SECTION V: Effects of Mining on Structures

V.A - Overview

The University collected information on the structures in the proximity of active underground coal mines between August 21, 2003 and August 20, 2008. The structures that met the PA DEP criteria for tracking were entered into the UGISdb and are explained within this section.

A total of 3,735 structures were tracked. Four-hundred-fifty-six reported effects were found, each required additional information and analysis (Appendix B1). Another 26 were analyzed from the 2nd assessment period for a total of 482 reported effects analyzed (Appendix B2). The majority of the reported effects were associated with the eight longwall mines. Characteristics of the structures were analyzed and discussed, with special attention to those with reported effects. The number of undamaged and reportedly damaged structures (i.e., dwelling, barn, commercial building, etc.) undermined during the assessment period were listed. Lastly, the resolution status and type of resolution were analyzed for all structure reported effects.

V.B - Data Sources

The impacts of undermining during the assessment period were determined by examining the following sources: 1) BUMIS reports, 2) 6-month mining maps submitted to the CDMO by mine operators, 3) paper files at the CDMO, 4) damage reports faxed to the CDMO by mine operators, 5) interviews with technical staff at the CDMO, 6) Subsidence Act (SA) reports, and 7) company supplied AutoCAD mine maps. All of the University's analysis was organized by mining type and category of structure.

The University determined the precise distance from mining to each structure as well as the overburden and topographic conditions. Agent Observations and Problem Tables in BUMIS supplemented observed conditions in the field. Structures with reported effects were compared to mining maps within the University GIS database. From these data several related conditions were assessed and summarized within this section.

V.B.1 - Structures Tracked

Pennsylvania law requires that approved subsidence control plans contain information about structures that will be undermined. In some cases, the size of the structure must be considered for tracking to occur. Performance standards for subsidence control are set forth in Pennsylvania Code, Title 25, Chapter 89.142a. The parts of the code of particular relevance to this report are summarized in Sections V.B.1.a to V.B.1.d.

V.B.1.a – Overburden Less Than 100-ft

§ 89.142a, requires the mine to maintain stability beneath structures when mining under overburden less than 100-ft.

V. B. 1. b. – Pre-mining Surveys

§ 89.142b, requires the mine operator to conduct pre-mining surveys of:

- Dwellings,
- Buildings accessible to the public,
- Noncommercial buildings customarily used by the public, and
- Barns, silos, and certain agricultural structures.

The surveys must be conducted prior to the time the structure lays within a 30-deg angle of the underground mine. Surveys must describe the pre-mining condition of the structure and, if the structure is historically or architecturally significant, the presence of any architectural characteristics that will require special craftsmanship to restore or replace.

V.B.1.c – Mining Beneath Structures and Features

§ 89.142c, the default standard for mining beneath structures and features is 50-pct coal support, although the PA DEP may require a greater percentage. Subsection (c) also clarifies alternatives to the coal support standard including surface measures which may be undertaken in conjunction with planned and controlled subsidence.

V.B.1.d – Prohibition on Irreparable Damage to Dwellings and Agricultural Structures Greater Than 500-ft^2

§ 89.142d, prohibits a mine operator from mining in a manner which would cause irreparable damage to dwellings and permanently affixed appurtenant structures, barns, silos, and certain permanently affixed structures of 500-ft^2 or more used for agricultural purposes. The proposed mining can occur if the mine operator obtains the consent of the structure owner to allow the damage to occur. Alternatively, the proposed mining can proceed if the mine operator, prior to mining, implements measures approved by the Department to minimize or reduce the irreparable damage which would result from subsidence.

V.B.2 – The 200-ft Buffer

The University used a 200-ft buffer zone around all areas mined during the 3rd assessment period as a basic criterion for inventorying structures. The buffer starts at the edge of the mined area and extends outward 200-ft. The buffer, constructed in ArcGIS, was used to determine if an individual structure fell within 200-ft of mining. Appendix C contains figures with the 200-ft buffer for each of the 50 operating mines discussed in this report.

V.B.3 – University's Process for Tracking Structures

To comply with the standards discussed above, the University developed a process to compile and categorize information about structures. This process contained seven steps:

> Step 1 - BUMIS data from the 50 mining operations active during the 3rd assessment period were extracted by the University using available query techniques.
>
> Step 2 – Other map sources, i.e. 6-month mining maps, subsidence control maps, mining company supplied AutoCAD files, etc., were searched. When data initially not found

during Step 1 was discovered, the locations of these structures were added to the UGISdb.

Step 3 – Information about each structure was collected and entered into the UGISdb. This information consisted of the following:

- Property Owner (name),
- Property ID (number),
- Property Number (typically the tax ID),
- County,
- Feature ID,
- Feature Number (number),
- Feature Type (dwelling, trailer, garage, cemetery, building, barn, silo, shed or outbuilding, bridge, driveway, grain bin, milk house, storage truck, tower, pool, septic tank, chicken coop, reservoir, dam, springhouse, and Rail Road sub-station),
- Feature Use (Residential, Recreational, Agricultural, Community/Institution, Public, Commercial, Industrial, and Unknown), and
- Problem (Yes or No).

Step 4 – Additional attributes for each structure contained within the UGISdb were analyzed. Characteristics identified and measured included the following:

- Topographic Location (valley bottom, hillside, hilltop),
- Mining Method (room-and-pillar, longwall panel or pillar recovery),
- Distance from Mining (feet),
- Overburden (feet), and
- Area (square feet).

Step 5 – Structures with reported effects occurring within the 3rd assessment period or before the 3rd assessment period but resolved during the period were identified. Special characteristics about these structures were entered into the UGISdb. These characteristics included:

- Reported Effects ID (number),
- Occurrence of Additional Reported Effects (number),
- Claim ID (structure assessment number),
- Cause (mining or other),
- Description of the Reported Effect,
- Occurrence Date,
- Intermediate Resolution Date,
- Final Resolution Date, and
- Resolution Status.

Step 6 – The extent of mining information discussed in Section III were utilized to establish a 200-ft buffer around the areas mined during the 3rd assessment period. All structures that fell outside the 200-ft buffer zone were eliminated with one exception.

That exception is as follows -- if a structure was associated with a reported effect within or prior to the 3rd assessment period, it was retained within the UGISdb.

Step 7 – The size of each structure was calculated and those that didn't meet the minimal square footage requirements ($\geq$ 500-ft^2) as outlined in § 89.142a (f)(1)(v) were eliminated with several exceptions. These exceptions to this size restriction were dwelling, garages, barns, silos, public and commercial buildings and towers, churches, and cemeteries.

The following analysis presents information from structures that passed these seven steps.

V.C – Summary Information about Structures Undermined During the 3rd Assessment Period

Impacts to structures from undermining are influenced by many factors. For example, the most effective means to minimize impacts is to leave protective or safety pillars. Section IV discusses the regulation and standards that define the characteristics of these safety pillars. In other cases, full extraction mining occurs and the pillars are removed to increase extraction rates. When this happens, planned subsidence is expected to follow. In Pennsylvania, two mining methods typically produce planned subsidence; longwall and pillar recovery. No structures were located over the six room-and-pillar mines with pillar recovery during the 3rd assessment period.

The fifty longwall and room-and-pillar mines undermined 3,735 structures with 456 structures reporting effects during the 3rd assessment period (Table V-1). Longwall mines have a higher percent of reported effects, 23.0-pct, than room-and-pillar mines, 1.5-pct.

Table V-1 - Summary of the number of structures, reported effects, and percentage of reported effects sorted by mining type occurring during the 3rd assessment period.

Mining Type	Undermined Structures	Reported Effects*	Percent with Reported Effects
Longwall	1,856	427	23.0
Room-and-Pillar	1,879	29	1.5
Total	3,735	456	12.2

* - Some structures had more than one reported effect.

Of the 456 reported effects, 301 were Company Liable representing 66.0-pct of the total. In addition, 59 were Company Not Liable accounting for 12.9-pct and 96 Unresolved for 21.1-pct of the total (Table V-2). Unresolved reported effects often had interim resolutions. The most striking trends from this table are the high percentage of Company Liable reported effects for longwall mines (70.2-pct), and the high percentage of Unresolved reported effects for room-and-pillar mines (72.4-pct). The higher percentage Company Liable reported effects are most likely related to the formation of subsidence basins associated with longwall panel extraction, while the higher percentage of Unresolved room-and-pillar cases occurred late in the 3rd assessment period.

Table V-2 - Summary of the resolution status sorted by mining type.

Mining Type	Company Liable	Percent Company Liable*	Company Not Liable	Percent Company Not Liable*	Unresolved	Percent Unresolved
Longwall	300	70.2	52	12.2	75	17.6
Room-and-Pillar	1	3.5	7	24.1	21	72.4
Total	301	66.0	59	12.9	96	21.1

* - based on all reported effects

V.C.1 – Features Undermined

Within BUMIS, the PA DEP categorizes structures by feature type. Thirty-one feature types are associated with the 3,735 undermined structures. The ten most common feature types are shown in Table V-3. All dwellings, garages, barns, trailers, buildings, silos, cemeteries, churches, and schools within the 200-ft buffer zone around mining or having a reported effect are tracked within the University's database. All other feature types must have the minimum area requirements of 500-ft^2 or are associated with a reported affect. Three-hundred-and-sixty-six structures, or 9.8-pct of the total, are classified as unknown.

Table V-3 – The ten most common structural features undermined.

Feature Type	Number	Percent Total
Dwelling	1,502	40.2
Garage	593	15.9
Barn	357	9.6
Shed	264	7.1
Trailer	230	6.2
Outbuilding	169	4.5
Building	95	2.3
Silo	35	0.9
Pool	32	0.9
Septic Tank	21	0.6
Total	3,298	88.1

V.C.2 – Notable Structural Features Undermined

Notable structural features undermined (< 0.5-pct of total) are cemeteries, towers, churches, schools, bridges, and dams.

