time a length of over 30 yds. has been worked with perfect roof control, that it is thought that by means of the burster it may be possible to work a face satisfactorily which would otherwise have been not only uneconomical but also very difficult to work by machine. This result is quoted with a view to showing that apart from replacing shot-firing the Coalburster may have definite advantages under certain specific circumstances.

As no additional remarks were offered, the discussion on the paper was declared closed.

OUTCROP WATER IN THE SOUTH YORKSHIRE COALFIELD.

BY HAROLD SAUL, B.Sc. (ENG.).

In the early days of mining, drainage would necessarily run to the lowest point in the workings and thence by free-drainage "levels" to some convenient point on the surface. The invention of the Newcomen Pump permitted the application of the same principle when workings passed below the lowest available of such points. A deep "level" along the lower limit of the workings drained all water made below the free levels, or leaking from them, to a pump placed at its lowest point.

It is not difficult to follow the process by which it was noted that the percolation of surface water at depths in this coalfield only a little more than 150 yds. was generally very slight, for it is clear that many of the shaft pumping sets were occupied mainly with water which ran down the untubbed shafts rather than with water inherent in the workings from them. At this stage, reached barely a century ago in this coalfield, the policy of drainage to the lowest working-point must have given place to the careful maintenance and protection by pillars of the higher drainage levels so that the deeper workings could continue unhampered by the cost and inconvenience of water, except such as could be dealt with by an occasional horse-pump. Very little imagination would then be required to suggest that if within one group of collieries it had been possible to deal with the water by a scheme which left many districts completely dry, it might also be possible to carry out a more ambitious co-operative scheme, to protect several owners with an even greater measure of economy. It is not surprising, therefore, that such possibilities have been mooted with a frequency growing with maturity of work in the various coalfields.

Unfortunately, from my own viewpoint, seekers for possible advantages from nationalization of mines seized upon this principle as one capable of general application. Before the Coal Conservation Committee in 1918, and at subsequent Royal Commissions, references were made to the "Haphazard and unco-ordinated manner in which mine water is dealt with," and to the enormous advantages to be gained by "Central Pumping Schemes." Since such schemes were to be capable of general application it appeared that they were to involve large pumping stations at depths considerably greater than was the existing average practice. It was, therefore, objected that the economy which might result from the reduction in the number of pumping stations would be more than lost by the increased head for pumping, and by the cost of provision and maintenance of means for conveying water to these stations. The objections were supported by reference to the

prohibitive cost and difficulties of the unfortunate scheme in the South Staffordshire Coalfield.

Since it appeared that schemes so defined stood condemned, and since the Mining Industry Act, 1920, made provision for other schemes which might be feasible, little public mention was made of the matter for several years. Recently, however, the numerous abandonments caused or hastened by the slump in trade have caused the problem of water in old workings to become more pressing in several coalfields, and several local committees have been set up to consider the question.

In South Wales, the rapid increase in the area of waterlogged workings on the north-eastern outcrop impelled Mr. J. M. Carey, H.M. Divisional Inspector of Mines, to put forward a scheme for a series of free-drainage levels some 33 miles in total length at a probable cost of £1,412,000, and to indicate possibilities of a similar nature farther west in that coalfield. The proposed levels were to drain a cover which apparently reaches a maximum thickness of 650 ft., and includes an extensive series of workings now waterlogged. It is not clear that the estimated outflow of 20,000 gal. per min. is that which would otherwise threaten working collieries, but figures were quoted which indicate that adits and pumping pits now abandoned used to deal with at least 10,000 gal. of water per min. It is also not clear whether the scheme must be complete to be effective, or whether parts of the new level could be connected to existing pumping stations for use at an earlier date. Consideration of this scheme during 1935 appears to have brought out doubts as to safety in constructing and maintaining the proposed levels in ground liable to underworking and fears of an excessive cost as compared with the present cost of pumping. The necessity for considerable quantities of water for colliery purposes was borne in mind. Meanwhile, one colliery company near the waterlogged area has found it necessary to take over an old colliery to the rise and install pumps capable of dealing with 5,000 gal. per min.

Near Bolton in Lancashire a waterlogged area is extending. A statement was made recently to the effect that sixteen collieries had closed down within a 4-mile radius of Westhoughton during the past ten years, and that collieries in that district are in danger of flooding. During the past few months, work at Stott's Pit, Westhoughton, has actually been stopped due to this cause.

In West Durham, a considerable area of old workings lies waterlogged, and a survey made recently for the South West Durham Development Board shows about 13,000,000 tons of coal to have been lost in this area, whilst collieries still working are burdened with a cost of over 3d. per ton of output to pump a weight of six times that of the coal drawn.

The report of the survey appears to deprecate any attempt to de-water the area already waterlogged, but it stresses the advisability of controlling the water to prevent any extension of waterlogging to the east.

In Lanarkshire a similar state of affairs prevails and a report of the survey has been made. Adjoining collieries are at considerable pains to protect their workings from further encroachment, and two common pumping stations have been established recently, each serving several collieries, one concerning more than one colliery company. Nevertheless, at least one recent abandonment has added to the area affected. A similar problem affects pits in Stirlingshire.

From the fact that a Royal Commission deliberated upon the South Staffordshire drainage question it might be assumed that the position

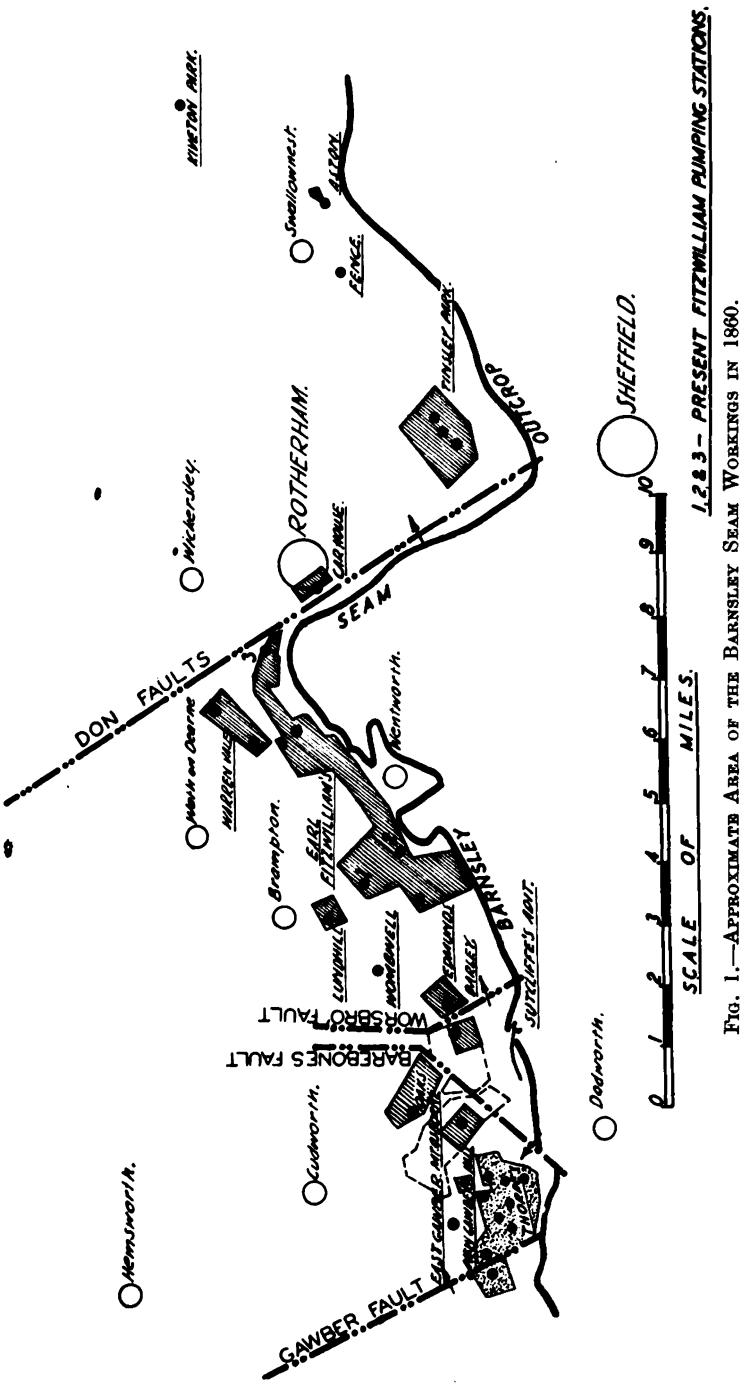

FIG. 1.—APPROXIMATE AREA OF THE BARNSLEY SEAM WORKINGS IN 1860.

in that coalfield is fairly well known. In that case, again, there appears to be a large waterlogged area which, under existing conditions

it would be uneconomic to drain. Fortunately, collieries lying north of this area appear to be protected to a great extent from further encroachment by a fault of large throw.

