Coal mining subsidence: A cautionary tale for surveyors

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For many centuries, subsidence as a consequence of mining activity has been a continuous problem in Britain. Despite the existence of legislation providing for compensation for damage as a consequence of coal mining activity, in the 1980s environmental concerns were also being expressed in Britain about the adverse affects of coal mining. Damage resulting from coal mining subsidence is widespread across the UK, and the legal implications of such makes it imperative that the public is properly informed of the proximity of any active mining areas, and those areas for which mining activity has now ceased. This article looks at the situation in the 1980s, the changes that were introduced, and considers the need for further change some 25 years later.

The extraction of minerals in Britain using underground mining techniques has taken place for centuries which has left a huge legacy of disused/abandoned mine workings. In the early 1800s concern was growing about the number of mining incidents involving loss of life and the need to prepare accurate plans of mine workings. As a result of these concerns the first Mine Records Office became established in 1840 and the first Act requiring the maintenance of plans of colliery workings was passed in 1850, with a requirement that such plans were to be updated every 6 months. The next legislative change came in 1860 when the requirement to prepare an "accurate" plan was introduced. However, it wasn’t until the introduction of the Coal Mines Regulation Act 1872 and the Metalliferous Mines Regulation Act 1872 that there became a statutory requirement to deposit mine plans when a mine was abandoned. In 1912 the first standard of qualification for surveyors in mines was introduced under the Coal Mines Act 1911 and thereafter there has been a need for mine surveyors to hold a certificate of competency.

Today the requirements for the appointment of a mine surveyor and their duties are set out in Regulations 27 and 28 of the Management and Administration of Safety and Health at Mines (MASHAM) Regulations 1993. In particular Regulation 28 requires "the surveyor for the mine to ensure so far as is practicable that the plans, sections and working papers of the mine which are required under the relevant statutory provisions (whether prepared by him or not) are suitable, complete and accurate." Before ceasing to be the surveyor for the mine the surveyor must transfer the plans and working papers to the owner of the mine together with a written report on the condition of those plans and sections. The mine surveyor’s duty to prepare and maintain the plans and sections for the mine needs to be read in conjunction with the owner’s and manager’s duty to take precautions against external dangers to workings.

To enable the mine manager and owner to discharge their statutory duties, the surveyor must prepare "accurate plans" showing hazards

Under the Mines (Precautions Against Inrushes) Regulations 1979 the manager has a duty to prevent any inrush into a mine of "gas from disused workings (whether mine workings or not); or water or material that flows or is likely to flow when wet from any source." The same regulations place an additional duty on the owner and manager of a mine to "ensure that they are at all material times in possession of all information which indicates or tends to indicate the presence or absence, in the vicinity of any working being carried on or proposed to be carried on in the mine, of:

- Any disused workings (whether mine workings or not, this would include boreholes);
- Any rock or stratum containing or likely to contain water (whether mine workings or not),
- Any peat, moss, sand, gravel, silt or other material that flows or is likely to flow when wet."

Section 2 of the Health and Safety at Work Act 1974 places responsibility on employers for the protection of their employees, and hence, as far as it is reasonably practical, a safe system of working. It follows that to enable the mine manager and owner to discharge their statutory duties, the surveyor must prepare “accurate plans” showing hazards including the cautionary zones identified in Regulation 6 of the Mines (Precautions Against) Inrushes Regulations 1979. Such cautionary zones may be summarised as being 37 m around disused mine workings and 45 m from other inrush hazards such as peat and surface water etc. The regulations indicate that where existing or proposed workings are under or near surface water such as a lake, reservoir, river or sea, there is a duty on the manager to ascertain the thickness of the intervening strata to determine whether they are a source of danger. Under section 38 of the Approved Code of Practice, this could include seismic hydrographic surveying to determine the configuration of the rock head, drift deposits and any buried channels. However it must be remembered that some hazardous circumstances may merit precautions to be adopted beyond the dimensions identified in Regulation 6 to enable the manager and owner to fully meet their duty under Regulation 4.
and their duty under The Health and Safety at Work Act 1974 and the Management of Health and Safety at Work Regulations 1992. To discharge this duty the mine owner and manager may need to consult other experts such as geotechnical engineers, hydro geologists or hydrologists.