V.C.2.a – Cemeteries

Eleven cemeteries were inventoried at four longwall mines. In general, these cemeteries were very small with an average of 2,771-ft^2. Five of the cemeteries were directly over longwall panels, four were over gate road entries, and two were outside of mining but within the 200-ft buffer zone. Only one cemetery reported an effect and it had a private waiver for damages.

V.C.2.b – Towers

Eleven towers were inventoried. Towers can range in function from supports for high-voltage transmission lines to transmission towers. For example, a high-voltage transmission lines cross the Beaver Valley Mine partially within the 200-ft mining barrier. At this site, the mine did not directly undermine these structures (Figure V-1a). Other mines with towers included Cumberland, Emerald, Enlow Fork, High Quality, and Eighty-Four. One tower over the Emerald Mine was reported to have been impacted by longwall mining causing it to be out of level (Figure V-1b). Subsidence impacts were mitigated with banding techniques (Figure V-1c, also see Section V.F.1).

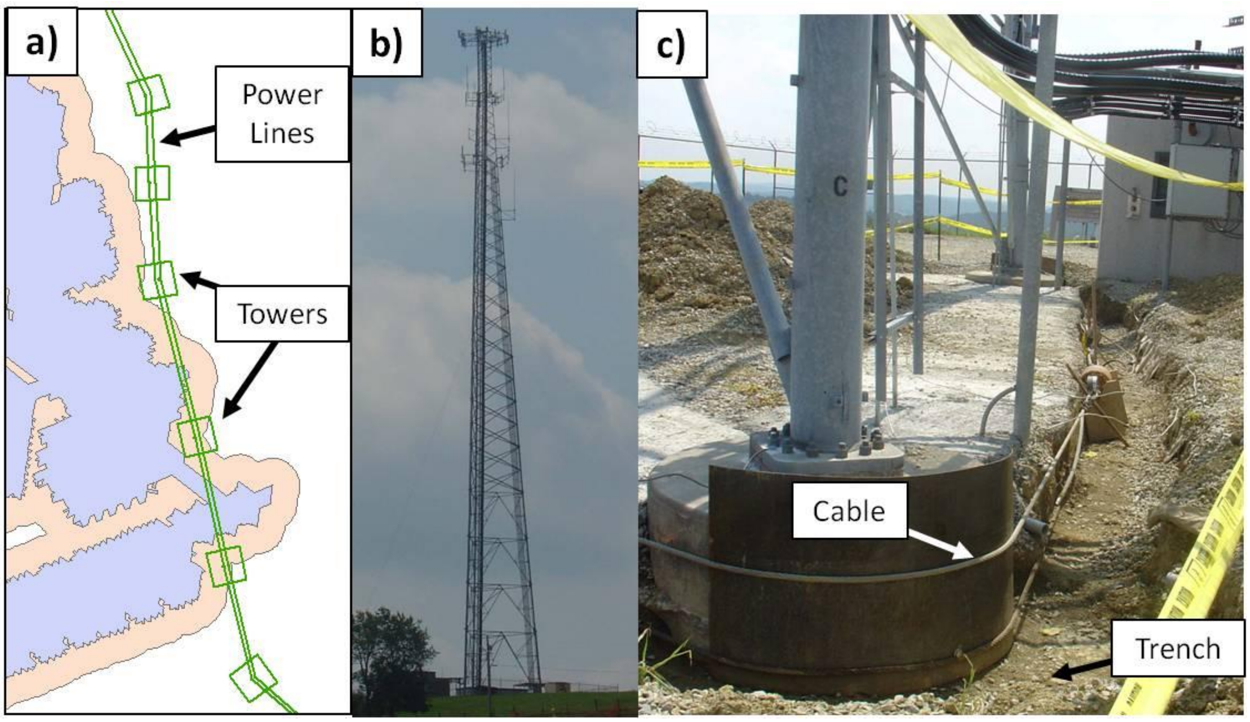

Figure V-1 – Map and photographs of a) the power lines crossing the Beaver Valley Mine, b) the transmission tower over the Emerald Mine, and c) banding to mitigate subsidence impacts (Photographs from PA DEP files).

V.C.2.c – Churches

Two churches were inventoried. One church, located in the 200-ft buffer zone, was not directly undermined by Mine Eighty-Four. A second church was undermined by a Bailey Mine longwall panel and had a reported effect. Foundation cracks were observed and an unspecified agreement was reached between the company and the land owner.

V.C.2.d – Schools

Six schools were inventoried. Five of the schools were undermined by room-and-pillar mines and one school was located in the 200-ft buffer zone. Two of the schools were community based and were relatively small in scale averaging 1,000-ft^2. The other four schools were public and were much larger averaging over 53,000-ft^2. No reported effects occurred to these six schools.

V.C.2.e – Bridges

Four bridges were inventoried. Two of the bridges were residential, one was community, and one was public. Three of the bridges were located directly over longwall panels. The fourth was above the longwall gateroad entry system. No reported effects occurred to these four bridges.

V.C.2.f – Dams

Two dams were inventoried. The larger and more significant of the two was the Ryerson Station Dam, constructed by the PA Department of Conservation and Natural Resources (DCNR) in 1960, creating a 62-acre recreational lake. The DCNR claimed that the mining operations to the northeast impacted the dam. The nature of damages were documented in the PA DEP Interim Report entitled "Ryerson Station Dam Damage Claim Number SA 1736," published on February 16, 2010. The report stated that during late spring and early summer of 2005, significant movements and structural damages occurred as longwall mining operations occurred in the vicinity of the dam (Figure V-2a). The PA DEP's Division of Dam Safety ordered DCNR to drain the Duke Lake and breach the dam to prevent further impounding of water in the reservoir (Figure V-2b). The PA DEP Interim report concluded that longwall mining operations did result in ground movements which damaged the Ryerson Station Dam. The mine operator claimed their longwall mining activity occurred at sufficient distances to not impact the dam. A final resolution is pending.

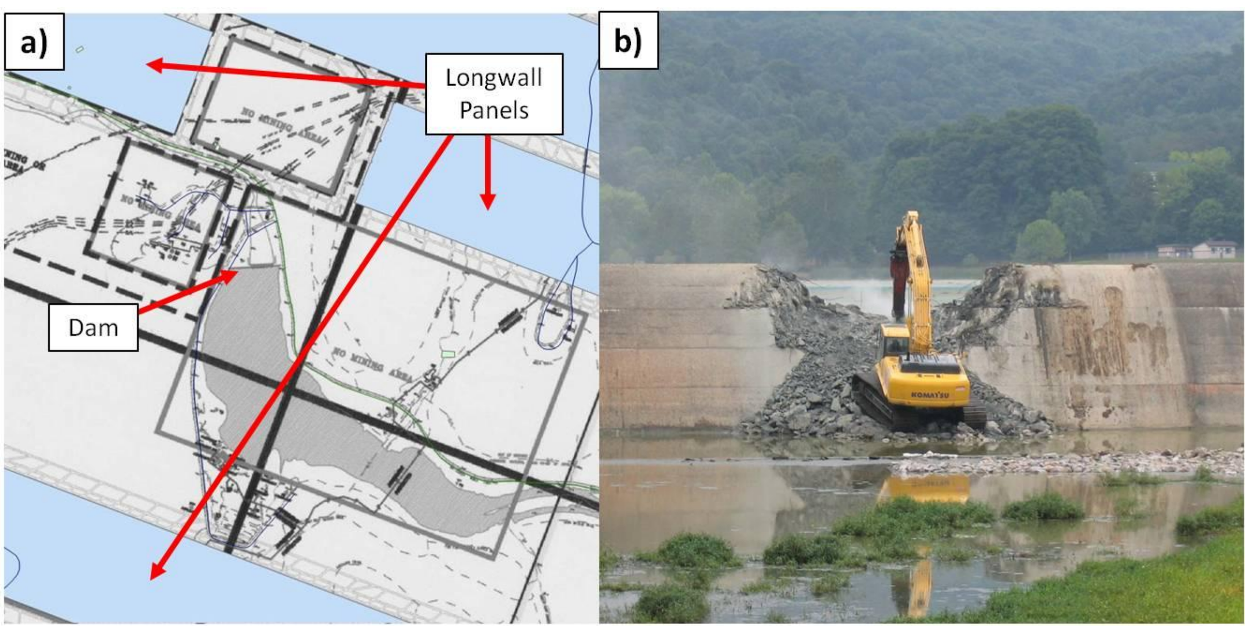

Figure V-2 – a) Map of the longwall panels in the vicinity of the dam and b) photograph of the dam in the act of being breached (Photograph from PA DEP files).

V.D – Structures and Longwall Mining

Longwall mining is an important underground bituminous coal extraction method in PA, accounting for 64-pct of all the acres mined (Table III-5). It also accounts for 50–pct of the structures undermined and 93.6–pct of the structures with reported effects (Table V-1).

V.D.1 – Structures Undermined

During the 3rd assessment period, 1,856 structures were undermined by longwall mines (Table V-4). Enlow Fork had the most structures undermined with 507 and Shoemaker the least with six. The number of structures was influenced by the proximity of the mine to populated areas. For example, the Bailey Mine had 216 structures spread over 6,311 acres (Table III-9) in rural Greene County. The average acres-per-structures ratio for Bailey Mine was 29.2. In contrast, the High Quality Mine had 218 structures over 501 acres (Table III-9) and Mine Eighty-Four had 321 structures over 1,984 acres (Table III-9) both in northern Washington County. The acres-per-structure ratios for these mines were 2.3 and 6.2 respectively. The average acres-per-structure for all longwall mines was 14.2.

