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DETERMINING PLANT SIZE FOR A NEW MINING VENTURE

by

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INTRODUCTION

Any sound mining investment must be based on a thorough
feasibility study that inevitably is arduous, costly, and time
consuming. No completely reliable shortcuts exist--the homework must
be done--but guides are available that ease the pain of zeroing in on
optimum project size, one of the principal targets.

The objective of this paper is to examine two such guides or
measures for pinpointing project size: (1) Changing capital require-
ments for each added increment of capacity, and (2) changing cash flow
resulting from these same size increases. Ideally, the guides would
be acutely sensitive to incremental changes in capacity and would
provide a clear picture of what is happening meanwhile to project
economics. To a large degree, they fulfill such requirements.

Shifts in the discounted cash flow rate of return due to size
change often are impossible to predict because they are influenced by
many variables. For this reason several feasibility studies are often
made at alternative production rates.

On an actual job, parameters of project size are determined by
such constraints as tonnage, depth, and configuration of the ore body,
investment capital available, and market for the product. To get a
clear picture of the influence of the one variable, project size change,
on project economics, we shall assume that none of these constraints
are pertinent to our project.

Computer analysis provides a quick and comparatively inexpensive means of thoroughly analyzing whatever data are available. Numerous computer programs exist for determining discounted cash flow rate of return. One such program, presented by Johnson and Bennett*, required 20 to 30 seconds of computer time for each project size, and a series of sizes requires only a few minutes. Computer costs are negligible, therefore, when compared with the cost of a feasibility study.

AN EXAMPLE

By examining the data estimated for a hypothetical project over a wide range of sizes, we will gain an insight into the changing economics due to size change. We will assume that no constraints to size exist and vary the project size from small (20,000 tons per day) to very large (90,000 tons per day) operations. We will plot the changing investment requirements for equal size increments (10,000 tons per day) of added capacity. We will plot both the cash flow increments added by these increases and the discounted cash flow rate of return over this same range.

For an example we have taken the data from a cost estimate previously made. The answers of interest to us, obtained by using the aforementioned program, are listed in table 1. Gross value of the ore was $4.50 per ton. Mill costs at the various alternative project sizes were based on recovery by flotation of both primary and byproduct metals.

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*Johnson, Edward E., and Harold J. Bennett. An Engineering and Economic Study of a Gold Mining Operation. BuMines Inf. Circ. 8374, 1968, 53 pp.

The mine is an open pit operation using rotary drilling of ore and waste and with truck haulage. Project life for each alternative production rate is assumed to be 30 years. The discounted cash flow rate of return is not significantly changed by assuming a long economic life.

Figure 1 graphs the trends of the economic guides or measures along with the discounted cash flow rate of return. For example, a preliminary estimate may indicate a size of about 40,000 tons per day (point A on figure 1). The smallest size to be considered is 30,000 tons per day, dictated, we'll say, by market commitments. The upper limit is 50,000 tons per day and is fixed by ore body accessibility and configuration. In this situation the graphs show that a 10,000-ton-per-day increase (from 40,000 to 50,000) can be added for comparatively little capital ($12,924,000), will yield the maximum additional cash flow (about $4,245,000), and will improve the discounted cash flow rate of return from 10.5 to 13.1 percent. A 30,000-ton-per-day plant, on the other hand, would require $18,348,000 less capital, would reduce the cash flow by $4,033,000, and would reduce the discounted cash flow rate of return from 10.5 to 8.1 percent. In this example, our guides clearly indicate trends in project economics. It is evident that management would choose the larger plant as the most favorable alternative investment.

VARIATION IN THE INVESTMENT INCREMENTS

The variation in investment increments of equal size are attributable in large measure to the influence of economies of scale. Grouping investment items according to the way they change with project size explains this investment variation. A generalized list of such investment items is shown in figure 2. One group, encompassing items that are fixed or change little with project size, includes prospecting costs, acquisition, real estate, etc. Another group varies almost proportionally with size change and comprises working capital and pre-mine stripping. The third group is composed of investment items that are affected by the economies of scale and includes mine and mill plant and machinery and other equipment.

