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LONGWALL MINING UNDER THE OCEAN AT CAPE BRETON COLLIERIES

B.W. Konda and J.K. Kochhar

September 1985

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LONGWALL MINING UNDER THE OCEAN AT CAPE BRETON COLLIERIES

by

B.W. Konda* and J.K. Kochhar**

ABSTRACT

Cape Breton is an island at the north-eastern extremity of mainland Nova Scotia on Canada's eastern seaboard. The Sydney Coalfield, located on the east coast of Cape Breton, is part of a large carboniferous basin beneath the Atlantic Ocean between the shores of Cape Breton and the province of Newfoundland. The coalfield is Pennsylvanian in age and contains the largest coal reserves in Eastern Canada. More than 98% of the coalfield is submarine.

Cape Breton Development Corporation (CBDC), a federal Crown corporation, currently operates two underground coal collieries, Lingan and Prince, producing nearly 2.5 million tonnes of saleable coal and has under development two new collieries, Phalen and Donkin-Morien. All currently operating and planned collieries are 'slope collieries'.

While room and pillar mining has been practised at shallower depths in the past, all current workings are based on 'U' layout longwall (advancing at Lingan and retreating at Prince) system with full caving. In designing submarine workings, the major concern is the prevention of ingress of seawater consistent with optimal extraction of resources. Guidelines based on experience and engineering are established for partial to full extraction. The important guideline followed in the Sydney Coalfield is that the strain at the seabed should not exceed 8.5 mm/m as the result of extraction.

The longwall faces are fully mechanized with ranging double drum shearers, armoured face conveyors and two-legged hydraulic shield supports. Roadheaders are deployed in maingates. The coal is transported to the surface by a system of belt conveyors whereas men and materials are transported

by a rope haulage system in the slopes and by diesel locomotives in the maingates.

Because of the submarine workings, mine openings cannot be at the desired location. Hence, efficient layout from the point of view of optimal extraction of resources is not feasible. As the mine progresses, the length of ventilation circuits and transportation distances for men and materials increase. This results in the requirement of higher ventilation pressures and reduced effective shift working time which contribute to higher costs and lower productivity. Efforts are being made to overcome these shortcomings by the introduction of advanced technology in all aspects of operations: ventilation design by computer simulations, methane control by cross-measure borehole drainage, environmental monitoring by computerized remote monitoring system and reduction in travel time by high-speed haulage system are a few of these aspects.

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EXPLOITATION MINIÈRE SOUS-MARINE PAR LA MÉTHODE DE LONGUES TAILLES DANS LES CHAMPS HOUILLERS DU CAP-BRETON

par

B.W. Konda* et J.K. Kochhar**

RÉSUMÉ

Le Cap-Breton est une île située à l'extrémité nord-est de la Nouvelle-Écosse sur la côte est du Canada. La houillère de Sydney se trouve sur la côte est du Cap-Breton et fait partie d'un important bassin houiller situé sous l'Océan Atlantique entre les côtes du Cap-Breton et la province de Terre-Neuve. La houillère date de l'époque pennsylvanienne et contient les plus importantes réserves de charbon de l'Est canadien. Plus de 98 % de la houillère est sous le niveau de la mer.

La Société de développement du Cap-Breton (SDCB) est une société de la Couronne qui exploite actuellement deux mines de charbon sous-marines, appellées Lingan et Prince, qui produisent environ 2,5 millions de tonnes de charbon de qualité commerciale; la Société est aussi en train d'aménager deux nouvelles mines, la Phalen et la Donkin-Morien. Toutes les mines exploitées et aménagées du bassin houiller du Cap-Breton sont des mines à plan incliné.

Alors que la méthode par chambres et piliers ait été utilisée autrefois dans les exploitations à peu de profondeur, aujourd'hui tous les travaux miniers sont conçus d'après un plan d'exploitation en "U" par longues tailles (avançantes à Lingan et rabattantes à Prince) avec foudroyage complet. Lors de la conception des chantiers d'exploitation sous-marins, une des préoccupations majeures est la prévention de l'infiltration de l'eau de mer en fonction de l'extraction optimale des ressources. Des directives éla-

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borées à partir de l'expérience et de la technologie sont établies afin d'effectuer l'extraction partielle à complète des ressources. Ainsi, la principale directive suivie au champs houiller de Sydney par suite de l'extraction est de ne pas laisser la tension au niveau du fond marin dépasser 8,5 mm/m.

L'exploitation des fronts de taille par longues tailles est complètement mécanisée grâce aux haveuses-chargeuses à deux tambours à bras prenant, aux convoyeurs blindés et aux étançons téléscopiques hydrauliques. On utilise de plus les tunneliers dans les galeries principales. Le transport du charbon à la surface de la mine s'effectue à l'aide d'un système de convoyeurs à bande tandis que le transport des hommes et des matériaux se fait par un système de roulage à câble dans les plans inclinés et par locomotives diesel dans les galeries principales.

En raison des travaux d'exploitation sous-marins, les ouvertures de mine ne peuvent être situées dans les endroits voulus. Par conséquent, il n'est pas possible d'effectuer un plan d'aménagement efficace au niveau de l'exploitation optimale des ressources. La progression des travaux dans la mine entraîne aussi une augmentation de l'étendue des circuits de ventilation et de la distance à parcourir pour le transport des hommes et des matériaux. Celà signifie donc une augmentation de la puissance du système de ventilation et une réduction du temps réel de travail par équipe ce qui contribue au coût d'exploitation plus élevé et à une baisse de la productivité. Des efforts ont été faits toutefois, pour surmonter ces difficultés en introduisant une technologie de pointe à tous les niveaux des opérations, en voici quelques exemples: conception d'un système de ventilation à l'aide de modèles simulés sur ordinateur, contrôle du méthane par drainage transversal des trous de forage, surveillance environnementale à l'aide d'un système informatisé de surveillance à distance et la réduction du temps alloué au déplacement dans la mine par la mise en place d'un système de transport rapide.

CONTENTS

	Page
ABSTRACT	i
RESUME	iii
INTRODUCTION	1
THE SYDNEY COALFIELD	2
UNDERSEA MINING	2
Regulations	5
Mining Planning	7
OPERATIONS	14
Lingan Colliery	14
Prince Colliery	17
Phalen Colliery	20
Donkin-Morien Project	22
Problems associated with Undersea Mining	22
CONCLUSIONS	23
ACKNOWLEDGEMENTS	24
REFERENCES	24
APPENDIX A	26
APPENDIX B	29

FIGURES

No.		Page
1.	Sydney Coalfield and adjacent carboniferous basin (after King and MacLean, 1976)	3
2.	Sydney Coalfield - sequence of seams	4
3.	Subsidence profiles for sub-critical, critical and super-critical extractions	6
4.	Subsidence at various width/depth ratios of extraction	9
5.	Subsidence profile panel and pillar	11
6.	Original roadway - after the pillar size was reduced	13
7.	CBDC - Collieries	15

No.		Page
8.	Lingan Mine	16
9.	Prince Mine	19
10.	Phalen Mine	21

INTRODUCTION

The first coal mined in North America was from the Sydney Coalfield in 1720. It was mined by the French settlers in the village of Port-Morien to supply the garrison at the fortress of Louisbourg. The Sydney Coalfield is located on the east coast of Cape Breton Island in the province of Nova Scotia, Canada. At the time of the Canadian Confederation in 1867, total coal production in Canada was slightly over 0.5 million tonnes per annum and nearly all of it was produced in Cape Breton. Substantial growth took place thereafter and submarine mining was systematically undertaken.

The coalfield has seen many ups and downs in coal production. By 1913, production from 25 collieries reached a peak level of 5.4 million tonnes per annum. It stayed fairly stable between the periods of the first and the second world wars at 3.8 to 4.9 million tonnes per annum. Thereafter, it declined drastically due to competition from cheaply available petroleum products, escalating costs and operating difficulties associated with working the collieries at greater and greater distances from the shoreline. By the mid 1960's the situation became desperate and in 1967 a federal Crown corporation, known as the Cape Breton Development Corporation (CBDC), was formed with a mandate to take over and phase out coal operations and to establish other suitable industries to provide alternative employment. At the time of the take over, coal production was about 3 million tonnes per annum from four (No. 12, No. 20, No. 26 and Princess) operating collieries. By the end of 1973, the coal production declined to less than one million tonnes per annum and only two (No. 26 and Princess) of the four inherited collieries remained in operation. However, the oil crisis of 1973 precipitated a major change in CBDC corporate mission. The objective of the CBDC was changed from phasing out coal mining in Cape Breton to that of making it a viable and economic source of energy. Under this new direction two new collieries (Lingan and Prince) were brought into production. Princess was closed in 1976 due to exhaustion of economical coal resources and in April of 1984, the last of the inherited collieries, the No. 26 Colliery, was shut down due to fire.