Table V-4 - Number of structures undermined and acres-per-structure, sorted by longwall mine (see Table III-9 for acreage data).

Mine Name	Total Structures Undermined	Acres-per-Mine	Acres-per-Structure
Bailey	216	6,311	29.2
Blacksville No.2	125	2,880	23.0
Cumberland	224	3,665	16.4
Eighty-Four	321	1,984	6.2
Emerald	239	2,855	11.9
Enlow Fork	507	6,339	12.5
High Quality	218	501	2.3
Shoemaker	6	72	12.0

V.D.2 – Structures with Reported Effects during the 3rd Assessment Period

Of 1,856 structures undermined by longwall mines, 427 had reported effects in BUMIS (Table V-5). Mine Eighty-Four had the highest number with 126 and Shoemaker had the lowest with zero. One way to evaluate the relative degree of structures with reported effects is to evaluate the acres-per-reported effects ratio for each mine. The High Quality Mine and Mine Eighty-Four had a much higher rate of reported effects, with 14.7 and 15.7 respectively, than the other six longwall mines (Table V-5). These two mines were the closest to the Pittsburgh metropolitan area (~ 25 miles south of downtown Pittsburgh) where there was less farm land and more residential development.

Table V-5 - Structures with reported effects sorted by mine.

Mine Name	Reported Effect*	Acres-per-Mine	Acres-per-Reported Effect
Bailey	53	6,311	119.1
Blacksville No.2	16	2,880	180.0
Cumberland	41	3,665	89.4
Eighty-Four	126	1,984	15.7
Emerald	42	2,855	68.0
Enlow Fork	115	6,339	55.1
High Quality	34	501	14.7
Shoemaker	0	72	
Total	427		

* - Twenty structures had two reported effects

Another way to evaluate the relationship between structures and reported effects is to compare the relative percentages of each mine (Figure V-3). The mines with the highest percentage of reported effects are Mine Eighty-Four with 39-pct, the Bailey Mine with 25-pct, and the Enlow Fork Mine with 23-pct. The mines with the lowest percentages are the Cumberland Mine with 18-pct, the Emerald and High Quality Mines with 16-pct, the Blacksville No.2 Mine with 13-pct, and the Shoemaker Mine with zero.

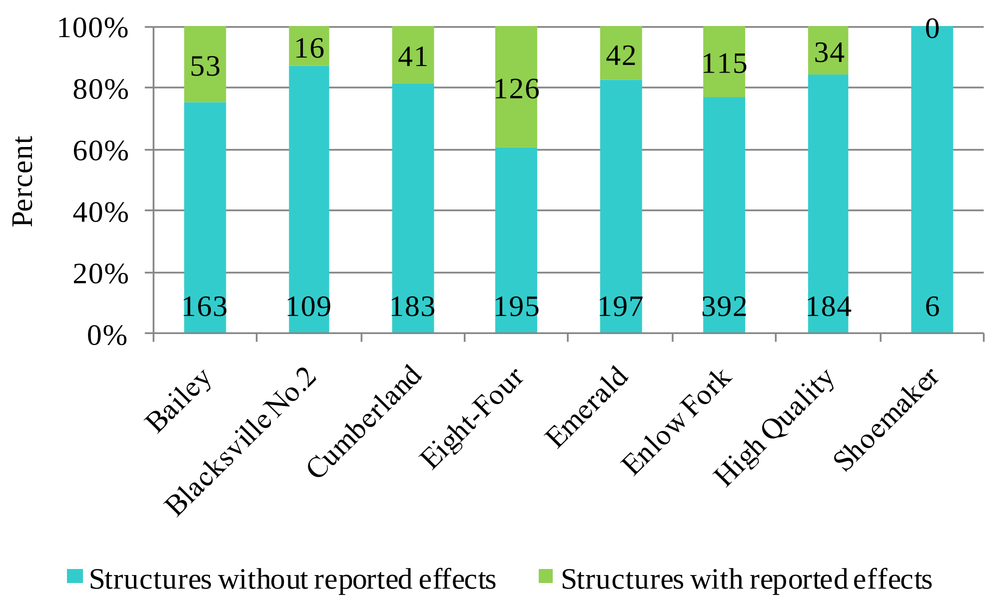

Figure V-3 - Relationship between structures with and without reported effects, sorted by mine.

V.D.3 – Relationship between the Position of Structures with and without Reported Effects and Position with Respect to the Longwall Panel

This report describes the various characteristics of Pennsylvania’s supercritical longwall subsidence basins (Sections I and IV). Surface strains and corresponding stresses are related to the position occupied in the subsidence basin (Agioutantis, et al., 1988 and Karmis, et al., 1992). To help illustrate this, a typical supercritical longwall panel is sectioned into components (Figure

V-4). A longwall panel is a large block of coal where mining is focused along one end. This is called the longwall face. Surrounding the longwall panel are room-and-pillar mining sections. These sections are functionally distinct and referred to as the main entries, bleeders and gate road entries. The longwall mining panel can be thought of containing two geometric parts: mid- and quarter-panels (Figure V-4). For supercritical panels, the most horizontal strain and greatest permanent alteration of the surface curvature should occur within the quarter-panel areas. Structures in the mid-panel areas typically experience 1) significant short-term dynamic subsidence as the longwall face passes underneath, 2) small long-term excessive horizontal strains, 3) non-permanent alteration of surface curvature and, 4) a permanent drop in elevation as the subsidence basin stabilizes. Much less strain and surface curvature changes, like those experienced over the quarter-panel section, are expected over the adjacent room-and-pillar mining areas, i.e. mains, bleeders, and gate road entries.

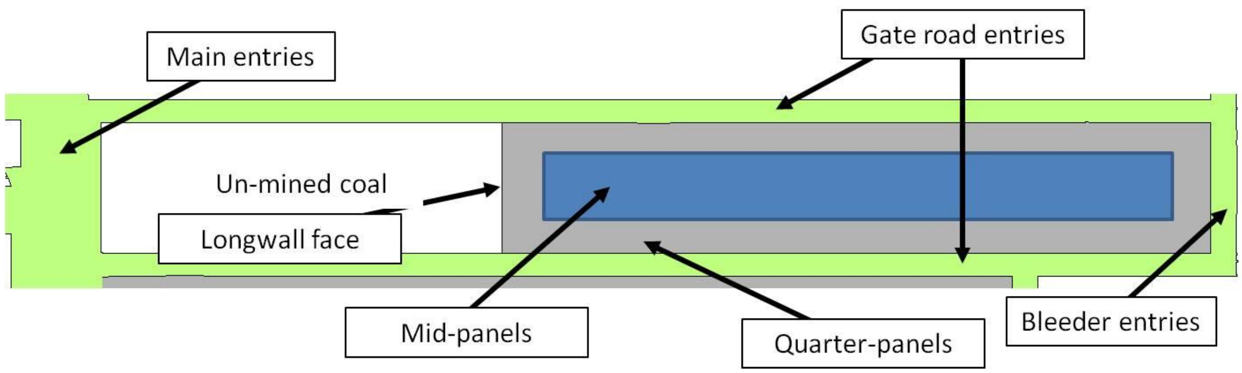

Figure V-4 – Conceptual drawing shows the two geometric components of a longwall panel (mid- and quarter-panels) and the three functional components of the room-and-pillar (main, bleeder, and gate road entries) mining methods.

The University identified the location of each structure with respect to the underlying mining method (Table V-6). The two longwall panel parts, i.e. quarter-panel and mid-panel, were listed separately, while all structures overlying main, bleeder, and gate road entries and within 200-ft of these areas were listed under the room-and-pillar category (Table V-6). Any structure beyond the 200-ft mining buffer was listed as outside current mining. Note the relatively high number of structures with reported effects in both categories of the longwall panels and that both categories have similar percentages. It is also worth noting that the category of Outside Current Mining produced a high percentage of reported effects for Room-and-Pillar Mining.

Table V-6 – Occurrence of reported effects based on the position with respect to mining method.

	Longwall		**Room-and-Pillar**	**Outside Current Mining**	**Total**
	Quarter-Panel	**Mid-Panel**			
Structures without Reported Effects*	347	297	351	419	1,414
Structures with Reported Effects**	147	122	36	103	408
Percent Reported Effects	29.8-pct	29.1-pct	9.3-pct	19.7-pct	
Total	494	419	387	521	1,822**

* - A total of eight structures could not be located
** - Structures with two reported effects were counted only once
*** - Structure undermined during the 2nd assessment period with unresolved reported effects were not counted

If the mid- and quarter panel categories are combined into one panel category and compared to the structures in the room-and-pillar category, a significant difference is observed (Figure V-5). Thirty percent of structures over longwall panel areas had reported effects, whereas nine-pct of structures over room-and-pillar mining areas had reported effects. These trends demonstrate the influence of the subsidence basin over the panel on structures with reported effects compared to conditions over the adjacent room-and-pillar areas.