Mine and mill plant, machinery, and equipment usually constitute the largest capital item. At a specific 60,000-ton-per-day porphyry copper mining and milling operation in the southwest, 74 percent of the total investment was required for such capital items.

The general pattern of changing cost per unit of production as project capacity increases is illustrated in figure 3, which is reproduced with permission of Mr. R. S. Shoemaker, Consulting Metallurgist, Mining and Metal Division, Bechtel Corp., San Francisco, Calif. His cost estimate is for the crushing and concentrating section of a magnetic beneficiation plant. The curves are a typical example of the changes in capital requirements for items affected by the

economies of scale. As shown in the upper curve, mill cost per ton day declines smoothly as capacity is enlarged. The lower curve illustrates the additional capital required as plant capacity is increased in steps of equal size. Costs for augmenting the mining plant, equipment, and machinery would follow a similar pattern. The sum of all capital items for each size increment was shown in figure 1.

VARIATIONS IN THE CASH FLOW INCREMENTS

Variation in the additional cash flow generated by increases in plant size is the second measure. Cash flow measures are the dollars left from gross revenue after all out-of-pocket production costs have been subtracted. Cash flow provides for the return of the original investment and any interest or profit.

We have assumed that the market is no constraint to project size, meaning that it will absorb any amount of product from the largest plant without lowering the selling price. Hence, increases in gross revenue would be proportional to increases in plant size. If there are economies of scale, costs will increase in lower proportion than gross revenue and project size. If there are diseconomies of scale, costs will increase in greater proportion than gross revenue and project size.

LABOR COST RELATIONSHIPS

Out-of-pocket costs then would determine cash flow--the higher the costs the smaller the cash flow. Usually the largest cost item is labor. Economies of scale also influence unit labor costs, which decline as size is increased from the smallest to the largest plants. Labor cost reductions diminish, however, as size continues to increase until they level out at the most efficient plant. Further incremental increases in project size then will show the same labor cost.

TAX COST RELATIONSHIPS

Because taxes are a large item in out-of-pocket costs, an accurate analysis of taxes must be made. Some tax benefits are designed to reduce costs on a new project. Payback period thus can be shortened and rate of return increased. This is because the discounting effect of interest is minimized. A dollar that will be received 1 year from now is worth more today than a dollar that will be received 10 years from now, owing to the time value of money. Similarly, cash flow dollars in the immediate future are worth more today than the same cash flow dollars some years hence. The discounted cash flow rate of return is based on today's value of tomorrow's cash flows. For this reason, tax relief at startup has a strong influence on the discounted cash flow rate of return. Thus, an accurate analysis of whatever tax data are available is essential to a sound economic appraisal of a project. In computer programming, an accurate estimate of taxes is

obtained from the data available, however preliminary they may be, and their effect on project economics is measured. Tax cost estimating is clarified and made easier by segregating capital expenditures into groups according to their impact on taxes. Figure 4 illustrates one possible breakdown of the total investment into such generalized groups. One group comprises nondepreciable items that have to be recovered through depletion. The second group are those that can be deferred and expensed ratably as the ore is mined. Another is made up of capital items that can be depreciated when estimating taxes. When programmed for computer analysis, the data available thus can be accurately analyzed.

Other out-of-pocket cost items are included to determine total costs. These costs, when subtracted from gross revenue, determine the changing cash flow with changing project size.

COMPARING THE ECONOMIC MEASURES WITH THE RATE OF RETURN

The curve for discounted cash flow rate of return, referring again to figure 1, differs in our example from the usual curve in that increasing plant size does not shorten project life. This enables us to examine the influence of production rate on project economics without the constraint of ore body size. This curve illustrates the fact that, while the economies of scale operate to reduce investment and increase cash flow, the rate of return improves. If, on the project
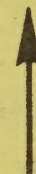
being considered, the investment required and the cash flow for equal incremental size increases stabilize at some large project size, the discounted cash flow rate of return will remain constant.

Graphs of the two measures of project economics--changing investment and changing cash flow--provide sensitive barometers depicting shifts in project economics. In the early stages of project investigation, they will be rough estimates, qualitative rather than quantitative in nature. As operating data are improved, the curves can be updated and refined to provide a supplementary guide for determining project size.

