72.627	39.41	.61	.50	38.91	.640	153.01	.00490	6.567
438 *	72.39	71.307	39.42	.60	.48	33.94	.634	148.99	.00510	6.655
439 *	71.07	69.986	39.43	.59	.46	38.96	.628	144.96	.00520	6.602
440 *	69.75	68.666	39.43	.59	.45	38.99	.622	140.92	.00530	6.542
441 *	68.43	67.345	39.44	.58	.43	39.01	.616	136.88	.00540	6.474
442 *	67.11	66.025	39.45	.57	.41	39.04	.609	132.83	.00550	6.399
443 *	65.79	64.704	39.46	.56	.40	39.06	.602	128.76	.00570	6.429
444 *	64.47	63.384	39.47	.55	.38	39.09	.595	124.69	.00570	6.225
445 *	63.15	62.063	39.48	.54	.37	39.11	.587	120.59	.00600	6.338
446 *	61.83	60.743	39.49	.53	.35	39.13	.579	116.49	.00610	6.224
447 *	60.51	59.422	39.49	.53	.34	39.16	.571	112.37	.00630	6.201
448 *										
449 *										
450 *										
451 *	FOR DESIGN OPTION # 1:									
452 *	-----									
453 *										
454 *										
455 *										
456 *	RATED FLOW=	132.0	SCFS							
457 *	FLOW AT MAXIMUM POWER=	146.5	SCFS							
458 *	CUTOFF FLOW=	59.4	SCFS							
459 *	RATED HEAD=	37.4	FT							
460 *	WEIGHTED AVG. NET HEAD=	37.5	FT							
461 *	MINIMUM HEAD=	18.7	FT							
462 *	MAXIMUM HEAD=	56.2	FT							

466 * AVG. ANN. ENERGY= 1249.664MWH
 467 * MAX. POWER= 358.11KW
 468 * CAPACITY FACTOR= .3984

469 *
 470 *
 471 * ECONOMIC ANALYSIS
 472 * -----

473 *
 474 * COSTS
 475 * -----

476 * DIVERSION STRUCTURE= 0.
 477 * HIGH PRESSURE PENSTOCK= 0.
 478 * POWERHOUSE CIVIL COST= 139752.
 479 * INTAKE COST= 0.
 480 * LOW PRESSURE PIPELINE= 0.
 481 * SWITCHYARD= 43185.
 482 * TURBINE, GENERATOR, CONTROLS, SWITCHGEAR= 557794.
 483 * UTILITY HOOKUP= 69160.
 484 * EXTRA COST= 0.
 485 * -----
 486 * TOTAL COST= 809901.
 487 *
 488 *
 489 *

490 * ECONOMIC FACTORS
 491 * -----

492 * O&M COST IN 1ST YEAR= 9848.3
 493 * DOWN PAYMENT= .100 (FRACTION OF FIRST COST)
 494 * MORTGAGE INTEREST RATE= .120
 495 * PERIOD OF MORTGAGE= 30.7
 496 * PROPERTY APPRECIATION RATE= .020
 497 * TAXABLE VALUE (PERMANENT)= .7855
 498 * TAXABLE VALUE (MACHINERY)= .11
 499 * MACHINERY DEPRECIATION LIFE= 20 YEARS, TO 20% MINIMUM
 500 * INITIAL MILL LEVY= .2372
 501 * INVESTMENT TAX CREDIT= .210 (FRACTION OF FIRST COST)
 502 * STATE INCOME TAX RATE= .0675
 503 * INFLATION RATE= .080
 504 * PROJECT LIFE= 40
 505 * INITIAL POWER COST= .064000 (\$/KWH)
 506 * INITIAL CAPACITY COST= 7.92940 (\$/ANNUAL CONTRACT KW/MO.)
 507 * RATE OF POWER COST INCREASE= .060
 508 * 5 YEAR ACRS DEPRECIATION

CASH FLOW

YEAR	DEPT SERVICE	INTST	DEPR.	ISM COST	PROP. TAX	STATE INC TAX	TAXABLE INCOME	TAX CREDIT	FED. INC TAX	TOTAL COST	ENERGY RATE	CAPACITY RATE	TOTAL REVENUE
1	90490.	87469.	121485.	9848.	19680.	0.	-144931.	170079.	0.	120018.	.06400	7.9294	93553.
2	90490.	87107.	178178.	10636.	20562.	0.	-342248.	170079.	0.	121688.	.06784	8.4052	99166.
3	90490.	36701.	170079.	11487.	21460.	0.	-526859.	170079.	0.	123436.	.07191	8.9095	105116.
4	90490.	86246.	170079.	12406.	22371.	0.	-706539.	170079.	0.	125267.	.07623	9.4440	111423.
5	90490.	85737.	170079.	13399.	23292.	0.	-880938.	170079.	0.	127181.	.08080	10.0107	118108.
6	90490.	85167.	0.	14470.	24220.	0.	-879601.	170079.	0.	129180.	.08565	10.6113	125194.
7	90490.	84528.	0.	15623.	25149.	0.	-872199.	170079.	0.	131266.	.09079	11.2480	132706.
8	90490.	83813.	0.	16878.	26073.	0.	-858295.	170079.	0.	133441.	.09623	11.9229	140669.
9	90490.	83011.	0.	18229.	26987.	0.	-837414.	170079.	0.	135706.	.10201	12.6383	149109.
10	90490.	82114.	0.	19687.	27884.	0.	-809043.	170079.	0.	138060.	.10813	13.3966	158055.
11	90490.	81109.	0.	21262.	28753.	0.	-772628.	170079.	0.	140505.	.11461	14.2003	167538.
12	90490.	79933.	0.	22963.	29587.	0.	-727570.	170079.	0.	143039.	.12149	15.0524	177591.
13	90490.	78722.	0.	24800.	30373.	0.	-673219.	170079.	0.	145663.	.12878	15.9555	188246.
14	90490.	77310.	0.	26784.	31100.	0.	-608873.	170079.	0.	148373.	.13651	16.9128	199541.
15	90490.	75722.	0.	28926.	31753.	0.	-533768.	170079.	0.	151169.	.14470	17.9276	211513.
16	90490.	73958.	0.	31240.	32317.	0.	-447078.	0.	0.	154047.	.15338	19.0033	224204.
17	90490.	71974.	0.	33740.	32772.	0.	-347907.	0.	0.	157001.	.16258	20.1435	237656.
18	90490.	69752.	0.	36439.	33099.	0.	-235281.	0.	0.	160028.	.17234	21.3521	251916.
19	90490.	67263.	0.	39354.	33275.	0.	-108142.	0.	0.	163119.	.18268	22.6332	267031.
20	90490.	64476.	0.	42502.	33275.	2339.	32318.	0.	5390.	173997.	.19364	23.9912	283053.
21	90490.	61354.	0.	45902.	36330.	10560.	145889.	0.	47359.	230641.	.20526	25.4307	300036.
22	90490.	57358.	0.	49575.	39669.	11538.	159398.	0.	53573.	244844.	.21757	26.9565	318038.
23	90490.	53942.	0.	53541.	43319.	12577.	173742.	0.	60171.	260097.	.23063	28.5739	337120.
24	90490.	49557.	0.	57824.	47309.	13679.	188978.	0.	67180.	276482.	.24446	30.2883	357348.
25	90490.	44645.	0.	62450.	51672.	14851.	205170.	0.	74628.	294091.	.25913	32.1056	378788.
26	90490.	39143.	0.	67445.	56443.	16098.	222386.	0.	82548.	313024.	.27468	34.0320	401516.
27	90490.	32982.	0.	72841.	61660.	17423.	240700.	0.	90972.	333386.	.29116	36.0739	425607.
28	90490.	26081.	0.	78669.	67366.	18834.	260193.	0.	99939.	355298.	.30863	38.2383	451143.
29	90490.	18352.	0.	84962.	73607.	20337.	280954.	0.	109489.	378884.	.32715	40.5326	478212.
30	90490.	9699.	0.	91759.	80433.	21939.	303078.	0.	119666.	404287.	.34678	42.9646	506904.
31	90490.	0.	0.	99100.	87902.	23645.	326671.	0.	130518.	341166.	.36758	45.5424	537319.
32	90490.	0.	0.	107028.	96072.	24736.	341722.	0.	137442.	365278.	.38964	48.2750	569558.
33	90490.	0.	0.	115590.	105012.	25861.	357268.	0.	144593.	391057.	.41302	51.1715	603953.
34	90490.	0.	0.	124837.	114795.	27022.	373301.	0.	151969.	418622.	.43780	54.2418	639055.
35	90490.	0.	0.	134824.	125500.	28217.	389811.	0.	159563.	448104.	.46407	57.4963	678352.
36	90490.	0.	0.	145610.	137217.	29445.	406781.	0.	167369.	479641.	.49191	60.9461	719053.
37	90490.	0.	0.	157259.	150041.	30706.	424191.	0.	175378.	513383.	.52142	64.6028	762197.
38	90490.	0.	0.	169840.	164078.	31996.	442015.	0.	183577.	549491.	.55271	68.4790	807928.
39	90490.	0.	0.	183427.	179446.	33313.	460218.	0.	191950.	588136.	.58587	72.5877	856404.
40	90490.	0.	0.	198101.	196271.	34656.	478761.	0.	200480.	629507.	.62102	76.9430	907788.

