MINISTRY OF WAR TRANSPORT.

Railway Accidents.

REPORT ON THE ACCIDENT

which occurred on 7th September 1945, near

SUN BANK HALT, LLANGOLLEN

on the

Great Western Railway.

GREAT WESTERN RAILWAY.

MINISTRY OF WAR TRANSPORT,
Berkeley Square House,
London, W.1.

26th November, 1945.

Sir,

I have the honour to report, for the information of the Minister of War Transport, in accordance with the Order dated 10th September 1945, the result of my Inquiry into the accident which occurred at about 4.51 a.m. on 7th September 1945 near Sun Bank halt, between Trevor and Llangollen, on the Ruabon-Barmouth line of the Great Western Railway. I was assisted at my Inquiry by Mr. C.T. Gardner, Deputy Director of Canals, Ministry of War Transport.

At about 3.30 a.m., while the line was closed, a portion of the bank of the Shropshire Union Canal, which is located on the steep hillside about 37ft. above the railway, gave way, and the consequent flood caused a severe breach in the 40ft. high double line railway embankment at the foot of the slope, leaving the rails suspended; the breach extended right through the embankment to its foot for a length of 95 - 120 ft. at rail level. The canal is owned and maintained by the London, Midland, and Scottish Railway Company.

Unfortunately the block and telephone wires were not severed, and at 4.51 a.m., the 3.35 a.m. Down mail and parcels train from Chester to Barmouth, the first train of the day, ran into the breach at a speed of about 35 m.p.h. The train comprised 2 bogie vans and 14 4-wheeled wagons, with a 20-ton brake van; 11 of the vehicles were vacuum-connected to the engine, which was No.6315, of the 2 - 6 - 0 type with tender. Except for the brake van the whole train was wrecked, and subsequently caught fire.

I regret to report that Driver D. Jones was killed instantly as the side of the engine cab was crushed. The fireman, G.C. Joy, and the guard, F.W. Evans, both had remarkable escapes from serious injury. Joy was thrown clear and half buried in falling earth, but in spite of severe shock and a broken wrist he walked forward 1½ miles to Llangollen and reported the accident. Evans' van was not very seriously damaged, and he climbed out by means of the overhanging rails and walked back 2 miles to Trevor signal box, to advise the signalman there; he also suffered from severe shock.

The weather at the time of the accident was fine and the night was very dark. The summer as a whole was reported to have been dry locally, but there was an exceptionally heavy thunderstorm in the district on the 5th August, about a month before the accident; rainfall was practically continuous locally for 24 hours, during which time 2 ins. of rain were recorded at Shrewsbury, 25 miles away.

The failure of the canal bank appears to have been brought about by general instability of the formation, due to a variety of causes.

DETAILS OF WRECKAGE, RESTORATION WORK ETC.

1. Engine No. 6315, as it fell, struck the opposing wall of the breach and came to rest, more or less upright, buried up to the running plate in soft earth, with the chimney about 12 ft. below rail level. The engine received no serious structural damage though it proved impossible to recover it intact; the tender remained coupled, and was found on its left hand side. The wrecked underframe of one of the two leading bogie vans was resting on top of the engine, behind and above which all the remaining vehicles were piled in a tangled mass of wreckage, the whole of it, including the brake van, within the confines of the breach.

Fire, which broke out almost at once, probably from the scattered firebox embers, quickly developed into a blaze, and completed the destruction of all the vehicles except the van, of which the body was only partially burnt.

The National Fire Service were called by the Llangollen Police at 5.25 a.m. and responded promptly. The Llangollen pump was on the scene at 5.36 a.m, followed by three others from Wrexham, 9 miles distant, at 5.52 a.m., 6.15 a.m. and 6.27 a.m. Sufficient water remained in the canal to supply the pumps and although the worst of the blaze was over by 6.43 a.m., the fire was not finally extinguished until 9.10 a.m. after burning for nearly 4½ hours.

2. Clearance of the wreckage presented exceptional difficulty, and was not completed until 4 p.m. Wednesday, 12th September, nearly 5½ days after the accident, and until this was done, little more than preparatory work was possible for the restoration of the line. A 45-ton breakdown crane was on the site on the 7th, but little progress was made on that day as the crane could not safely get near enough to the breach to make any heavy lifts. At 5.0 p.m., however, the services of two 8-ton winch lorries were obtained, through Western Command, from the Royal Artillery Mechanical Transport School at Rhyl, together with a working party under Captain N. Johnson, R.A; a similar lorry, with crew, was lent by a local timber merchant, Mr. Langshaw Rowland.

These lorries were anchored in the meadow at the foot of the embankment and the 8-ton pull of their winches was augmented to 32 tons by wire rope tackles and snatch blocks to drag the wreckage, piece by piece, sideways out of the breach. With their arrival, progress was continuous during daylight hours and, with very effective co-operation by the military personnel with the Company's breakdown staff, all the wreckage except the engine was cleared by the evening of Monday 10th September

On Tuesday, the 11th, the boiler, which was practically undamaged except for its fittings, was lifted clear of the engine frames by the crane, and the tender was pulled out sideways. After considerable excavation, unsuccessful attempts were made to lift out the engine frame with the crane, and later to drag it clear with the winches and tackles anchored to the rails. The frames were therefore cut through between the leading and driving coupled wheels, and were withdrawn in two parts on Wednesday 12th, using the power of two winch lorries supplemented by the winch of a bulldozer which had also been provided by the Royal Artillery.