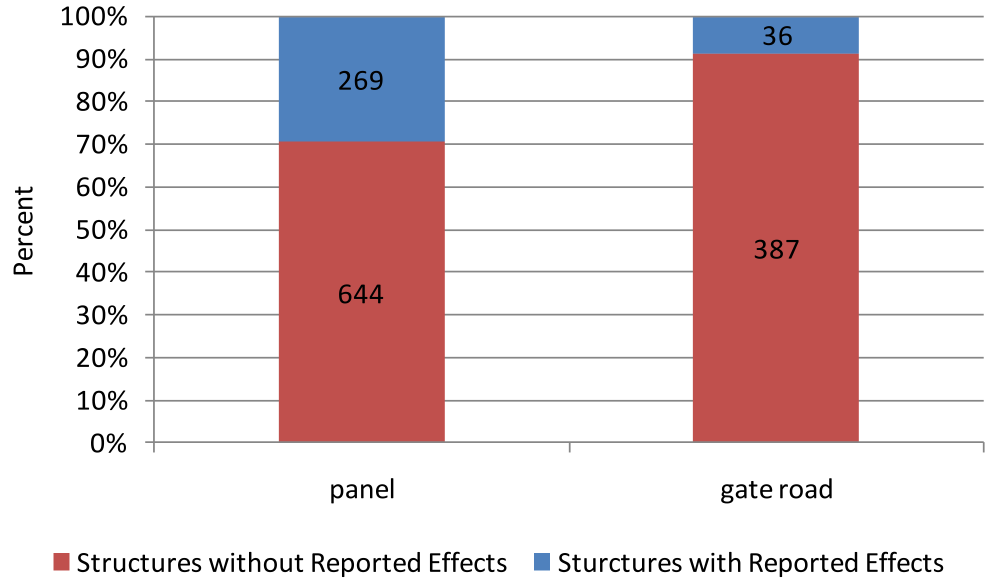

Figure V-5- Relationship between structures with and without reported effects as per mining method.

V.D.4 – Relationship between the Position of Structures with and without Reported Effects and Topography Conditions

The University identified the location of all structures with respect to its topographic condition. Each structure was placed in one of three topographic categories; hillside, valley bottom, and hilltop (Table V-7). The majority of the structures were located on hillsides, followed by valley bottom and hilltop.

Table V-7 – Occurrence of reported effects based on the topographic position.

	Hillside	Valley Bottom	Hilltop	Could Not Determine	Total
Structures without Reported Effects	629	513	270	7	1,419
Structures with Reported Effects	189	130	82	1	433
Percent Reported Effects	23.1-pct	20.2-pct	23.3-pct		
Total	818	643	352	9	1,856

The analysis of the topographic conditions of structures undermined did not show any significance. The percentage of structures with and without reported effects over hillsides, valley bottoms, and hilltops lay within a tight range of 20.2 to 23.3-pct (Figure V-6).

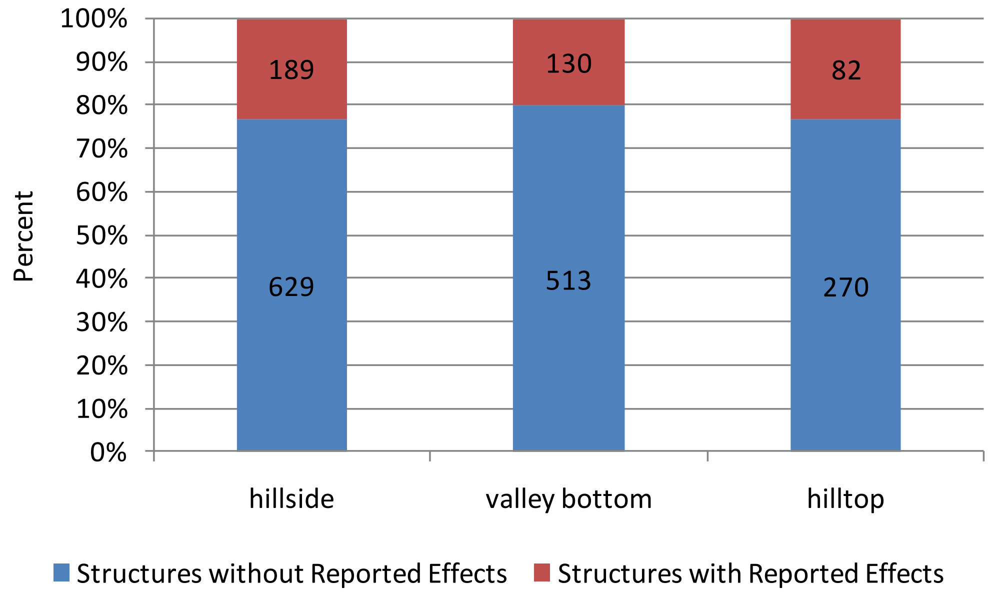

Figure V-6 - Relationship between structures with and without reported effects and topography.

V.D.5 – Days to Resolve Reported Effects

When an effect was reported, it was logged into the BUMIS database and an occurrence date was assigned. The discovery of a potential subsidence-related structure impact was not necessarily at the same time as the date of occurrence listed in BUMIS. This date was established when a reported effects case was logged into BUMIS. Regulations allowed the operator up to 10 days to file a report.

The University collected information related to the date of occurrence, interim resolution, and final resolution for every reported effect. There were 427 reported effects during the 3rd assessment period with 352 final resolutions. It took an average of 238 days to reach a final resolution on these cases (Table V-8). Seventy-five of these reported effects did not have a final resolution as of August 20, 2008. The 289 interim resolutions took an average of 107 days.

Table V-8 – Days to resolve reported effects for longwall mines.

	Interim Resolution	Final Resolution
Mean	107	238
Standard Deviation	219	281
Median	22	132
Minimum	0	0
Maximum	1,470	1,496
Number Resolved	289	352
Number Unresolved		75

V.D.6 – Resolution Status of Reported Effects

The resolution status at the end of the 3rd assessment period is presented in Table V-9. Of the 352 final resolutions, 85-pct, or 300, were assigned as Company Liable. The other 15-pct, or 52, were assigned as Company Not Liable. Of the remaining 75 reported effects, 63 had an interim resolution but no final resolution and 12 had an outstanding reported effect with no interim resolution (Table V-9).

Table V-9 - Resolution status at the end of the 3rd assessment period for all reported effects sorted by longwall mine.

Mine Name	Resolved		Unresolved		Total
	Company Liable	Company Not Liable	Interim Resolution	Outstanding Reported Effect (No Interim Resolution)	
Bailey	33	6	11	3	53
Blacksville No.2	11	2	2	1	16
Cumberland	26	7	5	3	41
Eighty-Four	91	12	19	4	126
Emerald	27	9	6	0	42
Enlow Fork	92	4	19	0	115
High Quality	20	12	1	1	34
Shoemaker					
Total	300	52	63	12	427

V.D.6.a – Final Resolution Status

For the 300 structures with reported effects where the company was found liable (Table V-10), the most common final resolution at 31-pct was for the company to purchase the property. Next was the unspecified resolution at 27-pct, where a private agreement was reached with the landowner and the details of the agreement were not made public. In 23-pct of the cases, the company compensated the land owner in some fashion. Pre-mining agreements were used in 12-pct of the company liable cases. The company performed repairs to a structure in only 6-pct of the liable agreements.

Table V-10 - Status of longwall mining final resolution where the company was liable.

Mine Name	Pre-mining	Unspecified	Appended to Another Case	Company Purchased Property	Compensated or Resolved	Repaired	Total
Bailey	5	6	2	7	13		33
Blacksville No.2		7		2	1	1	11
Cumberland	2	13		8	1	2	26
Eighty-Four	10	14		41	20	6	91
Emerald		17		5	1	4	27
Enlow Fork	14	23		30	24	1	92
High Quality	5	2			8	5	20
Shoemaker							
Total	36	82	2	93	68	19	300

For 52 structures with reported effects, the company was found not liable (Table V-11). The most cited reason for no liability was Not Due to Underground Mining with 77-pct of the total. Other less used reasons were Withdrawn (11.5-pct), No Actual Reported Effect (7.7-pct), and no Liability (3.8-pct).

Table V-11 - Status of longwall mining final resolution where the company was not liable.

Mine Name	With-drawn	No Actual Reported Effect	No Liability	Not Due to Underground Mining	Total
Bailey		1		5	6
Blacksville No.2			1	1	2
Cumberland	3			4	7
Eighty-Four	1			11	12
Emerald	2			7	9
Enlow Fork			1	3	4
High Quality		3		9	12
Shoemaker					
Total	6	4	2	40	52

V.D.6.b – Interim Resolution Status

Interim resolutions were an important tool for tracking the progress of a reported effect. Sixty-three interim resolutions were distributed in seven categories (Table V-12). The most popular interim resolution was currently monitoring with 51-pct of the totals. In many of these cases, visual observations or output from instrumentation was used to monitor important characteristics of the structure that were needed to arrive at a final resolution. Currently monitoring can also imply that mitigation measures were being applied (see Section V.F). The other six interim resolutions were used less frequently. For example, additional time may be needed to make sure the full impact of undermining can be assessed. In these cases, the interim resolution was listed as Awaiting Additional Effects. In Negotiation and Pending Owners Approval implied that a resolution is imminent. An interim resolution of Temporary Repairs implied that some work is being done in preparation of a permanent fix. Lastly, Unresolved implied a resolution was not imminent.

Table V-12 - Status of interim resolution where the company was liable.

Mine Name	P[1]	AAE[2]	CM[3]	IN[4]	POA[5]	TR[6]	U[7]	Total
Bailey	4		6			1		11
Blacksville No.2							2	2
Cumberland				1	1	3		5
Eighty-Four	1	3	6	1	1	3	4	19
Emerald			4		2			6
Enlow Fork		3	16					19
High Quality							1	1
Shoemaker								
Total	5	6	32	2	4	7	7	63

P[1] = Pending; AAE[2] = Awaiting Additional Effects; CM[3] = Currently Monitoring; IN[4] = In Negotiation; POA[5] = Pending Owner Approval; TR[6] = Temporary Repairs; and U[7] = Unresolved

V.D.6.c – Outstanding Reported Effects at the End of the 3rd Assessment Period and Reported Effects Occurring in the 2nd Assessment Period

There were 12 reported effects with no interim or final resolution at the end of the 3rd assessment period (Table V-13). Their date of occurrence ranged from July 20, 2004 until April 15, 2008, with an average length of time to the end of the assessment period of 689 days. This indicated that these reported effects had been particularly difficult to solve. The Emerald and Enlow Fork Mines did not have any outstanding reported effects.

