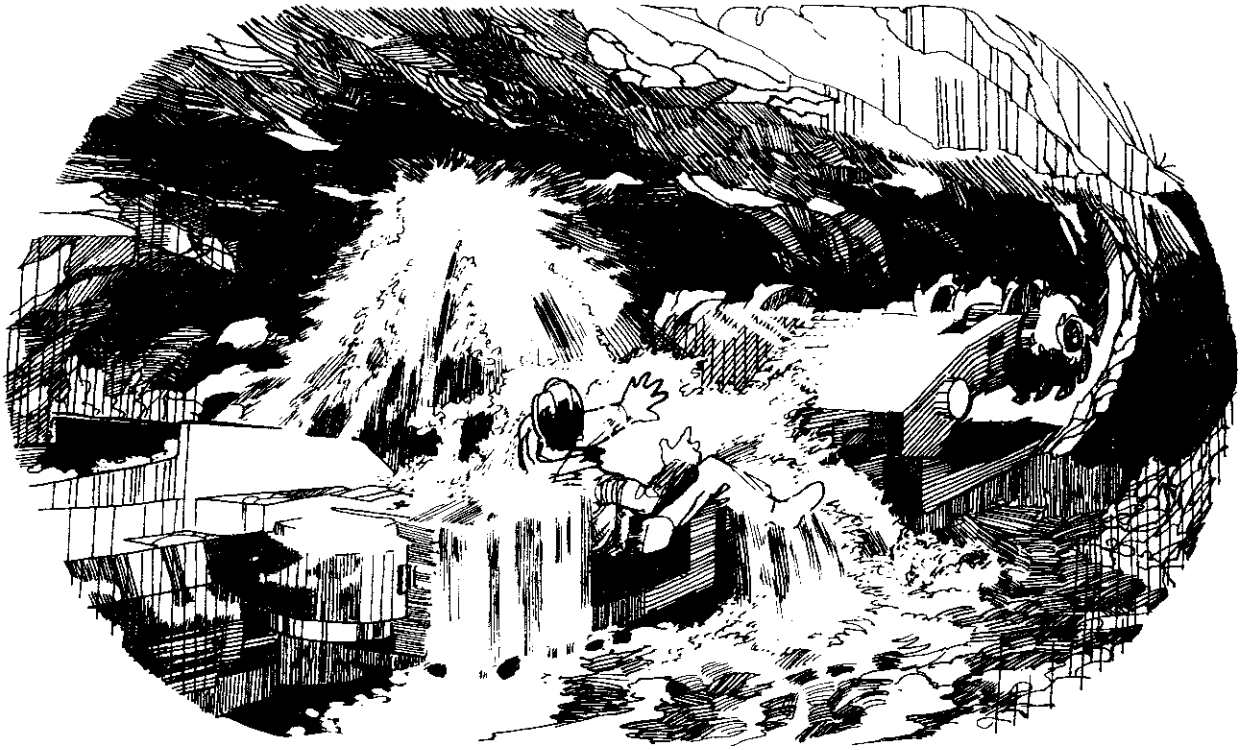
GUIDELINES FOR MINING NEAR WATER BODIES



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GUIDELINES FOR MINING NEAR WATER BODIES

PHASE III - FINAL REPORT

RECOMMENDED GUIDELINES FOR MINING UNDER SURFACE WATERS

Submitted to:

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ABSTRACT

The purpose of this study is to formulate practical guidelines for active underground mining in close proximity to water bodies. This was accomplished through systematic completion of three phases of study: I) Collection and Documentation of Data; II) Application of Existing Guidelines to Case Histories of Previous Inundations; and III) Development of Recommended Guidelines for Underground Coal Mining Near Bodies of Water.

Phase I of the study involved a worldwide data collection effort designed to obtain foreign and domestic guidelines for mining near water bodies, and accident records and case histories of accidental mine inundations. Within Phase II, existing guidelines were categorized and classified, and then evaluated as to their effectiveness in precluding past inundations had they been in effect at the time of inrush. Advantages and disadvantages of existing guidelines were defined.

Drawing on the broad data base established in previous study efforts, Phase III was directed at development of viable guidelines to promote the greatest possible coal extraction while precluding accidental mine inundation. Two levels of guidelines are presented; Level I Guidelines require little or no subsurface exploration on the part of the mine operator, while Level II Guidelines recommend various testing and

investigative procedures to permit greatest possible mineral extraction.

This report presents findings and conclusions of the study.

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INTRODUCTION

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INTRODUCTION

To fully understand the genesis of this project, we must first consider the chronological turn of events. In the early days of coal mining, very little importance was given to mine regulations, and most emphasis was placed on economics of coal removal. For the most part, miner safety was left to the individual companies, some of whom did not possess the necessary expertise to incorporate safety into the total development plan.

After several serious inundations, public concern prompted passage of regulations governing mining in close proximity to dangerous accumulations of water. Primarily, these regulations were directed at adjacent flooded workings rather than surface waters (since this was the major area of concern); rarely were these regulations rigidly enforced. Early regulations were usually rules-of-thumb guidelines, as very little specific information was available on exact causes of water inrushes. As more information became available concerning the cause of inundations (such as barrier pillar thickness at time of inrush), more stringent regulations were enacted. Since coal was a rather plentiful commodity, little regard was given to potential overrestrictiveness of these guidelines, especially in light of the consequences of underrestrictive guidelines, i.e., the potential for multiple loss of life. As a result, many areas were

essentially sterilized from development.

With the advent of the recent energy crisis, a new awareness for resource conservation was born. Project Independence calls for major expansion of the coal industry as one means of reducing our dependency on imported oil. As part of this expansion and conservation effort, we must encourage maximum recovery of our coal resources. Historically, we have ostracized enormous quantities of otherwise recoverable coal by inefficient mining practices and, quite frankly, lack of concern. Until recently, such an attitude was popular because of the seemingly endless coal reserves and relatively low cost of alternate energy sources such as natural gas and oil. Economics encouraged, and oftentimes dictated, the abandonment of many mining operations because more easily recoverable seams were so readily available.

The sudden awakening brought about by the energy crisis in the winter of 1973, which precipitated drastically increased coal prices, gave renewed hope to the coal industry and economic incentive to secure maximum coal recovery. In light of the present economics and energy conservation aspects of coal recovery, the Bureau of Mines initiated this study for the purpose of developing practical guidelines for mining in close proximity to bodies of water to assure adequate protection to coal miners while realizing maximum coal recovery. To efficiently

accomplish this task, the project was initially subdivided into three interrelated phases:

- Phase I – Collection and Documentation of Data
- Phase II – Application of Existing Standards to Case Histories of Previous Inundations
- Phase III – Development of Recommended Guidelines for Underground Coal Mining Near Bodies of Water

Because of the complexity and severity of this potential problem, an exhaustive literature research program was conducted during Phase I to document the success and failure of previously established guidelines for mining near water bodies. The coal producing regions of the United States were divided into five well defined regions (in order) to facilitate collection of voluminous amounts of data. In determining these subdivisions, emphasis was given to geologic, topographic, and climatological characteristics conducive to similar mining trends and potential water problems. Since the study involves only underground coal mining, only areas with deep mineable coal reserves were considered.

Utilizing printed questionnaires as a basis for information retrieval, over 800 form letters and 150 personal letters were sent to various individuals and agencies in virtually every corner of the world suspected to be knowledgeable in the area of mining near bodies of water. In addition, over 250 contacts were made by telephone to every identifiable source in the United States believed to have any involvement with

underground mine inundations or guidelines. Contacts included:

- State agencies (geological surveys, mining departments, regulatory agencies)
- Federal Agencies (such as MESA and the USBM)
- Coal Associations (NCA, BCR, State Trade Organizations)
- Insurance Agencies
- United Mine Workers (Safety Department)
- Coal Companies (known to operate near surface waters)
- Consulting Firms
- Recognized Experts
- Foreign Sources (500 form letters to 55 countries - from embassy officials to consulting mining engineers)

The cumulative result of all data collection efforts is a complete copy of all present state and federal guidelines for mining near water bodies - both past and current - and seemingly complete documentation of foreign guidelines as well. Additionally, all available information was obtained on past inundation accidents in order to provide a comprehensive understanding of the causative factors involved in these inrushes.

The second phase of study -- Application of Existing Guidelines to Case Histories of Previous Inundations -- sought to determine whether the various applicable guidelines should have prevented specific inundation accidents if those guidelines had been in effect or implemented when the

incident occurred. To assure a logical approach to the problem, a well-defined series of concentrated efforts was delineated. The first step was preparation of complete case histories for each documented mine inundation from the accident reports gathered in Phase I. Next, the completed case histories were carefully evaluated to pinpoint any similarities or trends that might warrant further study. Based on this evaluation, four general situations or categories defining causes of mine inundations were recognized: 1) mining under continental surface waters; 2) submarine mining; 3) mining near abandoned workings and water bearing zones; and 4) situations in which general mine planning was at fault.

When the four major categories of mine inundation incidents were defined, all guideline information gathered in Phase I was carefully reassessed and, where relevant and applicable, placed within one or more of the categories. Guidelines for each individual category were comparatively analyzed in detail, and then subdivided into distinct classes. The definition of each of these classes varies somewhat between categories, but generally represents the relative effectiveness in terms of miner safety and effective coal production of the guidelines within that class.

Tables, charts, and figures describing in detail the various

mining procedures, incident categories, and guideline classifications were drafted throughout each stage of Phase II. These illustrations, combined with comprehensive case history exhibits, visually portray the effectiveness of the guidelines in preventing accidental inundations. The graphic portrayals readily identify those aspects of the mining guidelines which are either overrestrictive or excessively weak. Based on this information, outstanding portions of effective provisions were easily defined for use in Phase III.

The final phase within this study, representing the primary goal of this project, is the development of recommended guidelines for underground coal mining under surface water bodies. To permit maximum flexibility and avoid needless loss of time and money in the development of underground mining operations, two distinct categories of guidelines are presented. The first category, Level I guidelines, requires little or no subsurface exploration or testing on the part of the mine operator, other than routine survey. However, the generalization of these recommended guidelines, designed to provide maximum protection to the miner, may sterilize a great amount of recoverable coal. Level II guidelines reduce this sterilization by illustrating methods of testing and evaluating specific conditions to permit safely exceeding the limitations set forth in Level I. Each technique presented includes a

discussion of its applicability, reliability, benefits, utilization, and factors of safety. Research needs are also defined.

The guidelines presented in this report will not totally preclude the possibility of an inundation because they do not offer protection against mining into unknown and unexpected water-filled abandoned workings or glacial and alluvial deposits. To avoid these relatively infrequent occurrences would require massive geological evaluation and constant borehole-pattern drilling in advance of mining at every working face in the country. The increased safety of the operation to an inundation hazard may be negated by the injuries and deaths that could result due to the additional men that would be required in the face area as a consequence of such a massive drilling effort. Adherence to these guidelines should, however, offer the best possible operational safety that can reasonably be attained.

The following sections of this report address Phase III of this study. Complete discussions of Phases I and II are presented in the respective Phase reports submitted to the United States Bureau of Mines at the conclusion of each study task.

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DEVELOPMENT AND PRESENTATION

OF LEVEL I GUIDELINES

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DEVELOPMENT AND PRESENTATION OF LEVEL I GUIDELINES

PURPOSE OF LEVEL I GUIDELINES

Guidelines that govern mining in the proximity of surface waters are necessary to ensure the safety of those who labor within these mines. The guidelines presented in this part of the report, termed Level I Guidelines, are designed to ensure the safety of people in the mine and the integrity of the surface waters with minimal consideration of operational testing. In addition, adherence to these guidelines should also prevent occurrence of an inrush when mining in areas where glacial or other water saturated alluvial deposits are known to occur, or in areas where flooded abandoned mines are known or suspected.

Adherence to these guidelines will require little or no surface or subsurface exploration or testing on the part of the mine operator, other than determining that a hazard exists. For example, where abandoned workings are known or suspected, the operator should procure and consult any and all mine maps related to these workings. Many maps of abandoned workings are available from mine map repositories of the United States Bureau of Mines and from related State agencies. Additional information may be available from the Mining Enforcement and Safety Administration (MESA) offices that were responsible for inspecting and

approving plans and developments for the now abandoned mine. Careful consideration of all available data may significantly affect planning and development of the presently active mine. For example, if it is found that while mining in the same seam a former operator approached closer to the property line than is acceptable under Level I Guidelines, the present operator should leave additional coal to compensate.

Adherence to Level I Guidelines will necessarily isolate from development some of the coal that is within the property limits of the mine operator. For instance, in the example cited above the operator would be required to leave an additional thickness of coal to meet the boundary pillar requirements of Level I Guidelines. If in so doing he precluded the development of, say, 500 acre feet of coal, the result is 900,000 tons that cannot be recovered. Level II Guidelines will define methodology which will permit recovery of some of these reserves. Under Level I, this coal is lost, but the safety of the operation is assured with little or no effort expended by the operator.

CURRENT GUIDELINES USED IN LEVEL I DEVELOPMENT

Many current State, Federal, and Foreign guidelines which fit the Level I category have been developed through the years and have demonstrated their applicability in preventing inundation accidents.

These are stated in Appendix A for convenience and for purposes of comparison with the Level I Guidelines presented here. In some instances, the Laws and Guidelines were developed as a consequence of an inundation; in others they were developed to prevent an inundation. It is no coincidence that the various guidelines presented in Appendix A have a great deal of similarity. Expert witness the world over was generally called upon for advice, assistance, testimony, and guidance in the formulation of these Laws, Acts, Rules, Codes, Orders, Regulations, and other Guidelines.

LEVEL I GUIDELINES

In order to ensure the safety of coal mine personnel and mine workings from the hazards of inundation, the following Level I Guidelines are recommended. These guidelines were taken almost totally from those currently observed, as listed in Appendix A. As discussed in the Phase II Study Report, precautionary measures utilized to preclude underground mine inundations can be logically delineated in specific guideline categories. Three major categories are recognized in the following discussion of Level I Guidelines:

1. Mining Under Continental Surface Waters
2. Mining Near Abandoned Workings and Natural Subsurface Hazards
3. General Mine Planning Procedures

In addition to these major categories, subcategories are defined where applicable to more accurately address specific conditions.

Specific guidelines are presented in Table 1; a discussion of the methodology of guideline development follows.

Mining Under Continental Surface Waters

A mining safety zone shall be established beneath and adjacent to any stream, river, and natural or artificial body of water that, in the opinion of the license or permit granting officials or other appropriate agency official, is sufficiently large to constitute a potential hazard to mining. The safety zone should extend 200 feet horizontally from the high water mark of each bank of such stream or river, or from the known perimeter of any other body of water, and should extend downward to the limit of the workable beds or to 350 feet, whichever is less. At the intersection of the 350 foot vertical depth line and the 200 foot horizontal line, the safety zone should continue downward on a line projected 25 degrees from the vertical. This safety zone is designated as the Zone of No Extraction and is shown in Figure 1.

This safety zone, modeled from guidelines in use in Pennsylvania and Australia, should protect the integrity of the surface waters while affording miner and mine working protection from massive surface water inundations. The only requirements on the operator are that he accurately

TABLE 1

LEVEL I GUIDELINES RECOMMENDED FOR MINING NEAR SURFACE WATERS OR HAZARDS WHICH COULD RESULT IN INUNDATION

CATEGORY	GUIDELINES	
	PARTIAL EXTRACTION	FULL EXTRACTION
Mining Under Continental Surface Waters	A mining safety zone should be established beneath any surface water body that, in the opinion of the mine superintendent and mine inspector, presents a potential hazard to the miners or the mine workings. The zone should extend 200 feet horizontally from the high water mark or perimeter of the water body and vertically downward from this point to a depth of 350 feet. At this point the safety zone should extend downward on a line projected 25° from the vertical. This safety zone is designated as the zone of no extraction.	Same as Partial Extraction Guidelines.
Mining Near Abandoned Workings and Natural Subsurface Hazards (Establish Barrier Pillars Around Abandoned Workings)	No mining should be permitted within 200 feet of any known or suspected abandoned workings (that are part of the present mine or any other prior mine) which cannot be inspected and certified free of dangerous accumulations of water. When these abandoned workings can be inspected and certified as safe, mining can proceed to within that distance permitted by the Property Boundary Barrier Pillar guidelines (presented below) or to within that distance corresponding to a pillar width to thickness ratio of 10 to 1, whichever is larger. Where faults are known to occur that could impair the strength of these barrier pillars, additional pillar width may be required as determined by the mine engineer and mine inspector.	Same as Partial Extraction Guidelines.
Mining Near Abandoned Workings and Natural Subsurface Hazards (Property Boundary Barrier Pillars)	A boundary pillar of unmined coal should be left to the property line of a width calculated by the equation $Pb = 10 + 2T + 5D$. Pb is the pillar width in feet, 10 is a constant safety factor, T is the thickness of the bed in feet rounded to the next highest integer, and D is the depth of the seam at the property line in hundred foot increments rounded to the next highest integer. This pillar thickness should be required on both sides of the property line. When mining on one side of the property line has approached closer than would be permitted by this guideline the advancing working should increase its property boundary barrier pillar requirement so that the cumulative pillar size is equal to 2 Pb. Where faults are known to occur, which could result in a connection between the abandoned and active workings or which could seriously weaken pillar stability and strength, additional pillar widths should be required. These additional width requirements should be based on the experience and judgment of the mine engineer and mine inspector.	Same as Partial Extraction Guidelines.

TABLE 1 (CONTINUED)

LEVEL I GUIDELINES RECOMMENDED FOR MINING NEAR SURFACE WATERS OR HAZARDS WHICH COULD RESULT IN INUNDATION

CATEGORY	GUIDELINES	
	PARTIAL EXTRACTION	FULL EXTRACTION
Mining Near Abandoned Workings and Natural Subsurface Hazards (Mining Near Wells, Shafts, or Other Openings) – Oil and Gas Wells –	Barrier pillars of not less than 300 feet in diameter should be left around all oil and gas wells that penetrate the coal seam (current Federal Guidelines).	Same as Partial Extraction Guidelines.
Mining Near Abandoned Workings and Natural Subsurface Hazards (Mining Near Wells, Shafts, or Other Openings) – Shafts and Other Mine Openings –	When mining in the area of any abandoned shafts, raises, or other openings that cannot be inspected and certified free of dangerous accumulations of water, a barrier pillar of 300 feet in diameter should be left around the opening; provided that at least a 100 feet radius of solid coal is left around the most extensive dimension, or length, of the opening. Where these openings can be inspected and certified safe, a pillar of width to thickness ratio 10 to 1 should be left around each opening. When mining in the area of abandoned slopes and like openings, the guidelines for mining near abandoned workings should be followed.	Same as Partial Extraction Guidelines.
Mining Near Abandoned Workings and Natural Subsurface Hazards (Mining Under Unconsolidated Deposits and Natural Reservoirs)	The consolidated roof strata separating natural reservoirs (and unconsolidated deposits that are likely to flow when wet) from the mine workings should be at least 180 feet thick. This same guideline should apply when mining under previous workings that cannot be inspected and certified free of dangerous accumulations of water. If these reservoirs or deposits intersect the coal bed, a pillar of unmined coal 200 feet wide should be left between the workings and the intersection.	Full extraction will require considerable surface and subsurface exploration and testing on the part of the mine operator and is therefore considered a Level II Guideline.
General Mine Planning Procedures	These are as shown in the text under the sub-headings of Management and Supervision, Mine Plan Mapping and Geologic Data, Water in Mines, and Escapeways.	Same as Partial Extraction Guidelines.

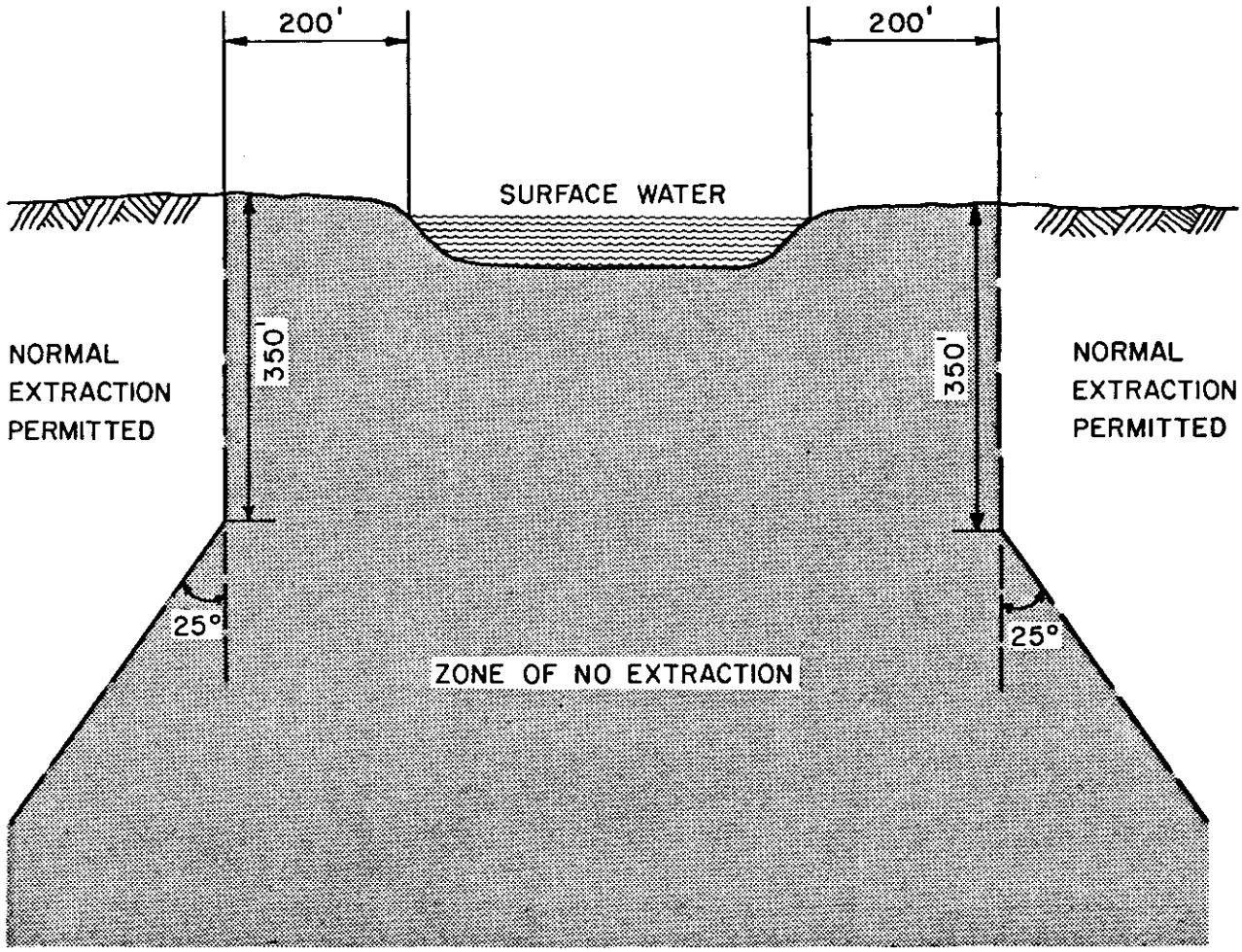

FIGURE 1. SAFETY ZONE FOR MINING UNDER CONTINENTAL SURFACE WATERS LEVEL I GUIDELINE

survey the Zone of No Extraction and incorporate this area into his mine plan. Level II Guidelines, presented later in this report, will allow additional recovery of coal reserves in this Zone, but only after an intense geologic and engineering data gathering effort.

The continuation of the safety zone at a 25° inclination from the 350 foot level is intended as protection against the subsidence inbreak angle due to roof falls and full extraction mining. Figure 2 gives an example of inbreak angles. These angles are influenced by the type of overlying rock, the dip and thickness of the coal seam, and also the direction, rate, and type of mining being conducted. Of course, workings at depths of 350 feet or greater usually do not induce surface subsidence effects as a result of localized roof failures. In one inundation case history, however, 344 feet of cover was not sufficient to prevent mine flooding when a safety barrier pillar underlying a stream was breached by a small development entry.

Consideration of Percentage Extraction

The percentage of the coal reserve base that can be recovered in the area designated Normal Extraction Permitted (Figure 1) will depend on many factors other than the surface waters. Some of these factors are: depth of the proposed workings beneath the surface; thickness and

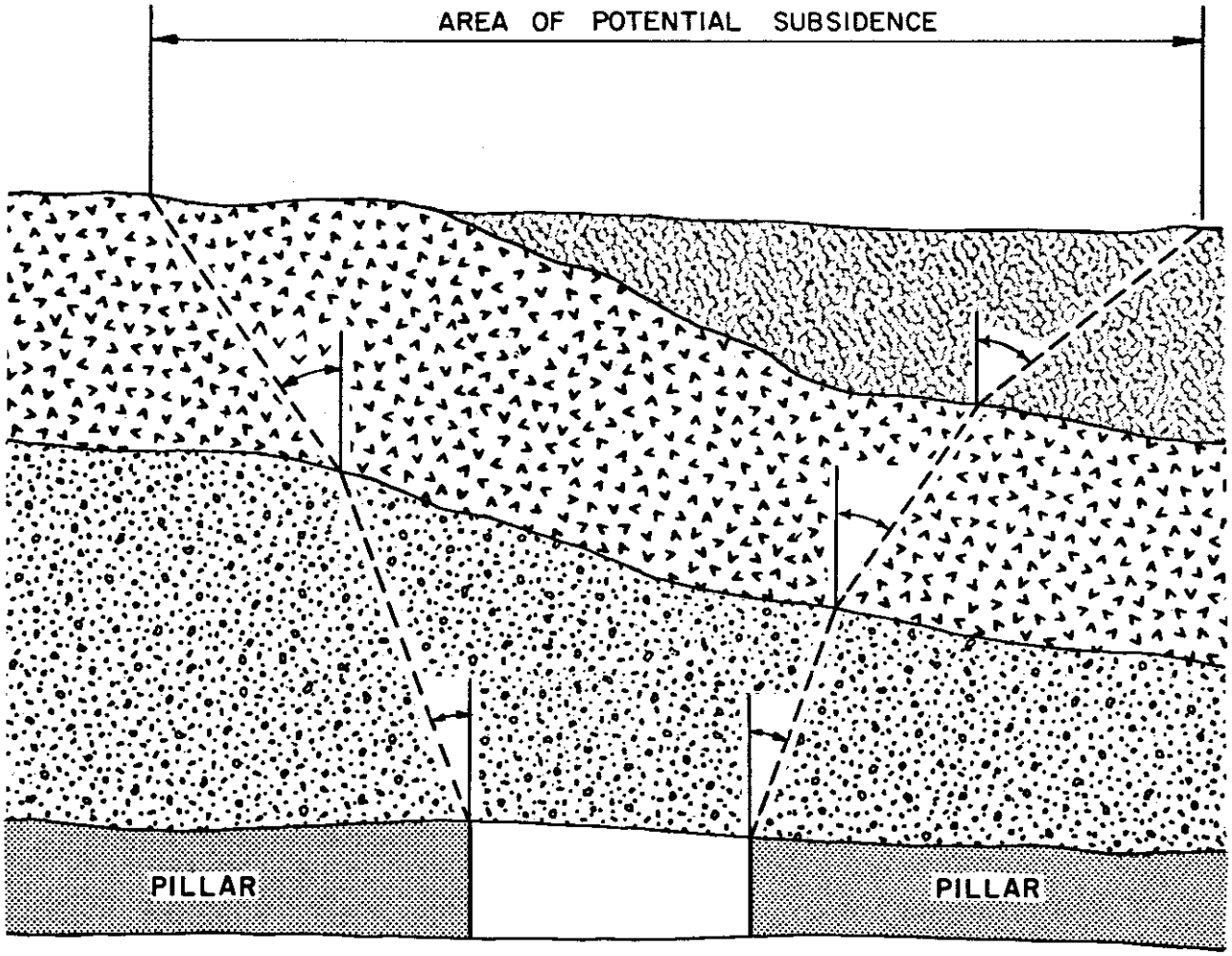

FIGURE 2. EXAMPLE OF POTENTIAL SUBSIDENCE AREA DUE TO INBREAK ANGLES.

integrity of consolidated rock structures in the overburden; thickness of the seam; strength and resistance to subsidence and cave-ins of the overburden rock structures; existence of abandoned workings and their proximity to the active workings; preference of mine officials for partial or full extraction mining methods; government restrictions which may limit recovery; and purchases of coal reserves by surface land owners. These factors should already have been considered in the mine development plan of the company.

Mining Near Abandoned Workings and Natural Subsurface Hazards

As with Continental Mining Under Surface Waters, the full and partial extraction guidelines for Mining Near Abandoned Workings will generally be identical. The requirements for Level I Guidelines ensure the safety of the miners with little or no subsurface exploration or testing on the part of the mine operator. This leaves large blocks of coal and overburden which generally afford adequate protection to the mine workings regardless of extraction methodology or percentages. The full and partial extraction guidelines for Mining Under Unconsolidated Deposits and Natural Reservoirs are necessarily different as denoted in Table 1.

Establish Barrier Pillars Around Abandoned Workings

Breaking through into abandoned workings presents the greatest

inundation hazard to underground mining. Even when these abandoned workings can be inspected and certified free of potentially dangerous accumulations of water, they still should be approached with caution. The disrupted rock mechanics in the strata above the abandoned workings can cause roof problems for the approaching mine which could possibly result in fracturing to overlying waters. Therefore, guidelines presented in this sub-section consider flooded and dry abandoned workings.

Whenever a working section approaches within 200 feet of any abandoned workings of that mine or any other mine that cannot be inspected, it should be assumed that these abandoned workings contain potentially hazardous accumulations of water and all mining should cease. The 200 foot stopping distance affords adequate protection to the mine workings while allowing for some degree of survey error in mine mapping. When the abandoned mine or workings can be inspected and certified free of dangerous accumulations of water, the active section can approach closer than 200 feet; but no closer than permitted by property boundary barrier pillar requirements, or no closer than the minimum effective pillar size as reflected by the width to thickness ratio of 10 to 1, whichever is applicable. Where faults are known to occur that could impair the strength of these barrier pillars, additional pillar width may be required as determined by the mine engineer and mine inspector.

Charles T. Holland, Professor Emeritus, West Virginia University, has found that pillar stability can generally be assured when the width to thickness ratio of a square pillar is at least 9 to 1. To allow for variability in the affecting parameters and for consideration of the crushed edges of the pillar due to uneven load distribution, a ratio of at least 10 to 1 should be adopted. Therefore, extraction in a 5 foot thick coal seam should leave square pillar supports of 50 feet. Pillars of smaller width are frequently utilized with very satisfactory results where the stress on the pillars is not great. For example, where pillar stress is 900 psi and 60 percent of the coal is recovered in first mining with 12 foot wide passageways, a factor of safety of about 2 is realized with pillar width of 21 feet. Determining the width of passageways and pillars is site specific for each individual operation considering the following factors: ability of roof rocks to span the passageway; mining method and equipment used; possibility of falls extending to the surface or to overlying beds which should be protected; and the possibility of squeezing of roof and floor rocks.

In summation, this guideline allows mining to within 200 feet of any abandoned workings which cannot be inspected, and to within a distance where pillar stability is assured by a minimum pillar width to thickness ratio equal to 10 to 1 for workings which can be inspected and certified

free of dangerous accumulations of water (or to the limit of the property boundary pillar requirement, whichever is larger).

Property Boundary Barrier Pillars

A boundary barrier pillar of solid coal should be left to the property line of each individual operation to guarantee the integrity of that mine and any adjacent mines, and to avoid the possibility of breakthrough into any abandoned workings which may have been mined near to or beyond their property limits. This guideline will offer protection to future mine workings if a present mine should be abandoned and allowed to fill with a dangerous accumulation of water.

The width of the property barrier pillar will depend upon the thickness of the seam being mined and the depth of that seam below the property line and is calculated as follows:

$$Pb = 10 + 2T + 5D,$$

where Pb is the width of the boundary barrier pillar in feet, T is the thickness of the bed in feet rounded to the next highest integer, and D is the depth of the bed at the property line in 100 foot increments rounded to the next highest integer. For example, a 50 inch thick seam (4 feet, 2 inches; T = 5) at a depth of 520 feet below the surface at the property line (D = 6) will require a 50 foot thick barrier pillar. This requirement

is imposed on both mine workings on each side of the property line and as such results in a total pillar thickness of 100 feet.

Where the coal on one side of the property line has been mined closer than is permitted by this guideline, the approaching workings must compensate and the width of the boundary barrier pillar should be increased. For instance, if in the above example the previous working had come to within 10 feet of the property limits, the approaching workings must leave a barrier pillar of 90 feet to provide the 100 foot total requirement.

Areas where faults occur within the coal that is to be left as a boundary barrier pillar may require additional pillar width to the fault line to so compensate. Faults, joints, and other types of fractures may be natural or man-made and may have bond strengths ranging from zero to values greater than the host rock. Additional pillar width that may be required to protect the mine workings under these conditions should be estimated, based on the experience and judgment of the mine engineer and mine inspector.

Mining Near Wells, Shafts or Other Openings

Oil and Gas Wells

Current Federal regulations require barriers of not less than

300 feet in diameter to be left around all oil and gas wells that penetrate the coal bed. It is recommended that the well be located within 30 feet of the pillar center. This protects the workings from potential inrush of natural gas or water (generally the water problem is more serious with abandoned wells). The 300 foot barrier pillar has proven satisfactory in protecting the mine workings from any leakage that may be associated with the well and in preventing accidental mining into the well casing itself. The Bureau of Mines and Energy Research and Development Administration are currently working on methods of sealing abandoned wells to permit mining through and recovery of these barrier pillars. These will be discussed more fully within the Level II Guidelines. At present there seems to be no reason to alter the current Federal requirement of leaving barrier pillars of unmined coal 300 feet in diameter as protection around oil and gas wells.

Shafts and Other Mine Openings

Generally, to protect the shaft entry and the surface buildings and equipment from subsidence, a barrier pillar of unmined coal is left around the shaft. These coal pillars are also left around slope and drift entries and around important galleries such as haulage ways, traveling ways, some drives, raises, and other mine structures which are needed for an

appreciable time. If the shaft is cased and grouted properly, it should offer no water seepage problem to the mine working.

Upon abandoning of the workings, these pillar supported areas offer cavities where substantial water accumulation may occur. The barrier pillar requirements outlined in this section offer protection in most instances; however, mining into raises, shafts and like structures is not necessarily prevented.

Where shafts, raises, and other vertically extended structures penetrate the coal seam, and cannot be inspected and certified free of dangerous accumulations of water, a 200 foot thick barrier pillar of unmined coal should be left around the structure as protection against inundation. This 200 foot stopping distance affords adequate protection to the mine workings while allowing for some degree of survey error in mine mapping. When these structures can be inspected and certified safe, a barrier pillar of width to thickness ratio of 10 to 1 should be left to guarantee present mine integrity. When mining in the area of abandoned slopes and other inclined openings, the guidelines for mining near abandoned workings should be followed.

Mining Under Unconsolidated Deposits and Natural Reservoirs

Whenever natural reservoirs or unconsolidated deposits that are

likely to flow when wet are known to exist above the coal seam or to intersect with the coal seam, a partial extraction guideline must be followed to prevent their inundation of the mine. Whenever these are known to exist above the worked seam, the thickness of the intervening strata separating them from the seam should be at least 180 feet. No mining should be permitted within that 180 feet of overlying strata. Holland has noted that roof falls generally do not extend vertically more than three times the passageway width, however, certain factors have very significant effects on the vertical extent of roof falls. Holland denotes these as: 1) How well the cleavage system is developed in the roof rocks. A well developed set of joints will promote falls of greater extent; 2) the stress system that is acting in the horizontal direction. Roof rock tension could extend the height of a fall, and open joints may be an indication of roof tension; 3) the strength of the rocks that compose the roof. Strong rocks such as sandstone usually mean shallower falls. Since Level I Guidelines preclude the compilation of this information, the 180 foot guideline has been adopted from present mining directives in this area. This guideline should also apply when mining under a previously mined seam whose workings cannot be inspected and certified free of dangerous accumulations of water.

When these natural reservoirs or unconsolidated deposits are known to intersect the coal bed, a pillar of coal large enough to protect

the integrity of the mine workings must be left. In order for this pillar to give adequate protection to the workings, it should be 200 feet wide or as wide as those required when mining near abandoned workings.

Guidelines in this sub-section apply totally to partial extraction techniques. Full extraction will require considerable surface and sub-surface exploration and testing by the mine operator and is therefore considered within the Level II Guidelines.

General Mine Planning Procedures

Upon reviewing case histories of mine inundations, it was found that some massive water influx occurred even though precautionary guidelines existed as defined under the other major guideline categories. Naturally, the benefits or protection realized by following established guidelines can only be as reliable as the superintendent of the operation responsible for their implementation and supervision. Even though a conscientious plan for guideline implementation may be practiced, poor or inadequate mapping can offset any attempt to ensure proper safety factors. Many other precautionary factors, critical to the safe operation of an underground mine, are a matter of good common sense and frequently do not lend themselves to documented guidelines. It is with this thought that the following General Mine Planning Procedure guideline recommendations are presented.

These guidelines were derived entirely from existing regulations and, if implemented, should effectively preclude accidental inundations with little or no subsurface exploration on the part of the mine operator.

Management and Supervision

Management-supervisory personnel have very significant influences on inrush potential, as all judgments and responsibilities lie under their jurisdiction. Existing guidelines are aimed at ensuring competent, qualified personnel in decision making positions. In some cases, exact duties of certain individuals are defined. Some of the guidelines which general management has the responsibility to implement are briefly outlined below:

- Take all steps necessary for obtaining existing information which indicates or tends to indicate the presence or absence of:

  a) abandoned contiguous workings
  b) rock strata containing or likely to contain water
  c) material that is likely to flow when wet

  in the vicinity of any proposed workings in a mine. It is management's responsibility to substantiate all collected data.

- Copies of all collected data should be distributed to all planning personnel to make possible complete evaluation and delineation of potential danger areas.

- Where it is thought that an abandoned, disused, or discon-

tinued working or excavation contains or is likely to contain a dangerous accumulation of water, the surveyor should, by notice in writing, inform the superintendent to that effect.

