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**Financial Evaluation of Mineral  
Deposits Using Sensitivity  
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# Financial Evaluation of Mineral Deposits Using Sensitivity and Probabilistic Analysis Methods

By Harold J. Bennett, Jerrold G. Thompson,  
Herbert J. Quiring, and Joseph E. Toland



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# FINANCIAL EVALUATION OF MINERAL DEPOSITS USING SENSITIVITY AND PROBABILISTIC ANALYSIS METHODS

by

Harold J. Bennett,<sup>1</sup> Jerrold G. Thompson,<sup>2</sup> Herbert J. Quiring,<sup>3</sup>  
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## ABSTRACT

The purpose of this study was to develop methods for the financial evaluation of mineral deposits. This includes the selection of the best alternative mining and processing methods and production rates. This was done by performing a financial evaluation through computer simulation using sensitivity and probabilistic risk analysis. The criterion used to measure the relative advantages of these investment and operating alternatives is the discounted-cash-flow rate of return.

Included is a description of the theory and methods used in the probabilistic analysis approach, which is based on the premise that the expression of a range of values in establishing an estimate for a parameter is more realistic than the choice of a single value. Numerous simulations are made using randomly selected values of the input parameters resulting in a frequency distribution of the rates of return and their relative probability of occurrence.

The sensitivity analysis method is described and combined with the probabilistic analysis to interrelate mineral reserves, capital investments, operating costs, and production rates. The ability to vary these input parameters on successive runs has permitted the selection of the best alternative mining and processing methods and production rates for a given mineral deposit. For illustrative purposes the evaluation of a mineral deposit was performed using three alternative mining and processing methods at three different quantities of resources and various production rates and prices.

The computer program used in this analysis was written in FORTRAN II for maximum compatibility and should run without modification on most computers

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having 8K (8,000-word) core memory, a card reader, and printer (120 characters per line).

## INTRODUCTION

This study was undertaken to develop a computer program for use in financially evaluating mineral deposits where uncertainty may exist in the gathered data. The program developed can be used to perform sensitivity and/or probabilistic financial analyses. Included in the report are techniques that may be used to select the best alternative investment opportunity, mining and processing methods, and production rate.

The Bureau of Mines responsibilities include an analysis of supply of all mineral commodities. Of special interest is the evaluation of marginal mineral deposits. A specific use for this program is in the evaluation of marginal mineral deposits for which sufficient data have been assembled to permit an engineering and economic evaluation and so indicate high-cost areas of production. This enables comparison of costs of various applicable mining and processing methods and indicates the feasibility of performing research to improve the economics of the marginal deposit.

Data gathered by the Bureau of Mines on a large low-grade gold deposit are used to illustrate the evaluation method. In the sensitivity approach an open-pit mining operation, using three alternative means of transporting the material to the mill and three alternative processing methods, is analyzed at various production rates. The discounted-cash-flow rate of return is used as the criterion to select a mining system, processing method, and production rate at different costs, grades, recovery, and prices. Probabilistic estimates for the selected mining system, processing method, and production rate are then entered into this program. The probabilistic approach more realistically indicates the risk involved due to uncertainty of the gathered data than does the sensitivity analysis.

As the deposit used in this report was submarginal and apparently has little potential at current prices, it was necessary to use grades and prices not necessarily representative in order to obtain results which would illustrate a technique. Since this is a preliminary evaluation, information indicating the interrelationship of grade and recovery are not considered, but would be necessary in a more detailed study after sufficient metallurgical data had been obtained.

The use of these methods, sensitivity and probabilistic analyses, are demonstrated in this report which supplements an earlier publication (10).<sup>5</sup>

## ACKNOWLEDGMENTS

The Bureau of Mines Western Field Operations Center, Spokane, Wash., coordinated the exploratory phase of the project during which geologic and

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<sup>5</sup>Underlined numbers in parentheses refer to items in the bibliography preceding the appendixes.

mineralogic data used in this study were gathered. Assay analysis and some metallurgical research on the material in the deposit was done at the Bureau of Mines Reno Metallurgy Research Center and Salt Lake City Metallurgy Research Center. Personnel at the Salt Lake City Metallurgy Research Center and the Intermountain Field Operations Center prepared cost estimates for the mining systems and processing methods. Personnel of the Denver Mining Research Center performed a statistical analysis of the assay data.

A risk analysis computer program was obtained from the American Metal Climax, Inc. (3). Experimentation with this program and experience gained from previous Bureau of Mines sensitivity analysis programs contributed to the development of the computer simulator used in this report.

## EVALUATION PROCEDURE FOR A PROSPECTIVE MINERAL OPERATION

### General

The end product of an evaluation of a mineral deposit is a financial analysis which provides management with key decision-making tools. There are numerous analytical methods or techniques, each providing a specific measuring indicator, which can be used to rank various investment alternatives.

Investment in the exploration and final exploitation of a mineral deposit occurs at different phases--the start of each phase being dependent upon the success of the preceding phase. A meaningful evaluation can be made during the early stages of exploration even though uncertainties exist, provided these uncertainties are considered in the evaluation. Successive evaluations can be made as the data becomes more reliable to provide management with information to aid in the decision to start the next phase or to discontinue the project.

A flowsheet illustrating a procedure to evaluate a prospective mineral operation is shown in figure 1.

Computer programs are just tools to aid in the evaluation phase by performing the manipulation of data after it has been assembled. It cannot supply unknown data nor can it eliminate the need for professional judgment. To perform a financial analysis it is necessary to estimate (1) physical characteristics of the deposit; (2) quantity and quality of the reserves; (3) applicable mining and processing methods; (4) a realistic production rate; (5) anticipated recovery; (6) market price; (7) required capital investment; and (8) anticipated operating cost. This data is used to estimate the cash inflows and outflows over the life of the operation and to compute a rate-of-return using the discounted-cash-flow method. The accuracy of estimating these variable factors is dependent upon the detail and type of data available, the variability of the data, correct identification of key parameters, and the degree of accuracy warranted. Depending on the desired degree of accuracy one would make preliminary, definitive, or detailed estimates. Similar methods could probably be developed for estimating the cost of a mining operation.

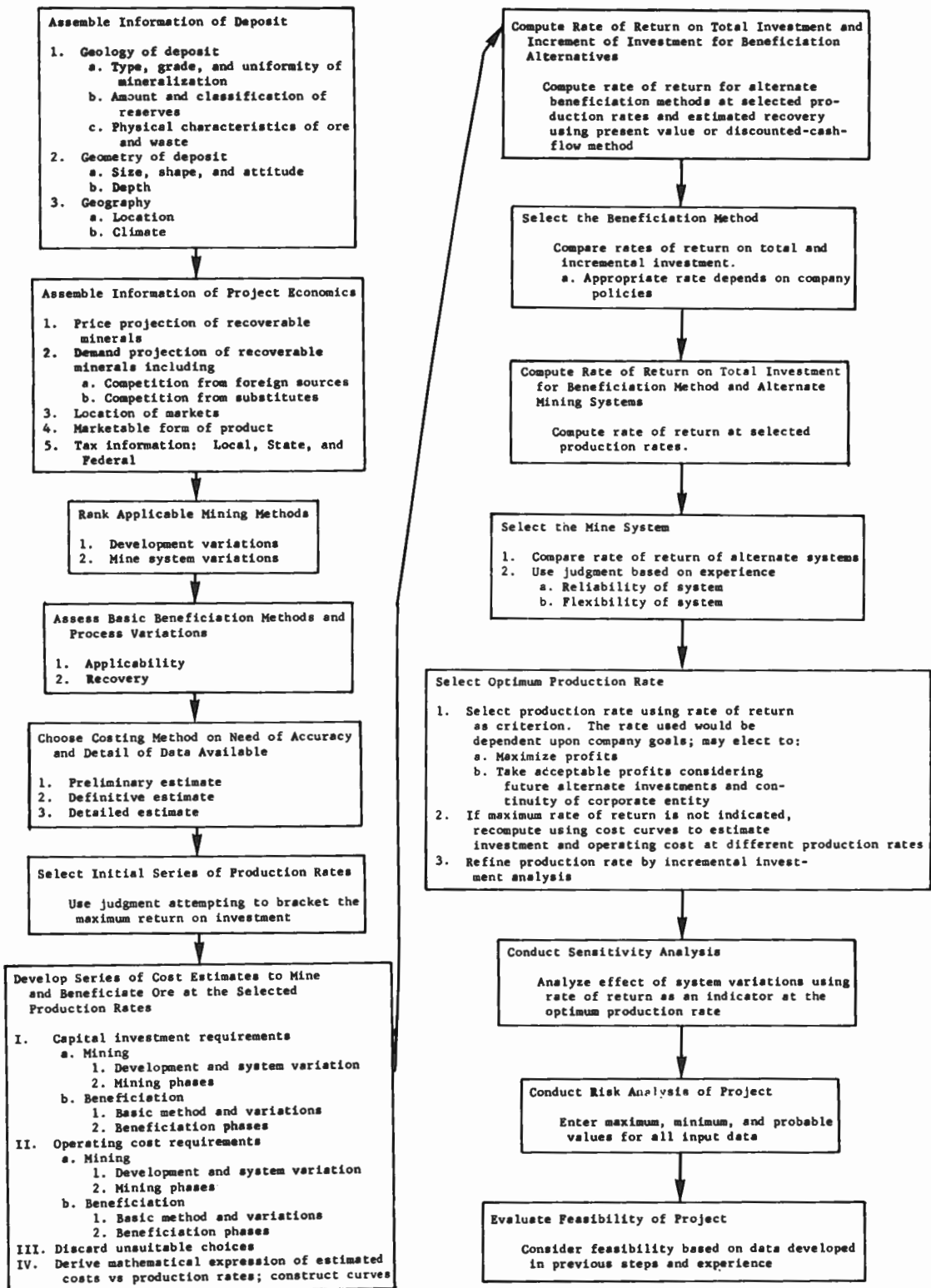


FIGURE 1. - Generalized Flow Diagram of a Project Evaluation Procedure.

The physical characteristics of a deposit, quantity, and quality of reserves are determined during an exploration program. This data influences the selection of a mining and processing method, the recovery, and the production rate. Values of these parameters are determined from an exploration program that varies considerably depending upon the type of deposit and the degree of detail desired in the information. It may consist of a geological reconnaissance plus a minimum number of drill holes from which the grade, reserves, mineralogy, and attitude of the deposit may be inferred. Evaluations are made at various stages of the exploration program in which the uncertainty of the data is considered. Results of the evaluation would indicate whether further exploration is warranted.

The recovery is dependent upon the mineralogic composition of the ore and the processing method used to recover the minerals.

The production rate is dependent not only on the physical characteristics of the deposit but also on factors such as processing method, plant design, changing technology, volume and stability of the market, and competition.

The rate of return which is the criterion used by many companies in evaluating an investment is the output of the analysis programs. This rate of return can be used to compare alternative investment opportunities or to eliminate investment in a project if the return is not acceptable. This analysis method can also be used to select the mining or processing methods applicable to the deposit which yields the greatest profits. The rate of return acceptable to a company is affected by the risk involved, projection of the market, company's goals, company's asset position, and alternative investment opportunities.

Risk involved can be indicated by the payback period where risk is a function of time and by probability of obtaining a certain rate of return in the investment where risk is a function of the uncertainty in the data.

Market projection can be used to estimate the life of a project; some markets may be short term or of unpredictable duration. Projected growth may motivate the producer to be satisfied with a low initial rate of return in anticipation of a higher one later.

Company goals may be reflected in a minimum rate of return because of the company's participation in a particular mineral market. Likewise, individual company goals may include increased size of operations and/or diversity of production.

The asset position will influence the amount of borrowed capital required and the resulting cost of this capital.

For each mineral deposit there is a production rate that requires minimum costs and produces maximum profits. This would normally be the ideal rate at which to operate but it may be restrained by economic conditions if not by physical factors. This more realistic production rate can be found through computer simulation using the cost input data applicable to the production

rate and making successive calculations. Therefore, to provide management with as many decision-making tools as possible the data should be presented in such a manner that the payback period, risk, and rate of return at various production rates and project lives are available.

### Method

A mineral deposit evaluation should consider all physical and economic parameters (grade, recovery, operating costs, etc.) in a logical sequential pattern and provide management with information necessary to make a decision to continue investment in a project or abandon it. To provide criteria for such decisions, evaluation must be made even when some parameters are incapable of being definitely fixed or ascertained. There will always be some degree of uncertainty until the deposit has been mined. For example, in exploring an ore body it is better to initially drill a few widely spaced holes and perform an evaluation on this limited data than to drill many holes. If the evaluation indicates the project has merit then additional holes can be drilled and the project can be successively reevaluated until the point is reached at which the project proceeds to the development stage or is terminated.

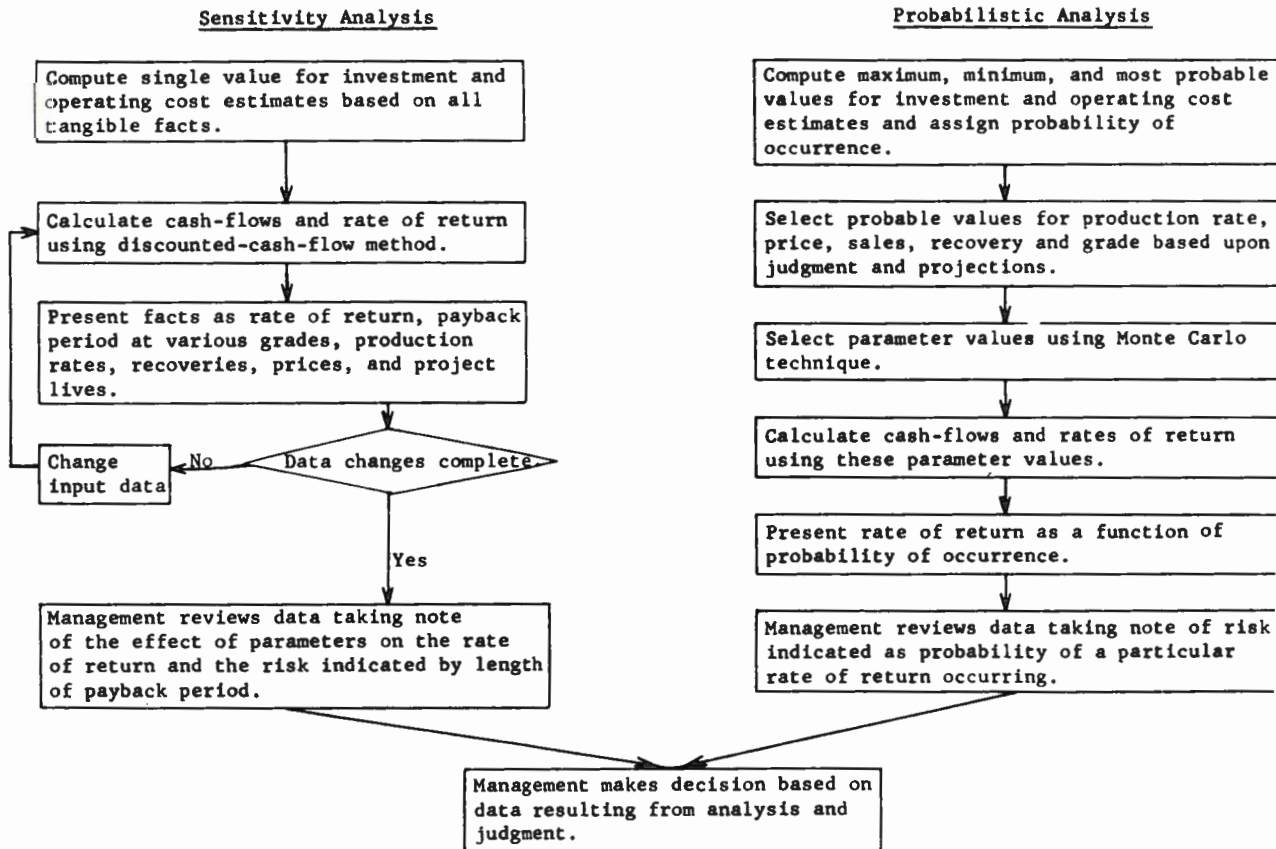


FIGURE 2. - Generalized Flow Diagram of Project Evaluation Using Sensitivity and Probabilistic Analysis Methods.

In recent years two new techniques have been introduced to aid in the evaluation of mineral deposits. These techniques can be described as sensitivity analysis and risk or probabilistic analysis. The use of computers permits consideration of all the parameters which would affect a financial analysis of a prospective mineral operation. Prior to the usage of computers only the more important parameters could be considered.

A flowsheet depicting how sensitivity analysis and risk or probabilistic analysis can be used in a financial analysis is shown in figure 2.

### Sensitivity Analysis

In the most commonly used sensitivity analysis method a single value or point estimate is assigned to each of the critical parameters used in the evaluation. The effect of variance or uncertainty in the data can be determined by varying one or all the values and making successive calculations. This method shows the effect of a single variable upon the overall feasibility of a project and the area of uncertainty which has the greatest effect on the results of the evaluation. This provides an indication of the areas where greater accuracy in the data is needed to improve the reliability of the study. The method consists of the following steps: (1) Gather information in which only single estimates of the parameter are quantified; (2) calculate cash flows in which single value estimates are used, compute the decision criterion (that is, rate of return, present value, etc.), and calculate the decision criterion's sensitivity; and (3) review the assumptions and estimates and make a decision based upon the rate of return or other quantifiable data. This decision may be moderated using judgment to evaluate nonquantifiable data. The sensitivity analysis only calls the attention of the decision maker to those parameters which could strongly affect the rate of return. It is frequently used to determine how much variation in a parameter would be necessary to reverse the decision based on average value estimates. It does not take into consideration the likelihood of the variation which must be left to subjective analysis.

Figure 3 shows the effect changes in the parameters of production rate and price per unit of product can have upon the rate of return. In this illustration  $\theta$  represents the price per unit of product and  $\Delta\theta$  represents the increase in price per unit of product. Changes in the production rate result in changes in operating and investment costs. The rate of return was calculated using the discounted-cash-flow rate of return method. This type of analysis, although it does not indicate the risk involved due to uncertainty in the data, is used in this report to select the best alternative mining system, processing method, and production rate based on maximizing profits. Specific examples of this analysis technique are included later in this report.

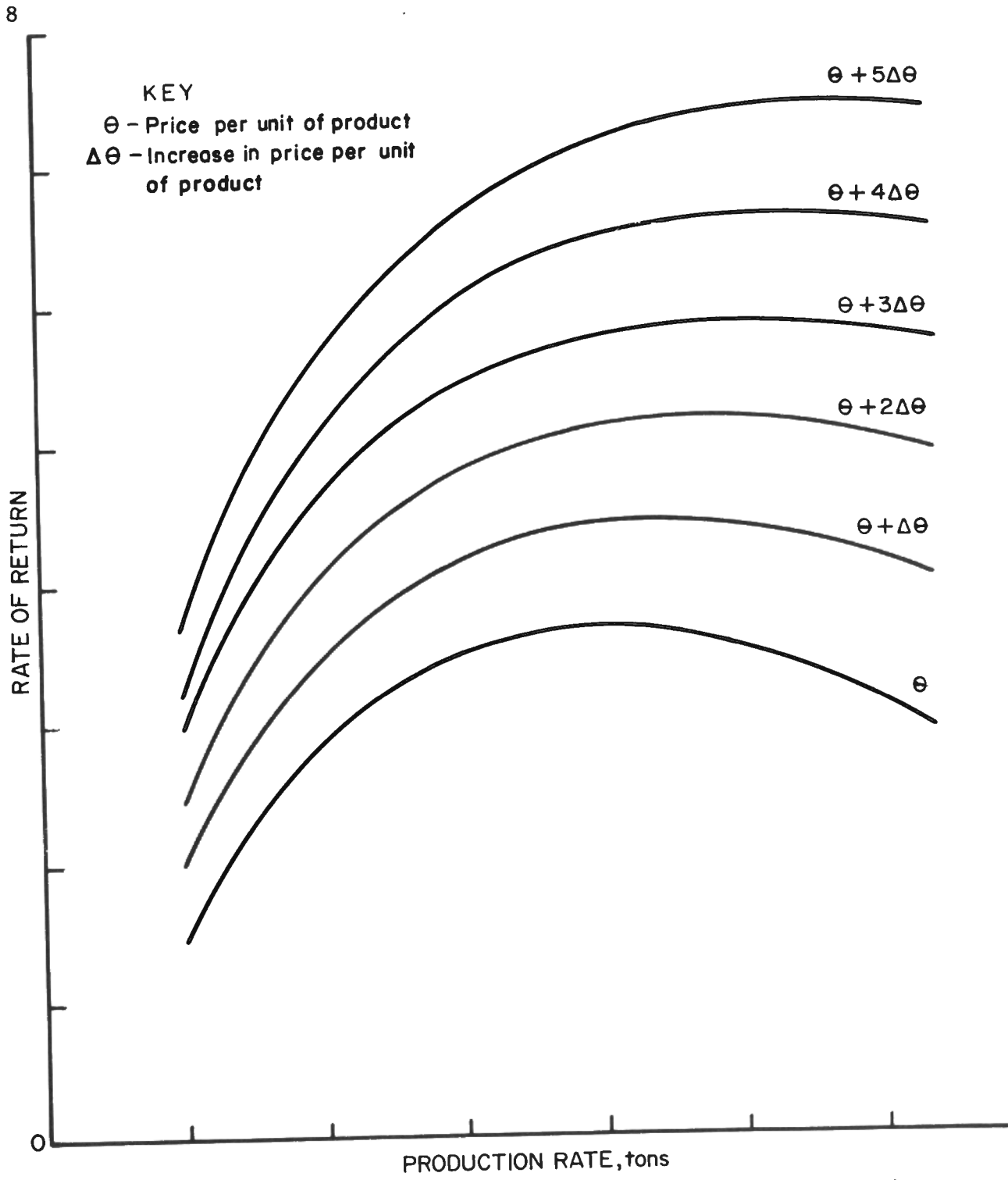


FIGURE 3. - Typical Output From a Financial Analysis Using Sensitivity Analysis.

Probabilistic Analysis

Another method used to evaluate the feasibility of exploiting a mineral deposit, in which the uncertainty of the data can be realistically expressed,

is referred to as a risk or probabilistic analysis. Risk analysis differs from sensitivity analysis in the following manner:

1. Instead of quantifying only single point estimates for input parameters, the uncertainty in these parameters is also quantified; this is done by estimating the most probable, the maximum and the minimum values, and the probabilities of their occurrence for each parameter.

2. In calculating the cash flows this uncertainty is used to compute a probability distribution of the rates of return; this results in rates of return and the probability of each rate's occurrence and is accomplished through Monte Carlo simulation techniques.<sup>6</sup>

3. In developing the decision the probability of a particular rate of return occurring provides a measure of the risk involved; judgment is again used to assess the impact of the nonquantifiable data.

The likelihood of a single or point estimate of any given variable in a financial analysis of a prospective mineral operation being correct is extremely small. Persons knowledgeable in a particular field can generally estimate a single value and assign a range, which is more realistic than stating a single value. The extent of the range is an indication of the uncertainty in the assigned value. The amount of this uncertainty is shown by the span of the range and the probabilities associated with values in that range. Such probability distributions are used to quantify uncertainty because they reflect the degree of confidence that an estimator has in his estimates. Value ranges, no matter how judgmental, are preferable to single values because they allow for the unknown. The unknown factors are the ones that create risk in an investment.

Estimating realistic probability distributions is not a difficult task and requires little knowledge of probability theory. The estimator first decides on a single or point estimate (the mode or mean) and the upper and lower practical limits for the parameter's value. (The mean and mode are coincident if the distribution is normal. The mean value is the arithmetic average while the mode is the most frequently occurring value or values.) As an example, the grade of ore in a deposit may range from a minimum of 0.03 to a maximum of 0.09 ounce per ton, with 0.06 ounce occurring most frequently. The estimator, based on knowledge and experience, may assign a probability of occurrence of 55 percent or 0.55 to the grade of 0.06 ounce per ton. As grade values approach the extremes they have a decreasing probability of occurrence. Note that the estimator plays an important role in the execution of an evaluation and therefore each estimate should be based on the advice of a person experienced in the subject being evaluated.

In normally distributed data the mean falls midway between the lower limits (LL) and the upper limits (UL) as shown in the three examples in figure 4. This indicates that approximately 68 percent of the data falls within

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<sup>6</sup>Methods of numerical solution and simulation relying on the use of random numbers and probability theory.

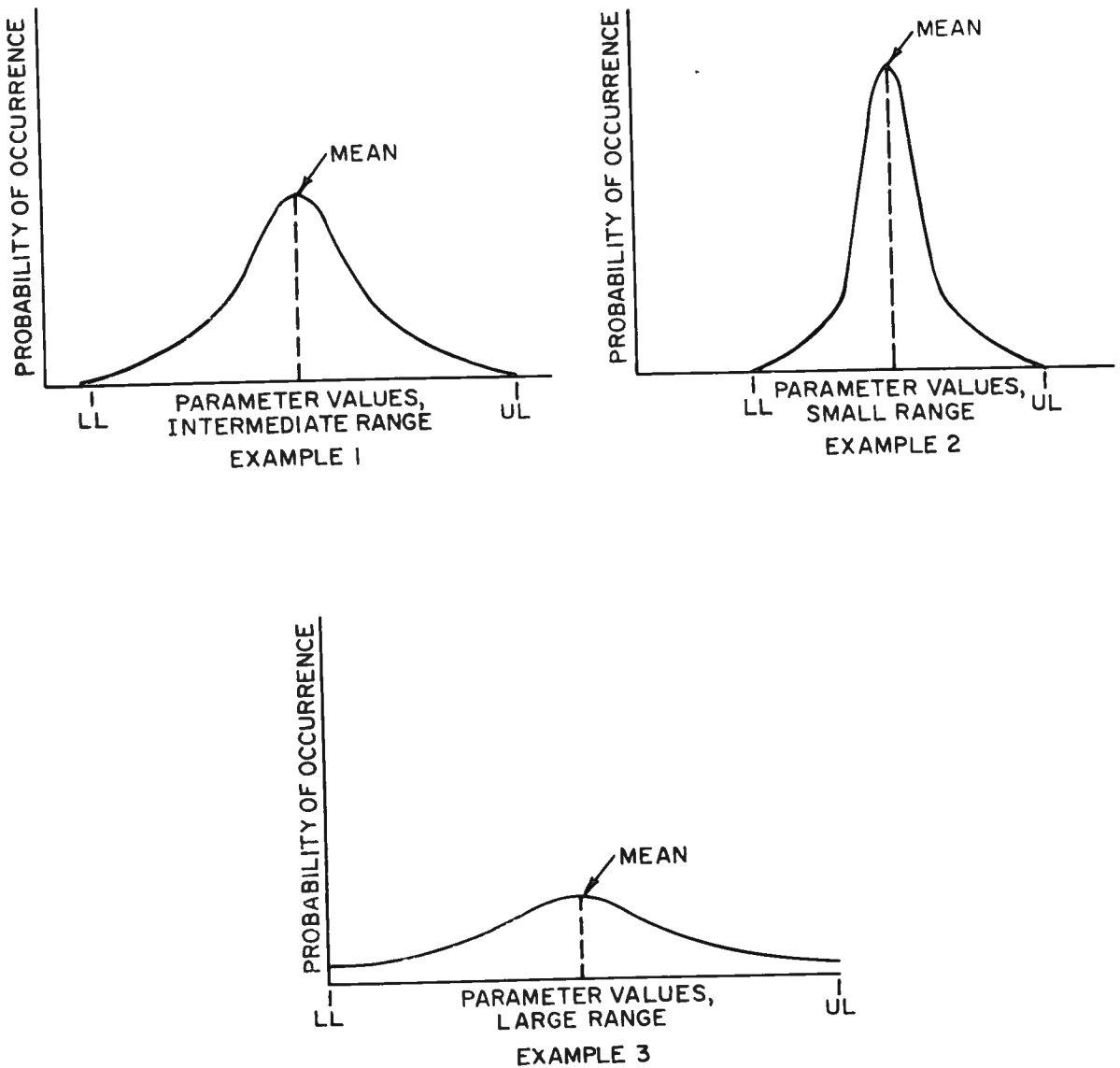


FIGURE 4. - Normal Distributions Illustrating Variety of Input. (LL = lower limits; UL = upper limits.)

one standard deviation, 95 percent within two standard deviations, and 99 percent within three standard deviations of the mean. No data are considered that fall outside three standard deviations. A variety of normal curves could result, depending upon the extent of the range and the probability of occurrence assigned to the mean. A narrow range with a great deal of confidence in the mean is shown in example two. Just the opposite idea is expressed in example three, where the range is broad, expressing a greater degree of uncertainty associated with the mean. The curves are symmetrical about the mean. The more confident the estimator is of the mean value of the parameter, the shorter the range and the more peaked the curve.

