# PROTECTION AGAINST INRUSHES IN THE UNITED KINGDOM

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## ABSTRACT

The paper describes an inrush of water from old workings into current workings at a mine in Wales when 2.3 million litres of water entered the workings. Two men were trapped by the inrush, one of whom was killed and the other was recovered uninjured after a period of 23 hours. Twenty five other persons received medical treatment. The precautions taken by the management of the mine before the inrush are described and the way about 2.6 million litres of water was drained by a cross measure bore hole in the months leading up to the inrush. Further precautionary holes were drilled in a heading approaching the area containing the old workings in accordance with the existing statutory requirements, but when one of the holes breached the old workings water was tapped under pressure and a further 2.3 million litres entered the workings very rapidly.

The paper reviews the statutory protection offered at the time of the inrush and the recommendations made concerning the amendment of legislation. The consultative document issued by the Health and Safety Executive is reviewed and the subsequent establishment of the Mines (Precautions against Inrushes) Regulations 1979. The operation of these regulations as they affect underground water situations is summarised.

## INTRODUCTION

1. In the period between 1900 and 1980 there were 258 deaths in United Kingdom coal mines caused by inrushes of water. This figure, although large, was dwarfed by the figures for deaths from other causes such as explosions and falls of ground and the statutory protection offered against inrushes of water was considered adequate until 1923 when 52 persons were killed in inrushes in three major incidents, the largest being at Redding Colliery, Stirlingshire, Scotland [1] where 40 persons were killed.

## 2. The Water Dangers Committee

After these incidents a Committee was appointed in 1924 by the Secretary for Mines to enquire into the methods prescribed and adopted to prevent danger in mines from accumulations of water or other liquid matter and to make recommendations. The Committee consisted of leading mining engineers of the day and they took evidence from fourteen organisations representing the various interests in the mining industry. The Committee became known as the Water Dangers Committee and their Report and its nineteen Appendicies [2] contained an outstandingly thorough and clear study of the subject.

3. The Report was published in 1927 and although no changes in the law of the United Kingdom relating to water dangers followed the work of the Committee appeared to have good effect as the number of deaths due to inrushes was reduced considerably. In the 56 years since 1925, 47 had no fatal accidents from this cause. 1973 however was a bad year because there were two inrushes in the United Kingdom. One at Lofthouse Colliery in Yorkshire [3] which claimed 7 lives and one at Cynheidre Colliery in Wales which claimed one life. In terms of deaths per 100,000 employed below-ground 1973 became the third worst year of this century for deaths from inrushes in the United Kingdom.

## 4. Cynheidre Mine

This mine is located in the Gwendraeth Valley at the Western end of the South Wales Coalfield. It is a large complex served by two pairs of shafts and three drifts lying within a circle of 5 km diameter. In 1973 the workings were confined to the Big Vein seam which was worked by mechanised longwall faces. The seam varied in thickness but normally about 2 m was extracted by shearer loaders. The seam analysis on an ash-free dry basis was about 90% carbon and 6% volatile. The seam was prone to outbursts of coal and firedamp and operated under a special Code of Precautions [4] to protect against this phenomenon. The mine employed about 1,200 men and produced about 20,000 tonnes gross each week of anthracite and was owned by the National Coal Board.

## THE INRUSH AT CYNHEIDRE

5. An inrush of water occurred at Cynheidre Colliery on 16 July 1973 in a heading which was approaching old workings. One man was killed by the inrush and another was trapped for 23 hours. The inrush flooded an adjacent longwall face and several persons working there had difficulty in making their way to safety. Of these 10 received treatment in the hospital but were not detained and 15 received treatment at the Colliery Medical Centre.

## 6. The Parts of the Mine Affected

Figure 1 shows the workings in the Big Vein seam which were involved in the inrush. This part of the mine was served by two level

roadways known as the 660 Horizon, which served principally as an intake airway (not shown in Figure 1 or Figure 2) and the 560 Horizon which served as a return and was some 100 m above the 660 Horizon. The BV1 and BV2 faces had been worked from the adjacent Pentremawr Colliery and were abandoned in 1966 and were allowed to fill up with water that was later to cause the inrush. The BV13 face was later worked from Cynheidre leaving a pillar to protect the 560 Horizon which was 12 m below the seam. When the BV13 finished at a fault a connection was made for ventilation purposes to the 560 Horizon. This connection, shown more clearly in Figure 2, was known as the 1 in 1, from the gradient at which it was driven. Later still this connection was extended back, first in the seam, and then across the BV13 goaf to the other gate which was then advanced through the fault at a dipping gradient of 1 in 5 to serve the BV18 face. As the 1 in 1 was then no longer required for ventilation, two separation doors were erected in that part of the roadway which was in the seam.

