

1998

A dragline simulation model for strip mine design and development

Hamid Mirabediny
University of Wollongong

Follow this and additional works at: <https://ro.uow.edu.au/theses>

University of Wollongong

Copyright Warning

You may print or download ONE copy of this document for the purpose of your own research or study. The University does not authorise you to copy, communicate or otherwise make available electronically to any other person any copyright material contained on this site.

You are reminded of the following: This work is copyright. Apart from any use permitted under the Copyright Act 1968, no part of this work may be reproduced by any process, nor may any other exclusive right be exercised, without the permission of the author. Copyright owners are entitled to take legal action against persons who infringe their copyright. A reproduction of material that is protected by copyright may be a copyright infringement. A court may impose penalties and award damages in relation to offences and infringements relating to copyright material.

Higher penalties may apply, and higher damages may be awarded, for offences and infringements involving the conversion of material into digital or electronic form.

Unless otherwise indicated, the views expressed in this thesis are those of the author and do not necessarily represent the views of the University of Wollongong.

Recommended Citation

Mirabediny, Hamid, A dragline simulation model for strip mine design and development, Doctor of Philosophy thesis, Department of Civil and Mining Engineering - Faculty of Engineering, University of Wollongong, 1998. <https://ro.uow.edu.au/theses/1219>

University of Wollongong Thesis Collections

University of Wollongong Thesis Collection

University of Wollongong

Year 1998

A dragline simulation model for strip mine design and development

Hamid Mirabediny
University of Wollongong

Mirabediny, Hamid, A dragline simulation model for strip mine design and development, Doctor of Philosophy thesis, Department of Civil and Mining Engineering - Faculty of Engineering, University of Wollongong, 1998. <http://ro.uow.edu.au/theses/1219>

This paper is posted at Research Online.

NOTE

This online version of the thesis may have different page formatting and pagination from the paper copy held in the University of Wollongong Library.

UNIVERSITY OF WOLLONGONG

COPYRIGHT WARNING

You may print or download ONE copy of this document for the purpose of your own research or study. The University does not authorise you to copy, communicate or otherwise make available electronically to any other person any copyright material contained on this site. You are reminded of the following:

Copyright owners are entitled to take legal action against persons who infringe their copyright. A reproduction of material that is protected by copyright may be a copyright infringement. A court may impose penalties and award damages in relation to offences and infringements relating to copyright material. Higher penalties may apply, and higher damages may be awarded, for offences and infringements involving the conversion of material into digital or electronic form.

A DRAGLINE SIMULATION MODEL FOR STRIP MINE DESIGN AND DEVELOPMENT

A thesis submitted in fulfilment of the
requirement for the award of the degree

Doctor of Philosophy

from

University of Wollongong



by

HAMID MIRABEDINY

(B.Sc., M.Sc. Mining Engineering)

Department of Civil and Mining Engineering

March 1998

IN THE NAME OF GOD

This thesis is dedicated to my dear *family*
and my dear *parents*

for their love and patience



AFFIRMATION

The work as presented in this thesis is an authentic record to the best of my own knowledge and belief and it is based on the work carried out in the Department of Civil and Mining Engineering at University of Wollongong. I hereby certify that this thesis contains no material which I have submitted, in whole or in part, for a degree at this or any other institution. The following publications have been based on this thesis:

Baafi, E.Y., **Mirabediny, H.** and Whitchurch, K., (1995), "*A Simulation Model for Selecting Suitable Digging Method for a Dragline Operation*", 25th International Symposium on the Application of Computers and Operations Research in the Mineral Industry, The Australasian Institute of Mining and Metallurgy, QLD, pp: 345-348.

Baafi, E.Y., **Mirabediny, H.** and Whitchurch, K., (1995), "*A Dragline Simulation Model for Complex Multi-Seam Operations*", Mine Planning and Equipment Selection 95, Singhal et al (eds.), A. A. Balkema, Rotterdam, pp: 9-14.

Mirabediny, H., (1995), "*Dragline Simulation: Case Studies*", ECS's Users Annual Conference, Published Internally, Bowral, NSW. pp: 8-15.

Mirabediny, H. and Baafi, E.Y., (1996). "*Effect of Operating Technique on the Dragline Performance: A Monitoring Data Analysis*", Mining Science and Technology, Geo, Y. and Golosinski, T. S. (eds.), A. A. Balkema, Rotterdam, pp: 479-485.