The skewed curve (a density function) differs from the normal curve in shape in that it is not symmetrical about a mean value. The upper limit and the lower limit need not be equidistant from the expected value or mode. The percentage of data points falling within a specified range can vary from one set of data to another.

A density function can be defined by as few as three values--the upper limit, the lower limit, and the mode or most frequently occurring value. Although three points can describe the function, five points are considered a minimum for the computer program. A more precise determination can be made by plotting a histogram and hand-fitting a curve to the histogram. To illustrate this, the following data are submitted:

X value	Frequency	X value	Frequency	X value	Frequency	X value	Frequency
3	1	7	6	11	3	15	1
4	2	8	5	12	2	16	1
5	4	9	3	13	2	17	1
6	7	10	4	14	1	18	0

Plotting this data results in a histogram (fig. 5). A smooth curve can be drawn through the values. The assumption is made that if sufficient data were available, points could be plotted approximating a continuous curve within this range.

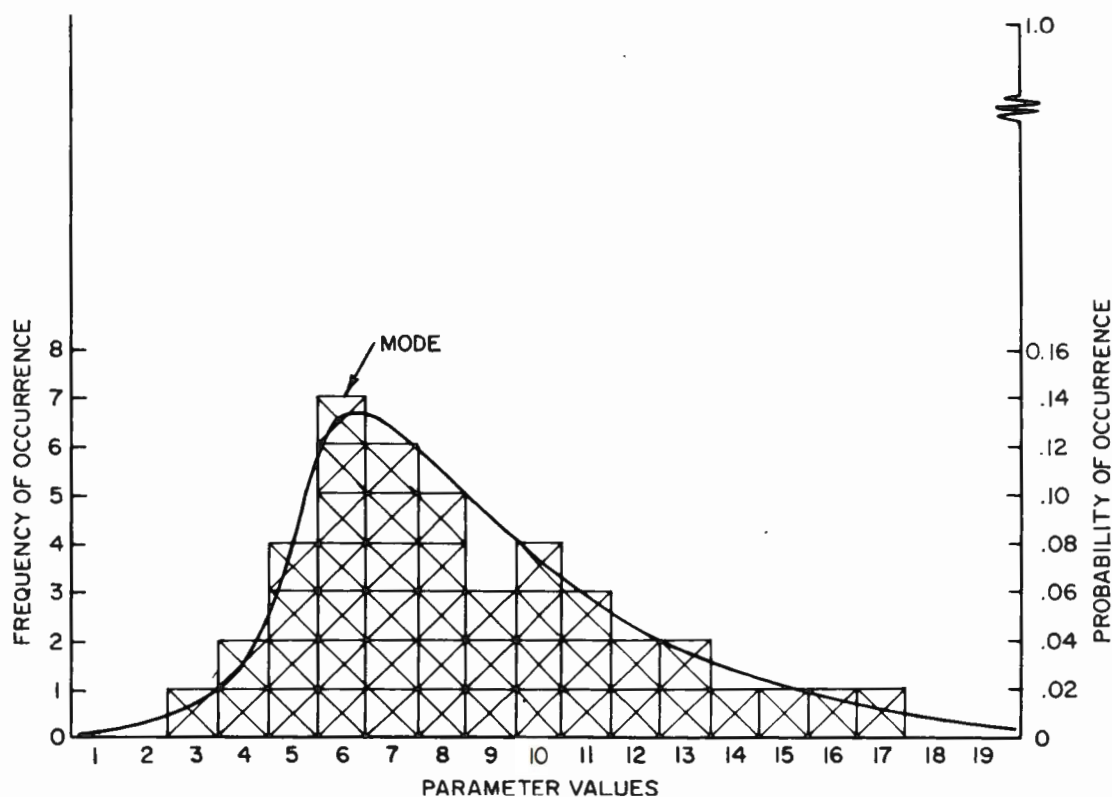


FIGURE 5. - Histogram Illustrating a Density Function.

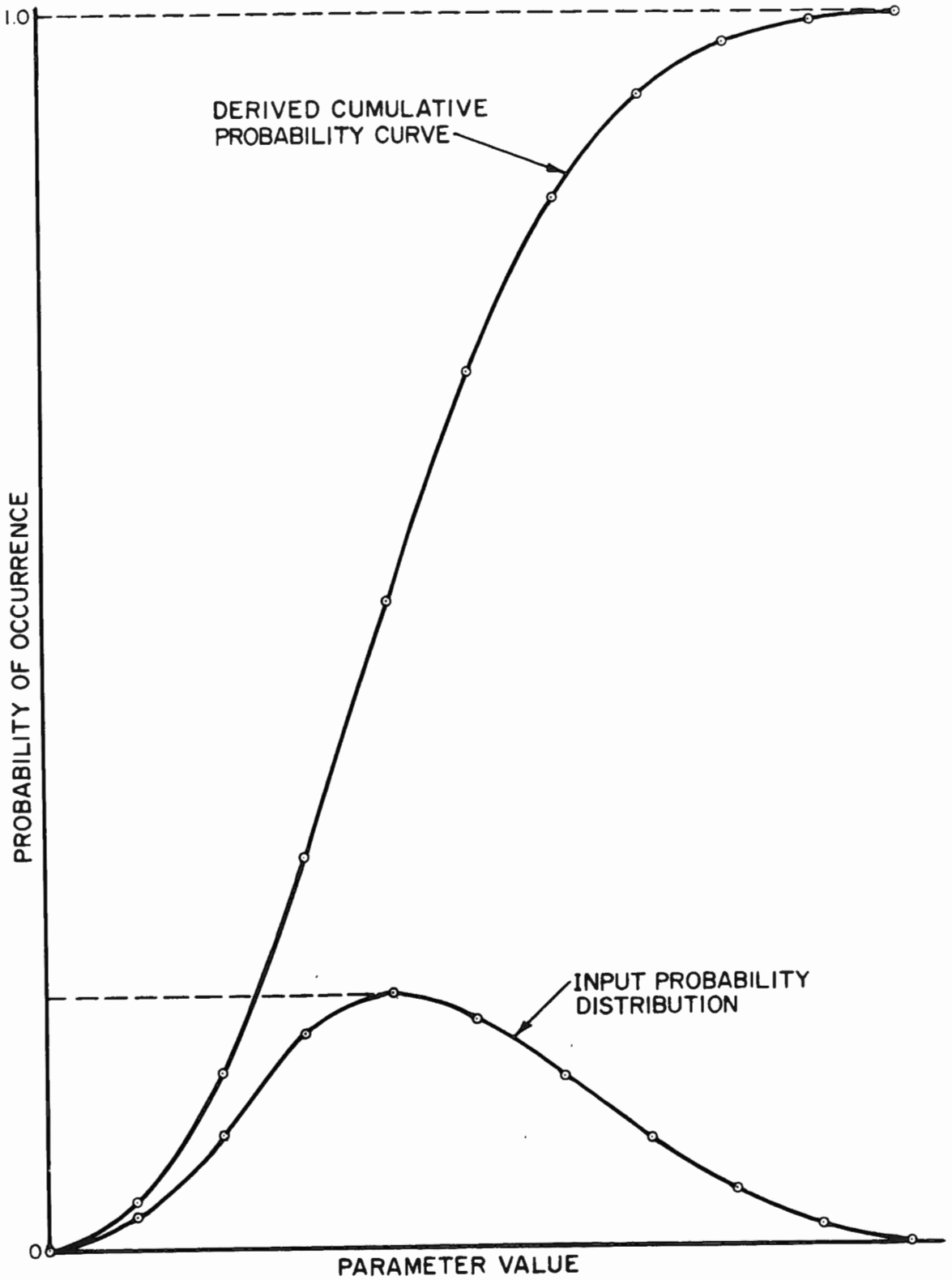


FIGURE 6. - Relationship of Input Probability Distribution and the Derived Cumulative Probability Curve.

In the approach used in this computer program, a curve as illustrated in figures 4 and 5 is used to determine a set of  $(x, y_{cum})$  points that describes a cumulative probability distribution,  $F(x)$ . This is done by summing the  $y$  values successively up to and including the maximum value of  $x$ . After establishing these points, regression techniques with appropriate weighting factors are employed to fit a curve using the equation  $F(x) = y_{cum} = \frac{1}{1 + \exp[-(a+bx)]}$  (23).

Figure 6 is a comparison of the plot of the input data and the resulting cumulative probability curve.

$$\text{Solving the above equation for } x \text{ results in } x = \frac{-\ln\left(\frac{1}{y_{cum}} - 1\right) - a}{b}.$$

Since  $F(x)$  is uniformly distributed over the range  $[\phi, 1]$ , random variates

$(x)$  are computed for a particular statistical population by using: (1) Coefficients  $a$  and  $b$  determined in the regression and (2) random numbers in the place of  $y_{cum}$ . (Random numbers in this simulation procedure are chosen through the use of a machine-independent random number generator whose range is the open interval  $(\phi, 1)$ .)

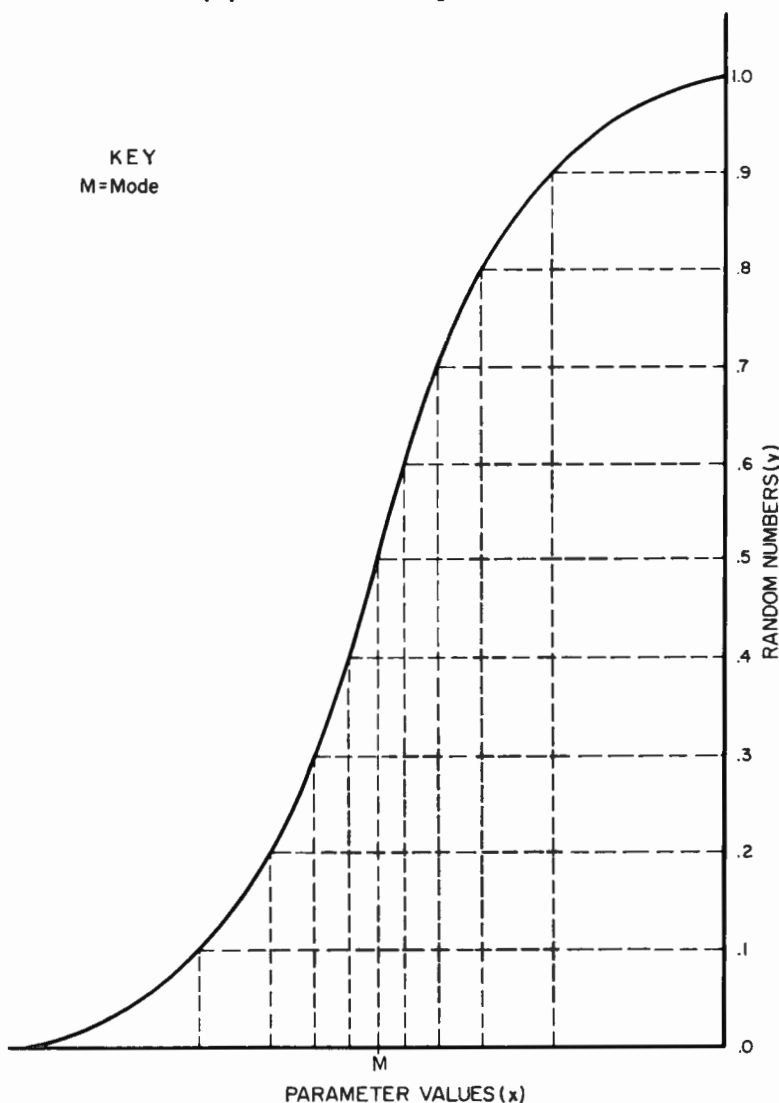


Figure 7 illustrates the way random numbers are utilized in the selection of random variates  $(x)$  according to their probability of occurrence. Associated with each interval on the  $y$  axis is a probability,  $F(x)$ . The probability of a random number falling within any one interval is  $1/10$ , any two intervals is  $2/10$ , etc., with the probability becoming  $10/10$  or certainty when considering the total of all 10 intervals. Choosing any random number within the range, tracing across to its intersection with the cumulative probability curve, and then tracing down, results in the choice of an  $x$  value. Continuing through the full

FIGURE 7. - Illustration Depicting Method of Selecting Random Parameter Values.

range of random numbers, the majority of the chosen  $x$  values are concentrated near the mode. Figure 8 shows curves resulting from skewed or peaked density functions.

The preceding discourse illustrates the use of the density function as an input to the program. It also shows the direct relationship of the input density function to the derived cumulative probability curve. Although the two curves appear different, they represent identical data sets.

The diagrams in figure 9 represent probability distributions for six different parameters as density functions. These parameters might be grade, recovery, price of product, production rate, operating cost, and investment. The numbers in the circles represent a possible sequence of randomly selected  $x$  values. Each column of numbers represents a vertical segment which has a corresponding value for  $x$ . The number 1 represents the first value of  $x$  selected randomly for each parameter to calculate the cash flow and rate of return. A simulation requires the choosing of one set of values for each parameter.

Although there may be some interdependence among input variables, such as grade and recovery, or production rate and operating costs, these relationships are generally not known during the early exploration stages of a deposit. As this information becomes available, it would be incorporated in the evaluation; the computer program could be altered to reflect this relationship. The simulation is complete when a rate of return is calculated for the life of the operation. Numerous simulations are made, each time selecting a different set of values for the parameters. The number 2 corresponds to the second set of values chosen; number 3, to the third set; number 4, to the fourth set, until the required number of simulations are completed.

(Note that values representing the mean, because of the larger area of the segment and corresponding greater number of random values, would be used most frequently in the calculations. The chosen values are weighted more heavily about the mean.)

A distribution curve is constructed using discounted-cash-flow rates from all of the simulations. This distribution curve, which is part of the computer program output, indicates the probability of occurrence associated with each rate of return and is an indication of the risk involved in the investment. An example of the output is shown in figure 10. An assumed range of the rate of return is from 2 to 28 percent. Example 1 is a curve which shows a likely value of 15 percent while the range of most likely values is 12 to 18 percent. Example 2, using the same range and mean, gives another possibility for variance in the rate of return. This curve shows a probability of returns occurring near the maximum and minimum values. Examples 3 and 4 show two other possibilities, both with a most frequently occurring value of 15 percent. However, example 3 shows a distinct, possible rate of return higher than 15 percent while example 4 shows a likely rate of return lower than 15 percent.

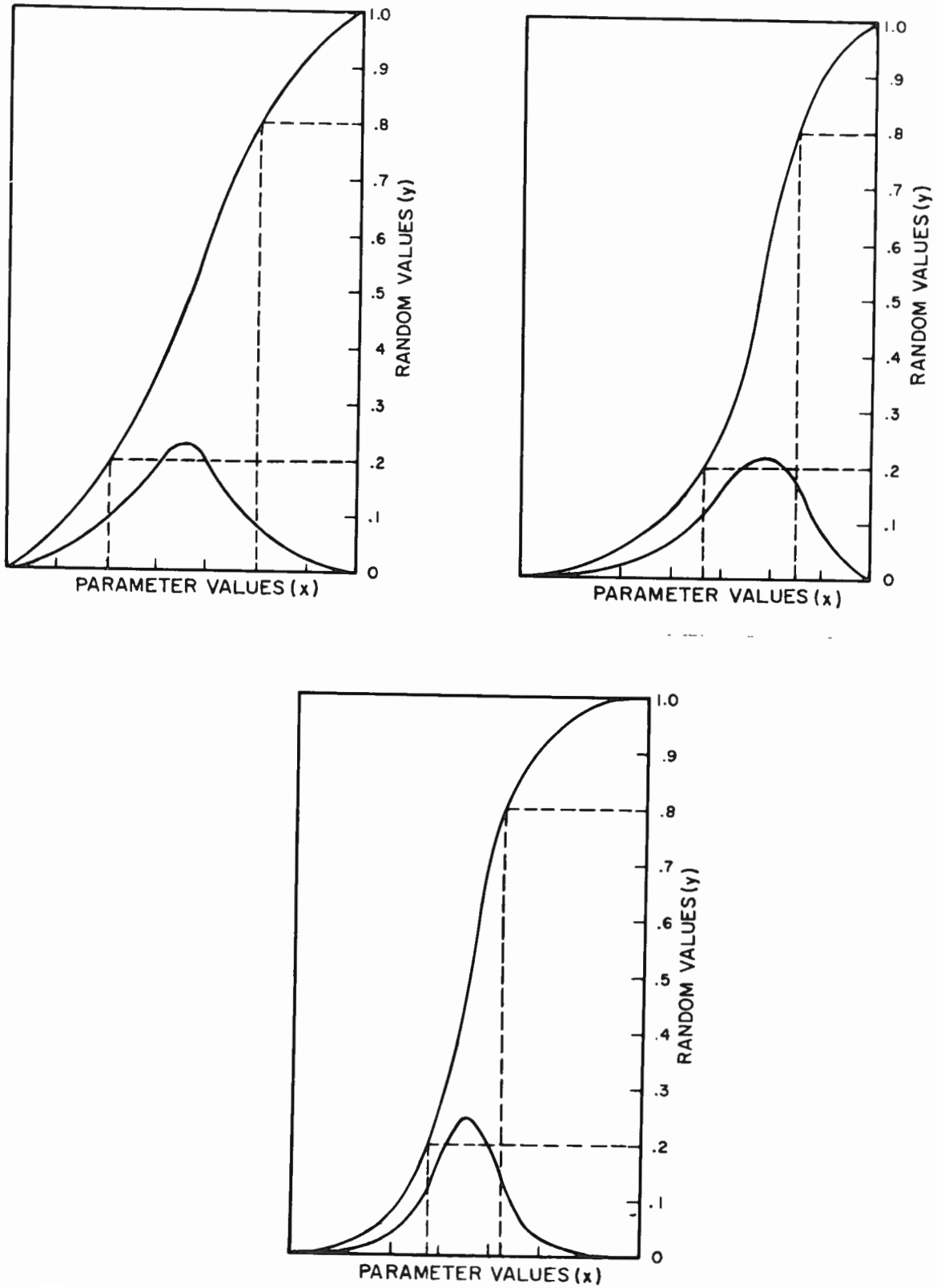


FIGURE 8. - Effect on the Range of  $x$  Given Random Numbers in the Range 0.2 to 0.8.

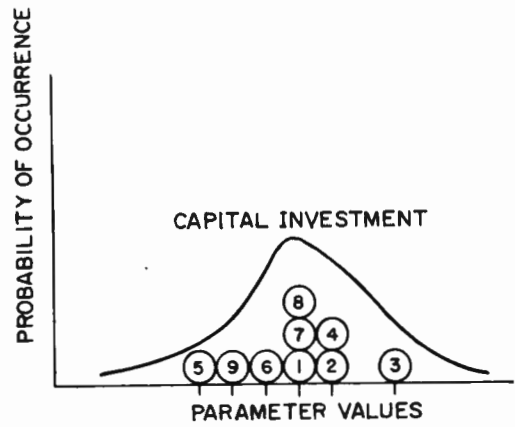
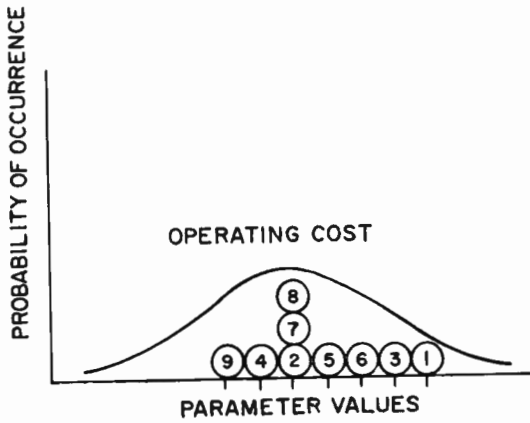
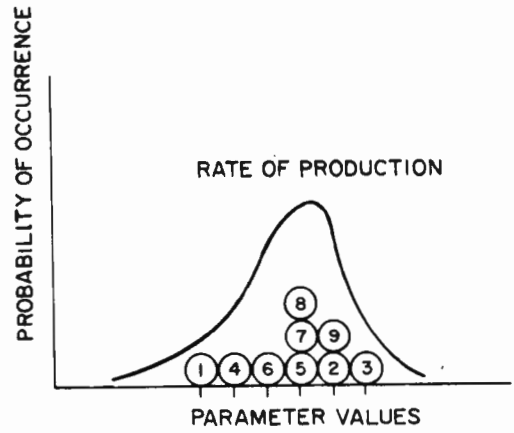
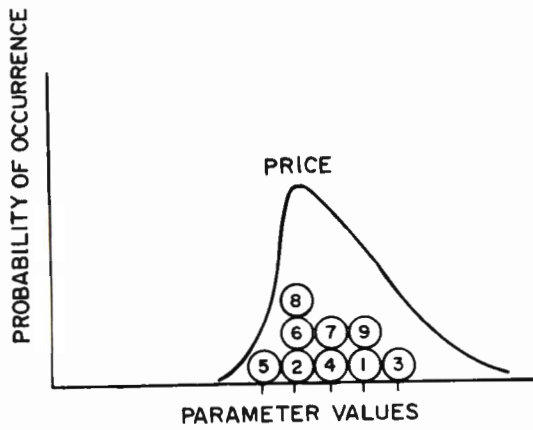
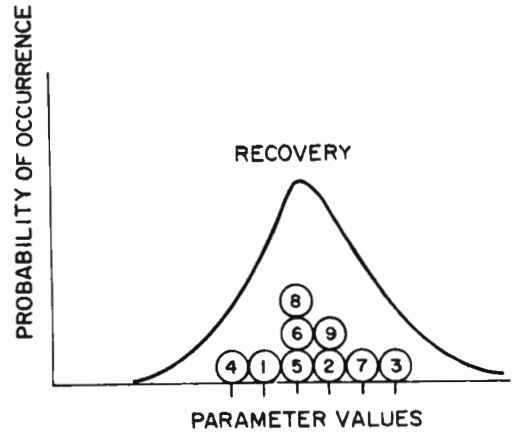
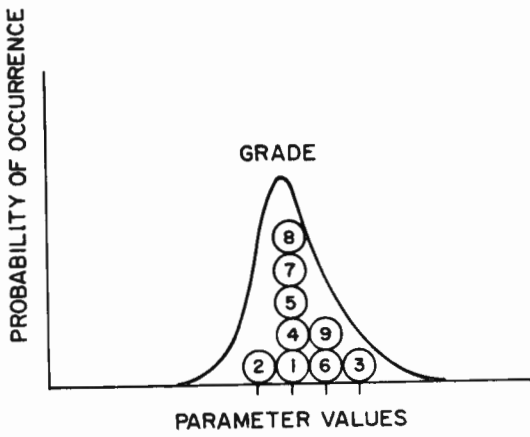


FIGURE 9. - Possible Order of Choice of Parameter Values Used in Simulation. (Numbers 1 to 9 illustrate sequence of random selection.)

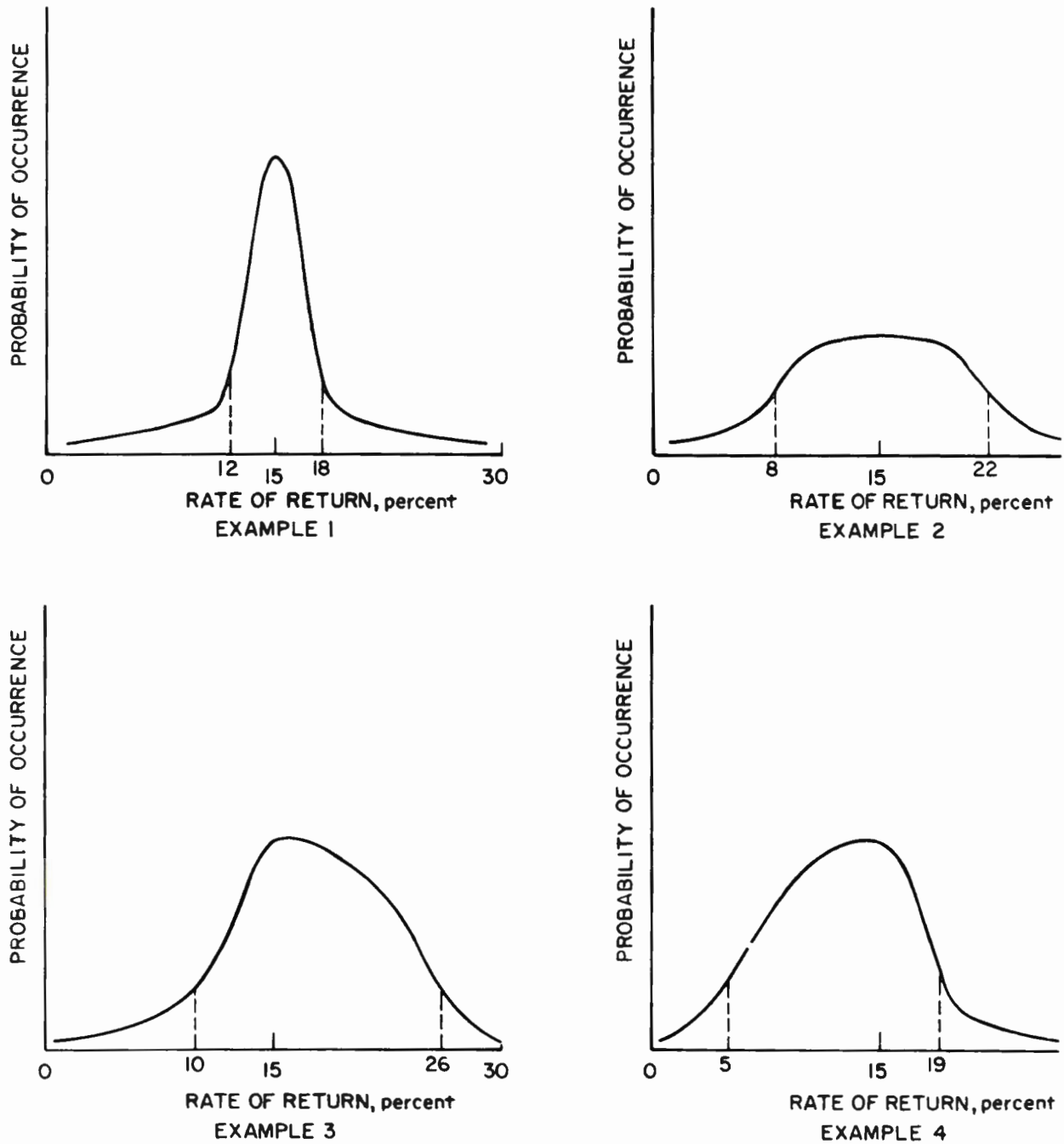


FIGURE 10. - Distributions Illustrating Different Possible Outputs for Rate of Return.

