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THE UNIVERSITY OF ALBERTA

COST MODELLING FOR COAL MINING DEVELOPMENT

by

Jorge Del Real

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

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To My Wife

Cecilia

Abstract

The research presented in this study is primarily concerned with the adaptation and formulation of a coal mining cost model for application to western Canadian coal mine development. After studying several available models, the Electric Power Research Institute (EPRI) model was selected. This model was adapted to Canadian conditions (metric system, Canadian taxes, Canadian royalties, etc.), and the software to perform the model was also written.

The end product is a model that represents a computerized process engineering approach to the analysis of production costs and mining requirements. The model is applicable to both surface or underground mining situations. The model estimates all capital and operating costs typically associated with the preproduction and production phases of a coal mining project. It also contains an uncertainty analysis procedure which uses a Monte Carlo simulation technique for estimating cost results in terms of probability distributions.

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Table of Contents

Chapter — Page

1. Introduction 1

2. Characteristics of Western Canadian Coal Mining 2

2.1 Coal Resources and Reserves 2

2.2 Mining Technology 5

2.3 Coal Preparation 10

2.4 Coal Distribution 14

2.5 Coal Production and Demand 16

2.6 Conclusion 19

3. Analysis and Evaluation of Coal Economic Models 20

3.1 Introduction 20

3.2 Economic Models for Western Canadian Coal Mining 22

3.3 Coal Economic Model Evaluation 23

3.3.1 Preliminary Coal Cost Estimation Models 23

3.3.1.1 O'Hara-Mular model 24

3.3.1.2 The B.C. Ministry of Mines and Petroleum Cost model (MMPR) 27

3.3.1.3 STRAAM Estimating Procedures 29

3.3.1.4 Fluor Utah model 32

3.3.1.5 Burzlaff-Lohrenz-Monash Model 34

3.3.1.6 EPRI model 35

3.3.2 Other Types of Model Analysis 37

3.3.2.1 JPL model 37

3.3.2.2 The Pensylvania Coal model (PCM) 38

3.3.2.3 US Bureau of Mines Circulars 38

3.3.2.4 VPI model 39

3.3.3 Model Selection 40

4. The EPRI Model 42

4.1 Introduction 42

4.2 Underground Model 45

4.2.1 Introduction 45

4.2.2 Submodel 1: Production Sizing 46

4.2.3 Submodel 2: Manpower requirements and costs 50

4.2.4 Submodel 3: Equipment and Construction Requirements and Costs 52

4.2.5 Submodel 4: Supplies Materials and Power Costs 58

4.2.6 Submodel 5: Preproduction Development 59

4.3 Surface Model 61

4.3.1 Introduction 61

4.3.2 Submodel 1: Primary Equipment Selection and Costs 69

4.3.3 Submodel 2: Supporting Capital Item Costs .78

4.3.4 Submodel 3:Manpower requirements and Costs 80

4.3.5 Submodel 4: Operating Supplies and Material Analysis 81

4.4 Financial Analysis 82

4.4.1 Introduction 82

4.4.2 Major Financial Analysis Options 82

4.4.2.1 Solving For Coal Value/t or Rate of Return on Equity 82

4.4.2.2 Solve For Either Point Value Results or a Range 83

4.4.2.3 Analysis using Constant Dollar or Escalating Values 84

4.4.2.4 Optional Capitalization Structure 85

4.4.2.5 Capital Costs Treatment 85

4.4.2.6 Optional Depreciation Methods 85

4.4.2.7 Optional Royalty Payments Calculation Methods 86

4.4.2.8 Optional Project Start Year 86

4.4.2.9 Assumptions 86

4.4.3 Capital and Operating Costs Analysis 87

4.4.3.1 Capital Costs Schedule 87

4.4.3.2 Operating Cost Analysis 89

4.4.4 Application of DCF Analysis 92

4.4.4.1 Line 101-Coal Value/Tonne 94

4.4.4.2 Line Item 102-Annual Production of Clean Coal 94

4.4.4.3 Line Item 103-Annual Sales Revenue 94

4.4.4.4 Line Item 104-Annual Operating Costs 95

4.4.4.5 Line Item 105-Gross Profit 95

4.4.4.6 Line Item 106-Loan Interest 95

4.4.4.7 Line Item 107-Resource Allowance .97

4.4.4.8 Line Item 108,110- Capital Cost Allowance 97

Fast (or Accelerated) Method: 97

Straight Line Method 98

Declining Balance Method 98

...................................98

4.4.4.13 Line Item 111- Net Income for Depletion Allowance 99

4.4.4.14 Line Item 112- Depletion Allowance 99

4.4.4.15 Line Item 113-Taxable Income 99

4.4.4.16 Line Item 114-Income Tax 99

4.4.4.17 Line Item 115-Royalty 100

4.4.4.18 Line Item 116-Investment Tax Credit 100

4.4.4.19 Line Item 117-Net Profit 100

4.4.4.20 Line Item 118-Additional Income (Salvage Value) 101

4.4.4.21 Line Item 119-Addback of Non Cash Costs 101

4.4.4.22 Line Item 120- Loan Principal Payment 101

4.4.4.23 Line Item 121- Net Cash Inflow ..102

4.4.4.24 Line Item 122-Acquisition Cost ..102

4.4.4.25 Line Item 123-Exploration 102

4.4.4.26 Line Item 124-Preproduction Development......................102

4.4.4.27 Line Item 126-Equipment 103

4.4.4.28 Line Item 127-Accrued Interest ..103

4.4.4.29 Line Item 128-Indirect Capital ..103

4.4.4.30 Line Item 129-Working Capital ...103

4.4.4.31 Line Item 130-Total Capital Expenditures 104

4.4.4.32 Line Item 131 and 132-Amount Funded from Equity and Loans Respectively 104

4.4.4.33. Line Item 133-Annual Net Cashflow 104

4.4.5 Coal Value/Tonne Calculation Procedure ...104

4.4.6 Rate of Return on Equity Calculation Method 109

5. Model Computational System Description 113

5.1 Introduction 113

5.2 System Description 116

5.2.1 Input Process 116

5.2.1.1 Input via Terminal 116

5.2.1.2 Input Via Files 119

5.2.2 Submodels Costing Process 121

5.2.3 Financial Analysis 122

5.2.4 Reports Generation 124

5.2.5 Uncertainty Analysis 125

5.3 Statistical Analysis 128

6. Computational System Validation 140

6.1 introduction 140

6.2 Test Using Original Model Input 140

6.2.1 Underground Model Test 140

6.2.2 Surface Model Test 141

6.3 Test Using Canadian Input Data 142

6.3.1 Underground Model Test 143

6.3.2 Surface Model Test 144

6.3.3 Preparation Plant Cost Validation 148

7. Conclusion and Recomendations 151

Bibliography...156

APPENDIX A: Royalty Formula for Coal Produced in Alberta.161
APPENDIX B: Variable and File Names......................166
APPENDIX C: Data Files Content...........................174
APPENDIX D: Underground Model Validation Using
Original Model Input Data....................185
APPENDIX E: Surface Model Validation Using Original
Model Input Data.........................189
APPENDIX F: Underground Model Validation Using
Canadian Input Data...........................193
APPENDIX G: Surface Model Validation Using Canadian
Input Data....................................200
APPENDIX H: User's Manual................................209

List of Tables

Table Page

2.1 Canadian Coal Production 17

4.1 Input Parameters for Underground Model...............48

4.2 Production Section Requirements & Costs..............55

4.3 Continuous Miner Costs 55

4.4 Roof Bolter costs 56

4.5 Conventional Mining Production Section Costs.........56

4.6 Longwall System Section Costs 57

4.7 Dragline Costs..62

4.8 Power Shovel Costs....................................64

4.9 Rubber Tired Loader Costs.............................65

4.10 Haul Truck Costs.....................................66

4.11 Dozer Costs..67

4.12 Scraper Costs..67

4.13 Loading Shovel Costs.................................67

4.14 Input Parameters for Surface Model...................71

4.15 Capital Allocation Schedule for Underground..........90

4.16 Capital Allocation Schedule for Open Pit.............91

4.17 Cash Flow Summary Table..............................93

5.1 Required Input for Surface Mining....................117

5.2 Required Input for Underground Mining...............117

5.3 Optional Input Values for Underground Mining........118

5.4 Optional Input Values for Surface Mining............118

5.5 Parameters Which Override Calculated Values (Under.) 120

5.6 Parameters Which Override Calculated Values (Surf.): 120
6.1 Underground System Output Using Default Input.......145
6.2 Underground System Output Using Conventional Method.145
6.3 Underground System Output Using B.C. Royalty Rate...146
6.4 Underground System Output Using Declining Balance...146
6.5 Surface System Output Using Default Input...........149
6.6 Surface System Output Using Open Pit Method.........149
6.7 Surface System Output Using B.C. Royalty Rate.......150
6.8 Surface System Output Using Declining Balance.......150

List of Figures

Figure Page

2.1 Map of Principal Coal Areas in Canada....................3

2.2 Strip Mining..7

2.3 Open Pit Mining...9

2.4 Room and Pillar Method.................................11

2.5 Schematic Rail Network Routes..........................15

3.1 Accuracy Ranges for Various Classes of Estimates.......21

3.2 Crude Guide Costs by the O'Hara Model..................25

3.3 Mine Operating Costs by the Straam Procedure...........30

4.1 Structure of the EPRI Underground Model................47

4.2 Mine Personnel Requirements in Underground Mining......51

4.3 Structure of the EPRI Surface Model....................70

4.4 Realtionship Between Strip Ratio & Support Eq. %.......79

4.5 Plot of Present Value with Respect of Coal Price......106

4.6 Solving a Nonlinear Equation by Linear Aprox..........107

4.7 Plot of Present Value with Respect of ROR.............110

4.8 Solving a Nonlinear Equation by Linear Approx.........112

5.1 Computing Model Flowchart.............................114

5.2 Financial Analysis Flowchart..........................123

5.3 Uncertainty Analysis Flowchart........................126

5.4 Probability Plot for Underground Rate of Return.......131

5.5 Probability Plot for Surface Rate of Return...........132

5.6 Probability Plot for Underground Coal value...........133

5.7 Probability Plot for Surface Coal Value.............134
5.8 Kolmogorov-Smirnov Test for Underground ROR.........136
5.9 Kolmogorov-Smirnov Test for Surface ROR.............137
5.10 Kolmogorov-Smirnov Test for Underground Coal Price..138
5.11 Kolmogorov-Smirnov Test for Surface Coal Price......139

1. Introduction

Coal mining costs are key information for utilities using coal and for planners forecasting the future price of coal. Coal mining is a complex process in which capital and labor are applied to coal reserves in the ground to produce a useful product: coal, ready for shipment to the consumer. In order to gain a better understanding of the factors influencing mining costs and to provide a systematic framework for estimating mining costs, a model of the coal mining process is required.

The main purpose of this thesis is to provide a coal mining cost model suitable to the requirements of western Canada. Many studies on coal cost models have been published during the last 10 years, but only some of them can be applied to western Canadian coal in a relatively direct way. For this reason and to satisfy the main purpose of this thesis, the following objectives have been formulated: evaluation of models currently available in order to find the best one from the western Canadian point of view, adaptation of such a model to be used under Canadian conditions and development of interactive software to manipulate the given model.

2. Characteristics of Western Canadian Coal Mining

2.1 Coal Resources and Reserves

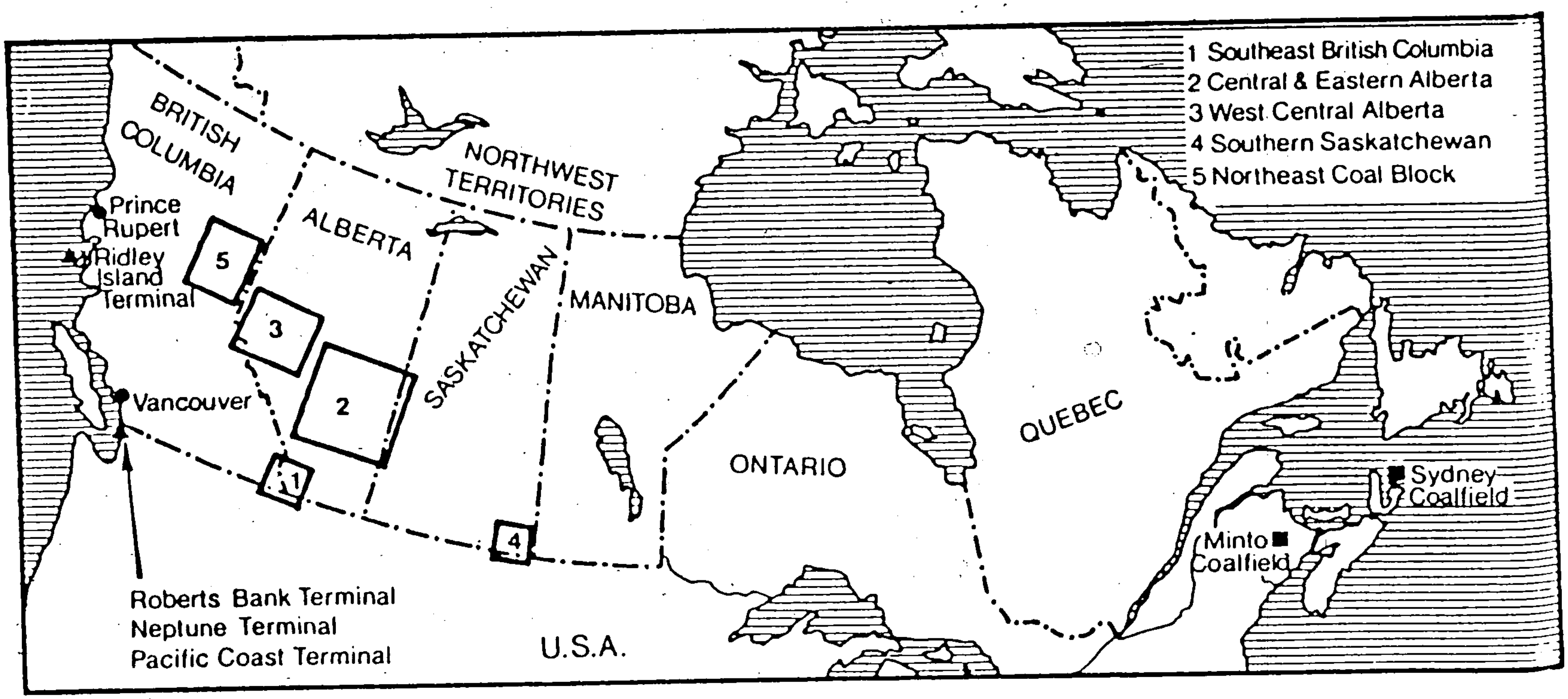
Coal of all ranks is widely distributed in mainland Canada, whereas in the Artic Archipelago only lower rank coal has been identified. The main production centres are located in western Canada (See Figure 2.1). Most of western Canadian coals have the advantage of having a low sulphur content, i.e. less than 0.5 percent. A description of these production centres is presented as follows:

a. South East British Columbia: The one underground and four open pit operations of the Crowsnest Pass are located around the community of Fernie, B.C. This district is the largest producer of coking coal in Canada. Seams are often steeply inclined, sheared and faulted. The recoverable coal reserves in this area are estimated at 5 300 million tonnes of proven coal and 10 000 million tonnes of inferred coal(27).

b. Central and Eastern Alberta: The central and eastern coal mines produce the largest amounts of thermal coal in Canada. Seams are generally tabular in shape, with ho[illegible]al dimensions of several kilometres a[illegible]ly uniform thickness for considerable di[illegible]. The proven reserves of recoverable coal [illegible]stimated at 9 800 million tonnes of coal (27).

Figure 2.1

MAP SHOWING PRINCIPAL COAL AREAS IN CANADA



Adapted from (26)

c. West-Central Alberta: The West-Central Alberta deposits are principally metallurgical coal, this district is centred at the locality of Hinton. The geological environment of this area is similar to that of South-Eastern B.C. The demostrated reserves of recoverable coal have been estimated at 2 330 million tonnes(27).

d. Southern Saskatchewan: Mining of lignite has been taking place in southern Saskatchewan since 1887. Six surface mines supply mine-mouth generating stations, as well as some shipments to Ontario and Manitoba Hydro and industrial users. These seams are similar to those in east-central Alberta in the fact that they are relatively uniform in thickness with extensive horizontal dimensions. The reserves of recoverable coal have been estimated at 3 300 million of proven tonnes, 2 700 millions of inferred tonnes and 15 000 millions of future tonnes(27).

e. Northeast British Columbia: In this region, formerly called the Peace River Coalfield, a world scale project involving the construction of two new coal mines is taking place. An initial production capacity of up to 8.8 million tonnes per year is being planned. Studies estimate that 85 percent of this deposit consists of high grade coking coal while the remaining 15 percent is considered to be high grade thermal coal(28). Seams are typical of mountain regions with changing thickness and inclination. The reserves of recoverable coal have been estimated at 5 300 million tonnes of proven coal and 10 000 million tonnes of inferred coal (27). The first coal from this region was shipped in December of 1983.

Other production centres in Canada are in the Maritimes. Cape Breton in Nova Scotia produces both metallurgical and thermal coal; further plans for expansion are underway. The Minto mine in New Brunswick produces a small quantity of thermal coal.

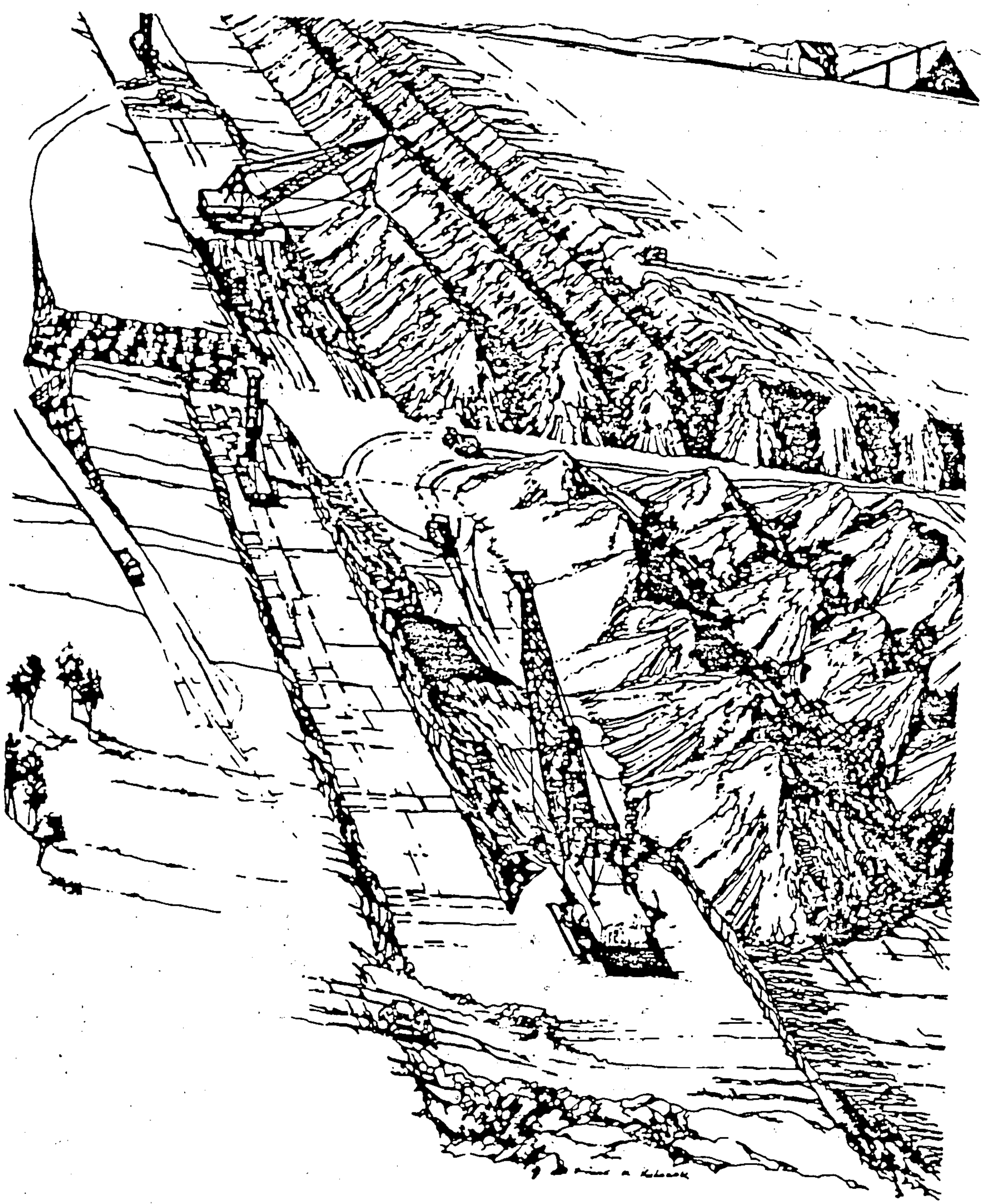
2.2 Mining Technology

Where conditions permit, surface mining has many advantages over underground methods. Large equipment can be used, resulting in lower unit costs. Production and manpower problems are normally fewer in surface than in underground operations, but there are some limitations and disavantages to surface mining operations. The maximum depth of work depends on the strip ratio that can be accepted. This ratio is the volume of overburden that must be removed per unit volume (or weight) of coal that can be extracted. Another limitation of surface methods are the possible environmental effects such as noise, dust or the appearance of the operation for the nearby residents. Also there are concerns about the alienation of valuable agricultural, forestal or recreational lands for mine use.

- <u>Plains Areas</u>(Central-East Alberta and Southern Saskatchewan): The relatively shallow and flat-lying coal seams of this area are ideal for applying strip mining (or area mining), as illustrated in Figure 2.2. Parallel adjoining trenches are excavated in sequence through the overburden: the coal is recovered from the botton of each trench as it is exposed and overburden from the next cut is then cast into the previously excavated trench. The main equipment used for this method are draglines for overburden removal and shovels and trucks for the coal extraction.
- <u>Foothills and Mountains</u> (South-East B.C., North-East B.C. and West-Central Alberta): Because of the tectonic movements that have taken place in these regions, the position, thickness and continuity of coal seams differ substantially within short distances. The mining method employed therefore, must be flexible enough to suit local conditions and configurations. Both surface and underground methods are used. Due to the variability in conditions there are few examples of what might be called "standard" practices. However the principal mining methods used in these regions illustrate the possible requirements and limitations.
  . <u>Open Pit Mining</u>: Where the coal has been folded and squeezed into huge masses near the surface,

Figure 2.2

STRIP (or AREA) MINING



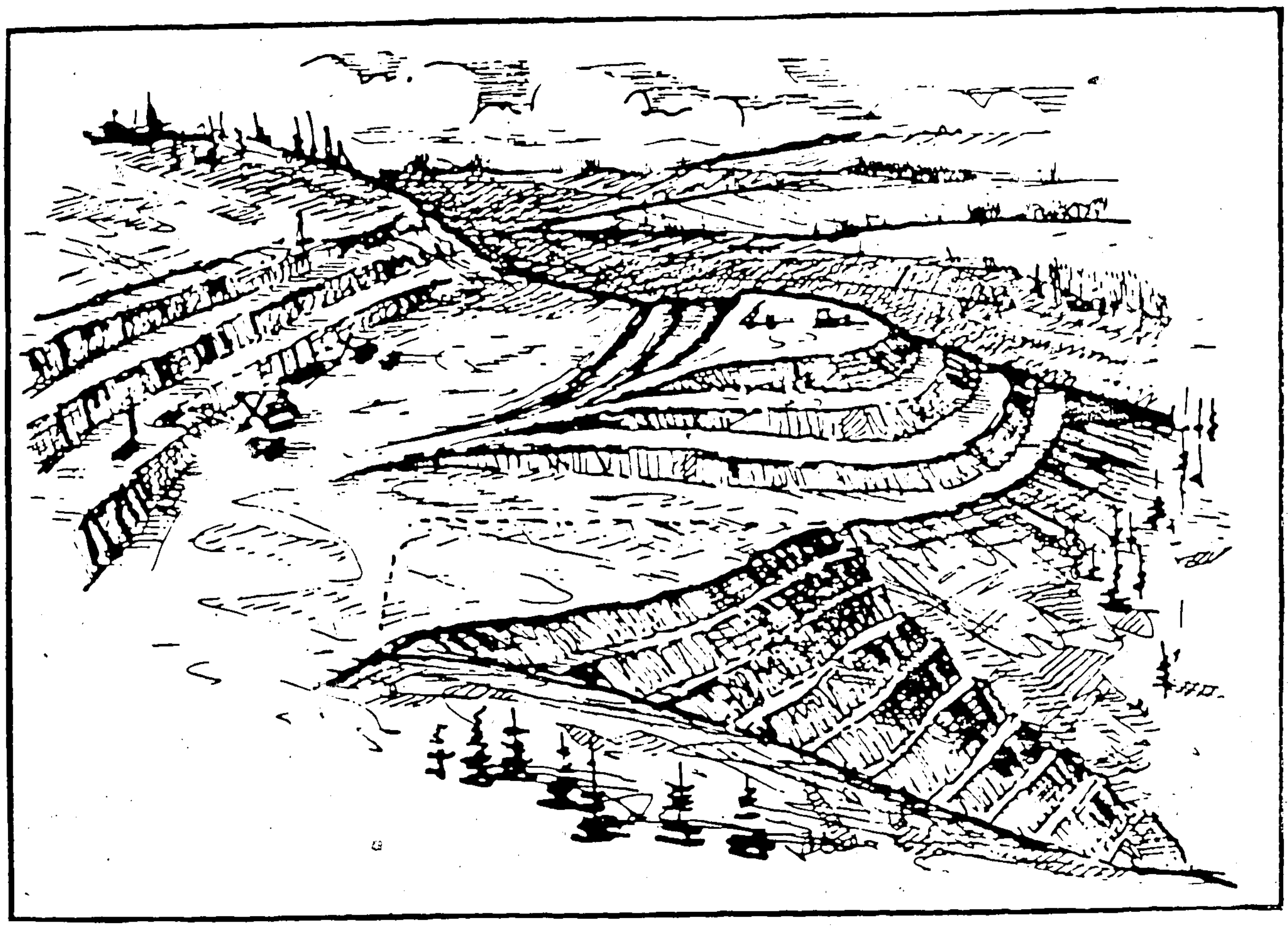
it can be mined by open pit procedures similar to those employed in hard rock mining pits (see Figure 2.3). The pit is excavated downward from the top in a sequence of steps like benches. In this type of operation, waste rock produced by mining and any waste from processing operations, cannot be placed in the excavation until the pit is mined out. The main extraction equipment for open pit mining are shovels and trucks for both overburden and coal.

Underground Mining: Only two companies currently operate underground mines in western Canadian mountain regions and there are none in the foothills. However, aproximately 70% of the coal ultimately obtained from these regions will come from underground mines(36).

Because most deposits have thick and/or steeply dipping seams, the application of mechanization is very difficult. However hydraulic mining has been succesfully developed in the last decade by Westar Mining (formerly B.C. Coal). The seams to be mined are inclined at angles ranging from 25 to 55 degrees. Hydraulic methods have good potential where conditions are right, but require fairly specific ground conditions, suitable inclination of roof rock and thickness of seams. Unless

Figure 2.3

OPEN PIT MINING



new methods become available, many seams in the mountains can be mined only by conventional underground methos i.e. room and pillars.

The room and pillar method is illustrated in Figure 2.4. This method consists of mining a grid of rooms separated by pillars of uniform cross section. Many grid layouts have been employed, including systems with rib and square pillars. A variation of this system is continuous mining. This method is essentially the same as room and pillar but the mining process is carried out using a continuous mining machine rather than hand methods, i.e. drilling, blasting and loading.

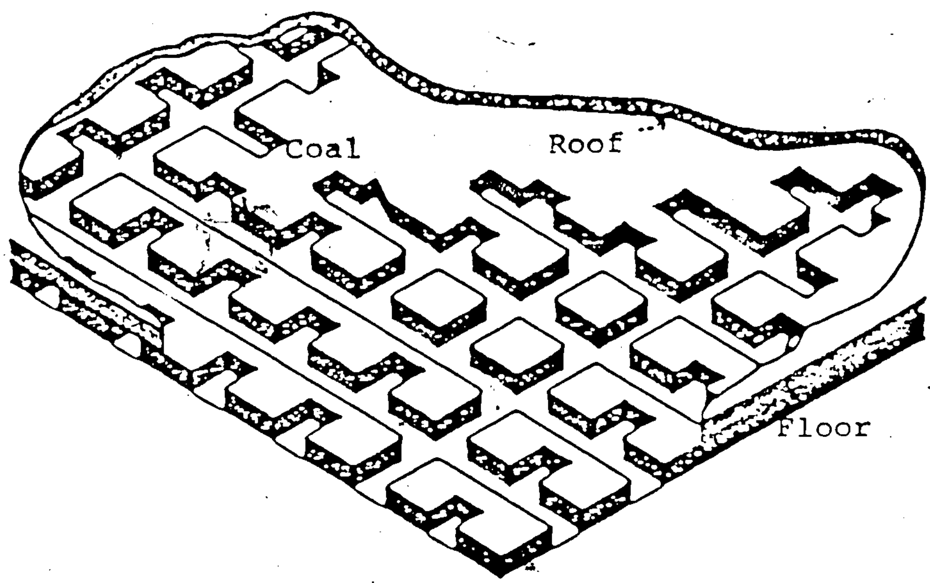
Another underground method that should be considered, is the longwall method. This method was tried at the Smoky River Mine (Alberta) but it was unsuccessful due to technical problems. However, this method has some advantages, especially those concerning safety. There are future proposals involving the longwall method in some new coal mining projects in western Canada.

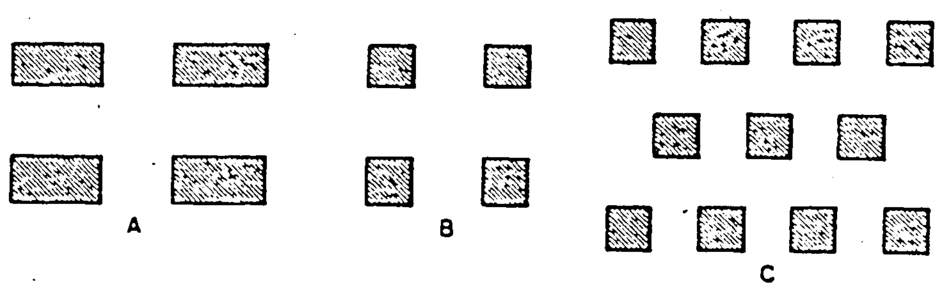
2.3 Coal Preparation

Coal as mined invariably contains some mineral matter which reduces its utility in several ways. The heat content of the coal is reduced in proportion to the amount of impurities present. Moreover, after coal is burned, the

Figure 2.4

ROOM AND PILLARS METHOD





A: rectangular pillars regularly spaced
B: square pillars regularly spaced
C: staggered checkerboard

remaining ash may create problems such as slag formation in the boilers, dust in the stack gases, and disposal. Sulphur in the mineral matter will produce sulphur dioxide in the stack gases giving rise to acid rain. When coal is used for metallurgical purposes the mineral matter in the coal reduces the stability of the coke and may also introduce contaminants in the products. If the coal is to be transported a long distance, it is necessary to reduce the mineral matter and moisture content, to lower the transportation costs. For all these reasons it is necessary to clean the raw coal.

Apart from the impurities, it is also necessary to consider the physical characteristics of the coal. This means separating the coal into certain size ranges after the mining or crushing processes. These sizes are classified normally in three types: coarse (200-18mm), medium (18-0.6mm) and fine (less than 0.6mm).

According to the impurities and physical characteristics of the coal, it is possible to distinguish three levels of preparation (29): breaking only, no fines beneficiation and total beneficiation.

- <u>Breaking Only</u>: This preparation is the ideal case, when the coal does not need to be cleaned. In this case the coal is only crushed. This type of preparation is commonly used for mine mouth thermal plants i.e. Lake Wabamun mines.
- <u>No Fines Beneficiation</u>: When the coal impurities are

more than the permissible standards and the percentage of fines is not large, no cleaning of the coarse size fraction (+0.6mm) is needed. In this case the cleaning process is carried out through a wet mechanical separation processes. The coal is processed in three stages: breaking (crushing and screening), cleaning, and conditioning (dewatering and drying). The most popular cleaning method is jigs such as Byron Creek and Obed Marsh mines.

- Total Beneficiation: When the degree of impurities and percentage of fines is high all size fractions must be cleaned. For the coarse and medium sizes the process is the same as in the No Fines Beneficiation process just described. As for the fines, they must be cleaned through a special wet mechanical process, and after being de-watered and dried, they may be agglomerated. Some examples of this method are Luscar-Sterco and Smoky River mines, in which the cleaning methods are heavy medium separation and froth flotation.

Unfortunately, except for the coals used in mine mouth power plants, the western Canadian coal usually must have total cleaning of all sizes because the percentage of fines produced by mining and crushing is excessive (about 30%). The yield (mass recovery) in the coal preparation plants in western Canada varies widely (56-92%) with a median value of about 70 percent.

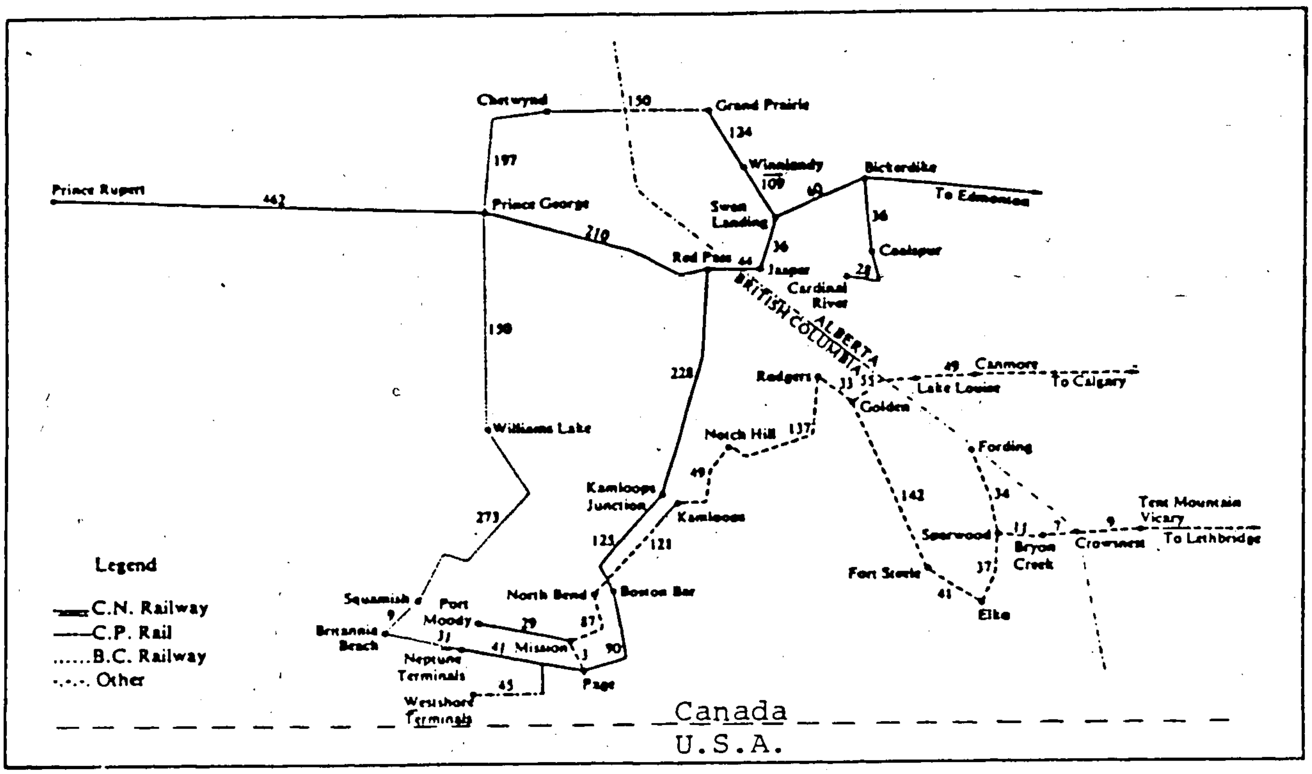
2.4 Coal Distribution

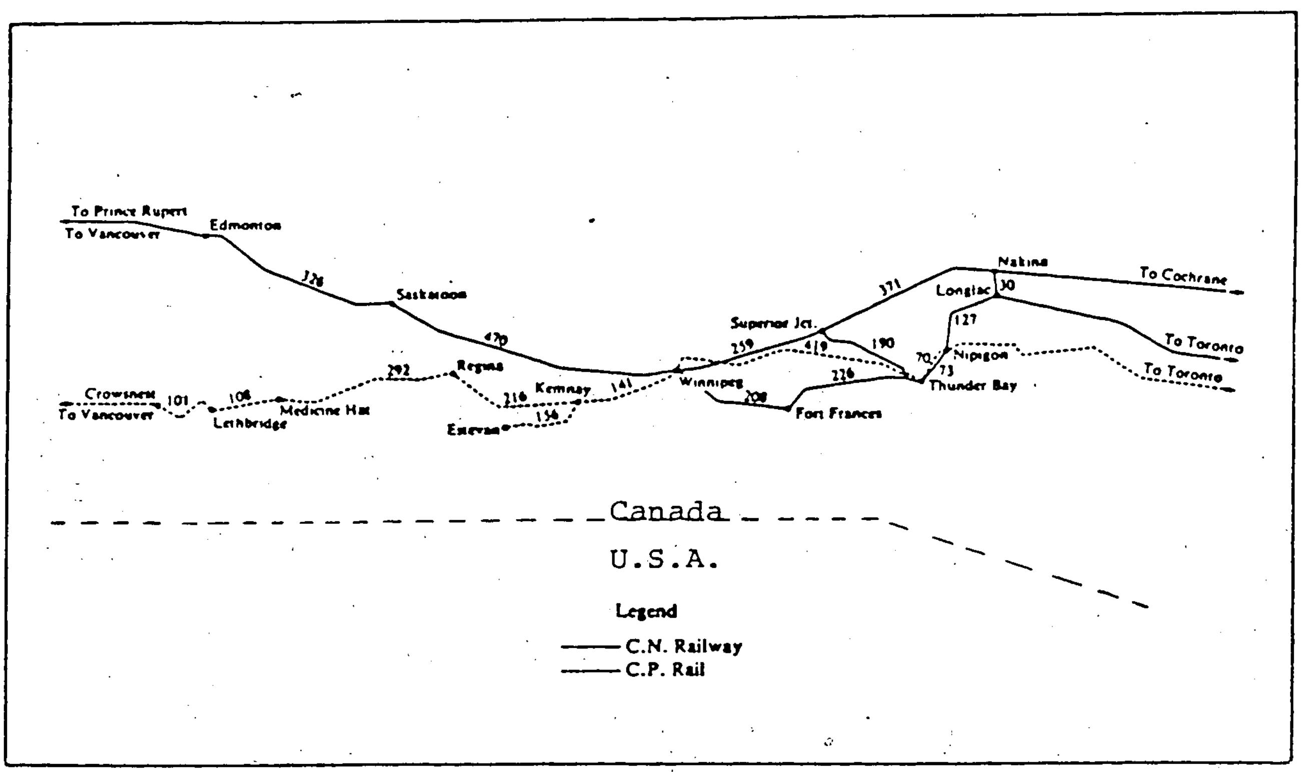
Because of the large distances between western Canadian mines and major coal markets, transportation is and will continue to be one of the most significant factors in determining whether western coal can be sold at competitive prices. To reach the markets in eastern Canada, coal must be hauled 2400 to 3200 kilometers, where it competes with coal moved 800 kilometers from the United States. For export, western coals are hauled an average of 1150 km through mountainous regions to reach west coast terminals. The situation is even more difficult for the North-East B.C. coal where a railway line including 9 km tunnel had to be built.

Most of the growth of western Canadian coal export in recent years has been due to the introduction of unit trains by both CN Rail and CP Rail. They use efficient loading and unloading facilities and specialized rolling stock to maximize equipment productivity and achieve low operating costs. In the case of North-East B.C. coal, industrial roads or railway spur lines will connect the mine with the existing B.C. Railway and subsequently with the CN main line(28). Figure 2.5 illustrates the schematic rail network for export and domestic consumers.

Figure 2.5

SCHEMATIC RAIL NETWORK ROUTES (Miles)





Adapted from (27)

2.5 Coal Production and Demand

In spite of the deteriorating world economic conditions that began in 1982, which forced Canada's coal exporting industry to make some adjustments, preliminary figures show that Canada produced and exported more coal in 1983 than in 1982 (see Table 2.1). In fact, in 1983, Canadian clean coal production reached an all time record of 44.5 million tonnes, a 5 percent increase over the 1982 production level.

The main increases were in thermal coal production, up to 7 percent with respect to 1982 production, but coking coal, almost all of which is exported, also had a small increase of 3 percent. This represent an important achievement given the current world coking coal market.

Even though the world recession is still on, coal forecasters are optimistic in regarding the future of coal demand, especially for thermal coal. Some reasons given for this optimism are (32):

- The attractive economics in the long term as compared to uncertainties in availability and costs of oil and gas.
- The availability and significant reserves.
- The existence of a rail transportation system.
- Other sources of energy like nuclear energy are still under development and will not represent a serious competitor for coal in the short term.

With regards to domestic consumption, the Alberta Energy Resources Conservation Board (ERCB) forecasts in

Table 2.1

CANADIAN COAL PRODUCTION (000t)

	1981	1982	1983
Bituminous			
Nova Scotia	2 539	2 800	2 550
New Brunswick	524	500	570
Alberta	6 895	7 300	6 700
B.C.	11 781	11 600	12 500
	21 739	22 200	22 320
Sub-bituminous			
Alberta	11 551	13 000	14 400
Lignite			
Saskatchewan	6 798	7 600	7 650
TOTAL	40 088	42 800	44 370

Source: (34) and (35)

1981 sub-bituminous coal requirements for electricity generation to increase from 11.4 million tonnes in 1981 to 20.6 million tonnes in 1990. In addition, Saskatchewan Power Corporation forecasts lignite requirements for the same purpose to rise from 5.6 million tonnes to around 7.8 million tonnes over the same period (33). Probably today this forecast is over optimistic, however, it is considered that this market will continue to grow in the 1980's, but at a slower rate than previously forecast (34).

The outlook for exports of metallurgical coal is clouded at present. Volume reductions averaged between 20 and 30% while price cuts were in the 15 to 20% range in 1983(34). The Japanese steel industry, Canada's major coal market, has been in a recession since 1982, and had reduced coal requirements in 1983. Probably this reduction will continue as the world recession remains.

