DEPARTMENT OF ENVIRONMENTAL PROTECTION
Office of Oil and Gas Management

DOCUMENT NUMBER: 800-0810-004

TITLE: Guidelines for Chain Pillar Development and Longwall Mining Adjacent to Unconventional Wells

EFFECTIVE DATE: Upon publication of notice as final in the *Pennsylvania Bulletin*

AUTHORITY: The Oil and Gas Act of 2012 (58 Pa. C.S. § 3201 *et seq.*), the Clean Streams Law (35 P.S. § 691.1 *et seq.*), the Coal and Gas Resource Coordination Act (58 P.S. § 501 *et seq.*), and 25 Pa. Code §§ 78a.73, 78a.78, 78a.81, 78a.91-92, and 78a.101-105.

POLICY: Coal operators and unconventional well operators developing resources in areas of active longwall coal mining should follow this policy to develop a method of temporarily inactivating and re-entering producing wells, and maintaining long-term pillar stability prior to, during, and after longwall panel removal that ensures protection of people and the environment.

PURPOSE: This guidance has been developed to facilitate appropriate unconventional well inactivation and re-entry procedures in advance of and subsequent to longwall panel removal, respectively; that will allow for continuous isolation of gas from workable coal seams, protection of mining personnel, and prevention of pollution of the waters of this Commonwealth, consistent with applicable law.

APPLICABILITY: This guidance applies to coal operators and unconventional well operators conducting operations in areas where workable coal seams are being developed using longwall mining techniques in the Commonwealth of Pennsylvania.

DISCLAIMER: The policies and procedures outlined in this guidance document are intended to supplement existing requirements. Nothing in the policies or procedures will affect regulatory requirements.

The policies and procedures herein are not an adjudication or a regulation. The Department of Environmental Protection (DEP) does not intend to give these rules that weight or deference. This document establishes the framework, within which DEP will exercise its administrative discretion in the future. DEP reserves the discretion to deviate from this guidance document if circumstances warrant.

PAGE LENGTH: 30 pages

I. BACKGROUND

A. Regulatory/Statutory Framework and Guidance Development Process

Coal mining and natural gas production have co-existed for a very long time. The more recent development of unconventional natural gas resources has presented an array of new issues. Unconventional wells, which extract gas from deep shale formations like the Marcellus, are characterized by gas volumes and pressures that are significantly higher than those observed at many conventional wells.

In 2011, the Coal and Gas Resource Coordination Act (58 P.S. § 501 *et seq.*) was amended to address the interface between modern longwall mining and unconventional gas development. The amendments mandated a comprehensive evaluation and update of the Joint Coal and Gas Committee Gas Well and Pillar Study (Gas Well Pillar Study) commissioned in 1956 by the Department of Mines and Mineral Industries and cited by reference in 25 Pa. Code § 78a.78 and associated Technical Guidance Document 550-2100-006. The evaluation was specifically intended to identify appropriate coal pillar geometries for maintaining the integrity of active and inactive wells and well clusters, including plugged wells, in circumstances where underground coal mining is occurring adjacent to oil and gas development. The 2011 amendments also allowed DEP to consider additional criteria or standards.

DEP, through its Oil and Gas Technical Advisory Board (TAB), established a technical committee to comprehensively address the subjects in the Coal and Gas Resource Coordination Act. The guidelines developed herein reflect contemporary longwall mining and unconventional well construction practices, and may not be directly applicable to future mining geometries or coal seam cover depths. In addition to the committee work and this guidance, the provisions of Section 3224 of the Oil and Gas Act (58 Pa. C.S. § 3224) are directly applicable to any coal and oil and gas operators in scenarios where a pillar must be permitted in advance of coal mining. Section III, Subsection G of this guidance specifically describes the applicable regulatory and statutory framework for scenarios not addressed herein.

Prior to the TAB committee work, DEP had been engaged in a multi-year effort to update the Coal Pillar Study respective of modern longwall mining techniques. To understand the present context more clearly, the work products associated with that effort, the John T. Boyd Company Gas Well Pillar Study Update and DEP's Review of the Gas Well Pillar Study Update Completed by the John T. Boyd Company (5000-RE-DEP4867), can both be accessed electronically on DEP's website.

B. Subsidence

During longwall panel extraction, two types of subsidence can affect gas wells:

(1) Conventional subsidence – primarily downward movement of the overburden above the coal seam, but can also include a horizontal component particularly in sloping terrain (Peng, 1992).

(2) Non-conventional subsidence – horizontal slip along weak horizontal planes above the pillar. These can occur at any point in the well, but seem to be most likely in the zone 200-600 feet below the surface (Su, 1991; Su, 2016; Hebblewhite and Gray, 2015; Mills, Puller and Salisbury, 2015; Mills, 2014).

Conventional subsidence can be predicted with reasonable accuracy. It is directly associated with the passage of the adjacent longwall panels, and very little further movement normally occurs with the extraction of subsequent longwall panels. Studies have also shown that the surface barely subsides above large chain pillars that maintain substantial stability factors. On the other hand, chain pillars with lower stability factors may deform, thereby resulting in additional subsidence above the chain pillar (Mark, 1990; Ditton and Frith, 2003).

Recent studies and assembled regional data have suggested that bedding plane slip associated with non-conventional subsidence may also cause gas well casing damage (Su, 2016). The amount of movement is difficult to predict, and some small horizontal slips may be associated with longwall mining taking place at distances greater than those due to conventional subsidence (Daigle and Mills, 2017; Hebblewhite and Gray, 2015).

C. Pillar Deformation

The chain pillars, including the floor beneath them, are the key structural elements maintaining stability at the seam level. They can be affected by three types of deformations:

(1) Pillar (and/or floor) deformation caused by the abutment loads that are generated when the longwall panel is extracted.

(2) Pillar deformation resulting from long-term rib degradation due to weathering.

(3) Long-term floor deformation, due to creep, and possibly exacerbated by groundwater.

When a coal pillar is developed, a "yield zone" is formed around its perimeter (Figure 1). Within the yield zone, the coal sheds load by deforming vertically and laterally. The yield zone also provides confinement to the rest of the pillar, allowing the vertical stress to build up within the pillar core. The peak vertical stress in the pillar occurs just beyond the edge of the yield zone (Wilson, 1972; Mark and Iannacchione, 1992; Gale, 1999; Su, 2010).

As additional load is added to the pillar by longwall mining, the yield zone expands and the peak stress migrates towards the pillar core. Experience has indicated that the yield zone typically extends no more than about 10-20 feet into the pillar for typical Pittsburgh seam mining. Significant deformations may be expected within this zone. Similarly, high stress levels and rapidly changing stress gradient may also generate significant deformations in the vicinity of the peak stress. In pillars with sufficiently large stability factors, however, there should be a substantial core which is subjected to relatively little deformation.

It may also be worth noting that none of the relevant field studies conducted to date observed any significant well deformations within the coal pillar at the seam level (Su, 2016; Scovazzo and Moran, 2013). It seems plausible that floor deformations would be more likely to occur near the entry and beneath the peak pillar stress than near the center of an adequately sized chain pillar.

The second and third pillar deformation mechanisms can occur long after the adjacent longwall panels are completed. For example, if the floor remains dry while a mining district is still active, but is flooded after the district is sealed, then floor deformation may develop, particularly for small pillars subject to high loads. Studies have shown that weathering can reduce the strength of parting materials in the Pittsburgh seam, but the effects only extend about 6.5 feet into the rib after 50 years (Biswas and Mark, 1999). Therefore, neither of these mechanisms seem likely to cause major deformations in the vicinity of the wells, provided the pillars are adequately sized.

