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Company Towns Versus Company Camps in Developing Alaska's Mineral Resources

By Robert Bottge

UNITED STATES DEPARTMENT OF THE INTERIOR

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

d/wk	day per week	st	short ton
h	hour	st/d	short ton per day
h/d	hour per day	yr	year

COMPANY TOWNS VERSUS COMPANY CAMPS IN DEVELOPING ALASKA'S MINERAL RESOURCES

By Robert Bottge[1]

ABSTRACT

When a company develops a mineral property in a remote area of Alaska, it must consider how best to house its personnel. This Bureau of Mines report examines the economics of two options: company towns and company camps. The price required to maintain a 15% discounted-cash-flow rate of return (DCFROR) was derived for hypothetical 1,000-st/d cut-and-fill mines and 50,000-st/d open-pit mines located in three different regions of the State. One set of hypothetical mines utilizes a townsite; the other utilizes a relatively new concept, a fly-in camp or commuting operation, in which two shifts of employees operate the mine and all associated facilities for 1 week before being replaced by a second crew.

The study shows that operating costs were higher for mines employing the commuting option than for mines having a company town because of the additional wages paid for overtime hours; however, the price required to obtain a 15% DCFROR for the single-product copper concentrate, f.o.b. the mill site, was significantly lower owing to the lower investment costs for the camp-type operation. The economic advantage for those mines utilizing the camp increases from south to north and from the coast toward the interior.

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INTRODUCTION

The development of mineral deposits in Alaska usually involves the need to provide living accommodations for employees. The options range from constructing a camp for which the company provides room and board to building a townsite which is administered by the company with housing for single people as well as those with families. The capital cost of providing housing for personnel in remote areas must be weighed against the operating costs inherent with each option. If the company operates only during the summer, it will likely opt for mobile bunkhouse units. However, if the company mines year-round, it may want to consider a different set of options. This report explores two housing options available for long-term permanent mining operations and analyzes the impact of each on the total cost of two mining ventures in three regions of the State.

A computerized costing system was used for developing cost data. The system developed for the Bureau of Mines was designed to estimate capital and operating costs within ±25% of actual costs for the 48 contiguous States (*3*).[2] For Alaska, the costs were modified to reflect higher local costs. While the exact values determined by the model should be viewed cautiously, this method seems reasonable for the purpose of comparing the cost of the housing options explored here.

For determining the price required to obtain a 15% discounted cash flow rate of return (DCFROR) for each mining scenario, a second computer program developed by the Bureau of Mines was utilized. The Mine Simulation Program (MINSIM8)[3] was capable of handling all data input without modification.

COMPANY TOWNS

Company towns are those communities in which 75% of the work force serves a single industry and its supporting companies (*15*). Commonly the towns are associated with resource-based or transportation-related industries involved in mining and smelting ore, cutting and processing trees, processing pulp and paper, or building, maintaining or servicing railroads.

Though the resource that motivates their creation will eventually be exhausted, many mine-related towns may be viewed as relatively permanent. However, when the projected mine life is less than 30 yr and the location is remote, the company often is compelled to build apartments or homes for its employees which it then rents to them, generally at a nominal fee. It must also provide schools, churches, a community center, streets, sewers, water, electricity, telephones, landscaping, stores, offices, and a hotel. Once the town is built, the company must operate and maintain all these facilities. In addition to running the mine and mill complex, the mine manager or superintendent also assumes final responsibility for the townsite.

The newer towns tend to be more isolated, more technologically intensive, and more carefully planned, and to have more government participation in community development (*12*). Tumbler Ridge, BC, Canada, exemplifies this new movement in town conception and development. Here, the Province of British Columbia has created an autonomous townsite to serve two new coal mines that are operated by a private company (*8*). Because an incorporated town might be eligible for government funds for such municipal services as schools, fire protection, hospitals, sewers, and water, the company's financial burden may be lower than if it had to provide these services itself.

COMPANY CAMPS

Camps differ from townsites in one principal way: while a townsite usually has a mix of single and married people housed in dormitories, apartments, mobile units, houses, and multifamily structures, a camp usually consists of either portable or permanent structures for housing working employees only. Housing facilities in a small company may consist of a bunkhouse for sleeping all employees and another unit for preparing and serving meals; larger companies may provide a number of bedrooms to sleep four to six employees off a central living area. Still larger companies may provide dormitories with a number of bedrooms off a corridor leading to a recreation room, dining room, and laundry. The number of square feet of living space varies with the company and the longevity of the project.

THE COMMUTING OPTION

Historically, company-run camps were in remote locations. Wages were high to entice employees, usually men, to work there. But turnover was high and the employees left as they accumulated a "nestegg," completed a contracted work tour, found employment closer to their homes, were lonely for their families, or just drifted on.

In an attempt to stabilize the workforce in remote locations and lower operating costs, companies operating in northern Canada have introduced a number of

[2]Italic numbers in parentheses refer to items in the list of references preceding appendix A.

[3]Further information on MINSIM8 may be obtained by contacting the Division of Minerals Availability, Bureau of Mines, Washington, DC.

commuting options. Employees are brought to a remote site at company expense, work a relatively short, predetermined work schedule, and then are returned to a home location. A number of scenarios have been implemented, including seven 12-h days at the work site and seven days at home (called seven on-seven off or seven-twelves), 20 days on and 10 days off, 30 days on and 14 days off, and 6 weeks on, 2 weeks off (*13*). The results of the various programs indicate that the shorter the work period, the lower the turnover rate (*13*).

In Alaska, the oil industry in Cook Inlet has long worked its platform employees 12-h days, 7 days on and 7 off. The same work schedule has been followed for the oil-related activities on the North Slope and the Trans-Alaska pipeline pump stations. At the Polaris Mine on Little Cornwallis Island, NT, Canada, "southerns" work 10 weeks on and 2 weeks off while the Native Inuit work either that schedule or 6 weeks on and 4 weeks off (*20*). In other Canadian mines, the system of seven on-seven off is often employed (*4, 9, 14*). Chenard said the seven on-seven off system seemed the most suitable for everybody involved (*6*). Cominco, Ltd., is planning to implement a commuting program for its employees at the Red Dog Mine in northwestern Alaska during the projected 50-yr life of the mine (*2*).

ECONOMIC CONSIDERATIONS

Labor is a major cost in any mining venture, and labor turnover reduces efficiency and raises operating costs. While the fly-in or commuting option is not a panacea for all remote mining ventures, it does provide some benefits for the company and for its personnel. Employees receive large paychecks and large blocks of time off to spend with their families or for other activities. The company tends to attract more mature, family-oriented people who give the company stability, good performance, fewer accidents, less absenteeism and lower turnover. (*3*). The company's capital costs for the venture are lower because it does not have to build, manage, and maintain a remote townsite.

To measure the impact of each housing option on the total economic picture for a mining venture, two types of mines are proposed in three geographically different parts of Alaska: Southeast, South-Central, and North-Central. An underground cut-and-fill operation producing 1,000 st/d and a 50,000-st/d open-pit mine are examined with the fly-in or commuting option and with the townsite option.

HYPOTHETICAL UNDERGROUND MINE EXAMPLE

The assumptions for the three cut-and-fill mining scenarios were essentially the same (table 1). Major cost differences occurred with the different regional locations. Capital and operating costs for the mines, concentrators, and town or camp sites increased from south to north and from coastal to interior locations. Regional capital and operating costs are discussed in some detail in appendixes A and B.

Major differences in capital and operating costs occurred with the choice of a town or camp site. For the townsite scenario, 428 people were required to fill the 102 positions in the mine (358 employees) and the concentrator (70 employees) for the three 8-h shifts each day. Appendix C discusses the number of employees likely to be employed in six types of underground mines and in open-pit mining.

A commuter campsite required 204 people for each week's crew (171 in the mine and 33 at the concentrator). Because each crew worked 1 week and was off 1 week, a total of 408 people was required. The difference in the total of 428 people for a townsite and 408 for a campsite was due to the number of hours worked; townsite employees worked 8 h/d, 5 d/wk, and campsite employees worked 12 h/d, 7 d/wk. Both the mine and the concentrator in the townsite and campsite operations were assumed to run 7 d/wk. The town would have to be large enough to house a pool of additional employees equal to 20% of the work force to fill in for those people on annual and sick leave, or in training, or for those who had quit. For the camp option, the towns and villages surrounding the point of embarkation would house the excess people for the mine and concentrator.