The outlook for expansions in the thermal coal export market is more promising, despite a damping of the optimism expressed a couple of years ago. Studies released within the past two years suggest that exports of Alberta's high grade thermal coal could reach 5 million tonnes by 1985 and possibly 10 million tonnes by 1990 (33). Indications now are that little more than half of the volumes forecasted may be realized (33). Even so, this represents a strong growth over the decade of the 1980s.

Other future sources of demand for coal include the use by in situ oil sands producers for steam production and the establishment of an electricity export market. The postponement of oil sand projects, however, will delay the increased coal requirements projected. According to recent ERCB estimates, 5 to 7 million tonnes per year of coal will be needed for in-situ operations around the end of this century(33).

2.6 Conclusion

It can be concluded that coal mining will play an important role for the rest of this century and probably in the beginning of the next, in the economy of western Canada. Both new coal mining projects and expansion of existing coal mining activities can be expected in western Canada in the next few years, especially for coal to be used in thermal plants.

The capital involved in any of these eventual projects is normally very large, and for this reason it is very important to minimize the risk taken by the investors. Evaluation tools such as modelling, simulation or geostatistics, can be useful in minimizing the investment risk.

3. Analysis and Evaluation of Coal Economic Models

3.1 Introduction

Mining project evaluation is the procedure of measuring whether the profit from mining is sufficient to justify the cost of developing the mine, building the plant and developing mine services. This procedure requires the estimates of capital cost, revenue, and operating cost.

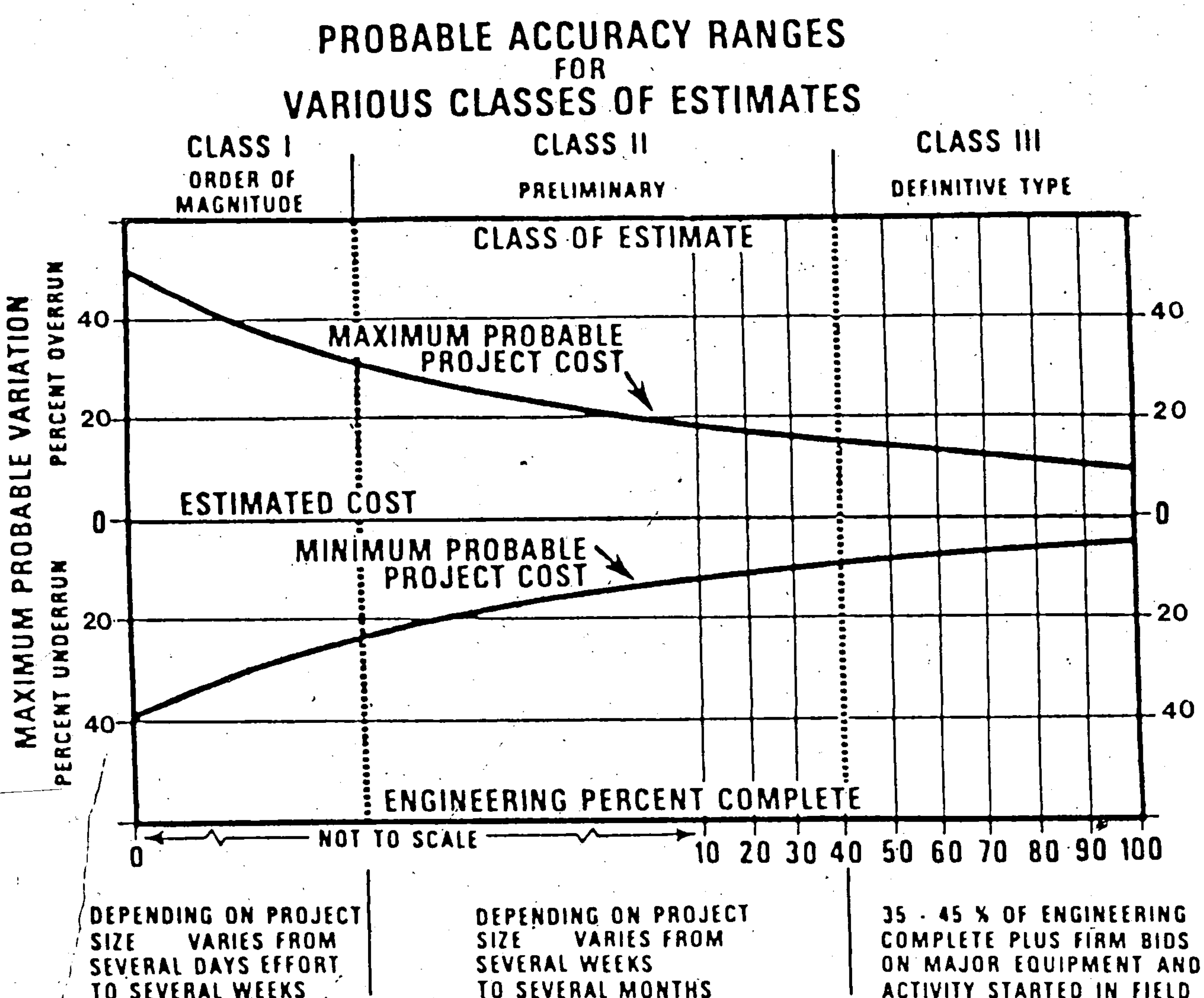
Accurate estimates of capital and operating costs are possible only when there is a detailed knowledge of physical quantities such as labor and productivity. This knowledge is normally achieved only after a substantial portion of the design engineering work has been performed. However, preliminary cost estimates of moderate accuracy can be attained in advance of design engineering by factoring known costs from similar mining projects.

The American National Standard Institute has grouped estimates into three classes (ANSI Standard Z94.2):

- Class I, is an order-of-magnitude estimate with an accuracy of +50% to -30%.
- Class II, is a preliminary (budget) estimate with an accuracy of +30% to -15%.
- Class III, is a definite estimate with an accuracy of +15% to -5%.

Figure 3.1 illustrates the classes defined above. Information regarding the basic mining and/or processing

Figure 3.1



Adapted from (2)

method, capacity, equipment specifications, flowsheet, site layout, etc, will increase as accuracy increases.

The class I estimates(order-of-magnitude) can be achieved using economic models. An economic model is normally a set of mathematical relations generally built from different operational experiences that depend on a few variables whose values are relatively easy to obtain. An economic model is useful for determining the sensitivity of project viability to changes in assumptions regarding coal prices, specific mine physical conditions, mining method, management strategy, and other exogenously determined variables. Ideally, an economic model should have a sound statistical basis, with all cost and operating data based on averages of actual experience or detailed engineering estimates adapted to specific site conditions.

3.2 Economic Models for Western Canadian Coal Mining

In considering the information outlined in Chapter 2, it can be concluded that substantial investments in coal mining are expected in western Canada for the near future. In this sense this thesis attempts to provide an economic model for these projects in order to provide Class I estimates of the economic parameters. Such a model would provide a useful tool for mining company management to assess the viability of these projects.

The development of a particular economic model normally requires a great expenditure of time and money. For this reason it was concluded that it may be more appropiate to adapt an existing model to western Canadian conditions. With this objective the problem now is to select the best coal mining economic model for this purpose.

Recently many coal mining economic models have been developed. However, only one of them, the North East Coal Study, is based on Canadian experience. The following section deals with finding the most appropiate coal mining economic model to be adapted to western Canadian conditions.

3.3 Coal Economic Model Evaluation

This section attempts to describe and evaluate the models available on the market and/or of which literature is accessible. They were divided into two groups: those considered having the same objective as this thesis (preliminary cost estimation), and those that in spite of their different orientation could be of some use for other types of studies. The first group will be analyzed in some depth, while the second will only be briefly described.

3.3.1 Preliminary Coal Cost Estimation Models

Conventional accounting tends to consider costs as either fixed (constant independent on mine size); variable (cost dependent on mine size); or semi-variable (a mixture of both). However recently, specialists consider that no cost is purely fixed, variable or semi- variable. All costs, to a greater or lesser extent, are semi-variable, but the dependance on the mine size follows a power function rather than a linear function. Thus, most of the models described follow the following form:

total cost=$a*x^b$, or cost/ton=$a*x^b/x$, where "x" is a suitable parameter such as annual tonnage of coal, "a" normally is a unit cost, and "b" is a constant which reflects the sensitivity to economy of scale. Thus, if we assume b= 0.6 on a production increase of 100 percent, the cost increase generated will be $2^{0.6}$ -1.0= 51.6 percent.

Each model analyzes the parameters in different ways. In general, the costs to be estimated by each model should be: mining capital cost, process plant capital cost, plant utilities and general services capital cost, and operating costs. Revenues and profits are also analyzed by some models.

3.3.1.1 O'Hara-Mular model

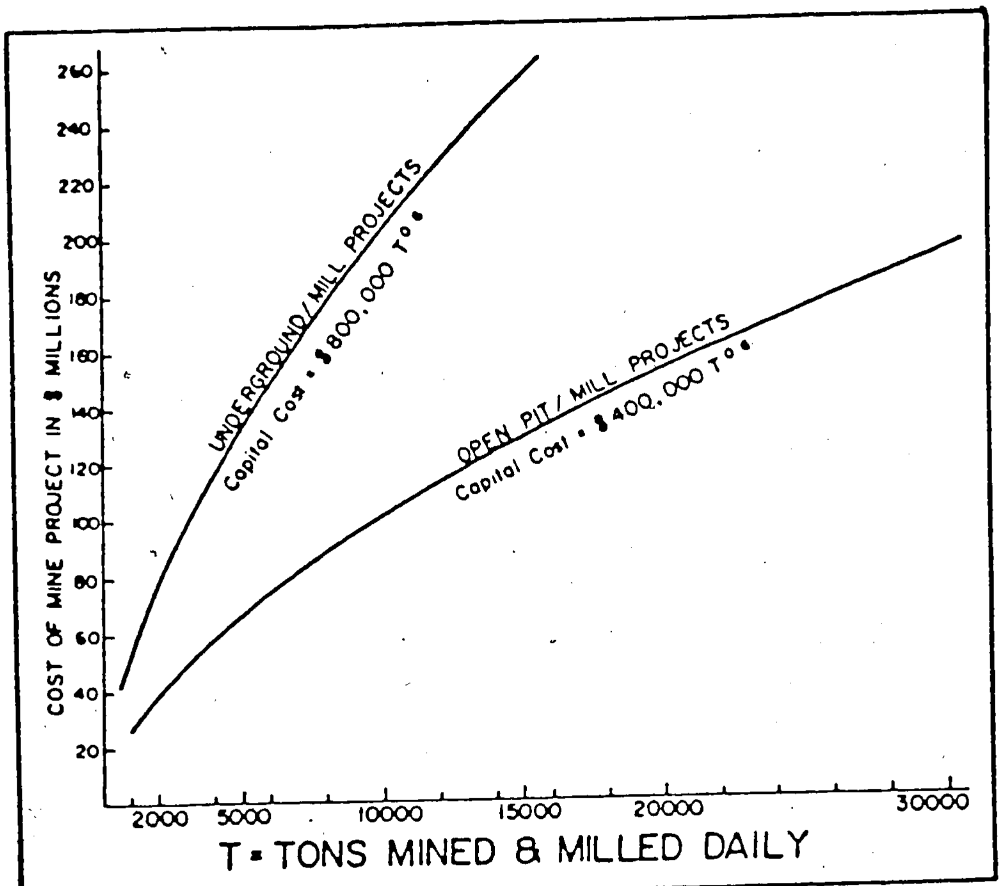
T.A. O'Hara, in a paper presented to the 81th Annual CIM General Meeting in 1979 (1), described a very simple and complete mining cost model. Based on this document, A.L. Mular through the Canadian Institute of Mining and Metallurgy published a handbook (2) for preliminary mining and mineral processing cost estimation. Finally, in 1982 O'Hara also made a new presentation, enlarging his model, in the Mining Industry Costs book (3) .

A crude guide to the average 1978 costs of mine projects, according to this model, is shown in Fig. 3.2.

Figure 3.2

CRUDE GUIDE COSTS OF MINE PROJECTS

BY THE O'HARA MODEL



Adapted from (1)

A more accurate estimate of over-all project capital cost can be made from the summation of cost items after judging the effect of specific local conditions on each item's capital and operating cost.

In his model, O'Hara analyzes capital cost for open pit mining, underground mining, processing plant, utilities and general services, defining cost parameter equations for each item and sub-item. Regarding production costs, these are divided into two categories, namely operating costs and supplies followed by administration and general services, which are estimated through procedures provided by the model. inally, based on the selling price and characteristics of the product, O'Hara gives a procedure to estimate the revenue.

To keep the O'Hara-CIM model updated, A.L. Mular(2) developed a cost indices system, which uses the Marshall and Swift Cost Index to provide coefficients that make the model applicable to any year.

Advantages of the model:

* is based mainly on Canadian mining experience.
* was built using the metric system.
* presents a detailed analysis of each mining item.
* structure is simple and easy to use.
* risk analysis is considered.
* both surface and underground mining are analyzed.

Disavantages of the model:

* not coal oriented.
* for those items useful in coal mining, in some cases, it is necesary to adjust the unit cost , for example, preproduction stripping.
* does not consider tax, royalties, and financial analysis.
* does not provide a complete cost analysis.

3.3.1.2 The B.C. Ministry of Mines and Petroleum Cost model (MMPR)

This model is a part of the Northeast Coal Study prepared for the British Columbia Government in 1976 (4). This model has been developed in order to facilitate estimation of various financial indicators and to determine the economic viability of proposed developments.

The input data of the model are catagorized as investment parameters, open pit mining parameters, underground mining parameters, price and production cost parameters. The output variables are essentially the return on capital invested and the payback period. In addition, the model provides procedures and algorithms for the estimation of each element of capital and operating cost either in open pit or underground mining. For the latter, it analyzes room and pillar, shortwall/longwall, and hydraulic mining. Estimates for preparation plant and other structures associated with mine site infrastructure are also considered. The constants and coefficients used by the algorithms were obtained from the analysis and adaptation of existing experience in coal operations in B.C., from operational characteristics of metal mines, and from preliminary feasibility studies submitted by project developers.

The model enables a sensitivity analysis of all parameters to be undertaken. This provides a proxy for a full risk analysis in which comparative impacts of alternative assumptions on the values of all input variables can be measured.

Based on the MMPR model and to assist in the evaluation of the proposed coal projects in northeast B.C., a computer system, called COALMOD (5) was developed. Model functions calculate annual total and net revenues and total operating and capital costs. Other available functions calculate annual tax payments to Federal, Provincial, and local Governments, using the current tax rules to derive eligible deductions. In simulation of fiscal policy effects, the models' available tax routines can be used to evaluate different tax and royalty rates and/or structures (e.g. an Alberta coal taxation environment).

Advantages of the model:

* is the only coal oriented model based on Canadian experience.
* provides a wide analysis of tax and royalties.

* both surface and underground methods are considered.
* has a financial and sensivity analysis.
* uses the metric system.

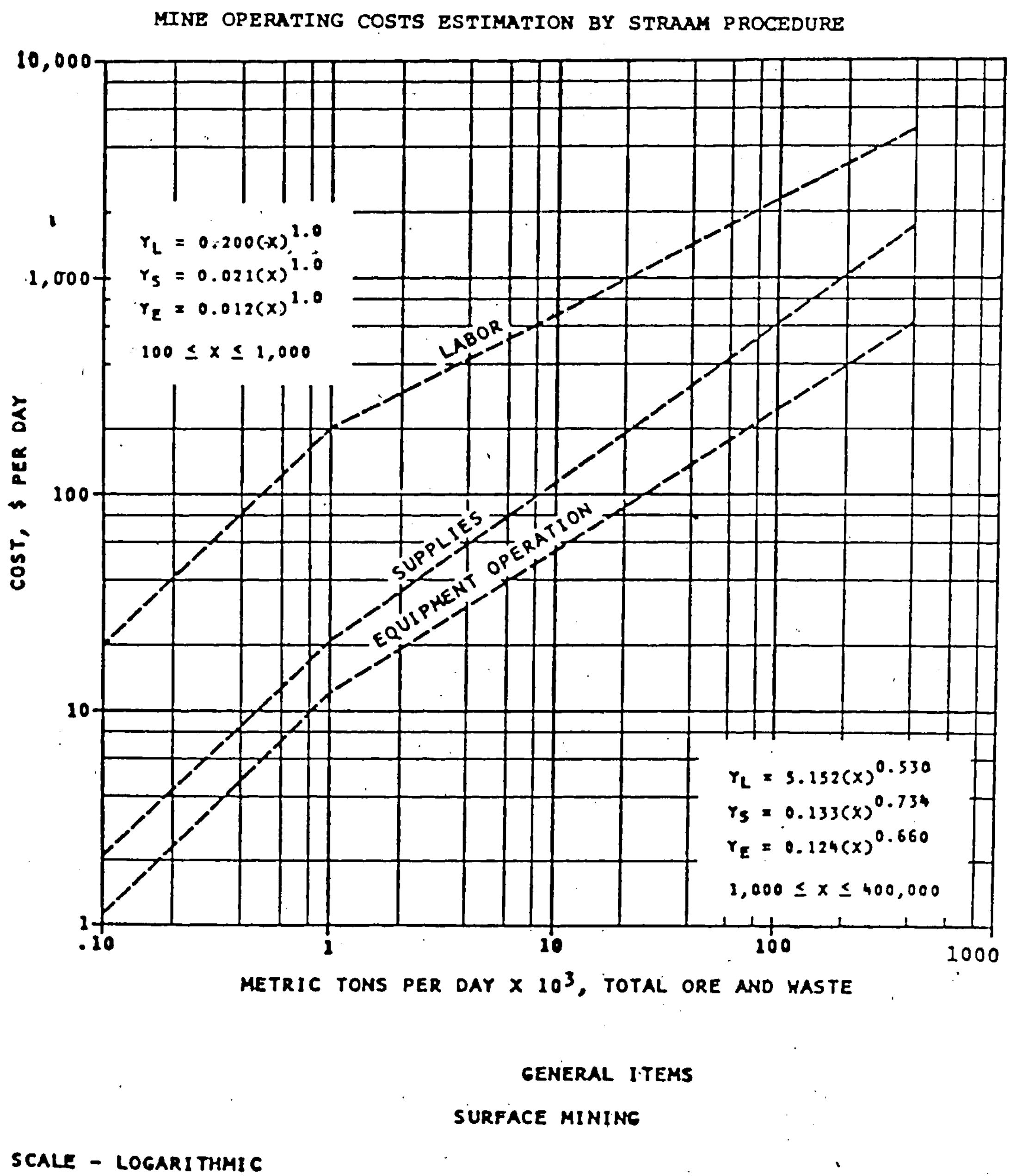
Disavantages of the model:

* the Canadian coal experience data is very sparse, particularly for underground mining, therefore the model might not be adequately tested.
* does not provide detailed capital equipment costs.
* requires too much input.

3.3.1.3 STRAAM Estimating Procedures

Under a contract from the U.S. Bureau of Mines, Straam Engineers prepared a manual for estimating costs for feasibility investigation (6). The main objective of this study was to develop a manual method for the preparation of feasibility type estimates for capital and operating costs of mining and primary beneficiation of various types of minerals. The equations, factors and curves were defined using averages obtained from 66 different sources in the U.S.A. and Canada. The model essentially intends to make a preliminary estimate with little hard data in order to ascertain if further more detailed estimates are justified. An example to show how the model is constructed, is presented in Figure 3.3.

Figure 3.3



Adapted from (6)

To use this model, general mine information, surface and/or underground parameters, beneficiation parameters, exploration information, and capital cost data must be provided. The model is not intended to determine the cost of any single component of a mining or beneficiation system. The combination of components summarized through the use of summary of item costs and tabulation of item cost work sheets, will produce a preliminary feasibility type estimate which should fall within 25% of the eventual actual cost.

To adjust cost data for inflation, cost indices are available. They are based on "Employment and Earning" and "Wholesale Prices and Price Indexes" systems, both published by the U.S. Department of Labor.

Advantages of the model:

* both Canadian and U.S. experience are considered.
* the samples are large enough to make the model reliable.
* a detailed cost analysis of each mine item is presented.
* uses the metric system.
* both surface and underground methods are considered.

Disavantages of the model:

* the model is applicable to all types of

minerals, except fossil fuels, hence it is not directly, applicable to coal, unless adaptations are made.

* taxes and royalties must be adapted to Western Canadian rules.
* does not present a financial analysis.

3.3.1.4 Fluor Utah model

Fluor Utah Inc., with Bonner & Moore associated Inc. as subcontractor, was employed by the Energy Research and Development Administration (ERDA) to determine and define models which are representative of current U.S. coal surface mining (8). Techniques were developed, documented and tested. Two types of models were built: detailed micro-models and broad macro-models.

The detailed micro-models provide estimates for a detailed part of a large scale surface mining complex. Individual models allow the user to analyze separately the following functions: overburden removal, coal load and haul, drilling and blasting, land reclamation, coal preparation, and mine administration.

The broad Macro-model provides a first order evaluation of new ventures for an entire mining complex. The functions considered are basically the same as those considered in the detailed micro-model, but require less input as some values are assumed by default.

The input that establishes the mining and financial parameters must be previously defined. As a result of a run of the model, the user should be able to: estimate capital investment and annual cost, select equipment and estimate unit cost for each mining function, estimate manpower and general requirements for the project, and analyze coal selling price and profit relationships.

The model was based on strippable coal resource regions defined in terms of surface geology and physical characteristics. Combinations of most applicable mining methods and regions in U.S. were selected to test the model. Hypothetical mining situations which where representative of typical mining problems and conditions encountered in the region were defined to form the models algebraic framework.

Advantages of the Fluor model:

* detailed micro-models and macro-models are available.
* is coal oriented.
* a flexible input is allowed.
* provides a very complete and wide output, including a financial analysis.

Disavantages of the model:

* was built using the Imperial system.
* supporting data was taken from the 8 most representative coal regions of U.S. Some of

these differ greatly from Canadian conditions.

* does not consider underground mining.
* presents little flexibility towards tax and royalties.

3.3.1.5 Burzlaff-Lohrenz-Monash Model

A model of discounted cash flow has been developed to simulate financial production scenarios for coal mines(31). The model includes development costs, fixed operating costs, bonus costs, and revenue. Investors are assumed to project future costs and units revenues and choose a production rate and duration which maximizes the present value of future profits. This assumption presumes that reasonable investors intend to make profit and do not commit large amounts of capital without some return.

Three geometries for the coal source were considered: uniform horizontal bed: multiple horizontal, parallel seams of coal; and a single uniform seam of coal of unlimited extent that dips at a fixed angle.

The model is based on classical and well established equations of mineral and energy resource mining, which can be used to display optimal rate of production and ultimate recovery for various cost and revenue values. The data used to establish these equations were compiled from information obtained from 15 surface and 4 underground mines, all of them located in different parts of The United States.

Advantages of the model:

* is coal oriented
* has financial analysis
* requires little input.
* both surface and underground system are analyzed

Disavantages of the model:

* mountain and foothill seams are not analyzed
* does not provide detailed investment costs
* the metric system is not considered
* tax and royalties are American
* does not consider Canadian data in compiling equation coefficients

3.3.1.6 EPRI model

The EPRI coal mining cost model (9) represents an engineering approach to the analysis of production costs and mining requirements of either surface or underground mining projects. The model estimates all capital and operating costs typically associated with preproduction and production phases of a coal mining project, and may be applied either to existing or proposed mines. The model was originally developed in 1976 by the NUS corporation for Electric Power Research Institute (EPRI), and an updated version was made in 1980.

The model's calculation procedures utilize an engineering process approach for determining primary mining requirements and costs, essentially taken from calculations made by the US Bureau of Mines (7). The process first utilizes the input data to arrive at the proper production sizing of the various production units. Once this sizing has been determined, the appropiate unit costs can be applied to subsequent analyses, which determine all costs required. Support requirements are mainly computed as a function of primary requirements. In this fashion, all capital and operating costs associated with a new or existing coal mining project can be estimated. The results of these analyses are entered into a financial analysis to obtain either coal value/ton (minimum required selling price) or the rate of return of the project at a given coal price.

The input of the model is composed of three types of parameters: physical , operational, and financial (10). The output for both underground and surface methods, is composed mainly of three kinds of information: production parameters, capital and operating costs, and financial analysis results.

Advantages of the model:

* is coal mine oriented.
* as the model is based on an engineering process approach to determine system parameters, it could be applicable either in U.S. or Canada.
* all functions of mining are considered.
* both surface and underground methods are

analyzed.

* has a financial analysis portion.

Disavantages of the model:

* considers only the Imperial system for measurements.
* tax and royalties do not correspond to the Canadian system.
* mountain and foothill seams are not considered

3.3.2 Other Models Analysed

3.3.2.1 JPL model

An algebraic model describing the life-cycle cost of an underground coal mine has been developed by the Jet Propulsion Laboratory (JPL) of the California Institute of Technology (11). In this model the annualized selling price of coal is based on the revenue required to cover all operating costs with amortized capital outlays, and yield a specified return on aggregate investment.

An algebraic expression for the selling price of clean coal, which is a function of labor and capital productivities, required return on investment, average wage rate, equipment availability, initial development cost, recovery factor, tonnage losses due to debris and washing, and a gross technology definition, is presented. The model not only accounts for the costs of physically extracting the coal, but also for the intangible costs resulting from health and safety regulations, resource conservation measures, and environmental improvements at both the working face and the surface.

3.3.2.2 The Pensylvania Coal model (PCM)

The PCM is a set of coal oriented data bases and computer programs developed under the Appalachian Regional Comission and the Pennsylvania Science and Engineering Foundation sponsorship, to simulate alternative futures for the Pennsylvania coal economy (12). The PCM uses linear programming to evaluate implications of various demand scenarios subject to a variety of reserve, production, transportation and environmental constraints (13). The model is built upon 1974 data bases on coal production and utilization that are manipulated by the user to present a variety of realistic estimations of Pennsylvania's coal economy and its implications (14). The model has both numerical and cartographic output.

The basis of PCM is linear programming using the simplex solution code. The model operates on the data base, in four stages, pre-processing, linear programming, reporting, and iteration.

3.3.2.3 US Bureau of Mines Circulars

The Bureau of Mines has issued a number of Information Circulars (15) which outline capital and operating costs for coal mines. These are primarily listings of typical costs for: construction equipment and working capital, manpower requirements, operating costs, federal and state taxes, expendable supplies, and other similar items. This material does not present any type of model, it only makes a detailed study of typical costs for the above items.

In the studies, the capital charges are discounted by the present worth factor and then totaled to give the present worth of the total mine investment. If it is assumed that mine production is constant over the life of the mine, and the sales are steady, the of cost run of mine coal may be computed. Since these documents follow simple procedures often used by small operators in industry, they could be quite useful.

3.3.2.4 VPI model

The Office of Coal Research (OCR), US Department of the Interior, has funded two contracts at the Virginia Polytechnic Institute and the State University (VPI & SU) with the objective of developing computer programs for the mining industry (15). The first project started in 196[illegible] and the [illegible] set of programs was released in 1975. This set contains 5 programs, one of which is Cost-Sched, which quantifies the cost benefit effect of operating and engineering decisions and permits mining scheduling and development of a coal producing property.

Cost-Sched was designed to provide the planning engineer with a tool to aid him in an evaluation of a mine after basic decisions concerning the capital costs and manpower requirements have been established. The program can be used to schedule the mine and determine the time when each production unit can be put into operation. It can be applied also to compute the total cost of mining during each stage of development until the mine is fully developed.

3.3.3 Model Selection

A total of 10 models have been analyzed, but only 6 of them are useful for the purposes of this thesis: O'Hara-Mular, MMPP STRAAM, Fluor Utah, Burzlaff-Lohrenz-Monash model, and EPRI. Each of these models has advantages and disavantages depending on the conditions of where they are to be applied. Under the conditions of western Canadian coal mining, the EPRI model appears to be the best. The few disavantages of the model are easily overcome: conversion to metric system from the Imperial system and adjustment of taxes, royalties and fringe benefits to western Canadian rules. On the other hand EPRI has some advantages that make it be very reliable. In fact, it is one of the few models in which each of its equations and algorithms are built based on an engineering process approach, and therefore, each parameter or variable has a rational justification. In addition, it is a coal oriented model for both surface and underground mining.

The other 5 models were not considered because from the western Canadian point of view they present some disavantages that are very difficult to overcome, for instance: O'Hara-CIM model is oriented toward metallic mines rather than coal mines. The MMPR model has some weakneses because of the sparse data base, the STRAAM model does not apply to fossil fuels mines, Fluor Utah does not consider underground mining systems, and the Burzlaff-Lohrenz-Monash (which in opinion of the author is the second in the ranking) does not provide detailed investment costs. For these reasons, and considering the advantages already mentioned, the EPRI model was the model selected as the basis for the modelling work for this thesis.

4. The EPRI Model

4.1 Introduction

A basic premise in designing the EPRI model was to provide an analytical tool which would reflect a practical assessment of mining costs. This objective is accomplished through the application of mining engineering analyses, cost analysis principles, and experienced mining judgement. In other words, the model's objective is achieved through the application of a process engineering approach.

The process engineering approach simulates what would be an engineering design of the project. It first utilizes the input data to define the physical and operational characteristics of the project and also the proper production sizing. Once the sizing is determined in terms of either production sections for underground mines or overburden stripping capacity requirements for surface mines, the appropiate primary equipment is assigned. After this, the corresponding unit costs from the model data base can be applied. Analyses, in both underground and surface models then determine the support or auxiliary equipment requirements as a function of the primary equipment needs and operating parameters. Manpower requirements and costs are dependent on equipment requirements. Other supplies and operating costs are largely calculated as a function of physical or operating characteristics such as production level, mining type, seam conditions or labour factors.

Total capital costs utilize the primary and support equipment requirements along with equipment lives, to arrive at deferred expenditures, other site construction costs and indirect capital costs.

The input data, from where the process engineering approach starts is categorized in three types:

* Required input: Constitute the minimun amount of information necessary to run the model.
* Default values input: This contains a list of default value inputs which are automatically assigned and used by the model unless otherwise specified by the user.
* Model calculated values with optional override: This category represents those costs or requirements which are calculated by the model based on the above categories. The user may override or delete the necessity for a particular calculation designating a value for any parameter listed in this category.

  An useful modification has been included in this input category. In the original model, the user was able to enter his own value for a given parameter before any estimation from the model was made. In the thesis model an estimation of all corresponding parameters are made before the user may impose his values. In this way, the operator can evaluate the effect at his imposition.

The general process approach developed for the models is represented in both surface and underground models, by submodels. The submodels are operative modules which characterize the models. They are executed in a sequence describing the primary dependencies. The submodels defined for both models are:

Underground Model:

* Submodel 1: Production Sizing
* Submodel 2: Manpower Requirements
* Submodel 3: Equipment and Construction Requirements and Costs
* Submodel 4: Supplies, Materials and Power Costs
* Submodel 5: Preproduction Development Costs

Surface Model:

* Submodel 1: Primary Equipment Requirements and Costs
* Submodel 2: Supporting Capital Item Costs
* Submodel 3: Manpower Requirements and Costs
* Submodel 4: Power, Supplies and Material Costs

Once the corresponding submodels have been executed and in consequence the engineering process aproach has been achieved, a financial analysis process is carried out. This financial analysis serves two purposes. The first is to structure the costs developed in the previous submodels into a form amendable for discounted cash flow analysis procedures. The second purpose is to conduct the discounted cash flow analysis, solving either for coal value/tonne or rate of return on equity. A sensitivity analysis can also be performed if desired. This sensitivity analysis procedure uses a Monte Carlo simulation technique for estimating the distribution of the costs.

The rest of this chapter will describe more in detail the EPRI model and the corresponding submodels indicating, when applicable, the modifications required to run the model under Canadian conditions. One important modification which was made to the whole model was to transform all measurements to the metric system, for this reason some input data, equation coefficients, output data, etc, were adapted to this units system.

4.2 Underground Model

4.2.1 Introduction

The application of an underground coal mining cost model to a proposed or existing coal mine project will result in estimates of both mining requirements and mining costs. The primary mining requirements computed include production section equipment, manpower requirements, machine productivity, manpower productivity, preproduction development time, and coal produced during development. Cost calculations generate both capital and operating costs corresponding to mining requirements.

Each of the submodels which make up the process engineering analysis (see Figure 4.1) will be discussed in the following pages. The input necessary to run those submodels is presented also in Table 4.1.

4.2.2 Submodel 1: Production Sizing

Using a combination of physical characteristics regarding the seam conditions (depth, thickness, etc) and operating conditions, regarding the mining system, annual production and working schedule, a machine productivity is selected from the data base of the model. This productivity value is then applied to calculations of shift production section requirements for raw and clean coal production.

No costs are calculated in this submodel. The production requirements which are calculated however, serve as the basis for many subsequent cost calculations.

Some assumptions are made in computing the production requirements:

* A single mine development plan (room and pillar) having ten entries in the mains and cross mains (two parallel five entry systems) is assumed to apply for all continuous and conventional mining systems
* A square coal deposit is assumed to accommodate the utilized mining plan.

Even though longwall methods to date have not been succesfully applied in western Canadian coal mining, this

Figure 4.1

STRUCTURE OF THE UNDERGROUND COAL MINING COST MODEL

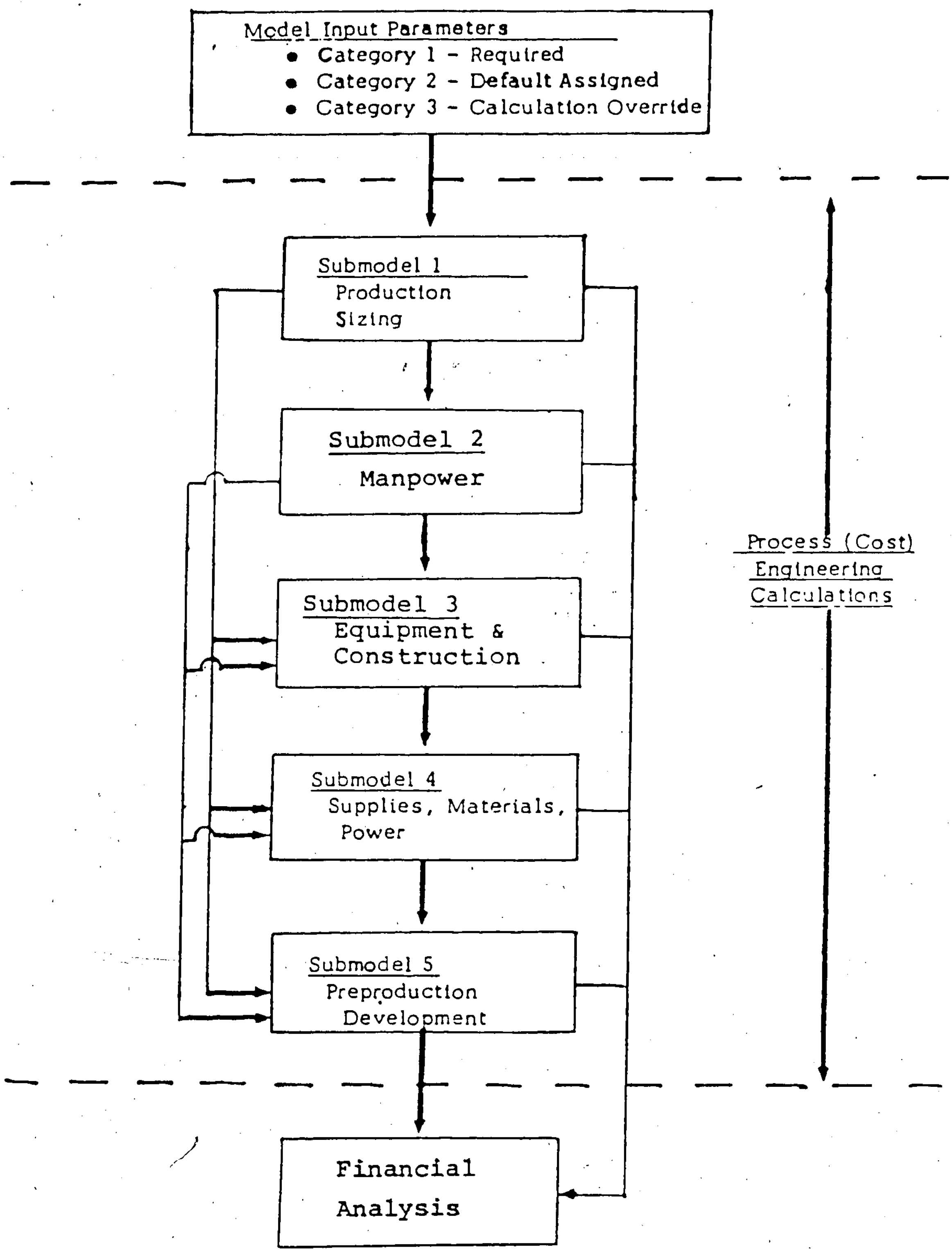


Table 4.1

INPUT PARAMETERS FOR UNDERGROUND MODEL

Category 1-Required Input Parameters:

Physical
- Depth of seam (m)
- Thickness of seam (m)
- Proportion of fines in clean coal
- Seam gradient (0 , 6)
- Roof conditions (good,poor)
- floor conditions (hard, rutted, rutted-wet)
- Proportion of fines in clean coal (%)
- Gas emission level (low,moderate,high)

Operating
- Mining system (continuous,conventional,longwall)
- Entry type (drift,shaft)
- Annual production (tonnes of clean coal)
- Production life (years)

Financial
- Portion of initial capital borrowed (%)
- Debt servicing rate (%)
- Length of loan payback period (years)
- Dollar equivalence ($Ca=X*$US)
- Project start year
- Acquisition cost ($)
- Type of analysis (point value or escalating dollar)
- Escalation factors (for escalating dollar analysis) or cost update factors (for constant dollar analysis)
  - Labour (%)
  - Supplies and Materials (%)
  - Power (%)
  - Production section equipments (%)
  - Haulage system (%)
  - Auxliary equipment (%)
  - Construction
- Escalation (%) for coal value/t (for escalating dollar case)
- Coal value/t in first production year (when solving ROR)
- Rate of return on equity desired (when solving for coal value)

Category 2-Optional Parameters (Default Assigned)

Physical
- Reject percentage (10 %)

Operating
Shifts/day(2)
Days/year (223)
Type of coal preparation -thermal, metallurgical, no cleaning-(thermal)
Seam recovery(60%)
Operating Efficiency (Mean=85%, S=8)
Available face time(minutes)/shift(Mean=340, S=30)

Financial
Cost range applicable-high, low, total- (low)
Indirect capital cost (10 %)
Labour overhead (40 % of direct labour)
Fringe benefits(35 % of direct labour)
Royalty payments(Province of Alberta formula)
Income tax (47% of taxable income)
Depreciation method -fast, straight, declining bal.-(fast)
Amortization -expensed, deferred-(deferred)
Investment tax credit (5 %)

Category 3-Parameters Which Can Override Calculated Values

Operating
Tonnes per machine shift
No. of production sections/shift
Hourly labour requirements
Salaried Personnel requirements
Development time(years)
Coal produced during development(tonnes)

Financial
Depreciable life
Hourly labour cost/year
Salaried personnel cost/year
Supplies and materials cost/tonne
Power cost/tonne
Annual operating cost (direct)
Initial production section cost
Initial haulage system cost
Initial auxiliary equipment cost
Preparation plant & unit train loading cost
Exploration cost
Mine abandonment cost
Mine entry contruction cost

method will also be included in this model for possible future projects. It is assumed that the mine plan contemplates one or two unit longwall mines with a face length of 152 m.

The output of this submodel includes the following information items:

- Annual raw coal production
- Shift output per production section
- Raw coal production per shift
- Number of production sections required per shift
- Tonnes of clean coal produced per year

4.2.3 Submodel 2: Manpower requirements and costs

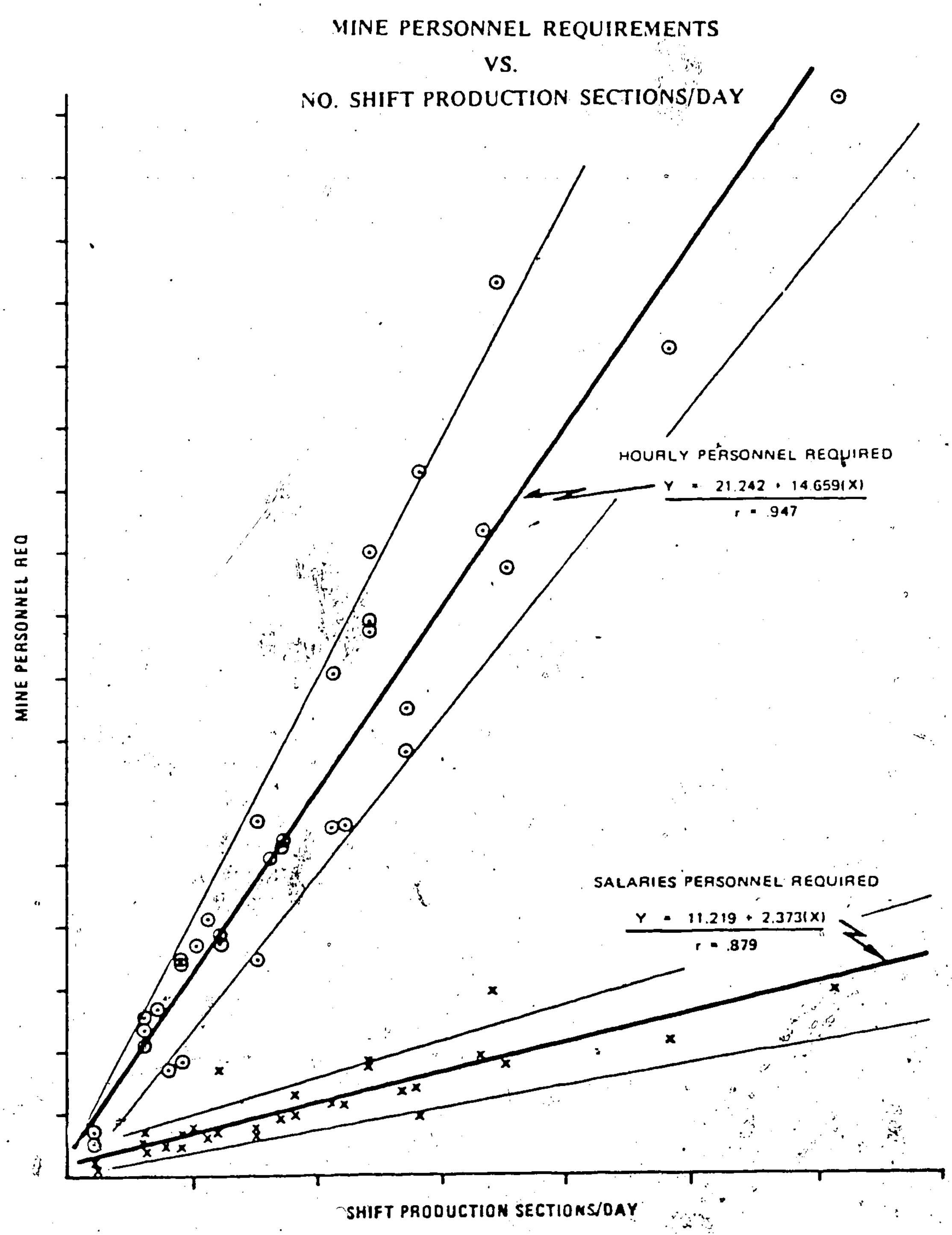
A factor relationship between production sections and personnel requirements was developed for use in this submodel. This relationship is based on empirical data from over 50 operating mines in U.S. Total manpower requirements are predicted from this linear relationship and the number of required production sections/day (see Figure 4.2).