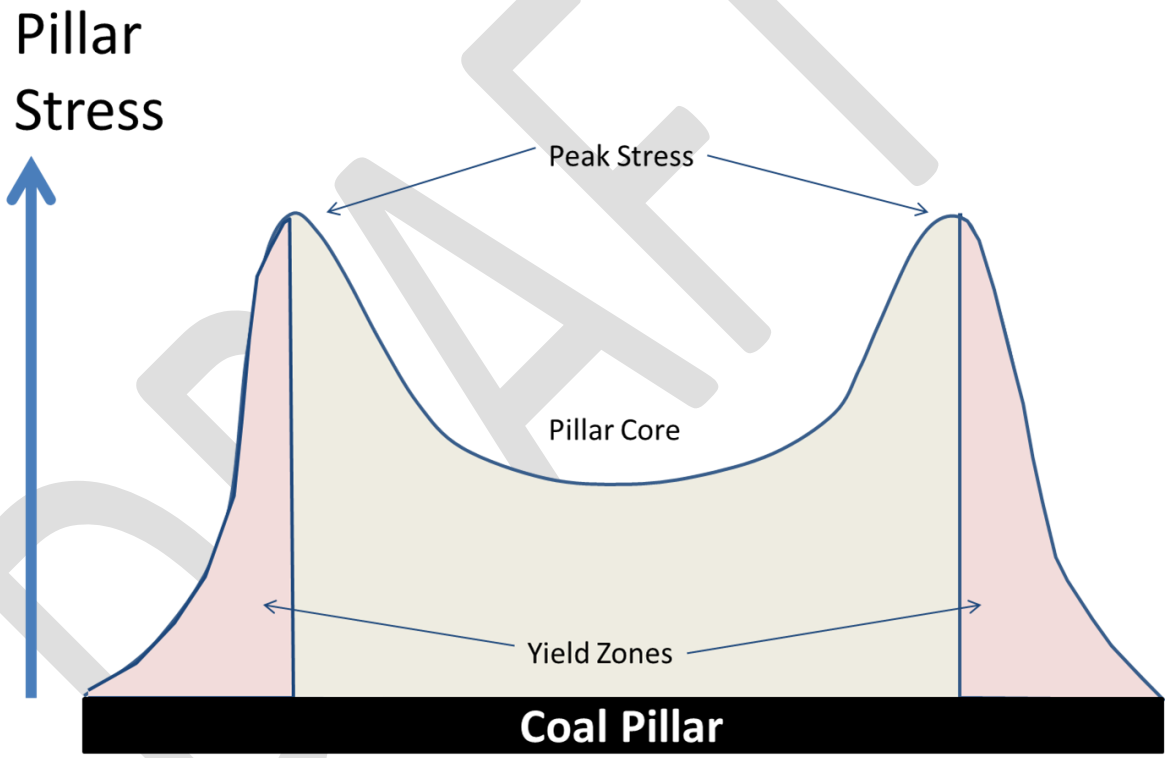


Figure 1: Conceptual view of the distribution of vertical stress within a coal pillar. The coal yields near the pillar ribs, and the stress builds up to a peak at the edge of the yield zone. During longwall mining, as additional load is applied to the pillar, the yield zones expand and the stress peaks migrate towards the pillar center.

II. PERMITTING PROCESS

This section addresses the permitting process in situations where an unconventional well or well cluster is in place and producing in an anticipated chain pillar location prior to the commencement of longwall mining. Such wells will be subject to all the subsidence and pillar deformation mechanisms described in Section I, and the mine environment would be at increased

risk if they remained in production while adjacent longwall panels were extracted. While chain pillars may be designed to carry the abutment loads, no practical chain pillar can be large enough to isolate a well from non-conventional subsidence. Therefore, for the foreseeable future, all unconventional wells should be inactivated in accordance with these guidelines, while the longwall mining process is ongoing.

In order to address the deformation mechanisms described in the previous section, longwall chain pillars that contain unconventional wells, and subsequently have longwall panels extracted on both sides, should maintain a stability factor, for isolated loading, of at least 2.0 (Mark, 2000). A stability factor of 2.0 is needed in order to:

(1) Minimize the likelihood of well damage during longwall panel extraction due to abutment loading.

(2) Account for potential long-term rib degradation.

(3) Minimize floor-bearing pressures.

(4) Account for unknowns regarding pillar stability and pillar mechanics.

A pillar system stability factor of 2.0 can be obtained by any combination of the following:

(1) Sufficiently large gateroad entry and crosscut centers.

(2) Adjusting the middle (track) entry to increase the size of the pillar encompassing the well(s).

(3) Partially filling the middle entry and crosscuts to reduce the effective height of the pillar encompassing the well(s).

If backfilling is to be used to increase the pillar stability to an acceptable level, the backfill will typically be installed during the headgate pass. Details addressed as part of the backfilling process should include:

(1) Method of backfilling, whether pumped into mine or gravity fed.

(2) Minimum backfill thickness (should be at least 2 feet or 1/8 of entry width to reduce the likelihood that floor heave does not fail the backfill slab).

(3) The design backfill thickness. The analysis should indicate that the backfill will sufficiently increase the pillar system stability factor to meet target, while leaving the No. 2 (track) entry partially open for ventilation even once it is within the longwall gob.

(4) Minimum backfill strength (should be equal to or larger than the in-situ strength of coal – approximately 900 pounds per square inch (psi), or otherwise demonstrated to be sufficient to provide pillar confinement).

(5) Standing support designed for this application.

The procedures that follow sequentially describe preventative actions that should be taken by coal operators and unconventional well operators to ensure that all operations are conducted in a manner that is safe and protective of the environment. The procedure covers the period that starts when development mining is within 500 feet of any operating unconventional well located in an anticipated pillar and concludes when the last longwall (tailgate) face mined has advanced 1,500 feet beyond the pillar location or to some shorter distance dictated by the mine's geometry. Figure 2 is a simplified process map that tracks the previously referenced preventative actions, as well as regulatory processes.

A. Before Longwall Gate Entry Development Mining is within 500 Feet of Anticipated Pillar

In accordance with Section 3224(a) of the Oil and Gas Act, an underground coal mine operator must notify the well operator and DEP prior to advancing longwall chain pillar development mining within 500 feet of any oil or gas wells. The coal mine operator accomplishes this notification by submitting a conditional coal pillar application (8000-PM-OOGM0112) and the accompanying plan (8000-PM-OOGM0112A) to DEP's Oil and Gas Program, and to the well operator. Per this guidance, an accompanying conditional inactive status application (8000-FM-OOGM0056) should also be submitted by the well operator for unconventional wells that are to be inactivated within the chain pillar(s). 25 Pa. Code 78a.102(4)(iii) establishes that an inactive status application must be accompanied by "other information necessary for DEP to make a determination on inactive status." DEP's Bureau of Mine Safety (BMS) and the Mine Safety and Health Administration (MSHA) should also be provided with copies of all materials included in the application package.

In anticipation of gate entry development mining, all annular spaces of all unconventional wells installed within the boundaries of the anticipated pillar should be opened to the atmosphere and bled down. This process will minimize the potential for gas incursion into the development passageways should a well be inadvertently contacted by a continuous miner. If applicable, annular spaces should be maintained open to the atmosphere until the second longwall (tailgate) face has been advanced to 1,500 feet beyond the pillar location, or to some shorter distance dictated by the mine's geometry. Appropriate setback distances for development mining are discussed in Section III.B. of this document.

Coal operators applying this guidance should include the following information in the application package:

<u>Conditional Pillar Application</u>

(1) Completed copies of Conditional Chain Pillar Permit in Association with Longwall Mine (8000-PM-OOGM0112) and Conditional Chain Pillar Plan in Association with Longwall Mine (8000-PM-OOGM0112A).

(2) Copy of cooperation letter between coal operator and unconventional well operator documenting measures taken consistent with provisions of this technical guidance document.

(3) General location map depicting gas well(s) within anticipated pillar, anticipated pillar location, footprint of the mine with associated tailgates and mains, configuration of nearest adjoining panels, and corehole locations used in floor stability analysis.

(4) Mining development plan addressing process, notifications, fire safety, ventilation, monitoring equipment, equipment calibration, and recordkeeping.

(5) Tabular summary of well coordinates for surveyed surface elevation and seam base elevation in decimal degrees.

(6) Tabular summary of well deviation survey interpolations at elevation of the seam base.

(7) Backfilling plan for ensuring a pillar system stability factor of 2.0 or greater and describing the timing, material emplacement method, backfill design material properties, material sampling and third-party testing plan, and recordkeeping.

(8) Long-term pillar stability analysis inclusive of estimated stability factors and procedure used to derive the estimates, planned relocation of gate roads and other entries to enhance stability and any resulting changes in the pillar geometry, a reference to backfilling or other remedial measures that will be employed, other relevant physical descriptors for the location, and any modeling assumptions applied.

(9) Long-term floor stability analysis inclusive of at least a site-specific lithologic description and rock strength estimate, if available; the stress transfer to mine floor that is expected to result from longwall panel extraction; and a topographic map depicting the location of the gas well(s), anticipated pillar, the surrounding core locations, and a radial buffer centered at the pillar and extending to 2,500 feet.

(10) Other materials judged necessary by the coal operator for completion of DEP's technical review. The intent of these materials should be described in the submission package. In certain cases, the coal operator may also need to submit a revised coal pillar application. This should be noted on the form (8000-PM-OOGM0112).

