INVESTIGATION OF ALLEGED SUBSIDENCE DAMAGE TO A RESIDENTIAL STRUCTURE IN INDIANA[1]

by

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Abstract. An investigation was undertaken by the Indiana Division of Reclamation (DOR) on behalf of the Indiana Department of Insurance (DOI) to determine if mine subsidence due to old underground works was resulting in structural damage to a residential structure in Alfordsville, Indiana. The owner had alleged that subsidence was causing damage to the structure and had filed a claim under the Indiana Mine Subsidence Insurance Fund. Previous reports that addressed the damage to the owner's house and their possible causes are summarized. Core drilling, gamma logs, borehole TV camera observations, and elevation surveys indicated no evidence of mine workings in the two coal seams present below the owner's house. The rock cores showed no signs of disturbance that would be expected if a mine collapse had occurred at shallow depth and progressed to the surface. The gamma logs were in agreement with core descriptions. Elevation measurements of points on the house indicated a continuing differential settlement of the house; surface elevation measurements in the vicinity of the house did not exhibit such a consistent trend. It is the authors' opinion that the observed indications of continuing differential settlement are due to local soil conditions and non-engineered construction modifications without regard to subsoil conditions

Additional Key Words: Indiana, subsidence, investigation, drilling, inclined, damage, structure.

Background

Beginning in 1988, a home owner in Alfordsville, Daviess County, Indiana, repeatedly alleged that ongoing damage to her house was resulting from the collapse of abandoned underground coal mines. She has periodically reported this to appropriate state and federal authorities. The authors first visited the house on Wednesday, January 23, 1991, purely as observers during an investigation being conducted by the Office of Surface Mining (OSM). OSM investigators concluded that a subsidence episode may have occurred and described damage similar to those noted by previous investigators and indicated two types of cracks inside the house; ones that would be normal in a 45-year-old house, and others that are caused by uneven settlement or strains. A settled area (40 ft x 75 to 80 ft) on the west side of the house was specifically referenced in their report as possible subsidence as in reports from earlier investigators.

Prior to this federal investigation, three consultants had independently studied the damage in this house. Donan Engineering of Jasper, Indiana, indicated that (1) the house could have been undermined, (2) the major cause of cracking in the house was settlement of the southern portion due to the weight of concrete walls in the basement (a 4.65 ton concrete wall was poured adjacent to the block on the south side and another concrete haunch, about one ton, was poured without any footing against the east wall [Figure 1]), (3) a portion of the original floor slab had been replaced with gravel to act as a gathering point for water coming from an adjoining broken cistern tank, (4) excess water under the basement floor may have softened the foundation strata and caused the major north-south crack in the basement, and (5) none of the problems with the house were due to subsidence from old underground mine workings.

A second report from Engineers International, Inc., of Westmont, Illinois, described the exterior and interior damage to the house. The report concluded that (1) the exterior cracks and

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cracks in the basement seemed to have originated several years ago but some have widened recently (these cracks are due to differential settlement), (2) a possibility of mine subsidence existed, (3) the damage to the house was initiated by blasting in neighboring surface mines although continuing recent damage may appear to be due to subsidence, and (4) increased damage due to subsidence could lead to major structural damage and possibly structural failure.

A third report from Signal Engineering, Evansville, stated that "The entire yard is subsiding in the pattern of "rooms" that prevailed in mining practice a hundred years ago ..." and that "None of the surface subsidence was easily apparent during earlier inspections in 1987 and 1988." Referring to the mine shaft for Mine No. 134 on Preliminary Coal Map No. 15 and a documented production of 640 tons, the affected area due to coal extraction was estimated to be 626 ft x 626 ft to 885 ft x 885 ft and the distance between the house and the mine shaft approximately 370 ft. It was concluded that the damage to the house was related to mine subsidence because the house was well within the area affected by mining.

Previous investigators have indicated the possibility of existence of old underground works beneath the house. Except for Donan Engineering, all have concluded that damage to the house was partially, if not fully, due to settlement that was resulting from continuing surface subsidence. Donan concluded that none of the problems in the house were subsidence related. Given the absence of information concerning any past mining in the immediate vicinity of the house, it was apparent that drilling would be required to provide adequate information for such determinations. Because distinct and obvious surface expressions of mine subsidence and information on the location of the structure in relation to any mining plan were all absent, drilling should have been an integral part of such determinations. OSM and Engineers International did, however, recommend drilling to determine if mine subsidence was indeed occurring.

