PROCEEDINGS:
WATER PROJECT DEVELOPMENT AND FINANCING IN THE 1990s

Edited by

Kate A. Berry

February 1991

Colorado State University

Colorado Water Resources Research Institute

Information Series No. 65

COLORADO WATER RESOURCES

RESEARCH INSTITUTE

WATER PROJECT DEVELOPMENT

AND FINANCING IN THE 1990s

Proceedings of a Conference sponsored by
AWRA-COLORADO SECTION
AND THE COLORADO
WATER RESOURCES RESEARCH INSTITUTE

Brittany Hill Restaurant
Thornton, Colorado
February 1, 1991

Edited by
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Denver, Colorado

Information Series No. 65

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PREFACE

The nineties promise to be a decade of change in western water resource management. Evidence of change is emerging in nearly every aspect of water management. Local, state and federal resource agencies, once quiescent, are in a state of flux, compelled to stretch their capabilities. There are alliances evolving between traditional rivals: cities and farmers, anglos and Indians, economists and engineers. Increasingly stringent regulatory requirements are being advanced to insure full consideration of environmental consequences. Growing public involvement is transforming the planning process. Even education in water resources is expanding to incorporate a multitude of disciplines and perspectives.

Challenges to the very foundation of reclamation and resource development policy pose a strong impetus for change. Faced with growing resistance to the status quo, resource managers are adopting new approaches to water supply and demand management. Nowhere are the transformations more visible than in the development and financing of water projects.

The purpose of this conference is to provide a forum to discuss the future of water project development and financing. These presentations chart current developments and innovations of interest to Coloradans. The presentations address:

- the evolution of the planning process
- planning for future water supplies
- the economics of new project development
- the bond market outlook
- alternative funding sources
- the changing roles of local, state and federal agencies
- alternatives to new project development
- public, professional and media perspectives of water development

This conference has been organized by the Colorado Section of the American Water Resources Association and the Colorado Water Resources Research Institute. The conference planning committee consists of: Bill Green, Jerry Kenny, Robert Ward and Kate Berry. Assistance from Evan Ela, David Mueller, Neil Grigg, Ken Salazar, Roger Vaughn, as well as all the authors, has made this conference possible. It is our hope that conference will contribute to and expand the ongoing discourse on water development and financing.

Kate Berry
Denver, Colorado

ECONOMIC SIZING OF WATER TRANSMISSION WITH HYDROPOWER FACILITIES

Ed A. Toms, P.E.[1], E. June Busse, P.E.[2], Curtis A. Thompson[3]

ABSTRACT

This paper studies the considerations involved in hydraulic and economic sizing of water transmission with hydropower generating facilities when the operational priorities of the facilities are potable water supply first and hydropower generation as a by-product. An existing raw water supply pipeline serving a major Front Range Colorado municipality connects a mountain reservoir to a water treatment plant. The pipeline is approximately ten miles long, traverses an 1,800 feet drop in elevation, and has a hydraulic profile that includes open channel and pressure flow. The pipeline's changing flow regime causes the water to become super saturated with air and this "air entrained" water reduces the efficiency of the treatment plant operations. Previous studies have concluded that the most cost-effective improvement to ensure meeting the recently upgraded safe drinking water regulations requires the pipeline to be modified to operate entirely under pressure flow (resulting in improved treatment efficiencies), and an additional benefit of pipeline pressurization is the opportunity to develop hydropower. Considerations analyzed for the pipeline/ penstock sizing include the minimum and maximum required delivery rates, hydraulic friction losses, hydraulic transients, and capital construction costs. The hydropower generation facility sizing includes consideration of the pipeline/penstock sizing and costs, the flow-duration curve for water supply operations, and capital construction costs. The uncommon penstock length for this proposed hydropower generating facility results in an analysis that emphasizes the interrelationship of hydraulics and material costs.

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INTRODUCTION

Many municipalities have discovered a source of energy that until recently had been neglected and considered a nuisance. This new source is the electricity that can be generated by hydroelectric power plants installed on water supply pipelines. In closed conduit water supply systems that traverse significant elevation changes, excessive pressure head is considered a nuisance and various means of dissipating this pressure have been developed. This dissipated pressure head was considered detrimental to the pipeline; however, in many cases it is a neglected source of economical energy.

The City of Boulder, Colorado is a leader in developing alternative/renewable sources of energy to keep costs (and taxes) low. The City has installed five hydropower units on its water supply pipelines and presently generates four megawatts of energy annually that had been previously neglected. A sixth hydropower development project being studied by the City is the Lakewood Pipeline, the subject of this study.

The Lakewood Pipeline is a raw water supply pipeline that is approximately 50,000 feet long, traverses an 1,800 feet drop in elevation, and has a hydraulic profile that includes open channel and pressure flow. Sections of the pipeline where the flow regime changes from open channel to pressure flow are sources of air entrainment that result in a water supply to the Betasso Water Treatment plant that is super saturated with air (CH2M-Hill 1980). This "air entrained" water has the potential to disrupt the plant's treatment operations and could cause the City to violate the recently upgraded safe drinking water regulations. By replacing the pipeline with a new, all-pressure flow pipeline, the City can improve their water treatment operations and, as a by product, develop hydropower to offset the cost of the new pipeline.

The following analysis estimates the optimal facility (pipeline and hydropower) sizes using the flow-duration curve procedure (Corps 1985). The facility sizing is performed in two phases. The first phase develops the rated capacity facility sizing approach, and the second phase analyzes the economics of the power production.

FACILITY SIZE ANALYSIS

Estimation of the optimum facility sizes requires comparing the costs of the pipeline and hydropower generating facilities with the benefits of the power revenues. Since capital costs increase much more rapidly than revenues for larger pipe diameters, it is not a simple matter of selecting a large pipe size and a corresponding generating facility size.