561 * UNUSED TAX CREDIT AFTER 15YR CARRYOVER= 170079.

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565 * RATE OF RETURN= .1390

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575 * OPTION CHOSEN= 1

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580 * POSITION RUNOFF(IN) ENERGY PMAX CF ROR UNUSED CREDIT

581 *

582 * 0. 3.873 637.683 358.11 .2192 .0030 170079.

583 * 1. 3.873 725.534 358.11 .2313 .0130 170079.

584 * 2. 3.873 772.242 358.11 .2452 .0240 170079.

585 * 3. 3.873 826.724 358.11 .2635 .0370 170079.

586 * 4. 3.873 832.157 358.11 .2812 .0490 170079.

587 * 5. 3.873 934.438 358.11 .2979 .0600 170079.

588 * 6. 3.873 984.932 358.11 .3140 .0720 170079.

589 * 7. 3.873 1035.073 358.11 .3299 .0830 170079.

590 * 8. 3.873 1091.093 358.11 .3478 .0970 170079.

591 * 0. 4.994 794.126 358.11 .2531 .0290 170079.

592 * 1. 4.994 867.174 358.11 .2764 .0460 170079.

593 * 2. 4.994 930.235 358.11 .2965 .0600 170079.

594 * 3. 4.994 986.667 358.11 .3145 .0720 170079.

595 * 4. 4.994 1042.912 358.11 .3324 .0850 170079.

596 * 5. 4.994 1110.459 358.11 .3540 .1020 170079.

597 * 6. 4.994 1178.384 358.11 .3756 .1190 170079.

598 * 7. 4.994 1246.330 358.11 .3973 .1380 170079.

599 * 8. 4.994 1314.349 358.11 .4190 .1590 170079.

600 * 0. 6.116 910.337 358.11 .2902 .0550 170079.

601 * 1. 6.116 975.106 358.11 .3108 .0700 170079.

602 * 2. 6.116 1034.795 358.11 .3299 .0830 170079.

603 * 3. 6.116 1103.511 358.11 .3534 .1010 170079.

604 * 4. 6.116 1186.334 358.11 .3732 .1210 170079.

605 * 5. 6.116 1264.238 358.11 .4030 .1440 170079.

606 * 6. 6.116 1342.051 358.11 .4278 .1690 170079.

607	*	7.	6.116	1420.022	358.11	.4527	.1970	170079.
608	*	8.	6.116	1499.128	358.11	.4779	.2310	170079.
609	*	9.	7.237	998.786	358.11	.3184	.0750	170079.
610	*	1.	7.237	1064.596	358.11	.3394	.0900	170079.
611	*	2.	7.237	1151.600	358.11	.3671	.1120	170079.
612	*	3.	7.237	1239.279	358.11	.3950	.1360	170079.
613	*	4.	7.237	1326.391	358.11	.4228	.1630	170079.
614	*	5.	7.237	1413.262	358.11	.4505	.1950	170079.
615	*	6.	7.237	1500.894	358.11	.4784	.2320	170079.
616	*	7.	7.237	1591.276	358.11	.5072	.2770	159128.
617	*	8.	7.237	1686.563	358.11	.5376	.3320	112109.
618	*	9.	8.359	1063.231	358.11	.3339	.0900	170079.
619	*	1.	8.359	1154.452	358.11	.3680	.1130	170079.
620	*	2.	8.359	1249.710	358.11	.3934	.1390	170079.
621	*	3.	8.359	1343.726	358.11	.4283	.1690	170079.
622	*	4.	8.359	1436.929	358.11	.4580	.2040	170079.
623	*	5.	8.359	1531.669	358.11	.4882	.2460	170079.
624	*	6.	8.359	1630.664	358.11	.5198	.2990	135121.
625	*	7.	8.359	1737.237	358.11	.5538	.3630	82492.
626	*	8.	8.359	1856.482	358.11	.5913	.4430	22616.
627	*	9.	9.480	1133.046	358.11	.3612	.1070	170079.
628	*	1.	9.480	1235.174	358.11	.3937	.1350	170079.
629	*	2.	9.480	1335.215	358.11	.4256	.1660	170079.
630	*	3.	9.480	1433.518	358.11	.4570	.2030	170079.
631	*	4.	9.480	1533.675	358.11	.4889	.2470	170079.
632	*	5.	9.480	1639.549	358.11	.5226	.3040	130211.
633	*	6.	9.480	1754.853	358.11	.5594	.3750	76146.
634	*	7.	9.480	1835.687	358.11	.6011	.4640	8412.
635	*	8.	9.480	2042.390	358.11	.6511	.5810	0.
636	*	9.	10.602	1210.095	358.11	.3857	.1280	170079.
637	*	1.	10.602	1316.511	358.11	.4197	.1600	170079.
638	*	2.	10.602	1419.806	358.11	.4526	.1970	170079.
639	*	3.	10.602	1525.340	358.11	.4862	.2430	170079.
640	*	4.	10.602	1638.084	358.11	.5222	.3030	130651.
641	*	5.	10.602	1762.249	358.11	.5617	.3790	73354.
642	*	6.	10.602	1904.334	358.11	.6070	.4780	0.
643	*	7.	10.602	2078.877	358.11	.6627	.6090	0.
644	*	8.	10.602	2268.211	358.11	.7230	.7620	0.
645	*	MEASURED CURVE:		1225.718	358.11	.3907	.1320	170079.