As compared with South Yorkshire the cases just enumerated are, with the exception of South Wales, notably greater in the size of the present problem relative to the area, considered in terms of present output, which would derive benefit from remedial measures. The consequent burden on these areas of the cost of such measures would thus be proportionately greater. In the case of South Wales, the magnitude of the scheme recently proposed would justify delay for mature consideration.

It is not sufficient, however, to consider the magnitude of the present problem. The extent of the South Yorkshire Coalfield would probably keep down to an average of less than $\frac{1}{3}$d. per ton the cost of all the work which could economically be carried out by a central body for very many years. But this extent also provides potentialities for a correspondingly vast water problem in its several workable seams. It is many years since mining engineers first awoke to this, and proposals for joint action date from that time.

In his Presidential Address to the South Yorkshire Viewers' Association in 1860, Mr. R. R. Maddison said: "We find many of the collieries heavily watered, and as year by year the workings extend toward the dip, it becomes more and more necessary that provision should be made for the prevention of surface water passing down into them. Probably no better plan could be devised than by keeping intact the chief main north and south throws or faults and by leaving a sufficient quantity of coal ungot on either side of them." The water-logged area in all seams at that time was probably insignificant in extent by present standards, yet is probably the source of much of the water now being pumped.

Little notice appears to have been taken of the suggestion, and it may be of interest to trace briefly the subsequent progress of outcrop water in the Barnsley Seam, as being the most extensively worked seam in the South Yorkshire Coalfield.

The approximate extent in 1860 of workings in the Barnsley Seam is shown on Fig. 1. It will be seen that work was in its most advanced stage north of the Don Faults. For a length of about 8 miles immediately north of the Don Faults, Earl Fitzwilliam's Collieries were dealing with outcrop water by a system which still exists, and will be referred to later. Under its protection the Lundhill, Edmunds, and Wombwell Main Collieries were already at work at much greater depths. It must be remembered, however, that these deeper collieries, although thus freed from seam water, had to install and maintain shaft pumping sets to deal with the feeders made in the shafts, which were not tubbed.

Farther north, in the Barnsley area, the position even in 1860 was much more complicated by reason of its more advanced development and greater number of undertakings. The Oaks Colliery had been at work over 30 years at a depth of 285 yds. and was still a dry pit. Immediately to the rise lay the workings of three large undertakings, the Darley Main, Mount Osborne, and East Gawber groups. Between these workings and the outcrop lay a large number of collieries under many different owners. One owner, however, named Thorpe, had a number of collieries covering a large area, which at North Gawber extended from the outcrop as far to the deep as did East Gawber and Mount Osborne workings. Farther south, the boundary of the area was

very irregular, and actually had smaller colliery undertakings working isolated areas inside it. Thorpe's North Gawber area lying north of the Gawber Fault was drained to the one shaft. South of this fault, however, there were several paths by which water could pass through the workings to the dip, even while Thorpe's new Willow Bank Pit was being sunk and pumps installed. A large engine at New Gawber Hall, owned by Messrs. Sturgess & Co., appears to have been dealing with the bulk of Thorpe's southerly outcrop water even at this time. Each remaining colliery between the Gawber and the Worsborough Faults appears to have provided for its own drainage, and the larger undertakings, Darley, Mount Osborne, and East Gawber, were practically dry, excepting again for shaft water.

The history of the next few years appears to have been the natural one of the exhaustion of the old pits, throwing a heavier drainage burden on neighbouring pits and hastening their end also. Until 1877, however, the deeper pits had little trouble, for the bulk of the water in the area continued to be dealt with by Sutcliffe's adit, supported by Martins Main pumps and by the New Gawber and Willow Bank engines.

The Mount Osborne group apparently relied upon this protection, and although a rise-side barrier was left this must have been very weak in several places. The Darley Main rise barrier probably was rather stronger and the East Gawber Colliery certainly left a substantial barrier. Prudence in the latter case may have been encouraged by the fact that the first face to approach New Gawber workings suffered an outbreak of water!

In 1877 New Gawber Hall Colliery closed down and water immediately found its way through the Mount Osborne barrier. In the next two years, seven more pits in the district were abandoned, followed in 1880 by the abandonment of Willow Bank. There was now a direct path or paths through Thorpe's workings from the outcrop workings to the Mount Osborne barrier, and serious trouble followed.

The pumping arrangements at the Mount Osborne Pits could not have been of great size, for a total make of water of 400-530 gal. per min. appears to have been so much in excess of their capacity as to have filled some acres of the dip-side workings by the middle of 1883. Coal winding ceased and water winding was resorted to, but a wet winter appears to have been responsible for the ultimate rising of the water up the shafts and the abandonment of the four collieries in 1884.

Although the rise-side barrier at East Gawber appears to have continued to be sound, that separating East Gawber and Mount Osborne was not so sound. Later work adjacent to this barrier from East Gawber appears to have encountered leakage at the rate of 350 gal. per min., which persisted until the colliery closed in 1901.

There does not appear to have been any immediate appreciable leakage to Darley Main from Mount Osborne, but the abandonment of Martins Main, to the rise of Darley Main, in 1884, had its own effect, which appears to have been helped by a trespass of about the same date from an outcrop pit adjacent to Martins Main. Darley Main was abandoned in 1885, and the exact rate at which water entered to fill up the pits was never recorded.

The approximate extent of the waterlogged area in 1882 and 1884 is shown on Fig. 2. The water trouble now threatened the Oaks Colliery for the first time. Protected as this was by a substantial barrier, it had continued a dry pit until 1883, and the whole make of water from

the barrier had never exceeded 4 gal. per min. until that time. When the leakage to Mount Osborne continued to beat the pumps there, however, the growing accumulation in the dips began to force water through the Oaks barrier, and during 1883 this grew from 13 to 50 gal. per min. This growth continued as the head on the barrier increased, until in 1887 the leakage was 120 gal. per min. Subsequent work, started in 1891 in a hitherto undeveloped district adjacent to the barrier, caused a further influx of from 90 to 120 gal. per min., and although this abated

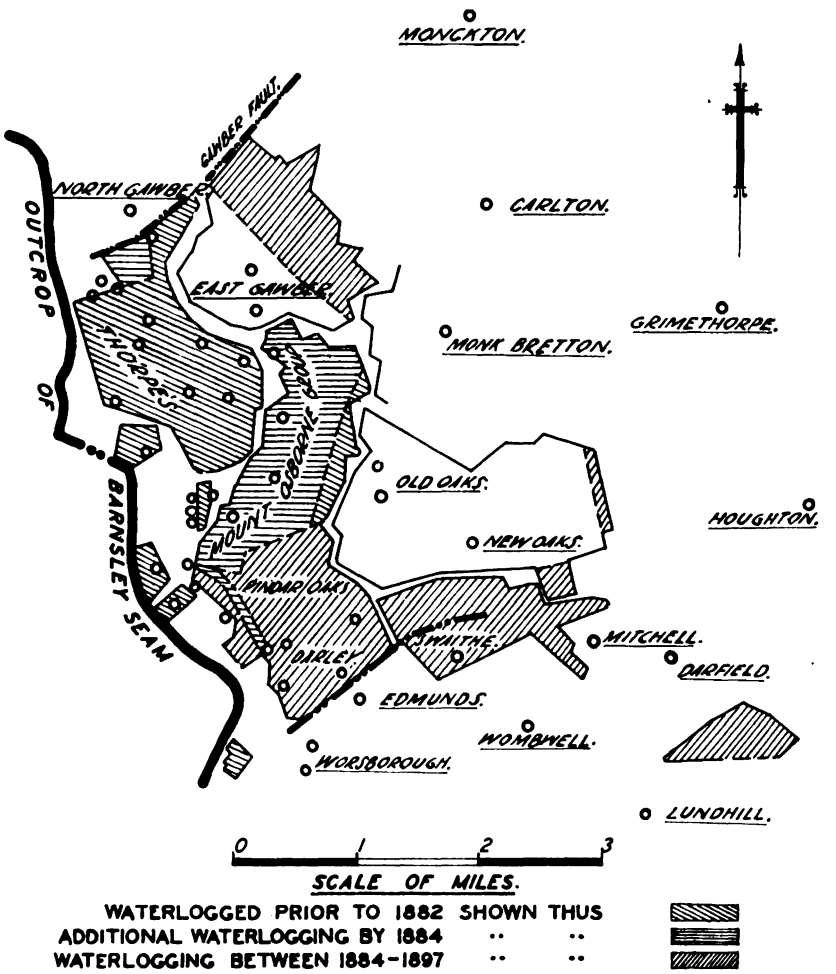

FIG. 2.—AREAS WATERLOGGED IN THE BARNSLEY SEAM.

somewhat as the ground settled, a considerable leakage has continued through this barrier up to the present time.