- The surveyor should ensure that the superintendent is at all times aware of the faces which are being advanced.

- The surveyor should be responsible for correct establishment of survey pegs necessary for measurement, direction, and inclination of such workings and shall provide the superintendent with correct, relevant survey data in writing.

- The surveyor should inform the superintendent in writing when workings are approaching limited work areas as imposed by abandoned workings, surface waters, or other dangers.

- All survey work should be performed by a competent registered engineer or surveyor.

Mine Plan Mapping and Geologic Data

To fully assess inrush potentials, supervisory personnel must have current, complete, and accurate information on existing conditions in the mine area. Needless to say, decisions and plans of action for mine development which are designed to guard against massive inundations can only be as dependable as the accuracy and completeness of collected information. General guidelines which pertain to mapping and geologic data gathering include:

- All mine surveys and map preparation should be conducted by a competent registered engineer or surveyor.

- All materials submitted with applications for permits or approvals must be supervised and certified by a competent registered engineer or surveyor.

- All collected geologic data should be reviewed and evaluated by a competent geologist and/or mining engineer.

- The operator of a mine must have an accurate, up-to-date map of that mine, drawn to a consistent scale, and kept in a safe, fireproof location on the surface which minimizes danger of map destruction. Such a map should include the following pertinent information:

  Surface: Surface features may be shown directly on the mine map, or on a transparent or translucent sheet, which, when overlain on a map of underground workings, shows true and exact relations of surface features to mine workings and excavations. Surface features to be shown include:

  - Name and address of the mine
  - Scale and orientation of the map
  - Boundary lines and names of all surface property owners
  - Boundary lines of the coal rights pertaining to each mine
  - All coal outcrop lines
  - Topographic features such as hills, ravines, intermittent and permanent streams, bodies of standing waters (with elevations and estimated depths)
  - Location and identification of municipal subdivisions (state, county, townships)
  - Location of all railroads and sidings, highways, and other roads
  - Location and identification of mine buildings and facilities
  - Location of all utilities and pipelines
  - Location and depth of holes drilled for oil, gas, water, or geologic information that penetrate a workable seam

- Location of mine openings
- Location and description of a permanent bench mark or monument near the main mine opening

Underground: Whether or not combined on the same sheet with surface features, at least one set of underground mine maps must be composed on the same scale. Pertinent information to be recorded on the mine map includes:

- Name and address of the mine
- Scale and orientation of the map
- Boundary lines of coal rights and owner identification
- Structure contours and dip of the coal bed being mined at not greater than 10' elevation intervals
- Location of all drill holes that penetrate the mined bed
- All shaft, slope, drift, and tunnel openings and auger and strip mined areas of the bed being mined
- Location of all ventilation fans
- Location and exact extent of adjacent active or abandoned underground workings above, below, or in the same seam. If abandoned workings are known to exist in an area, but exact extent is not known, it should be so indicated
- Up-to-date locations of active work areas, worked out areas, and abandoned areas
- Locations of entries and aircourses with direction of airflow indicated by arrow
- Location of all escapeways
- Location and exact extent of all water pools, water bearing strata, or fluid-like materials which tend to flow when wet (quicksands, peat, etc.)
- Location and elevation of any body of water dammed or held back in any portion of the mine
- The location and description of at least two permanent base line points coordinated with the underground and surface mine traverses,

and the location and description of at least two permanent elevation bench marks used in connection with establishing or referencing mine elevation surveys

- The elevation of tops and bottoms of shafts and slopes, and the floor at the entrance to drift and tunnel openings
- The elevation of the floor at intervals of not more than 200 feet in:

  1) At least one entry of each working section, and main and cross entries
  2) The last line of open crosscuts of each working section, and main and cross entries before such sections and main and cross entries are abandoned
  3) Rooms advancing toward or adjacent to property or boundary lines or adjacent mines

- The owner, agent or manager of a mine should take all reasonable steps to determine whether there is any material below the surface which could affect active, or soon to be active, areas in a mine as to cause danger to miners working in that mine . All facts pertaining to such conditions must be presented to the manager.

The general guidelines presented above are the most notable precautionary measures. Any inability to accurately record the information described above will cause reliance on faulty data, resulting in potentially dangerous operating conditions.

Water in Mines

Proper and efficient handling of water in a mine can help protect against accidental flooding and can reduce effects of water infiltration.

General guidelines pertaining to water in mines include:

- Keeping all passageways and working places used by persons and equipment well drained and free of water while occupied.

- Prohibiting construction of any restraining dam or structure where rupture of such would imperil the safety of any miner in that mine or any other mine. (In emergency situations, installing a temporary restraining dam may be acceptable, but only after approval by the proper regulatory agency.)

- Forbidding men to work in any portion of a mine where a body of water is dammed or held back at a higher elevation in the same mine (unless approval is obtained by the proper regulatory agency).

- Establishing and maintaining storm water trenches and embankments to protect surface machinery and underground workings from flooding, at every shaft or other similar opening from the surface which connects with underground workings.

- Closing a mine whenever the lives of miners employed herein are jeopardized by reason of high water or overflow of adjacent streams, until the danger has passed.

- Keeping watch on all reasonably accessible sources of flooding danger, all artificial constructions for conserving or transporting water which may cause water to converge or accumulate.

Escapeways

Establishing safety or escapeways during the course of mining affords excellent protection for miners in case of sudden inrush of water. Generally, in any mine, where there is a potential danger of a sudden inrush from any source, additional openings should be provided that

permit miners to escape without using the traveling ways likely to be inundated. Locations of such escapeways should be dictated by a responsible regulatory agency.

Occasionally the mining plan will consist of a single entry, stope, riase or small drift which does not lend itself to escapeway construction. As a minimum, notification should be posted at the entry to that area, that no escapeway is available.

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DEVELOPMENT AND PRESENTATION

OF LEVEL II GUIDELINES

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DEVELOPMENT AND PRESENTATION OF LEVEL II GUIDELINES

PURPOSE OF LEVEL II GUIDELINES

The recommended guidelines presented in this section of the report, termed Level II Guidelines, are those where various testing and investigative procedures are outlined, whose adherence would promote the greatest possible mineral extraction while precluding accidental mine inundation. This section of the report also discusses the economic benefits which could accrue if these guidelines are incorporated into the mine development plan. The type and extent of the required testing and investigative procedures are fully defined for each circumstance encountered, and the reliability of the resulting mine development in terms of mine safety and recommended factors of safety is addressed. In addition, the appropriate geophysical, rock mechanics, and mining engineering design and analysis techniques are discussed. Level II Guidelines define the methodology to follow in recovery of some of the coal reserves that are necessarily lost through Level I requirements.

Some of the uncertainties of subsurface strata relate to the non-homogeneities encountered, such as:

(a) Differing permeabilities of the various sedimentary strata.
(b) Differing permeabilities of faults and other fractures and the difficulty in predicting their hydraulic continuity.

(c) Shatter zones frequently found adjacent to faults which tend to be highly permeable aquifers.
(d) Dikes, veins, sills and other intrusive strata that form impermeable barriers in the host rock.
(e) Other non-homogeneities such as old river beds, channels, grouted well casings, etc.

Methods of testing and investigating for these non-homogeneities and other factors influencing mining are discussed in subsequent sections of this report.

CURRENT GUIDELINES USED IN LEVEL II DEVELOPMENT

The current State, Federal, and Foreign guidelines which fit the Level II category are summarized in Appendix B. Where necessary, the Level I Guideline is repeated in order to facilitate a more complete understanding. Guidelines for mining under the sea are also included and are further discussed in Appendix C. While there is no present, and little future potential for, mining under the sea in the United States, the guidelines and special mining considerations that have been developed in other nations do have potential application in operations beneath overlying flooded mines, large river systems, stored surface waters, and other subsidence related problems. In light of this fact, these engineering concepts warrant consideration.

LEVEL II GUIDELINES

Level II Guidelines have been developed with the intent of recovering the greatest percent of coal reserves possible while providing for a working environment safe from inundation hazards. Application of and adherence to these guidelines should have precluded the occurrence of prior coal mine inundations that were reported in the Phase II report of this study. Guidelines presented here are taken in part from current guidelines that have proven applicable to inundation prevention. In addition, methodology has been developed for investigative and testing procedures to define mining limits. These techniques should permit mining up to safe limitations in areas of differing parameters or in areas where inundation hazards are known or suspected to exist. For ease of discussion, guidelines are divided into the following major categories:

- Mining Under Continental Surface Waters
- Mining Near Abandoned Workings
- Mining Under Natural Subsurface Hazards

Major categories are subdivided as needed to address specific considerations. The General Mine Planning Procedures category, presented in Level I Guidelines, is considered applicable to Level II operations and need not be repeated here. These guidelines are applicable when mining under any water body that, in the opinion of the mine inspector and responsible government permit granting agency, could present a hazard to underground mining

operations. A thorough review of inundation case histories reveals that during seasonal high water flow or flooding conditions, even normally small water bodies present potential hazards to underground mining. Therefore, it is recommended that the mine inspector and permit granting agency take into consideration such factors as normal and peak volume flow, watershed area and flow, and water-table levels.

Guidelines presented here are applicable to flat lying beds and beds that are inclined less than 30%. When applying guidelines to inclined beds, the strata overlying that part of the bed closest to the water body should be evaluated for strength and cohesiveness.

Level II Guidelines are not directly applicable to mining steeply inclined beds such as are often found in Pennsylvania anthracite fields. In order to develop guidelines for these conditions, much more empirical data would need to be gathered. These steeply pitching beds can outcrop in river beds or in abandoned strip pits that have filled with unconsolidated deposits. Values for such parameters as slip plane frictional coefficients between the coal bed and surrounding rock, the strength of the coal in the overlying pillar, the time dependent effect of permeability on strength, the minimum pillar height required to protect the workings, the pressure head above and the permeability of the overlying coal all need to be assessed. Guidelines for these steeply inclined workings are beyond the scope of this report.

Specific Level II Guidelines are presented in Table 2. Unless otherwise denoted, these guidelines presume that no additional hazards (faults, impermeable zones, etc.), other than those specifically addressed, have been delineated by the investigative and testing procedures that are conducted in advance of mining. The assumptions, considerations, and methodology used in developing Table 2 are presented in the sections following.

Mining Under Continental Surface Waters

In order for mining to progress into the safety zone established under Level I Guidelines, the operator should ensure that he is in possession of as much geologic and prior mining information related to interlying strata between the water body and working seam that is available. He should know, to the extent possible, the location, extent, and thickness of unconsolidated and cohesive strata that overlie and underlie the coal bed. Location and extent of old workings and unmined beds that should be protected should also be known. Reservoir beds and zones of high permeability should be delineated along with fault zones and any associated shatter zones or zones of impermeability. Water problems experienced by prior mining in overlying seams should also be evaluated for potential applicability to present mining conditions. This data, along

TABLE 2

LEVEL II GUIDELINES RECOMMENDED FOR MINING UNDER SURFACE WATERS OR HAZARDS WHICH COULD RESULT IN INUNDATION

CATEGORY	PARTIAL EXTRACTION GUIDELINES[1]	FULL EXTRACTION GUIDELINES
I. MINING UNDER CONTINENTAL SURFACE WATERS	1. Cohesive roof rock equal to five times the width of the heading must exist between the coal bed and the water body. Cohesiveness is determined by: a) Strength of the water saturated specimen equal to or greater than 4,000 psi as determined by uniaxial compression testing. b) The rock quality designation (RQD) must be determined quantitatively be geologic core evaluation. c) The thickness of the strata that fits requirement "a" must, when multiplied by the rock quality designation (RQD) determined in "b", be equal to or greater than five times the width of the mine heading. 2. Pillars must be designed for stability according to the procedure described in the text, or an equivalent procedure that can be shown to give the same degree of pillar dependability. A factor of safety of at least 2 should be applied. 3. Coal bed floor rock must be evaluated for strength by uniaxial compression tests conducted on water saturated core samples taken from the bedding plane. A factor of safety of 4 should be applied to the results of these tests. Pillar design must consider the strength of the floor rock so that the maximum potential load transferred from the pillar (including the safety factor) does not exceed the bearing capacity of the floor rock as defined by uniaxial testing. 4. When mining for the first time under a water body, or when mining any coal bed overlying the bed of first extraction, two development headings (for ventilation purposes) kept as narrow as possible should be driven through the safety zone. These headings should not exceed 15 feet in width unless special approval has been received from the responsible government agency.	1. At least 100 feet of intervening strata should exist for each 1 foot of extracted seam thickness; and, the cumulative tensile strain induced on the floor of the water body from all underlying mining operations should not exceed 10 parts per thousand. Tensile strain is calculated as shown in the text. 2. Full extraction mining should not be considered where total overburden thickness is less than 700 feet unless the overburden is monitored for stability by techniques such as microseismic monitoring. If monitoring is used, the overburden requirement can be reduced to 350 feet for a 3.5 foot thick coal bed. 3. Partial extraction mining can be conducted, as defined by the partial extraction guidelines, if cumulative tensile strain is at or near 10 parts per thousand.
II. MINING NEAR ABANDONED WORKINGS[2]		
A. Establish Barrier Pillars Around Abandoned Workings	1. Locator boreholes should be drilled from the advancing face which is nearest to the abandoned mine, through the 200 foot barrier pillar (required by Level I Guidelines) to determine the location of abandoned workings. The equipment and materials necessary to plug the borehole upon breakthrough	1. Same as for Partial Extraction Guidelines

1) Denotes room-and-pillar first mining, or mining of approximately 50 percent of the coal reserve

2) These guidelines should be considered applicable to partial and full extraction workings unless otherwise denoted.

TABLE2 (CONTINUED)

LEVEL II GUIDELINES RECOMMENDED FOR MINING UNDER SURFACE WATERS OR HAZARDS WHICH COULD RESULT IN INUNDATION

CATEGORY	PARTIAL EXTRACTION GUIDELINES	FULL EXTRACTION GUIDELINES
II. MINING NEAR ABANDONED WORKINGS A. Establish Barrier Pillars Around Abandoned Workings (Continued)	1. (Continued) must be available to the drill crew. The water head pressure or atmospheric conditions in the abandoned workings should be determined.	
	2. Unless down hole instrumentation definitely establishes that no water exists in the abandoned workings, even though pressure or gravity flow does not occur at breakthrough, the workings should be assumed flooded. If it is subsequently determined that the abandoned workings are dry, mining may proceed up to the limits of the boundary barrier pillar requirement (when approaching the property line) as defined by Pb = 10 + 2 T + 5 D where Pb is the pillar width in feet, 10 is a constant safety factor, T is the thickness of the bed in feet rounded to the next highest integer, and D is the depth of the seam at the property line in hundred foot increments rounded to the next highest integer; or normal mining operations should be permitted when property limits are not a factor to be considered in this development.	2. Same as for Partial Extraction Guidelines
	3. Water may be drained from abandoned workings through a drift or auger entry, if possible, or from boreholes drilled from the surface. Water also may be drained through the 200 foot barrier pillar to the active workings and pumped to the surface. This latter method is potentially hazardous, however, and should only be done under the direction of knowledgeable and experienced personnel. The permits necessary to discharge the water on the surface will need to be procured.	3. Same as for Partial Extraction Guidelines
	4. If the abandoned workings are not initially dry or drained of water, an effective safety barrier pillar should be sized by utilizing modeling techniques and unconfined compressive strength tests. A factor of safety of 4 should be used in pillar design. Whenever the water pressure head is equal to or greater than 5 atmospheres, consideration should be given to draining these workings. The permeability of the unmined barrier pillar should also be determined for consideration of its affect on water and flow and further pillar development. Two proving headings (for ventilation purposes) kept as narrow as possible and protected by boreholes (as defined in the guideline titled "Drilling Boreholes in Advance of Mining") would be a safe	4. Same as for Partial Extraction Guidelines

TABLE 2 (CONTINUED)

LEVEL II GUIDELINES RECOMMENDED FOR MINING UNDER SURFACE WATERS OR HAZARDS WHICH COULD RESULT IN INUNDATION

CATEGORY	PARTIAL EXTRACTION GUIDELINES	FULL EXTRACTION GUIDELINES
II. MINING NEAR ABANDONED WORKINGS	4. (Continued)	
A. Establish Barrier Pillars Around Abandoned Workings (Continued)	mining plan to utilize for developing the barrier pillar up to the limits determined by this recommended testing procedure. These headings should be limited to 15 feet in width. The mining crew should be alert for signs of pillar instability, excessive water leakage, strong sulfur smell or other indicators of water, and mining halted or re-evaluated as necessary. The permeability of the pillar can be reduced and its strength increased by introduction of grout or other cementing agent.	
B. Drilling Boreholes in Advance of Mining	1. Two center face holes or lead holes should be spaced about 2 to 4 feet apart in the center of the section advancing toward an abandoned working, and maintained at a distance of 20 to 30 feet in advance of the heading. Side face holes located about 2 feet in from the rib should be drilled at an angle of 15° to the advance and maintained at a distance of 20 to 30 feet in front of the workings. These holes should be drilled on one or both sides of the advancing heading as required by the relative location of the abandoned workings. Rib holes should be drilled every 10 feet at an angle of 30° to the advance for a total length of 30 feet. These holes should be drilled on one or both sides of the advancing heading as required by the relative location of the abandoned workings.	1. Same as for Partial Extraction Guidelines
	2. These guidelines should not apply when the abandoned workings are part of the active mine and it can be safely determined, by the mine inspector, that no hazard to mining exists. In this case, mining may progress to the boundary barrier when approaching the property line, (as determined by the equation $Pb = 10 + 2T + 5D$) or normal mining operations should be permitted if the property limits are not being approached.	2. Same as for Partial Extraction Guidelines
C. Mining Under Flooded, Abandoned Workings	1. At least 100 feet of cohesive roof strata (as defined in "Partial Extraction Guidelines for Mining Under Continental Surface Waters") should be present between the abandoned and active workings.	1. At least 100 feet of intervening strata should exist for each 1 foot of extracted seam thickness; and, the cumulative tensile strain induced on the floor of the water body from all underlying mining operations should not exceed 10 parts per thousand. Tensile strain is calculated as shown in the text.

TABLE 2 (CONTINUED)

LEVEL II GUIDELINES RECOMMENDED FOR MINING UNDER SURFACE WATERS OR HAZARDS WHICH COULD RESULT IN INUNDATION

CATEGORY	PARTIAL EXTRACTION GUIDELINES	FULL EXTRACTION GUIDELINES
II. MINING NEAR ABANDONED WORKINGS C. Mining Under Flooded, Abandoned Workings (Continued)	2. Development headings should not be greater than 15 feet in width. A permit issued by the responsible government agency should be required if headings are to be greater than 15 feet in width.	2. Full extraction mining should not be considered where total overburden thickness is less than 700 feet unless the overburden is monitored for stability by techniques such as microseismic monitoring. If monitoring is used, the overburden requirement can be reduced to 350 feet for a 3.5 foot thick coal bed. 3. Partial extraction mining can be conducted, as defined by the partial extraction guidelines, if cumulative tensile strain is at or near 10 parts per thousand.
D. Property Boundary Barrier Pillars	1. Level I Guidelines for property boundary barrier pillars should not be altered for increased mineral recovery unless the mining proposal ensures inspection and certification that all of the affected workings are free from hazardous accumulations of water, and the proposal has: a) Been agreed to by the interested mining companies and superintendents. b) Been approved by the mine inspector. c) Received permit approval from the responsible government regulatory agency. d) Considered eventual interconnection of the mining operations either by accident or development plan. e) Considered the development plans from all affected mining companies.	1. Same as for Partial Extraction Guidelines
E. Mining Near Wells, Shafts or Other Openings	1. Oil and gas wells Mining should not come closer to active oil and gas wells than the 300 foot diameter barrier pillar required by current Federal regulations (± 30 ft.). When these wells are abandoned, however, they can be sealed and the barrier pillar mined through, provided that the seals are tested for leakage prior to mining. A method of sealing and leak testing is described in the text. 2. Shafts and other mining openings When these abandoned openings can be inspected and certified free of hazardous accumulations of water they can be mined through as in normal pillar recovery operations.	1. Same as for Partial Extraction Guidelines 2. Same as for Partial Extraction Guidelines

TABLE 2 (CONTINUED)

LEVEL II GUIDELINES RECOMMENDED FOR MINING UNDER SURFACE WATERS OR HAZARDS WHICH COULD RESULT IN INUNDATION

CATEGORY	PARTIAL EXTRACTION GUIDELINES	FULL EXTRACTION GUIDELINES
II. MINING NEAR ABANDONED WORKINGS E. Mining Near Wells, Shafts or Other Openings (Continued)	2. Shafts and other mining openings (Continued) When they cannot be inspected, drill holes should be driven to the opening and down-hole testing conducted to determine if water is present. If the tests show no water, the pillar can be recovered as in normal operations. If the tests show water, it should be drained out of the opening before the pillar is mined. After draining, it should be ascertained by monitoring that there is no further leakage into the opening. If leakage exists to an extent that could prove hazardous to the mining operations, the opening should be plugged and filled in, much the same as with abandoned oil and gas wells. After plugging, the opening should again be tested for leakage. If there is no further hazardous accumulation of water due to leakage, normal pillar recovery operations can be conducted.	
III. MINING UNDER NATURAL SUBSURFACE HAZARDS	1. Cohesive roof rock equal to 5 times the width of the heading must exist between the coal bed and the water body. Cohesiveness is defined in Partial Extraction Guidelines I. 1. 2. Pillars should be designed according to the procedure described in the section of this report entitled "Partial Extraction Guidelines" for "Mining Near Continental Surface Waters," or according to an equivalent procedure. A factor of safety of at least 2 should be applied. 3. Coal bed floor rock must be evaluated for strength by uniaxial compression tests conducted on core samples taken from the bedding plane . Pillar design must consider the strength of the floor rock so that the maximum potential load transferred from the pillar (including the factor of safety) does not exceed the bearing capacity of the floor rock as defined by uniaxial testing. A factor of safety of at least 4 should be applied.	1. At least 100 feet of intervening strata should exist between the coal bed and potential hazard for each 1 foot of extracted coal thickness; and, the cumulative tensile strain induced on the floor of the water body from all underlying mining operations should not exceed 10 parts per thousand. Methods of computing tensile strain are shown in the section of this report entitled " Full Extraction Guidelines" for "Mining Near Continental Surface Waters." 2. Full extraction mining should not be considered where total overburden thickness is less than 700 feet. Mining can be conducted closer to the natural hazard if the intervening strata is evaluated for strength and cohesiveness by RQD and uniaxial core testing and is monitored for stability by techniques such as microseismic array. If monitoring is used, the overburden requirement can be reduced to 350 feet for a coal bed up to 3.5 feet thick. Maximum tensile strain of 10 parts per thousand should be considered when mining between 350 to 700 feet.

TABLE 2 (CONTINUED)

LEVEL II GUIDELINES RECOMMENDED FOR MINING UNDER SURFACE WATERS OR HAZARDS WHICH COULD RESULT IN INUNDATION

CATEGORY	PARTIAL EXTRACTION GUIDELINES	FULL EXTRACTION GUIDELINES
III. MINING UNDER NATURAL SUBSURFACE HAZARDS	4. When mining for the first time under potential hazards, or when mining any coal bed overlying the bed of first extraction, two development headings (for ventilation purposes) kept as narrow as possible should be driven through the hazardous area. These headings should be the only development permitted until the hazard has been passed or until the cohesiveness of the roof rock, underlying a potential hazard, has been demonstrated to the satisfaction of the mine inspector by extensive development mining and monitoring. These headings should not exceed 15 feet in width unless special permit approval has been received from the responsible government agency.	3. Partial extraction mining can be conducted, as defined by the partial extraction guideline, when the cumulative tensile strain is at or near 10 parts per thousand.

with mine development plans for the area within the safety zone, should be presented for permit approval to the responsible government agency. With the above information, Level II Guidelines will allow partial and full extraction resource recovery in the safety zone of no mining that was established by Level I Guidelines.

Geologic stratigraphy should be obtained by coring of the strata within the safety zone directly below and adjacent to the water body, from the surface to the strata below the coal bed. Much information can be gleaned from core evaluations, as discussed in the following sub-section entitled "Partial Extraction Guidelines". The location and number of holes to be cored will depend on the extent of the water body, presence of discontinuities, nature of sedimentary deposits (flat bedded or inclined), presence of lenticular deposits or intrusive structures and the percentage core recovery. These corings must be evaluated by qualified, competent individuals who will be responsible for submitting these core evaluations to the responsible government agency. Those conducting the coring program must be able to determine the required locations, distance between drill holes, and total number of corings needed. Frequently, holes for reserve evaluation and mine planning are drilled on 330 foot centers; however, this may prove inadequate for proper evaluation of strata under continental surface waters. This

requirement should be subject to final approval by the responsible government agency prior to issuance of a permit to mine within the safety zone.

Generally, the cost of coring will average about $14 per foot of strata. The cost of the coring and core evaluation program will need to be evaluated against the benefits accruing from this additional resource recovery.

Additional information may be obtainable from aerial photography. Color or color infrared low level photography would probably be the most applicable type of aerial data gathering as it would allow adequate resolution of small or localized surface structures. Some of the structures that could be detected include faults, fracture traces, general stratigraphy, subsidence areas, streams and rivers, ponds and lakes, impoundments, watershed divides, and drainage areas.

Partial Extraction Guidelines

Existing regulations related to mining near the surface are frequently based on local conditions and experiences. For example, extensive evaluations of surface subsidence due to partial extraction mining in England has shown that overburden thickness of 150 feet is generally sufficient to prevent subsidence problems and to protect the integrity of mine rooms that are limited to 10 feet in width. Where the operator has sufficient information

about intervening strata to determine that hazardous conditions would not ensue if he mined closer than 150 feet, mining is permitted to within 60 feet of the surface or 10 times the height of the coal seam, whichever is greater. In Pennsylvania, mining is permitted under surface water bodies where test drilling has shown at least 35 feet of competent rock cover overlying the coal. In addition, most submarine mining regulations (such as those of the United Kingdom, Nova Scotia, British Columbia, Japan, and Chile) require about 200 feet of overlying strata to the seabed. While most of these guidelines are based on extensive research and testing, it is important to note that they are usually site specific. As such, they cannot be universally adopted.

Roof Rock Evaluation

For purposes of this Level II Guideline and in order to protect the integrity of the mine, it is recommended that partial extraction mining can be practiced wherever cohesive roof rock strata that is equal in thickness to 5 times the width of the mined rooms exists between the workings and the water body. (Partial extraction mining, as used here, refers to room-and-pillar first mining of approximately 50 percent of the reserve). The cohesiveness of the rock can be determined by various laboratory and in-situ testing procedures such as uniaxial and triaxial

testing, core evaluation, and seismic velocity testing.

For evaluation purposes, a core stringer should be taken from the first coherent rock strata below the surface, down to the level of the coal bed; or until it has been determined that the minimum required roof rock thickness does exist.

Much information on natural subsurface hazards can be obtained from exploratory drilling; however, a great deal of important additional information to fill in strata profiles between drill holes must be obtained by seismic techniques. Seismic evaluation of the strata overlying the coal seam is necessary to reveal the location and extent of subsurface hazards such as channel sands and alluvial deposits. Guidelines for these subsurface hazards are discussed in Section III, "Mining Under Natural Subsurface Hazards".

From the standpoint of cohesiveness, the most applicable data derivable from a geological examination of cores is the rock quality designation (RQD). Rock quality designation is a quantitative measurement of the extent of the cored strata that is intact. Deere and others describe a method of specifying RQD by core logging[9]. The ratio of the total length of intact cored strata that are 4 inches long, or longer, compared to the total length of the hole drilled, gives a measure of RQD. For example, if the total core run is 75 feet with intact strata of 4 inches

TABLE 3 - Uniaxial Compressive Strength of Some Coal Mine Rocks, psi

Southern Illinois Coal Area

Shale (Main Roof)	2,500 to 4,500
Limestone (Immediate Roof)	6,600 to 15,900
Shale (Immediate Roof)	5,000
Clay-Shale	1,400
Clay-Shale (Immediate Roof)	5,400 to 7,600
Sandstone (Sub-Floor)	6,900

Source: Dr. H. Reginald Hardy, Jr. [18].

Pennsylvania Coal Area

Floor Rock:	
Sandstone	9,400 to 12,600
Red Siltstone	5,000
Shaly Siltstone	3,500 to 6,700
Roof Rock:	
Siltstone	6,500 to 29,100
Limestone	3,400 to 4,200
Red Shale	2,200 to 2,900
Shale	3,700
Sandstone	9,500 to 12,600

Source: Engineering Characteristics of the Rocks of Pennsylvania, Bureau of Topographic and Geologic Survey, 1972.

or longer comprising 50 feet, the RQD is 50/75 or 67 percent. RQD percentage values of 0-25 denote very poor quality rocks, 25-50 are poor, 50-75 are fair, 75-90 are good, and 90-100 are excellent. This is one step in evaluation of cohesiveness of the intervening strata. In addition to the RQD, core examination also gives a measure of fracture

or parting spacing as well as qualitative indicators of cohesiveness such as rock type and recementation of fractures.

Uniaxial and triaxial compressive tests determine the strength characteristics of rock strata under laboratory conditions. These laboratory derived values are indicative of the relative strength characteristics of in-situ rocks. Values for some typical rocks are shown in Table 3. The geometry of the cores used was generally 2 or 2.5 to 1, height to thickness ratio, with a core diameter of 2 inches.

A classification of the strength categories of intact rock determined by uniaxial compression testing is shown in Table 4. Rocks that are classified low strength and above (≥ 4000 psi) can be considered as acceptable, cohesive roof rock.

TABLE 4 - Engineering Classification for Intact Rock

Class	Description	Uniaxial Compressive Strength, psi
A	Very high strength	> 32,000
B	High strength	16,000-32,000
C	Medium strength	8,000-16,000
D	Low strength	4,000- 8,000
E	Very low strength	< 4,000

Source: D. V. Deere and R. P. Miller [8].

Additional research is needed to determine the proper methodology

in core evaluation. At present only that part of a core that remains intact when a test specimen is cut from it, is used in unconfined compression tests. A method of evaluating the total core would prove beneficial in making an average strength determination.

Onodera describes how to measure moduli of elasticity for in-situ (E in-situ) and intact (E intact) rock to determine rock soundness and crack coefficient characteristics by conducting seismic velocity tests[33]. Rock soundness is determined by the ratio of $E_{intact}/E_{in-situ}$, and E_{intact} -- $E_{in-situ}/E_{intact}$ is referred to as the crack coefficient. His method of classifying rocks according to these measurable characteristics are shown in Table 5. A geological description of these various classifications is also given. This method of evaluation, however, is not as universally applied or accepted as is uniaxial compression testing.

In summation, there must exist between the water body and the mine workings, cohesive roof rock at least equal in thickness to 5 times the width of the passageway. This roof rock must:

1) Be evaluated to determine the rock quality designation;
2) Be equal to or greater than 4,000 psi in compressive strength as determined by uniaxial tests;
3) The thickness of the strata that fits requirement 2 above must, when multiplied by the rock quality designation, give a resultant roof rock thickness equal to or greater than 5 times the mine room width.

The permeability of these roof rocks will also be of interest to the

TABLE 5 - Classification of In-Situ Rock

		Soundness Classification of Rocks In-Situ		Geological Diagnostics of Rock Grade
Symbol	Grade	Soundness-Crack Coefficient		Geologic Description
A	Excellent	0.75-1.00	<0.25	Fresh, no alteration, few joints
B	Good	0.50-0.75	0.25-0.50	More or less jointed, joints only slightly open; some weathing along surfaces
C	Available	0.35-0.50	0.50-0.65	More or less parted by joints with or without minor clay filling; rock fresh but joint surfaces weathered
D	Deficient	0.20-0.35	0.65-0.80	Joints rather widely opened containing clay fill, water in joints, rock more weathered
E	Bad	<0.20	0.80-1.00	Advanced weathering; conspicuously jointed, cracked or crushed

Source: T. F. Onodera[33].

mine operator. Some typical permeabilities of rocks encountered in coal mining are given in Table 6.

TABLE 6 - Typical Permeabilities of Rocks Normally Encountered in Coal Mining

Material	Permeability Range gal per day/ft^2*
Clay	10^{-5} to 10^{-3}
Shale	1 to 100
Limestone	1 to 100
Sandstone	10 to 1000

*As defined by Meinzer, the rate of flow in gallons a day through a square foot of the cross section of material, under 100 per cent hydraulic gradient, at a temperature of 60°F.

Source: The Water Encyclopedia[44].

The greater the permeability, the greater will be the seepage of water into the mine. Therefore, the amount of water that will require pumping from the mine will be directly related to the permeability of the strata underlying the water body.

Not all coal mining operations below or near surface waters will prove to have large water inflows. In room-and-pillar mining where ground disturbance above workings is a minimum, the quantity of water entering the mine will primarily depend on in-situ permeability of fracture systems and the specific yield of water bearing zones in the overburden and floor strata. A classification of geological features likely to

influence the ground water regime between mine openings and surface waters is given below[37]:

(a) Sedimentary systems where the strata is composed of layers of material of different permeability, i.e. sandstone/shale or sandstone/coal/clay.

(b) Gouge-filled faults and seams tending to form impermeable barriers within rock masses.

(c) Shatter zones forming highly permeable aquifers within a rock mass. These are often found adjacent to faults.

(d) Dykes or other intrusive zones having a different permeability than the host rock.

(e) Solution channels.

Indirect methods of strata evaluation involving aerial photography, correlation of downhole and surface observations, and seismological testing may provide valuable data on the geometry of geological features. However, the intrinsic hydraulic properties of such features can usually be determined only by localized testing. The most important hydraulic property which must be assessed in estimating water inflows is the permeability of overburden material and coal. Permeability can sometimes be determined from pump-in-pressure-tests in drill holes conducted at and near grade of an underground mine opening or tunnel. Two widely used methods of conducting pressure tests use single packer and double packer methods respectively. Figure 3 illustrates a single packer set-up

utilized at a tunnel project in Australia; such a set-up may be applicable for permeability testing in coal operations located under water bodies. Packer testing sometimes gives erroneous results due to leakage, especially where the strata is friable. A series of packer tests, however, may give a good indication of strata permeability.

Assuming steady flow in accordance with Darcy's law, that the ground is saturated, and that the rock is or can be regarded as a homogeneous, isotropic, pervious medium, Goodman et al. [15] have derived an approximate equation for permeability making use of an assumed value for the radius of influence of the drill hole:

$$K = 8q/(2 \qquad P) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where, = length of the hole being pressure tested, cm or ft.
K = permeability for water in units of cm/sec, or ft./min.
P = gage pressure usually measured at the collar and corrected for the water table elevation and for the friction losses in the pipe between the meter and the discharge point in the bottom of the hole, pounds per foot[2]
q = pumping rate into the hole, pounds per min.

Thus, on the basis of water loss measurements in pressure tests conducted in drill holes, it is possible to assign a value of permeability to given regions in a rock mass along the line of a planned tunnel or underground mine opening. If in addition, geological studies can outline or give an indication of the location of zones of expected water inflow, it is possible

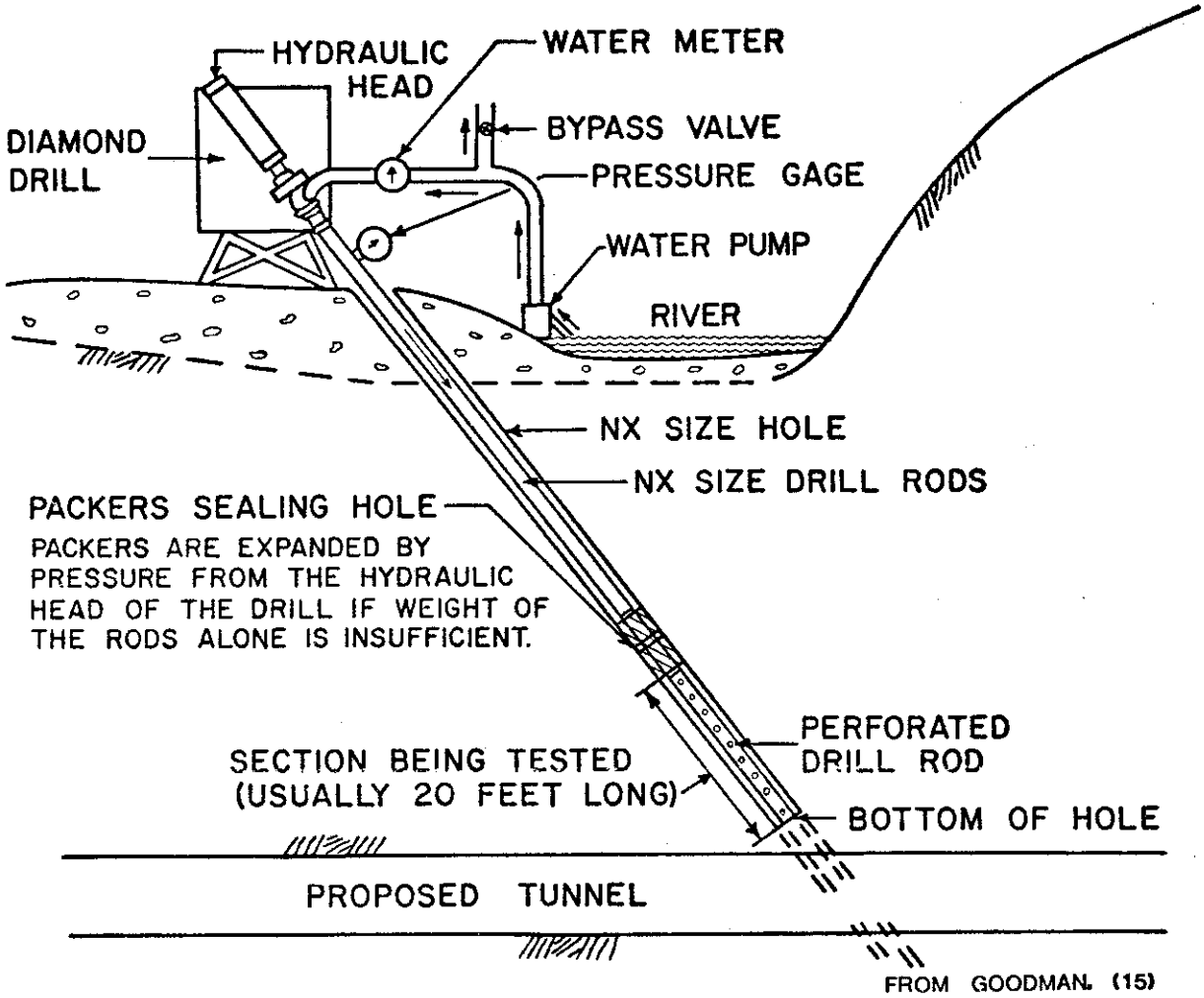

FIGURE 3. SINGLE PACKER ARRANGEMENT AS PROPOSED FOR PERMEABILITY TESTING OF OVERBURDEN AND COAL

to offer prediction of the size and duration of water inflows as underground workings advance through a water-bearing zone.