THE SYDNEY COALFIELD

The Sydney Coalfield, with 2.5 billion tonnes of remaining in situ coal resources, is the largest and most important coalfield in Eastern Canada. It is part of a large carboniferous basin beneath the Atlantic Ocean, between the shores of Cape Breton and the province of Newfoundland. More than 98% of the coalfield is submarine (Figure 1). It is Pennsylvanian in age. The coal bearing sequence contains eleven major coal seams (Figure 2) ranging from 1-4.5 m in thickness with all but the two youngest seams outcropping on land. All coal in the Sydney Coalfield is classified as high volatile 'A' bituminous. The rank increases from west to east and with increasing depth of cover.

Although six of the eleven seams are considered to be of economic importance only two, Harbour and Phalen, have been worked extensively in the submarine area adjacent to the coast. Generally, the seams dip gently seaward (north) at between 4°-10° although locally it could vary from 2°-40°. Structurally, the coalfield has been left relatively undisturbed by tectonic activity. Although some faulting has occurred along the margins of the basin, the mining operations have been spared of any major effect. However, there are extensive sandstone channels which, on occasion, cut into the seams and bring roof control problems in addition to the potential risk of frictional ignition.

UNDERSEA MINING

In working under the sea, while there are no restrictions imposed by the damage to surface features (property damage, etc.) due to mining subsidence, it is the safety of the colliery, men and materials which will be the key factor limiting extraction. The extraction ratio has to be safe so as not to induce sufficient tensile strain at the seabed to cause breakage resulting in the inrush of seawater.

In a given geological environment when mining coal, the surface will not subside beyond a certain maximum, irrespective of the area of extraction. Maximum subsidence will never exceed the thickness of extraction. The ratio of actual subsidence to maximum possible subsidence is known

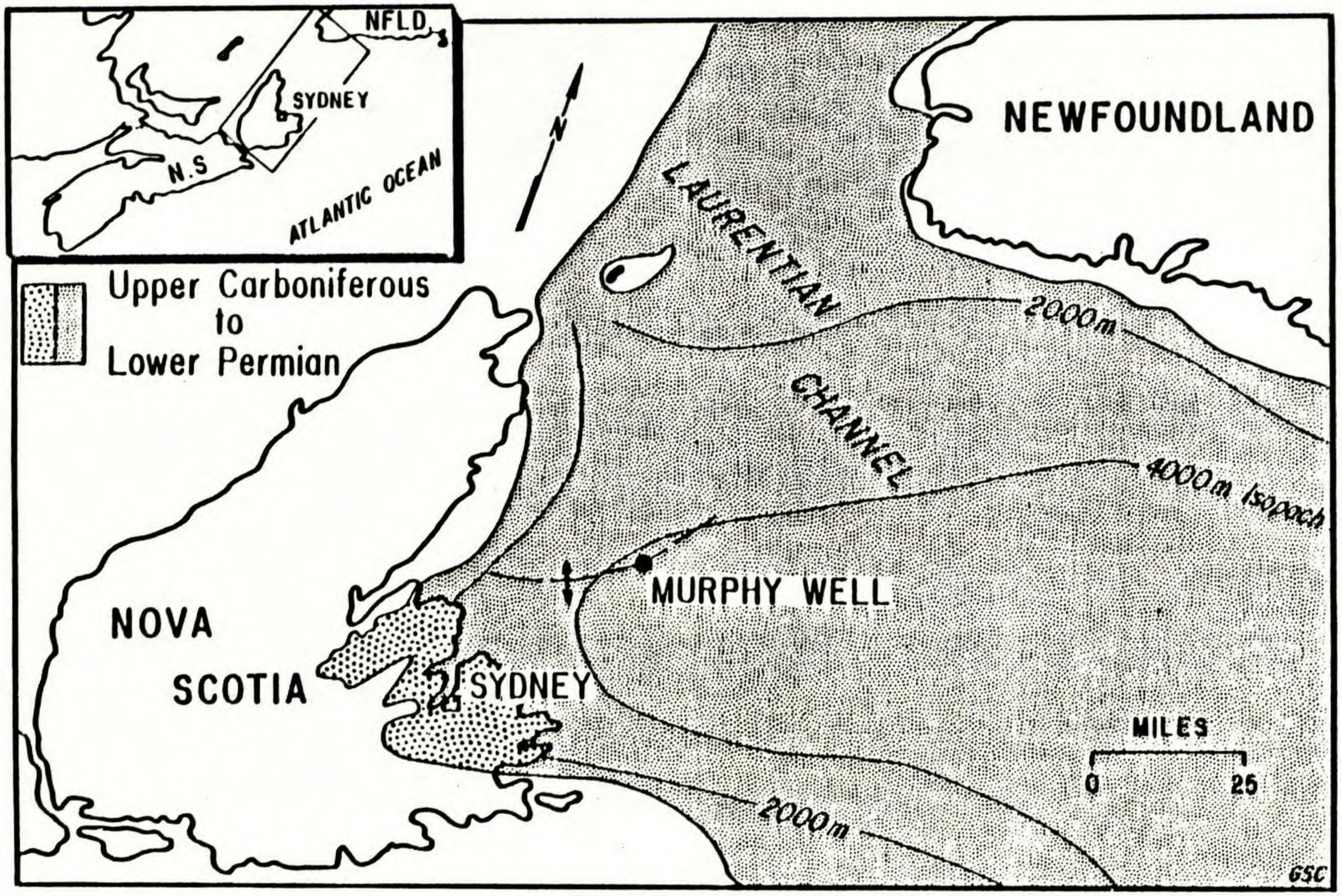


Figure 1 - Sydney Coalfield and adjacent carboniferous basin (after King and MacLean, 1976)

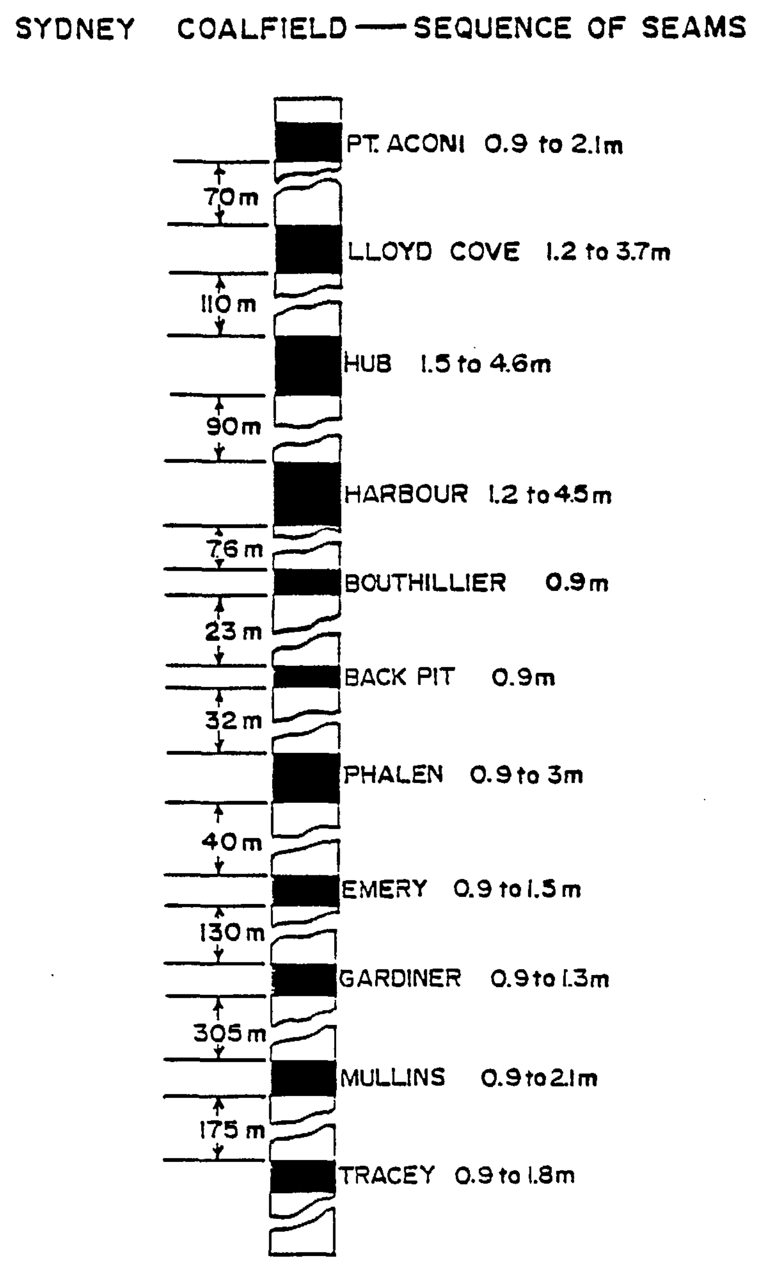

SYDNEY COALFIELD — SEQUENCE OF SEAMS
PT. ACONI 0.9 to 2.1m
70m
LLOYD COVE 1.2 to 3.7m
110 m
HUB 1.5 to 4.6m
90m
HARBOUR 1.2 to 4.5m
76 m
BOUTHILLIER 0.9m
23 m
BACK PIT 0.9m
32 m
PHALEN 0.9 to 3m
40 m
EMERY 0.9 to 1.5 m
130 m
GARDINER 0.9 to 1.3m
305 m
MULLINS 0.9 to 2.1m
175 m
TRACEY 0.9 to 1.8m

Figure 2

as subsidence factor. It depends on the ratio of the width of extraction and the depth at which extraction takes place. As the width of extraction increases, the amount of subsidence will increase. The maximum subsidence will occur when the width reaches some critical value in relation to the depth below surface. This is known as critical width and its value will depend mainly on the nature of the strata. In the Sydney Coalfield a width of extraction equal to 1.4 times the depth at which extraction takes place is estimated to be the critical width. As the extraction panel has both width and length and as subsidence occurs in both directions, a critical area has to be considered. When the area of extraction is smaller than the critical, it is known as sub-critical area and the subsidence will be less than maximum. If the area of extraction is larger than critical, i.e. super-critical, the maximum subsidence does not increase but the area over which it occurs will increase (Figure 3).