Planning studies require assumption of an initial facility flow rate capacity. For this analysis, a previously developed flow-duration curve with a peak flow of 20 million gallons per day (MGD) was used (Figure 1, JMM 1989) and the required flow capacity of the facilities was assumed to be the flow rate at 30 percent exceedance, 21.15 cfs. The 30 percent exceedance value was judged to be more conservative than the average annual flow or values less than 30 percent exceedance, and appropriate for the planning

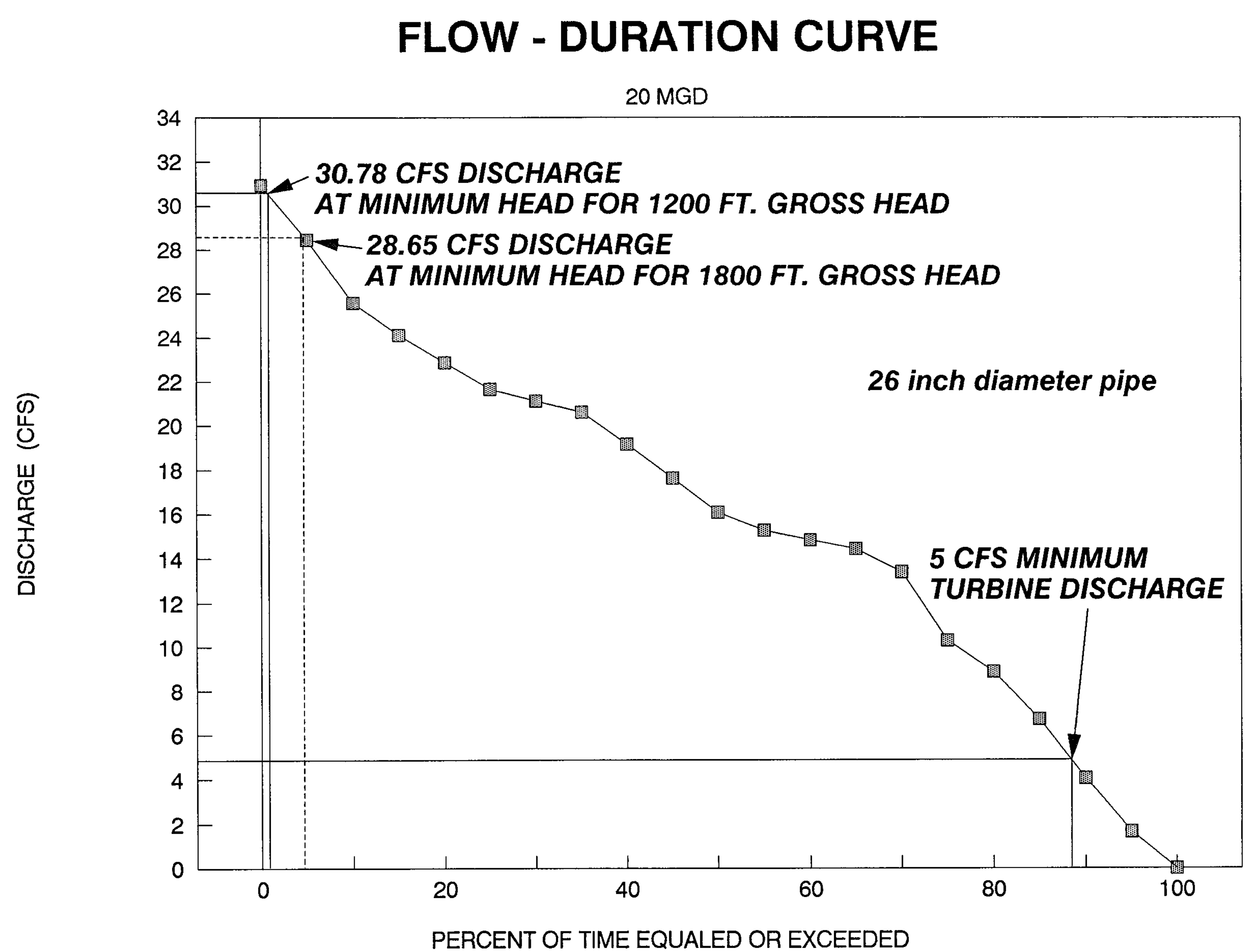

Figure 1 - Flow-duration curve with a peak flow of 20 MGD.

stage of this project. A detailed analysis of this assumption should be performed when the project progresses to the design stage.

The pipeline is tentatively planned to be replaced in two stages. For this analysis it was assumed that the first stage will replace approximately 19,500 linear feet of pipe from the existing treatment plant up to Sugarloaf Saddle. The second stage was assumed to be replaced sixteen years later and would finish the construction from the treatment plant to Lakewood Reservoir. The first and second stages have 1200 feet and 1800 feet static pressure head, respectively.

The net head corresponding to the assumed hydraulic capacity normally defines the conditions at which the unit would be rated (Corps 1985), assuming that all units are running at full gate and no water is being spilled. Rated head is defined as that head where rated power is obtained with turbine wicket gates fully opened. This head is the minimum head at which rated output can be obtained. Above rated head, the generator capacity limits power output, so the unit's full rated capacity can be obtained at all heads above the rated head. Below rated head, the maximum power output with turbine gates fully open is less than rated capacity. The rated heads corresponding to the 21.15 cfs discharge are 1079 feet and 1591 feet for the 1200 and 1800 gross head stages, respectively. Using the assumed hydraulic capacities and rated heads, and an assumed fixed average overall efficiency of 82 percent, the plant's installed capacity can be computed. The installed capacity for the 1200 feet and 1800 feet gross head stages are 1584 kW and 2336 kW, respectively.