Determining the Width of the Heading

The width of the mined rooms will depend upon the strength and horizontal stress component of the roof rock and its ability to span the opening. The rock quality designation (RQD) for the immediate roof rock (as defined by the quantitative geological examination of cores) is one tool that can be used as an indicator of roof stability. An RQD of 50 percent or greater indicates a quality of rock which will safely span an opening of from 20 to 40 feet without requiring additional, heavy support. "Additional heavy support" denotes when portions of the overburden load is transferred away from the roof and the pillars to the artificial support constructed in the mine entry. Roof bolting and other light support systems which only hold loose rock surrounding the opening are not considered additional, heavy support systems. Roof rock with an RQD of less than 50 percent will require heavy support such as beams, yielding arch supports, cribbing, etc.

In addition to uniaxial testing and RQD evaluations, there are other methods of determining rock strength and cohesiveness. Dr. H. Reginald Hardy, Jr. and others have developed a fracture density classification

method for cored strata[18]. They relate this evaluation to rock strength and cohesiveness to predict roof control problem areas in the mine. The results of these site specific evaluations have not as yet been published.

Pillar Dimensioning

Pillars should be dimensioned as needed for stability and to accommodate the room width. Holland and Gaddy have developed a formula for estimating strength of coal pillars where:

$$S = \frac{K \quad L}{T} \qquad (1 \quad \frac{L}{T} \quad 12) \qquad (2))$$

where S is unit strength in psi, L is the least width of the pillar in inches, T is the pillar thickness in inches, and K is determined by:

$$K = S_c \quad D \qquad (3))$$

where S_c is the strength of the specimen as tested in the laboratory and D is the edge dimension of the cubical specimen being tested[19]. The units of K are pounds per inches to the 1.5 power. To determine S_c in equation (3), a representative sample of the coal seam is secured. From this sample, 20-25 cubical specimens, preferably 3 inches on a side, are cut. The cubical specimens are water saturated and tested wet in a uniaxial compression test. The average strength determined by the 20-25 tests is then used as the value for sample strength in equation (2). For example, if a representative sample has an average

specimen strength of 4,000 psi, then K is approximately equal to 4,000 times $\sqrt{3}$ or 6950 lbs/in.$^{1.5}$.

The shape of the pillar will also influence its strength as shown in Table 7. The circular pillar has the greatest relative strength; however, a square or rectangular shaped pillar is generally better suited to mine development. Moreover, the least width dimension appears to have the greatest effect on, and appears to be directed related to, relative strength.

TABLE 7 – Relative Supporting Strength of Pillars Having Various Cross-Sectional Shapes and the Same Area

Shape of Pillar	Least Width Feet	Strength psi	Relative Strength
Circle	58.5	3100	1.30
Hexagon	56.0	3000	1.25
Square	52.5	2900	1.21
Rectangle L × 1½ L	42.7	2600	1.08
Rectangle L × 2 L	37.0	2400	1.00

Source: C. T. Holland[20].

To determine the stress on the pillar, we can generally assume that overburden pressure equals 1 psi for every foot of overburden thickness. When mining a seam at a depth of 500 feet with 50 percent extraction, the average load on the pillars will be equal to $\frac{500 \text{ psi}}{.5}$ or 1000 psi.

When applying a factor of safety of 2, the pillar should be designed to withstand 2,000 psi. A factor of safety of 2 is applied to accommodate irregularities in the seam and uneven load distribution on the pillar. Referring back to equation (2), when S = 2,000 psi, K = 6950 lbs/in.$^{1.5}$, and T = 60 inches, we can determine a value for L, the least width of the pillar. Therefore,

$$L = \left(\frac{ST}{K}\right)^2$$

or L is approximately equal to 300 inches or 25 feet. For 50 percent extraction with square pillars, the room would necessarily be about 10 feet wide. Extraction of greater than 50 percent could probably be considered, or room width could be increased to accommodate the mining equipment.

A reliable pillar monitoring system can also be used to warn of any impending failure in the roof or pillars. A microseismic array monitoring system can be considered such a reliable monitoring system. Hardy reports that microseismic monitoring can effectively be done from the surface (to evaluate strata 1000 to 1500 feet deep) or it can be done from within the underground mine workings[18]. The hardware for a seven array station to effectively monitor a 500 by 500 foot area would cost from $50,000 to $75,000. This hardware is reusable with replacement required for approximately $2,000 worth of geophones and related equipment for each monitoring site. Unless a long term need could be

discerned for this equipment, the mining company would probably wish to contract with a service agency to do this work.

Holland has shown that mine pillars free from water and working under a factor of safety of 1.6 to 3 have stood for more than 34 years with no evidence of failure; and will probably not fail over several times this long[20]. When mining under surface waters, however, the pillars may become wet which would tend to significantly reduce their strength. This is why in originally defining S_c the specimens are saturated prior to testing.

Floor Rock Evaluation

So far we have defined methods of evaluating, and acceptable values for, cohesive roof rock and coal pillars. All that remains is to determine the bearing strength of coal bed floor rock. Cores should be taken in the floor to a depth equal to twice the width of the mine heading. Phillips has shown that bearing capacity of laboratory tested core samples can be determined based on the theory of elasticity with a factor of safety of 4 by:

$$P = 1.81\ S_o, \qquad (4)$$

where P is the safe bearing capacity and S_o is the tensile strength of the rock[34]. A 2 to 1 ratio of sample height to thickness was used. Unfor-

tunately, field evaluations of the theory are not provided.

Prandtl, however, observes that for clay the bearing strength in the mine is at least equal to 2.6 times the laboratory derived uniaxial compressive strength[35]. Dulaney evaluated the strength of shale floors and found that the ratio of bearing strength in the mine to the uniaxial compressive strength for wet shale samples ranged from 1.2 to 3.2[12].

It is safe to assume that uniaxial compressive tests will give satisfactory measures of the bearing strength of mine floor rock. Therefore, the pillar must be designed so that the load it imparts to the floor rock is within the bearing strength capabilities of that rock as determined by these uniaxial tests when a factor of safety of 4 is applied to the results of these tests. A factor of safety of 4 is recommended due to the scarcity of empirical data to confirm the results of laboratory unconfined compressive tests. Better correlating and predictive methods could probably result in a reduction of this recommended factor of safety. Some typical values of bearing strength, as determined by Dulaney, are given in Table 8. The geometry of the core samples used by Dulaney were 2 to 1, height to thickness ratio. The samples tested ranged from 1 inch squares up to 12 inch squares.

TABLE 8 - Compressive Strength and Bearing Strength of Coal Bed Floor Shales

Coal Bed	Unconfined Compressive Strength psi		Bearing Strength as found in the Mine psi
	dry	wet	
Elkhorn No. 3	3436	1341	1950
C Seam	4257	1968	5540
Upper Banner	3655	1250	4088
America	5857	1381	2272
Mary Lee	4447	1575	1994

Source: R. L. Dulaney (12).

Development Plan

If any abandoned workings exist in the same seam or overlying seam, or if natural reservoirs or unconsolidated materials that are likely to flow when wet overlie the workings, the applicable guidelines pertaining to those hazards should also be considered.

When mining is to be conducted for the first time under the water body or in any bed overlying the bed of first extraction, a safe development plan would consist of 2 headings (to meet ventilation requirements) kept as narrow as possible, driven through the safety zone. These headings should not exceed 15 feet in width unless special permit approval has been received from the responsible government agency. The mining crew should be alert for increasing water leakage, sulfur smells, or other indicators

of potential water hazards and the operation halted or reevaluated if these occur.

Full Extraction Guidelines

Full extraction mining should not be attempted unless at least 100 feet of intervening strata exists, between the bed and the surface waters or interlying hazardous strata, for each 1 foot of extracted seam thickness; and, it has been determined that the cumulative effect of multiple seam mining does not induce a tensile strain of more than 10 parts per thousand at the floor of the water body.

Stefanko has indicated that longwall mining under overburden of 650 feet or less can experience many roof control problems that make the system untenable and hence uneconomical[42]. In addition, submarine mining regulations in Nova Scotia require at least 700 feet of overburden to the seabed for subsidence protection before allowing full extraction mining to take place. However, National Coal Board guidelines require only about 350 feet of overburden in submarine mining areas. For these reasons, it is recommended that full extraction mining not be considered under roof that is shallower than 700 feet unless the overlying strata is to be monitored by techniques such as microseismic monitoring. If microseismic monitoring is to be used, the overburden can be as shallow

as 350 feet, for coal beds that are 3.5 feet or less in thickness. Microseismic monitoring should detect fracture zones extending toward the water body and allow the mining operation to be halted or reevaluated before a potentially hazardous situation occurs. If mining is to be conducted in the intervening strata between 350 and 700 feet, the tensile strain limitation of 10 parts per thousand should be followed.

Tensile strain, which is a measure of the intensity of disturbance of the surface at the bottom of the water body, can be computed as follows:

$$E_{max} = CR, \qquad (5)$$

where E_{max} is the maximum tensile strain, C is K_2 times S_{max}, K_2 is a constant (ranging from 0-1) derived from local observations, S_{max} is a multiplier for local surface subsidence (ranging from 0-1), R is the ratio T/D, T is the thickness of the seam and D is the depth of the seam. K_2 and S_{max} are site specific values which can only be determined through extensive observations. If no empirical observations are available, K_2 and S_{max} should be assigned maximum values of 1 for calculation purposes. For example, if we are evaluating the maximum tensile strain, where no empirical data exists, for a coal bed 4 feet thick at a depth of 1200 feet, E_{max} is simply $\frac{4}{1200}$ or 3.3 parts per thousand. For multiple bed mining, the tensile strain is cumulative. If another overlying or

underlying bed is being mined at a depth of 1600 feet and a thickness of 5 feet, the additional tensile strain would be approximately 3.1 parts per thousand for a total tensile strain of 6.4 parts per thousand.

Actual values of K_2 and S_{max} average 0.75 and 0.8 for the United Kingdom. These values should be determined empirically for each area where extensive multiple seam longwall mining is to be conducted. These values can be artifically reduced by means of stowing, strip packing, single packings, etc. where stow material (rubbish, waste, debris) is placed into the void created by longwall mining to effectively reduce overburden subsidence. Some specific stowing materials and techniques are more effective than others. For example, solid stowing with more than 80% solid rock is more effective than using 50% rock and 50% dirt. The effects of these on K_2 and S_{max} should be part of the empirical observations.

When considering tensile strain, the question arises as to whether consideration should be given to the subsidence effects of old partial extraction workings that cannot be inspected in the vicinity of the active operation as well as to prior full extraction workings. These effects are generally minimal due to the resealing of fractures over time. In addition, roof collapse and material swell and recompaction reduces the subsidence effect of pillar failures while also increasing pillar strength.

When the maximum tensile strain of 10 parts per thousand has been attained, no further full extraction mining should be conducted; however, partial extraction with stable pillar design can be considered at this point. The tensile strain guideline will assure ground support near and under the surface waters for the projected life of all present and future mining operations. The permeability of the overlying strata should again be considered and maximum potential seepage planned for by construction of sump areas and by providing for adequate pumping capacity.

Mining Near Abandoned Workings

Establish Barrier Pillars Around Abandoned Workings

Level I Guidelines require a barrier pillar thickness of 200 feet around any abandoned workings that cannot be inspected and certified free of potentially dangerous accumulations of water. In order to mine closer than 200 feet, the nature of the intervening strata and the exact location of the abandoned workings relative to the advancing mine should be known. Presence and pressure of any water contained within the abandoned workings should also be ascertained. This additional requirement necessitates the implementation of Level II Guidelines. Level II guidelines will allow additional mining, up to total recovery of the barrier pillar, where safety can be assured by proper application of the investigative and testing procedures described below.

The best way to locate abandoned workings is by a borehole locator program. This involves radially drilling from the advancing face that is nearest to the abandoned mine, through the 200 foot barrier pillar until the abandoned workings are located. Equipment and materials necessary to cap the borehole upon breakthrough must be available to the drill crew. The water head pressure or atmospheric conditions in the abandoned workings can also be determined at this time for their effects on development planning for this pillar. Methods of performing these tests include use of in-line pressure gages and vacuum pump-vacuum container systems for sample isolation.

If water is not encountered upon breakthrough, it should not be assumed that the abandoned workings are dry; the drill bit may have entered at a level above the water line. Unless definitive measures are taken which absolutely establish that no water exists (as determined by down-hole instrumentation), the mine should be assumed flooded.

If it is subsequently determined that the abandoned workings are dry, and present no hazard to the advancing workings, the same guidelines should apply as in Level I where these workings are inspected and certified safe. Mining may then proceed up to the limits of the boundary barrier pillar requirement, if mining is near the property line, or normal mining operations should be permitted if property limits are not

a consideration. If permanent barrier pillars are to be left where the property line is not a consideration, a pillar width to thickness ratio of 10 to 1 is recommended.

If it is found that the workings do contain water, there are several alternatives open to the mine operator. One alternative is to drain the water by a drift or auger entry, if possible. Another alternative is to drill boreholes from the surface to pump water from the workings. It is also possible to drain through the unmined coal pillar to the active workings. This method is potentially hazardous and should only be done under the direction of knowledgeable and experienced personnel. The necessary permits would be needed to allow proper discharge of this mine water on the surface.

Another alternative is to maintain an effective safety barrier pillar between the flooded and active workings. Pillar strength should be accurately determined by modeling and uniaxial laboratory testing. Modeling consists of dimensioning the test specimen to scale with the actual pillar. Uniaxial laboratory testing should be done as previously discussed in the section entitled "Partial Extraction Guidelines for Mining Under Continental Surface Waters". Again, the testing should be done with water saturated samples to simulate actual conditions. A factor of safety of 4 should be applied to these strength determinations. If these flooded, abandoned workings are on the up-dip, they present an increased hazard

due to the gravitational pressure head. Whenever the pressure head is equal to or greater than 5 atmospheres, consideration should be given to draining the abandoned workings.

Pillar permeability should also be assessed if these workings are to be utilized for any length of time. Permeability may be assessed by packing a borehole a measured distance into the pillar, then injecting an easily detectable liquid or vapor into the void to determine the time rate of flow. High permeability could hamper further development of the barrier pillar by allowing an intolerable inflow of water into the advancing face. With this strength and permeability information, the necessary minimum barrier pillar size can be determined and mining can progress to these new limits. A mining plan to be used within this potentially hazardous zone could include driving two headings as narrow as possible (protected by boreholes to detect uncharted, abandoned workings as described in the following section), up to and along this newly defined boundary. Headings should be limited to 15 feet in width. The mining crew should be alert for increasing water leakage, strong sulfur smells, or other indicators of potential water hazards and the operation halted or reevaluated if these occur. If no problems are encountered by this exploratory heading, normal mining procedures can be resumed to the pillar limits. If additional protection is required, the permeability of the pillar can be reduced and its strength increased by introduction of grout or other cementing agent.

Drilling Boreholes in Advance of Mining

The requirement to find abandoned workings by drilling a locator borehole into the 200 foot barrier pillar before mining does not obviate the need for constant borehole drilling as protection for advancing workings. A locator borehole will only give an indication of the extent of the old workings. Proper protection for the advancing heading can only be given by a continuous borehole pattern.

Current State, Federal, and Foreign guidelines generally require boreholes to be drilled and maintained at least 20 feet in advance of workings in the vicinity of abandoned mines - one borehole to be centrally located in advance of the face and one each in the left and/or right rib (as required by the relative locations of the abandoned and advancing workings) at an angle of 45° to the advance. The center hole must be maintained at a minimum advance of 20 feet with rib holes of 20 feet drilled every 8 feet. A typical borehole pattern in advance of mining is shown in Figure 4.

Although this guideline is almost universally accepted, it nevertheless has the potential to miss sizeably flooded workings due to the limited depth, number, and spatial pattern of the boreholes. The theoretical envelope of safety afforded by existing guidelines appears adequate until we assume a single abandoned heading as shown in Figure 5. In

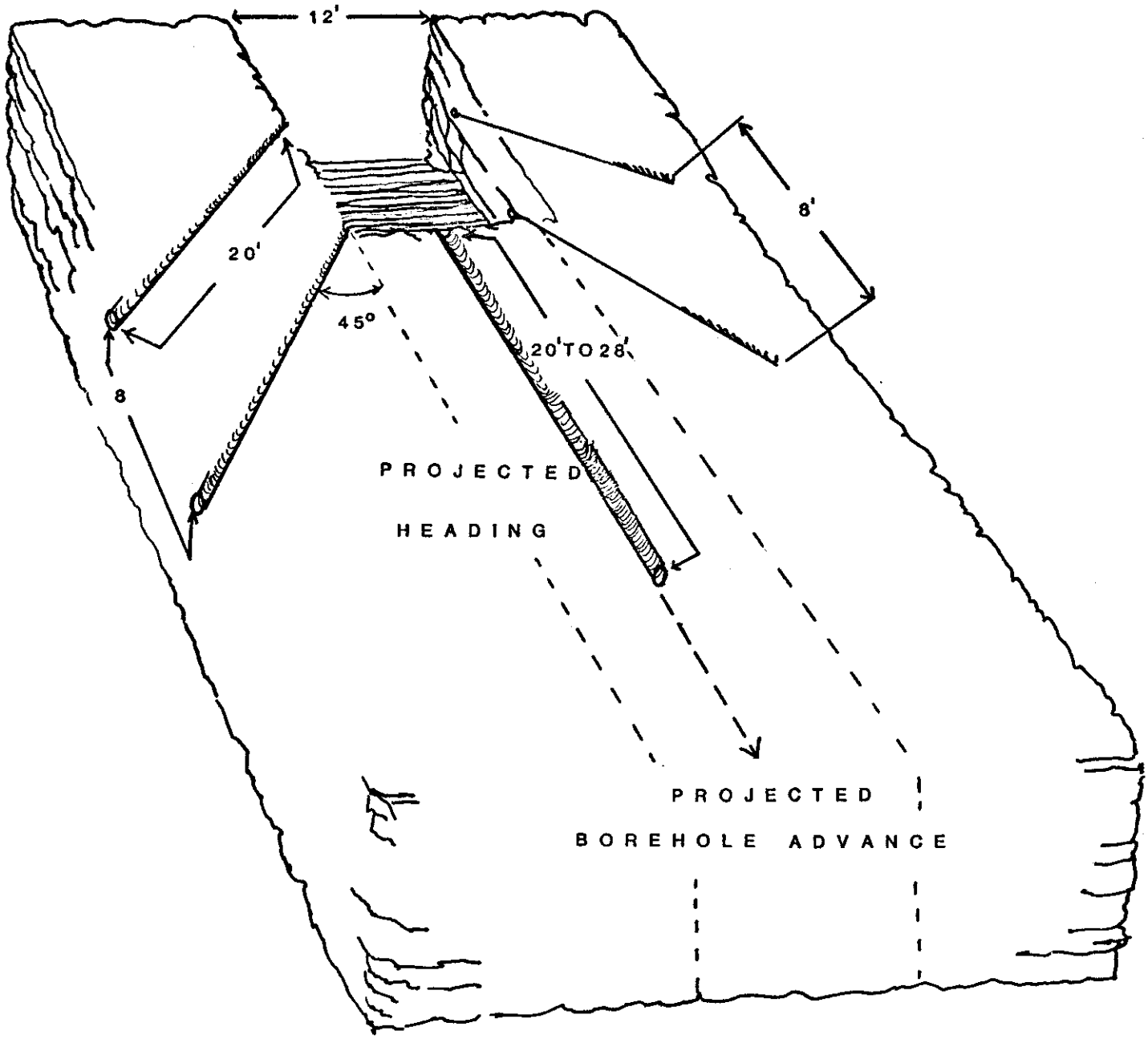

FIGURE 4. CURRENTLY REQUIRED BOREHOLE PATTERN IN ADVANCE OF MINING

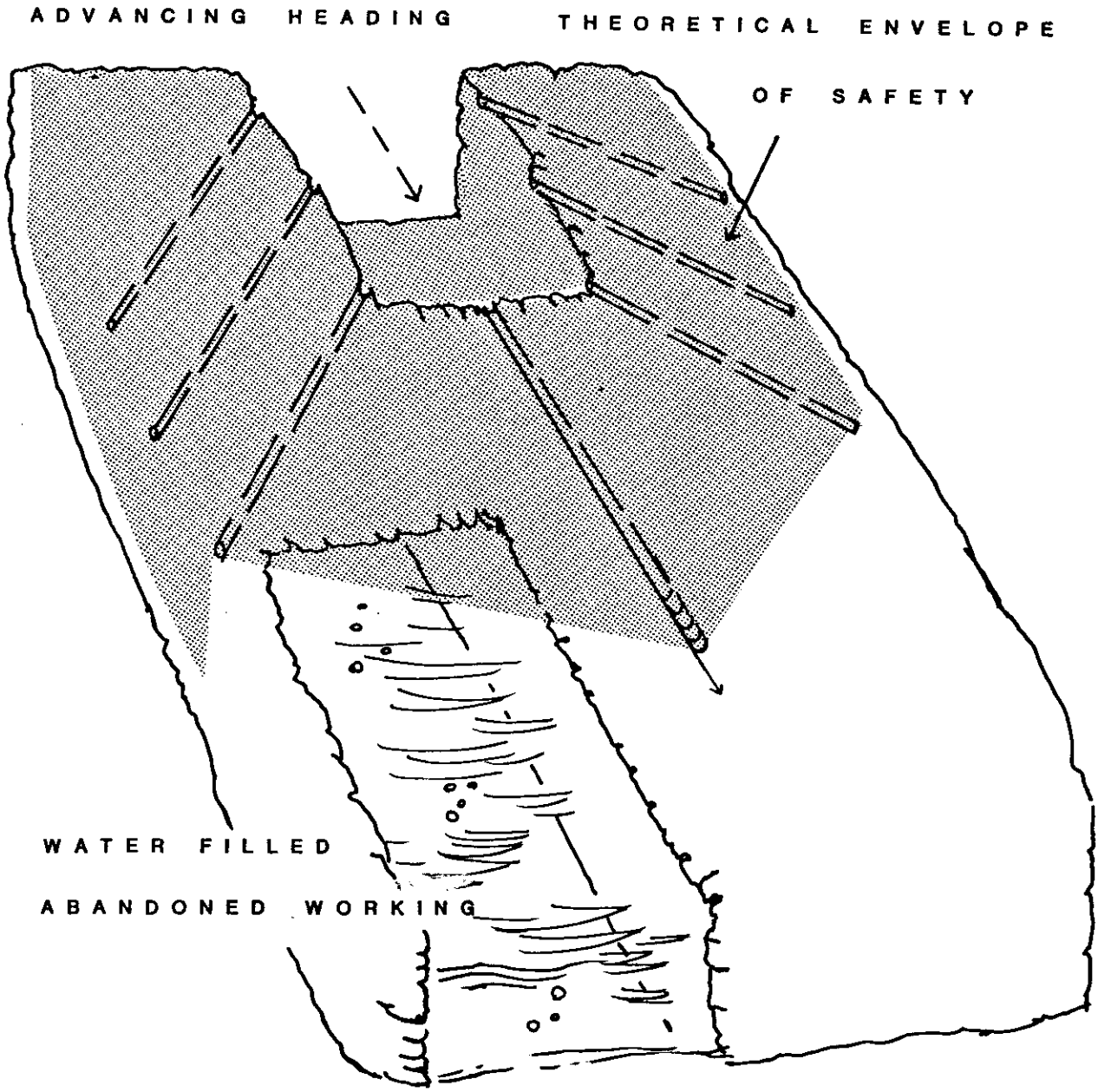

FIGURE 5. PENETRATION OF THEORETICAL ENVELOPE OF SAFETY AFFORDED BY PRESENT GUIDELINES

this circumstance, present guidelines would not assure borehole contact with the abandoned workings until they were separated by a dangerously thin pillar of unmined coal; possibly too late to prevent an inundation. In order to reduce the possibility of this occurring, a change in the rib hole pattern is proposed. It is recommended that rib holes be drilled at an angle of 30° to the advance for a length of 30 feet at 10 foot intervals; side face holes about 2 feet from the rib should be drilled at an angle of 15° to the advance and maintained at a length of 20 feet; and 2 center face holes or lead holes spaced about 2 to 4 feet apart in the center of the advancing section should be maintained 20 to 30 feet in advance. Since the lead holes must be maintained at least 20 feet in advance of the workings, we propose the following methodology for a continuous miner section:

a) Drill the lead holes 30 feet in advance of the heading; drill the side face holes about 2 feet in from the rib, on one or both sides as required by the relative location of the abandoned workings, a length of 30 feet at an angle of 15° to the advance.

b) Drill rib holes in one or both corners as required by the relative location of the abandoned workings. These holes are to be drilled at an angle of 30° to the advance for a length of 30 feet.

c) Move the drill crew and equipment out of the heading and advance the workings by 10 feet.

d) Move the miner out of the face area, roof bolt, and advance ventilation as required.

e) Drill face holes, which are now 20 feet in advance, at least an additional 10 feet. Drill new rib holes at a 30° angle to a distance of 30 feet.

f) Repeat, c, d, and e as required.

For a conventional mining section:

a) Same as a above.

b) Same as b above.

c) Drill holes for explosive charge.

d) Undercut the seam, charge and blast the boreholes.

e) Load the coal out of the section, roof bolt and advance ventilation as required.

f) Repeat c, d, and e until the section has advanced 10 feet.

g) Same as e for continuous miner.

h) Repeat c, d, e, f, and g as required.

The ideology behind the 10 foot advance in mining and rib hole spacing is that is fails in line with the current ventilation requirements of the 1969 Coal Mine Health and Safety Act which requires brattice cloth or tubing to be maintained within 10 feet of the working face. Also, the rib holes angled at 30° give a better "look" at what lies in advance of the workings, as shown in Figure 6. By implementing the proposed guidelines, borehole contact would be made with the abandoned mine, as shown in Figure 7, when the workings were 30 feet apart; while under existing guidelines, contact is made at a much shorter distance.

This requirement should not be applied when the abandoned workings are part of the present mine and it can be safely determined, by the

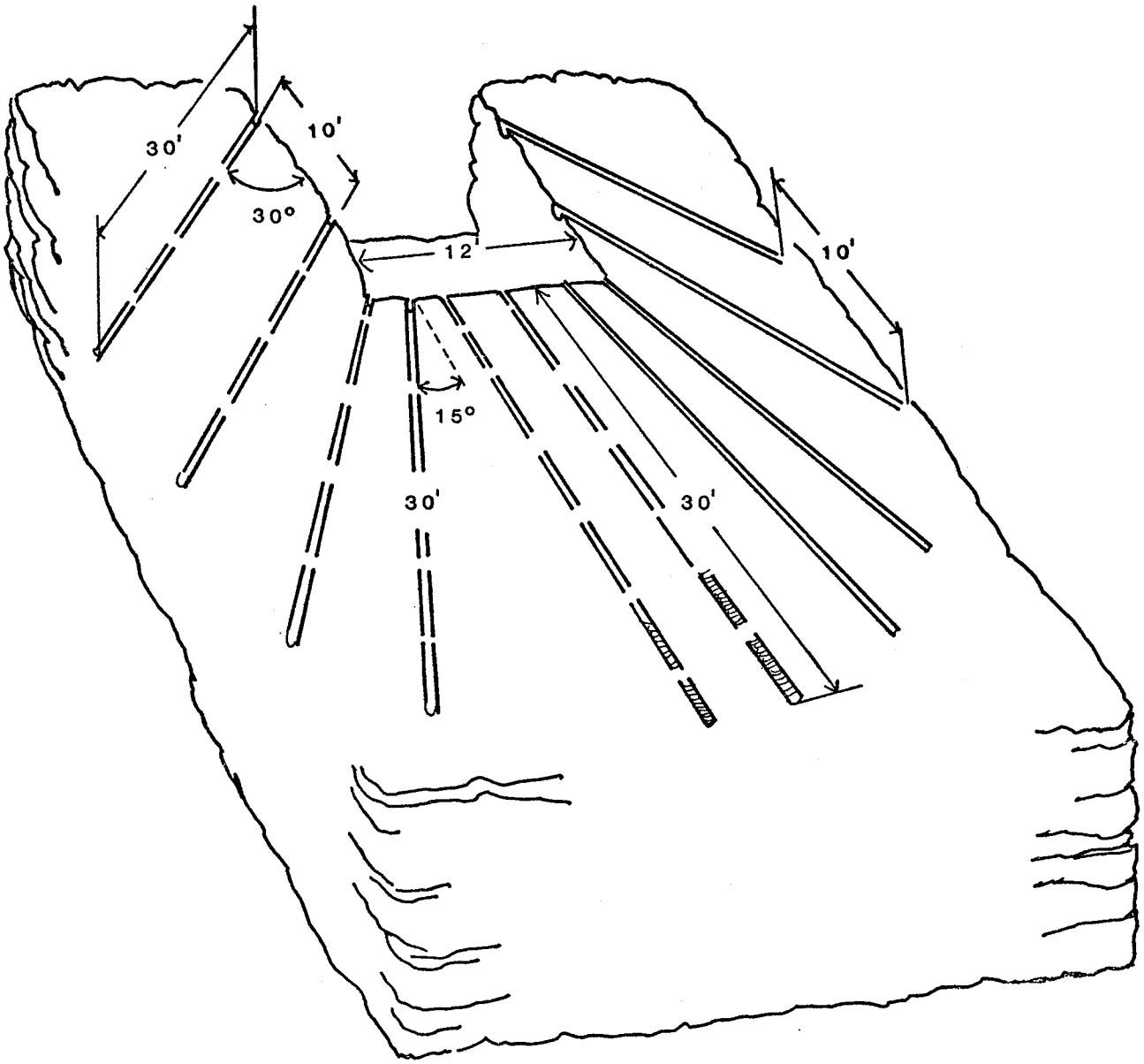

FIGURE 6. PROPOSED BOREHOLE PATTERN
IN ADVANCE OF MINING

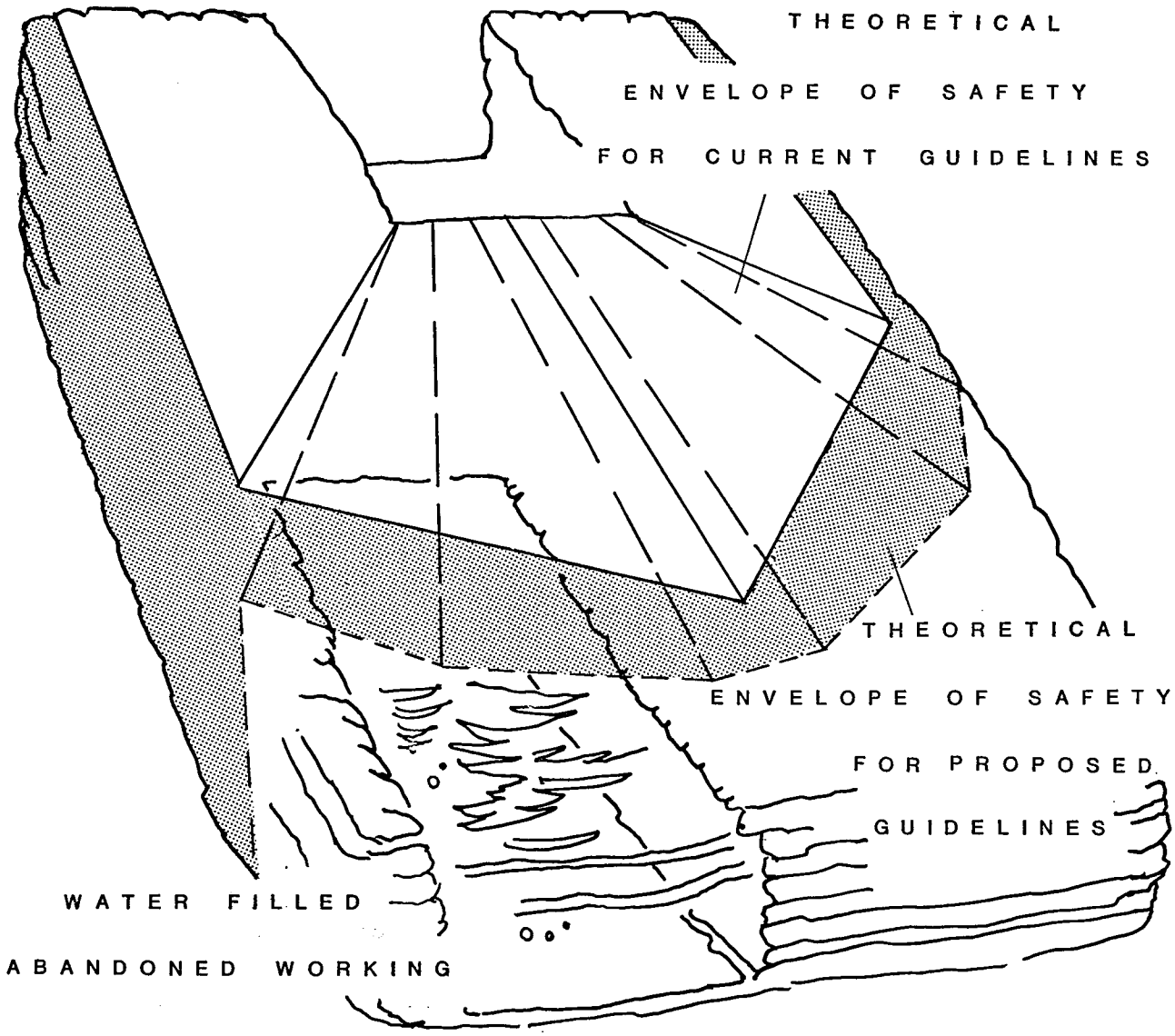

FIGURE 7. AN EXAMPLE OF THE INCREASED SAFETY AFFORDED BY THE PROPOSED GUIDELINES

mine inspector, that these are not flooded. In this case, normal mining operations should be permitted. If partial extraction is to be conducted, the safety pillar should be sized according to property boundary barrier pillar requirements, if mining is near the property limits.

Mining Under Flooded Abandoned Workings

Mining under flooded, abandoned workings can be hazardous due to the vertical extent of roof falls and also because of the increased, localized stress on the floor of the abandoned mine due to remaining pillars. It is not difficult to envision an instance where a roof fall in the active mine, under an area of severe pillar stress in the abandoned mine, could result in the pillar punching through into the active workings.

In order to ensure safe operations under a flooded, abandoned mine, it is recommended that at least 100 feet of cohesive rock strata, as defined by RQD and compressive strength testing, interlie between the flooded, abandoned mine and the presently active mine. It is also recommended that development headings be no greater than 15 feet in width in order to ensure that adequate intervening strata will remain in the event of a roof fall of vertical extent 2 or 3 times the width of the heading. If headings are to be greater than 15 feet in width, a permit should be acquired from the responsible government agency.

Additional research is needed in this area to determine safe limitations to mining that do not unnecessarily isolate reserves from recovery. The 100 feet of intervening, cohesive rock strata that is recommended here may prove to be too restrictive; however, this is recommended to ensure the safety of the mining operation until future research and observation denote more practical limitations.

Property Boundary Barrier Pillars

Level I Guidelines for property boundary barrier pillars are designed to protect the integrity of the present and any future mine operations from accidental breakthrough into abandoned or active workings. These guidelines should not be altered for increased mineral recovery unless it has been agreed by the interested mine superintendents, approved by the mine inspector, and permit approval received from the responsible regulatory agency so that mining can progress up to the property line. Application of this Level II requirement could allow for eventual interconnection of all of the mining operations for total pillar recovery or permit mining to within new barrier pillar limits that have been determined safe. This can only be done when all of the workings can be inspected and certified free from any hazardous accumulations of water or when a borehole locator program and down-hole instrumentation certifies the safety of the workings. Mining development plans should be a part of this

agreement with all superintendents and the mine inspector aware of, and in agreement with, the methods in which mine developments are to take place.

These guidelines shall be applicable to any partial or full extraction mining method.

Mining Near Wells, Shafts or Other Openings

Oil and Gas Wells

Whenever active oil and gas wells penetrate the coal seams, there should be no mining closer than the 300 foot diameter barrier pillar required by Level I Guidelines. The 300 foot diameter barrier pillar is used to prevent large amounts of methane from seeping into the mine workings and to protect against accidentally mining into these wells. Even with large barriers, however, some gas seepage does occur, especially through the face cleats of the coal bed. Zabetakis, et al., have measured methane contributions from nearby oil and gas wells to be 58 to 70 percent of the total methane volume released into the workings being surveyed[46]. Measurable inflows of methane were noted from wells separated from the workings by over 700 feet of unmined coal.

The possibility exists that a barrier pillar around an oil or gas well, as protecting against inundation, could be much smaller than 300 feet. As

protection against large methane emissions, however, it is recommended that this current requirement for active wells be continued. When these wells have been abandoned, however, they can be effectively plugged to permit additional coal recovery. Application of this Level II Guideline will allow up to total recovery of this barrier pillar.

The Bureau of Mines successfully demonstrated a technique for well plugging and monitoring during 1971. Methodology for locating and mining through these plugged wells can be obtained from Bureau of Mines TPR 56, 1972, or from the Energy Research and Development Administration office, Morgantown, West Virginia. In short, this procedure involves pulling the casing and cleaning the hole prior to plugging. About 100 feet of neat cement is set in a column immediately above the oil or gas reservoir and cement plugs are placed below, through, and above the coal seam.