REGULATIONS

Under the Canadian Labour Code, Coal Mines (CBDC) Safety Regulations 1978, revised 1982-84 section under 115 states that -

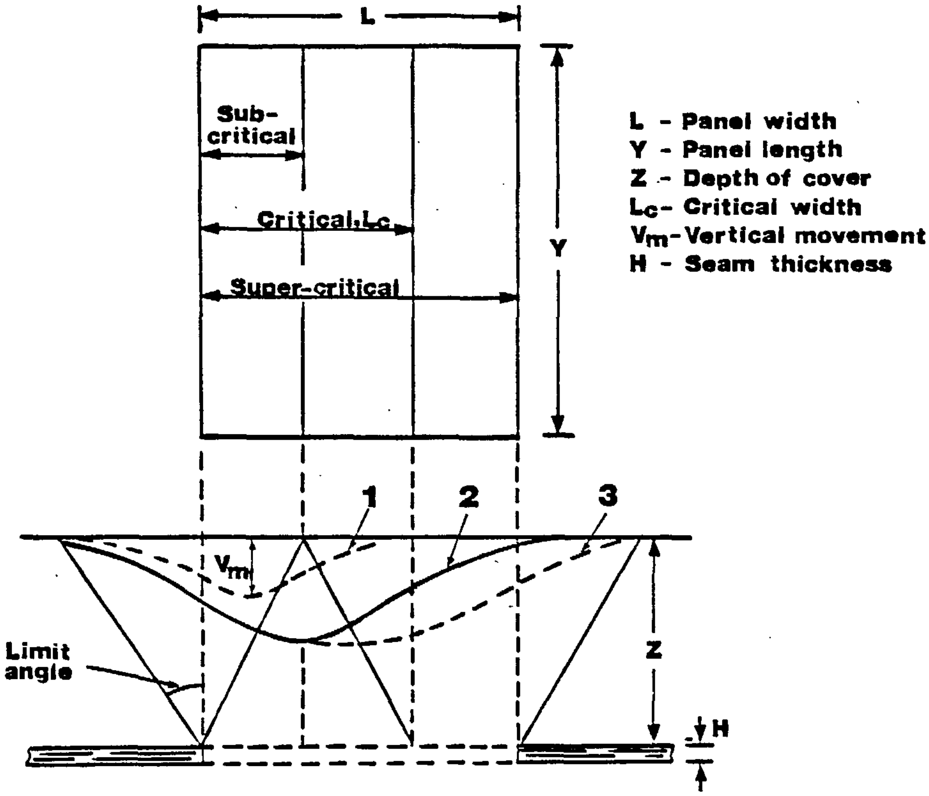
No mine shall be worked below the sea bottom or below any other body of water except under the following conditions:

a) no submarine seam of coal or stratified deposit shall be worked under less cover than 55 m of solid measure, except that an owner or lessee of any area may drive passageways to win the mineral to be worked and such passageways may have a cover less than 55 m but not less than 30 m of solid measure;

b) a solid barrier of unworked mineral of not less than 50 m shall be left between the workings of a submarine lease and any other submarine lease;

c) before mining is commenced in any submarine area, plans of the proposed workings shall be approved in writing by the Chief Inspector and no change shall be made in the approved plans without the written consent of the Chief Inspector;

d) where the presence of geological faults is suspected in an area of a mine that is less than 300 m below the sea bottom and workings are being carried on upon the longwall system, coal pillars are being extracted or a total extraction of coal is being undertaken,



Subsidence Profiles For Sub-critical, Critical and Super-critical Extractions.

Figure 3

an exploring drift or drifts shall be driven in the line of the main road in advance of the main workings at a distance of at least 50 m in a seaward direction level course or to the dip, as the case may be, but where the ground has been already proved by the workings in another seam, compliance with this condition is waived;

e) barriers of coal at least 10 m thick shall be left against all faults where the throw or dislocation of the faults exceeds 10 m or where the chocks or sides thereof are more than 60 cm apart, but narrow places may be driven through such faults for the purpose of mining the coal beyond if the size and number of such narrow places are approved in writing by the Chief Inspector;

f) where the depth of cover below the sea bottom is less than 150 m, soundings shall be taken at least 300 m in advance of any workings for the purpose of determining the depth of water, and levels shall be taken at least once in every three months for the purpose of determining the depth of the overhead cover and such soundings and levels shall be marked on the plan of the workings.

From the proposed regulations under the Canada Labour Code, Part IV, Section XXII states, in summarized form:

a) no longwall extraction shall be carried out when the thickness of cover is less than 110 m or when the thickness of carboniferous strata is less than 60 m,

b) coal seams shall be extracted at such thicknesses and depths that the tensile strain induced at the seabed shall not exceed 0.01 (10 mm/m), and

c) no room and pillar shall be carried out where the thickness of cover is less than 60 m and carboniferous strata is 45 m.

<u>MINING PLANNING</u>

There is no single colliery design or layout that can satisfy the variety of conditions which exist in any coalfield. The Sydney Coalfield is no exception to this rule. An added factor is that the mine design or layout has to take into consideration the fact that 98% of the coal reserves are submarine. Of the various parameters considered for mine planning and design, the most important factor is that relating to the necessity of maintaining an impervious strata over the workings in order to prevent an ingress of seawater. The extractions are planned in such a way that the strain due to subsidence on the seabed is kept below critical levels.

Reference is made in the proposed regulations to tensile strain on the seabed. This is an important consideration since rock is strong in compression and weak in tension. Calculation of tensile strain is not difficult to make and it is based on numerous observations that show the maximum tensile strain is proportional to the maximum subsidence over the workings and inversely proportional to the depth of workings. Maximum subsidence will depend on a variety of parameters, but their effects can be calculated and expressed in terms of a subsidence factor.

The National Coal Board of U.K. has developed an empirical method of calculating the subsidence factor. A graphical representation of this is given in Figure 4. Using the graph prediction of maximum subsidence can be made with reasonable accuracy for any given geometry of workings.

Maximum tensile strain is calculated by the following formula:

$$E_{max} = \frac{k\ S_{max}}{D} = \frac{k\ a\ t}{D}$$

where, E_{max} = maximum tensile strain

k = a numerical constant assumed from observations in coal mines to be 0.75

S_{max} = maximum subsidence caused by extraction of a critical or super-critical area in a given coal seam

D = depth of cover between the workings and seabed

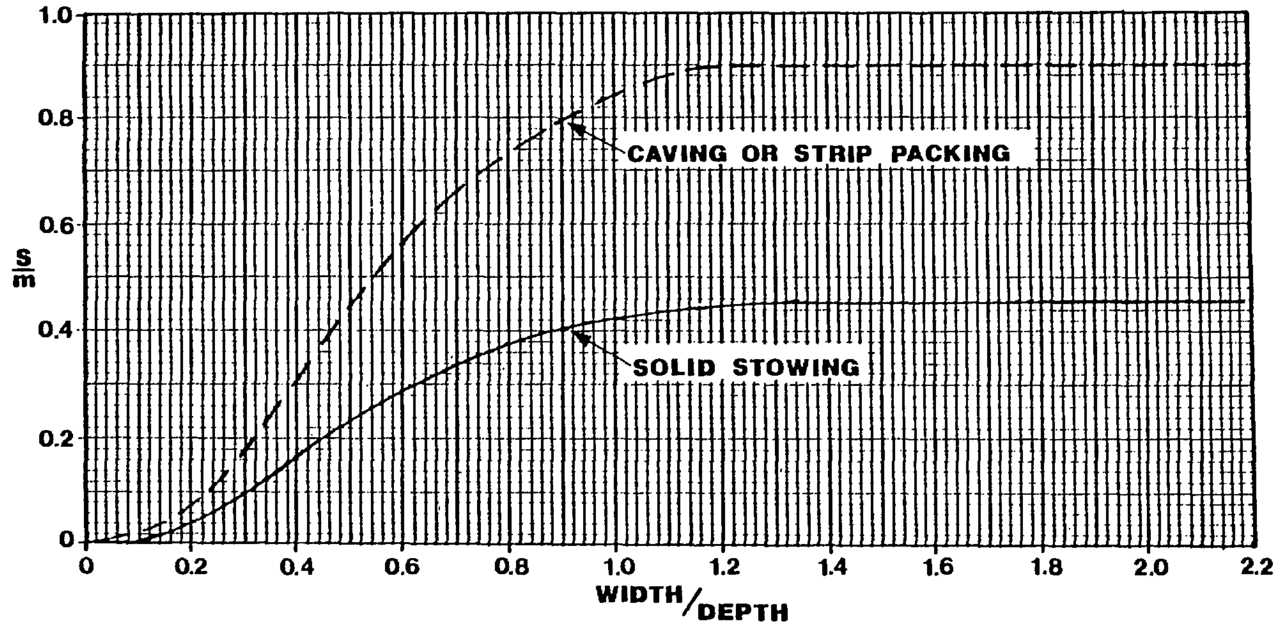
a = subsidence factor

t = thickness of total extraction

When two or more contiguous seams are to be mined in the same area, combined thicknesses of extraction must be used in all calculations.