Based on the flow and net head characteristics of the system, assume that an impulse turbine will be installed. The minimum discharge for an impulse turbine is 20 percent of the rated head (Corps 1985). Therefore, the minimum discharge is 5 cfs for both stages. This discharge corresponds to 1192 feet and 1786 feet for the 1200 feet and 1800 feet gross head systems, respectively. Heads greater than these will occur only at streamflows of less than the minimum generating streamflow of 5 cfs. These heads are the maximum generating heads. The minimum head will be about 80 percent of the maximum head (Corps 1985). The minimum heads that corresponds to the 1200 feet and 1800 feet systems are 954 feet and 1428 feet, respectively.

The portion of streamflow which can be used for power generation is limited by the turbine characteristics. The flow-duration curve should be reduced to include only the usable flow range. The minimum generating head defines the upper flow limit. The minimum head of 954 feet, for the 1200 gross head system, corresponds to the upper flow limit of 30.78 cfs. The minimum head of 1428 feet, for the 1800 gross head system, corresponds to the upper flow limit of 28.65 cfs. Applying these limits, the usable portion of the flow-duration curve can be defined.

Using the flow duration data and the net head versus discharge data, a head-duration curve can be developed. Figure 2 illustrates a head duration curve for a 26 inch diameter pipe with 1800 feet of gross head. The area under the curve defines the head range where power generation is produced. Design head is defined as the head at which the turbine will operate at best efficiency and is the mid-point of the usable head range for this preliminary analysis. Since it is usually desirable to obtain best efficiency in the head range where the project will operate most of the time, the design head is normally specified at or near average head.

A power-duration curve then can be developed by computing the power using the flow-duration curve, assuming the average efficiency of the system to be 82 percent. The unadjusted usable generation curve is not a true power-duration curve, because the generation values are plotted at the percent exceedance points corresponding to the flows upon which they are based. At flows greater than rated discharge, there is a reduction in power output due to reduced head. The data is rearranged in a usable power-duration curve as shown in Figure 3 for a 26 inch diameter pipe at 1800 feet of gross head.

Two simplifications were made in this analysis. An average overall efficiency has been assumed for all discharge levels, and the full gate discharge was assumed to be equal to the rated discharge for all heads. In actual operation, turbine efficiencies may vary substantially with both head and discharge. At streamflows larger than the rated

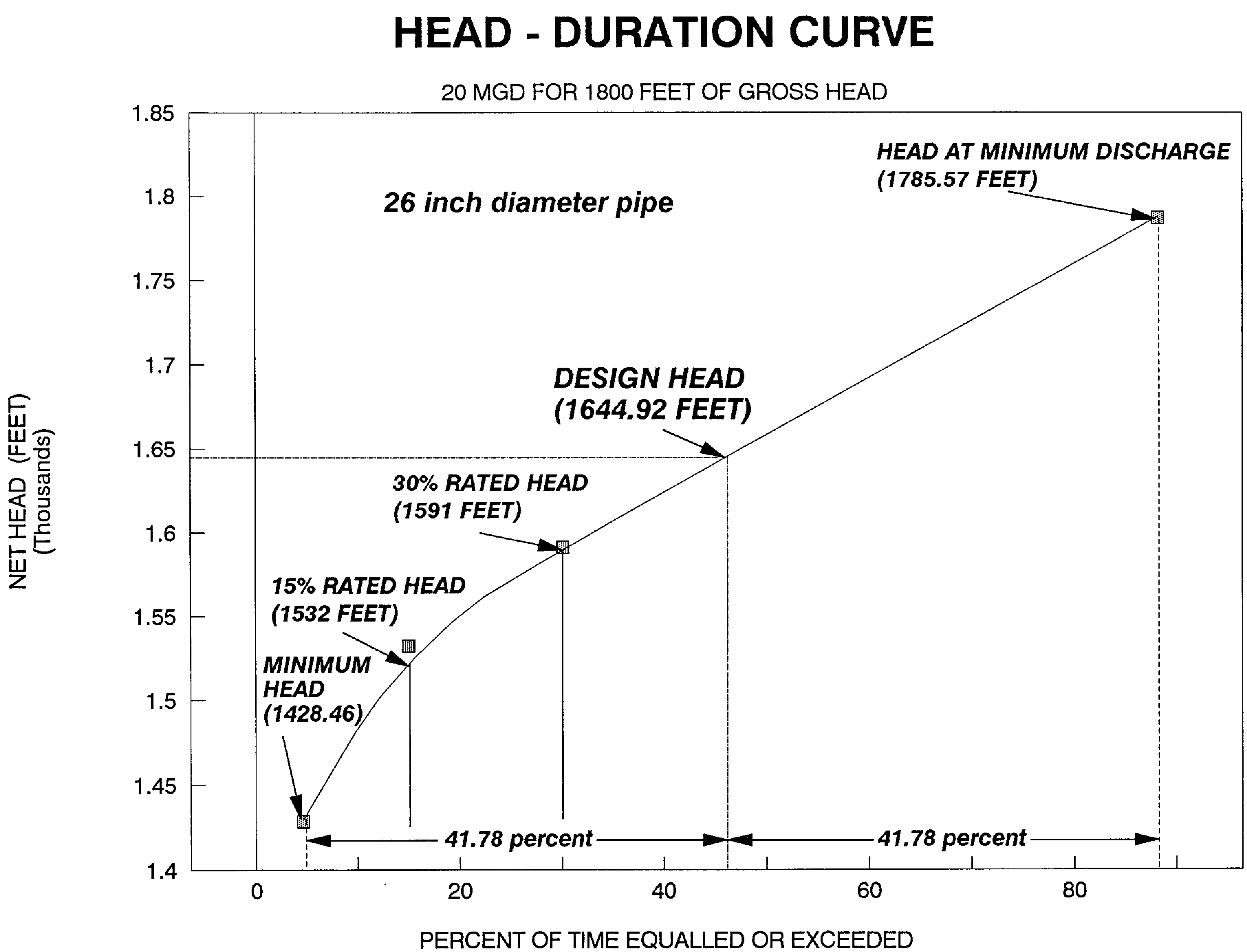

Figure 2 - Head-duration relationship at 1800 feet of gross head.