7. In 1973 it was decided to develop a longwall face to be known as the BV12 to work the 120 m pillar protecting the 560 Horizon by driving a heading in coal from the left hand gate of the BV13, near the top of the 1 in 1 drift, to the flooded main gate of the BV2. In addition to the usual planning requirements two extra matters had to be taken into account when starting the BV12 face development heading. Firstly the drivage had to conform with the Outburst Code [4] , a consequence of which was that the heading had to start between the top of the 1 in 1 separation doors so that the products of any outburst would pass directly down the 1 in 1 into the return which was the 560 Horizon. To cater for the possibility of gas from an outburst backing against the ventilation into the BV13 roadway an 'outburst' door was erected inbye of the two separation doors. This was similar to these doors but opened in the opposite way (Figure 2). The heading was ventilated by intake air via ventilation tubes passing through the doors.

8. The second matter was the dewatering of the BV2. It was decided by the management to do this from the BV12 development heading and a detailed scheme of both precautionary and dewatering holes was drawn up. Figure 4 shows the log of these holes that were drilled in accordance with that scheme, and it illustrates how thoroughly this aspect was dealt with. When the heading had advanced to a position 17 m from the old workings a dewatering hole, complete with stuffing box and stand pipe, would be established. When the time came for the hole to be drilled however, it proved impossible to keep it open in the soft outburst type coal that was encountered. A feature of the outburst phemonemon which has always been present at this mine is that bore holes, especially those of large diameter, are often very difficult to drill due to cavitation at the drill bit and drill holes often produce very large amounts of coal cuttings. A second dewatering hole was tried from the heading with a similar result.

9. The plan was changed and a 62 m long cross measure dewatering hole was bored at a calculated inclination to intersect the BV2

roadway from the 560 Horizon (Figure 2) and this was successful. The initial flow from this hole was estimated visually to be 550 litres per minute and visual estimates continued to be recorded for 12 days by which time the make had reduced to 20 litres per minute. From these estimates the total make of water which came from the bore hole was calculated to be 2.6 million litres. The advance of the BV12 development heading had been stopped while this dewatering operation was being done from the 560 Horizon.

10. When the original scheme was drawn up an estimate was made of the quantity of water lying in the waterlogged area. The roadways servicing the BV2 and BV1 Districts had been stopped off, and although their condition was not known, it was believed that if they had not closed completely they would be full of firedamp. However the stopping at the entrance to the BV2 gate which formed the high side of the pillar and which dipped at a shallow gradient inbye allowed water to drain through it and the make was measured and found to be 20 litres per minute. The level at the outbye end of the roadway therefore indicated the level of water in the old workings (Figure 1). The area of old workings below this level was measured and an assumed void ratio was applied to calculate the likely volume of water in the old workings. Little information was available on the likely void ratio in old workings in the Big Vein seam, but the recently completed gob drivage across the BV13 waste had shown the waste to be almost completely closed, and this prompted the adoption of a figure of 5% for residual voids. On that basis the volume of water in the old workings was 2.95 million litres. This figure took on a new significance when compared with the estimated production from the cross measure bore hole of 2.6 million litres and the similarity of the two figures appear to justify the various assumptions and estimates made in the derivation. The possibility that the two figures were similar simply through unfortunate coincidence did not appear to require consideration. Furthermore the residual make from the bore hole was estimated to be exactly the make from the old workings as measured before dewatering. It was therefore accepted by the management that all water had been drained from the old workings and the BV12 development heading resumed its progress towards the old workings. As was to be discovered later the estimates were wrong.

11. The Law at the Time

Precautionary holes were again advanced as required by United Kingdom law at that time. The relevant regulations which were extant at that time [5] required no working which was approaching and within 37 m of any place containing or likely to contain an accumulation of water or material that flows when wet or of any disused workings, not being workings which have been examined and found to be free from accumulations of water or material that flows when wet, to exceed 2.4 m in width and in respect of every such working the manager of the mine had to ensure that bore holes were at all times maintained in advance near the centre of the working of a length not less than 5 m and on each flank at

intervals not exceeding 5 m. In fact the bore holes used for this purpose were longer than the legal requirements.

12. Some residual water was expected in the old workings and when a trickle of water appeared at the face of the heading when it had been advanced to within 8 m of the old workings this caused no alarm. It was decided that a final precautionary hole would be bored on 16 July 1973.