The townsite not only had more employees, but each employee could be expected to add anywhere from 0.7 to 1.8 additional people to the townsite, depending upon how strongly the company encouraged families to live there. In January and February 1982, the town of Faro, YT, Canada, had 2,128 people when the Anvil Mining Co. had 767 direct employees, a ratio of 2.77:1 (*11*). In 1973, the town of Clinton Creek, YT, Canada, had 515 people living

TABLE 1.—Mine assumptions

Assumptions	Underground cut-and-fill mine		Open-pit mine	
	Town	Camp	Town	Camp
Total employees, mine	358	171	428	204
Total employees, concentrator	70	33	378	180
Work tours, hours per week	40	84	40	84
Type of ore deposit	Copper		Copper	
Reserves . . . st	5,200,000		345,000,000	
Ore grade . . . %	5		0.5	
Mining rate, ore . . st/d	1,000		35,000	
Mining rate, waste st/d	0		15,000	
Mine life . . . yr	15		30	
Mine-mill operating efficiency . . . %	90		90	
Ore recovery . . . %	95		100	
Mine locations were remote from major cities	Yes		Yes	
Ground transportation connected mine to supply sources	Yes		Yes	
All price determinations were at the mine site before smelter and refining charges and transportation costs	Yes		Yes	
15% DCFROR on investment was assumed	Yes		Yes	
Straight-line depreciation was used on all items	Yes		Yes	
Standard State and Federal taxes were assumed	Yes		Yes	

at the site of the Clinton Mine Division of Cassiar Asbestos Corp., Ltd., which had 296 direct employees, a ratio of 1.74:1 (*5*). In this report a ratio of 2.66:1 was arbitrarily chosen, which meant that the townsite contained 1,150 people. A ratio of 2.66:1 indicated that the company's policy was to encourage workers with families to settle in the town and stabilize the work force.

A townsite for 1,150 people cost considerably more than a campsite for 204, not only because of the physical size of the town, but also because of the need for larger diesel electric generators, domestic water facilities, fire protection, shopping and recreational areas, etc. On the other hand, the campsite cost more to operate. The difference was in the salaries. Personnel in the town worked five 8-h days per week; camp employees worked seven 12-h days, which included 44 h of overtime per week.

Table 2 summarizes capital and annual costs for a 1,000-st/d underground mining venture for three regions of Alaska utilizing a campsite or a townsite. Total initial capital costs are given for each venture, including the initial housing and electrical costs. Because housing and electrical costs are the major components being varied in the study, they are also shown separately in the second column. Direct annual operating costs, without depreciation, are given to show the impact of the greater wages in the camp situation. The required price (revenue) per short ton of copper metal and per short ton of ore mined are also given for each scenario. In both cases, the required price assumes a 15% DCFROR on the respective investment. The table indicates that the combination of relatively lower capital costs and relatively higher annual operating costs in the mining scenario utilizing a campsite produced a cheaper copper price f.o.b. the mill than a mining situation utilizing a townsite. Further, as capital and annual costs increase from south to north, the choice of a campsite becomes more advantageous.

HYPOTHETICAL OPEN-PIT MINE EXAMPLE

To check the validity of the calculations made in the first example, a second one was constructed. An open-pit mine moving 35,000 st/d of ore and 15,000 st/d of waste was proposed. All assumptions made for the underground mine applied to the open-pit example except those regarding total personnel and the ore deposit (table 1).

The method and cost factors for determining capital and operating costs for the open-pit mine were the same as those employed for the underground mine, with one exception: the open pit miners were paid less than the underground miners.

Table 3 summarizes capital and annual costs and required concentrate prices for a 50,000-st/d open pit mine in three regions of Alaska. The table 3 data indicate that

TABLE 2.—Capital and annual costs and required copper prices by region for 1,000-st/d underground mine[1]

Region	Total initial capital costs,[2] millions	Initial housing and electrical capital costs, millions	Total annual operating costs,[3] millions	Required revenue per st copper[4]	Required revenue per st ore mined[5]
Southeast Alaska:					
Camp	$93.7	$21.5	$32.2	$1,514	$196
Town	162.2	86.1	27.4	2,025	262
South-Central Alaska:					
Camp	123.2	27.9	33.5	1,733	224
Town	205.5	112.0	31.1	2,490	322
North-Central Alaska:					
Camp	150.5	34.9	37.8	2,001	258
Town	261.4	140.0	35.8	3,020	390

[1]Required price is the price to maintain a 15% DCFROR on investment.
[2]Includes environmental impact statement, exploration, access, mining, beneficiation, housing, and electrical costs; the latter 2 categories are also shown separately in the next column.
[3]Direct operating costs including mining, beneficiation, administration, transportation, housing, and electrical costs.
[4]Total revenues over the life of the project (including depreciation and amortization costs) divided by total short tons of recovered copper.
[5]Total revenues over the life of the project (including depreciation and amortization costs) divided by the total ore mined.

TABLE 3.—Capital and annual costs and required copper prices by region for 50,000-st/d open-pit mine[1]

Region	Total initial capital costs,[2] millions	Initial housing and electrical capital costs, millions	Total annual operating costs,[3] millions	Required revenue per st copper[4]	Required revenue per st ore mined[5]
Southeast Alaska:					
Camp	$774.3	$58.2	$96.8	$1,800	$28
Town	893.8	172.1	89.0	2,022	31
South-Central Alaska:					
Camp	1,020.7	75.6	102.7	2,265	35
Town	1,175.6	223.7	97.0	2,580	40
North-Central Alaska:					
Camp	1,239.0	94.5	113.9	2,693	42
Town	1,433.6	279.6	109.7	3,104	48

[1]Required price is the price to maintain a 15% DCFROR on investment.
[2]Includes environmental impact statement, exploration, access, mining, beneficiation, housing, and electrical costs; the latter 2 categories are also shown separately in the next column.
[3]Direct operating costs including mining, beneficiation, administration, transportation, housing, and electrical costs.
[4]Total revenues over the life of the project (including depreciation and amortization costs) divided by total short tons of recovered copper.
[5]Total revenues over the life of the project (including depreciation and amortization costs) divided by the total ore mined.

the open-pit mines having campsites were cheaper to construct than those having townsites. The operating cost for the campsite facility was greater than that utilizing a townsite. Over the life of the mine, the price required to maintain a 15% DCFROR was less for those facilities having a campsite. As with the examples using underground mines, the cost advantage for an operation using a campsite became greater from south to north and from coastal areas toward the interior.

CONCLUSIONS

In developing a remote site, a mining company must decide whether to place its personnel at the mine site or at a distant site from which they commute. Which option is chosen is based in part on company philosophy, but economics can play a big role in making the final decision. As seen from the hypothetical mine examples presented here, mine operations having fly-in or commuter campsites are cheaper to build and require fewer people at the site than those employing a town; therefore, initial investment costs are less. However, if a commuter or fly-in type campsite is used, operating costs are higher, primarily owing to higher personnel costs. From the standpoint of regional economics, about the same number of people are employed with either option; however, each employee earns considerably more money working 84 h every other week at a campsite than he would working 40 h each week at a townsite. But while wage costs are higher with a fly-in or commuter option, turnover, sickness, and absenteeism are relatively lower (*3*). The price required to obtain a 15% DCFROR for the single-product copper concentrate, f.o.b. the mill site, was significantly lower. The economic advantage for mines utilizing the camp increases from south to north and from the coast toward the interior.

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APPENDIX A.—CAPITAL COSTS

Certainly a major consideration in the choice of a town or a camp is cost. While precise costs may be closely estimated once the go-ahead is given on a project, most economic evaluations require only order of magnitude estimates. Deriving order of magnitude cost estimates is difficult owing to the dearth of precise data available. While the literature often contains cost estimates for new projects, closer scrutiny reveals a lack of precision on what components are included.

At least two publications can be used to estimate construction costs in Alaska: "Building Construction Cost Data" (*10*)[1] and the Corps of Engineers booklet "Cost Engineering" (*21*). The former publication lists average construction cost indexes for typical "average" building construction projects for 162 cities in the United States and Canada. The latter publication lists location factors to apply to the construction of repetitive-type facilities for all 50 States and at military locations within each State.

A comparison of cost factors for Anchorage versus Washington, DC, in reference 10 shows a factor difference of 1.41; reference 21 shows a factor difference of 1.90 between Elmendorf Air Force Base (which borders Anchorage) and Washington, DC. A comparison of construction indexes for cities in other States often shows differences of less than 5%. It is interesting, then, that the difference in the two Anchorage estimates is nearly 35%. If two sources differ so widely on a construction site where extensive experience exists, one must wonder how accurately construction costs away from that area can be estimated.

ESTIMATING CONSTRUCTION COSTS IN ALASKA

In an attempt to estimate capital costs for Alaskan projects in a consistent manner, a map showing escalation factors for each part of the State was developed (fig. A-1—in pocket). The escalation factors are based on the Corps of Engineers booklet, "Cost Engineering" (*21*) with subjective modifications based upon the collection of cost data and estimates by the author over the last 12 yr.