Since a claim against Indiana Subsidence Insurance Fund had been filed and previous studies were not conclusive, it became important to resolve the cause of the observed structural damage. Past surface and underground coal mining in the Alfordsville area have been documented on Preliminary Coal Map No. 15 and Quadrangle maps. However, the areal extents of some old works have not been outlined and only locations of the air shafts are indicated. Such is the case with two shafts located west of the home owner's property in Alfordsville; these were used to mine the Blue Creek Coal Member. In addition to the lack of information about the extents of some older underground mines in the region, there may be some undocumented mines in the area as well. Hence, the possibility that the home owner's property may have been undermined could not be demonstrated or ruled out on the basis of existing information. In order to obtain sufficient information to determine if subsidence is occurring as a result of past mining activity, an investigation was planned that included a drilling program to establish the existence, if any, of abandoned underground works.

Field Investigation

Core drilling and surveying were the primary field activities undertaken in the course of this investigation. The drilling program was designed to (1) determine if a coal seam of minable thickness exists below the house, (2) determine if such coal seam(s) had been previously mined, and (3) evaluate the state of the old works (if present) and the overlying strata in the vicinity of the house for signs of disturbance that may possibly indicate mine subsidence. The house and adjacent areas were surveyed for changes in elevation to document any ongoing vertical settlement over the duration of the project. Where possible, the drill holes were examined using a borehole TV camera.

Core Drilling

Preliminary reconnaissance of the property and adjacent area was undertaken to determine if there were any obvious indications of mine subsidence and to provide information important for establishing the location of the drill holes. The drilling plan was designed to retain the flexibility to use information obtained from previous holes to assist in locating the remaining holes. The final locations of the holes were changed to achieve the stated objective of the drilling program as economically as possible. The final locations are shown in Figure 2.

Under the plan, the first hole would be drilled vertically about 150 to 200 ft from the house to provide protection in the event that old works exist and explosive gas is present. It would extend to

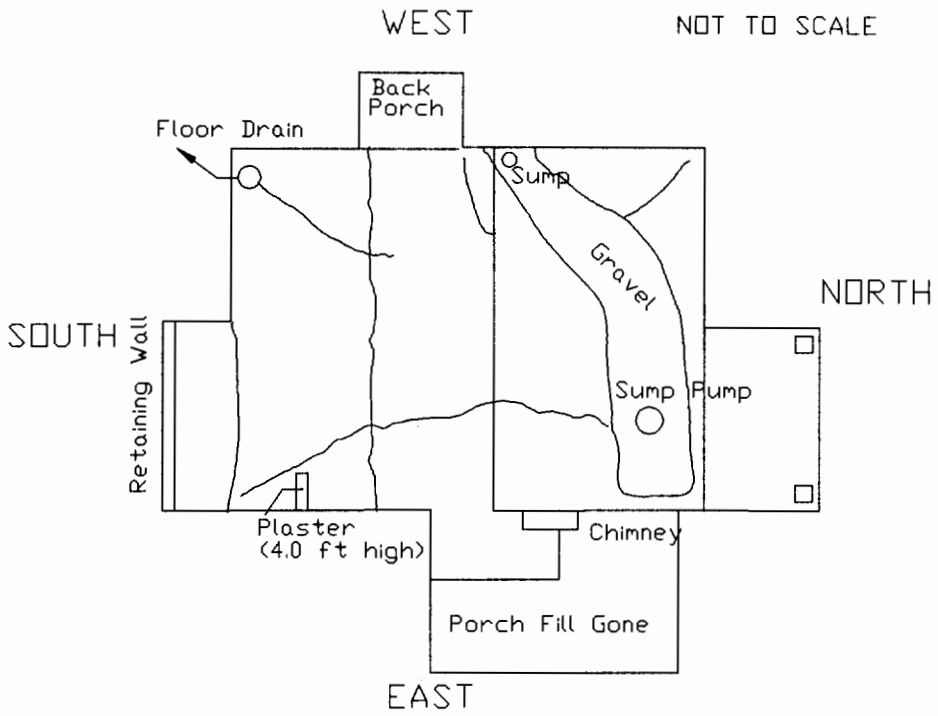

Figure 1. Basement floor plan of the house showing mapped cracks in relation to other relevant structural features.