13. The Inrush

This was bored by Frank Evans, the man who died, and Michael Williams, the man who had the ordeal of being trapped. The two were experienced and competent drillers who had undertaken the precautionary drilling programme throughout the development. A hand held compressed air driven drilling machine was used with 46 mm diameter bits and scrolled rods supplied in 1.5 m lengths. Three other persons, including the undermanager and an assistant unit engineer, were also at the face of the heading. The final hole had been advanced 7 m when some water started to come through the hole. As Williams started to withdraw the rods he was knocked backwards by the force of the water on the rods and everyone sensed it was time to go. They all got to the bottom of the heading, lead by the undermanager, in about one minute. Five other men were working there and the flow of water was increasing rapidly. The assistant unit engineer left rapidly down the 1 in 1 in order to reach a pump, and was fortunate to escape along the 560 Horizon despite being overtaken by the water. The others rushed through the separation doors to the BV13 supply gate, but Evans paused briefly at the bottom of the heading and shouted to Williams as he was about to go through the first door calling him back and saying he would not get through that way. Williams turned just as the water came up to his waist and he joined Evans with difficulty for the violence of the water was now such that they had to cling to the bars between the arch supports on opposite sides of the roadway near the top of the 1 in 1. The two men hung there back to back through the main period of the inrush. This had now become a raging torrent and water was coming in over the arches and between the lagging sheets in addition to the general flow in the roadway. When the force of the water reduced Williams turned round to find that Evans had vanished: he had been carried by the current against girder work at the top of the 1 in 1. When the flow ceased Williams found both his exits blocked and the conveyor signals and loudspeaker system out of order.
On looking down the 1 in 1 drift he saw Evans' body washed into the girder work and he feared that the level of the water in the 1 in 1 drift would rise to engulf him. Efforts made to enter the BV12 heading by rescue men on the day of the inrush were unsuccessful due to the water that had flowed taking debris with it to block all the entrances. On the following day the colliery general manager, with a party of men, examined the situation at the ventilation doors from the BV13 supply gate, where the water level had gone down. He found he could squeeze over the top of consolidated fine coal to

the top of the first ventilation door and by removing small sections of the door frame near the crowns of the arches managed to pull himself through. There were partial voids between the door frames which speeded up progress. After several hours of scraping at loose materials mainly by hand he was able to wriggle through above the 'outburst' door frame into the area at the top of the 1 in 1 drift. He found Williams alive but weak and he dragged him by his hands through the way he had come and back to the rescue party. Williams reported Evans' death and his body was later removed.

14. When the inrush occurred the urgent concern of the under manager upon reaching BV13's supply gate was for the safety of 55 persons employed in salvage work in the BV18. He managed to issue a warning through the loudspeaker system which enabled these men to leave immediately. Even so they met torrents of water coming both from the 560 Horizon via the 1 in 1 and from the 1 in 5 drift, that is to say, along both means of egress from the face. The last to escape found great difficulty in fording the water.

15. When the rescue phase was over that of recovery began. The BV12 development heading was full of debris but a current of air was coming down from the direction of the old workings. During the inrush a plug of foul air had come from the old workings and had required investigation by a rescue team in self-contained breathing apparatus, but this had cleared and this prompted an examination of the old workings in the BV1 and BV2 districts.

16. When the stopping erected at the outbye end of the middle road between the old BV1 and BV2 districts was broken down (Figure 1) the roadway was found to be readily travellable as far as the top of the BV2 face. A travelling track was restored along the face as far as was practicable to a point where survey work showed to be close to the BV2 lower roadway into which the BV12 heading had bored. The workings were now dry and an air current of about 5 $m^3/s$ was passing down into the development heading. On the basis of this information the recovery of the development heading started.

17. The ample dimensions of the old roadways came as a surprise. A survey of the roads that had been flooded indicated that 1.9 m litres had been stored in the roadways alone. An estimate of the water produced in the inrush suggested that the void ratio in the gob was just under 4%. Although that might not seem too far away from the assumed figure of 5%, the extent of the flooded area was such that an error of 1% in the estimated void ratio represented a quantity of 0.6 m litres. This illustrates the extreme difficulty of estimating accurately the amount of water contained in old workings, even when some factual evidence is available. The inspection of the old workings showed that it would have been possible to pump out water along the middle gate of the BV1/BV2 area and thus reduce the volume and the head of the water in the old workings by about half.

18. Attempts were later made to re-drill the cross-measure bore hole. It was found to be blocked at 17 m and although it was with

difficulty reopened to 32 m out of a total length of 62 m, it was impossible to relocate the hole beyond that level, which correlated with the roof of the Gras seam.