Once both hourly and salaried personnel requirements have been computed, the direct labour costs associated with each manpower level requirement is estimated. Additional costs for fringe benefits are also computed.

The assumptions made in the calculation procedures are the following:

* The average daily 1982 labour rate for hourly employees in western Canada is $128 and the average

Figure 4.2



Adapted from (9)

for salaried personnel is $34 500 per year (16).

* The Union Welfare Fund cost considered in the original project does not applies to Canada. For this reason it was replaced by the fringe benefits cost which is estimated as 35 percent of the direct labour costs(2).
* Labour productivity calculations are based on both salaried and hourly personnel requirements and annual product tonnage.

The output generated by this submodel is:

- Hourly labour requirements per day
- Hourly labour requirements per shift production section
- Direct labour cost per shift production section
- Direct annual labour cost
- Fringe benefit costs
- Salaried personnel annual requirements
- Salaried personnel direct annual costs
- Total manpower direct annual costs
- Productivity per manday.

4.2.4 Submodel 3: Equipment and Construction Requirements and Costs

Based on the results of the production sizing, particularly the number of production sections required per shift to maintain the desired annual production level, the majority of the initial capital equipment costs may be estimated in this submodel. The equipment categories addressed are: production section equipment, haulage system equipment, and auxiliary equipment.

A fixed set of equipment items which constitute a production section, is established for each mining method. The equipment making up a production section and their costs are presented in tables 4.2, 4.3, 4.4, 4.5, and 4.6. The attendant costs associated with each of the equipment items is then aggregated to arrive at a total cost per production section for each mining system. The haulage system equipment is calculated with respect to annual tonnage. Initial haulage costs are computed on the basis of the total metres involved in opening the mine during the production phase. Replacement costs for this equipment will be scheduled in the financial analysis.

An example of how the model defines the number of pieces of equipment for a given project is presented below. Let us suppose that 6 production sections are required (from production sizing) and conventional room and pillar method has been selected; the following equipment, according to table 4.2 would be assigned:

* 7 cutting machines (6 for production, 1 backup)
* 6 coal drills
* 7 loading machines (6 for production, 1 backup)
* 13 shuttle cars (12 for production, 1 backup)
* 12 ratio feeders
* 6 roof bolters

* 6 scoop trams
* 6 section belts

Construction capital requirements address the costs for ventilation shaft construction mine entries construction, preparati plant constructi and other surface construction. Calculation of these costs are based on a mining system, physical characteristics of the mine, and type of coal cleaning desired.

The assumptions considered in this submodel were:

* An all belt haulage system is assumed for main and secondary coal conveyance. Supplies, personnel, and equipment transport are by track and locomotive.
* Continuous and conventional mining systems utilize shuttle cars and belt conveyors to transport coal to secondary haulage or main line haulage systems.
* A backup cutting machine, loading machine, shuttle cars and continuous miner (for continuous mining system) will be purchased for each 5 production sections per shift.

For the coal cleaning, an important modification has been introduced to the original model in order to adapt it to western Canadian coal conditions. In fact, in western Canada there are three categories of coal preparation: thermal export, thermal mine-mouth power plant, and metallurgical. A thermal mine-mouth operation normally requires only a breaking process, while the metallurgical and thermal export operations require a cleaning process to

Table 4.2

Production Section Requirements & Costs ($000)

Equipment Item	No Req.	Mean Cost	Standard Deviation
Continuous Miner	1	From Table 4.3	From Table 4.3
Roof Bolter	1	From Table 4.4	From Table 4.4
Shuttle Car	2	288.3	45.5
Ratio Feeder	2	149.0	12.5
Scoop Trams	1	56.0	10.1
Section Haulage Belt	1	162.9	15.3
Support Item Costs		103.3	

Table 4.3

Continuous Miner Data Base Costs ($000)

Seam Height meters	feet	Mean Cost	Standard Deviation
0.78 - 0.97	2.5 - 3.19	406.7	48.6
0.97 - 1.03	3.2 - 3.39	420.2	52.1
1.04 - 1.12	3.4 - 3.69	425.2	48.1
1.13 - 1.21	3.7 - 3.99	433.8	43.5
1.22 - 1.36	4.0 - 4.49	457.8	33.4
1.37 - 1.40	4.5 - 4.59	457.2	29.9
1.41 - 1.52	4.6 - 4.99	464.0	21.0
1.53 - 1.85	5.0 - 6.09	468.6	22.7
1.86 - 1.88	6.1 - 6.19	473.5	24.4
1.89 - 1.94	6.2 - 6.39	476.0	23.8
1.95 - 2.00	6.4 - 6.59	477.1	23.1
2.01 - 2.44	6.6 - 7.99	477.3	24.2

Table 4.4

Double Boom Roof Bolters Data Base Costs ($000)

Seam Height(m)	Mean Cost	Standard Deviation
< 1	124.3	6.4
1-1.2	132.2	9.3
>1.2	142.0	27.4

Table 4.5

Conventional Mining Production Section Costs ($000)

Equipment Item	Mean Cost	Standard Deviation
Cutting Machine	261.1	17.7
Coal Drill	107.2	
Loading Machine	191.5	9.7
Shuttle Cars	144.2	45.5
Radio Feeders	75.0	12.5
Roof Bolter	From Table 4.4	
Scoop Tram	56.0	10.1
Section Haulage Belt	162.9	21.0
Support Equipment Items	103.3	

Table 4.6

Longwall System Section Costs ($000)

Equipment Item		Mean Cost	Standard Deviation
Longwall System			
(152 mt)(shearer, face conveyor, self advancing support, elect & control eq.)			
Seam Heights: meters	feet		
0.91- 1.52	3- 4.99	6864.0	1033.4
1.53- 2.44	4- 8.00	7491.0	1353.7
Section Haulage Belt			
0.88- 914	2.5-3000	163.0	21.0
Continuous Miner		From Table 4.3	From Table 4.3

reduce the impurities. Unlike most U.S. coals, many western Canadian coals contain a large proportion of fines. These fines must be cleaned particularly if the coal is to be used for coking. For this reason, the equations for preparation plant costs developed by MMPR cost model (4) was deemed to be applicable for western Canadian coals rather than the EPRI equations. Therefore the model has adopted two types of beneficiation:

- Thermal mine-mouth power plant coal preparation: In this case, the EPRI equation for breaking-only was applied (19). This equation considers a production level of 700 t per hour, an average of 3000 hour per year, and a unit cost of US$5540 per tonnes/hour.

$$\text{Capital Cost} = \left[\frac{\text{Raw Coal}/3000}{700}\right]^{.7} * 5540 * (\text{Raw Coal}/3000)$$

  Where

  Raw Coal is the plant input (t/year)

- Metallurgical and export coal Preparation: In this case the MMPR equation for preparation plant investment is applied (4). This equation considers a unit cost of $15 per tonne of coal processed and a unit cost of $44 per tonne of fine coal cleaned.

$$\text{Cap. Cost} = 1.4 * \left[15 * 10^6 * \left(\frac{\text{Raw Coal}}{10^6}\right)^{.6} + 44 * 10^6 * f * \left(\frac{\text{Clean Coal}}{10^6}\right)^{.6}\right]$$

Where

f is the fraction of fines in clean coal (-0.6mm)

1.5 is the 1977-1982 update index

Clean Coal is the plant output

The equation above presented include the wash plant, coal c yer, breaker station, raw coal silos, clean coal silos, thickeners, and load out facilities.

The output generated by this submodel is:

- Production section equipment requirements and costs
- Preproduction haulage system costs
- Production phase haulage system costs
- Auxiliary equipment costs
- Preproduction ventilation construction costs
- Production phase ventilation construction costs
- mine entry construction costs
- Entry haulage or hoist system cost
- Preparation plant construction cost
- Exploration costs
- Mine abandonment cost

4.2.5 Submodel 4: Supplies Materials and Power Costs

The methodology employed in this submodel for estimating supply and material costs involves the use of an empirical relationship between costs and productivities. The computation of power costs is based on a relationship with supplies and materials cost per tonne. Power, supplies and materials are computed for clean coal tonnage and translated into annual costs.

The only assumption made for this submodel is that the mathematical expressions for both power and supplies and materials are the same for any mining system, mine type or regional location.

the output produced by this submodel is:

- Supplies and materials cost per tonne of clean coal
- Supplies and Materials annual costs
- Power cost per tonne of clean coal
- Power annual cost
- Total supplies, materials and power cost per tonne of clean coal
- Total Supplies, materials and power annual cost

4.2.6 Submodel 5: Preproduction Development

The costs involved in opening the mains and cross mains of the mining plan are computed in this submodel. Also computed here are development time and coal production resulting from the mine opening activities. The costs involved in these mine functions are essentially a combination of labour, supplies, materials, and power. These direct operating costs qualify as a capital investment during the preproduction period.

The labour costs and other direct expenses are estimated considering the amount of time involved in the preproduction phase. This time is computed for both calendar years as well as unit shifts. The scheduling of production sections is based in the mine plans established by this submodel. Once the development time is calculated, the time assumed for construction activities is added to arrive at the total time for project start to the full production phase. The timing for construction activities is partly based on the type of mine entry construction required.

Based on the unit shift calculations, the coal produced during development is also calculated in this submodel.

The assumptions considered in this submodel are:

* Productivity during the development period is stored and sold in equal increments during the two years immediately preceding the first year of full production.
* Productivity during the preproduction period is 75 percent of the projected productivity during the full production phase.

The output generated by this submodel is:

- Labour costs
- Supplies and materials costs
- Power costs
- Overhead costs
- Fringe benefits costs
- Total direct development costs
- Development time (years)
- Development time (unit shifts)
- Coal produced during development
- Total construction and development time (years)

4.3 Surface Model

4.3.1 Introduction

The application of the surface coal mining cost model to a proposed or existing coal mining project will result in estimates of mining requirements and mining costs. The primary mining requirements computed include those for overburden removal, overburden drilling, coal drilling, coal loading, coal hauling, and reclamation. Once the primary equipment has been defined, the unit costs of the model data base (Tables 4.7, 4.8, 4.9, 4.10, 4.11, 4.12 and 4.13) are applied.

One of three major mining system options may be specified by the model user: area mining (or strip mining), open pit mining, or contour mining.

In the open pit mining case, an important modification has been introduced with respect to the original model. What the original model called open pit mining is basically the same as strip mining, with the difference that the overburden thickness considered is not thick enough to justify the use of draglines, and the coal seam is thick enough to require the use of two or more benches for the coal extraction. In this sense, shovels and trucks are the

Table 4.7

Dragline Data Base Costs (1982)

Drag. Bucket m	Capacity cu.yds.	Mean (US$10)	S.D. (US$10)
6.12	8	1.90	1.98
6.88	9	3.30	1.42
7.74	10	3.46	1.42
8.41	11	3.80	1.07
9.17	12	3.89	1.10
9.94	13	4.28	0.57
10.70	14	4.28	0.57
11.47	15	4.28	0.57
12.23	16	4.28	0.57
13.00	17	4.40	0.57
13.76	18	5.25	1.56
14.53	19	6.10	1.43
15.29	20	5.91	1.22
16.05	21	6.15	1.18
16.82	22	6.61	1.03
17.58	23	7.34	0.32
18.35	24	8.02	1.40
19.11	25	8.19	1.40
19.88	26	8.19	1.26
20.64	27	8.19	1.26
21.41	28	8.31	1.42
22.18	29	9.08	2.13
22.94	30	9.25	1.79
23.70	31	9.59	1.71
24.46	32	9.59	1.71
25.23	33	10.09	1.33
25.99	34	10.09	1.33
26.76	35	10.61	1.75
27.52	36	10.33	1.80
28.29	37	11.03	2.58
29.05	38	11.03	2.58
29.82	39	11.03	2.58
30.58	40	11.03	2.58
31.35	41	12.24	3.14
32.11	42	12.24	3.14
32.87	43	12.57	3.30
33.64	44	12.57	3.30
34.40	45	12.57	3.30
35.17	46	14.48	3.15
35.93	47	14.48	3.15
36.70	48	14.48	3.15

Dragline Data Base Costs (1982)

(Continued)

Drag. m	Bucket Capacity cu.yds.	Mean (US$10)	S.D. (US$10)
32.46	49	15.94	0.91
38.23	50	15.94	0.91
38.99	51	16.50	1.35
39.76	52	16.50	1.35
40.52	53	16.50	1.35
41.28	54	16.50	1.35
42.05	55	16.50	1.67
42.81	56	16.50	1.67
43.58	57	17.40	2.28
44.34	58	17.40	2.28
45.11	59	17.40	2.28
45.87	60	17.40	2.28
46.64	61	17.40	2.28
47.40	62	17.40	2.28
48.17	63	17.18	2.70
48.93	64	17.18	2.70
49.69	65	20.16	
50.46	66	20.16	
51.22	67	19.10	1.51
51.99	68	19.10	1.51
52.75	69	19.10	1.51
53.52	70	20.90	3.30
54.28	71	20.90	3.30
55.04	72	20.90	3.30
55.81	73	22.33	3.07
56.58	74	22.33	3.07
57.34-61.16	75-80	24.93	5.00
61.93-68.81	81-90	27.33	3.99
69.57-71.87	91-94	30.15	
72.63	95	31.87	2.44
73.40-87.92	96-115	31.87	
88.69-91.95	116-120	33.60	
92.51-137.62	121-180	47.98	1.28

Table 4.8

Power Shovel Cost (1982)

Bucket Capacity m	cu.yds.	Mean (US$000)	S.D. (US$000)
7.64-9.17	10-12	2075.1	202.7
9.94	13	2499.8	543.4
10.70-11.47	14-15	2633.1	898.2
12.26	16	2490.9	513.4
13.00	17	2493.1	665.4
13.76	18	2347.5	671.5
14.53	19	2782.1	618.2
15.29	20	3457.1	1247.3
16.05	21	3502.8	1022.6
16.82	22	3456.3	1247.3
17.58-24.46	23-32	4013.0	1121.4

Table 4.9

Rubber Tired Loaders Costs

Bucket Capacity m	cu.yds.	Mean (US$000)	S.D. (US$000)
0.76	1	59.5	8.2
1.53	2	71.7	9.3
2.29	3	99.2	9.0
3.06	4	135.1	11.9
3.82	5	189.3	27.0
4.59	6	206.4	14.0
5.35-6.11	7-8	264.9	32.1
6.88		433.4	36.4

Table 4.10

Haul Truck Costs (1982)

Capacity (tonnes)	Mean (US$000)	S.D.(US$000)
20	69.4	
30	217.8	
35	221.6	19.5
40	254.5	
45	261.6	
50	288.5	70.9
55	389.4	
60	364.4	
65-70	404.0	
75	405.3	73.7
80	479.7	
85	504.7	35.4
100-120	424.1	
150	673.3	
170	887.9	121.6

Table 4.11

Dozer Costs (1982)

Capacity m	Capacity cu.yds	Mean (US$000)	S.D. (US$000)
3.06	4	72.2	22.6
6.88	9	122.3	15.2
9.94	13	177.5	20.4
14.53	19	238.1	25.3
17.58	23	334.9	44.7

Table 4.12

Scraper Unit Costs (1982)

Capacity Struck m	Capacity Struck cu.yds.	Capacity Heaped m	Capacity Heaped cu.yds.	Price (US$000)
10.7	14	15.3	20	261.5
16.0	21	23.7	31	435.1

Table 4.13

Loading Shovel Costs (1982)

Bucket Capacity (LBC) m	cu.yds.	Mean (US$000)	S.D. (US$000)
1.5-3.0	2-4	368.0	44.2
3.8	5	448.3	62.2
4.6	6	523.0	42.8
5.3	7	574.3	108.3
6.1-6.9	8-9	543.3	193.8

equipment defined to remove both the overburden and coal. The model does not consider the open pit method used in the Canadian foothills or mountains regions, described in Chapter 2. The procedure used by the original model to estimate the equipment required to remove the overburden, starts by estimating the volume of overburden to be removed. This calculation is based on the overburden depth and the mine area required to satisfy the production requirements. Due to the unpredictable shapes of the coal seams in the foothill and mountain regions, this procedure cannot be applied. For this reason, the strip ratio (volume of overburden required to extract one tonne of coal) has been included as an input datum from which it is possible to estimate the volume of overburden to be removed according to the production requirements. The remaining parameters are calculated using the same procedure as that used in the original model.

Although contour mining has not been used to date in western Canadian coal, it is included in this model in order to make some comparisons with the traditional strip or open pit methods.

The major cost categories developed by the model include primary equipment costs, support equipment costs, preparation plant costs and construction costs. Other cost categories addressed by the model include those for preproduction development, exploration and indirect capital.

Each of the submodels which make up the process engineering analysis are presented in sequence describing the primary dependencies in Figure 4.3. Each submodel will be discussed in the following pages. The input to run these submodels is presented in table 4.14.

4.3.2 Submodel 1: Primary Equipment Selection and Costs

The purpose of this submodel is to analyze each unit operation involved in surface coal mining to arrive at equipment sizing, quantities required and associated costs. The input parameters describing the characteristics of the coal seam (thickness, depth, strip ratio, etc) along with key operating requirements (annual production level, reject factors, preparation requirements, etc) provide the primary design parameters necessary to size each of the unit operations.

An example of how the submodel estimates the primary equipment in area (strip) mining is presented in the following relationships:

* Dragline Cycles/Month (CPM)= (MOHO*3600)/CYCO

Where

MOHO= Scheduled monthly operating hours

CYCO= Dragline cycle time in seconds (input)

Theoretical Bucket Capacity Requirements (TBC)= COB/CPM

Figure 4.3

STRUCTURE OF THE SURFACE COAL MINING COST MODEL

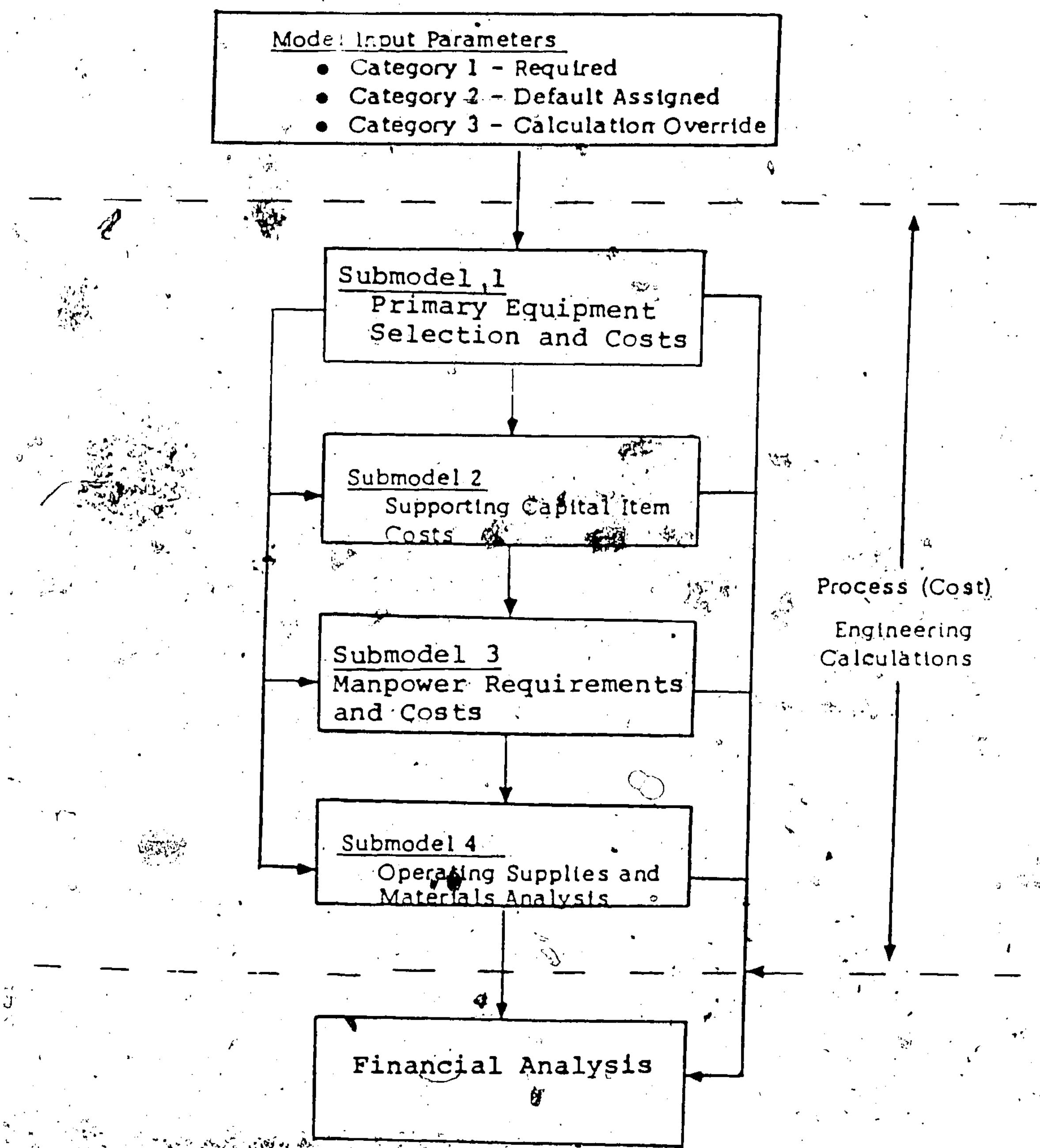


Table 4.14

INPUT PARAMETERS FOR SURFACE MODEL

Required Input Parameters

Physical:
Seam thickness (m)
Overburden thickness(m)
Topsoil thickness(m)
Single or multiple seam (yes/no)

Operating:
Mining system (strip, open pit, contour)
Annual production (tonnes)
Mine life (years)

Financial:
Length of loan payback period (years)
Portion of initial capital borrowed (%)
Debt servicing rate (%)
Acquisition cost (US$/Km)
Dollar equivalence (Ca$ to US$)
Project start year
Type of analysis (constant or escalating dollar)
Escalation factors or cost update factors
- Base year
- Labour
- Primary equipment
- Supporting equipment
- Operating
- Construction

Escalation (%) for coal value/tonne (under escalating cost option)
Coal value/t in 1st production year when solving for ROR
ROR when solving for coal coal value/t

Optional Parameters

Physical:
Reject percentage (10%)
Recovery % (default Mean= 90, S= 0)
Dilution (default 10%)
Coal density
- Bituminous= 1.459 tonnes/m (IDC=2)
- Lignite= 1.418 tonnes/m (IDC=1). Bituminous is default.

Exploration required (161874 m /hole)

Operating:
Type of coal preparation -thermal, metallurgical- (thermal)
Drilling overburden
- Assumes 1 drill/working place, except for lignite where no drilling is required.

- Degree of overburden consolidation (low, moderate, high; moderate is default)

Overburden excavation (strip mine)

- number of working places (default 1)
- Operator efficiency (Mean= 75%, S= 7)
- Bucket fill factor (Mean= 80%, S= 8)
- Scheduled monthly operating hours (720 hours)
- Cycle time (Mean= 60 sec., S= 6)

Overburden excavation (open pit)

- Scheduling monthly operating hours (720 hours)
- Cycle time (Mean= 35 sec., S= 3)
- Operator efficiency (Mean= 75%, S=7)
- Bucket fill factor (Mean= 80%, S= 8)
- Number of working places (1)
- Max. bucket size (15.29 m or 20 cu.yds.)
- Number of loading passes to fill truck (7)
- Truck travel time loaded (Mean=135 sec., SD=13)
- Truck travel time empty (3/5 of time loaded)
- Turn, spot, dumptime (Mean= 200 sec., S= 20)

Overburden excavation (Contour)

Dozer:

- Scheduled monthly operation hours (336)
- Swell factor (Mean=36.6 , S=3)
- Average haul distance (Mean= 36.5 m, S= 3)
- Max. blade capacity in loose material (14.53 m or 19 cu.yds.)
- Operator efficiency (Mean=75 %, S= 7)
- Operating efficiency (Mean=80%, S=8)
- Material factor (Mean= 80%, S= 8)
- Weather factor (Mean=80%, S= 8)

Scraper:

- Scheduled monthly operation hours (336)
- Load time in overburden (Mean= 60, S=6)
- Maneuver and spread time (Mean= 40, S=4)
- Max. scraper capacity (16.0 m)
- Swell factor (Mean= 25, S=0)
- Average haul distance (Mean= 183 m, S=18)
- Operator efficiency (Mean= 75%, S=7)
- Operating efficiency (Mean=80%, S=8)
- Material factor (Mean= 80%, S= 8)
- Weather factor (Mean=80 %, S=8)

Coal drilling:

- Required?(yes, 1 drill/working place, 146.4mmdrill bit)

Coal loading

- Scheduled monthly operating hours= 336 hours)
- Coal load cycle time (Mean= 75 , S=7)
- Bucket fill factor (Mean= 75%, S=7)

Coal Hauling

- Number of loading passes (Mean=7, S=0)
- Truck travel time loaded (Mean= 800 sec, S=80)
- Truck travel time empty (3/5 of time loaded)
- Turn, spot, dump time (Mean= 200, S=20)

Reclamation

Spoil handling (strip mine):

- Width of pit (Mean=30.5 m, S=3)
- Angle of spoil (36)
- Scheduled monthly operating hours (168)
- Swell of overburden (Mean=25, S=2)
- Max. blade capacity of dozers (14.53 m)
- Operator efficiency (Mean=75%, S=7)
- Material factor (Mean=80%, S=8)

Topsoil handling (strip mining, open pit mine):

- Max. scraper capacity (16)
- Loading time in topsoil (Mean=50 , S=5)
- Maneuver and spread time (Mean=42, S=4)
- Travel time loaded (Mean=410, S=41)
- Travel time empty (3/5 of loaded time)
- Scheduled monthly operating hours (335)
- Operator efficiency (Mean= 75%, S=7)

Spoil handling (open pit):

- Width of windrow (Mean=6.1 m, S=0)
- Angle of spoil (36)
- Swell factor (Mean=25, S=2)
- Blade capacity (14.53 m)
- Operator efficiency (Mean=75%, S=7)
- Material factor (Mean=80%, S=8)

Financial Parameters

Fringe benefits (35 %)
Labour overhead (40% of direct labour)
Royalty (Prov. of Alberta system)
Exploration, development drilling cost/m (US$60/m)
Income tax (47%)
Depreciation method (Straight line)
Investment tax credit (5 %)
Depreciable life of equipment (years)

- Dragline (mine life)
- Dragline bucket (10)
- Shovel (mine life)
- Shovel bucket (10)
- Overburden haul trucks (10)
- Dozers and scrapers (5)
- Overburden drills and coal drills (10)
- Coal loading shovel (mine life)
- Front end loaders for coal (5)
- Coal haul trucks (10)
- Dozers and scrapers for reclamation (5)

Capitalization - deferred or expensed- (deferred)
Indirect capital (15% of primary eq.+ support eq.+ contruction cost)
Salvage value % of original equipment cost

Dragline (10%)
Shovels (10%)
10 years life equiment (5%)
5 years life equipment (10%)

Parameters Which Override Calculated Values

Physical:
Land area requirements (m)

Operational:
Total Hourly Personnel
Total salaried Personnel

Financial
Exploration and development drilling costs (total)
Total annual supplies and materials costs (US$/year)
Support capital %
Total annual operating cost
Preproduction development cost (total)
Preparation Plant Cost

Where

COB= Cubic metres of overburden to be removed each month

Required Bucket Capacity(RBC)= TBC/(OEFO*BFFO)

Where

OEFO= Operator efficiency

BFFO= Bucket fill factor

Number of Draglines(ND)= RBC/BCMX

Where

BCMX= Max. bucket capacity (input)

Dragline Bucket Capacity (DBC)= RBC/ND

Dragline Costs= ND*(Cost Per Dragline)

Where

Cost per Dragline is taken from Table 4.7.

In addition to primary equipment analysis, exploration and development drilling costs are also estimated; however the procedure for this estimation has been modified with respect to the original model. The original model estimates this cost as a function of the area required to be explored. However, this procedure cannot be applied to foothill and mountain regions for the reasons already explained. For this reason the MMPR (4) procedure of estimation will be applied; this model consideres $2 per tonne of clean coal produced in one year as the exploration cost.

The assumptions made for this submodel include the following:

* Area mining systems use dragline for overburden removal
* Open pit systems use truck and shovels for overburden removal
* Contour mining systems use dozers and scrapers for overburden removal
* Mining analysis of multiple seam deposits can be approximated by summing all coal seam thicknesses to arrive at a single value, the same for the interburden. This is only valid for area and contour mining.
* The equipment assumed for reclamation is dozers and scrapers for area mining, dozers for open pit, and the production equipment for contour mining.
* In contour mines the coal is transported by contract hauling.

The output generated by this submodel is presented below:

Overburden removal - Area mining system

- Number of draglines
- Dragline bucket capacity
- Dragline cost.

Overburden removal - Open pit system

- Number of shovels or loaders
- Shovel or loader bucket capacity

- Shovel or loader costs
- Number of haul trucks
- Truck capacity
- Haul truck cost.

Overburden removal-Contour system

- Number of dozers
- Blade capacity
- Dozers cost
- Number of scrapers
- Scraper capacity
- Scraper costs.

Overburden drilling

- Number of drills
- Drill size
- Drill cost

Coal drilling.

- Number of drills
- Drill size
- Drill cost.

Coal loading

- Number of loading shovels
- Bucket capacity
- Shovel costs.

Coal hauling

- Number of trucks
- Truck capacity
- Truck costs.

Reclamation

- Number of dozers
- Blade capacity
- Dozer costs
- Number of scrapers
- Scraper capacity
- Scraper costs.

Total Primary Equipment Cost

4.3.3 Submodel 2: Supporting Capital Item Costs

In this submodel, equipment directly associated with the major stripping equipment, auxiliary equipment and other capital items including site construction and facilities, are computed on a percentage basis of total project capital costs. This percentage is obtained from a relationship of support equipment percentage of initial capital as a function of strip ratio (see Figure 4.4).

Preparation plant construction costs are computed separately in this submodel using the same procedure outlined in the prior section for the underground model.

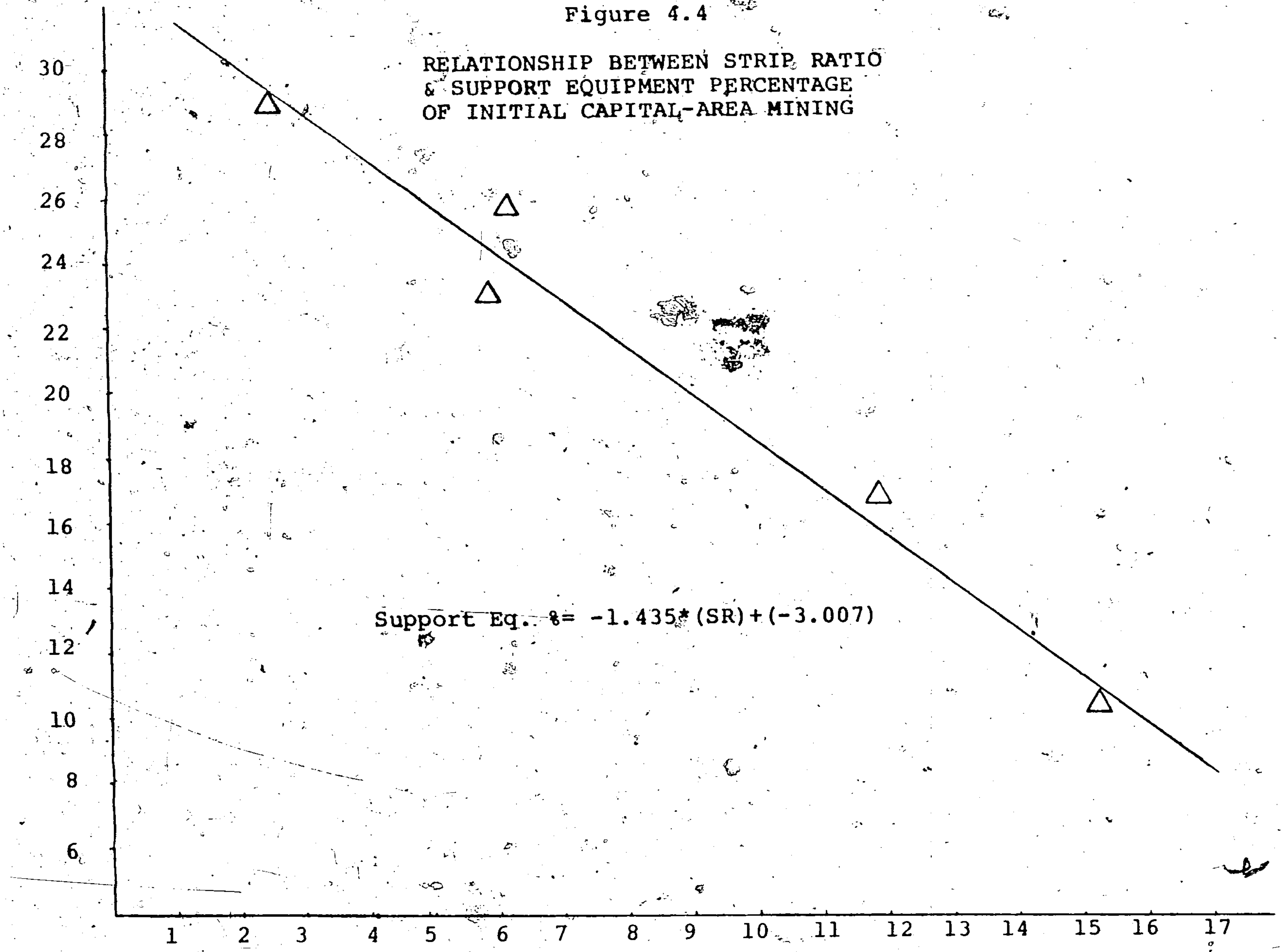
The main assumption made in this submodel is that area open pit mining systems exhibit similar support capital percentage factors.

The output produced by this submodel is presented below

- Support capital cost
- Preparation plant capital cost
- Construction cost

Figure 4.4

RELATIONSHIP BETWEEN STRIP RATIO
& SUPPORT EQUIPMENT PERCENTAGE
OF INITIAL CAPITAL-AREA MINING



Adapted from (9)

- Support equipment cost

4.3.4 Submodel 3:Manpower requirements and Costs

In strip mining both hourly and salaried personnel requirements are computed as a function of strip ratio and annual production. In both open pit and contour mining systems, the manpower assignments are made to primary equipment items. Support personnel is calculated as a factor of primary manpower requirements. Salaried personnel requirements are estimated as a function of total hourly personnel. Average daily wages and annual salaries are then applied to these requirement data to arrive at total manpower cost per year.

The assumptions considered for this submodel are the same as those made in Submodel 2 of the underground model.

The results generated by this submodel are:

- Hourly labour requirements
- Hourly labour direct annual costs
- Fringe benefit costs
- Salaried personnel requirements
- Salaried personnel costs
- Total manpower requirements
- Salaried personnel direct annual costs
- Productivity

4.3.5 Submodel 4: Operating Supplies and Material Analysis

The operating costs considered in this submodel include all direct costs other than labour costs, for example explosives, oil, tires, power, etc.

In area and open pit mining the supplies and materials cost is calculated based on a relationship with strip ratio and annual production. In contour mining, the estimation of this cost is on a relationship with annual production and labour requirements.

Operating costs for the preparation plant are calculated separately since they are often not required for surface operations. With regard to this cost, as in the preparation plant capital investment cost, two procedures are considered. One is for thermal mine-mouth power plant coal which uses the EPRI equation for breaking only while the other procedure is for metallurgical and export coal which takes the MMPR(4) equation for preparation plant operating cost.

In this submodel the preproduction costs are also estimated. The calculation procedure assumes that 50 percent of total labour and non labour costs are used for preproduction strip and open pit mining and 25 percent for contour mining.

The output generated by this submodel is:

- Annual supplies and materials cost
- Annual Preparation plant operating cost
- Total direct non labour costs

- Preproduction costs.

4.4 Financial Analysis

4.4.1 Introduction

The submodels compute the initial equipment, construction and operating cost required as input for the conduct of the financial analysis portion of the model. This section provides the process for organizing, structuring, and analyzing all costs previously developed in the submodels.

The financial analysis process is composed of two phases. The first phase deals with the structuring of the costs developed in previous submodels into a form and format suitable for cash flow analysis procedures. The second phase is the actual cash flow analysis process. Before explaining the financial analysis process, the major options of the model will be discussed.

4.4.2 Major Financial Analysis Options

4.4.2.1 Solving For Coal Value/t or Rate of Return on Equity

Solving for coal value/tonne (i.e. minimum acceptable selling price) assumes that the target rate return on equity is known. On the other hand, solving for rate of return on equity requires that a coal value/t be an input.

4.4.2.2 Solve For Either Point Value Results or a Range

The data base for most major equipment and construction items, as well as some operating expenses, is presented in terms of means and standard deviation values. Under the point value option, a simple cost answer will be generated utilizing the mean value of each cost range. In the uncertainty analysis, a minimun of 10 model iterations will be conducted selecting values for each cost item, at random, for each iteration. This procedure is often called a *Monte Carlo Approach*.

An important contribution to the model was included in this part. In fact, while the original model uses the normal distribution only for the randomization process, the thesis model allows a choice of the following distributions:

- Physical parameters: Normal (default), Lognormal and Uniform.
- Operational parameters: Normal, Lognormal (default) and Uniform.
- Financial parameters: Normal, Triangular (default).

The values that result from the model iterations will be used to calculate means and standard deviations for each cost; a final financial analysis is run using these mean costs, the rates of return (or coal prices) for each iteration are also calculated. In addition, confidence limits with a probability of 95% are estimated.

A sub-option in the method was developed. This procedure involves running the uncertainty process with all low or all high ranges for equipment, construction and operating costs random values. Thus if the user has chosen a low range for any of these items, only values less or equal than the mean will be taken from the randomization process. On the other hand, if the user has selected high range, only values greater or equal than the mean will be taken (see Appendix F or G). In this way a best and worst case scenario for a given investment can be estimated.

4.4.2.3 Analysis using Constant Dollar or Escalating Values

Constant dollar assumes that all capital and operating unit costs remain static relative to a benchmark year. All cash flows are also expressed in terms of the selected base year with no inflation factors applied.

The escalating dollar option assumes that both capital and operating costs are increased annually according to an assumed percentage value of inflation for each category. The inflation factors are specified by the model user.

4.4.2.4 Optional Capitalization Structure

The portion of the total initial capital requirements (those incurred prior to the production phase) which is funded by equity or loan funds may be specified by the user. The debt/equity ratio is a required input along with the annual debt servicing percentage and loan payback period. It is then assumed that all capital requirements incurred in each preproduction year will be funded according to the debt/equity ratio specified. Interest is accumulated and the outstanding loan amounts up to the last preproduction year. The total loan amount commitments up to that point along with the accummulated interest form the total principal amount to be repaid by annuities starting in the first year of full production.

4.4.2.5 Capital Costs Treatment

There are two methods for the recovery of the capital costs. The first method is to depreciate the costs using the depreciation types available in the model. This is the method typically employed in feasibility studies. The second method involves writing off all the costs in the same year they are projected to occur.

4.4.2.6 Optional Depreciation Methods

Three depreciation methods can be selected from the model: fast (or accelerated), declining balance, and straight line. It should be noted that only the fast or declining balance methods are applicable to mines in Canada.

4 .2.7 Optional Royalty Payments Calculation Methods

There are two methods to assign the percentage of revenue which makes up the royalty payments. The first method is a straight percentage specified by the user (e.g. B.C.). The second method is that used in the Province of Alberta which will be explained later on.

4.4.2.8 Optional Project Start Year

The beginning of the project in terms of a calendar year start date is a user input. The start date refers to the beginning of site related activities such as site preparation and construction.

The updating of the data base from 1982 to any project start year, is made through updating factors per item entered by the user.

4.4.2.9 Assumptions

The assumptions considered in the financial analysis are listed below:

- The model only applied to new projects, therefore, it is assumed that all expenditures will take place in the future. The pivot year for discounted cash flow analyses is the first project year.
- It is assumed that all transactions of cash disbursements and receipts take place at the end of each year.
- Rate of return calculation is applied only

to the equity portion of capital investment.

- Debt financing is assumed only for capital requirements during the preproduction phase of the project. The remaining expenditures are assumed to be funded from project operations.
- Equipment repurchases to replace original equipment are assumed to be at the same price (plus escalation if applicable).
- All data base costs in the model reflect those in effect for the year 1982 (Marshal & Swift Index).
- The coal price either as input or output of the model, is at the mine site. No transportation costs are considered.

4.4.3 Capital and Operating Costs Analysis

4.4.3.1 Capital Costs Schedule

The total capital cost category is divided into the initial capital (incurred prior to the first year of full production) and deferred capital (capital incurred after full production begins).