The example below shows the calculation of maximum tensile strain for a full caving wallface 210 m long with a seam thickness of 2.2 m and depth of workings 300 m:

$$E_{max} = \frac{k\ a\ t}{D} = \frac{0.75 \times 0.65 \times 2.2}{300} = 0.0036 \text{ or } 3.6 \text{ mm/m}$$



Subsidence at various width/depth ratios of extraction.
(N.C.B. Subsidence Engineers Handbook)

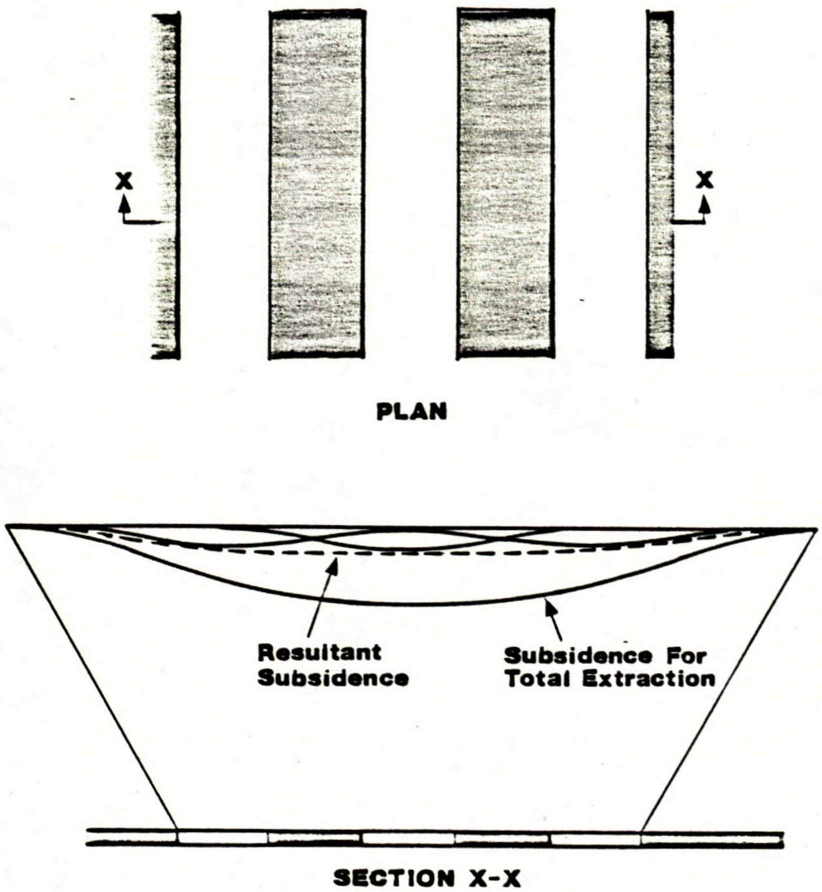
Figure 4

While the tensile strain allowed by regulations at the seabed is 10 mm/m maximum, CBDC planning has been conservative and has adopted 8.5 mm/m maximum. This practice has always been followed and in the history of the Sydney Coalfield there never has been any heavy seepage of water.

When working under shallow submarine depths mining normally starts with room and pillar system. Longwall mining is not possible because of subsidence and tensile strain at seabed considerations. Once under sufficient cover, the panel and pillar system of mining is favoured because it permits greater percentage of extraction and higher productivity as compared to room and pillar. Until 1965 CBDC practised longwall mining with no barrier pillars between the panels for total extraction. Longwall gate roadways were brushed at the face and packed on both sides of the roadways. They were supported with 4.6 m rigid steel arches and were re-arched when required. Continuous back brushing and re-arching was a major hinderance in the program to mechanise the walls. Recognizing this, in 1965 it was decided to adopt the panel and pillar method of mining to gain improved roadway conditions and higher productivity (Figure 5).

The panel and pillar system of mining is being practised at both operating mines. Longwall panels of substantial length (up to 3500 m) but limited width (180-220 m) are extracted with each panel separated from the next by a long pillar. The widths of the panel and the pillar are so designed that the maximum subsidence does not give the tensile strain beyond 0.0085. Design, therefore, is governed by the depth of cover between the seam roof and the seabed and the total thickness of extraction (seam or seams).

Roadway stability is another important factor that is taken into consideration in designing the width of pillars in relation to panels. Gate entries, as components of longwall systems, are single entries in 'U' type layout with relatively large cross-sectional areas. Stress exerted on the gateroads is caused by the abutment pressure on the coal rib. The pressure varies with the geometry of workings and the road stability will vary with the roadway cross-section, the system of roadway support, the dimensions and quality of the roadside packs and the nature of roof and floor. Redistribution of stress due to mining is an important parameter that determines the convergence. In general, the judgement of pillar width has been very much on the basis of quantitative assessment taking into account local knowledge and



SUBSIDENCE PROFILE
PANEL AND PILLAR

Figure 5

previous experience. Under these circumstances, it is easier to make pillars too large for stability of the roadways but as a result valuable resources are wasted. Conversely, a pillar width that is too small will give poor roadway conditions leading to repeated back brushing and poor productivity.

It has been experienced that when a pillar was designed for certain width and subsequently was reduced due to operational reasons, the roadway conditions deteriorated substantially (Figure 6) causing ventilation and transportation problems. The pillar width is designed in such a way that it gives good protection to ribside gate roadway against excessive convergence between longwall faces. Based on the geological conditions of the coalfield, average pillar loads calculated and the history of the old roadways, the CBDC experience indicates that when the load on a pillar exceeded 52 MPa, the roadway suffered deterioration necessitating back brushing. This experience relates to roadways supported with rigid steel arches of 19.4 kg/m weight in the tailgates and 30 kg/m weight in the maingates. The average load on the pillar is calculated by the formula:

$$L = \frac{0.0255 \times D}{1 - R}$$

where, L - load in MPa (Mega pascals)

D - depth in metres

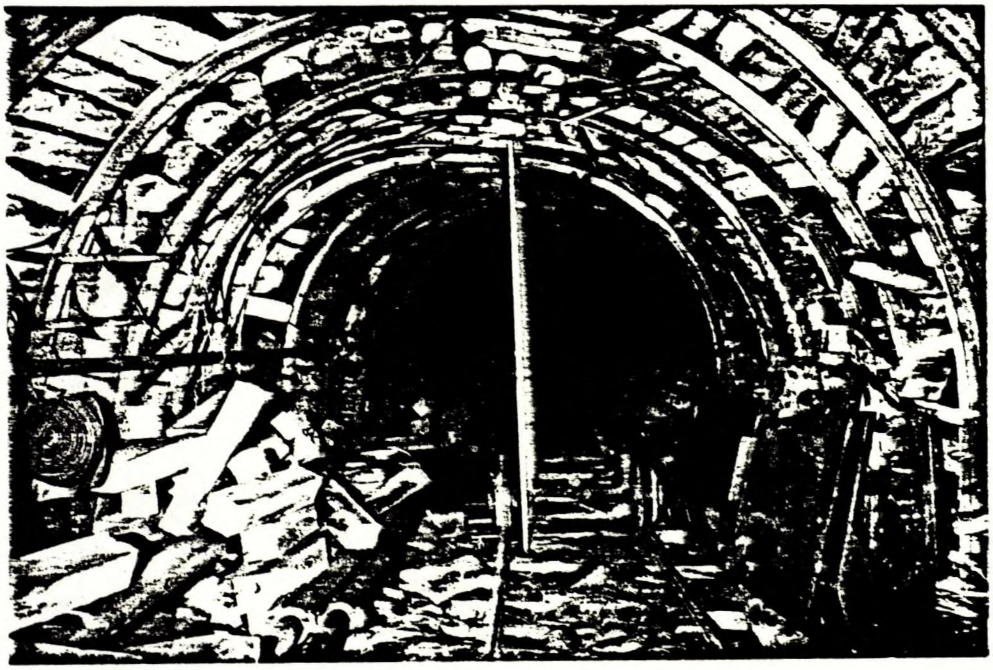
R - is the ratio of extraction = $\frac{\text{Panel Width}}{\text{Panel + Pillar}}$

For example, working at a depth of 600 m, a wallface of 210 m wide and a 90 m pillar between adjacent walls of 210 m, the load on the pillar (L) is given by:

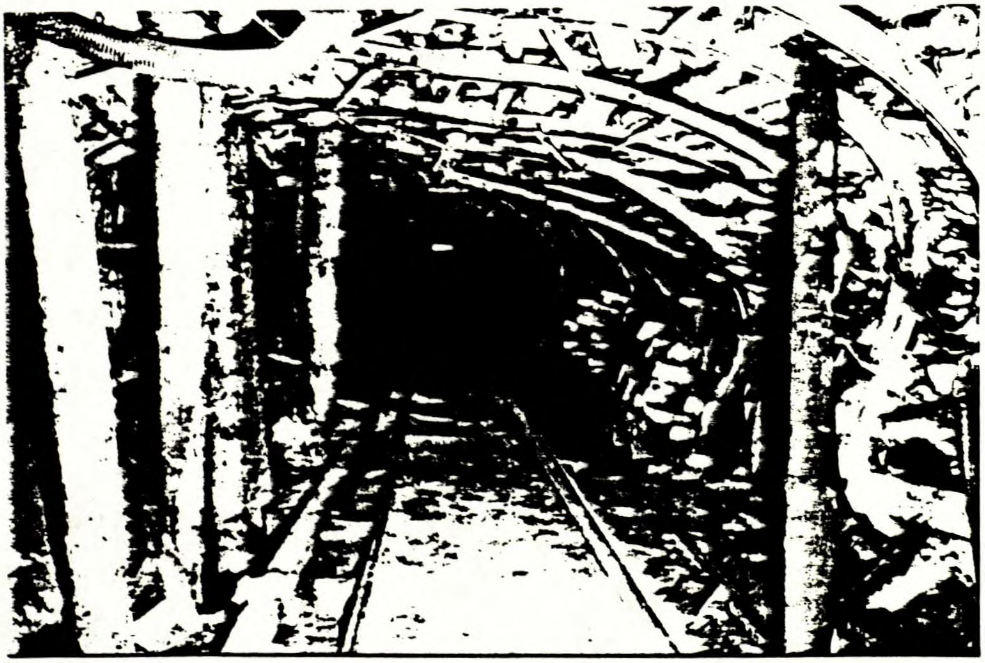
$$L = \frac{0.0255 \times 600}{1 - \frac{210}{210 + 90}} = \frac{15.3}{0.3}$$

$$= 51.0 \text{ MPa}$$

This is within the critical 52 MPa range and therefore, the roadway under these circumstances will remain stable.



Original roadway



After the pillar size was reduced

Figure 6

OPERATIONS

CBDC currently operates two collieries, Lingan and Prince, producing nearly 2.5 million tonnes per annum of saleable coal and has under development two new collieries, Phalen and Donkin-Morien (Figure 7). All currently operating and planned collieries are "slope collieries". It also owns and operates a coal preparation plant with 3 million tonnes of saleable coal per annum capacity, a railroad consisting of 130 km of track along with a modern computerized transportation maintenance centre and an international shipping pier.

LINGAN COLLIERY

Lingan Colliery is located near the town of New Waterford. The drivage of slopes commenced in 1971. Room and pillar mining was practised at shallow depths and later, when the cover permitted, the system was changed to panel and pillar method. The first advancing longwall panel went into production in 1974 and the design capacity of 1.4 million tonnes of saleable coal per annum was achieved by 1977 (Figure 8).

The workings are in the Harbour Seam which is the fourth in the sequence of identified seams. The seam is 2.2 m thick and the coal is high volatile 'A' bituminous with an average ash content of 4.5%, sulphur content of 1.6%, volatile matter of 30-34% and has an average calorific value of 32,564 KJ/kg (14,000 BTU/lb). The run of mine coal is washed and separated into metallurgical and thermal fractions.

The colliery is served by four slopes and a fifth slope is driven from underground. All the slopes are supported by 4.9 m x 3.7 m rigid steel arches. To date the slopes have been advanced 4.6 km from the surface. No. 1 and No. 2 slopes serve as main returns and are connected to the fan shaft. No. 3 and No. 4 slopes serve as main intakes. No. 2, No. 3 and No. 4 slopes are equipped with direct rope haulage systems for the transportation of men and materials. No. 3 slope is also equipped with belt conveyor system for coal transportation with a capacity of 1200 tonnes/hour from a level bunker to the surface and 1500 tonnes/hour below the bunker. The 500 tonnes level bunker was installed in 1982. The colliery ventilation is produced by 1350 KW Sheldon Centrifugal fan with variable inlet vanes exhausting at the rate of 190 m^3/s at 450 mm w.g.

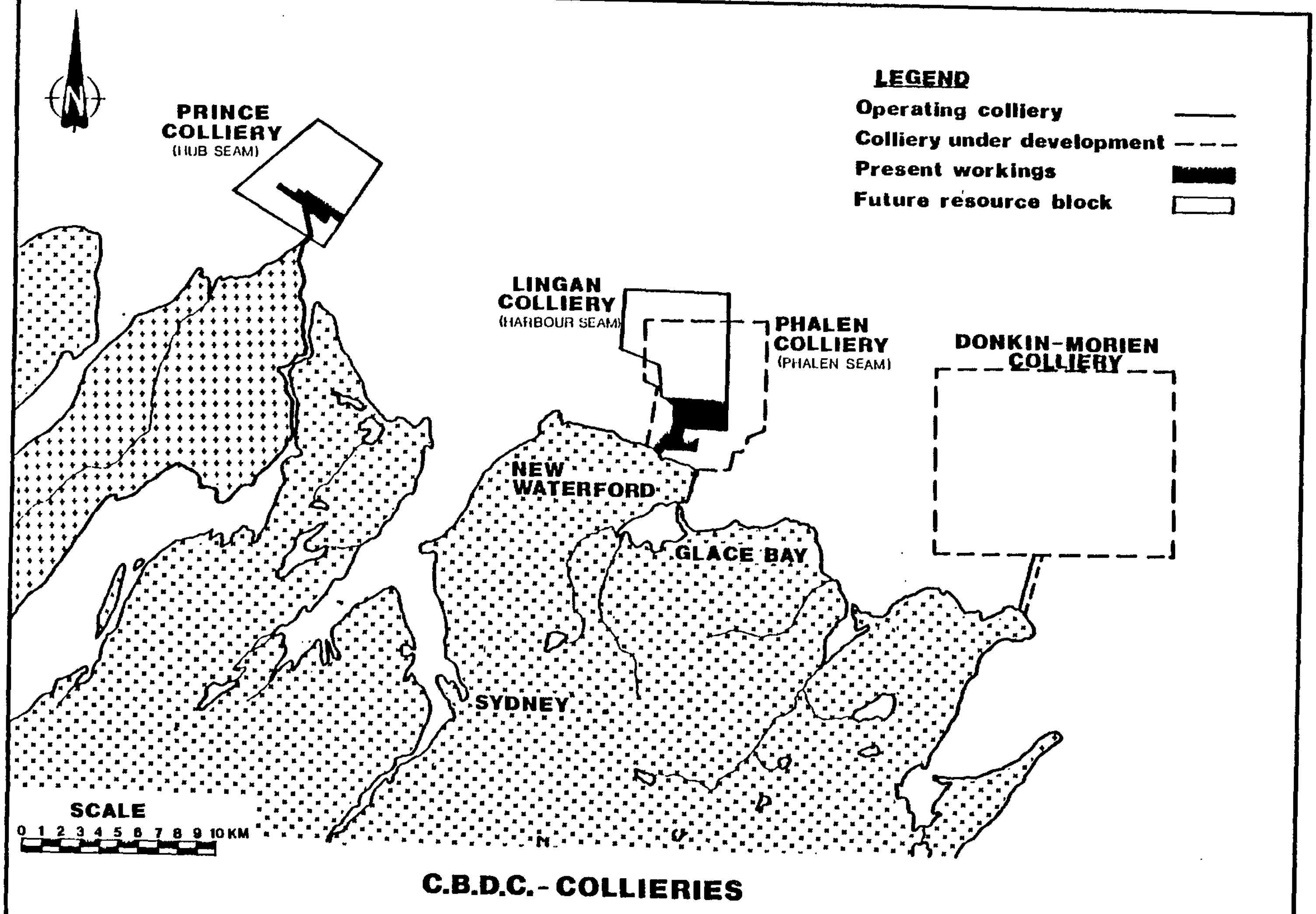

LEGEND
Operating colliery
Colliery under development
Present workings
Future resource block
PRINCE
COLLIERY
(HUB SEAM)
LINGAN
COLLIERY
(HARBOUR SEAM)
PHALEN
COLLIERY
(PHALEN SEAM)
DONKIN-MORIEN
COLLIERY
NEW
WATERFORD
GLACE BAY
SYDNEY
SCALE
0 1 2 3 4 5 6 7 8 9 10 KM
C.B.D.C. - COLLIERIES