APPENDIX C

Computer Program Listing

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1.000 C***** SMALL HYDROPOWER DESIGN AND SENSITIVITY PROGRAM *****
2.000 DIMENSION PIPE(50),DIA(50),CH(50),PWCOST(100),PEN6(9),PEN7(9)
3.000 DIMENSION CONVEY(50),FRACP(50),FRA(J(50),PHSE(6),PEN5(9),ADJST(99)
4.000 DIMENSION PHSEO(6),PHSE1(6),PHSE2(6),PHSE3(6),QA(50),TA(50)
5.000 DIMENSION PHSE4(6),TURB0(7),TURB1(7),TURB2(7),TURB3(7),TURB4(7)
6.000 DIMENSION Q(10),PEN0(9),PEN1(9),PEN2(9),PEN3(9),PEN4(9),COSPEN(9)
7.000 DIMENSION COSTUR(7),OMCOS(100),ENRATE(100),TAX(100),DEPR(100)
8.000 DIMENSION ADJINC(100),PBAL(100),SITAX(100),PTAX(100),REV(100)
9.000 DIMENSION CAP(100),CAPRTE(100),ENERGY(100),CRED(100),PTRATE(100)
10.000 REAL INTST,INTK0,INTK1,MINOR(50)
11.000 REAL INTKF0,INTKF1,INFL,NOTURB,NTURBD,INCCOST,INT(100)
12.000 REAL JDIA(50),KM(50),JCT(50),L(50)
13.000 INTEGER PERIOD,CURVES,OPTS,OPTION,G,HIGHPR(50),MORTLF
14.000 READ(5,5)AL1,AL2,AL3,AL4,AL5,AL6,AL7,AL8,AL9,AL10,AL11,AL12,AL13,A
15.000 1L14,AL15,AL16,AL17,AL18,AL19,AL20
16.000 READ(5,120) FDU0,FDU1,FDU2,FDU3,FDU4,FDU5,FDU6,FDU7
17.000 READ(5,120) FDL0,FDL1,FDL2,FDL3,FDL4,FDL5,FDL6,FDL7
18.000 READ(5,120) PPTU0,PPTU1
19.000 READ(5,120) PPTL0,PPTL1
20.000 READ(5,120) EREAC0,EREAC1,EREAC2,EREAC3,EREAC4
21.000 READ(5,120) EIMP0,EIMP1,EIMP2,EIMP3,EIMP4,EIMP5,EIMP6,EIMP7,EIMP8
22.000 READ(5,120) DIVST0,DIVST1
23.000 READ(5,120) INTK0,INTK1,INTKF0,INTKF1
24.000 READ(5,115) PPCOS0,PPCOS1,PPCOS2,PPCOS3,PPCOS4
25.000 READ(5,115) SWTCH0,SWTCH1,SWTCH2,SWTCH3,SWTCH4
26.000 I=0
27.000 5 FORMAT (20A4)
28.000 DO 10 I=1,9
29.000 10 READ(5,125) PEN0(I),PEN1(I),PEN2(I),PEN3(I),PEN4(I),PEN5(I),PEN6(I
30.000 1),PEN7(I)
31.000 I=0
32.000 DO 20 I=1,6
33.000 20 READ(5,125) PHSEO(I),PHSE1(I),PHSE2(I),PHSE3(I),PHSE4(I)
34.000 I=0
35.000 DO 30 I=1,7
36.000 30 READ(5,125) TURB0(I),TURB1(I),TURB2(I),TURB3(I),TURB4(I)
37.000 I=0
38.000 READ(5,125) UTIL0,UTIL1,UTIL2,UTIL3,UTIL4
39.000 READ(5,120) INTST,APREC,PERIOD,INFL,DWNPMT,PROPTX,TXCR,SENSI
40.000 READ(5,102) MORTLF,TARIFF,CAPPMT,TARINC,STTX,Q10ACT
41.000 READ(5,120) PPT,AREA,ELEV1,QAACH,QMIN,POSCH,OPTS,POSTEP,RUNSTP
42.000 READ(5,115) TAIL0,TAIL1,TAIL2,TAIL3,TAIL4,SPILLC
43.000 READ(5,102) K
44.000 I=0
45.000 DO 35 I=1,K
46.000 35 READ(5,120) TA(I),QA(I)

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47.000      40   FORMAT(////,'PREDICTED FLOW-DURATION CURVE AFTER MINIMUM FLOWS',/,
48.000          1'-----',/,)
49.000          2'-----',/,,'% EXCEEDENCE',5X,'Q(C
50.000          3FS)',/,,'-----',/)
51.000      50   FORMAT(F8.0,F14.2)
52.000      60   FORMAT(////,'-----',/,,'DESIGN OPTION=',I2,,,'-----'
53.000          1'-----',/,)
54.000      70   FORMAT(///,'MINIMUM FLOW=',F5.0,'CFS',//)
55.000     100   FORMAT(2I8,7F8.0)
56.000     102   FORMAT(I8,8F8.0)
57.000     105   FORMAT(5F8.0,I2)
58.000     110   FORMAT('PIPE #',F3.0,'    CONVEYANCE=',F10.7,'    DIAMETER=',F7.3,'"
59.000          1    CH=',F4.0)
60.000     115   FORMAT(6E12.6)
61.000     120   FORMAT(9F8.0)
62.000     125   FORMAT(2F6.0,6E11.6)
63.000           Q10=QAACH*3.056
64.000           RUNM=PPTUO+PPTU1*PPT
65.000           RUN=0.
66.000           G=0
67.000           POS=POSCH
68.000           PRINT(6,5)AL1,AL2,AL3,AL4,AL5,AL6,AL7,AL8,AL9,AL10,AL11,AL12,AL13,
69.000          1AL14,AL15,AL16,AL17,AL18,AL19,AL20
70.000           PRINT(6,40)
71.000           A=0.0
72.000           RORMAX=0.
73.000           DO 130 I=1,4
74.000             A=A+1.
75.000             EX=.1*A
76.000             Q(I)=Q10*(POS/POSTEP*(FDUO+FDU1*EX+FDU2*EX**2.+FDU3*EX**3.)
77.000            1+(POSTEP-POS)/POSTEP*(FDL0+FDL1*EX+FDL2*EX**2.+FDL3*EX**3.))-QMIN
78.000             EX=EX*100.
79.000             IF(Q(I).LE.0.0) Q(I)=0.0
80.000     130   PRINT(6,50) EX,Q(I)
81.000             A=4.
82.000             I=0
83.000             DO 140 I=5,10
84.000               A=A+1.
85.000               EX=.1*A
86.000               Q(I)=Q10*(POS/POSTEP*(FDJ4+FDU5*EX+FDU6*EX**2.+FDU7*EX**3.)+(POSTEP
87.000              1P-POS)/POSTEP*(FDL4+FDL5*EX+FDL6*EX**2.+FDL7*EX**3.))-QMIN
88.000               EX=EX*100.
89.000               IF(Q(I).LE.0.0) Q(I)=0.0
90.000     140   PRINT(6,50) EX,Q(I)
91.000           PRINT(6,70) QMIN
92.000     200   READ(5,100) N,J,TYPE,NOTURB,QCUT,QMAX,WIDTH,FISHSC,PRINT
93.000           READ(5,102)CURVES,EXTRA,HNMIN,HNMAX,EFFOTH
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94.000      I=0
95.000      PRINT(6,60) G+1
96.000      IF (TYPE.EQ.1.) GO TO 250
97.000      PRINT (6,500)
98.000      GO TO 260
99.000      PRINT (6,550)
100.000     250 DO 300 I=1,N
101.000     260 READ (5,105) PIPE(I),DIA(I),CH(I),L(I),FRACP(I),HIGHPR(I)
102.000      CONVEY(I)=L(I)*855580./(CH(I)**1.85*DIA(I)**4.87)
103.000     300 PRINT(6,110) PIPE(I),CONVEY(I),DIA(I),CH(I)
104.000      A=0.
105.000      IF(J.LT.1) GO TO 800
106.000      I=0
107.000      DO 400 I=1,J
108.000      READ (5,120) JCT(I),JDIA(I),KM(I),FRACJ(I)
109.000     400 MINOR(I)=KM(I)*522./JDIA(I)**4
110.000     500 FORMAT('TURBINE TYPE= IMPULSE',//)
111.000     550 FORMAT('TURBINE TYPE= REACTION',//)
112.000     800 QR=Q10
113.000      PMAX=0.
114.000      I=0
115.000      PM=0.
116.000      PL=0.
117.000      A=0.
118.000      F=QMAX
119.000      DO 850 I=1,N
120.000     850 PL=CONVEY(I)*FRACP(I)**1.85+PL
121.000      I=0
122.000      IF(J.LT.1) GO TO 902
123.000      DO 900 I=1,J
124.000     900 PM=MINOR(I)*FRACJ(I)**2.+PM
125.000     902 IF(TYPE.GT.1.0) GO TO 905
126.000      EQ=EREACO
127.000      E1=EREAC1
128.000      E2=EREAC2
129.000      E3=EREAC3
130.000      E4=EREAC4
131.000      IF (TAIL0.GT.0.) GO TO 937
132.000      GO TO 910
133.000     905 EQ=EIMP0
134.000      E1=EIMP1
135.000      E2=EIMP2
136.000      E3=EIMP3
137.000      E4=EIMP4
138.000 C***** GET RATED FLOW STARTING POINT *****
139.000     910 E=EQ+E1*F+E2*F**2.+E3*F**3.+E4*F**4.