Meanwhile, Swaithe Main Colliery, which was already dealing with a substantial shaft-feeder in addition to the water from the old Edmunds' Main Colliery, had been receiving a further feeder from the abandoned Darley Main Colliery. About 1891 the dip-side workings at Swaithe were exhausted and work was transferred to an area of coal which had been left against Darley Main workings between the Worsborough and Barebones Faults. The consequences of this were, an accumulation in

the dip workings on the one hand, and an increased feeder to Swaithe on the other. The complete removal of the area of coal just referred to would admit outcrop water freely to Swaithe workings. Fortunately this was not carried out, but by 1894, with water accumulated to within 20 yds. of Swaithe pit-bottom, the Oaks, Wombwell, and Mitchell Main already in serious difficulties and the closing of Swaithe in sight, the Divisional Inspector of Mines called a meeting of colliery representatives

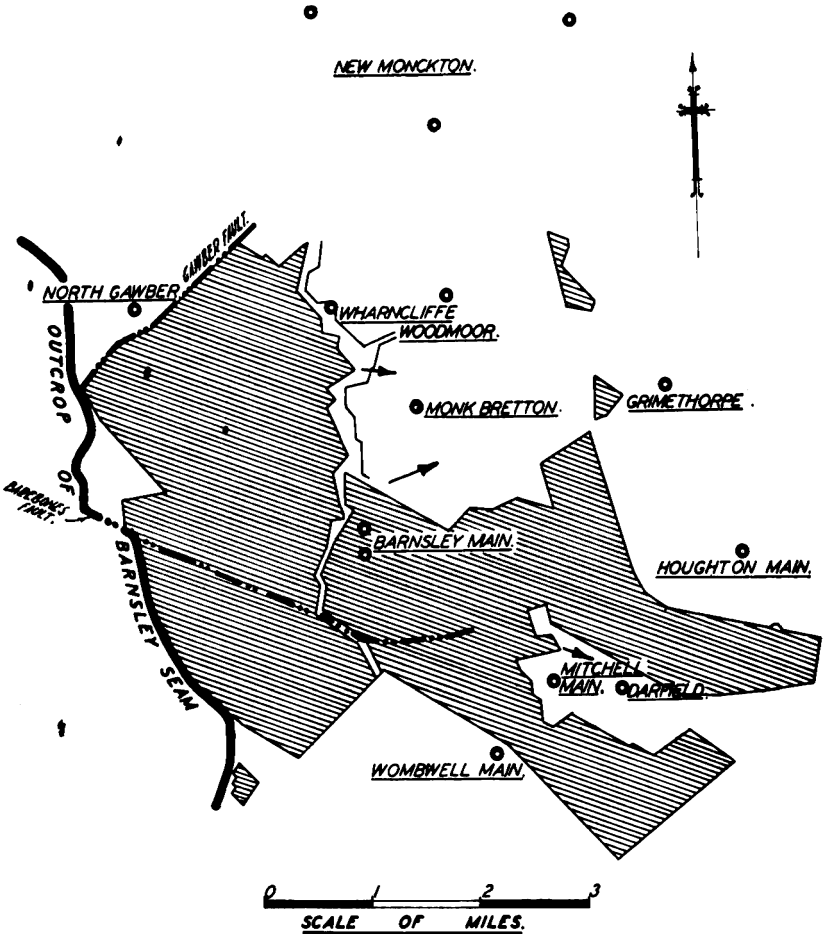

FIG. 3.—APPROXIMATE PRESENT POSITION OF WATERLOGGED BARNSLEY SEAM WORKINGS.

in an effort to secure joint action in dealing with the problem. His proposals were not carried through, and when in 1897 Swaithe did close down, the water very quickly rose up the shafts until the whole make of water ran through to neighbouring collieries. Fig. 2 shows the waterlogged areas at this time, and from it will be seen how great a dip-ward advance was permitted by allowing the water to run uncontrolled through Swaithe workings. The width of the royalty at which the water could have been caught was approximately 1,400 yds., and the lift to the surface, 230 yds. The present length of barrier under

pressure in working collieries as a direct result of allowing it to run away is 15,300 yds., and the pumping lift, averaged by volume, 400 yds.

Reverting to the leakage through the barrier between Mount Osborne and Oaks, this had continued to be pumped mainly at the old Oaks Colliery, but a very little which passed this level had been pumped from in-bye at the New Oaks Colliery, sunk in 1869. In 1907 in-bye pumping at New Oaks ceased and accumulation in the dip workings commenced, to be augmented in 1909 by the shaft water. The Oaks workings filled up, and leakage to Monk Bretton commenced. At this Colliery there had always been a small leakage from the old East Gawber workings, but this had gravitated to the shaft and the new leakage meant the introduction of fairly heavy in-bye pumping. By 1918 dip work at Monk Bretton had ceased in turn, and in order to

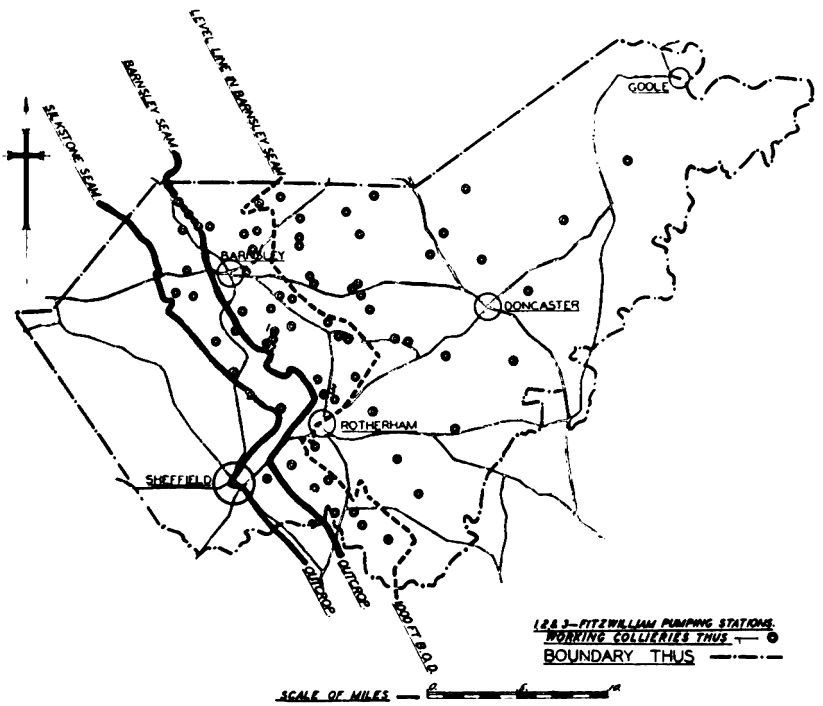

FIG. 4.—SOUTH YORKSHIRE MINES DRAINAGE SCHEME, 1929 AND 1936.

prevent the growth of pressure on the Grimethorpe barrier the water was drawn off to Grimethorpe Colliery. Thus has continued to the present day the pumping of what is undoubtedly outcrop water. Fig. 3 shows the approximate present extent of the waterlogged area.

It is still impossible to say how this complicated problem will be dealt with. De-watering of the Mount Osborne and other workings to the rise appears to be impracticable under present conditions. It seems likely that some scheme for dealing with leakage through the "continuous barrier" lying to the rise of Swaithe, the Oaks, Monk Bretton, and Carlton Collieries, will ultimately prove to be the most economical solution. Pumping at Grimethorpe Colliery continues, and it has been suggested that the water now running through Swaithe workings should also be dealt with. It must be remembered, however, that such steps will be of little value unless provision is also made for

the prevention of the entry of appreciable feeders of water from external sources behind the defences so created.