Figure 7

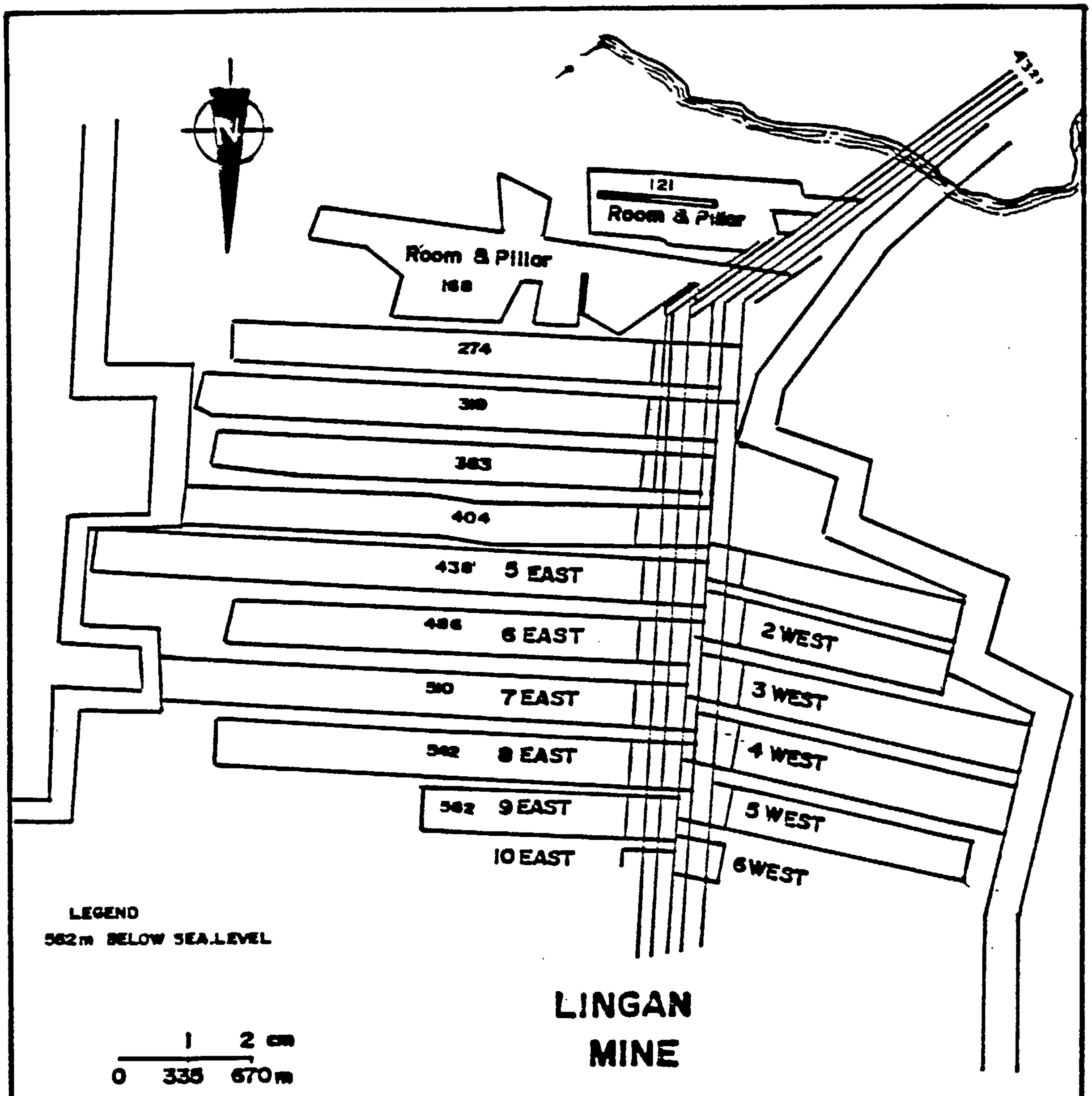

N
121
Room & Pillar
Room & Pillar
168
274
383
404
438 5 EAST
6 EAST
510 7 EAST
8 EAST
562 9 EAST
10 EAST
2 WEST
3 WEST
4 WEST
5 WEST
6 WEST
LEGEND
562m BELOW SEA LEVEL
1 2 cm
0 335 670m
LINGAN
MINE

Figure 8

Currently the workings are laid out on panel and pillar systems and are based on 'U' layout advancing longwall techniques with full caving. The colliery production at the design level of 1.4 million tonnes of saleable coal is maintained by operating two to three longwalls at any one time. Each face is about 210 m wide and is equipped with double ended ranging drum shearer, armoured face conveyor and two-legged hydraulic powered shield supports. Roadheaders are deployed in the maingates. For details see Appendix A.

The maingates of the longwall faces are supported by 29.7 kg/m weight, 4.3 m diameter rigid steel arches and serve for ventilation intake and transportation of coal, men and materials. The gateside packs are built either by hardwood chocks or monolithic packing. In the maingates, the coal is transported by belt conveyors and diesel locomotives are used for the transportation of men and materials. The tailgates are supported by 21 kg/m weight, 4.3 m or 3.7 m diameter rigid steel arches and serve for ventilation return, men and materials transportation and methane drainage. The transportation in the tailgate is by endless rope haulage.

The workings at present are at a depth of about 600 m below sea level and the methane emission rate in the district is about 20 m^3/tonne. Methane drainage by cross-measure boreholes in the return gate is being practised. A Seiger methane monitoring system is used on each wallface with automatic power cutoff at 1.25% of methane concentration. A computerized remote environmental monitoring system is now installed and is expected to be fully operational by the end of the year. This will monitor wallface ventilation, fan performance and methane drainage on a continuous basis.

PRINCE COLLIERY

Prince Colliery is located near Point Aconi and mines coal from the Hub Seam, third in the sequence of identified seams. Hub Seam is 2.2 m thick with an ash content of 9.0%, sulphur content of 3.9%, volatile matter of 34.6% and has a calorific value of 30,681 KJ/kg (13,191 BTU/lb). The coal produced is of thermal quality.

The colliery was planned to produce 400,000 tonnes of coal per year by room and pillar method of working. However after about three years of operation, it was realized that the colliery was not economical due to poor coal quality and floor and roof control problems. At the same time, offshore drilling indicated the presence of good coal resources down dip under the ocean west of then projected slopes. A decision was taken to abandon room and pillar section, extend the slopes seaward and turn west to mine the indicated coal reserves. By 1979, the slopes had advanced 4 km from the surface location and the cover was sufficient to have an experimental longwall of 60 m width. Although advancing longwall method of mining was generally the norm in the coalfield, it would not have been economical to operate a 60 m longwall advancing face due to restrictions imposed by gateroad brushing and its dilution effect. Hence a decision was made to have trial retreat wall. Single entry 'U' layout was employed and the gates were driven inseam only. Because of shallow depths, the panel and pillar layout was used. The pillars between successive walls are 60 m wide. With increasing depth, the wall widths have been gradually increased to about 120 m.

By early 1980, the development was completed and the wall was equipped with rehabilitated equipment redundant at other operations. The equipment consisted of double ended ranging arm shearer, hydraulic chock roof supports and armoured face conveyor. From the start, the operation proved successful and the productivity was higher compared to the traditional advancing longwalls. The target production of one million tonnes per year was achieved in 1984 by operating one retreat longwall at any one time (Figure 9). Currently the ninth retreat wall is in operation and it is equipped with a modern machinery and support system. For details see Appendix B.

The workings are at a distance of about 4.5 km from the surface. The colliery is served by three operating slopes from surface to shoreline (2100 m) and by five slopes from the shoreline down dip to the workings. Three slopes are used for ventilation intake and coal, men and materials transportation and two slopes serve only as ventilation returns. Return slopes are connected to a ventilation fan shaft 145 m deep near the shoreline. There are two ventilation fans operating in parallel and exhausting 60 m^3/s of air at 250 mm w.g. The Hub Seam is relatively less gassy as compared with the Harbour Seam and thus far, methane drainage is not found necessary. A high speed 522 KW, 5 km endless rope haulage system has been installed and it is expected to be operational in the near future.