3. In the meantime, the Engineering Department had decided to restore the Up line across the gap by a temporary bridge, constructed of war emergency timber stored at Ruabon; the design comprised five 18 ft. and two 15 ft. spans with four 14 in. x 14 in. timbers under each rail, carried on 6 piers of 14 in. x 14 in. and 12 in. x 12 in. piles. Pile driving commenced at 11.0 a.m. on the 10th and the bridge was completed, with the permanent way, by 4.0. p.m. on the 17th.

It was, however, considered advantageous in the long run, to retain the Up line in the Engineer's hands until sufficient block stone and ash filling had been tipped from the bridge to enable the Down line to be restored. Progress was such that a single line train service was instituted over the Up line from 7.0 a.m. on the 20th while tipping continued from the Down line; normal double line working was resumed, under speed restriction, at 12.15 p.m. on the 22nd, after a lapse of 15 days. The superstructure of the temporary bridge was recovered, but the piles were left in the bank.

Altogether, approximately 1900 cubic yards of filling were tipped, and in addition, two Royal Artillery bulldozers were used to push back about 3,000 cubic yards of debris from the meadow into which it had been washed by the flood from the canal.

4. It will be seen from the foregoing that the work of clearance and restoration was a complicated emergency task involving long hours of arduous work, for which credit is due to all concerned, including the Royal Artillery personnel and the Engineering staff of the London, Midland, and Scottish Railway, whose work on the repair of the canal bank proceeded concurrently (see Para. 19 below).

DESCRIPTION.

5. With reference to the attached plans and cross sections, the main road, the canal, and the railway ascend the valley of the River Dee in a westerly direction from Ruabon. At the site of the accident, they are on the left bank of the river i.e. on the northern hillside, 102 ft., 77 ft. and 40 ft. respectively above the flat alluvial meadow on the inside of a bend in the river. The general slope of the hillside is approximately 1 in 3.

6. The canal, named the Ellesmere Canal, was authorised in the year 1793; in 1847 it was leased in perpetuity to the London and North Western Railway Company, and by the Railways Act 1921 it was vested in the London, Midland, and Scottish Railway Company who are now responsible for its maintenance. By the London, Midland, and Scottish Railway (Canals) Act 1944, the canal was formally closed to navigation and now serves as a feeder to the main Wolverhampton to Ellesmere Port navigation canal which it joins at Hurleston, approximately 45 miles form Llangollen.

The canal is approximately 20 ft. wide and 2 ft. 9 ins. deep. It commences at sluice gates immediately above the Horseshoe Falls of the River Dee at Llantisilio, 2 miles above Llangollen; thence it runs approximately on a contour for 13 miles in an Easterly direction, with only 1 ft. 0 ins. fall in that distance to the first lock, after which there is a series of descending locks to the junction at Hurleston. For the feed to the main canal and under various arrangements to supply water to industrial undertakings, notably Monsanto Chemicals Ltd. at Acrefair, near Ruabon, the Company needs to maintain an average daily flow through the canal of 11½ million gallons; there are also agreements for water supplies to neighbouring farmers, etc. By the London, Midland, and Scottish Railway Act of 1944, the Company were empowered to abstract a maximum of 12½ million gallons per day from the River Dee at Llantisilio.

According to the geological maps of the district, and to reports prepared by Mr. A. Reid, Mining Engineer of the London, Midland, & Scottish Railway, and by Mr. F.B. Clark, Mining Consultant to the Great Western Railway, the general formation of the hillside is of glacial moraine type overlying the Silurian rock. Further up the hill, about 270 yards from the roadway, there is a fault, above which the carboniferous limestone rock comes to the surface.

7. Mr. Reid suggested, from the character of the strata exposed by the breach, that the canal and roadway were originally constructed on natural terraces in the "boulder clay" moraine formation, the natural hill side forming the lower portion of the 1 in 1.5 slope between the railway and the canal, with tipped earth above it to form the towpath and the outer canal bank. Mr. Gardner and I see no reason to dissent from this view, which receives some confirmation from the marked variation in the width of the towpath platform, which is 12-15 ft. in the neighbourhood of the breach.

The slope between the canal and the railway on either side of the breach is covered with undergrowth and young trees, mainly sycamores, the largest of which have trunks about 15 inches diameter. There were no trees of any size at the actual site of the breach, as a dry stone counterfort wall, to which I refer later, was constructed there in 1938; there are also four other counterforts close together (see Fig.2) close to the breach on the Ruabon side, which were built in 1922.

8. The Railway was constructed as a single line in 1859, 66 years after the canal, and was subsequently doubled. At the site, its embankment appeared to be of brown loamy earth, tipped against the natural hill side. As stated, the height of the embankment is 40 ft. above the level of the meadow and its width at rail level is 39 ft, with the two tracks out of centre to the outside; the average slope of the bank is also about 1 in 1.5. There are no drains of any kind in the embankment, nor is there a surface drain at the inside cess. The stone ballast extends to a depth of about 4 ins. below the sleepers.

For a short distance on the Ruabon side of the breach, the railway formation is partly cut into the hillside, which is supported by a rubble masonry retaining wall 160 ft. long, with a maximum height of 12 ft. (see Fig.2). So far as can be determined, this wall, which has no weep holes, is the original one, and it appeared to be in first class condition.