Either full or partial extraction can be conducted once the well is safely plugged. (Methods of testing the effectiveness of these plugs include the use of sulfur hexafluoride tracer gas.) Mining through these plugs does not damage the extraction equipment nor the plug itself. Cleaning the hole removes the potential water hazard while plugging affords protection from future inflows.

Shafts and Other Mine Openings

When these shafts and other openings are still being used, the barrier pillars surrounding them are necessary for protecting surface structures as well as the openings themselves, and should not be mined. When these are abandoned, however, application of Level II Guidelines will allow mining through as in normal pillar recovery provided they can be inspected and certified free of potentially hazardous accumulations of water. If they cannot be inspected, a borehole should be drilled to the opening and down-hole testing conducted to determine if water is present. If the tests show no water, the pillar can be recovered as in normal operations. Where water exists, it should be drained out of the opening before the pillar is mined.

After draining the water, it should be determined that no further leakage into the opening (from surface waters, overlying reservoirs, etc.) is occurring. If there is leakage, the opening should be plugged and filled in, much the same as with abandoned oil and gas wells. Testing for plug effectiveness should be conducted and, if adequate, the pillar can be mined. This requirement, of course, may vary with specific conditions. For example, if these pillars are the last, or close to the last, reserves of the mine, and if the leakage is quite small so that water presence will not be a hazard to mining operations, the pillar may be pulled as in normal

operations. This is a decision that should be considered by the mine inspector.

Mining Under Natural Subsurface Hazards

Partial Extraction Guidelines

The location and extent of subsurface hazards to mining, such as channel sands and alluvial deposits, should be ascertained by seismic testing prior to mining within the 180 foot restricted zone of Level I. The underlying strata down to the coal bed should then be evaluated by coring and laboratory testing for cohesiveness and strength.

The thickness of the interlying cohesive roof rock (which has been evaluated by the testing methods described in the "Partial Extraction Guidelines for Mining Under Continental Surface Waters") should be equal to 5 times the width (5W) of the advancing heading. Application of this guideline will allow recovery of those coal measures that exist within the 5W to 180 foot interval required by Level I. This intervening strata should also be relatively impermeable, as well as cohesive, to reduce the leakage of water into the mine. Water in the mine can reduce the effective strength of pillars and roof and floor rocks. An 8 foot measure of shale or rock of equivalent permeability is usually sufficient to keep the workings dry. Some typical permeabilities of roof rock were given in Table 6. When

mining for the first time under these potential hazards, or when mining in any bed overlying the bed of first extraction, two development headings kept as narrow as possible should be driven through the hazardous area. These headings should be the only development permitted until the hazard has been passed or until the cohesiveness of the roof rock has been demonstrated to the satisfaction of the mine inspector by extensive development mining and monitoring. Two headings are required to satisfy ventilation requirements. These headings should not exceed 15 feet in width unless special permit approval has been received from the responsible government agency.

Hazardous natural strata includes reservoirs and unconsolidated material that is likely to flow when wet; such as moss, peat, sand, gravel, silt, mud, or rocks consisting of loosely coherent or uncemented particles. Holland has shown that roof falls generally do not extend vertically more than 3 times the heading width (20). Since cohesive rock usually means shallower roof falls, the guidelines specified here will adequately protect the workings provided that the pillars and rooms are properly sized to accommodate the applied stresses.

Full Extraction Guidelines

Level I Guidelines do not allow full extraction mining under natural subsurface hazards. Application of Level II requirements, however,

permits full extraction in these underlying coal beds.

The same guidelines as proposed for full extraction when Mining Under Continental Surface Waters should be applied here. At least 100 feet of intervening strata should exist for each 1 foot of extracted coal thickness. The tensile strain limit of 10 parts per thousand at the base of the natural subsurface hazard should also be considered as in Mining Under Continental Surface Waters.

Mining can be conducted closer to the natural hazard or abandoned working than is permitted by the 100 feet to 1 foot ratio, if the intervening strata is evaluated for strength and cohesiveness by RQD and uniaxial core testing and is monitored for stability by techniques such as microseismic array equipment. The height of the caved zone and induced fractures should also be monitored by the microseismic equipment and the operation halted if caving and fractures become too extensive.

Full extraction mining should not be done when less than 700 feet of overburden exists between the coal and the surface because of economic, roof control, and subsidence related reasons unless monitoring techniques are to be used. If monitoring is used, the overburden requirement can be reduced to 350 feet for coal beds up to 3.5 feet thick. When mining in the strata between 350 and 700 feet, the maximum tensile strain of 10 parts per thousand should be considered.

FUTURE RESEARCH NEEDS

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FUTURE RESEARCH NEEDS

A set of guidelines should be developed which would detail procedure, equipment needs, parameters to be measured, steps to be followed, and degree of caution to be exercised during exploration for, and drainage or safe isolation of, abandoned workings. Methods of determining water pressures and potential water volumes should also be studied.

1. Means by which abandoned workings can be located and the level of confidence that can be expressed in these methods should be evaluated. These would include:

   - Surface indications of old workings such as abandoned shafts, drifts, or tipples.

   - Collecting and analyzing all available old mine maps, claims, and other legal documents.

   - Evaluating the physical indicators (such as sulfur smell, water seepage, etc.) delineated in the active workings.

   - Borehole patterns from active workings that overlie, underlie, or are in the same bed as the abandoned workings.

   - Seismic and other geophysical techniques.

2. Alternate methods of drainage should be evaluated, including:

   - Drilling boreholes from the surface to the abandoned workings to tap and drain the water.

   - Drilling boreholes through the abandoned workings to open abandoned workings below (which pose no threat to future mining operations), for water drainage.

   - Draining the abandoned workings from overlying or underlying active workings.

- Methods of draining abandoned workings in the same seam from approaching active workings.

3. Methods of isolating abandoned workings so that they have no affect on present workings also should be considered, including:

   - Barrier pillars of sufficient size surrounding accurately located abandoned workings.

   - Use of grout, cement, or other material to significantly reduce the permeability and increase the strength of barrier pillars allowing closer mining without drainage.

These three areas of research would delineate which methods are the safest, most efficient, recover the greatest additional coal reserves, and offer the best benefit/cost ratio.

Under present guidelines, a 200 foot barrier pillar must be left adjacent to abandoned workings in the same coal bed that cannot be inspected and certified free of hazardous accumulations of water. When accurate mapping of these workings is not available, it must be assumed that they were developed to the property line, as shown in Figure 8.

If methods were available to accurately determine the location and extent of these abandoned workings, development could progress to the limits determined by property boundary barrier pillar requirements proposed in Level I guidelines. For example, using the formula $Pb = 10 + 2T + 5D$ (see Level I guidelines), if development is in a 5 foot seam that is 1000 feet deep, a 70 foot barrier pillar must be left on both sides of the

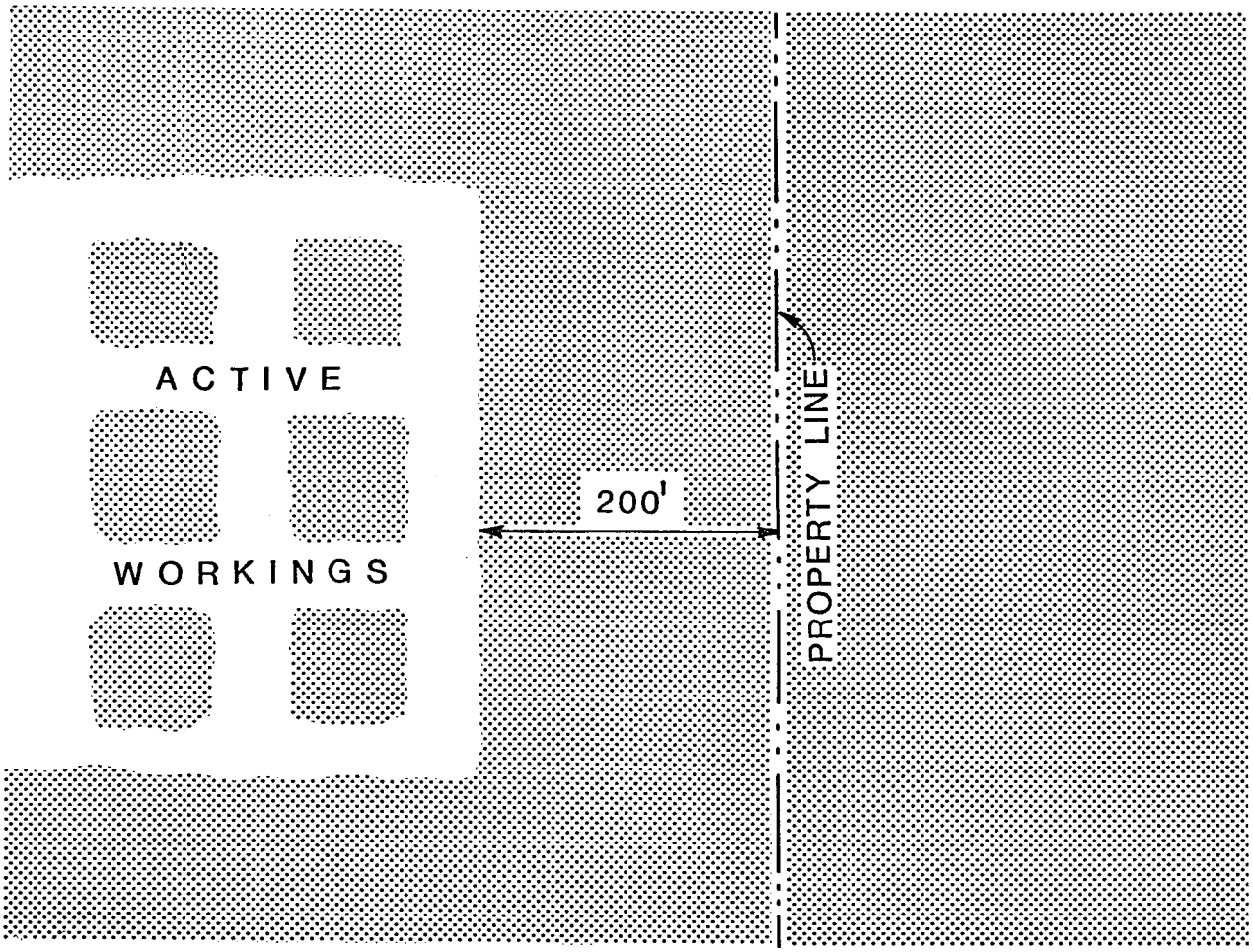

FIGURE 8. CURRENT BARRIER PILLAR REQUIREMENT WHEN LOCATION AND EXTENT OF ABANDONED WORKINGS ARE UNKNOWN.

property line. Figure 9 shows how additional reserves can be recovered if the abandoned workings are accurately mapped. The worst case in Figure 9 allows development to within 140 feet of the property line; the best case shows development to within 70 feet of the property line. In a 5 foot seam with 50 percent mining, an additional 4500 tons of reserve, for each additional acre that is opened for development, could be recovered.

According to a recent publication by the Environmental Protection Agency entitled "Water Pollution Prevention and Control", there are at least 100,000 abandoned, flooded mines within the United States. If we can assume that, by accurate determination of their location and extent, we could free an average of 25 acres for new development at each mine, we could recover, at 50% extraction in 5 foot seams, an additional 11 billion tons of coal.

In addition to accurately locating these abandoned workings, research should be conducted to determine the applicability of alternate methods of drainage. If the abandoned workings in the above example could be safely and effectively drained it is possible that new mining could be permitted to progress up to the property boundary limits. This would free additional reserves for recovery.

If it is determined that drainage of the abandoned mine would be uneconomical at the time, means of safely isolating it from the present workings should be studied and evaluated. These methods of isolation

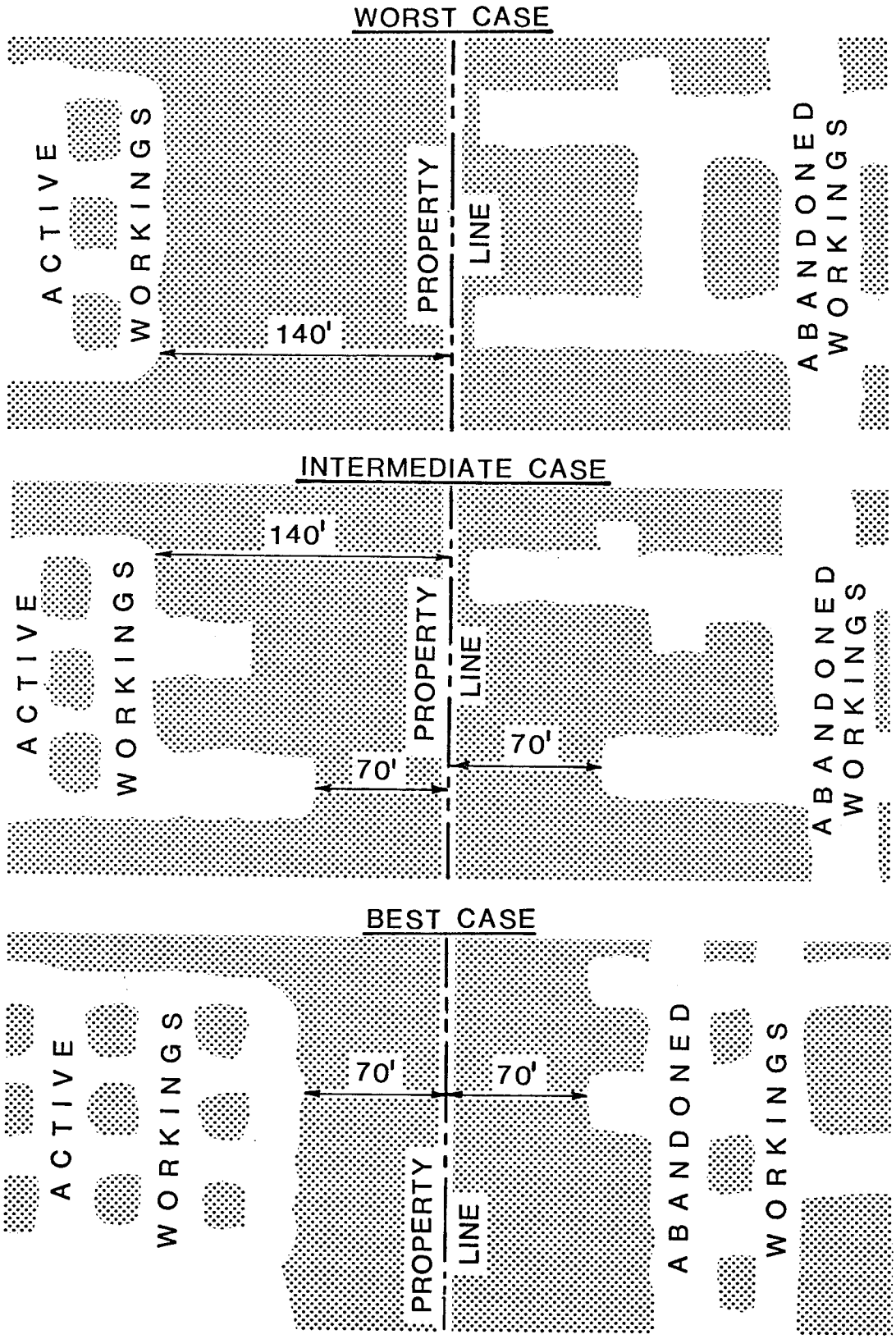

FIGURE 9 RECOVERY OF ADDITIONAL RESERVES THROUGH THE IMPLEMENTATION OF LEVEL I GUIDELINES WHEN ABANDONED WORKINGS CAN BE ACCURATELY LOCATED.

should consider that at some time in the future it may become economical to drain the flooded workings to recover the barrier pillar.

An additional area of research should involve guidelines for mining under flooded, abandoned workings. The guidelines that are recommended in the text, under Level II, require at least 100 feet of cohesive intervening strata. In many instances, this may tend to be restrictive and may isolate large quantities of coal from development. It is estimated that at least 5 percent of the coal reserve base, or about 20 billion tons, would be lost to development due to this guideline.

Currently, not much information exists on the problems related to mining under or over abandoned workings, especially partially extracted abandoned workings. The objective of this research effort would be to evaluate the factors, both positive and negative, currently encountered in mining over or under prior extracted seams. From this evaluation, guidelines based on field measurements to allow the greatest possible resource recovery could be developed.

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APPENDICES

APPENDIX A

CURRENT STATE, FEDERAL, AND FOREIGN GUIDELINES WHICH FIT THE LEVEL I CLASSIFICATION

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STATE, FEDERAL OR FOREIGN COUNTY	GUIDELINE	PUBLICATION OF LAW	EFFECTIVE DATE	REGULATING AGENCY
Pennsylvania (Bituminous)	MINING CLOSE TO ABANDONED WORKINGS Section 291. The superintendent shall not permit the mining of coal within fifty feet of an abandoned mine or any abandoned portion of any mine containing a dangerous accumulation of water, ... The superintendent shall not permit the mining of coal in any seam the entire distance to a property boundary line not including boundaries around reservations or along crop lines, when, on the adjoining property there are mine workings in said seam within three thousand feet of said boundary line, but shall leave a barrier pillar, from the operation to the property boundary line, of not less than ten feet plus two feet for every foot or part of a foot of thickness of the bed measured from the roof to the floor, plus five feet for each one hundred feet or part of one hundred feet of cover over the bed at the boundary line; and, where the coal on one side of the property boundary line shall have been mined prior to the effective date of this act closer to the property boundary line than hereinbefore permitted, then the barrier pillar to be left in the mine approaching the boundary line shall be at least equal, when added to that already left in the adjoining mine, to that hereinbefore required on both sides of said property boundary line; provided, that if, in the opinion of the mine inspector in the district or the superintendent of either mining property, the barrier pillar, as hereinbefore required, is deemed insufficient, then after due notice to the operator or operators of the mining property adjoining a barrier pillar of unmined coal, one-half of which shall be on each side of the property boundary line, except as provided above in this section, shall be left, of such thickness as in the judgment of the mine inspector in the district and of the superintendent or owner of either mining property is deemed necessary to afford safety and protection; ...	Bituminous Coal Mining Laws of Pennsylvania for Underground Mines	1961	Department of Mines and Mineral Industries (Now the Department of Environmental Resources)
Pennsylvania (Bituminous)	MINING IN SAFETY ZONES The General Assembly of the Commonwealth of Pennsylvania hereby enacts as follows: ESTABLISHMENT OF SAFETY ZONES Section 1. A safety zone is hereby established beneath and adjacent to every stream, river and natural or artificial body of water in the Commonwealth that is sufficiently large to constitute a hazard to mining in the opinion and in the discretion of the department. Such safety zone shall, in the case of such streams and rivers, extend horizontally two hundred feet from the high water mark of each band. In the case of any other body of water sufficiently large to constitute a hazard to mining in the opinion and in the discretion of the department, it shall extend horizontally two hundred feet from the known perimeter. In any case, the zone shall extend downward to the limit of the workable beds.	Bituminous Coal Mining Laws of Pennsylvania for Underground Mines	1961	Department of Mines and Mineral Industries (Now the Department of Environmental Resources)

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STATE, FEDERAL OR FOREIGN COUNTY	GUIDELINE	PUBLICATION OF LAW	EFFECTIVE DATE	REGULATING AGENCY
Pennsylvania (Bituminous)	Section 5. The superintendent shall not permit the mining of coal within fifty feet of any abandoned mine containing a dangerous accumulation of water, (Provided, that the thickness of the barrier pillars shall be greater and shall be in proportion of one foot of pillar thickness to each one and one-quarter feet of water head, if in the judgment of the engineer of the property and that of the district inspector it is necessary for the safety of the persons working in the mine). The superintendent shall not permit the mining of coal the entire distance to a property boundary line, but shall leave a barrier pillar from the operation to the property boundary line of not less than ten feet plus two feet for every foot or part of a foot of thickness of the bed measured from the roof to the floor plus five feet for each one hundred feet or part of one hundred feet of cover over the bed at the boundary line; and where the coal on one side of the property boundary line shall have been previously mined closer to the property boundary line than hereinbefore permitted, then the barrier pillar to be left in the mine approaching the boundary line, shall be at least equal (when added to that already left in the adjacent mine), to that hereinbefore required on both sides of said property boundary line: Provided further, that, if in the opinion of the district mine inspector, or the superintendent of either property, there is a faulty condition or liability of squeezing, and the barrier pillar as hereinbefore required is deemed insufficient, then, after due notice to adjoining owner or owners, a barrier pillar of unmined coal (one-half of which shall be on each side of the property boundary line, except as provided above in this section) shall be left, of such thickness as in the judgment of the district mine inspector, and the superintendent or owner of either property is deemed necessary to afford safety and protection;	An Act to Provide for the Health and Safety of Persons Employed In and About the Bituminous Coal Mines of Pennsylvania	1935	Department of Mines
Pennsylvania (Bituminous)	MINE FOREMAN; DRAINAGE Section 224. (a) The mine foreman shall see that the water is drained out of the working places before the men enter, and that the working places are kept as free from water as practicable during working hours. (b) Whenever any working place in a mine approaches within fifty feet of abandoned workings, in such mine as shown by surveys certified by a registered engineer or surveyor, or within two hundred feet of any other abandoned workings of such mine, which cannot be inspected and which may contain dangerous accumulations of water or gas, or within two hundred feet of any workings of an adjacent mine, ... It shall be unlawful to work or employ men to work in any portion of a bituminous coal mine in which a body of water is dammed or held back at a higher elevation in the same mine by natural or artificial means, unless permission to do so is given in writing by the secretary.	Bituminous Coal Mining Laws of Pennsylvania for Underground Mines	1961	Department of Mines and Mineral Industries (Now the Department of Environmental Resources)

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STATE, FEDERAL OR FOREIGN COUNTY	GUIDELINE	PUBLICATION OF LAW	EFFECTIVE DATE	REGULATING AGENCY
Alabama	PROTECTION AGAINST WATER AND GAS Rule 30. (c) In every mine where there is danger of a sudden inburst of water, additional passageways, shall be constructed as are necessary in the opinion of the Department, to insure the escape of workmen. (d) Except in emergencies no restraining dam shall be installed in any mine where the rupture of such dam would imperil the safety of men in said mine or other mine, ...	Mine Safety Rules of the State of Alabama	December 15, 1962	Department of Industrial Relations
Virginia	APPROACHING ABANDONED WORKINGS Section 45.1-93. ... within fifty feet of abandoned workings in such mine as shown by surveys made and certified by a competent engineer or surveyor, or within two hundred feet of any other abandoned workings or such mine, which cannot be inspected.	Mining Laws of Virginia	1966	Department of Labor and Industry
Kentucky	BOREHOLES IN ADVANCE OF FACE, WHEN REQUIRED Section 352.371. Whenever any working place approaches within fifty feet of abandoned areas in the mine as shown by surveys made and certified by a registered engineer, or within two hundred feet of any other abandoned areas of the mine which cannot be inspected and which may contain dangerous accumulations of water or gas, or within two hundred feet of any workings of an adjacent mine, ...	Laws Governing the Mining of Coal and Clay	1967	Department of Mines and Minerals
West Virginia	MINE MAPS Supervision by Professional Engineer or Licensed Land Surveyor; Seal and Certification; Contents, Extensions; Repository; Availability; Traversing; Copies; Archive; Final Survey and Map; Penalties. Section 22-2-1. (16) The location of any body of water dammed in the mine or held back in any portion of the mine, but such bodies of water may be shown on overlays or tracings attached to the mine maps used to show contour lines, as provided under subdivision ten of this section; (17) The elevation of any body of water dammed in the mine or held back in any portion of the mine; (18) The abandoned portion or portions of the mine; (19) The location and description of at least two permanent base line points	Mining Laws of West Virginia	1974	Department of Mines

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STATE, FEDERAL OR FOREIGN COUNTY	GUIDELINE	PUBLICATION OF LAW	EFFECTIVE DATE	REGULATING AGENCY
West Virginia	MINE MAPS (Contd.) Section 22-2-1. (Contd.) coordinated with the underground and surface mine traverses, and the location and description of at least two permanent elevation bench marks used in connection with establishing or referencing mine elevation surveys; (20) Mines above or below; (21) Water pools above; (22) The location of the principal streams and bodies of water on the surface. Duties; Ventilation; Loose Coal, Slate or Rock; Props; Drainage of Water; Man Doors Section 22-2-8. (a) The duties of the mine foreman shall be to keep a careful watch over the ventilating apparatus, the airways, traveling ways, pumps and drainage. The mine foreman shall have all water drained or hauled out of the working places where practicable, before the miners enter, and such working places shall be kept dry as far as practicable while the miners are at work.	Mining Laws of West Virginia	1974	Department of Mines
Indiana	APPROACHING ABANDONED WORKINGS Section 86. Whenever any working place in an underground mine approaches within 50 feet of abandoned workings in such mine as shown by surveys made and certified by a competent engineer or surveyor, or within 200 feet of any other abandoned workings of such mine, which cannot be inspected and which may contain dangerous accumulations of water or gas, or within 200 feet of any workings of an adjacent mine, ...	Mining Laws of the State of Indiana	March 8, 1955	Indiana Bureau of Mines and Mining
Ohio	ADDITIONAL OPENING FOR PROTECTION AGAINST INUNDATION Section 4153.15. At any mine where there is a stream or body of water on the surface, or in the workings of the mine, at a higher level, which is likely to break through into such mine, and inundate either the traveling or escapement way of such mine, so as to prevent the egress of persons employed therein, the owner, lessee, or agent shall provide and maintain an additional opening by means of which such persons may escape without using the traveling or escapement way likely to be inundated. No owner, lessee, agent, or operator of a mine shall willfully refuse or neglect to comply with this section.	Mining Laws of Ohio	1975	Department of Industrial Relations, Division of Mines

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Ohio	PRECAUTIONS WHEN WORKING PLACE APPROACHES COMPLETED WORKINGS OR ABANDONED MINES Section 4153.39. When any working place approaches within fifty feet of accurately surveyed completed workings in the same mine, or within two hundred feet of any other abandoned workings, that cannot be inspected and which may contain dangerous accumulations of water or gas, ... Completed workings are accurately surveyed when a competent engineer or surveyor has certified as to the surveying and recording thereof. No owner, lessee, agent, or operator of a mine shall willfully refuse or neglect to comply with this section.	Mining Laws of Ohio	1975	Department of Industrial Relations, Division of Mines
Oklahoma	RESTRICTIONS ON MINING NEAR ABANDONED WORKINGS Section 321. Driving toward abandoned mines. No operator shall be permitted to mine coal within two hundred (200) feet of any abandoned mine workings containing a dangerous accumulation of water, ... MAP OR PLAN OF MINES - NECESSITY - REQUISITES Section 341. Such map or plan shall further show accurately the tracks and sidetracks of all railroads, the location and depth of holes drilled for oil, gas, or water that penetrate the workable coal seam, and the location and elevation above the coal seam of any body of water that might endanger the lives of miners working therein shall also be shown. FOREMAN'S DUTIES AS TO TIMBERS AND DRAINAGE Section 562. The mine foreman shall see that all water be drained or hauled out of all working places before the miner enters, and as far as practicable, kept dry while the miner is at work.	Mining Laws of the State of Oklahoma	1973	State of Oklahoma

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Arkansas	WATER IN MINES Section 233-7285. Whenever and wherever a coal mine in this State becomes dangerous from high water or overflow of streams adjacent thereto, whereby the lives of miners employed therein are jeopardized by reason of such high water, it shall be the duty of the managers of such coal mine to call the miners out of the same, and forbid their working therein until such danger is past, and failure to do so is hereby made a high misdemeanor, and, upon conviction thereof, shall be fined in any sum not less than five hundred ($500.00) dollars nor more than five thousand ($5,000.00) dollars, or by imprisonment not less than six months nor more than one year.	Mining Laws of the State of Arkansas	1962	State of Arkansas
Illinois	Section 26.12. No accumulation of ice or obstructions of any kind shall be permitted in any shaft in which men are hoisted or lowered; nor shall any dangerous gases or steam be discharged into the shaft in such quantities or at such times as to interfere with the safe passage of men. All surface or other water which flows therein shall be conducted by rings or otherwise to receptacles provided for the same in such manner as to prevent water from falling upon men while passing into or out of the mine or while in the discharge of their duties about the shaft bottom. MINE PLANS Section 33.02. Such map or plan shall accurately show the surface boundary lines of the coal rights pertaining to each mine, and all sections or quarter-section lines or corners within the same; the lines or town lots and streets; the tracks and side-tracks of all railroads and the location of all wagon roads, rivers, streams, ponds, location and depth of holes drilled for oil, gas or water that penetrate a workable coal seam, and the elevation above the coal seam of any stream or body of water that might endanger the mine. Section 34.04. During pillar recovery in any mine when working places approach within 50 feet of abandoned sealed workings, as shown by surveys made and certified by a competent engineer or surveyor, which may contain dangerous accumulations of water or gas, or within 200 feet of any workings of an adjacent mine, ...	The Coal Mining Act	July, 1971	Department of Mines and Minerals

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Colorado	WORKING PLACES KEPT FREE FROM WATER Section 92-6-6. The mine foreman shall see that the working places are kept as free from water as practicable during working hours. PRECAUTIONS NEAR ABANDONED MINES Section 92-6-7. Whenever any working place approaches within two hundred feet of abandoned workings that cannot be inspected and that may contain dangerous accumulations of water or gas, ... SURFACE MAPS Section 92-7-5. When the mine map does not show surface features the surface map shall be made on transparent or translucent cloth or paper, so that it may be laid on the map of the underground workings to show the true relations of the surface features to the mine workings and excavations. It shall show all surface features overlying the coal seam such as ravines, intermittent and permanent streams, bodies of standing water, county, township and section lines, township and section numbers, town lots, streets and roads, the location of the mine openings, the position and names of buildings, coke ovens, railroad track, side tracks and mine tramways or haulageways, boundary lines of the property, the elevation above sea level of some point, bench mark, or permanent monument near the main opening of the mine; and all outcrops of coal seams where the same are visible. If the surface map be made on tracing cloth it shall be returned to the owner for extension.	Coal Mining Laws of the State of Colorado	1966	State of Colorado
New Mexico	WORKING IN VICINITY OF ABANDONED AREA - ADVANCE WORKINGS - PRECAUTIONS Section 63-14-19. When any working has approached within one hundred (100) feet of any portion of an abandoned mine not known to be free from gas or dangerous accumulation of water or explosive gas, ...	New Mexico Mine Safety Code for All Mines	1972	State of New Mexico

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Utah	MINE MAP Section 5. The map shall show the following features: 1. Boundary lines and thickness of boundary barrier pillars. 2. Elevations at the top and bottom of shafts, slopes, raises and planes. 3. Locations and elevations of underground bodies of water. 4. Locations and depth of bore holes and of gas and oil wells, and location of oil and gas pipe lines. APPROACHING ABANDONED WORKINGS - IMPOUNDING WATER Section 33. (a) Whenever any working place in an underground mine approaches within 50 feet of abandoned workings in such mine as shown by surveys made and certified by a competent engineer or surveyor, or within 200 feet of any other abandoned workings of such mine, which cannot be inspected and which may contain dangerous accumulations of water or gas, or within 200 feet of any workings of an adjacent mine, ... (b) Water shall not be impounded by means of a dam or wall in any section of a mine ...	General Safety Orders for Utah Coal Mines	January 1, 1967	Industrial Commission of Utah
Pennsylvania (Anthracite)	ESTABLISHMENT OF SAFETY ZONES Section 1. A safety zone is hereby established beneath and adjacent to every stream, river and natural or artificial body of water in the Commonwealth that is sufficiently large to constitute a hazard to mining in the opinion and in the discretion of the department. Such safety zone shall, in the case of such streams and rivers, extend horizontally two hundred feet from the high water mark of each bank. In the case of any other body of water sufficiently large to constitute a hazard to mining in the opinion and in the discretion of the department, it shall extend horizontally two hundred feet from the known perimeter. In any case, the zone shall extend downward to the limit of the workable beds.	An Act by the General Assembly of the Commonwealth of Pennsylvania	December 22, 1959	Department of Mines and Mineral Industries (Now the Department of Environmental Resources)

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Pennsylvania (Anthracite)	PASSAGEWAYS, WELL DRAINED Section 237. Passageways used by persons and roads used for transportation in any mine shall be well drained. REGULATIONS, PLACES APPROACHING INACCESSIBLE WORKINGS Section 238. Whenever a place is approaching inaccessible workings, the operator shall establish and clearly show on the map furnished the mine foreman a stopping distance not less than one hundred feet from the said inaccessible workings and such stopping point shall not be passed ... No such stopping distance shall be less than one hundred feet from the said inaccessible abandoned workings, nor need it be greater than the distance calculated in accordance with the rule commonly used in the establishing of barrier pillars, namely, one percent of the depth below drainage times the thickness of the coal seam plus thickness of seam times five, excepting in such cases where calculation in accordance with said rule established a stopping distance of less than one hundred feet. This act does not permit the driving of gangways, chambers or other excavations into barriers which are subject to their maximum water pressure, as calculated in accordance with the rule here established, ... The term "mining engineer", as used in this act, shall mean the person who shall, in behalf of the operator, have charge or general supervision of the work of compiling the mine map. MAP TO SHOW BOUNDARY LINES, PIPE LINES, STREAMS, ROADS, ETC. Section 302. The map shall also accurately show the boundary lines of the lands of the said coal mine or colliery and the proximity of the workings thereto, all pipelines, streams or other bodies of water, buildings and structures, roads and highways and in case any mine contains any water dammed up in any part thereof, it shall be the duty of the operator or superintendent to cause the true location of the said dam to be accurately marked on said map or plan, together with the tidal elevation, inclination of strata and area of said workings containing water, and whenever any workings or excavations are approaching the workings where such dam or water is contained or situated, the operator, superintendent, or mine foreman, shall notify the inspector of the same without delay. BARRIER PILLAR BETWEEN ADJOINING PROPERTIES Section 312. It shall be obligatory on the owners of adjoining coal properties to leave, or	Anthracite Mining Laws of Pennsylvania	November 29, 1965	Department of Mines and Mineral Industries (Now the Department of Environmental Resources)

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Pennsylvania (Anthracite)	BARRIER PILLAR BETWEEN ADJOINING PROPERTIES (Contd.) Section 312. (Contd.) cause to be left, a pillar of coal in each seam or vein of coal worked by them, along the line of adjoining property, of such width, that taken in connection with the pillar to be left by the adjoining property owner, will be a sufficient barrier for the safety of the employes of either mine in case the other should be abandoned and allowed to fill with water; such width of pillar to be determined by the engineers of the adjoining property owners together with the inspector of the district in which the mine is situated, and the surveys of the face of the workings along such pillar shall be made in duplicate and must practically agree. A copy of such duplicate surveys, certified to, must be filed with the owners of the adjoining properties and with the inspector of the district in which the mine or property is situated. WORKED OUT OR ABANDONED PARTS OF MINE TO BE KEPT FREE OF BODIES OF GASES Section 508. All worked out or abandoned parts of a mine in operation, so far as practicable, shall be kept free of dangerous bodies of gases or water, and if found impracticable to deep the entire mine free from an accumulation of gases or water, the mine inspector must be immediately notified, and later confirmed in writing.	Anthracite Mining Laws of Pennsylvania	November 29, 1965	Department of Mines and Mineral Industries (Now the Department of Environmental Resources)
FEDERAL	MINE MAP (STATUTORY PROVISIONS) Section 75.1200 The operator of a coal mine shall have in a fireproof repository located in an area on the surface of the mine chosen by the mine operator to minimize the danger of destruction by fire or other hazard, an accurate and up-to-date map of such mine drawn on scale. Such map shall show: (a) The active workings; (b) All pillared, worked out, and abandoned areas, except as provided in this section; (c) Entries and aircourses with the direction of airflow indicated by arrows; (d) Contour lines of all elevations; (e) Elevations of all main and cross or side entries; (f) Dip of the coalbed; (g) Escapeways; (h) Adjacent mine workings within 1,000 feet; (i) Mines above or below; (j) Water pools above; and (k) Either producing or abandoned oil and gas wells located within 500 feet of such mine and any underground area of such mine; and, (l) Such other information as the Secretary may require. Such map shall	Code of Federal Regulations Mineral Resources	September, 1972	Mine Enforcement Safety Administration

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FEDERAL	MINE MAP (STATUTORY PROVISIONS) (Contd.) Section 75.1200. (Contd.) identify those areas of the mine which have been pillared, worked out, or abandoned, which are inaccessible or cannot be entered safely and on which no information is available. ADDITIONAL INFORMATION ON MINE MAP Section 75.1200-1. Additional information required to be shown on mine maps under section 75.1200 shall include the following: (a) Name and address of the mine; (b) The scale and orientation of the map; (c) The property or boundary lines of the mine; (d) All drill holes that penetrate the coalbed being mined; (e) All shaft, slope, drift, and tunnel openings and auger and strip mined areas of the coalbed being mined; (f) The location of all surface mine ventilation fans; the location may be designated on the mine map by symbols; (g) The location of railroad tracks and public highways leading to the mine, and mine buildings of a permanent nature with identifying names shown; (h) The location and description of at least two permanent base line points coordinated with the underground and surface mine traverses, and the location and description of at least two permanent elevation bench marks used in connection with establishing or referencing mine elevation surveys; (i) The location of any body of water dammed in the mine or held back in any portion of the mine; provided, however, such bodies of water may be shown on overlays or tracings attached to the mine maps used to show contour lines as provided under paragraph (m) of this section; (j) The elevations of tops and bottoms of shafts and slopes, and the floor at the entrance to drift and tunnel openings; (k) The elevation of the floor at intervals of not more than 200 feet in: (1) At least one entry of each working section, and main and cross entries; (2) The last line of open crosscuts of each working section, and main and cross entries before such sections and main and cross entries are abandoned; (3) Rooms advancing toward or adjacent to property or boundary lines or adjacent mines; (l) The elevation of any body of water dammed in the mine or held back in any portion of the mine; and, (m) Contour lines passing through whole number elevations of the coalbed being mined. The spacing of such lines shall not exceed 10-foot elevation levels except that a broader spacing of contour lines may be approved by the District	Code of Federal Regulations Mineral Resources	September 1972	Mine Enforcement Safety Administration