The escalation factors assume that a road system will be built to exploit a major property and that the company will not be required to pay for that road. Therefore, the factors will not apply until some form of ground transportation exists. In general, the escalation factors are lowest along the coast and increase in mountainous areas and in higher latitudes. The area north of the Brooks Range is the most expensive area in which to construct any facility.

The factors shown on figure A-1 represent multiples of a cost to construct a similar facility in Washington, DC (or Seattle, which is 1.01). In a sense, facilities are costed-out in Seattle and "moved" to the location in Alaska using the appropriate escalation factor.

The factors given on figure A-1 assume that facilities will be permitted in the area. The factors include lands that are designated wilderness, wildlife preserves, and national parks. Because of political factors, however, these areas are not likely to be exploited. The factors do not consider the politics of development, only the physical aspects and their impact on costs.

For the study discussed in the main body of the report, non-specific sites were chosen in three parts of the State, or regions. The region and the escalation factors follow: southeast, 2.00; south-central, 2.60; north-central, 3.25.

Although there may be a number of escalation factors within each area of the State, for this report one factor has been chosen to represent each region. The Southeast region is defined as that part of Alaska east of 141° longitude (fig. A-1). The South-Central region is defined here as that part of Alaska south of 64° north latitude. The North-Central region is defined as that part of Alaska north of 64° and south of 68° north latitude.

To obtain the total capital costs for the facilities in each part of the State, the cost for underground and open-pit mines developed by O'Hara (*19*) was computed, updated from 1978 to 1984 using the Bureau's cost-estimating system (CES) program (*7*), and multiplied by the appropriate escalation factor. The various capital cost components in the CES program were adjusted until that total matched the total estimate using O'Hara's equations times the escalation factor. Two components in the CES program were not used: electrical and town and campsite costs. CES assumed power would be provided by a power company, but in Alaska, it would be diesel generated. Electrical capital costs were based upon Wohlford (*23*) updated to 1984. CES provided no estimates for townsite costs or for the total installed cost for large camps. The author estimated these costs from published data (*2, 19, 22*) and discussions with mining people during the past 12 yr.

Figures A-2 and A-3 show curves and equations for calculating the 1984 cost to design and completely install either a town or a campsite.[2] The curves reflect the data in references 2, 19 and 22 adjusted to 1984.

Calculations for the camps turn out to be approximately double the direct cost of living space plus community center space estimated by CES (*7*). In addition to the basic units, a campsite requires roads, walkways, utilities, a sewer system, landscaping, and outdoor recreation facilities. As the campsite becomes larger, the community center grows. As the campsite grows from 20 to 200 people, the space per person increases as more amenities are added for the workers' convenience. Beyond 200 employees, the space per employee diminishes because all of the amenities have been provided and the increase in the unit space per person is less than one unit per person. A 200-plus-employee camp includes space for kitchen and dining rooms, lounge and recreation rooms, laundry, infirmary, gymnasium, hobby rooms, commissary, library, post office, maintenance, and storage.

[1]Italic numbers in parentheses refer to items in the list of references preceding this appendix.

[2]The curves and equations shown on each figure estimate housing facility costs (y-axis) given employees (x-axis).

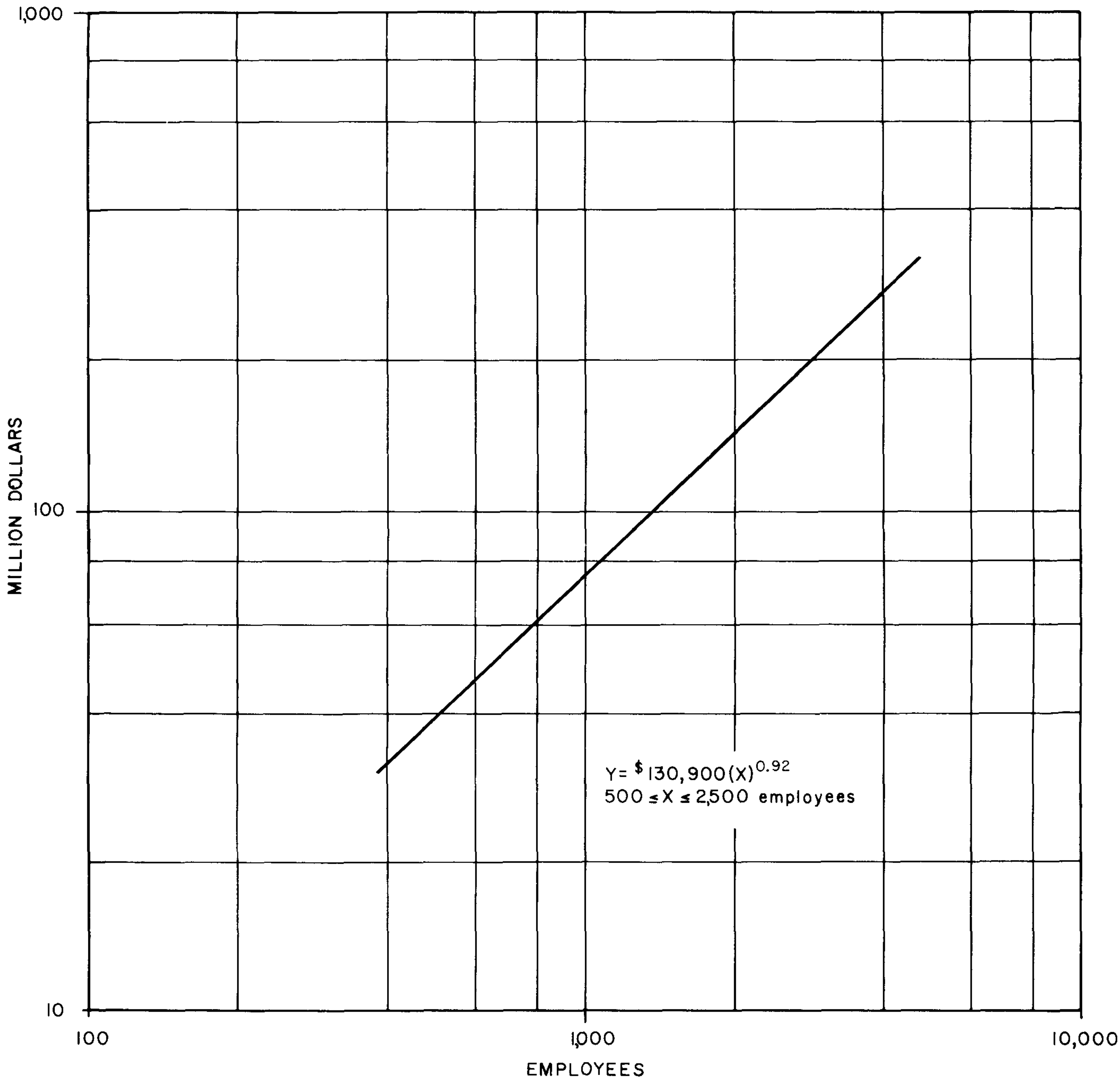

FIGURE A-2.—Townsite costs versus total employees, 1984 dollars.