TABLE 1.–SIMPLIFIED DATA FROM COMPUTER PRINT OUT

(PROJECT LIFE 30 YEARS FOR ALL PRODUCTION RATES; DOLLAR FIGURES IN THOUSANDS)

PRODUCTION RATE (TPD)	30,000	40,000	50,000
TOTAL INVESTMENT	$ 119,345	$ 137,686	$ 150,610
AVERAGE CASH FLOW	$ 9,884	$ 13,917	$ 18,162
DISCOUNTED CASH FLOW RATE OF RETURN	8.1%	10.5%	13.1%
ADDITIONAL CAPITAL REQUIRED	$ 21,763	$ 18,348	$ 12,924
ADDITIONAL AVERAGE CASH FLOW	$ 3,870	$ 4,033	$ 4,245
	↑	↑	↑

POINT A

FIGURE 1

Additional investment required
as the project is increased in size
from 20,000 tons per day in
increments of 10,000 tons per day

Additional average cash flow
provided from each 10,000-ton-
per-day increase in capacity

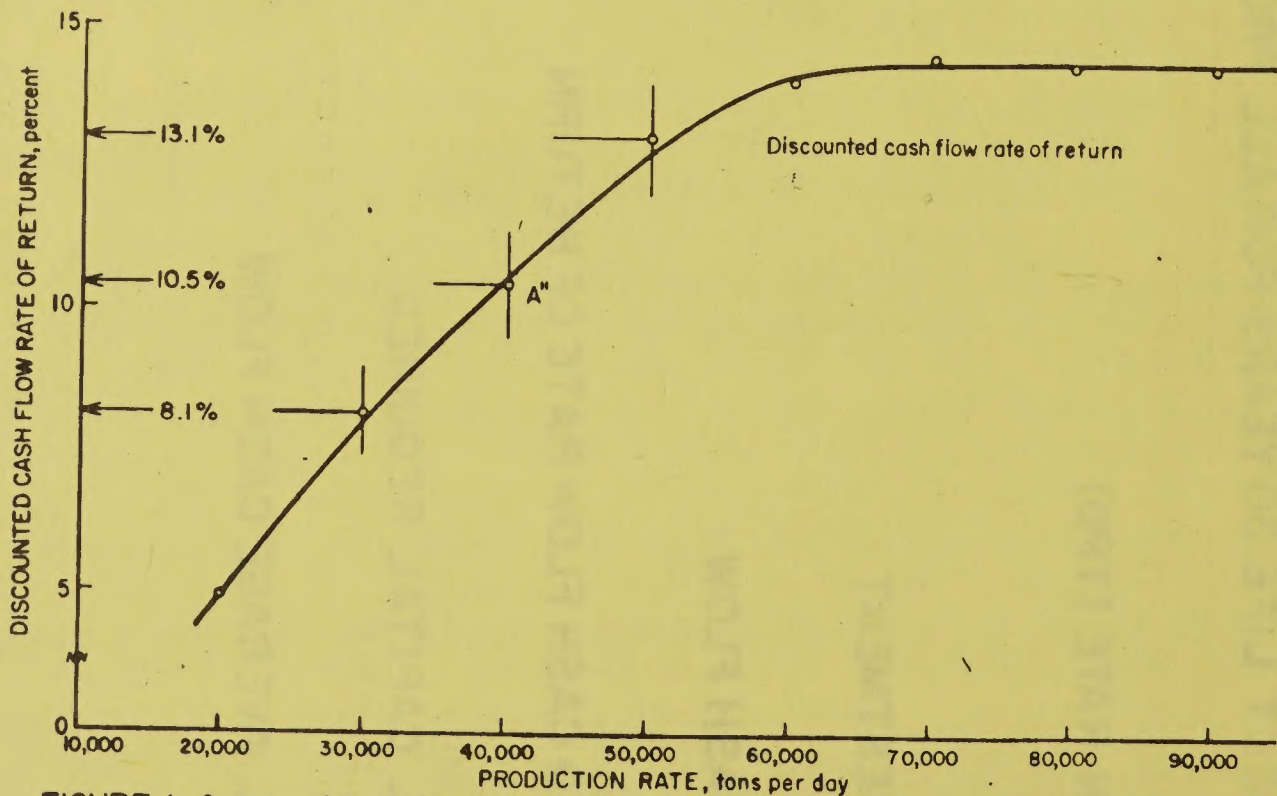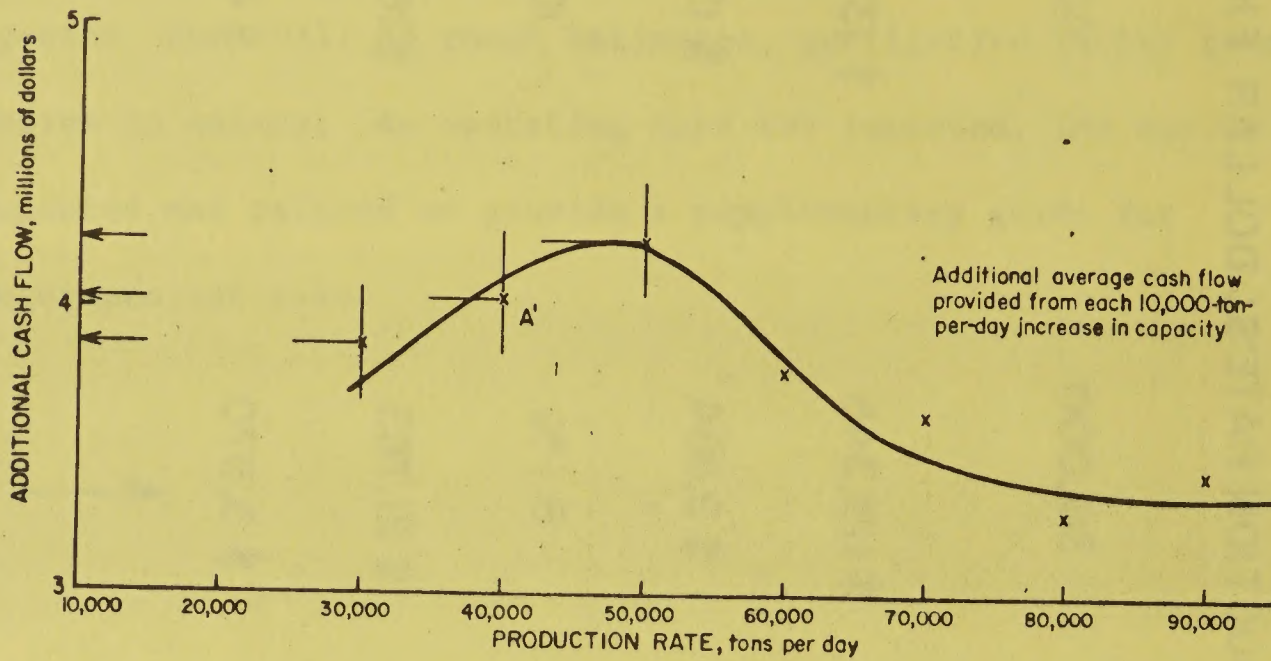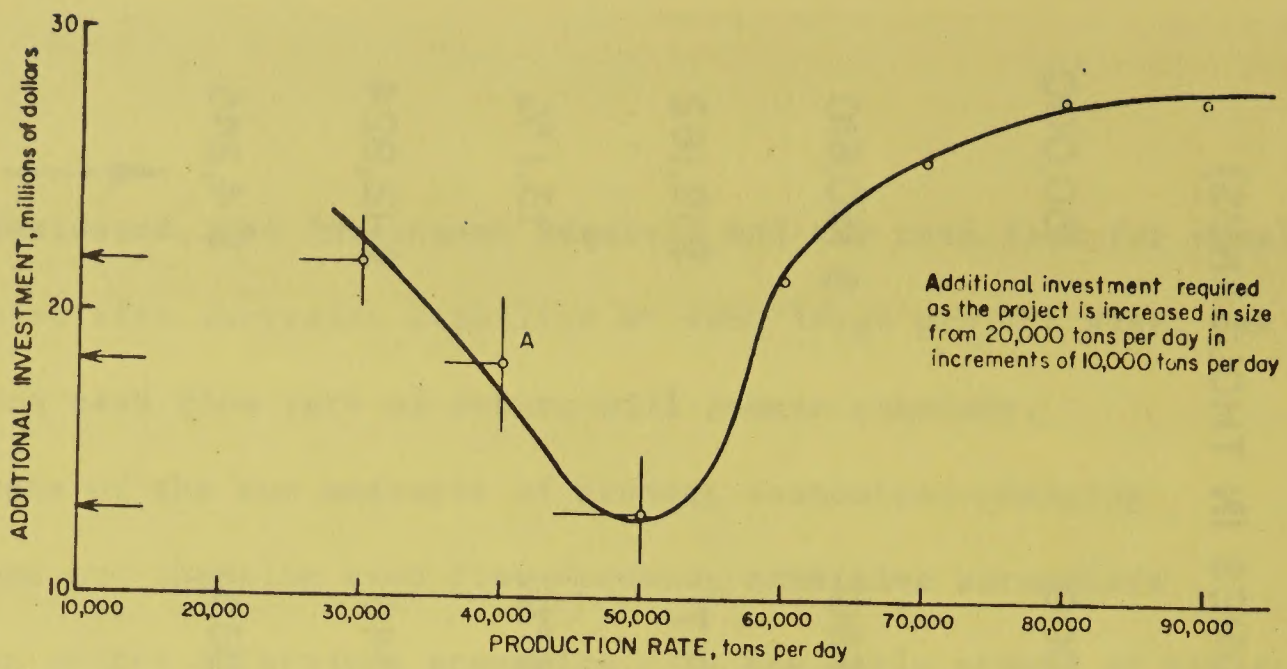Discounted cash flow rate of return