Specific examples of this analysis technique are included later in this report.

#### Computer Program

A simplified flow diagram of the computer program specifically developed to perform both sensitivity and probabilistic analysis is shown in figure 11.

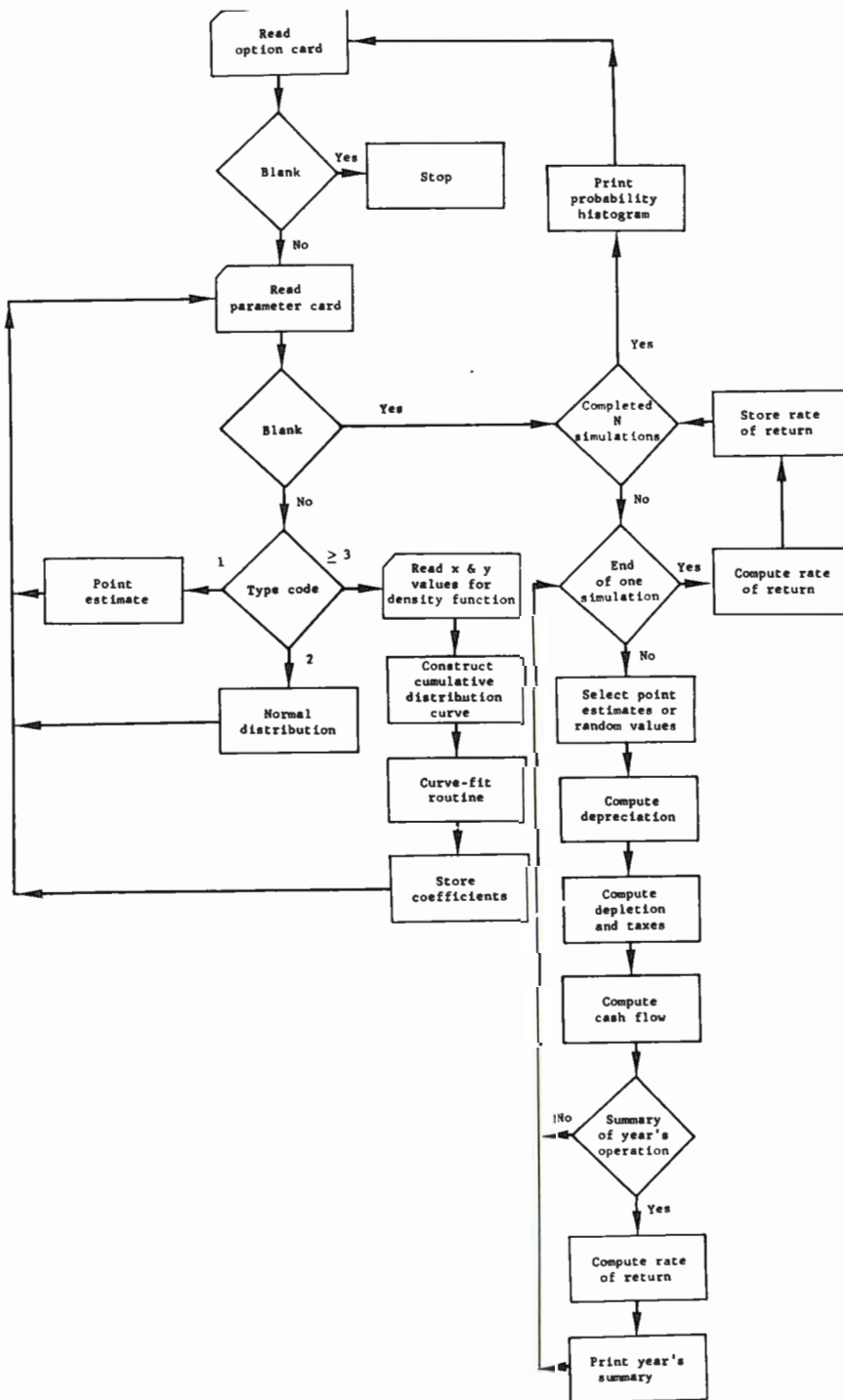


FIGURE 11. - Simplified Flow Diagram of Computer Program.

lation. This summary contains the values of the input data used to calculate revenues, the amount of depletion, depreciation, Federal, State, and local taxes, cash flow, and percent rate of return for each year of the operation.

This program was written in FORTRAN II for maximum compatibility and should run without modification on most computers having 8K (8,000-word) core storage, a card reader, and printer. The major inputs to the program are capital investments, operating costs, grade, recovery, production rate, life of operation, and price received for the product. To allow for varying economic equipment lives and equipment replacement, the capital investment can be entered at different time periods. Operating costs can be entered each year as separate costs for particular phases of the mining and milling operation.

Depreciation is computed (a choice of straight-line, double-declining-balance, or sum-of-the-year digits methods may be selected). Depletion allowance as well as Federal, State, and local taxes are calculated. Investment tax credit is optional.

If elected, a summary of the revenue-cost pattern can be printed for each simulation.

The salvage value and cumulative cash flow are also printed. In the probability analysis a probability histogram representing many simulations of the mineral operation is constructed illustrating various rates of return and their associated probabilities of occurrence. The rates of return are calculated using the following discounting method:

$$P = F \cdot \frac{e^r - 1}{re^{rt}},$$

where P = present value;

F = future sum;

e = 2.71828 (approximate);

r = annual rate of interest as a decimal;

t = number of years from zero date.

Detailed instructions as to the format of the input data and use of the program are contained on comment cards in the computer program listed in appendix A.

#### APPLICATION OF THE EVALUATION PROCEDURE TO A GOLD DEPOSIT

##### General

This gold-bearing deposit was investigated by the Bureau of Mines to determine its potential as a source of gold. All pertinent data concerning the deposit were made available by the owners of the property. Gross value of all the production starting in about 1895 and occurring sporadically through 1956 was \$3.2 million.

The mine workings occur in a rather complex system of diversely oriented steeply dipping veins and a flattened, cone-shaped breccia pipe which has been explored and exploited through three main level adits, several sublevel openings, a glory hole, and a system of interconnecting raises, winzes, and shafts. Early mining of the vein-type gold ores was done by open stope methods; the later attempt to exploit the low-grade disseminated breccia pipe ore employed a glory hole ore pass to drop open-pit mined material down to a conveyor haulage system in a lower level adit.

The total amount of drifting and raising is in excess of 20,000 feet; more than 12,000 feet of surface trenching and more than 12,000 feet of diamond drilling had been done.

Results of metallurgical testing conducted on the material in the deposit with developed flowsheets were made available and used in this analysis.

A limited drilling program was completed by the Bureau of Mines to provide additional data as to the degree and extent of the mineralization.

Metallurgical research was performed using material from the deposit to investigate applications of known commercial processing methods as well as development of new methods.

A more detailed report covering the Bureau of Mines program, mineralogy, and geology of the deposit are contained in Bureau of Mines Report of Investigations 7305 (1).

### Geology and Mineralization

Early mining efforts in the district were confined to lodes emplaced along shear zones and to relatively narrow quartz-filled fissure veins worked strictly for high-grade gold ores. Later attempts were made to exploit a large, low-grade disseminated gold deposit.

In this deposit it is thought that the majority of the gold is carried by pyrite, although a limited amount of free gold is reported to be present with a small amount of silver. Pyrite is the dominant sulfide mineral. Minor chalcopyrite occurs, and a very small amount of molybdenite and thin coatings of a dark gray metallic mineral that may be chalcocite are also in evidence. Gangue minerals in the veins are primarily quartz, with small percentages of calcite and barite.

Hydrothermal alteration in the rocks within and surrounding the ore deposit is evidenced by silicification, sericitization in the shale, feldspar, and in the latite porphyry, and by bleaching in the shale.

There is a large gold-bearing mineralized zone characterized by both fissure veins and disseminated gold-bearing pyrite in the area. Within this zone four mineralized structures are apparent:

1. Sulfides (primarily pyrite) disseminated through a sill-like latite porphyry intrusive body and occurring in a network of irregular fractures within the intrusive rock.
2. An irregular, cone-shaped breccia pipe filled with mineralized shale fragments and a small amount of latite, porphyry fragments in a matrix of silica and pyrite. Pyrite also occurs in numerous fractures and vugs within the pipe.
3. Gold-bearing pyrite deposited along bedding planes, fractures, and fault surfaces in silicified, sericitized shale and pyrite disseminated in shale without regard to bedding planes or fracture surfaces.
4. Quartz veins and mineralized shear zones cutting the shale latite and breccia pipe.

The core of this mineralized zone, centered around the breccia pipe, has been mined for the vein-type ores and to a moderate extent for the gold-bearing material from the breccia pipe. The central part of the zone has been extensively explored by trenching and drilling on the surface and by horizontal and vertical drilling in the underground workings.

A geologic map and cross sections of the deposit are shown in figures 12 and 13.

### Resources

Based on an engineering and geological evidence and assay values, an estimated 25 million tons of marginal gold resources having an average value of \$2.32 per ton at \$35 per ounce of gold was inferred in the shale, brecciated shale, and intrusive latite porphyry of the core area. There was evidence which indicated the resources could be increased to 31 and 45 million tons at respectively lower grades. This evaluation was made on the basis of resources of 24, 32, and 45 million tons.

### Mine Plant Design

#### General

Capital investment, operating, and working capital costs were estimated for daily mine production rates of 7,000, 13,600, 19,600, and 29,400 tons. An analysis was completed at these production rates and estimated resources of 24, 32, and 45 million tons resulting in operations of various life spans. Curves were fitted to the data from which investment and operating costs were obtained for various production rates within the production rates of 7,000 to 29,400 tpd. The curves fitted to the operating costs have a hyperbolic function of

$$y = a_0 + \frac{a_1}{x},$$

where  $y$  = operating costs, cents/ton;

$a_0, a_1$  = constants;

$x$  = production rate, tons/day;

$$y = a + bx.$$

A linear relationship,  $y = a + bx$ , exists for the capital investment,

where  $y$  = capital investment, total dollars;

$a, b$  = constants;

$x$  = production rate, tons/day.

Although not included in this analysis, these equations could be incorporated into the computer program to perform a sensitivity analysis for various production rates, ore-waste ratios, and quantities of ore reserves. Also these expressions could be incorporated in the program to perform marginal or incremental investment analysis to select the best alternative rate of production and in turn, plant size.

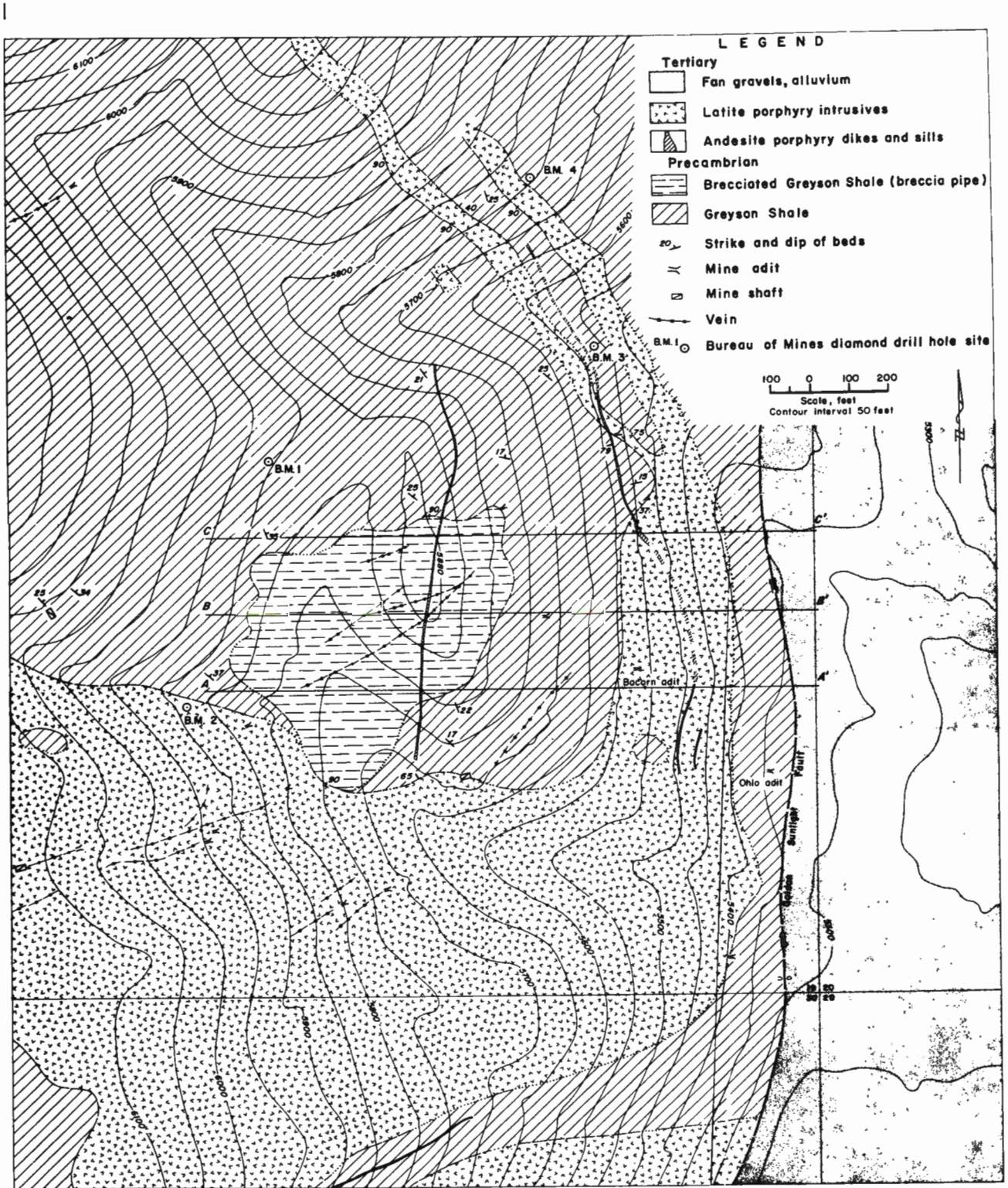


FIGURE 12. - Geological Map.

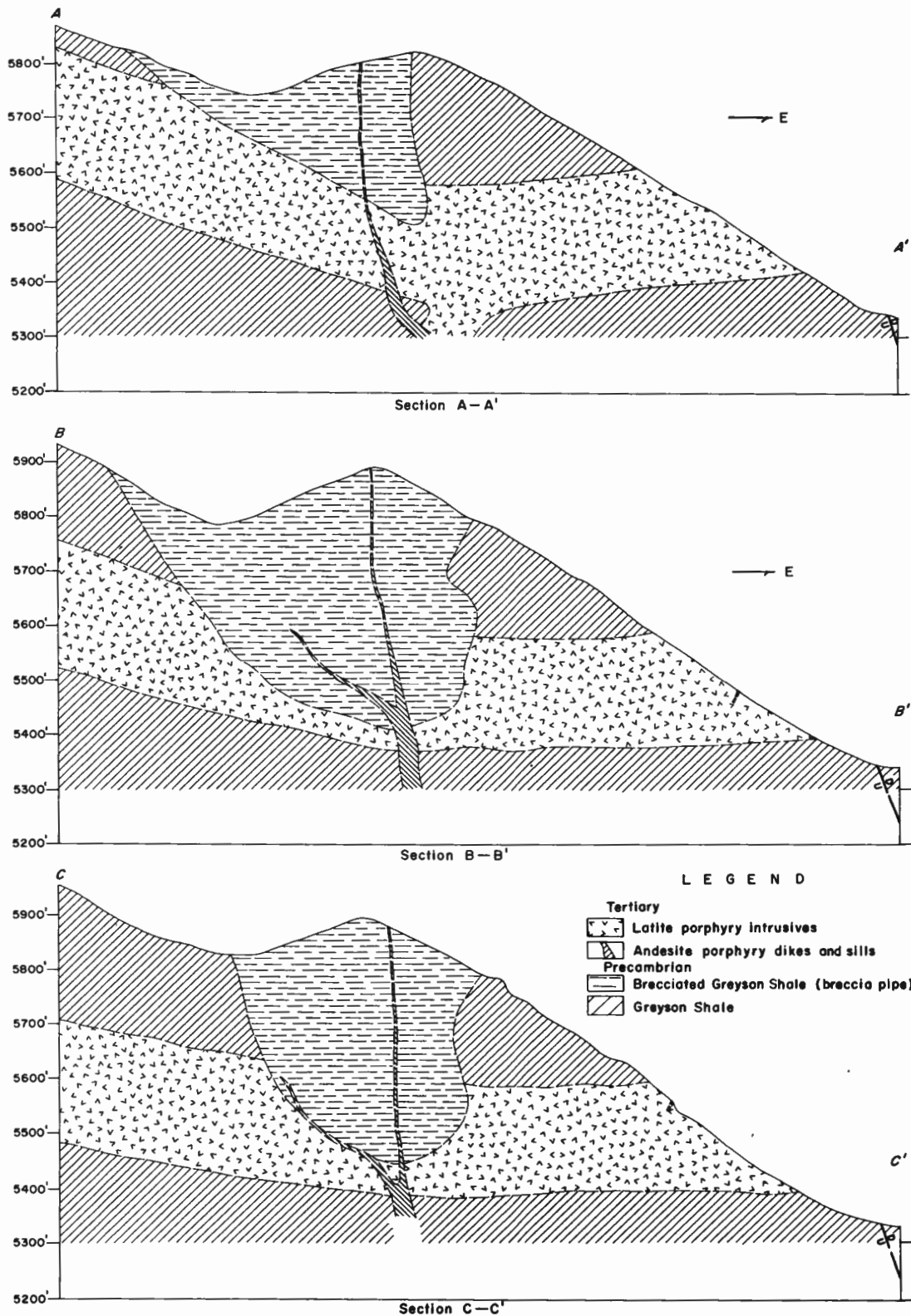


FIGURE 13. - Cross Sections.

Estimated costs include that of mine development such as road construction, plantsite preparation and plant construction, including tailings disposal. No costs are included for land acquisition, company formation, exploration, metallurgical research, water acquisition, corporation overhead, or stripping of waste. Preliminary investigations indicate there is little overburden to remove prior to mining. A major portion of the haulage is down-grade with the load.

It is assumed the mine operates two shifts per day, 5 days per week, with maintenance performed on down-shift, while the mill operates three shifts per day, 7 days per week, with maintenance performed concurrently. Stockpiled material provides feed to the mill on mining down shifts; if necessary a skeleton mine production crew provides additional material on weekends.

### Mining Method

It is assumed the deposit could be best exploited using an open-pit mining method. Three alternatives as to the type of haulage system to transport the ore from the pit to the millsite are considered. The alternatives are: (A) truck conveyor; (B) truck-haul; and (C) truck-raise. Henceforth, these will be referred to as system A, B, and C, respectively.

Ripping instead of drilling and blasting and use of scrapers for haulage are considered not to be applicable to the material. Drilling and blasting pattern varies depending upon the production rate; equipment size, supplies, and labor costs are estimated for each production rate. Manpower requirements are estimated on basis of men needed for supervision, operation, maintenance, and general overhead. Drilling equipment consists of large diesel or electric powered drills for primary blasting and small drills and auxiliary equipment for secondary blasting. The blasting agent is ANFO. Equipment is provided to construct and maintain the haulage roads--loading and haulage equipment is contingent upon the type of haulage system used.

Appendix B contains a detailed list of capital and operating costs for the 13,600 tpd mining operation using system B.

The estimated mining costs are indicative of the equipment necessary to move the material where a minimum cost of operation is sought, particularly in the loading and haulage phase. In a deposit in which the ore grade and rock type are extremely variable, many faces may have to be mined simultaneously to blend the ore and provide a relatively constant quality of material to the mill. In this case the number of loading and haulage units required would increase and capacity of the units would decrease. If the rock type and grade are relatively constant throughout, few but larger units can be used, which could result in better costs and logistics.

In this evaluation due to lack of more complete assay data, no allowance was made for blending of the ore or removal of waste within the assumed ore body.

At this stage of the project it is thought all the material would be transported to the millsite and crushed; there is no waste to be removed. This was true of the small open-pit operation and there is insufficient data to indicate otherwise in this preliminary analysis.

A computer program, which simulated the haulage cycle using various combinations of truck sizes and shovels at different haulage distances, was used in the selection of the loading and haulage equipment (4).

### System A

Trucks loaded in the pit with power shovels haul the broken material to a conveyor system which transports it to a stockpile at the millsite. If need be, the material could be sized prior to placing on the conveyor.

The capital investment and direct operating costs at the four selected production rates are shown in tables 1 and 2.

TABLE 1. - Capital investment summary, mining system A

Capital equipment	Capital investment, dollars			
	7,000 tons per day	13,600 tons per day	19,600 tons per day	29,400 tons per day
Drill and blast.....	102,800	173,000	230,200	232,100
Load.....	301,800	523,900	524,000	883,700
Haul and road maintenance.....	485,600	665,300	944,600	1,192,400
General.....	138,900	139,000	142,000	142,000
Subtotal <sup>1</sup> .....	1,029,100	1,501,200	1,840,800	2,450,200
Working capital.....	63,700	70,000	80,500	101,500
Total capital investment.....	1,092,800	1,571,200	1,921,300	2,551,700

<sup>1</sup>Includes, on a prorated basis, indirect cost, fee, and contingency.

TABLE 2. - Operating cost summary, mining system A

Unit	Operating cost per ton, dollars			
	7,000 tons per day	13,600 tons per day	19,600 tons per day	29,400 tons per day
Operating and maintenance material.....	0.079	0.062	0.054	0.049
Power.....	.009	.007	.004	.004
Supervisory labor.....	.002	.001	.001	.001
Maintenance labor.....	.036	.019	.019	.017
Direct labor.....	.113	.064	.046	.033
Administration and service.....	.027	.016	.013	.010
Payroll overhead.....	.044	.025	.020	.015
Total direct and indirect cost.....	.310	.194	.157	.129

System B

Rear dump trucks, loaded with material in the pit with power shovels, transport the broken material to a crusher at the millsite. The maximum adverse grade on the haulage road is 8 percent, generally favoring the load. A detailed list of estimated capital investment and direct operating costs at a production rate of 13,600 tpd are shown in appendix B. The estimated capital investment and direct operating costs at the four selected production rates are contained in tables 3 and 4.

TABLE 3. - Capital investment summary, mining system B

Capital equipment	Capital investment, dollars			
	7,000 tons per day	13,600 tons per day	19,600 tons per day	29,400 tons per day
Drill and blast.....	102,700	173,100	230,100	232,100
Load.....	301,600	523,800	610,800	883,600
Haul and road maintenance.....	396,000	530,300	620,300	760,100
General.....	156,700	156,900	160,100	160,100
Subtotal <sup>1</sup> .....	957,000	1,384,100	1,621,300	2,035,900
Working capital.....	64,900	76,600	96,500	121,800
Total capital investment.....	1,021,900	1,460,700	1,717,800	2,157,700

<sup>1</sup>Includes, on a prorated basis, indirect cost, fee, and contingency.  
(See appendix B.)

TABLE 4. - Operating cost summary, mining system B

Unit	Operating cost per ton, dollars			
	7,000 tons per day	13,600 tons per day	19,600 tons per day	29,400 tons per day
Operating and maintenance material.....	0.075	0.061	0.064	0.056
Power.....	.009	.007	.005	.005
Supervisory labor.....	.002	.001	.001	.001
Maintenance labor.....	.036	.019	.019	.017
Direct labor.....	.107	.060	.047	.036
Administration and service.....	.027	.016	.012	.010
Payroll overhead.....	.047	.024	.145	.172
Total direct and indirect cost.....	.303	.188	.168	.141

System C

Trucks, loaded in the pit with power shovels, transport the broken material to a raise centrally located within the pit with respect to the mass of the ore. The material passes through the raise and is conveyed via an adit to the millsite. This material is crushed at the collar of the raise by a portable crushing system or a crusher at the bottom of the raise. The adit is about 1,000 feet in length, and the raise is about 450 feet in height.

A method similar to this had been used prior to 1950 using a dozer to move the material to a centrally located raise. No sizing of the material was necessary prior to conveying the material through the adit.

The estimated capital investment and direct operating costs at the four selected production rates are contained in tables 5 and 6.

TABLE 5. - Capital investment summary, mining system C

Capital equipment	Capital investment, dollars			
	7,000 tons per day	13,600 tons per day	19,600 tons per day	29,400 tons per day
Drill and blast.....	102,800	173,000	230,300	232,100
Load.....	523,800	523,800	523,800	883,700
Haul and road maintenance.....	293,200	510,400	709,600	772,500
General.....	351,500	351,500	354,700	354,700
Subtotal <sup>1</sup> .....	1,271,300	1,558,700	1,818,400	2,243,000
Working capital.....	59,600	67,600	75,900	103,200
Total capital investment.....	1,330,900	1,626,300	1,894,300	2,346,200

<sup>1</sup>Includes, on a prorated basis, indirect cost, fee, and contingency.