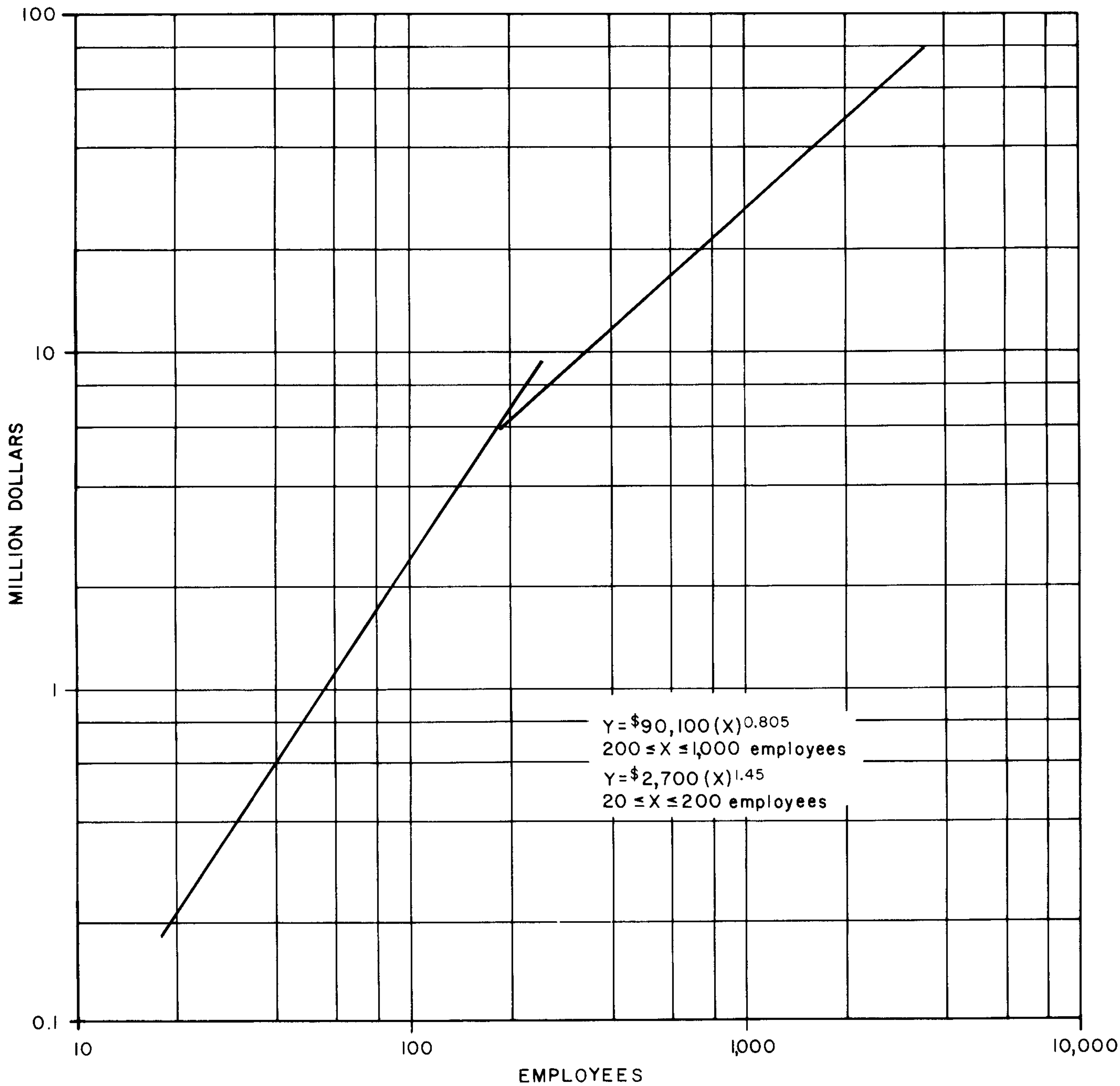

FIGURE A-3.—Campsite costs versus total employees, 1984 dollars.

APPENDIX B.—OPERATING COSTS

ESTIMATING SALARY COSTS IN ALASKA

Salaries for long-term hardrock mining in Alaska were not available. The average hourly wage rate for metal, nonmetal, and sand and gravel employees in March 1984 was $19.64 (*1*). This figure included sick, holiday, and vacation pay, shift differential, and overtime pay. As March was not a high-overtime month in Alaska, the figure was considered to be representative for long-term hardrock mining.

The national average mine and plant wage for January 1975, the base year for the Bureau of Mines' costing program, was $5.61. Based on typical manning tables and wage rates for that time, an average salary could have been $5.85/h for underground mining, $5.60/h for surface mining, and $5.45/h for mine plant and concentrating. Adjusting these January 1975 estimated wage rates to January 1984 was done by dividing the January 1984 average of $11.56/h by $5.61. The quotient of 2.06 was multiplied times the various rates times 1.35 for benefits to obtain a 1984 estimated figure of $16.27/h for underground mining, $15.57/h for surface mining, and $15.16/h for mine plant and beneficiation.

Estimating salaries for Alaska is difficult because the State is so large and economic conditions vary from region to region. For State employees, Alaska has a regionalized pay schedule in which salaries for like work are adjusted to reflect the varying cost to live in each region of Alaska. The following salary relationships were derived from the General Government/Noncollective Bargaining Schedule:

Factor	Area
1.000	Contiguous States and Canada.
1.225	Ketchikan, Juneau, Anchorage.
1.272	Petersburg, Wrangell, Sitka, Palmer.
1.313	Haines, Skagway, Seward, Kenai, Kodiak.
1.412	Cordova, Fairbanks.
1.463	Valdez.
1.565	Aleutian Islands, Dillingham.
1.616	Bethel, Nenana, Hooper Bay, Nome.
1.677	Galena, Tanana, McGrath, Fort Yukon, Barrow.

Applying the factor of 1.225 to the estimated salaries derived above gave $19.93/h for underground mining, $19.07/h for surface mining, and $18.57/h for mine plant and beneficiation employees near Ketchikan, Juneau, or Anchorage. These numbers compared favorably with the average mining wage of $19.64/h in March 1984.

The following escalation factors were applied to the base salaries of $16.27/h for underground miners, $15.57/h for surface miners, and $15.16/h for mine plant and beneficiation:

Region	Camp	Town
Southeast	1.225	1.225
South-Central	1.225	1.412
North-Central	1.412	1.677

The factors for camps and townsites were not the same in the South-Central and North-Central locations because the assumption was made that personnel for a South-Central mine with a camp were headquartered in Anchorage and personnel for a North-Central mine with a camp were located in Fairbanks. The labor cost for a townsite away from these two metropolitan areas was higher to compensate people for the higher cost of living in a remote site.

Based upon the factors listed above, total annual costs per employee at an underground operation with a campsite or townsite in each region were as follows:

Region	Camp		Town	
	Mine	Mill	Mine	Mill
Southeast	$54,900	$51,200	$41,500	$38,600
South-Central	54,900	51,200	47,800	44,500
North-Central	63,300	59,000	56,700	52,900

The above figures represent total company costs per employee; gross individual wages would be about 11% less. Camp labor costs are for 84 h/wk, of which 44 h are overtime; town labor costs are for 40 h/wk.

The annual costs for employees at an open-pit operation with a campsite or townsite in each region were as follows:

Region	Camp		Town	
	Mine	Mill	Mine	Mill
Southeast	$52,600	$51,200	$39,700	$38,600
South-Central	52,600	51,200	45,700	44,500
North-Central	60,600	59,000	54,300	52,900

As with the underground examples, gross individual wages would be about 11% less than figures cited here.

ESTIMATING OTHER OPERATING COSTS IN ALASKA

In constructing the models for this study, the following factors were used to escalate the cost of materials and supplies and equipment operation for each region:

Region	Factor
Southeast	1.40
South-Central	1.52
North-Central	1.65

The factors for materials and supplies used in mining, concentrating, and equipment operations were derived by multiplying the Alaska construction factor times 20% and adding 1. The factors accounted for the extra cost of moving supplies to Alaska and the extra cost of operating and maintaining equipment in a remote northern location.

The operating costs for the town and campsites were calculated separately, and the final escalated number was entered into CES. In addition to camp food and town maintenance costs, the cost of daily or thrice weekly air support was added to the town or camp operating costs.

APPENDIX C.—ESTIMATING THE WORK FORCE SIZE

For making generalized estimates of the work force in a mining venture, one must know the type of mining proposed. In actuality, the size of the workforce depends on the size, depth, and configuration of the ore body, the type of beneficiation required, and the company's preference in setting staffing requirements. Compounding the difficulty in making the estimates is finding base line data. Once base line data are found, one needs enough discrete examples to generate a curve for each type of mining. The last requirement is exceptionally difficult as many underground mines utilize several types of mining methods simultaneously.

For this report work force data from the 1969, 1970, and 1971 Canadian Mining Manuals were used (*16-18*). These were the only years in which complete data for the mine, mill, plant, and office staffs were compiled. Employment statistics were used only once for each company in the 3-yr period unless the total production or total employment varied from the previous year's data by more than 25%; in those cases, the company's statistics were used for the second or third year, in addition to the first year. Production-employee relationships that seemed anomolous were not included. Generally, the mines having the highest and lowest number of employees per unit of production were excluded on the assumption that a mistake was made in reporting or because conditions in the highly variant mine were unique to that mine. The results are given in tables C-1 through C-7; graphs of the data are given in figures C-1 through C-7.

Total production-employee relationships are shown for the following types of mining: blasthole, cut and fill, long hole, open pit, open stope, room and pillar, and shrinkage stope. Each graph shows the number of mines in the sample, a first-order polynomial equation (least squares), a correlation coefficient of the curve against the data, and a curve plot one standard deviation unit above and below the data-generated curve.

Although other types of equations fit some of the data better, a simple least-squares curve was used here to show the increase in employees with increased production. Correlation coefficients ranged from 0.873 for shrinkage-stope mining to 0.989 for room-and-pillar mining. The median correlation coefficient was 0.927.

A pair of lines located one standard deviation unit above and below each least-squares curve was also plotted. Statistically, 68.3% of the mines employing the type of mining graphed should have work forces within ± 1 standard deviation unit of the calculated curve. Employment at 95% of the mines should fall within 1.96 standard deviation units of the calculated least squares curve.