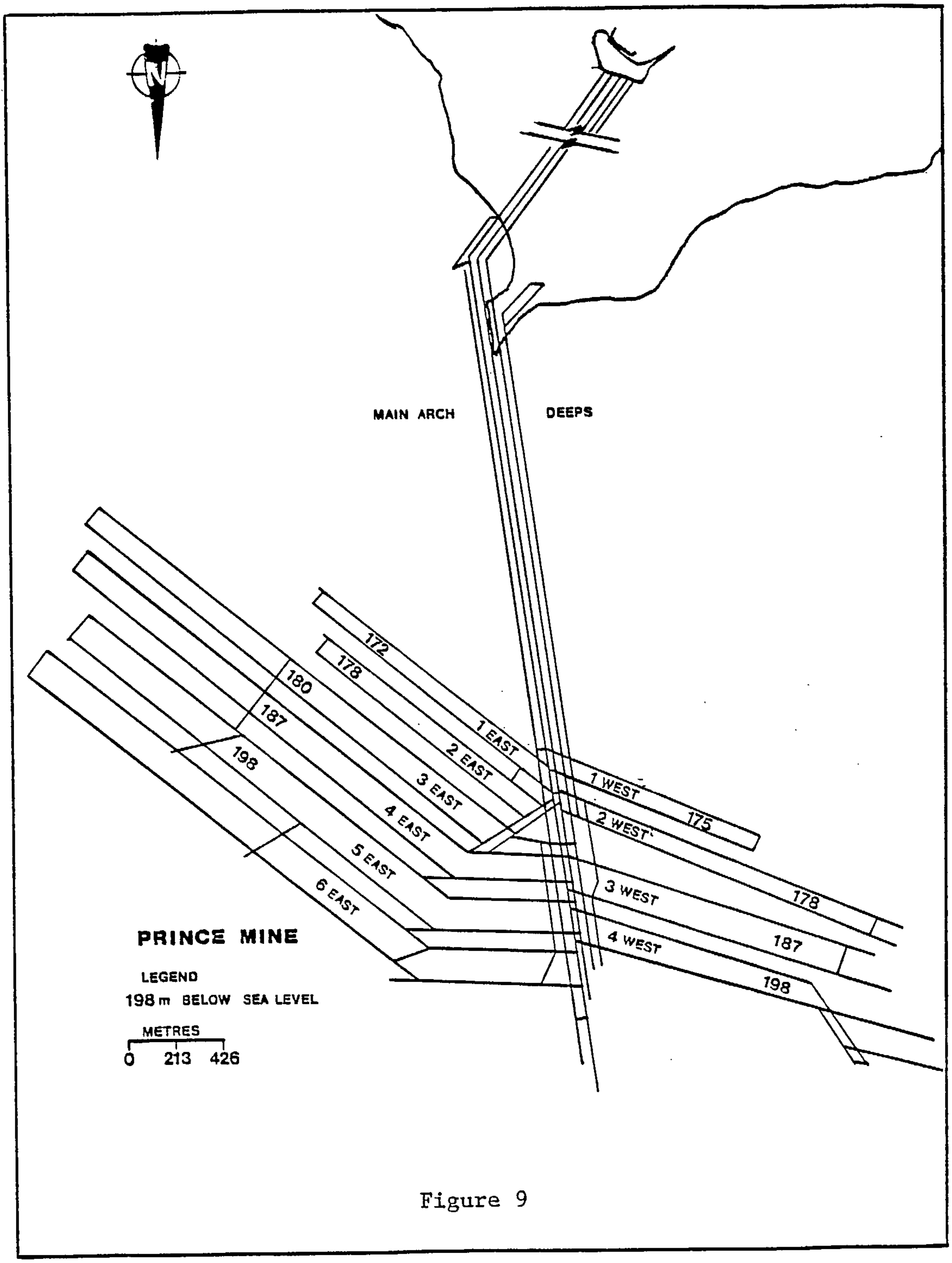

N
MAIN ARCH
DEEPS
172
178
180
187
198
1 EAST
2 EAST
3 EAST
4 EAST
5 EAST
6 EAST
1 WEST
2 WEST
3 WEST
4 WEST
175
178
187
198
PRINCE MINE
LEGEND
198 m BELOW SEA LEVEL
METRES
0 213 426

Figure 9

PHALEN COLLIERY

Phalen Colliery is being developed at a budgeted cost of $185 million to produce 1.5 million tonnes of saleable coal per annum. It will operate three retreat longwall faces at any one time and will deploy a work force of 750. The construction commenced in the middle of 1984 and by the end of August 1985, the slopes (Nos. 2, 3, & 4) have advanced to over 1200 m. The slopes are being driven using high pressure (350 bars) water jet assisted road headers (Anderson Strathclyde RH22 and Dosco Mark II B) and are supported by heat treated rigid 5.5 m diameter steel arches of 21 kg/m weight. The finished cross-sectional area of each slope is 18 m^2.

The Phalen resource block contains 108 million tonnes of high volatile 'A' to medium volatile bituminous coal. The coal can be washed to produce approximately equal portions of metallurgical and thermal coals. The seam thickness varies from 1.5-2.3 m and it is split in the western part of the resource block.

At Phalen Colliery, the Phalen Seam will be worked below the present workings in the Harbour Seam of Lingan Colliery. The colliery layout therefore has to consider the implications of interaction between the Harbour and Phalen Seam workings. Taking this into consideration, the resource block is divided into three sections and the workings are laid out as shown in Figure 10. With this layout, it is feasible to operate more than three longwall faces simultaneously as long as the mining method used is panel and pillar system. However, once the cover is sufficient for total extraction, with no barrier pillars between successive walls only three longwall operations will be feasible. It is planned to mine coal by single entry longwall retreat system with inseam gateroad driveages and a back bleeder system for ventilation. The ventilation design calls for the operation of two fans in parallel with a total capacity of 280 m^3/s.

The Phalen Seam is gassy and the gas emission rate is expected to be comparable to that at Lingan Colliery. Methane drainage is comtemplated and a computerized remote environmental monitoring system will be installed. The trunk belt coal conveying system is designed for a capacity of 2200 tonnes per hour. Men and materials will be transported by rope haulage systems in the slopes and return gates and by locomotives in the maingates.

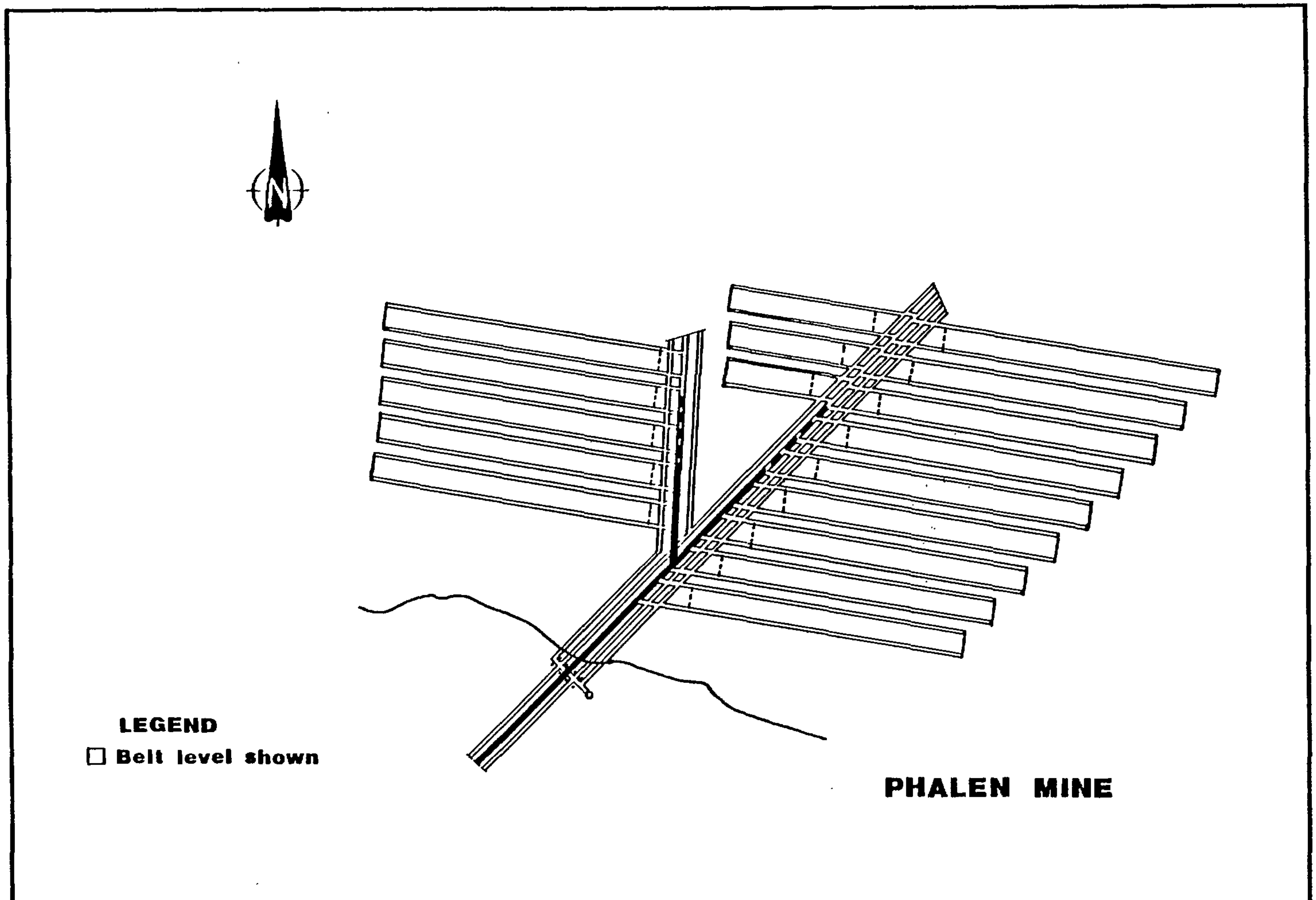


Figure 10

DONKIN-MORIEN PROJECT

An offshore drilling program in the Donkin area of Cape Breton confirmed the existence of a major block of coal. It indicated four potentially mineable coal seams with an estimated in situ coal reserves of 1.5 billion tonnes to the east and north of the village of Donkin. The geology is relatively simple with no major disturbances.