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140.000      C1=E1*F+2.*E2*F**2.+3.*E3*F**3.+4.*E4*F**4.
141.000  920  ER=ELEV1*(E+C1)-PL*(E*2.85+C1)*(F*QR)**1.85-PM*(E*3.+C1)*(F*QR)**2
142.000      IF (ER.GE.-.1) GO TO 930
143.000      QR=QR-.5
144.000      GO TO 920
145.000  C***** GET RATED FLOW *****
146.000  C***** FLOW AT MAXIMUM POWER *****
147.000  930  IF (TAILO.GT.0.0) GO TO 937
148.000      QE=QR*QMAX
149.000  932  F=QE/QR
150.000      IF (TYPE.EQ.1.) GO TO 934
151.000      IF (F.GE..36) GO TO 934
152.000      EFF=EIMP5+EIMP6*F+EIMP7*F**2.+EIMP8*F**3.
153.000      GO TO 936
154.000  934  EFF=E0+E1*F+E2*F**2.+E3*F**3.+E4*F**4.
155.000  936  P=(QE*ELEV1-PL*QE**2.85-PM*QE**3.)*EFF/11.815
156.000      IF (P.GE.PMAX) PMAX=P
157.000      IF (P.GE.PMAX) QPMAX=QE
158.000      QE=QE-.5
159.000      IF (QE.LE.(QCUT*QR)) GO TO 937
160.000      GO TO 932
161.000  C***** INTEGRATE NET HEAD *****
162.000  937  T1=0
163.000      T2=0.
164.000      T3=0.
165.000      WTHN=0.
166.000      QSTR=QR+QMIN
167.000      ELEV=ELEV1-(TAILO+TAIL1*QSTR+TAIL2*QSTR**2.+TAIL3*QSTR**3.+TAIL4*Q
168.000      STR**4.)
169.000      HNR=ELEV-PL*QR**1.85-PM*QR**2.
170.000      IF (TAILO.GT.0.) QPMAX=Q10*2.98-QMIN
171.000      QE=QPMAX
172.000  938  I=0
173.000      IF (TAILO.EQ.0.) GO TO 942
174.000      QSTR=QE+QMIN
175.000      TAIL=TAILO+TAIL1*QSTR+TAIL2*QSTR**2.+TAIL3*QSTR**3.+TAIL4*QSTR**4.
176.000      QT=QCUT*QR
177.000      PMAX=0.
178.000      HNB=0.
179.000  939  QS=QE-QT+QMIN
180.000      IF (QS.LE.0.) QS=0.
181.000      ELEV=ELEV1-TAIL+SPILLC*QS**(2./3.)
182.000      HN=ELEV-PL*QT**1.85-PM*QT**2.
183.000      IF (HN.GT.(HNMAX*HNR)) GO TO 940
184.000      IF (HN.LT.(HNMIN*HNR)) GO TO 941
185.000      F=QT/QR
186.000      EFF=E0+E1*F+E2*F**2.+E3*F**3.+E4*F**4.

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187.000 P=QT*HN*EFF
188.000 IF (P.LT.PMAX) GO TO 940
189.000 PMAX=P
190.000 HNB=HN
191.000 940 QT=QT+QR/100.
192.000 IF (QT.GT.QE) GO TO 941
193.000 IF (QT.GT.(QMAX*QR)) GO TO 941
194.000 GO TO 939
195.000 941 IF (HN.GT.(HNMAX*HNR)) GO TO 951
196.000 HN=HNB
197.000 GO TO 944
198.000 942 HLP=PL*QE**1.85
199.000 HM=PM*QE**2.
200.000 HN=ELEV1-HLP-HM
201.000 IF (HN.LT.(HNMIN*HNR)) GO TO 949
202.000 IF (HN.GT.(HNMAX*HNR)) GO TO 951
203.000 944 T=1.
204.000 IF ((QE+QMIN).GT.Q10) T=(3.*Q10-QE-QMIN)/20./Q10
205.000 IF ((QE+QMIN).GT.Q10) GO TO 948
206.000 IF (T2.GT.0.) T=T2+.05
207.000 945 IF (T.GT.4) GO TO 946
208.000 FDC1=FDU0+FDU1*T+FDU2*T**2.+FDU3*T**3.
209.000 FDC2=FDL0+FDL1*T+FDL2*T**2.+FDL3*T**3.
210.000 GO TO 947
211.000 946 FDC1=FDU4+FDU5*T+FDU6*T**2.+FDU7*T**3.
212.000 FDC2=FDL4+FDL5*T+FDL6*T**2.+FDL7*T**3.
213.000 947 ER=QE-Q10*(POS/POSTEP*FDC1+(POSTEP-POS)/POSTEP*FDC2)+QMIN
214.000 IF (ER.LE.0.) GO TO 948
215.000 T=T-.0001
216.000 GO TO 945
217.000 948 T1=T-T2
218.000 T2=T
219.000 IF (T.GT.1.) GO TO 951
220.000 IF (HN.LT.(HNMIN*HNR)) T3=T2
221.000 WTHN=WTHN+HN*T1
222.000 IF (QE.GT.Q10) QE=QE-Q10/50.
223.000 IF (QE.GT.Q10) GO TO 950
224.000 949 QE=QE-QR/100.
225.000 950 IF (QE.LT.(QCUT*QR)) GO TO 951
226.000 GO TO 938
227.000 C*****ADJUST RATED FLOW, REPEAT *****
228.000 951 WTHN=WTHN/(T2-T3)
229.000 DEC=.1
230.000 IF (TAILO.EQ.0.) GO TO 952
231.000 IF ((4*HNR-WTHN).GE.(-.02*HNR)) DEC=.01
232.000 IF ((HNR-WTHN).GE.(-.002*HNR)) GO TO 953