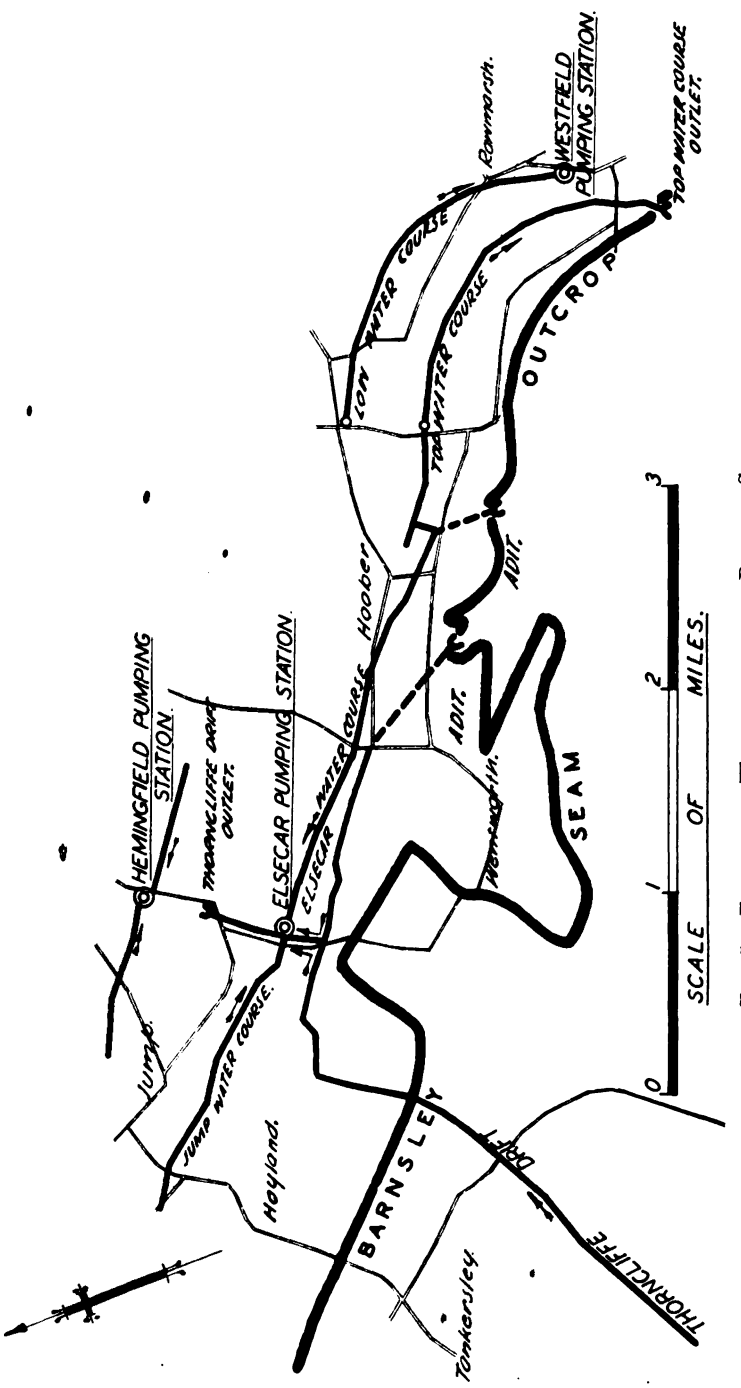

FIG. 5.—FITZWILLIAM WATER-LEVELS AND PUMPING STATIONS.

It is very noticeable that in other parts of the coalfield the water-logging is much less extensive than in the Barnsley area. This may be

attributed to the late development of the seam in other areas and the consequent larger size of the royalties. These royalties have only recently become worked out, and in several cases the necessity for protecting lower seams has compelled the owners to continue the Barnsley Seam pumping. Where the cessation of pumping is actually occurring, simple measures are being taken by the South Yorkshire Mines Drainage Committee to eliminate, or at least to limit, the consequences to deeper collieries. The Committee was empowered on August 7th, 1929, by a scheme under the Mining Industry Act, 1920 (1929, Statutory Rules and Orders No. 803, amended as to boundaries on October 23rd, 1936).

The scheme now affects an area of about 640 sq. miles (Fig. 4) containing a " group " of 69 large collieries. The objects of the Committee are specified as " those of co-ordinating and assisting the protection of the mines in the group from damage by water." It has powers in connexion with the acquisition and utilization of land and plant, inspection and entry of mines, and the carrying out of works and research. Provision is made for the defraying of the expenses of the scheme by levies on collieries in the group of rates on the basis of " the benefit derived or to be derived from the operations of the Committee."

These powers were obtained only after the expenditure of many years of effort. Reference has already been made to the abortive attempt of Mr. F. N. Wardell to secure joint action when the closing of Swaithe Colliery was imminent, and the results of this failure have been sketched. Work was continued by Mr. Pickering, but was interrupted by his untimely death. In 1917 a similar but more serious crisis threatened, with the approach of the exhaustion of Earl Fitzwilliam's Barnsley Seam collieries. At a meeting of the South Yorkshire Coal Trade Association, held early in 1918, it was decided to take over the Fitzwilliam Barnsley Seam drainage system. A voluntary body, the South Yorkshire Pumping Association, was formed of the 15 collieries then affected, to purchase and operate the system until the creation of a body with wider powers to deal with the whole coalfield. A Committee of the South Yorkshire Coal Trade Association was also appointed to investigate the situation in the Barnsley area. Continuous efforts by the Chairman and members of the Pumping Association were made to secure the wider powers, first by an attempt to promote a Bill in Parliament and later by Order. The lapse of eleven years before obtaining these was due to the trouble necessary to overcome very extensive and somewhat misguided opposition from public authorities.

The Drainage Committee's first action was to take over formally the Fitzwilliam Drainage Scheme, and work on the maintenance and improvement of the Scheme has been continued.

Fig. 5 shows the position of the Fitzwilliam Barnsley Seam pumping stations and drainage levels. The Thorncliffe-Elsecar water-drift was originally a Barnsley Seam adit and is therefore included. It was extended over a century ago, however, to drain part of Messrs. Newton, Chambers & Co.'s coal- and ironstone-mines and cuts the Thorncliffe and intermediate seams.

The length of water-levels now in use for passing water totals about 12½ miles, and about half of this length can be travelled at the present time. Most of the water flows out by gravity along the adits, the quantity dealt with in that way probably varying between 200 and 2,450 gal. per min., according to the season. Water which either leaks from the adits or is made to the deep is caught by levels from three pumping

stations, which deal with a quantity averaging only about 370 gal. per min. although varying from 240 to 1,650 gal. per min.

It has already been noted that this Scheme, although having only three pumping stations, deals effectively with a length of 8 miles of outcrop. It must not be imagined that no other pumping stations have ever been necessary, but it does seem fairly certain that the total number in operation at one time has never exceeded three. For example, in 1742 an engine was in operation on a higher level at Elsecar, and in 1797 another was pumping from a depth of over 80 yds. at Upper Haugh. The first-named engine was removed to a lower level as development proceeded, and the second-named was cut out by the extension of an adit to cut the pumping level, probably when the pit came into the possession of Earl Fitzwilliam. In much the same way it is now proposed to extend the same adit so as ultimately to cut out the present Elsecar pumping station and extend the free drainage to a length of about 6 miles. A length of 1½ miles of adit has already been repaired to this end. The maintenance of this drainage scheme might well provide sufficient material for a separate paper in itself, for the shafts and levels are, or were, nearly all unlined and of great age, and the behaviour of such on the extraction of lower seams is a subject upon which there appears to have been much speculation but little informative writing.

It is not sufficient, however, to maintain an existing system of outcrop drainage to be assured of protection for deeper collieries. The existence of an abandoned shaft or drift to the deep of such a system may well provide a means of access to the seam in question for quantities even greater than those dealt with by the protective system. In the case of the Fitzwilliam Scheme, part of the benefit derived from it may well have been nullified by the abandonment of the old Warren Vale and Rawmarsh Collieries on the closing down of Swinton Common Colliery.