Although the railway ascends the valley generally in a westerly direction, it is on a local falling gradient of 1 in 75 at the site. Consequently, on the Ruabon side of the breach, towards Sun Bank halt, the level of the railway gradually becomes closer to that of the canal, and the slope between them is less steep. On the Llangollen side, the railway begins to curve away from the hill side and the canal about 200 yards from the breach, and its embankment becomes two-sided.

9. The first intimation that there was anything wrong was received by Mr. H. Cuffin, night supervisor of the power station at the Monsanto Chemical Works, which takes its water supplies from a branch of the canal about 3 miles below the breach. According to his account, the two pumps which were working at the time lost their suction from the canal at approximately 4.20 a.m. Mr. Cuffin then examined the adjacent screens, and found them clear but he noted that the water level had dropped 4 ins; he managed, however, to get the pumps working again and went out to examine the "boom" screens about 100 yards from the pump house as he thought there might have been some obstruction there.

When he found, at about 5.10 a.m, that the water-level was down outside the boom, he realised that the fall of the level in the canal was general, and went back to reduce the factory loads; at 5.35 a.m. he received news of the breach by telephone. Mr. Cuffin suggested that, having regard to the intervening distance of 3 miles, the breach might have occurred round about 3.30 a.m., and in the absence of any further evidence as to the time, this estimate was considered to be reasonable by the London, Midland, & Scottish Company's Engineers.

10. The train was running at about 35 m.p.h. with steam shut off on the falling gradient, and in the darkness neither Fireman Joy nor Guard Evans had any warning of the breach in the embankment ahead of them. The train passed Trevor signal box, approximately 2 miles on the Ruabon side of the Breach, at 4.47 a.m, at which time Signalman Williams sent "Train Entering Section" to Signalman Hall at Llangollen Goods Junction, 1⅝ miles beyond it. Owing to an intermediate stop at Llangollen passenger station, this particular train generally takes about 15 minutes to clear the 3⅝ mile section, so that it was not until 5.10 a.m. that Williams, with a following train waiting at Trevor, telephoned to Hall to know whether the mail train had reached him.

Hall at once called up the station but got no reply until 5.20 a.m. when he learnt from the shunter on duty that the mail had not arrived. On Hall's instructions the shunter went back along the main road in the Post Office van and returned at 5.35 a.m. with the news that the canal had "burst its banks" and that the train was on fire. Hall sent the station porter to advise the Police, but they had already been notified at 5.15 a.m. by Mr. Edwards, landlord of the Sun Trevor Inn, about 250 yards from the site, and had summoned the National Fire Service. Signalman Williams had the first news of the accident from Guard Evans, who reached Trevor box at 5.30 a.m.

11. At 5.15 a.m. Mr. Edwards also called Canal Labourer F. Chase, who is responsible for the maintenance of the canal section concerned, approximately 2 miles in length. Chase was assisted by Mr. Edwards to place stop planks in the canal at Llandyn Bridge about 950 yards above the breach, where the level was found to be 10 ins. below normal. Chase then went to Bridge No. 41. 165 yards below the breach, where he found there was hardly any water left. In the meantime he had sent his son on a bicycle to warn the neighbouring lengthman to close the Llantisilio sluices, 3½ miles above the breach, which was done at 6.10 a.m.

12. Chase stated that during his 15 years experience of the length, he had never observed any leakage at the site of the breach, though maintenance was troublesome elsewhere on his length (see later). He passed the site at about 4.0 p.m. on 6th September, about 12 hours before the accident, as he walked along the towpath on his second inspection on that day, and observed no leakage there nor any signs of movement of the bank. The Great Western Company's ganger, W.G. Jones, has an understanding to inform Chase of any leakage which may appear at the foot of the canal embankment, and he too noticed nothing wrong when he passed the site at about 4.45 p.m. on the 6th as he walked the track. Jones stated that the track in the neighbourhood required no more than normal maintenance apart from a troublesome rail joint about 200 yards from the breach on the Ruabon side.

Nothing abnormal was noticed by the crew of the 7.25 p.m. passenger train from Ruabon to Barmouth on the 6th, which passed the site at about 7.57 p.m; this was the last train over the line before the accident. The driver, who had worked regularly over the line for 25 years said that the running was invariably good, with a solid feel to the road.

13. With the arrival of daylight at approximately 5.45 a.m. Chase examined the breach, where he was joined at 7.20 a.m. by Mr. W.P. Bowen, Canal Inspector, Ellesmere District. According to their accounts the breach, when first examined, was about 9. ft. wide at the level of the canal; the edge of the clay puddle was about 1 ft. 0 ins. below the normal water level, and the puddle was intact under the bed of the canal. There was still a little water flowing, but most of it had already gone.

14. When I arrived at the site, 28 hours after the accident, the breach had been widened to about 15 ft. at canal level by further falls of earth. On the slope between the canal and the railway, a width of about 30 ft. was maintained, increasing rapidly to a maximum of 120 ft. at the top of the railway embankment, and to about 200 ft. at its foot. The outline of the V-shaped scoured channel is shown by Figs. 3 and 4, and Fig. 2 shows the extent of the debris which was washed into the meadow to a maximum depth of about 5-6 ft. It was estimated that about 2 million gallons or nearly 12,000 cubic yards of water were discharged.