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233.000      QR=QR-DEC*Q10
234.000      A=A+1.
235.000      IF (A.GT.25.) GO TO 953
236.000      GO TO 930
237.000 952   IF ((ABS(WTHN-HNR)).LE.(.005*HNR)) GO TO 953
238.000      QR=((ELEV1-WTHN)/(PL+PM))*((PL+PM)/(PL*1.85+PM*2.))
239.000      A=A+1.
240.000      IF (A.GT.50.) GO TO 953
241.000      GO TO 930
242.000 C***** FOR RATED FLOW, INTEGRATE OPERATION *****
243.000 953   T1=0.
244.000      WTHN=0
245.000      T2=0
246.000      IF (TAIL0.GT.0.) QPMAX=Q10*2.98-QMIN
247.000      QE=QPMAX
248.000      PMAX=0.
249.000      ANOZ=0.
250.000      T3=0.
251.000      G=G+1
252.000      ET=0.
253.000      QSTR=QR+QMIN
254.000      ELFV=ELEV1-(TAIL0+TAIL1*QSTR+TAIL2*QSTR**2.+TAIL3*QSTR**3.+TAIL4*Q
255.000 1STR**4.)
256.000      HNR=ELEV-PL*QR**1.85-PM*QR**2.
257.000      IF (PRINT.GT.1.) GO TO 960
258.000      IF (TAIL0.EQ.0.) GO TO 954
259.000      PRINT (6,1020)
260.000      GO TO 960
261.000 954   PRINT (6,955)
262.000 955   FORMAT(///,10X,'NOZZLE',/,', Q(CFS) AREA(SQ FT) HL(FT) HN(FT) EFF
263.000 1P(KW) TIME E(MWHR)')
264.000      PRINT (6,956)
265.000 956   FORMAT('-----')
266.000      1---')
267.000 957   FORMAT(F8.3,F8.5,2F8.2,F5.3,F8.2,F7.5,F9.3)
268.000 960   I=0
269.000      IF (TAIL0.EQ.0.) GO TO 969
270.000      QSTR=QE+QMIN
271.000      TAIL=TAIL0+TAIL1*QSTR+TAIL2*QSTR**2.+TAIL3*QSTR**3.+TAIL4*QSTR**4.
272.000      QT=QCUT*QR
273.000      PMAXB=0.
274.000      HNB=0.
275.000 961   QS=QE-QT+QMIN
276.000      IF (QS.LE.0.) QS=0.
277.000      ELEV=ELEV1-TAIL+SPILLC*QS**(2./3.)
278.000      HN=ELEV-PL*QT**1.85-PM*QT**2.

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279.000 IF (HN.GT.(HNMAX*HNR)) GO TO 962
280.000 IF (HN.LT.(HNMIN*HNR)) GO TO 963
281.000 F=QT/QR
282.000 EFF=(E0+E1*F+E2*F**2.+E3*F**3.+E4*F**4.)*EFFOTH
283.000 P=QT*HN*EFF/11.815
284.000 IF (P.LT.PMAXB) GO TO 962
285.000 PMAXB=P
286.000 ELEVB=ELEV
287.000 HNB=HN
288.000 QPMAXB=QT
289.000 EFFB=EFF
290.000 962 QT=QT+QR/100.
291.000 IF (QT.GT.QE) GO TO 963
292.000 IF (QT.GT.(QMAX*QR)) GO TO 963
293.000 GO TO 961
294.000 963 IF (HN.GT.(HNMAX*HNR)) GO TO 992
295.000 P=PMAXB
296.000 ELEV=ELEVB
297.000 HN=HNB
298.000 HL=ELEV-HN
299.000 QT=QPMAXB
300.000 EFF=EFFB
301.000 GO TO 977
302.000 969 HLP=PL*QE**1.85
303.000 HM=PM*QE**2.
304.000 970 HL=HLP+HM
305.000 HN=ELEV-HL
306.000 IF (HN.LT.(HNMIN*HNR)) GO TO 990
307.000 IF (HN.GT.(HNMAX*HNR)) GO TO 992
308.000 ANOZ=QE/((64.4*HN)**.5)
309.000 F=QE/QR
310.000 IF (TYPE.EQ.1.) GO TO 975
311.000 IF (F.GE..36) GO TO 975
312.000 EFF=(EIMP5+EIMP6*F+EIMP7*F**2.+EIMP8*F**3.)*EFFOTH
313.000 GO TO 976
314.000 975 EFF=(E0+E1*F+E2*F**2.+E3*F**3.+E4*F**4.)*EFFOTH
315.000 976 P=QE*HN*EFF/11.815
316.000 977 IF (RUN.GT.RUNM) GO TO 981
317.000 T=1.
318.000 IF ((QE+QMIN).GT.Q10) T=(3.*Q10-QE-QMIN)/20./Q10
319.000 IF ((QE+QMIN).GT.Q10) GO TO 984
320.000 IF (T2.GT.0.) T=T2+.05
321.000 978 IF (T.GT.0.4) GO TO 979
322.000 FDC1=FDU0+FDU1*T+FDU2*T**2.+FDU3*T**3.
323.000 FDC2=FDL0+FDL1*T+FDL2*T**2.+FDL3*T**3.
324.000 GO TO 980

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325.000 979 FDC1=FDU4+FDU5*T+FDU6*T**2.+FDU7*T**3.
326.000 FDC2=FDL4+FDL5*T+FDL6*T**2.+FDL7*T**3.
327.000 980 ER=QE-Q10*(POS/POSTEP*FDC1+(POSTEP*POS)/POSTEP*FDC2)+QMIN
328.000 IF(ER.LE.0.0) GO TO 984
329.000 T=T-.0001
330.000 GO TO 978
331.000 981 I=1
332.000 982 IF ((QE+QMIN).LE.QA(I)) GO TO 983
333.000 I=I+1
334.000 IF (I.LT.K) GO TO 982
335.000 983 T=TA(I-1)-(QA(I-1)-QE-QMIN)*(TA(I-1)-TA(I))/(QA(I-1)-QA(I))
336.000 984 T1=T-T2
337.000 IF(T1.LE.0.000) T1=0.
338.000 T2=T
339.000 IF(T.GT.1.) GO TO 992
340.000 IF (HN.LT.(HNMIN*HNR)) T3=T2
341.000 EN=8.76*T1*P
342.000 ET=ET+EN
343.000 WTHN=WTHN+HN*T1
344.000 IF (PRINT.GT.1.) GO TO 988
345.000 IF (TAILO.EQ.0.) GO TO 937
346.000 PRINT(6,1025) QSTR,QT,ELEV,TAIL,HL,HN,EFF,P,T1,EN
347.000 GO TO 988
348.000 987 PRINT (6,957) QE,ANQZ,HL,HN,EFF,P,T1,EN
349.000 988 IF(P.GE.PMAX) PMAX=P
350.000 IF (TAILO.EQ.0.) GO TO 939
351.000 IF (P.GE.PMAX) QPMAX=QT
352.000 GO TO 990
353.000 989 IF(P.GE.PMAX) QPMAX=QE
354.000 990 IF (QE.GT.Q10) QE=QE-Q10/50.
355.000 IF (QE.GT.Q10) GO TO 991
356.000 QE=QE-QR/100.
357.000 991 IF(QE.LT.(QR*QCUT)) GO TO 992
358.000 GO TO 960
359.000 992 CF=ET/PMAX/8.76
360.000 IF(G.GT.OPTS) GO TO 1325
361.000 PRINT(6,993) G
362.000 WTHN=WTHN/(T2-T3)
363.000 QLOW=QR*QCUT
364.000 HNMN=HNR*HNMIN
365.000 HNMN=HNR*HNMAX
366.000 993 FORMAT(///,'FOR DESIGN OPTION #',I2,' : ','/','-----'
367.000 1,///)
368.000 PRINT (6,994) QR,QPMAX,QLOW,HNR
369.000 994 FORMAT('RATED FLOW=',12X,F7.2,'CFS','/','FLOW AT MAXIMUM POWER=',1X,F
370.000 17.2,'CFS','/','CUTOFF FLOW=',11X,F7.2,'CFS','/','RATED HEAD=',12X,F8.2
371.000 2,'FT')