At these old collieries a considerable feeder, amounting, it was said, to 350 gal. per min., was dealt with by the shaft pumps. On the cessation of pumping this quantity was immediately available at a depth of 270 yds., where only a barrier known to be ineffective barred its further progress.

Three shafts were plugged and measurement of the in-bye feeder, supported by underground examination four years after plugging, seems to indicate the complete effectiveness of the operation. Since that time the Swinton Common shafts have also been plugged. These shafts were tubbed, but the tubbing in one of them was leaking and its ultimate complete failure would have nullified previous work. Watertight plugs were therefore inserted and the shafts filled. This case is noteworthy also for the fact that by the removal of any risk from tubbing leakage, shaft-pillars were liberated in lower seams. In recognition of this a voluntary contribution was made by the royalty-owner towards the cost of the plugging. Will the proposed Mining Royalties Bill make provision for similar action under national ownership? In many cases consideration of the value of the preservation of minerals, added to protection of the mines, might well make the difference between economic practicability of protection schemes and the reverse.

The whole of the Swinton Common Royalty, lying to the deep of the Fitzwilliam Westfield pumps, is now permanently secured against introduction into the Barnsley Seam of water not inherent in it. It has

been very surprising to note that of the large quantity of water previously dealt with, less than 30 gal. per min. remain as inherent water when the shafts have been sealed.

In these days of tubbed or cemented shafts it is not always realized that this proportion of shaft to in-bye water was very common in the older pits. Investigation reveals that it is the rule rather than the exception, and despite the fact that barriers were so badly robbed in the Barnsley area which has been referred to at length, it seems quite likely that if a body such as the South Yorkshire Mines Drainage Committee had existed forty years ago, and had merely taken inexpensive measures for sealing old shafts as these were abandoned, the present-day problem would have been of considerably smaller dimensions.

Unfortunately the source of the feeders to shaft pumps in old collieries can usually be determined only by a careful and systematic examination of the shafts and pit-bottoms, and the condition of the shafts and water-lodges is not usually such as to encourage even the most inquisitive investigator. Conditions are often complicated by the presence of extra shafts which have not been travelled for years, and by numerous intermediate insets and water-lodges which divert the water into surprising paths.

The most recent of several examples of this is now being provided by old Aston Colliery. Here there are four shafts, three of which were sunk to the Barnsley Seam and one to the High Hazel Seam. There are other pits to the Sough and Furnace coals, but as these fall entirely within the zone of surface water it is unnecessary to consider them. Pumps were placed at the Hazel and Barnsley insets dealing with feeders of some 150 and 100 gal. per min., respectively. Of the feeder drawn from the Barnsley Seam Lodge about 50% was pumped there from in-bye. When the colliery ceased work some years ago this in-bye pumping ceased, but shaft pumping has continued. On recent notice of abandonment being given to the Committee it was found that the in-bye feeder could not be pumped as cheaply from the Aston workings as from the colliery likely to receive it, but that if it were to be joined by the pit-bottom water then serious embarrassment would result to several collieries.

Careful examination of the shaft-bottom showed that probably the whole of the water then being dealt with by the Barnsley pump had fallen down the shafts, and it was decided that it could be dealt with permanently by effective plugs in the shafts. The plugs already placed in two of the shafts have demonstrated the correctness of this by diverting to the Hazel pump a considerable additional feeder. The pump is running continuously, and the attendant reports that the overflow from the Lodge down the third shaft " is almost equal to the quantity delivered at the surface " !

It will be observed that in the last two examples, quantities of from 30-50 gal. per min. running to the deep have apparently been ignored. This is a rational procedure, for in each case the colliery likely to receive the small quantity is already maintaining pumping plant and collecting water. The power cost for an extra 100 yds. lift on such a small quantity would not exceed £400 per annum, which provides little justification for the maintenance of a separate pumping station by the Committee. On the other hand, there is at least one case where an equal quantity can be caught at a shaft lodgement and pumped direct to the surface, saving inconvenience in workings now dry at a depth

460 yds. greater. In this case the total maintenance cost of a small pumping station would be less than half the minimum power cost to the deeper colliery, and there could be no question as to the desirability of maintaining the small pump.

Perhaps some reference should be made to the clause in the Mines Drainage Order which refers to notice by colliery companies of intention to pierce or remove existing barriers. It is evident that in the removal of existing barriers often lies the possibility of serious embarrassment to other companies, and quite frequently to the company proposing to carry out the operation. It is gratifying to note that in cases where notice is not compulsory under the Order, most companies give this notice as a matter of courtesy, and this is of great value to the Committee, even if it is not always possible, as in some instances, to return the service without breaking confidence. Notice is not always given, however, of the intention to leave a barrier. While it is natural that companies would not wish to add unnecessarily to the external considerations already influencing them, it is possible that considerable economy might result, particularly in the more newly-developed seams, from the co-ordination of barriers which run approximately on the strike-line. They might, for instance, be adjusted slightly to strengthen a small fault, to bridge a gap between two faults, or to cut out " pockets " in which high-pressure water may ultimately accumulate. The many important factors affecting, and affected by, the positioning of boundaries and barriers make it impossible to envisage the Utopian ideal of a barrier across the coalfield in each seam at 100 yds. depth. It is sugggested, however, that cases may arise in which the Drainage Committee could give a useful lead.

In a recent case in which it was necessary for a colliery company to give public notice of proposed extension to workings, it was noticed that direct admission to deeper collieries would ultimately be given to very heavy outcrop feeders if complete extraction took place as proposed. With the willing co-operation of the colliery company it was possible to arrange for a barrier 1,550 yds. in length to be left in the seam most immediately concerned, and in others if found necessary. This addition will close a potential gap in a barrier of 14,000 yds. in total length round one of the most heavily water-bearing areas in the coalfield.

In conclusion, I desire to thank the Chairman (Mr. A. T. Thomson) and members of the South Yorkshire Mines Drainage Committee for permission to present this paper, and for constant help and sympathy in a somewhat wide range of duties.

Professor Douglas Hay (Chapeltown): I think I am correct in saying that the South Yorkshire Mines Drainage Scheme is the first really successful pumping scheme that has been established in any British coalfield. For many years there has been a great deal said in several districts about the water question and the best way of dealing with it, but in no other district has any really successful attempt been made. I personally feel that a great deal of credit is due to all those who were responsible for commencing the first voluntary scheme in 1918, and later, in 1929, the scheme which we now have. I think that those connected with this coalfield will some day owe a much greater debt of gratitude to those gentlemen than is realized at the present day. I have no doubt that this scheme will serve as a model for other districts.

Unfortunately, in many districts, it is almost too late to establish a successful scheme. A number of years ago when I was in Durham it was obvious that a co-operative drainage scheme would have been of the greatest value to that county. To-day, consideration is being given to the establishment of such a scheme, but the difficulties in the meantime have become so great that the task is much more complicated. In South Yorkshire, however, matters were taken in time, and, if given the full support of all the collieries in the coalfield, doubtless the water question will be successfully controlled in the years to come.

Mr. A. Blenkinsop (Rotherham): I congratulate the author of the paper on the survey of water difficulties and dangers that, ever since mining began, have been a tax on the skill, resource, and capital of the industry. One cannot but admire the engineers of the past who, with great enterprise, undertook the work of engineering and constructing those free-drainage levels described by the author, whereby not only was their own rise coal effectively drained but also the coal lying to the dip, and the coal lying unworked still farther to the dip, in which those engineers had no immediate interest, was also protected from the water burden carried by those free levels.

The Fitzwilliam levels were taken over by the South Yorkshire Drainage Committee, and I believe they drain an area of 8 miles of outcrop. They deal, according to the author, with a maximum quantity of water of about 4,100 gal. per min. It is an enormous quantity of water, and if it were not dealt with in that way it might become a serious danger, certainly a great nuisance, to many people working to the dip.

Unfortunately, that pioneering example shown by the Earls Fitzwilliam was not followed by many who, in their turn, worked coal farther to the dip. Indifferent as to the effects of tapping potential reservoirs of water lying against the faults or of the cumulative effects of leakages from shaft-linings, often in desperation robbing barriers which they knew should be left for permanent protection against adjoining water, they have saddled the South Yorkshire Coalfield with an unnecessarily heavy burden of pumping and drainage costs.

The author has shown how the rise, or outcrop, water has been allowed to percolate to depths which make pumping expensive, and if no concerted action is now taken this percolation will continue to breed difficulties of such magnitude that the exploitation of many of the low-lying seams to the dip of this water will become uneconomic and practically impossible. There are also vast areas of coal in some of the upper seams yet unworked that should be safeguarded now by concerted action.