19. It took nearly three months to restore and complete the development heading. Most of the supports had been washed away and the sides had been gouged out to widths of up to 2.5 m. It was found that at the time of the inrush the face of the heading was in fact 10 m from the ribside of the BV2 roadway, which was 1.2 m further away than the rib as shown in Figure 4, but the sandstone roof had been strong enough to span all the enlarged sections and there were no major falls of roof. Coal taken from the sides of the funnel through which the inrush came contained much outburst type coal, as did the face and sides of the original heading. This type of coal is so weak that a lump can be reduced to powder with mild pressure from the fingers.

20. The magnitude of this disaster could have been much worse if the whole of the volume of the water in the old workings had passed into the BV18 face. Despite careful planning and estimation on the part of management, and full compliance with the legal requirements as they stood at the time, the inrush occurred and the implications were considered by the investigators.

21. Conclusions of the investigation.

The following factors contributed to the occurrence at Cynheidre:

21.1 The dewatering cross-measure bore hole passed through geological disturbed strata without being lined and these two features combined to cause the hole to become blocked.

21.2 Because of the blockage the dewatering cross-measure bore hole gave a false impression that all the water in the old workings had been drained.

21.3 The estimates of water in the old workings were based on void ratios which were subsequently shown to be wrong. The total volume of water that should have been drained through the cross-measure bore hole was about twice the estimated volume.

21.4 The implication of Regulation 4 of the Coal and Other Mines (Precautions against Inrushes) Regulations 1956 was that a bore hole of a certain length when contacting water under pressure would control the flow of water in such a way as to give adequate warning for the drillers to allow them to make their escape. At Cynheidre the final bore hole was over 1½ times the statutory minimum yet failed to give this protection to the men who were at the face of the heading. The speed with which the water flowing through the hole increased may have been affected by the nature of the outburst type coal which was contained in the seam in this part of the mine.

21.5 Hindsight and the partial inspections of the BV1 and BV2 districts which were possible after the inrush showed that much of the water in the old workings could have been removed expediently

by pumping from these old workings.

## THE LAW RELATING TO WATER DANGERS

22. United Kingdom law, as it applied at the time of the circumstances of the Cynheidre inrush [5] was summarised in paragraph 11. The same Regulations also dealt with dangers which arose in connection with workings approaching the surface, a rock or stratum containing or likely to contain water and workings which were within 45 m of peat, moss, sand, gravel, silt or other material that flows when wet. The Regulations were reinforced by Sections 75 to 77 of the Mines and Quarries Act 1954 [6] which required the owner and manager of a mine to acquire the basic information necessary to deal with external dangers to workings such as the thickness and nature of the strata and to ensure that each of them furnished the other with that information together with details of steps they had taken as a result of that information. This law had remained unchanged for many years and had previously been contained in Section 68 of the Coal Mines Act 1911.

23. The Water Dangers Committee Report that was published in 1927 [2] had already concluded that Section 68 of the Coal Mines Act of 1911 was inadequate. It had considered that in some cases the precautions required by the law did not provide an adequate factor of safety, while in other cases it was a criminal offence to omit precautions which were partly or even wholly unnecessary. The law applied equally to disused workings which were not likely to contain accumulations of water as well as those that were, and the Committee pointed out that 'the approach of workings to disused places under conditions in which there cannot be any apprehension of danger from water is of regular systematic occurrence under different systems of working in many collieries' and that in certain circumstances 'to insist upon literal compliance with Section 68 (of the Coal Mines Act 1911) is unnecessary in the interests of safety of workmen or of the mine'. They pointed out that advance boreholes could and often had missed the old workings; that flank boreholes were not properly specified and the area covered by them was uncertain; that the distance of 37 m may be inadequate if there was any uncertainty in the plans; and that the method of controlling the water from the boreholes was not stipulated.

24. The Committee considered that the circumstances of water danger problems varied infinitely and made it impossible to form one set of rules that could apply in all cases. Instead they recommended the principle of deciding each case on its merits. They

felt however that the precautions to be prescribed in each case should not be left to one person alone, but that the manager should be required to notify HM Inspectorate of Mines and Quarries and the Unions representing those that worked in the mine of any working approaching within 91 m in any direction of a place containing or likely to contain water or a disused working that could not be examined, and state the precautions he proposed to take. They also suggested that the proposed construction of underground water dams should be dealt with in the same way. They considered that a Committee representing the Owners, HM Inspectorate and the Unions representing those who worked in the mine should then consider the proposed precautions.