Table V-13 – Summary of cases for longwall mines where there is no interim or final resolution at the end of the 3rd assessment period.

Mine Name	Outstanding Reported Effects
Bailey	3
Blacksville No.2	1
Cumberland	3
Eighty-Four	4
Emerald	0
Enlow Fork	0
High Quality	1
Shoemaker	0
Total	12

V.D.6.d – Relationship between a Structure's Distance from a Longwall Panel and Reported Effects Resolution Category

The University determined the distance of each structure from the edge of the closest longwall panel. With this information and the overburden data, the projection angle every structure makes with the edge of the closest longwall panel can be determined. When the angle is zero degrees, the structure is located directly above a longwall panel. As the structure becomes more distant from the panel, the angle increases. Increases in overburden have an opposite effect. As the overburden increases with respect to a fixed distance from the edge of the panel, the projection angle decreases. Deformations associated with the longwall subsidence basin generally diminish rapidly as the distance from the panel increases. It is therefore reasonable to expect less impact to structures as the distance from a longwall panel increases; however, many factors can create exceptions to this rule. Some of these factors are the stiffness or strength of the overburden, the slope of the surface, the thickness of the colluviums (or soil) layers, and the magnitude and direction of the in-situ horizontal stress field.

The relationship between the structure's distance from a longwall panel and the reported effects resolution category can be determined using the projection angle discussed above. This relationship provides insight as to what resolution outcome can be expected as the projection angle increases. Figure V-7 shows that a significant percentage of structures from every resolution category were located directly over the longwall panel, i.e. zero-deg projection angles. When the entire spectrum of resolutions were examined, it was clear that Repaired and Pre-Mining final agreements occur most often when structures were located very near to a longwall panel (< 35-deg). Conversely, when the projection angle is large (> 35-deg), companies more often resorted to Compensation and Company Purchased Property as a final resolution.

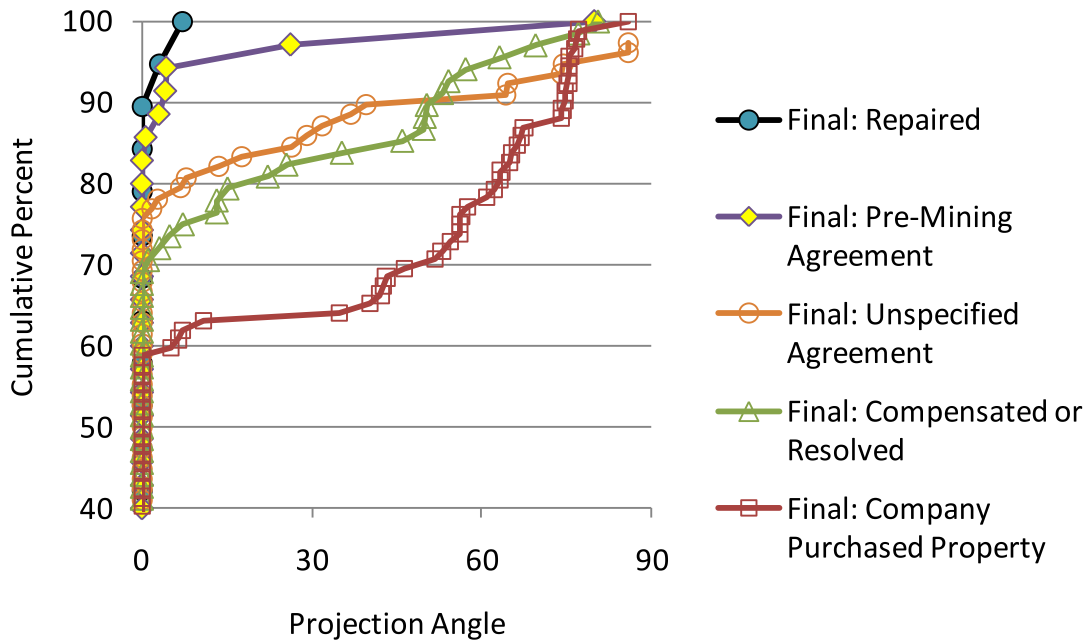

Figure V-7 – Relationship between projection angles and resolution category. Each data point represents the angle between the structure and the edge of mining.

V.D.7 – Resolved Reported Effects from the 2nd Assessment Period

Twenty-six structures from the 2nd assessment period were resolved during the 3rd assessment period. All of these reported effects were from longwall mines. The Bailey Mine had the most cases with 12 followed by Enlow Fork with seven, Cumberland with three, Eighty-Four with two, and Blacksville No.2 and High Quality with one each. It took an average of 643 days to resolve these cases with a minimum of 199 and a maximum of 1,175 days (Table V-14). All of these reported effects were found to be Company Liable.

Table V-14 – Days to resolve reported effects from the 2nd assessment period.

	Final Resolution
Mean	643
Standard Deviation	324
Median	509
Minimum	199
Maximum	1,175
Number Resolved	26
Number Unresolved	0

V.E – Structures and Room-and-Pillar Mining

Room-and-pillar mining is an important mining method in Pennsylvania, accounting for 36-pct of all the acres mined (Table III-5, Section III). It also accounts for 50–pct of the structures undermined but only 6.4–pct of the structures with reported effects. This is largely due to the pervasive use of "safe" pillar designs that minimize unplanned mine subsidence.

V.E.1 – Structures Undermined

During the 3rd assessment period, 1,879 structures were undermined by 42 room-and-pillar mines (Table V-15). The structures were not uniformly distributed over these mines. For example, the Clementine Mine had the most with 307 and Dunkard No.2 and TJS No.4 had the least with zero structures undermined. Table V-13 also shows the average acres-per-structure for all room-and-pillar mines. Mines with the densest concentration of structures (less than five acres-per-structure) were Agustus, Clementine No.1, Darmac No.3, Miller, Parkwood, Rampside, Ridge, Sarah, Toms Run, Twin Rocks, and Windber No.78. Mines with the lowest concentration of structures (greater than 20 acres-per-structure) were Crawdad No.2, Dooley Run, Josephine No. 3, Little Toby, Madison, Penfield, and Triple K No.1. Two mines, Dunkard No.2 and TJS No. 4 did not undermine structures during the 3rd assessment period. The average acres-per-structure for all room-and-pillar mines was 14.5, very similar to the 14.1 average for all longwall mines.

Table V-15 - Number of structures undermined and acres-per-structure, sorted by room-and-pillar mine (see Table III-8 and Figure III-8 for acreage data).

Mine Name	Total Structures Undermined	Acres-per-Structure	Mine Name (continued)	Total Structures Undermined	Acres-per-Structure
4 West (PR)	56	7.4	Nolo (PR)	124	7.5
Agustus	36	3.1	Ondo	96	6.1
Beaver Valley	47	7.5	Parkwood	48	3.7
Cherry Creek	54	9.9	Penfield	8	29.4
Clementine No.1	307	3.7	Penn View	17	17.7
Crawdad No.2 (PR)	4	103	Quecreek	83	8.3
Darmac No.2	44	5.1	Rampside	3	1
Darmac No.3	8	1.3	Ridge	28	3
Dooley Run (PR)	1	30	Rossmoyne	23	9.6
Dora No.8	26	14.7	Roytown	34	7.6
Dunkard No.2 (PR)	0	ND	Sarah	4	2
Dutch Run	54	11.9	Stitt	26	7.2
Genesis No.17	11	19.9	Titus (PR)	14	18.6
Geronimo	24	19.2	TJS No.4	0	ND
Gillhouser Run	8	18.3	TJS No.5	13	8.9
Josephine No.3	2	71.5	TJS No.6	7	9.9
Keystone East	81	5.3	Toms Run	16	3.1
Little Toby	22	25.1	Tracy Lynne	124	5
Logansport	71	13.2	Triple K No.1	4	25.8
Madison	16	29.9	Twin Rocks	172	3.3
Miller	100	1.6	Windber No.78	62	2.4

ND – Not determined because no structures are present

PR – Room-and-pillar mines with pillar recovery (all structures are over room-and-pillar mining areas, none are over pillar extraction areas)

V.E.2 – Structures with Reported Effects

Of 1,879 structures undermined by room-and-pillar mines, 29 had reported effects (Table V-16). Seven mines had structures with reported effects. Clementine No.1 had the highest number with 15. Thirty-six room-and-pillar mines had no structures with reported effects during the 3rd assessment period.

Table V-16 - Structures with reported effects sorted by mine.

Mine Name	Total Structures	Structure with Reported Effects
Clementine No.1	307	15
Ondo	96	5
Tracy Lynne	124	3
Ridge	28	2
Stitt	26	2
Josephine No.3	2	1
Triple K No.1	103	1
Total	686	29

V.E.2.a – Resolution Status of Reported Effects

Of the 29 reported effects, eight had a final resolution with one Company Liable and seven had Company Not Liable (Table V-16). The average days to resolution for these seven reported effects was 107. There were a large percentage of reported effects listed as interim resolutions and outstanding. Three mines contained all 18 of these reported effects, Clementine No.1, Ondo, and Tracy Lynne. All of the 18 interim resolutions and three outstanding reported effects occurred after April 4, 2007. The average days to the interim resolution was 47.

Table V-17 - Resolution status of all reported effects sorted by room-and-pillar mine.