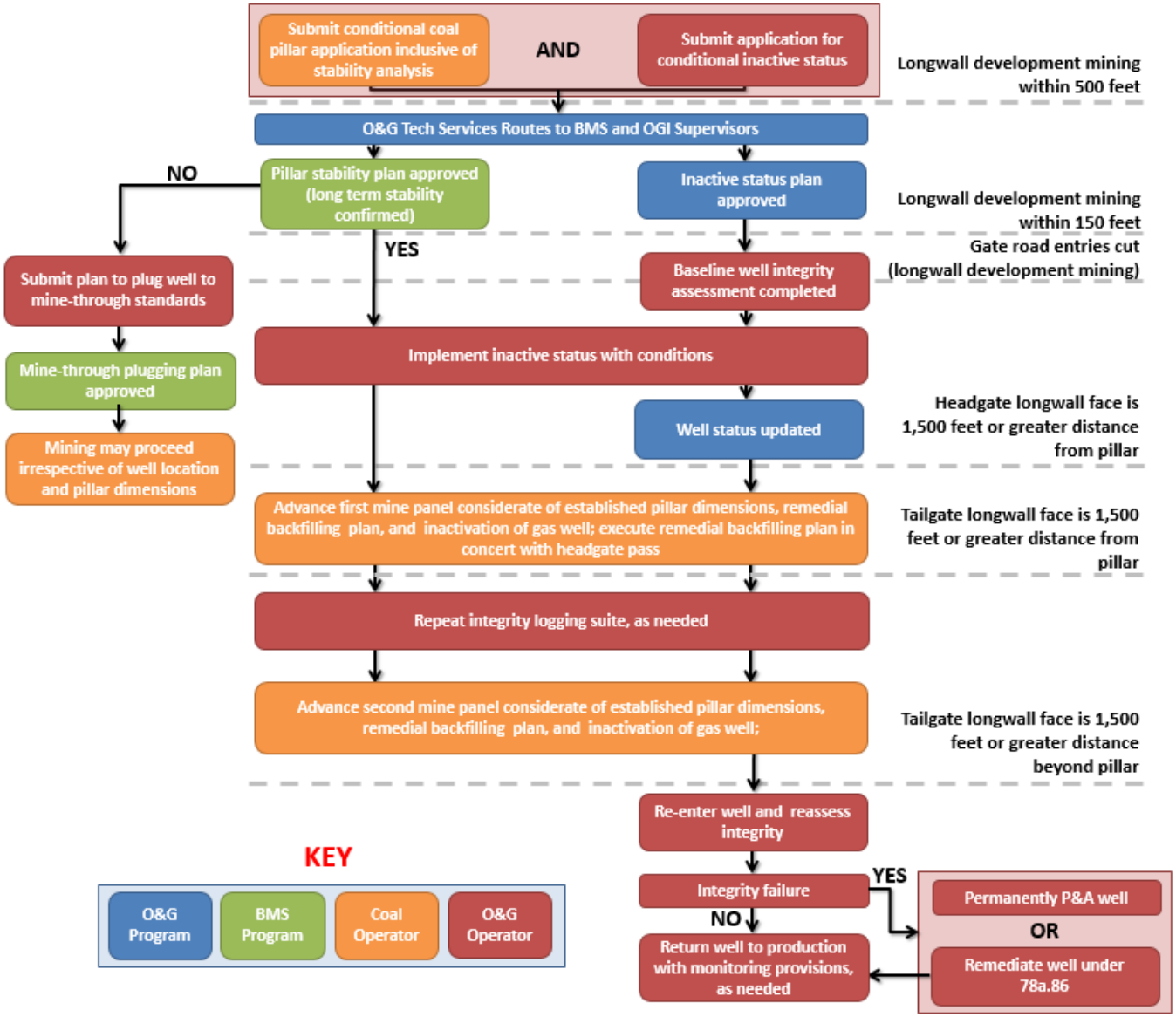


Figure 2: Process map detailing longwall chain pillar permitting procedure for coal operators and unconventional well operators with assets in areas of active longwall mining. Note that situations where the pillar location is less than 1,500 feet from the longwall setup entry are addressed individually in the sections that follow.

Unconventional well operators applying this guidance should include the following information in the application package:

Activities in Advance of Longwall Mining

(1) Application for Inactive Well Status (8000-FM-OOGM0056) inclusive of a listing of all supporting documents that have been supplied to support the application.

(2) Temporary well inactivation procedure inclusive of the following, minimum components:

a. Measures for safely entering the well and isolating the production zone using a mechanical plug and cement as indicated in e., below;

b. method for determining the cement top in the production casing annulus;

c. the procedure for perforating and squeezing cement outside the production casing, if cement is needed to isolate uphole sections of that annular space for the purposes of temporary well abandonment;

d. a description of the placement/justification for all mechanical and cement plugs, minimally to include a mechanical plug emplaced to isolate the production zone (this mechanical plug should ideally be set within 100 vertical feet of the producing formation top; shallower set depths must be accompanied by an approved alternative method) and followed by a minimum, 200-foot cement plug; and any intervening fluid-bearing (gas, oil, or brine) intervals that will be isolated with discrete mechanical plugs. For the purposes of temporary inactivation, fluid-interval systems may be isolated using a single mechanical plug, provided that a reasonable grouping of oil-, gas-, or brine-bearing zones is permissible. The final mechanical plug set inside the production casing should also be followed by a 200-foot cement plug, providing that the top of that plug does not extend above the depth that is 200 feet below the base of the deepest workable coal seam;

e. a description of the pressure test procedure that will be used to confirm casing integrity. All wells on a pad being managed under this guidance, unless permanently plugged, must be pressure tested. The internal casing pressure tests should ensure that both the sections of the well immediately above the deepest and shallowest mechanical plugs set prior to longwall mining are tested by applying surface pump pressures calculated as follows: Deepest Plug = 1.1 times the virgin reservoir pressure, or a technically justified surrogate pressure, minus the fluid hydrostatic pressure at the mechanical plug depth and Shallowest Plug = 1.1 times the virgin reservoir pressure, or a technically justified surrogate pressure. No more than 10% leak-off is acceptable over a 30-minute test interval and if the calculated surface pump pressure necessary to meet the criteria above is negative, a minimum surface applied pressure of 100 psi should be selected; and

f. a listing of any casing integrity electrical logs, mechanical logs, directional surveys, and borehole camera work that will be run from 200 feet below the targeted workable coal seam to the surface. The objective of this well assessment is to determine production casing thickness; internal casing deformation and the orientation of that deformation; the relative position of the well; and cement quality and the presence and composition of fluids in the production annulus for production casing strings cemented over the interval most susceptible to casing deformation.

Recommended logging tools include a minimum 40-arm caliper log and a high-resolution, acoustic log capable of imaging production casing thickness/deformation and production annulus cement/fluids. A wellbore deviation survey is also recommended. Azimuth controlled tools should be considered to characterize both the nature and orientation of any deformation. Borehole video surveys may be important in certain circumstances to verify logging results.

The recommended timing for running the logging suite for the first (headgate) panel is prior to advancement of the longwall face within 1,500 feet of the pillar location, unless the pillar is closer than 1,500 feet from the longwall setup entry. In such cases, the logging suite should be run prior to commencement of mining in association with that panel and implemented at the well(s) closest to full extraction mining and towards the middle of the chain pillar. It is not necessary to log all wells. The selection should be based on a representative fraction of construction designs, e.g., cement top position in the production annulus, and cover depths.

For multi-well pads; a second well should be logged on pads with at least 11 wells, a third well should be logged on wells with at least 21 wells, and so forth at increments of 10 additional wells. Considerations should also be given for well construction designs, cover depths, and well location on the pad when choosing additional wells for representative logging based on the pad total well count. Logging of all additional wells on the pad should also take place prior to advancement of the headgate panel to within 1,500 feet of the pillar location; unless a different mining geometry applies.

It is also recommended that the unconventional well operator consider running the chosen logging suite before the second (tailgate) panel is advanced to within 1,500 feet of the pillar location for all wells identified for logging.

(3) Temporary inactivation diagram schematically depicting the wellbore configuration, casing set depths and specifications (OD, rating, and type), estimated cement tops for all casing strings, true vertical depths (TVDs) in feet for

the target zone and all non-target fluid-bearing intervals, and a depiction of the approximate placement depths for all mechanical and cement plugs.

(4) General specifications for all cements and gels that will be used during the temporary inactivation operation.

(5) Current Well Record (8000-FM-OOGM0004aU) and Completion Report (8000-FM-OOGM0004bU).

(6) Well Location Plat (8000-PM-OOGM0002).

(7) All relevant electrical and mechanical logs available for the well. Lithology (gamma-ray) and wellbore deviation data; and information on cement (cement bond logs or equivalent) and well integrity are most critical for the assessment of the conditional inactive status application, but may not be essential in all cases.

(8) Graphical monthly averages of production histories (including surface-measure wellhead pressures in psi and flow rates in thousand cubic feet per day (MCFPD)).

Note that construction details may vary significantly for operating wells located in anticipated pillar locations. The intent of the temporary inactivation procedure described above is to ensure that sections of the well below the deepest workable coal seam have been addressed in a way that could be accepted as permanent plugging and abandonment in the event that mining-induced deformation prohibits a well from being brought safely back into production. These standards are established in 25 Pa. Code §§ 78a.91-92. Please also note that any non-compliance or violations associated with the casing and cementing provisions of 25 Pa. Code Chapter 78a, Subchapter 78a may render a well ineligible for temporary inactivation under this guidance.