TABLE 6. - Operating cost summary, mining system C

Unit	Operating cost per ton, dollars			
	7,000 tons per day	13,600 tons per day	19,600 tons per day	29,400 tons per day
Operating and maintenance material.....	0.070	0.060	0.051	0.049
Power.....	.011	.007	.003	.005
Supervisory labor.....	.002	.001	.001	.001
Maintenance labor.....	.036	.019	.019	.017
Direct labor.....	.102	.060	.042	.033
Administration and service.....	.027	.016	.013	.010
Payroll overhead.....	.042	.024	.018	.015
Total direct and indirect cost.....	.290	.187	.147	.130

Figures 14 and 15 show the relationship of the capital investment less working capital and the direct operating costs versus the rate of production for all mining systems.

Figure 16 shows a comparison of the capital investment less working capital required per ton of daily capacity for the three mining systems.

#### Processing Method

##### General

Design of a process to recover the minerals in the deposit should consider the various types of mineralized rock, namely the oxides of breccia and

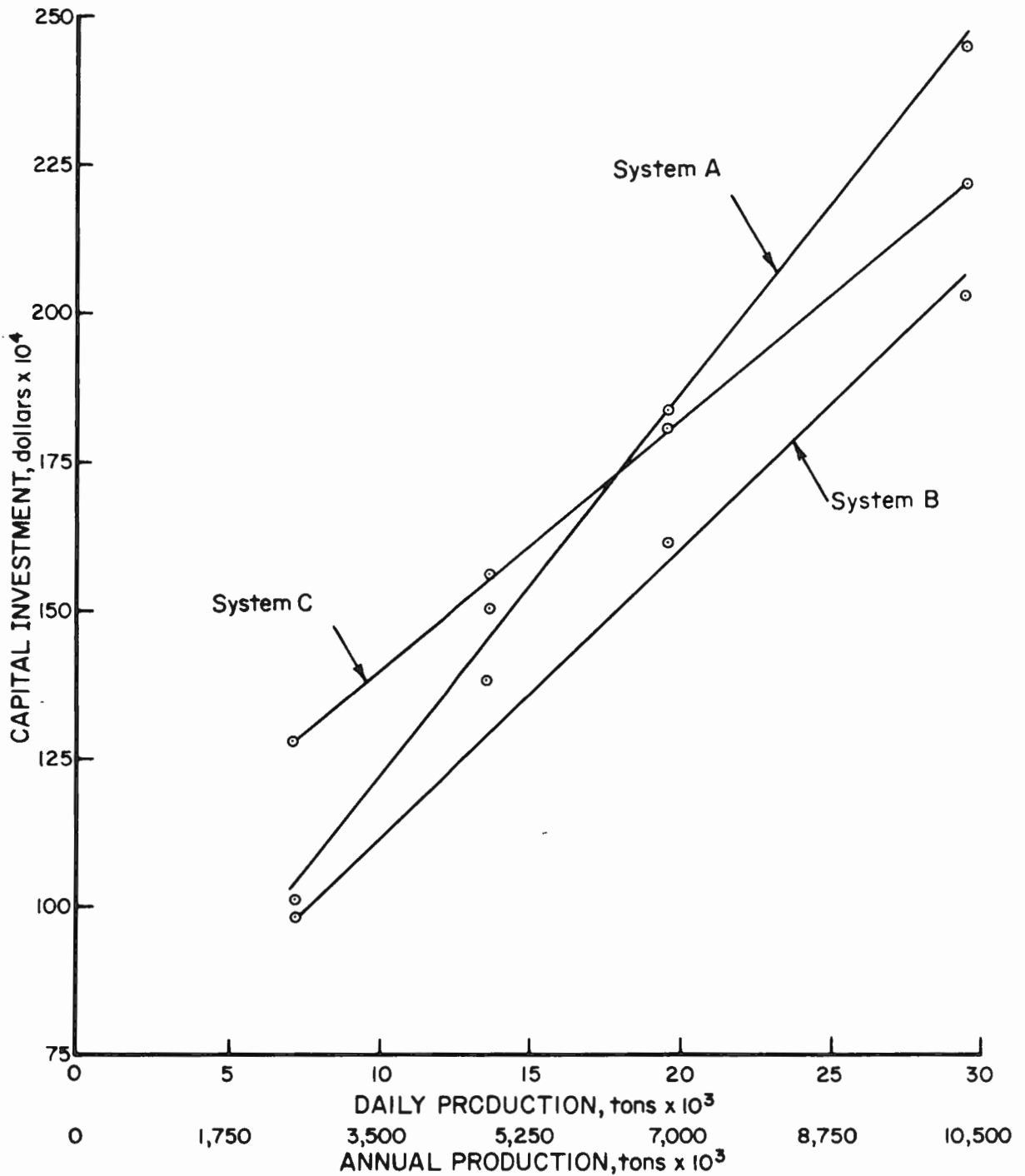


FIGURE 14. - Capital Investment Versus Rate of Production for Mine Systems A, B, and C.

bedded shale, sulfides of breccia and bedded shale, and porphyry. Prior to the design and operation of a pilot plant in 1945, the gold ores had been concentrated by crushing to about 1 inch and by screening. The values in the minus 10-mesh material were recovered by amalgamation.

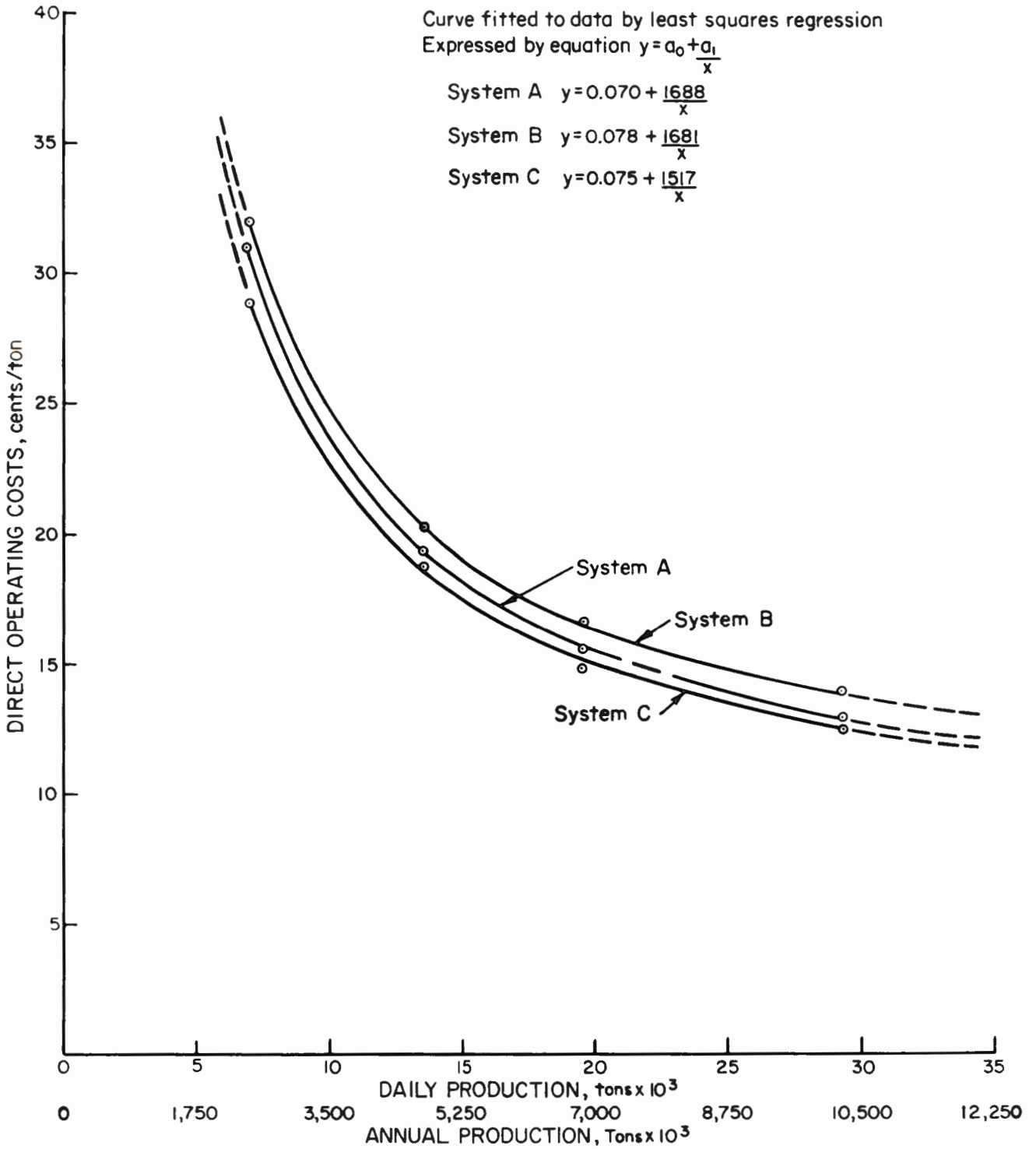


FIGURE 15. - Direct Operating Costs Versus Rate of Production for Mine Systems A, B, and C.

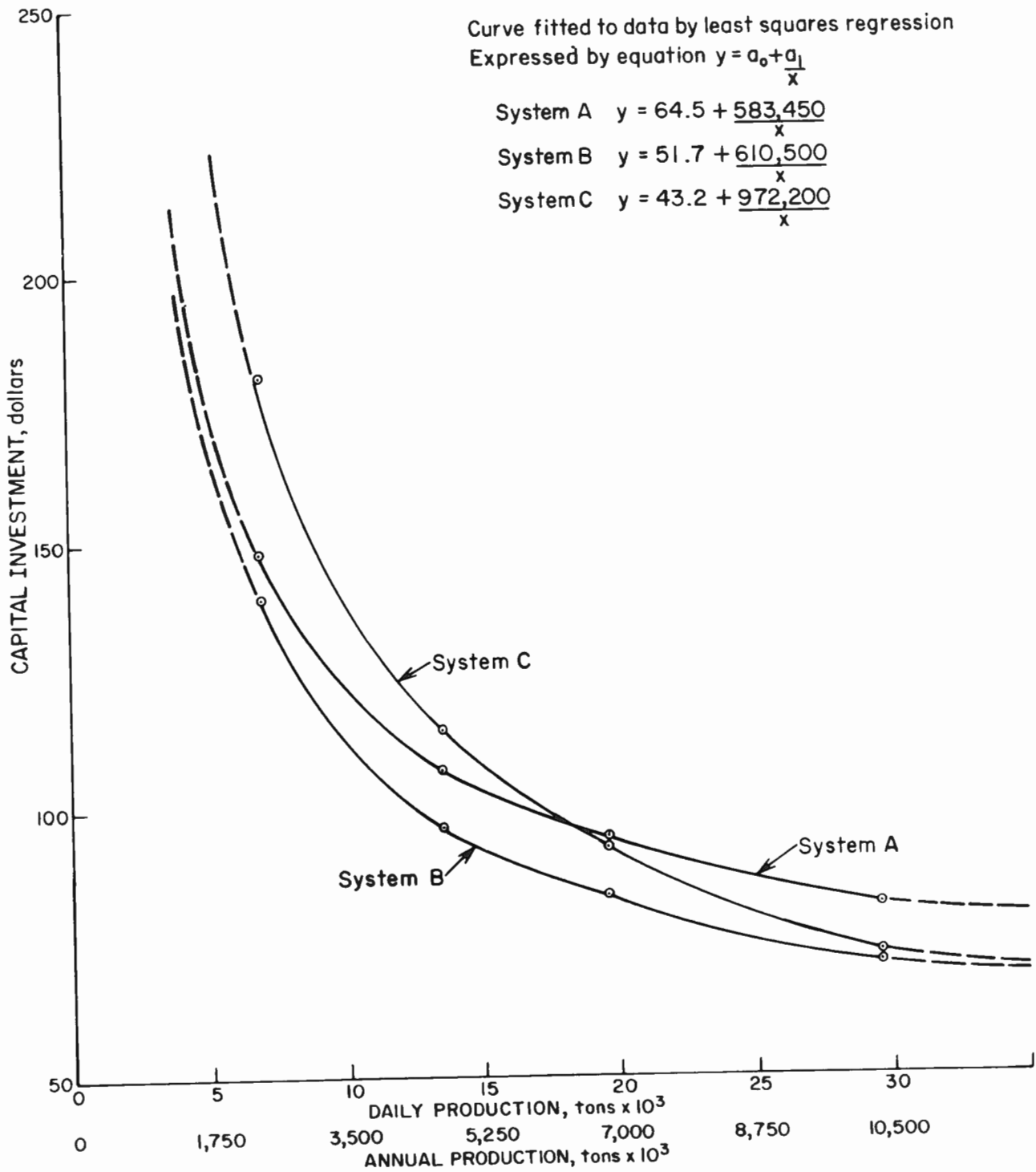


FIGURE 16. - Capital Investment Per Ton of Daily Capacity Versus Rate of Production for Mining Systems A, B, and C.

Subsequent to 1945 two processing methods were developed through metallurgical research of the material contained in the deposit. These two methods in addition to a standard cyanide process are considered in this report. Each method is considered and analyzed on the basis of capital investment, operating costs, expected recovery of values in the deposit, and the probability of achieving the expected results. Henceforth, these three methods will be referred to as A, B, and C. Each method employing the use of cyanide has different recovery rates, operating costs, and capital investments. Costs were estimated for each method at production rates of 5,000, 9,700, 14,000, and 21,000 tons. It is assumed the mill operates three shifts per day, 7 days per week.

#### Method A

This is a standard cyanide process in which all the mined material is treated.

To obtain some information on the amenability of the ore to standard cyanide leaching, a composite sample of three different types and grades of rock from the deposit was prepared. Laboratory scale tests on this sample provided specific data which was extrapolated to a commercial scale operation that simulated practice of the standard cyanide process illustrated in the flowsheet in figure 17. The flowsheet involves two-stage crushing to minus 1 inch followed by ball mill grinding to 60 percent minus 200 mesh in closed circuit with cyclones. The 50 percent solids pulp is leached with dilute cyanide solution in agitator tanks. The pregnant solution is separated and the residue is washed in a series of countercurrently operated thickeners. Gold is recovered from the pregnant solution by conventional zinc precipitation and inplant smelting. Recovery is approximately 76 percent of the gold contained in the mined material.

Capital investment and direct operating costs at the selected production rates are in tables 7 and 8.

TABLE 7. - Capital investment summary, processing method A

Capital equipment	Capital investment, dollars			
	5,000 tons per day	9,700 tons per day	14,000 tons per day	21,000 tons per day
Crushing.....	1,267,800	1,508,300	1,909,800	2,328,000
Grinding.....	1,750,600	3,270,000	4,734,400	6,913,600
Leaching.....	3,614,700	5,378,800	6,704,300	8,550,300
Clarify, precipitate, and melting.	509,700	736,000	905,300	1,141,800
Facilities.....	714,300	1,089,300	1,425,400	1,893,400
Utilities.....	856,900	1,307,600	1,710,800	2,271,900
Subtotal <sup>1</sup> .....	8,714,000	13,290,000	17,390,000	23,099,000
Working capital.....	941,000	1,620,000	2,340,000	3,541,000
Total capital investment.....	9,655,000	14,910,000	19,730,000	26,640,000

<sup>1</sup>Includes, on a prorated basis, indirect cost, fee, contingency, and interest during construction. (See appendix B.)

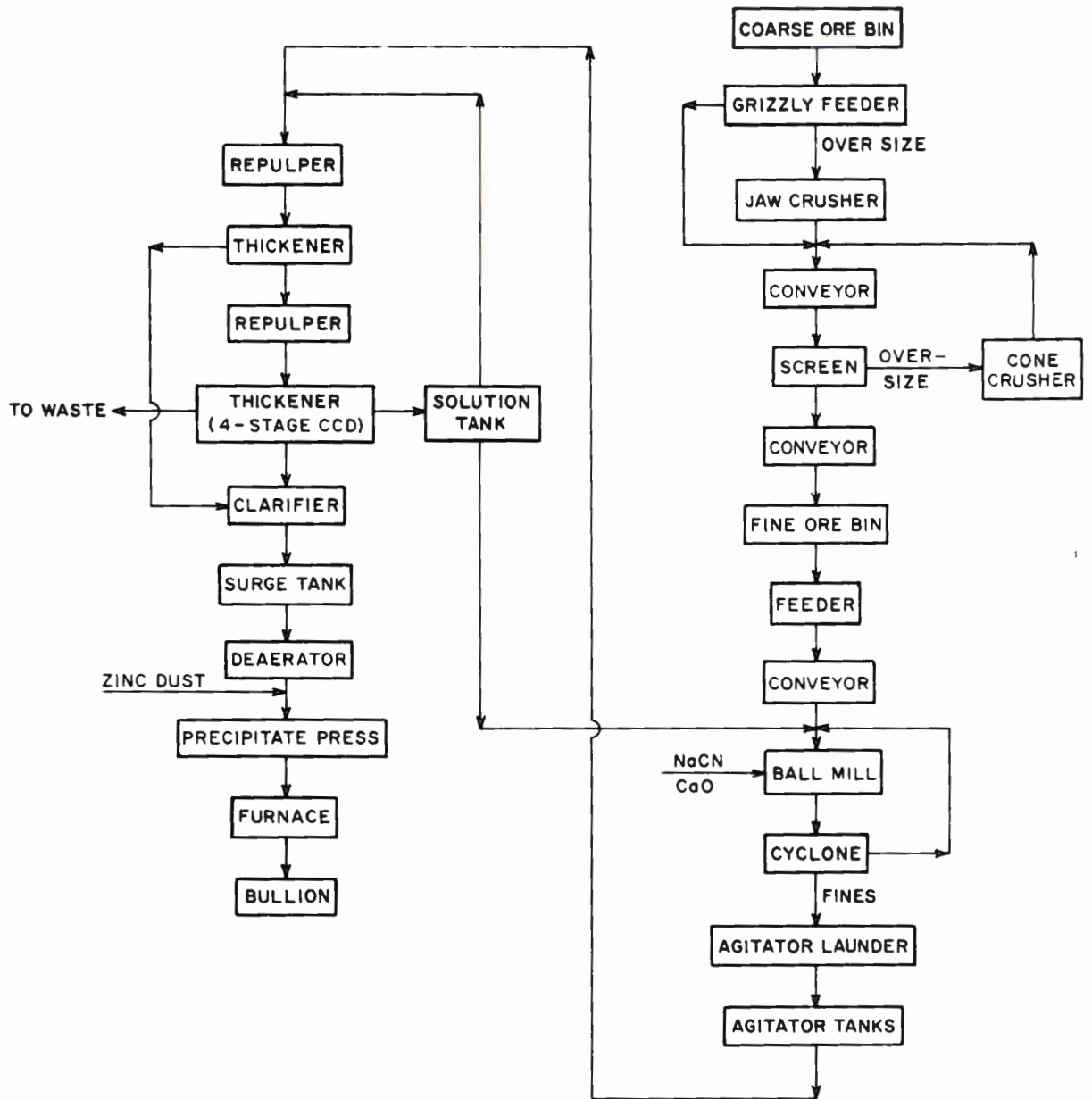


FIGURE 17. - Flowsheet of Process Method A.

TABLE 8. - Operating cost summary, processing method A

Unit	Operating cost per ton, dollars			
	5,000 tons per day	9,700 tons per day	14,000 tons per day	21,000 tons per day
Reagents and steel balls and liners....	0.762	0.762	0.762	0.762
Operating and maintenance material.....	.151	.122	.111	.099
Power.....	.181	.176	.186	.171
Supervisory labor.....	.035	.024	.021	.018
Maintenance labor.....	.107	.086	.078	.070
Direct labor.....	.089	.048	.035	.028
Administration and overhead.....	.153	.112	.098	.086
Payroll overhead.....	.058	.040	.033	.029
Total direct and indirect cost.....	1.536	1.370	1.324	1.263

Method B

This process, involving heavy media separation and flotation, was developed by parties interested in exploiting the deposit about 1945. A pilot mill was constructed in which the results of the laboratory research were proven. Figure 18 is a flowsheet of the process.

In this process, the ore is crushed to minus 1.25 inches in two stages. Minus 8-mesh material amounting to about 8 percent of the feed is screened out and the plus 8-mesh material is attrition-ground to produce an additional 24 percent of minus 8 mesh. The residual plus 8-mesh material goes to a sink-float plant. The sink product, which amounts to 22 percent of the original plant feed, is crushed in rolls to about five-eighths of an inch and screened at one-quarter of an inch. The plus 1/4-inch fraction is ground in a ball mill and the discharge is screened at 8 mesh. The plus 8-mesh fraction recycles to the sink-float plant. The float product from the sink-float plant, which constitutes 60 percent of the mill feed, is discarded.

The combined minus 8-mesh products are classified in closed circuit with a ball mill. The classifier overflow is minus 48 mesh and represents 40 percent of the original plant feed. The classifier overflow is froth floated to recover a pyrite concentrate that is roasted, cooled, and agitation-leached for 20 hours in cyanide solution. The leach residue is washed in a thickener and recovered on a drum filter. The pregnant solution is treated by conventional methods to recover the gold.

Flotation tailings are made alkaline by the addition of lime, conditioned for an hour, thickened to 50 percent solids, and aerated for 8 hours by air-lift-type agitation to oxidize ferrous salts taken into solution during flotation. The conditioned tailings then are leached with cyanide for 30 hours in a series of three agitated tanks. Pregnant solution is removed in a thickener and goes to gold precipitation. The residue is washed countercurrently in three thickeners and finally recovered on a drum filter.

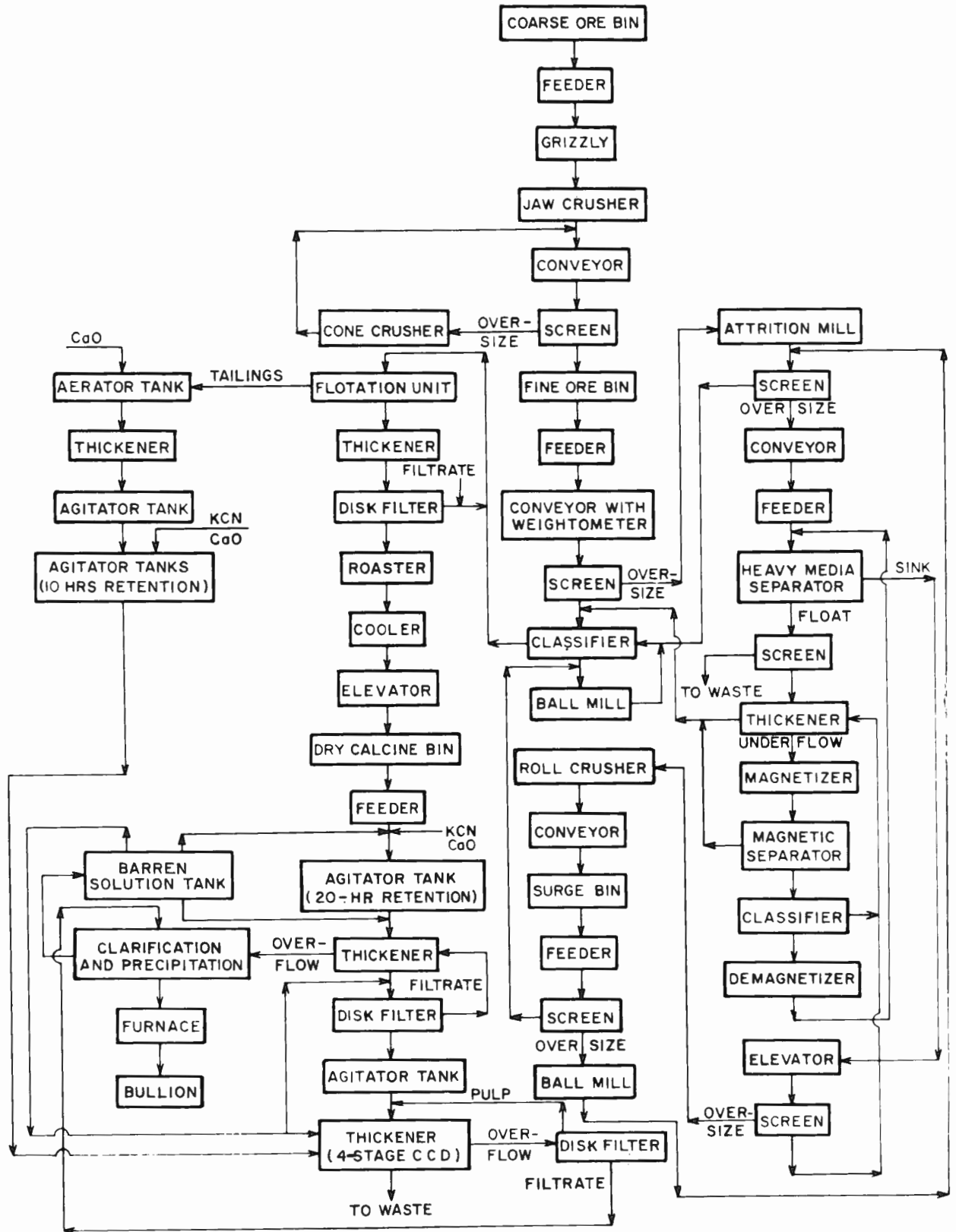


FIGURE 18. - Flowsheet of Process Method B.

Recovery averages about 75 percent of the gold contained in the mined material.

Tables 9 and 10 contain the estimated capital investment and direct operating costs at four different production rates.

TABLE 9. - Capital investment summary, processing method B

Capital equipment	Capital investment, dollars			
	5,000 tons per day	9,700 tons per day	14,000 tons per day	21,000 tons per day
Crushing.....	1,235,800	1,401,900	1,833,900	2,252,300
Sink-float.....	1,792,500	3,133,800	4,298,500	6,128,800
Flotation.....	1,229,200	2,344,400	3,358,700	4,999,700
Roasting and calcine.....	984,300	1,781,200	2,488,800	3,616,400
Cyanide.....	1,904,600	2,834,700	3,533,200	4,506,900
Clarify, precipitate, and melting.	166,600	225,600	269,700	331,600
Facilities.....	731,300	1,172,200	1,578,300	2,183,600
Utilities.....	877,700	1,406,200	1,893,900	2,620,700
Subtotal <sup>1</sup> .....	8,922,000	14,300,000	19,255,000	26,640,000
Working capital.....	694,000	1,106,000	1,591,000	2,495,000
Total capital investment.....	9,616,000	15,406,000	20,846,000	29,135,000

<sup>1</sup>Includes, on a prorated basis, indirect costs, fee, contingency, and interest during construction.

TABLE 10. - Operating cost summary, processing method B

Unit	Operating cost per ton, dollars			
	5,000 tons per day	9,700 tons per day	14,000 tons per day	21,000 tons per day
Reagents and steel balls and liners....	0.245	0.245	0.245	0.245
Operating and maintenance material.....	.155	.132	.124	.115
Power.....	.149	.143	.143	.148
Supervisory labor.....	.046	.031	.026	.023
Maintenance labor.....	.105	.089	.083	.077
Direct labor.....	.166	.088	.066	.051
Administration and overhead.....	.189	.136	.120	.107
Payroll overhead.....	.079	.052	.044	.038
Total direct and indirect cost.....	1.134	.916	.851	.804

### Method C

This process illustrated by the flowsheet in figure 19 was developed by a company interested in the deposit. The overall recovery is about 42 percent of the gold contained in the mined material.