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372.000 PRINT (6,1012) WTHN,HNMN,HNMX
373.000 995 PRINT (6,1000) ET
374.000 PRINT (6,1010) PMAX
375.000 1000 FORMAT(///'AVG. ANN. ENERGY=' ,6X,F10.3,'MWH')
376.000 1010 FORMAT('MAX. POWER=' ,12X,F8.2,'KW')
377.000 1012 FORMAT('WEIGHTED AVG. NET HEAD=' ,F8.2,'FT' ,/, 'MINIMUM HEAD=' ,10X,F
378.000 18.2,'FT' ,/, 'MAXIMUM HEAD=' ,10X,F8.2,'FT')
379.000 PRINT(6,1015) CF
380.000 1015 FORMAT('CAPACITY FACTOR=' ,8X,F6.4)
381.000 1020 FORMAT(///,'QSTREAM QTURB GROSS TAILWATER HL HN EFF P
382.000 1 TIME ENERGY ' ,/, ' (CFS) (CFS) HEAD(FT) ELEV(FT) (FT) (F
383.000 2T) (KW) (MWHR) ' ,/, '-----
384.000 3-----')
385.000 1025 FORMAT(F8.2,F8.3,4F7.2,F5.3,F7.2,F8.5,F9.3)
386.000 C ***** COST OF DESIGN *****
387.000 C
388.000 PENCOS=0.
389.000 PHCOST=0.
390.000 INCOST=0.
391.000 PIPCOS=0.
392.000 SWCOST=0.
393.000 TURCOS=0.
394.000 UTLCOS=0.
395.000 IF (WIDTH.LE.0.) DIVSTR=0.
396.000 IF (WIDTH.LE.0.) GO TO 1040
397.000 DIVSTR=DIVST0+DIVST1*WIDTH
398.000 1040 IF (CURVES.GT.1) GO TO 1310
399.000 IF (G.GT.1) GO TO 1140
400.000 I=0
401.000 DO 1050 I=1,9
402.000 1050 COSPEN(I)=PEN0(I)+PEN1(I)*HNR+PEN2(I)*HNR**2.+PEN3(I)*HNR**3.+PEN4
403.000 1(I)*HNR**4.
404.000 I=0
405.000 IF(HNR.LE.800.) GO TO 1057
406.000 DO 1056 I=1,7
407.000 1056 COSPEN(I)=PEN5(I)+PEN6(I)*HNR+PEN7(I)*HNR**2.
408.000 1057 IF (PMAX.LE.10.) GO TO 1060
409.000 IF (PMAX.LE.100.) GO TO 1070
410.000 IF (PMAX.LE.500.) GO TO 1080
411.000 IF (PMAX.LE.1000.) GO TO 1090
412.000 IF (PMAX.LE.1500.) GO TO 1100
413.000 IF (PMAX.LE.2000.) GO TO 1110
414.000 IF (PMAX.LE.3000.) GO TO 1120
415.000 IF (PMAX.LE.4000.) GO TO 1130
416.000 PENCST=(PMAX-4000.)/1000.*(COSPEN(9)-COSPEN(8))+COSPEN(8)
417.000 GO TO 1140

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418.000 1060 PENCST=PMAX/10.*COSPEN(1)
419.000      GO TO 1140
420.000 1070 PENCST=(PMAX-10.)/90.*(COSPEN(2)-COSPEN(1))+COSPEN(1)
421.000      GO TO 1140
422.000 1080 PENCST=(PMAX-100.)/400.*(COSPEN(3)-COSPEN(2))+COSPEN(2)
423.000      GO TO 1140
424.000 1090 PENCST=(PMAX-500.)/500.*(COSPEN(4)-COSPEN(3))+COSPEN(3)
425.000      GO TO 1140
426.000 1100 PENCST=(PMAX-1000.)/500.*(COSPEN(5)-COSPEN(4))+COSPEN(4)
427.000      GO TO 1140
428.000 1110 PENCST=(PMAX-1500.)/500.*(COSPEN(6)-COSPEN(5))+COSPEN(5)
429.000      GO TO 1140
430.000 1120 PENCST=(PMAX-2000.)/1000.*(COSPEN(7)-COSPEN(6))+COSPEN(6)
431.000      GO TO 1140
432.000 1130 PENCST=(PMAX-3000.)/1000.*(COSPEN(8)-COSPEN(7))+COSPEN(7)
433.000 1140 I=0
434.000      PENCOS=0.0
435.000      DO 1145 I=1,N
436.000          IF (HIGHPR(I).GT.1) GO TO 1145
437.000          PRES=HNR*.86667
438.000          THICK=DIA(I)/(32000./PRES-1.)
439.000          CP=4700.*(1./(1+.01*DIA(I)/THICK))**.5
440.000          VEL=QR*183.35/DIA(I)**2.
441.000          PRES=HNR/2.308+CP*VEL/74.308
442.000          THICK=DIA(I)/(32000./PRES-1.)
443.000          XSEC=3.1416*(((DIA(I)+THICK)/2.))**2.-(DIA(I)/2.))**2.)
444.000          IF (G.EQ.1) PNCST=PENCST/XSEC
445.000 1145 IF (HIGHPR(I).EQ.1) PENCOS=PENCOS+PNCST*XSEC*L(I)
446.000      I=0
447.000      DO 1150 I=1,6
448.000 1150 PHSE(I)=PHSE0(I)+PHSE1(I)*PMAX+PHSE2(I)*PMAX**2.+PHSE3(I)*PMAX**3.
449.000      1+PHSE4(I)*PMAX**4.
450.000      IF (TYPE.EQ.1.) GO TO 1180
451.000      IF (HNR.GE.1000.) GO TO 1160
452.000      IF (HNR.GE.500.) GO TO 1170
453.000      PHCOST=PHSE(4)-(HNR-250.)/250.*(PHSE(4)-PHSE(3))
454.000      GO TO 1190
455.000 1160 PHCOST=PHSE(2)-(HNR-1000.)/1000.*(PHSE(2)-PHSE(1))
456.000      GO TO 1190
457.000 1170 PHCOST=PHSE(3)-(HNR-500.)/500.*(PHSE(3)-PHSE(2))
458.000      GO TO 1190
459.000 1180 PHCOST=PHSE(6)-(HNR-25.)/75.*(PHSE(6)-PHSE(5))
460.000 1190 IF (FISHSC.GT.2.) GO TO 1235
461.000      IF (FISHSC.GT.1.) GO TO 1200
462.000      INCOST=INTKF0+INTKF1*QR
463.000      GO TO 1210
464.000 1200 INCOST=INTK0+INTK1*QR

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465.000 1210 I=0
466.000      PIPCOS=0
467.000 1220 DO 1230 I=1,N
468.000      LE=L(I)
469.000      IF (HIGHPR(I).EQ.1) LE=0.
470.000 1230 PIPCOS=PIPCOS+(PPCOS0+PPCOS1*DIA(I)+PPCOS2*DIA(I)**2.+PPCOS3*DIA(I)
471.000      1)**3.+PPCOS4*DIA(I)**4.)*LE/FRACP(I)
472.000 1235 SWCOST=SWTCH0+SWTCH1*PMAX+SWTCH2*PMAX**2.+SWTCH3*PMAX**3.+SWTCH4*P
473.000      1MAX**4.
474.000      I=0
475.000      DO 1240 I=1,7
476.000 1240 COSTUR(I)=TURB0(I)+TURB1(I)*PMAX+TURB2(I)*PMAX**2.+TURB3(I)*PMAX**
477.000      13.+TURB4(I)*PMAX**4.
478.000      IF (HNR.GE.1500.) GO TO 1250
479.000      IF (HNR.GE.800.) GO TO 1260
480.000      IF (HNR.GE.400.) GO TO 1270
481.000      IF (HNR.GE.200.) GO TO 1280
482.000      PLD=PL
483.000      PMD=PM
484.000      HNMIND=HNMIN
485.000      HNMAXD=HNMAX
486.000      EFFTHD=EFFOTH
487.000      IF (HNR.GE.100.) GO TO 1290
488.000      TURCOS=COSTUR(7)-(HNR-25.)/75.*(COSTUR(7)-COSTUR(6))
489.000      GO TO 1300
490.000 1250 TURCOS=COSTUR(2)-(HNR-1500.)/500.*(COSTUR(2)-COSTUR(1))
491.000      GO TO 1300
492.000 1260 TURCOS=COSTUR(3)-(HNR-800.)/700.*(COSTUR(3)-COSTUR(2))
493.000      GO TO 1300
494.000 1270 TURCOS=COSTUR(4)-(HNR-400.)/400.*(COSTUR(4)-COSTUR(3))
495.000      GO TO 1300
496.000 1280 TURCOS=COSTUR(5)-(HNR-200.)/200.*(COSTUR(5)-COSTUR(4))
497.000      GO TO 1300
498.000 1290 TURCOS=COSTUR(6)-(HNR-100.)/100.*(COSTUR(6)-COSTUR(5))
499.000 1300 UTLCOS=UTIL0+UTIL1*PMAX+UTIL2*PMAX**2.+UTIL3*PMAX**3.+UTIL4*PMAX**
500.000      14.
501.000      TOTCOS=DIVSTR+PENCOS+PHCOST+INCCOST+PIPCOS+SWCOST+TURCOS+UTLCOS+EXT
502.000      1RA
503.000      GO TO 1320
504.000 1310 TOTCOS=EXTRA
505.000 1320 OPMCOS=17200.*(PMAX/1000.)**.543
506.000      ***** ECONOMIC ANALYSIS *****
507.000 C 1325 I=0
508.000      CREDIT=TXCR*TOTCOS
509.000      DEPSUM=0.0
509.500      STSUM=0.0
510.000      PERMCS=DIVSTR+PHCOST+EXTRA