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FEDERAL	ADDITIONAL INFORMATION ON MINE MAP (Contd.) Section 75.1200-1. (Contd.) Manager for steeply-pitching coalbeds. Contour lines may be placed on overlays or tracings attached to mine maps. ABANDONED AREAS, ADJACENT MINES; DRILLING OF BOREHOLES (STATUTORY PROVISIONS). Section 75.1701. Whenever any working place approaches within 50 feet of abandoned areas in the mine as shown by surveys made and certified by a registered engineer or surveyor, or within 200 feet of any other abandoned areas of the mine which cannot be inspected and which may contain dangerous accumulations of water or gas, or within 200 feet of any workings of an adjacent mine, ...	Code of Federal Regulations Mineral Resources	September 1972	Mine Enforcement Safety Administration
United Kingdom	PRECAUTIONS AGAINST EXTERNAL DANGERS TO WORKINGS Section 75. (1) In the case of every mine, the owner thereof and the manager thereof shall each be charged with the duty – (a) of taking such steps as may be necessary for securing that he is at all material times in possession of all information which indicates or tends to indicate the presence or absence, in the vicinity of any workings carried on or proposed to be carried on in the mine, of – (I) any disused workings (whether mine workings or not); (II) any rock or stratum containing or likely to contain water (whether dispersed or in natural cavities); (III) any peat, moss, sand, gravel, silt or other material that is likely to flow when wet; and (b) of taking such steps as may be necessary for the purpose of substantiating any such information which comes into his possession (whether in consequence of the discharge of the duty imposed upon him by the foregoing paragraph or not). (2) In the case of every mine, the owner thereof and the manager thereof shall each be charged with the duty – (a) forthwith after any such information as is mentioned in paragraph (a) of the foregoing subsection comes into his possession (whether in consequence of the discharge of the duty imposed upon him by the paragraph or not), of furnishing to the other particulars of the information; and (b) forthwith after taking any steps in discharge of the duty imposed upon him by paragraph (b) of that subsection, of furnishing to the other particulars of the steps taken and of any conclusion reached as a result of taking them.	Mines and Quarries Act of 1954	1954	Health and Safety Executive

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United Kingdom	PRECAUTIONS AGAINST EXTERNAL DANGERS TO WORKINGS (Contd.) Section 77. It shall be the duty of the manager of every mine to take, with respect to every working in the mine, such steps as may be necessary to prevent any inrush into the workings of gas from disused workings (whether mine workings or not) or of water or material that flows when wet (whether from disused workings or from any other source). Section 78. (1) Where an inspector is of opinion, with respect to a working in a mine, that there is a danger of the occurrence of such an inrush into the working as is mentioned in the last foregoing section, being a danger that in his opinion is capable of being averted, and either no steps for averting the danger have been taken or steps that have been taken for that purpose appear to the inspector to be inadequate or improper, he may serve on the manager of the mine a notice specifying the working, stating that he is of opinion aforesaid with respect thereto, and that, as the case may be, no steps for averting the danger have been taken or steps so taken appear to him to be inadequate or improper, and imposing all or any of the following requirements, that is to say: - (a) a requirement that the manager shall, before the expiration of such period beginning with the date on which the notice becomes operative as may be specified therein, execute such works for the purpose of averting the danger as may be specified in the notice; (b) a requirement that, until such works have been executed, no person shall (save for the purpose of executing the works or saving life) be permitted by the manager to be in the mine or in such part thereof as may be specified in the notice; (c) a requirement that operations for getting minerals in the working shall, to such extent as may be specified in the notice, be discontinued until such works have been executed, or shall not be continued otherwise than in accordance with such a system of working as may be so specified. (2) Where an inspector is of opinion, with respect to a working in a mine, that there is a danger of the occurrence of such an inrush into the working as is mentioned in the last foregoing section, being a danger that in his opinion is not capable of being averted, he may serve on the manager of a mine a notice specifying the working, stating that he is of opinion aforesaid with respect thereto, and requiring that operations for getting minerals in the working be permanently discontinued and, if the inspector thinks fit, imposing, in addition, either or both of the following requirements, that is to say; - (a) a requirement that the manager shall, before the expiration of such period beginning with the date on which the notice becomes operative as may be specified therein, execute such works for the purpose of protecting the rest of the mine as may be so specified; (b) a requirement that, until such works have been executed, no person shall (save for the purpose of executing the works or saving life) be permitted by	Mines and Quarries Act of 1954	1954	Health and Safety Executive

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United Kingdom	PRECAUTIONS AGAINST EXTERNAL DANGERS TO WORKINGS (Contd.) Section 78. (Contd.) the manager to be in the mine or in such part thereof as may be specified in the notice. (3) The provisions of Part XV of this Act with respect to references upon notices served by inspectors shall apply to a notice served under either of the foregoing subsections, and any such notice shall, if it is so specified therein, become operative forthwith.	Mines and Quarries Act of 1954	1954	Health and Safety Executive
United Kingdom	It is the duty both of the owner and of the manager of every mine – (a) to take such steps as may be necessary for securing that he is at all material times in possession of all information which indicates the presence or absence in the vicinity of any workings carried on or proposed to be carried on, of – (I) any disused workings; (II) any rock or stratum containing, or likely to contain, water; (III) any peat, moss, sand, gravel, silt or other material that is likely to flow when wet; and (b) to take such steps as may be necessary for the purpose of substantiating any such information (75). It is the duty of the mine manager to take, with respect to every working in the mine, such steps as may be necessary to prevent any inrush into the working of gas from disused workings or of water or material that flows when wet (77). Where an inspector is of opinion, with respect to a working in a mine, that there is a danger of the occurrence of an inrush of gas, water or material that flows when wet into the working, and that the danger is capable of being averted, he may – (a) require the manager to execute within a specified time limit specified works for the purpose of averting the danger; (b) require that until such works have been executed only specified persons shall be permitted by the manager to be in the mine or in any specified part of the mine; (c) require that operations for getting minerals in the working shall to such extent as may be specified be discontinued until such works have been executed, or shall not be continued otherwise than in accordance with such system of working as may be specified. Where an inspector is of opinion with respect to a working that there is a danger of the occurrence of an inrush of gas, water or material that flows when wet into the working, and that the danger is not capable of being averted, he may – (a) require that the manager shall, within a specified time limit, execute specified works for the purpose of protecting the rest of the mine; (b) require that until such works have been executed only specified persons shall be permitted by the manager to be in the mine or in a specified part of the mine (78). 1. The owner, agent and manager of a mine shall from time to time	Safety in Coal Mines	1955	International Labor Office

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United Kingdom	cause all reasonable steps to be taken to ascertain from all available information and evidence whether there is any material below the surface which may so affect any workings being, or about to be, carried on at that mine as to cause danger to persons working therein and shall ensure that the facts so ascertained are in the possession of the manager. 2. (1) No working which is approaching and within 150 feet of the surface shall be carried on in any mine unless the manager has sufficient information about the nature of the material between the working and the surface to determine whether it may cause danger to persons working in the mine: Provided that this paragraph shall not apply where there is another working or a disused working vertically above the working at a distance not less than 30 feet or five times the thickness of the seam to be worked, which ever is the greater. (2) No working shall be carried on at any place in any mine if there is evidence that within 150 feet thereof there may be any material which when wet is likely to flow, including peat, moss, sand, gravel and silt, unless the manager has sufficient information to determine the nature, position, thickness and extent thereof. (3) No working shall be carried on at any place in any mine if there is evidence that within 150 feet thereof there may be any rock or stratum likely to contain water (whether dispersed or in natural cavities) unless the manager has sufficient information about the nature or position thereof to determine that it is not dangerous to persons working in the mine, or sufficient information about the nature, position, thickness and extent thereof to determine whether it may cause danger to such persons. 4. No work other than work necessary for the preservation of the mine or for the sinking of shafts or the driving of drifts from the surface shall be carried out in any mine within 60 feet, or (if greater) ten times the maximum height of the working or proposed working, of – (a) any material described in paragraph (2) of regulation 2, ...	Safety in Coal Mines	1955	International Labor Office
United Kingdom	THE COAL AND OTHER MINES (PRECAUTIONS AGAINST INRUSHES) REGULATIONS, 1956, Having Effect as if Made Under Section One Hundred and Forty-One of the Mines and Quarries Act, 1954. 1. These regulations shall apply to every mine of coal, stratified ironstone, shale or fireclay, and in these regulations "mine" means such a mine. 2. (1) Without prejudice to the generality or section seventy-five of the Act, no working which is approaching and within one hundred and fifty feet of the surface shall be carried on in any mine, unless the manager has sufficient information about the nature of the material between the working and the surface to determine whether it may cause danger to persons working in the mine: Provided that this paragraph shall not apply where there is another working or a disused working vertically above the working in question at a distance not less than thirty feet or five times the thickness of the seam to be worked which-ever is the greater. (2) No working shall be carried on at any place in any mine if there is evidence that within one hundred and fifty feet thereof there may be any peat, moss, sand, gravel, silt or other material that is likely to flow when wet, ...	The Coal and Other Mines (Precautions Against Inrushes) Order 1956	January 1, 1957	Mines and Quarries

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United Kingdom	THE COAL AND OTHER MINES (PRECAUTIONS AGAINST INRUSHES) REGULATIONS (Contd.) (3) No working shall be carried on at any place in any mine if there is evidence that within one hundred and fifty feet thereof there may be any rock or stratum containing or likely to contain water (whether dispersed or in natural cavities) ... 4. Without prejudice to the generality of section seventy-seven of the Act, no working which is approaching and within one hundred and twenty feet of any place containing or likely to contain an accumulation of water or material that flows when wet or of any disused workings, not being workings which have been examined and found to be free from accumulations of water or material that flows when wet, ... 5. The manager of every mine shall ensure that no person carries out any work, other than work necessary for the preservation of the mine or for the sinking of a shaft or the driving of an outlet from the surface, in any working in the mine within sixty feet or ten times the height of the working (which ever is the greater) of – (a) any peat, moss, sand, gravel, silt or other material that is likely to flow when wet; or (b) any rock or stratum containing or likely to contain water (whether dispersed or in natural cavities) not being rock or stratum which by reason of its natural position is not dangerous; except in accordance with special regulations applicable to that mine. 6. (1) In these regulations the following expressions have the meanings hereby respectively assigned to them, that is to say – "the Act" means the Mines and Quarries Act, 1954; "mine" has the meaning assigned thereto in regulation one. (2) The Interpretation Act, 1889 (d), shall apply to the interpretation of these regulations as it applies to the Interpretation of an Act of Parliament.	The Coal and Other Mines (Precautions Against Inrushes) Order 1956	January 1, 1957	Mines and Quarries
Canada	CHAPTER 188 Section 88. (1) Where the workings in any mine are approaching any abandoned workings, whether in or belonging to that mine or any other mine, the owner, agent, or manager in charge of the present workings shall report the circumstances in writing to the Inspector for the district in which the workings are situate before the present workings reach within three hundred feet of the abandoned workings; and no work shall be done within three hundred feet of the abandoned workings until a definite method of proceeding with the work has been submitted to and approved by the Inspector. (2) This section shall not apply where the abandoned workings can be readily examined, and a knowledge obtained of the conditions prevailing therein.	Legislation – Coal Mines Regulation Act	1924	Canadian Legislature

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Canada	CHAPTER 217. Section 8. (1) When an advancing section of a mine approaches abandoned workings situated in the same seam, whether these belong to the mine aforesaid or not, the owner, agent, or manager shall report the circumstances in writing to the Inspector for the district before the advancing roadways or faces come within five hundred feet of the abandoned workings, and operations shall cease until the details of the method to be followed when advancement is resumed have been submitted to the Inspector and have received his approval. (2) In no circumstances shall the advancing section approach nearer than one hundred and fifty feet to abandoned workings situated in the same seam ... (3) Subject to such modifications as the Chief Inspector deems necessary, subsections (1) and (2) shall apply, mutatis mutandis, to the case of live and abandoned workings situated in different seams when the abandoned workings and advancing sections are separated by less than one hundred and eighty feet of solid measures. (4) This section shall not apply where it is possible to examine the abandoned workings to the extent that a definite knowledge of the conditions prevailing in all parts thereof can be obtained.	Legislation – Coal Mines Regulation Act	1948	Canadian Legislature
Canada	ALBERTA Section 132. When any working has approached within 120 feet of a place which is likely to contain a dangerous accumulation of water or gas or of disused workings (not being workings which have been examined and found to be free from accumulations of water and gas), ...	Safety in Coal Mines	1955	International Labor Office
Canada	CHAPTER 3. Section 14. (1) The owner, agent, or manager of every mine shall keep in the office of the mine accurate plans on a scale in accordance with good engineering practice, and up to a date not more than three months last past, as follows: – (a) A surface plan showing the licences or leases on which mining is being carried out and showing all lakes, streams, main roads, railways, power transmission-lines, buildings, shaft openings, adits, surface workings, diamond-drill holes collared on surface, dumps, and tailings ponds and their overflow.	Coal Mines Regulation Act, and Regulations Respecting Gas Testers	1967	Department of Energy, Mines and Resources

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Canada	GENERAL RULES, Section 28. Rule 136. (a) No bulkhead or dam to impound water shall be constructed underground without the written permission of the inspector, and then only when constructed in accordance with plans and specifications that have been approved by him. Rule 138. (b) (I) Where the workings in a mine are approaching any abandoned workings, whether in or belonging to that mine or any other mine, the manager in charge of the present workings shall report the circumstances in writing to the inspector before the present workings reach within three hundred feet of the abandoned workings; and (II) No work shall be done within three hundred feet of the abandoned workings until ...	Coal Mines Regulation Act, and Regulations Respecting Gas Testers	1967	Department of Energy, Mines and Resources
Republic of South Africa	WATCH TO BE KEPT Section 2.10.12. Provide that adequate watch be kept on all reasonably accessible sources of danger from flooding of the mine or works, and that he or his representative be immediately informed of any possibility of such danger; Section 2.10.13. Provide for adequate watch to be kept on all artificial constructions at his mine or works for conserving water or which may cause water to converge or accumulate, and give notice without delay to the manager, or his representative, of all mines or works situated below such constructions of any possibility of flooding by reason of such constructions; PLANS OF DAMS, COFFER-DAMS, ETC. Section 2.10.14. Submit for approval to the Government Mining Engineer plans and specifications giving details of construction and catchment area of any dam to be constructed for the purpose of conserving water and of any coffer-dam or other barricade which is to be constructed underground for keeping back water under a pressure exceeding seven bars;	Coal Mining Laws of South Africa	1956	South Africa Department of Mines

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Republic of South Africa	PREVENTION OF FLOODING Section 5.1.1. At every mine and at every works storm-water trenches and embankments shall be established and kept in good order for the protection from flooding of all machinery on surface and all underground workings where persons are employed. Section 5.1.2. The collor of every shaft or other similar opening from the surface, situated in low-lying ground, which connects with underground workings where persons are employed, shall be raised so as to afford efficient protection against flooding. WORKINGS NEAR WATER OR GAS: PRECAUTIONS Section 7.10.1. The manager shall ensure that the surveyor is at all times aware of the faces which are being advanced. Section 7.10.2. The surveyor shall inform the manager in writing when the face of a working is being advanced within, or is being advanced so as to come within, 30 metres of – (a) any abandoned, disused or discontinued working or excavations; or (b) any place on the surface where there may be an accumulation of water. Section 7.10.3. Where such abandoned, disused or discontinued workings or excavation contains or is likely to contain a dangerous accumulation of water or noxious or inflammable gas, or where there is a dangerous accumulation of water at such place on the surface, the manager shall by notice in writing inform the surveyor to that effect. Section 7.10.4. Before the face of the working being advanced reaches a distance of 15 metres from any place where there is, or is likely to be, a dangerous accumulation of water or noxious or inflammable gas, the surveyor shall give the manager written notification of the position of the working relative to such place. Section 7.10.7. For the purpose of regulation 7.10 the term surveyor shall mean a person appointed in terms of regulation 2.12. In the case of a mine for which no surveyor has been appointed in terms of regulation 2.12, the manager shall assume the	Coal Mining Laws of South Africa	1956	South Africa Department of Mines

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Republic of South Africa	WORKINGS NEAR WATER OR GAS: PRECAUTIONS (Contd.) Section 7.10.7. (Contd.) responsibilities of the surveyor under this regulation. Section 7.11.1. The manager shall take reasonable precautions to ensure that every person employed in the workings of a mine is safeguarded against inundation by water or mud or a flow of rock, sand, silt or other similar material.	Coal Mining Laws of South Africa	1956	South Africa Department of Mines
Belgium	Section 62. Mine operators shall be bound to acquire all information concerning the position, extent, and depth of old workings and natural reservoirs (water-bearing faults and natural wells) that may exist in or near their concessions.	Safety in Coal Mines	1955	International Labor Office

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Pennsylvania (Bituminous)	Section 5. The superintendent shall not permit the mining of coal within fifty feet of any abandoned mine containing a dangerous accumulation of water, until said danger has been removed by driving a passageway to tap and drain off said water, as provided for in this act: ... and provided further, that if it shall be agreed by the superintendents or owners of adjacent coal mines, that the property boundary line is so located that there is no danger to property or lives in mining coal on either or both sides of the property boundary line up to said property boundary line, then in such cases, mining to the property boundary line shall be lawful if such agreement is first approved by the district mine inspector, and if all danger from accumulated water and gas shall have first been removed by driving a passageway to tap and drain off any accumulations of water and gas as provided for in this act.	An Act to Provide for the Health and Safety of Persons Employed In and About the Bituminous Coal Mines of Pennsylvania	1935	Department of Mines
Pennsylvania (Bituminous)	MINE FOREMAN; DRAINAGE Section 224. (b) Whenever any working place in a mine approaches within fifty feet of abandoned workings, in such mine as shown by surveys certified by a registered engineer or surveyor, or within two hundred feet of any other abandoned workings of such mine, which cannot be inspected and which may contain dangerous accumulations of water or gas, or within two hundred feet of any workings of an adjacent mine, the mine foreman shall see that a borehole or boreholes shall be drilled to a distance of at least twenty feet in advance of the face of such working place. Such boreholes shall be drilled sufficiently close to each other to ensure that the advancing face will not accidentally hole through into such workings. Boreholes shall also be drilled not more than eight feet apart in the rib of such working place to a distance of at least twenty feet and at an angle of forty-five degrees. Such rib holes shall be drilled in one or both ribs of such working place as may be necessary for adequate protection of persons working in such place. No water or gas from any portion of an abandoned mine, or from any idle portion of an active mine, and no borehole from the surface shall be tapped except under the immediate instruction and direction of the mine foreman with the use of approved safety lamps. MINING CLOSE TO ABANDONED WORKINGS Section 291. The superintendent shall not permit the mining of coal within fifty feet of an abandoned mine or any abandoned portion of any mine containing a dangerous accumulation of water, until said danger has been removed by driving a passageway to tap and drain off said water, as provided in this act. ... and provided further, that if it shall be agreed by the mine inspector in the district and superintendents of such adjoining coal mining properties that such property boundary line	Bituminous Coal Mining Laws of Pennsylvania for Underground Mines	1961	Department of Mines and Mineral Industries (Now the Department of Environmental Resources)

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Pennsylvania (Bituminous)	MINING CLOSE TO ABANDONED WORKINGS (Contd.) Section 291 (Contd.) is so located that there is no danger to property or lives in mining coal in either or both sides of the property boundary line up to said property boundary line, then in such cases mining to the property boundary line shall be lawful, if all danger from accumulated water and gas shall have first been removed by driving a passageway to tap and drain off any accumulations of water and gas, as provided for in this act. If any of the parties in interest fails to agree on the carrying out of any of the provisions of this section, any one of said parties may appeal to the secretary who shall determine the matter. OPENING FOR DRAINAGE ON OTHER LANDS Section 298. (c) In any mine or mines, or portions thereof, wherein water may have been allowed to accumulate in large and dangerous quantities, putting in danger the adjoining or adjacent mines and the lives of the miners working therein, and when such can be tapped and set free and flow by its own gravity to any point of drainage, it shall be lawful for any operator or person having mines so endangered, with the approval of the mine inspector in the district, to proceed to remove the said danger by driving a drift, or drifts, protected by boreholes, as provided for by this act, and in removing said danger it shall be lawful to drive across property lines if needful. AUGER MINING, SPECIAL REQUIREMENTS Section 603. (d) Auger holes shall not intersect underground mine workings known to contain or suspected to contain dangerous quantities of impounded water, except to drain such areas under controlled conditions and then only after all necessary precautions have been taken to safeguard life and property. TUNNELS UNDER BEDS OF NAVIGABLE STREAMS Section 1. Be it enacted, &c. That from and after the passage of this act, whenever the power or manufacturing or mining plant of any company, heretofore or hereafter incorporated under the laws of the Commonwealth of Pennsylvania, is situated upon or near the bank of any navigable stream within this Commonwealth, and such company has the right, either as the owner in fee or by lease or other arrangement, to mine coal from or under lands adjoining or adjacent to such opposite bank of said navigable stream, or is the owner of a majority of the capital stock of any company that has the right, either as owner in fee or by lease or other arrangement, to mine coal from or under lands adjoining or adjacent to such opposite bank of said navigable stream, such company	Bituminous Coal Mining Laws of Pennsylvania Underground Mines	1961	Department of Mines and Mineral Industries (Now the Department of Environmental Resources)

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Pennsylvania (Bituminous)	TUNNELS UNDER BEDS OF NAVIGABLE STREAMS (Contd.) Section 1. (Contd.) shall have the right and lawful authority to construct, operate, and maintain tunnels under said navigable stream, so as to connect said coal lands, and any mine operated in connection with said coal lands, with said power or mining plant of said company: Provided, however, before any company begins the construction of any tunnel, it shall make application to and secure the approval of, the Water and Power Resources Board or such other authority as shall, at the time of such application, have jurisdiction over navigable streams under the laws of the Commonwealth of Pennsylvania the same as now vested in said Water and Power Resources Board: Provided, however, that said corporation or corporations, constructing said tunnel to tunnels, shall pay to the Commonwealth of Pennsylvania the fair market value for all coal mined in constructing said tunnel or tunnels. MINING IN SAFETY ZONES The General Assembly of the Commonwealth of Pennsylvania hereby enacts as follows: ESTABLISHMENT OF SAFETY ZONES Written Authorization Needed to Mine Within Safety Zone Section 2. (a) No mining or removal of minerals whatsoever shall be permitted within the safety zone unless authorization is specifically granted in advance and in writing by the Department of Mines and Mineral Industries. (b) Such authorization shall only be granted upon application of the operator and/or the lessor. Such application shall be accompanied by four copies of a plan of the proposed mining operation. The plan shall indicate the thickness of the unconsolidated strata, the thickness of the rock strata and coal beds overlying the bed to be mined, the thickness of the bed, the widths of the openings to be made and the width of the pillars to be left, and any other special features that may be deemed necessary as affecting the contemplated first mining. (c) The Department of Mines and Mineral Industries shall make periodic examinations to determine the accuracy of all plans, maps and drawings submitted to them under the provisions of this act. Requirements for Plan Approval Section 3. In no instance will any plan be approved if there is less than thirty-five feet of rock cover. Factors considered in plan approval shall include thickness of bed, width of mine openings, width of pillars and such other factors as are deemed applicable by the Department of Mines and Mineral Industries.	Bituminous Coal Mining Laws of Pennsylvania for Underground Mines	1961	Department of Mines and Mineral Industries (Now the Department of Environmental Resources)

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Pennsylvania (Bituminous)	ESTABLISHMENT OF SAFETY ZONES (Contd.) Pillar Recovery Section 4. No pillar recovery shall be undertaken until such time as the plans are approved by the Department of Mines and Mineral Industries. Application for pillar recovery shall be accompanied by four copies of the plan which shall include such information as shall be determined by the department. The approval or disapproval shall be based on the factors of depth, the thickness of the bed, the percentage of pillars proposed to be extracted and to be left, the effect on pillars remaining in overlying beds, and any other special features that may be deemed necessary by the department. Proof of Rock Cover Section 5. (a) Proof of the existence of thirty-five feet of rock cover shall accompany any plans submitted. (b) Said proof of rock cover is to be ascertained by test holes drilled on intersecting lines forming rectangles or squares where the cover thickness is less than fifty feet. These holes shall be drilled on spacing of not more than thirty-five feet centers. Copies of Plans and Proof of Rock Cover to be Signed Section 6. All copies of the aforementioned plans and proof of rock cover must indicate the location of the test holes and the depth of the rock cover, and they must be signed before submission to the Department of Mines and Mineral Industries by a Registered Mining Engineer representing the operator and a Registered Mining Engineer of the lessor and/or owner. Approval or Disapproval of Plans Section 7. (a) After examination and approval of the plans by a Registered Mining Engineer for the Department of Mines and Mineral Industries and the secretary of the department, they shall sign all copies. The original shall be retained in the department, one copy shall be forwarded to the State mine inspector for the area in which the mining is to be carried on, one copy is to be forwarded to the Registered Mining Engineer representing the operator and/or the lessor or owner, and one copy is to be forwarded to the operator. (b) If the plan is disapproved, the Registered Mining Engineer for the Department of Mines and Mineral Industries and the secretary of the department shall note their	Bituminous Coal Mining Laws of Pennsylvania for Underground Mines	1961	Department of Mines and Mineral Industries (Now the Department of Environmental Resources)

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Pennsylvania (Bituminous)	ESTABLISHMENT OF SAFETY ZONES (Contd.) Approval or Disapproval of Plans (Contd.) Section 7. (Contd.) reasons and attach a copy to each set of plans. One copy of the plan shall then be returned to the operator, one to the State mine inspector for the area, one to the Registered Mining Engineer for the operator and/or owner or lessor and one shall be retained by the department. Notice to Miners Working Within the Safety Zone Section 8. After approval of the plan by the Department of Mines and Mineral Industries, no mining or removal of minerals may begin within the safety zone until the mine foreman has conspicuously posted a notice on the outside of the mine and has orally notified each miner affected that he is working in the safety zone.	Bituminous Coal Mining Laws of Pennsylvania for Underground Mines	1961	Department of Mines and Mineral Industries (Now the Department of Environmental Resources)
Alabama	TAP WATER IN ADJOINING COAL MINE Section 11. (a) In any coal mine, or coal mines, or parts thereof, wherein water may have been allowed to accumulate in large and dangerous quantities, putting in danger the adjoining or adjacent coal mines, and the lives of the miners working therein, and when such can be tapped and set free and flow by its own gravity to any point of drainage, any operator or person having a mine so endangered, with the approval of the Department, may proceed and remove the said danger by driving a drift or drifts protected by bore holes as provided by this Act, and in removing said danger, it shall be lawful to drive across property lines if needful. All coal removed in such driving from adjacent lands shall be paid for on the basis of 25 cents per ton of 2,000 pounds. No person shall dam or in any way obstruct the flow of water from said mine or parts thereof, when so set on any part of its passage to point of drainage.	Coal Mining Laws of the State of Alabama	1960	Division of Safety and Inspection, Department of Industrial Relations
Alabama	PROTECTION AGAINST WATER AND GAS Rule 30. (a) Notice shall be given to the Department in writing before any mine working shall be allowed to approach within fifty (50) feet of any part of a winze, stope or other opening in which there is a known or suspected dangerous accumulation of water, the level of which may be above the level of the approaching working. (b) Notice shall be given to the Department in writing before starting to advance	Mine Safety Rules of the State of Alabama	December 15, 1962	Department of Industrial Relations

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Alabama	PROTECTION AGAINST WATER AND GAS (Contd.) Rule 30. (Contd.) a mine working within one hundred (100') feet of another mine working that is likely to contain a dangerous accumulation of gases or water. Workings, when approaching such places, shall not exceed eight (8') feet in width, and the person or persons driving such place shall constantly keep a sufficient distance ahead, not less than ten (10') feet in advance, one borehole near the center of the working, and one in each corner fifteen (15') feet deep, at an angle of forty-five (45°) degrees, at intervals of six (6') feet. These holes shall not be used for blasting but separate holes for blasting not over four (4') feet deep, must be drilled.	Mine Safety Rules of the State of Alabama	December 15, 1962	Department of Industrial Relations
Virginia	APPROACHING ABANDONED WORKINGS Section 45.1-93. It shall further be the duty of the mine foreman to have boreholes kept not less than twenty feet in advance of the face, and where necessary, one each cut on sides of the working places that are being driven toward and dangerous proximity to, an abandoned mine or part of mine which may contain flammable gas or which is filled with water. These holes shall be drilled whenever any working place in an underground mine approaches within fifty feet of abandoned workings in such mine as shown by surveys made and certified by a competent engineer or surveyor, or within two hundred feet of any other abandoned workings of such mine, which cannot be inspected. These holes must be drilled not more than fifteen feet apart.	Mining Laws of Virginia	1966	Department of Labor and Industry
Kentucky	BOREHOLES IN ADVANCE OF FACE, WHEN REQUIRED Section 352.371. Whenever any working place approaches within fifty feet of abandoned areas in the mine as shown by surveys made and certified by a registered engineer, or within two hundred feet of any other abandoned areas of the mine which cannot be inspected and which may contain dangerous accumulations of water or gas, or within two hundred feet of any workings of an adjacent mine, a borehole or boreholes shall be drilled to a distance of at least twenty feet in advance of the working face of such working place and shall be continually maintained to a distance of at least ten feet in advance of the advancing working face. When there is more than one borehole, they shall be drilled sufficiently close to each other to ensure that the advancing working face will not accidentally hole through into abandoned areas of adjacent mines. Boreholes shall also be drilled not more than eight feet apart in the rib of such working place to a distance of at least twenty feet and at an angle of forty-five degrees. Such rib holes shall be drilled in one or both ribs of such working place as may be necessary for adequate protection of miners in such place.	Laws Governing the Mining of Coal and Clay	1967	Department of Mines and Minerals

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Indiana	APPROACHING ABANDONED WORKINGS Section 86. Whenever any working place in an underground mine approaches within 50 feet of abandoned workings in such mine as shown by surveys made and certified by a competent engineer or surveyor, or within 200 feet of any other abandoned workings of such mine, which cannot be inspected and which may contain dangerous accumulations of water or gas, or within 200 feet of any workings of an adjacent mine, a borehole or boreholes shall be drilled to a distance of at least 20 feet in advance of the face of such working place. Such boreholes shall be drilled sufficiently close to each other to ensure that the advancing face will not accidentally hole through into such workings. Boreholes shall also be drilled not more than 8 feet apart in the rib of such working place to a distance of at least 20 feet and at an angle of 45 degrees. Such rib holes shall be drilled in one or both ribs of such working place as may be necessary for adequate protection of persons working in such place.	Mining Laws of the State of Indiana	March 8, 1955	Indiana Bureau of Mines and Mining
Ohio	PRECAUTIONS WHEN WORKING PLACE APPROACHES COMPLETED WORKINGS OR ABANDONED MINES Section 4153.39. When any working place approaches within fifty feet of accurately surveyed completed workings in the same mine, or within two hundred feet of any other abandoned workings, that cannot be inspected and which may contain dangerous accumulations of water or gas, boreholes shall be drilled at least twenty feet in advance of the face, and forty-five degree angle rib holes shall be drilled at least twenty feet deep and not more than eight feet apart in one or both ribs as may be necessary for adequate protection. Completed workings are accurately surveyed when a competent engineer or surveyor has certified as to the surveying and recording thereof.	Mining Laws of Ohio	1975	Department of Industrial Relations, Division of Mines
Oklahoma	RESTRICTIONS ON MINING NEAR ABANDONED WORKINGS Section 321. Driving toward abandoned mines. No operator shall be permitted to mine coal within two hundred (200) feet of any abandoned mine workings containing a dangerous accumulation of water, except as hereinafter provided, until said danger has been removed. BORE HOLES Section 322. In any place that is being driven towards, or in dangerous proximity to an abandoned	Mining Laws of the State of Oklahoma	1973	State of Oklahoma

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Oklahoma	BORE HOLES (Contd.) Section 322. (Contd.) mine or part of mine suspected of containing inflammable, noxious or poisonous gases, or which may contain water, boreholes shall be kept not less than eighteen (18) feet in advance of the face and on the sides of such working places. Holes of the same depth shall be drilled diagonally, not more than ten (10) feet wide, and no water or gas from the abandoned mine or part of the mine, and no boreholes from the surface shall be knowingly tapped until the employees, except those engaged at such work, are out of the mine. Such work is to be done under the immediate supervision of the mine foreman. PRECAUTIONS IN DANGEROUS WORKINGS Section 525. In any place that is being driven towards or in dangerous proximity to an abandoned mine or part of mine suspected of containing inflammable, noxious, or poisonous gases, or which may be inundated with water, boreholes shall be kept not less than twelve feet in advance of the face, and on the sides of such working places said side holes of the same depth shall be drilled diagonally not more than eight feet apart, and at any place driven to tap water or gas, shall not be more than ten feet wide, and no water or gas from an abandoned mine, or part of a mine, and no boreholes from the surface shall be tapped until the employees, except those engaged at such work, are out of the mines, and such work is to be done under the immediate supervision of the mine foreman.	Mining Laws of the State of Oklahoma	1973	State of Oklahoma
Arkansas	BOREHOLES IN MINE Section 9320. "The owner, agent, or operator shall provide that a borehole shall be kept twenty (20) feet in advance of the face of each and every working face, and at a forty-five (45) degree angle at intervals of eight (8) feet on each rib of said working face when driving toward an abandoned mine or parts of a mine suspected of containing inflammable gases, or be inundated with water."	Mining Laws of the State of Arkansas	1962	State of Arkansas
Illinois	MINE PLANS Section 34.04. During pillar recovery in any mine when working places approach within 50 feet of abandoned sealed workings, as shown by surveys made and certified by a competent engineer or surveyor, which may contain dangerous accumulations of water or gas, or within 200 feet of any workings of an adjacent mine, boreholes shall be drilled to a dis-	The Coal Mining Act	July, 1971	Department of Mines and Minerals

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Illinois	MINE PLANS (Contd.) Section 34.04. (Contd.) tance of at least 20 feet in advance of the face of such working place. Such boreholes shall be drilled sufficiently close to each other to ensure that the advancing face will not accidentally hole through into such workings. Boreholes shall also be drilled not more than 8 feet apart in the rib of such working place to a distance of at least 20 feet and at an angle of 45 degrees. Such rib holes shall be drilled in one or both ribs of such working place as may be necessary for adequate protection of persons working in such place. The above provisions shall apply to any working place in any mine at any time should conditions warrant same in the interest of safety.	The Coal Mining Act	July, 1971	Department of Mines and Minerals
Colorado	PRECAUTIONS NEAR ABANDONED MINES Section 92-6-7. Whenever any working place approaches within two hundred feet of abandoned workings that cannot be inspected and that may contain dangerous accumulations of water or gas, boreholes shall be kept at least twenty feet in advance of the face, and forty-five degree angle rib holes shall be drilled at least twenty feet deep. These holes shall be not more than eight feet apart. PITCHING VEINS FREE FROM WATER Section 92-10-24. (1) Any owner wishing to operate coal veins, seams pitching over twenty-five degrees under workings of the same mine or any adjoining mine where water exists, shall see that such workings are previously made free from water and are kept free from water so long as he shall work said vein.	Coal Mining Laws of the State of Colorado	1966	State of Colorado
New Mexico	WORKING IN VICINITY OF ABANDONED AREA - ADVANCE WORKINGS - PRECAUTIONS Section 63-14-19. When any working has approached within one hundred (100) feet of any portion of an abandoned mine not known to be free from gas or dangerous accumulation of water or explosive gas, the advance workings or headings shall not exceed sixteen (16) feet in width and there shall be constantly at least one (1) borehole, eighteen (18) feet in advance, drilled centrally in the face of each heading; and when within fifty (50) feet of conjectured location of the workings, in addition to the center hole, there shall also be drilled in advance at least two (2) holes, for each nine (9) feet advance of the face, one (1) on each side of the heading at an angle of thirty (30) degrees to forty-five (45) degrees with the axis of the entry or workings, which holes shall be drilled at least eighteen (18) feet deep.	New Mexico Mine Safety Code for All Mines	1972	State of New Mexico

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Utah	APPROACHING ABANDONED WORKINGS - IMPOUNDING WATER Section 33. (a) Whenever any working place in an underground mine approaches within 50 feet of abandoned workings in such mine as shown by surveys made and certified by a competent engineer or surveyor, or within 200 feet of any other abandoned workings of such mine, which cannot be inspected and which may contain dangerous accumulations of water or gas, or within 200 feet of any workings of an adjacent mine, a borehole or boreholes shall be drilled to a distance of at least 20 feet in advance of the working place. Such boreholes shall be drilled sufficiently close to each other to ensure that the advancing face will not accidentally hole through into such workings. Boreholes shall also be drilled not more than 8 feet apart in the rib of such working place to a distance of at least 20 feet and at an angle of 45°. Such rib holes shall be drilled in one or both ribs of such working place as may be necessary for adequate protection of persons working in such place.	General Safety Orders for Utah Coal Mines	January 1, 1967	Industrial Commission of Utah
Pennsylvania (Anthracite)	*AUTHORIZATION NEEDED TO MINE WITHIN SAFETY ZONE Section 2. (a) No mining or removal of minerals whatsoever shall be permitted within the safety zone unless authorization is specifically granted in advance and in writing by the Department of Mines and Mineral Industries. (b) Such authorization shall only be granted upon application of the operator and/or the lessor. Such application shall be accompanied by four copies of a plan of the proposed mining operation. The plan shall indicate the thickness of the unconsolidated strata, the thickness of the rock strata and coal beds overlying the bed to be mined, the thickness of the bed, the widths of the openings to be made and the width of the pillars to be left, and any other special features that may be deemed necessary as affecting the contemplated first mining. (c) The Department of Mines and Mineral Industries shall make periodic examinations to determine the accuracy of all plans, maps and drawings submitted to them under the provisions of this act. *"Authorizing" in original. REQUIREMENTS FOR PLAN APPROVAL Section 3. In no instance will any plan be approved if there is less than thirty-five feet of rock cover. Factors considered in plan approval shall include thickness of bed, width of mine openings, width of pillars and such other factors as are deemed applicable by the Department of Mines and Mineral Industries.	An Act by the General Assembly of the Commonwealth of Pennsylvania	December 22, 1959	Department of Mines and Mineral Industries (Now the Department of Environmental Resources)