The estimates generated from the equations include all the personnel necessary to operate the facility 3 shifts per day, 7 d/wk, including mining, concentrating, surface plant, and office. The assumption was made that the mine complex was remotely located and hence required a surface plant facility to maintain the mine, mill, and living area, be it a townsite or a campsite. If the operation was drawing personnel from an existing town or city in close proximity, possibly one-fourth to one-third fewer people would be required in the surface plant and office personnel.

Utilizing the Bureau of Mines' CES program requires that the total workforce be split into mining and milling segments. Making the split is difficult for many of the same reasons specified above in estimating the workforce. In addition to the variation in personnel requirements that comes with the unique characteristics of each ore body, each type of ore recovery technique requires a different quantity of workers. Among underground mining techniques, room-and-pillar mining and open-stope mining tend to employ the least amount of labor and shrinkage-stope mining the most. Owing to a lack of data, no curve was constructed for square-set mining, which is probably the most labor intensive mining technique.

Table C-8 shows one split between mine and mill personnel for seven types of mining. The splits were made on the basis of the curves shown in figures C-1 through C-7 minus the mill personnel as calculated from O'Hara (*19*). Forty percent was added to direct mill personnel estimates for plant and office personnel at underground mines; 10% was added at open-pit mines.

TABLE C-1.—Cut-and-fill mining data

Year	Company	Mineral concentrates	Other types of mining[1]	Tonnage, ore + waste	Mine		Mill		Surface plant		Office staff	Total employees
					Salaried staff	Hourly workers	Salaried staff	Hourly workers	Salaried staff	Hourly workers		
1971	Bralorne Can-Fer	Au		280	8	69	1	10	4	17	13	122
1971	Eldorado Nuclear	U		1,350	44	128	20	36	17	87	84	416
1971	Hallnor Mines	Au, Ag		349	12	97	2	21	3	18	8	161
1971	Madsen Red Lake	Cu		551	10	87	4	23	10	37	17	188
1971	Opemiska Copper Mines	Cu, Au, Ag	OS	3,966	32	372	10	38	12	83	80	627
1971	Sullivan Mining	Cu, Zn, Pb		1,100	25	190	9	37	5	58	30	354
1970	Aunor Gold Mines	Au		750	11	215	3	28	4	64	27	352
1970	Madsen Red Lake	Au		721	11	141	5	32	6	50	30	275
1970	Opemiska Copper Mines	Cu, Au, Ag	SH, SL	2,300	39	348	9	39	8	70	59	572
1970	Orchan Mines	Zn, Cu	LH, OP	1,100	17	86	12	47	9	69	18	258
1969	Bralorne Can-Fer	Au		430	11	89	3	12	5	31	12	163
1969	Giant Yellow Knife Mines	Au	SH	1,250	38	206	13	60	7	38	30	392
1969	Nigadoo River Mines	Pb, Zn, Cu, Ag	OS, SH	1,100	19	157	9	32	5	54	24	300
1969	Quemont Mines	Cu, Au, Ag, Zn, Fe	SL	1,252	29	205	21	31	13	62	33	394

[1]Certain cut-and-fill mines also reported other types of mining as follows: LH—long hole; OP—open pit; OS—open stope; SH—shrinkage stope; SL—sublevel caving.

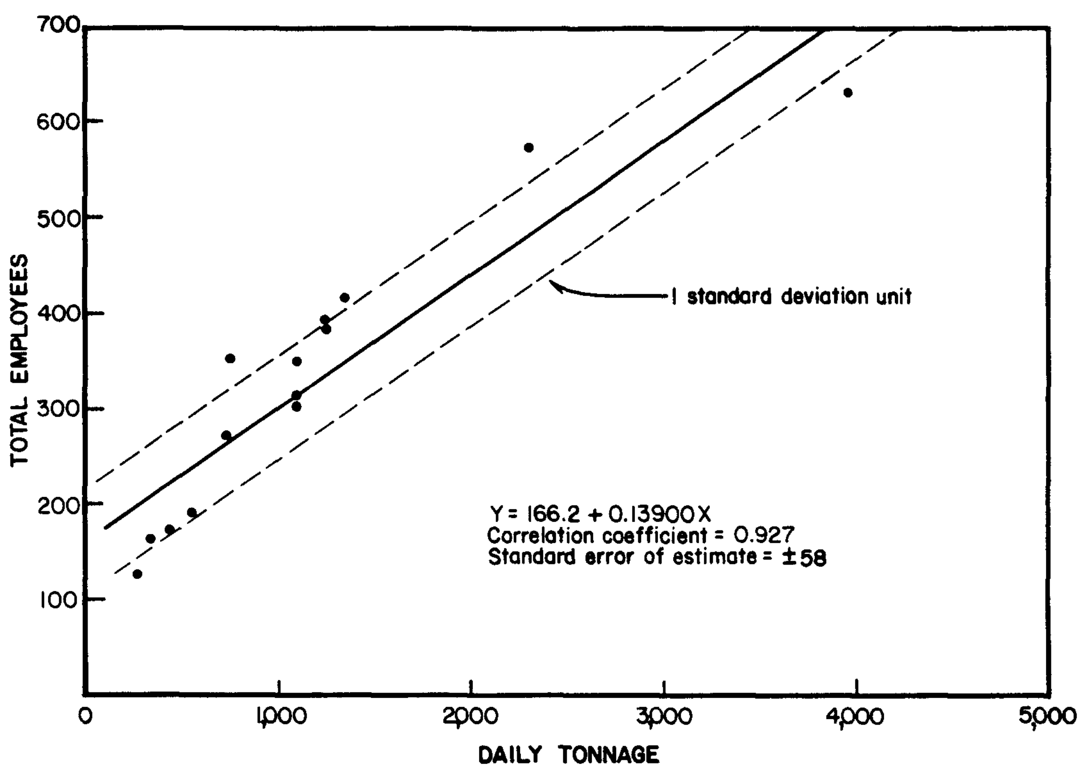

FIGURE C-1.—Total employees versus daily tonnage in cut-and-fill mining.

TABLE C-2.—Blasthole mining data

Year	Company	Mineral concentrates	Other types of mining[1]	Tonnage, ore + waste	Mine Salaried staff	Mine Hourly workers	Mill Salaried staff	Mill Hourly workers	Surface plant Salaried staff	Surface plant Hourly workers	Office staff	Total employees
1971	Heath Steel Mines	Pb, Zn, Cu	OS	3,200	11	157	13	39	6	105	41	372
1971	Mattigame Lake Mines	Zn, Cu, Ag	SL	4,100	31	198	13	55	16	112	60	485
1971	Reeves, McDonald	Pb, Zn		775	5	50	5	12	3	21	9	105
1971	Tribag Mining Co.	Cu		500	6	66	4	21	4	32	17	150
1970	Heath Steel Mines	Pb, Zn, Cu	OS	2,100	6	56	10	54	8	57	32	223
1970	Kam Kotia Mines	Cu, Zn		2,420	15	135	7	41	4	65	27	294
1970	Mattigame Lake Mines	Zn, Cu		4,028	51	214	14	44	11	42	68	544
1970	Noranda Mines, Geco Div.	Cu, Zn, Au, Pb	CF	4,450	44	210	18	80	23	92	72	539
1970	Pamour Porcupine Mines	Au, Ag	CF, SH	1,706	24	172	11	45	9	69	30	360
1970	Sherritt Gordon Mines	Ni, Cu	SL	4,150	42	234	13	70	3	36	46	444
1969	Manitou Barvue Mines	Zn, Cu, Pb, Au, Ag	CF, SH	1,304	16	128	11	42	7	53	19	276
1969	Sherritt Gordon Mines	Ni, Cu	SL	4,150	60	205	25	69	22	144	30	555

[1]Certain mines using blasthole mining also reported other types of mining as follows: CF—cut and fill; OS—open stope; SH—shrinkage stope; SL—sublevel caving.