In consideration of the objective to comply with permanent plugging and abandonment standards below the deepest workable coal seam, the emplacement of cement outside the production casing in scenarios where perforating and squeezing is deemed necessary should accomplish the following:

(1) Perforated and squeezed interval should be sufficiently shallow and separated from the production annulus primary cement top to optimize the likelihood of establishing production annulus circulation prior to pumping cement. In situations where a well operator fails to establish circulation for a given perforated interval, provisions should be made to address any well integrity concerns as part of the re-entry plan.

(2) The calculated cement top should minimally cover all fluid-bearing intervals outside the production casing and also tie back above the intermediate casing shoe. DEP recommends that the targeted cement top is at least 100 feet above the shallowest fluid-bearing interval and 200 feet above the intermediate casing shoe, whichever is shallowest. A CBL should be run to confirm the actual cement top in the production annulus.

(3) The calculated cement volume should be sufficiently conservative to prevent a permanent cement top from resulting at or above a depth that falls within 200 feet below the base of the deepest workable coal seam, as depths below this benchmark are not expected to experience any deformation resulting from current or future coal removal.

Perforating the production casing does introduce casing integrity impairments and the implications of this procedure must be carefully considered by the operator and DEP on a site-specific basis. A CBL should always be run for known partially cemented production casing strings, and if an operator believes that perforating and squeezing cement might amplify instead of mitigate risk, a plan to forgo this recommended procedure should be submitted along with the conditional inactive status application for DEP consideration. The plan should consider the following factors:

(1) The presence of flowing gas or other fluids in the production annulus, or pressure associated with gas or other fluids in the production annulus.

(2) The presence of uncemented zones in the production annulus that have the potential to flow.

(3) Consideration of whether the objectives of the primary cement job were achieved.

(4) The current cement top in the production annulus and the probability of successfully executing the recommended perforating and squeezing procedure.

(5) Anticipated future pressures that the well production casing will be subjected to and the risks that this poses if the casing has been perforated.

(6) Prior data suggesting that the likelihood of not being able to successfully re-enter the well is low.

(7) Any other technical justification for not following the recommended perforating and squeezing procedure.

In circumstances when the recommended perforating and squeezing procedure is not implemented and well re-entry is not possible, the unconventional well operator will be required to use any means available to plug and abandon the well in a manner compliant with DEP regulations.

Appendix A provides plugging schematics for fully cemented and partially cemented production casing strings for exemplary purposes.

Conditional Inactive Status Application Re-entry Procedure and Long-term Monitoring (the following information should be submitted for all unconventional wells within the footprint of the anticipated chain pillar): Activities After Longwall Mining

(1) Well re-entry procedure inclusive of the following, minimum components:

a. measures for safely entering the well to conduct integrity assessment and drill out plugs in order to return the well to production;

b. a listing of any casing integrity electrical logs, mechanical logs, directional surveys, and borehole camera work that will be run from 200 feet below the targeted workable coal seam to the surface. The objective of the well assessment is to determine production casing thickness; internal casing deformation and the orientation of that deformation; the absolute position of the well casing; and cement quality and the presence and composition of fluids in the production annulus for production casing strings cemented over the interval most susceptible to casing deformation. Recommended logging tools include a minimum 40-arm caliper log and a high-resolution, acoustic log capable of imaging production casing thickness/deformation and production annulus cement/fluids. A wellbore deviation survey is also recommended. Azimuth controlled tools should be considered to characterize both the nature and orientation of any deformation. Borehole video surveys may be important in certain circumstances to verify logging results. Tools run should repeat or be comparable to those described under (2)f. on page 9;

c. a description of the pressure test procedures that will be used to confirm casing integrity prior to the cleanout of any temporary plugs, and again subsequent to cleaning out the well's production casing to the top of the cement plug placed immediately adjacent to the mechanical plug used to isolate the production interval. All temporarily inactivated wells on a pad that an unconventional well operator intends to bring back into production and being managed under this guidance must be pressure tested. Each internal casing pressure test should ensure that the length of casing from the surface to the shallowest and deepest plugs are tested to the same pressures determined above under (2)e. on page 8, with no more than 10% leak-off of surface pressure acceptable over a 30-minute test interval;

d. a description of the procedure to re-equip the well and return it to production; and

e. the details of any additional pressure tests or well integrity assessments determined necessary by the unconventional well operator during plug drill out or other re-entry operations.

(2) Well long-term monitoring procedure defining monitoring activities for the duration of the active mine permit and inclusive of the following, minimum components:

a. A summary of baseline well integrity metrics, minimally including:

i. tubing pressure in psi and most recent date measured;

ii. production casing pressure in psi and most recent date measured;

iii. flow in MCFPD from wellhead to on-site production infrastructure and most recent date measured;

iv. production annulus pressure in psi or flow in MCFPD and most recent date measured, and an indication of how the annulus has been maintained for the preceding 6 months leading up to the assessment, i.e., shut-in, open, or other (describe);

v. external casing annulus pressures in psi, flow in MCFPD, or leaks; if gas is present, but cannot be quantified in terms of pressure or flow. For the external casing strings, the annular spaces should be designated, and the most recent date measured and configuration of the annular spaces provided, i.e., casing string cut-off and outside wellhead or casing string contained under wellhead; and

vi. any open violations of the Oil and Gas Act or 25 Pa. Code Chapter 78a. relating to casing and cementing for gas wells on the planned coal pillar.

b. a description of how the well will be equipped for real-time, continuous electronic monitoring;

c. response thresholds and actions associated with real-time, continuous, electronic well-integrity monitoring;

d. unconventional well operator personnel/positions and contact information for individuals responsible for real-time, continuous, electronic well-integrity monitoring; and

e. and coal operator personnel/positions and contact information for individuals responsible for coordinating safety operations at the mine.

B. Post-Longwall Gate Entry Development

Casing Integrity Testing/Implementation of Conditional Inactive Status

Any time subsequent to development mining around wells drilled in anticipated pillar locations, but at least 60 calendar days prior to advancement of the first longwall (headgate) face to a distance within 1,500 feet of the anticipated pillar location, the

unconventional well operator should notify the DEP Oil and Gas Inspector of its intent to temporarily inactivate the well in advance of mining; determine the actual cement top in the production annulus, as needed; pressure test the production casing; and run the suite of logs designated in Subsection A of this Section. A start date for commencement of this work should be provided to the DEP Oil and Gas Inspector at the time of notification so that the inspector may be available to confirm that procedures have been executed in accordance with the plan submitted under Subsection A of this Section. In cases where the pillar is located closer than 1,500 feet from the longwall setup entry, the unconventional well operator should notify the DEP Oil and Gas Inspector at least 60 calendar days prior to commencement of headgate mining.

Prior to submission of any well logging information, logs should be interpreted and annotated by the unconventional well operator in coordination with an independent professional with expertise in the interpretation of the selected logging suite. In most cases, the independent professional will be a representative from the logging service company.

Electronic copies (pdf/graphical and LAS format) of all logs run to assess baseline integrity and determine the actual cement top in the production annulus should be submitted using DEP's GreenPort submission portal at least 30 calendar days prior to advancement of the first longwall (headgate) face to within 1,500 feet of the subject well. Electronic copies of the casing pressure test results should also be submitted to the DEP Oil and Gas Inspector and Supervisor within the same timeframe. Additionally, DEP's Oil and Gas Inspector and Supervisor should be notified by email and/or telephone after the logs have been uploaded into the GreenPort system. In cases where the pillar is located closer than 1,500 feet from the longwall setup entry, the unconventional well operator should submit the information at least 30 calendar days prior to commencement of headgate mining.

Upon successful completion of temporary inactivation and prior to advancement of the first longwall (headgate) face to within 1,500 feet of the anticipated pillar location, the unconventional well operator should electronically submit a compilation of daily activity reports that summarize the inactivation procedure, confirm the details of the operation for the inspector, and allow clerical personnel to update the status of the well appropriately in DEP's database. In cases where the pillar is located closer than 1,500 feet from the longwall setup entry, the unconventional well operator should submit the information as soon as it can be reasonably compiled.

C. First Longwall (Headgate) Face Within 1,500 Feet of Unconventional Well

Execution of Backfilling Plan

Within 30 calendar days of the first longwall (headgate) face advancing to within 1,500 feet of the anticipated pillar, the coal operator should notify DEP's BMS and MSHA of their intent to execute the remedial backfilling plan submitted with the pillar permit application package and described in Subsection A of this Section. In cases where the pillar is located closer than 1,500 feet from the longwall setup entry with respect to the first longwall (headgate) panel, BMS and MSHA should be notified whenever the first longwall begins.

During execution of the remedial backfilling plan, cement placement in all middle (track) entries, crosscuts, and intersections that immediately adjoin the large pillars through which the wells are installed should be completed prior to the second longwall (tailgate) face advancing to within 1,500 feet of the pillar. In cases where the pillar is located closer than 1,500 feet from the longwall setup entry, the backfilling should be completed prior to commencement of mining in association with the second longwall (tailgate) face.