The capital structure defined for underground model is presented below:

* Initial Capital(Prior to full production year)
  . Acquisition cost
  . Production section equipment

. Haulage system (preproduction)
. Auxiliary equipment
. Exploration costs
. Site preparation and construction
. Indirect capital (engineering, fees, etc.)
. Preproduction development cost
. Entry haulage system
. Accrued interest

* Deferred Capital Expenditures(during full production phase)
  . Working Capital (first year of production)
  . Equipment Replacements (production, haulage, auxiliary, entry haulage)
  . Equipment additions(haulage system)
  . Additional construction (ventilation, mine abandonment)

The capital structure defined for the surface model is listed below:

* Initial Capital
  . Acquisition cost
  . Exploration cost
  . Primary equipment costs(stripping, drilling, loading, hauling, reclamation)
  . Support equipment
  . Construction costs
  . Indirect capital (engineering, fees, etc)
  . Preproduction development costs

- Accrued interest

<u>Deferred Capital Expenditures</u>(during full production phase)

- Working capital (first year of full production)
- Primary equipment replacements (stripping, drilling, loading, hauling, reclamation)

The model provides procedures (based upon mining experience) regarding the calculation and allocation during the mine life of the various costs. Tables 4.15 and 4.16 represent examples, for underground and surface model respectively, of how each of these capital items are allocated.

4.4.3.2 Operating Cost Analysis

The structuring of operating costs involves analysis of the results of submodels 2, 3 and 4 for underground model and submodels 3 and 4 for surface model. Other costs which must be included are the allowance for labour overhead (general administrative costs) and insurance fees. The estimation of the labour overhead is a percentage (40% default) of direct labour costs. The calculation of insurance fees is also a percentage (2%) of the cumulative investment in those items for construction and equipment in the year prior

Table 4.15

CAPITAL EXPENDITURE ALLOCATION SCHEDULE

	Construction And Development Phase		PreProduction Development Phase		Full Production Phase	
	-4	-3	-2	-1	+1	+2
INITIAL CAP						
Acquisition Cost	100%					
Production Section Eq.			50%	50%		
Haulage System			50%	50%		
Auxiliary Eq.			50%	50%		
Exploration	100%					
Indirect Cap.	✓	✓	✓	✓		
Preproduction Dev.			50%	50%		
Entry Haulage Syst.		100%				
Accrued Int.					100%	
Site Prep. and Const.						
- Vent Shafts	25%	25%	25%	25%		
- Mine Entries Const.		100%				
- Prep. Plant		50%	50%			
- Other Surface Const.	25%	25%	25%	25%		
DEFERRED CAP						
Working Cap.					100%	
Equip. Repc. (Based on Eq. Life)						
Eq. Additions						
- Haulage (Evenly allocated over 1st half of mine life)					✓	✓
Additional Const.						
- Ventilation Const. (Evenly every second year of production phase beginning yr. + 2)						✓
- Mine Abandonment (Last year of Production)						

Table 4.16

INITIAL CAPITAL ALLOCATION SCHEDULE FOR AREA AND OPEN PIT MINES

	% Allocated/Year Construction and Development			Preproduction Development
Capital Cost	Year -4	Year -3	Year -2	Year -1
Acquisition Cost	100%			
Exploration Cost	100%			
Primary Equipment Cost				
Overburden Stripping		30%	40%	30%
Overburden Drilling		20%	30%	50%
Coal Drilling		20%	30%	50%
Coal Loading		20%	30%	50%
Coal Hauling		20%	30%	50%
Reclamation Equipment		20%	30%	50%
Support Equipment		20%	30%	50%
Construction Costs (including prep. plant)	25%	25%	25%	25%
Indirect Capital (15% of primary eq. + support eq. + construction costs each year)	X	X	X	X
Preproduction Development Costs				100%
Accrued Interest (listed in first full production year)	X		X	X

to full production. Therefore the final expression for the annual operating cost is:

OC=MACO+(LACO*FRBE)+MACO*OVHE+NLOC+INS

Where

MACO= Manpower cost

LACO= Labour cost

FRBE= Fringe benefits percentage (35%)

OVHE= Overhead cost percentage (40%)

NLOC= Non labour operating costs

INS = Insurance fees (2%)

4.4.4 Application of DCF Analysis

The costs that are required as input to the cashflow summary table have been structured for direct entry to many of the line item accounts (Table 4.17). This table has been adjusted from the original model to Canadian conditions. The remaining items in the table then utilize these values to calculate costs for such items as gross profits, royalty, loan interest, income taxes, depletion allowances, net profit, working capital, net cash flow, and others. The calculation of coal value/tonne or rate of return on equity is the ultimate solution generated by the DCF. The remainder of the analysis will provide a line by line description of the costs and calculations involved in developing each line item on the cashflow summary Table. The main references used to adapt the EPRI DCF to Canadian scheme were (17), (18), (20), (21), (22) and (43).

Table 4.17

CASH FLOW SUMMARY TABLE
****

Calendar Year of the Project: / Relative Year of Full Prod. / LINE | CASHFLOW ITEMS	1984 -2	1985 -1	1986 1	1987 2	...	2000 14
101 Coal Value/Tonne					...	
102 Annual Production Clean Coal					...	
103 Annual Sales Revenue					...	
104 -Annual Operating Cost					...	
105 =Gross Profit					...	
106 -Interest Payment					...	
107 -Resource Allowance (25%)					...	
108 -Capital Cost Allowance					...	
110 -Explor.,Preprod., and Const.					...	
111 =Net Income for Earned Deple.					...	
112 -Depletion Allowance (25%)					...	
113 =Taxable income					...	
114 -Income Tax (47%)					...	
115 -Royalty					...	
116 +Investment Tax Credit					...	
117 =Net Profit					...	
118 +Additional Income (S. Value)					...	
119 +Addback of Noncash					...	
120 -Loan Principal Payment					...	
121 =Net Cash Inflow					...	
CAPITAL EXPENDITURES						
122 Acquisition Cost					...	
123 Exploration					...	
124 Preproduction Development					...	
125 Construction					...	
126 Equipment					...	
127 Accrued Interest					...	
128 Indirect Capital					...	
129 Working Capital					...	
130 Total Annual Capital Exp.					...	
131 -Amount Funded From Equity					...	
132 Amount Funded From Loans					...	
133 Annual Net Cashflow					...	

4.4.4.1 Line 101-Coal Value/Tonne

This is the ultimate solution to the DCF analysis when Rate of Return (ROR) is known. This value is the dollars amount per tonne of run-of-mine coal which will generate an annual revenue sufficient to offset all direct operating costs, tax and royalty requirements, capital recovery expenses, and all other indirect expenses to provide the return to equity as specified by the input. An iterative solution method is used for this calculation. The line item must be solved by: assigning values to it, working through the remaining line items for each year, computing for the annual net cashflow results in line item 133, and then computing the present value of these cash flow streams at the return to equity specified by the input.

A complete description of the calculation of coal value/tonne and ROR will be developed further on.

4.4.4.2 Line Item 102-Annual Production of Clean Coal

This item represents the amount of coal/year which is shipped from the mine, and is the result of applying reject factors to the raw coal production. The annual amount of clean coal for each full production year is constant in this model.

4.4.4.3 Line Item 103-Annual Sales Revenue

This is the total dollar amount received each year from which all operating costs and other expenses are deducted. To calculate the annual sales revenue, it is necessary to multiply line items 101 and 102, the $ value/tonne of coal times the amount produced.

4.4.4.4 Line Item 104-Annual Operating Costs

The costs included in this category are direct labour costs, labour overhead charges, fringe benefit expenses, supplies and materials costs, power costs, and insurance fees. These expenses are incurred after the first year of full production. Prior to that time, all similar costs are categorized as preproduction development expenses and are capitalized.

4.4.4.5 Line Item 105-Gross Profit

It is the gross amount of income realized taking into account only direct operating costs. This line item is calculated by subtracting line item 104 from line item 103, sales minus operating costs.

4.4.4.6 Line Item 106-Loan Interest

This line item represents the interest portion of the annuity payments made to repay the loans required during each year of the preproduction period. The portion of the total capital expenditures (line 131) which is to be financed by debt capital each year of the preproduction phase is determined by the debt ratio value .

It is assumed that the annuity payments will begin with the first full production year. Debit amounts prior the first production year. The amount compounded by this mean becomes the accrued interest amount for line item 128. The total accrued interest is added to the cumulative loan amounts in year 1 of production to form the total principal amount for repayment.

The method of computing the interest payment portion of the annuity therefore, first requires a calculation of accrued interest.

Accrued Int.=

$$\sum_{n=1}^{p-2}(\text{Loan Amt}_n)*(1+i)^{p-n+1} - \sum_{n=1}^{p-2} \text{Loan Amt.}$$

n= year of project life

i= debt servicing percentage

p= 1st year of production phase

Total Debt Principal(D)= $\sum_{n=1}^{p-1} (\text{Loan Amt})_n + \text{Accrued Int.}$

Annuity Payment Req (A)=

$$(\text{Total Debt Principal})* \ (i*(1+i)^m/((1+i)^m-1))$$

i= debt servicing rate

m= loan repayment duration (years)

The Interest and Principal portion of annuity payment for any year m is given by:

$I_n = (D-P1-P2-,....P_{n-1}) *(1+i) -1$

$P_n = A-I_n$

The values of I are to be entered on line 108 in the appropiate year. The value of P is the cost to be used in line 120, Loan Principal Payment. The value of accrued interest should be entered on line 127 during the first production year.

the first production year.

4.4.4.7 Line Item 107-Resource Allowance

The Resource Allowance is a flat 25 percent income tax deduction from gross profit. This allowance was introduced in 1974 to offset the fact that provincial mining taxes and royalties were no longer deductable in the calculation of taxable income.

4.4.4.8 Line Item 108,110- Capital Cost Allowance

This charge is for recovery of the capital costs for the preproduction development, construction, indirect capital exploration and equipment. There are three depreciation methods available for application of this charge: fast (default), straight line, and declining balance. However, only the fast and declining balance methods are applicable for new mines in Canada.

Replacement or addition of equipment will be assumed to continue to utilize the originally specified depreciation method. The total of all depreciation charges are summed and entered on line 108 of the cash flow summary table.

The procedures used for computing the depreciation charges are listed below.

Fast (or Accelerated) Method:

This method allows the operator to recover the initial investment during the first years of production, this means that during this time all profits will be used for this purpose, and therefore there are no taxes. This period is known as the "payback period".

Straight Line Method

This method provides a fixed annual charge for each expenditure classification.

Annual Charge= OI/EL

OI= amount of original investment equipment

EL= equipment life

Declining Balance Method

In this method, a depreciation rate is applied each year to the remaining book value (BV) of the asset. The current maximun rate allowed is 30 percent. The annual charge (AC) is computed as:

AC= 0.3*BVi

BVi= BVi-AC

BV1=OI

If the user has selected *expense* for the treatment of the capitalization, then the depreciation of this cost will start in the years during which they occur (line item 110). This option would be used by a company which had income from other operations from which the development expenses could be deducted.

4.4.4.13 Line Item 111- Net Income for Depletion Allowance

This is the income to which can be applied the depletion allowance deduction. It is calculated by subtracting line items 106, 107 and 108 or 110 from line item 105, gross profit.

4.4.4.14 Line Item 112- Depletion Allowance

Depletion allowance is a mean of recovering the value of a depleting resource. The method used by the model is the Canadian earned depletion which is a fixed percent of Net Income (default 25%). This tax deduction is limited to one third of the exploration and development costs, and applies only after the payback period.

4.4.4.15 Line Item 113-Taxable Income

This is the income subject to federal and provincial income taxes, and is the result of subtracting line item 112, depletion allowance, from line item 111.

4.4.4.16 Line Item 114-Income Tax

Income tax is compo[illegible] of federal tax, 36% of taxable income, and provincia[illegible], 11% in Alberta and 15% in B.C. of taxable income[illegible]s gives a flat tax of 47% and 51% in Alberta and B.C [illegible]pectively.

4.4.4.17 Line Item 115-Royalty

Royalty payments paid to the provincial government for mineral rights are included in this category. The calculation process required for western Canada differs greatly from that used in the original model.

Two processes for calculating the percentage of revenue that represent the royalty payments are included in this model. The first is the method used in British Columbia whioh assign a straight percentage (3.5%) on the gross revenue less the transportation costs. The second is the method used in the Province of Alberta which involves a sliding scale depending upon the profitability of the project (see Appendix A).

4.4.4.18 Line Item 116-Investment Tax Credit

The Investment Tax Credit is an income tax deduction equal to a percentage depending upon region and on the cost of qualified assets (mining and processing equipment). An amount may be deducted from tax otherwise payable equal to the lesser of:

- The investment tax credit
- $1500+(Tax Otherwise Payable-$15000)/2

4.4.4.19 Line Item 117-Net Profit

This value is the book income amount after taxes. The net profit can be calculated by subtracting all the cash expenses i.e. interest, royalty, income tax, etc, from the gross profit.

4.4.4.20 Line Item 118-Additional Income (Salvage Value)

This item is the result of the sale of equipment at the end of their lives. The sale of this equipment is considered recaptured capital cost. The method of computing salvage value (SV) is based on a percentage of original investment (OI). The capital cost categories for which SV applies is as follows:

Category	Default SV(%)
Prod. Section Eq.	10
Haulage System	5
Auxiliary Equip.	5
Entry Haulage Sytem	5
Trucks and Drills	10
Dozers and Scrap.	10
Dragl. and Shovels	0

4.4.4.21 Line Item 119-Addback of Non Cash Costs

This item totals all previously deducted non-cash costs which were charged strictly for reducing tax liability. These charges include resource allowance, depletion allowance, and capital cost allowance.

4.4.4.22 Line Item 120- Loan Principal Payment

This payment is on the increasing amount paid each year to satisfy initial loan payback requirements. From a constant annuity payment, the interest charges (108) are declining annually while the principal amount increases.

4.4.4.23 Line Item 121- Net Cash Inflow

This value expresses the actual cash flow realized, after all operating expenses, as a result of the project operation. Its calculation is the sum of Net Profit (117) plus Additional Income (118) plus Addback of Non Cash (119) and minus Loan Principal Payment (120).

4.4.4.24 Line Item 122-Acquisition Cost

This is the initial investment required for purchase of property or mineral rights. The value for this capital cost is a user specified input.

4.4.4.25 Line Item 123-Exploration

The exploration occurs in the first year of the project life and is either expended in the first project year or capitalized.

4.4.4.26 Line Item 124-Preproduction Development

The expenses involved in opening and preparing a mine for extraction are considered development expenses. Construction costs of mine opening and other surface activities involved in preparing the mine surface are considered in line 128.

4.4.4.27 Line Item 126-Equipment

The equipment costs involve capital required for production section equipment, auxiliary equipment and haulage equipment for underground system and primary production equipment, reclamation equipment and support equipment for surface system.

4.4.4.28 Line Item 127-Accrued Interest

This is the amount accumulated by compounding the individual loan amounts in each year prior to the last year of the preproduction phase. At that point the accrued interest is added to the cumulative loan amount to form the total principal to be repaid at the stated debt service rate.

4.4.4.29 Line Item 128-Indirect Capital

This charge is for various technical support services which are required for the project. It is calculated as a function of primary production equipment and construction costs. The cost of indirect capital is charged over the production phase of the project.

4.4.4.30 Line Item 129-Working Capital

This capital charge is for startup operating expenses incurred prior to receiving any revenue from operations. Two estimation methods for this item were considered in this model. The first is the original one which calculates the working capital as 25 percent on the sum of operating costs and royalty payments. The second is that used in the Province of Alberta which estimates this cost as 5 percent of operating costs plus 15 percent of amortization charges.

4.4.4.31 Line Item 130-Total Capital Expenditures

It is the sum of items 122 through 129.

4.4.4.32 Line Item 131 and 132-Amount Funded from Equity and Loans Respectively

These capital expenditures are assumed to be funded from equity and debt(loan) funds according to the capitalization structure described by the user input.

The input for debt and equity is expressed as a percentage of total capital. It is therefore, necessary to use the respective percentage factor and the value of item 130 to arrive at the correct values for line 131 and 132.

4.4.4.33 Line Item 133-Annual Net Cashflow

This is the balance between net cash inflow and outflow. It is the value which is discounted to arrive at the overall present value of the project. Annual net cashflow is computed by subtracting the equity portion of capital expenditures (131) from net cash inflow from operations (121).

4.4.5 Coal Value/Tonne Calculation Procedure

The estimate of the coal value/tonne for each set of cost values computed by previous submodels, requires an iterative solution of the completed Cash Flow Summary Table. In other words, this line item must be solved by assigning values to it, working through the remaining line items for each year, computing the annual net cash flow results in line item 133 and then, computing the present value of these cash flow streams at the return to equity specified by the input.

The average value/tonne result which will satisfy the DFC procedure is the dollar per tonne figure which yields a zero present value (PV) of the cash flow stream. For any given year, the PV calculation is represented by

$$PVn = (Cash\ Flow)n/(1+i)^{n}$$

Where

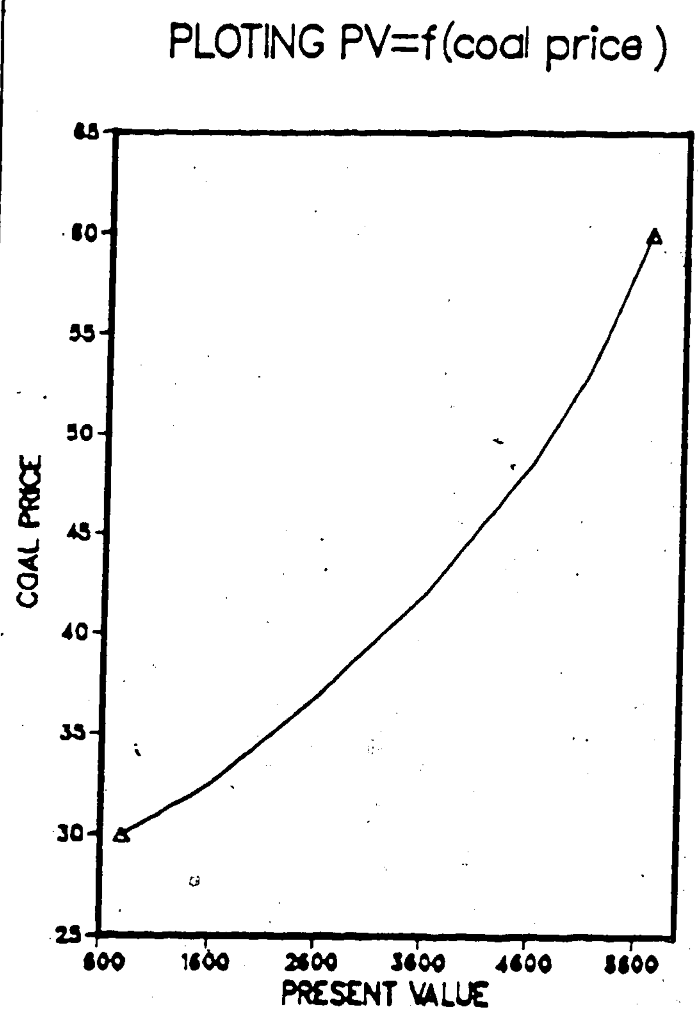
n= Year of the project

i= Rate of return

The relation presented above yields a nonlinear relationship between the present value and the coal price (see Figure 4.5). At this point, there is an important difference as the EPRI model assumed the present value coal price relationship to be linear. In the opinion of the author this assumption was a serious defect in that model.

The method employed in this model for arriving at the correct solution involves an iteration process which starts by assigning initial values of $15 per tonne and $50 per tonne to line item 101 of the cashflow table. Then, by calculating all subsequent line items and arriving at the annual net cash flow (line item 134), the present values of the cashflow stream for the coal prices of $15 and $50 are

Figure 4.5

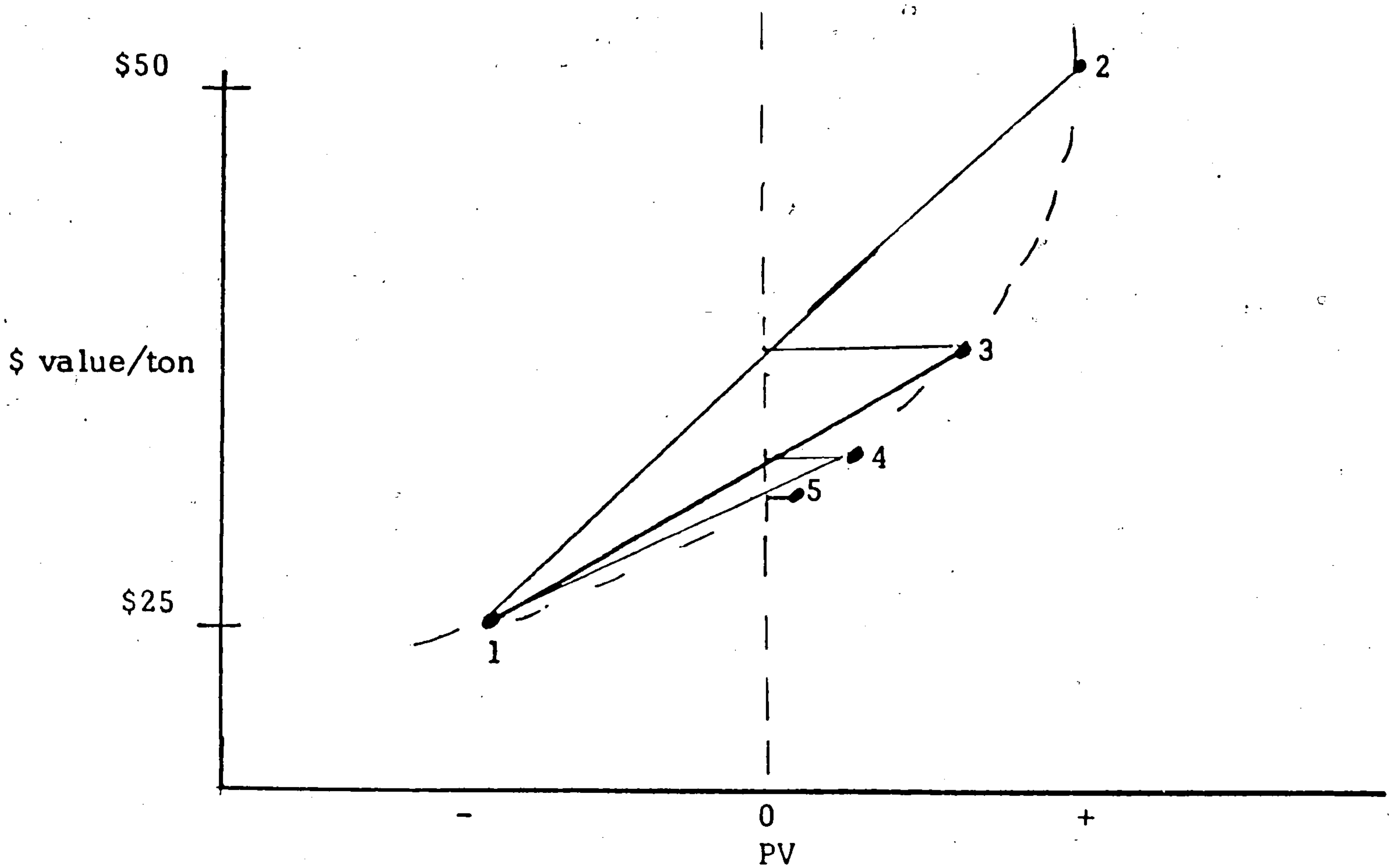


Rate of Return= 20%

Figure 4.6

SOLVING A NONLINEAR EQUATION BY LINEAR APROXIMATION

PV= f(Coal Price)



In the display above, the repetitive linear solutions for PV-0 took five trials to arrive at the $ value/ton which provides a PV within the specified tolerance.

computed. The objective of this procedure assumes a linear relationship between the pair of points ($15, PV_{15} and $50, PV_{50}) to estimate the answer. Using the estimate as one point the process is repeated. The procedure for arriving at the PV= 0 for this situation involves the following steps:

1. Examine the results of the last trial and use the $/tonne value of that trial and the $/tonne value from the previous trials which meet the following criteria:
   - first, the $/tonne value having the PV nearest to zero of the opposite sign, or if they both have the same sign,
   - then, choose the $/tonne value having the PV of the same sign which is closest to zero value.
2. Apply a linear fit to the last two points selected using a form of the equations previously presented and solve once again for PV=0 using the following equation:

$$\$/tonne = (Larger\ \$/t) - \left[\frac{Larger\ \$/t - Smaller\ \$/t}{PV_{larger} - PV_{smaller}}\right] * PV_{larger}$$

In the equation above the terms larger and smaller are used simply to distinguish between the values selected by the previously presented selected criteria.

The iteration process described above is repeated until the present value reachs the value of zero. However, a tolerance is permited; if the result falls within +- 10000, the coal price is assumed to be acceptable. A graphic display of this approach for a nonlinear case is presented on Figure 4.6.

4.4.6 Rate of Return on Equity Calculation Method

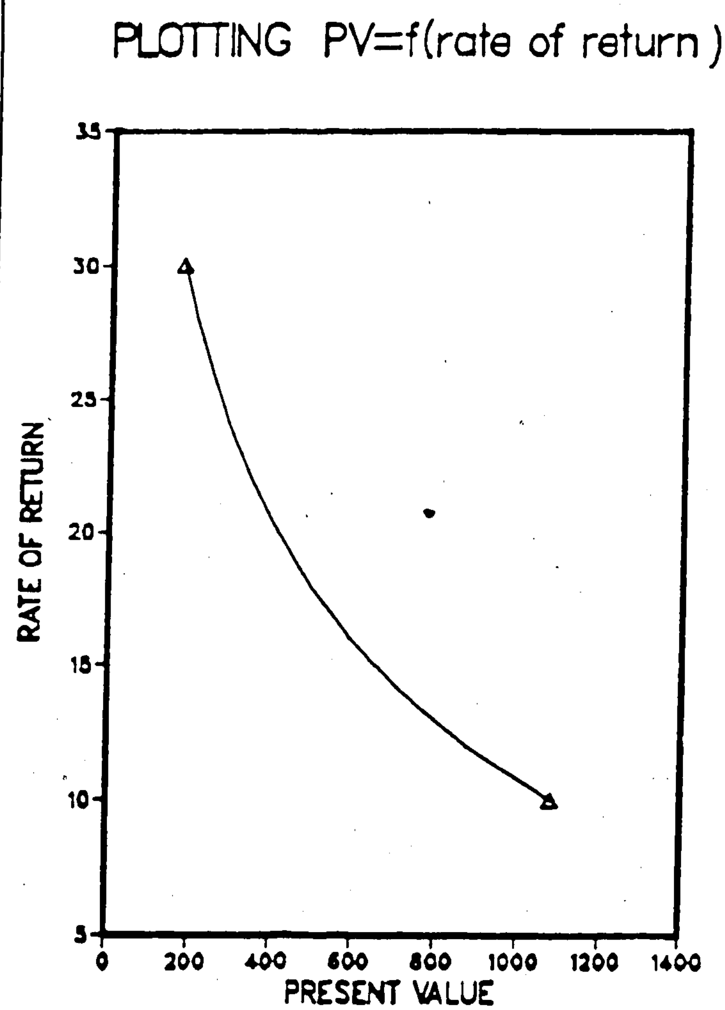
The solution of rate of return (ROR) is similar to the procedure used in solving for coal value/tonne when ROR is known. The mechanics are less involved since the annual net cashflow does not have to be computed for each ROR trial.

The ROR selected will be that which generates a PV=0 in the nonlinear relation PV= (Cashflow)n/$(1+i)^n$. See Figure 4.7.

The procedure to arrive at the proper ROR involves an iteration process which starts by applying two fixed ROR values (10% and 30%) and then discounts the cashflow stream at these rates to arrive at the present values. A linear relationship between the two point (10%,PV_{10} and 30%,PV_{30}) is developed from where the iterative linear approximation[6] starts. Similar to the procedure outlined for the coal value/tonne non linear solution, an iterative linear approximation to the correct ROR solution is employed. The following steps are again used to approach the correct ROR.

1. Examine the results of the last trial; use the ROR value from the previous trials which meets the following criteria.
   - First, the ROR having the PV closest to zero of the

Figure 4.7



Coal Price= $25

opposite sign or, if non existant,

- choose the ROR having a PV of the same sign which is closest to zero in value.

2. Apply a linear fit to the two points selected and again solve for ROR at PV=0 using the equation:

ROR=

Larger ROR+[Smaller ROR/(PVlarger-PVsmaller)]*PVlarger

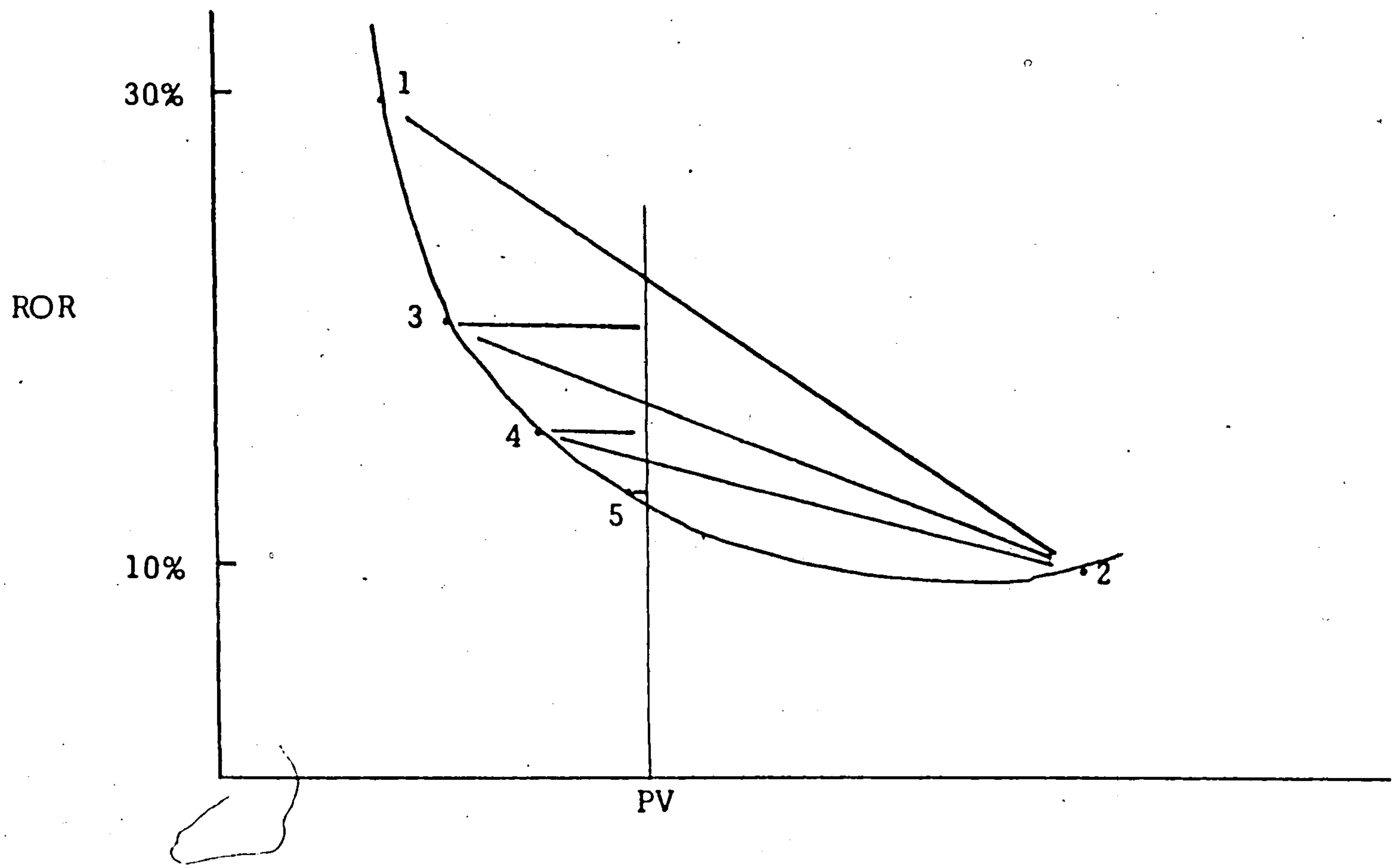
The terms larger and smaller are used to distinguish between the two points selected by the criteria.

The iteration process described above is repeated until the present value reachs the value of of zero. However, a tolerance is permited; if the resulting ROR yields a PV within +-10000, that ROR is considered to be acceptable. The approach is graphically illustrated in Figure 4.8.

Figure 4.8

SOLVING A NONLINEAR EQUATION BY LINEAR APROXIMATION

PV= f(ROR)



In the example presented above, it was assumed that five trials were required before an acceptable ROR was determined.

5. Model Computational System Description

5.1 Introduction

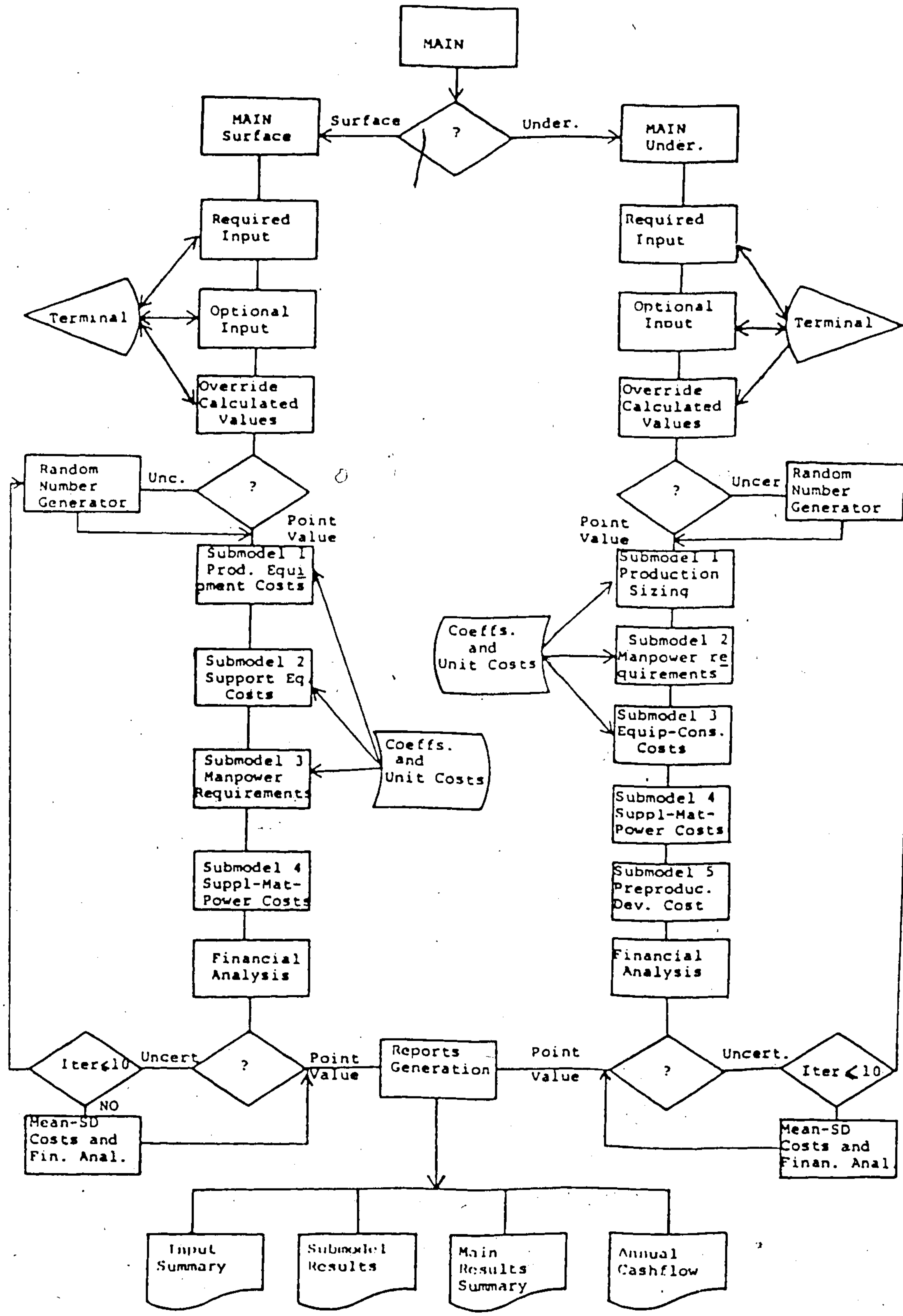
The purpose of the computing system described in this section is to perform the calculational procedures required in analyzing the costs and requirements of proposed coal mining projects. The main output of this computing system is a value or range of values for either the coal price per tonne, or rate of return on equity that yields a zero present value of the cashflow stream. The program specifications are derived mainly from the original EPRI model and from the model modifications described in Chapter 4.

The system was designed for an interactive operational mode, which provides a conversational interface between the user and the model. The results are displayed on the user's terminal. However, a copy is also written into a temporary file which can be printed later if desired.

The general system diagram is shown in Fig. 5.1. It can be appreciated that there are two main subsystems: underground and surface. Both subsystems have the same structure which is composed of 5 main processes: Input, cost determination, financial analysis, uncertainty analysis and output. Each system process, together with a statistical analysis, is described in more detail in the following pages.

Figure 5.1

COMPUTING MODEL FLOWCHART



The terminology defined in naming the variables and files is as follows:

- Program File Names: These are composed of three parts. The first part is a prefix indicating an underground program (EU), surface program (ES), or a common program (E). The second part is the program name, and the third part is a suffix which indicates source (S) or object program (O).
- Variable Names: These are composed of two parts. The first one is a prefix of which the first letter indicates an underground variable (U), or a surface variable (S), the second letter of this prefix indicates a required variable (R), an optional variable (O) or a calculated variable (C), and the last four letters represent the name of the variable.
- Data File Names: These are also composed of two parts. The first is a prefix which indicates an underground file (EU) or a surface file (ES). The other 4 letters express the file name itself.

The programs which make up the system, the data files, input variables names and calculated variable are listed in Appendix B.

The model's options, to be established during the input phase were detailed in Chapter 4, and are enumerated below:

* Underground or Surface systems.
* Rate of Return or Coal Price output.
* Constant or Escalating Dollar.

* Point Value or Uncertainty Analysis.
* Low, Total or High range for equipment, construction and operating costs.
* Province of Alberta or Percentage Royalty.
* Fast, Straight or Declining Balance Depreciation.
* Deferred or Expensed Capitalization.

5.2 System Description

5.2.1 Input Process

5.2.1.1 Input via Terminal

As mentioned in the previous sections, there are three types of input: required, optional, and parameters which override calculated values. Each input has three types of data: physical, operational and financial. Data should also be entered in terms of mean and standard deviation to be used for the uncertainty analysis option.

The required input must be entered in order to run the model. This data defines the coal deposit which is to be analyzed. Tables 5.1 and 5.2 show an example of the required data for underground and surface systems.

The optional input has default values which the user can either accept or alter . Tables 5.3 and 5.4 show an example of the default values for underground and surface systems.

Table 5.1

REQUIRED INPUT FOR SURFACE MINING WITH TYPICAL VALUES

Seam Thicks. (Mean)(cm)	200	Seam Thicks. (SD)(cm)	20
Overbdn Thicks.(Mean)(m)	15	Overbdn Thicks.(SD)(m)	2
Topsoil Thicks.(Mean)(cm)	100	Topsoil Thicks.(SD)(cm)	10
Single or Mult. Seam	sin	Mining System	area
Annual Production (000t)	1500	Mine Life(Years)	30
% Capital Borrowed	30	Debt Serv. Rate (%)	10
Loan Paybk Period(Yrs)	10	Acquisition Cost/sq.km(Mean)	197600
Acquisition Cost(SD)	1000	Dollar Equivalence	0.80
Project Start Year	1982	Type of Analysis	unc
Dollar Type Analysis	con	Base Year	1982
Labor Upd/Esc Factor	0	Prim. Eq. Upd/Esc Factor	0
Supp. Eq. Upd/Esc Factor	0	Operating Upd/Esc Factor	0
Construc. Upd/Esc Factor	0	Coal Value Esc. Factor	0
Coal Value/tonne	14	Rate of Return	0

Table 5.2

REQUIRED INPUT FOR UNDERGROUND MINING WITH TYPICAL VALUES

Seam Depth (m)(Mean)	122	Seam Depth(m) (SD)	10
Seam Thickn.(cm) (Mean)	300	Seam Thickn.(cm) (SD)	30
Seam Gradient	0	Roof Conditions	good
Floor Conditions	ha	Gas Level	low
Mining System	cont	Entry Type	shaft
Annual Production (1000t)	210	Production Life	18
Analysis Type	unc	Eq. Cost Range	tot
Contruc. Cost Range	tot	First Calendar Year	1982
Dollar Analysis Type	con	Base Year	1982
Labor Upd-Esc Factor	0	Power Upd/Esc Factor	0
Equip. Upd/Esc Factor	0	Haulage Upd/Esc Factor	0
Aux.Eq. Upd/Esc Factor	0	Supp.Mat. Upd/Esc Factor	0
Constr. Upd/Esc Factor	0	Capital Borrowed(%)	20
Debt Servicing Rate(%)	10	Loan Payback (years)	20
Dollar Eq.(CA$=X US$)	0.85	Coal Value/Tonne	25
Rate of Return	0	Acqu. Cost (Mean)($000)	0
Acqu. Cost (SD)($000)	0		

Table 5.3

OPTIONAL INPUT VALUES (UNDERGROUND)

Mean Reject Percentage	0	SD Reject Percentage	0
Shifts per Day	2	Days per Year	138
Coal Preparation	none	Seam Recovery	65
Mean Operator Eff.	85	SD Operator Eff.	4
Mean Available Face Time	340	SD Available Face Time	15
Indirect Capital (%)	10	Capital Overhead (%)	2
Fringe Benefits (%)	30	Royalty Payments (%)	1
Income Tax (%)	47	Depreciation Method	fast
Preprod. Treatment	def	Investment Tax Credit	5

Table 5.4

OPTIONAL PARAMETERS DEFAULT VALUES (SURFACE)

Reject (%)	0	Mean Recovery (%)	90
SD Recovery (%)	9	Dilution(%)	8
Coal Type	bitu	Exploration Required (sq. m)	161874
Coal Density (k/cu.m)	1504	Coal Preparation	none
Drilling Ovbdn (Work.Pl)	0	Overbdn Consolidation	low
Coal Loading Op. hrs/Mo	336	Mean Coal Load Cy. Time(s)	75
SD Coal Load Cy. Time(s)	7	Mean Bucket Fill Factor	75
SD Bucket Fill Factor	7	# of Loading Passes	10
Mean Truck Travel Time Ld	1200	SD Trck Trvl Time Ld(s)	120
Mean Trk Trvl Time Emp(s)	700	SD Trk Travel Time Emp(s)	70
Mean Other Times(s)	300	SD Other Times(s)	30

The parameters which override calculated values are variables calculated by the system. The user may impose his own values prior to further calculation. The system estimates those variables first and then shows them to the operator, who either accepts or modifies them. Tables 5.5 and 5.6 show an example of this process for underground and surface systems.