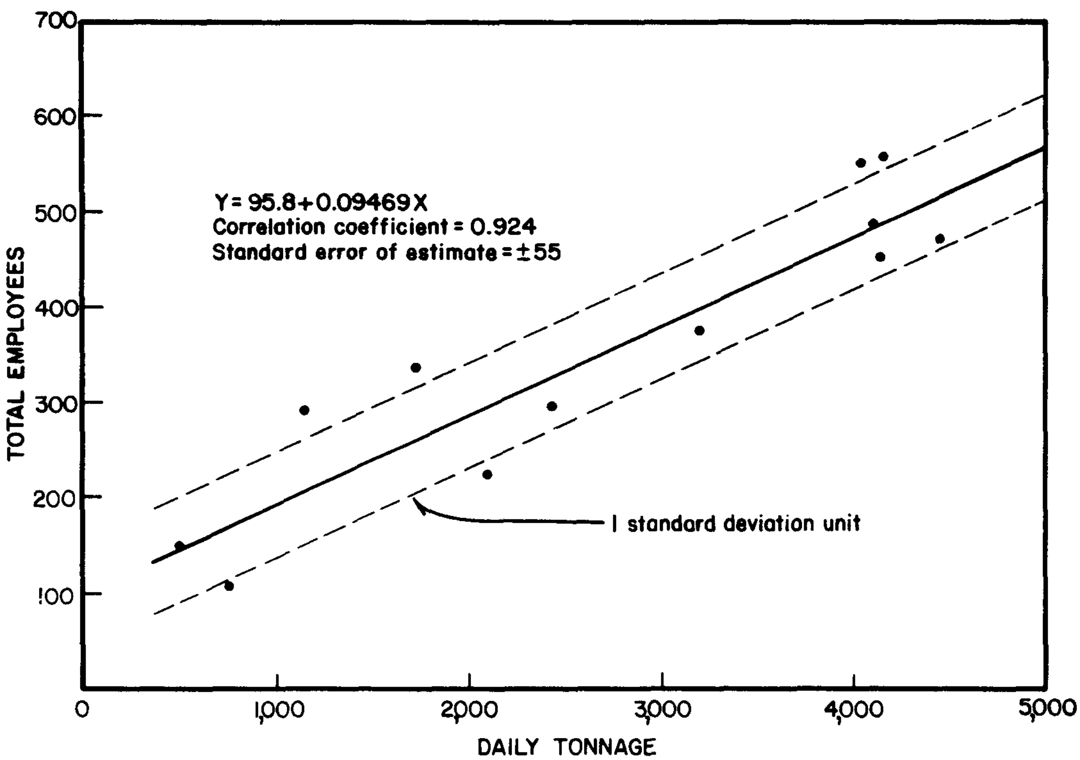

FIGURE C-2.—Total employees versus daily tonnage in blasthole mining.

TABLE C-3.—Open-stope mining data

Year	Company	Mineral concentrates	Other types of mining[1]	Tonnage, ore + waste	Mine: Salaried staff	Mine: Hourly workers	Mill: Salaried staff	Mill: Hourly workers	Surface plant: Salaried staff	Surface plant: Hourly workers	Office staff	Total employees
1971	Algoma Steel Corp.	Fe		4,150	36	214	12	46	27	153	89	577
1971	East Malartic Mines	Au	BH, SL	1,650	14	176	9	23	8	49	21	300
1971	KRC Operators	MoS	BH, SH	330	7	28	4	12	1	22	5	79
1971	Teck Corp.	Ag, Pb, Zn		130	4	25	2	11	1	5	4	52
1971	Venus Mines	Au, Ag, Pb, Zn, Cd		325	7	28	5	19	1	2	5	67
1971	Wilroy Mines	Cu, Zn, Pb, Ag		1,520	8	105	7	26	4	43	29	222
1970	Lake Shore Mines	Au, Ag	BH, SH	1,365	8	105	9	18	10	25	10	185
1970	Leitch Mines	Ag, Pb, Zn		140	4	35	2	11	3	5	7	67
1970	Zenmac Metal Mines	Zn, Cu, Cd		105	2	15	1	8	2	4	6	38
1969	MacLeod-Mosher	Au, Ag	BH, SL	1,284	10	116	8	21	2	33	9	199

[1]Certain open-stope mines also reported other types of mining as follows: BH—blasthole; SH—shrinkage stope; SL—sublevel caving.

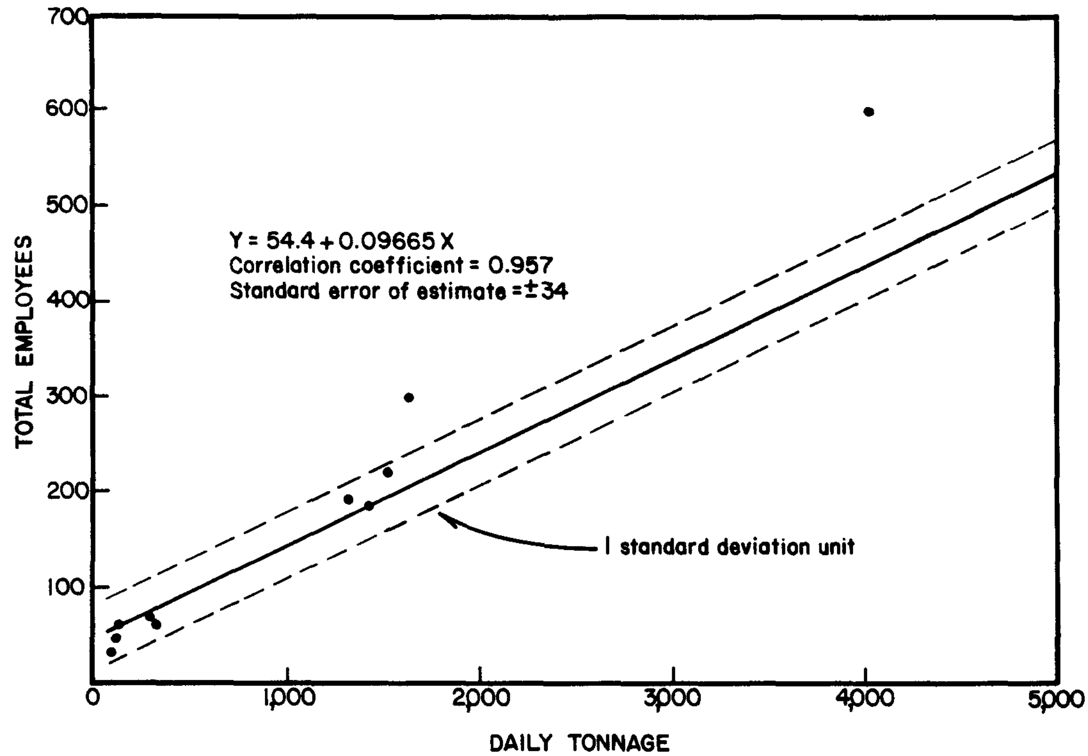

FIGURE C-3.—Total employees versus daily tonnage in open-stope mining.

TABLE C-4.—Long-hole mining data

Year	Company	Mineral concentrates	Other types of mining[1]	Tonnage, ore + waste	Mine: Salaried staff	Mine: Hourly workers	Mill: Salaried staff	Mill: Hourly workers	Surface plant: Salaried staff	Surface plant: Hourly workers	Office staff	Total employees
1971	Consolidated Canadian Faraday	Ni, Cu, PGM	CF, SL	320	3	22	10	26	3	24	12	100
1971	Kam Kotia Mines	Cu, Zn, Au, Ag		2,395	12	121	7	38	4	84	23	289
1970	Brunswick Mine & Smelting	Pb, Zn, Cu	OS	5,200	46	325	37	203	51	193	77	[2]932
1970	Camflo Mines	Au	SH	1,146	6	62	3	25	2	18	11	127
1970	Consolidated Canadian Faraday	Ni, Cu, PGM	CF	650	13	72	5	19	7	26	18	160
1970	Consolidated Rambler	Cu, Au, Ag	SL	1,200	14	93	8	29	5	[3]50	15	214
1970	Dresser Minerals	Ba, Ag, Pb, Cu	CF	860	7	53	4	25	1	16	11	117
1970	East Malartic Mines	Au	SH	1,653	30	199	6	29	5	24	35	328
1970	Giant Mascot Mines	Ni, Cu	SH	1,600	12	98	5	21	3	21	16	176
1970	Manitou Barvue Mines	Ag, Cu, Zn, Au, Asbestos	SH	1,080	18	110	11	42	11	42	20	254
1970	St. Lawrence Columbium and Metals Corp.	Pyrochlorite		1,475	6	70	9	31	2	21	17	156
1969	Barnat Mines	Au, Ag	CF	625	12	80		[3]15	1	13	7	128
1969	Dresser Minerals	Ag, Pb, Cu, Zn, Ba	CF	1,120	7	48	3	23	1	22	14	118
1969	Wilroy Mines	Cu, Zn, Pb, Au, Ag		645	9	115	10	26	7	56	28	251

[1]Certain mines using long-hole mining also reported other types of mining as follows: CF—cut and fill; OS—open stope; SH—shrinkage stope; SL—sublevel caving.
[2]Included in calculations, not plotted in figure C-4.
[3]Estimate based upon the average percent the work group comprises of the total for all of the companies.