25. The investigation of the Cynheidre inrush in 1973 gave new relevance to what the Water Dangers Committee had said as early as 1927. The Report following the investigation of the inrush at Lofthouse Colliery [3] which had been published earlier in 1973 had considered different circumstances. The inrush at Lofthouse had occurred on an active longwall face operating some 200 m below the surface and had come from old unchartered workings which had been abandoned before the time when the law required details of abandoned mine workings to be deposited. The Report recommended, inter alia, changes in planning procedures where extraction of areas of coal was being considered and all available evidence should be listed, and where positive information was not available concerning old shafts and workings prior to 1900 the coal should not be worked. The Report also considered some aspects of the application of Regulation 4 of the Coal and Other Mines (Precautions Against Inrushes) Regulations 1956. The precautions required by that Regulation had not been taken at Lofthouse because the existance of old workings was not suspected and the Report concluded that other defects in Regulation 4 could be overcome by the establishment of Special Regulations applying to specific circumstances at specific mines.

26. The Cynheidre inrush occurred however in circumstances where Regulation 4 applied and despite the application of precautions in excess of the requirements of the law the loss of life was not avoided.

## 27. Proposals to Modify the Coal and Other Mines (Precautions Against Inrushes) Regulations 1956

In order to reduce the possibility of a similar accident occurring again it was considered necessary to modify Regulation 4 of these Regulations. Work started on re-drafting and the first draft was produced by the Health and Safety Executive in November 1975. The Health and Safety at Work Etc. Act 1974 had come into operation in the United Kingdom by this time and had brought into being the Health and Safety Commission with an executive arm in the form of the Health and Safety Executive. HM Inspectorate of Mines and Quarries, in common with other Inspectorates dealing with health and safety matters in other industries, became a part of the new organisation. The final draft of the proposals were published in November 1977 and the Health and Safety Commission directed that consultation about the proposals should take place with interested parties. The intention was to extend the application of the proposed regulations to all mines so that miscellaneous mines were included whereas the 1956 Regulations applied to mines of coal, stratified ironstone, shale and fireclay only, and the consultation procedures were suitably extended. In order to consolidate the law on precautions against inrushes it was proposed that the general provisions in Section 75, 76 and 77 of the Mines and Quarries Act 1954 relating to precautions against external danger to workings should be incorporated in the new regulations. The new regulations became law on 9 April 1979 [7].

## 28. The New Regulations

Under the Mines (Precautions Against Inrushes) Regulations 1979 the specific but limited requirements of the 1956 regulations were replaced by a more general requirement for the manager of a mine, where there may be a risk of an inrush into a working, to prepare a 'scheme of work' to ensure the safety of the mine and the persons engaged in the work. Details of the scheme have to be notified not less than 30 days before the work commences to HM District Inspector of Mines and Quarries and to the workmen's representatives appointed at the mine. The Regulations also require that where the manager of a mine, not withstanding the proximity of an accumulation or possible accumulation of gas or water or material that flows when wet, is of the opinion that there is no danger of an inrush and that no scheme of work is necessary, he must give notice of his opinion to the District Inspector and to the workmen's representatives. The Regulations in no way detract from the general responsibilities of employers and employees for safety under the Health and Safety at Work Etc. Act 1974. The adoption of the requirement for a

'Scheme of Work' to be prepared by the mine manager allows for each case of danger, or apprehended danger, to be dealt with on its merits, rather than within a specific framework. Schemes of Work have to be prepared and submitted 30 days before work commences when workings are within 45 m of the surface, material that flows or is likely to flow when wet or a stratum likely to contain water, or within 37 m of any disused working. Schemes of Work and Notices given by the manager of his opinion that an inrush will not occur must also be kept at the office of the mine and posted in covered accommodation provided in accordance with requirements of the Mines and Quarries Act 1954 until the working is completed.

29. The Manager's 'Scheme of Work'

These schemes provide the defences against the possibility of inrushes causing loss of life and such schemes should include consideration of the following factors.

29.1 Survey and Appraisal

In making the most accurate appraisal possible of the situation, the manager should consult the colliery surveyor and planner and any person who could assist with personal knowledge of the disused working and the manner in which it may have changed with time. Sources other than the mine working plan should be specified. If water is known to be or likely to be present, calculations of the likely quantities and pressures should be made but should be used with caution and only to confirm or refute other evidence. If there is doubt about the possible presence of unchartered workings, the recommendations of the Lofthouse report [3] would apply. The possibility of entering old workings for the purpose of restoring ventilation, pumping them dry, and examining them, should be carefully considered before committing the scheme to a drilling programme.