5.2.1.2 Input Via Files

The data files contain mainly unit costs for equipment, manpower and preparation plant. These costs are used for the submodels' costing process. Except for manpower costs, all other costs are expressed in U.S. dollars which are converted to Canadian dollars using the "dollar equivalence" parameters required during input.

The data files required by the system are the following: equation coefficients for underground conventional system (EUCVCO), equation coefficients for underground continuous system (EUCNCO), production equipment costs for underground system (EUCOST), overburden shovel and front loader costs (ESSHTH), dragline costs(ESDRCO), and truck, drill, coal shovel, dozer, scrapers, and preparation plant cost (ESSHTH). The formatted contents of each file mentioned above are in Appendix C.

The key to selecting the appropiate cost is the estimated size of the corresponding equipment. If this

Table 5.5

PARAMETERS WHICH OVERRIDE CALCULATED VALUES
(UNDERGROUND)

Tonnes/Machine Shift	764	Production Sections/Shift	1
Hourly Labor Requirements	40	Salaried Personnel Req.	10
Development Time(Yrs)	1.00	Coal Prod. During Dvlpment	158148
Production Equipment Life	12	Haulage System Life	12
Aux. Equipment Life	12	Hourly Labor Cost/Yr	919
Salaried Pers. Cost/Yr	397	Supp.& Material Cost/t	6.00
Power Cost/t	0.59	Annual Operating Cost	2541
Initial Prod. Section Cos	2294	Initial Aux. Equipment Cost	0*
Initial Hlage System Cost	0*	Plant & Unit Train Loading	0
Exploration Cost	0*	Mine Abandonment Cost	0*
Mine Entry Cost	0*		

* User assigned value

Table 5.6

PARAMETERS WHICH OVERRIDE CALCULATED VALUES

(SURFACE)

Land Requirements (SQ. M.)	18
Total Hourly Personnel	79
Total Salaried Personnel	38
Explor. and Develop. Drilling Cost	0
Supplies and Materials Cost	6170149
Support Capital (%)	24
Total Annual Operating Cost	13630819
Total Preprod. Develop. Cost	4697383
Preparation Plant Cost	0

size does not coincide exactly with the standard file sizes, the next largest is chosen from the file.

5.2.2 Submodels Costing Process

All costs on which the financial analysis is developed are calculated here. This includes: equipment costs, manpower costs, supplies and material costs, construction costs, power costs, and preproduction development costs. These costs are estimated through different submodels which were explained in sections 2 and 3 for the underground and surface systems. Each submodel is a separate subroutine of the system.

The underground system is formed by five submodels, they are:

- Submodel 1, Production Sizing
- Submodel 2, Manpower Requirements and costs
- Submodel 3, Equipment and Construction Requirements and costs
- Submodel 4, Supplies, Materials, and Power costs
- Submodel 5, Preproduction Development costs

For the surface system there are 4 submodels:

- Submodel 1, Equipment Requirements and Costs
- Submodel 2, Construction and Support Equipment Requirements and Costs
- Submodel 3, Manpower Requirements and Costs
- Submodel 4, Supplies, Materials and Power Costs

The manpower and equipment costs are calculated by first estimating the units required and then applying the cost per unit taken from data files. The preparation plant cost depends on the type of preparation selected during the input process (export or mine-mouth power plant) and the output production required. The other costs (supplies, materials, power and preproduction development) are calculated as a function of the manpower cost and production required,

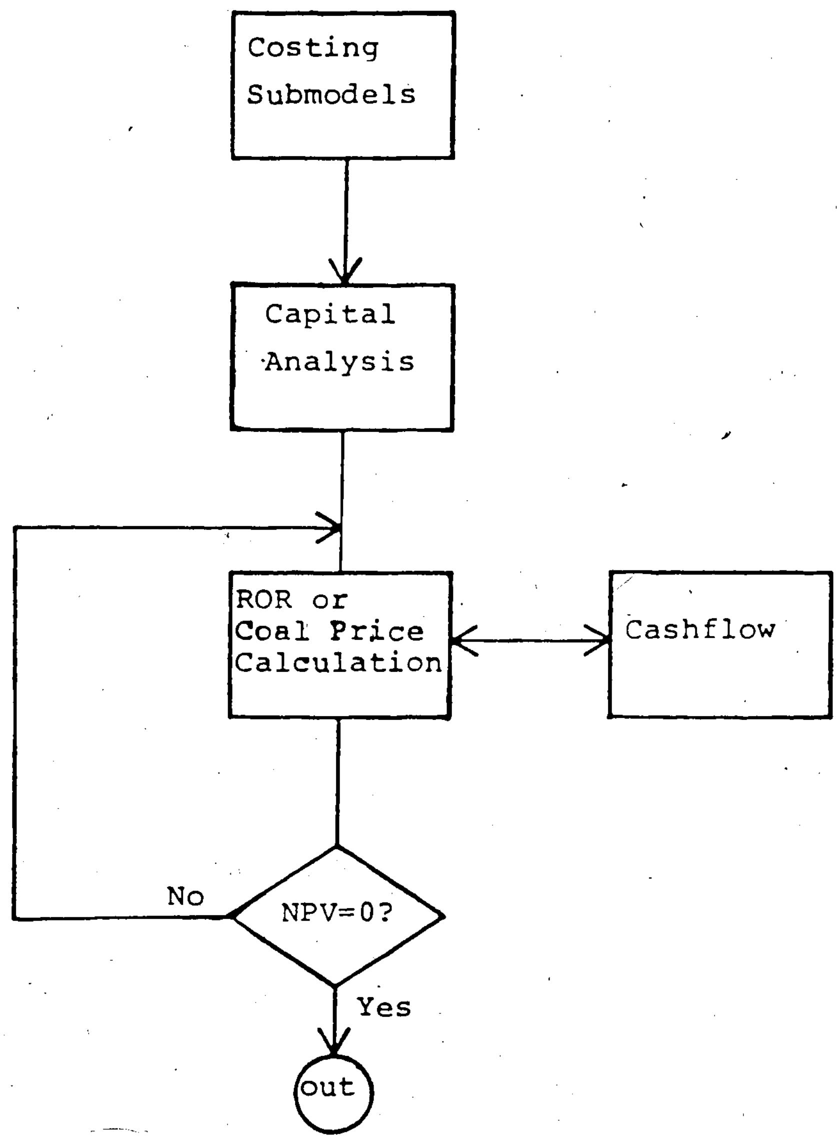
5.2.3 Financial Analysis

The financial analysis is carried out by three subroutines (see Fig 5.2): Capital Analysis, Cashflow, and Rate of Return (or Coal Price) calculations. The Capital Analysis estimates all capital and operating costs during the mine's life. In other words, all those cashflow items corresponding to fixed and direct cost, such as acquisition, exploration, preproduction development, construction, equipment, indirect capital, annual operating cost, salvage value, and capitalization, are estimated here. The original model provides procedures to assign the proportional amounts of costs throughout the mine's life. Other cashflow items such as capital amount funded from equity, capital amount funded from loans, interest payments, accrued interest, and loan principal payments, are also calculated here.

The cashflow program builds the annual cashflow through out the mine's life. The process begins with the calculation

Figure 5.2

FINANCIAL ANALYSIS FLOWCHART



of the remaining cashflow items not yet calculated. The value of these items depends on the annual sale revenue. This way, gross profit, depreciation, resource allowance, depletion allowance, income tax, royalties, investment tax credit, and working capital are estimated. With all these elements defined, the program calculates the annual net cashflow.

A third subroutine calculates the rate of return (or coal price) according to the procedure explained in Chapter 4, which uses an iteration process to find the rate of return (or coal price) that makes the annual net cashflow present value zero. Therefore it can be concluded that this subroutine calls the cashflow subroutine with as many different rates of return (or coal value) as required for the iteration process.

5.2.4 Reports Generation

The Report Generation Process is formed by two programs which produce four outputs. The first of them (OUT) makes the Input Summary Report and the Costing Submodels Output. The other program (CFPR) prints the Main Results Report and the Annual Cash Flow Summary.

The Input Summary Report shows the user all the parameters defined during the input process. These reports are printed in both the terminal and the output file.

The Costing Submodels Report presents the results of each submodel in terms of quantity and costs. These reports are written for both the terminal and the output file.

The Main Results Report contains the main output variables from the financial analysis. When uncertainty analysis has been chosen, this report also presents the rate of return (or coal price) obtained from each iteration. For the uncertainty analysis, there are two rates of return (or coal price): one is calculated from the final financial analysis carried out on the mean costs obtained from the iterations, and the second is the mean rate of return (or coal value) estimated from the rates of return generated from each iteration. For this last case a standard deviation is also estimated. The Main Result Report is printed in both the terminal and the output file.

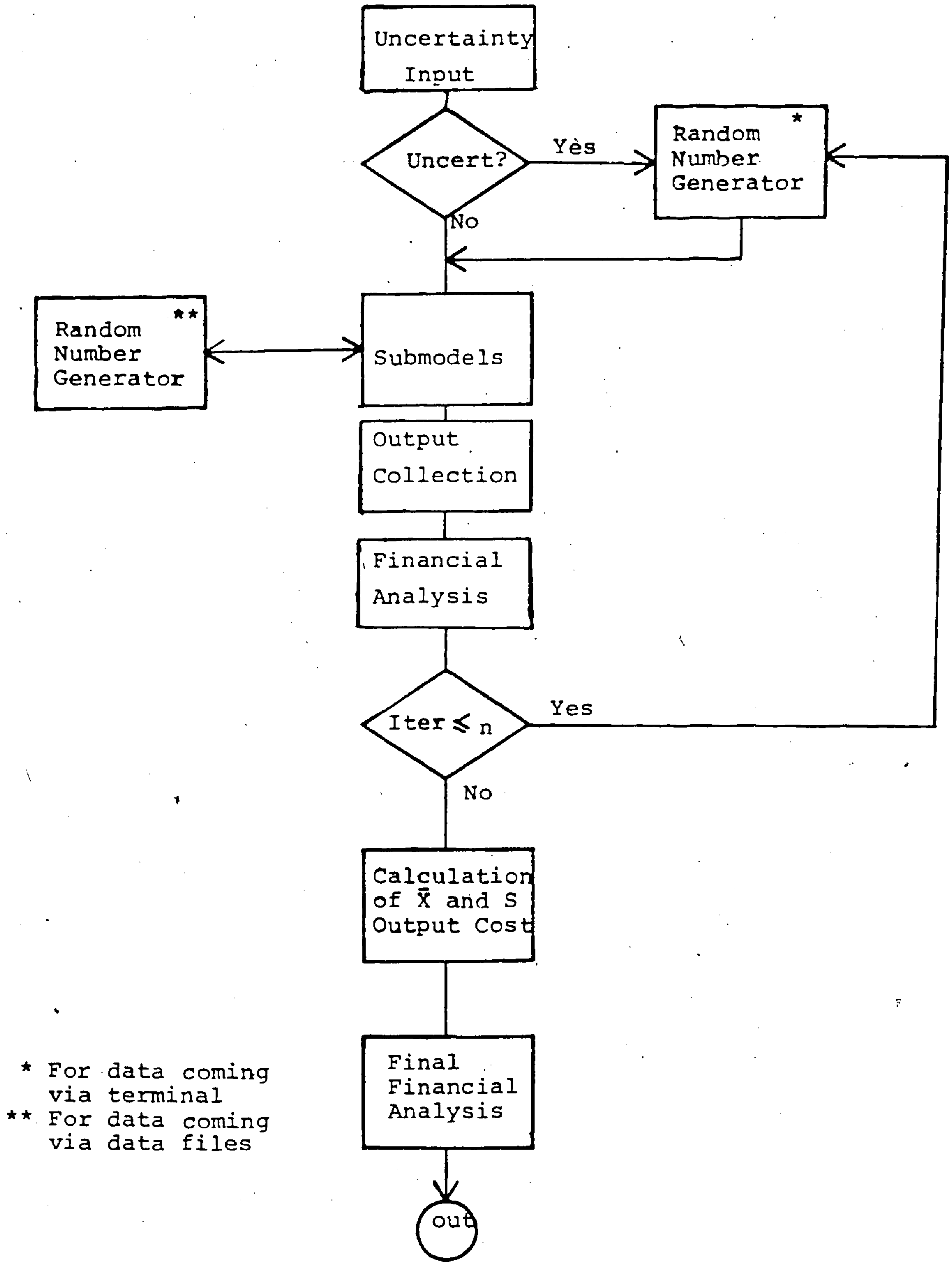
The Annual Cashflow Summary is the cashflow through out the mine's life. This report is only written in the output file. Appendix F presents examples of each of the output reports mentioned above.

5.2.5 Uncertainty Analysis

Figure 5.3 shows the details of the uncertainty analysis process. The randomizer routines use different distribution functions according to the type of data. The default functions assigned are: Normal, for physical parameters; Lognormal, for operational parameters and Triangular for financial parameters. The randomization can be carried out through three kinds of ranges : low, total or high. This means that if the low range is selected, only

Figure 5.3

UNCERTAINTY ANALYSIS FLOWCHART



random values less or equal than the mean will be considered. If high range is chosen, only random values greater than the mean will be considered. Total range considers any random value. These options allow the user to estimate the worst and best case for a given input.

Four main subroutines were developed for this purpose. All of them use the statistical functions Normal, Lognormal and Triangular provided by the computing library *SLAM (25). The routines developed were:

- Input Parameters for Uncertainty: This program provides the option to assign values to parameters defining the uncertainty process.
- Terminal Input Parameters Randomizer: This program assigns a random value to each input parameter which was defined in terms of mean and standard deviation.
- File Input Data Randomizer: This program assigns a random value to data coming from files which were expressed in terms of mean and standard deviation.
- Mean and Standard Deviation Cost Calculation: This program stores the output of each iteration and after the last one, it calculates the mean and standard deviation for each output cost.

As seen in Fig. 5.3, submodels and financial analysis processes are repeated the number of times defined by the user. After the iteration process, a mean and standard deviation for each output cost is calculated and, based on these mean values, the financial analysis is executed once more to obtain the mean rate of return (or mean coal price) and cashflow values produced by the uncertainty analysis. The output for this process is presented in the submodel results in terms of mean and standard deviation for each cost. The main results summary contains the mean rate of return (or coal value) for each iteration as well the corresponding standard deviation.

5.3 Statistical Analysis

When the uncertainty option is chosen, the system produces a number of rate of return (or coal price) outputs. After the last iteration, a mean and a standard deviation is calculated based on this sample. In order to better understand the results and to confirm their reliability , a statistical analysis of the output was made.

In order to minimize the error caused by the randomization, a very important factor as the definition of the sample size should be considered. In fact, seed numbers are used in generating random numbers through the distribution functions mentioned in the prior section. Different random numbers are generated depending on the values of these seed numbers and, in consequence, runs having the same input will produce different output if different seed numbers have been used. Uncertainties associated with these errors can be reduced by increasing the amount of data, this is confirmed by the Law of Large Numbers. This Law states that the probability that the difference between $\bar{X}$ (mean) and E[X] (expected value) approaches zero if the sample size approaches infinity (25). On the other hand, the Central Limit Theorem, states that the distribution of the sum of n independent samples of X approaches the normal distribution as n approaches infinity (25). It is difficult to say what sample size is sufficient for assuming the compliment of both theorems, however, relatively small sample size, like 15 to 20 are often sufficient (25). In order to confirm this suggested sample size, a test was made. In this test two series of runs, each with different initial seed numbers was carried out. The results of the test are presented as follows:

Iteration	Mean Coal Price (Seed #1)	Mean Coal Price (Seed #2)	% Relative Difference
6	51.32	49.14	+4.4
8	50.63	48.29	+3.5
10	51.30	48.67	+5.4
12	49.72	48.32	+2.9
14	50.82	49.45	+2.7
16	50.52	49.50	+2.0
18	51.72	51.21	+1.2
20	51.22	50.98	+0.4

The input data used for this test is shown in Appendix D

As can be observed above, the differences between the means become insignificant (approx. 1% or less) with 18 or more iterations. For this reason it was decided that a sample size of 20 iterations would be appropiate.

With the 20 iterations, 20 rates of return (or coal prices) were obtained. The sample frequency distribution was tested using normal probability paper. Figures 5.4, 5.5, 5.6, and 5.7 show examples of results' behavior for underground rate of return, surface rate of return, underground coal price, and surface coal price. As seen in these figures, the plots are relatively linear, thus a straight line could be drawn through these points indicating that the output's behavior is normal. To reinforce this conclusion, the Kolmogorov-Smirnov test(24) with a confidence of 95% (α = 5%) was applied. This test compares the cumulative probability of the normal function generated with the mean and standard deviation obtained from the experimental data against the experimental cumulative probability obtained from the sample. As shown in Figures 5.8, 5.9, 5.10 and 5.11 each example easily passed the test at the 95% confidence level. After this test and assuming that each point of the sample (rate of return or coal price) is an independent event, it is concluded that the simulation output has a normal or Gaussian behavior. It was found that tests carried out using combinations of distributions other than normal also produced a Gaussian distribution. This occurs as a consequence of the Central Limit Theorem because all the variables tend to be independent and additive.

Figure 5.4

PROBABILITY PLOT FOR UNDERGROUND RATE OF RETURN

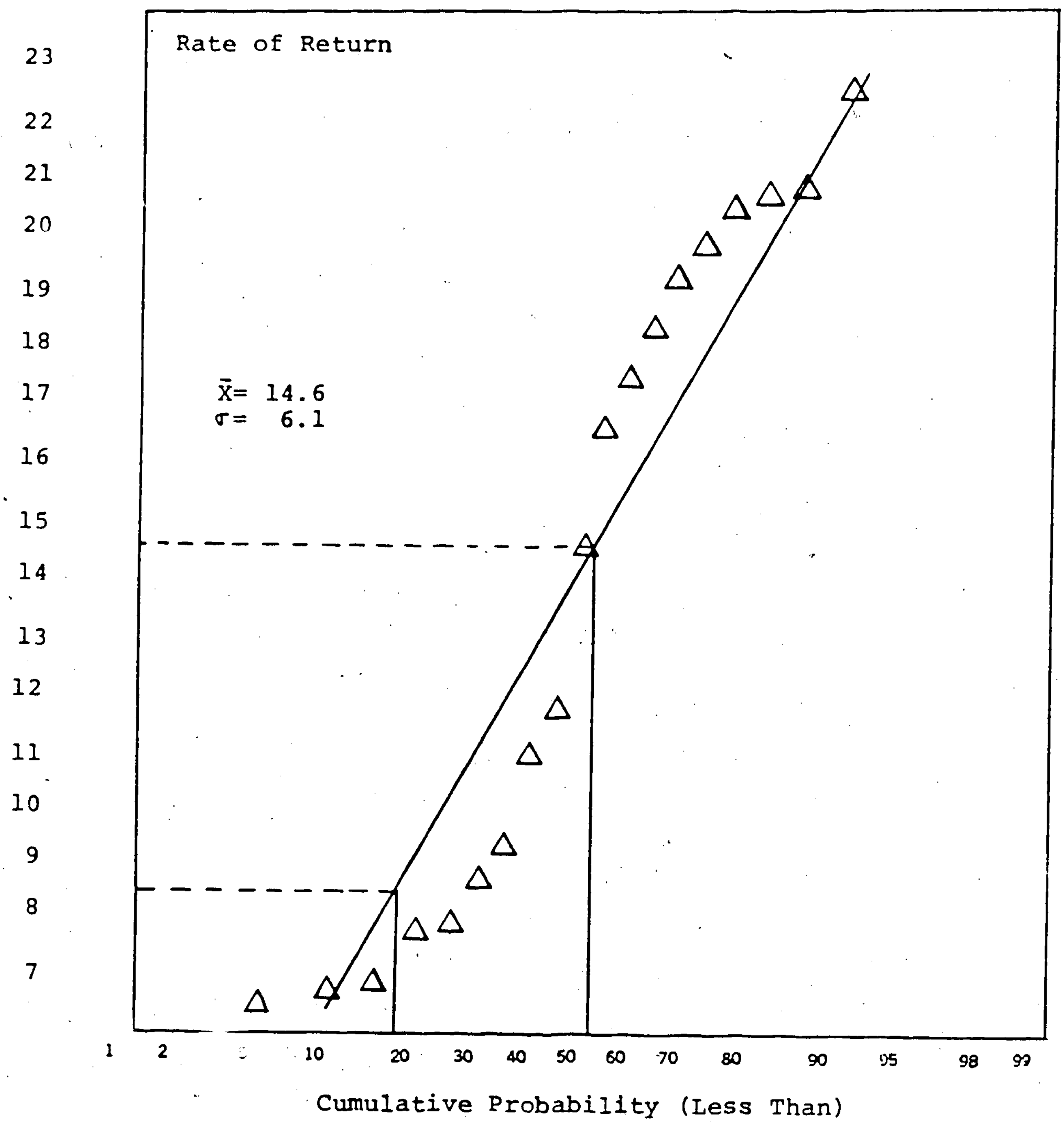


Figure 5.5

PROBABILITY PLOT FOR SURFACE RATE OF RETURN

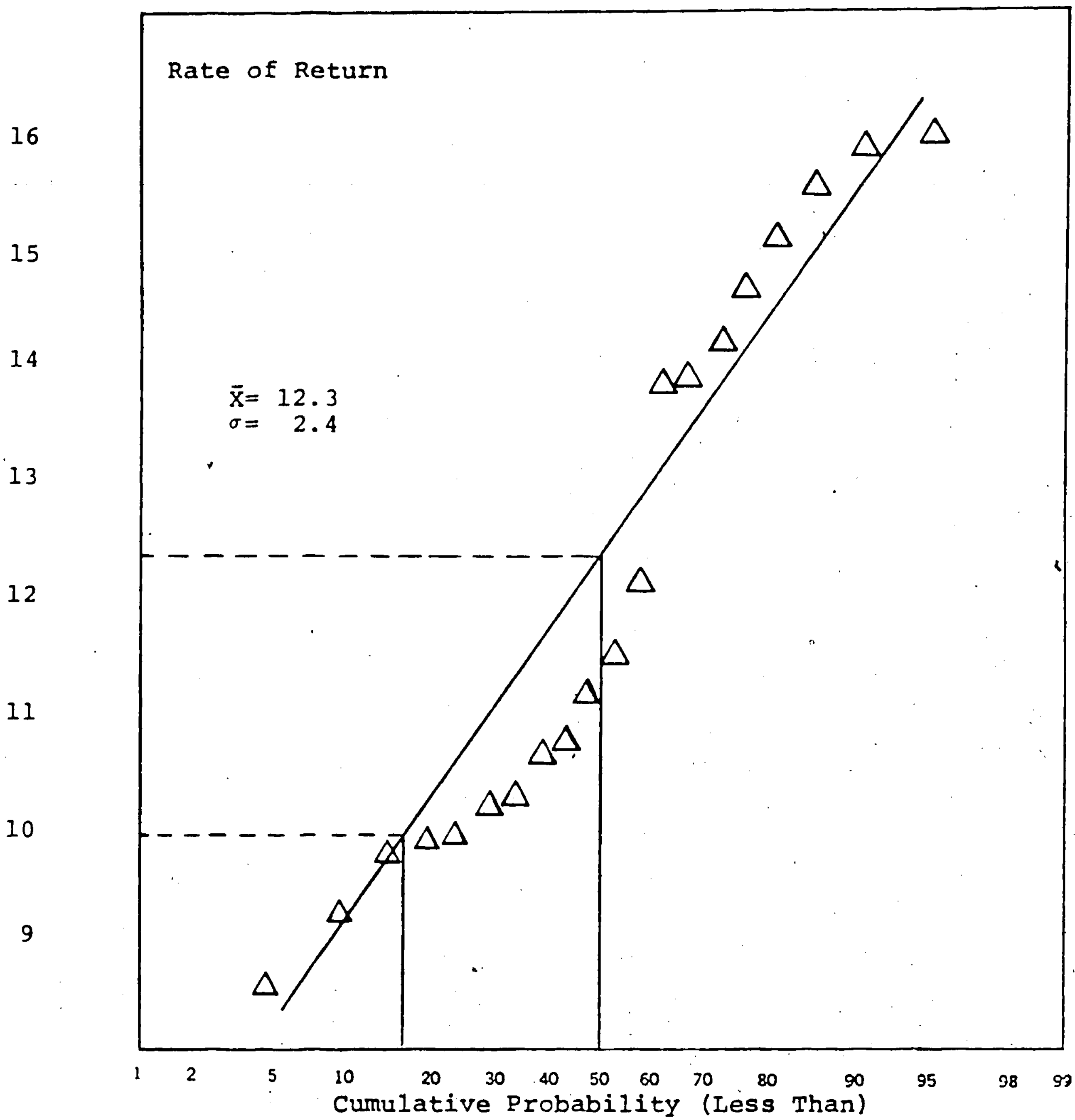


Figure 5.6

PROBABILITY PLOT FOR UNDERGROUND COAL VALUE

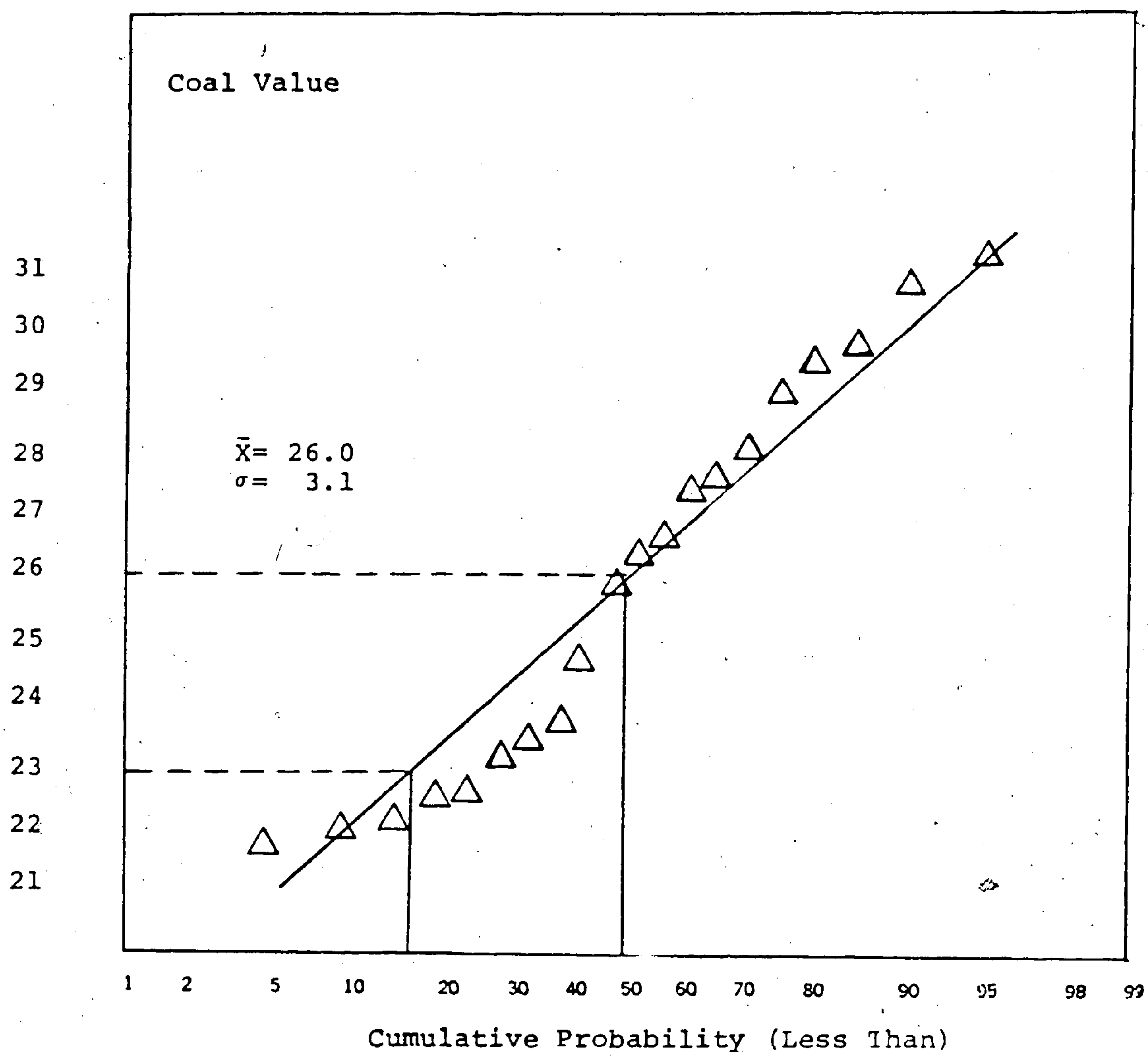
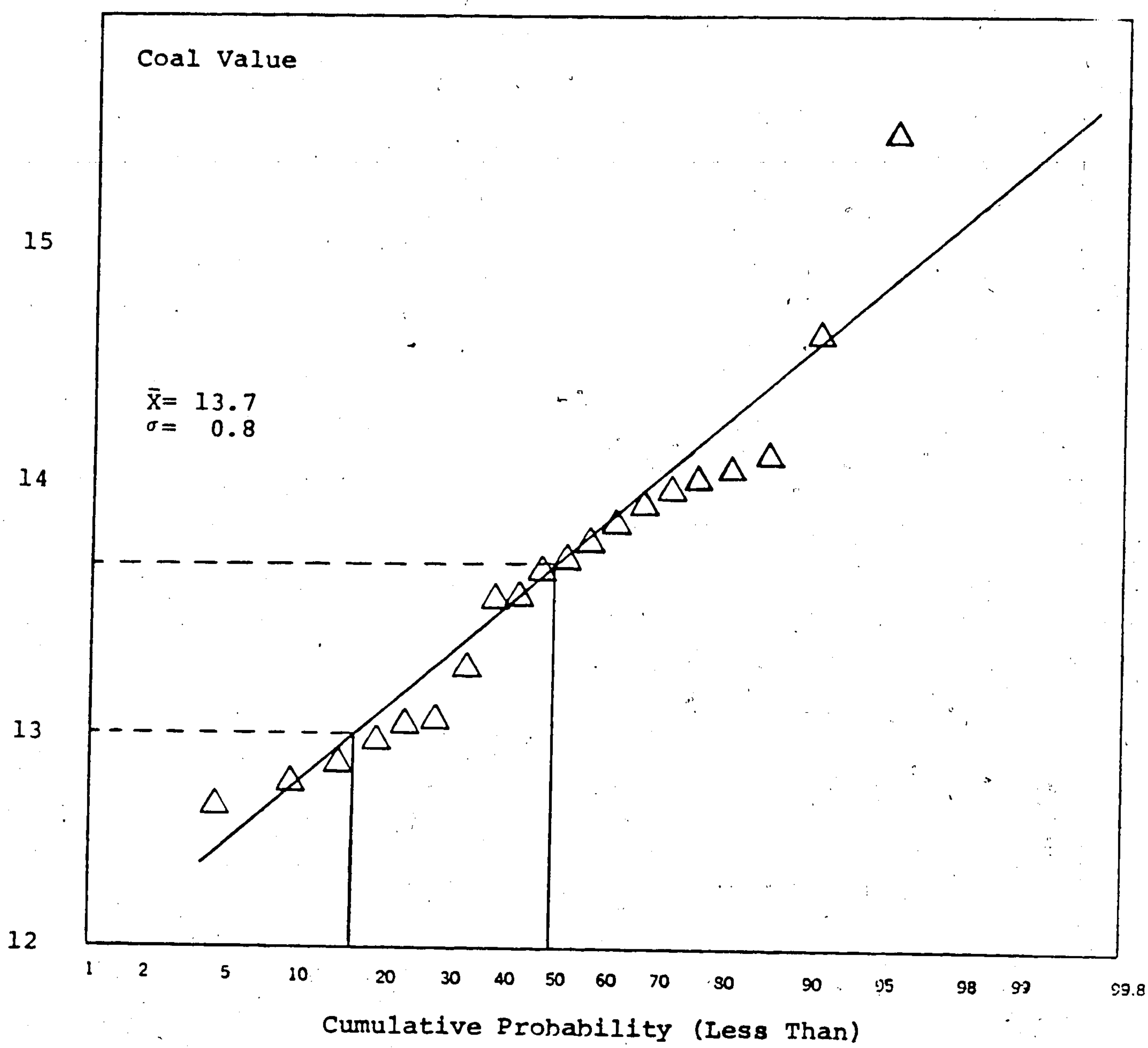


Figure 5.7

PROBABILITY PLOT FOR SURFACE COAL VALUE



When there is no prior knowledge of the population variance, an exact confidence interval for the mean can be determined if the underlying population has a normal distribution. If the sample size n is small and the population standard deviation is not known, the t-distribution can be used to determine the corresponding upper and lower limit of confidence. On this basis, the appropiate confidence limits are estimated as follows:

$(1-\alpha)$% Lower Confidence Limit= $\bar{X}-t_{\alpha,f}*S/\sqrt{n}$

$(1+\alpha)$% Upper Confidence Limit= $\bar{X}+t_{\alpha,f}*S/\sqrt{n}$

Where $(1-\alpha)$ is the confidence level, n the sample size (for this case the number of iterations defined), $\bar{X}$ the sample mean, S sample standard deviation, and $t_{\alpha,f}$ the corresponding value given by t-distribution for the confidence level α and f= n -1 degree of freedom. The values of t are obtained from the subroutine MDSTI of the computing library *IMSL. For this case a 95% of confidence was assumed, this means that α=5%. If the confidence limits are not satisfactory, it can be concluded that the sample is small and more iterations are required.

Figure 5.8

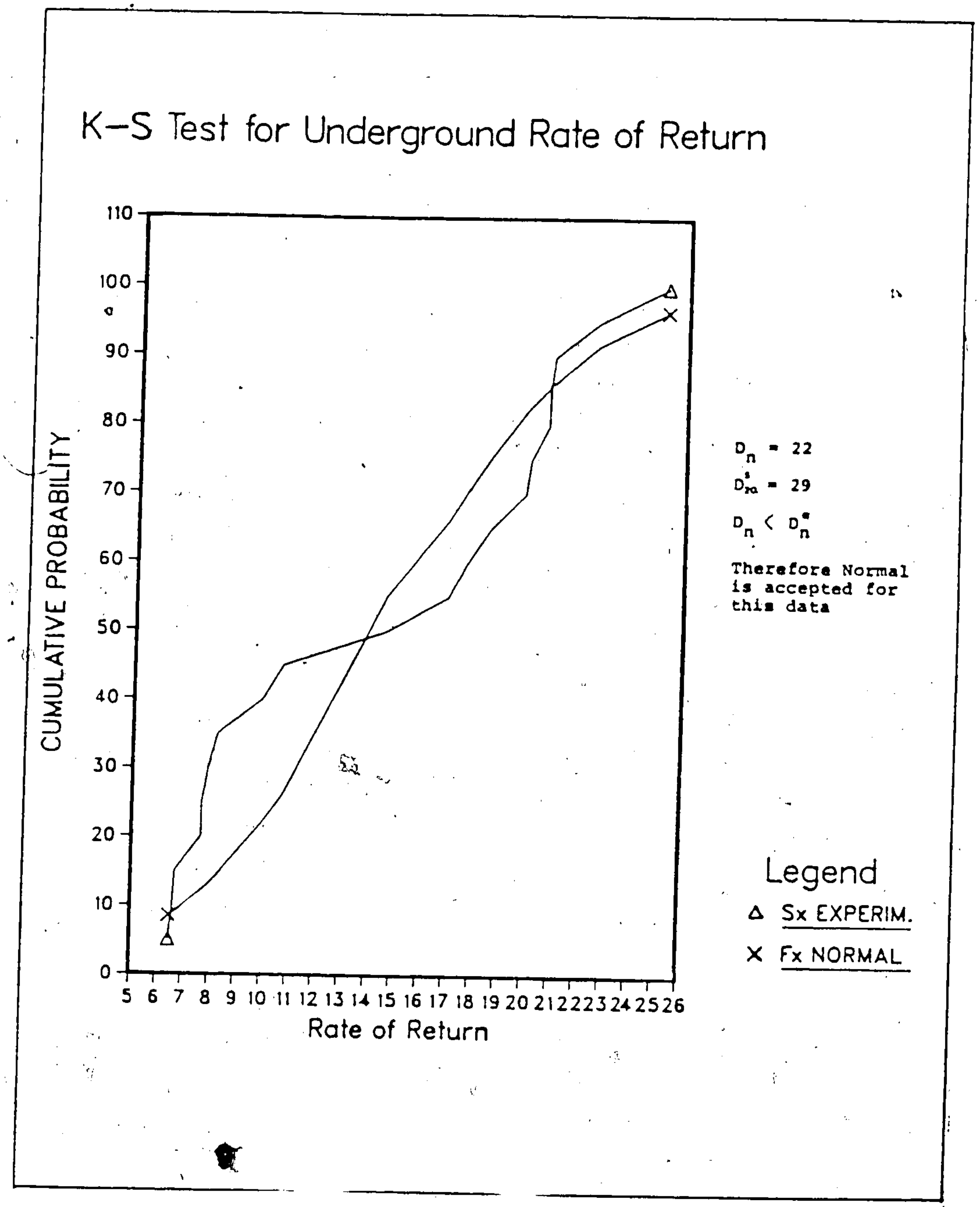

K–S Test for Underground Rate of Return
CUMULATIVE PROBABILITY
110
100
90
80
70
60
50
40
30
20
10
0
5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
Rate of Return
$D_n = 22$
$D_n^* = 29$
$D_n < D_n^*$
Therefore Normal is accepted for this data
Legend
Δ Sx EXPERIM.
X Fx NORMAL

Figure 5.9

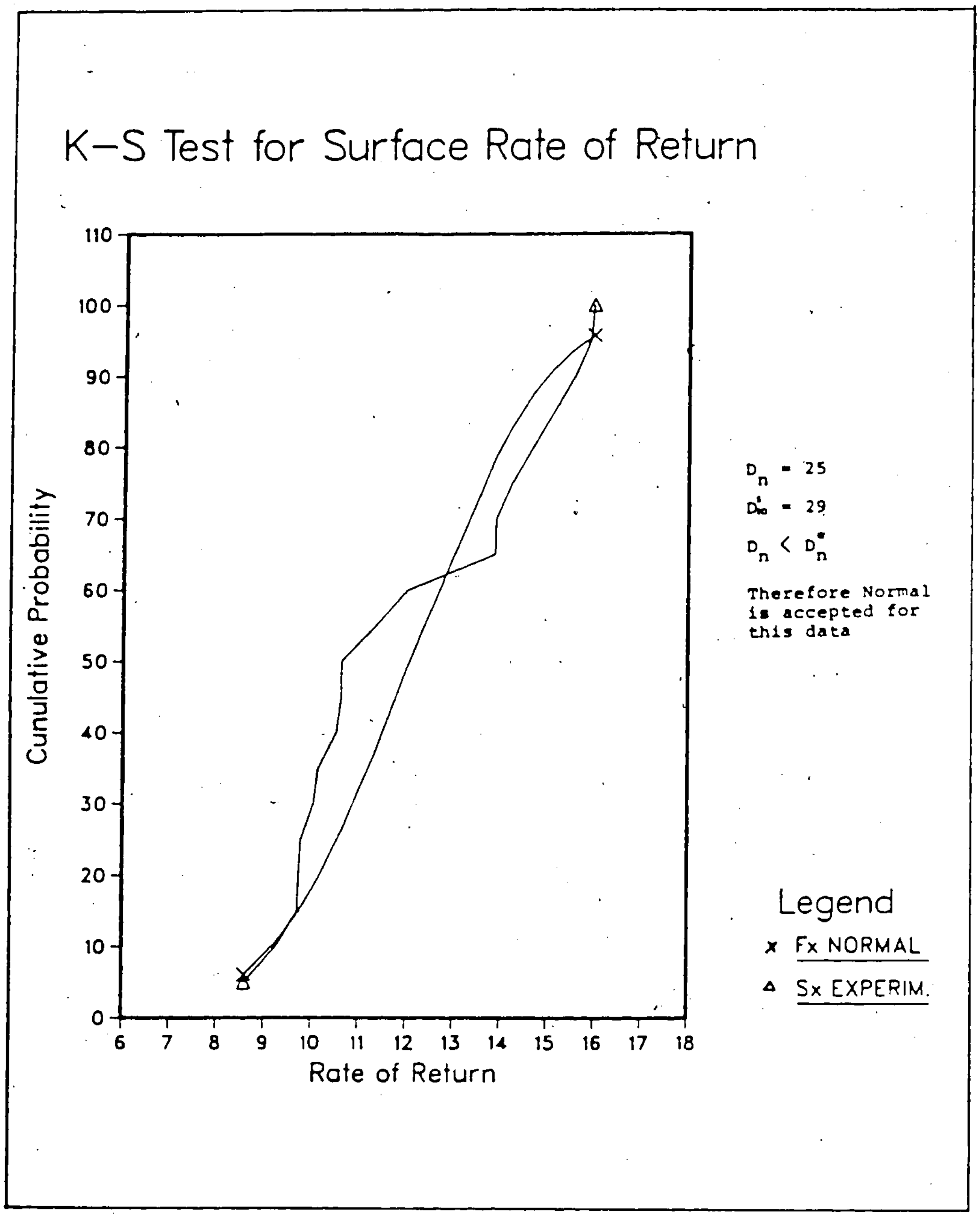

K–S Test for Surface Rate of Return
Cunulative Probability
Rate of Return
110
100
90
80
70
60
50
40
30
20
10
0
6 7 8 9 10 11 12 13 14 15 16 17 18
Dn = 25
D'∞ = 29
Dn < D*n
Therefore Normal is accepted for this data
Legend
Fx NORMAL
Sx EXPERIM.