Mirabediny, H., (1996), "*The Use of Monitoring Data in Conjunction with Dragline Simulation*", ECS's Users Annual Conference, Published Internally, Bowral, NSW. pp: 17-24.

Baafi, E.Y., **Mirabediny, H.** and Whitchurch, K., (1997), "*Simulation of Dragline Operations*", International Journal of Surface Mining and Reclamation, No. 11 (March 97), pp: 7-13.

Mirabediny, H. and Baafi, E.Y (1998), "*Dragline Digging Methods in Australian Strip Mines: A Survey*", First Australasian Coal Operators Conference (COAL98) , Wollongong, NSW).

Mirabediny, H. and Baafi, E.Y. (1998), "*Statistical Analysis of Dragline Monitoring Data*", (Accepted for presentation at 28th International Symposium on the Application of Computers and Operations Research in the Mineral Industry, London).

HAMID MIRABEDINY

ACKNOWLEDGMENT

I would like to express my sincere gratitude to all persons who contributed to the success of this project. Most importantly to my supervisor Associate Professor E Y Baafi for his continuous support, guidance and inspiration provided during the course of this study and for his constructive critical review of all aspects of the thesis.

I gratefully acknowledge the support, hospitality and assistance provided by Associate Professor R N Chowdhury, Head of the Department, and the staff of the Department of Civil and Mining Engineering. In addition, I wish to express my deep appreciation to Dr J Shonhardt for his helpful comments and proof reading of the thesis and Mr P Turner for his assistance during the preparation of the thesis.

A very special acknowledgment is due to all staff of ECS International Pty Ltd. of Bowral, particularly to Mr J Barber, Mr A Cram, Mr K Whitchurch, Mr R De-Jongh and Mr B Smedley for their helpful support, encouragement, assistance and providing access to their MINEX software and their computer facilities.

My grateful appreciation is also extended to managers and staff of Bulga Coal, Warkworth Mining, Callide Coalfields and Shell Australia in NSW and QLD, particularly to Mr D Wilford, Mr R Tochowicz, Mr G Mackenzie, Mr E Crawford and Mr R Broadley for providing permission to visit their operations and providing to access their geological and dragline monitoring data.

The assistance and financial support provided by the Ministry of Culture and Higher Education of the Iranian government for sponsorship throughout the period of this project is deeply appreciated. Last, but not the least, I sincerely thank and appreciate my wife Parvin Niknafs, my daughter Yasaman and my new born son Matin, who accepted all pains and strain to make me free to do the work. I also wish to thank my parents and members of my family in Iran for their patience and continuous encouragement throughout the stay in Australia.

ABSTRACT

During recent years, the Australian coal industry has increasingly used large walking draglines as the dominant waste removal equipment in open cut coal mines. Because of the nature of the coal formations, dragline operations in Australian coal mining situations are quite complex and draglines are frequently used in applications beyond their normal capabilities. With the current trend to increasing dragline sizes in most of the Australian coal mines, the draglines become the highest capital investment item in these mines. It is therefore necessary to give detailed attention to the optimising operating procedures of the dragline.

Dragline productivity and its stripping capabilities are directly affected by the selection of digging method, strip layout and pit geometry. Every mine has a unique combination of geological conditions. The operating methods that work well at one mine may not necessarily work at another site. Selection of an optimal stripping method, strip layout and pit geometry for a given dragline must be considered with respect to the geological conditions of the mines. With increasing geological complexity of Australian strip mines, it is becoming more important to use sophisticated techniques such as computerised mine planning methods to assist in optimising the dragline operations.

A computerised dragline simulation model (CADSIM) has been developed for use in selection of optimum strategies for a dragline operation. The procedure developed links with a geological ore body model to develop a geological database for simulation. CADSIM model can be used in selection the most cost effective dragline digging method. A specific simulation language, "DSLX", was used to program seven common and innovative dragline methods currently used in Australian open cut mines. The DSLX language uses predefined functions to build strip geometry, working benches, blast profiles and spoil piles. The outputs from CADSIM model in form of volumetric, swing angles and hoist distances data were then aggregated with dragline specifications and site time study data to compare productivity and costs of the selected digging methods. The results of two case studies showed that this procedure lends itself to the "optimum" solution for dragline mine planning and design problems for a given coal deposit.