It is but natural that every colliery concern should consider its own immediate interests of primary importance. It cannot be expected voluntarily to provide for the interests of its neighbours without some sort of compensation. At the same time, it may be blissfully unaware of immediate water troubles liable to threaten its existence, examples of which have been described in the paper.

We recognize that the whole subject of water drainage demands constant study and daily observation of the cause and effect of any new development or interruption in the work of the coalfield. In order to get such work done properly and effectively, the closest co-operation and liaison is necessary between all adjoining collieries. It is such work as

this that the South Yorkshire Mines Drainage Committee are endeavouring to carry out, and the author has clearly described the difficulties and nature of the work.

The author points out what has been accomplished by the filling up of abandoned shafts, and I would like to know whether there are other shafts that have been abandoned which might be so treated. Does the author consider it economically feasible to leave barriers against known water-bearing faults as recommended by Mr. Maddison in 1860? A figure of ⅓d. per ton of output is stated as the probable cost of necessary work that could be economically carried out by a central body for the protection of the South Yorkshire Coalfield. This estimate is, however, qualified by the author by stating: "But this extent also provides potentialities for a correspondingly vast water problem in its several workable seams." I would like to know what he means by that. In his calculations, has the author provided for the leaving of water-barriers and for supporting barriers, or for the extraction of all the coal? What, in his opinion, would be the effect on the present levels and water-barriers if the lower seams were worked?

It would also be interesting to know how the Swinton Common shafts were plugged to eliminate danger from pillar extraction. In regard to the Oaks barrier, it is stated that the influx of water abated somewhat as the ground settled, and I wonder whether the author could give further information about this. If all the coal is worked out without leaving a barrier will the ground settle sufficiently to obstruct water to any great extent?

I would like to thank the author for this valuable contribution to the *Transactions*, which is worthy of serious consideration on the part of all concerned in the working of coal, not only in Yorkshire but also elsewhere, and I hope it will convince them of the importance of co-ordinated water control.

Major H. J. Humphrys (Doncaster): The author is to be congratulated on the compilation of a paper giving authoritative and comprehensive information on a subject of great importance. I would like to have more information about the Newcomen engines at Elsecar and Westfield, one of which, I believe, is the original Newcomen engine.

Is a water-barrier across the coalfield for each seam the Utopian ideal the author represents it to be? There is a lot of evidence in the paper as to the inadequacy of barriers, and I believe it is becoming common practice to dispense with them between adjoining collieries. A barrier originally adequate in size becomes inadequate to prevent seepage if the pressure on it increases, and the possibility of a barrier being pierced cannot be overlooked. The provision of a barrier in an upper seam entails the leaving of supporting pillars in the lower seams of ever-increasing size as the depth becomes greater.

It is stated that the make of surface water is comparatively small, and I believe the rainfall on a belt of land 1 mile in length and 100 ft. in breadth represents approximately 15 gal. of water per min. throughout the year. Is a huge drainage level for each seam out of the question? Such a level might be constructed by joining present and prospective levels.

The paper deals mainly with the water problem in the Barnsley Bed, and the author points out the disadvantages we labour under to-day because the advice tendered by Mr. F. N. Wardell and Mr. W. H. Pickering—and I believe I am right in saying Mr. C. E. Rhodes—was

not accepted at the time. Is not the present the proper time to deal in a comprehensive manner with the protection of the lower seams in order to avoid the consequences of the delays of the past? Can the author say whether the South Yorkshire Mines Drainage Committee have any plans for dealing with this question? I venture to say that they are showing great wisdom in plugging old shafts in the manner described in the paper.

Mr. John Brass, Junr. (Tankersley): I think one point upon which Mr. Saul could enlighten me is in connexion with the estimated ½d. per ton. I should like to know whether that sum applies solely to the problem as treated in the paper, which is the problem of the Barnsley Bed, or whether it is calculated to include also any of the other seams that are now being worked at the outcrop collieries.

Mr. N. E. Webster (Sheffield): The broad objects of this undertaking have already been dealt with by Mr. Blenkinsop, and they are ones which deserve the whole-hearted support of all the coal-owners in the district. They have not always received this support, as we perceive from a study of the history of the subject.

With regard to detail, I also have been somewhat interested in the suggestion that a good deal more might be done by the co-ordination of barriers. It is a subject to which I have given much thought, because, as the result of a number of years' experience in North Wales, my own views on barriers are somewhat indefinite. I have left barriers 200 yds. in width in certain seams without the slightest apparent effect. Water from the rise has percolated through in apparently undiminished volume, in spite of what must be regarded as a reasonable width of barrier and a very considerable cost in loss of minerals. On the other hand, certain of my neighbours, who stated that they did not repose any confidence in barriers and proceeded to work out everything in their immediate vicinity, suffered no injury whatever when the collieries around them were forced to stop, and we all anticipated that they would be flooded out. The ground had obviously made up to such a degree that it had become impervious to the passage of water. It is difficult to lay down any hard and fast rule as to what particular conditions will enable a barrier to be satisfactory and those which will mean that it is a sheer waste of money and entirely ineffective.

Apart from that, I should like to say that I shall be very pleased indeed when the Committee have time to study the question of the outcrop water in our own particular vicinity. I would remind the Committee that at the moment I am responsible for some 2,500 gal. per min., which is equal to five or six times the tonnage of coal that we are raising and makes the figure of 4,000 gal. dealt with by this Committee appear a rather less significant figure than might otherwise be the case. At all events, I do just remind the Committee that there is a very serious problem awaiting them when those of us who are at the present time dealing with enormous volumes of outcrop water in the Parkgate Seam cease to be called upon to do so for our own particular interests.

Mr. R. Clive (Chapeltown): I think one of the important functions of the Drainage Committee has been the collection of information from the whole of the collieries in the district and the tabulation thereof on one plan. This has enabled the Committee to obtain a comprehensive picture of the best way of carrying out remedial work, and in this work Mr. Saul has collected and prepared his information in a most excellent manner.

I think another important function is the taking over of old shafts and water-levels, and maintaining the pumping at the higher levels. The plugging of shafts, and the plugging of drifts through faults, is another way in which the collieries can derive benefit without incurring heavy expense, as the expense of plugging a shaft or a drift, when once done, is not a continuing expense. One of the most difficult functions the Committee have to perform is the taking over of any pumping at an existing colliery. It is more difficult to arrange and to visualize what will be the best way of finally carrying out the protection of the collieries to the dip.

With regard to the cost, my own feeling is that no Committees, no matter how efficient they may be, are able to carry out the work in connexion with pumping as economically as a working colliery can carry out its own pumping. Mr. Saul refers to the additional cost of power for pumping a small quantity of water (30-50 gal. a min.), for an additional 100 yds. of lift, which should not exceed £400 per annum. It seems to me that this is a very high figure for the cost of power (by which I presume he means cost of electricity). I have taken out two other cases in which the cost of power at a colliery, calculated at a ¼d. a unit, works out at about £110 per annum per 100 yds. for 100 gal. a min., which is probably about a tenth of the figure given by Mr. Saul. The figure of a ¼d. per unit might be considered low by some people, but there are a very large number of collieries producing electric current round about that figure. That is one direction in which a colliery can do its work more cheaply than Drainage Committees can, which have to buy their current from a power-company, and generally have to pay a high figure for it.

Mr. J. W. Shaw (Barnsley): The information Mr. Saul has gathered is of the greatest value to the whole coalfield, and, after many attempts, it appears that at last something is being done to prevent this water from going farther to the dip. I have always contended that the "continuous barrier," mentioned in the paper, is of the utmost importance, and that it should never be pierced. For many years I checked the water leaking through this barrier from the East Gawber Colliery, and found it never varied from 21 gal. a min. It is interesting to note that the water oozed through where the barrier is shown to be from 400 to 450 yds. in extent. I have confidence that it is fairly accurately shown. Immediately before the East Gawber workings were stopped at this barrier, on account of the explosion, they were surveyed by Messrs. G. J. Kell & Sons, Barnsley, and I afterwards had the particulars put on the Monk Bretton plan. Farther south, I would not say the same for the Rosa (Mount Osborne group) barrier. It was always supposed that the Rosa workings had encroached on this barrier; this is supported by the fact that damage was caused to buildings on the Monk Bretton side, long before Monk Bretton worked in that direction. However, the leakage through this part of the "continuous barrier" was of small account; it was so scattered I could not measure it, but I should put it at rather less than that from East Gawber.