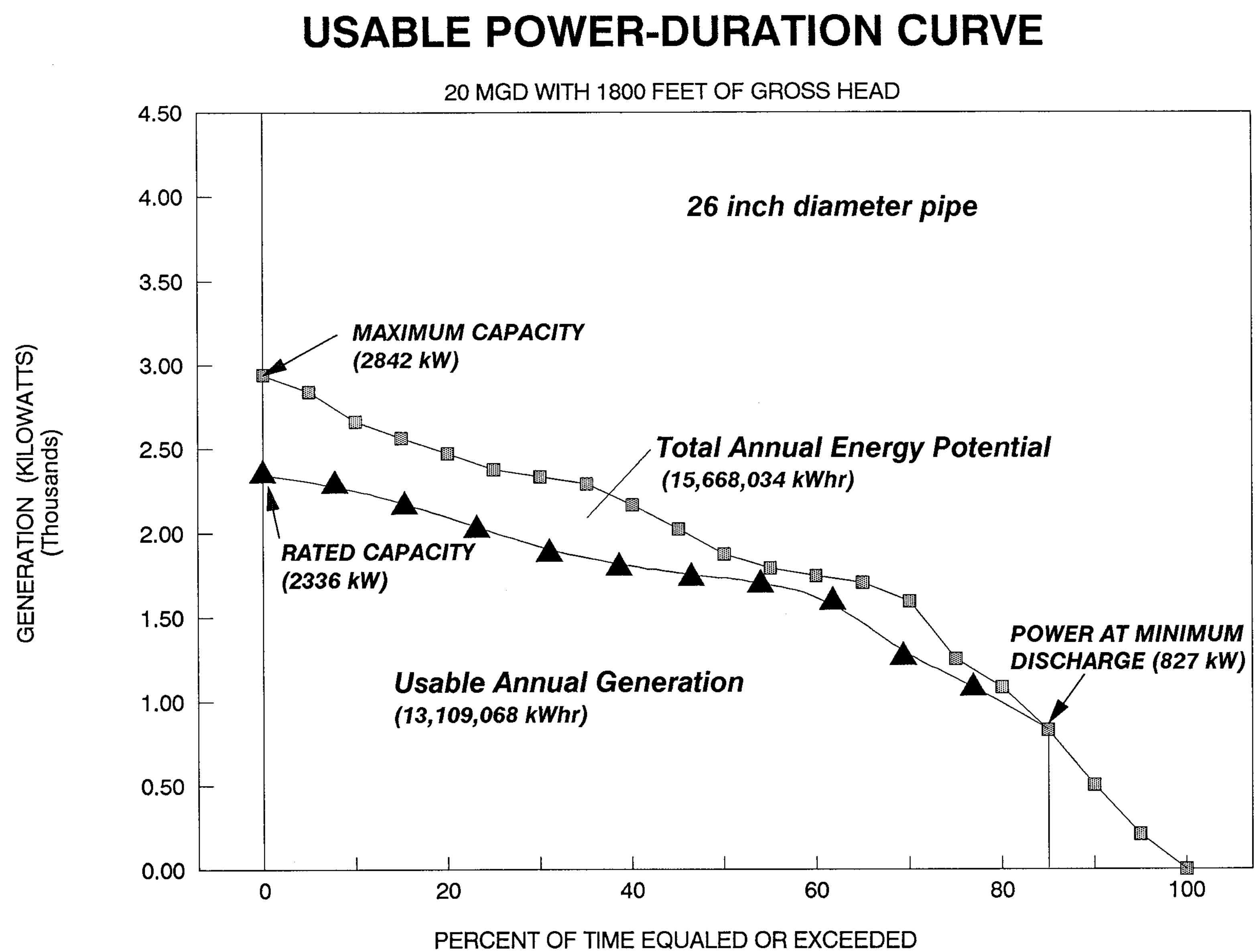

Figure 3 - Usable power-duration relationship at 1800 feet of gross head.

discharge, the full gate discharge decreases with the reduced head. For preliminary studies, these simplifications are appropriate (Corps 1985). For more advanced studies, these variables must be taken into account.

The power-duration curve is based on all of the completed years in the period of record. It can be treated as an annual generation curve, describing the average annual output over the period of record. The average annual energy can be obtained by integrating the power-duration curve and multiplying by the number of hours in a year. The average annual energy for the 1200 feet and 1800 feet gross head systems are 8,827,000 kWhr and 13,109,000 kWhr, respectively. These values are less than the total annual energy potential which is based on maximum capacity for the systems. The total annual energy potential and maximum capacity for the 1200 feet and 1800 feet gross head systems are 10,413,000 kWhr at 2043 kW and 15,668,000 kWhr at 2842 kW, respectively.

The analysis outlined in this section was used to develop the annual power generation and plant capacity for a range of pipe sizes; 22 inch, 24 inch and 26 inch. Interactive spreadsheets were developed for the different gross heads for each of the three pipes.

ECONOMIC ANALYSIS

Utilizing the present worth benefit-cost ratio method an economic analysis was performed to develop the relationship between the benefits from the development and the costs expended for the different pipe system configurations. The pipe system configuration with the highest benefit-cost ratio was selected as the optimal system configuration.

Economic assumptions were made to estimate the costs and benefits of the systems. Capacity and energy values were escalated each year at a rate of 1 percent per year for the 35 year project life. Operational and maintenance costs were escalated at 2 percent per year for the project life. The discount rate was assumed to be 7 percent per year for the present worth calculations.

The first 15 years of the economic analysis is based on a 1200 feet gross head system. The last 20 years of the project was based on the full available gross head of 1800 feet. The hydropower cost is based on the 1800 feet gross head plant capacity for the different pipe sizes. The hydropower unit costs were developed using the Corps of Engineers graphs (EPRI 1983). The pipe costs were calculated for installed costs. These costs included material, excavation, bedding, and backfill.