TABLE OF CONTENTS

AFFIRMATION	i
ACKNOWLEDGMENT	ii
ABSTRACT	iii
TABLE OF CONTENTS	iv
LIST OF FIGURES	ix
LIST OF TABLES	xv
LIST OF SYMBOLS AND ABBREVIATIONS	xvii

CHAPTER ONE: GENERAL INTRODUCTION

1.1 GENERAL.....	1-1
1.2 STATEMENT OF THE PROBLEM.....	1-2
1.2.1 Development of a Database for Digging Methods	1-4
1.3 OBJECTIVES OF THE THESIS	1-15

CHAPTER TWO: OVERBURDEN REMOVAL WITH A DRAGLINE

2.1 INTRODUCTION	2-1
2.2 DRAGLINE DIGGING OPTIONS	2-2
2.3 DRAGLINE DIGGING METHODS.....	2-5
2.3.1 Simple Side Casting Method.....	2-5
2.3.2 Standard Extended Bench Method	2-7
2.3.3 Split Bench (Deep Prestrip Method)	2-9
2.3.4 Lowwall In-Pit Bench Method	2-10
2.3.5 Extended Key Cut Method	2-12
2.3.6 Multi-Pass Extended Key cut.....	2-13
2.3.7 Multi Seam Operations.....	2-15
2.4 BLASTING FOR THE DRAGLINE.....	2-18
2.4.1 Throw Blasting	2-19
2.5 SUMMARY	2-23

CHAPTER THREE: STRIP MINE PLANNING AND DESIGN

3.1 INTRODUCTION	3-1
3.2 STRIP MINE PLANNING	3-3
3.3 ELEMENTS OF STRIP MINE DESIGN	3-5
3.3.1 Assessment of Mining Boundary and Limits	3-5
3.3.2 Pit Layout and Orientation	3-8
3.3.3 Dragline Size Selection	3-10
3.4 COMPUTERISED DRAGLINE MINE PLANNING SYSTEMS	3-15
3.4.1 Computerised Dragline Simulators	3-15
3.4.2 Commercial Dragline Simulation Software	3-19
3.4.3 Blasting Computer Modelling	3-25
3.5 SUMMARY	3-26

CHAPTER FOUR: DEVELOPMENT OF A DRAGLINE SIMULATION MODEL

4.1 INTRODUCTION	4-1
4.2 CADSIM MODELLING APPROACH	4-2
4.2.1 Dragline Simulation with DSLX	4-5
4.2.2 An Example of a Macro in DSLX language	4-8
4.2.3 Simulation of Dragline Digging Methods in CADSIM	4-10
4.2.4 Using the CADSIM Model as a Strip Mine Planning Tool	4-12
4.3 SUMMARY	4-13

CHAPTER FIVE: DEVELOPMENT OF A GEOLOGICAL DATABASE

5.1 INTRODUCTION	5-1
5.2 GEOLOGICAL MODELLING	5-2
5.2.1 Geological Modelling Techniques	5-2
5.2.2 Gridded Seam Model	5-5
5.3 DEVELOPMENT OF A GEOLOGICAL DATABASE	5-9
5.3.1 Generation of Grids in the Geological Model	5-10
5.3.2 Definition of Sections	5-14
5.3.3 Creating Output Files from the Geological Model	5-15
5.3.4 Definition of Strip Layout	5-20
5.3.5 Width of Influence	5-20
5.4 SUMMARY	5-22

CHAPTER SIX: SIMULATION OF THE DRAGLINE OPERATIONS

6.1 INTRODUCTION	6-1
6.2 ELEMENTS OF DRAGLINE SIMULATION MODEL	6-2
6.2.1 Initial Pit Design.....	6-2
6.2.2 Dragline Positions	6-3
6.2.3 Volumetric Calculation of the Cut Units.....	6-6
6.2.4 Spoiling Calculations	6-10
6.2.5 Swing Angle and Hoist Calculations.....	6-12
6.2.6 Design of Coal Haulage Ramps	6-14
6.2.7 Design of Curvature Strips	6-15
6.2.8 Walking Grade Control Between Mining Blocks	6-17
6.2.9 Design of Post Blasting Profiles.....	6-19
6.3 THE CADSIM DRAGLINE SIMULATOR	6-22
6.3.1 Running a Simulation.....	6-24
6.3.2 User Inputs and Simulation Outputs	6-25
6.3.3 Final Design and 3D View of the Simulated Pit	6-29
6.4 SUMMARY	6-31