15. Fig.4 also gives some indication of the layers of strata exposed by the breach. The layer of artificial red clay puddle round the canal bed appeared to be homogeneous and about 1 ft. 6 ins. to 2 ft. 0 ins. thick, with its upper edge almost level with the towpath. It was washed away for about 2-3 ft. only from the outside edge of the canal and the remaining width of about 20 ft. appeared to be intact, as stated by Chase.

Mr. Reid and Mr. Clark examined the site together on 17th September, and their reports as to the nature of the strata are in substantial agreement. Mr. Reid stated:-

> "A careful examination of the breach immediately below the towpath shows 18 inches of blue clay and 15 inches of yellow clay both impervious in situ and of a plastic nature on which the Canal puddle rests and which appeared to be intact.
>
> I am not aware if these clays extend under the bed of the Canal.
>
> Underlying the clays above referred to the strata consist of boulders, nodules, clay and sand of a semi-porous nature, the face of which was very damp.
>
> There is evidence that this glacial deposit persists under and on each side of the Canal.
>
> The contour of the ground on the north side of the Canal rises very steeply and to a considerable height.
>
> It would appear that the natural drainage from the uplying lands has been passing in this glacial deposit under the Canal down to the River Dee, forming subterranean lakes and channels, the extent and number of which it is impossible to determine, and due to the shape of the breach in the Railway it might be concluded that the crust overlying one of these has suddenly collapsed at this point, freeing the water which may have accumulated in the strata between the Railway and Canal.
>
> I could find no evidence of any collapse on the bed of the Canal."

At a further examination, after the artificial puddle under the canal had been removed, Mr. Reid found that the blue and yellow clay extended right under the canal and for several yards east and west of the breach. In his subsequent report he confirmed his own and Mr. Clark's opinion that these clays were "in situ or natural strata, adding that they were highly impervious and formed an almost perfect seal for the canal water. Mr. Reid also referred in this report to "sandy clays and gravel drifts associated with boulder clay of a semi-porous nature underlying the blue and yellow clays," and mentioned the existence of an impervious layer of reddish clay between the boulder clay and the Silurian rock.

Mr. Clark suggested that the thickness of the boulder clay layer was irregular, varying from zero to 30 ft. The surface of the underlying Silurian rock was located under the railway embankment at 21 - 25 ft. below rail level, close to its natural outcrop at the level of the alluvial meadow, when the piles were driven for the temporary bridge.

16. The stability of the canal bank at the site of the breach came under suspicion in 1938 as the result of a longitudinal crack about 5.ft. 0 ins. long and $\frac{1}{8}$ in. wide which appeared in the towpath. As a result, a dry stone counterfort wall was constructed to reinforce the bank (see Para. 7 above); its outline is shown by Fig. 2. As a further precaution a length of box puddle, shown in Fig. 4, was introduced into the towpath bank. There was no further movement until the present failure occurred approximately 7 years later.

The information with regard to these reinforcement works was furnished by Mr. F. Everitt, District Engineer, L.M.S.R., Crewe, and by his Canals Assistant, Mr. W.E.F. Phillips, also by Inspector Bowen and Labourer Chase, who first discovered the crack in the towpath. The other four counterfort walls (1922) were evidently built as a precautionary measure, but I was unable to ascertain whether there had been any signs of failure of the bank at that time.

Maintenance of the canal in this area was described as troublesome, and there is evidence that it has been so in the more distant past. Significant examples are noted at (i) and (ii) below, while (iii) and (iv) refer to other incidents in the neighbourhood which appear to be relevant in the light of subsequent events.

(i) Serious leakage from the bed of the canal occurs from time to time for a length of about 50 yards East of Wenffrwd Bridge No. 42 (see Fig. 1). This length is 290-340 yards from the site of the breach, and, according to Chase, the leakage is sufficient to reveal itself by a swirl in the water and by waterlogging of the meadow below. A stock of some tons of clay is kept on the bank nearby for repairs, but after it is placed in the bed of the canal it gradually sinks and the leaks re-appear. Chase stated that the leaks were reduced for a time but not stopped altogether, when the bed of the canal at this point was lined with corrugated iron sheets in 1933. It was found in 1937 that the ground had subsided under the sheets.

(ii) The marked narrowing of the canal, and its evident diversion nearer to the hillside 50 yards West of the breach was shown on a plan dated 1850, but not on one dated 1805, and it seems reasonable to assume that this re-alignment may have been undertaken on account of some weakness in the bank which appeared after the canal was constructed. For approximately 60 yards at this point there is a brick waterway wall on the outside of the canal which replaced a stone wall about the year 1900.

Further, the 1805 plan refers to the taking of a plot of land "covered by gravel in the Meadow below the base by Water breaking out". This plot was practically at the site of the present breach.

(iii) In 1933, a cavity appeared in the roadway behind the northern abutment of Bridge No.42. The opening was only about 2 ft. 0 ins. diameter at the surface, but the cavity below was much larger, requiring two lorry loads of material to fill it. Holes also appear from time to time in the canal bank close to the north eastern wing wall of the bridge and have to be filled in.

(iv) From the distorted shape of the masonry arch, there appears to have been considerable settlement at one time of the northern abutment, but the bridge is of considerable age and there was no record of when the settlement took place.