Historical examples
There are numerous records of mining disasters with variable amounts of information to describe the cause and circumstances. The following examples have been chosen for illustrative purposes only:

The Landshipping Disaster
Landshipping is near the eastern shore of the Daugleddau near the confluence of the Eastern and Western Cleddau rivers in Pembrokeshire South Wales. Very close to the foreshore at Landshipping Quay was a shaft known as the Garden Pit and the mine workings extended under the estuary. On 14 February 1844 it is understood that the tidal waters of the Daugleddau and Cleddau rivers broke into the mine and 40 of the 58 employees, underground at the time lost their lives. Because the inrush occurred in the days before comprehensive public enquiries the reasons for the inrush are open to debate [1, 2].

The Tynewydd Disaster
Tynewydd Colliery was situated in the Rhondda Valley not far from the town of Porth. The shafts were sunk in 1852 by the Troedyrhiw Coal Company to work the No. 2 and No. 3 Rhondda coal seams. A barrier of unworked coal separated the workings of Tynewydd Colliery from the disused flooded workings of Cymmer Colliery. However the width of this barrier proved to be far from adequate and on 11 April 1877 the water from Cymmer broke into the Tynewydd workings. There were 14 men underground at the time, three drowned in the initial inrush. The others were trapped in two different locations in the mine [3]. As a result of heroic efforts by rescuers, nine of the trapped workers were brought safely from the mine workings. For the first time Albert Medals of gallantry were awarded with three of the rescuers awarded Albert Medals (1st class) and 21 were awarded 2nd class Albert Medals.

Knockshinnoch Disaster
Knockshinnoch Castle Colliery was situated in Ayrshire, Scotland and worked the Main Coal and Turf Coal seams. An underground development roadway (No. 5 Heading) was being driven at a variable rising gradient that had increased in steepness to 1 in 2. On Wednesday 30 August 1950 the No. 5 heading made contact with the base of the surface superficial deposits which appeared to be a bed of stones. The heading was stopped and made secure, but on 7 September 1950 an inrush of peat and moss from the surface flowed into the mine resulting in a subsidence hole some 12-14 m deep and 0.8 ha in extent at the surface [4]. As a result 13 men died and thanks to the strenuous efforts of rescuers 116 were brought safely to the surface. It became apparent during the investigation by Sir Andrew Bryan that the 1:10 560 scale Geological Survey Map for the district showed the presence of peat in the location where the inrush occurred. As a result of this incident Section 1 of the Mines and Quarries Act 1954 makes reference to the need for the mine to be planned and laid out in accordance with statutory provisions [5].

Preparing an “accurate mine plan."
For those involved in the preparation of an “accurate plan” there are many things to consider and it must be recognised that absolute accuracy is unachievable, hence the statutory duty “to ensure as far as is practicable” that the plans are accurate. In this regard, it is important for the responsible surveyor to keep records of the work he has undertaken to prepare the plan and bring any concerns about accuracy and completeness to the attention of the mine owner and manager. Where practical the working plan should be annotated to identify the hazard (paragraph 185 of MASHAM Regulations). The electronic survey equipment of today enables higher standards of surveying accuracy to be achieved than ever thought possible in the past. However, when a modern mine is working in areas of historic mining, it is equally important to ensure that the accuracy of the disused workings shown on the plan is properly considered. Some historical references on the accuracy of mine plans can be found in the 1927 report prepared by the Departmental Committee on the Prevention of Dangers in Mines from Accumulations of Water advises that “It is seldom that records have been preserved to enable old plans to be checked or verified. Under these circumstances we think plans made prior to 1887 should not be regarded as indicating the actual position of workings, but must be treated only as evidence that old workings exist in the neighbourhood. From 1887 to 1911 the standard of accuracy greatly improved, and reasonable reliance can be placed on plans made after the former date, providing the history of the surveying of the particular mine is satisfactory.”

The 1935 joint report prepared by the Committees of the Chartered Surveyors Institution and the Institute of Mine Surveyors produced advice on accuracy based upon the principles enunciated by former Directors-General of the Ordnance Survey; namely:

- “The foundation structure upon which all plans and surveys of mines are based is obviously a plan of the surface features of the area of the mine and this can only be produced on some system of projection by which a portion of the earth’s spheroidal surface is represented upon a plane surface. Projections may be considered as graphical representations of certain properties of the curved surface.