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Pennsylvania (Anthracite)	PILLAR RECOVERY Section 4. No pillar recovery shall be undertaken until such time as the plans are approved by the Department of Mines and Mineral Industries. Application for pillar recovery shall be accompanied by four copies of the plan which shall include such information as shall be determined by the department. The approval or disapproval shall be based on the factors of depth, the thickness of the bed, the percentage of pillars proposed to be extracted and to be left, the effect on pillars remaining in overlying beds, and any other special features that may be deemed necessary by the department. PROOF OF ROCK COVER Section 5. (a) Proof of the existence of thirty-five feet of rock cover shall accompany any plans submitted. (b) Said proof of rock cover is to be ascertained by test holes drilled on intersecting lines forming rectangles or squares where the cover thickness is less than fifty feet. These holes shall be drilled on spacing of not more than thirty-five feet centers. COPIES OF PLANS AND PROOF OF ROCK COVER TO BE SIGNED Section 6. All copies of aforementioned plans and proof of rock cover must indicate the location of the test holes and the depth of the rock cover, and they must be signed before submission to the Department of Mines and Mineral Industries by a Registered Mining Engineer representing the operator and a Registered Mining Engineer of the lessor and/or owner. APPROVAL OR DISAPPROVAL OF PLANS Section 7. (a) After examination and approval of the plans by a Registered Mining Engineer for the Department of Mines and Mineral Industries and the secretary of the department, they shall sign all copies. The original shall be retained in the department, one copy shall be forwarded to the State mine inspector for the area in which the mining is to be carried on, one copy is to be forwarded to the Registered Mining Engineer representing the operator and/or the lessor or owner, and one copy is to be forwarded to the operator. (b) If the plan is disapproved, the Registered Mining Engineer for the Department of Mines and Mineral Industries and the secretary of the department shall note their reasons and attach a copy to each set of plans. One copy of the plan shall then be returned to the operator, one to the State mine inspector for the area, one to the Registered Mining Engineer for the operator and/or owner or lessor and one shall be retained by the department.	An Act by the General Assembly of the Commonwealth of Pennsylvania	December 22, 1959	Department of Mines and Mineral Industries (Now the Department of Environmental Resources)

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Pennsylvania (Anthracite)	NOTICE TO MINERS WORKING WITHIN THE SAFETY ZONE Section 8. After approval of the plan by the Department of Mines and Mineral Industries, no mining or removal of minerals may begin within the safety zone until the mine foreman has conspicuously posted a notice on the outside of the mine and has orally notified each miner affected that he is working in the safety zone.	An Act by the General Assembly of the Commonwealth of Pennsylvania	December 22, 1959	Department of Mines and Mineral Industries (Now the Department of Environmental Resources)
Pennsylvania (Anthracite)	REGULATIONS, PLACES APPROACHING INACCESSIBLE WORKINGS Section 238. Whenever a place is approaching inaccessible workings, the operator shall establish and clearly show on the map furnished the mine foreman a stopping distance not less than one hundred feet from the said inaccessible workings and such stopping point shall not be passed until after the coal company officials, the mining engineer and the mine inspector have agreed on the width of any such approaching place or places, the point at which test holes shall be started and the location of the test holes. The test holes shall not be less than twenty feet in advance of the working face with sufficient flank holes on each side of said place. No such stopping distance shall be less than one hundred feet from the said inaccessible abandoned workings, nor need it be greater than the distance calculated in accordance with the rule commonly used in the establishing of barrier pillars, namely, one percent of the depth below drainage times the thickness of the coal seam plus thickness of seam times five, excepting in such cases where calculation in accordance with said rule establishes a stopping distance of less than one hundred feet. This act does not permit the driving of gangways, chambers or other excavations into barriers which are subject to their maximum water pressure, as calculated in accordance with the rule here established, unless the said waterhead is reduced by pumping or other means. The term "mining engineer", as used in this act, shall mean the person who shall, in behalf of the operator, have charge or general supervision of the work of compiling the mine map.	Anthracite Mining Laws of Pennsylvania	November 29, 1965	Department of Mines and Mineral Industries (Now the Department of Environmental Resources)
FEDERAL	ABANDONED AREAS, ADJACENT MINES; DRILLING OF BOREHOLES (STATUTORY PROVISIONS). Section 75.1701. Whenever any working place approaches within 50 feet of abandoned areas in the mine as shown by surveys made and certified by a registered engineer or surveyor, or within 200 feet of any other abandoned areas of the mine which cannot be inspected and which may contain dangerous accumulations of water or gas, or within 200 feet of any workings of an adjacent mine, a borehole or boreholes shall be drilled to a distance of at least 20 feet in advance of the working face of such working place and shall be continually maintained to a distance of at least 10 feet in advance of the advancing working face. When there is more than one borehole, they shall be drilled sufficiently	Code of Federal Regulations Mineral Resources	September, 1972	Mine Enforcement Safety Administration

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FEDERAL	ABANDONED AREAS, ADJACENT MINES; DRILLING OF BOREHOLES (STATUTORY PROVISIONS) (Contd.) Section 75.1701. (Contd.) close to each other to ensure that the advancing working face will not accidentally hole through into abandoned areas or adjacent mines. Boreholes shall also be drilled not more than 8 feet apart in the rib of such working place to a distance of at least 20 feet and at an angle of 45 degrees. Such rib holes shall be drilled in one or both ribs of such working place as may be necessary for adequate protection of miners in such place.	Code of Federal Regulations Mineral Resources	September 1972	Mine Enforcement Safety Administration
FEDERAL	OPERATIONS UNDER WATER (STATUTORY PROVISIONS) Section 75.1716. Whenever an operator mines coal from a coal mine opened after March 30, 1970, or from any new working section of a mine opened prior to such date, in a manner that requires the construction, operation, and maintenance of tunnels under any river, stream, lake, or other body of water, that is, in the judgment of the Secretary, sufficiently large to constitute a hazard to miners, such operator shall obtain a permit from the Secretary which shall include such terms and conditions as he deems appropriate to protect the safety of miners working or passing through such tunnels from caveins and other hazards. Such permits shall require, in accordance with a plan to be approved by the Secretary, that a safety zone be established beneath and adjacent to such body of water. No plan shall be approved unless there is a minimum of cover to be determined by the Secretary. No such permit shall be required in the case of any new working section of a mine which is located under any water resource reservoir being constructed by a Federal agency on December 30, 1969, the operator of which is required by such agency to operate in a manner that protects the safety of miners working in such section from caveins and other hazards. OPERATIONS UNDER WATER; NOTIFICATION BY OPERATOR Section 75.1716-1. An operator planning to mine coal from coal mines opened after March 30, 1970, or from working sections in mines opened prior to such date, and in such manner that mining operations will be conducted, or tunnels constructed, under any river, stream, lake, or other body of water, shall give notice to the Coal Mine Safety District Manager in the district in which the mine is located prior to the commencement of such mining operations.	Code of Federal Regulations Mineral Resources	July 1, 1974	Mine Enforcement Safety Administration

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FEDERAL	PERMIT REQUIRED Section 75.1716-2. If in the judgment of the Coal Mine Safety District Manager the proposed mining operations referred to in section 75.1716-1 constitute a hazard to miners, he shall promptly so notify the operator that a permit is required. APPLICATIONS FOR PERMITS Section 75.1716-3. An application for a permit required under this section shall be filed with the Coal Mine Safety District Manager and shall contain the following general information: (a) Name and address of the company. (b) Name and address of the mine. (c) Projected mining and ground support plans. (d) A mine map showing the locations of the river, stream, lake, or other body of water and its relation to the location of all working places. (e) A profile map showing the type of strata and the distance in elevation between the coal bed and the river, stream, lake or other body of water involved. The type of strata shall be determined by core test drill holes as prescribed by the Coal Mine Safety District Manager. ISSUANCE OF PERMITS Section 75.1716-4 If the Coal Mine Safety District Manager determines that the proposed mining operations under water can be safely conducted, he shall issue a permit for the conduct of such operations under such conditions as he deems necessary to protect the safety of miners engaged in those operations.	Code of Federal Regulations Mineral Resources	July 1, 1974	Mine Enforcement Safety Administration
United Kingdom	PRECAUTIONS AGAINST EXTERNAL DANGERS TO WORKINGS Section 76. (1) It shall be the duty both of the owner and of the manager of every mine to take, with respect to any workings carried on or proposed to be carried on in the mine in the vicinity of the sea, a lake or river or any other body of surface water (whether accumulated naturally or artificially) such steps as may be necessary for ascertaining the total thickness of the strata lying between the workings and the surface water.	Mines and Quarries Act of 1954	1954	Health and Safety Executive

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United Kingdom	"1. The owner, agent and manager of a mine shall from time to time cause all reasonable steps to be taken to ascertain from all available information and evidence whether there is any material below the surface which may so affect any workings being, or about to be, carried on at that mine as to cause danger to persons working therein and shall ensure that the facts so ascertained are in the possession of the manager. 2. (1) No working which is approaching and within 150 feet of the surface shall be carried on in any mine unless the manager has sufficient information about the nature of the material between the working and the surface to determine whether it may cause danger to persons working in this mine: Provided that this paragraph shall not apply where there is another working or a disused working vertically above the working at a distance not less than 30 feet or five times the thickness of the seam to be worked, which ever is the greater. (2) No working shall be carried on at any place in any mine if there is evidence that within 150 feet thereof there may be any material which when wet is likely to flow, including peat, moss, sand, gravel and silt, unless the manager has sufficient information to determine the nature, position, thickness and extent thereof. (3) No working shall be carried on at any place in any mine if there is evidence that within 150 feet thereof there may be any rock or stratum likely to contain water (whether dispersed or in natural cavities) unless the manager has sufficient information about the nature or position thereof to determine that it is not dangerous to persons working in the mine, or sufficient information about the nature, position, thickness and extent thereof to determine whether it may cause danger to such persons. 3. (1) No working which – (a) is approaching and within 150 feet of the surface, or (b) is within 150 feet of any material described in paragraph (2) of the last preceding regulation, or (c) is within 150 feet of any material described in paragraph (3) thereof (other than material which by reason of its nature or position is not dangerous), shall exceed 10 feet in width unless the conditions specified in the following paragraph are satisfied. (2) The aforesaid conditions are that – (a) notice of the proposed working has been sent by the owner, agent or manager to the inspector of the division; and (b) either – (I) The inspector of the division has within one month notified the manager that he has no objection to proposed workings or the proposed working subject to compliance with conditions for ensuring the safety or persons working in the mine, or (II) It has been determined in manner provided by the Act for settling disputes that the proposed working, or the proposed working subject to compliance with conditions for ensuring the safety of persons working in the mine, would not be dangerous to such persons; and (c) where any such conditions for ensuring safety are imposed, they are complied with. 4. No work other than work necessary for the preservation of the mine or for the sinking of shafts or the driving of drifts from the surface shall be carried out in any mine within 60 feet, or (if greater) ten times the maximum height of the working or proposed working, of –	Safety in Coal Mines	1955	International Labor Office

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United Kingdom	(a) any material described in paragraph (2) of regulation 2, or (b) any material described in paragraph (3) thereof (other than material which by reason of its nature or position is not dangerous), except in accordance with special regulations for the mine."	Safety in Coal Mines	1955	International Labor Office
United Kingdom	THE COAL AND OTHER MINES (PRECAUTIONS AGAINST INRUSHES) REGULATIONS, 1956, Having Effect as if Made Under Section One Hundred and Forty-One of the Mines and Quarries Act, 1954. 1. These regulations shall apply to every mine of coal, stratified ironstone, shale or fireclay, and in these regulations "mine" means such a mine. 2. - (1) Without prejudice to the generality of section seventy-five of the Act, no working which is approaching and within one hundred and fifty feet of the surface shall be carried on in any mine, unless the manager has sufficient information about the nature of the material between the working and the surface to determine whether it may cause danger to persons working in the mine: Provided that this paragraph shall not apply where there is another working or a disused working vertically above the working in question at a distance not less than thirty feet or five times the thickness of the seam to be worked whichever is the greater. (2) No working shall be carried on at any place in any mine if there is evidence that within one hundred and fifty feet thereof there may be any peat, moss, sand, gravel, silt or other material that is likely to flow when wet, unless the manager of the mine has sufficient information to determine the nature, position, thickness and extent thereof. (3) No working shall be carried on at any place in any mine if there is evidence that within one hundred and fifty feet thereof there may be any rock or stratum containing or likely to contain water (whether dispersed or in natural cavities) unless the manager of the mine has sufficient information about the nature or position thereof to determine that it is not dangerous to persons working in the mine or sufficient information about the nature, position, thickness and extent thereof to determine whether it may cause danger to such persons. 3. Without prejudice to the generality of section seventy-seven of the Act, no working which - (a) is approaching and within one hundred and fifty feet of the surface; or (b) is within one hundred and fifty feet of any peat, moss, sand, gravel, silt or other material that is likely to flow when wet; or (c) is within one hundred and fifty feet of any rock or stratum containing or likely to contain water (whether dispersed or in natural cavities) not being rock or stratum which by reason of its nature or position is not dangerous; shall exceed ten feet in width, unless the manager has given to the inspector for the district notice of his intention to work to a greater width and the inspector has within thirty days, by notice served on the manager, consented to that working exceeding ten feet in width. 4. Without prejudice to the generality of section seventy-seven of the Act, no working which is approaching and within one hundred and twenty feet of any place containing or likely to contain an accumulation of water or material that flows when wet or of any disused workings, not being workings which have been examined and found	The Coal and Other Mines (Precautions Against Inrushes) Order 1956	January 1, 1957	Mines and Quarries

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United Kingdom	THE COAL AND OTHER MINES (PRECAUTIONS AGAINST INRUSHES) REGULATIONS (Contd.) to be free from accumulations of water or material that flows when wet, shall exceed eight feet in width, and in respect of any such working the manager shall ensure that boreholes are at all times maintained in advance near the center of the working of a length not less than fifteen feet and on each flank at intervals not exceeding fifteen feet. 5. The manager of every mine shall ensure that no person carries out any work, other than work necessary for the preservation of the mine or for the sinking of a shaft or the driving of an outlet from the surface, in any working in the mine within sixty feet or ten times the height of the working (whichever is the greater) of – (a) any peat, moss, sand, gravel, silt or other material that is likely to flow when wet; or (b) any rock or stratum containing or likely to contain water (whether dispersed or in natural cavities) not being rock or stratum which by reason of its natural position is not dangerous; except in accordance with special regulations applicable to that mine.	The Coal and Other Mines (Precautions Against Inrushes) Order 1956	January 1, 1957	Mines and Quarries
Canada	CHAPTER 188 Rule 15. Where a place is likely to contain a dangerous accumulation of water, the working approaching such place shall not exceed eight feet in width, or such greater width as may be permitted by the Chief Inspector of Mines, and there shall be constantly kept at a sufficient distance, not being less than five yards in advance, at least one borehole near the centre of the working, and sufficient flank boreholes on each side.	Legislation – Coal Mines Regulation Act	1924	Canadian Legislature
Canada	CHAPTER 217. Section 8. (1) When an advancing section of a mine approaches abandoned workings situated in the same seam, whether these belong to the mine aforesaid or not, the owner, agent, or manager shall report the circumstances in writing to the Inspector for the district before the advancing roadways or faces come within five hundred feet of the abandoned workings, and operations shall cease until the details of the method to be followed when advancement is resumed have been submitted to the Inspector and have received his approval. (2) In no circumstances shall the advancing section approach nearer than one hundred and fifty feet to abandoned workings situated in the same seam until the exact position of these has been established by a borehole, or boreholes, drilled from the live workings and the abandoned workings have been drained of all standing water above the level of the adjoining workings. (3) Subject to such modifications as the Chief Inspector deems necessary, subsections (1) and (2) shall apply, mutatis mutandis, to the case of live and abandoned	Legislation – Coal Mines Regulation Act	1948	Canadian Legislature

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Canada	CHAPTER 217. (Contd.) Section 8. (Contd.) workings situated in different seams when the abandoned workings and advancing sections are separated by less than one hundred and eighty feet of solid measures. (4) This section shall not apply where it is possible to examine the abandoned workings to the extent that a definite knowledge of the conditions prevailing in all parts thereof can be obtained. Section 49. (Water-covered Coal Areas) No submarine seam of coal or stratified deposit thereof shall be mined under less cover than one hundred and eighty feet of solid measures: Provided that the owner, agent, or lessee of any submarine coal area may drive passageways to win the coal to be mined under less cover than one hundred and eighty feet, but not less than one hundred feet of solid measures unless the condition of the strata overlying such proposed passageways warrants the Chief Inspector permitting a lesser cover than one hundred feet of solid measures; and provided further that nothing herein contained shall prevent any owner, agent, or lessee from winning water-covered coal areas, where other means of access thereto are not available, by caisson, shaft, or concrete revetment, or by any safe method whereby any shaft or opening may be safely and securely sunk or driven and maintained through such water-covered areas, but any coal or stratified deposit so reached shall be mined and operated subject to the provisions of this section.	Legislation - Coal Mines Regulation Act	1948	Canadian Legislature
Canada	ALBERTA Section 132. "When any working has approached within 120 feet of a place which is likely to contain a dangerous accumulation of water or gas or of disused workings (not being workings which have been examined and found to be free from accumulations of water and gas), the working approaching such place shall not exceed 8 feet in width or height or such greater widths as may be permitted by the Director of Mines and there shall be constantly kept at a sufficient distance, not being less than 15 feet in advance, at least one borehole near the centre of the working face and sufficient flank boreholes on each side at intervals of not more than 15 feet. In case of overlaying accumulations of water, the District Inspector, after consultation with the engineer and the mine manager, may require that solid pillars be left in or the area dewatered. Every such direction in this connection by a District Inspector shall be complied with."	Safety in Coal Mines	1955	International Labor Office

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Canada	GENERAL RULES, Section 28. Rule 138. (a) Where any working in a mine approaches a place where there is or may be an accumulation of water, boreholes shall be kept well in advance, and such additional precautions shall be taken as may be deemed necessary to obviate the danger of a sudden breaking-through of the water. (b) (I) Where the workings in a mine are approaching any abandoned workings, whether in or belonging to that mine or any other mine, the manager in charge of the present workings shall report the circumstances in writing to the inspector before the present workings reach within three hundred feet of the abandoned workings; and (II) No work shall be done within three hundred feet of the abandoned workings until a definite method of proceeding with the work has been submitted to and approved by the inspector. Section 90. (2) If the seam be twelve feet or more in thickness, an additional hole fifteen feet in length shall be bored ahead of the working face at an angle of not less than twenty degrees with the roof of the place.	Coal Mines Regulation Act, and Regulations Respecting Gas Testers	1967	Department of Energy, Mines and Resources
Republic of South Africa	Section 12. "Where a place contains or is likely to contain a dangerous accumulation of water or noxious gases, any working approaching that place shall have boreholes kept in advance, and such additional precautionary measures shall be taken as may be deemed necessary to obviate the danger of a sudden breaking through of such water or gases, and such working place must not exceed 8 feet in width. A certificated surveyor shall exercise supervision at every such working place and shall be responsible for the correct direction of such working, and for the breaking through of such water or gases without accident. In the case of a mine for which there is certificated mine surveyor, the manager shall have the powers and responsibilities and perform all the duties conferred or imposed on a certificated surveyor in this regulation."	Safety in Coal Mines	1955	International Labor Office
Republic of South Africa	WORKINGS NEAR WATER OR GAS: PRECAUTIONS Section 7.10.5. Where the face of the working reaches a distance of 15 metres from any place where there is, or is likely to be, a dangerous accumulation of water or noxious or inflammable gas – (a) the manager shall cause –	Coal Mining Laws of South Africa	1956	South Africa Department of Mines

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Republic of South Africa	WORKINGS NEAR WATER OR GAS: PRECAUTIONS (Contd.) Section 7.10.5. (Contd.) (I) the dimensions of such working to be restricted to not more than 2.5 metres in width and 2.5 metres in height or to such greater dimensions as the Inspector of Mines may permit; (II) suitably directed boreholes to be drilled from such working sufficient in number and length to give ample warning of the water or gas; and (III) such additional precautions to be taken as circumstances may indicate to be necessary to ensure the safety of persons... Section 7.10.6. The precautions and responsibilities set out in regulation 7.10.5. shall continue until a holing is affected or until the face of the working passes beyond a distance of 15 metres from such place. Section 7.10.8. Whenever any shaft is being sunk or any heading advanced through ground which contains, or is likely to contain, an accumulation of water which may constitute a danger, the manager shall cause suitably directed boreholes to be drilled from such shaft or heading, sufficient in number and length to give ample warning of the presence of water, and shall cause such additional precautions to be taken as circumstances may indicate to be necessary to ensure the safety of persons. BOUNDARY PILLARS Section 7.12.2. No person shall mine, or cause or permit any other person to mine, such boundary pillars unless permission thereto has been obtained in terms of regulation 7.12.3 or 7.12.4. Section 7.12.3. On the joint application of the owners of adjoining mines, the Inspector of Mines may give permission to cut through or work the respective boundary pillars under such conditions as he may prescribe in writing. Section 7.12.4. In the absence of such joint application, the Government Mining Engineer may give permission to work or cut through such pillars under such conditions as he may prescribe in writing.	Coal Mining Laws of South Africa	1956	South Africa Department of Mines

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Belgium	Section 63. Soundings in the coal or the rock shall be taken whenever there is reason to suspect the existence of bodies of water near the workings. The number, length, and arrangement of the trial boreholes shall be fixed by the mine management according to local circumstances and with special regard to the thickness and composition of the seams, the hardness of the coal and the rocks to be penetrated, the arrangement of the working faces, and the presumed height of the bodies of water that it is feared to encounter. Section 64. During working hours the workers drilling trial boreholes shall always have within reach the necessary material for blocking up the holes immediately in case of need. Section 65. Before releasing a body of water the mine management shall take all the necessary precautions to safeguard the workers from any accidents that might result from the operation. In the register that is required to be kept by section 67 mention shall be made of the precautionary measures that have been decided upon. Section 66. The officials supervising the drillers shall be mentioned as such in the staff register; they shall report to the overman on the state of the boreholes before the arrival of each shift. Section 67. A register shall be kept showing the position of the boreholes at each workplace.	Safety in Coal Mines	1955	International Labor Office
France	Section 138. The roads or workplaces driven in a district where an inrush of water may be feared shall be preceded by divergent boreholes at least 3 m long, the number, length and arrangement of which shall be determined by the operator. Section 139. The operator shall notify the district inspector of mines before drilling into a body of water when the presumed pressure exceeds 30 m of water or when the drilling is to be done in coal. He shall specify in instructions the measures to be taken to ensure safety in all the districts which may be affected by an inrush of water.	Safety in Coal Mines	1955	International Labor Office

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STATE, FEDERAL OR FOREIGN COUNTY	GUIDELINE	PUBLICATION OF LAW	EFFECTIVE DATE	REGULATING AGENCY
Germany	Section 11. (1) For mine workings in which bodies of water may be tapped, the following regulations shall apply: (a) The workings shall be driven under the direction of the surveyor. (b) If trial borings are made, the number, position and depth of the boreholes shall be entered daily in a special register (Bohrliste). (c) Material for blocking up the boreholes and for damming the roads shall be kept in readiness on the spot. (d) A safe and lighted way of escape shall be available and shall be notified, before the work is begun, to all men engaged in releasing gas or water. (e) Care shall be taken that those employed in other mine workings are not endangered by an inrush of water or gas. (f) The actual work for the purpose of releasing gas or water shall only be undertaken in the presence of a supervisory official. (2) Coalgetting shall only be carried on in places where no inrush of water is to be feared. (3) Water shall not be drained off through the coal. (4) Subsection (1) shall also apply in places where an inrush from water-bearing strata or an outburst of harmful gas may be expected.	Safety in Coal Mines	1955	International Labor Office
Netherlands	Section 67. If the possibility is to be reckoned with that, in consequence of the advance of the workings, connection may be established with places that contain water or harmful gases, or for other reasons danger from inrushes of water or outbreaks of gas is to be feared, trial boreholes shall be drilled and suitable measures taken to ensure safety. "1. When draining a 'simpel' (worked out and packed strip along the lower side of a road) by means of trial boreholes from the top of a lower rise heading or cross-cut in the coal, the trial boreholes in the coal shall be at least 4 m long provided that if there are large quantities of water, for example when draining old workings in the coal that stand several metres deep in water, the trial boreholes shall be correspondingly longer. 2. In the vicinity of the water, the coal face shall be kept as small as possible and, if necessary, shall be protected against extrusion by means of sprags on both sides of the borehole. 3. During the drawing off of the water, no workers shall be present in the workplaces below the discharge opening. 4. (1) The mine manager shall immediately notify the Inspector General of Mines if faults are discovered in workings less than 30 m measured vertically below the top of the coal measures, in so far as the height of the throw of these faults is not accurately known. (2) If there is a possibility that the overburden behind the faults is lower than in front of them, work at the place shall not be continued before it has been made certain by borings that no inrushes of water or quicksand are to be feared."	Safety in Coal Mines	1955	International Labor Office

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APPENDIX C

SUBMARINE MINING

AND

SUBSIDENCE PREDICTIVE METHODS

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APPENDIX C

SUBMARINE MINING

GENERAL DISCUSSION

Eight foreign countries with active submarine mining operations have been identified, including Japan, Chile, Taiwan, Turkey, Spain, Australia, Canada, and the United Kingdom. Most of these countries have been confronted with serious mine inundations at some time. Major floodings in Japan between 1900 and 1959 took 611 lives - with 235 men lost in a single incident in 1915. Fatal inrushes also occurred in Chile, Australia, and Spain. Unfortunately, detailed information concerning many of these accidents is not available.

Data that was gathered indicates that most submarine inundations have been attributed to failure of thin, consolidated rock cover or interception of water bearing faults and high flow aquifers. In some cases, mining to within 100 feet of the sea floor was accomplished before breakthrough occurred.

Various mining guidelines are utilized to prevent inrush occurrences in submarine mining operations. The most widely used submarine mining guidelines involve the limit angle of 35 degrees, as defined in previous Phase Reports.

A line projected downward to the mineral seam at an angle of 35° from the vertical away from the body of water on all sides establishes the boundary or perimeter. Within this boundary, no mining is permitted within approximately the first 200 feet of cover. Below this zone of no mining, partial extraction (about 50 percent) is permitted. The zone where full extraction can take place is variable with cover thicknesses based on local geology and experiences. The Nova Scotia guideline is the most restrictive, however, requiring at least 700 feet of cover.

Presently the United Kingdom and Canada have substantial submarine coal production, and guidelines utilized have been developed throughout their long mining history. These guidelines have been enhanced by years of subsidence studies which enable prediction of the potential for failure of strata supporting man-made structures or surface waters. (Subsidence predictive methods are discussed in detail in the following section.)

According to the accident record, these guidelines, although they differ in their requirements, afford reasonably good protection. Since many miners in these submarine operations are working one or two miles from the nearest onshore escapeway, a great deal of precaution is taken to eliminate possibilities of an inrush. Precautions against seabed breaching are also taken to prevent sterilization of considerable coal resources.

National Coal Board guidelines afford good protection for their submarine mining regions. Thorough review of these explicit guidelines

indicates a wide variety of problems are anticipated and considered in development of safety precautions. Major considerations include:

- Strength, type and thickness of overlying rock strata including the coal left in pillars.

- Recognition of deep buried channels in the floor of the seabed which could be mistaken for solid rock cover. Actual rock cover in such instances would be much less than predicted.

- Mapping of faults with regard to their displacement and possible water bearing capacity.

- Location of water bearing strata, aquifers or fracture zones, which may convey unacceptable quantities of water into mine workings.

- Consideration of previous and proposed mining to determine combined rock strain effects on overlying strata if new mining proceeds.

- Consideration of previous mining to prevent inadvertent contact with flooded mine workings.

- Use of proving headings for controlled seaward advance of mine workings and to provide on-site testing of rock integrity and permeability.

The specific requirements of the National Coal Board for full and partial extraction mining methods are summarized below:

- Longwall Mining

  - No extraction permitted (panels) with less than 344 feet of cover between seabed and top of seam, or with less than 197 feet of carboniferous strata overlying the seam.

  - The sum total of all mining is not permitted to induce a tensile strain at the seabed exceeding 10 parts per thousand. Analysis and testing methods (subsidence predictive methods) to evaluate tensile strain are presented in the following section.

- The stability of old pillars must be considered in assessing strain predicted.

- Positions of working edges (ribs and face lines) may be staggered to minimize strain.

- Particular attention must be given to the "hump" in the subsidence trough caused by chain pillars and pack walls, especially for multi-seam mining.

- If solid stowing is adopted, subsidence predictions (strain calculations) are permitted using half the seam thickness for the best methods, others being judged by their own merits.

• Room-and-Pillar (Partial Extraction)

- No partial extraction where cover between top of seam and seabed is less than 197 feet, and where thickness of carboniferous rock is less than 148 feet.

- Minimum dimension of pillar, where seam thickness is equal or less than 6.5 feet, shall not be less than h/10 (h = depth of seam). For seam thicknesses greater than 6.5 feet the minimum width is h/10 plus the thickness of the seam. The above applies when the width of extraction (room) does not exceed 20 feet. Depth determinations must include 1/2 the depth of sea water. Where bottom rock is plastic when wet the minimum pillar width shall not be less than h/6 including 1/2 the depth of water.

• Room-and-Pillar (Pillar Extraction)

- All requirements and restrictions apply as for longwall mining discussed above.

- Other Requirements

  - All potentially dangerous sources of water (faults, aquifers, etc.) must be mapped, including effects of mining induced subsidence and resultant increased permeability of rock strata.

  - Elevations of all seabed and consolidated rock interfaces, thicknesses of unconsolidated material, and locations of any buried river channels shall be indicated.

  - Any reductions in thickness of carboniferous rock units must be determined. When minimum thickness is not met, only a proving heading is permitted in such areas.

  - Exemptions from the provisions above may be permitted only through application and subsequent approval.

The restrictions and requirements of the Province of Nova Scotia, Canada are summarized below:

- Full Extraction Methods

  - Total extraction of the coal in the submarine field may be carried out safely by allowing 100 feet of cover for every foot of seam mined, providing a minimum cover of 700 feet is met.

  - Where any workings are carried on using the longwall system (or where pillars are pulled) less than 1,000 feet below sea bottom, any suspect areas (faults) must be first explored with a proving heading in a seaward direction 150 feet in advance of the workings. If this ground is proven by other workings, exceptions to the above may be granted.

- Partial Extraction Methods (Room-and-Pillar)

  - Weight of overburden, ultimate crushing strength of coal, and method of extraction must all be considered.

  - The following list of approved pillar sizes shall assist submarine mine planning. These approved pillar sizes were established using an average crushing strength of 2,500 pounds per square inch and weight of overburden using 150 pounds per cubic feet.

Approved Pillar Sizes

Cover (ft.)	Seams over 5.5' and under 7.0'		Seams 7.0' and over	
	Size of Pillar (ft.)	Percent left in pillar	Size of Pillar (ft.)	Percent left in pillar
200-300	32 x 48	50.0	32 x 48	50.0
300-350	34 x 50	51.5	34 x 50	51.5
350-400	36 x 52	53.0	36 x 53	53.0
400-500	38 x 54	54.3	38 x 54	54.3
500-550	40 x 56	55.6	40 x 56	55.6
550-600	40 x 56	55.6	43 x 59	57.5
600-650	41 x 57	56.2	43 x 59	57.5
650 or over	45 x 61	58.5	47 x 63	59.5

- All Methods

  - No mining (workings) is permitted under less than 180 feet of solid rock cover. Entries to win coal may be driven under not less than 100 feet of solid cover. Mining under less cover by less efficient mining methods is only permitted if sterilization of significant coal resources would otherwise result.

  - In all workings where the overhead cover is less than 500 feet, levels shall be taken at least every three months and soundings taken at reasonable distances. Such data will indicate depth of water at least 1,000 feet in advance of workings.

- No new lift or level of coal may be worked from an existing mine without acquiring a new permit.

- In submarine mining areas, a 150 foot barrier between properties shall be left, 75 feet on each side.

SUBSIDENCE PREDICTIVE METHODS

(Abstracted From "Subsidence Engineers Handbook"
National Coal Board - Mining Department 1975)

HORIZONTAL SEAMS

One of the most critical factors controlling fracture of overlying strata is the width (W) or the mine void. If (W) is kept small, unfractured strata will bridge the void as shown in Figure C1. However, as the width is increased, fracturing will commence and arch upwards. Depending on depth of the seam (h), seam thickness (t), and overlying rock type, the critical width (W_c) is achieved when fracturing progresses to the surface (see Figure C2). Critical widths are achieved both by increasing (W) at a given depth or by excavating the same width at a shallower depth. The resulting sag of the surface is referred to as the subsidence trough.

The width or area of surface disturbance is greater than the extracted width or area. Figure C3 illustrates the increased width of disturbance which is equal to twice the depth times the tangent a (angle of draw or limit angle a). The angle of draw is thought to be decreased with increased depth of workings and the occurrence of thick sandstones overlying the coal seam. In Europe, this angle is approximately 35 degrees; however, the subsidence effect is small beyond 25 degrees. The amount of subsidence (s) varies across the excavation and reaches a max-

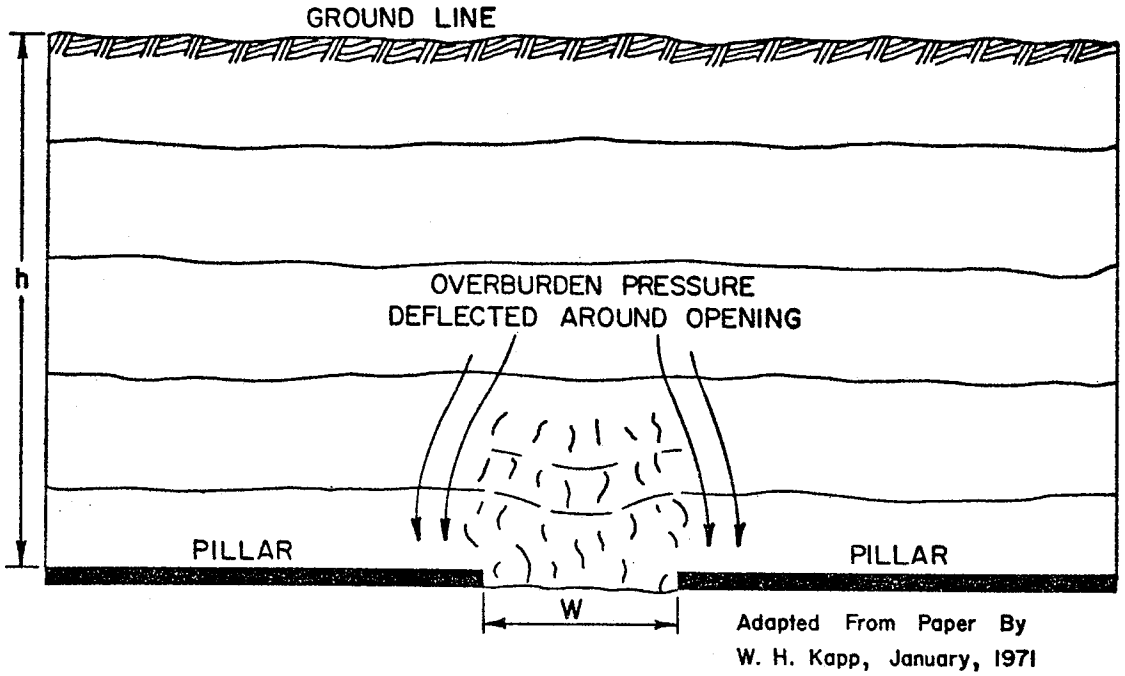


FIGURE C1. DEVELOPMENT OF ARCH OVER SMALL MINE VOID (W).

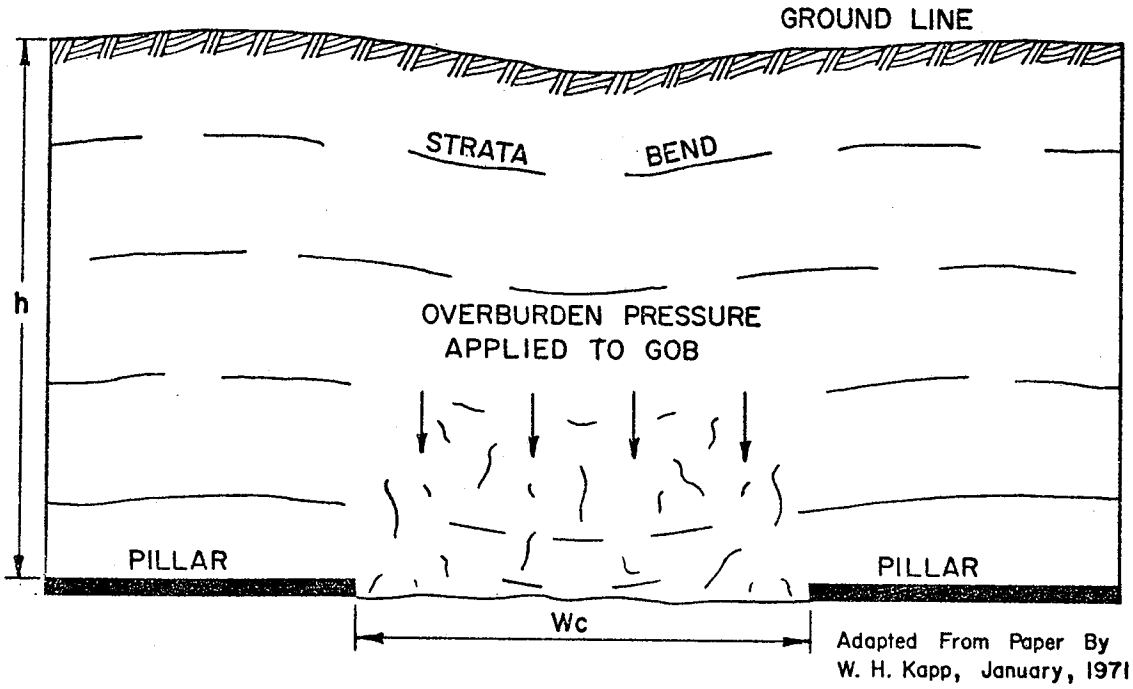


FIGURE C2. DEVELOPMENT OF SUBSIDENCE TO SURFACE AT CRITICAL VOID WIDTH (Wc).