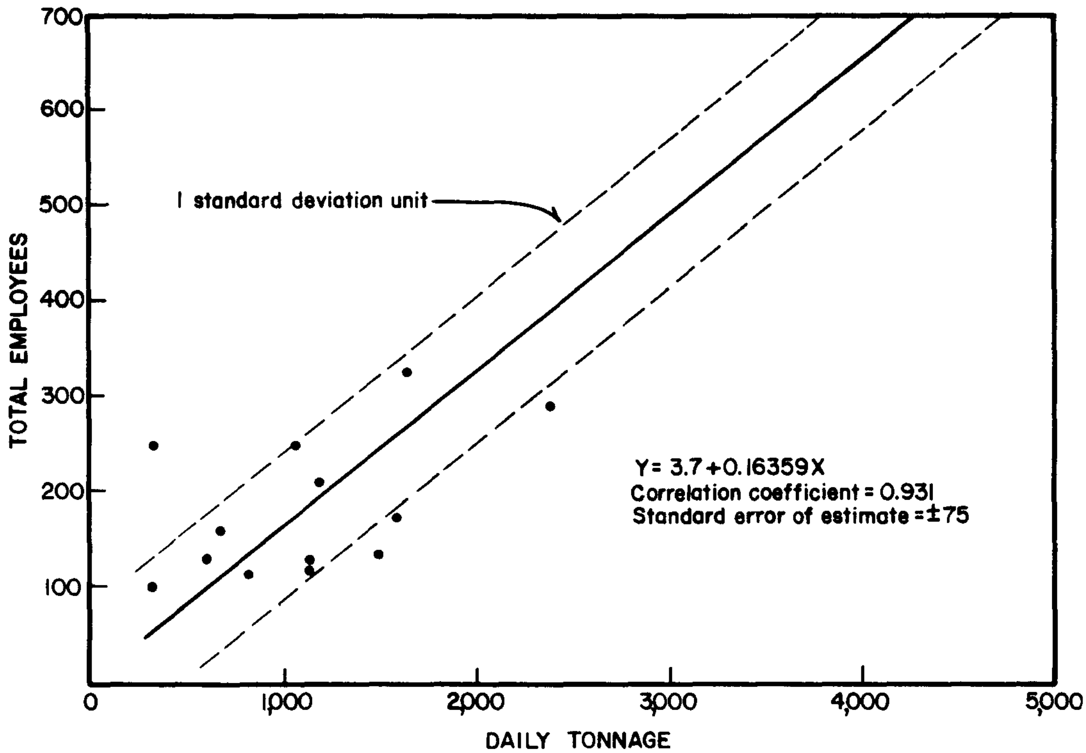

FIGURE C-4.—Total employees versus daily tonnage in long-hole mining.

TABLE C-5.—Shrinkage-stope mining data

Year	Company	Mineral concentrates	Other types of mining[1]	Tonnage, ore + waste	Mine		Mill		Surface plant		Office staff	Total employees
					Salaried staff	Hourly workers	Salaried staff	Hourly workers	Salaried staff	Hourly workers		
1971	Echo Bay Mines	Ag, Au		200	8	34	3	15	6	31	17	114
1971	Sisco Mines	Ag, Co		182	8	51	2	11	1	6	8	87
1970	Anglo-Rouyn Mines	Cu	OS	1,001	20	135	4	22	6	45	20	252
1970	Canadian Jamieson Mines	Cu, Zn	BH	590	9	65	9	32	2	20	9	146
1970	Deer Horn Mines	Ag, Co		55	5	18	1	12	3	1	4	44
1970	Dickenson Mines	Au, Ag	CF	537	18	133	3	29	4	39	18	244
1970	Preissac Molybdenite	Mo, Bi	LH, OS	1,150	17	165	4	36	3	39	[2]22	286
1970	Renabie Mines	Au	BH	508	13	89	2	18	3	20	12	157
1970	Sisco Mines	Ag, Co		170	8	60	2	11	9	58	9	157
1969	Agnico Mines	Au, Co, Cu		300	6	35	2	16	2	18	10	89
1969	Anglo Rouyn	Cu		1,150	18	103	4	18	4	44	28	219
1969	Echo Bay Mines	Ag, Cu		150	6	36	4	14	2	36	17	115
1969	Wasamac Mines	Au, Ag		1,130	19	127	5	28	6	42	[2]19	246

[1]Certain shrinkage-stope mines also reported other types of mining as follows: BH—blasthole; CF—cut and fill; LH—long hole; OS—open stope.
[2]Estimate based upon the average percent the work group comprises of the total for all of the companies.

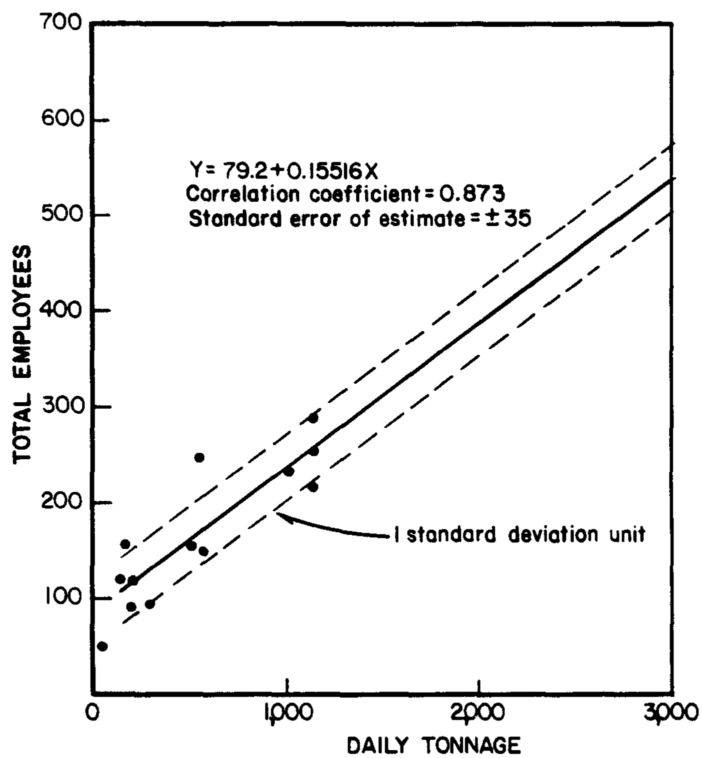

FIGURE C-5.—Total employees versus daily tonnage in shrinkage-stope mining.

TABLE C-6.—Room-and-pillar mining data

Year	Company	Mineral concentrates	Tonnage, ore + waste	Mine		Mill		Surface plant		Office staff	Total employees
				Salaried staff	Hourly workers	Salaried staff	Hourly workers	Salaried staff	Hourly workers		
1971	Canadian Exploration	WO_3	1,000	12	53	15	19	5	39	24	167
1971	Tantalum Mining	Ta_2O_5	600	3	20	4	10	5	22	13	77
1970	Canadian Exploration	Pb, Zn	1,633	16	91	10	21	5	62	30	235
1970	Denison Mines	U, Y	4,700	68	385	25	107	19	153	103	[1]860
1970	Gaspe Copper Mines	Cu, Mo, Au, Ag	3,550	34	172	11	73	76	292	99	[1]757
1970	Tantalum Mining	Ta_2O_5	427	4	25	3	9	5	27	14	87

[1]Included in calculations, not plotted in figure C-6.

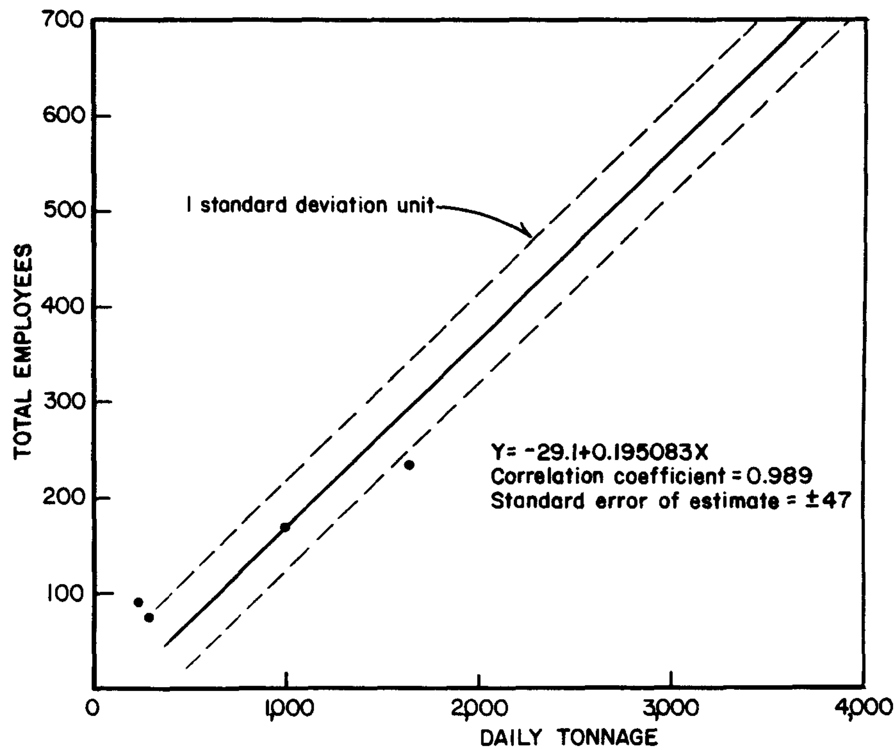

FIGURE C-6.—Total employees versus daily tonnage in room-and-pillar mining.