CHAPTER SEVEN: DRAGLINE PERFORMANCE ANALYSIS

7.1 INTRODUCTION	7-1
7.2 DRAGLINE MONITORING SYSTEM	7-2
7.2.1 Cycle Time Components	7-4
7.3 ANALYSIS OF FIELD DATA	7-6
7.3.1 Descriptive Statistics	7-7
7.3.2 Frequency Histograms and Best Fit Analysis.....	7-9
7.3.3 Correlation.....	7-12
7.4 SUMMARY	7-17

CHAPTER EIGHT: DRAGLINE PRODUCTIVITY AND COST ANALYSIS

8.1 INTRODUCTION	8-1
8.2 PRODUCTIVITY ANALYSIS	8-2
8.2.1 Definition of Various Productivity Terms.....	8-2
8.2.2 Prime and Total Productivity Calculation	8-3
8.2.3 Block by Block Productivity Calculation.....	8-6

8.2.4 Strip by Strip Productivity Calculation	8-8
8.2.5 Annual Productivity Calculation	8-9
8.2.6 Sensitivity Analysis	8-14
8.3 STOCHASTIC (RISK) ANALYSIS	8-15
8.3.2 Case Study Stochastic Analysis.....	8-18
8.4 COST ANALYSIS	8-24
8.4.1 Capital Costs	8-25
8.4.2 Operating Costs	8-26
8.4.3 Blasting and Major Equipment Cost Calculation.....	8-31
8.4.4 Discounted Average Cost Method	8-33

CHAPTER NINE: VALIDATION OF THE CADSIM MODEL

9.1 INTRODUCTION	9-1
9.2 MODEL VALIDATION	9-1
9.2.1 Manual Technique.....	9-2
9.2.2 Comparison with DAAPA3	9-2
9.2.3 Comparison with Actual Data	9-6
9.3 SUMMARY	9-13

CHAPTER TEN: APPLICATIONS OF THE CADSIM MODEL

10.1 INTRODUCTION	10-1
10.2 CASE STUDY 1.....	10-2
10.2.1 Geology of the Deposit.....	10-2
10.2.2 Surface Mining Layout.....	10-4
10.2.3 Dragline Digging Methods	10-5
10.2.4 Simulation Results	10-10
10.2.5 Dragline Productivity Calculation	10-20
10.2.6 Comparison of the Digging Methods	10-23
10.3 CASE STUDY 2.....	10-27
10.3.1 Geology of the Deposit.....	10-28
10.3.2 Mining Layout	10-29
10.3.3 Dragline Digging Method.....	10-30
10.3.4 Dragline Pit Optimisation.....	10-33
10.3.5 Detailed Simulation Results for the Optimised Pit	10-42
10.4 SUMMARY	10-48