Mine Name	Final Resolution			Interim Resolution	Outstanding Reported Effect (No Interim Resolution)	Total
	Company Liable	Company Not Liable	Day to Resolution			
Clementine No.1		2	41 & 134	13		15
Ondo				4	1	5
Tracy Lynne				1	2	3
Ridge	1	1	7 & 283			2
Stitt		2	20 & 135			2
Josephine No.3		1	131			1
Triple K No.1		1	90			1
Total	1	7		18	3	29

V.E.2.b – Cause of Reported Effects

Pillar failure was the overwhelming cause of the reported effects listed in BUMIS for room-and-pillar mines with a total of 21 cases (Table V-18). Almost every BUMIS description listed cracks as the damage to the overlying structure. These cracks occurred in foundations, basement walls, brick exteriors, and chimneys, and ranged in size from open separations to hairline cracks in walls.

Table V-18 – Cause of reported effects sorted by room-and-pillar mine.

Cause	Final Resolution		Interim Resolution Pending	Outstanding (No Interim Resolution)	Total
	Company Liable	Company Not Liable			
Pillar Failure		2	16	3	21
Other		4			4
Unknown	1		2		3
Underground Mining		1			1
Total	1	6	18	3	29

V.E.3 – Potential Cause of Pillar Failures

Marino (1986) discussed three mine instability mechanisms capable of causing the overburden to fail and increasing the potential for surface subsidence. These three mechanisms are immediate roof rock collapse, pillar crushing, and pillars punching into the roof or floor. With any of these mechanisms, excessive roof-to-floor entry convergence can occur at the mine level. This convergence can be transmitted through the overburden and can result in the formation of a subsidence basin on the surface. These subsidence basins would be, in principle, similar in character to those developed during longwall mining. However, their character would be highly dependent on the shape of the deformations underground. Also, the magnitude of vertical subsidence would be generally much less then for longwall mining. Deformations within a subsidence basin can result in damage to any structure that may be present on the surface.

Since pillar failures dominate the list of reported effects, it is relevant to understand the probable cause and potential effects. In some ways, the term "pillar failure" is restrictive and may be a misnomer. Mark and Iannacchione (1992) examined the behavior of coal pillars with different characteristics and found: 1) pillars with width-to-height ratios less than 4 are prone to failure under elevated overburden loads, and 2) pillars with width-to-height ratios greater than 4 are, in general, much less likely to fail. Failure refers to the pillar's inability to hold the load applied from the overburden. Once a pillar fails, its' load transfers to adjacent pillar structures and thus begins a phase of significant deformation.

Mine layouts using pillars with width-to-height ratios less than 4 are more likely to have failures that result in rapid deformations as the pillars soften. The University did not observe pillars with a width-to-height ratio less than 4, so this kind of failure is not anticipated. Many pillars with width-to-height ratios greater than 4 were observed. When these pillars are stronger than the underlying floor rock and have sufficient overburden loads, they have the potential to punch into the floor strata. Over time, interaction with water may weaken the floor. When the foundation under a pillar ruptures and fails, the floor material either squeezes or heaves into the adjacent mine opening (See Figure I-5). This squeezing or heaving can cause significant roof-to-floor entry convergence.

To help design pillar layouts capable of resisting squeezes and heaves, the National Institute for Occupational Safety and Health (NIOSH) developed software called "The Analysis of Retreat Mining Pillar Stability (ARMPS). This model helps define pillars capable of carrying both development and abutment loads (Mark and Chase, 1997). The ARMPS program provides a means to test the stability characteristics of pillars systems associated with many of the 18 pillar failures listed in Table V-16.

V.E.3.a - Clementine No.1 Pillar Failures

At the Clementine No.1 Mine, from May 11, 2006 to June 16, 2008, 15 structures with reported effects occurred over a fairly large portion of the mine. In one section of the mine, five reported effects occurred within a relatively confined area (Figure V-8). As noted from the mine map, the Clementine No.1 Mine developed main entries with a continuous haulage mining unit.

Continuous haulage mining systems use a conveyor belt, located in the center entry, to remove the coal from the working faces. Crosscuts are typically driven at 70-deg angles from the belt entry to optimize the continuous haulage equipment. This gives the sections a V-shaped appearance. The main entries are protected with regularly spaced barrier pillars. Production panels are driven off the main entries, again at a 60 to 70-deg angles. Production panels utilize a similar pillar layout as the adjacent main entries.

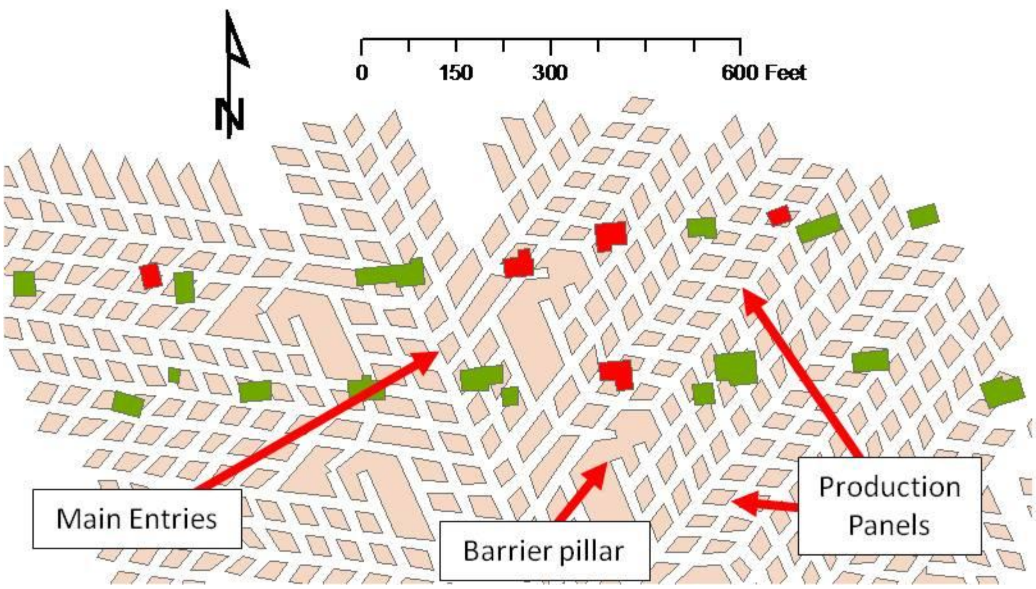

Figure V-8 – Area of the Clementine No.1 Mine where five structures with reported effects occur. This area contains main entries, production panels, and barrier pillars. Barrier pillars provide protection for the main entries. Note – Red = structures with reported effects, and Green = structures without reported effects.

An ARMPS investigation was conducted using general pillar layout configurations measured from the 6-month mining maps (Figure V-9). The average size of pillars located in the production panels were 28-ft wide by 33-ft long. The average width of the entries was 20-ft and the mining height was assumed to be 4-ft, yielding an extraction ratio of 65-pct. The overburden for the five structures with reported effects in this area ranged from 391 to 460-ft. The output from the ARMPS program indicated this pillar layout had a development stability factor of 2.11, well within the pillar safety factor of 2.0 required by the PA DEP (Anon, 1997). The ARMPS program manual indicates that the risk of pillar failures increases significantly when the stability factor is less than 1.5. However, changes in the local mining conditions, i.e. increase extraction thickness, pillars with dimensions less than those sited above, wider entry dimensions, etc., can act to locally reduce this stability factor. For example, if the mining height is increase from 4-ft to 5-ft, the stability factor decreases to 1.77.

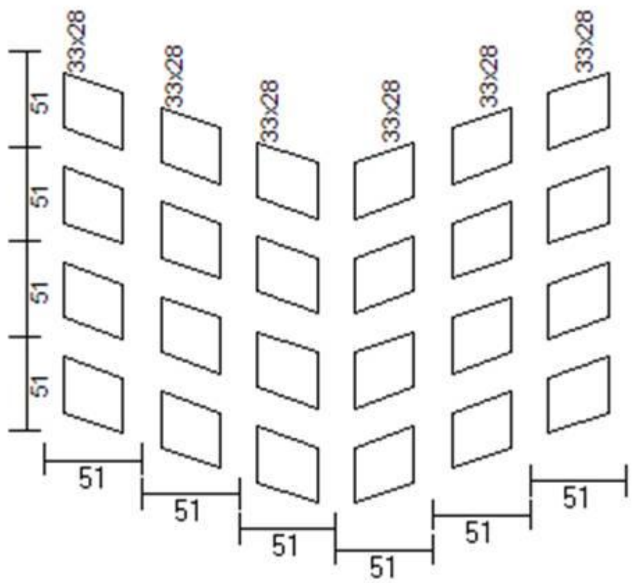

Figure V-9 – Mine layout used for Clementine No.1 ARMPS investigation.

In this example, the stability of the pillar layout was acceptable. However, if any of the local conditions listed above change, this layout might not prevent pillar squeezes and could be responsible for the formation of a surface subsidence basin. Unfortunately, the University was not able to find any information concerning the local conditions encountered underground.

V.E.3.b - Ondo Pillar Failures

In one small area of the Ondo Mine, a series of pillar failures may have occurred over a relatively short period of time. From November 11, 2007 to April 24, 2008, five structures with reported effects (Figure V-10) occurred over a production panel. Typically production panels are developed and abandoned in a relatively short period of time, often measured in months. The pillar sizes in the production panels are slightly smaller than those in the adjacent main entries. The main entries generally function for longer periods of time, typically measured in years. Overburdens for these five structures ranged from 378 to 402-ft. Note that three of the structures were outside the production panel with one over a solid barrier and two over the adjacent main entries. One of the key “signs of trouble” for this area was the phrase “Area Heaved” written on the 6-month mining map (Figure V-10).