29.2 Drainage

The estimated amount of water that might have to be dealt with in a dewatering scheme should be related to the volume of the current workings and the paths which the water would take if it flowed freely or if the drainage facilities provided were overwhelmed. Dip places at risk should be clearly identified. Before drilling starts, the facilities required to deal with the highest estimate of water quantity and head should be prepared, and measuring instruments should be in position. The capacity of sumps, pipelines and pumps should be carefully noted.

29.3 Boring

A clear distinction should be made between precautionary boreholes and dewatering boreholes. The length of precautionary boreholes should be related to the nature of the ground, and while the old statutory minimum of 5 m may be taken as a guideline, this should be exceeded if there is any indication of incompetence in the strata.

Their pattern should cover an appropriate area. For dewatering, a minimum of 2 holes should be specified with stand pipes which have been tested to twice the anticipated water pressure. Means for removing blockages should be provided and if the strata contains material likely to be eroded by the passage of water, the hole should be lined. In some cases it may be necessary to determine the position of the inbye end of the borehole, and the specialised survey equipment required for this should be specified and obtained in good time.

29.4 Communications

The value of good communications when things go wrong has been shown repeatedly. Broadcast facilities should be well sited and water-proof.

29.5 Method of Work

If it is intended to approach closer to the danger area than the specified distance before it has been established that the danger no longer exists, then the method of work should be described by referring to the proposed :-

(1) width of working
(2) equipment installed
(3) system of support
(4) number of persons employed
(5) pattern of precautionary boreholes

29.6 Establishing the End of the Water Danger

It is always difficult to be certain that the danger has been eliminated. Reduction in pressure and quantity at more than one dewatering hole is good evidence. A further indication may be provided by the analysis of the atmosphere at the mouth of a hole after the flow of water has ceased. The analysis of the water itself can also contribute. By establishing the norm for meteoric waters in a mine by analysing samples, any change may indicate the ingress of water from disused workings or from other sources.

30. The proposals to issue the Mines (Precautions Against Inrushes) Regulations 1979 were anticipated in South Wales in December 1976 and the National Coal Board required managers of mines to prepare and submit 'Schemes of Work' to meet the anticipated regulations, but without prejudice to existing law. Experience with the preparation and execution of schemes was well established by the time the new regulations became law in 1979 and to date 104 have been prepared and completed without incident.

31. The author wishes to thank Mr J S Marshall, HM Chief Inspector of Mines and Quarries, for permission to prepare this paper.