CHAPTER ELEVEN: SUMMARY AND CONCLUSIONS

11.1 SUMMARY 11-1

11.2 CONCLUSIONS 11-6

11.3 RECOMMENDATIONS FOR FURTHER STUDIES 11-9

REFERENCES

APPENDIX A: DSLX’S LANGUAGE SYNTAXES AND FUNCTIONS

A.1 VARIABLES IN DSLXA-1

 A.1.1 Declaration of Variables..... A-4

A.2 DSLX'S LANGUAGE FUNCTIONS.....A-6

 A.2.1 Read and Write Functions A-6

 A.2.2 Points Operational Functions A-9

 A.2.3 String Functions A-11

 A.2.4 Drawing Functions A-16

APPENDIX B: LIST OF COMPUTER PROGRAMS

APPENDIX C: EXAMPLES OF THE OUTPUT REPORTS

C.1 GENERAL REPORT FILEC-2

C.2 DIG LEVELS REPORT FILEC-3

C.3 COAL AND PARTING VOLUMES REPORTC-4

C.4 REHANDLE REPORT.....C-5

C.5 DETAILED REPORTC-6

**APPENDIX D: FREQUENCY HISTOGRAMS OF THE PERFORMANCE
PARAMETERS AND BEST FIT RESULTS**

APPENDIX E: PIT OPTIMISATION OF THE VALIDATION CASE STUDY

LIST OF FIGURES

Figure	Page
1.1- Comparison of coal production by principal mining method in NSW.....	1-2
1.2- Dragline digging methods used by most of Australian open cut coal mines	1-11
1.3- Increases in the dragline size over the last two decades.....	1-13
1.4- A schematic of the modelling approach	1-17
2.1- Dragline excavating a key cut in a normal underhand mode	2-2
2.2- Dragline removing an advance bench in an overhand chopping mode	2-3
2.3- Dragline pulling back material by chopping against the highwall from a spoil side pad.....	2-4
2.4- Plan and section view of a Simple Side Casting method	2-6
2.5- General view of a standard Extended Bench method combined with a thrown blasting technique.....	2-8
2.6- A typical cross section of the Split Bench dragline digging method.....	2-10
2.7- A general view of the Lowwall In-Pit Bench chop cut method	2-11
2.8- A general view of the Extended Key Cut method.....	2-13
2.9- Sequence used to complete a Multi-Pass Extended Key Cut.....	2-14
2.10- Three seam operation, Single Highwall and Double Lowwall method.....	2-16
2.11- Three seam operation, Double Highwall and Single Lowwall method.....	2-17
2.12- An example of the throw blasting technique used for a dragline pit.....	2-20
2.13- Details of a throw blasting technique	2-20
3.1- A general view of a multi-seam strip mine in Hunter Valley, NSW.....	3-2
3.2- The mine planning process.....	3-3
3.3- Concepts used to develop a stripping ratio grid	3-7
3.4- A stripping ratio map.....	3-8
3.5- Dragline effective reach calculation for a Simple Side Casting method	3-12
3.6- Dragline standard machine selection chart.....	3-14
3.7- A sample 2D range diagram output of <i>DAAPA</i> (V-3.1).....	3-20
3.8- A sample 2D range diagram output of <i>DRGX</i>	3-22
3.9- A sample 2D range diagram output of <i>Dragline</i>	3-23
3.10- A 3D view of a simulated pit created by <i>3D DIG</i> software	3-24
4.1- The modelling flow diagram for the <i>CADSIM</i> system	4-2

4.2-	Concepts of the "PNTINTS" function	4-6
4.3-	Concepts of the " VOLCOMP " function	4-7
4.4-	Points and strings used to construct the dragline pit for the example	4-8
4.5-	Relationship of the main program and subroutines in the EXTBENCH module of the CADSIM model	4-11
5.1-	A regular set of 3D blocks used to model a deposit.....	5-3
5.2-	An example of a Cross-sectional model.....	5-4
5.3-	An example of a String model.....	5-5
5.4-	Grid modelling of a topography surface from borehole collars	5-8
5.5-	Example of intersecting sections and girded surfaces	5-10
5.6-	Triangulating a seam floor surface using borehole data.....	5-13
5.7-	Converting the triangulated surface of the seam floor to a 2D grid	5-13
5.8-	Concepts of the merged grids.....	5-14
5.9-	Plan view of the radial and parallel sections	5-15
5.10-	Generation of the access ramp strings	5-18
5.11-	Creating the RAMP grid by triangulation of the digitised ramp strings	5-19
5.12-	Merging grids to generate final reference surface	5-19
5.13-	Concepts used for sampling band for different types of sections.....	5-21
6.1-	Subdivision of the mining blocks.....	6-4
6.2-	Concepts used to locate a dragline position	6-5
6.3-	Calculation of the dragline walking pattern	6-5
6.4-	Intersecting two open strings (STR1 and STR2) to generate a closed string (STR3).....	6-7
6.5-	Area calculation for a polygon using coordinates	6-8
6.6-	Calculation of centroid point of an area	6-9
6.7-	Planes used to form a key cut.....	6-10
6.8-	Creating a dragline pad using spoiling slices	6-11
6.9-	Arguments used in "SPOIL" function	6-12
6.10-	Concepts used for the swing angle calculation.....	6-13
6.11-	Effect of permit surface on the available spoil room in vicinity of a ramp...6-16	
6.12-	Effect of pit curvature on volume inside and outside the curve	6-17
6.13-	An example of a simulated post blasting profile.....	6-20