Figure 5.10

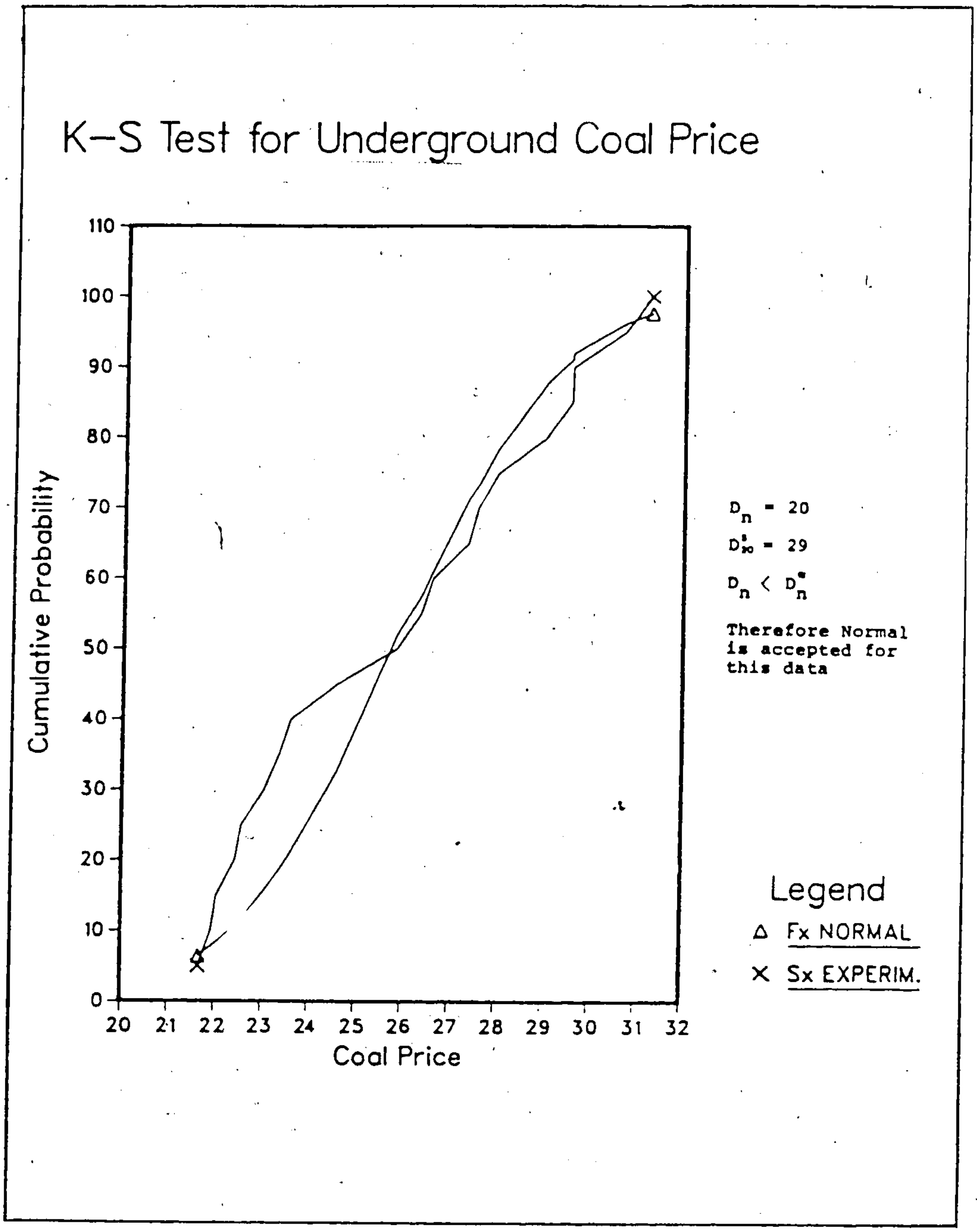
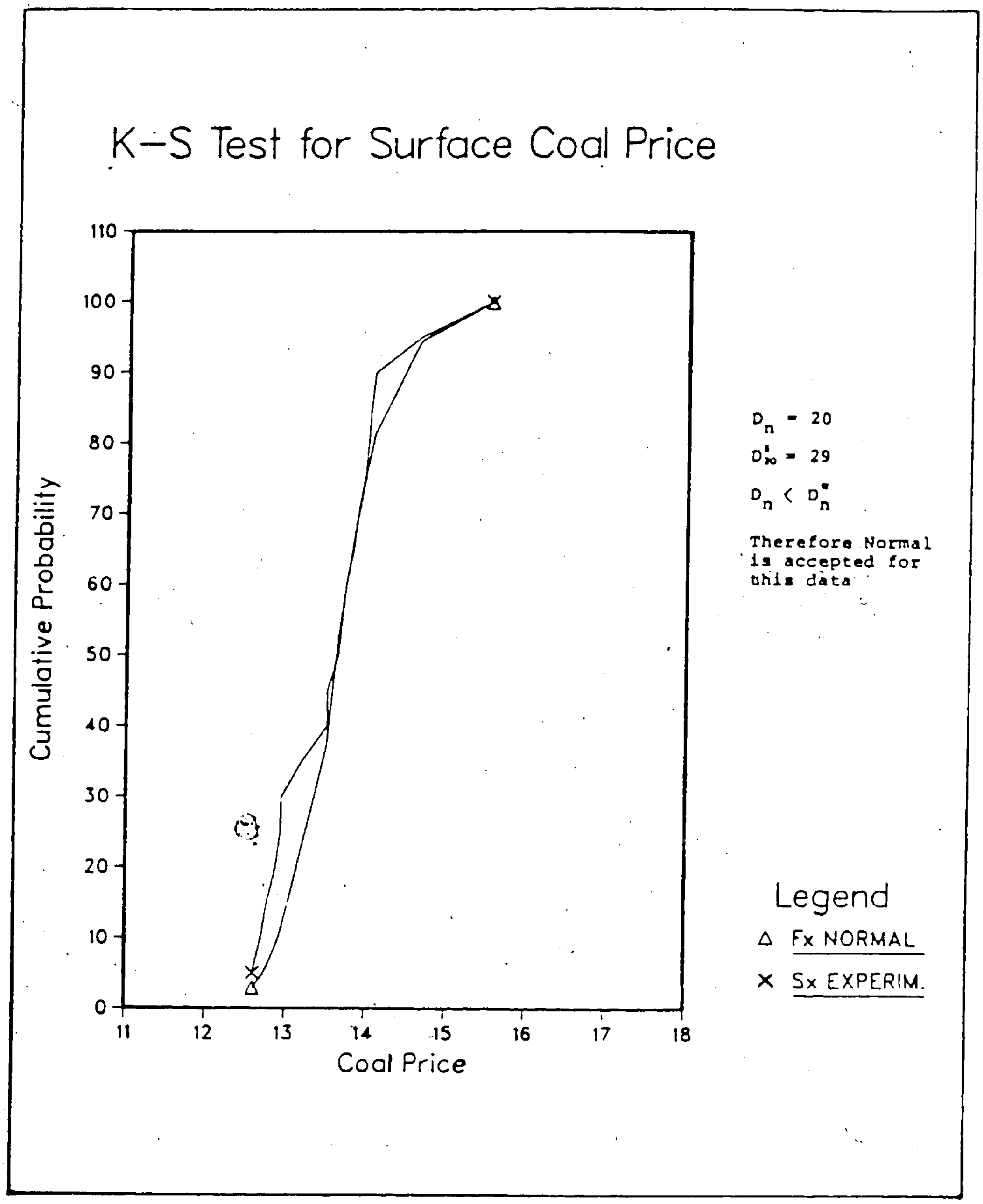

K–S Test for Underground Coal Price
Cumulative Probability
0
10
20
30
40
50
60
70
80
90
100
110
20 21 22 23 24 25 26 27 28 29 30 31 32
Coal Price
D_n = 20
D^*_{30} = 29
$D_n < D^*_n$
Therefore Normal is accepted for this data
Legend
Δ Fx NORMAL
X Sx EXPERIM.

Figure 5.11


K–S Test for Surface Coal Price
Cumulative Probability
0
10
20
30
40
50
60
70
80
90
100
110
Coal Price
11
12
13
14
15
16
17
18
D_n = 20
D^*_{30} = 29
$D_n < D^*_n$
Therefore Normal
is accepted for
this data
Legend
Δ Fx NORMAL
× Sx EXPERIM.

6. Computational System Validation

6.1 introduction

The model's software described in the previous chapter was tested with actual data in order to ensure its degree of accuracy. Two types of tests were carried out. The first one used the data with which the original model was tested. This test was used to debug the code. The second test was used to check the accuracy for Canadian projects. The Canadian data was provided by the Coal Mining Research Centre (CMRC) for the underground model and by Luscar Ltd for the surface model.

6.2 Test Using Original Model Input

The model was tested for surface and underground systems and the results were compared with those obtained from the EPRI. Due to the modifications and improvements made to the model and also because the unit costs were updated from 1980 to 1982, a perfect match of the results could not be expected. However, allowing for these expected differences in the results, it is possible to validate the thesis model software system against the EPRI model.

6.2.1 Underground Model Test

Both the input and output for this test are presented in Appendix D. The input coincides exactly with Test Case 2 carried out in the EPRI model (9). A comparison between the main costs generated by both models is presented below. To make this comparison consistent, the costs of the original model are divided by 0.8 (for Canadian dollar conversion) and multiplied by 1.12 (1980-1982 update index).

	Original Model($000)	Thesis Model($000)	Deviation(%)
Manpower	7475	7793	+ 3.2
Prod. Equipment	20095	18466	- 5.4
Site Preparation and Construction	60867	55909	- 8.1
Supplies, Mat.	8840	8869	+ 0.3

The coal price generated by the original model was $50.4 per tonne with a standard deviation of $4.04. The coal price obtained by the thesis model was $51.2 per tonne with a standard deviation of $2.7. The difference between the results from the thesis model and those from the original model stem from the modifications and inprovments made to the thesis model.

6.2.2 Surface Model Test

Both the input and the output for this test are presented in Appendix E. The input was taken from Test Case 3 of the original model (9). A comparison between the main costs generated by both models is presented below. Again, the costs of the original model were divided by 0.8 (Canadian dollar conversion) and multiplied by 1.12

(1980-1982 updated index).

	Original Model($000)	Thesis Model($000)	Deviation(%)
Prod. Equip.	21107	20127	-4.6
Support Equip.	6442	6101	-5.5
Supplies, Mat.	7529	8033	+6.6
Manpower	4990	5651	+11.6

The rate of return generated in the original model was 29.7 percent while the rate of return generated in the thesis model was 31.6 percent, which represents a difference of 0.9 ROR units. The rates of return do not match exactly because of the reasons outlined in the introduction to this section.

6.3 Test Using Canadian Input Data

This test represents the most important validation since the purpose of this project was to create a model applicable to the western Canada's coal industry. However, because of the difficulties in obtaining Canadian coal mining cost information, the output validation could not be expected to be as precise as it was in the p ior test. The input for the underground model was taken from the Atlas Mine Project (west Alberta) carried out in 1978 (44). The input for the surface model was taken from an unnamed strip mine under study in central Alberta (45).

6.3.1 Underground Model Test

Although the information provided to make the test was complete, it was not very appropiate for carrying out a wide test due to the fact that the given project takes place in an existing mine rather than in a new one as assumed in the model and therefore several costs were assumed to be zero. Another problem was that the production required was very low (210 000 t per year) and no preparation plant was required. The project occurred in 1978, therefore the data base had to scaled for inflation which tends to introduce errors. In spite of these problems, it was felt that the data would be adequate to make an order of magnitude check of the model. The input parameters and the output generated by the model with the uncertainty analysis is presented in Appendix F. Through the examination of the results of this test, the following conclusions can be made:

- Production Equipment: The number of continuous miners, roof bolters, shuttle cars, section haulage belts and ratio feeders, are the same in the model as in the real project. The number of cutting machines was also the same but in the project they were not purchased because they were already in the old mine. The primary hauling equipment was totally different because the model assumes scoop trams for the continuous method while the project assigns conveyor chains for this purpose.
- Manpower Requirements: The project assigns 53 hourly

and 10 salaried workers, whereas the model estimates 40 hourly paid workers and 11 monthly paid workers.

. Annual Operating Cost: The project arrives at $2 750 000 per month for this item, while the model estimates it as $2 540 000 per month.

Even though not many items can be compared because of the problems already mentioned, the above comparison is good enough to affirm that the underground model performs reasonably well when tested with actual western Canadian coal data within Class I estimates.

In addition to the run which was carried out, listed in Appendix F, other options were executed: conventional rather than continuous method, a flat 3.5 percent royalty rather than the province of Alberta formula and declining balance depreciation rather than fast. The corresponding summary output for each option is shown in Tables 6.1, 6.2, 6.3 and 6.4.

6.3.2 Surface Model Test

Apart from the omission of preparation plant data, the data used for the surface model was complete and appropriate. The input parameters and the output generated by the model using uncertainty analysis is presented in Appendix G. In studying the results obtained with this test, the following observations can be made:

. Production Equipment: The number of draglines, overburden drills, coal drills and dozers assigned

Table 6.1

UNDERGROUND SYSTEM - DEFAULT VALUE INPUT

SUMMARY OUTPUT

CONSTANT DOLLAR-POINT VALUE OPTION

Coal Value/Tonne	25.00
Project Start Year	1982
Full Production Years	1986-1999
Rate of Return	17.17
Capitalization	
-Debt (%)	20
-Equity	80
Debt Servicing P[illegible]ge	10
Payback Period ([illegible]	12

Table 6.2

UNDERGROUND SYSTEM - CONVENTIONAL METHOD

SUMMARY OUTPUT

CONSTANT DOLLAR-POINT VALUE OPTION

Coal Value/Tonne	25.00
Project Start Year	1982
Full Production Years	1986-1999
Rate of Return	19.21
Capitalization	
-Debt (%)	20
-Equity	80
Debt Servicing Percentage	10
Payback Period (yrs)	12

Table 6.3

UNDERGROUND SYSTEM - ROYALTY RATE 3.5%

SUMMARY OUTPUT

CONSTANT DOLLAR-POINT VALUE OPTION

Coal Value/Tonne	25.00
Project Start Year	1982
Full Production Years	1986-1999
Rate of Return	18.64
Capitalization	
-Debt (%)	20
-Equity	80
Debt Servicing Percentage	10
Payback Period (yrs)	12

Table 6.4

UNDERGROUND SYSTEM - DECLINING BAL. DEPREC.

SUMMARY OUTPUT

CONSTANT DOLLAR-POINT VALUE OPTION

Coal Value/Tonne	25.00
Project Start Year	1982
Full Production Years	1986-1999
Rate of Return	24.82
Capitalization	
-Debt (%)	20
-Equity	80
Debt Servicing Percentage	10
Payback Period (yrs)	12

by the project and the model was identical. The project considered 3 trucks while the model assigned 2. The project used 6 topsoil scrapers while the model assigned 13. The project also used an additional coal loader as a backup for the shovel.

- Manpower Requirements: The project considers a few more hourly people and less salaried personnel, but the total manpower is very similar.
- Both the supporting capital, and supplies and material costs fall in the same range for both the project and the model.
- The operating cost also fall in the same range for both the project and the model.
- The total costs and the rate of return obtained from the model was considered acceptable in comparison with the project.

The poor agreement between the number of scrapers assigned by the project and the model is because the model procedure for defining the scrapers required is based on 1830m haul and 16Km/h speed, this results in a mean travel time of 411 seconds when loaded. However the time considered for the project was 900 seconds which probably is out of range. The number of scrapers assigned if 411 seconds travel time time is used is 7, which is totally acceptable when working with Class I estimates. The other results were close enough to be confident that the surface model will make reasonable predictions when using western Canadian data.

In addition to the run presented in Appendix G, other options were executed: open pit rather than area mining, a flat 3.5 percent royalty rather than the province of Alberta formula, and declining balance depreciation rather than fast. The corresponding summary output for each of these options are shown in Tables 6.5, 6.6, 6.7 and 6.8.

6.3.3 Preparation Plant Cost Validation

Because none of the previous validations included a coal cleaning process, a separate validation was necessary for the preparation plant cost estimating procedure.

The test for the metallurgical coal equation, is presented below. This test was carried out with data provided by S.G. Butcher (42).

- Raw coal: 5.83 million tonnes/year
- Clean coal: 3.5 million tonnes/year
- Fines: 20%
- Model capital cost: $88.45 millions.
- Study capital cost: $84.83 millions
- deviation: +4.1%

For thermal coal (breaking-only), an input of 1.5 million tonnes was considered. According to the model, the corresponding preparation plant costs $8.1 million. Unfortunately, in this case, no existing data was obtained. However, according to the opinion of specialists of CMRC (the authors of (42)), that value appeared reasonable.

Table 6.5

SURFACE MODEL - DEFAULT VALUE INPUT

SUMMARY OUTPUT

CONSTANT DOLLAR-POINT VALUE OPTION

Coal Value/Tonne	14.00
Project Start Year	1982
Full Production Years	1986-2011
Rate of Return	19.51
Capitalization	
-Debt (%)	30
-Equity	70
Debt Servicing Percentage	10
Payback Period (yrs)	8

Table 6.6

SURFACE MODEL - OPEN PIT METHOD

SUMMARY OUTPUT

CONSTANT DOLLAR-POINT VALUE OPTION

Coal Value/Tonne	14.00
Project Start Year	1982
Full Production Years	1986-2011
Rate of Return	3.66
Capitalization	
-Debt (%)	30
-Equity	70
Debt Servicing Percentage	10
Payback Period (yrs)	16

Table 6.7

SURFACE SYSTEM - ROYALTY 3.5%

SUMMARY OUTPUT

CONSTANT DOLLAR-POINT VALUE OPTION

Coal Value/Tonne	14.00
Project Start Year	1982
Full Production Years	1986-2011
Rate of Return	21.62
Capitalization	
-Debt (%)	30
-Equity	70
Debt Servicing Percentage	10
Payback Period (yrs)	8

Table 6.8

SURFACE SYSTEM - DECLINING BAL. DEPREC.

SUMMARY OUTPU_

CONSTANT DOLLAR-POINT VALUE OPTION

Coal Value/Tonne	14.00
Project Start Year	1982
Full Production Years	1986-2011
Rate of Return	18.73
Capitalization	
-Debt (%)	30
-Equity	70
Debt Servicing Percentage	10
Payback Period (yrs)	8

7. Conclusion and Recommendations

The conclusion of this thesis should compliment the main purpose described in Chapter 1. In the Introduction it was stated that the main objective of this thesis was to provide a coal mining [illegible]nomic model which w[illegible]e applicable to western Canadian conditions. To achieve this objective, the following steps were defined: find the most appropiate available model, adapt and improve such a model, develop the interactive software to manipulate the given model and validate the system.

The model selected was designed under U.S. conditions. For this reason many of its features were incompatible with western Canadian coal mining. It was therefore necessary to make many adaptations to the original model. The modifications made to the original model are summarized below:

- Conversion of all units and factors from the Imperial system to the metric system.
- Replacement of Union Welfare Fund cost for the Fringe Benefits used in Canada.
- Replacement of the American salaries and wages rate for Canadian rates.
- Modification of the "parameters which override calculated values" input process. The new model makes an estimation of those parameters before any change can be done by the user.
- Redefinition of the type of coal preparation in

terms of thermal mine-mouth power plant, thermal export, and metallurgical processing. For the first type, the model uses the original equation for "breaking-only" preparation. For thermal export and metallurgical coals, the MMPR(4) equation for preparation plants was used in the model.

- Replacement of the so called open pit used in the original model by the open pit method used in the Canadian foothill and mountain regions (similar to hard rock mining).
- Redesigning of the cashflow table according to Canadian taxation procedures: This included modification of the depreciation methods and elimination of the amortization, redefinition of the income tax in provincial and federal taxes, redefinition of the investment tax credit, etc.
- Change of the rate of return and coal price calculating procedure (The present value equation is considered non-linear and is solved by iterative linear approximations).

Apart from mentioned adaptations, some additional features were incorporated to increase the efficiency and reliability. These are summarized below:

- The software was designed in an interactive and conversational mode which provides a user friendly system.
- The procedure used in the Province of Alberta for

calculating the royalty payments was included in the model.

- In the uncertainty analysis, a choice among four different distributions functions is possible (normal, uniform, lognormal and triangular) instead of only normal as in the original model.
- A novel procedure for estimating the best and worst case for a project was also included.
- A more detailed output was provided giving number and types of equipment required.

The new model obtained after the above modifications and improvments was tested against the data with which the original model was tested, and also with western Canadian coal mining data. After the validation, it can be concluded that the main purpose of this study has been achieved. This model is able to perform what was defined in Chapter 3 as Class I Estimates (order-of-magnitude) with an accuracy of +50% to -30%, under western Canadian coal mining conditions.

Even though the study that was made achieved the defined goal, more should be done to further improve the model and the computing system to make them even more useful. To carry out these improvments some recommendations are listed below.

1. The Data Base: The model developed in the thesis used the data base (unit costs) from the original model which was taken from U.S. mines. The model could be more precise if this data base were obtained from western

Canadian mines and suppliers.

2. Input: A more flexible input could be useful, especially for the item "parameters which override calculated values". After the model has estimated all requirements and costs for the project, the user should be able to adjust all the parameters that have been calculated, to his site conditions.
3. Output: A more detailed output could be given presenting unit costs, dollars per tonne and further itemized break downs.
4. Reports: The model should be able to print two more reports which could be useful for the user. They are "Total Capital Analysis" and "Operation Cost" reports. These should be broken down to the main items of which they are composed.
5. Testing: In order to fully test the model's reliability, it would be worthwhile to carry out an ample test of it with all its options and using existing Canadian data as input.
6. The transportation costs should be incorporated into the model (now the model gives the minegate price of the coal). This cost item represents at times up to 40 percent of the total cost of the delivery of coal to market. The transportation cost is particularly important for coal sold offshore because this coal is normally priced FOB harbor rather than the mine.
7. Some other items like access roads, railroads, townsite

assistance, etc. could also be incorporated to the model.

8. The coal preparation cost estimating procedure could be changed using an engineering process approach rather than empirical equations. The same applies to some of the other items that use mathematical relations, i.e. obtained from the experience to define some required items and its costs.

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CIM: Canadian Institute of Mining and Metallurgy

NTIS: National Technical Information Service

AIME: American Institute of Mining Engineering

EI: Engineering Index

APPENDIX A

ROYALTY FORMULA FOR COAL PRODUCED IN ALBERTA CROWN LEASES

Appendix A: Royalty Formula for Coal Produced in Alberta Crown Leases

The royalty formula for coal produced in Alberta was developed in 1976 (20), but its application was defined later through several regulations published by The Department of Energy and Natural Resources (21 and 22).

The rate of royalty for a month for all agreements granting coal rights shall be the greater of:

- 5% or
- The rate calculated in accordance with the following equation:

  $$X = K(1 - C/R)$$

  Where

  X is the rate of royalty payable expressed as a percentage of annual sales revenue (at minegate)

  K is the project factor for a coal project as determined in accordance with the following equation:

  $$K = 50/[1+(C/R)*(.30*I/C-1)]$$

  Where

  I is an amortization of all capital costs (depreciable and not depreciable) in a straight line fashion

  C represents the annual operating costs

  R is the annual sales revenue

Where C exceeds R, C/R is deemed to be 1. Figure A.1 presents a graphical behavior of the equation above explained.

There are some exceptions for the Alberta formula which are explained below:

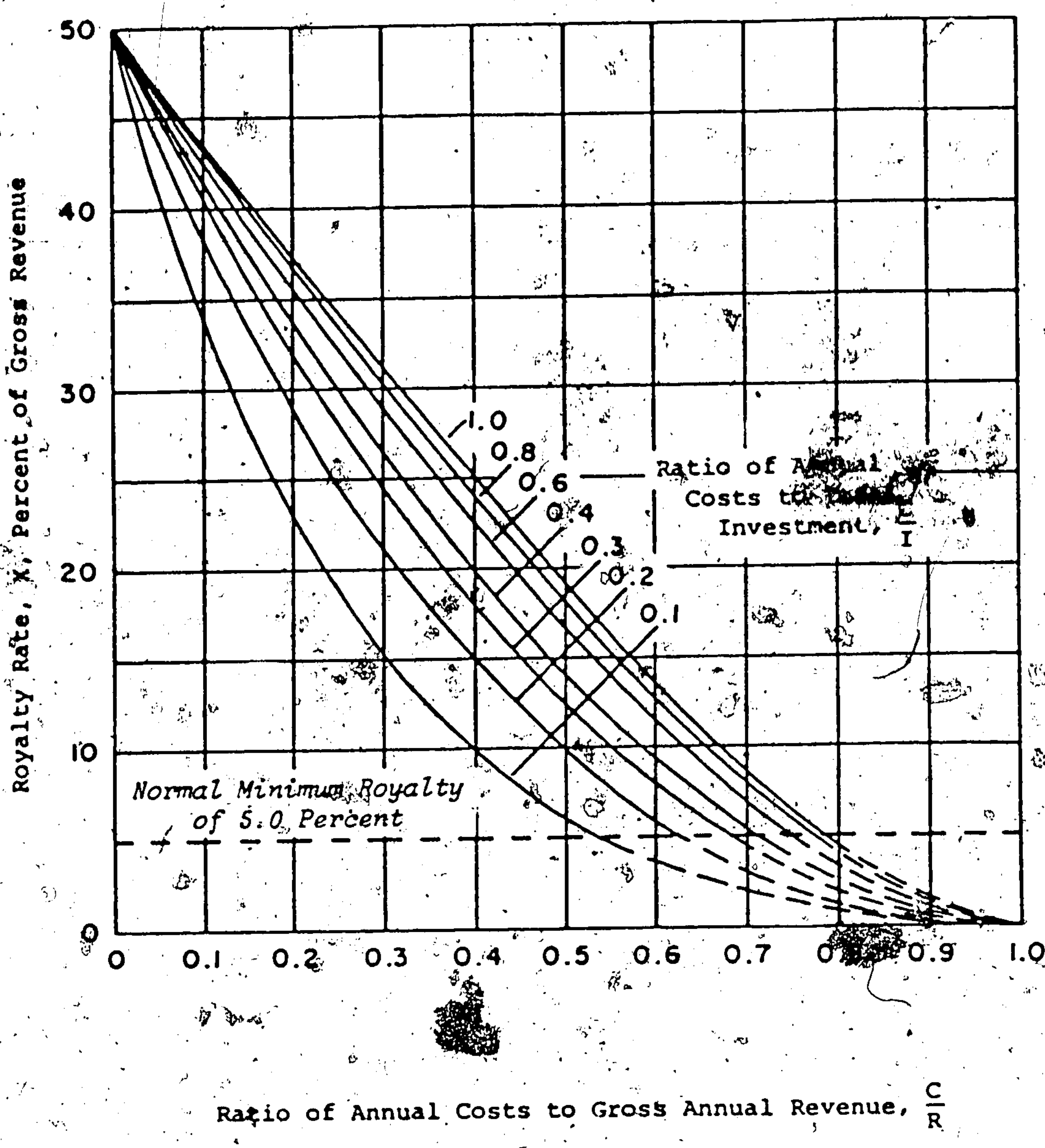
* If the project produces or is capable of producing clean coal at a rate of more than 100000 tonnes per year, the royalty payable on the coal obtained from the coal project is:
  - During the first year after the commencement date, 15% of the percentage computed.
  - During the second year after the commencement dat 30% of the percentage computed.
  - During the third year after the commencement date, 45% of the percentage computed.
  - During the fourth year after the commencement date, 60% of the percentage computed.
  - During the fifth year after the commencement date, 75% of the percentage computed.
  - During the sixth year after the commencement date and for the remaining mine life, the total percentage computed.
* If the project does not produce and it is not capable of producing more than 100000 tonnes of clean coal, the percentages over the royalty rate computed are the following:
  - first year, 0.75%.

- second year, 1.5%.
- third year, 2.25%.
- fourth year, 3%.
- fifth year, 3.75%.
- remaining mine life, 5%.

* The royalty payable on coal obtained from the coal project prior to its commencement date shall be a flat 0.75% of the annual sales revenue.

Figure A.1

ROYALTY RATES APPLICABLE TO COAL PRODUCCTION FROM ALBERTA



Source: (20)

APPENDIX B

VARIABLE AND FILE NAMES

EPRI.MAIN	:	Main system monitor pogram
EPRI.SURF.S	:	Main surface subsystem monitor progran
EPRI.UNDER.S	:	Main underground subsystem monitor progran
UNDER.O	:	Underground system objects file
SURF.O	:	Surface system objects file
EU.OCV.S	:	Override underground calculated values
EU.OPIN.S	:	Underground optional input
EU.REIN.S	:	Underground required input
EU.SUB1.S	:	Underground Submodel 1
EU.SUB2.S	:	Underground Submodel 2
EU.SUB3.S	:	Underground Submodel 3
EU.SUB4.S	:	Underground Submodel 4
EU.SUB5.S	:	Underground Submodel 5
EU.CAAN.S	:	Underground Capital Analysis
EU.CAFL.S	:	Underground cashflow
EU.RRCV.S	:	Underground rate of return or coal value calculator.
EU.OUT.S	:	Input data and submodels output printer
EU.CFPR.S	:	Main output summary and cashflow printer
EU.IUNC.S	:	Optional input for uncertainty option
EU.RAND.S	:	Terminal input randomizer
EU.STAT.S	:	Mean and SD output calculator
ES.SET.S	:	Surface default data initialyzer
ES.OCV.S	:	Override surface calculated values
ES.OPIN.S	:	Surface optional input
ES.REIN.S	:	Surface required input
ES.SUB1.S	:	Surface Submodel 1
ES.SUB2.S	:	Surface Submodel 2
ES.SUB3.S	:	Surface Submodel 3
ES.SUB4.S	:	Surface Submodel 4
ES.CAAN.S	:	Surface capital analysis
ES.CAFL.S	:	Surface cashflow
ES.RRCV.S	:	Surface rate of return or coal value calculator
ES.OUT.S	:	Input data and submodels output printer
ES.CFPR.S	:	Main output summary and cashflow printer
ES.RAND.S	:	Terminal input data randomizer
ES.IUNC.S	:	Optional input for uncertainty option
ES.STAT.S	:	Mean and SD output calculator
E.RANDOM.S	:	Cost data randomizer
E.MEAN.S	:	Integer mean calculator
E.ISTD.S	:	Integer SD calculator
E.RMEAN.S	:	Real mean calculator
E.STD.S	:	Real SD calculator

DATA FILES

EUCOST	: Underground unit costs file
EUCVCO	: Equation coefficients for underground continuous system
EUCNCO	: Equation coefficients for under. conventional system
ESSHTH	: Overburden shovel and front loader costs
ESDRCO	: Dragline costs
ESHDSS	: Truck, drill, coal shovel, dozer, scraper, preparation plant, wages, and salaries costs.
ITEM	: Cashflow items

VARIABLES

UNDERGROUND REQUIRED INPUT

URSMDX	: Mean seam depth	URSMDS	: SD seam depth
URSMTX	: Mean seam thickness	URSMTX	: SD seam thickness
URPROD	: Annual Production	URLIFE	: Production life
URCABO	: Capital borrowed	URDERA	: Debt servicing rate
URLOLE	: Length of loan payback	URDOEQ	: Dollar equivalence (Ca-US)
URPRST	: Project start year	URACOX	: Mean acquisition cost
URACOS	: SD acquisition cost	URCOVA	: Coal Value
URLAFA	: Labor upd/esc factor	URSMFA	: Supp.&Mat upd/esc factor
URPOFA	: Power upd/esc factor	URPEFA	: Prod. eq. upd/esc factor
URHGFA	: Haulage upd/esc factor	URAEFA	: Aux. eq. upd/esc factor
URCOFA	: Constr. upd/esc factor	URCVFA	: Coal value esc. factor
URRORE	: Rate of return	URBAYE	: Base year
URSEGR	: Seam gradient	URSYST	: Mining system
URENTR	: Entry type	URDOAN	: Dollar analysis type
URANTY	: Type of analysis	URCREQ	: Cost range for eq.
URCRCO	: Cost range for constr.	URROCO	: Roof conditions
URFLCO	: Floor conditions	URGALE	: Gas emision level

UNDERGROUND OPTIONAL INPUT

UORPEX	: Mean reject %	UORPES	: SD reject %
UOSHPD	: Shift per day	UODAPY	: Days per year
UOSERE	: Seam recovery %	UOOPEX	: Operating efficiency
UOOPES	: SD Operating eff.	UOFATX	: Mean available face time
UOFATS	: SD available face time	UOINCA	: Indirect Capital
UOLAOV	: Labor overhead	UOFRBE	: Fringe benefits
UOROPA	: Royalty payment	UOINTA	: Income tax
UODEME	: Depreciation method	UOCOPR	: Coal preparation
UOPRTR	: Preprod. treatment		

UCTPMS	: Tonnes/machine shift	UCPSPS	: Prod. sections/shift
UCHOLA	: Hourly labor req.	UCSAPE	: Salaried Personnel Req.
UCDETI	: Development time	UCCPDD	: Coal prod. during dvlpment
UCLIPE	: Prod. eq. life	UCLIHS	: Haulage system life
UCLIAE	: Aux. eq. life	UCALHC	: Hourly labor cost/yr
UCSACO	: Salaried pers. cost/yr	UCSMCT	: Supp.&mat. cost/tonne
UCPOCT	: Power cost/tonne	UCAOCO	: Annual operating cost
UCPSCO	: Initial prod.sect. cost	UCBPHC	: Initial haulage cost
UCAECO	: Initial aux. eq. cost	UCPPCC	: Preparation plant cost
UCEXCO	: Exploration cost	UCABCO	: Mine abandonment cost
UCWOCA	: Working capital	UCRCPY	: Raw coal production/yr
UCRCPS	: Raw coal prod./shift	UCCCPY	: Clean coal production/yr

SUBMODEL 1

UCRCPY	: Annual raw coal produc.	UCRCPS	: Raw coal prod/shift
UCCCPY	: Clean coal produc/yr (t)		

SUBMODEL 2

UCLRPS	: Ho[illegible] req/sh.p.s.	UCLCPS	: Labor cost/shift
UCFBCY	: Fr[illegible]efits/yr		
UCMACD	: Tota[illegible]npower cost	UCPPMD	: Productivity/manday
UCSACO	: Salaried cost/yr		

SUBMODEL 3

UCPRHC	: Produc. haulage syst.cost	UCOSCC	: Other Surface const.
UCBPVC	: Preprod. ventil. construc	UCPRVC	: Produc.ventil construc.
UCMECC	: Mine entry construction	UCEHCO	: Entry haul./hoist system

SUBMODEL 4

UCSMAC	: Supp&mat annual cost	UCPOAC	: Power annaul cost
UCCTPT	: Total supp&mat,power cost	UCTACO	: Supp&mat,power cost/yr

SUBMODEL 5 (Development Costs)

UCBPLA	: Labor	UCBPSM	: Suppl. and materials
UCBPPO	: Power	UCBPOV	: Payroll overhead
UCBPFB	: Fringe benefits	UCBPTC	: Total costs
UCDETS	: Develop. time(unit shifts)	UCCDTI	: Const+develop. time

SURFACE REQUIRED VARIABLES

SRSTHX: Mean seam thickness
SROTHX: Mean overbdn thickness
SRTTHX: Mean topsoil thickness
SRPROD: Annual production
SRLAFA: Labor upd/esc factor
SRSEFA: Support eq. up/es factor
SRCOFA: Construc. upd/esc factor
SRCOVA: Coal Value/tonne
SRLOLE: Loan payback lentgh
SRDERA: Debt servicing rate
SRACOS: SD acquisition cost
SRBAYE: Base year
SRSIMU: Single/mult. seam
SRDOAN: Dolar analysis type

SRSTHS: SD seam thickness
SROTHS: SD overbdn thickness
SRTTHS: SD topsoil thickness
SRLIFE: Mine life
SRPEFA: Prod. eq. upd/esc factor
SROPFA: Operating upd/esc factor
SRCVFA: Coal value upd/esc factor
SRRORE: Rate of return
SRCABO: Capital borrowed
SRACOX: Mean acquisition cost
SRPRST: Project start year
SRDOEQ: Dollar equivalence (CA-US)
SRSYST: Mining system
SRANTY: Type of anlysis

SURFACE OPTIONAL

SOREJE: Reject %
SORECS: SD recovery
SOEXRE: Exploration required
SOAWPL: Area excav. working pl.
SOAOES: SD area excav.oper. eff.
SOAFFS: SD area bucket fillfac.
SOACTX: Area excav. Cycle time
SOOMOH: Open excav. oper. hrs/mo
SOOCTS: SD open excav.cycle time
SOOPES: SD open exc. operat. eff
SOOBFS: SD open exc. bucket f.f.
SOOBSI: Open exc. bucket size
SOOTLX: Open trvl time loaded
SOOTEX: Open trvl time empty.
SOOVTX: Open turn,spot,dump time
SOCODE: Coal density

SORECX: Mean recovery
SODILU: Dilution
SODROV: Drilling ovbdn working places
SOAOEX: Mean area excav. operator eff.
SOAFFX: Mean area bucket fill factor
SOAMOH: Area operating hours/month
SOACTS: SD area excav.cycle time
SOOCTX: Mean open excav. cycle time
SOOOEX: Mean open excav. operator eff.
SOOBFX: Mean open exc. bucket fill fac.
SOOWPL: Open excac. working places
SOOLPA: # of loading passes
SOOTLS: SD open trvl time loaded
SOOTES: SD open trvl time empty
SOOTVS: SD open turn,spot,dump time
SOCDMH: Contour operating hrs/month

SOCDMH: operating hour/month
SOCDSS: SD swell factor
SOCDHS: SD haul distance
SOCDOX: Mean operator eff.
SOCDEX: Mean operating eff.
SOCDMX: Mean material factor
SOCDWX: Mean weather factor
SOCSMH: Operating hrs/month
SOCDSX: Swell factor
SOCDHX: Mean haul distance
SOCDBC: Blade capacity
SOCDOS: SD operator eff.
SOCDES: SD operating eff.
SOCDMS: SD material factor
SOCDWS: SD weather factor

CONTOUR SCRAPER

SOCSMH: Operating hrs/month
SOCSLS: SD load time in overbdn
SOCSVS: SD maneuver-spread time
SOCSSX: Mean swell factor
SOCSHX: Mean haul distance
SOCSOX: Mean operator eff.
SOCSEX: Mean operating eff.
SOCSMX: Mean material factor
SOCSWX: Mean weather factor
SOCWPL: coal drillig work. pl.
SOCSLX: Load time in overbdn
SOCSVX: Mean maneuver-spread time
SOCSMC: Capacity
SOCSSS: SD swell factor
SOCSHS: SD haul distance
SOCSOS: SD operator eff.
SOCSES: SD operating eff.
SOCSMS: SD material factor
SOCSWS: SD weather factor

COAL LOADING AND HAULING -

SOLOOH: Operating hrs/month
SOCLTS: SD cycle time
SOLOPX: Mean # of passes
SOTLTX: Trck trvl time loaded
SOTTEX: Trck trvl time empty
SOVATX: Mean turn,Spot,dump time
SOCLTX: Mean cycle time
SOBFFX: Bucket fil factor
SOLOPS: SD # of passes
SOTLTS: SD trck trvl time loaded
SOTTES: SD trck trvl time empty
SOVATS: SD turn,spot,dump time

RECLAMATION:

SPOIL HANDLING (Area Mine)

SORAWX: Mean width of pit
SORAAS: Angle of spoil
SORASX: Mean swell of overbdn
SORABC: Dozer blade capacity
SORAOS: SD operator eff.
SORAWS: SD width of pit
SORAOH: Operating hrs/month
SORASS: SD swell of overdbn
SORAOX: Mean operator eff.
SORAMF: Material factor

TOPSOIL HANDLING(Area,open pit)

SORTSC: Scraper capacity
SORLTS: SD loading time
SORTMS: SD Maneuver-spread time
SORTLS: SD trvl time loaded
SORTES: SD trvl time empty
SORTOX: Mean operator eff.
SORLTX: Mean loading time
SORTMX: Maneuver-spread time
SORTLX; Mean trvl time loaded
SORTEX: Mean trvl time empty
SORTOH: Operating hrs/month
SORTOS: SD operator eff.

SPOIL HANDLING(Open pit)

SOROWX: Mean width of windrow	SOROWS: SD width of windrow
SOROSA: Angle of spoil	SOROSX: Mean swell factor
SOROSS: SD swell factor	SOROBC: Blade capacity
SOROOX: Mean operator eff.	SOROOS: SD operator eff.
SOROMX: Mean material factor	SOROMS: SD material factor

FINANCIAL PARAMETERS

SOFRBE: Fringe benefits	SOLAOV: Labor overhead
SOROPA: Royalty payment	SOEXDE: Exploration dev. cost
SOINTA: Income tax	SODEME: Depreciation method
SOLIDR: Dragline life	SOLIDB: Drag. bucket life
SOLISH: Shovel life	SOLISB: Shovel bucket life
SOLIOT: Overbdn truck life	SOLIDS: Dozers & scrap. life
SOLDRI: Drills life	SOLICS: Coal shovel life
SOLIFE: Front end life	SOLICT: Coal truck life
SOLDSR: Reclam. dz-scrap. life	SOINCA: Indirect capital
SOSVDR: Dragline salvage value	SOSVSH: Shovel salvage value
SOSV10: 10 yrs life eq. sa. va.	SOSV05: 5 yrs life eq. sa. va.
SODCPM: Drilling cost/m	

SURFACE PARAMETERS WHICH OVERRIDE CALCULATED VALUES

SCARRE: Land area requirements	SCHOPE: Hourly personnel req.
SCSAPE: Salaried personnel req.	SCEDCO: Expl. dev. drilling cost
SCSMCO: Suppl.-mat. cost/yr	SCSUCA: Support capital
SCAOCO: Annual operating cost	SCPDCO: Preproduc. develop. cost
SCWOCA: Working Capital	SCPPCO: Preparation plant cost

SUBMODEL 1

SCACCO: Acquisition cost	SCNDRA: Number of draglines
SCDRBC: Dragline bucket cap.	SCDRCO: Dragline cost
SCNSHO: Number of overbdn shovels	SCSHBC: Shovel bucket capacity
SCSHCO: Overbdn shovel cost	SCNOHT: Number of haul trucks
SCOTCA: Truck capacity	SCOTCO: Trucks cost
SCNDOZ: Number of dozers	SCDBCA: Dozer Blade capacity
SCDOCO: Dozers cost	SCNSCR: Number of scrapers
SCSCAP: Scraper capacity	SCSCCO: Scrapers cost
SCNDRI: Number of overbdn drills	SCODSI: Drill size
SCODCO: Overbdn drills cost	SCNCDR: Number of coal drilss
SCCDCI: Coal drill size	SCCDCO: Coal drills cost
SCNCSH: Number of coal shovels	SCCSCA: Bucket capacity
SCCSCO: Coal shovels costs	SCNCTR: Number of coal trucks
SCCTCA: Coal truck capacity	CSCTCO: Coal trucks cost
SCNRDO: Number of dz for reclam.	SCRDCA: Reclamation dz capacity
SCRDCO: Reclamation dz cost	SCNRSC: Number of scrap. for recl.