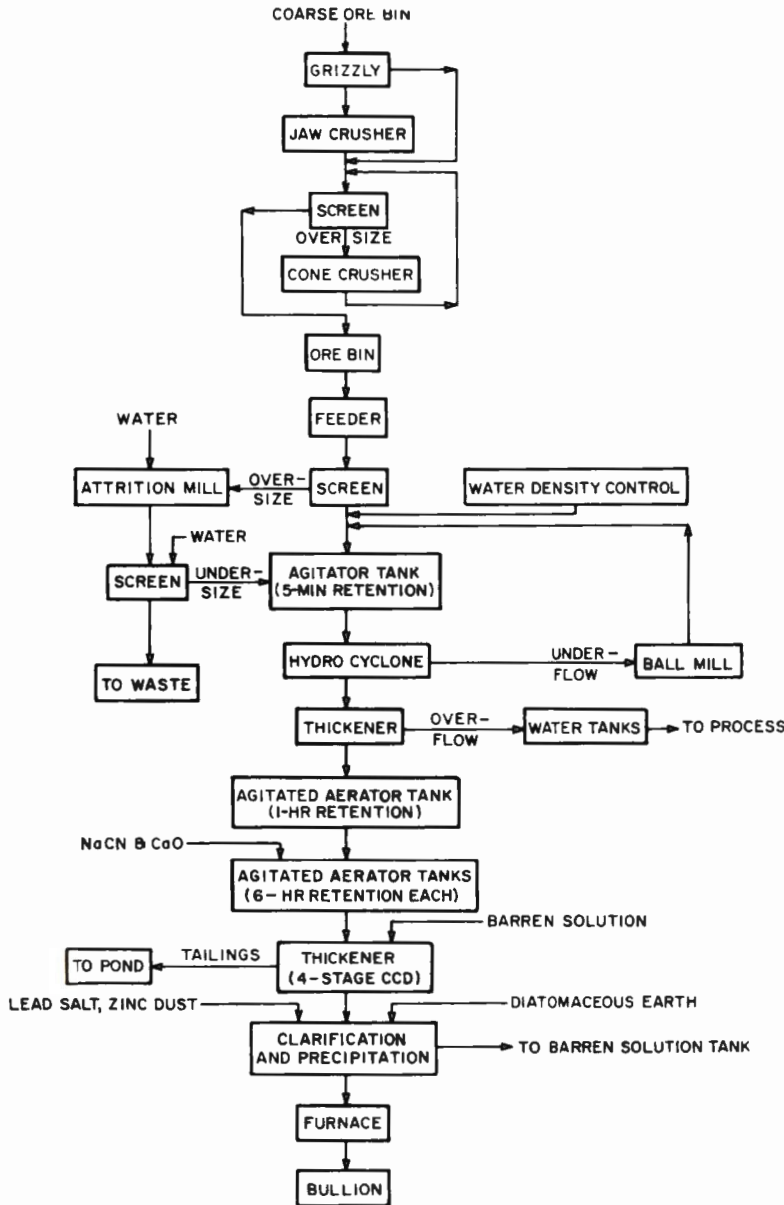


FIGURE 19. - Flowsheet of Process Method C.

Figure 22 shows a comparison of the capital investment less working capital required per ton of daily capacity for the three processing methods at various production rates.

The ore is crushed in two stages to minus 1 inch and the minus 10 mesh, which amounts to about 10.5 percent of the feed, is screened out. The minus 1-inch plus 10-mesh material is attrition-ground to produce additional minus 10-mesh material amounting to 6 percent of the original feed. This fine material is removed by wet screening and the plus 10-mesh fraction is discarded. The combined minus 10-mesh products are then ground to 48 mesh (60 percent minus 200 mesh) in a ball mill in closed circuit with a cyclone. After thickening to 50 percent solids, the resulting pulp is treated by standard cyanide agitation leaching.

The estimated capital investment and direct operating costs at the four selected production rates are in tables 11 and 12.

A graphical comparison of the capital investment less working capital and direct operating costs of the three processing methods at various production rates is shown in figures 20 and 21.

TABLE 11. - Capital investment summary, processing method C

Capital equipment	Capital investment, dollars			
	5,000 tons per day	9,700 tons per day	14,000 tons per day	21,000 tons per day
Crushing.....	1,343,900	1,404,800	1,833,900	2,252,300
Grinding.....	1,849,400	3,349,500	4,678,500	6,798,000
Leaching.....	1,493,300	2,223,600	2,769,800	3,532,900
Clarify, precipitate, and melting..	164,400	222,700	265,400	326,600
Facilities.....	485,100	720,100	954,800	1,291,000
Utilities.....	581,900	864,300	1,145,600	1,549,200
Subtotal <sup>1</sup> .....	5,918,000	8,785,000	11,648,000	15,750,000
Working capital.....	523,000	839,000	1,202,000	1,847,000
Total capital investment.....	6,441,000	9,624,000	12,850,000	17,597,000

<sup>1</sup>Includes, on a prorated basis, indirect costs, fee, contingency, and interest during construction.

TABLE 12. - Operating cost summary, processing method C

Unit	Operating cost per ton, dollars			
	5,000 tons per day	9,700 tons per day	14,000 tons per day	21,000 tons per day
Reagents and steel balls and liners....	0.298	0.298	0.298	0.298
Operating and maintenance material.....	.095	.078	.071	.066
Power.....	.094	.084	.086	.086
Supervisory labor.....	.029	.019	.016	.014
Maintenance labor.....	.068	.055	.051	.046
Direct labor.....	.101	.054	.040	.031
Administration and overhead.....	.117	.082	.071	.063
Payroll overhead.....	.049	.032	.027	.023
Total direct and indirect cost.....	.851	.702	.660	.627

#### Analysis of Alternative Methods

Alternative mining and processing methods incur different capital investments and operating costs. Each processing method has a different recovery while the process which provides the higher recovery generally requires the greater capital investment. Some mining alternatives may require higher capital investment but have lower operating costs and are more flexible and reliable. While one alternative might be readily eliminated because of unusually high costs, the elimination of others may not be as well defined. In these cases a financial analysis of the different alternatives could be used to aid in establishing the relative merits of the various methods.

Most of the analytical methods for decision making identify the alternative that offers the greatest expected profit. Using this approach, however, management must decide whether to select the alternative yielding the most profit or the one which might yield lower profit but involve less risk or less uncertainty.

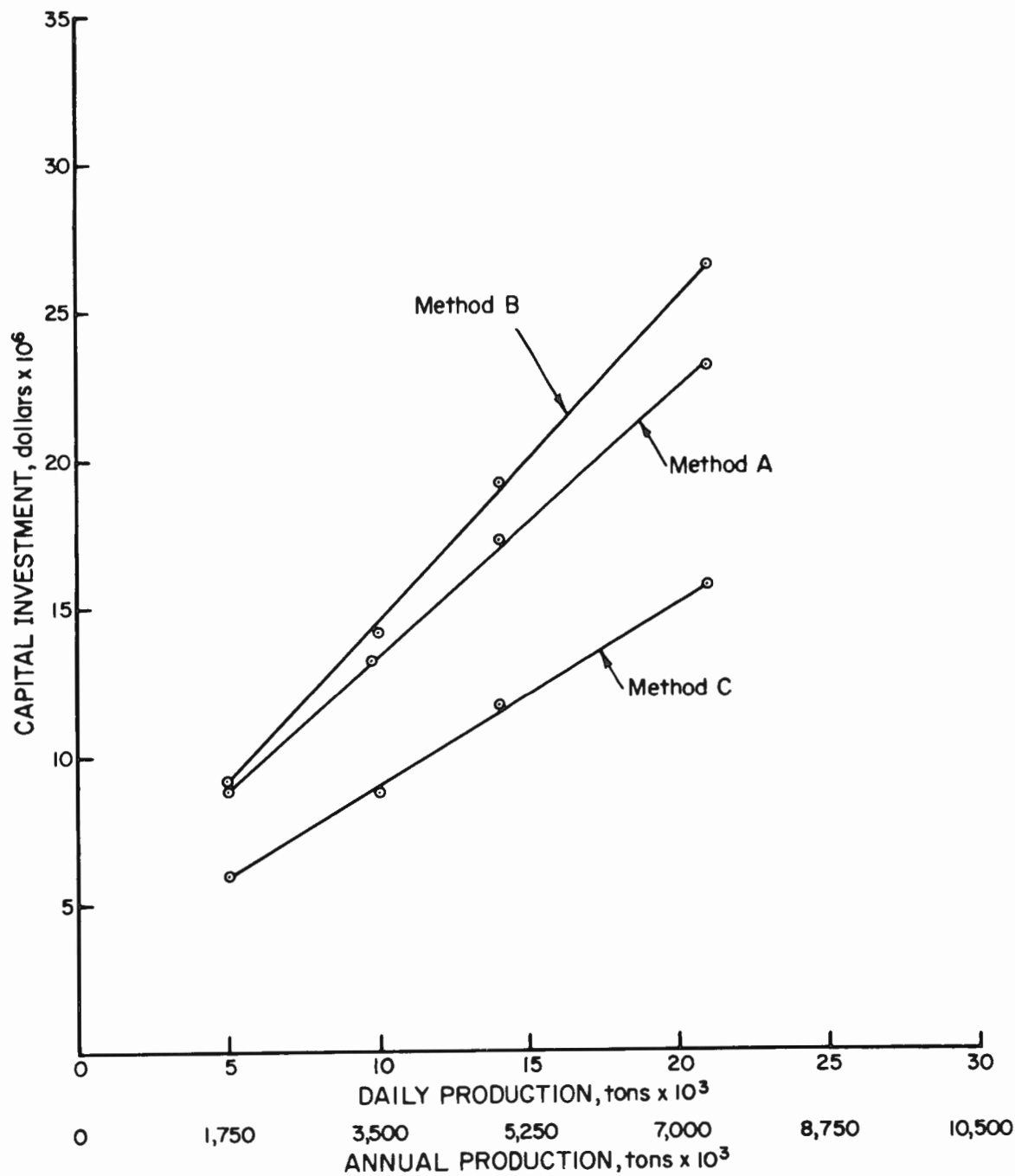


FIGURE 20. - Capital Investment Versus Rate of Production for Processing Methods A, B, and C.

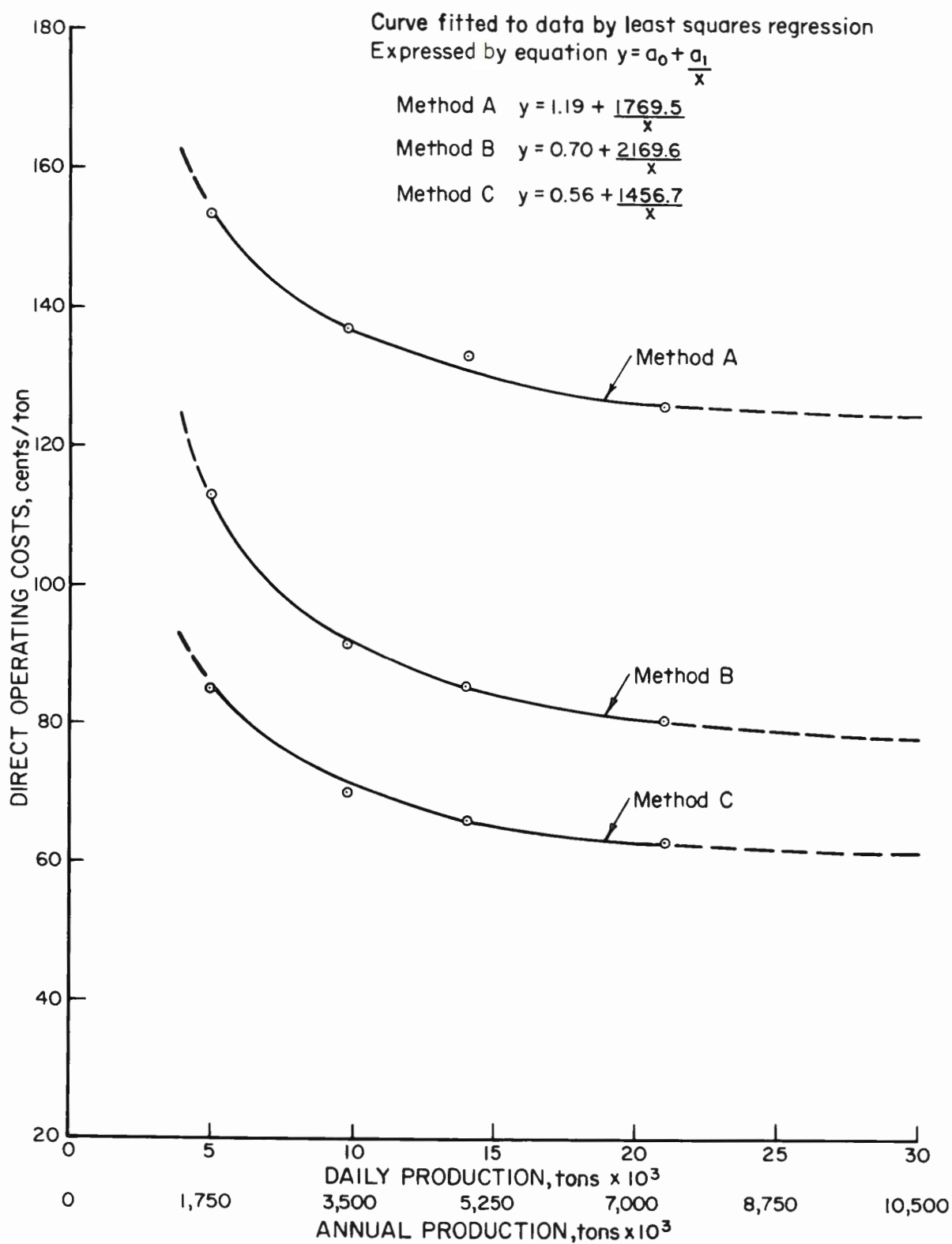


FIGURE 21. - Direct Operating Costs Versus Rate of Production for Processing Methods A, B, and C.

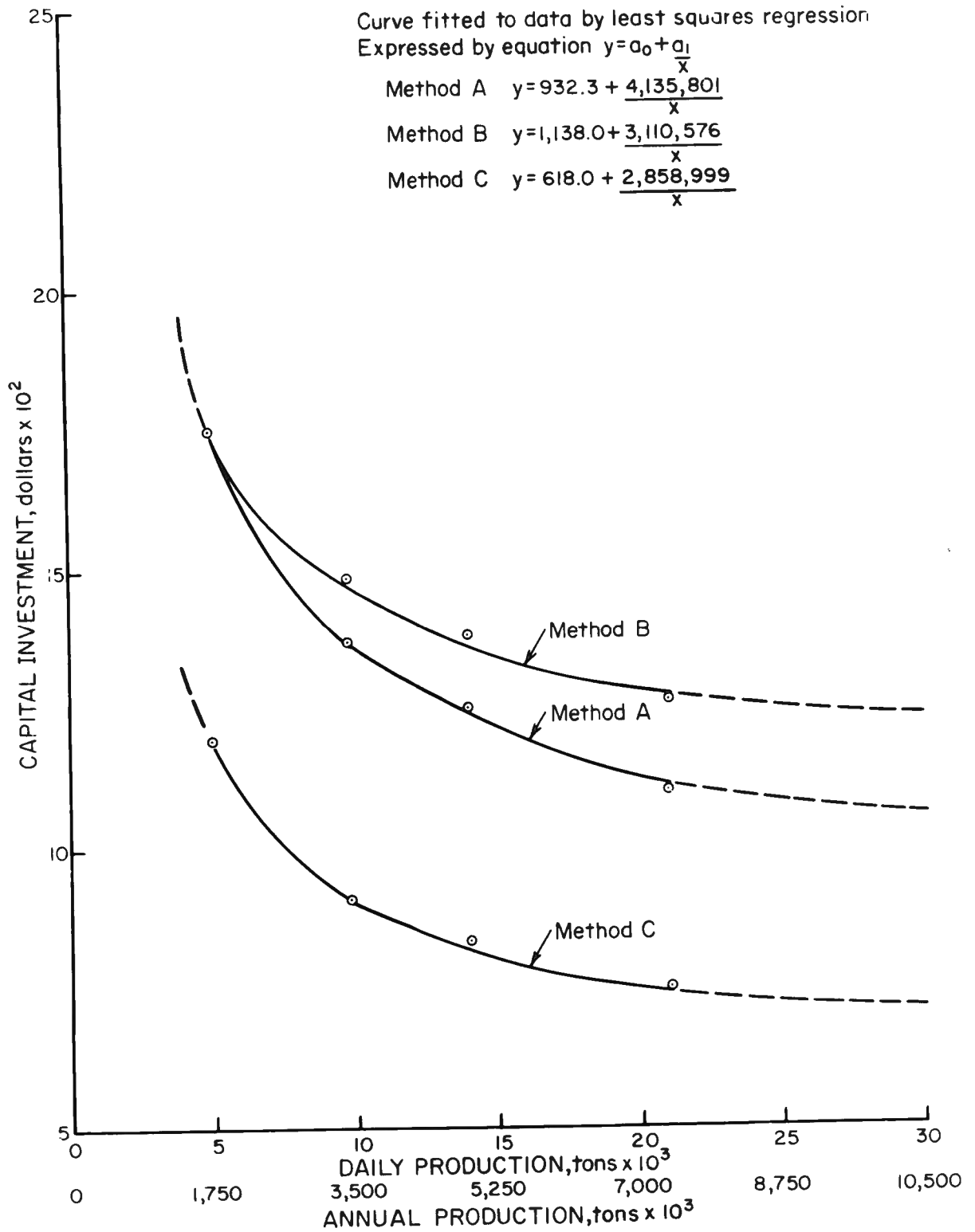


FIGURE 22. - Capital Investment Per Ton of Daily Capacity Versus Rate of Production for Processing Methods A, B, and C.

Two methods commonly used in an analysis are the net present value and the discounted-cash-flow. The two methods differ in the measure indicating the rank of desirability. In the net present value method, the cash inflows and outflows for each alternative are discounted at some specified rate to obtain the present value. The present value of the cash inflows are deducted from the present value of the cash outflows for each alternative. The alternative yielding the most positive net present value is considered the most profitable.

In the discounted-cash-flow method the rate of return is the discounted rate which equates the present values of the cash inflows with the cash outflows. The alternative yielding the higher rate of return is the most profitable.

The discounted-cash-flow method is used in this paper. The ore processing method is chosen prior to the selection of the mining system because the stream of cash inflows is dependent upon the recovery rates of the processing methods. Figure 23 is a flowsheet of the procedure used in this financial analysis.

To aid in the decision making process, an analysis is made of the incremental investment required to implement each alternative. Results of this analysis provide a measure of the return on the incremental investment.

As per an example from Shillinglaw (18), an operator had the choice of purchasing two pieces of equipment: A for \$50,000 or B for \$75,000. The purchase of A would result in an annual savings of \$10,000 and of B in an annual savings of \$13,000. The incremental investment was \$25,000, resulting in an incremental annual savings of \$3,000 per year. The minimum acceptable rate of return was 12 percent. Following is an example of an analysis using the discounted-cash-flow method and a time period of 10 years:

	Alternative A	Alternative B	B versus A
Initial investment.....	\$50,000	\$75,000	-
Annual savings.....	\$10,000	\$13,000	-
Rate of return, percent.....	15	12	-
Incremental investment.....	-	-	\$25,000
Incremental annual savings.....	-	-	\$3,000
Incremental rate of return, percent.	-	-	4

Even though alternative B provided the minimum acceptable rate, it would be disregarded because the rate of return on the added increment was only 4 percent.

#### Selection of Processing Method

The present values of the cash outflows and inflows are equated to determine a rate of return on the investments for each alternative processing method. Cash outflows were the estimated capital investment. Average annual cash inflows are computed by deducting direct operating costs from the estimated value of the recoverable minerals. The economic life of the operation

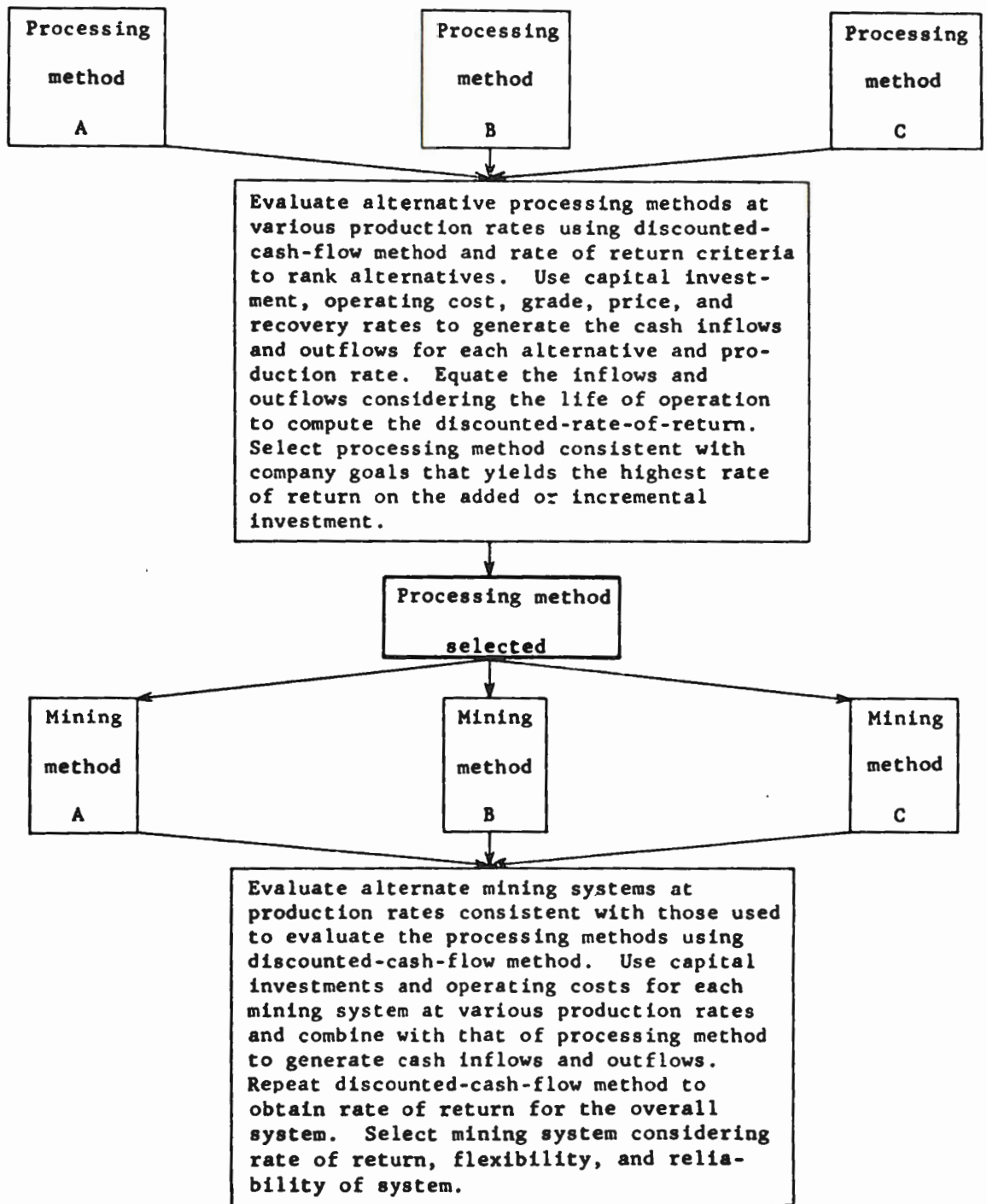


FIGURE 23. - Flowsheet Illustrating Method Used to Select Mining and Processing Method.

for the various rates of production are based on an assumed resource of 45 million tons. The rate of return is determined for each production rate. This provides a means of ranking the alternatives on the basis of profit on the total capital investment.

In addition, an analysis is made of the return on the incremental investment required in the choice of one alternative as compared to another at each production rate. This is done by calculating the discount rate that equates the present values of the incremental cash outflows to incremental cash inflows. Annual incremental cash inflows are computed by deducting the annual cash flows of the alternatives from each other, the same as in calculating the incremental capital investments. This analysis provides a means of indicating whether the alternative providing the greatest return on total investment is yielding a satisfactory return on the incremental capital required to attain this maximum return on total investment. The rate which provides a satisfactory return would be determined by management.

Tables 13, 14, 15, and 16 are the results of this type of an analysis. Alternative processing method B is selected as it yields the maximum return on total and incremental investment. In an actual situation factors other than maximum profit may favor the selection of another alternative.

TABLE 13. - Rate of return on total capital investment and incremental investments for alternative processing methods A, B, and C at 5,000 tpd, 25-year life

	Total investment analysis			Return on incremental investment analysis	
	Alter- native A	Alter- native B	Alter- native C	Alter- natives C and B compared	Alter- natives C and A compared
Capital investment <sup>1</sup> .	\$9,655,000	\$9,616,000	\$6,441,000	-	-
Incremental investment.....	-	-	-	\$3,175,000	\$39,000
Rate of return on total investment, percent <sup>2</sup> .....	15.9	18.7	13.4	-	-
Rate of return on incremental investment, percent.....	-	-	-	28.7	20.6

<sup>1</sup>Includes working capital.

<sup>2</sup>Investment discounted for first year of analysis with operation beginning in the second year. A grade and price of 0.10 ounce gold per ton and \$40 per ounce, respectively, were used. A recovery of 76, 75, and 42 percent for methods A, B, and C, respectively, was used. Depreciation, depletion, and taxes were considered.

TABLE 14. - Rate of return on total capital investment and incremental investments for alternative processing methods A, B, and C at 9,700 tpd, 13-year life

	Total investment analysis			Return on incremental investment analysis	
	Alter- native A	Alter- native B	Alter- native C	Alter- natives C and B compared	Alter- natives C and A compared
Capital investment <sup>1</sup> .	\$14,910,000	\$15,406,000	\$9,624,000	-	-
Incremental investment.....	-	-	-	\$5,782,000	\$5,286,000
Rate of return on total investment, percent <sup>2</sup> .....	21.4	24.6	19.4	-	-
Rate of return on incremental investment, percent.....	-	-	-	32.4	24.9

<sup>1</sup>Includes working capital.

<sup>2</sup>Investment discounted for first year of analysis with operation beginning in the second year. A grade and price of 0.10 ounce gold per ton and \$40 per ounce, respectively, were used. A recovery of 76, 75, and 42 percent for methods A, B, and C, respectively, was used. Depreciation, depletion, and taxes were considered.