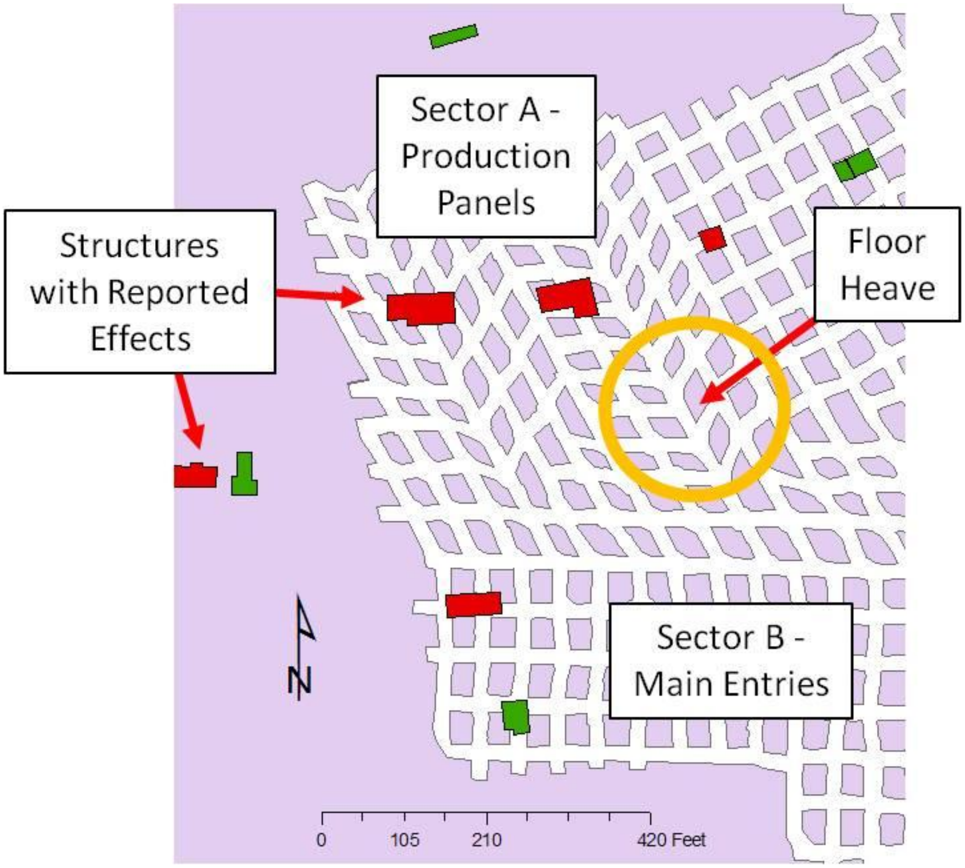

Figure V-10 – Area within the Ondo Mine where five structures with reported effects occurred within two distinct pillar layouts, A & B. Note – Red = structures with reported effects, and Green = structures without reported effects.

The Sector A mine layout consisted of pillars, averaging 27-ft wide by 37-ft long with entries 21-ft wide. The extraction ratio within Sector A was approximately 65-pct and the coal thickness was assumed to be 4-ft. Crosscuts were driven on 70-deg angles left and right from the central belt entry (Figure V-11a). Sector B had slightly larger pillars, averaging 30-ft wide and 40-ft long with 20-ft wide entries. The extraction ratio was approximately 60-pct. This area had crosscuts driven at 90-deg angles producing rectangular pillars (Figure V-11b).

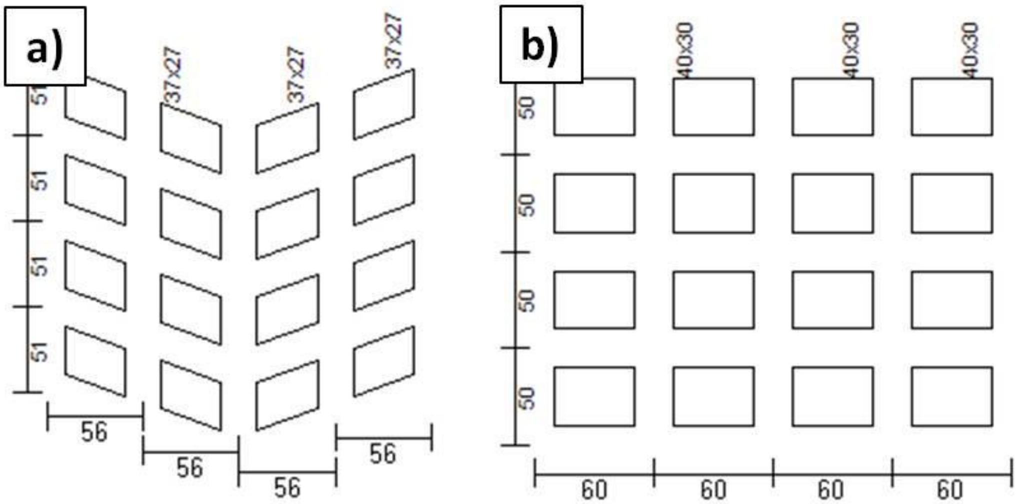

Figure V-11 – Two distinct mine layouts used in area where five structures reported effects at the Ondo Mine. Map a) Sector A with an extraction ratio of 65-pct, and b) Sector B with an extraction ratio of 60-pct.

The ARMPS program was used to investigate the two pillar layouts show in Figure V-11. The layout conditions were measured from the 6-month mining maps. The output from the ARMPS program indicated that Sector A production panels had a development stability factor of 2.45 while the Sector B main entry developments have a stability factor of 3.02. While both Sector A and B layouts have stability factors in excess of 1.5, a localized thickening of the coalbed, decrease in floor rock strength, or an increase in overburden could shift the stability factor into the unstable zone. The 6-month mining map identified an area of floor heave (Figure V-10); indicating unstable conditions existed within Sector A.

V.E.3.c – Tracy Lynne Pillar Failures

From April 3, 2008 to July 18, 2008, three structures with reported effects occurred over a relatively concentrated portion of the Tracy Lynne mine (Figure V-12). In this portion of the mine, large areas of the Lower Kittanning Coalbed remain unmined. Overburden for these structures range from 436 to 498-ft. The extraction ratio is 62-pct and the average pillar sizes in the production panels were 30-ft wide by 42-ft long with entries 21-ft wide. For this section, a stability factor of 2.25 was calculated for a 4-ft extraction height.

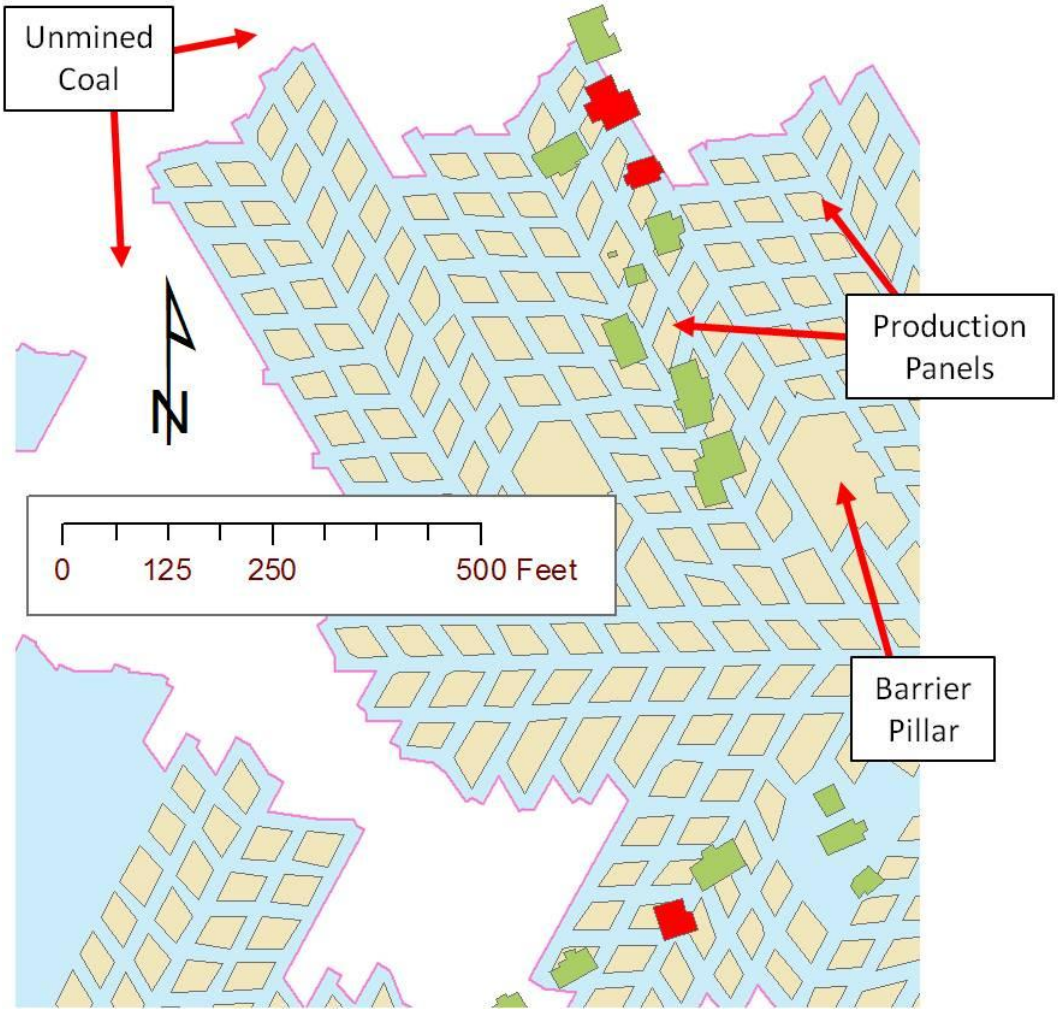

Figure V-12 - Section of the Tracy Lynne Mine where three structures with reported effects occurred. Note – Red = structures with reported effects, and Green = structures without reported effects.