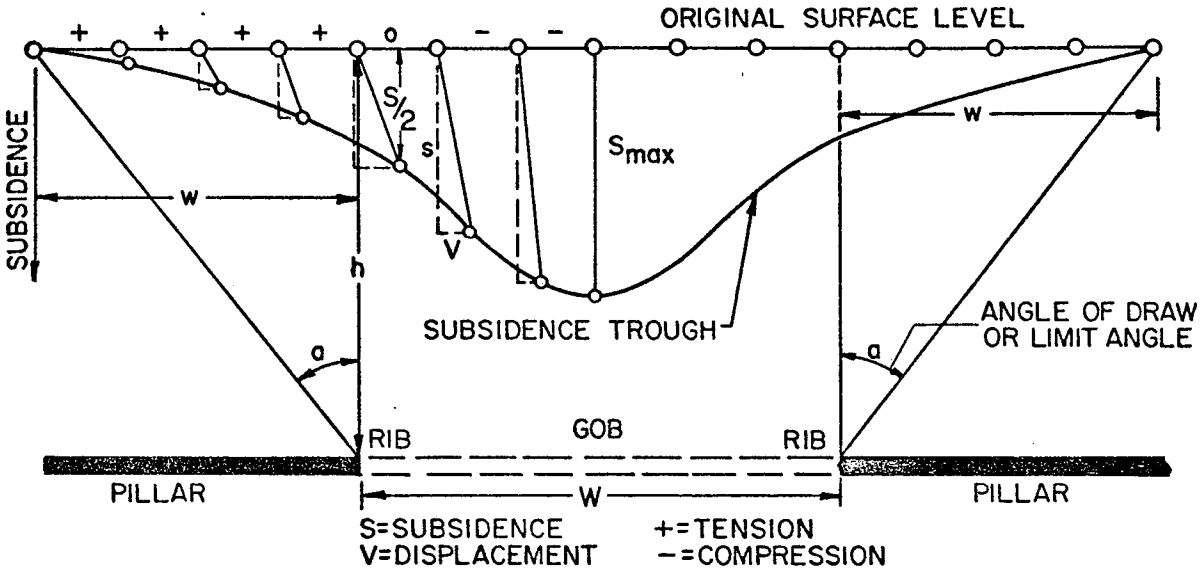


FIGURE C3. MOVEMENT OF SURFACE POINTS ALONG SUBSIDENCE TROUGH.

Adapted From National Coal Board Subsidence Handbook, 1975

imum (S) at the center. If a supercritical width (+W) is reached or exceeded, maximum subsidence (S_{max}) occurs. Resultant rock displacement (V) creates tensile (+) and compressive (-) strains in strata toward the point of inflection (near both ribs) inward to the center of the void. At the point of inflection or transition, subsidence is found to be half (S/2) of the maximum in the profile. For (- W), the transition point is found over the rib and for (W_c) it is more toward the gob. An angle between the horizontal and another upward from the edge of the rib to the point of maximum tensile strain is referred to as the "angle of break".

The amount of surface disturbance, or movement, is a function of overburden type, inclination of the strata, surface topography, thickness

and depth of seam, width of excavation and resulting angle of draw. The above phenomena applies to individual rooms, extracted longwall panels (where length of panel is 1.4 times the depth) and full extraction room-and-pillar workings. Any remaining chain pillars and pack walls will produce a hump in the subsidence trough.

Measurement of subsidence value (s) is accomplished by precision leveling at surface subsidence stations. Such leveling data permits graphical illustrations of (S), (h) and (W). Discussions of maximum trough subsidence are often facilitated by eliminating seam thickness (t) in place of (S/t), percentage of seam thickness. The subsidence development curve, Figure C4, was established from surface measurements taken over 157 British coal mines, 100 to 2,600 feet deep. These mines had seam thicknesses ranging from 2 to 18 feet; dips to 25 degrees; widths (with full caving) between 100 to 1,500 feet; and yielding width/depth (W/h) ratios from 0.05 to 4.0.

Adapted From National Coal Board
Subsidence Handbook, 1975

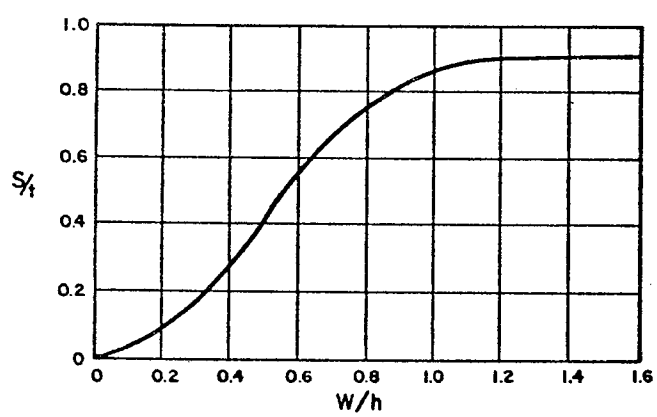


FIGURE C4. RELATIONSHIP OF PERCENTAGE SUBSIDENCE TO (W/h).

From this figure, it is evident that the percentage of seam thickness subsided is negligible (as are surface damages) if the W/h ratio is less than 0.25 and that subsidence to the extent of 90 percent seam thickness is achieved when the W/h ratio exceeds 1.2. This is a general rule and does not necessarily hold true of all coal basins. For instance, measurement of ground subsidence in the Sidney Basin coal measures of Australia indicate corresponding values are considerably less than 0.9 of the original seam thickness. Currently, maximum subsidence values are multiplied by a reducing factor of 0.85 for use in the Sidney Basin. Corresponding values for U. S. longwall mining might be less than 0.75 because of the practice of leaving entry pillars.

A number of subsidence predictive methods have been developed; among these are the National Coal Board's, which merit special mention. Knowing the width (W) and depth (h) of workings, the ratio of maximum subsidence (S) to seam thickness (t) is obtained from Figure C5, which was developed empirically in the United Kingdom. If solid stowing (pneumatic) is used, subsidence reduction is 50 percent. The limiting conditions for this figure's application, permitting its use within 10 percent accuracy, are:

(1) where working panels extend for a distance of 0.7 times the depth in front and beyond the surface where subsidence is to be predicted, or total length of the panel (L) must be about 1.4h.

(2) no center gate stowing in panels or other zones of spatial packing, apart from those in main and tail gates.

Adapted From National Coal Board
Subsidence Handbook, 1975

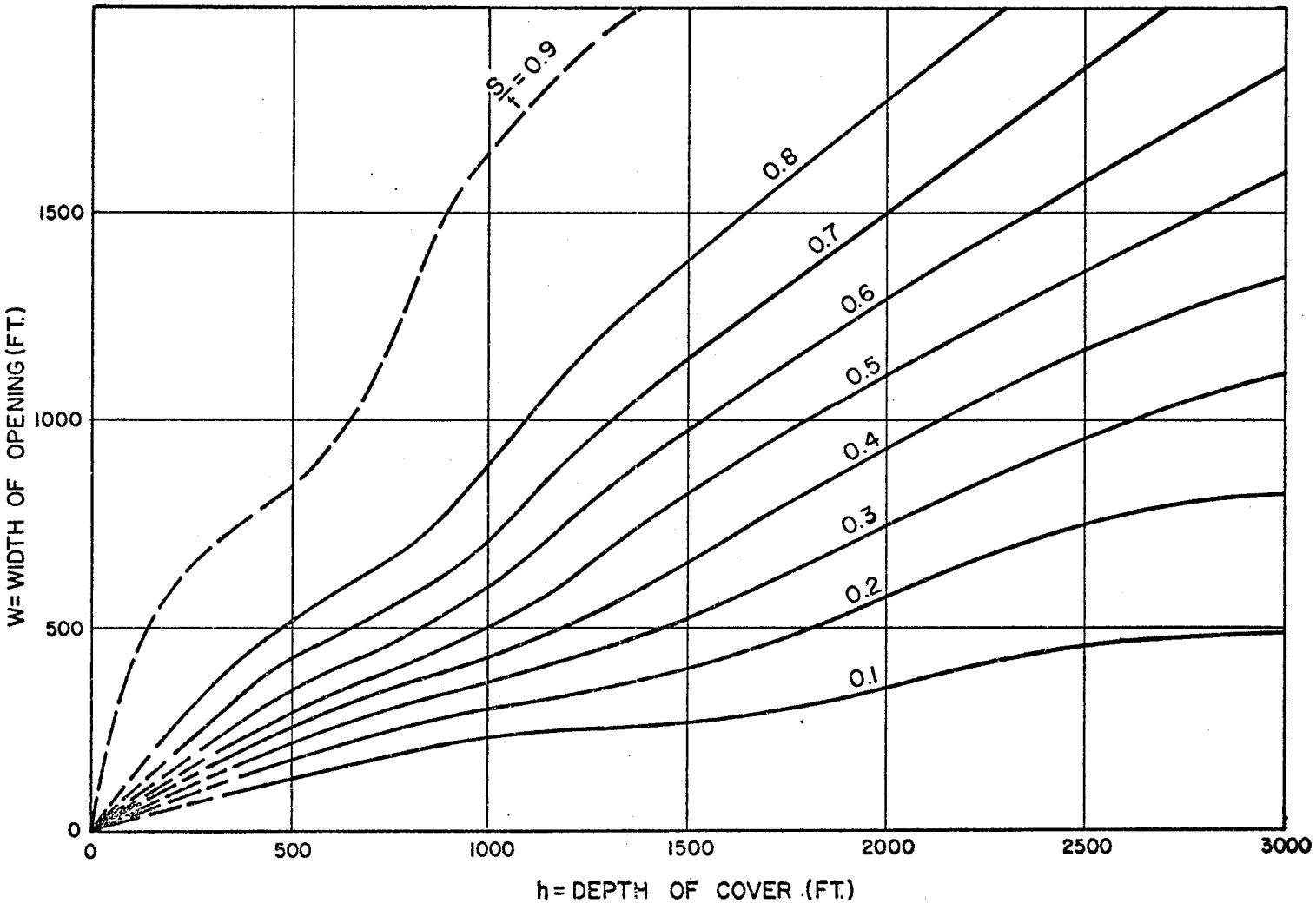


FIGURE C5. RELATIONSHIP BETWEEN MAXIMUM SUBSIDENCE, WIDTH AND DEPTH.

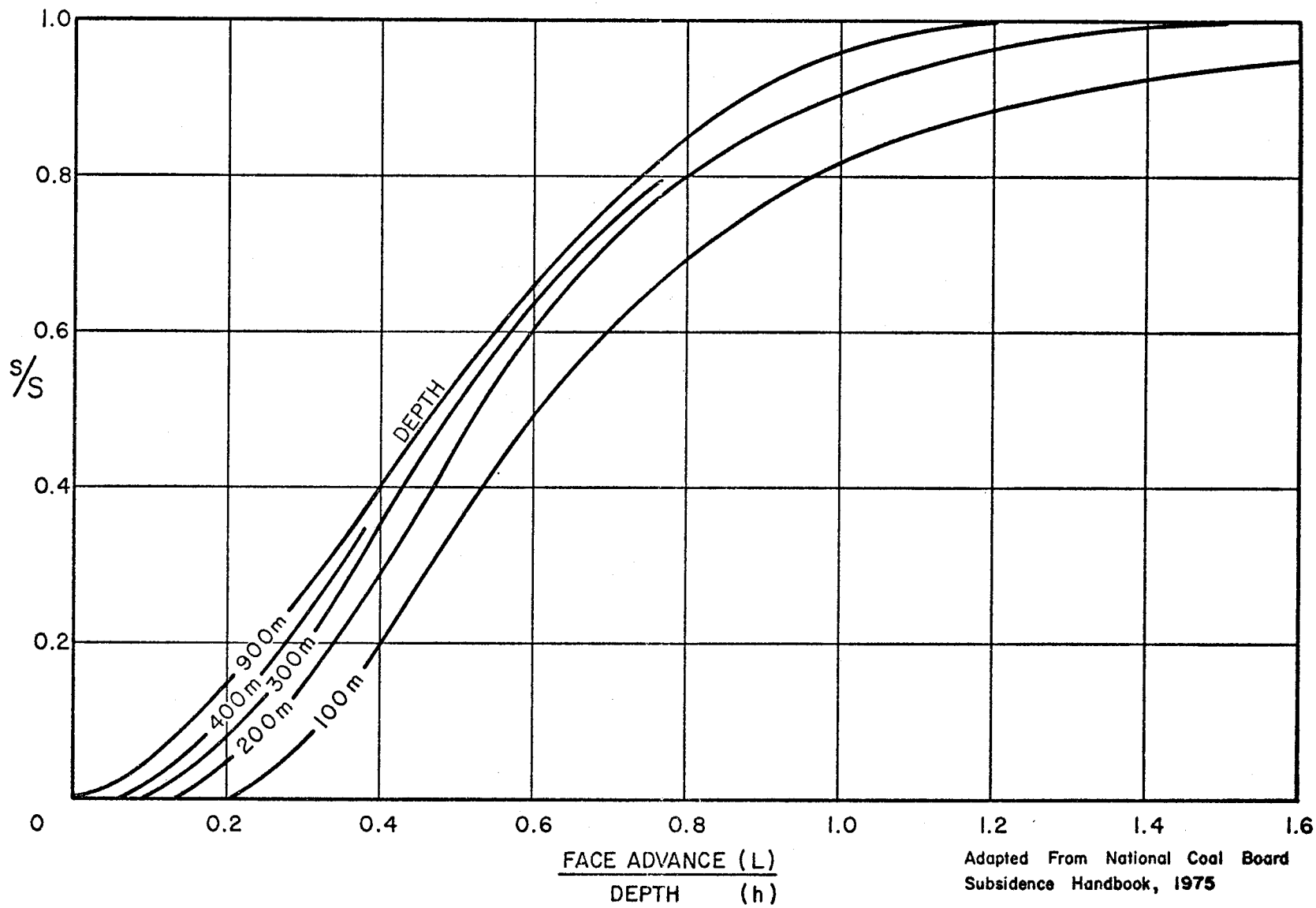
(3) panels are not developed parallel and an average value is usually chosen.

When a panel does not have sufficient length (1.4 h), Figure C6 values must be used as a reduction factor in accordance with the proportion of maximum subsidence which the limiting face advance permits.

Subsidence reduction is calculated by considering the length (L) of face travel as a fraction of the depth, applying the appropriate partial subsidence curve for any given depth (h). Distance traveled (L) as a fraction of depth is read off the horizontal scale and Figure C5's subsidence factor is multiplied by the corresponding vertical scale correction factor.

If, for example, a caved face traveled only 150m, working a panel 180m wide, in 1.5m thick seam at a depth of 300m, Figure C5 indicates $S/t = 0.61$. Therefore, $S = 0.6 \times 1.5$m or 0.915m, which corresponds to S_{max} for $L = 1.4$ times the depth (about 420m). Applying the correction factor from Figure C6, where advance over h is 0.5 (150/300) on the bottom scale, the value of s/S is 0.51 or S is 51 percent of 0.915m or 0.467m (actual maximum subsidence). Experience in the United Kingdom indicates it is possible to achieve an S/t value of 0.9 for both deep and shallow workings if the shallow working panels are wide enough.

In addition to the value of S, discussed above, the remaining profile values of subsidence must be determined to ascertain the complete effects of mining. The shape of a subsidence trough is a function of width/



Adapted From National Coal Board Subsidence Handbook, 1975

FIGURE C6. CORRECTION GRAPH FOR LIMITED FACE ADVANCE.

depth ratios as determined from field observations. For any width/depth value, a curve can be established relating s/S ratios at any distance out from the center of panel, with d/h, the distance from center, given in terms of depth. Graphs relating s/S to d/h for various W/h ratios were used to develop Figure C7, a family of curves from which the subsidence values s/S for any subsidence trough can be obtained. The following table of values (Table C1) were used to plot the curves and can be conveniently used in place of Figure C7.

The usual method for plotting the subsidence profile for a particular mine extraction is provided below.

If a longwall face 160 meters wide (W) works a 1.4 meter thick seam (t) at a depth of 400 meters (h) the W/h ratio is 0.4. From Figure C3 it is then determined S/t equals 0.37 or S is 0.518 meters. For remaining vertical movements (s) within the trough, assumed values of s/S are tabulated as shown below in column 1. From Table C1, distances in terms of h are chosen for corresponding values of s/S for W/h ratio of 0.4 (column 3). Having determined S is 0.518 meters, s in meters (column 2) for the assumed values of s/S are calculated; for example if s/S is 0.5 then s is 0.5 x 0.518 or 0.259.

The point of inflection, shown in the subsidence profile (Figure C8), marks the transition of tensile to compressive strains inward towards the center of the panel. This point also agrees with the position of half-maximum

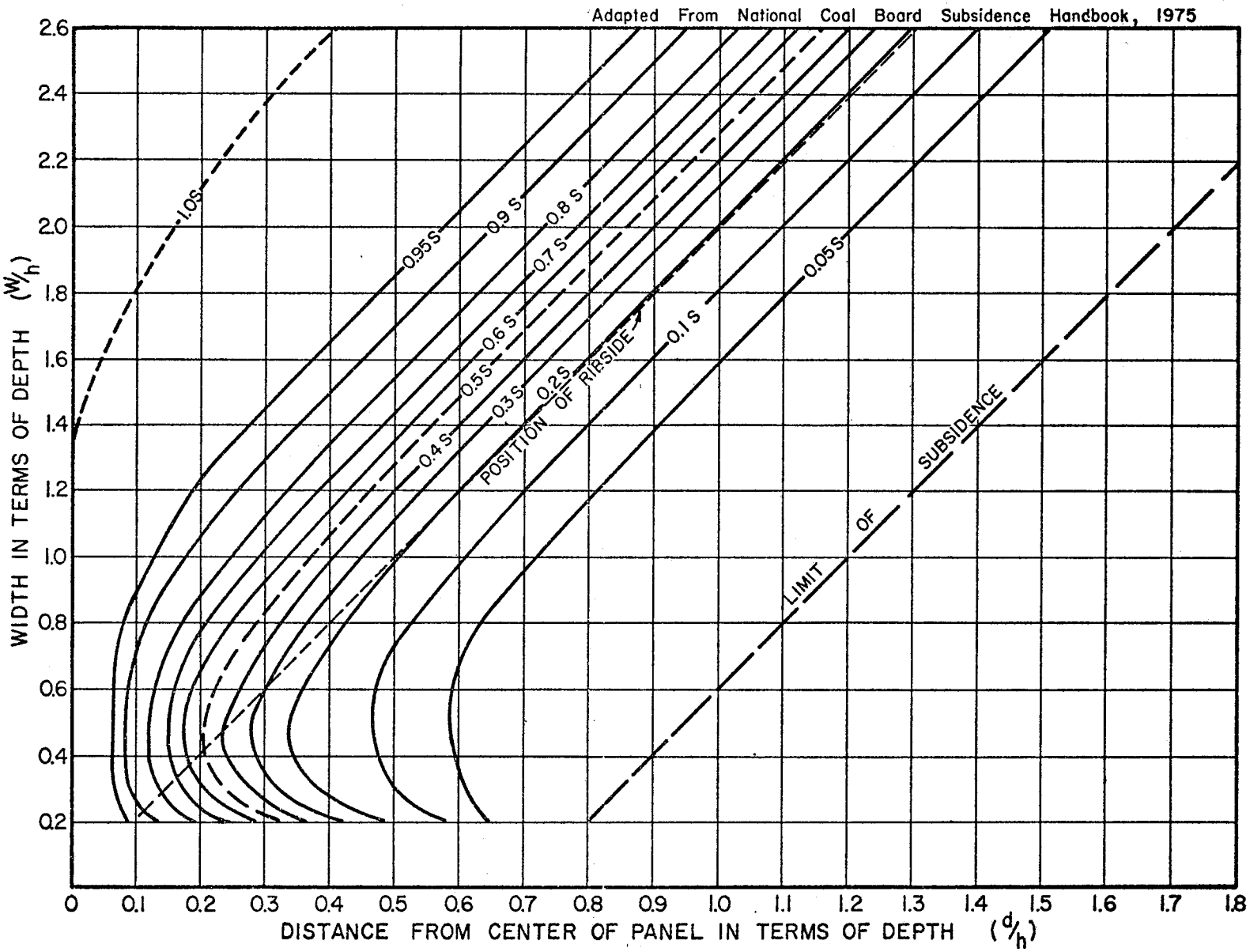
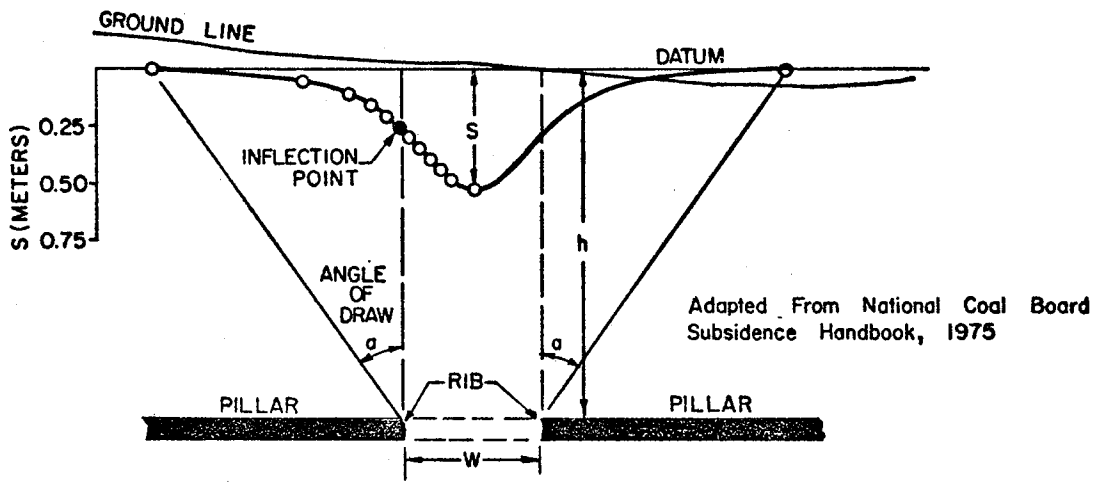


FIGURE C7. PREDICTION OF SUBSIDENCE (S) PROFILES.

TABLE C1. RELATIONSHIP BETWEEN W/h AND d/h FOR VARIOUS POINTS ON A SUBSIDENCE PROFILE.

Values of s/S	0	0.05	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	0.95	1.00
w/h RATIO OF PANEL	DISTANCES FROM PANEL CENTRE IN TERMS OF DEPTH												
2.6	2.00	1.51	1.39	1.29	1.24	1.19	1.16	1.12	1.08	1.03	0.95	0.87	0.41
2.4	1.90	1.41	1.29	1.19	1.14	1.10	1.06	1.02	0.98	0.93	0.85	0.77	0.31
2.2	1.80	1.31	1.19	1.09	1.04	1.00	0.96	0.92	0.88	0.83	0.75	0.67	0.23
2.0	1.70	1.21	1.09	0.99	0.94	0.90	0.86	0.82	0.78	0.73	0.65	0.57	0.16
1.8	1.60	1.11	1.00	0.90	0.84	0.80	0.76	0.72	0.68	0.63	0.55	0.47	0.10
1.6	1.50	1.01	0.90	0.80	0.74	0.70	0.66	0.62	0.58	0.53	0.45	0.37	0.05
1.4	1.40	0.91	0.80	0.70	0.64	0.60	0.56	0.52	0.48	0.43	0.35	0.27	0.01
1.3	1.35	0.86	0.75	0.65	0.59	0.55	0.51	0.47	0.43	0.38	0.30	0.23	0
1.2	1.30	0.81	0.70	0.60	0.54	0.50	0.46	0.42	0.38	0.33	0.25	0.19	0
1.1	1.25	0.77	0.65	0.55	0.50	0.45	0.42	0.38	0.34	0.29	0.21	0.16	0
1.00	1.20	0.72	0.61	0.51	0.45	0.41	0.37	0.33	0.29	0.24	0.18	0.13	0
0.98	1.19	0.71	0.60	0.50	0.44	0.40	0.36	0.33	0.28	0.24	0.17	0.12	0
0.96	1.18	0.70	0.59	0.49	0.43	0.39	0.35	0.32	0.27	0.23	0.16	0.11	0
0.94	1.17	0.69	0.58	0.48	0.42	0.38	0.34	0.31	0.26	0.22	0.16	0.11	0
0.92	1.16	0.68	0.57	0.47	0.41	0.37	0.33	0.30	0.26	0.21	0.15	0.10	0
0.90	1.15	0.68	0.57	0.46	0.40	0.36	0.32	0.29	0.25	0.20	0.14	0.10	0
0.88	1.14	0.67	0.56	0.45	0.40	0.36	0.32	0.28	0.24	0.20	0.13	0.10	0
0.86	1.13	0.66	0.55	0.45	0.39	0.35	0.31	0.27	0.23	0.19	0.13	0.09	0
0.84	1.12	0.65	0.54	0.44	0.38	0.34	0.30	0.26	0.22	0.18	0.12	0.09	0
0.82	1.11	0.64	0.53	0.43	0.37	0.33	0.29	0.26	0.21	0.17	0.12	0.08	0
0.80	1.10	0.63	0.52	0.42	0.36	0.32	0.28	0.25	0.21	0.17	0.11	0.08	0
0.78	1.09	0.63	0.52	0.42	0.36	0.32	0.28	0.24	0.20	0.16	0.11	0.08	0
0.76	1.08	0.62	0.51	0.41	0.35	0.31	0.27	0.23	0.20	0.16	0.11	0.07	0
0.74	1.07	0.61	0.50	0.40	0.34	0.30	0.26	0.23	0.19	0.15	0.10	0.07	0
0.72	1.06	0.61	0.50	0.39	0.34	0.30	0.26	0.22	0.18	0.15	0.10	0.07	0
0.70	1.05	0.60	0.49	0.39	0.33	0.29	0.25	0.21	0.18	0.14	0.10	0.07	0
0.68	1.04	0.60	0.49	0.38	0.32	0.28	0.24	0.21	0.17	0.14	0.10	0.07	0
0.66	1.03	0.60	0.48	0.38	0.32	0.28	0.24	0.20	0.17	0.14	0.09	0.06	0
0.64	1.02	0.59	0.48	0.37	0.31	0.27	0.23	0.20	0.17	0.13	0.09	0.06	0
0.62	1.01	0.59	0.47	0.37	0.31	0.27	0.23	0.19	0.16	0.13	0.09	0.06	0
0.60	1.00	0.59	0.47	0.36	0.30	0.26	0.22	0.19	0.16	0.13	0.09	0.06	0
0.58	0.99	0.59	0.47	0.35	0.30	0.25	0.22	0.18	0.16	0.13	0.09	0.06	0
0.56	0.98	0.59	0.47	0.35	0.29	0.25	0.21	0.18	0.15	0.12	0.08	0.06	0
0.54	0.97	0.59	0.47	0.34	0.29	0.25	0.21	0.18	0.15	0.12	0.08	0.06	0
0.52	0.96	0.59	0.47	0.34	0.28	0.24	0.21	0.17	0.15	0.12	0.08	0.06	0
0.50	0.95	0.59	0.47	0.34	0.28	0.24	0.21	0.17	0.15	0.12	0.08	0.06	0
0.48	0.94	0.59	0.47	0.33	0.28	0.23	0.20	0.17	0.15	0.12	0.08	0.06	0
0.46	0.93	0.59	0.47	0.33	0.28	0.23	0.20	0.17	0.15	0.12	0.08	0.06	0
0.44	0.92	0.59	0.47	0.33	0.28	0.23	0.20	0.17	0.15	0.12	0.08	0.06	0
0.42	0.91	0.59	0.47	0.34	0.28	0.24	0.20	0.17	0.15	0.12	0.08	0.06	0
0.40	0.90	0.59	0.47	0.34	0.28	0.24	0.21	0.18	0.15	0.12	0.08	0.06	0
0.38	0.89	0.60	0.48	0.35	0.29	0.24	0.21	0.18	0.15	0.12	0.08	0.06	0
0.36	0.88	0.60	0.48	0.35	0.29	0.25	0.21	0.18	0.15	0.12	0.08	0.06	0
0.34	0.87	0.60	0.49	0.36	0.30	0.25	0.22	0.19	0.16	0.12	0.08	0.06	0
0.32	0.86	0.60	0.49	0.37	0.31	0.26	0.22	0.20	0.16	0.13	0.09	0.06	0
0.30	0.85	0.61	0.50	0.38	0.32	0.27	0.23	0.20	0.17	0.13	0.09	0.06	0
0.28	0.84	0.61	0.51	0.39	0.33	0.28	0.24	0.21	0.18	0.14	0.09	0.07	0
0.26	0.83	0.62	0.52	0.41	0.35	0.30	0.26	0.22	0.19	0.15	0.10	0.07	0
0.24	0.82	0.62	0.53	0.43	0.36	0.32	0.28	0.24	0.20	0.16	0.11	0.07	0
0.22	0.81	0.63	0.55	0.46	0.39	0.34	0.30	0.26	0.21	0.17	0.11	0.08	0
0.20	0.80	0.64	0.57	0.48	0.41	0.37	0.32	0.28	0.23	0.19	0.13	0.08	0

Adapted From National Coal Board Subsidence Handbook, 1975



s/S (1)	s(meters) (2)	Distance in terms of h (3)	Distance in meters (4)
0	0	0.90	360
0.05	0.026	0.59	236
0.10	0.052	0.47	188
0.20	0.104	0.34	136
0.30	0.155	0.28	112
0.40	0.207	0.24	96
0.50	0.259	0.21	84
0.60	0.310	0.18	72
0.70	0.363	0.15	60
0.80	0.414	0.12	48
0.90	0.466	0.08	32
1.00	0.518	0.00	0

FIGURE C8. TABULATION AND PLOTTING OF SUBSIDENCE PROFILE VALUES.

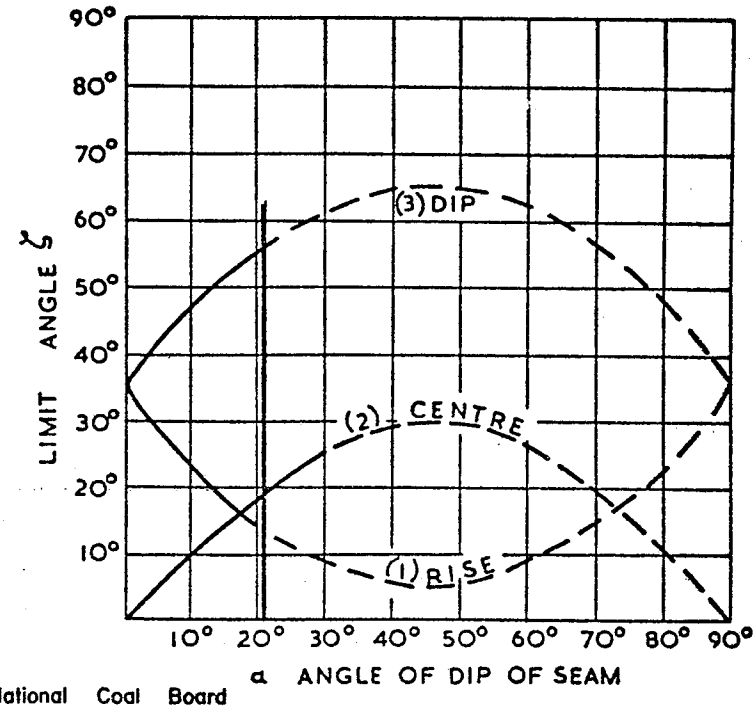
subsidence S or S/2. This inflection point has been found to migrate inwards with increasing W/h values or for increasing panel widths while maintaining the same cover. The precise location of maximum subsidence and point of zero subsidence are difficult to determine within 3 percent

accuracy. Contributing to these problems are movement of monitoring stations, rainfall and temperature.

TILTED SEAMS

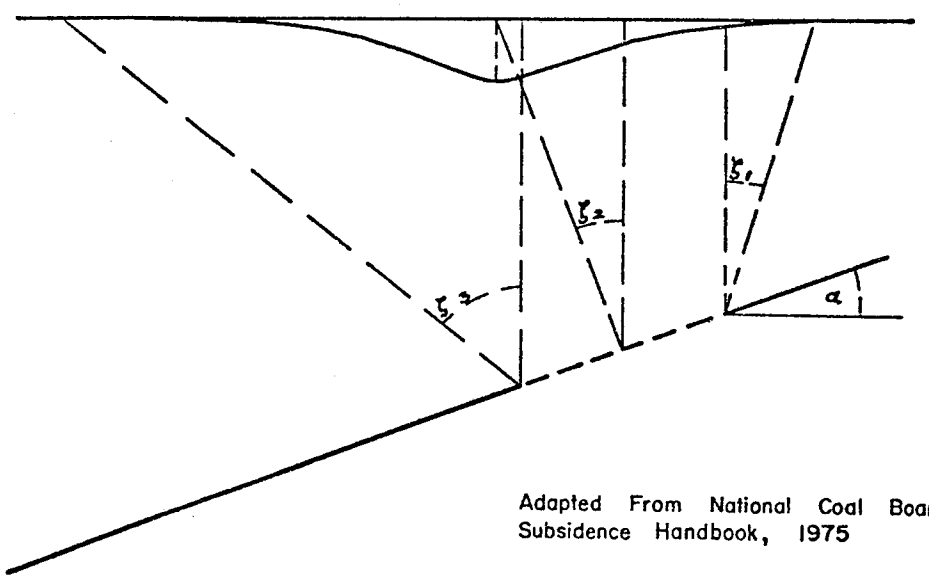
The above subsidence profile discussions are applicable to level seams. However, most coal beds dip somewhat and thereby cause displacement of the subsidence trough toward the dip. From Figure C9 variations in limit angles can be determined. It should be noted, however, that such data obtained from field experience is extremely limited for seams pitching more than 25 degrees. Figure C10 illustrates the displacement of the trough profile determined in the foregoing example. Resultant surface tilting can be determined from the subsidence profile values tabulated above. For example, if two points 92 and 112 meters from the center (20 meters apart) undergo 0.196 and 0.147 meters of subsidence, respectively, the difference of 0.049 meters over the 20 meters of station separation produces a tilt or slope of 0.0025 or 0.17 degrees. In many cases the original mining plan may not be followed to completion and resultant subsidence may increase. As an extra precautionary measure, maximum possible subsidence should be anticipated when planning a new operation.

The above profiles do not consider the so-called "hump" or possible flattening of the trough resulting from center gate or other packing zones. For deep lying seams, the critical width may extend across two or three



Adapted From National Coal Board Subsidence Handbook, 1975

FIGURE C9 . VARIATIONS IN LIMIT ANGLE FOR TILTED SEAM.



Adapted From National Coal Board Subsidence Handbook, 1975

FIGURE C10. DISPLACEMENT OF TROUGH PROFILE FOR TILTED SEAM.

panels and their respective support zones which decrease maximum subsidence. The National Coal Board has examined such cases of reduced subsidence and developed the following graph (Figure C11) which relates s (at top of hump) to the otherwise predicted S. Figure C11 plots s/S against w/h for the mean of stowed center gates and solid coal pillars, the latter being left between adjacent panels. As indicated, wide pack walls (greater than 0.7h) produce a subsidence of 0.4S where equivalent width solid pillars almost eliminate subsidence. It should also be noted that packs and pillars provide little subsidence reduction when small.

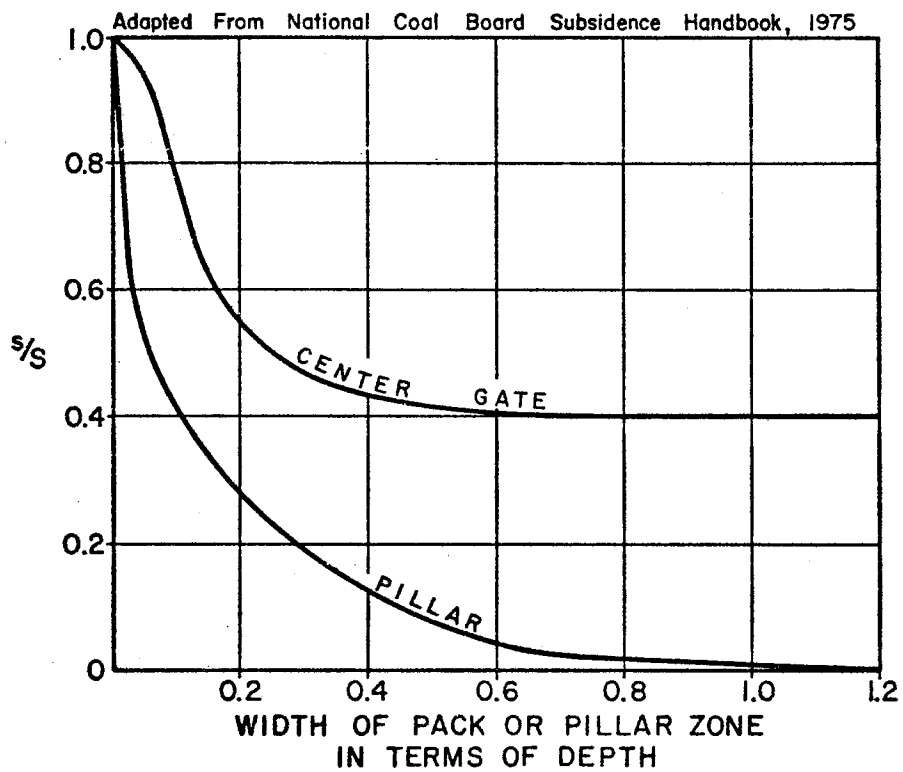


FIGURE C11. SUBSIDENCE REDUCTION OVER CENTER GATES AND SOLID COAL PILLARS.