TABLE 15. - Rate of return on total capital investment and incremental investments for alternative processing methods A, B, and C at 14,000 tpd, 9-year life

	Total investment analysis			Return on incremental investment analysis	
	Alter- native A	Alter- native B	Alter- native C	Alter- natives C and B compared	Alter- natives C and A compared
Capital investment <sup>1</sup> .	\$19,730,000	\$20,846,000	\$12,850,000	-	-
Incremental investment.....	-	-	-	\$7,996,000	\$6,880,000
Rate of return on total investment, percent <sup>2</sup> .....	23.1	26.5	20.9	-	-
Rate of return on incremental investment, percent.....	-	-	-	34.6	26.9

<sup>1</sup>Includes working capital.

<sup>2</sup>Investment discounted for first year of analysis with operation beginning in the second year. A grade and price of 0.10 ounce gold per ton and \$40 per ounce, respectively, were used. A recovery of 76, 75, and 42 percent for methods A, B, and C, respectively, was used. Depreciation, depletion, and taxes were considered.

TABLE 16. - Rate of return on total capital investment and incremental investments for alternative processing methods A, B, and C at 21,000 tpd, 6-year life

	Total investment analysis			Return on incremental investment analysis	
	Alter- native A	Alter- native B	Alter- native C	Alter- natives C and B compared	Alter- natives C and A compared
Capital investment <sup>1</sup>	\$26,640,000	\$29,135,000	\$17,597,000	-	-
Incremental investment.....	-	-	-	\$11,538,000	\$9,043,000
Rate of return on total investment, percent <sup>2</sup> .....	24.2	26.8	20.9	-	-
Rate of return on incremental investment, percent.....	-	-	-	35.2	30.1

<sup>1</sup>Includes working capital.

<sup>2</sup>Investment discounted for first year of analysis with operation beginning in the second year. A grade and price of 0.10 ounce gold per ton and \$40 per ounce, respectively, were used. A recovery of 76, 75, and 42 percent for methods A, B, and C, respectively, was used. Depreciation, depletion, and taxes were considered.

#### Selection of Mining System

The investment and operating cost of the three alternative mining systems are combined with that of processing method B and each is evaluated at various production rates and at the assumed grade, recovery, price, and resources of 0.10 ounce of gold per ton, 75 percent, \$40, and 45 million tons, respectively. The computed rate using the discounted-cash-flow method, in addition to the reliability and flexibility of the system, is considered when choosing the final alternative. Management may wish to select a system providing less than maximum profit in order to obtain reliability and flexibility. Reliability and flexibility refer to the equipment in the mining system. Reliability is reflected in the percent downtime anticipated for repair and maintenance and the resulting lost production. Flexibility infers the adaptability of the equipment to a change in the pattern of the mining operation. The evaluation, using the various production rates, is performed using the sensitivity analysis portion of the computer program.

The results of this evaluation are the rates of return at the various production rates in table 17. Because there is very little difference in the rates of return for the different haulage systems, system B (truck-haul) is selected since it is judged to be the more flexible.

TABLE 17. - Comparison of the rate of return of the alternative mining systems A, B, and C and the alternative processing method B at various production rates<sup>1</sup>

Annual production, tons	Life, years	Mine system		
		A	B	C
11,250,000	4	20.1	20.6	20.6
7,350,000	6	23.1	23.4	23.3
6,430,000	7	23.4	23.5	23.5
4,900,000	9	21.9	21.9	22.1
3,395,000	13	20.6	20.8	20.6
1,750,000	25	14.3	14.3	11.8

<sup>1</sup>A grade, price, and recovery of 0.10 ounce gold per ton, \$40 per ounce, and 75 percent, respectively, were used.

Table 18 contains an operating cost summary including taxes, insurance, and depreciation for mining system and processing method B. These costs were computed considering a 45-million-ton resource and life of 25, 13, 9, and 6 years.

#### Selection of Production Rate

Numerous papers have been either published or presented at technical meetings describing methods of determining the best alternative production rate for a particular deposit (2, 5, 12). For a mineral operation having a processing plant, this production rate dictates the plant size. The rate of production is affected by the physical and economic factors peculiar to the mineral deposit being evaluated and the management policy of the particular company involved. Physical factors can influence the type of mining method used to exploit the deposit, which in turn affects the production rate. Economic factors such as product demand, risk due to time as well as uncertainty of data, acceptable rate of return, available investment opportunities, and cost of capital also influence the selection of the production rate.

A high rate of production at a reduced margin of profit has economic advantages in that it may delay adverse technologic changes and deter development of substitutes or competitive services. This is reflected in the company's desired payback period (for example, a proposed petrochemical plant is often considered marginal if the payback period is longer than 5 years). Certain mining projects may be subject to this criterion if they provide a product that is dependent on markets of short or unpredictable duration. Within limits, as the production rate is increased the advantages of economies of scale are realized. Increased investment usually results in greater productivity and lower operating costs. Finally a point is reached at which diminishing returns on investment drop below the desired return.

TABLE 18. - Operating cost summary for mining system and processing method B

	Operating cost per ton, dollars			
	25-year life <sup>1</sup>	13-year life <sup>2</sup>	9-year life <sup>3</sup>	6-year life <sup>4</sup>
<b>Mine:</b>				
Operating and maintenance material.....	0.075	0.061	0.064	0.056
Power.....	.009	.007	.005	.005
Supervisory labor.....	.002	.001	.001	.001
Maintenance labor.....	.036	.019	.019	.017
Direct labor.....	.107	.060	.047	.036
Administration and services.....	.027	.016	.012	.010
Payroll overhead.....	.047	.024	.020	.016
Subtotal.....	.303	.188	.168	.141
<b>Mill:</b>				
Reagents and steel balls and liners....	.245	.245	.245	.245
Operating and maintenance material.....	.155	.132	.124	.115
Power.....	.149	.143	.143	.148
Supervisory labor.....	.046	.031	.026	.023
Maintenance labor.....	.105	.089	.083	.077
Direct labor.....	.166	.088	.066	.051
Administration and services.....	.189	.136	.120	.107
Payroll overhead.....	.079	.052	.044	.038
Subtotal.....	1.134	.916	.851	.804
Total direct cost.....	1.437	1.104	1.019	.945
State and local tax.....	.040	.037	<sup>5</sup> .073	<sup>5</sup> .088
Federal tax.....	-	-	-	-
Depreciation.....	.271	.367	.483	.615
Insurance.....	.057	.046	<sup>6</sup> .042	<sup>6</sup> .039
Subtotal.....	.368	.450	.598	.742
Total cost.....	1.805	1.554	1.617	1.687

<sup>1</sup>25-year life based on mining 7,000 tpd, milling 5,000 tpd, and average annual tonnage of 1,750,000 tons.

<sup>2</sup>13-year life based on mining 13,600 tpd, milling 9,700 tpd, and average annual tonnage of 3,395,000 tons.

<sup>3</sup>9-year life based on mining 19,600 tpd, milling 14,000 tpd, and average annual tonnage of 4,900,000 tons.

<sup>4</sup>6-year life based on mining 29,400 tpd, milling 21,000 tpd, and average annual tonnage of 7,350,000 tons.

<sup>5</sup>Revenues computed using a price of \$35 per ounce, a grade of 0.06 ounce of gold per ton, and a recovery of 75 percent.

<sup>6</sup>Insurance computed at 1 percent of insurable capital investment and prorated on average annual tonnage.

In lieu of selecting a production rate based on overall maximum profits, or some other criterion which may differ from company to company, an incremental investment analysis is used to select the production rate using a grade of 0.10 ounce gold per ton, a recovery factor of 75 percent, a price of \$40 per ounce, and a minimum acceptable rate of return of 15 percent.

Using the discounted rate of return as a decision criterion in selecting alternatives, the time pattern for the required investments should be equivalent. In choosing a slow, intermediate, or rapid rate of production the economic life of the operation varies for a mineral deposit having a constant quantity of reserves of a particular grade. In this instance the number of annual cash flows is unequal, the number depending upon the years of economic life. To adjust for this, an assumption can be made for reinvestment of the original capital to generate a number of cash flows so that the total number of cash flows of the different alternatives equal that of the alternative having the longest economic life. The reinvestment opportunities and resultant earnings will vary for each company.

In this example it is assumed the original capital investment for the production rate alternatives having the shorter economic lives could earn an annual after-tax return of 10 percent after the economic life of the operation. These inflows are then combined with those derived from the operation in performing an incremental investment analysis. Using this data, the discounted-cash-flow method, and a minimum cutoff rate of return of 15 percent, an economic life of 9 to 13 years was approximated. These production rates, derived by use of the sensitivity analysis method, are then used in the probabilistic analysis method to determine risk involved due to the uncertainty of the data.

#### Results of the Sensitivity Analysis Method

As previously stated, mining system B and processing method B are selected as being best suited to exploit this deposit. In order that the financial analysis would reflect the uncertainty of the data, the analysis was made assuming a resource of 24, 32, and 45 million tons. The grade was varied from 0.06 to 0.10 ounce of gold per ton by increments of two. In addition, the price of gold was varied from \$35 to \$50 per ounce by increments of three. Other inputs to the computer program are the point estimates for the operating costs and capital investments at the various production rates. (Estimates for these inputs were obtained from the curves in figs. 14, 15, 19, and 20.) The output from the program simulation is a summary (table 19) which includes the input data used in the cash flow calculations and the results of these calculations such as depletion, depreciation, taxes, cash flow, and rate of return. Payback of capital investment occurs in the year the rate of return changes to a positive value.

TABLE 19. - Summary printout of sensitivity analysis using point estimates as input data

Period, years	Grade, ounce per ton	Recovery, percent	Price, dollars	Mining cost, dollars per ton	Processing cost, dollars per ton	Tonnage, thousands	Depletion, thousand dollars	Local tax, thousand dollars	State tax, thousand dollars	Federal tax, thousand dollars	Investment, thousand dollars <sup>1</sup>	Depreciation, thousand dollars	Cash flow, thousand dollars <sup>2</sup>	Rate of return, percent
1	0.000	0.000	0	0.000	0.000	0	0	82	0	0	21,630	2,217	-21,712	-
2	.060	.750	50	.174	.850	4,900	1,500	1,212	0	0	0	2,217	3,108	-
3	.060	.750	50	.174	.850	4,900	1,500	1,212	0	0	0	2,217	4,796	-
4	.060	.750	50	.174	.850	4,900	1,401	1,415	46	173	0	2,217	4,373	-
5	.060	.750	50	.174	.850	4,900	1,401	1,415	54	205	0	2,217	4,333	-
6	.060	.750	50	.174	.850	4,900	1,397	1,422	53	205	<sup>3</sup> 540	2,217	3,787	-
7	.060	.750	50	.174	.850	4,900	1,397	1,422	53	205	0	2,217	4,327	3.663
8	.060	.750	50	.174	.850	4,900	1,397	1,422	53	396	0	2,217	4,136	7.276
9	.060	.750	50	.174	.850	4,900	1,397	1,422	53	434	0	2,217	4,098	9.718
10	.060	.750	50	.174	.850	4,900	1,397	1,422	53	434	0	2,217	5,785	12.062

Salvage value = 0.

Cumulative cash flow = 17,032.

<sup>1</sup>Capital investment entered in the first year and discounted for 1 year with the operation beginning in the second year.

<sup>2</sup>The computer-printed values of the cash flows may differ slightly from the cash flow values which may be calculated using the printed parameters; this is due to scaling and rounding.

Working capital, a capital investment, is entered as a negative cash flow in the initial years and a positive cash flow in the last year. This sum appears in the printed cash flow summary but not in the investment column.

<sup>3</sup>Investment in sixth year required to replace some mining equipment.

The rate of return with the associated payback periods calculated using the cash inflows and outflows at the various production rates are shown in figure 24. The life of the operation at various production rates can be determined by dividing the total resources by the annual production rates. It can be noted that the deposit has very little potential at the current price of \$35 per ounce, an average grade of 0.06 ounce per ton, and 75-percent recovery

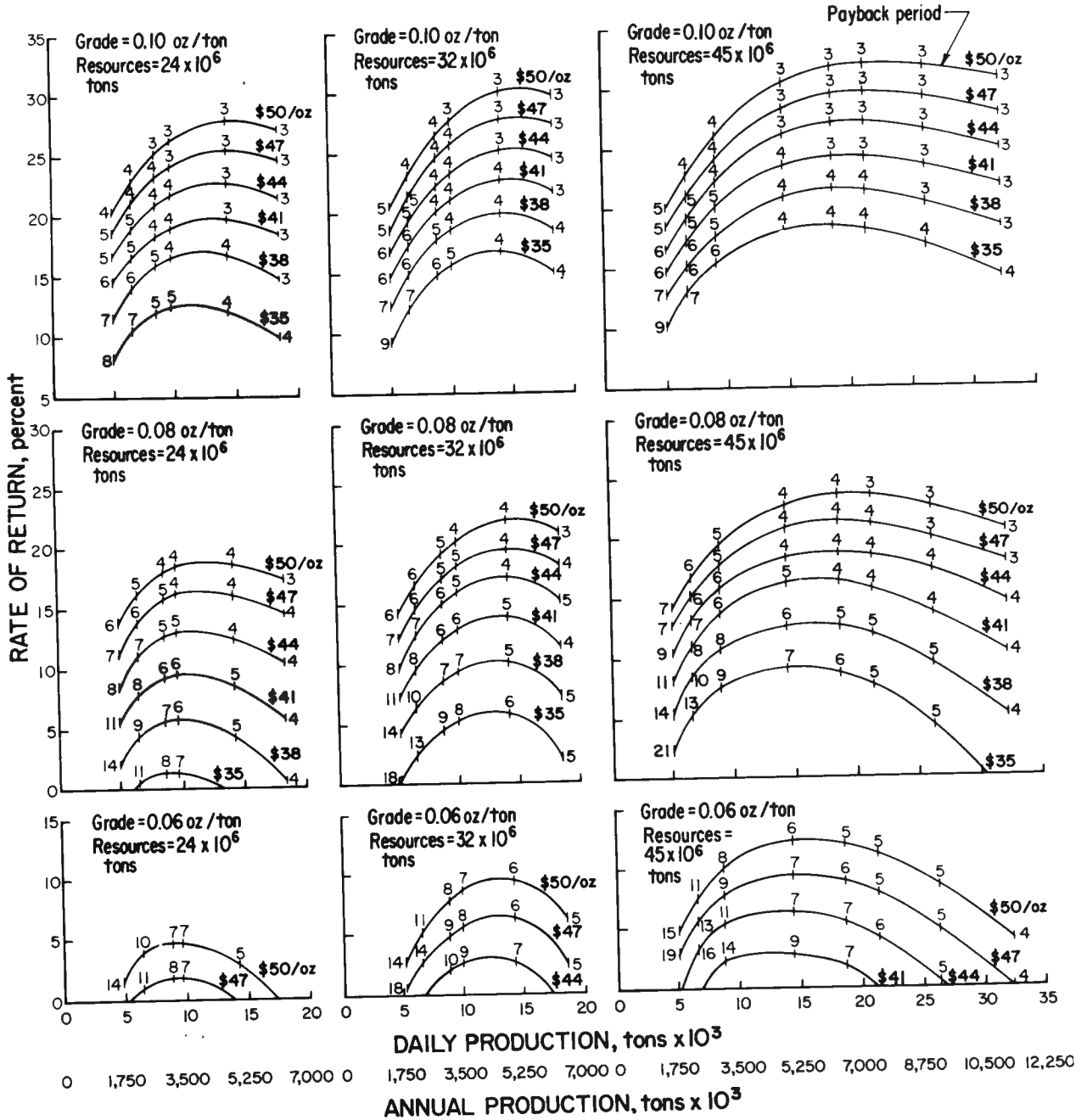


FIGURE 24. - Rate of Return and Payback Period at Various Grades, Value of Product, Amount of Resources, and Production Rates at 75-Percent Recovery.

at a resource of 24, 32, or 45 million tons. Even at the most likely resource of 24 million tons and an expected grade of 0.077 ounce per ton the deposit possesses little potential. The risk related to the length of the payback period, as noted by the numerical values along the curves, decreases as the production rate increases. Risk due to time and measured by payback period can be balanced against the opportunity to reinvest money at an equivalent or higher rate of return. If risk is not a factor, a company may select a longer payback period if the rate of return is greater and would occur for a longer period of time than return on any foreseeable alternative investment opportunity.

The risk involved is due not only to the length of time required to recover the initial investment, but also the uncertainty of the data. There is uncertainty in the estimates of resources, ore grade, and future price. Presented as illustrated, management can assess the benefits of an exploration project using judgment as to price and geologic inference to assign values of probable grade and reserves. Management also weighs the alternatives of producing at a particular grade and price and the effect different prices and production rates have on the rate of return.

The curves presented in figure 24 consist of a continuous series of points that are assumed to represent the optimum rate at which a particular plant of the specified capacity should operate. If long-term increased production is desired, a plant of similar design but increased capacity requiring more capital investment should be constructed to obtain continual operation at the optimum rate. On a short-term basis it may be more practical to operate below optimum rate initially, expanding toward the optimum rate during the economic life of the enterprise.

#### Results of the Probabilistic Analysis Method

The operation is evaluated using a 9-year and a 13-year economic life which was determined using incremental investment analysis to select the best alternative production rate. Parameter values and their probability of occurrence were estimated for grade, recovery, operating costs, production rate, and capital investments. These values, entered as point estimates, normal distributions, or density functions are shown on pages 52 and 53. The grade, recovery, operating costs, and annual production rate are entered as density functions, the capital investments as normal distributions, and working capital and price as point estimates.

In order to obtain an acceptable curve-fit to the cumulative distribution, constructed by the program from data representing a density function, it is necessary to use a minimum of five data points. Better curve definition is obtained through the use of additional intermediate data points which are estimated by graphically plotting and manually fitting a curve to the known data points. In defining a normal distribution only the anticipated minimum and maximum values are required, representing three standard deviations on either side of the mean. Entering data as a point estimate, normal distribution, or density function is at the discretion of the estimator and is a reflection of his confidence in the estimate.

Input parameter values for the probability analysis  
for a 9-year operation

Grade <sup>1</sup>		Recovery <sup>1</sup>	
Ounce per ton	Probability of occurrence	Rate, percent	Probability of occurrence
0.03	0.00	71	0.00
.04	.10	73	.15
.06	.80	75	.70
.08	.10	77	.15
.09	.00	79	.00
Mine operating cost <sup>1</sup>		Production <sup>1</sup>	
Dollars per ton	Probability of occurrence	Tons per year, thousands	Probability of occurrence
0.13	0.00	4,400	0.00
.15	.25	4,600	.10
.18	.50	4,900	.80
.20	.25	5,300	.10
.22	.00	5,400	.00
Mine capital investment <sup>2</sup> (5-year life), thousand dollars		Mill capital investment <sup>2</sup> (life), thousand dollars	
490 minimum value 590 maximum value		18,000 minimum value 22,000 maximum value	
Mine capital investment <sup>2</sup> (life), thousand dollars		Mill operating cost <sup>1</sup>	
		Dollars per ton	Probability of occurrence
980 minimum value		0.62	0.00
1,200 maximum value		.74	.10
		.85	.80
		.96	.10
		1.08	.00
Working capital <sup>3</sup>		Price <sup>4</sup>	
\$1,687,500		\$35 per ounce	

<sup>1</sup> Entered as a density function.

<sup>2</sup> Entered as a normal distribution.

<sup>3</sup> Entered as a point estimate.

<sup>4</sup> Entered as a point estimate and then incremented for a series of computer simulations.

Input parameter values for the probability analysis  
for a 13-year operation

Grade <sup>1</sup>		Recovery <sup>1</sup>	
Ounce per ton	Probability of occurrence	Rate, percent	Probability of occurrence
0.03	0.00	71	0.00
.04	.10	73	.15
.06	.80	75	.70
.08	.10	77	.15
.09	.00	79	.00
Mine operating cost <sup>1</sup>		Production <sup>1</sup>	
Dollars per ton	Probability of occurrence	Tons per year, thousands	Probability of occurrence
0.13	0.00	2,800	0.00
.16	.10	3,100	.10
.19	.80	3,400	.80
.22	.10	3,700	.10
.24	.00	3,800	.00
Mine capital investment <sup>2</sup> (7-year life), thousand dollars		Mill capital investment <sup>2</sup> (life), thousand dollars	
396 minimum value 484 maximum value		13,620 minimum value 16,770 maximum value	
Mine capital investment <sup>2</sup> (life), thousand dollars		Mill operating cost <sup>1</sup>	
		Dollars per ton	Probability of occurrence
850 minimum value 1,040 maximum value		0.66	0.00
		.83	.10
		1.00	.80
		1.16	.10
		1.29	.00
Working capital <sup>3</sup>		Price <sup>4</sup>	
\$1,182,600		\$35 per ounce	

<sup>1</sup> Entered as a density function.

<sup>2</sup> Entered as a normal distribution.

<sup>3</sup> Entered as a point estimate.

<sup>4</sup> Entered as a point estimate and then incremented for a series of computer simulations.

This input data is used to simulate a 9-year and a 13-year mining operation. One simulation in the computer program corresponds to a complete operation of a specific life (that is, 9 or 13 years).

The computer program output includes a plot of each data set entered as a density function and a superimposed plot of the resultant cumulative distribution curve. A summary listing of the results of each simulation is optional. The final output is a probability histogram which summarized the rates of return and their corresponding probability of occurrence. The summary, table 20, includes the input data used in the cash flow calculations and the results of these calculations, such as depletion, depreciation, taxes, cash flow, and rate of return for each year in the simulation. Note the values that were randomly selected for parameters which were entered as normal distributions and density functions. The frequency distribution of rates of return and corresponding probability of occurrence are printed only when the required number of simulations have been completed. Figure 25 contains the output for 100 simulations of a 9-year and a 13-year operation; examples 1 and 3, 9-year and 13-year operations, respectively, were obtained using the data listed on pages 52 and 53. The results in examples 2 and 4, 9-year and 13-year operations, respectively, reflect a 20-percent decrease in the span between the extreme values of the input data represented by normal distributions and density functions.

In the evaluation of a mineral deposit shortening the span may be accomplished by obtaining more detailed information on the deposit. For example, through further drilling more assay data with values clustered about the mean or mode may have been obtained. This resulted in the estimator having greater confidence than before that these values approximate the average grade of the deposit. This confidence is reflected in the analysis by the estimator increasing the probability of these values occurring and possibly decreasing the range between the extreme values. This increased confidence can be expressed similarly for the other parameters.

In a risk analysis, it is recommended that the number of simulations be increased until the mean and extreme values of the rate of return histogram begin to stabilize (fig. 26). These rate of return distributions resulted from the use of identical input data for a 9-year operation but a different number of simulations. Example 1 resulted from 100 simulations; example 2, from 250; example 3, from 500; and example 4, from 1,000.

Figure 27 shows the results of this analysis calculated at different prices for the recovered product using the input data listed on page 52. In example 1, a price of \$44 per ounce was used. Zero percent rate of return occurs most frequently, with all the returns being less than 10 percent. At a price of \$47 per ounce, used in example 2, a 5-percent rate of return occurs most frequently with a high probability of obtaining a zero percent return. The results in example 3 were obtained using a price of \$50 per ounce which indicated a 44-percent chance of receiving a 9-percent or higher rate of return. A price of \$56 per ounce was used in example 4 in which the range of rates of return is 6 to 18 percent, with 15 percent occurring most frequently. There is a 49-percent probability of obtaining a return of 13 percent or higher. A price of \$35 per ounce was not included in this illustration since it resulted in a zero percent rate of return.

TABLE 40. - Summary printout of probabilistic analysis using randomly selected values as input data

Period, years	Grade, ounce per ton	Recovery, percent	Price, dollars	Mining cost, dollars per ton	Processing cost, dollars per ton	Tonnage, thousands	Depletion, thousand dollars	Local tax, thousand dollars	State tax, thousand dollars	Federal tax, thousand dollars	Investment, thousand dollars <sup>1</sup>	Depreciation, thousand dollars	Cash flow, thousand dollars <sup>2</sup>	Rate of return, percent
1	0.000	0.000	0	0.000	0.000	0	0	81	0	0	21,326	2,187	-21,407	-
2	.061	.747	50	.168	.892	4,900	1,462	1,204	0	0	0	2,187	2,998	-
3	.060	.747	50	.172	.802	4,988	1,618	1,235	0	0	0	2,187	5,003	-
4	.056	.742	50	.178	.847	4,915	1,021	1,281	32	116	0	2,187	3,676	-
5	.058	.748	50	.165	.782	4,850	1,386	1,376	54	207	0	2,187	4,294	-
6	.055	.734	50	.164	.813	5,086	1,095	1,309	38	141	<sup>3</sup> 531	2,184	3,259	-
7	.049	.743	50	.178	.847	4,911	484	1,111	6	9	0	2,184	2,763	0.831
8	.057	.759	50	.155	.856	4,768	1,222	1,342	45	327	0	2,184	3,851	4.933
9	.051	.764	50	.163	.855	4,938	783	1,210	22	172	0	2,184	3,167	7.276
10	.057	.752	50	.168	.862	4,959	1,204	1,353	43	350	0	2,184	5,469	10.011

Salvage value = -0.

Cumulative cash flow = 13,072.

<sup>1</sup>Capital investment entered in the first year and discounted for 1 year with the operation beginning in the second year.

<sup>2</sup>The computer-printed values of the cash flows may differ slightly from the cash flow values which may be calculated using the printed parameters; this is due to scaling and rounding.

Working capital, a capital investment, is entered as a negative cash flow in the initial years and a positive cash flow in the last year. This sum appears in the printed cash flow summary but not in the investment column.

<sup>3</sup>Investment in sixth year required to replace some mining equipment.