Casing Integrity Logging

Any time subsequent to advancement of the first longwall (headgate) face beyond wells drilled in anticipated pillar locations, but at least 60 calendar days prior to advancement of the second longwall (tailgate) face to a distance within 1,500 feet of the nearest well, the unconventional well operator should run the suite of logs designated in Subsection A of this Section (these logs should repeat or be comparable to logs run in advance of temporary inactivation) at a representative number of well locations chosen at their discretion. Well design/construction details and location in the anticipated chain pillar, as well as any logging data already collected at similar depths of cover, are all potential considerations that the unconventional operator should consider when determining if this intermediate suite of logs should be run. Prior to submission of any well logging information, logs should be interpreted and annotated by the unconventional well operator in coordination with an independent professional with expertise in the interpretation of the selected logging suite. In most cases, the independent professional will be a representative from the logging service company. In cases where the pillar is located closer than 1,500 feet from the longwall setup entry, the unconventional well operator should run the suite of electrical logs at least 60 calendar days prior to commencement of tailgate mining.

Electronic copies (pdf/graphical and LAS format) of all logs run to assess integrity should be submitted using DEP's GreenPort submission portal at least 30 calendar days prior to advancement of the second longwall (tailgate) face to within 1,500 feet of the subject well. Additionally, DEP's Oil and Gas Inspector should be notified by email and/or telephone after the logs have been uploaded into the GreenPort system. In cases where the pillar is located closer than 1,500 feet from the longwall setup entry, the well operator should submit the information at least 30 calendar days prior to commencement of tailgate mining.

D. Second Longwall (Tailgate) Face 1,500 Feet Beyond Unconventional Well

After the second longwall (tailgate) face has been advanced at least 1,500 feet beyond the pillar location, or reached the end of the panel being mined, the unconventional well operator may begin executing the re-entry plan described in Subsection A of this Section. The unconventional well operator should notify the DEP Oil and Gas Inspector and Supervisor at least 30 days prior to commencing re-entry.

Casing Integrity Testing

As part of the re-entry process and to confirm well integrity, the unconventional well operator should run the suite of logs and complete the casing pressure testing designated

in Subsection A of this Section. Prior to submission of any well logging information, logs should be interpreted and annotated by the unconventional well operator in coordination with an independent professional with expertise in the interpretation of the selected logging suite. In most cases, the independent professional will be a representative from the logging service company.

Electronic copies (pdf/graphical and LAS format) of all logs run to assess integrity should be submitted using DEP's GreenPort submission portal at least 30 calendar days prior to submission of the application to return the well to active status (8000-FM-OOGM0123). Electronic copies of the casing pressure test results should also be submitted to the DEP Oil and Gas Inspector and Supervisor within the same timeframe. Additionally, DEP's Oil and Gas Inspector and Supervisor should be notified by email and/or telephone after the logs have been uploaded into the GreenPort system.

Submission of Application to Return Unconventional Well to Active Status and Implementation of Long-term Monitoring Plan

If the well was successfully re-entered and cleaned out, as specified in the re-entry procedure; and the casing pressure tests executed during the re-entry procedure meet the requirements of 25 Pa Code 78a.84(f) (no more than 10% leak-off over a 30-minute test interval), the unconventional well operator should submit the application to return the well to active status (8000-FM-OOGM0123) along with a compilation of daily activity reports that summarize the re-entry procedure, confirm the details of the operation for the inspector, and allow clerical personnel to update the status of the well appropriately in DEP's database. The unconventional well operator should also implement the long-term monitoring plan described in Subsection A of this Section.

E. Departures from DEP Model Plan

In certain instances, limitations may exist. For example, downhole conditions or other operational issues may prevent the plan to execute development mining and backfilling, temporarily inactivate a well, or successfully re-enter a well from being implemented as approved. The next section of the guidance addresses alternatives that may be considered in these situations.

III. CONTINGENCIES AND ALTERNATIVES

A. Minimum Stability Factor

In instances where a stability factor of 2.0, as described in Section I of this guidance, cannot be met even by remedial backfilling or other approved measures; the unconventional well operator, in coordination with the coal operator, should make plans to permanently plug and abandon the well to mine-through standards. These standards are established in Section 13(b) of the Coal and Gas Resource Coordination Act, 25 Pa. Code §§ 78a.91-92, and Section 3220(a) of the Oil and Gas Act, and are shown schematically in Appendix B. It may not be necessary to prepare the casing for accommodation of subsidence by cutting or perforating in this case, as the well will not be intentionally mined through during longwall operations. The plan for permanently plugging and abandoning the well to mine-through standards must be reviewed and

approved by DEP's Bureau of Mine Safety and MSHA, as established in Section 3224(f) of the Oil and Gas Act and Section 13(d) of the Coal and Gas Coordination Act, respectively. Additionally, the DEP Oil and Gas Inspector and Supervisor should be provided with a copy of the plan. Execution of plugging should take place prior to advancement of the first longwall (headgate) face to within 1,500 feet of the anticipated pillar location. In cases where the pillar is located closer than 1,500 feet from the longwall setup entry, the well operator should complete plugging prior to commencement of headgate mining.

B. Longwall Gate Entry Development Setbacks

Since the 1957 Gas Well Pillar Study, a well-to-pillar-rib setback distance of 50 feet has usually been considered standard.[1] One goal of an adequate setback distance is to prevent mine development from inadvertently intersecting with a well. Though the likelihood of this taking place is extremely low, the consequences would be very high because the well is expected to be in full production during this phase. An inadvertent well intersection would be the cumulative result of three kinds of errors:

(1) Uncontrolled well deviations.

(2) Surveying discrepancies (discrepancies between underground and surface locations).

(3) Mining error (off sights).

Well deviations are typically no more than 1%, or 10 feet for a 1000-foot deep well section. The deviations are determined using accurate downhole techniques, and so should be known with a high degree of accuracy. Surveying errors should also be minimal. Mine development equipment sometimes gets off sights, but that should be less likely in the vicinity of an unconventional gas well due to the heightened awareness by the coal operator. Finally, even if mine development were to inadvertently intersect a well, it seems highly unlikely that it would cut through the several strings of cemented well casings before mining stopped.

For all these reasons, it seems that the well-to-pillar-rib setback distance should probably be determined by pillar mechanics considerations, rather than the risk of inadvertently intersecting a well. It is suggested that 50 feet from the surface location, or 40 feet from the known seam level location of the well, should be adequate to place the well in the relatively stable central core of the pillar, as well as minimize the likelihood that mine development will intercept the well. Other precautions regarding continuous miner development near a well that could be included in the plan are listed in Appendix C. In instances when a setback distance of 40 feet at the seam level cannot be achieved, the coal operator should submit a contingency plan for maintaining safe operations for

[1] The 1957 Gas Well Study did not discuss the setback distance directly. Rather, it required 100 foot square pillars, centered on the gas well, to be employed whenever the depth of cover exceeded 250 feet. However, it also proposed that 60 foot square pillars (setback distance = 30 feet) could be used when the depth of cover was less than 150 feet. There is no mention of surveying errors or well deviations that might result in an accidental intersection with the well. Instead, the discussion implies that the 100-foot pillar size was selected because that was the largest size that the coal operators thought could be conveniently developed.

review by DEP's BMS and MSHA in advance of submitting the pillar permit application package detailed in Section II of this guidance.

C. Long-Term Floor Stability

Accurate geotechnical information specific to the mine floor underlying the pillar should be available from various sources. In some cases, mine floor materials may be identified as being at risk for failure based on lithology/material properties (Hasenfus and Su, 2005). This situation is typically manifest when mine pool waters are permitted to interact with the mine-floor substrate sometime subsequent to panel extraction. If the risk is judged to be elevated, this should be addressed in the long-term monitoring plan under Section E, below.

D. Casing Pressure Test Failure

When the requirements of 25 Pa. Code § 78a.84(f) (no more than 10% leak-off over a 30-minute test interval) are not met during re-entry, the unconventional well operator may not return the well to active production until a corrective action plan under 25 Pa. Code § 78a.86 is submitted to the Oil and Gas Inspector and Supervisor and approved by the Oil and Gas Inspector. In all cases where the production casing fails a casing pressure test, the unconventional well operator must notify DEP within 24 hours per 25 Pa. Code § 78a.86. If the unconventional well operator determines that it is not feasible to bring the well back into production, it must be equipped with a functional vent in accordance with 25 Pa. Code § 78a.92(a)(3) and a permanent plugging certificate must be submitted per the requirements of 25 Pa. Code § 78a.124.

E. Mine Monitoring in Active Longwall Districts

After a well has been tested and placed back in service, there is little likelihood that it will be affected by additional abutment loads or conventional subsidence. A well could be affected by floor heave or unconventional subsidence, but the associated deformations would probably be small and highly unlikely to result in a sudden major well failure. There is, however, some risk that long-term deformations could damage a well sufficiently to cause some gas to leak.