The reconstruction and widening of Bridge No. 42 was under consideration in 1939 and, having regard to (i), (iii) and (iv) above, the advice of the Company's Mining Engineer at the time, Mr. W.J. Davies, was sought in the design of the new foundations. Mr. Davies' report was in similar terms to those of Mr. Reid and Mr. Clark with regard to the general geological formation, but the following extract therefrom is of interest in relation to Mr. Reid's report 6 years later:-

"The contour of the ground to the north of the bridge rises rapidly in a northerly direction to a considerable height. It would appear that from time immemorial water has been flowing from the uplying lands under the canal, and in contact with the bottom part of the puddle in the Canal (where it existed) into the River Dee, and it is only reasonable to conclude that the continual attrition of this water under the puddle has been responsible for the disappearance of the quantities of clay referred to by the District Engineer".

17. The existence of this natural flow of water is confirmed by the presence of a spring of clear cold water at the foot of the railway embankment at the site of the breach, from which the Great Western platelayers obtain drinking water; the flow increases after heavy rain. This spring was covered by the debris from the breach but has since re-appeared 40 - 50 yards West of its original site. There are also springs on the north side of the main road and in the grounds of Wenffrwd House (see Fig.1), also a small but constant flow of water into the meadow from an old culvert which passes under the railway embankment and apparently leads straight into the hillside about 220 yards West of the breach. The surface drainage from the road is directed into the canal.

18. Apart from the major leakage and disappearance of the clay puddle in the neighbourhood of Bridge No.42, Chase referred to 6 or 7 other troublesome points on his length, notably a few yards East of Bridge No. 41, where leakage from the canal brought about a minor slip in the bank above the railway two years ago; it was at about this point that the constant lifting of a rail joint was required, as mentioned by ganger Jones. Chase, however, was quite sure that the canal was watertight in the neighbourhood of the breach, and he considered that no leakage of any consequence would escape his notice, particularly as the canal water was always clear.

On account of these numerous and constant points of leakage Chase made it his business to patrol his length twice daily and he expressed regret that the general tidying work, clearance of undergrowth, etc. were in arrears. He added, however, that he had always had the necessary assistance when he had asked for it and a good supply of fresh puddle. Close attention was always paid to his reports by Inspector Bowen, with whom he was in touch by telephone.

19. A partial water supply to the Monsanto Chemical Works was restored during the week end following the accident. Temporary dams were constructed on each side of the breach and the engineering staff of the Monsanto Company laid one 12 ins. and four 6 ins. cast iron pipes between them. The natural flow through these pipes under the very slight head was supplemented by portable pumps and hose, and three 12 ins. pipes were put in later by the L.M.S.R. This arrangement provided a sufficient flow of water for the time being, as the main navigation canal is not wholly dependent on the supply from this branch during the winter months.

In the repair of the canal bank, the faces of the breach were trimmed back and benched, and a drain of rough stone blocks was laid in the bank from the railway to the towpath. This drain extended in depth from the surface of the bank to the bottom of the scoured channel shown in Fig.4, and its toe rested on the brick rubble and stone blocks which were tipped by the Great Western engineers in the first stages of filling the breach in the Railway embankment. The original section was restored by earth filling, tipped by a long chute

from the roadway; the filling was heavily rammed on each side of the drain as it was built up.

The canal bed is being re-puddled between the temporary dams, and before the flow is restored a pool of water will be left for a period between the dams to test the new puddle for leaks, during which time temporary arrangements will be made to pump water across the gap.

CONCLUSION.

20. It is clear that the maintenance of the canal has received the close attention of all concerned in the face of considerable natural difficulties, and in particular I should mention the conscientious way in which Inspector Bowen and Labourer Chase have discharged their duties. Further, I am satisfied that the failure was not brought about by erosion and disintegration of the puddled bank as the result of an undetected local leak; the trouble was obviously more deep-seated, and in all probability, may be attributed to the unstable character of the underlying boulder clay formation which is evidently of water-bearing type.

21. With the interplay of cause and effect, it was difficult to form any definite opinion from the examination of the breach itself, but the experiences described in Para. 16 above point unmistakably to the conclusion that the boulder clay on this hillside is an unsatisfactory foundation on which to carry the load of engineering works of any kind; though it is impossible to speak with certainty when natural forces are at work, it does not appear unreasonable to assume that the failure of the canal bank and other incidents in the neighbourhood may have been made due to voids in this formation, eroded by suoterranean water channels, as suggested by the Mining Engineers' reports.

The load of the canal works superimposed on the natural terrace would no doubt aggravate any tendency of the boulder clay to collapse under the influence of water erosion, and although the bank had stood firm for a century or more, the effect of such erosion may well have been cumulative. The exceptionally heavy day's rainfall about a month before the accident may perhaps have contributed, and a further contributory cause may have been the imperceptible but cumulative effect of the transmitted vibration of heavy motor traffic on the main road, which has only developed in recent years.

Alternatively, there is the possibility that sliding may have occurred at the damp surface between the layer of yellow clay shown in Fig. 4, and the gravelly boulder clay below it, but on the whole, I consider that erosion of the boulder clay itself by natural water channels is the more likely explanation of the two. I do not think that the continual trouble experienced with the one rail joint on the Ruabon side of the breach can be regarded as evidence of any tendency to general movement of the railway embankment; it is probably due to a local patch of soft formation, caused no doubt by leakage from the canal at this point, to which reference has been made.