Interactive spreadsheets were developed to compute the different size pipe's benefit-cost ratios. The 22 inch, 24 inch and 26 inch pipes have a 0.75, 0.77 and 0.75 benefit-cost ratios, respectively.

ENVIRONMENTAL IMPACT

At the outset, a water supply system appears to be the cleanest location for installing a hydro power plant. There would appear to be no need for meeting minimum fish release requirements or the risk of endangering the wildlife habitat (special circumstances of the Lakewood Pipeline require resolution of this issue). However, during construction of the project, there may be some temporary disturbance to the plant life in the nearby areas. The turbines are at the end of a raw water line and before the water treatment plant, so proper precautions can be taken to prevent possible contamination of the treated water. The City maintains strict control over the greases and lubricants used in its hydropower facilities, and continuously monitors for traces of these compounds in the raw water.

CONCLUSIONS

A design engineer using the maximum capacity of the plant to size hydropower facilities might overestimate the hydropower revenues. This would result in an unrealistically low project cost estimate. Another possible problem would be an oversized turbine for the system. If the turbine is sized for the maximum capacity it may only operate at full capacity for very short time periods. It is also possible that the turbine would not perform at peak design because of uncertainties in the pipe friction head loss and estimated water availability.

The optimum penstock size was estimated to be 26 inch diameter with a benefit to cost ratio of 0.95 for maximum capacity. The present value of the power would be $8,135,000 and the present value of the costs would be $8,565,000. The plant size would be 2.9 MW. However, using the rated capacity of the turbine, a 24 inch diameter penstock was estimated to be optimum with a benefit to cost ratio of 0.77. The present value of the power would be $5,955,000 and the present value of the costs would be $7,778,000. The plant size would be 2.1 MW.

Actual system operations should be investigated and the planning assumptions re-evaluated prior to preliminary design of the system. The system operations will have a significant impact on the optimal penstock and rated plant size.

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FINANCING PROGRAM FOR SMALL WATER RESOURCES PROJECTS

Daniel L. Law[4]

ABSTRACT

As a result of the Safe Drinking Water Act of 1986 and the promulgation of associated regulations in 1989, Colorado's communities needed a program to help alleviate the financial burdens associated with upgrading their water resources infrastructure. In addition to the Safe Drinking Water Act requirements, many smaller communities need financial assistance to rehabilitate, upgrade or expand their existing water supply infrastructure to meet current system needs regardless of future growth projections.

The Colorado Water Resources and Power Development Authority has identified and implemented a streamlined process to finance projects of ten million dollars or less. The program is focused on smaller communities with a population greater than 1,000 and with water supply infrastructure needs such as storage, transmission, treatment and distribution. With recent legislative changes, the Authority can now assist governmental agencies with their financing needs and move quickly to issue bonds for project financing. The Authority's program will be able to save these communities, on a present value basis, from two to ten percent of a project's cost.

Although there are existing funding programs for financially-distressed communities with water supply problems, no program was in place to help relatively stable communities with their water supply improvements. The program developed by the Authority will help these communities with the expenses associated with bond financing. The Authority's program includes credit enhancing features such as pooled financing, funding the debt service reserve fund and purchasing bond insurance. The first series of bonds for the program were sold in October of 1990.

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ECONOMIC EFFICIENCY AND WATER PROJECT DEVELOPMENT REVISITED

W. Ashley Ahrens[5] and Edward F. Harvey[6]

ABSTRACT

Development and operation of surface water projects typically create large upfront costs with annual benefits accruing into the distant future. The water resource economist is charged with comparing hard dollar and soft costs, such as potential losses in recreational amenities, with long-term benefits to determine the net benefits of the project. Only in this way can the overall desirability of the project be determined and compared with other water development projects. Economists use benefit-cost analysis as a tool to evaluate the economic efficiency of a water project.

Federally funded water projects are required to demonstrate economic efficiency in order to receive funding. Locally funded projects, on the other hand, are not subject to this requirement, although a host of permits must be acquired from federal natural resource agencies prior to project construction. Sponsors of local water projects are generally more concerned with a project's financial feasibility, or whether project costs can be repaid through the sale of vendable outputs. However, the increased importance of environmental amenities, the loss of which are often viewed as a cost attributable to the project, will undoubtedly require sponsors of local water projects to comply with increasingly strict criteria, such as economic efficiency, in order to initiate project construction.

There are instances where major water development proposals have avoided a full examination of economic efficiency or financial feasibility. By avoiding these considerations, project proponents can incur risks of faulty evaluation of their water developments.

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INTRODUCTION

This paper examines the utility of benefit-cost (B-C) analysis in evaluating water resource developments in today's regulatory and public policy environment. An abbreviated overview of benefit-cost analysis and its historic role is provided. Key components or technical aspects are also highlighted. Finally, the future prospects and suggested role for such analyses is postulated.

ABBREVIATED HISTORY OF BENEFIT-COST ANALYSIS

Economic efficiency studies were originally and more commonly known as benefit-cost analyses during their origination and wide spread application in the late 1950's and 1960's. Federal government officials, and to a limited extent public and private policy makers, relied upon B-C analysis to determine whether proposed new infrastructure developments or other ventures were worth pursuing. The central focus of B-C analysis in its heyday of the 1960's was to translate primary economic benefits into dollar terms and compare them with project costs on some common basis (e.g., total present value benefits versus total present value costs, annual benefits versus costs, etc.). If the ratio of benefits to costs was at least one, the project could receive official blessing. Many people originally referred to these type of analyses as cost-benefit, rather than benefit-cost, analyses. Under the leadership of the U.S. Bureau of Reclamation, benefit-cost analyses became increasingly widespread and sophisticated.