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511.000 DEPRCS=TOTCOS-PERMCS
512.000 FINCED=(1.0-DWNPMT)*TOTCOS
513.000 DEPR(1)=.15*TOTCOS
514.000 DEPR(2)=.22*TOTCOS
515.000 DO 1330 I=3,5
516.000 1330 DEPR(I)=.21*TOTCOS
517.000 I=0
518.000 A=0
519.000 DO 1340 I=6,PERIOD
520.000 1340 DEPR(I)=0.0
521.000 I=0
522.000 DEPTSV=(1.+INTST)**MORTLF*INTST/((1.+INTST)**MORTLF-1.)*FINCED
523.000 DEPTS=DEPTSV
524.000 PBAL(1)=FINCED
525.000 DO 1422 I=1,PERIOD
526.000 OMCOS(I)=OPMCOS*(1.+INFL)**(I-1)
527.000 ENRATE(I)=TARIFF*(1.+TARINC)**(I-1)
528.000 CAPRTE(I)=CAPPMT*(1.+TARINC)**(I-1)
529.000 PTRATE(I)=PROPTX*(1.+INFL)**(I-1)
530.000 ENERGY(I)=ENRATE(I)*ET*1000.
531.000 CAP(I)=CAPRTE(I)*CF*PMAX*12.0
532.000 REV(I)=ENERGY(I)+CAP(I)
533.000 A=A+1.
534.000 IF (I.GT.20) GO TO 1342
535.000 PTAX(I)=(PERMCS*(1.+APREC)**I*.0855+DEPRCS*(1.-.04*A)*.11)*PTRATE(
535.500 1)
536.000 GO TO 1344
537.000 1342 PTAX(I)=(PERMCS*(1.+APREC)**I*.0855+.022*DEPRCS)*PTRATE(I)
538.000 1344 INT(I)=PBAL(I)*INTST
539.000 PBAL(I+1)=PBAL(I)-DEPTSV+INT(I)
540.000 IF (INT(I).LE.0.0) INT(I)=0.0
541.000 ADJST(I)=REV(I)-OMCOS(I)-PTAX(I)-INT(I)-STSUM-DEPR(I)
542.000 IF (ADJST(I).LE.0.) GO TO 1346
543.000 STSUM=0.
544.000 SITAX(I)=STTX*ADJST(I)
545.000 GO TO 1349
546.000 1346 STSUM=-ADJST(I)
547.000 SITAX(I)=0.0
548.000 1349 ADJINC(I)=REV(I)-OMCOS(I)-PTAX(I)-SITAX(I)-INT(I)-DEPSUM-DEPR(I)
549.000 IF (ADJINC(I).LE.0.0) GO TO 1410
550.000 IF (ADJINC(I).GT.25000.) GO TO 1350
551.000 TAX(I)=.16*ADJINC(I)
552.000 GO TO 1390
553.000 1350 IF (ADJINC(I).GT.50000.) GO TO 1360
554.000 TAX(I)=4000.+ .19*(ADJINC(I)-25000.)
555.000 GO TO 1390
556.000 1360 IF (ADJINC(I).GT.75000.) GO TO 1370

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557.000 TAX(I)=8750.+.3*(ADJINC(I)-50000.)
558.000 GO TO 1390
559.000 1370 IF(ADJINC(I).GT.100000.) GO TO 1380
560.000 TAX(I)=16250.+.4*(ADJINC(I)-75000.)
561.000 GO TO 1390
562.000 1380 TAX(I)=26250.+.46*(ADJINC(I)-100000.)
563.000 1390 DEPSUM=0.0
564.000 IF (TAX(I).GT.25000.) GO TO 1405
565.000 IF (CREDIT.GE.TAX(I)) GO TO 1400
566.000 TAX(I)=TAX(I)-CREDIT
567.000 CREDIT=0.0
568.000 GO TO 1420
569.000 1400 CREDIT=CREDIT-TAX(I)
570.000 TAX(I)=0.0
571.000 GO TO 1420
572.000 1405 IF (CREDIT.GE.(.9*TAX(I)+2500.)) GO TO 1407
573.000 TAX(I)=TAX(I)-CREDIT
574.000 CREDIT=0.0
575.000 GO TO 1420
576.000 1407 CREDIT=CREDIT-(.9*TAX(I)+2500.)
577.000 TAX(I)=.1*TAX(I)-2500.
578.000 GO TO 1420
579.000 1410 DEPSUM=-ADJINC(I)
580.000 TAX(I)=0.0
581.000 1420 CRED(I)=CREDIT
582.000 IF (I.GE.15) CREDIT=0.
583.000 1421 IF(I.GT.MORTLF) DEPTSV=0.0
584.000 1422 PWCOST(I)=OMCOS(I)+PTAX(I)+SITAX(I)+DEPTSV+TAX(I)
585.000 ROR=1.0
586.000 A=0
587.000 1425 I=0
588.000 PWREV=0.
589.000 PWCST=DWNPMT*TOTCOS
590.000 DO 1430 I=1,PERIOD
591.000 PWCST=PWCST+PWCOST(I)/(1.+ROR)**I
592.000 1430 PWREV=PWREV+REV(I)/(1.+ROR)**I
593.000 IF (A.GT.0) GO TO 1440
594.000 IF ((PWREV-PWCST).GE.0.) ROR=4.
595.000 A=2
596.000 IF (ROR.EQ.4.) GO TO 1425
597.000 1440 IF((PWREV-PWCST).GE.0.) GO TO 1460
598.000 ROR=ROR-.0010
599.000 IF (ROR.LE.0.) GO TO 1460
600.000 GO TO 1425
601.000 1460 IF (RUN.GT.RUNM) GO TO 1560
602.000 IF(G.GT.OPTS) GO TO 1509
603.000 IF(ROR.LT.RORMAX) GO TO 1465
604.000 RORMAX=ROR