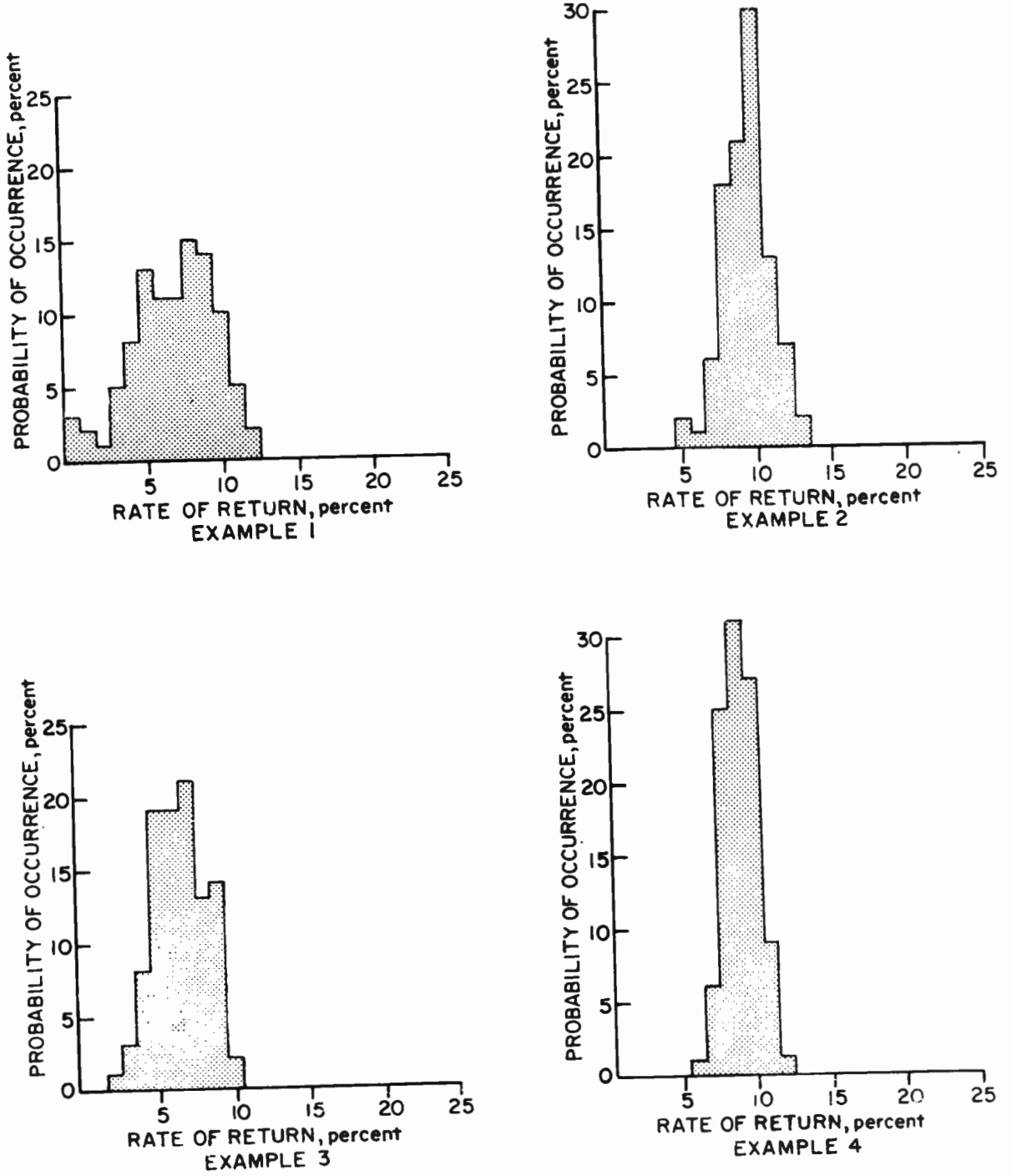


FIGURE 25. - Comparison of Rate of Return Distributions Illustrating the Effect of Data Span Reduction.

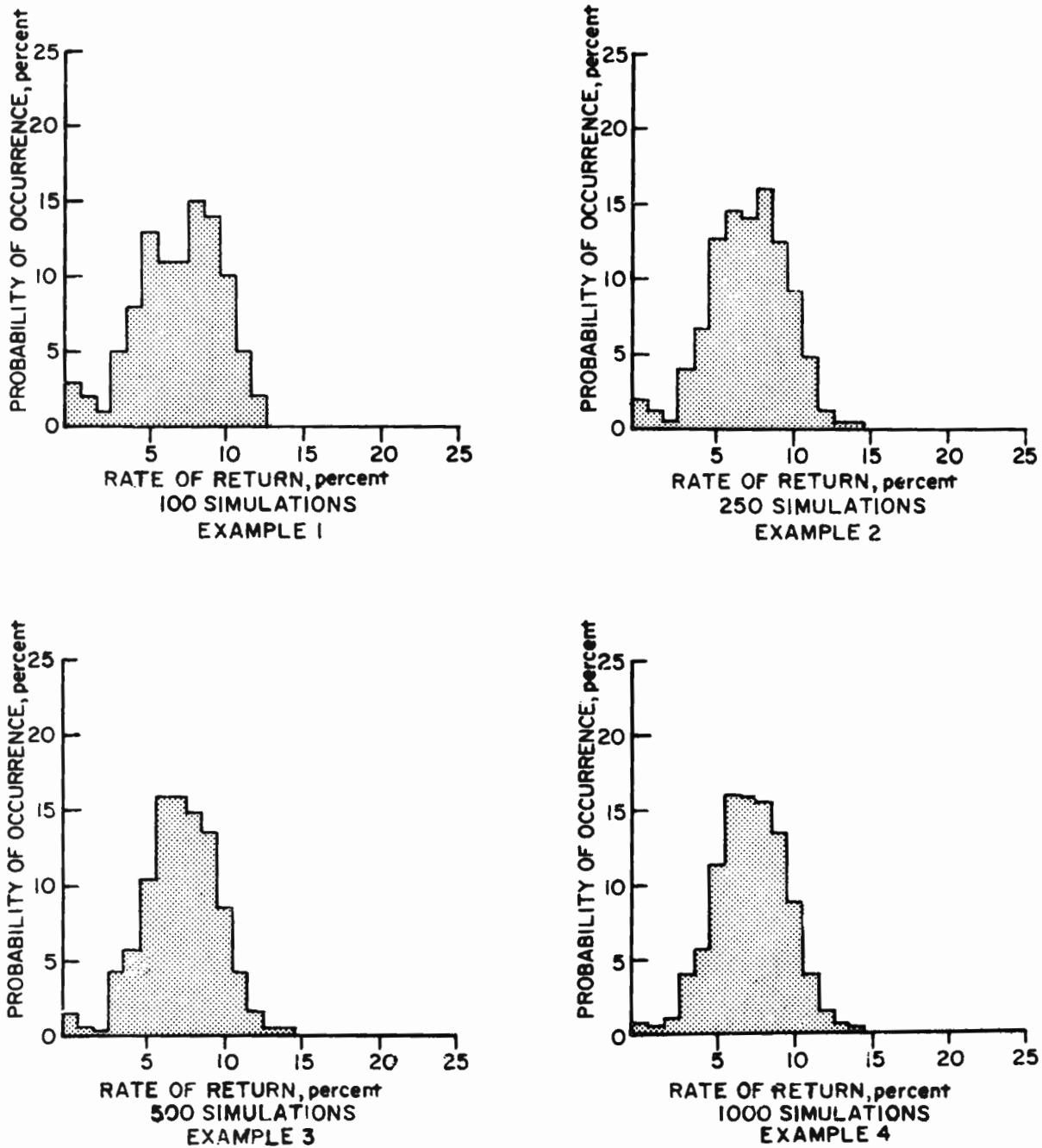


FIGURE 26. - Comparison of Rate of Return Distributions Illustrating an Increasing Number of Simulations.

Using these results as a measure, the deposit has no potential at \$35 per ounce, assuming a 9-year life and a resource of 45 million tons. Even at the price of \$56 per ounce there is only a 49-percent probability that the return would be 13 percent or higher.

Results of the 13-year operation were somewhat less favorable.

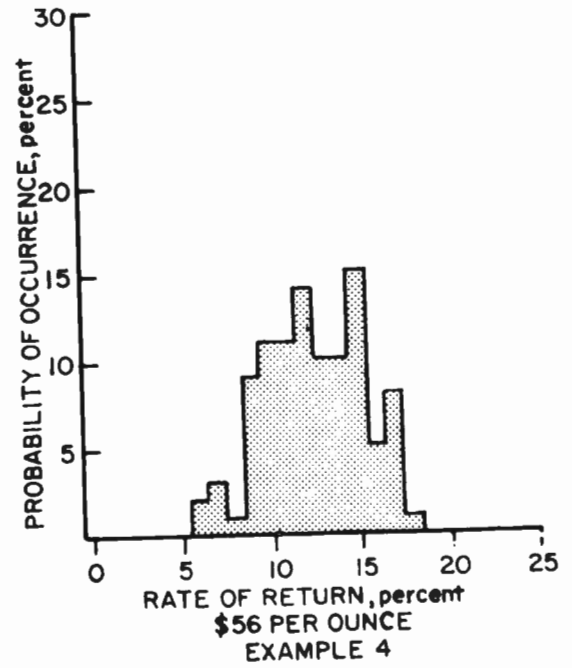
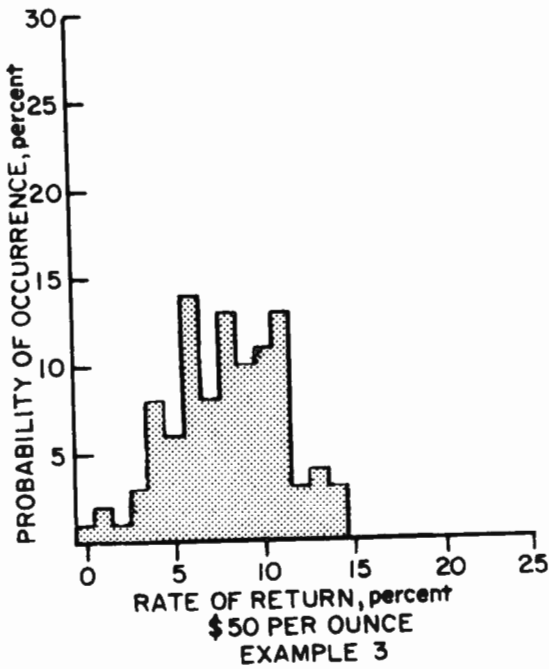
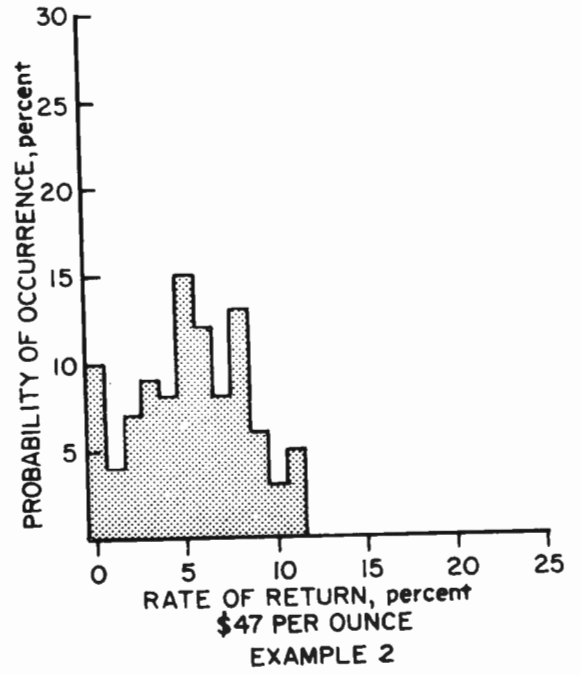
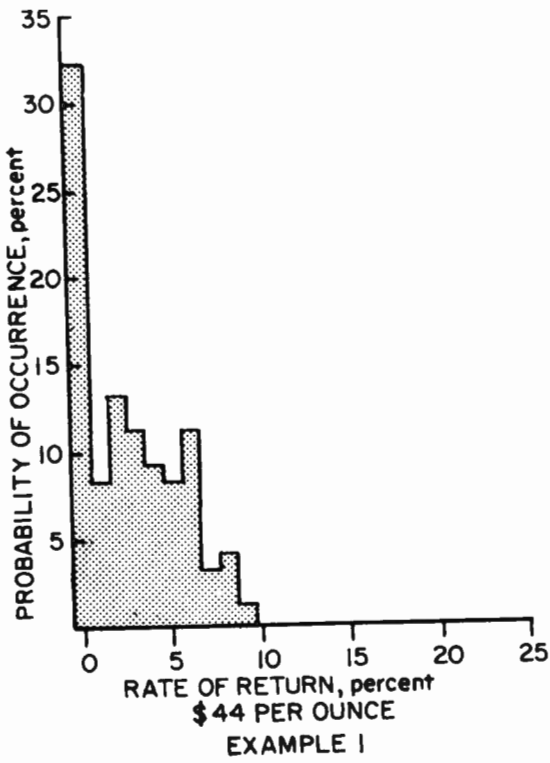


FIGURE 27. - Rate of Return Distributions Illustrating Change Due to Price Increase.

### Summary of Results

The sensitivity analysis approach, using estimated single values, is probably the most common method used in the evaluation of a financial venture. This method determines the relative sensitivity of a particular parameter's value and indicates those parameters which have the most influence on the measuring criterion (that is, rate of return, net present value, etc.). This enables the evaluator to concentrate his efforts on refining those estimated values of parameters having the greatest effect on the rate of return. In using single-value estimates, the estimator is aware that these values could vary due to basic uncertainties in the data. The effect of these uncertainties can be determined by performing numerous simulations using various parameter values. The result, however, is still a single rate of return providing no indication of risk nor the degree of interaction between parameter values. It does not indicate the likelihood of obtaining this particular rate of return.

The principle weakness of sensitivity analysis, failure to provide a probability of occurrence for the rate of return, is overcome by the probabilistic analysis method. This method, based on statistical theory, provides an indication of the risk involved in an investment due to uncertainty in the input data. This uncertainty is incorporated in the analysis by estimating probability of value occurrence for the input parameters. Results of this analysis provide the most probable rate of return and a measure of the dispersion about this most probable value. Associated with each value of rate of return is its probability of occurrence.

In the final analysis, any evaluation technique is only as good as the estimates of its input parameters and must be used in conjunction with sound managerial judgment. These techniques only provide management with tools to aid in the decision-making process.

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## APPENDIX A.--COMPUTER PRINTOUT OF COMPILER SHEET

A PROBABILISTIC MODEL FOR FINANCIALLY  
EVALUATING A PROPOSED MINING INVESTMENT

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\*\*\*\*\*

INPUT TO THIS MODEL CAN BE ANY COMBINATION OF POINT ESTIMATES, NORMAL DISTRIBUTIONS AND/OR DENSITY FUNCTIONS. THE SIMULATOR CAN BE USED FOR EITHER SENSITIVITY OR PROBABILISTIC RISK ANALYSIS.

\*\*\*\*\*

## INPUT DATA REQUIREMENTS

## OPTION CARD - ONE REQUIRED FOR EACH SET OF SIMULATIONS

COL 1- 2 LIFE OF OPERATION IN YEARS (25 YEAR MAX.)  
BLANK = END OF JOB

COL 5- 8 NUMBER OF SIMULATIONS DESIRED

COL 11 METHOD OF DEPRECIATION OPTION  
BLANK = STRAIGHT LINE  
1 = DOUBLE DEQLINING BALANCE  
2 = SUM OF YEARS DIGITS

COL 14-23 REAL ESTATE VALUE

COL 26-29 NUMBER OF LIST SUMMARIES DESIRED

COL 32 OPTION TO CLEAR OR RETAIN PARAMETER VALUES AT END OF SET OF SIMULATIONS  
BLANK = CLEAR VALUES  
1 = RETAIN VALUES

COL 35 INVESTMENT TAX CREDIT OPTION  
BLANK = NO  
1 = YES

COL 77 BLANK

COL 78 PLUS SIGN

COL 79 PERIOD

COL 80 ASTERISK

PARAMETER CARDS - A MAXIMUM OF 20 INPUT PARAMETERS CAN BE ENTERED FOR EACH YEAR. FOR THE FIRST OPTION OR SET OF SIMULATIONS ALL INPUT PARAMETERS HAVE INITIAL VALUES OF ZERO. PARAMETER VALUES ASSIGNED DURING ANY SET OF SIMULATIONS MAY BE OPTIONALLY RETAINED FOR SUBSEQUENT SIMULATIONS.

THE LAST PARAMETER ENTRY IN EACH OPTION OR SET OF SIMULATIONS MUST BE FOLLOWED BY A BLANK CARD TO BEGIN THE SIMULATION PHASE. THIS IN TURN IS FOLLOWED BY ANOTHER OPTION CARD.

COL 1- 2 CATEGORY  
 BLANK = BEGIN SIMULATION  
 1 = GRADE  
 2 = RECOVERY  
 3 = PRICE  
 4 = TONNAGE  
 5- 7 = CAPITAL INVESTMENT - MINING  
 8- 9 = CAPITAL INVESTMENT - PROCESSING  
 10 = WORKING CAPITAL  
 11-15 = OPERATING COST - MINING  
 16-20 = OPERATING COST - PROCESSING  
 COL 5-44 ALPHABETIC DESCRIPTION OF CATEGORY  
 COL 45-46 FIRST YEAR OF ESTIMATE  
 COL 49-50 LAST YEAR OF ESTIMATE  
 COL 53-54 NUMBER OF DATA POINTS  
 1 = POINT ESTIMATE  
 2 = NORMAL DISTRIBUTION  
 3-25 = DENSITY FUNCTION - REQUIRES 3-25 X-Y CARDS  
 COL 57-58 YEARS DEPRECIATED (CAPITAL INVESTMENT ONLY)  
 COL 61-70 POINT ESTIMATE VALUE OR MINIMUM VALUE FOR  
 NORMAL DISTRIBUTION  
 COL 71-80 MAXIMUM VALUE FOR NORMAL DISTRIBUTION

X-Y CARDS - ONE CARD REQUIRED FOR EACH (X,Y) PAIR. IT IS RECOMMENDED THAT DENSITY FUNCTIONS BE DESCRIBED WITH AT LEAST FIVE (X,Y) POINTS, THREE OF WHICH MUST HAVE POSITIVE Y-VALUES.

COL 1-10 X-VALUE ON DENSITY FUNCTION  
 COL 11-20 Y-VALUE ON DENSITY FUNCTION  
 THE SUMMATION OF ALL THE Y-VALUES USED IN DESCRIBING THE FUNCTION MUST EQUAL ONE.

#### OUTPUT LIST SUMMARY

VALUES FOR TONNAGE THRU CASH FLOW ARE IN THOUSANDS

\*\*\*\*\*

#### LIST OF VARIABLES

ASTR AN ASTERISK USED IN PLOTTING  
 ATAX SUMMATION OF LOCAL TAXES  
 BLNK A BLANK USED IN PLOTTING  
 CARY TAX LOSS CARRY FORWARD  
 CASH CASH FLOW FOR A PARTICULAR YEAR  
 COEF COEFFICIENT VALUES  
 FOR A POINT ESTIMATE THE FIRST COEFFICIENT IS THE POINT ESTIMATE VALUE AND THE SECOND COEFFICIENT IS ZERO. IN A NORMAL DISTRIBUTION

C THE FIRST COEFFICIENT IS THE MINIMUM VALUE  
 C AND THE SECOND COEFFICIENT IS THE MAXIMUM  
 C VALUE. IN A DENSITY FUNCTION THE FIRST AND  
 C SECOND COEFFICIENTS ARE CONSTANTS IN THE  
 C CUMULATIVE PROBABILITY CURVE EQUATION.  
 C  
 C CRDT INVESTMENT TAX CREDIT  
 C CUMI CUMULATIVE MINING INVESTMENT  
 C CUPR CUMULATIVE PROCESSING INVESTMENT  
 C CUSH CUMULATIVE CASH FLOW  
 C CUWC CUMULATIVE WORKING CAPITAL  
 C DEPL DEPLETION  
 C DEPR DEPRECIATION  
 C FTAX FEDERAL TAX  
 C GROS GROSS REVENUE  
 C ITC INVESTMENT TAX CREDIT OPTION  
 C L NUMBER OF YEARS OF DEPRECIATION FOR A CAPITAL  
 C INVESTMENT  
 C LIFE LIFE OF THE OPERATION  
 C LS NUMBER OF LIST SUMMARIES DESIRED  
 C METH METHOD OF DEPRECIATION  
 C N NUMBER OF DATA POINTS  
 C NAME ALPHABETIC DESCRIPTION OF CATEGORY  
 C NCAT CATEGORY NUMBER  
 C NFYR FROM-YEAR OF PARAMETER  
 C NS NUMBER OF SIMULATIONS DESIRED  
 C NTYR TO-YEAR OF PARAMETER  
 C PCT ALLOWABLE ITC PERCENTAGE  
 C PERD A PERIOD USED IN PLOTTING  
 C PLUS A PLUS SIGN USED IN PLOTTING  
 C PROP PROPERTY VALUE  
 C RAND RANDOM NUMBER GENERATOR SUBROUTINE  
 C RATE RATE OF RETURN SUBROUTINE  
 C RR RATE OF RETURN  
 C SLVG SALVAGE VALUE  
 C STAX STATE TAX  
 C STDV STANDARD DEVIATION  
 C TINC TAXABLE INCOME  
 C VALU VALUES DETERMINED FOR USE IN THE SIMULATION  
 C SUBSCRIPTS CORRESPOND TO CATEGORIES LISTED  
 C UNDER PARAMETER CARDS ABOVE  
 C X(1) POINT ESTIMATE VALUE OR MINIMUM VALUE FOR  
 C A NORMAL DISTRIBUTION  
 C Y(1) MAXIMUM VALUE FOR A NORMAL DISTRIBUTION  
 C YCAL THE CALCULATED "Y" VALUES FOR THE CUMULATIVE  
 C PROBABILITY CURVE  
 C YEAR NUMBER OF YEARS A PARTICULAR INVESTMENT  
 C IS DEPRECIATED  
 C YRAN RANDOM VALUE FROM RANDOM NUMBER GENERATOR  
 C YVEL TAX RATE OR MILL LEVY

C\*\*\*\*\*  
 C\*\*\*\*\*  
 C

DIMENSION X(25),Y(25),YCAL(25),WT(25),CARY(25),CRDT(25),  
 1 CASH(25),VALU(20),SUMY(2),R(2,4),PT(119),DEPR(2,25),

```

2   COEF(20,25,2),YEAR(5,25),NAME(20)
   EQUIVALENCE (X(1),CASH(1)),(Y(1),CARY(1)),(YCAL(1),
1   CRDT(1)),(WT(1),VALU(1))
   COMMON IA1(30),IA2(30),IA3(30),POW(30)
   IR=13
   NRAN=1
5   DO 30 J=1,25
     DO 10 I=1,20
       COEF(I,J,1)=0.0
       COEF(I,J,2)=0.0
10  CONTINUE
     DO 20 I=1,5
       YEAR(I,J)=0.0
20  CONTINUE
30  CONTINUE
C*****
C   READ OPTION CARD
C*****
40  READ 50,LIFE,NS,METH,PROP,LS,KLER,ITC,BLNK,PLUS,PERD,ASTR
50  FORMAT(I2,2X,I4,2X,I1,2X,F10.0,2X,I4,2X,I1,2X,I1,41X,4A1)
   IF(LIFE) 60,60,70
60  STOP
C*****
C   PRINT OPTIONS
C*****
70  PRINT 80,LIFE,PROP,NS
80  FORMAT(1H1,17HLIST OF OPTIONS--//13H LIFE OF THE
1   11HOPERATION--//I3,6H YEARS//17H PROPERTY VALUE--
2   F11.0,6H DOLLARS//24H NUMBER OF SIMULATIONS--//I5//
3   25H METHOD OF DEPRECIATION--
   IF(METH=1) 90,110,130
90  PRINT 100
100 FORMAT(1H+,25X,13HSTRAIGHT LINE)
   GO TO 150
110 PRINT 120
120 FORMAT(1H+,25X,24HDOUBLE DECLINING BALANCE)
   GO TO 150
130 PRINT 140
140 FORMAT(1H+,25X,19HSUM OF YEARS DIGITS)
150 IF(ITC) 300,300,160
160 PRINT 170
170 FORMAT(1H0,21HINVESTMENT TAX CREDIT)
;*****
;   READ PARAMETER CARD
;*****
300 READ 310,NCAT,NAME,NFYR,NTYR,N,L,X(1),Y(1)
310 FORMAT(I2,2X,20A2,4(I2,2X),2F10.0)
   IF(NCAT) 60,800,320
;*****
;   DETERMINE COEFFICIENTS FOR PT, ESTIMATE OR NORMAL DISTRIBUTION
;*****
320 DO 370 J=NFYR,NTYR
     LL=NCAT-4
     IF(LL) 350,350,330
330   IF(LL=5) 340,340,350

```

```

340     YEAR(LL,J)=L
350     IF(N=2) 360,360,380
360     COEF(NCAT,J,1)=X(1)
        COEF(NCAT,J,2)=Y(1)
370 CONTINUE
    GO TO 300
C*****
C  LINEAR REGRESSION TO COMPUTE COEFFICIENTS FOR DENSITY FUNCTION
C*****
380 READ 390,(X(I),Y(I),I=1,N)
390 FORMAT(2F10.0)
    Z=0.0
    DO 430 I=1,N
        Z=Y(I)+Z
        IF(Z) 420,420,400
400     IF(Z=1.0) 410,420,420
410     YCAL(I)=ALOG(Z/(1.0-Z))
        WT(I)=(Z+(1.0-Z))**2
        GO TO 430
420     YCAL(I)=0.0
        WT(I)=0.0
430 CONTINUE
    SUMY(1)=0.0
    SUMY(2)=0.0
    R(1,1)=0.0
    R(1,2)=0.0
    R(2,2)=0.0
    DO 440 I=1,N
        SUMY(1)=SUMY(1)+YCAL(I)+WT(I)
        SUMY(2)=SUMY(2)+YCAL(I)+WT(I)*X(I)
        R(1,1)=R(1,1)+WT(I)
        R(1,2)=R(1,2)+WT(I)*X(I)
        R(2,1)=R(1,2)
        R(2,2)=R(2,2)+WT(I)*X(I)*X(I)
440 CONTINUE
    R(1,3)=1.0
    R(1,4)=0.0
    R(2,3)=0.0
    R(2,4)=1.0
    DO 490 I=1,2
        LL=I+1
        DO 450 J=LL,4
            R(I,J)=R(I,J)/R(I,I)
450     CONTINUE
        DO 480 J=1,2
            IF(J=I) 460,480,460
460     DO 470 K=LL,4
            R(J,K)=R(J,K)-R(J,I)*R(I,K)
470     CONTINUE
480     CONTINUE
490 CONTINUE
    Z=R(1,3)+SUMY(1)+R(1,4)+SUMY(2)
    ZN=R(2,3)+SUMY(1)+R(2,4)+SUMY(2)
    DO 500 J=NFYR,NTYR
        COEF(NCAT,J,2)=Z