22. The action which was taken in 1938 to reinforce the bank by a counterfort wall after it had shown signs of weakness, and to construct the box puddle trench, has, in the event, proved insufficient, but it is easy to be wise after a major failure has directed attention to past incidents which may be related thereto. Prompt action was taken by the District Engineer when the crack in the towpath was reported by Chase, and having regard to the small dimensions of this crack, there appears to have been little justification for an alarmist view at the time; the works which were then undertaken may be regarded as a proper maintenance precaution in the circumstances, and I do not consider that any blame rests with the London, Midland, and Scottish Company's Engineers for omission to take more drastic steps.

23. It was particularly unfortunate that the block and telephone wires remained intact, so that no warning was received of the break in the line. Daylight patrolling of the railway was properly carried out by the permanent way staff, and there had been no experience in recent times to suggest that anything more was required.

24. The construction of the railway embankment at the foot of the hillside close below the canal presupposed the risk of a breach should the canal bank give way; there is, however, no mention of the canal in the Act which authorised the Railway, nor in Captain (later Colonel) F.H. Rich's Report to the Board of Trade of his Inspection of the line on 27th May 1862. Indeed, there has been no reason hitherto to suppose that such risk was other than negligible, but the present experience, which has drawn attention to the unreliable character of the ground on which the canal rests, suggests that this may no longer be the case, having regard also to the vibration of modern traffic on the road.

The thorough strengthening measures which have been undertaken in the repair of the canal bank should prevent the recurrence of a failure at the same point. Nevertheless, the character of the formation appears to be such that the canal water may still present a potential threat to the safety of the railway for a length of 150 - 200 yards on either side, and in these circumstances it appears to be for consideration whether it is desirable to retain the canal as such over the length concerned, now that there is no longer any obligation to maintain it for navigation.

25. In the event of closure, arrangements would have to be made to maintain the flow of water for the main canal feed, industrial supplies etc., and the available fall (approximately $\frac{1}{4}$ in. in 400 yards) is so slight that, without provision for artificial head, a very large cross-sectional area of pipe would be required to carry the necessary flow of $11\frac{1}{2}$ million gallons per day. Although the load on the boulder clay slope would be materially reduced if such pipe or pipes were set well back on the canal bed and the overburden of the towpath bank removed, the risk of subsidence would remain in some degree, and in the event of a pipe fracture a considerable volume of water might be discharged as before.

If, however, arrangements could be made to provide a foot or two of artificial head, either by pumping from the canal into a raised enclosure or directly into pipes, a number of pipes of manageable size should be sufficient to carry the necessary flow; nor should it be difficult to arrange for automatic stoppage of the pumps, and the discharge of the surplus water by a spillway, should the velocity of the water on the delivery side increase as the result of a major pipe fracture, or its pressure fall. If the pipes were to be extended westward through the Wenffrwd bridge, there would be an added advantage that the continual leakage trouble there would be eliminated once and for all. I recommend that some such measure should receive consideration, also that conditions should be reviewed at other points in the valley where the railway lies below the canal.

26. Alternatively, some degree of protection might be provided by an alarm device to sound a warning in the signal boxes on either side in the event of a collapse of the canal bank, supplemented perhaps by an arrangement to examine the line before passage of the first train in the morning, as has been in force since the accident; any such apparatus would have to be of unquestionable reliability, and as free as possible from liability to sound false alarms, which would tend to depreciate its value. No warning device, however, can give complete protection, and I think it would be altogether preferable to remove or at any rate minimise the risk by piping the water over the length of canal concerned.

27. As a precaution against possible movement of the railway embankment on the wet plane above the Silurian rock, Mr. Reid suggested that the water percolating through the boulder clay might be tapped at some point close above the railway and led underneath it. Such drainage works, if successful, might serve in some measure to stabilise the boulder clay formation itself, and no doubt their practicability will also be considered.

28. In conclusion, I should acknowledge the valuable assistance I have received throughout the course of this investigation from Mr. Gardner, and from the officers of the two Railway Companies concerned.

I have the honour to be, Sir,
Your obedient Servant,

G.R.S. WILSON

Lieut. Colonel.