Certain reflections upon the increasing importance of B-C analysis and its accuracy produced a number of criticisms which began to surface in the 1970's and expanded during the 1980's. Some of the more prominent shortcomings are summarized:

(1) Only selected project costs were incorporated into many traditional B-C analyses. Environmental impacts and losses to a number of resources such as recreation or aesthetics were not reflected on the cost side of the ledger. In recent years, an attempt has been made to broaden the scope of the cost accounting, but with only a mixed reception.

(2) The benefit calculation in the early years relied upon projections and assumptions which were not thoroughly documented or supportable. In some instances, simplistic and generalized projections could lead to rosy forecasts.

(3) The time frame for B-C analyses varied, but invariably extended beyond the span of political relevance. Near term affects versus murky, uncertain benefits or costs in a distant time frame were not appropriately weighed to the satisfaction of some critics.

(4) A particularly insightful criticism related to the accounting stance of B-C analyses. The benefits would accrue to certain parties, often in the local project area or in one region, while the costs would be born by parties or institutions in very different geographic areas. Under these circumstances, project proponents could very clearly embrace the need and benefits of a project, since they did not have to bear a commensurate proportion of the costs. Under the Federal approach for project approval and authorization, this circumstance was ripe for political bargaining or "pork barreling".

The harshest critics of B-C analysis came to believe that the mathematically oriented calculations of a B-C ratio were cynically manipulated to produce any result one could desire. In fact, selected projects in the United States and elsewhere in the world were singled out as having misleading B-C ratios which falsely justified these projects.

Economists and other practitioners during the 1980's responded to various criticisms of B-C analysis with a host of technical "fixes". These greatly broadened the complexity of such analyses and increased the number of assumptions with which one could criticize the outcome. Legitimate criticism continues about the validity of B-C analyses, but the fundamental precepts of this tool are still considered in evaluating projects today. For example, environmental impact statements attempt to identify and quantify all impacts on environmental resources. If possible, such impacts are translated into dollar terms.

FUNCTIONAL ELEMENTS OF BENEFIT-COST ANALYSIS

Although B-C analysis appears to be a straight forward accounting process, a thorough analysis is multi-faceted and somewhat complex. The rigorous B-C evaluation consists of several key dimensions and assumptions. Dimensions relate primarily to the accounting stance, time period of the analysis and the nature of potential effects. Key assumptions include the choice of the discount rate and prices to be used in the quantification of effects.

Key dimensions. In general, the accounting stance to be used in the analysis is defined by the geographical reach of potential project effects. For example, the accounting stance of a water project in Colorado could include the U.S. as a whole, the state or a subset of counties or municipalities. Generally, a national perspective for locally sponsored projects is inappropriate, since many project effects (e.g., increased personal earnings) of interest to local sponsors would result from inter-regional transfers and could not be charged to the project. A local accounting stance (e.g., county) might preclude important potential effects in the broader regional market or costs which would be externalized elsewhere. In sum, the accounting stance should be chosen so that project effects of major interest to local sponsors and their constituents can be isolated and quantified to the extent possible along with the cost burden.

Due to discounting, project effects which occur in the distant future add relatively little to the determination of net benefits and can increase the imprecision of the analysis. Thus, the time horizon should be of adequate length so that important project effects can be isolated and evaluated for relevance. Appreciation for the benefits of long term investment should not be dismissed, however.

Development of a water project typically generates an array of benefits and costs. The analyst needs to be cognizant of project effects and the nature of parties which may be potentially impacted. Project effects can be tangible, involving gains in personal income, business profits, local government tax receipts and new water supplies. These effects generally occur in well defined populations and can be characterized and quantified in a clear manner. Intangible effects may include flood control benefits, the loss of riparian habitat, changes in recreational benefits, or quality of life values. The affected population is disperse and difficult to identify for the purposes of quantification. Furthermore, quantification of impacts in dollar terms can be challenging and costly.

Key assumptions. The choice of the discount rate is a particularly critical assumption in benefit-cost analysis. The rate puts benefits and costs which occur at different times in the future on a comparable dollar basis. The discount rate can be based on one of three perspectives -- the rate of return in the private sector, the rate of return on competing, public sector projects and the social rate of time preference. Each perspective has merits and detractions which should be considered on the basis of the specific project being evaluated and the philosophical orientation of project sponsors and their constituents.

The use of prices in the quantification of project effects involves important assumptions. In general, the benefit-cost analysis should be undertaken in constant dollars which excludes the effects of inflation on prices. This greatly simplifies the analysis but is defensible only if the relative price of project outputs is not expected to change appreciably in the future. Furthermore, actual, observed prices should be used where possible in the quantification of project effects. For project outputs such as hydroelectric power, business profits and municipal water supplies this is generally not difficult. Market price information, however, is not generally available for flood protection, water-based recreation and the preservation of riparian habitats. Instead, values generally must be imputed through indirect measures or determined from primary, site-specific data. The methodologies available for obtaining such information are usually complex. Furthermore, the validity of results are often questioned and of dubious quality.

FUTURE PROSPECTS

The goal of benefit-cost analysis, or the expression of all project-related economic effects in dollar terms regardless of when they occur or to whom they accrue, is indeed lofty. Because of the numerous dimensions and assumptions which are incorporated into benefit-cost analysis, an element of judgement and a thorough understanding of the particular project being evaluated and its economic effects are critical.

Past experience with benefit-cost analysis has demonstrated it shortcomings as an analytical tool in certain instances. Incomplete benefit and cost accounting, faulty projections, internally inconsistent accounting stances and outright manipulation of assumptions to produce favorable results have occurred.

Nonetheless, benefit-cost analysis is still a promising tool for evaluating the economic feasibility of water development projects and providing input into the decision making process. The increasing sophistication of the economist's tools and greater responsiveness on the part of project proponents, due in part to enhanced public scrutiny, expands the prospects for benefit-cost analysis in the future. A complete analysis brings to the forefront critical issues, all of which may not be amenable to quantification but which must be somehow addressed if the project is to successfully move forward.