Gas accidentally released from a leaking well into a coal mine or into the fractured zone above a panel could migrate and pose a risk to miners. The specific risk is associated with the accumulation of hazardous concentrations of gas in open areas of the worked-out area where they could pose a hazard to active workings. Also, longwall bleeder ventilation systems may not have the capacity to dilute and carry additional gas away from active workings without being overwhelmed.

In most longwall mines, weekly examinations conducted in accordance with an approved ventilation plan provide an evaluation of the effectiveness of bleeder systems in removing methane from the worked-out area. When recommissioned wells are present, weekly exams may not be adequate to provide an early warning to miners in case of a hazardous leak.

An enhanced bleeder examination and evaluation protocol should be developed on a site-specific basis prior to the recommissioning of a well. The protocol should be suitable to the conditions and ventilation system at the mine, and it should consider the condition of the well as determined from casing integrity logging and testing. An enhanced bleeder examination and evaluation protocol could include one or more of the following:

(1) Continuous or more frequent monitoring at underground bleeder evaluation points.

(2) Continuous or more frequent monitoring at bleeder fan on surface.

(3) Continuous or more frequent monitoring at bleeder fan shaft legs or in the bleeder air split immediately before it joins another split of air.

The monitoring protocol must be robust enough to identify hazardous levels of gas in the mine workings before they pose a risk to the miners.

The enhanced monitoring plan may also be adjusted over time. For example, a leaking well would pose the greatest risk if it were located near the active longwall face in the tailgate entries. More vigilance might, therefore, be appropriate initially, but the level of monitoring might be reduced once the well is located between two completely mined panels. Once the longwall is several panels away, further reductions might be appropriate. No enhanced monitoring is anticipated for wells located in sealed areas.

The long-term monitoring plan may be submitted as part of the conditional pillar permit application. The plan should describe the conditions that are expected, and those conditions should be verified just prior to well recommissioning. If there is a discrepancy between the anticipated and the actual conditions, then the plan should be adjusted.

Section II of this guidance specifies that real-time, electronic, long-term monitoring of the well be conducted in all cases by the well operator. 25 Pa. Code 78a.73(a)-(b) and 78a.81(a) establishes the basis for this monitoring. Protocols should be established whereby warnings are automatically transmitted to the coal operator. A verification protocol should be implemented to confirm that the warnings will be, in fact, transmitted. However, gas pressure and flow vary during normal production, and a hazardous leak may be insignificant compared to the well's production. In addition, monitoring may be inconclusive during shut-in periods. For these reasons, well monitoring cannot substitute entirely for in-mine monitoring.

F. Other General Departures from Conditional Inactive Status or Mine Backfilling Plans

In circumstances where field conditions warrant a modification to proposals for temporarily inactivating wells in advance of mining, re-entering wells, evaluating casing integrity, executing mine backfilling plans, or other aspects of the project not specifically addressed under the other headings in this section; the well or coal operator should notify the appropriate regulatory official as soon as reasonably practicable to discuss a contingency plan. The contingency plan should not be implemented without DEP

approval, except in circumstances where the intent of the original proposal is satisfied and the contingency is equivalent or superior to the previously approved plan.

G. Other Potential Considerations

Wells not specifically addressed in this guidance, including previously plugged assets; are subject to the existing process requirements of Section 3224 of the Oil and Gas Act and the mechanical integrity requirements of Section 12.1(b)(1) and (2) of the Coal and Gas Resource Coordination Act. In scenarios where room and pillar mining is not being conducted or the 1957 Joint Coal and Gas Committee Gas Well and Pillar Study does not apply, operators must ensure that well integrity in proposed pillar locations is sufficient to provide protection of the workable coal seam and coal miners based on criteria and standards applied by DEP on a case-by-case basis.

For any wells permanently plugged in advance of mining that are not plugged to mine-through standards, the unconventional well operator must ensure through logging, pressure testing, or some other DEP approved method that the vent is functional and has integrity post-mining. In these cases, the unconventional well operator, coal operator, and DEP may also consider opportunities to collaborate and gather data relating to subsidence and deformation processes over the portion of the well scheduled for permanent plugging that penetrates from the surface through the coal seam. Data gathered through logging or other subsurface monitoring programs may prove fruitful for informing decision making at other locations where mining by wells is planned, as it is likely to show the immediate impacts of longwall panel extraction. It also could establish a long-term monitoring point if the floor of the mine becomes flooded over time.

Finally, depending on the timing and geometry of the mine, a test borehole program may be developed in concert with the unconventional well operator, coal operator, and DEP. The goal of a test borehole program is to collect data relating to subsidence and deformation processes in association with mining at a chain pillar location that has similar characteristics or is more likely to be mechanically impacted in comparison to the anticipated chain pillar location where unconventional wells have been drilled. A properly designed test borehole program consisting of drilling, test borehole construction, logging, and other subsurface monitoring programs may allow for the development of proposals that consider alternatives to the DEP Model Plan.

IV. SYSTEMATIC DATA COLLECTION AND FUTURE DEVELOPMENT

It is important to approach the level of coordination between coal and unconventional well operators in a manner considerate of the current state of understanding of subsidence and deformation processes to ensure that the fundamental intent of Section 3202 of the Oil and Gas Act is preserved. This is particularly critical for the earliest wells that will be encountered. Although the occurrence of subsidence and associated deformation is anticipated, the site-specific factors specifically controlling the degree of subsidence are subject to further study. As this guidance is implemented, the collection of data in a systematic way help inform future activities and dictate updates to the criteria and processes established in this document. To facilitate this, the electronic form Post-Longwall Mining Gas Well Assessment Instructions (Unconventional Operators Only) (8000-FM-OOGM0159U) should be used to record

information in association with these operations. The assembled data are inclusive of the following:

(1) Mine Permit Number

(2) Mine Name

(3) Coal Operator

(4) Well Operator

(5) API/U.S. Well Number (permit number)

(6) Coal Seam

(7) Depth of Cover (ft)

(8) Pillar Dimensions (ft)

(9) Maximum Setbacks Between Well and Pillar Perimeter (X1, X2, Y1, and Y2; feet)

(10) Cement Top for Production Casing (ft)

(11) Extent of Measured Deformation Inside Production Casing (maximum and minimum reduction in internal diameter in inches)

(12) Depth of Maximum Deformation (feet)

(13) Orientation of Maximum Deformation (azimuth)

(14) Longitudinal Orientation of Longwall Panel (azimuth)

(15) Average Deformation Over Deformed Interval (average offset in feet)

(16) Length of Deformed Interval (feet)

(17) Lithology at Maximum Offset

(18) Nearest Abutting Lithology Above Maximum Offset

(19) Nearest Abutting Lithology Below Maximum Offset

(20) Pressure Test Failure (Y/N)

(21) Successful Remediation (Y/N – if Y to (20))

(22) Pressure Test Leak-Off Rate (psi/minute)

(23) Well Log Available (Y/N)

(24) Comments

In cases where a mine floor failure occurs at some later point in time, the above information should be augmented with the following details using the electronic form Post-Longwall Mining Floor Failure Instructions (8000-FM-OOGM0158):

(1) Mine Permit Number

(2) Mine Name

(3) Well Operator

(4) API/U.S. Well Number (permit number)

(5) Depth of Cover (ft)

(6) Post-Mining Floor Failure (Y/N)

(7) Any Impacts Noted During Initial Longwall Panel Extraction? (Y/N)

(8) Lithology of Mine Floor

(9) Maximum Depth of Impacts Below Seam Base (feet)

(10) Time Since Last Longwall Panel Extraction (months)

(11) Flooded Conditions (Y/N)