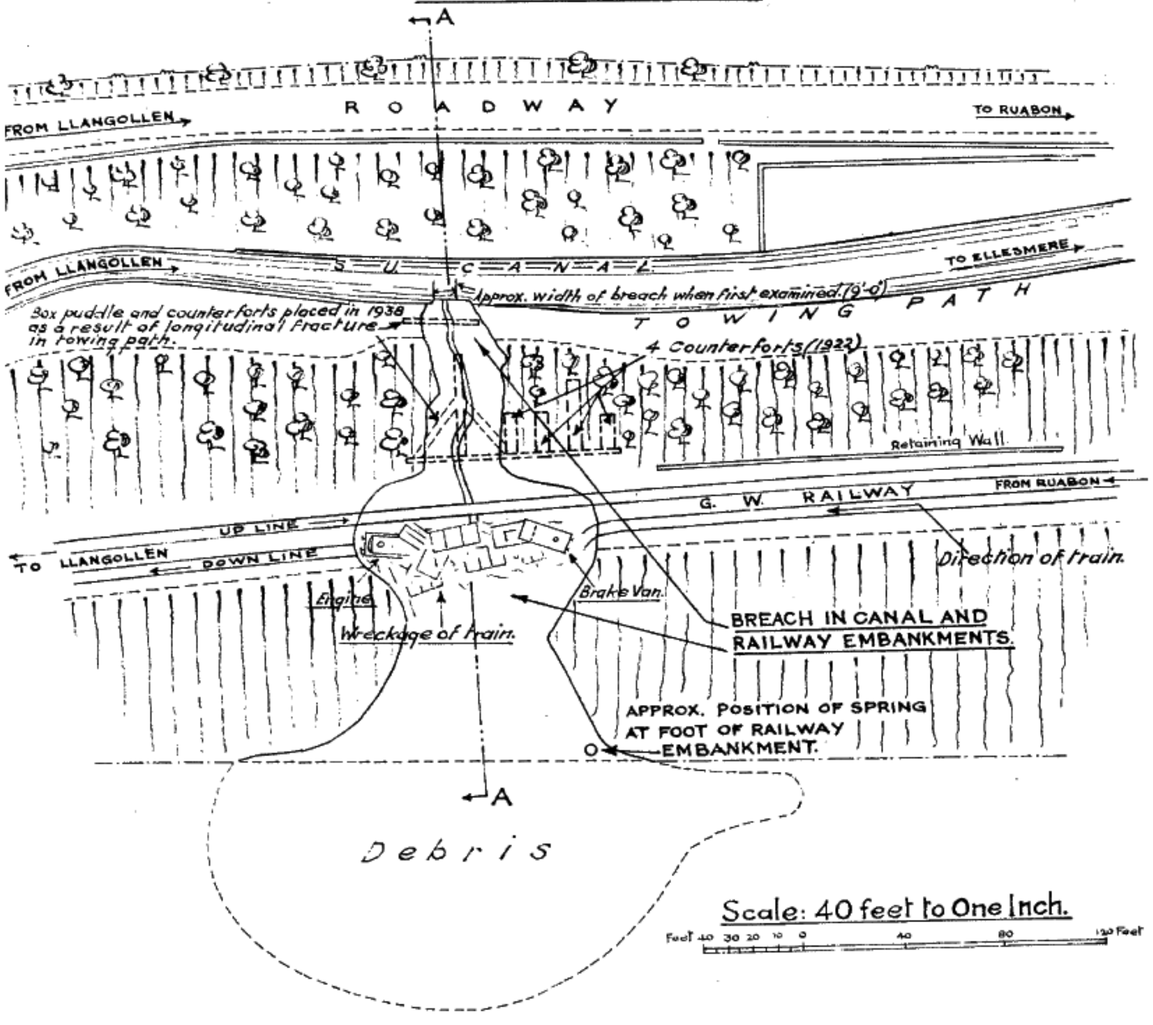
The Director General,
Ministry of War Transport.

GREAT WESTERN RAILWAY.

ACCIDENT NEAR LLANGOLLEN. 7·9·45.

FIG. 2.

ENLARGED SITE PLAN.



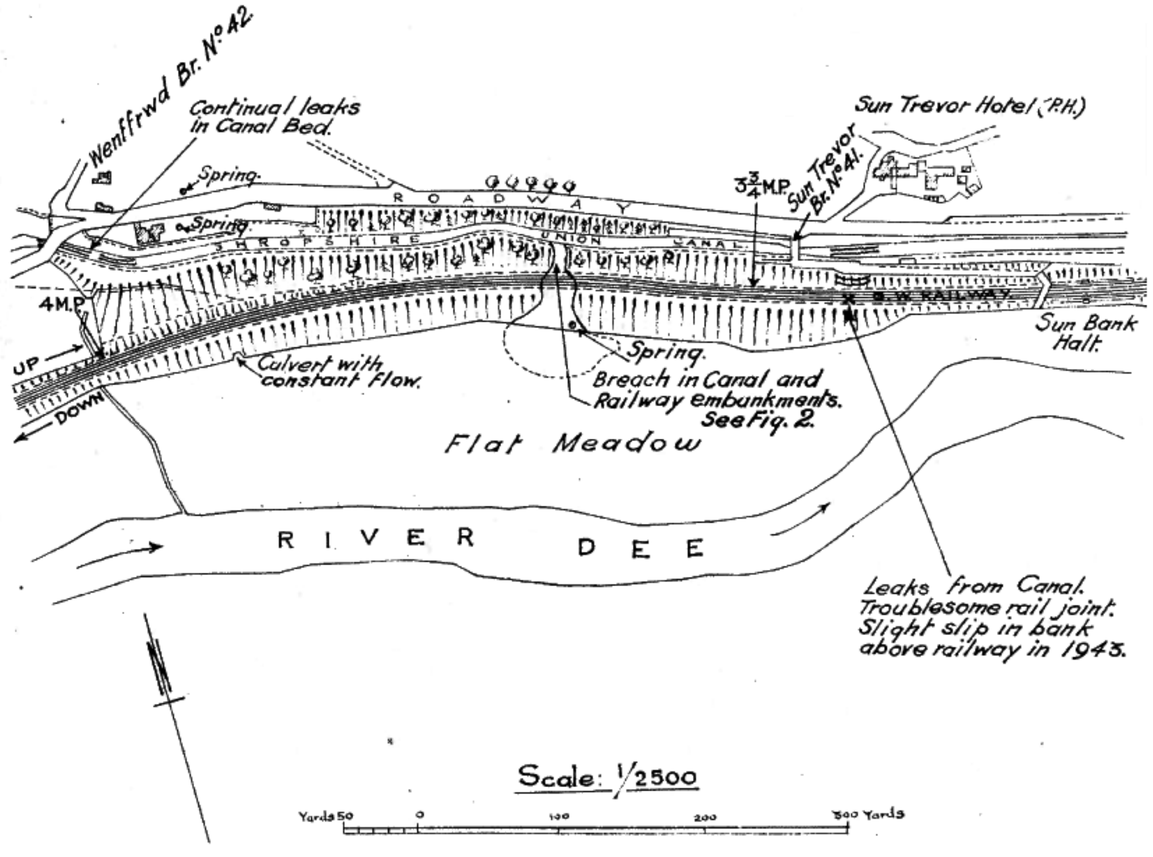
Scale: 40 feet to One Inch.