- Although it is not possible to represent upon a plane surface any portion of a spherical or spheroidal surface with entire truthfulness, yet some property of the curved surface may be selected and represented within the limits of error of plotting and map production. Various systems of projection are designed to represent correctly particular qualities such as correctness of areas, distances, or azimuths, but there is no system of projection which can combine correct representation of all qualities. For the purpose of this report, we are only concerned with the system adopted for the production of our six inch and 1/2500 National Plans, namely, projection by spheroidal co-ordinates plotted as plane rectangular co-ordinates.

In addition to the fundamental difficulty of representing the true position of any point on or beneath the earth’s surface upon the plane surface of a plan there are instrumental errors of survey, both angular and linear (which can be reduced to fine limits by repetition), and further limitations of the correct representation to scale of the calculated position of any point.
• It follows therefore that any examination of the "accuracy" of representation of any point upon a plan by reference to its true position is not capable of proof and no practical standard can be set up by reference to the exact or true position of any point or detail. Such a determination can only be made within certain defined limits, which may be small or large, depending upon the instruments used, the time devoted to the work and the personal ability and care of the surveyor concerned.

• The standard of accuracy attained must therefore be measured-first, by the limit of error applicable to each surveying operation made to produce the plan, and secondly, by the limit of error applicable to the plotting of the results of the survey upon the plan. Every surveying operation must be carried out in such a way as to prove itself within specified limits or several repeated observations must agree within specified limits and have a certain limit of average error."

When looking at these statements today it is important for the reader to appreciate that from the mid-1800s for virtually a century the most common items of mine surveying equipment were the Vernier Theodolite and the Miner's Dial which both used vernier scales for angular reading which typically gave direct graduation readings of between five minutes and ten seconds of arc. The Miner's Dial was based on a magnetic compass with sighting vanes whilst the Vernier Theodolite often had the ability to attach a Tubular Compass [6] (at that time said to be the most precise type as yet designed for surveying instruments). The uses of such instruments with magnetic compasses were fraught with the difficulties of:

• Variations in the bearing of magnetic north to true north (and now comparison to National Grid North)

• Localised variations produced by the presence of metalliferous minerals in the mine workings; or even steelwork, in the form of roadway supports and track work.

Given this background today's surveyors need to exercise care when looking at the records of disused workings in the vicinity of their mine; and in this regard it would be prudent for the appointed mine surveyor to record the extent of research undertaken into the subject and the conclusions reached to demonstrate that he has met the "as far as reasonably practical" requirement (see paragraphs 195 and 196 of the MASHAM Regulations). The report and findings should be given to the manager and owner for them to consider the hazards further and take the appropriate action. The following matters are not an exhaustive list for the surveyor to consider but should be sufficient to trigger more research where necessary:

• Primary sources of mine plan records include catalogues and lists compiled and maintained by various bodies (such as Coal Authority, local authorities, national archives, local archives, British Geological Survey and HSE Mines Inspectorate) relating to coal, oil shale, and other minerals. As well as the catalogues and lists of plans held by these bodies there are plans held in private ownership by the former mine owners, their agents and others. When researching the existence of plans of disused workings the mine surveyor should not limit his research to 115 m outside the boundary of the mine (see paragraph 20 of the Approved Code of Practice in the Prevention Against Inrushes in Mines 1993).

• In terms of the plans examined it is important to look at all available plans of the same workings to compare completeness and orientation. Where the plans show magnetic north or a combination of magnetic and true north the surveyor may need to research the local declination at the time of plan preparation to verify the orientation of the workings. In some cases different plans of the same workings have been known to show significantly different orientation of the workings. In such instances the differences need thorough examination and a report prepared. In some instances the workings on the plan are shown "open ended" at their extremities which may suggest they are incomplete, any transference of these workings to a modern mine plan should accurately reflect the "open ended" nature of the original plan and the working plan should be annotated accordingly. Many abandonment plans have signed endorsements on them from the surveyor and manager at the time of abandonment verifying the accuracy and completeness of a plan, in the absence of such endorsements the mine surveyor needs to ensure the research is thorough.