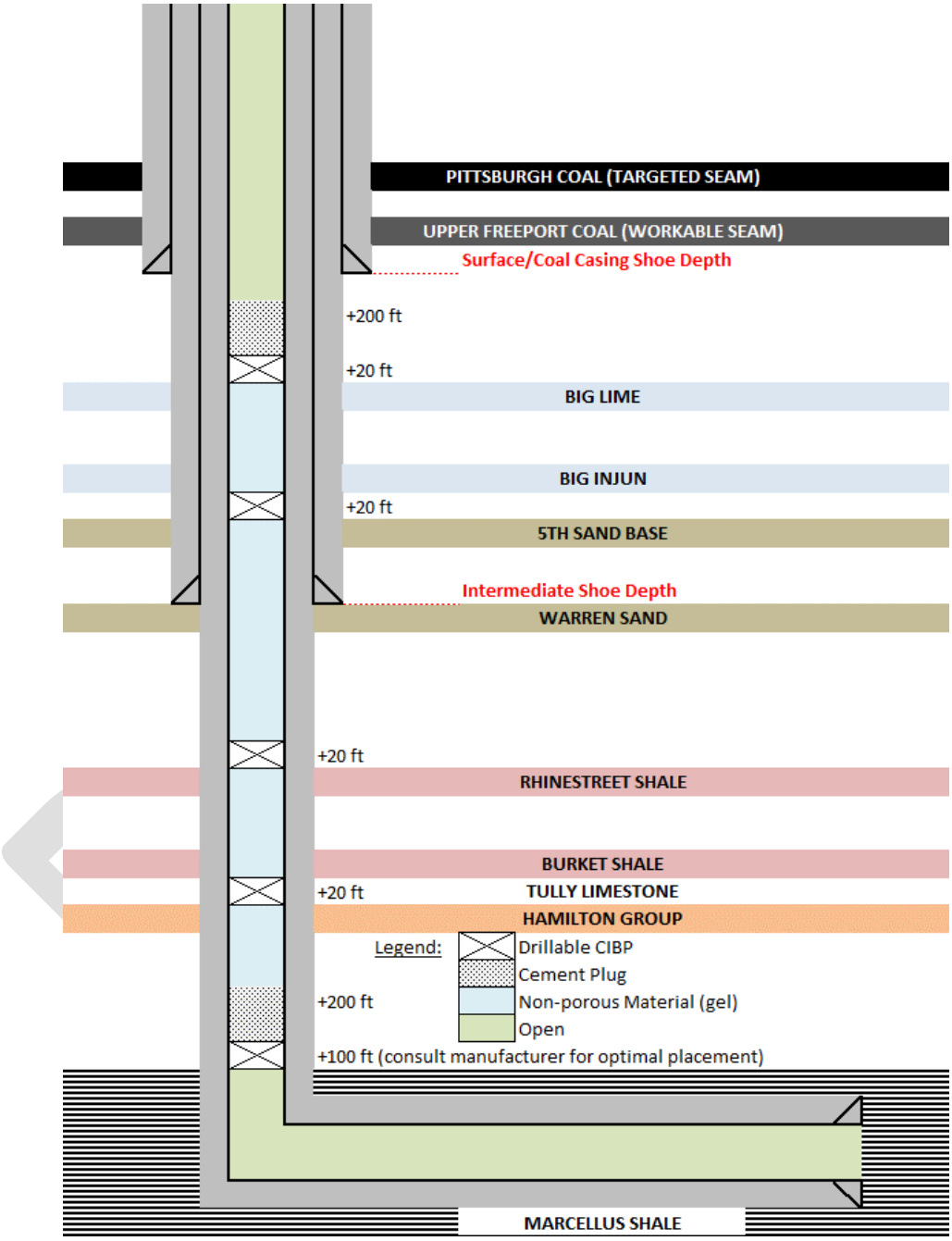
(12) Successful Remediation (Y/N)

(13) Final Plugging Disposition (Vent/Mine-Through – if N to (7))

(14) Comments

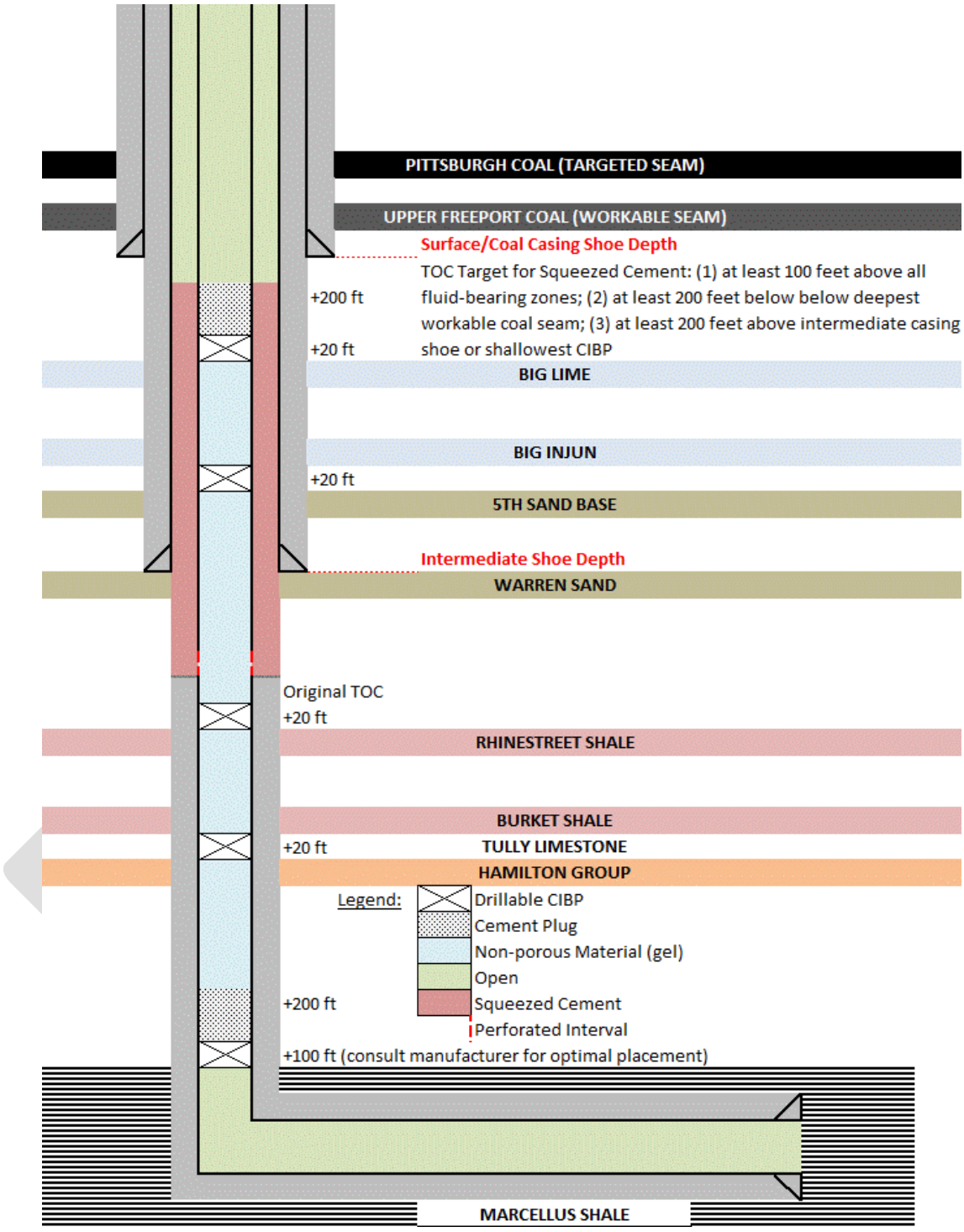
V. APPENDICES

- A: Plugging schematics
  - Production casing cemented to surface



Although coal protective casings separate from intermediate casings are required under 78a.83(g) and 78a.1, note that in certain cases some workable coals beyond the current conventions for longwall mining or under approved alternate methods may have been isolated with intermediate casing and cement tops should be adjusted accordingly. Internal casing plugs depicted as "+ number ft." Upper cement plug should remain at least 200 feet below deepest workable coal or surface/coal casing shoe.