Feet 40 30 20 10 0 40 80 120 Feet

FIG. 1.

GENERAL SITE PLAN.

Ordnance Survey Sheet: DENBIGH. 34.16.



Scale: 1/2500

Yards 50 0 100 200 300 Yards

GREAT WESTERN RAILWAY.

ACCIDENT NEAR LLANGOLLEN. 7·9·45.

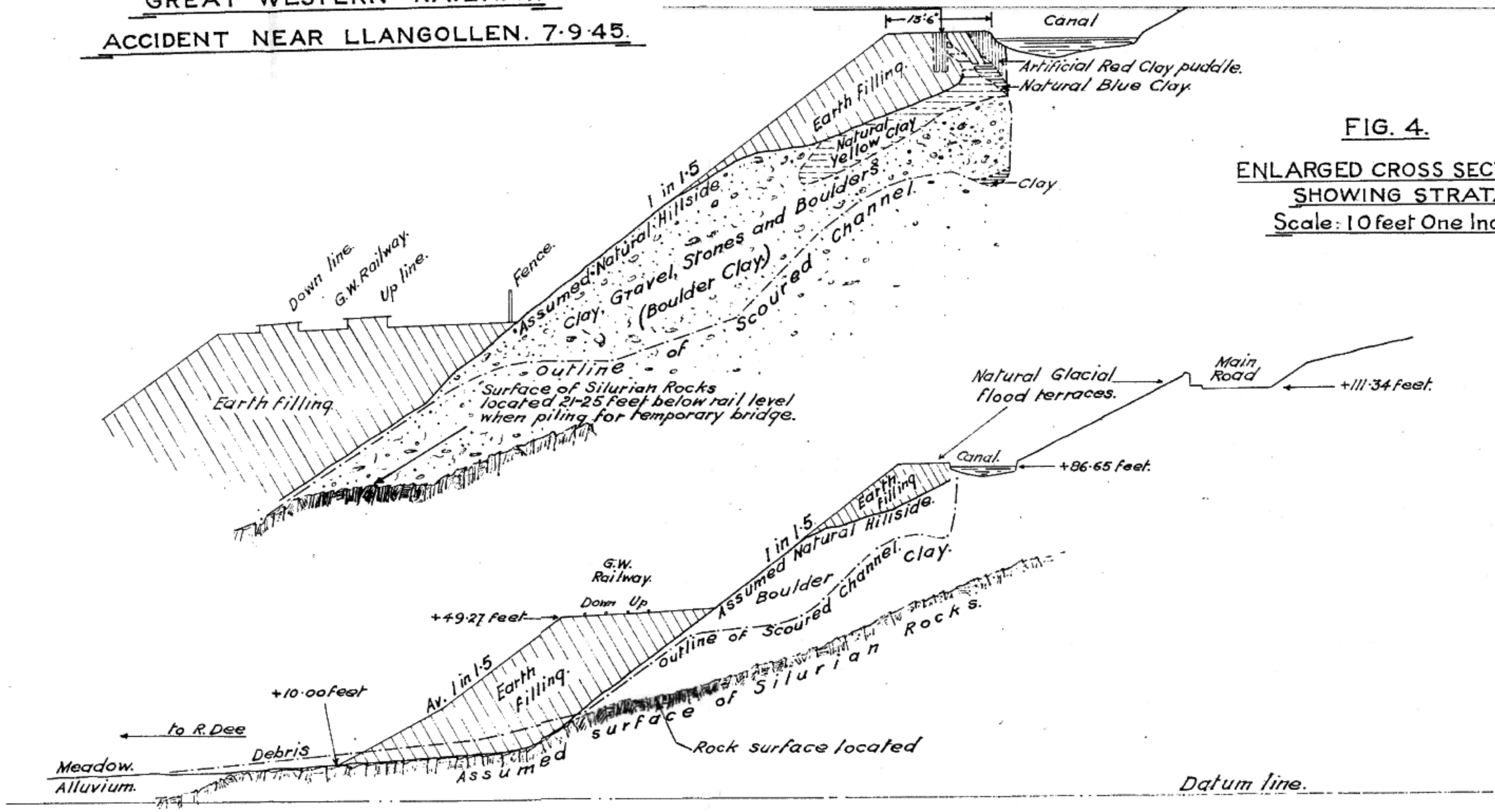


FIG. 3. GENERAL CROSS SECTION AA.

Scale: 20 feet to One Inch.

FIG. 4.

ENLARGED CROSS SECTION SHOWING STRATA.

Scale: 10 feet One Inch.