The more serious leakage from Monk Bretton to Grimethorpe is from the Oaks. A good barrier was left, running about east, from the "continuous barrier" down to Mitchell's barrier. I travelled this for many years, and it kept perfectly dry, even after the New Oaks workings had filled up. In 1912, some unfortunate workings in the Dunsill Seam started a leak in this barrier from the Old Oaks, which necessitated the in-bye pumping at Monk Bretton mentioned in the paper. The extent

of the leakage was 30 gal. a min., and it kept at that until the workings were exhausted, and pumping stopped in 1918. If Grimethorpe is now getting more water than the quantities I have given, it is the result of the working of lower seams under these barriers. The barriers are good, and, if they have been disturbed, I should look for the leakages to decrease when they have had time to settle down and silt up.

When the Barnsley Bed pits in this area are abandoned I have no doubt Mr. Saul will bear in mind the weakness of the tubbing in some of these shafts; and also that some of them were used as furnace shafts, which must have reduced their useful life by many years.

The history of the outcrop water in the Barnsley area has been one of lost opportunities, and Mr. Saul and the South Yorkshire Mines Drainage Committee deserve all the help that mine-owners can give them. The results of their labours have already been of great benefit to the collieries to the dip, and will be felt to a greater extent as time passes.

Mr. John Brass (Cawthorne) wrote: I wish to congratulate Mr. Saul on the lucid description of the position with regard to outcrop water in the South Yorkshire Coalfield, and the steps taken to mitigate it to some extent.

It was a pity that action was not taken at an early date in the Worsborough area with regard to the outcrop water entering the Barnsley Seam. All that was done was to endeavour to plug up the old Swaithe Main shafts. It is doubtful whether effective measures can be taken now except at very great expense, which might not be warranted.

As pointed out by the author in his paper, the problem of outcrop water is not confined to the Barnsley Seam only. It will certainly extend to all workable seams down to the Parkgate. So far as the Silkstone Seam is concerned, it is not known yet whether it is of a workable section south-east of the Mitchell Main Colliery Co. In a coalfield such as that of South Yorkshire, where there are so many workable seams, the problem of dealing with outcrop water becomes complicated, because pillars of coal must be left not only to support water-levels in each individual seam but also for the support of water-levels in the overlying seams, and this will entail leaving intact considerable areas of coal. The question of dealing with water in seams above the Barnsley Seam will also have to be faced. For instance, the Melton Field Seam is overlain by a porous sandstone rock, known as the " Melton Field Rock." Near the outcrop this rock contains substantial quantities of water, and in time, as the seam is further developed, this water will find its way to the deep.

It will be seen that, so far as South Yorkshire is concerned, one pumping scheme will not be sufficient to carry out the intentions of the Drainage Committee. Several schemes will be entailed, the first of which is the existing one. Another will be required to deal with the water at present being pumped at Grimethorpe Colliery. Other schemes will be necessary for the Parkgate Seam, the Melton Field Seam, the Silkstone Seam in the Sheffield district, and so on.

It is a matter for serious consideration as to whether, in view of all the difficulties, " Central Pumping Schemes " will provide the necessary safeguards, or whether it would not be as economical for each colliery to do its own pumping. Collieries lying farthest away from the outcrop are making contributions towards the cost of pumping from which they may not receive benefits for thirty or forty years, and in some cases

dip-side coal of collieries will be worked out before that of neighbouring collieries lying to the rise.

Investigations in regard to the impermeability or otherwise of goaf should be made. Some authorities hold that well-fallen goaves create a better barrier than pillars of coal, which are liable to cracking. Possibly Mr. Saul will express his views on this matter.

Another point which should be noted is that the faults in the South Yorkshire Coalfield have not been used as barriers in a way in which they might have been. Drifts which have pierced faults of 20 yds. and over should be dammed as soon as they have ceased to be of use. The drainage authority should pay attention to this point, because, if it had been done in the past, a large quantity of water would have been prevented from flowing to the dip.

Whatever the general problems facing Drainage Committees may be, there is no doubt that the scheme known as the Fitzwilliam Pumping Scheme, operated by the South Yorkshire Mines Drainage Committee, has been of great value to many collieries, and if a similar scheme had been put into operation in the Worsborough area forty years ago it is probable that the water which is now being pumped at Grimethorpe Colliery would have been considerably reduced in quantity, if not stopped altogether.

Captain S. Walton-Brown (Seghill) wrote: Mr. Saul has set out his particulars in a very interesting manner. In my opinion, every coal-field should have a Mines Drainage Committee in order that up-to-date information regarding water problems may always be readily available. Had these committees been in existence in the past many of our present troubles might have been averted.

Has Mr. Saul any particular ideas as to what action should be taken in the neighbourhood of outcrops in new areas to obviate water getting through to lower levels? What responsibility should be borne by royalty-owners who accumulate water in old workings at higher levels to the detriment of those who later on work coal to the dip? When the State owns the royalties this question is bound to arise, and presumably the State will have regard to liabilities as well as assets in its judicious management of a new holding.

Are any particulars available as to the effect of accumulations of water and the incidence of explosions of gas or coal-dust in the neighbourhood thereof?

Mr. Ernest Chicken (Blackhall) wrote: The facts so ably submitted by the author reveal a situation all too common in the older and more intensively worked areas of the various coalfields. It is without question that a more rational system of development in the earlier days of mining would have eliminated many of the difficulties now encountered. The present desire to group small concerns into large comprehensive units will undoubtedly improve the position as far as development in virgin areas is concerned.

The West Durham case mentioned by the author is well known to me, and it is very doubtful whether these mines will ever be reopened. It will be necessary, however, to control the level of the water to prevent any further extension to the east. The report on the situation in Lanarkshire also reveals that no special action could be justified at the present stage. Although these reports do not give much hope at present,

I should like to refer to the recent paper published in the *Transactions*.*

The colliery dealt with is situated in North West Durham, and is one of a group worked by one company. As stated in reply to the discussion, as long as the royalty to be worked is able to bear the heavy charges of pumping, all will be well, but as further exhaustion takes place, the remaining coal will not warrant the cost of pumping, and the water will then find its way to collieries farther east. Similar to those mentioned by the author, these collieries are old and are working to the dip of others already abandoned and flooded, with consequential results.

We are always wise after the event, and it might be suggested that coal-mining should have been commenced by sinking shafts, first at the deepest part of the coalfield and working forward to the rise. Unfortunately, coal was originally found at the surface outcrops, and it was only natural that the shallow areas would be developed first.

On the East Coast of Durham where large areas of sea coal are being worked, the Commissioners of Woods and Forests demand a suitable inland barrier to be maintained between each colliery (whether connected with the same group or not) as a protection against water. This may appear to be approaching a system of nationalization, but is certainly a step in the right direction, and if it had been in operation 100 years ago many of the water problems now being faced in the various coalfields would have been obviated.

I am interested in the method of plugging the old shafts as described in the paper, as during the sinking of Blackhall Colliery, 26 years ago, the feeders from the magnesian limestone became so heavy (14,000 gal. per min.) that the pumps were flooded and had to be withdrawn. The shaft-bottom was then filled in with cement concrete, and afterwards holes were bored through the plug and cement was forced into the surrounding strata under pressure. After a period, sinking was recommenced through the plug, and the feeders were effectively sealed.

Mr. G. T. Newbould (Rawmarsh) wrote: Mr. Saul's interesting paper shows that the old system of drainage at Earl Fitzwilliams Collieries has been of great service to other collieries to the deep. I have travelled portions of the drainage levels referred to, and although the Barnsley level line in the Rawmarsh district is anything but straight the small fall was kept remarkably even. If I remember correctly the fall in a distance of nearly 2 miles—Low Stubbin to the Westfield engine—was only about 12 ft.

The Westfield Newcomen engine mentioned was described in the *Transactions* of the Midland Institute (1917-18, xxiv., 167). I have since found a note-book dated 1822 containing the following: " Bill for castings (Beam and cylinder) to new Parkgate Colliery engine from Dale Abbey Ironworks . . ." It thus appears that Earl Fitzwilliam's own engineers erected the engine. I always thought this probable, because no makers name could be found on the engine. Can Mr. Saul or any member give me any information about the Dale Abbey Ironworks?