6.14-	A post blasting profile	6-21
6.15-	The general flowchart of the computer programs developed in the CADSIM model.....	6-23
6.16-	The use of the old highwall toe as the starting point for pit design.....	6-25
6.17-	Cross-section view of simulation for a two highwall pass operation.....	6-29
6.18-	The 3D view of all the spoil strings generated in the simulated sections.....	6-30
6.19-	Output gridded surface of the simulated area, created from spoil strings	6-30
6.20-	A 3D view of the dragline simulation for the entire sections.....	6-31
7.1-	A general block diagram of a Dragline Monitoring System.....	7-3
7.2-	On-board equipment of a Tritronics 9000 dragline monitoring system	7-4
7.3-	Comparison of the dragline mean performance parameters	7-8
7.4-	Histograms of the performance parameters and best fit results	7-10
7.5-	Scatter plot of swing time vs swing angle for the entire data set on highwall side	7-12
7.6-	Scatter plot of swing time vs swing angle for the entire data set on lowwall side	7-13
7.7-	Scatter plot of swing time vs swing angle for swings > 40° on highwall side	7-13
7.8-	Scatter plot of swing time vs swing angle for swings < 40° on highwall side	7-14
7.9-	Scatter plot of swing time vs swing angle for swings > 40° on lowwall side	7-14
7.10-	Scatter plot of swing time vs swing angle for swings < 40° on lowwall side	7-14
7.11-	Scatter plot of filling time vs filling depth for the highwall side	7-16
7.12-	Scatter plot of dump time vs dump height for the highwall side	7-16
7.13-	Scatter plot of filling time vs filling depth for the lowwall side	7-16
7.14-	Scatter plot of dump time vs dump height for the lowwall side.....	7-17
8.1-	A generic flowchart for the stochastic analysis of productivity	8-16
8.2-	Effect of number of simulation replications on the convergence coefficient	8-18
8.3-	Probability histograms of simulation results for annual prime productivity	8-19
8.4-	Probability histograms of simulation results for annual total productivity ...	8-19

8.5-	Ascending cumulative graph for annual productivity	8-20
8.6-	Descending cumulative graph for annual productivity.....	8-21
8.7-	A summary graph of the effect of strip width on prime productivity.....	8-22
8.8-	A summary graph of the effect of strip width on total productivity	8-22
8.9-	Sensitivity analysis of prime productivity against uncertain input variables	8-23
8.10-	Costing flow chart	8-24
8.11-	Breakdown of operating costs for a 43 m ³ bucket Marion 8050 dragline.....	8-24
9.1-	Sample outputs from the CADSIM model for the simple case study	9-5
9.2-	Sample outputs from DAAPA3 for the simple case study	9-5
9.3-	A typical stratigraphic sequence of the case study pit.....	9-7
9.4-	Schematic long cross section of the dragline passes	9-7
9.5-	Three seam operation, single highwall and double low wall method	9-9
9.6-	Dragline removes the second interburden from the lowwall side	9-10
9.7-	Comparison of the results from the dragline monitoring system and the	
9.8-	CADSIM model for the highwall side stripping	9-12
9.9-	Comparison of the results from the dragline monitoring system and the	
	CADSIM model for the lowwall side stripping	9-12
10.1-	A typical long cross-section of the deposit.....	10-2
10.2-	A typical stratigraphic sequence of the first case study.....	10-3
10.3-	A schematic block diagram of strips in the mine pit.....	10-5
10.4-	Dimensional diagram of a walking dragline	10-6
10.5-	A schematic view of the dragline positions during the excavation of a block in an Extended Bench method.....	10-7
10.6-	A schematic view of the dragline positions during the excavation of a block using the In-Pit Bench method	10-8
10.7-	A schematic view of the dragline positions during the excavation of a block using the Extended Key Cut method.....	10-10
10.8-	The frequency distribution of the dragline block depths.....	10-11
10.9-	Cross section through the first strip in the northern area	10-11
10.10-	Changes in the stripping parameters for the Extended Bench method along the strip	10-12