SUBMODEL 2

SCCOCO: Construction cost

SCSECO: Support equipment cost

SUBMODEL 3

SCHLRE: Hourly labor required
SCHLFB: Fringe benefits per year
SCSACO: Salaried annual cost
SCMACO: Manpower annual cost

SCHLCO: Hourly labor annual cost
SCSARE: Salaried personnel req.
SCMARE: Manpower requirements
SCMAPR: Productivity/man day

SUBMODEL 4

SCPPOC: Prep. plant operat. cost

SCNLOC: Non labor operating cost

APPENDIX C

Data Files Content

PRODUCTION SIZING EQUATION FOR CONTINUOUS AND CONVENTIONAL UNDERGROUND SYSTEMS

TPMS= (A*H +B*H+C)*OEF*AFT/390

Where
A= a*10.76
B= b*3.28
C= c*3.28
H= Seam thickness(m)
OEF= Operator efficiency factor
AFT= Available face time per shift
a, b, c are defined in the following two tables
10.76 and 3.28 are meters-feet convertion factors

r: Roof conditions
f: Floor conditions
g: Gas emission
s: Seam grade

EQUATION COEFFICIENTS FOR CONTINUOUS METHOD

rfgs	a	b	c
1110	1325	81800	82275
1116	2375	71300	104325
1210	1325	81800	82275
1216	4100	55100	133200
1310	3275	57200	130125
1316	-0025	90200	60825
1120	3137	45100	125662
1126	26237	-185300	610762
1220	3137	45700	125662
1226	4787	29200	160312
1320	2837	52600	92062
1326	4112	37300	136687
1130	3375	32700	134825
1136	1195	4[illegible]100	113550
1230	3375	3[illegible]700	134925
1236	0000	65700	50700
1330	3525	31500	117375
1336	4050	25200	135750
2110	3575	61400	114825
2116	3050	65600	106950
2210	2375	71000	96825
2216	-0025	90200	60825
2310	-0537	90700	51337
2316	-0012	84400	69712
2120	3137	45700	125662
2126	26237	-185300	610762
2220	3137	45700	125662
2226	4412	33700	147187
2320	2837	52600	92062
2326	2837	52600	92062
2130	3375	32700	134925
2136	1926	44000	113737
2230	3375	32700	134925
2236	0000	65700	50700
2330	3525	31500	117375
2336	4050	25200	135750
1110	-0025	90200	60825
1116	-0025	90200	60825
1210	-0025	90200	60825
1216	-3912	121300	2512
1310	-2112	90700	67912
1316	-0837	75400	112537
1120	4787	29200	160312
1126	26237	-185000	610762
1220	4787	29200	160312
1226	4787	29200	160312
1320	4187	31900	142012
1326	1187	61900	79012
1130	4050	25200	135750
1136	4050	25200	135750
1230	4050	25200	135750

rfgs	a	b	c
1236	4050	25200	135750
1330	4050	25200	135750
1336	3150	27600	131850
2110	-0837	94300	40837
2116	-0837	94300	40837
2210	-1137	94600	53437
2216	-1737	100300	33337
2310	2162	99500	105637
2316	0912	68700	102487
2120	2837	52600	92062
2126	24287	-161900	542512
2220	2837	52600	92062
2226	2837	52600	92062
2320	4187	31900	142012
2326	1187	61900	79012
2130	4050	25200	135700
2136	4050	25200	135700
2230	4050	25200	135700
2236	4050	25200	135700
2330	4250	17400	144450
2336	3150	27600	131850
1110	-11637	183700	-116362
1116	-9687	164200	-75412
1210	-11637	183700	-116362
1216	-7437	143200	-38662
1310	6362	10300	215437
1316	-0987	83800	61087
1120	2837	52600	92062
1126	22112	-144500	509887
1220	2837	52600	92062
1226	-0076	81400	38062
1320	-3600	100200	-4800
1326	-1875	80400	51075
1130	2250	37200	113250
1136	1350	46800	95250
1230	1425	46200	96375
1236	-0450	63600	56250
1330	2775	33600	102825
1336	4350	17400	144450
2110	-16962	257500	-372037
2116	-16962	257500	-372037
2210	-8412	154900	-72787
2216	-4287	116800	-8212
2310	-0912	86200	40612
2216	-2562	102700	3962
2120	2837	52600	92062
2126	22112	-144500	509887
2220	2837	52600	92062
2226	-0762	81400	38062
2320	-3600	100200	-4800
2326	-1875	80400	51075
2130	2250	37200	113250
2136	1150	48800	91050
2230	2550	37200	113250

2236	-0450	63600	36250
2330	2275	33600	102825
2336	4350	17400	144450

EQUATION COEFFICIENT FOR CONVENTIONAL METHOD

rfgs	a	b	c
1110	7687	-12300	426712
1116	8012	-15550	433537
1210	5337	11200	377362
1216	8537	-20800	444562
1310	15075	-85150	574675
1316	11900	-53400	508000
1120	12350	-59050	525000
1126	9512	-30950	466237
1220	7800	-13600	429600
1226	9412	-30350	465337
1320	13525	-72750	551425
1326	10462	-91900	486437
1130	-2812	76400	255112
1136	-2812	76400	255112
1230	-2812	76400	255112
1236	0387	4440	322312
1330	-4050	88350	226300
1336	-3875	86950	228925
2110	17537	-133600	701962
2116	17537	-133600	701962
2210	19255	-147100	727275
2216	19162	-146600	726337
2310	17612	-132150	692837
2316	17725	-133050	694525
2120	18687	-142800	719215
2126	18437	-140800	715463
2220	17875	-135600	705712
2226	17875	-135600	705712
2320	17025	-127450	684025
2326	17025	-127450	684025
2130	17537	-133600	201962
2136	17537	-133600	201962
2230	17537	-133600	201962
2236	17537	-133600	201962
2330	17025	-127450	684025
2336	17025	-127450	684025
1110	9700	-31750	464250
1116	1700	-31750	464250
1210	9700	-31750	464250
1216	12012	55000	513187
1310	12275	-61750	521575
1316	12325	-72150	522325
1120	3037	28850	342412
1126	4150	17350	366900
1220	2987	29250	341662

rfgs	a	b	c
1226	6437	-5650	415312
1320	11487	-55450	509762
1326	11650	-56750	512200
1130	-2825	75750	254475
1136	-1887	65650	276337
1230	-2875	76150	253725
1236	-1262	60700	276062
1330	4212	2750	400637
1336	4462	0750	404387
2110	15575	-116550	665775
2116	15575	-116550	665775
2210	16475	-123750	679275
2216	15575	-116550	665775
2310	13375	-94200	609025
2316	13537	-95500	611462
2126	15575	-116550	665775
2126	15575	-116550	665775
2220	15575	-116550	665775
2226	15575	-116550	665775
2320	12762	-89300	599837
2326	12762	-89300	599837
2130	15575	-116550	665775
2136	15575	-116550	665775
2230	15575	-116550	665775
2236	15575	-116550	665775
2330	14387	-102300	624212
2336	14387	-102300	624212
1110	4012	22550	343037
1116	3125	28850	331225
1210	3100	23450	341350
1216	7170	-11550	416875
1310	9125	-37900	470275
1316	6425	-10900	413575
1120	1037	46350	298412
1126	2725	29350	334225
1220	0987	46850	297362
1226	5162	45500	386687
1320	9125	-37900	470275
1326	6425	-10900	413575
1130	-4912	93950	109162
1136	-3162	76450	245912
1230	-0512	49950	301562
1236	-0987	53750	294437
1330	2625	14100	372775
1336	-0075	41100	316075
2110	1125	-76200	575275
2116	1125	-76200	575275
2210	11212	-76900	576587
2216	11125	-76200	575275
2310	10112	-64050	539837
2316	10112	-64050	539837
2120	11125	-76200	575275
2126	11125	-76200	575275
2220	11125	-76200	575275

rfgs	a	b	c
2226	11125	-76200	575275
2320	11287	-75800	564512
2326	9862	-61500	534587
2130	11125	-76200	575275
2136	11125	-76200	575275
2230	11125	-76200	575275
2236	11125	-76200	575275
2330	12462	-87550	589187
2336	11062	-73550	559787

UNDERGROUND EQUIPMENT UNIT COSTS (US$000)

Cont. Miner	09740700049000
" "	10342000052000
" "	11242520048600
" "	12143380043500
" "	13645780033400
" "	14045720029900
" "	15246400021000
" "	18546860022700
" "	18847350024400
" "	19447600023800
" "	20047710023100
" "	24447730024200
Roof Bolter	100124300 6400
" "	120132200 9300
" "	14200027400
Shutle Cars	28830045500
Ratio Feeders	14900012500
Scoop Trams	5600010100
Section Belt	16290015300
Support Items	103300
Cutting Machi	26110017700
Coal Drill	107200
Loading Machi	191500 9700
Shutle Cars	28830045500
Ratio Feeders	14900012500
Scoop Trams	5600010100
Section Belt	16290015300
Support Items	103300
Longwall Eq.	15268640010334
" "	24474910013537
Section Belt	16300 210
DMHF	428 40
DCHF	328 22
Develop. Others	271878 400
Ventilation	94286247589
Slope Entry	9728
Slope Convey	688
Slope Hoist	828780
Slope Track	224

Shaft Entry	20353	
Shaft Hoist	718200	
Drift Entry	171000	
Break. Prep.	5540	700
Coarse Prep.	15834	834
Fine Prep.	31657	889
Other Surfac.	22374064410	
Explor. Drill. 152	21	
" " 305	23	
" "	25	
Mine Abandon.	182400	
Wage/day-Sal/yr00000012834500		

DRAGLINE COSTS (US$000000)

190	198
330	142
346	142
380	107
389	110
428	57
428	57
428	57
428	57
440	57
525	156
610	143
591	122
615	118
661	103
734	32
802	140
819	140
819	126
819	126
831	142
908	213
925	179
959	171
959	171
1009	133
1009	133
1061	175
1033	180
1103	258
1103	258
1103	258
1103	258
1224	314
1224	314

1257	330
1257	330
1257	330
1448	315
1448	315
1448	315
1594	91
1594	91
1650	135
1650	135
1650	135
1650	135
1650	135
1650	135
1740	228
1740	228
1740	228
1740	228
1740	228
1740	228
1718	270
1718	270
2016	0
2016	0
1910	151
1910	151
1910	151
2090	330
2090	330
2090	330
2233	307
2233	307
2493	500
2493	500
2493	500
2493	500
2493	500
2493	500
2733	399
2733	399
2733	399
2733	399
2733	399
2733	399
2733	399
2733	399
2733	399
2733	399
3015	0
3015	0
3015	0
3015	0
3187	244
3187	244

3187	244
3187	244
3187	244
3187	244
3187	244
3187	244
3187	244
3187	244
3187	244
3187	244
3187	244
3187	244
3187	244
3187	244
3187	244
3187	244
3187	244
3187	244
3187	244
3360	0
3360	0
3360	0
3360	0
3360	0
4798	128

SURFACE EQUIPMENT UNIT COST (US$000)

Haul trck	20	694	
"	30	2178	
"	35	2216	195
"	40	2545	
"	45	2616	
"	50	2885	709
"	55	3894	
"	60	3644	
"	65	4040	
"	70	4040	
"	75	4053	737
"	80	4797	
"	85	5047	354
"	100	4241	
"	110	4241	
"	120	4241	
"	150	6733	
"	170	8879	1216
Dozer Cost	4	722	226
"	9	1223	152
"	13	1775	204
"	19	2381	253

"	23	3349	447
Scrp Cost	14	2615	
"	21	4351	
"	32	5482	
Ld Shov Co	2	3680	442
"	3	3680	442
"	4	3680	442
"	5	4483	622
"	6	5230	428
"	7	5743	1083
"	8	5433	1938
"	9	5433	1938
Plant Cost		5443	
"		15547	
"		31102	
Wage/day		140	
Salary/yr		35500	

SURFACE TRUCK UNIT COSTS (US$000)

595	82
717	93
992	90
1351	119
1893	270
2064	140
2649	321
2649	321
4334	364
20751	2027
20751	2027
20751	2027
24998	5434
26331	8982
26331	8982
24909	5134
24931	6654
25475	6715
27821	6182
34571	12473
35028	10226
34563	12473
40130	11214

APPENDIX D

UNDERGROUND MODEL VALIDATION USING ORIGINAL MODEL INPUT DATA

REQUIRED PARAMETER VALUES

Seam Depth (m)(Mean)	167	Seam Depth(m) (SD)	16
Seam Thickn.(cm) (Mean)	198	Seam Thickn.(cm) (SD)	19
Seam Gradient	0	Roof Conditions	good
Floor Conditions	ha	Gas Level	low
Mining System	cont	Entry Type	shaft
Annual Production (1000t)	1000	Production Life	15
Analysis Type	unc	Eq. Cost Range	tot
Construc. Cost Range	tot	First Calendar Year	1982
Dollar Analysis Type	con	Base Year	1982
Labor Upd-Esc Factor	0	Power Upd/Esc Factor	0
Equip. Upd/Esc Factor	0	Haulage Upd/Esc Factor	0
Aux.Eq. Upd/Esc Factor	0	Supp.Mat. Upd/Esc Factor	0
Constr. Upd/Esc Factor	0	Capital Borrowed(%)	50
Debt Servicing Rate(%)	10	Loan Payback (years)	7
Dollar Eq.(CA$=X US$)	0.80	Coal Value/Tonne	49
Rate of Return	15	Acqu. Cost (Mean)($000)	1500
Acqu. Cost (SD)($000)	150		

OPTIONAL INPUT VALUES

Mean Reject Percentage	25	SD Reject Percentage	3
Shifts per Day	2	Days per Year	224
Coal Preparation	meta	Seam Recovery	60
Mean Operator Eff.	85	SD Operator Eff.	4
Mean Available Face Time	340	SD Available Face Time	15
Indirect Capital (%)	10	Capital Overhead (%)	40
Fringe Benefits (%)	35	Royalty Payments (%)	8
Income Tax (%)	47	Depreciation Method	strg
Capitalization Method	def	Investment Tax Credit	5
Fines in Clean Coal(%)			

DEFAULT PARAMETERS FOR UNCERTAINTY

Distribution for Physical Parameters	norm
Distribution for Operational Parameters	logn
Distribution for finantial Parameters	tria
Max. Lim. for Triag. Distrib. (%) (0=SD)	10
Min. Lim. for Triag. Distrib. (%) (0=SD)	10
Max. Lim. for Unifr. Distrib. (%) (0=SD)	10
Min. Lim. for Unifr. Distrib. (%) (0=SD)	10
Number of Iterations	20
Equip. Cost Range (low,high,tot)	tot
Construc. Cost Range(low,high,tot)	tot
Operating Cost Range(low,high,tot)	tot
Seed Number for NORMAL	939291
Seed Number for LOGN	654321
Seed Number for UNFRM	321456
Seed Number for TRIAG	818283

PARAMETERS WHICH OVERRIDE CALCULATED VALUES

Tonnes/Machine Shift	504	Production Sections/Shift	6
Hourly Labor Requirements	197	Salaried Personnel Req.	39
Development Time(Yrs)	2.26	Coal Prod. During Dvlpment	537799
Production Equipment Life	12	Haulage System Life	12
Aux. Equipment Life	12	Hourly Labor Cost/Yr	6242
Salaried Pers. Cost/Yr	1491	Supp.& Material Cost/t	8.40
Power Cost/t	0.82	Annual Operating Cost	23037
Initial Prod. Section Cos	8812*	Initial Aux. Equipment Cost	4386*
Initial Hlage System Cost	2277*	Plant & Unit Train Loading	33533
Exploration Cost	356	Mine Abandonment Cost	497
Mine Entry Cost	4483862		

SUBMODELS OUTPUT

I PRODUCTION SIZING

	MEAN	STD DEV
Annual Raw Coal Production	1300280	39624
Shift Output per Production Section	473	35
Raw Coal Production per Shift	2899	86
No. Production Sections / Shift	6	0
Actual Tonnes of Clean Coal Produced	1000000	

II MANPOWER REQUIREMENTS
(1982Dollars)

	MEAN	STD DEV
HOURLY LABOR		
Hourly Labor Reqs/Day	214	14
Hourly Labor Reqs/Shift	16	0
Direct Labor Cost/Shift Prod. Sect.	2080	70
Direct Annual Cost ($000)	6242	387
Fringe Benefits ($000)	2185	135
SALARIED PERSONNEL		
Annual Requirements	42	2
Direct Annual Costs ($000)	1491	119
TOTAL MANPOWER		
Direct Costs ($000)	7733	506
Productivity per Manday	16.80	0.96

III-1 EQUIPMENT REQUIREMENTS

Continuos Miners	6
Roof Bolters	6
Shuttle cars	13
Ratio Feeders	12
Scoop Trans	6
Section Haulage Belts	6
Cutting Machine	12
Loading Machine	1

III-2 EQUIPMENT AND CONSTRUCTION COSTS
(1982 Dollars)

	MEAN	STD DEV
PRODUCTION EQUIPMENT ($000)		
Production Section Costs	8812	298
Preproduction Haulage System Costs	4386	66
Production Phase Haulage System Costs	2991	313
Auxiliary Equipment Costs	2277	26
SITE PREPARATION AND CONSTRUCTION ($000)		
Preproduction Ventilation Construction	3414	344
Production Phase Vent. Construction	11282	1289
Mine Entry Construction	4484	451
ENTRY HAULAGE OR HOIST SYSTEM		
Entry Haulage or Hoist System	921	13
Preparation Plant Construction	33533	1265
Other Surface Construction	2275	54
EXPLORATION ($000)		
Total Cost of Exploration	356	43
MINE ABANDONMENT ($000)		
Total Cost of Abandonment	497	134

IV SUPPLIES, MATERIALS & POWER COSTS
(1982 Dollars)

	MEAN	STD DEV
SUPPLIES AND MATERIALS		
Cost/Tonne of Clean Coal	8.08	0.13
Annual Costs ($000)	8080	128
POWER		
Cost/Tonne of Clean Coal	0.79	0.01
Annual Costs ($000)	789	13
TOTAL		
Supplies, Materials and Power Cost/t	8.87	0.14
Annual Costs(Supp.,Mat. &Power)($000)	8869	141

V PREPRODUCTION DEVELOPMENT
(1982 Dollars)

	MEAN	STD DEV
DIRECT DEVELOPMENT COSTS ($000)		
LABOR	4441	373
Supplies and Materials	4686	198
Power	458	19
Payroll Overhead	1777	149
Fringe Benefits	1555	130
TOTAL COSTS ($000)	12917	682
OTHER DATA		
Development Time (yrs)	2.38	0.08
Development Time(Unit Shifts)	2135	169
Coal Produced During Develop.	580370	30684
Total Construct. and Develop. Time(yrs)	5	0

SUMMARY OUTPUT
****

ITERATION	COAL VALUE
1	52.65
2	55.32
3	51.37
4	52.14
5	52.72
6	47.48
7	46.89
8	48.62
9	50.03
10	50.39
11	49.11
12	52.22
13	56.12
14	53.46
15	47.20
16	50.35
17	53.62
18	52.24
19	51.27
20	47.95

CONSTANT DOLLAR-UNCERTAINTY OPTION

Coal Value/Tonne	51.18	
Mean and SD Coal Value/Tonne	51.23	2.74
Upper Confidence Limit (95%)	53.8	
Project Start Year	1982	
Full Production Years	1987-1996	
Rate of Return	15.00	
Capitalization		
-Debt (%)	50	
-Equity	50	
Debt Servicing Percentage	10	
Payback Period (yrs)	9	

APPENDIX E

SURFACE MODEL VALIDATION USING ORIGINAL MODEL INPUT DATA

INPUT REQUIRED VALUES

Seam Thicks. (Mean)(cm)	456	Seam Thicks. (SD)(cm)	10
Overbdn Thicks.(Mean)(m)	30	Overbdn Thicks.(SD)(m)	10
Topsoil Thicks.(Mean)(cm)	61	Topsoil Thicks.(SD)(cm)	1
Single or Mult. Seam	sin	Mining System	area
Annual Production (000t)	2000	Mine Life(Years)	15
% Capital Borrowed	50	Debt Serv. Rate (%)	10
Loan Paybk Period(Yrs)	10	Acquisition Cost($000)(Mean)	1500
Acquisition Cost(SD)	0	Dollar Equivalence	0.80
Project Start Year	1982	Type of Analysis	pv
Dollar Type Analysis	con	Base Year	1982
Labor Upd/Esc Factor	0	Prim. Eq. Upd/Esc Factor	0
Supp. Eq. Upd/Esc Factor	0	Operating Upd/Esc Factor	0
Construc. Upd/Esc Factor	0	Coal Value Esc. Factor	0
Coal Value/tonne	19	Rate of Return	0

OPTIONAL PARAMETERS DEFAULT VALUES

Reject (%)	0	Mean Recovery (%)	90
SD Recovery (%)	9	Dilution(%)	8
Coal Type	none	Exploration Required (sq. m)	161874
Coal Density (k/cu.m)	1504	Fines in Clean Coal(%)	20
Drilling Ovbdn (Work.PI)	1	Overbdn Consolidation	mod
Coal Loading Op. hrs/Mo	336	Mean Coal Load Cy. Time(s)	75
SD Coal Load Cy. Time(s)	7	Mean Bucket Fill Factor	75
SD Bucket Fill Factor	7	# of Loading Passes	10
Mean Truck Travel Time Ld	800	SD Trck Trvl Time Ld(s)	120
Mean Trk Trvl Time Emp(s)	480	SD Trk Travel Time Emp(s)	70
Mean Other Times(s)	200	SD Other Times(s)	30

OVERBURDEN EXCAVATION (Area Mine)

Shifts per day	2	Mean Operator Eff.	75
SD Operator Eff.	7	Mean Bucket Fill Factor	80
SD Bucket Fill Factor	8	Operating Hours/Month	720
Mean Cycle Time(s)	60	SD Cycle Time(s)	6

OVERBURDEN RECLAMATION (Area Mine)

Mean Width of Pit(m)	31	SD Width of Pit(m)	3
Angle of Spoil	36	Operating Hours/Month	336
Mean Overbdn Swell Fac	25	SD Overbdn Swell Fac	2
Dozer Blade Cap.(Cu m)	15	Mean Operator Eff.	75
SD Operator Eff.	7	Material Factor(%)	80

TOPSOIL HANDLING (Area and Open Pit)

Scraper Capacity(cu m)	16	Mean Loading Time(s)	50
SD Loading Time(s)	5	Mean Mnver-Spread Time(s)	42
SD Mnver-Spread Time(s)	4	Mean Trvl Time Loaded(s)	410
SD Trvl Time Loaded	41	Mean Trvl Time Empty(s)	246
SD Trvl Time EMpty(s)	24	Operating Hours/Mo	336
Mean Operator Eff.	75	SD Operator Eff.	7

FINANCIAL PARAMETERS

Fringe Benefits(%)	35	Labor Overhead(%)	40
Royalty Payment(%)	12	Investment Tax Credit	5
Income Tax(%)	47	Depreciation Method	strg
Dragline Depreciable Life	15	Drag. Bucket Deprec. Life	10
Ovbdn Shovel Deprec. Life	15	Shovel Bucket Deprec. Life	5
Ovbdn Trucks Deprec. Life	10	Dozers-scrap. Deprec. Life	5
Drills Depreciable Life	10	Coal Shovel Deprec. Life	15
Front End Deprec. Life	5	Coal Trucks Deprec. Life	10
Recl.Dz-Scr Deprec. Life	5	Capitalization Method	def
Indirect Capital(%)	15	Dragline Salvage Value(%)	0
Shovels Salvage Value(%)	0	10 Yrs Eq. Salvage Value(%)	10
5 Yrs Eq. Slvge Value(%)	10	Drilling Cost/m	60

* PARAMETERS WHICH OVERRIDE CALCULATED VALUES

Land Requirements (SQ. M.)	5
Total Hourly Personnel	114
Total Salaried Personnel	50
Explor. and Develop. Drilling Cost	6000000
Supplies and Materials Cost	9533356
Support Capital (%)	23
Total Annual Operating Cost	9761640
Total Preprod. Develop. Cost	2556432
Preparation Plant Cost	0

SUBMODELS OUTPUT

I PRIMARY EQUIPMENT SELECTION

Land Area Req.(Sq km.)	5
Number of Draglines	1
Dragline Bucket Cap. (Cu. m.)	33
Number of Overburden Drills	1
Overburden Drill Size(mm)	229
Number of Coal Drills	1
Coal Drill Size (mm)	146
Number of Coal Loaders/Shovels	1
Coal Loading Bucket Cap. (Cu.m.)	12
Number of Coal Trucks	1
Coal Truck Capacity(tonnes)	135
Number of Spoil Handling Dozers	3
Spoil Handling Dz Capacity(Cu. m.)	15
Number of Topsoil Handling Scraper	2
Topsoil Handling Scraper Capacity	18

I PRIMARY EQUIPMENT COSTS($000)

(1982Dollars)

	MEAN	STD DV
Land Adquisition Cost	1	0
Exploration Cost	6000	0
Dragline Cost	16498	0
Overbdn Drill Cost	783	0
Coal Drill Cost	311	0
Coal Loading Shovel Cost	713	0
Coal Hauling Cost	883	0
Reclamation Dozer Cost	937	0
Reclamation Scrap. Cost	1142	0
TOTAL PRODUCTION EQUIP. COST	20127	0

II SUPPORTING CAPITAL ITEM COSTS

	MEAN	STD DV
Preparation Plant Cost($000)	0	0
Construction Costs($000)	1883	0
Support Equipment Cost($000)	4208	0

III MANPOWER REQUIREMENTS AND COSTS

(1982Dollars)

	MEAN	STD DV
Hourly Labor Requirements	114	0
Hourly Labor Annual Cost ($000)	3787	0
Fringe Benefits($000)	1325	0
Salaried Personnel Requirements	50	0
Salaried Pers. Annual Cost($000)	1863	0
Total Manpower Requirements	164	0
Total Manpower Annual Cost($000)	5651	0
Productivity/Man Day(t/man day)	53	0

IV SUPPLIES AND MATERIAL OPERATING COSTS($000)

(1982Dollars)

	MEAN	STD DV
Annual Supplies & Materials Cost	8033	0
Annual Prep. Plant Operating Cost	0	0
TOTAL DIRECT NON LABOR OP. COST	0	0
Preproduction Development Cost	2556	0

SUMMARY OUTPUT
****

CONSTANT DOLLAR-POINT VALUE OPTION

Coal Value/Tonne	19.00
Project Start Year	1982
Full Production Years	1986-1996
Rate of Return	31.63
Capitalization	
-Debt (%)	50
-Equity	50
Debt Servicing Percentage	10
Payback Period (yrs)	8

APPENDIX F

UNDERGROUND MODEL VALIDATION USING CANADIAN INPUT DATA

REQUIRED PARAMETER VALUES

Seam Depth (m)(Mean)	122	Seam Depth(m) (SD)	12
Seam Thickn.(cm) (Mean)	300	Seam Thickn.(cm) (SD)	30
Seam Gradient	0	Roof Conditions	good
Floor Conditions	ha	Gas Level	low
Mining System	cont	Entry Type	shaft
Annual Production (1000t)	210	Production Life	18
Analysis Type	unc	Eq. Cost Range	tot
Contruc. Cost Range	tot	First Calendar Year	1982
Dollar Analysis Type	con	Base Year	1982
Labor Upd-Esc Factor	0	Power Upd/Esc Factor	0
Equip. Upd/Esc Factor	0	Haulage Upd/Esc Factor	0
Aux.Eq. Upd/Esc Factor	0	Supp.Mat. Upd/Esc Factor	0
Constr. Upd/Esc Factor	0	Capital Borrowed(%)	20
Debt Servicing Rate(%)	10	Loan Payback (years)	10
Dollar Eq.(CA$=X US$)	0.85	Coal Value/Tonne	25
Rate of Return	0	Acqu. Cost (Mean)($000)	0
Acqu. Cost (SD)($000)	0		

OPTIONAL INPUT VALUES

Mean Reject Percentage	0	SD Reject Percentage	0
Shifts per Day	2	Days per Year	194
Coal Preparation	none	Seam Recovery	65
Mean Operator Eff.	85	SD Operator Eff.	4
Mean Available Face Time	340	SD Available Face Time	15
Indirect Capital (%)	10	Capital Overhead (%)	2
Fringe Benefits (%)	30	Royalty Payments (%)	1
Income Tax (%)	47	Depreciation Method	fast
Capitalization Method	def	Investment Tax Credit	5
Fines in Clean Coal(%)	20		

DEFAULT PARAMETERS FOR UNCERTAINTY

Distribution for Physical Parameters	norm
Distribution for Operational Parameters	logn
Distribution for finantial Parameters	tria
Max. Lim. for Triag. Distrib. (%) (0=SD)	10
Min. Lim. for Triag. Distrib. (%) (0=SD)	10
Max. Lim. for Unifr. Distrib. (%) (0=SD)	10
Min. Lim. for Unifr. Distrib. (%) (0=SD)	10
Number of Iterations	20
Equip. Cost Range (low,high,tot)	tot
Construc. Cost Range(low,high,tot)	tot
Operating Cost Range(low,high,tot)	tot
Seed Number for NORMAL	939291
Seed Number for LOGN	654321
Seed Number for UNFRM	321456
Seed Number for TRIAG	818283

PARAMETERS WHICH OVERRIDE CALCULATED VALUES

Tonnes/Machine Shift	764	Production Sections/Shift	1
Hourly Labor Requirements	40	Salaried Personnel Req.	10
Development Time(Yrs)	1.00	Coal Prod. During Dvlpment	225761
Production Equipment Life	12	Haulage System Life	12
Aux. Equipment Life	12	Hourly Labor Cost/Yr	985
Salaried Pers. Cost/Yr	347	Supp.& Material Cost/t	6.30
Power Cost/t	0.62	Annual Operating Cost	3095
Initial Prod. Section Cos	1768	Initial Aux. Equipment Cost	0*
Initial Hlage System Cost	0*	Plant & Unit Train Loading	0
Exploration Cost	0*	Mine Abandonment Cost	0*
Mine Entry Cost	0*		

I PRODUCTION SIZING

	MEAN	STD DEV
Annual Raw Coal Production	210000	0
Shift Output per Production Section	770	74
Raw Coal Production per Shift	540	1
No. Production Sections / Shift	1	0
Actual Tonnes of Clean Coal Produced	210000	

II MANPOWER REQUIREMENTS
(1982Dollars)

	MEAN	STD DEV
HOURLY LABOR		
Hourly Labor Reqs/Day	40	0
Hourly Labor Reqs/Shift	20	0
Direct Labor Cost/Shift Prod. Sect.	2538	86
Direct Annual Cost ($000)	985	33
Fringe Benefits ($000)	295	10
SALARIED PERSONNEL		
Annual Requirements	10	0
Direct Annual Costs ($000)	347	13
TOTAL MANPOWER		
Direct Costs ($000)	1331	38
Productivity per Manday	21.00	0.0

III-1 EQUIPMENT REQUIREMENTS

Continuos Miners	1
Roof Bolters	1
Shuttle cars	2
Ratio Feeders	2
Scoop Trans	1
Section Haulage Belts	1
Cutting Machine	2
Loading Machine	0

III-2 EQUIPMENT AND CONSTRUCTION COSTS
(1982 Dollars)

	MEAN	STD DEV
PRODUCTION EQUIPMENT ($000)		
Production Section Costs	1765	8
Preproduction Haulage System Costs	0	0
Production Phase Haulage System Costs	828	66
Auxiliary Equipment Costs	0	0
SITE PREPARATION AND CONSTRUCTION ($000)		
Preproduction Ventilation Construction	2669	102
Production Phase Vent. Construction	2122	194
Mine Entry Construction	0	0
ENTRY HAULAGE OR HOIST SYSTEM		
Entry Haulage or Hoist System	0	0
Preparation Plant Construction	0	0
Other Surface Construction	2243	11
EXPLORATION ($000)		
Total Cost of Exploration	0	0
MINE ABANDONMENT ($000)		
Total Cost of Abandonment	0	0

IV SUPPLIES, MATERIALS & POWER COSTS
(1982 Dollars)

	MEAN	STD DEV
SUPPLIES AND MATERIALS		
Cost/Tonne of Clean Coal	6.21	0.32
Annual Costs ($000)	1305	68
POWER		
Cost/Tonne of Clean Coal	0.61	0.03
Annual Costs ($000)	128	7
TOTAL		
Supplies, Materials and Power Cost/t	6.82	0.35
Annual Costs(Supp.,Mat. &Power)($000)	1433	74

V PREPRODUCTION DEVELOPMENT
(1982 Dollars)

	MEAN	STD DEV
DIRECT DEVELOPMENT COSTS ($000)		
LABOR	985	33
Supplies and Materials	1391	135
Power	136	13
Payroll Overhead	20	1
Fringe Benefits	295	10
TOTAL COSTS ($000)	2827	159
OTHER DATA		
Development Time (yrs)	1.00	0.0
Development Time(Unit Shifts)	388	0
Coal Produced During Develop.	224258	21596
Total Construct. and Develop. Time(yrs)	4	0

SUMMARY OUTPUT
****

ITERATION	RATE OF RETURN
1	14.04
2	17.68
3	17.83
4	19.25
5	19.53
6	18.16
7	15.57
8	22.44
9	17.30
10	22.43
11	18.43
12	13.96
13	16.26
14	16.44
15	16.33
16	14.65
17	19.07
18	20.60
19	19.03
20	15.90

[illegible]NT DOLLAR-UNCERTAINTY OPTION

C[illegible]ue/Tonne	25.00	
Pr[illegible]tart Year	1982	
Ful[illegible]uction Years	1986-1999	
Rate[illegible]urn	18.01	
Mean[illegible]SD Rate of Return	17.75	1.93
Lower C[illegible]idence Limit (95%)	16.8	
Capi[illegible]on		
-[illegible])	20	
-Eq[illegible]	80	
Deb. Serv[illegible]tage	10	
Payback Per[illegible] (yrs)	9	

CASH FLOW SUMMARY TABLE
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LINE	CASHFLOW ITEMS	1982	1983	1984	1985	1986	1987	1988	1989
	Calendar Year of the Project:	1982	1983	1984	1985	1986	1987	1988	1989
	Relative Year of Full Prod.	-4	-3	-2	-1	1	2	3	4
101	Coal Value/Tonne	25	25	25	25	25	25	25	25
102	Annual Production Clean Coal	0	73914	73914	73914	210000	210000	210000	210000
103	Annual Sales Revenue	0	1847850	1847850	1847850	5250000	5250000	5250000	5250000
104	-Annual Operating Cost	0	0	0	0	3164548	3164548	3164548	3164548
105	=Gross Profit	0	1847850	1847850	1847850	2085452	2085452	2085452	2085452
106	-Interest Payment	0	0	0	0	245217	229831	212906	194288
107	-Resource Allowance (25%)	0	0	0	0	460058	463905	468136	472791
108	-Capital Cost Allowance	0	0	0	0	1380177	1391716	1404410	1418373
110	-Explor.,Preprod., and Const.	0	0	0	0	0	0	0	0
111	=Net Income for Earned Deple.	0	1847850	1847850	1847850	0	0	0	0
112	-Depletion Allowance (25%)	0	0	0	0	0	0	0	0
113	=Taxable income	0	1847850	1847850	1847850	0	0	0	0
114	-Income Tax (47%)	0	868489	868489	868489	0	0	0	0
115	-Royalty	0	13858	13858	13858	78761	160044	228464	299603
116	+Investment Tax Credit	0	29387	29387	29387	0	0	0	0
117	=Net Profit	0	994890	994890	994890	-78761	-160044	-228464	-299603
118	+Additional Income (S. Value)	0	0	0	0	0	0	0	0
119	+Addback of Noncash	0	0	0	0	1840235	1855621	1872546	1891164
120	-Loan Principal Payment	0	0	0	0	153864	169250	186175	204793
121	=Net Cash Inflow	0	994890	994890	994890	1607610	1526327	1457907	1386768
	CAPITAL EXPENDITURES								
122	Acquisition Cost	0	0	0	0	0	0	0	0
123	Exploration	0	0	0	0	0	0	0	0
124	Preproduction Development	0	938087	938087	938087	0	0	0	0
125	Construction	1229634	1229634	1229634	1229634	0	180340	180340	180340
126	Equipment	0	587740	587740	587740	119241	119241	119241	119241
127	Accrued Interest	0	0	0	0	482449	0	0	0
128	Indirect Capital	0	117548	117548	117548	0	0	0	0
129	Working Capital	0	0	0	0	527849	0	0	0
130	Total Annual Capital Exp.	1229634	2873009	2873009	2873009	647090	299581	299581	299581
131	-Amount Funded From Equity	983708	2298408	2298408	2298408	647090	299581	299581	299581
132	Amount Funded From Loans	245926	574601	574601	574601	0	0	0	0
133	Annual Net Cashflow	-983708	-1303518	-1303518	-1303518	960520	1226746	1158326	1087187

CASH FLOW SUMMARY TABLE

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LINE	Calendar Year of the Project: / Relative Year of Full Prod. / CASHFLOW ITEMS	1990 / 5	1991 / 6	1992 / 7	1993 / 8	1994 / 9	1995 / 10	1996 / 11	1997 / 12
101	Coal Value/Tonne	25	25	25	25	25	25	25	25
102	Annual Production Clean Coal	210000	210000	210000	210000	210000	210000	210000	210000
103	Annual Sales Revenue	5250000	5250000	5250000	5250000	5250000	5250000	5250000	5250000
104	-Annual Operating Cost	3164548	3164548	3164548	3164548	3164548	3164548	3164548	3164548
105	=Gross Profit	2085452	2085452	2085452	2085452	2085452	2085452	2085452	2085452
106	-Interest Payment	173809	151282	126502	99244	69260	36278	0	0
107	-Resource Allowance (25%)	477910	483542	489737	496552	504048	512293	521363	521363
108	-Capital Cost Allowance	1433733	1450628	1469213	1268001	768080	715184	715184	127444
110	-Explor.,Preprod., and Const.	0	0	0	0	0	0	0	0
111	=Net Income for Earned Deple.	0	0	0	221655	744064	821697	848905	1436645
112	-Depletion Allowance (25%)	0	0	0	55413	186016	205424	212226	359161
113	=Taxable income	0	0	0	166242	558048	616273	636679	1077484
114	-Income Tax (47%)	0	0	0	78133	262282	289648	299239	506417
115	-Royalty	372573	488770	486483	487720	450751	421309	393683	401652
116	+Investment Tax Credit	0	0	0	0	29387	29387	29387	0
117	=Net Profit	-372573	-488770	-486483	-399611	-125598	-65297	-26856	169415
118	+Additional Income (S. Value)	0	0	0	0	0	52896	52896	52896
119	+Addback of Noncash	1911643	1934170	1958950	1819966	1458144	1432901	1448773	1007968
120	-Loan Principal Payment	225272	247799	272579	299837	329821	362803	0	0
121	=Net Cash Inflow	1313798	1197601	1199888	1120518	1002725	1057697	1474813	1230279
	CAPITAL EXPENDITURES								
122	Acquisition Cost	0	0	0	0	0	0	0	0
123	Exploration	0	0	0	0	0	0	0	0
124	Preproduction Development	0	0	0	0	0	0	0	0
125	Construction	180340	180340	180340	180340	180340	180340	180340	180340
126	Equipment	119241	119241	119241	0	587740	587740	587740	0
127	Accrued Interest	0	0	0	0	0	0	0	0
128	Indirect Capital	0	0	0	0	0	0	0	0
129	Working Capital	0	0	0	0	0	0	0	0
130	Total Annual Capital Exp.	299581	299581	299581	180340	768080	768080	768080	180340
131	-Amount Funded From Equity	299581	299581	299581	180340	768080	768080	768080	180340
132	Amount Funded From Loans	0	0	0	0	0	0	0	0
133	Annual Net Cashflow	1014217	898020	900307	940178	234645	289617	706733	1049939

CASH FLOW SUMMARY TABLE

LINE	CASHFLOW ITEMS	1998	1999	
	Calendar Year of the Project:	1998	1999	
	Relative Year of Full Prod.	13	14	
101	Coal Value/Tonne	25	25	
102	Annual Production Clean Coal	210000	210000	6356055
103	Annual Sales Revenue	5250000	5250000	158901375
104	-Annual Operating Cost	3164548	3164548	94188612
105	=Gross Profit	2085452	2085452	64712763
106	-Interest Payment	0	0	3175089
107	-Resource Allowance (25%)	521363	521363	12409064
108	-Capital Cost Allowance	169609	-1211257	25040629
110	-Explor.,Preprod., and Const.	0	0	0
111	=Net Income for Earned Deple.	1394480	2775346	24087981
112	-Depletion Allowance (25%)	348620	693836	3046648
113	=Taxable income	1045860	2081510	21041333
114	-Income Tax (47%)	491554	978309	9889420
115	-Royalty	409557	421988	8629504
116	+Investment Tax Credit	0	0	264483
117	=Net Profit	144749	681213	2786892
118	+Additional Income (S. Value)	10731	1211257	2760878
119	+Addback of Noncash	1039592	3942	40496341
120	-Loan Principal Payment	0	0	5060351
121	=Net Cash Inflow	1195072	1896412	40983760
	CAPITAL EXPENDITURES			
122	Acquisition Cost	0	0	0
123	Exploration	0	0	2
124	Preproduction Development	0	0	6291114
125	Construction	180340	0	14098744
126	Equipment	0	0	8713679
127	Accrued Interest	0	0	992157
128	Indirect Capital	0	0	705288
129	Working Capital	0	-527849	0
130	Total Annual Capital Exp.	180340	-527849	29808825
131	-Amount Funded From Equity	180340	-527849	25740668
132	Amount Funded From Loans	0	0	4068157
133	Annual Net Cashflow	1014732	2424261	15243092

APPENDIX G

SURFACE MODEL VALIDATION USING CANADIAN INPUT DATA

INPUT REQUIRED VALUES

Seam Thicks. (Mean)(cm)	200	Seam Thicks. (SD)(cm)	20
Overbdn Thicks.(Mean)(m)	15	Overbdn Thicks.(SD)(m)	1
Topsoil Thicks.(Mean)(cm)	100	Topsoil Thicks.(SD)(cm)	10
Single or Mult. Seam	sin	Mining System	area
Annual Production (000t)	1500	Mine Life(Years)	30
% Capital Borrowed	30	Debt Serv. Rate (%)	10
Loan Paybk Period(Yrs)	10	Acquisition Cost($000)(Mean)	1495
Acquisition Cost(SD)	0	Dollar Equivalence	0.80
Project Start Year	1982	Type of Analysis	unc
Dollar Type Analysis	con	Base Year	1982
Labor Upd/Esc Factor	0	Prim. Eq. Upd/Esc Factor	0
Supp. Eq. Upd/Esc Factor	0	Operating Upd/Esc Factor	0
Construc. Upd/Esc Factor	0	Coal Value Esc. Factor	0
Coal Value/tonne	14	Rate of Return	