Mention is made of watertight plugs being inserted in some of the old shafts, and I should like Mr. Saul to describe briefly the method of plugging.

Mr. H. E. B. Daniell and Mr. L. H. Forster (Ryton) wrote: We wish to congratulate Mr. Saul on his very valuable paper. The

* "Increased Feeders of Water at Clara Vale Colliery and Measures taken to Deal with Them," by H. E. B. Daniell and L. H. Forster, *Trans. Inst. Min. E.*, 1935-6, xci., 260, 346; and 1936-7, xcii., 239.

historical records given by Mr. Saul are very interesting and must have entailed a great amount of research. We regret that, due to the very different conditions under review from those with which we are accustomed, we cannot add many useful comments or criticisms. We quite agree with Mr. Saul that when water can be collected at the higher levels, each case should be considered upon its merits, as a simple calculation generally shows whether the water should be collected at a higher level or allowed to drop lower. Central pumping stations have their use, but these must of necessity be at the lowest level, and all feeders must gravitate to that level. The question of collecting the higher level feeders is most important in cases where feeders of about 3,000 gal. per min. at 400-500 ft. head obtain, but in the area under review, where the feeders are comparatively small, the question may not be so serious.

We had hoped that Mr. Saul would attempt to answer the question "What thickness of barrier is considered effective?", but he does not commit himself. In considering this question, has Mr. Saul taken into account barriers which are probably cut by faults or the various kinds of strata and varying heads?

It is very interesting to know that plugs in the shaft are so effective. In many coalfields this method is found to be quite ineffective, as when the water is stopped at one place it always seems to make its way out at another. It is often found impossible to prevent bodies of water making their way to the lowest level worked at a colliery. The presence of beds of sandstone with or without faults often defeat the best-laid plans.

The work carried out by the South Yorkshire Mines Drainage Committee appears to have been most valuable, although from the paper even their work seems to have been limited in scope, and it is sincerely hoped that a more authoritative, and even national, body will take the whole subject of mine drainage in hand. In the present state of affairs it is almost impossible to compel a weak member to join a scheme.

Mr. Harold Saul (Rotherham), in reply to the discussion, said: May I first of all thank you very much for your reception of my paper, and then thank those who have been so helpful to me during the past six years. It is usually impossible to acknowledge in my reports the source of my information, but my Committee realize that I am dependent upon the goodwill of those holding it, and they appreciate the willing help which I receive at practically every colliery in the field. I am glad to take this opportunity of expressing my gratitude.

I think it is a great pity that the tremendous decrease in the first cost of pumping plant has allowed the question of driving adits to be overlooked. I know of few cases in the coalfield where mines have recently driven adits, but in these a very substantial benefit is being received.

Several members are apparently under the impression that the Drainage Committee deal only with the Barnsley Seam. Half the tonnage in the coalfield affected is still worked from the Barnsley Seam. It is thus quite natural that that seam has received the most attention, and, I suppose, will continue to do so for some time to come because the workings are becoming exhausted. Most other seams are, by comparison, just being developed, and their trouble is to come. At the end of the paper I mention a recent case in which, with the willing co-operation of a colliery company, the completion of a barrier was arranged for. That barrier is in the Parkgate and Silkstone Seams.

In regard to the estimated cost of ⅓d. per ton, I have worked out a rough scheme for all seams which I believe will deal with the outcrop

water question completely if carried out at the proper time. As far as possible I have tried to utilize existing barriers near the outcrops. In many cases it is quite impracticable to work these out, in others, nearly so, and it seemed that they might safely be left out of consideration. There are certain places where no barrier or convenient fault exists to form a collecting ground. In such cases it might be necessary to purchase a barrier, but it can be taken that the third of a penny would probably cover any such purchase.

The work in the Barnsley Seam to overcome the trouble outlined in the paper will be very expensive to carry out. Forty years ago a few thousand pounds would have met the cost, and therefore it is necessary to qualify the estimate I give by stating that it is on the assumption that the work is carried out as and when it becomes necessary. Shafts lying to the rise of a line of protection would bring additional water to the drainage scheme concerned, but open shafts lying to the dip of the line would tend to defeat the object of the whole scheme. It is most important that such shafts should be plugged as early as possible, for if shafts are left open until they are full of water, subsequent effective plugging becomes a much more expensive matter. In my view, a shaft should not be allowed to stay open 20 years or more, and impose a burden on other collieries, when, for quite a small sum, it could be plugged, if only temporarily.

That it is economically feasible to leave barriers against water-bearing faults is, I think, demonstrated by the fact that it is already being done in several collieries. By water-bearing faults I take it that faults which bring down heavy feeders are meant, and not just " dripping " faults. Such barriers need not be of great thickness. As I see it, the main object of such a barrier is to ensure that there is no sliding of the fault, and that the " leather bed " will not be disturbed. I have already dealt elsewhere with the size of such barriers. It is fairly evident that on the downthrow side of a fault it is safer to leave a thinner barrier than on the upthrow side. This is not because of the difference in level but because the roof breaks will run almost parallel to the fault on the downthrow side, whereas on the upthrow side they will cut the fault, thus giving a much shorter line of communication between the workings and the fault-slip.

Another question dealt with provision for the leaving of water-barriers and pillars to support them, and with the extraction of all the coal. The working of lower seams can give trouble, depending a great deal upon the thickness of the seam and upon the manner in which it is extracted. In any case, where workings are taken under water-levels or barriers it might be possible to arrange, without unduly interfering or attempting to interfere with the working of the coal, for such under-working to be as systematic as possible. In this connexion also I would like to refer to Mr. Shaw's contribution, and to suggest that the most significant phrase in his contribution is that they had no leakage " even after the New Oaks workings had filled up." In my view, the permanent watertightness of barriers, when coal is worked underneath, depends to a very great extent upon whether pressure is on the barrier at the time the coal is worked. If it is not appreciable, then in many cases lower seams might safely be worked, for breaks forming on settlement would tend to close again, and in the absence of high pressure might very well silt up completely. If there is pressure on the barrier when underworking takes place I think it may be a very different story.

At Swinton Common there were two shafts. Both were tubbed for a length of about 100 yds., and the tubbing in one was already leaking. The Committee therefore asked permission to put in plugs below the tubbing, so that if and when this should fail, the water would not run down into the Barnsley and lower seams and give widespread trouble. The royalty-owner, whose consent to the plugging was required, put forward the suggestion that if the shafts were to be abandoned the shaft-pillars in lower seams could be removed. It seemed possible, however, that in this event the proposed plugs might be cracked by settlement, or, if not, the shafts might collapse below them. The method of plugging with clay was therefore adopted. I would not like to say that, in all cases, clay plugs are superior or even equal to concrete, but where a shaft is to be abandoned permanently there is much to be said for them. It may be interesting here to note that a thickness of less than 30 yds. of suitable filling held 120 ft. of water without leakage.

Mr. Blenkinsop asked whether the ground would settle sufficiently to obstruct water to any great extent if all the coal was worked out. That appears to depend very much upon the method of working the colliery, upon the thickness of the seam, and the type of roof. There is another point. At the present time we are keeping large roads open long after the goaf has settled. I think there is considerable doubt whether some of the roads that I have seen to-day will ever close tightly, and in placing any reliance upon the goaf becoming impervious, the position of the roads should be taken into account.

In this connexion it may be stated that an example exists of a "goaf-barrier" in which great care was taken to obtain continuous packing and freedom from roof falls in the goaf. Obviously, seams with rock roof such as the Melton Field are not ideal for such a scheme.

Major Humphrys mentioned Newcomen engines. The engine at Elsecar was installed in 1787, and while conceivably it may have been removed there from the position which was occupied by such an engine in 1742, I cannot take it back to 1709.

Reference was made to the suggestion that a 100-yd. barrier was a Utopian ideal. Circumstances would show whether such a barrier could be relied upon to hold the maximum pressure available, but in any case it provides a line along which a pumping scheme could be established if necessary to keep the pressure to a lower figure.

The Committee have in mind the question of a drainage level for each seam. In some cases the outcrop workings are almost complete, if not abandoned, and it would be rather an expensive proposition to drive a level there, although in certain cases it might not be impracticable.

Mr. Webster said that his views on barriers were confused. That is very natural. It is almost impossible to lay down hard and fast rules, and I agree with him that it is difficult to find two cases where behaviour is identical.

Further discussion on the paper was adjourned.