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List of Figures

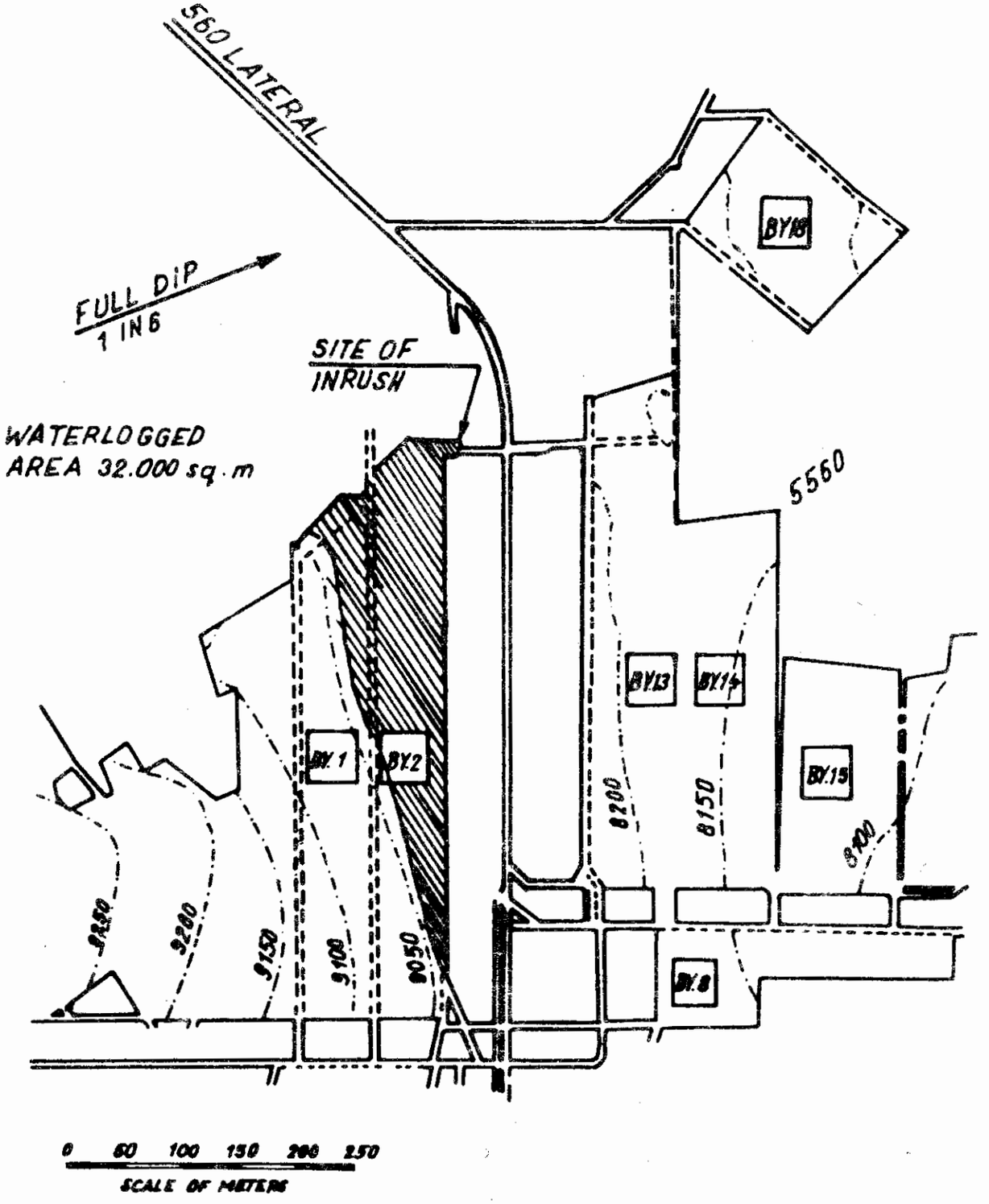


Fig. 1