Subsidence produces horizontal strains (e) by producing changes in lengths of a section of ground. This change is usually expressed in mm/m, for example, 0.01 would be 10mm/m. The direction of change resulting in compression or extensions is indicated by (-) and (+) signs, respectively. Zones of maximum extension and compression are designated by (+E) and (-E), respectively. The transition point between -e and +e occurs near ribside when the w/h ratio is greater than 1.35 and over the rib if less. Maximum compression occurs at the panel center when widths are less than 0.42h, but with greater ratios two compression zones are developed. Table C2 provides values of e/E used in Figure C12 to illustrate strain changes associated with increasing panel widths for 0.42h, 0.9h and 1.5h (See Figure C13). The middle diagram (b) does not vary greatly from 0.5h to 1.4h. Figure C14 shows how the compression (-e) on such humps compares with maximum compression (-E).

The relationship of strains, extension and compression is of interest as w/h ratios change. The intensity of +E is 25 percent greater than -E for critical width panels. However, for more narrow width panels -E is significantly greater than +E, in fact, twice as great for panel widths of 0.43h. Figure C15 illustrates these relative amounts of strain for increasing w/h ratio panels. The vertical scale, S/h, is chosen since strain is proportional to subsidence and inversely proportional to depth, or maximum

TABLE C2.

RELATIONSHIP OF VARIOUS STRAIN VALUES IN A SUBSIDENCE PROFILE.

	Extension (+E)												Compression (—E)					
Values of e/E	**0**	**0.20**	**0.40**	**0.60**	**0.80**	**1.00**	**0.80**	**0**	**0.20**	**0.40**	**0.60**	**0.80**	**1.00**	**0.80**	**0.60**	**0.40**	**0.20**	**0**
w/h RATIO OF PANEL	DISTANCES FROM PANEL CENTRE IN TERMS OF DEPTH																	
3.0	2.2	1.78	1.67	1.61	1.56	1.50	1.46	1.36	1.34	1.31	1.28	1.25	1.19	1.10	1.03	0.96	0.90	0.70
2.6	2.0	1.58	1.47	1.41	1.36	1.30	1.26	1.16	1.14	1.11	1.08	1.05	0.99	0.90	0.83	0.77	0.70	0.50
2.2	1.8	1.38	1.27	1.21	1.15	1.10	1.06	0.96	0.94	0.91	0.88	0.85	0.79	0.70	0.63	0.57	0.50	0.30
2.0	1.7	1.28	1.17	1.11	1.05	1.00	0.96	0.86	0.84	0.81	0.78	0.75	0.69	0.60	0.53	0.47	0.40	0.20
1.8	1.6	1.17	1.07	1.01	0.95	0.90	0.86	0.76	0.73	0.71	0.68	0.65	0.59	0.50	0.43	0.37	0.30	0.10
1.6	1.5	1.08	0.97	0.91	0.85	0.80	0.76	0.66	0.63	0.61	0.58	0.55	0.49	0.40	0.33	0.27	0.20	0.03
1.4	1.4	0.98	0.87	0.81	0.75	0.70	0.66	0.56	0.53	0.51	0.48	0.45	0.39	0.30	0.23	0.17	0.10	0
1.3	1.35	0.93	0.82	0.76	0.70	0.65	0.61	0.51	0.49	0.46	0.43	0.40	0.34	0.25	0.18	0.12	0.05	0
1.2	1.3	0.88	0.77	0.71	0.66	0.61	0.56	0.46	0.44	0.41	0.38	0.35	0.29	0.20	0.13	0.07	0.02	0
1.1	1.25	0.83	0.72	0.66	0.61	0.56	0.52	0.42	0.39	0.37	0.33	0.31	0.24	0.15	0.09	0.03	0	0
1.0	1.2	0.79	0.68	0.62	0.57	0.51	0.47	0.37	0.35	0.32	0.29	0.26	0.20	0.10	0.05	0	0	0
0.98	1.19	0.78	0.67	0.61	0.56	0.50	0.46	0.36	0.34	0.31	0.28	0.25	0.19	0.09	0.04	0	0	0
0.96	1.18	0.77	0.66	0.60	0.55	0.49	0.45	0.35	0.33	0.30	0.27	0.24	0.18	0.09	0.04	0	0	0
0.94	1.17	0.76	0.65	0.59	0.54	0.48	0.44	0.35	0.32	0.30	0.26	0.23	0.17	0.08	0.03	0	0	0
0.92	1.16	0.75	0.64	0.58	0.53	0.47	0.43	0.34	0.31	0.29	0.25	0.22	0.16	0.07	0.02	0	0	0
0.90	1.15	0.74	0.63	0.57	0.52	0.46	0.42	0.33	0.30	0.28	0.24	0.21	0.15	0.06	0.02	0	0	0
0.88	1.14	0.73	0.62	0.56	0.51	0.46	0.41	0.32	0.29	0.27	0.24	0.21	0.15	0.05	0.01	0	0	0
0.86	1.13	0.72	0.61	0.55	0.50	0.45	0.40	0.31	0.29	0.26	0.23	0.20	0.14	0.05	0	0	0	0
0.84	1.12	0.71	0.60	0.54	0.49	0.44	0.39	0.30	0.28	0.25	0.22	0.19	0.13	0.04	0	0	0	0
0.82	1.11	0.70	0.59	0.53	0.48	0.43	0.38	0.29	0.27	0.25	0.21	0.18	0.12	0.03	0	0	0	0
0.80	1.10	0.69	0.58	0.53	0.48	0.42	0.37	0.29	0.26	0.24	0.20	0.17	0.11	0.02	0	0	0	0
0.78	1.09	0.68	0.57	0.52	0.47	0.41	0.36	0.28	0.26	0.23	0.20	0.17	0.11	0.02	0	0	0	0
0.76	1.08	0.67	0.57	0.51	0.46	0.40	0.36	0.27	0.25	0.22	0.19	0.16	0.10	0.01	0	0	0	0
0.74	1.07	0.67	0.56	0.50	0.45	0.39	0.35	0.26	0.24	0.22	0.18	0.15	0.09	0.01	0	0	0	0
.072	1.06	0.66	0.55	0.49	0.44	0.38	0.34	0.26	0.24	0.21	0.17	0.15	0.09	0	0	0	0	0
0.70	1.05	0.65	0.54	0.48	0.44	0.37	0.33	0.25	0.23	0.20	0.17	0.14	0.08	0	0	0	0	0
0.68	1.04	0.64	0.54	0.47	0.43	0.37	0.32	0.24	0.22	0.20	0.16	0.13	0.07	0	0	0	0	0
0.66	1.03	0.64	0.53	0.47	0.42	0.36	0.31	0.24	0.22	0.19	0.16	0.13	0.07	0	0	0	0	0
0.64	1.02	0.63	0.53	0.46	0.41	0.35	0.31	0.23	0.21	0.19	0.15	0.12	0.06	0	0	0	0	0
0.62	1.01	0.63	0.52	0.45	0.41	0.34	0.30	0.23	0.21	0.18	0.15	0.12	0.05	0	0	0	0	0
0.60	1.00	0.62	0.52	0.45	0.40	0.34	0.29	0.22	0.20	0.18	0.14	0.11	0.05	0	0	0	0	0
0.58	0.99	0.62	0.51	0.44	0.39	0.33	0.29	0.22	0.19	0.17	0.14	0.10	0.04	0	0	0	0	0
0.56	0.98	0.61	0.51	0.44	0.39	0.33	0.28	0.22	0.19	0.17	9.13	0.10	0.03	0	0	0	0	0
0.54	0.97	0.61	0.51	0.43	0.39	0.32	0.28	0.21	0.19	0.16	0.13	0.09	0.03	0	0	0	0	0
0.52	0.96	0.60	0.51	0.43	0.38	0.32	0.27	0.21	0.18	0.16	0.12	0.09	0.02	0	0	0	0	0
0.50	0.95	0.60	0.51	0.43	0.38	0.32	0.27	0.21	0.18	0.16	0.12	0.08	0.02	0	0	0	0	0
0.48	0.94	0.60	0.51	0.43	0.38	0.31	0.27	0.20	0.18	0.15	0.12	0.08	0.01	0	0	0	0	0
0.46	0.93	0.60	0.51	0.43	0.38	0.31	0.27	0.20	0.18	0.15	0.11	0.08	0.01	0	0	0	0	0
0.44	0.92	0.60	0.51	0.43	0.39	0.31	0.27	0.20	0.18	0.15	0.11	0.07	0.01	0	0	0	0	0
0.42	0.91	0.60	0.51	0.44	0.39	0.31	0.27	0.20	0.18	0.15	0.11	0.07	0	0	0	0	0	0
0.40	0.90	0.61	0.52	0.45	0.40	0.32	0.28	0.21	0.18	0.15	0.11	0.07	0	0	0	0	0	0
0.38	0.89	0.61	0.53	0.45	0.41	0.32	0.28	0.21	0.18	0.15	0.11	0.07	0	0	0	0	0	0
0.36	0.88	0.62	0.53	0.46	0.42	0.33	0.29	0.21	0.18	0.15	0.11	0.07	0	0	0	0	0	0
0.34	0.87	0.62	0.54	0.48	0.43	0.34	0.30	0.22	0.19	0.15	0.11	0.07	0	0	0	0	0	0
0.32	0.86	0.63	0.55	0.49	0.45	0.35	0.30	0.22	0.19	0.16	0.12	0.97	0	0	0	0	0	0
0.30	0.85	0.65	0.57	0.51	0.47	0.37	0.32	0.23	0.20	0.16	0.12	0.08	0	0	0	0	0	0
0.28	0.84	0.66	0.58	0.54	0.49	0.39	0.33	0.24	0.21	0.17	0.13	0.08	0	0	0	0	0	0
0.26	0.83	0.68	0.60	0.57	0.51	0.41	0.35	0.26	0.22	0.18	0.14	0.09	0	0	0	0	0	0
0.24	0.82	0.70	0.63	0.60	0.54	0.44	0.37	0.28	0.23	0.20	0.15	0.10	0	0	0	0	0	0
0.22	0.81	0.72	0.66	0.63	0.58	0.47	0.39	0.30	0.25	0.21	0.16	0.11	0	0	0	0	0	0
0.20	0.80	0.74	0.69	0.66	0.61	0.49	0.42	0.32	0.27	0.23	0.18	0.12	0	0	0	0	0	0

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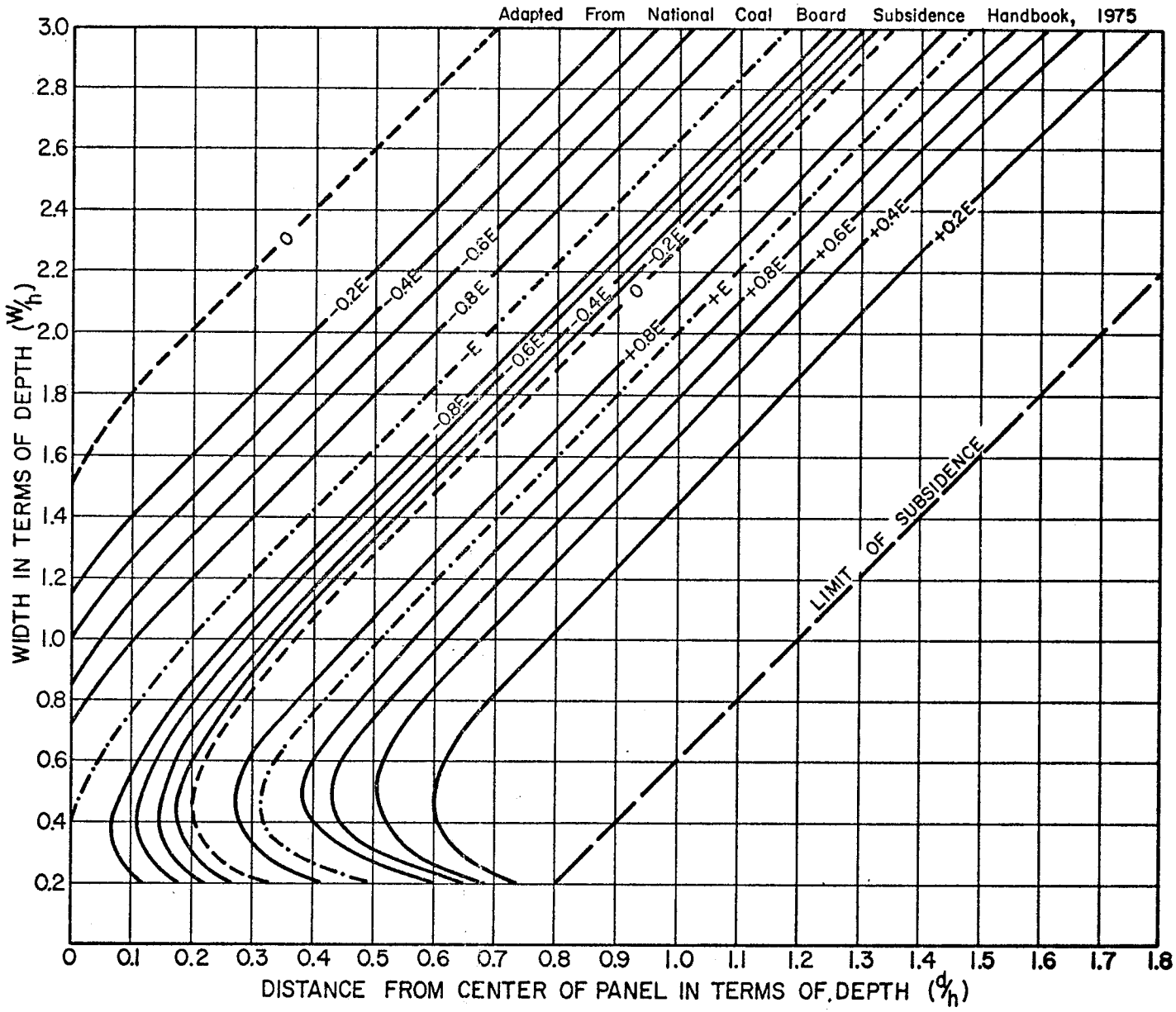


FIGURE C12. PREDICTION OF STRAIN PROFILES.

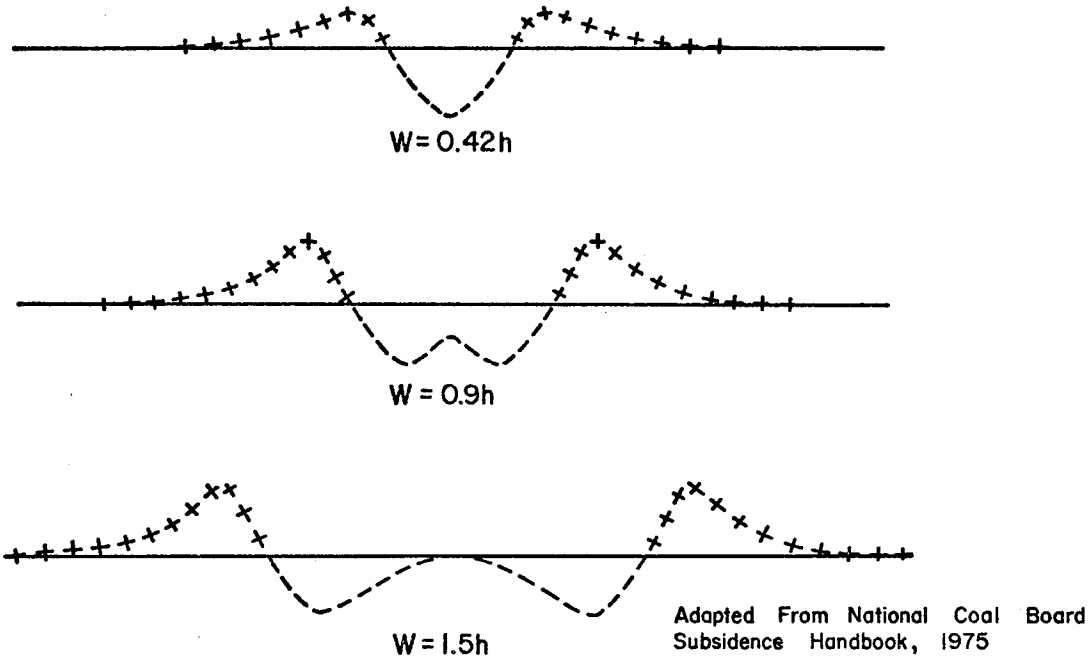


FIGURE C13. PRINCIPAL TYPES OF STRAIN PROFILES.

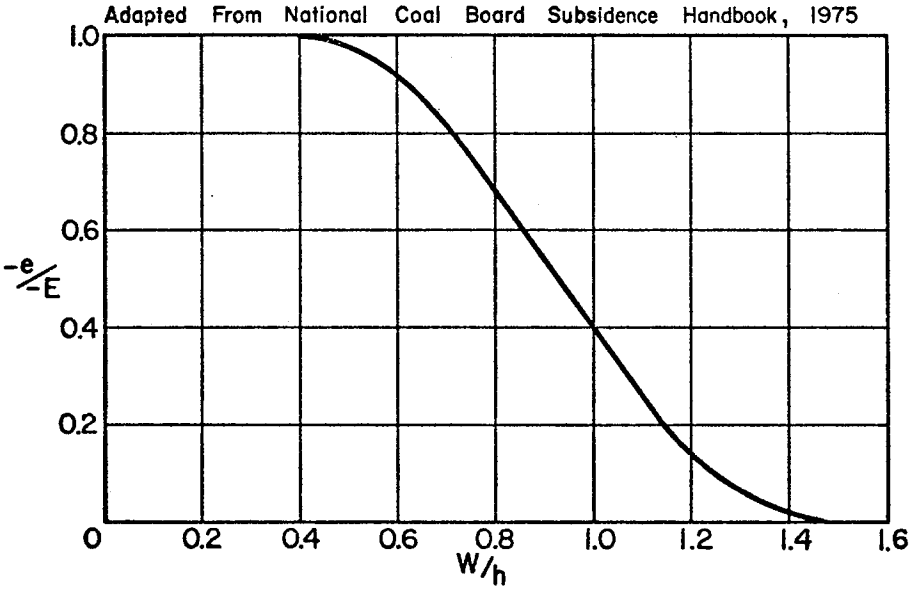


FIGURE C14. COMPRESSIVE STRAIN AT PANEL CENTER RELATIVE TO MAXIMUM COMPRESSION.

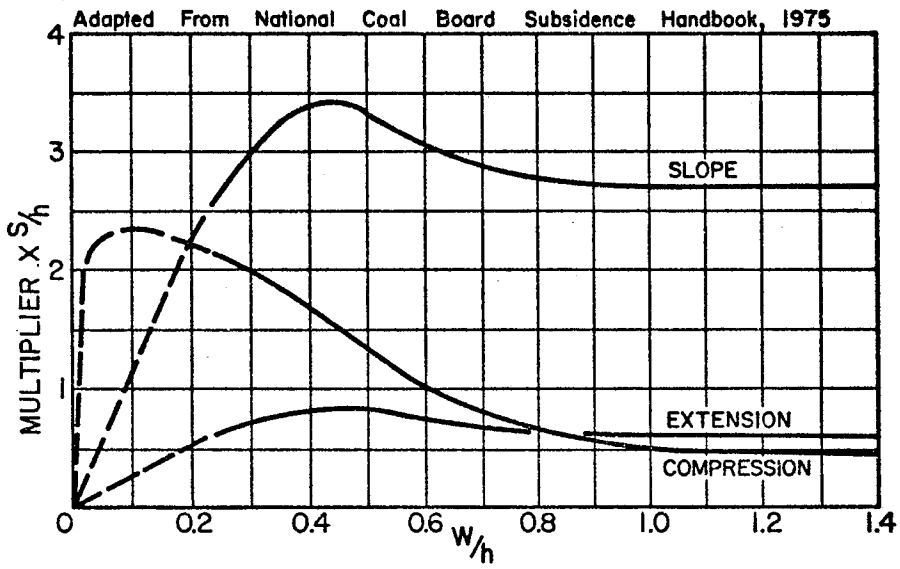


FIGURE C15. PREDICTION OF MAXIMUM SLOPE AND STRAINS FOR VARYING VALUES OF W/h.

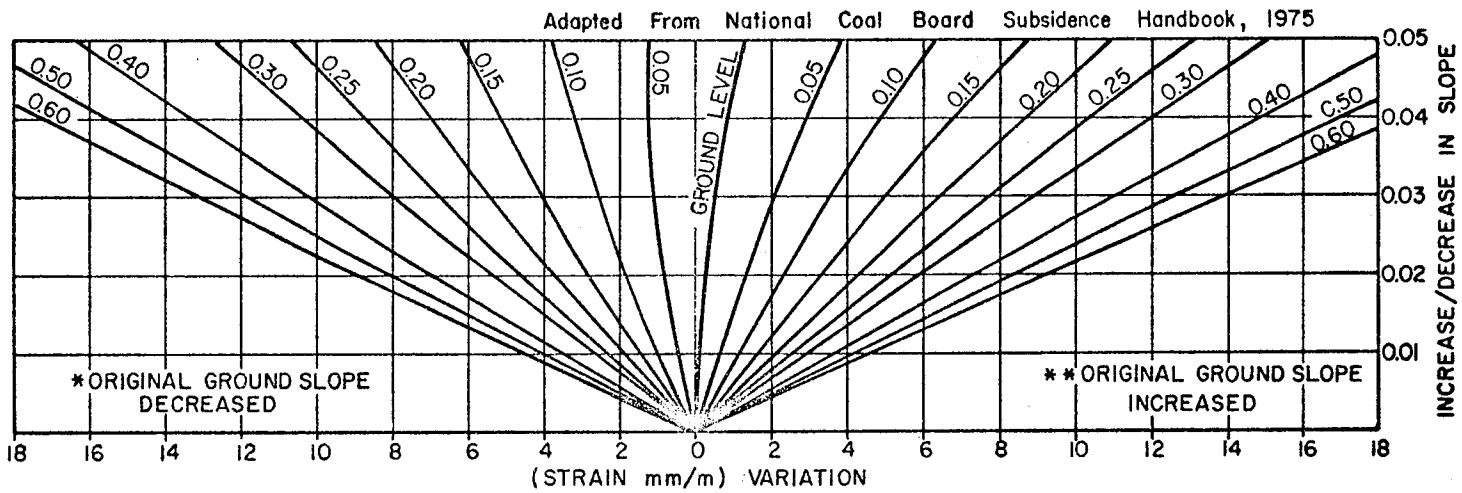
strain is proportional to S/h, S being the maximum strain over the workings. The slope in Figure C15 is the maximum slope (G) in a subsidence trough derived by the multiplier S/h.

Although previous methods of determining +E merely used 0.75S/h for panel widths to 0.7h, it has been found that Figure C15 values are more accurate. One method which facilitates quick determination of G, +E or -E is the calculation of S/h then multiplied by the corresponding value (W/h) from Figure C15. This figure only applies when no center gate or other cause for a hump (reduction is S) exists.

The above mentioned predictive methods for calculating ground strains apply to essentially level terrain and corrections are required when the surface slopes. The following nomograms are utilized to correct such strain values. Figure C16a applies to bay lengths (lengths between stations measuring subsidence) computed horizontally and Figure C16b, along the slope. When predicting strains as indicated above, the strain adjustment must be added to tensile strain and subtracted from compressive strain.

When the surface is level and the seam is dipping, a correction factor increases tensile strain on the dip side and decreases it on the rise side. Although this phenomena still requires some investigation for sloping surfaces, correction factors listed in Table C3 below are useful within the gradient range 1 in 1.5 to 1 in 10 for level surfaces. For example, if a seam is dipping at 1 in 3 and the calculated strain for a level seam were 1mm/m, the corrected strain would be 0.46 mm/m on the rise and 1.54 on the dip side.

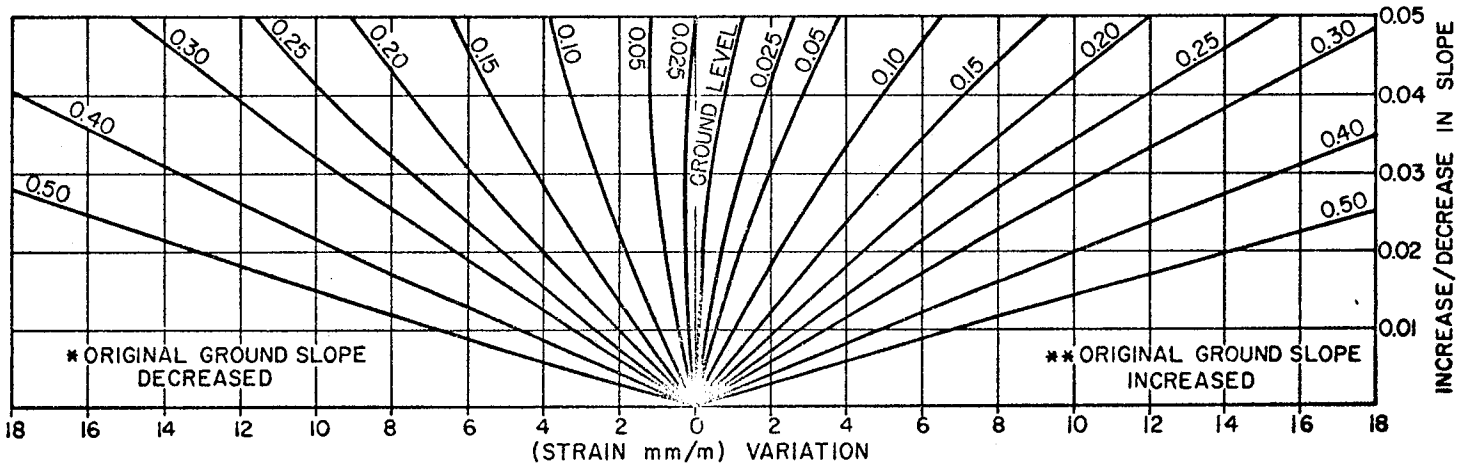
Prediction of strain values from the radius of curvature (p) of a subsidence profile has proved useful. The smaller the radius of curvature, the greater the strain; hence, strain is proportional to $1/p$. Angle θ, differential slope, is small, and if considered in radians for a given bay length (l), then p equals l/θ and strain is proportional to θ/l. Although much could be said concerning proper selection of bay lengths, a useful and



a. GRADIENTS BASED ON HORIZONTAL LENGTHS

* SUBTRACT FROM EXTENSION ADD TO COMPRESSION WHEN PREDICTING STRAINS, THE REVERSE WHEN APPLIED TO MEASURED STRAINS.

** ADD TO EXTENSION, SUBTRACT FROM COMPRESSION WHEN PREDICTING STRAINS, THE REVERSE WHEN APPLIED TO MEASURED STRAINS.



b. GRADIENTS BASED ON SLOPE LENGTHS

FIGURE C16. NOMOGRAM FOR CALCULATING VARIATION IN STRAIN DUE TO SLOPING SURFACE.

TABLE C3. EFFECTS OF SEAM GRADIENT ON TENSILE STRAIN.

GRADIENT	Proportion of Normal Tensile Strain	
	Rise	Dip
1 in 1.5	0.29	1.71
1 in 2.0	0.35	1.65
1 in 2.5	0.41	1.59
1 in 3.0	0.46	1.54
1 in 3.5	0.51	1.49
1 in 4.0	0.56	1.44
1 in 4.5	0.60	1.40
1 in 5.0	0.64	1.36
1 in 5.5	0.69	1.31
1 in 6.0	0.73	1.27
1 in 6.5	0.76	1.24
1 in 7.0	0.80	1.20
1 in 7.5	0.83	1.17
1 in 8.0	0.85	1.15
1 in 8.5	0.87	1.13
1 in 9.0	0.89	1.11
1 in 9.5	0.91	1.09
1 in 10	0.92	1.08

Adapted From National Coal Board Subsidence Handbook, 1975

accurate length is 0.05h or one twentieth the depth. Mean values of strains proportional to θ/l have been ascertained by the NCB within usable limits of accuracy and are shown on the following graph (Figure C17).

The relationship of subsidence to time for any point of interest near an excavation has also received in-depth study in the United Kingdom. As a face advances toward a point P on the surface, detectable subsidence occurs when the face is within 0.75h, reaching about 15 percent of S_{max} when the face is below this point, or more accurately below on a line drawn

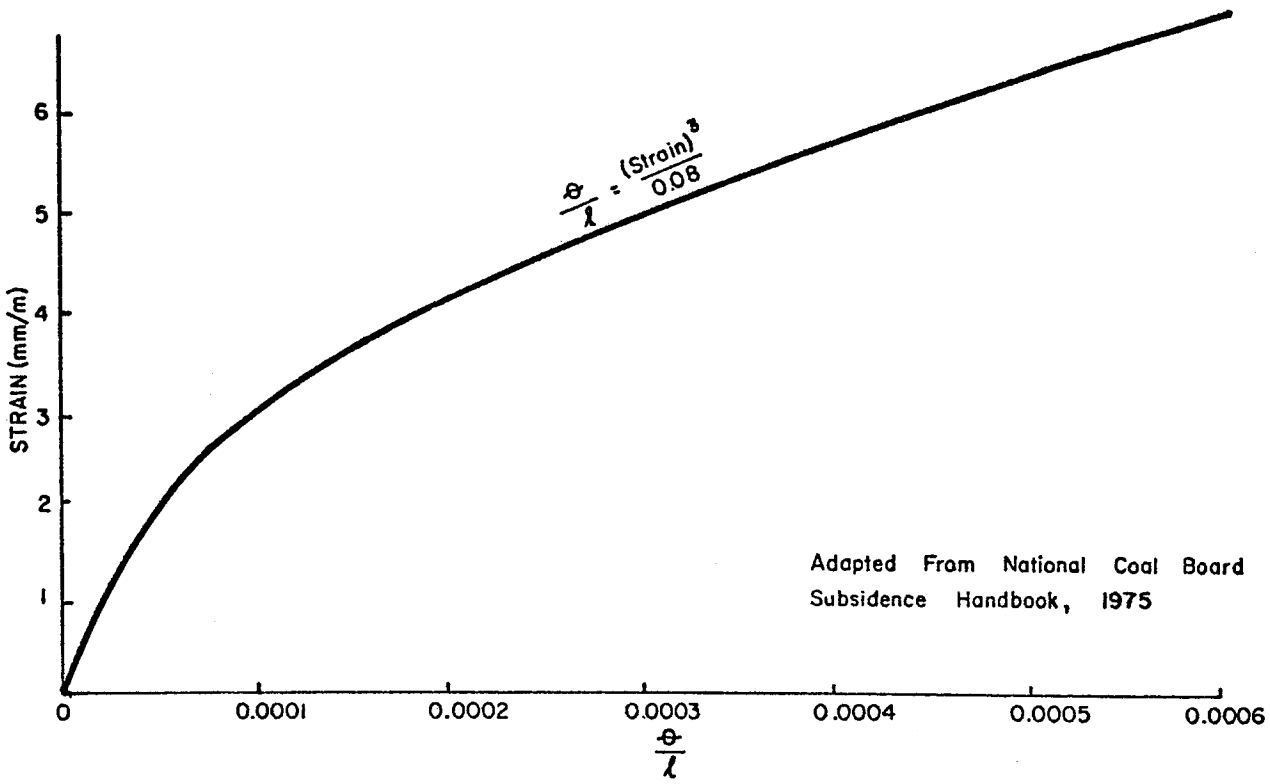


FIGURE C17. GRAPH FOR PREDICTING STRAIN.

normal to the dip and intersecting the face. When the face advances a distance 0.7h farther from the point, regardless of whether advancement continues, all noticeable subsidence is complete. Field observations further indicate two types of subsidence occur, an active and time-dependent or residual subsidence. Both occur together until active subsidence ceases, at which time residual continues, the amount varying according to the distance from the face. At points where combined subsidence was the fastest, most residual subsidence occurs, other points having less toward the angle of draw. Maximum residual subsidence is typically about 0.09S at the point of S/2. Figure C18 illustrates typical subsidence development discussed above. Exceptions or variations of the above subsidence development may

Adapted From National Coal Board Subsidence Handbook, 1975

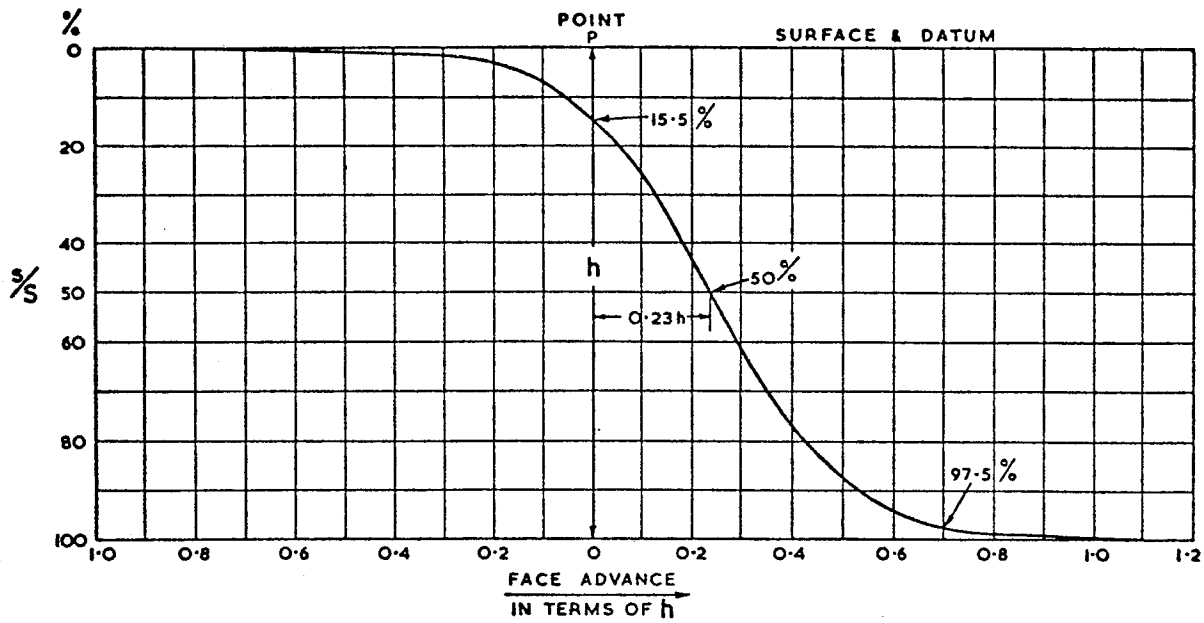


FIGURE C18. SUBSIDENCE DEVELOPMENT CURVE FOR TYPICAL CONDITIONS.

result when unusually strong strata exist, in which case residual subsidence is increased.

Room-and-pillar subsidence reacts differently where size and number of pillars, soft bottom thickness of underclay, seam thickness and depth of cover are determining factors. The type of work accomplished in the gob, whether full caving, strip-packing or solid stowing, has little effect on development behavior, as demonstrated by Figure C19.

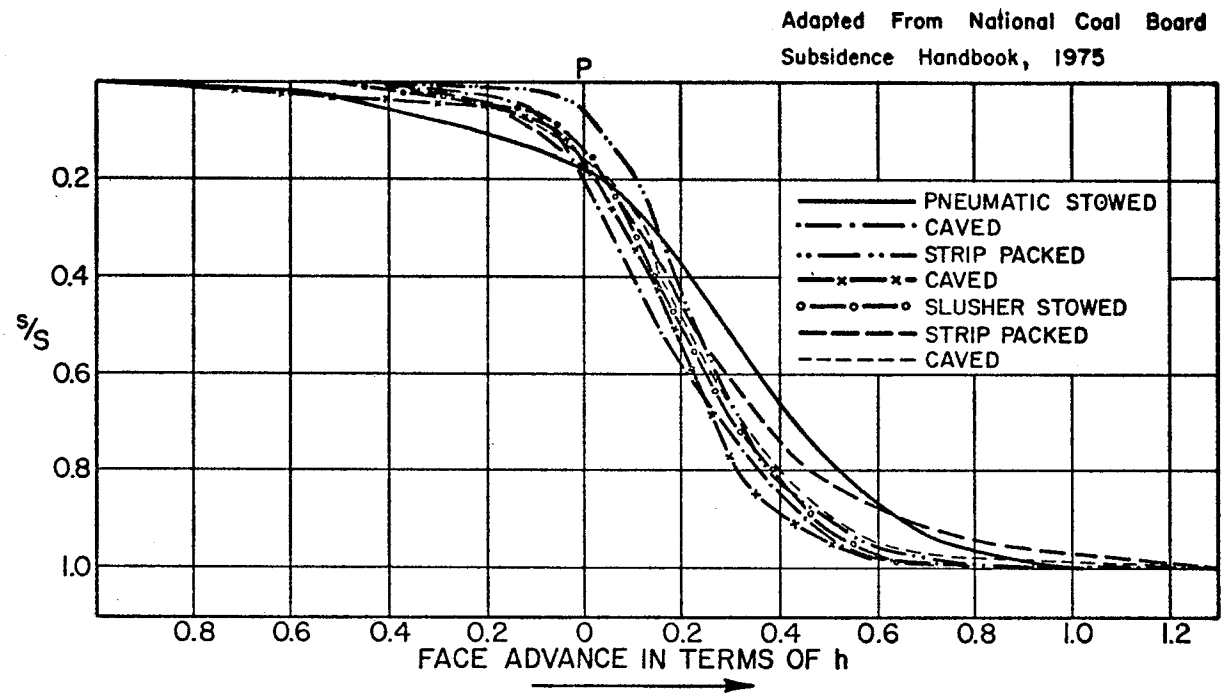


FIGURE C19. SUBSIDENCE DEVELOPMENT WITH VARIOUS GOB TREATMENTS.

It must be stressed that while the above methods of subsidence related predictions are useful, this information was derived from British case histories, many of which involve longwall mining and gob stowing. Thus, application to United States mining and overburden conditions must be done with caution. Other relevant sources of information include: State of the Art of Subsidence Control - Abandoned Mines by General Analytics, Inc. for Appalachian Regional Commission; Factors in the Design of Mine Pillars for the Support of Overburden Permanently by Charles T. Holland.