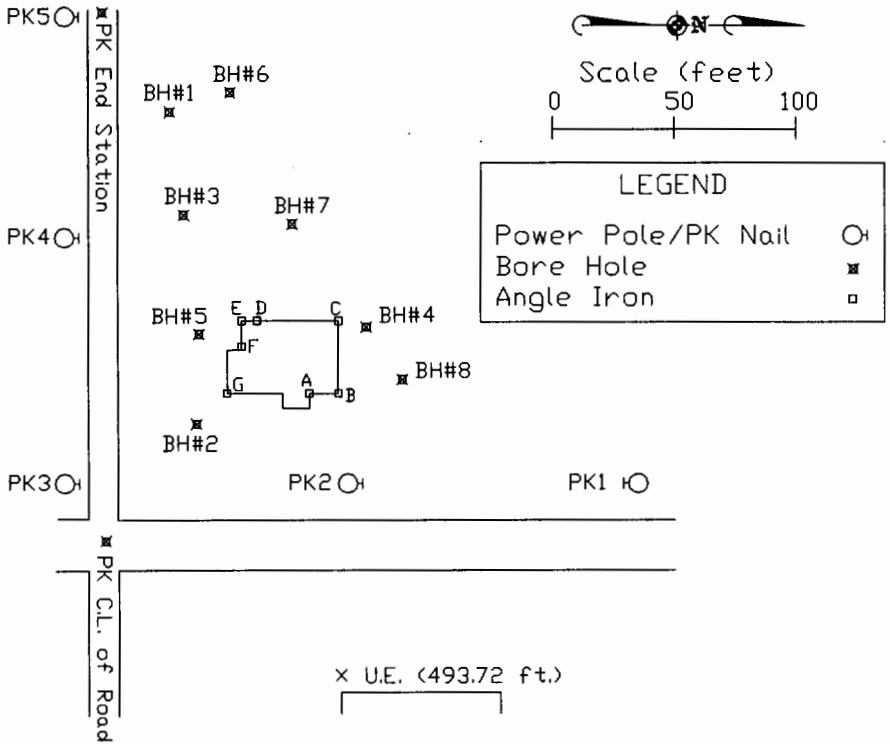

Figure 2. Location of borehole and survey monitoring points with respect to the house.

sufficient depth to locate approximate coal horizons, intercept the coal seam below the Blue Creek Coal Member (approximately 120 ft), and establish geologic control for the project. The second hole would also be vertical and very close to and west of the house for similar purposes. The third and fourth holes would be inclined holes (approximately 25° to 30° from the vertical) and located near the NW and SW corners of the house to gain access to areas below the foundation at these locations. A fifth hole would be drilled as needed. The depths and locations of all holes were to be based on details from the previous hole(s).

Cores would be recovered and color photographs taken after the first hole was completed. The cores were to be examined for disturbance in the overburden strata due to failure at the coal horizon if old works were present. They would then be wrapped in plastic and stored properly in the event geotechnical tests were required at a later time. Upon completion of the drilling program, the holes were to be plugged with Portland cement from the bottom to about 8 to 10 ft below the surface; the rest of the hole would be filled with soil to reclaim the drill hole. The areas disturbed as a result of drilling were to be revegetated to correspond with the original landscape.

Elevation Survey

The house was surveyed to determine the elevations of strategic points to obtain baseline data for future surveys if and when necessary. Steel angle sections were glued at various locations on the house for this purpose. Data from surveys would also provide information on any future claims that the drilling program may have resulted in further deterioration of the house.

Results and Discussion

A total of 8 holes were drilled around the house (BH #1 through BH #8, Figure 2); drilling depth ranged from 40 to 123 ft. Cores were recovered from four holes (BH #2 through BH #5); the remaining holes were rotary drilled. BH #3 - BH #5 were inclined while the rest of the holes were vertical. Each hole was gamma logged upon completion of drilling. An effort was also made to view all drill holes with a Borehole TV Camera. A series of elevation control points were also established on the house and its vicinity to determine if subsidence was occurring.

Geologic Data Interpretation

A lithologic log for BH #2 is shown in Figure 3; this is typical of the area around the house. Brownish yellow and granular top soil was observed up to a depth of 9 ft. Moisture and clay content increased with depth to 13 ft. Some underclay and siderite was observed between 11 to 13 ft. The moisture content in the clayey unconsolidated material was estimated to be at or above its plastic limit which indicates a flowing tendency of the soil. Bedrock was encountered from 17 to 24 ft and consisted of gray shale sometimes banded with sandstone. A 3-ft coal seam (referred to as the coal seam) was encountered at 24 ft. It was underlain by about 1.25 ft of underclay. Alternate layers of sandy shale and sandstone were observed below the underclay to a depth of 48 ft, which was underlain by a competent sandstone strata to a depth of 57 ft where drilling was terminated.