The overlying Upper Freeport Coalbed was mined in mid 1990's by the Roaring Run Mine. The Upper Freeport was approximately 300-ft above the Lower Kittanning Coalbed at the Tracy Lynne Mine. The Roaring Run Mine layout was similar to that used by the Tracy Lynne Mine. The University believes the influence of multiple-seam mining for development room-and-pillar mining should be minimal, especially in this case where the interburden is approximately 300-ft.

V.F – Room-and-Pillar Mines with Pillar Recovery

Room-and-pillar mines with pillar recovery are not covered in this section because the full extraction mining associated with this method did not undermine a single structure during the 3rd assessment period.

V.G – Mitigation Measures for All Methods of Mining

Mitigation measures, as defined in Section V.D.6.b. under interim resolutions, are sometimes used by companies to reduce the impact of subsidence to structures. Typically, companies prepare a report prior to undermining that 1) predicts the potential subsidence characteristics associated with the structure under review and 2) outlines site-specific mitigation measures.

Subsidence prediction consists of final surface movements and deformations estimates, as well as dynamic surface deformations associated with the passage of the underlying longwall face. These data are used to develop the appropriate mitigation measure and determine when these measures should be initiated and how long they should be left in-place. There are five general categories of mitigation measures. They are banding, bracing, bridging, trenching, and cribbing. Each technique is described below.

V.G.1 – Banding

One of the most common mitigation methods is banding (Figure V-13a). Typically, polypropylene or nylon rope or steel cables are wrapped around the structures and tensioned (Figure V-13b). Most of these bands are located at the foundation level but some can be used higher on the structure as needed. The forces are distributed through wood boards placed between the rope or cables and the corners of the structure. The ropes and cables are tensioned with a turn-buckle that consistently applies the force. A spring is used to relieve sudden changes in the lateral force, and this force is monitored with a gage (Figure V-13c).

Figure V-13 - Photographs of a) residential structure with polypropylene rope around the foundation, b) steel cable spring and tension assembly, and c) spring and gage assembly (photographs courtesy of N. Iannacchione).

V.G.2 – Bracing

Bracing is typically applied to stiffen a structure. It does this through a supporting beam or a connecting wire or rope that steadies and holds the structure in the correct position against vertical and horizontal rotations. Bracing can be made of wood or metal. This measure is generally applied diagonally between intersecting components on the structure (Figure V-14)

Figure V-14 - Photograph of bracing (photograph courtesy of N. Iannacchione).

V.G.3 – Bridging

Bridging is used to strengthen and stiffen a structure against differential movement. It is generally applied within the attic of the structure (Figure V-15). Bridging reinforces levels within a structure, decreasing the impact of differential settlement. This can be an effective means of withstanding the passage of a subsidence wave propagating through a large structure.

Figure V-15 - Bridging applied to a structures attic to stabilize the roof (Photograph from PA DEP files).

V.G.4 – Trenching

One of the most effective measures to reduce high surface horizontal strains is trenching (Figure V-16). In general, a trench is excavated near the structure to absorb horizontal strain. The trench should extend to a depth approximately 2-ft below the lowest point in the structure's foundation. Typically, the trench is covered over with planks to satisfy safety concerns.

Figure V-16 - Photograph of a trench excavated adjacent to a structure to mitigate high horizontal strains (Photograph from PA DEP files).

V.G.5 – Cribbing

Cribbing is one of the most cost effective mitigation measures. In general, cribbing is used to arrest vertical movement within a structure (Figure V-17). Most cribs are constructed of wood and can withstand considerable vertical movement without losing their load bearing capacity. Wood cribs are not effective when significant horizontal movement occurs.

Figure V-17 – Photograph of cribbing (photograph courtesy of N. Iannacchione).

V.G.6 – Mitigation Measure Effectiveness

Some companies rely on these measures, while others prefer compensation to the property owner. Regardless, there is little doubt that these measures can be effective. For example, Figure V-18a (before) and Figure V-18b (after) photographs show the application of mitigation measures applied to this historic structure. It should be noted that this structure did sustain some minor damage that was later repaired.

Figure V-18 – Photographs of a) historic farm house in 2001 treated with several mitigation techniques, i.e. banding, cribbing, and trenching and b) farm house on May 21, 2003 (Photograph from PA DEP files).

V.H – Summary Points

The University collected information concerning 3,735 structures. The precise distance to mining of each structure as well as the overburden and topographic conditions were measured. Each structure was compared to mining maps within the UGISdb and categorized according to requirements of PA law.

The University found 456 reported effects listed within the PA DEP files. Three broad categories of liability were analyzed:

- Company Liable = 301 (66.0-pct),
- Company Not Liable = 59 (12.9-pct), and
- Unresolved = 96 (21.1-pct).

Longwall mines had a higher percent of reported effects per structure, 23-pct, than room-and-pillar mines, 1.5-pct. In addition, the percentage of company liable effects was much higher for longwall mines with 70.2-pct compared to 3.5-pct for room-and-pillar mines.

Thirty-one feature types were identified. The most common features were dwellings (1,502), followed by garages (593), barns (357), sheds (264), trailers (230), outbuildings (169), buildings (95), silos (35), pools (32), and septic systems (21). There were several notable structural features of importance including cemeteries, towers, churches, schools, bridges, and dams.

Mitigation measures were sometimes used by companies to reduce the impact of subsidence to structures. In many cases the company prepared a report prior to undermining that 1) predicted the potential subsidence characteristics associated with the structure under review and 2) outlined site-specific mitigation measures.

There are five general categories of mitigation measures:

- Banding - Polypropylene / nylon rope or steel cables are wrapped around the structures and tensioned,
- Bracing - Typically applied to stiffen a structure,
- Bridging - Used to strengthen and stiffen a structure against differential movement,
- Trenching - An effective measures to reduce high surface horizontal strains, and
- Cribbing - Used to arrest vertical movement within a structure.

V.H.1 – Longwall Mining

Longwall mines undermined 1,856 structures. Enlow Fork had the most with 507 and Shoemaker the least with 6. The average acres-per-structure for all longwall mines was 14.2. The total number of reported effects from longwall mines during the 3rd assessment period was 427. A final resolution occurred in 352 of the 427 cases, taking an average of 238 days. Seventy-five of these reported effects did not have a final resolution as of August 20, 2008.

At the end of the 3rd assessment period the following conditions existed:

- 300 structures with company liable for the reported effects
  - Company Purchased the Property, 31-pct,
  - Unspecified Resolution, 27-pct,
  - Company Compensated the land owner, 23-pct,
  - Pre-Mining Agreements, 12-pct, and
  - Structures Repaired, 6-pct.
- 52 structures with company not liable for reported effects
  - Not Due to Underground Mining, 77-pct,
  - Withdrawn, 11.5-pct,
  - No Actual Reported Effect, 7.7-pct, and
  - No Liability, 3.8-pct.
- 63 structures with interim resolutions
  - Currently Monitoring, 50.8-pct,
  - Temporary Repaired, 11.1-pct,
  - Unresolved, 11.1-pct,
  - Awaiting Additional Effects, 9.5-pct
  - Pending, 7.9-pct,
  - Pending Owner Approval, 6.3-pct, and
  - In Negotiation, 3.2-pct.

- 12 reported effects have no interim or final resolution with an average length of time of 689 days

Twenty-six reported effects from the 2nd assessment period were resolved during the 3rd assessment period. A final resolution occurred in all 26 cases, taking an average of 643 days.

Twenty-three percent of the structures located over longwall panels had reported effects. The average acres-per-structure for all longwall mines was 14.2. The analysis of the topographic conditions of structures undermined did not show any significance.

The relationship between the structures distance from a longwall panel and the reported effects provided insight as to what resolution outcome can be expected as the distance from mining increases. The final resolution of Repaired and Pre-Mining agreements occurred most often when structures were located very near to a longwall panel (< 35-deg). Conversely, when the projection angle was large (> 35-deg), companies more often resorted to purchasing properties as a final resolution.

V.H.2 – Room-and-Pillar Mining

Room-and-pillar mines had 50-pct of the structures undermined but only 1.5-pct of the structures with reported effects. This was largely due to the pervasive use of "safe" pillar designs that minimizes unplanned mine subsidence. During the 3rd assessment period, 1,879 structures were undermined by 42 room-and-pillar mines. The average acres-per-structure for all room-and-pillar mines was 14.5.

Of 1,879 structures undermined by room-and-pillar mines, 29 had reported effects. Seven mines reported effects with Clementine No.1 showing the highest number with 15. Thirty-six room-and-pillar mines did not have any structures with reported effects during the 3rd assessment period. Of the 29 reported effects, eight had a final resolution; one Company Liable and seven Company Not Liable. The average days to resolution for these seven reported effects was 107. There were 18 interim resolution and three outstanding reported effects, all of which occurred after April 4, 2007. The average days to the interim resolution was 47.

Pillar failure was the overwhelming cause of the reported effects listed in BUMIS for room-and-pillar mines with a total of 21 cases. The ARMPS program was used to test the stability characteristics of pillars systems associated with many of the 18 pillar failures. In all cases the ARMPS stability factor was calculated to be greater than 2.0 and met the PA DEP requirement of a pillar safety factor greater than or equal to 2.0. However, minor changes in the assumed conditions can significantly increase the risk for unstable conditions in the pillars and adjacent roof and floor strata.