- Production casing partially cemented



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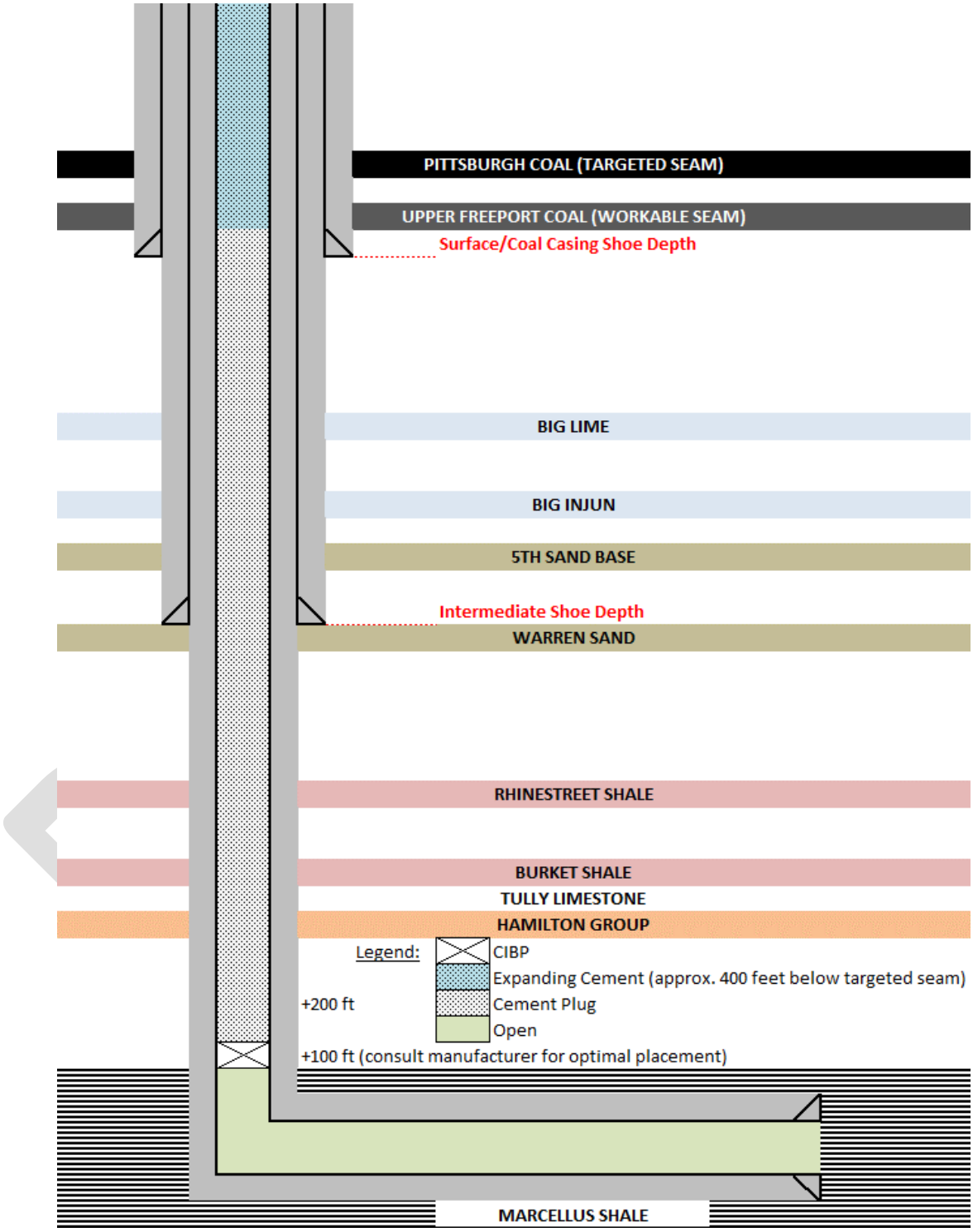
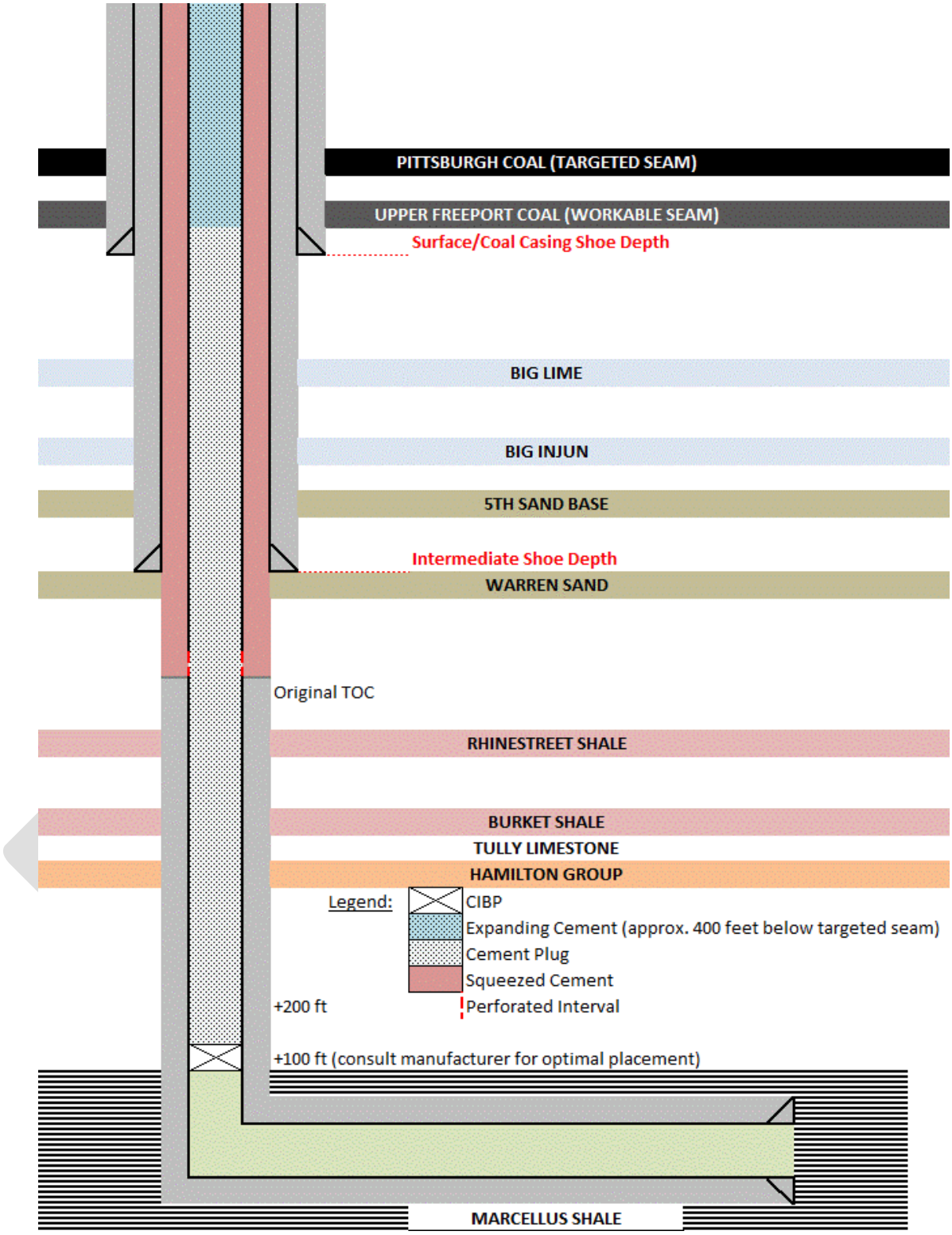
- B: Plugging solid schematic
    - Production casing cemented to surface



Note that expanding cement may only be required in certain situations. In certain cases, casing strings over the mine interval may also need to be cut or perforated. These additional measures are determined by DEP's BMS and MSHA based on offset distances between longwall mining and the vertical section of the wellbore.

- Production casing partially cemented



Note that expanding cement may only be required in certain situations. In certain cases, casing strings over the mine interval may also need to be cut or perforated. These additional measures are determined by DEP's BMS and MSHA based on offset distances between longwall mining and the vertical section of the wellbore.

- C: Best Practices and Precautions for Gateroad Development Near an Active Unconventional Well

    1) When mining is within 50 feet of a line drawn perpendicular to the entry or cross cut being mined and the well, tests for methane shall be made with a hand-held methane detector and a probe at least every 10 minutes. These methane tests shall continue until mining has progressed to a point 50 feet in by the perpendicular line. The zone shall also be free from accumulations of coal dust and coal spillage and rock dust shall be placed on the roof, rib and floor to within 20 feet of the face. Methane test shall be performed by a PA Certified machine runner or a PA Certified mine official.

    2) Firefighting equipment, including fire extinguishers, rock dust and enough fire hose to reach the working face shall be available near the working place.

    3) Sufficient supplies of roof support and ventilation materials shall be available near the working place.

    4) A minimum of 9,000 cubic feet of air per minute shall be used to ventilate the working face when mining in the vicinity of the well. The ventilation plan and methane and dust control plan shall be complied with.

    5) Equipment, including the section fan, shall be checked for permissibility and serviced on the shift prior to mining past the well.

    6) The methane monitor on the continuous mining machine shall be calibrated on the shift prior to mining past the well. The calibration may be checked during the first half of the shift if the well is to be mined-by during the second half of the shift.

    7) Check survey stations shall be advanced to within 300 feet of a line drawn perpendicular to the gateroad entry and the furthest outby well in an abutment pillar. After development mining is completed past the furthest inby well, a check survey station shall be advanced within 300 feet of a line drawn perpendicular to the gateroad entry and the well to verify that the minimum barrier is provided. If the minimum barrier thickness is not present, a mitigation plan should be submitted to DEP to address the reduced barrier width.

    8) Sight spads shall be installed at the last open crosscut near the place to be mined. A laser or additional sights shall be used to ensure that the sight line is not more than 50 feet from the well.

    9) Development of the pillar adjacent to a gas well shall be under the direct supervision of the mine foreman or a certified person designated by the mine foreman. Instructions concerning the mining past operation shall be issued only by the mine foreman or the person designated by him to be in charge.

10) The above mining procedures and a drawing of the area will be reviewed with all personnel involved in the mining through operation prior to approaching the well. Additionally, the entire shift that the mine-by is expected to occur will be apprised of this situation.

11) Each working section shall post a person at the mine phone while mining in the zone.

12) A copy of the approved plan is to be posted in the section.

13) No personnel shall be in remote locations of the mine without communication while mining is being conducted within the zone.

14) DEP shall be notified 48 hours prior to entering the zone.

- D: References

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