FIGURE 1.-Graphs of Data from Computer Program Published by Johnson and Bennett.
Project Life for each Size Plant Estimated at 30 Years.
Tax Costs Estimated using Sum of the Years Digits Depreciation Method.
Capital Requirements Estimated for Mine and Concentrator Equipment,
Purchase Price, Pre Mine Stripping, Real Estate and Working Capital.

PROJECT INVESTMENT ANALYSIS FOR PLANT SIZE DETERMINATION

FOR DCF RATE OF RETURN ESTIMATE

INVESTMENT REQUIREMENTS

PROSPECTING COSTS PURCHASE—ACQUISITION REAL ESTATE LEGAL—RECORDING FEES ASSESSMENT WORK EXPLORATION COSTS	INVESTMENTS USUALLY VARY LITTLE OR ARE FIXED REGARDLESS OF THE SIZE OF THE OPERATION
WORKING CAPITAL PRE-MINE STRIPPING	INVESTMENT OFTEN PROPORTIONAL TO OPERATING COSTS

DEVELOPMENT COSTS
 	
BUILDINGS AND IMPROVEMENTS
 	
MACHINERY, EQUIPMENT AND PLANT
 	
    MINE   5-YR LIFE
            10-YR LIFE
            20-YR LIFE
            LIFE OF PROJ.
    MILL   5-YR LIFE
            10-YR LIFE
            20-YR LIFE
            LIFE OF PROJ.
	THESE COSTS USUALLY VARY WITH PLANT SIZE AND SOME ARE INFLUENCED BY THE ECONOMIES OF SCALE. SEGREGATING THEM INTO EXPECTED LIFE IS AN INDICATOR OF RE-INVESTMENT REQUIREMENTS