```

```
COEF(NCAT,J,1)=ZN
```

```
500 CONTINUE
```

```
DO 510 I=1,N
```

```
Z=EXP(COEF(NCAT,NFYR,2)+COEF(NCAT,NFYR,1)*X(I))
```

```
YCAL(I)=Z/(1.0+Z)
```

```
510 CONTINUE
```

```
C*****
```

```
C INSTRUCTIONS FOR DOUBLE CURVE GRAPH
```

```
C*****
```

```
Z=X(1)
```

```
ZN=X(N)
```

```
PRINT 520,NAME
```

```
520 FORMAT(1H1,45X,20A2)
```

```
DO 530 I=1,N
```

```
X(I)=X(I)-Z
```

```
530 CONTINUE
```

```
SY=0.0
```

```
DO 550 I=1,N
```

```
IF(SY-YCAL(I)) 540,550,550
```

```
540 SY=YCAL(I)
```

```
550 CONTINUE
```

```
SX=118.0/X(N)
```

```
SY=50.0/SY
```

```
DO 660 I=1,51
```

```
PT(1)=PERD
```

```
DO 580 J=2,119
```

```
IF(I=51) 570,560,560
```

```
560 PT(J)=PERD
```

```
GO TO 580
```

```
570 PT(J)=BLNK
```

```
580 CONTINUE
```

```
DO 640 J=1,N
```

```
JI=X(J)*SX+1.5
```

```
JS=YCAL(J)*SY+1.5
```

```
IF(JS) 590,590,600
```

```
590 JS=1
```

```
600 JJ=52-JS
```

```
IF(JJ=I) 620,610,620
```

```
610 PT(JI)=PLUS
```

```
620 JS=Y(J)*SY+1.5
```

```
JJ=52-JS
```

```
IF(JJ=I) 640,630,640
```

```
630 PT(JI)=ASTR
```

```
640 CONTINUE
```

```
PRINT 650,PT
```

```
650 FORMAT(1X,119A1)
```

```
660 CONTINUE
```

```
PRINT 670,Z,ZN,SX,SY
```

```
670 FORMAT(1H ,9HX(MIN) = ,F17.5,5X,9HX(MAX) = ,F17.5,5X,
```

```
1 10HX SCALE = ,F12.5,5X,10HY SCALE = ,F12.5)
```

```
GO TO 300
```

```
;*****
```

```
; DETERMINE RANDOM VALUES FOR SIMULATION
```

```
;*****
```

```
800 DO 810 I=1,119
```

```

      PT(I)=0.0
810 CONTINUE
      PCT=0.07
      IF(LIFE=7) 820,820,860
820 GO TO (830,830,830,840,840,850,850),LIFE
830 PCT=0.0
      GO TO 860
840 PCT=0.023333
      GO TO 860
850 PCT=0.046667
860 ZN=0.0
      DO 2110 LI=1,NS
          SLVG=0.0
          DO 870 J=1,LIFE
              DEPR(1,J)=0.0
              DEPR(2,J)=0.0
              CARY(J)=0.0
870 CONTINUE
          CUSH=0.0
          CUMI=0.0
          CUPR=0.0
          CUWC=0.0
          DO 1960 J=1,LIFE
              DO 930 I=1,20
                  IF(COEF(I,J,2)) 910,880,890
C
C POINT ESTIMATE
C
880 VALU(I)=COEF(I,J,1)
      GO TO 930
C
C NORMAL DISTRIBUTION
C
890 STDV=(COEF(I,J,2)-COEF(I,J,1))/6.0
      Z=0.0
      DO 900 K=1,12
          CALL RAND(IR,NRAN,YRAN)
          Z=Z+YRAN
900 CONTINUE
      VALU(I)=(Z-6.0)+STDV+(COEF(I,J,1)+COEF(I,J,2))/2.0
      GO TO 930
C
C DENSITY FUNCTION
C
910 CALL RAND(IR,NRAN,YRAN)
920 VALU(I)=(-ALOG(1.0/YRAN-1.0)-COEF(I,J,2))/COEF(I,J,1)
      IF(VALU(I)) 910,910,930
930 CONTINUE
C*****
C DEPRECIATION SCHEDULES
C*****
      DO 1100 I=1,5
          XX=YEAR(I,J)
          IF(XX) 1100,1100,1000
1000 HOLD=VALU(I+4)

```

```

        SLVG=SLVG+HOLD
        JJ=1+I/4
        JI=XX
        JI=J+JI-1
        IF(LIFE=JI) 1010,1020,1020
1010   JI=LIFE
1020   IF(METH=1) 1030,1050,1070

```

```

C
C
C   STRAIGHT LINE METHOD

```

```

1030   HOLD=HOLD/XX
        DO 1040 K=J,JI
            DEPR(JJ,K)=DEPR(JJ,K)+HOLD
            SLVG=SLVG-HOLD
1040   CONTINUE
        GO TO 1100

```

```

C
C
C   DOUBLE DECLINING BALANCE METHOD

```

```

1050   DBL=2.0/XX
        DO 1060 K=J,JI
            WORK=DBL*HOLD
            DEPR(JJ,K)=DEPR(JJ,K)+WORK
            SLVG=SLVG-WORK
            HOLD=HOLD-WORK
1060   CONTINUE
        GO TO 1100

```

```

C
C
C   SUM OF YEARS DIGITS METHOD

```

```

1070   WORK=0.0
        N=XX
        DO 1080 K=1,N
            XX=K
            WORK=WORK+XX
1080   CONTINUE
        DO 1090 K=J,JI
            XX=JI-K+1
            XX=XX*HOLD/WORK
            DEPR(JJ,K)=DEPR(JJ,K)+XX
            SLVG=SLVG-XX
1090   CONTINUE
1100   CONTINUE

```

```

)*****
) MONTANA TAX ROUTINE -- REFERENCE MONTANA STATE TAX COMMISSION
)*****

```

```

        VALU(5)=VALU(5)+VALU(6)+VALU(7)
        VALU(8)=VALU(8)+VALU(9)
        CRDT(J)=PCT*(VALU(5)+VALU(8))
        CUMI=CUMI+VALU(5)
        CUPR=CUPR+VALU(8)
        CUWC=CUWC+VALU(10)
        COST=0.0
        DO 1200 I=11,20
            COST=COST+VALU(I)

```

```

1200          CONTINUE
              COST=COST*VALU(4)
              GROS=VALU(1)*VALU(2)*VALU(3)*VALU(4)
              YVEL=0.10811

C
C          REAL ESTATE TAX
C
              ATAX=PROP*YVEL

C
C          METALLIFEROUS MINES TAX
C
              WORK=GROS
              HOLD=WORK-500000.
              IF(HOLD) 1220,1220,1210
1210          ATAX=ATAX+0.0125*HOLD
              WORK=500000.
1220          HOLD=WORK-400000.
              IF(HOLD) 1240,1240,1230
1230          ATAX=ATAX+0.01*HOLD
              WORK=400000.
1240          HOLD=WORK-250000.
              IF(HOLD) 1260,1260,1250
1250          ATAX=ATAX+0.0075*HOLD
              WORK=250000.
1260          HOLD=WORK-100000.
              IF(HOLD) 1280,1280,1270
1270          ATAX=ATAX+0.005*HOLD

C
C          PERSONAL PROPERTY TAX
C
1280          XX=0.12
              ATAX=ATAX+XX*CUMI*YVEL
              HOLD=ATAX

C
C          IMPROVEMENT TAX
C
              IF(J=3) 1290,1290,1300
1290          XX=0.028
1300          ATAX=ATAX+XX*CUPR*YVEL

C
C          PRODUCTION LEVY
C
              WORK=GROS-COST-0.024*CUPR-DEPR(1,J)
              IF(WORK) 1410,1410,1400
1400          ATAX=ATAX+WORK*YVEL

C
C          PERCENTAGE DEPLETION ALLOWANCE
C
1410          DEPL=0
              TINC=GROS-DEPR(1,J)-DEPR(2,J)-COST-ATAX
              IF(TINC) 1450,1450,1420
1420          IF(0.5*TINC-0.15*GROS) 1430,1440,1440
1430          DEPL=0.5*TINC
              GO TO 1450
1440          DEPL=0.15*GROS

```

```

1450      TINC=TINC-DEPL
C
C      CORPORATION LICENSE TAX
C
      HOLD=(GROS-HOLD-DEPL)*0.045
      IF(HOLD) 1470,1470,1460
1460      ATAX=ATAX+HOLD
      TINC=TINC-HOLD
C
C      UNUSED TAX LOSS CARRY-FORWARD
C
1470      WORK=0.0
      IF(TINC) 1670,1680,1475
1475      IF(J-1) 1530,1530,1480
1480      JI=1
      JJ=J-1
      IF(J-6) 1500,1500,1490
1490      JI=J-5
1500      DO 1530 I=JI,JJ
      IF(TINC-CARY(I)) 1510,1510,1520
1510      CARY(I)=CARY(I)-TINC
      GO TO 1680
1520      TINC=TINC-CARY(I)
      WORK=WORK+CARY(I)
      CARY(I)=0.0
1530      CONTINUE
C
C      MONTANA STATE TAX
C
      STAX=0.055*TINC
      TINC=TINC-STAX
C
C      FEDERAL INCOME TAX
C
      IF(TINC=25000.) 1540,1540,1550
1540      FTAX=0.22*TINC
      GO TO 1560
1550      FTAX=5500.+0.48*(TINC-25000.)
C
C      INVESTMENT TAX CREDIT
C
1560      IF(ITC) 1570,1800,1570
1570      JI=1
      IF(J-7) 1590,1590,1580
1580      JI=J-6
1590      XX=FTAX
      IF(XX=25000.) 1610,1610,1600
1600      XX=25000.+(XX-25000.)/2.0
1610      DO 1640 I=JI,J
      IF(XX-CRDT(I)) 1620,1620,1630
1620      CRDT(I)=CRDT(I)-XX
      FTAX=(FTAX-25000.)/2.0
      IF(FTAX) 1690,1800,1800
1630      XX=XX-CRDT(I)
      CRDT(I)=0.

```

```

1640          CONTINUE
              IF(FTAX=25000.) 1660,1660,1650
1650          XX=XX+(FTAX=25000.)/2.0
1660          FTAX=XX
              GO TO 1800

C
C          TAX LOSS CARRY-FORWARD
C
1670          CARY(J)=-TINC
1680          STAX=0.0
1690          FTAX=0.0
C*****
C  COMPUTE CASH FLOW
C*****
1800          CASH(J)=TINC+DEPR(1,J)+DEPR(2,J)+DEPL-FTAX-
              1          VALU(5)-VALU(8)-VALU(10)+WORK
              IF(J=1) 1810,1810,1820
1810          CASH(J)=CASH(J)-PROP
1820          IF(LIFE=J) 1830,1830,1900
1830          CASH(J)=CASH(J)+SLVG+CUWC
C*****
C  LIST YEARLY SUMMARY
C*****
1900          IF(LS) 1960,1960,1910
1910          CALL RATE(CASH,RR,J)
              IF(J=1) 1920,1920,1940
1920          PRINT 1930
1930          FORMAT(1H1,35HYEAR GRADE RECOV PRICE MINCOST
              1          40H PRODCOST TONNAGE DEPLET ATAX STAX
              2          41H FTAX INVEST DEPREC CSHFLO RETURN)
1940          VALU(4)=VALU(4)/1000.0
              CMIN=VALU(11)+VALU(12)+VALU(13)+VALU(14)+VALU(15)
              CPRO=VALU(16)+VALU(17)+VALU(18)+VALU(19)+VALU(20)
              DEPL=DEPL/1000.0
              ATAX=ATAX/1000.0
              STAX=STAX/1000.0
              FTAX=FTAX/1000.0
              XX=(VALU(5)+VALU(8))/1000.0
              SX=(DEPR(1,J)+DEPR(2,J))/1000.0
              SY=CASH(J)/1000.0
              CUSH=CUSH+SY
              PRINT 1950,J,(VALU(I),I=1,3),CMIN,CPRO,VALU(4),
              DEPL,ATAX,STAX,FTAX,XX,SX,SY,RR
1950          FORMAT(1H0,I3,F8.3,F7.3,F8.2,2F9.3,F9.0,F8.0,3F7.0,
              1          F9.0,F8.0,F9.0,F8.3)
1960          CONTINUE
              IF(LS) 2100,2100,1970
1970          LS=LS-1
              SLVG=SLVG/1000.0
              PRINT 1980,SLVG,CUSH
1980          FORMAT(1H0,16HSALVAGE VALUE = ,F9.0,50X,11HCUMULATIVE
              1          12HCASH FLOW = ,F10.0)
C*****
C  EXPECTED PERCENT RATE OF RETURN HISTOGRAM
C*****

```

```

2100 CALL RATE(CASH,RR,LIFE)
      JS=RR+1.5
      PT(JS)=PT(JS)+1.0
      ZN=ZN+RR
2110 CONTINUE
      Z=0.0
      ZN=ZN/NS
      PRINT 2120,NS
2120 FORMAT(1H1,39X,36HEXPECTED RATE OF RETURN DISTRIBUTION//
1      3X,44H**CURVE REPRESENTS THE PROBABILITY A LISTED
2      48HPERCENT RATE OF RETURN HAS OF OCCURRING BASED ON,
3      15,14H SIMULATIONS**//)
      DO 2180 I=1,119
      PT(I)=PT(I)/NS*100.0
      IF(PT(I)) 2150,2150,2130
2130 JS=PT(I)+0.5
      Z=Z+PT(I)
      JI=I-1
      PRINT 2140,JI,PT(I),(ASTR,K=1,JS)
2140 FORMAT(1H ,I2,8H OCCURS ,F5.1,4H PCT,100A1)
      GO TO 2180
2150 IF(Z-99.999) 2160,2190,2190
2160 PRINT 2170
2170 FORMAT(1H )
2180 CONTINUE
2190 PRINT 2200,ZN
2200 FORMAT(//1H0,22HMEAN RATE OF RETURN = ,F6.2)
C*****
C RETURN TO READ NEW OPTION CARD
C*****
      IF (KLER) 5,5,40
      END

```

SUBROUTINE RATE(CASH,RR,NY)

```

;*****
; FOR CALCULATING THE RATE OF RETURN USING THE BISECTION METHOD
;*****
      DIMENSION CASH(25)
      RR=.00001
      HOLD=0.0
      PREV=0.0
10 Z=0.0
      IF(RR-1.18) 40,40,20
20 PRINT 30
30 FORMAT(10X,34HRATE OF RETURN EXCEEDS 118 PERCENT)
      GO TO 140
40 DO 50 JJ=1,NY
      Z=Z+CASH(JJ)*(EXP(RR)-1.)/(RR*EXP(RR+JJ))
50 CONTINUE
      IF(Z) 60,140,100

```

RATE ESTIMATE HIGH

C

```

60 IF(HOLD) 70,70,80
70 RR=0.0
   GO TO 140
80 PREV=HOLD
   HOLD=RR
   AVL=ABS(RR-PREV)
   IF(AVL=.0005) 140,140,90
90 RR=RR-AVL/2.0
   GO TO 10

```

C

C

C

RATE ESTIMATE LOW

```

100 IF(PREV) 110,110,120
110 HOLD=RR
   RR=RR+1.
   GO TO 10
120 PREV=HOLD
   HOLD=RR
   AVL=ABS(RR-PREV)
   IF(AVL=.0005) 140,140,130
130 RR=RR+AVL/2.
   GO TO 10
140 RR=RR*100.0
   RETURN
   END

```

SUBROUTINE RAND(IR,N,Y1)

```

C*****
C UNIFORM (0,1) RANDOM NUMBER GENERATOR, METHOD TRAU SWORTHE
C  $F(X) = 1 + X^{**2} + X^{**29}$ 
C REF = CANAVOS, PROCEEDINGS OF 22ND NATIONAL CONFERENCE ACM (1967)
C ALSO RANDOM NUMBERS, BY TRAU SWORTHE, MATH OF COMPUTATION V19, 1965
C IR = START OF SEQ., IR GREATER THAN 0 BUT LESS THAN  $2^{**29}$ .
C Y1 = UNIFORM RANDOM NUMBER, OPEN INTERVAL (0,1)
C N = 1 IS RESTART PERIOD FROM IR, = 2 IS CONTINUE PERIOD
C NOTE = PROGRAM SETS N=2 AFTER N=1 ON FIRST ENTERING PROGRAM
C*****

```

```

COMMON IA1(30),IA2(30),IA3(30),POW(30)
N1=29
Y1=0.0
MAX=28+IR
IF(N=2) 10,40,40
10 DO 20 I=1,29,2
   IA2(I)=0
   IA2(I+1)=1
   POW(I)=0.5**I
   POW(I+1)=0.5**(I+1)
20 CONTINUE
   IA2(29)=1
30 N1=N1+29
   N2=N1-MAX

```

```
40 DO 110 I=1,29
    IF(I-2) 50,60,70
50    ITEMP=IA2(28)
    GO TO 80
60    ITEMP=IA2(29)
    GO TO 80
70    ITEMP=IA3(I-2)
80    IA3(I)=ITEMP+IA2(I)
    IF(IA3(I)-2) 100,90,90
90    IA3(I)=0
100   IA1(I)=IA2(I)
    IA2(I)=IA3(I)
110 CONTINUE
    IF(N-2) 120,170,170
120 IF(N2) 30,170,130
130 N1=29-N2
    N2=N1+1
    N=2
    IZ=0
    DO 140 I=N2,29
        IZ=IZ+1
        IA2(IZ)=IA1(I)
140 CONTINUE
    IF(N1) 150,170,150
150 DO 160 I=1,N1
        IZ=IZ+1
        IA2(IZ)=IA3(I)
160 CONTINUE
170 DO 180 I=1,29
        IZ=30-I
        ITEMP=IA2(IZ)
        Y1=Y1+PDW(I)+ITEMP
180 CONTINUE
    RETURN
    END
```

APPENDIX B.--CAPITAL INVESTMENT AND OPERATING COST SUMMARY FOR MINING  
13,600 TPD AND PROCESSING 9,700 TPD USING METHOD B

TABLE B-1. - Capital investment summary, mining system B

	<u>Capital investment, dollars</u> <u>(13,600 tons per day)</u>
Capital equipment:	
Drill and blast.....	136,200
Load.....	412,300
Haul and road maintenance.....	417,400
General.....	<u>123,500</u>
Total direct.....	1,089,400
Engineering.....	54,500
Overhead and administration.....	<u>54,500</u>
Subtotal.....	1,198,400
Contingency at 10 percent.....	<u>119,800</u>
Subtotal.....	1,318,200
Fee.....	65,900
Working capital.....	<u>76,600</u>
Total capital investment.....	1,460,700

TABLE B-2. - Mining equipment list

Item	Quantity required.	Cost per item, dollars	Total cost, dollars
<b>Drilling and blasting equipment:</b>			
Drill, primary.....	1	90,000	90,000
Drill, secondary.....	1	17,400	17,400
Compressor.....	1	13,300	13,300
Drill, hand-held.....	4	750	3,000
Truck, powder.....	1	12,500	12,500
Total.....	-	-	136,200
<b>Loading equipment:</b>			
Shovel (9 cubic yd).....	1	379,700	379,700
Dozer.....	1	32,600	32,600
Total.....	-	-	412,300
<b>Haulage and road maintenance equipment:</b>			
Trucks (35-ton).....	5	67,720	338,600
Motor patrol.....	1	28,000	28,000
Truck, water.....	1	9,000	9,000
Truck, service.....	1	9,500	9,500
Front-end loader.....	1	32,300	32,300
Total.....	-	-	417,400
<b>General equipment cost:</b>			
Truck, pickup.....	2	2,500	5,000
Repair shop and equipment.....	1	90,000	90,000
Road construction.....	1	28,500	28,500
Total.....	-	-	123,500

TABLE B-3. - Operating cost summary, mining system B,  
13,600 tpd

	<u>Cost per ton,</u> <u>dollars</u>
Unit:	
Blasting agent and accessories.....	0.023
Drill bits and steel.....	.003
Parts, fuel, and lube.....	.035
Power.....	.007
Supervisory labor.....	.001
Maintenance labor.....	.019
Direct labor.....	.060
Administration and services.....	.016
Payroll overhead.....	<u>.024</u>
Total.....	.188

TABLE B-4. - Capital investment summary,  
processing method A

	<u>Capital investment, dollars</u> <u>(9,700 tons per day)</u>
Capital equipment:	
Crushing.....	1,046,000
Grinding.....	2,267,700
Leaching.....	3,730,100
Clarify, precipitate, and melting.....	<u>510,400</u>
Total direct cost.....	7,554,200
Indirect cost, contingency, and fee.....	3,021,700
Facilities.....	1,057,600
Utilities.....	<u>1,269,500</u>
Subtotal.....	12,903,000
Interest during construction.....	387,000
Working capital.....	<u>1,620,000</u>
Total capital investment.....	14,910,000

TABLE B-5. - Processing equipment list

Item	Quantity required	Cost, dollars		Total cost, dollars
		Material	Labor	
Crushing equipment:				
Truck hopper.....	1	5,800	600	-
Shaking grizzly.....	1	15,100	1,500	-
Primary crusher.....	1	176,500	17,600	-
Conveyor belt (36 x 260).....	1	43,400	9,500	-
Shaking grizzly.....	1	12,400	1,200	-
Conveyor belt (18 x 240).....	1	20,100	4,400	-
Apron feeder (42 x 10).....	3	25,200	5,000	-
Conveyor belt (30 x 100).....	1	10,600	2,300	-
Conveyor belt (36 x 85).....	1	16,200	3,600	-
Conveyor belt (36 x 70).....	1	13,300	2,900	-
Vibrating screen (6 x 16).....	2	15,500	1,500	-
Secondary crusher.....	1	109,900	11,000	-
Weightometer.....	1	4,400	900	-
Conveyor belt (30 x 185).....	1	25,600	5,600	-
Conveyor belt (30 x 100).....	1	12,100	2,700	-
Conveyor belt tripper.....	1	5,500	500	-
Dust collector.....	1	11,000	1,100	-
Concrete silo.....	3	65,400	6,500	-
Subtotal.....	-	588,000	78,400	666,400
Foundations.....	-	-	-	41,800
Structures.....	-	-	-	52,300
Buildings.....	-	-	-	156,800
Instrumentation.....	-	-	-	15,700
Electrical.....	-	-	-	31,400
Piping.....	-	-	-	15,700
Painting.....	-	-	-	10,500
Miscellaneous.....	-	-	-	55,400
				379,600
Direct total cost.....	-	-	-	1,046,000

TABLE B-5. - Processing equipment list--Continued

Item	Quantity required	Cost, dollars		Total cost, dollars
		Material	Labor	
<b>Grinding equipment:</b>				
Slot feeder.....	6	100,200	12,000	-
Belt conveyor.....	1	35,000	7,700	-
Belt conveyor.....	1	37,000	8,100	-
Belt scale.....	1	11,300	1,100	-
Cutter.....	1	2,000	200	-
Ball mill.....	4	811,600	81,200	-
Ball load.....	4	107,000	-	-
Trommel.....	4	3,100	300	-
Bucket elevator.....	1	24,600	5,400	-
Cyclone feed pump.....	1	14,900	1,500	-
Cyclone.....	2	5,400	500	-
Subtotal.....	-	1,152,100	118,000	1,270,100
Foundations.....	-	-	-	80,600
Structures.....	-	-	-	69,100
Buildings.....	-	-	-	460,800
Instrumentation.....	-	-	-	46,100
Electrical.....	-	-	-	149,800
Piping.....	-	-	-	46,100
Painting.....	-	-	-	23,000
Miscellaneous.....	-	-	-	122,100
				997,600
Direct total cost.....	-	-	-	2,267,700

TABLE B-5. - Processing equipment list--Continued

Item	Quantity required	Cost, dollars		Total cost, dollars
		Material	Labor	
Leaching equipment:				
Steady head tank.....	4	10,800	1,100	-
Agitator tank.....	4	248,800	24,900	-
Repulper.....	5	36,100	3,600	-
Thickener mechanism.....	5	358,200	43,000	-
Thickener tank.....	5	607,000	60,700	-
Distributor box.....	3	700	100	-
Underflow pump.....	4	32,500	3,200	-
Overflow pump.....	3	42,900	4,300	-
Water storage tank.....	1	53,900	5,400	-
Barren solution tank.....	1	10,600	1,100	-
Barren solution pump.....	1	7,400	700	-
Seal water pump.....	1	2,500	200	-
Sampler.....	1	2,500	200	-
Receiver.....	1	200	-	-
Cyclone.....	2	2,300	200	-
Decant tower.....	2	46,900	4,700	-
Water pump.....	2	18,300	1,800	-
Thickener bypass pump.....	1	14,900	1,500	-
Surge tank.....	1	1,600	200	-
Mill solution tank.....	2	86,600	8,700	-
Mill solution pump.....	1	7,400	700	-
Pregnant solution tank.....	1	13,500	1,300	-
Pregnant solution pump.....	1	6,500	600	-
Wash down pump.....	1	2,300	200	-
Tailing pond dam.....	1	234,400	-	-
Subtotal.....	-	1,848,800	168,400	2,017,200
Foundations.....	-	-	-	96,900
Structures.....	-	-	-	96,900
Buildings.....	-	-	-	645,800
Instrumentation.....	-	-	-	80,700
Electrical.....	-	-	-	113,000
Piping.....	-	-	-	484,300
Painting.....	-	-	-	24,200
Miscellaneous.....	-	-	-	171,100
				1,712,900
Direct total cost.....	-	-	-	3,730,100

TABLE B-5. - Processing equipment list--Continued

Item	Quantity required	Cost, dollars		Total cost, dollars
		Material	Labor	
Clarifying, precipitating, and melting equipment:				
Slurry tank.....	2	7,900	800	-
Slurry pump.....	1	2,500	200	-
Precoat, wash pump.....	1	2,900	300	-
Clarifier filter.....	3	80,800	8,100	-
Solution surge tank.....	1	26,200	2,600	-
Deaerator.....	1	26,800	2,700	-
Moisture trap.....	1	1,600	200	-
Vacuum pump.....	2	10,700	1,100	-
Precipitate feed pump.....	1	8,600	900	-
Receiver.....	1	1,400	100	-
Zinc injector pump.....	1	1,400	100	-
Precoat tank.....	1	5,000	500	-
Precipitate precoat pump.....	1	1,600	200	-
Precipitate press.....	3	63,400	6,300	-
Melting furnace.....	1	13,300	1,000	-
Remelting furnace.....	1	3,100	200	-
Subtotal.....	-	257,200	25,300	282,500
Foundations.....	-	-	-	18,000
Structures.....	-	-	-	18,000
Buildings.....	-	-	-	102,900
Instrumentation.....	-	-	-	10,300
Electrical.....	-	-	-	23,100
Piping.....	-	-	-	25,700
Painting.....	-	-	-	2,600
Miscellaneous.....	-	-	-	27,300
				227,900
Direct total cost.....	-	-	-	510,400

TABLE B-6. - Operating cost summary, processing method A, 9,700 tpd

	<u>Cost per ton,</u> <u>dollars</u>
Unit:	
Materials:	
Steel balls.....	0.187
Steel liners.....	.078
Sodium cyanide.....	.255
Lime.....	.110
Zinc dust.....	.017
Fluxes.....	.079
Diatomaceous earth.....	.036
Power.....	.176
Direct labor supervision.....	.007
Direct labor.....	.048
Maintenance labor supervision.....	.017
Maintenance labor.....	.086
Maintenance material.....	.085
Operating supplies.....	.037
Payroll overhead.....	.040
Administration and overhead.....	<u>.112</u>
Total.....	1.370