10.11-	Changes in the mining parameters along the first strip for the In-Pit Bench digging method.....	10-14
10.12-	Changes in the mining parameters for the Extended Key Cut method	10-14
10.13-	Effect of the strip width on the stripping parameters for the Extended Bench method.....	10-15
10.14-	Impact of strip width on productivity for the Extended Bench method	10-16
10.15-	Effect of the strip width on the stripping parameters for the In-Pit Bench method.....	10-17
10.16-	Coal loading operation at the case study mine	10-18
10.17-	The use of loader and dozers as support equipment for coal loading and haulage operation at the case study mine	10-18
10.18-	Impact of the strip width on productivity for the In-Pit Bench method	10-19
10.19-	Effect of the strip width on the mining parameters for the Extended Key Cut method.....	10-20
10.20-	Impact of the strip width on productivity for the Extended Key Cut method.....	10-21
10.21-	Annual productivity estimations for the first 6 years employing different digging methods	10-23
10.22-	Comparison of the different operational parameters for the three digging methods	10-25
10.23-	Comparison of the different productivity terms for the three digging methods	10-25
10.24-	Proportional cost of the components for the three digging methods.....	10-27
10.25-	Discounted Average Cost of the various components.....	10-25
10.26-	A typical cross section throughout the deposit.....	10-28
10.27-	Thick coal seam and thick overburden at the second case study mine.....	10-29
10.28-	Strip layout and the northern sections used for the second case study.....	10-30
10.29-	A typical cross section of the dragline digging method	10-31
10.30-	Rehandle figures for the two strip widths in the northern area	10-34
10.31-	Rehandle figures for the two strip widths in the southern area	10-35
10.32-	A typical long NS cross section of the first dig level (Case A).....	10-37
10.33-	A typical long NS cross section of the second dig level (Case B)	10-37

10.34-	Simulation results in the northern area for the two dig level cases	10-39
10.35-	Simulation results in the southern area for the two dig level cases.....	10-40
10.36-	Final view of the strip 4 after simulation	10-42
10.37-	Rehandle components for the optimum pit in the southern area.....	10-43
10.38-	Annual productivity estimation for the optimum pit in the southern area ..	10-44
10.39-	A general view of the dragline pit in the southern area after simulation of strip 8.....	10-45
10.40-	A general 3D view of the dragline pit in the northern area after simulation.....	10-45
10.41-	Rehandle components for the optimum pit in the northern area	10-47
10.42-	Annual productivity estimation of the optimum pit in the northern area	10-47
A.1-	Concepts of the "PNTINTS" function	A-10
A.2-	Concepts of the "PNTINTSB" function	A-11
A.3-	Concepts of the "STREXTR" function	A-12
A.4-	Concepts of the "STROPER" function.....	A-13
A.5-	Concepts of the "STRINSCS" function.....	A-14
A.6-	Concepts of the "STRINSOS" function	A-14
E.1-	Effect of the strip width on rehandle	E-2
E.2-	Effect of the strip width on swing angle.....	E-2
E.3-	Effect of the strip width on cycle time	E-3
E.4-	Effect of the strip width on total productivity	E-3
E.5-	Effect of the strip width on prime productivity	E-4
E.6-	Effect of the strip width on proportion of total volume	E-5
E.7-	Effect of the strip width on time spent in each pass	E-5
E.8-	Dragline working depths in each section.....	E-7
E.9-	Coal seam thickness in each section.....	E-7
E.10-	Dragline rehandle in each section.....	E-7

LIST OF TABLES

Table	Page
1.1-	The summary results of the digging method survey.....1-5
3.1-	A part of the standard machine selection3-14
5.1-	An example of a collar data file5-11
5.2-	An example of a data type file.....5-11
5.3-	An example of a pick interval file5-11
5.4-	An example of a coordinate (SnCOO.STR) file content.....5-16
5.5-	An example of a layer file (SnLAY.STR) content5-17
5.6-	An example of a SnCUT.STR file content.....5-17
5.7-	An example of a strip file content5-20
5.8-	An example of a width file (WIDTH.TAB) content5-21
6.1-	An example of an output dig report file6-18
6.2-	An example of part of REPORT.TXT output file6-28
7.1-	Comparison of average and standard deviation of performance parameters...7-8
7.2-	Statistics of the cycle time components for highwall side mining7-9
7.3-	Statistics of the cycle time components for lowwall side mining7-10
8.1-	Estimation of annual dig hours for a walking dragline8-11
8.2-	A block by block productivity calculation of an In-Pit Bench method8-12
8.3-	A strip by strip productivity calculation of a Split Bench digging method.....8-13
8.4-	Random variables used for the stochastic productivity calculation8-17
8.5-	Best fit analysis results on stochastic simulation outputs.....8-20
8.6-	Statistics from best fit analysis on the simulation outputs8-20
8.7-	Statistics of the result of simulation for different strip widths8-21
8.8-	Typical weekly and annual cost of a dragline operator8-27
8.9-	Typical factors for various equipment.....8-30
8.10-	Equipment operating cost calculation8-32
8.11-	Calculation of blasting cost8-33
8.12-	Cash Flow analysis of the Dozer operation using a Discounted Average Cost method.....8-34
8.13-	Cash Flow analysis of the Dragline operation using a Discounted Average Cost method.....8-35