• As well as looking at all the available plans it is important to look at the records deposited with the plans. The amount of information deposited with abandonment plans can vary from a single report provided by the Mines Inspector to a complete set of survey records, comprising survey and levelling note books together with survey calculations. The inspector's report will give the reason for abandonment and the last date of working; this should be compared with the last date shown on the mine
plan. Where there is an obvious time lapse, doubt must exist about the completeness of the plan. The survey records will also provide an insight into the quality of the survey work and the method of correlation with the surface features. All the mines operated by British Coal from 1947 to 1994 required plans in compliance with mining statutes and their own codes and rules. Three versions were issued, the first in 1951, the second in 1975 and the third in 1984. Even where the plans of disused workings have been orientated and plotted onto maps depicting features taken from Ordnance Survey maps, care needs to be exercised. The original County Map Series published by the Ordnance Survey were based on a Cassini Projection [7] and localised meridians (Winterbotham had counted in excess of 150 [8] local results) which resulted in plan distortion on a national basis. Accordingly the Cassini Projection was replaced with the Transverse Mercator Projection which was more suitable for a long narrow country like Britain. The projection had the benefit of stretching the topography equally in all directions, an effect known as orthomorphism. The country was retriangulated between 1936 and 1953 (using 326 primary control stations and more than 22 000 reference points) to create OSGB36 (Ordnance Survey Great Britain 1936) co-ordinates and these were used extensively by the surveyors of mines until the introduction of global positioning systems (GPS).

- GPS, together with the processing packages available allow survey data to be represented in various co-ordinate systems such as the World Geodetic System 1984 (WGS84); the International Terrestrial Reference Frame (ITRF); the International GNSS Service (IGS) and the European Terrestrial Reference System 1989 (ETRS89). Transformations are then available to convert these projections to the projections used in individual countries. OSTN02 is the transformation used to convert between ETRS89 and OSGB36 to calculate Nation Grid co-ordinates used in Great Britain. Osgm02 is the precise geoid model then used to convert precise ETRS89 heights to Ordnance Datum.

- Using GPS, together with these transformations and the geoid model, the National Grid co-ordinates of a point can be obtained. These co-ordinates will however, not be sufficiently accurate for survey control without a minimum observation period of four hours for the GPS base station and the use of RINEX (Receiver Independent Exchange) data when post processing the observed data. The RINEX data is available for the previous 30 days free of charge from the Ordnance Survey website together with transformation software if required. Once accurate GPS control has been obtained, surface features identified on original survey drawings can be resurveyed, allowing the original survey to be adjusted to tie into the National Grid. By digitising the original drawings and adjusting to National Grid they can then be inserted onto the digital base mapping available from the Ordnance Survey and their agents. Subject to the accuracy of the original survey and any corrections used it would then be possible to identify possible risks when planning any development within the area of the former mine workings.

- When looking at the survey records of mines that have recently been abandoned and in relation to the accuracy of mine workings at active mines, consideration should be given to the requirements of paragraph 2 of appendix 3 of The Management and Administration of Safety and Health at Mines Regulations 1993 which requires the mine surveyor to “review the necessity for re-correlation of the mine from time to time and at intervals not exceeding five years.” A prudent surveyor will record the extent and nature of each review and the conclusions reached.

- Carefully examine all published editions of Ordnance Survey topographical plans and Geological Maps produced by the British Geological Survey together with associated field slips (linked to geological plans). In this connection it is worthwhile referring to the inrush of water from disused mine workings at Lofthouse colliery in Yorkshire on 21 March 1973 and the report produced by J W Calder the Chief Inspector of Mines and Quarries at the time. In his conclusions he identified that “important decisions relating to the safe working of the mine were taken at the planning stage by surveyors and were accepted by the manager and Section 1 appointees (owner) who did not call for and examine the supporting information.” One of his recommendations was that “when an area of coal under consideration includes old shafts or workings prior to 1960, the utmost care should be taken during the preliminary investigation to ascertain their position and extent. In the absence of positive information the coal should not be worked.” This statement is a salutary reminder to everyone involved in such assessments.

Conclusions

Mine surveyors have a duty to prepare “accurate” plans and sections “as far as is reasonably practicable”. Today’s mine surveyors have at their disposal GPS systems that can be supplemented with electronic theodolites and distance measuring equipment to achieve very high standards of spatial positioning. In the preparation of mine plans the surveyor should examine all available records of features which could constitute a hazard and bring them to the attention of the mine manager and owner to enable them to discharge their statutory duties. Where the hazards cannot be accurately defined the minerals should be left un-worked. Where the hazards can be defined and appraised, the manager and owner need to consider the need for appropriate action which may necessitate consultation with appropriate experts to discharge their statutory duties effectively including statutory notifications.

References

[9] Ordnance Survey- Great Britain’s national mapping agency; Ordnance Survey coordinate systems.
[10] Ordnance Survey website

Acknowledgement

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