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605.000 OPTION=G
606.000 ND=N
607.000 JD=J
608.000 PLD=PL
609.000 PMD=PM
610.000 HNMIND=HNMIN
611.000 HNMAXD=HNMAX
612.000 EFFTND=EFFOTH
613.000 EOD=E0
614.000 E1D=E1
615.000 E2D=E2
616.000 E3D=E3
617.000 E4D=E4
618.000 TYPED=TYPE
619.000 NTURBD=NOTURB
620.000 QCUTD=QCUT
621.000 QPMAXD=QPMAX
622.000 1464 QRD=QR
623.000 OPMCSO=OPMCOS
624.000 TOTCSO=TOTCOS
625.000 DIVSTD=DIVSTR
626.000 PHCSO=PHCOST
627.000 EXTRAD=EXTRA
628.000 1465 PRINT (6,1470) DIVSTR,PENCOS,PHCOST,INCOSt,PIPCOS,SWCOST,TURCOS,UT
629.000 1LCOS,EXTRA,TOTCOS
630.000 IF (PRINT.GT.1.) GO TO 1501
631.000 1470 FORMAT(//,'ECONOMIC ANALYSIS',//,'-----','//','COSTS',//,'
632.000 1-----',//,5X,'DIVERSION STRUCTURE=',21X,F9.0//,5X,'HIGH PRESSURE PE
633.000 2NSTOCK=',18X,F9.0//,5X,'POWERHOUSE CIVIL COST=',19X,F9.0//,5X,'INT
634.000 3AKE COST=',29X,F9.0//,5X,'LOW PRESSURE PIPELINE=',19X,F9.0//,5X,'S
635.000 4WITCHYARD=',30X,F9.0//,5X,'TURBINE GENERATOR CONTROLS SWITCHGEAR='
636.000 5,3X,F9.0//,5X,'UTILITY HOOKUP=',25X,F9.0//,5X,'EXTRA COST=',30X,F9
637.000 6.0//,5X,'-----',//,5X,
638.000 7'TOTAL COST=',30X,F9.0//)
639.000 PRINT (6,1475) OPMCOS,DWNPMT,INTST,MORTLF,APREC,PROPTX,TXCR,STTX,I
640.000 1NFL,PERIOD,TARIFF,CAPPMT,TARINC
641.000 1475 FORMAT('ECONOMIC FACTORS',//,'-----',//,5X,'O&M COST IN 1
642.000 1ST YEAR=',7X,F9.1//,5X,'DOWN PAYMENT=',15X,F9.3,3X,'(FRACTION OF F
643.000 2IRST COST)',//,5X,'MORTGAGE INTEREST RATE=',5X,F9.3//,5X,'PERIOD OF
644.000 3 MORTGAGE=',9X,F9.1//,5X,'PROPERTY APPRECIATION RATE=',X,F9.3//,5X
645.000 4,'TAXABLE VALUE (PERMANENT)=' ,8X,'.0855',//,5X,'TAXABLE VALUE (MACH
646.000 5INERY)=' ,8X,'.11',//,5X,'MACHINERY DEPRECIATION LIFE=',6X,'20 YEARS
647.000 6, TO 20% MINIMUM',//,5X,'INITIAL MILL LEVY=',10X,F9.4//,5X,'INVESTM
648.000 7ENT TAX CREDIT=',6X,F9.3,3X,'(FRACTION OF FIRST COST)',//,5X,'STATE
649.000 8 INCOME TAX RATE=',6X,F9.4//,5X,'INFLATION RATE=',13X,F9.3//,5X,'P
650.000 9PROJECT LIFE=',15X,19//,5X,'INITIAL POWER COST=',9X,F9.6,3X,'($/K
651.000 9WH)',//,5X,'INITIAL CAPACITY COST=',6X,F9.5,3X,'($/ANNUAL CONTRACT

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652.000 9KW/MO.)',/,5X,'RATE OF POWER COST INCREASE=',F9.3/,5X,'5 YEAR ACR
653.000 9S DEPRECIATION',///)
654.000 PRINT (6,1480)
655.000 1480 FORMAT('CASH FLOW',/,',-----',/,',YEAR DEPT INTST DEPR
656.000 1. O&M PROP. STATE TAXABLE TAX FED. TOTAL ENER
657.000 2GY CAPACITY TOTAL',/,5X,'SERVICE',22X,'COST TAX INC TAX IN
658.000 3COME CREDIT INC TAX COST RATE RATE REVENUE',/,',-----
659.000 4-----
660.000 5-----',/)
661.000 I=0
662.000 DO 1490 I=1,PERIOD
663.000 DEPTSV=DEPTS
664.000 IF(I.GT.MORTLF) DEPTSV=0.
665.000 1490 PRINT (6,1500) I,DEPTSV,INT(I),DEPR(I),OMCOS(I),PTAX(I),SITAX(I),A
666.000 1DJINC(I),CRED(I),TAX(I),PWCOST(I),ENRATE(I),CAPRTE(I),REV(I)
667.000 1500 FORMAT(I3,3F9.0,F8.0,F9.0,F7.0,F10.0,2F8.0,F9.0,F8.5,F9.4,F9.0)
668.000 1501 PRINT (6,1502)CRED(15)
669.000 1502 FORMAT (/,,'UNUSED TAX CREDIT AFTER 15YR CARRYOVER=',F9.0)
670.000 PRINT (6,1506) ROR
671.000 1506 FORMAT (/,/,,'RATE OF RETJRN=',F6.4/,',-----
672.000 1-----
673.000 2-----',/,',-----
674.000 3-----',///)
675.000 GO TO 1510
676.000 1509 PRINT (6,1540) POS,RUN,ET,PMAX,CF,ROR,CRED(15)
677.000 1510 IF(G-OPTS) 200,1511,1520
678.000 1511 POS=0.
679.000 RUN=PPTLO+PPTL1*PPT
680.000 QAA=AREA*.07367*RUN
681.000 Q10=3.056*QAA
682.000 N=ND
683.000 J=JD
684.000 TYPE=TYPED
685.000 PRINT (6,1550) OPTION
686.000 IF (SENS1.EQ.2.) STOP
687.000 NOTURB=NTURBD
688.000 QCUT=QCUTD
689.000 QPMAX=QPMAXD
690.000 PRINT=2.
691.000 PL=PLD
692.000 PM=PMO
693.000 HNMIN=HNMINO
694.000 HNMAX=HNMAXD
695.000 EFFOTH=EFFTHD
696.000 EO=EOO
697.000 E1=E1O

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698.000      E2=E2D
699.000      E3=E3D
700.000      E4=E4D
701.000 1515  QR=QRD
702.000      OPMCOS=OPMCSD
703.000      TOTCOS=TOTCSD
704.000      DIVSTR=DIVSTD
705.000      PHCOST=PHCSD
706.000      EXTRA=EXTRAD
707.000      GO TO 1530
708.000 1520  POS=POS+1.
709.000 1530  IF(POS.LE.POSTEP) GO TO 953
710.000 1540  FORMAT(F6.0,F10.3,F11.3,F8.2,2F7.4,F12.0)
711.000 1550  FORMAT(///,'-----','//,'OPTION CHOSEN=' ,I2,'//','-----'
712.000      1----' ,////,'POSITION  RUNOFF(IN)  ENERGY  PMAX      CF      ROR  UNU
713.000      2SED CREDIT' ,//,'-----'
714.000      3-----')
715.000      POS=0.
716.000      IF (RUNSTP.LE.0.) STOP
717.000      RUN=RUN+((PPTU1-PPTL1)*PPT+PPTU0-PPTL0)/RUNSTP
718.000      QAA=AREA*.07367*RUN
719.000      Q10=3.056*QAA
720.000      RUNM=PPTU0+PPTU1*PPT
721.000      IF(RUN.LE.RUNM) GO TO 953
722.000      Q10=Q10ACT
723.000      GO TO 953
724.000 1560  PRINT (6,1570) ET,PMAX,CF,ROR,CRED(15)
725.000 1570  FORMAT ('MEASURED CURVE: ' ,F11.3,F8.2,2F7.4,F12.0)
726.000      END

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