An alternate location for BH #1 had to be selected near the southwest corner of the house due to problems encountered in obtaining permission from appropriate land owners (Figure 2). This hole was drilled vertically. Because the purpose of this hole was to establish geologic control, drill cuttings were examined and the lithology was compared with the typical log on Preliminary Coal Map No. 15. However, no cores were recovered. Some signs of coal-like material similar to that expected near an outcrop were observed at 22 ft. A distinct coal seam was encountered at about 108 ft. The stratigraphy above and below this unnamed coal member in the Mansfield Formation was used to establish an approximate horizon in the geologic sequence where cores for this investigation would be obtained. Drilling was terminated at a depth of 123 ft because (1) the records show that the abandoned shafts known in the area were associated with mining the Blue Creek Coal Member, (2) no coal mining at such great depths are on record in this area, and (3) for the reported total tonnage of 640 tons of coal mined as per Preliminary Coal Map No. 15, mining to such depths would be uneconomic at this mine.

BH #2 was drilled vertically near the southeast corner of the house to obtain cores (Figure 2). The core description has been shown as a typical log in Figure 3. BH #3 was inclined and drilled at an angle of 25° from the vertical to investigate the rectangular depression in the back yard that was referred to in Engineer's International and OSM

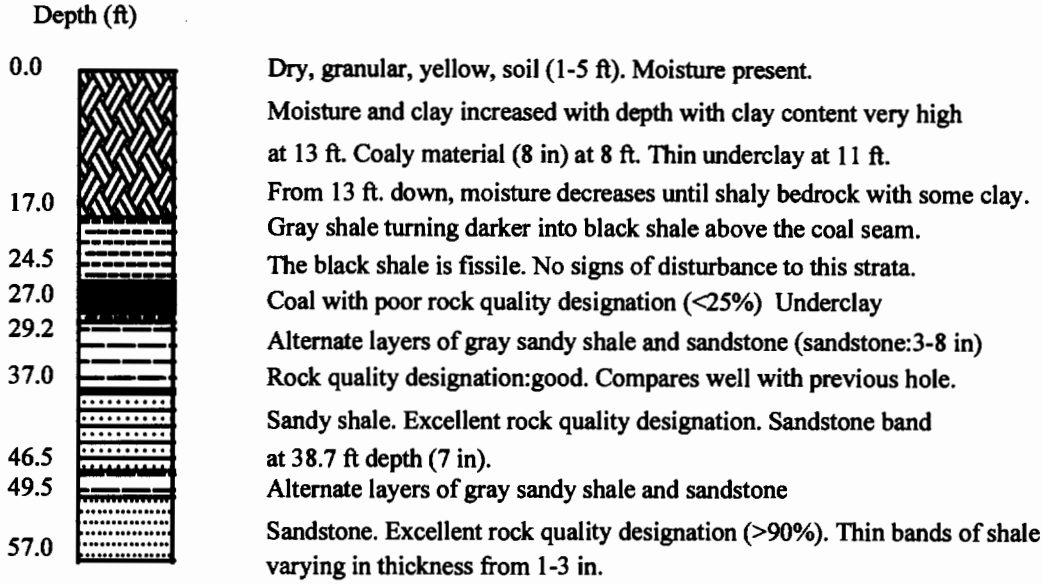

Figure 3. Typical lithologic description of soil and rock overburden strata around the house.

reports. BH #4 was also inclined and drilled towards the house to intercept the coal seam below the house foundation. The coal seam below the foundation on the south side of the house was intercepted by BH #5; this area is also where a concrete wall has been poured in the basement (Figure 1). The lithologic description of BH #2, #3, #4, and #5 are more or less identical except for variations due to changes in surface topography.

BH #6, #7, and #8 (Figure 2) were rotary drilled well below the coal seam until competent rock was encountered; the depths of these holes were 40 ft, 42.5 ft, and 42 ft, respectively. The location of these holes correspond with areas that the owner reported to have been subsiding recently. The exact locations were decided through consultation with the owner and examination of the information obtained during the early stages of the project. These were drilled to determine if there were any voids at the coal seam horizon below any of these areas. None of the holes encountered a void in the coal seam. No cores were recovered from these holes. However, the lithologic descriptions based on examination of drill cuttings were in agreement with other holes even though exact thickness of strata were difficult to determine.