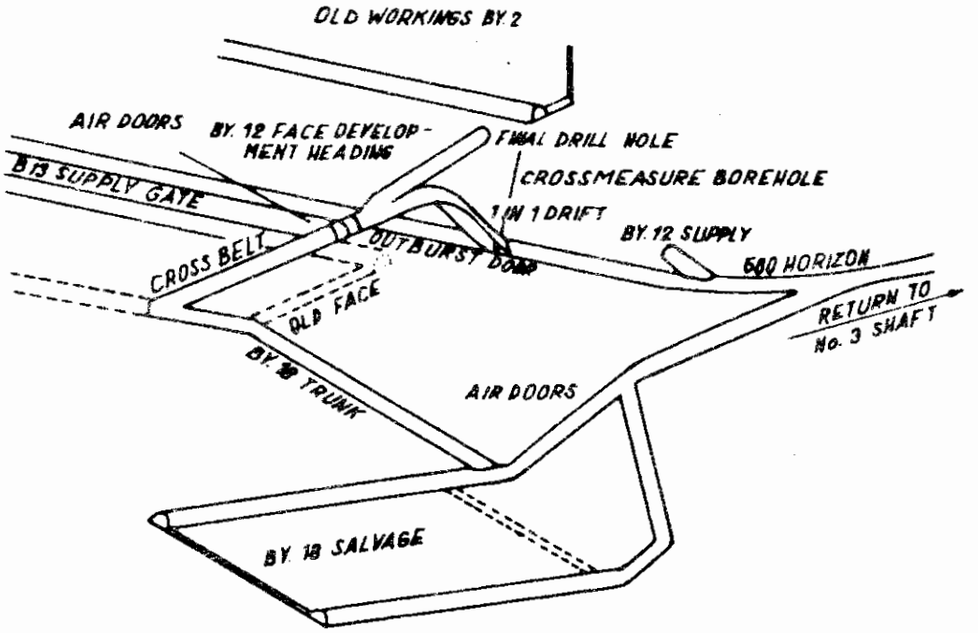


Fig. 2

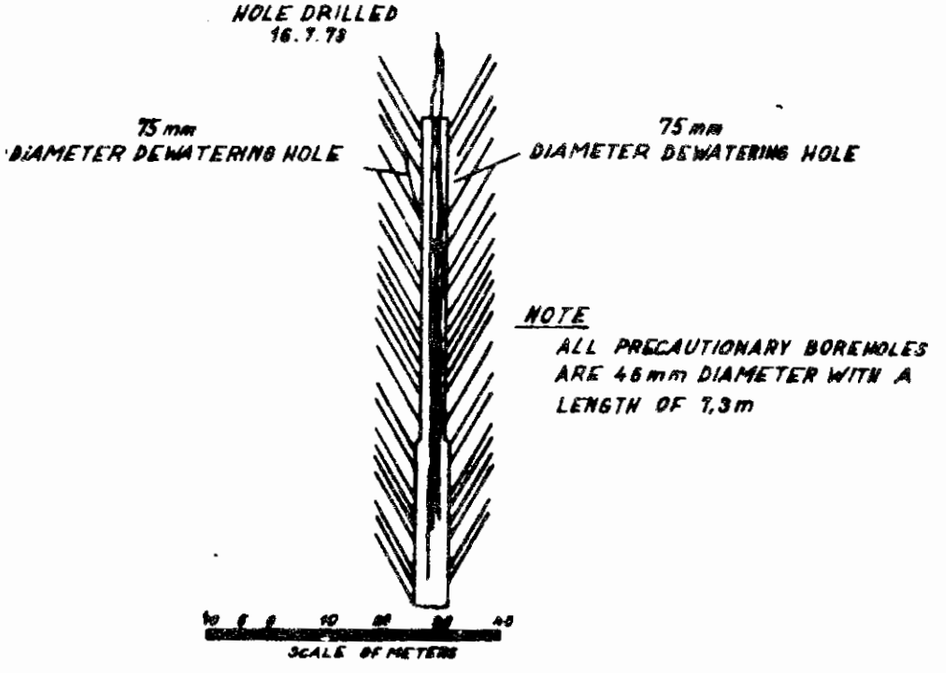


Fig. 3

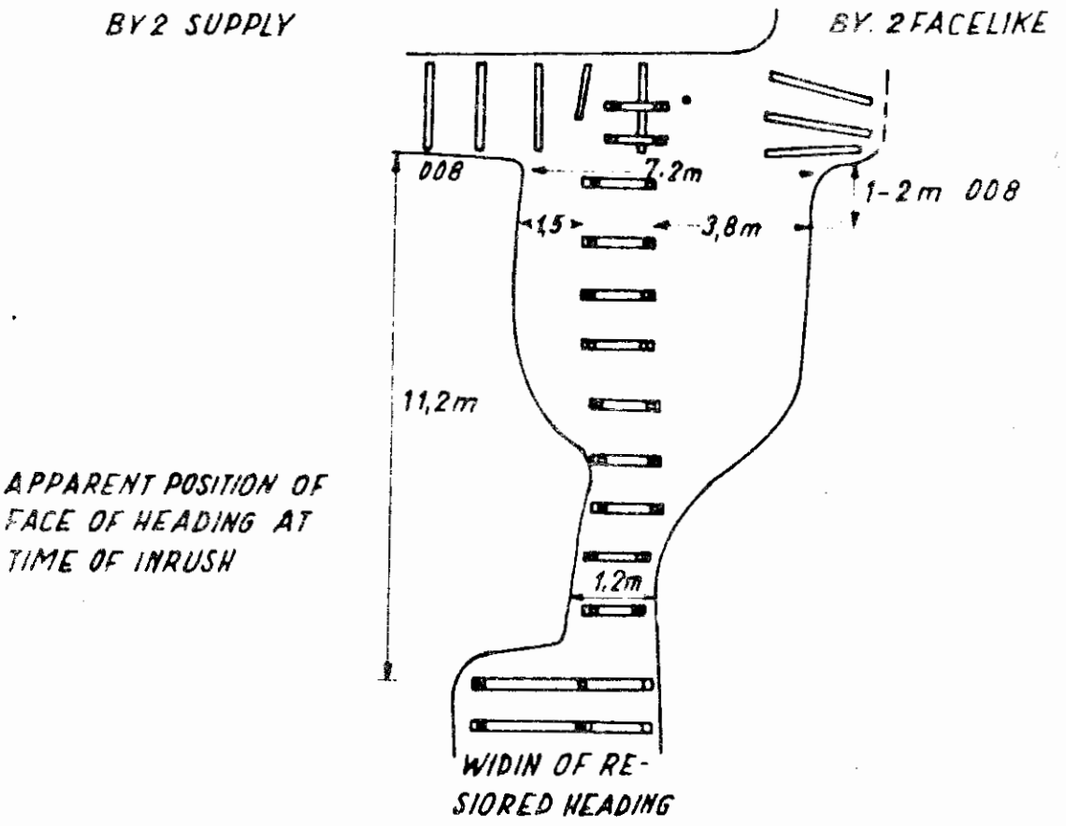


Fig. 4