OPTIONAL PARAMETERS DEFAULT VALUES

Reject (%)	0	Mean Recovery (%)	90
SD Recovery (%)	9	Dilution(%)	8
Coal Type	none	Exploration Required (sq. m)	161874
Coal Density (k/cu.m)	1504	Fines in Clean Coal(%)	20
Drilling Ovbdn (Work.Pl)	0	Overbdn Consolidation	low
Coal Loading Op. hrs/Mo	336	Mean Coal Load Cy. Time(s)	75
SD Coal Load Cy. Time(s)	7	Mean Bucket Fill Factor	75
SD Bucket Fill Factor	7	# of Loading Passes	10
Mean Truck Travel Time Ld	1200	SD Trck Trvl Time Ld(s)	120
Mean Trk Trvl Time Emp(s)	700	SD Trk Travel Time Emp(s)	70
Mean Other Times(s)	300	SD Other Times(s)	30

OVERBURDEN EXCAVATION (Area Mine)

Shifts per day	2	Mean Operator Eff.	75
SD Operator Eff.	7	Mean Bucket Fill Factor	80
SD Bucket Fill Factor	8	Operating Hours/Month	720
Mean Cycle Time(s)	60	SD Cycle Time(s)	6

OVERBURDEN RECLAMATION (Area Mine)

Mean Width of Pit(m)	31	SD Width of Pit(m)	3
Angle of Spoil	36	Operating Hours/Month	336
Mean Overbdn Swell Fac	25	SD Overbdn Swell Fac	2
Dozer Blade Cap.(Cu m)	15	Mean Operator Eff.	75
SD Operator Eff.	7	Material Factor(%)	80

TOPSOIL HANDLING (Area and Open Pit)

Scraper Capacity(cu m)	16	Mean Loading Time(s)	50
SD Loading Time(s)	5	Mean Mnver-Spread Time(s)	60
SD Mnver-Spread Time(s)	4	Mean Trvl Time Loaded(s)	900
SD Trvl Time Loaded	41	Mean Trvl Time Empty(s)	550
SD Trvl Time EMpty(s)	24	Operating Hours/Mo	336
Mean Operator Eff.	75	SD Operator Eff.	7

FINANCIAL PARAMETERS

Fringe Benefits(%)	35
Royalty Pay.: Prvce of ALTA	Formula
Income Tax(%)	47
Dragline Depreciable Life	30
Ovbdn Shovel Deprec. Life	30
Ovbdn Trucks Deprec. Life	10
Drills Depreciable Life	10
Front End Deprec. Life	5
Recl.Dz-Scr Deprec. Life	5
Indirect Capital(%)	15
Shovels Salvage Value(%)	0
5 Yrs Eq. Slvge Value(%)	10
Labor Overhead(%)	40
Investment Tax Credit	5
Depreciation Method	fast
Drag. Bucket Deprec. Life	10
Shovel Bucket Deprec. Life	5
Dozers-scrap. Deprec. Life	5
Coal Shovel Deprec. Life	30
Coal Trucks Deprec. Life	10
Capitalization Method	def
Dragline Salvage Value(%)	0
10 Yrs Eq. Salvage Value(%)	10
Drilling Cost/m	60

PARAMETERS FOR UNCERTAINTY

1	Distribution for Physical Parameters	norm
2	Distribution for Operational Parameters	logn
3	Distribution for finantial Parameters	tria
4	Max. Lim. for Triag. Distrib. (%) (0=SD)	10
5	Min. Lim. for Triag. Distrib. (%) (0=SD)	10
6	Max. Lim. for Unifr. Distrib. (%) (0=SD)	10
7	Min. Lim. for Unifr. Distrib. (%) (0=SD)	10
8	Number of Iterations	20
9	Equip. Cost Range (low,high,tot)	tot
10	Construc. Cost Range(low,high,tot)	tot
11	Operating Cost Range(low,high,tot)	tot
12	Seed Number for NORMAL	123456
13	Seed Number for LOGN	654321
14	Seed Number for UNFRM	321456
15	Seed Number for TRIAG	456321

PARAMETERS WHICH OVERRIDE CALCULATED VALUES

Land Requirements (SQ. M.)	[illegible]
Total Hourly Personnel	105
Total Salaried Personnel	44
Explor. and Develop. Drilling Cost	4500000
Supplies and Materials Cost	8127550
Support Capital (%)	23
Total Annual Operating Cost	8239711
Total Preprod. Develop. Cost	2258617
Preparation Plant Cost	0

SUBMODELS OUTPUT

I PRIMARY EQUIPMENT SELECTION

Land Area Req.(Sq km.)	18
Number of Draglines	1
Dragline Bucket Cap. (Cu. m.)	29
Number of Overburden Drills	0
Overburden Drill Size(mm)	0
Number of Coal Drills	1
Coal Drill Size (mm)	146
Number of Coal Loaders/Shovels	1
Coal Loading Bucket Cap. (Cu.m.)	9
Number of Coal Trucks	2
Coal Truck Capacity(tonnes)	104
Number of Spoil Handling Dozers	6
Spoil Handling Dz Capacity(Cu. m.)	15
Number of Topsoil Handling Scraper	14
Topsoil Handling Scraper Capacity	16

I PRIMARY EQUIPMENT COSTS($000)

(1982Dollars)

	MEAN	STD DV
Land Adquisition Cost	1495	34
Exploration Cost	4500	0
Dragline Cost	13731	2547
Overbdn Drill Cost	0	0
Coal Drill Cost	299	12
Coal Loading Shovel Cost	673	23
Coal Hauling Cost	1212	205
Reclamation Dozer Cost	1709	418
Reclamation Scrap. Cost	7582	1585
TOTAL PRODUCTION EQUIP. COST	17627	2809

II SUPPORTING CAPITAL ITEM COSTS

	MEAN	STD DV
Preparation Plant Cost($000)	0	0
Construction Costs($000)	1455	166
Support Equipment Cost($000)	3387	380

III MANPOWER REQUIREMENTS AND COSTS

(1982Dollars)

	MEAN	STD DV
Hourly Labor Requirements	105	0
Hourly Labor Annual Cost ($000)	3346	109
Fringe Benefits($000)	1171	38
Salaried Personnel Requirements	44	0
Salaried Pers. Annual Cost($000)	1531	63
Total Manpower Requirements	149	0
Total Manpower Annual Cost($000)	4877	119
Productivity/Man Day(t/man day)	44	0

IV SUPPLIES AND MATERIAL OPERATING COSTS($000)

(1982Dollars)	MEAN	STD DV
Annual Supplies & Materials Cost	8127	254
Annual Prep. Plant Operating Cost	0	0
TOTAL DIRECT NON LABOR OP. COST	0	0
Preproduction Development Cost	2258	73

SUMMARY OUTPUT
****

ITERATION	RATE OF RETURN
1	20.81
2	18.81
3	23.66
4	20.70
5	22.60
6	20.84
7	18.03
8	20.77
9	14.80
10	25.80
11	22.80
12	23.86
13	22.75
14	20.57
15	23.67
16	19.61
17	18.71
18	15.85
19	18.98
20	22.59

CONSTANT DOLLAR-UNCERTAINTY OPTION

Coal Value/Tonne	14.00	
Project Start Year	1982	
Full Production Years	1986-2011	
Rate of Return	20.85	
Mean and SD Rate of Return	20.81	2.13
Lower Confidence Limit (95%)	19.8	
Capitalization		
-Debt (%)	30	
-Equity	70	
Debt Servicing Percentage	10	
Payback Period (yrs)	7	

CASH FLOW SUMMARY TABLE

LINE	CASHFLOW ITEMS	1982	1983	1984	1985	1986	1987	1988	1989
	Relative Year of Full Prod.	-4	-3	-2	-1	1	2	3	4
101	Coal Value/Tonne	14	14	14	14	14	14	14	14
102	Annual Production Clean Coal	0	0	0	0	1500000	1500000	1500000	1500000
103	Annual Sales Revenue	0	0	0	0	21000000	21000000	21000000	21000000
104	-Annual Operating Cost	0	0	0	0	8529948	8529948	8529948	8529948
105	=Gross Profit	0	0	0	0	12470052	12470052	12470052	12470052
106	-Interest Payment	0	0	0	0	1253178	1174546	1088051	992906
107	-Resource Allowance (25%)	0	0	0	0	2804218	2823876	2845500	2869286
108	-Capital Cost.Allowance	0	0	0	0	8412656	8471630	8536501	5648259
110	-Explor.,Preprod., and Const.	0	0	0	0	0	0	0	0
111	=Net Income for Earned Deple.	0	0	0	0	0	0	0	2959601
112	-Depletion Allowance (25%)	0	0	0	0	0	0	0	739900
113	=Taxable income	0	0	0	0	0	0	0	2219701
114	-Income Tax (47%)	0	0	0	0	0	0	0	1043259
115	-Royalty	0	0	0	0	397400	850901	1278047	1761048
116	+Investment Tax Credit	0	0	0	0	0	0	0	529129
117	=Net Profit	0	0	0	0	-397400	-850901	-1278047	-55477
118	+Additional Income (S. Value)	0	0	0	0	0	0	0	0
119	+Addback of Noncash	0	0	0	0	11216874	11295506	11382001	9257445
120	-Loan Principal Payment	0	0	0	0	786318	864950	951445	1046590
121	=Net Cash Inflow	0	0	0	0	10033156	9579655	9152509	8155378
	CAPITAL EXPENDITURES								
122	Acquisition Cost	1469038	0	0	0	0	0	0	0
123	Exploration	4500000	0	0	0	0	0	0	0
124	Preproduction Development	0	0	0	2252891	0	0	0	0
125	Construction	362062	362062	362062	362062	0	0	0	0
126	Equipment	0	4192911	6289368	10482280	0	0	0	0
127	Accrued Interest	0	0	0	0	2332791	0	0	0
128	Indirect Capital	54309	683245	997714	1626651	0	0	0	0
129	Working Capital	0	0	0	0	1598441	0	0	0
130	Total Annual Capital Exp.	6385409	5238218	7649144	14723884	1598441	0	0	0
131	-Amount Funded From Equity	4469787	3666753	5354401	10306719	1598441	0	0	0
132	Amount Funded From Loans	1915622	1571465	2294743	4417165	0	0	0	0
133	Annual Net Cashflow	-4469787	-3666753	-5354401	-10306719	8434715	9579655	9152509	8155378

CASH FLOW SUMMARY TABLE

LINE	CASHFLOW ITEMS	1990	1991	1992	1993	1994	1995	1996	1997
	Calendar Year of the Project:	1990	1991	1992	1993	1994	1995	1996	1997
	Relative Year of Full Prod.	5	6	7	8	9	10	11	12
101	Coal Value/Tonne	14	14	14	14	14	14	14	14
102	Annual Production Clean Coal	1500000	1500000	1500000	1500000	1500000	1500000	1500000	1500000
103	Annual Sales Revenue	21000000	21000000	21000000	21000000	21000000	21000000	21000000	21000000
104	-Annual Operating Cost	8529948	8529948	8529948	8529948	8529948	8529948	8529948	8529948
105	=Gross Profit	12470052	12470052	12470052	12470052	12470052	12470052	12470052	12470052
106	-Interest Payment	888247	773123	646485	507184	353953	185399	0	0
107	-Resource Allowance (25%)	2895451	2924232	2955891	2990717	3029024	3071163	3117513	3117513
108	-Capital Cost Allowance	8686354	720563	0	0	0	9213490	5792232	0
110	-Explor.,Preprod., and Const.	0	0	0	0	0	0	0	0
111	=Net Income for Earned Deple.	0	8052134	8867676	8972151	9087075	0	3560307	9352539
112	-Depletion Allowance (25%)	0	2013033	2216919	2243037	2271768	0	871691	0
113	=Taxable Income	0	6039101	6650757	6729114	6815307	0	2688616	9352539
114	-Income Tax (47%)	0	2838377	3125855	3162683	3203194	0	1263649	4395693
115	-Royalty	1798072	2542453	2638411	2734176	2829701	2106948	2202113	2297388
116	+Investment Tax Credit	0	0	0	0	0	0	0	0
117	=Net Profit	-1798072	658271	886491	832255	782412	-2106948	-777146	2659458
118	+Additional Income (S. Value)	1045213	0	0	0	0	201545	0	0
119	+Addback of Noncash	11581805	5657828	5172810	5233754	5300792	12284653	9781436	3117513
120	-Loan Principal Payment	1151249	1266373	1393011	1532312	1685543	1854097	0	0
121	=Net Cash Inflow	9677697	5049726	4666290	4533697	4397661	8525153	9004290	5776971
	CAPITAL EXPENDITURES								
122	Acquisition Cost	0	0	0	0	0	0	0	0
123	Exploration	0	0	0	0	0	0	0	0
124	Preproduction Development	0	0	0	0	0	0	0	0
125	Construction	0	0	0	0	0	0	0	0
126	Equipment	10452130	0	0	0	0	15207267	0	0
127	Accrued Interest	0	0	0	0	0	0	0	0
128	Indirect Capital	0	0	0	0	0	0	0	0
129	Working Capital	0	0	0	0	0	0	0	0
130	Total Annual Capital Exp.	10452130	0	0	0	0	15207267	0	0
131	-Amount Funded From Equity	10452130	0	0	0	0	15207267	0	0
132	Amount Funded From Loans	0	0	0	0	0	0	0	0
133	Annual Net Cashflow	-774433	5049726	4666290	4533697	4397661	-6682114	9004290	5776971

CASH FLOW SUMMARY TABLE

LINE	Calendar Year of the Project: / Relative Year of Full Prod. / CASHFLOW ITEMS	1998 / 13	1999 / 14	2000 / 15	2001 / 16	2002 / 17	2003 / 18	2004 / 19	2005 / 20
101	Coal Value/Tonne	14	14	14	14	14	14	14	14
102	Annual Production Clean Coal	1500000	1500000	1500000	1500000	1500000	1500000	1500000	1500000
103	Annual Sales Revenue	21000000	21000000	21000000	21000000	21000000	21000000	21000000	21000000
104	-Annual Operating Cost	8529948	8529948	8529948	8529948	8529948	8529948	8529948	8529948
105	=Gross Profit	12470052	12470052	12470052	12470052	12470052	12470052	12470052	12470052
106	-Interest Payment	0	0	0	0	0	0	0	0
107	-Resource Allowance (25%)	3117513	3117513	3117513	3117513	3117513	3117513	3117513	3117513
108	-Capital Cost Allowance	0	0	9352539	54378	0	0	0	9352539
110	-Explor.,Preprod., and Const.	0	0	0	0	0	0	0	0
111	=Net Income for Earned Deple.	9352539	9352539	0	9298161	9352539	9352539	9352539	0
112	-Depletion Allowance (25%)	0	0	0	0	0	0	0	0
113	=Taxable income	9352539	9352539	0	9298161	9352539	9352539	9352539	0
114	-Income Tax (47%)	4395693	4395693	0	4370135	4395693	4395693	4395693	0
115	-Royalty	2392694	2487969	2099751	2195046	2290457	2385908	2481325	1850388
116	+Investment Tax Credit	0	0	0	0	0	0	0	0
117	=Net Profit	2564152	2468877	-2099751	2732980	2666389	2570938	2475521	-1850388
118	+Additional Income (S. Value)	0	0	1045213	0	0	0	0	201545
119	+Addback of Noncash	3117513	3117513	12470052	3171891	3117513	3117513	3117513	12470052
120	-Loan Principal Payment	0	0	0	0	0	0	0	0
121	=Net Cash Inflow	5681665	5586390	11415514	5904871	5783902	5688451	5593034	10821209
	CAPITAL EXPENDITURES								
122	Acquisition Cost	0	0	0	0	0	0	0	0
123	Exploration	0	0	0	0	0	0	0	0
124	Preproduction Development	0	0	0	0	0	0	0	0
125	Construction	0	0	0	0	0	0	0	0
126	Equipment	0	0	10452130	0	0	0	0	15883117
127	Accrued Interest	0	0	0	0	0	0	0	0
128	Indirect Capital	0	0	0	0	0	0	0	0
129	Working Capital	0	0	0	0	0	0	0	0
130	Total Annual Capital Exp.	0	0	10452130	0	0	0	0	15883117
131	-Amount Funded From Equity	0	0	10452130	0	0	0	0	15883117
132	Amount Funded From Loans	0	0	0	0	0	0	0	0
133	Annual Net Cashflow	5681665	5586390	963384	5904871	5783902	5688451	5593034	-5061908

CASH FLOW SUMMARY TABLE

Calendar Year of the Project:		2006	2007	2008	2009	2010	2011	
Relative Year of Full Prod.		21	22	23	24	25	26	
LINE	CASHFLOW ITEMS							
101	Coal Value/Tonne	14	14	14	14	14	14	
102	Annual Production Clean Coal	1500000	1500000	1500000	1500000	1500000	1500000	39000000
103	Annual Sales Revenue	21000000	21000000	21000000	21000000	21000000	21000000	546000000
104	-Annual Operating Cost	8529948	8529948	8529948	8529948	8529948	8529948	221778648
105	=Gross Profit	12470052	12470052	12470052	12470052	12470052	12470052	324221352
106	-Interest Payment	0	0	0	0	0	0	7863072
107	-Resource Allowance (25%)	3117513	3117513	3117513	3117513	3117513	3117513	79089566
108	-Capital Cost Allowance	6329033	0	0	0	9352539	-9113512	80809201
110	-Explor.,Preprod., and Const.	0	0	0	0	0	0	0
111	=Net Income for Earned Deple.	3023506	9352539	9352539	9352539	0	18466051	156459513
112	-Depletion Allowance (25%)	0	0	0	0	0	0	10356348
113	=Taxable Income	3023506	9352539	9352539	9352539	0	18466051	146103165
114	-Income Tax (47%)	1421047	4395693	4395693	4395693	0	8679041	68668477
115	-Royalty	1944296	2083854	2179438	2275149	1913948	2008691	54025572
116	+Investment Tax Credit	0	0	0	0	0	0	529129
117	=Net Profit	-341837	2872992	2777408	2681697	-1913948	7778319	23938245
118	+Additional Income (S. Value)	0	0	0	0	1045213	9167890	12706619
119	+Addback of Noncash	9446546	3117513	3117513	3117513	12470052	-5995999	170255115
120	-Loan Principal Payment	0	0	0	0	0	0	12531888
121	=Net Cash Inflow	9104709	5990505	5894921	5799210	11601317	10950210	194368091
	CAPITAL EXPENDITURES							
122	Acquisition Cost	0	0	0	0	0	0	1469038
123	Exploration	0	0	0	0	0	0	4500000
124	Preproduction Development	0	0	0	0	0	0	2252891
125	Construction	0	0	0	0	0	0	1448248
126	Equipment	0	0	0	0	10452130	0	83411333
127	Accrued Interest	0	0	0	0	0	0	2332791
128	Indirect Capital	0	0	0	0	0	0	3361919
129	Working Capital	0	0	0	0	0	-1598441	0
130	Total Annual Capital Exp.	0	0	0	0	10452130	-1598441	96443429
131	-Amount Funded From Equity	0	0	0	0	10452130	-1598441	86244434
132	Amount Funded From Loans	0	0	0	0	0	0	10198995
133	Annual Net Cashflow	9104709	5990505	5894921	5799210	1149187	12548651	108123657

APENDIX H

User's Manual

I. Operating Environment

The model's computing system has been developed and implemented on the University of Alberta's Amdahl 5860 under the MTS operating system. The storage allocation for both subsystems is aproximately the following:

- Source program files : 200 pages (1 page= 4096 characters)
- Object files 80 pages
- Data files: 12 pages

The source programs file, object programs files and data file are stored in the tape 072913 at the computing services tape library of The University of Alberta. Any file of that tape can be recovered from any terminal conected with the Amdahl 5860 using the following commands:

```
MOUNT 072913 9tp *t*
RUN *FS 0=*t*                (Ref. 41)
RESTORE tapefile1 diskfile1
RESTORE tapefile2 diskfile2
RESTORE tapefilen diskfilen
LIST
STOP DISMOUNT
```

The files in the tape were recorded in the following order:

. SOURCE: Contains the source programs for both underground and surface systems.

. SUROBJ: Contains the surface model object files.

. UNDOBJ: Contains the underground model object files.

. UCVCO: Contains the equation coefficients required to run the underground model when conventional method has been selected.

- UCNCO: Contains the equation coefficients required to run the underground model when the continuous method has been selected.
- UCOST: Contains all costs required to run the underground model.
- $SSHT_L$: Contains the shovel and front loader costs.
- SDRCO: Contains the dragline costs
- ESHDSS: Contains the truck, drill, coal shovel, dozers, scrapers, and preparation plant costs.

It would also be necessary to restore some operational files like: ITEMS, MONITOR and EPRI, they were recorded after the files above described.

The CPU time to process a typical uncertainty process is aproximately .85 sec, and the virtual memory required for the same conditions is 51 pages for surface subsystem and 45 for underground subsystems.

All routines are written in Fortran 77 using the MTS compiler FORTRANVS (37). Each program was compiled separately and gathered in one object file per subsystem using the public program *OBJUTIL (38). In each of the object files there is a master program which conducts the whole system. Other public programs used by the system are *SLAM (39) to generate random values, and *IMSLLIB(40) to find the *t* value from t-distribution, when uncertainty analysis has been chosen.

It is noticeable that the public programs used by the model (starting with "*") belong to The University of Alberta and they are not included in the model's software.

The system is completly interactive and can run from any MTS terminal, however, when using a CRT conected directly to the computer (not through modem) the command %f(fast) can be used making the system very much faster. The reports are stored in a temporary file and the user can send it to the printer through a procedure which will be explained below.

II. Input Requirements

As mentioned before, the input parameters have been categorized into three types: Category 1 is the minimun amount of information necessary to run the model, tables 1 and 2 presents the requirements for this type of input. Category 2 parameters are automatically assigned by the default values when the program is initiated, Tables 3, 4 and 5 show the requirements for this kind of data. Category 3 parameters are calculated by the program based on the previous input and model formulation, unless otherwise specified by the user (see Tables 6 and 7 for requirements specifications.

During the input process, the user should keep in mind the following:

- If the portion of capital borrowed is zero, the debt servicing rate and length of loan payback must be zero also.
- The dollar equivalence parameter is a conversion factor for converting the US dollar to the Canadian dollar (e.g $0.8US = $1.0Can)
- Base year is only required for the constant dollar analysis .

- The escalation factor for coal value is only required for the escalating dollar option.
- The factors defined for the constant dollar analysis update the corresponding costs from the 1982 data base to the base year specified by the user. For the escalating dollar analysis, these values represent escalation factors which are applied to the appropiate cost for each year of the project.
- Coal value/tonne and rate of return are mutually exclusive parameters; only one parameter may be assigned by the user.
- Those parameters entered in term of mean and standard deviation will be randomized if the uncertainty option is selected, otherwise only the mean used in calculations. If any standard deviation is given a zero value, then this parameter will not be varied during the uncertainty analysis.

The following conditions should be considered during the optional input process:

- Royalty payments are expressed by either assigning a straight percentage over the annual revenue or by calculating this percentage through a special formula which applies to the province of Alberta. In this latter case, the user should enter a "1" in that field.
- When running the surface system option, the program selects the type of primary equipment to be used for overburden excavation as follows: Area, draglines; Open Pit, shovels and trucks; Contour, dozers and scrapers. Reclamation of spoil material assumes the usage of dozers and/or scrapers.
- All parameters in terms of mean and standard deviation will

be randomized if the uncertainty option is chosen, otherwise only the mean is considered

The parameters which override calculated values, are estimated first by the system and presented to the user who may alter them. If any of those parameters are changed; a second run of the system takes place overriding the corresponding calculations.

III. Data File Description

All files in the system contain unit costs except for EUCNCO and EUCVCO which contain equation factors to be used in underground submodel 1. The data base has been obtained from the original American EPRI model and updated to 1982. Therefore except for manpower costs, all costs are in US dollars which are internally converted to Canadian dollars using the dollar equivalence parameter. The access to all files is direct using the Fortran direct access mode.

The data files description for each file is detailed in Tables 8, 9, 10 and 11. There is another special kind of file also used by the system called ITEM. This is a file of characters which contains the cashflow item names; it is used by the cashflow printer routine and its length is 35 characters per record.

IV. Running Procedure

The system was designed to be self explanatory during the running time, therefore except for the input requirements presented in the second part of this appendix, the user only has to execute the following instruction.

SOURCE EPRI

This command activates the main program which prints a logo on the screen and asks for the type of system to be run (surface-surf or underground -under). After this the user only has to reply to the questions asked by the system. First the program starts with the required input, asking the value for each as presented below.

```
REQUIRED INPUT

     Depth of Seam (m) (mean, std dev)-------------------- 122,10
     Thickness of Seam (cm) (Mean, std dev)--------------- 300,30
     Seam Gradient (0,6)---------------------------------- 0
     Roof Conditions (good,poor)-------------------------- poor
     Floor Conditions (Hard-ha,Rutted-ru,Rutted wet-rw)--- ha
     Gas level (low,moderate-mod,high)-------------------- low
     Mining System (cont,conv,long)----------------------- cont
     Mine Entry (slope,shaft,drift)----------------------- shaft
     Annual Production (1000 tonnes)----------------------
```

When all required parameters have been entered, they are shown to the user who has the chance to modify any of them by entering the corresponding item number and value:

```
                    REQUIRED PARAMETER  VALUES

 1  Seam Depth (m)(Mean)          200    2  Seam Depth(m) (SD)              20
 3  Seam Thickn.(cm) (Mean)       160    4  Seam Thickn.(cm) (SD)           10
 5  Seam Gradient                   0    6  Roof Conditions               good
 7  Floor Conditions             ha      8  Gas Level                     low
 9  Mining System                cont   10  Entry Type                   slope
11  Annual Production (1000t)    1000   12  Production Life                 20
13  Analysis Type                 unc   14  First Calendar Year            tot
15  Dollar Analysis Type          con   16  Base Year                     1982
17  Labor Upd-Esc Factor            0   18  Power Upd/Esc Factor             0
19  Equip. Upd/Esc Factor           0   20  Haulage Upd/Esc Factor           0
21  Aux.Eq. Upd/Esc Factor          0   22  Supp.Mat. Upd/Esc Factor         0
23  Constr. Upd/Esc Factor          0   24  Capital Borrowed(%)             20
25  Debt Servicing Rate(%)         10   26  Loan Payback (years)            20
27   Dollar Eq.(CA$=X US$)       0.80   28  Coal Value/Tonne                50
29  Rate of Return                 17   30  Acqu. Cost (Mean)($000)       1000
31  Acqu. Cost (SD)($000)         100

  IF YOU WISH TO ALTER ANY VALUE, ENTER ITEM NUMBER, ELSE  99
```

Aft r the required input process has been completed, the optional input process starts by presenting each variable with its corresponding default value which can be modified if desired:

OPTIONAL INPUT VALUES

1	Mean Reject Percentage	25	2	SD Reject Percentage	3
3	Shifts per Day	2	4	Days per Year	211
5	Coal Preparation	crse	6	Seam Recovery	60
7	Mean Operator Eff.	85	8	SD Operator Eff.	4
9	Mean Available Face Time	340	10	SD Available Face Time	15
11	Indirect Capital (%)	10	12	Capital Overhead (%)	40
12	Fringe Benefits (%)	35	13	Royalty Payments (%)	1
14	Income Tax (%)	47	15	Depreciation Method	fast
16	Preprod. Treatment	def	17	Investment Tax Credit	5

IF YOU WISH TO ALTER ANY VALUE, ENTER ITEM NUMBER, ELSE 99

If the user has chosen the uncertainty analysis the following optional input will be processed:

DEFAULT PARAMETERS FOR UNCERTAINTY

1	Distribution for Physical Parameters	norm
2	Distribution for Operational Parameters	logn
3	Distribution for finantial Parameters	tria
4	Max. Lim. for Triag. Distrib. (%) (0=SD)	10
5	Min. Lim. for Triag. Distrib. (%) (0=SD)	10
6	Max. Lim. for Unifr. Distrib. (%) (0=SD)	10
7	Min. Lim. for Unifr. Distrib. (%) (0=SD)	10
8	Number of Iterations	5
9	Equip. Cost Range (low,high,tot)	tot
10	Construc. Cost Range(low,high,tot)	tot
11	Operating Cost Range(low,high,tot)	tot
12	Seed Number for NORMAL	939291
13	Seed Number for LOGN	654321
14	Seed Number for UNFRM	321456
15	Seed Number for TRIAG	818283

IF YOU WISH TO ALTER ANY VALUE, ENTER ITEM NUMBER, ELSE 99

The third input process step is the parameters which override calculated values, for which the system executes a run of each submodel and presents the corresponding values that have been just calculated based on the parameters defined for the two first steps; then the user can either accept or modify them:

PARAMETERS WHICH OVERRIDE CALCULATED VALUES

1	Tonnes/Machine Shift	412	2	Production Sections/Shift	8
3	Hourly Labor Requirements	255	4	Salaried Personnel Req.	49
5	Development Time(Yrs)	2.60	6	Coal Prod. During Dvlpment	671611
7	Production Equipment Life	12	8	Haulage System Life	12
9	Aux. Equipment Life	12	10	Hourly Labor Cost/Yr	7376
11	Salaried Pers. Cost/Yr	1690	12	Supp.& Material Cost/t	11.55
12	Power Cost/t	1.12	13	Annual Operating Cost	28798
14	Initial Prod. Section Cos	10256	15	Initial Aux. Equipment Cost	4653
16	Initial Hlage System Cost	4438	17	Plant & Unit Train Loading	5424
18	Exploration Cost	711	19	Mine Abandonment Cost	379

IF YOU WISH TO ALTER ANY VALUE, ENTER ITEM NUMBER, ELSE 99

When input processes are finished, the modelling process begins by presenting on the screen the input parameters which define the process, each submodel output and the main summary results. During the time of the process, the user makes no intervention other than pressing the key RETURN. When the run is over, the user may either restart the process again or leave it. The reports are retained in a temporary file called -OUT and to print it the user has two options:

- Reassign the temporary file to a permanent file, and later if he wishes, to list it in a teletype terminal.
- Send it to the Xerox printer using the following commands:

```
CONTROL *PRINT* FORMAT=FMTL1 PRINTON=ONESIDE
COPY -OUT TO *PRINT*
RELEASE *PRINT*
```

Table H.1

REQUIRED INPUT PARAMETER

	Data type	Valid Range	Notes
Seam Depth (m)	I	> 0	Mean, SD
Seam Thickn.(cm)	I	> 0	Mean, SD
Seam Gradient	I	0, 6	
Roof Conditions	A	good, poor	
Floor Conditions	A	ha, ru, rw	ha: Hard ru: Rutted rw: Rutted wet
Gas Level	A	low, mod, high	mod: Moderate
Mining System	A	cont, conv, long	cont: Continuous conv: Conventional long: Long wall
Entry Type	A	slope,shaft,drift	
Annual Production (t)	I	> 0	
Production Life	I	1-30	
Analysis Type	A	pv, unc	pv: Point value unc: Uncertainty analysis
First Calendar Year	I	> 1982	
Dollar Analysis Type	A	con, esc	con: Constant dollar esc: Escalating dollar
Base Year	I		
Labor Upd-Esc Factor	I	0-100	
Power Upd/Esc Factor	I	0-100	
Equip. Upd/Esc Factor	I	0-100	
Haulage Upd/Esc Factor	I	0-100	
Aux.Eq. Upd/Esc Factor	I	0-100	
Supp-Mat Upd/Esc Factor	I	0-100	
Constr. Upd/Esc Factor	I	0-100	
Capital Borrowed (%)	I	0-100	
Debt Servicing Rate(%)	I	0-100	
Loan Payback (Years)	I	0-30	
Dollar Eq.(CA$=X US$)	R	> 0	
Coal Value/tonne	I	> 0	
Rate of Return	I	0-100	
Acqu. Cost	I	> 0	Mean, SD

Table H.2

INPUT REQUIRED PARAMETERS

	Daya Type	Valid Range	Notes
Seam Thicks. (cm)	I	>0	Mean, SD
Overbdn Thicks.(m)	I	>0	Mean, SD
Topsoil Thicks.(cm)	I	0-Ov. Thicks.	Mean, SD
Mining System	A	area,open,cont	area: Sttrip mining open: Open Pit cont: Contour
Annual Production (t)	I	>0	
Mine Life (years)	I	1-30	
% Capital Borrowed	I	0-100	
Debt Servicing Rate(%)	I	0-100	
Loan Paybk Period(Yrs)	I	1-30	
Acquisition Cost/sq. m	I	0-5	Mean, SD
Dollar Equivalence	R	>0	
Project Start Year	I	>1982	
Type of Analysis	A	pv, unc	pv: Point value unc: Uncertainty analysis
Dollar Type Analysis	A	con, esc	con: Constant dollar esc: Escalating dollar
Base Year	I	>1982	
Labor Upd/Esc Factor	I	0-100	
Prim. Eq. Upd/Esc Factos	I	0-100	
Supp. Eq. Upd/Esc Factor	I	0-100	
Operating Upd/Esc Factor	I	0-100	
Construc. Upd/Esc Factor	I	0-100	
Coal Valus Esc. Factor	I	0-100	
Coal Value/tonne	I	>0	
Rate of Return	I	0-100	

Table H.3

OPTIONAL INPUT PARAMETERS

	Data Type	Valid Range	Notes
Mean Reject Percentage	I	0-100 (25)	Mean, SD
Shifts per Day	I	1-3 (2)	
Days per year	I	1-365 (226)	
Coal Preparation	A	ther,meta,none none	ther: Thermal meta: Metallurgical Default: ther
Percentage of Fines	I	>0	
Seam Recovery	I	0-100 (60)	
Operator Efficiency.	I	0-100 (85)	Mean, SD
Available Face Time	I	0-1000 (340)	Mean, SD
Indirect Capital (%)	I	0-100 (10)	
Capital Overhead(%)	I	0-100 (40)	
Fringe Benefits (%)	I	0-100(35)	
Royalty Payments(%)	I	0-100	
Income Tax (%)	I	0-100	
Depreciation Method	A	fast,deba,strg	fast: Accelerated deba: Declaning balance strg: Straight line Default: fast
Cost Treatment	A	def, exp	def: Deferred exp: Expensed Default: def
Investment Tax Credit(%)	I	0-100(5)	

Table H.4

OPTIONAL PARAMETERS

	Data Type	Valid Range	Notes
Reject (%)	I	0-100(20)	
Recovery (%)	I	0-100(90)	Mean, SD
Dilution (%)	I	0-100(8)	
Coal Type	A	bitu, lign	bitu: Bituminous lign: Lignite Default: bitu
Exploration Required (sq. m)	I	>0 (161874)	
Coal Density (k/cu.m)	I	>0(1459)	
Coal Preparation	A	ther,meta,none none	ther: thermal meta: metallurgical Default: ther
Percentage of Fines	I	>0	
Drilling Ovbdn (Work.Pl)	I	>0(1)	
Overburden Consolidation	A	low,mod,high	mod: Moderate Default: mod
Coal Loading Op. hrs/Mo	I	0-744(336)	
Coal Load Cy. Time(s)	I	>0 (75)	Mean, SD
Bucket Fill Factor	I	>0(75)	
# of Loading Passes	I	>0 (7)	
Mean Truck Travel Time Ld(s)	I	>0 (800)	Mean, SD
Mean Trk Trvl Time Emp(s)	I	>0 (480)	Mean, SD
Mean Other Times(s)	I	>0 (200)	Mean, SD
OVERBURDEN EXCAVATION (Area Mine)			
Shifts per day	I	1-3 (2)	
Operator Efficiency	I	0-100(75)	Mean, SD
Bucket Fill Factor	I	0-100(80)	Mean, SD
Operating Hour/Month	I	0-744(720)	
Mean Cycle Time(s)	I	>0 (60)	
OVERBURDEN RECLAMATION (Area Mine)			
Mean Width of Pit(m)	I	0-300 (31)	Mean, SD
Angle of Spoil	I	0-369 (36)	
Operating Hours/Month	I	0-744 (350)	
Overbdn Swell Factor	I	0-100 (25)	
Dozer Blade Cap.(Cu. m)	I	3-18 (15)	
Operator Efficiency (%)	I	0-100 (75)	Mean, SD
Material Factor (%)	I	0-100 (80)	

Table H.4 (cont)

TOPSOIL HANDLING (Area and Open Pit)

	Data Type	Valid Range	Notes
Scraper Capacity(cu m)	I	10-25 (18)	
Loading Time(s)	I	>0 (50)	Mean, SD
Maneuver-Spread Time(s)	I	>0 (42)	Mean, SD
Travel Time Loaded(s)	I	>0 (410)	Mean, SD
Travel Time Empty(s)	I	>0 (246)	Mean, SD
Operating Hours/Month	I	0-744(335)	
Mean Operator Efficiency	I	0-100(75)	Mean, SD

FINANCIAL PARAMETERS

	Data Type	Valid Range	Notes
Fringe Benefits(%)	I	0-100 (35)	
Labor Overhead(%)	I	0-100 (40)	
Royalty Payments	I	0-100 (1)	
Investment Tax Credit	I	0-100 (5)	
Income Tax(%)	I	0-100 (47)	
Depreciation Method	A	fast,strg,deba	fast: Accelerated strg:Straight deba: Declaning Balance Default: fast
Dragline Depreciable Life	I	0-30 (20)	
Dragline Bucket Depreciable Life	I	0-30 (10)	
Ovbdn Shovel Deprec. Life	I	0-30 (20)	
Shovel Bucket Depreciable Life	I	0-30 (5)	
Ovbdn Trucks Deprec. Life	I	0-30 (10)	
Dozers-Scraper Depreciable Life	I	0-30 (5)	
Drills Depreciable Life	I	0-30 (10)	
Coal Shovel Depreciable Life	I	0-30 (20)	
Front End Deprec. Life	I	0-30 (5)	
Coal Trucks Depreciable Life	I	0-30 (10)	
Recl.Dz-Scr Deprec. Life	I	0-30 (5)	
Cost Treatment	A	def,exp	def: Deferred exp: Expensed Default: def
Indirect Capital(%)	I	0-100 (15)	
Dragline Salvage Value	I	0-100 (0)	
Shovels Salvage Value(%)	I	0-100 (0)	
10 Years Equip. Salvage Value	I	0-100 (10)	
5 Yrs Eq. Slvge Value(%)	I	0-100 (10)	
Drillig Cost/m	I	>0 (66)	

Table H.5

DEFAULT PARAMETERS FOR UNCERTAINTY

	Data Type	Valid Range	Notes
Distrib. for Physical Parm.	A	Norm, logn, unfr	norm: Normal logn: Log Normal unfr: Uniform Default: Normal
Distr. for Operational Data	A	norm, logn, unfr	Default: logn
Distrib. for finantial Data	A	tria, norm	tria: Triangular Default: tria
Max. Lim. for Triag. Distr.	I	0-100 (10)	
Max. Lim. for Unifr. Distr.	I	0-100 (10)	
Number of Iterations	I	> 1 (10)	
Equip. Cost Range	A	low, high, tot	tot: Total Default: tot
Construc. Cost Range	A	low, high, tot	Default: tot
Operating Cost Range	A	low, high, tot	
Number seed for NORMAL	I	> 0 (939291)	
Number seed for LOGN	I	> 0 (654321)	
Number seed for UNFRM	I	> 0 (321556)	
Number seed for TRIA	I	> 0 (818283)	

Table H.6

PARAMETERS WHICH OVERRIDE CALCULATED

	Data Type	Valid Range	Notes
Tonnes/Machine Shift	I	> 0	
Productio Sections/Shift	I	1-12	
Hourly Labor Requirements	I	> 0	
Salaried Personnel Req.	I	> 0	
Development Time(Yrs)	R	1-10	
Coal Produced During Develop.	I	>0	
Production Equipment Life	I	1-20	
Haulage System Life	I	1-20	
Aux. Equipment Life	I	1-20	
Hourly Cost/Year	I	> 0	
Salaried Pers. Cost/Yr	I	> 0	
Supplies-Materials Cost/Year	I	> 0	
Power Cost/t	R	> 0	
Annual Operating Costs	I	> 0	
Initial Prod. Section Cos	I	> 0	
Auxiliary Equipment Cost	I	> 0	
Initial Hlage System Cost	I	> 0	
Prep. Plant Cost	I	> 0	
Exploration Cost	I	> 0	
Mine Abandonment Cost	I	> 0	
Mine Entry Construction Cost	I	> 0	

Table H.7

PARAMETERS WHICH OVERRIDE CALCULATION

	Data Type	Valid Range	Notes
Land Requirements (SQ. M.)	I	>0	
Total Hourly Personnel	I	>0	
Total Salaried Personnel	I	>0	
Explor. and Develop. Drilling Cost	I	>0	
Supplies and Materials Cost	I	>0	
Support Capital (%)	I	0-100	
Total Annual Operating Cost	I	>0	
Total Preprod. Develop. Cost	I	>0	
Preparation Plant Cost	I	>0	

Table H.8

EQUATION COEFFICIENTS FILES (EUCNCO and EUCVCO) DATA DESCRIPTION

Unit Number : 2 (EUCNCO) and 3(EUCVCO)
User Program : EU.SUB1

Field	Data Type	Length	Field Description
1	I	1	Roof Conditions
2	I	1	Floor Conditions
3	I	1	Gas Level
4	I	1	Seam Gradient
5	R	7.3	A Coefficient
6	R	7.3	B Coefficient
7	R	7.3	C Coefficient

Table H.9

UNDERGROUND UNIT COSTS FILE (EUCOST) DATA DESCRIPTION

Unit Number : 7
User Program : EU.SUB2 and EU.SUB3

Field	Data Type	Length	Field Description
1	A	15	Cost Description
2	I	3	Equipment Cap.
3	I	6	Mean Cost
4	I	5	SD Cost

Table H.9

SHOVEL AND FRONT LOADER COST FILE (ESSHTL) DATA DESCRIPTION

Unit Number : 8
User Program : ES.SUB1

Field	Data Type	Length	Description
1	R	6.1	Mean Cost($000)
2	R	5.1	SD Cost($000)

Table H.10

DRAGLINE COSTS FILE(ESDRCO) DATA DESCRIPTION

Unit Number : 7
User Program : ES.SUB1

Field	Data Type	Length	Description
1	R	5.2	Mean Cost($000000)
1	R	3.2	SD Cost ($000000)

Table H.11

OTHER UNIT COSTS FILE (ESHDSS) DATA DESCRIPTION

Unit Number : 9
User program : ES.SUB1 and ES.SUB3

Field	Data Type	Length	Description
1	A	10	Cost description
2	I	4	Equipment Cap.
3	R	6.1	Mean Cost($000)
4	R	4.1	SD Cost ($000)