CITY OF COLORADO SPRINGS
LONG RANGE WATER SUPPLY PLANNING

Phillip H. Tollefson[7]

ABSTRACT

Colorado Springs, Colorado has been one of the fastest growing communities in the West over the last 30 years. Due to its location high on the Divide between the Arkansas and Platte River Basins, water supply is a major continuing challenge. Of its currently developed water supplies, only about 20% are derived from local sources on and around Pikes Peak. The balance must be imported via pipeline from the Arkansas River and the Western Slope.

The estimated firm yield of the City's currently developed water supplies is about 131,000 acre-feet per year; the estimated 1991 water demand is 77,000 acre-feet per year. Thus, existing water supplies are adequate well into the next century. However, the total capacity of the City's existing three raw water delivery systems is 110,000 acre-feet per year. Based on current growth projections, it is expected that additional importation capacity will be necessary by the year 2010.

The City is beginning to plan for its next major raw water delivery system, and has identified a range of alternatives for preliminary consideration. Future planning activities will further define the various alternatives as well as lay the foundation for necessary permitting processes. Current growth projections indicate the need for additional system capacity of about 65,000 acre-feet per year in order to satisfy anticipated demands through the year 2040. Initial studies indicate that the current construction costs would be in excess of $300,000,000, and could require that 55 separate permits be obtained prior to construction. The magnitude of this project necessitates that many different issues be examined such as:

- water conservation
- expansion of non-potable systems
- groundwater development

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- enhancement of local diversions via exchange
- direct reuse
- potential institutional arrangements
- a wide range of environmental and recreational concerns

The combination of project magnitude and complexity of existing federal and state permitting processes may be expected to require considerable effort over the next 20 years to assure that water requirements can be met.

CITY OF LOVELAND
WATER SUPPLY STUDY

Jeff Heden[8], Larry Howard[9] and Joe Stibrich[10]

ABSTRACT

The City of Loveland, Colorado (the city), fifty miles north of Denver, retained the engineering services of Camp, Dresser & McKee, Inc (CDM), and funding assistance from the State of Colorado Water Conservation Board (CWCB), for the purpose of conducting a comprehensive water resources study. The objective was to determine the city's ability to provide a reliable supply of water over a 30 year period until its projected service population reaches 101,000, from the 1985 level of 38,000.

The study was divided into three phases which:

1. Quantify the ability of the city's water sources to provide adequate water supplies during selected drought events and provide information for choosing a feasible drought protection level.

2. Identify and evaluate twelve alternatives according to engineering, environmental and social criteria, singly and in combination, to mitigate drought impacts and determine the type, size, location and implementation schedule for the recommended alternative.

3. Conduct a feasibility study of the recommended alternative pursuant to CWCB criteria.

The city hopes to complete Phase III in 1991.

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INTRODUCTION

The City of Loveland, Colorado, located 50 miles north of Denver, experienced rapid population growth during the 1970's following relatively constant growth in prior decades. Water supplies in past years were adequate to meet increasing demands. These included Big Thompson River direct-flow rights, ownership in a number of private irrigation ditch and reservoir companies, and ownership of shares in the Colorado-Big Thompson (C-BT) and Windy Gap projects.

A 1980 Water/Wastewater Master Plan for the city initiated overdue system infrastructure improvements. An expansion of the water treatment facilities to 30 mgd in 1981 eliminated the need for watering restrictions. A year-long, city-wide water metering program was completed in 1982. Metering reduced high water demands resulting from a relatively inexpensive flat-rate water billing system.

STUDY BACKGROUND

Memories of the devastating 1976 Big Thompson Canyon flood which had interrupted the city's sources of raw water were still fresh in people's minds. The C-BT system's 9 ft. diameter siphon that normally carried water north across the river past the city's diversion point was washed away. The city had no emergency reservoir storage to draw from. The city's river diversion was completely plugged, and more than 24 hours were required to clear it. The quality of the water available when it was cleared was poor, but it was used because no alternative sources were available.

During the period of high population growth and increasing water demand following the flood, additional water had to be exchanged from other diverters on the river to meet high summer demands. Adequate direct flow rights were not available in the river during the late summer months, and Loveland had no upstream storage reservoir to draw from. In 1978, the city completed a 600 ac-ft, off-channel reservoir in Green Ridge Glade, immediately upstream of the water treatment plant. The city was then supplying about 8,500 ac-ft annually to 28,000 people utilizing its direct flow rights, C-BT water, and this limited storage.

By the early 1980's, Loveland recognized the need to formalize its water resources planning into a Raw Water Program. The City Council set up an appointed, advisory Water Board, and hired a full-time Water Resources Engineer. The city's scattered portfolio of water rights was organized into a Water Court decree, formalized in 1985, allowing the cooperative use of city-owned rights at alternate points of diversion for many city-related uses. Neighboring ditch companies and farmers cooperated with the city in negotiating the decree so that each entity's water rights were protected from the changes in historical diversions that the city proposed. This decree allowed the city the needed flexibility to use its various water rights at the water treatment plant, plus direct water to irrigate city parks and open space, trade water with other irrigators for mutual benefit, and store direct flow water rights for subsequent consumptive use by the city.

STUDY INCEPTION

The Water Board felt a comprehensive, detailed water supply study should be conducted so the best overall water management alternative(s) could be undertaken. Many residents felt a large reservoir would best serve the city's interests, while others were convinced that additional water rights and/or C-BT Project units would suffice. In 1986, the city contracted with the engineering firm of Camp, Dresser and McKee, Inc. (CDM) of Denver, Colorado, to conduct a three-phase study to determine the following:

(1) The ability of the city's water supply system to provide adequate water during a selected drought event over the next thirty years.