FIGURE 2

Approximate added capital required
as the plant is increased in size
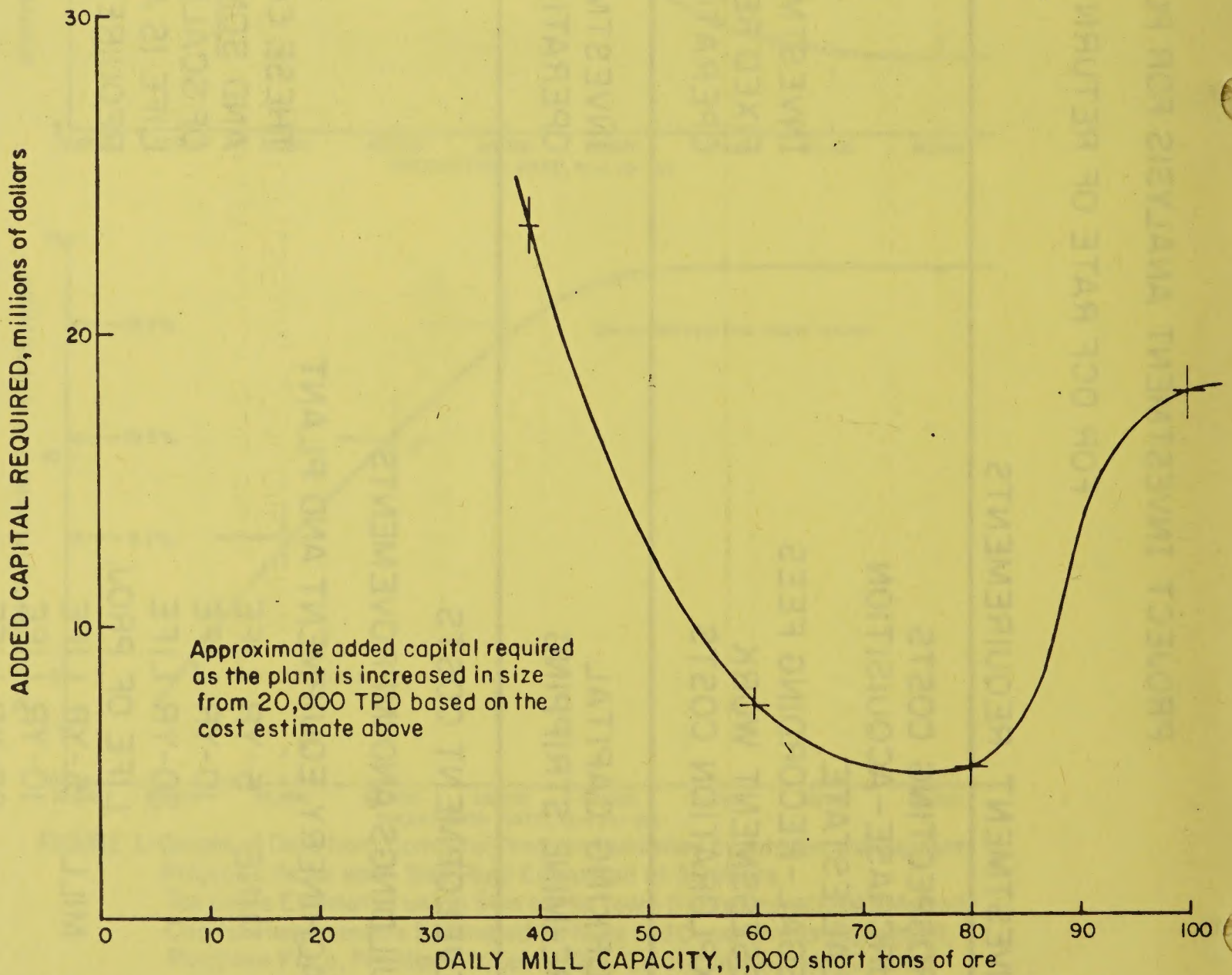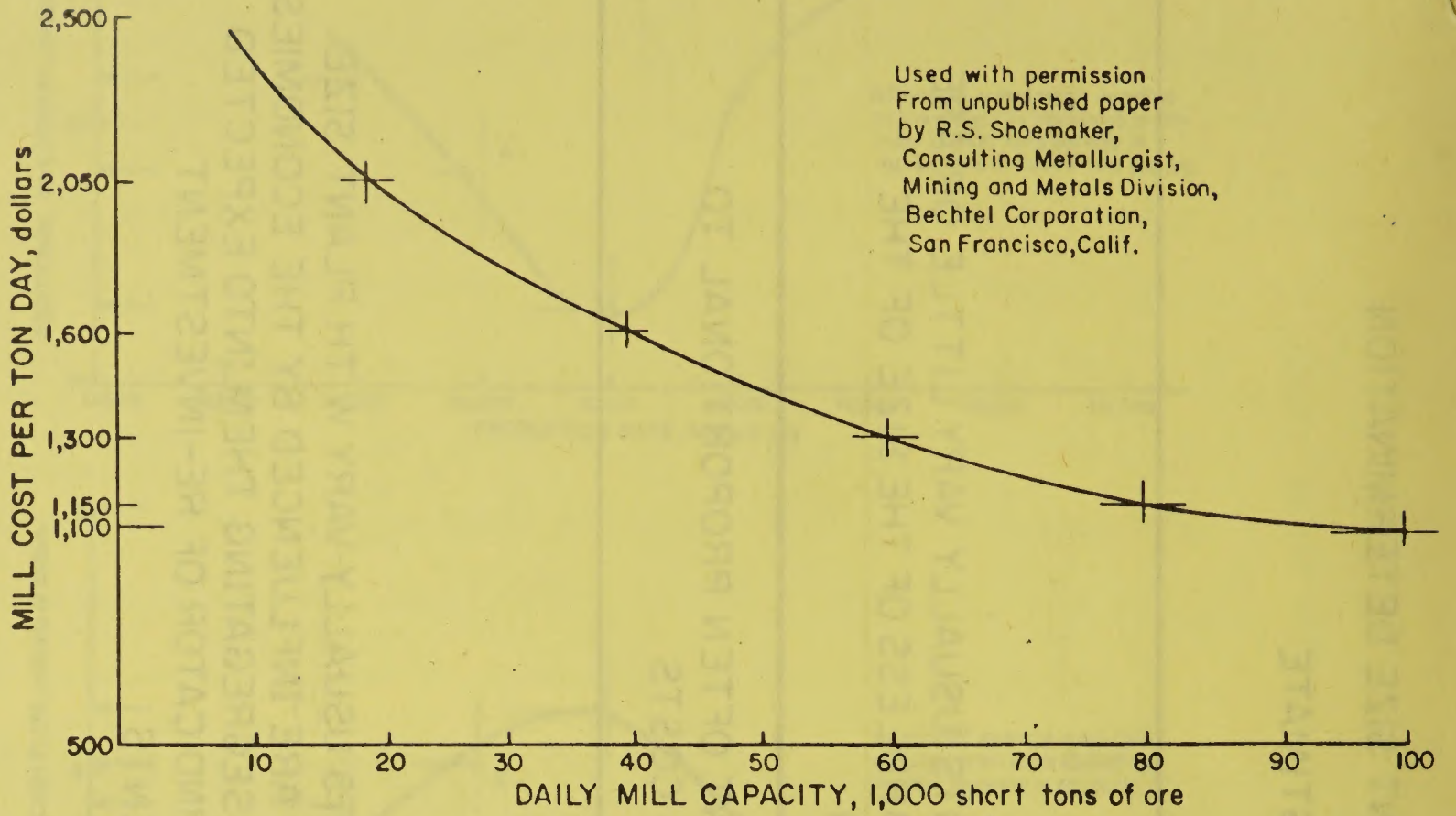from 20,000 TPD based on the
cost estimate above