The results of drilling at BH #6 and BH #8 are pertinent to resolving the causes or origin of surface effects that had been identified during previous investigations as potential mine subsidence features.

BH #6 was drilled at the center of a small circular depression south of the garage in the back yard. Augering was relatively easy and the washout contained rotten leaves and had a pungent odor. The soil at about 0 to 8 ft depth contained crushed stone and organic matter. Hard brick was encountered at about 8 ft. Once bedrock was reached, drilling was steady to the end of the hole. This indicates an abandoned cistern or well approximately 8 ft in depth. Within the bedrock, the drilling program identified no indications of mine subsidence at this location. On the contrary, the observation of the surface depression is consistent with an abandoned cistern.

BH #8 exhibited an extremely high moisture content from a depth of 12 to 16 ft. The drill behaved as if it were passing through mud. The strata were high in clay content. The rate of auguring increased as the drill passed through this soft strata. At depths below this soft material, in the bedrock, coal, and sub-coal rock strata, drilling rates were again steady and normal to the maximum depth of 42 ft. No indications of past subsidence or voids were noted at depths below the soft strata. The possibility of there having been a cistern in this vicinity cannot be ruled out because (1) one was referred to by the previous owner of the house (Donan Engineering

Report) and (2) there is a circular area around this hole that is somewhat depressed.

Gamma Ray Logs

Gamma logging of the holes, though not originally planned, was accomplished at the end of the drilling program. It served to verify rock types with their approximate depths. Gamma logging for the entire hole was successful for BH #2, #4, #5, and #8. The other holes had practically squeezed shut at the bedrock horizon. The detailed logs from the recovered cores and those from cuttings of the speed drilled holes were found to be in good agreement with the gamma ray logs.

Borehole TV Camera

The borehole TV camera was lowered in the first five holes to study the lithology. The water level in all holes had risen above the bottom of the PVC casing. Unfortunately, the turbidity of the water was so high that no clear picture could be obtained. In one hole (BH #2), a suspicion arose concerning apparent water flow inside the hole as indicated by movement of suspended particles across the camera lens. It was determined that the movement while real, was created by heat generated from the light source and the position of the camera lens with respect to the light and not flow of water.

Field Survey

The locations of the survey control points on the house are shown in a plan view on Figure 2 (A through G). Additional elevations of PK nails in power poles around the house were also taken (PK 1 to PK 5); PK C/L was located at the center of the road. Surface elevations adjacent to the drill holes (1 to 3 ft) were taken before and after drilling the holes. The elevation of the points on and around the house are tabulated in Table 1; elevations near drill holes are shown in Table 2. Data for 5/29/91 appears to have a noticeable and almost consistent increase in elevation (0.009 to 0.016 ft for PK 1 through PK 5 and 0.011 to 0.019 ft for the angle sections A-G). After this survey, only points B, C, E, F, and G have shown a change greater than ±0.01 ft. If this is assumed to be the baseline data then all points show a net upward movement except point G. A more consistent result is obtained if the data for 6/26/91 are considered as baseline information; most of the PK points do not show a change more than ±0.01 ft and the observed damage in the house is consistent with the recorded pattern of movements.

The following comments are pertinent using 6/26/91 data as baseline information and the data obtained through 8/14/91 (Table 1):

(1) The PK points show a net change in elevation from -0.004 to +0.010 ft; PK C/L changed -0.001 ft. The data for 8/14/91 was taken after heavy rain and all points have indicated an increase in elevation since the previous survey.

(2) The south side of the house (Figure 2, points E, F, and G) has shown a consistent downward movement trend while the north side has shown a consistent upward trend. The magnitudes of movement are thus opposite (downward movement of one part of the house resulting in uplift of other parts) although not equal and can be seen in Table 1.

Conclusions

(1) Only one coal seam, approximately 3 ft thick, is present under this property to a depth of 60 ft. This coal seam is identified as an un-named coal belonging to the Mansfield Formation between the Blue Creek Coal Member and the Mariah Hill Coal Bed. The identification is based on the core log descriptions from all holes drilled as a part of this investigation and the more generic log in Preliminary Coal Map No. 15. However, the elevation of this coal seam is comparable to that of the Blue Creek Coal Member in neighboring areas based on drill logs available at the Indiana Geological Survey. Therefore, the possibility of this being the Blue Creek Coal Member cannot be ruled out. Another unnamed Mansfield coal seam exists at approximately 108 ft (BH #1).