(2) The selection of the best overall alternative(s) to meet the water supply demands forecast for the thirty year study period.

(3) To study the feasibility of the recommended alternative(s). The project was jointly funded by the Colorado Water Conservation Board (CWCB) and the City of Loveland Water Utility.

PHASE I

Purpose. Phase I of the study was conducted to address the following:

- o Project city water demands at 2% (low), 3.5% (moderate), and 5% (high) growth rates.
- o Use current and anticipated water rights ownership to determine water availability per month for 25-, 50-, 100- and 200-year drought events.
- o Compare water supply availability to system demands to identify monthly deficits in supply over the thirty year study period.
- o Recommend a drought protection planning level for the city, using the chosen growth rate and drought level.

Method. Public participation has been solicited and received throughout the study process. Considering input from citizens, ditch companies, and affected landowners promotes a sense of ownership in the study that might not otherwise exist. Citizens are invited to all Water Board meetings, and during Phases I and II of the study, well-attended public information meetings were held.

Limited streamflow data on the Big Thompson River was correlated to and augmented by the longer record available from the Cache la Poudre River. Western slope records such as those from the C-BT and Windy Gap projects often displayed drought patterns different from those on the eastern slope. One thousand (1,000) years of synthetic Big Thompson River streamflow and C-BT inflow data were generated, based on the statistical parameters of the historical records. The 1000-year synthetic records, however, included more extreme droughts and more variations of wet and dry sequences than were observed in the historic data. These records were used in a set of models written by CDM to identify the four levels of drought events and the corresponding water supply deficits.

Results and Conclusions. The results and conclusions reached during Phase I of the study defined a set of "design conditions" to be used for Phase II, as follows: Loveland would become increasingly vulnerable to drought conditions as the population increased; the 3.5% moderate growth rate scenario was chosen for planning purposes, the service population would increase to 101,000 people with an annual raw water demand of over 21,000 ac-ft; a deficit of over 2,745 ac-ft was projected to occur during a 100-year drought event for that service population. The City Council chose to plan so that under the "design conditions" a 100-year drought event could be experienced by the service population while suffering no deficits. It was determined in Phase I that current supplies are more than adequate, but additional water must be made available to eliminate the deficits encountered under the 30-year moderate growth scenario for the 100-year drought.

PHASE II

Purpose. In Phase II of the study, the city directed CDM to evaluate unique, specific actions called "Plan Elements" that the city could take to reduce or eliminate the water supply deficits projected to occur under the design conditions. Those Plan Elements included implementing water conservation measures; expanding Green Ridge Glade Reservoir or building another reservoir; purchasing additional C-BT or Windy Gap water; reusing Windy Gap water; acquiring additional direct flow rights; using water stored pursuant to the city's 1985 transfer decree; utilizing ground water; or arranging municipal-agricultural lease agreements with area farmers.

Method. The evaluations were made using refined versions of the models written during Phase I. They quantified the ability of those Plan Elements to reduce the 100-year deficit under the design conditions, and estimated their costs of implementation. Social and environmental impacts of each viable Plan Element were identified by the consultant, and assessed by the City Council and Water Board.

Based on the evaluation of the individual Plan Elements, three additional alternatives, comprised of combinations of the Plan Elements, were formulated for consideration utilizing the following strategies: to minimize cost; to improve management of the city's water supply through diversification of raw water sources and increased storage of transferred water; and to provide adequate emergency raw water storage. The alternatives were evaluated based on deficit reduction, cost, and social and environmental impacts. They were:

(1) Acquire additional C-BT units and No. 1 priority direct-flow rights on the Big Thompson River (least-cost alternative).

(2) Acquire additional C-BT units, and increase the city's storage capacity to provide adequate emergency storage supply and improve management of the city's transferred water.

(3) Construct a 7,350 ac-ft reservoir at an available alternate location to provide greater opportunities to utilize the city's transferred water, greater emergency raw water storage, and better overall management capabilities.

The first two Alternatives were felt by the City Council and Water Board to represent the only viable combinations of Plan Elements which should be considered. The third was selected as a way to provide more efficient use of the city's transferred water.

RECOMMENDATIONS AND CONCLUSIONS

Following evaluation of these alternatives and discussion with the City Council and Water Board, CDM recommended that in order to provide protection against a 100-year drought at the design demand, the city's water supply portfolio should be augmented by six actions:

(1) Expand the current Green Ridge Glade Reservoir to an active capacity of 3,000 ac-ft.

(2) Purchase 1245 units of the C-BT Project in addition to the amount projected to be acquired through normal development over the 30-year planning horizon.

(3) Implement exchanges for stored transferred water.

(4) Consider applying for a flood right on the Big Thompson River in conjunction with the expanded reservoir.

(5) Develop and implement a new water conservation plan.

(6) Expand the city's water treatment capacity to 46 mgd as required by growth in demand.

Following City Council acceptance of these recommendations in early 1988, a series of eight consecutive annual water rate increases was approved. The total compounded increase was approximately 42%. Sixty four percent of that amount (a 27% total compounded increase), is earmarked for the Raw Water Program. The first went into effect in January 1989. The revenue generated is expected to allow the purchase of bonds to fund the total estimated $12M cost of the reservoir expansion. In addition, 693 of the recommended 1,245 additional C-BT Project units have been purchased.

CONCLUSIONS

Planning is expected to continue in 1991 with the beginning of Phase III of the study. This will be a feasibility study/economic analysis, to be conducted in accordance with CWCB guidelines. It is expected to include preliminary dam investigations including hydrology and geotechnical investigations, layouts, and cost estimates. Construction of the reservoir project is expected to occur in the mid- to late 1990's.

The city has adopted the recommendations made by the consultant, and is planning their implementation. Public involvement has been an important part of the process. Citizen input indicates Loveland residents generally understand the need for additional storage and C-BT ownership, and are willing to work toward that end.