To exploit these resources feasibility studies were conducted and the decision was taken to drive two exploratory tunnels to the Harbour Seam. The first of the two tunnels is driven with a 7.6 m diameter "M-300" prototype full face tunnel boring machine (TBM) designed and developed in Canada. CBDC and CANMET were two active participants in the development and testing of TBM along with the National Research Council, the Department of Supply and Services, Beaver Underground Structures Ltd. and Lovat Tunnel Equipment Inc. (Toronto). The tunnel was driven 3522 m in a period of 15 months between October 1983 and December 1984. During this period TBM availability time was 68% and actual cutting time was 38% of the total available time. With the gaining of experience, the TBM performance towards the end improved significantly. For example, the tunnel advanced 1105 m between October and December 1984 for an average weekly advance of 96 m.

The machine is dismantled and is being overhauled to drive the second tunnel, 1000 m of which was driven by conventional drill and blast method. It has a finished cross-sectional area of about 30 m^2 compared with about 40 m^2 with TBM. The driveage with TBM is expected to start by the end of the year. Colliery layout will be similar to Phalen and with two tunnels it will be feasible to mine up to 2 million tonnes of coal per annum. However, the final design capacity can go up to 4 million tonnes per annum with four tunnels of 7.6 m diameter each.

PROBLEMS ASSOCIATED WITH UNDERSEA MINING

The Sydney Coalfield is primarily submarine. The knowledge of its geology detail for planning purposes is rather limited. This is due not only to the fact that exploration by offshore drilling is expensive but also that the offshore drillholes sterilize coal resources around them. Added to this, the colliery openings cannot be at the desired location. Hence, efficient layout from the point of view of optimal extraction of resources is not feasible. As the colliery progresses, the length of ventilation circuits increase because it is not possible to establish ventilation shafts near the working areas as is done when collieries are on land. This results in the requirement of higher ventilation pressures which in turn results in increased leakages and lower ventilation efficiency. Methane control by vertical boreholes from the surface is also impractical. In addition, increased transportation distances for men and materials result in reduced effective shift working time and contributes to lower productivity or output per manshift. For example, at No. 26 Colliery before its shutdown in early 1984, shift available time was reduced by three hours of travelling time despite the use of reasonable efficient modes of transportation like trolley locomotive, direct rope haulage and diesel locomotives.

However, efforts are being made to overcome these shortcomings by the introduction of advanced technology and automation in all aspects of operations. Seismic surveys are carried out to determine the thickness of subsea sediments, the structural geology of the resource block and to optimize the location of offshore boreholes. Echo sounders are deployed to determine seawater depths. Ventilation design by computer simulations, overcoming high ventilation pressures by the installation of booster fans underground, improving the capture ratio of the cross-measure borehole methane drainage, methane monitoring by computerized environmental monitoring systems and reduction of travel time by the introduction of high speed haulage system are some of the other aspects.

CONCLUSIONS

Coal mining undersea is not much different to that underland. Methods of planning and development are similar excepting that there is increased potential hazard from the ingress of seawater. This requires a successful reconcilation of limited geological knowledge with optimal extraction of resources. For partial or total extraction under the sea, there are regulatory and other guidelines established and followed. Some of the important variables involved are the solid rock cover above the coal seam or seams, the total thickness of extraction, the allowable tensile strain at the seabed and leaving barriers against the proximity of faults, offshore boreholes and old workings.

In the last ten years CBDC has successfully introduced state-of-the-art longwall mining technology to the coal mines in the Sydney Coalfield and increased productivity from about 2.5 tonnes per manshift in 1975 to about 6.9 tonnes in 1984. Now that all the inherited old mines are closed and the new mines are expected to be planned and equipped with up-to-date technology, there is room for further improvements in the productivity and reducing costs.

However, it must be recognized that while the Sydney Coalfield has a large coal resource base, access to these resources can only be gained at increasing depths associated with increasingly greater distances from the coast. Therefore, to make significant further gains in productivity consistent with safety and reasonable cost, a variety of site specific technological needs have to be addressed and resolved. Pre-drainage of methane, cleaning and controlled recirculation of ventilation air, offshore islands for ventilation shafts and control of outbursts are some of the areas of investigation fraught with promise for this coalfield.

ACKNOWLEDGEMENTS

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APPENDIX A

GENERAL

1. Name of Mine - Lingan
2. Name of Face - 6 West
3. Length of Face - 229.200 m

SUPPORTS - RUN OF FACE

4. Manufacturer - Hemscheidt
5. Type - two-leg shield
6. Setting Pressure - 4600 psi
7. Yield Pressure - 6300 psi
8. Leg Dia. - 8.75"

SUPPORTS - FACE END

9. Manufacturer - Hemscheidt
10. Type - four-leg chock
11. Setting Pressure - 3730 psi
12. Yield Pressure - 4640 psi
13. Leg Dia. - 4.133"

PUMPS

14. Manufacturer - Hauhinco
15. Capacity 30 gpm, Pressure 5000 psi
16. Location - Coal Level

POWER LOADER

17. Manufacturer - Anderson Strathclyde
18. Type - 270 A.M.B.R.O.A.S.
19. Type of Haulage - 22" Mechanical - Eicotrack Chainless
20. Horse Power - 300
21. Height of M/C base above top of Arc. - 91.5"
22. Length of Arms - 64"
23. Cowls - None
24. Drum Speed - 36-55 rpm
25. Drum Width - 30 ins.
26. Drum Dia. - 64 ins.
27. Number of Starts - 3 - Forward attack and radial

FACE CONVEYOR

28. Manufacturer - Dowty Mecca
    Driveframe - Dowty Mecca
    Gearbox - Dowty Mecca S200
    Pan - Dowty Mecca
    Chain - Reilloc
29. Pan Width - 764 mm, Height - 222 mm, Length - 1500 mm
30. Gearbox Ratio - 33.45 - 1
31. Sprocket Teeth - 7
32. Chain Speed - 206 fpm
33. Chain No. of Strand - 2
34. Chain Size - 22 x 86 mm
35. Chain Crs. - 600.0 mm
36. AFC Capacity - 600 tons/hr
37. Motor BE HP 200 Speed 1800
38. Motor TE HP 200 Speed 1800

STAGELOADER

39. Length - 100-150'
40. Width - 30"
41. Speed (Chain) - 254 fpm
42. Type - Huwood
43. HP - 140

ROADHEADER

44. Type Dimensions Dosco Mark IIA - STD L-7400 m, H-1640 m, W-2858 m
    - DP 200 Dual Purpose
45. Boom Details - Trunk - 2738 mm x 533 mm
    - Cutting Head - 50.8 mm x 50.8 mm
46. Motor - Hydraulic pump - 120 HP, Cutting Head - 100 HP
47. Side Discharge
48. Excavation Details - 2.13 m x 1.83 m

LEVEL BELT

49. Two Huwood L-120 with 140 HP motors

APPENDIX B

GENERAL

1. Name of Mine - Prince
2. Name of Face - 4 West
3. Length of Face - 97.54 m

SUPPORTS - RUN OF FACE

4. Manufacturer - Hemscheidt
5. Type - two-leg shield - Compact Design
6. Setting Pressure - 3500 psi
7. Yield Pressure - 6300 psi
8. Leg Dia. - 8.75"

SUPPORTS - FACE END

9. Manufacturer - Hemscheidt
10. Type - four-leg chock
11. Setting Pressure - 3770 psi
12. Yield Pressure - 4640 psi
13. Leg Dia. - 4.133"

PUMPS

14. Manufacturer - Peroni
15. Capacity - 30 gpm, Pressure - 5000 psi
16. Location - Coal Level

POWER LOADER

17. Manufacturer - Anderson Strathcylde
18. Type - F.I.D.D.
19. Type of haulage - 22" Mechanical - DYNATRACK Chainless
20. HP - 300
21. Height of M/C base above top of Arc. - 91.5"
22. Length of Arms - 64"
23. Cowls - None
24. Drum Speed - 51 rpm
25. Drum Width - 27 ins.
26. Drum Dia. - 60 ins.
27. Number of Starts - 3 - Forward attack and radial

FACE CONVEYOR

28. Manufacturer - Halbach & Braun
    Driveframe - Halbach & Braun (Janel)
    Gearbox - Halbach & Braun
    Pan - Halbach & Braun
    Chain - Halbach & Braun
29. Pan Width - 732 mm, Height - 222 mm, Length - 1500 mm
30. Gearbox Ratio - 39.33-1
31. Sprocket Teeth - 8
32. Chain Speed - 221 fpm
33. Chain No. of Strand - two
34. Chain Size - Outboard - 22 x 86 mm
35. Chain Crs. - 640 mm
36. AFC Capacity - 600 tons/hr
37. Motor BE NIL
38. Motor TE HP 2-140, Speed 1725

STAGELOADER

39. Length - 100-150'
40. Width - 30"
41. Speed (Chain) - 254 fpm
42. Type - Huwood
43. HP - 75 - P100 Gearbox

LEVEL BELT

44. Three Huwood L-120 with 140 HP motors