TABLE C-7.—Open-pit mining data

Year	Company	Mineral concentrates	Tonnage, ore + waste	Mine[1]		Mill		Surface plant		Office staff	Total employees
				Salaried staff	Hourly workers	Salaried staff	Hourly workers	Salaried staff	Hourly workers		
1971	Advocate Mines	Asbestos	41,000		119	10	167	21	133	53	503
1971	Brenda Mines	Cu, Mo	48,000		83	18	73	17	104	49	344
1971	Cassiar Asbestos Mines—Clinton Creek Div.	Asbestos	46,000		54	17	81	26	127	79	384
1971	Endako Mines	Mo	50,000		102	27	89	32	150	172	572
1971	Granisle Copper	Cu	10,400		43	10	40	6	38	20	157
1971	Jones & Laughlin Mining	Fe	22,000		86	20	132	18	112	42	410
1971	Lake Asbestos of Quebec	Asbestos	45,000		200	11	[2]88	19	155	27	500
1971	National Steel Corp. of Canada	Fe	10,500		76	16	74	14	49	21	250
1971	New Imperial Mines	Cu	12,500		40	9	30	8	35	20	142
1971	Wesfrob Mines	Fe, Cu	18,000		35	13	52	13	70	23	206
1970	Bethlehem Copper Corp.	Cu	45,000		129	19	105	17	169	41	480
1970	British Columbia Molybdenum	Mo	22,500		67	19	44	26	70	36	262
1970	Endako Mines	Mo	36,000		112	27	87	30	155	70	481
1970	Granby Mining	Cu	19,100		66	6	38	5	41	18	174
1970	Granisle Copper	Cu	16,100		40	10	42	5	39	18	154
1970	Iron Ore Co. of Canada—Scheffer Div.	Fe	90,000		280	[2]43	[2]200	70	290	224	1,107
1970	Jones & Laughlin Mining	Fe	20,000		84	14	105	18	43	50	314
1970	National Steel Corp. of Canada	Fe	10,800		68	16	84	21	108	21	318
1970	New Imperial Mines	Cu	12,500		40	9	30	8	83	20	190
1970	Pickends, Mather & Co.	Fe	21,000		108	16	71	19	128	30	372
1970	Steep Rock Iron Mines	Fe	33,300		142	[2]18	[2]79	35	120	53	447
1969	Bethlehem Copper Corp.	Cu	33,500		162	13	54	18	61	43	351
1969	Granby Mining	Cu	17,200		60	3	43	4	26	17	153
1969	Hilton Mines	Fe	19,500		113	16	77	17	122	33	378
1969	Indusmin Nepheline Syenite	Syenite	1,400		10	7	36	3	21	11	88

[1]Salaried staff positions are included with mine hourly personnel.
[2]Estimate based upon the average percent the work group comprises of the total for all of the companies.

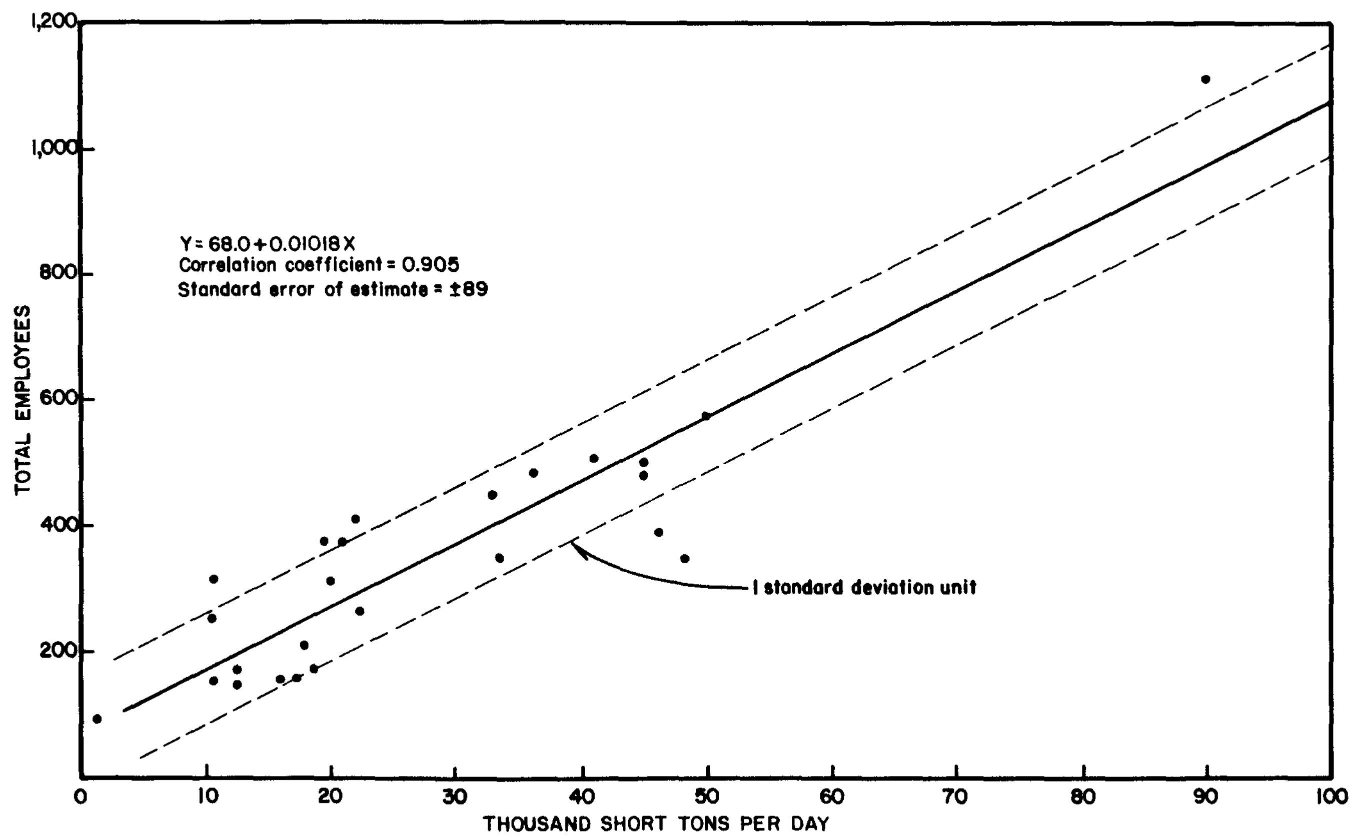

FIGURE C-7.—Total employees versus daily tonnage in open-pit mining.

TABLE C-8.—Estimates of mine and mill personnel by type of mining[1]

Underground mining at rate of	500 st/d	1,000 st/d	1,500 st/d	2,000 st/d	3,000 st/d	4,000 st/d	5,000 st/d
Blasthole:							
Mine	[2]110	140	175	215	295	375	460
Mill	35	50	60	70	85	100	110
Total	145	190	235	285	380	475	570
Cut and fill:							
Mine	200	255	315	375	500	620	NC
Mill	35	50	60	70	85	100	NC
Total	235	305	375	445	585	720	NC
Long hole:							
Mine	50	115	190	260	410	560	710
Mill	35	50	60	70	85	100	110
Total	85	165	250	330	495	660	825
Open stope:							
Mine	65	100	140	175	260	340	NC
Mill	35	50	60	70	85	100	NC
Total	100	150	200	245	345	440	NC

Underground mining at rate of	500 st/d	1,000 st/d	1,500 st/d	2,000 st/d	3,000 st/d	4,000 st/d	5,000 st/d
Room and pillar:							
Mine	35	115	205	290	470	650	835
Mill	35	50	60	70	85	100	110
Total	70	165	265	360	555	750	945
Shrinkage stope:							
Mine	120	185	250	NC	NC	NC	NC
Mill	35	50	60	NC	NC	NC	NC
Total	155	235	310	NC	NC	NC	NC

Open-pit mining at rate of	10,000 st/d	20,000 st/d	30,000 st/d	40,000 st/d	50,000 st/d	60,000 st/d	70,000 st/d
Mine	50	100	160	230	305	380	455
Mill	120	170	210	240	270	295	320
Total	170	270	370	470	575	675	775

NC Not calculated; beyond the limits of the data.
[1]All numbers are rounded to the nearest unit of 5.
[2]Position shifts per 24-h day, 8 h per shift.