FIGURE 3.- Capital Requirements for Equal Increments of Additional Mill Capacity.

INVESTMENT REQUIREMENTS GROUPED FOR TAX ESTIMATING

PROSPECTING COSTS
PURCHASE-ACQUISITION
REAL ESTATE   NON-DEPRECIABLE ITEMS
LEGAL-RECORDING FEES
ASSESSMENT WORK
EXPLORATION COSTS OVER   RECOVERED ONLY THROUGH DEPLETION ALLOWANCE
    $400,000 IN A 4-YR PERIOD

WORKING CAPITAL

EXPLORATION COSTS UP TO   MAY BE DEFERRED AND EXPENSED RATABLY AS
    $400,000 IN A 4-YR PERIOD   ORE IS MINED
DEVELOPMENT COSTS

BUILDINGS AND IMPROVEMENTS

MACHINERY, EQUIPMENT, AND
PLANT
    MINE   5-YR LIFE
            10-YR LIFE
            20-YR LIFE
            LIFE OF PROJ.
    MILL   5-YR LIFE
            10-YR LIFE
            20-YR LIFE
            LIFE OF PROJ.

INVESTMENT CREDIT ALLOWED

MINE AND MILL INVESTMENTS ARE KEPT SEPARATE
FOR MINE DEPLETION ALLOWANCE AND STATE
PRODUCTION LEVY ESTIMATES

FIGURE 4