(2) No mine voids were encountered in any of the drill holes at the upper coal seam horizon (about 25 ft below surface). Similarly, no mine voids were encountered in the lower coal seam at 108 ft depth.

(3) The bedrock strata above the coal seam do not show any signs of disturbance that would be expected in a situation where mine collapse would have occurred at a depth of 25 ft. Rock strata below this coal seam were also intact and showed no signs of disturbance that may sometimes be observed if the lower coal seam at 108 ft depth had been mined.

Table 1. Elevation of points on the house, A to G and around it, PK points (feet above MSL)

Date/Point	PK1	PK2	PK3	PK4	PK5	PK C.L.	A	B	C	D	E	F	G
05/29/91	501.259	495.186	491.851	491.277	486.454	490.919	499.340	499.134	497.697	496.870	496.763	497.484	496.956
06/26/91	501.275	495.199	491.860	491.289	486.470	490.937	499.355	499.151	497.716	496.889	496.782	497.499	496.967
07/15/91	501.275	495.199	491.863	491.292	486.466	490.936	499.356	499.151	497.711	496.883	496.772	497.491	496.955
08/12/91	501.277	495.202	491.856	491.293	486.477	490.928	499.360	499.153	497.717	496.884	496.766	497.481	496.925
08/14/91	501.277	495.203	491.864	491.299	486.477	490.936	499.360	499.163	497.726	496.889	496.770	497.486	496.927

Table 2. Elevation of points adjacent to drill holes (feet above MSL)

Date/Point	BH#1	BH#2	BH#3	BH#4	BH#5	BH#6	BH#7	BH#8
07/15/91	489.421	493.841	492.321	496.513	494.401	489.741	493.611	496.810
08/14/91	489.530	493.960	492.390	496.810	494.240	489.698	493.770	496.740

(4) BH #4 and BH #5 intercepted the coal seam below the approximate edge of the house foundation. Since inclined drilling continued well beyond this depth, cores were also recovered from a horizontal extent of 10 to 13 ft on the inner side of the foundation below the basement. These cores also showed no signs of being disturbed from any source.

(5) The clay content of the unconsolidated material in all holes increased with depth and was particularly high from 7 to 15 ft. The moisture content within this range also appears to be close to its plastic limit. Therefore, heavy loading conditions such as those created by the two concrete blocks cast in the basement (Figure 1), could easily mobilize the shear strength at these horizons and cause considerable settlement.

(6) Water in the drill holes was quite turbid and no useful information could be obtained from the Borehole TV Camera.

(7) The survey data do not indicate any trends of subsidence movement during the two and a half month monitoring period. There is practically no change in elevation of the PK points. However, differential movement of the house has been observed and appears to be consistent with changes in loading conditions due to non-engineered construction modifications. The allegation that such movements are due to an abandoned underground mine collapse is not supported by the data obtained through this study.

Most points on the house showed almost no change in elevation except for those on the south side (Figure 2, points E, F, and G). The southeast corner of the house (point G) shows the maximum downward movement which decreases rapidly with increasing distance from the house (Figure 2, points F, E, and A).

The movement of points A through F on the house appears to be a reaction to the larger downward movement of the southeast corner point G. The existing damage in the house and the soft clayey strata in the unconsolidated overburden tend to camouflage such effects.

(8) The likelihood that coal extraction from the mines which operated through the two shafts located to the west of the house (identified as Mine No. 134 on Preliminary Coal Map No. 15), progressed close to this house, is very low. The house is more than 600 ft away and ventilation at those times (early 1900's) would have been difficult. Assuming that the coal seam encountered at about 25 ft depth is the Blue Creek Coal Member, the areal extent covered by a 640-ton production will depend on the extraction ratio. For only 25% extraction, the area covered will be 146 ft x 146 ft; a higher extraction would only decrease this distance. This is considerably less than the distance between the shaft and the house.

(9) If a mine void existed in this area since the time on record (early 1900's), mine collapse should have already occurred and mine subsidence observed on the surface with the observed configuration of bedrock above the coal seam.

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References

Rheem, Edward L., 1987, Report completed for the home owner on file at Indiana Division of Reclamation at Jasonville, Indiana.

Donan Engineering, 1988, Report to Duncan-Dollahan Claim Service, Inc., Evansville, Indiana on file at Indiana Division of Reclamation at Jasonville, Indiana.

Sadaghiani, M, 1990, Report from Engineer's International to Indiana Farmers Insurance Group on file at Indiana Division of Reclamation at Jasonville, Indiana.