8.14-	Cash Flow analysis of the Drill & Blasting operation using a Discounted Average Cost method	8-36
9.1-	Dragline specifications used in the testing case	9-3
9.2-	Pit geometry and productivity parameters.....	9-3
9.3-	Comparison of the results from DAAPA3 and the CADSIM model.....	9-4
9.4-	The dimensional parameters of the BE 1370-W walking dragline	9-7
9.5-	Strip and material parameters used for simulation	9-8
9.6-	Comparison of the monitoring data and the dragline simulation results.....	9-11
10.1-	The selected grids and layer definition for simulation	10-4
10.2-	Dimension terminology of a P&H 9020-S walking dragline	10-6
10.3-	The estimated annual productivity using the cumulative time method	10-22
10.4-	Average values of different operational parameters for the three digging methods	10-24
10.5-	Discounted Average Cost of the various cost centres	10-26
10.6-	Strip and material parameters used for the dragline simulation	10-32
10.7-	Dimension terminology of the BE 1350-W.....	10-33
10.8-	Summary of the simulation results in the northern area.....	10-34
10.9-	Summary of the simulation results in the southern area.....	10-34
10.10-	Summary of dragline simulation in northern area for two dig level cases ..	10-39
10.11-	Summary of dragline simulation in southern area for two dig level cases ..	10-39
10.12-	Summary of the dragline simulation results for strip 4 in the south	10-41
10.13-	Simulation results of the optimum pit in the southern area.....	10-43
10.14-	Simulation results of the optimum pit in the northern area.....	10-46
A.1-	List of the Arithmetic functions used by DSLX.....	A-7
A.2-	List of the Trigonometric functions used by DSLX	A-8
E.1-	Results of simulation for 50m wide strips.....	E-6

LIST OF SYMBOLS AND ABBREVIATIONS

2D	:	Two Dimensional
3D	:	Three Dimensional
ACARP	:	Australian Coal Association Research Program
ACRIL	:	Australian Coal Industry Laboratories
ADPC	:	Australian Dragline Performance Centre
ASCII	:	American Standard for Communication Interchange
bcm	:	bank cubic metre
BE	:	Bucyrus Erie (commercial name)
CAD	:	Computer Aided Drafting
CADSIM	:	Computer Aided Dragline Simulator (a dragline simulation model developed in this thesis)
Co.	:	Cooperation
DAC	:	Discounted Average Cost
DCF	:	Discounted Cash Flow
deg	:	degree
DMS	:	Dragline Monitoring System
DSLX	:	Dragline Simulation Language for X windows (commercial name)
ft	:	feet
GMS	:	Gridded Seam Modelling
hr	:	hour
IDW	:	Inverse Distance Weighted
IRR	:	Internal Rate of Return
km	:	kilometre
l	:	litre
lbs	:	pound
m	:	metre
m ³	:	cubic metre
Max	:	Maximum
Mbcm	:	$\times 10^6$ bank cubic metre
Min	:	Minimum

MSL	:	Maximum Suspended Load
Mt	:	$\times 10^6$ tonne
MUF	:	Maximum Usefulness Factor
N.A.	:	Not Available
No.	:	Number
NPV	:	Net Present Value
NSW	:	New South Wales
Op. hr	:	Operating hours
PC	:	Personal Computer
QLD	:	Queensland
R	:	Correlation Coefficient
R^2	:	Coefficient of Determination
R_e	:	Dragline effective reach
Reh	:	Rehandle
SDE	:	Specific Dig Energy
sec	:	second
SF	:	Swell Factor
St. Dev.	:	Standard Deviation
t	:	tonne
y	:	year