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FLOODING AT RHYD Y CAR, MERTHYR TYDFIL

ON 26th & 27th DECEMBER 1979

REPORT ON FLOODING INCIDENT

May 1986

SIR ALEXANDER GIBB & PARTNERS
CARDIFF OFFICE
124 CATHEDRAL ROAD
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CHAPTER 1

TERMS OF REFERENCE

1.1 INVITATION

In a letter reference SWAG 352/GW dated 30th August 1985, the National Coal Board (NCB) invited Sir Alexander Gibb & Partners (Gibb) to assist them in defending a High Court action concerning a flooding incident at Rhyd-y-Car, Merthyr Tydfil on 27th December 1979.

It was indicated in the NCB's letter that Gibb would be required to report on certain aspects of the flooding incident with a view to giving expert evidence at the trial on behalf of the defendants.

Gibb in their letter reference 84712F/M.2407 dated 3rd September 1985 accepted the NCB's invitation to carry out the work and proposed in that letter that the Institute of Hydrology, Wallingford, should examine the hydrology aspects of the site.

Copies of the above letters are enclosed at Appendix A.

1.2 DETAILS OF WORK TO BE DONE

The NCB in their letter reference SWAG 352/GW dated 16th December 1985, indicated the particular aspects of the flooding incident they wished Gibb to examine. Enclosed with that letter was a bundle of documents which gave details about the incident.

A copy of the letter is enclosed at Appendix B.

The photographs referred to in the letter were handed to Gibb on 4th February 1986.

There were three aspects which Gibb were requested to consider as follows:

(i) To examine a report prepared by Mr. Hugh Payne, for the NCB, which dealt with the hydrology of the affected catchment and to come to an independent conclusion as to whether or not Mr Payne's findings can be supported. Also to comment upon the report prepared by Mr. M.A. Perry, the Plaintiff's Engineer. Any differences of opinion were to be highlighted.

(ii) To test the assertion in the NCB's defence that in all the circumstances, it was not necessary to construct a grill at the entrance to the culvert which became blocked, the consequences of which resulted in the flooding incident.

(iii) To examine the effect of the embankment and blocked culvert on the consequent flood.

1.3 ADJUSTMENTS TO THE SCOPE OF WORK TO BE DONE

At a meeting in the Aberaman Offices of the NCB's Opencast Executive on 18th February 1986, Gibb presented their preliminary findings and sought clarification on the scope of work to be done.

At that meeting it was agreed to amend the scope of work to be done by Gibb as given below:

(i) An examination of other culverts remote from the affected catchment which were considered in Mr. Payne's report was not to be carried out and Gibb's study was to be confined to the on-site culverts. It was agreed that the study report should address the technical aspects of the flooding incident independently, making relatively few references to Payne's report.

(ii) The NCB agreed to provide survey information of the stream, contemporary with the flooding incident to enable a check to be made on the volume of water impounded by the blocked culvert.

(iii) To consider the effect of the flood flow downstream of the blocked culvert by using the survey information in (ii) above.

(iv) To make enquiries with Mid Glamorgan County Council, the highway authority, in order to find out if the road on top of the embankment over the blocked culvert is a highway maintainable at the public expense.

A copy of the notes of the meeting is enclosed at Appendix C.

1.4 SCOPE OF THIS REPORT

This report sets out the findings of the study undertaken by Gibb of certain aspects relating to the flooding incident at Rhyd-y-Car on 27th December 1979.

CHAPTER 2

DESCRIPTION OF FLOODING AT RHYD-Y-CAR ON 27TH DECEMBER 1979

2.1 LOCATION

Rhyd-y-Car is situated to the South West of Merthyr Tydfil on its urban fringe; see Figure 2.1.

2.2 DESCRIPTION OF SITE

A large part of the catchment of the Nant Rhyd-y-Car comprises an area of old mine workings which has left the land in a derelict state. Within the area of tipping from the old mine workings, the streams pass through a number of culverts to accommodate former roadways, tramways and railways.

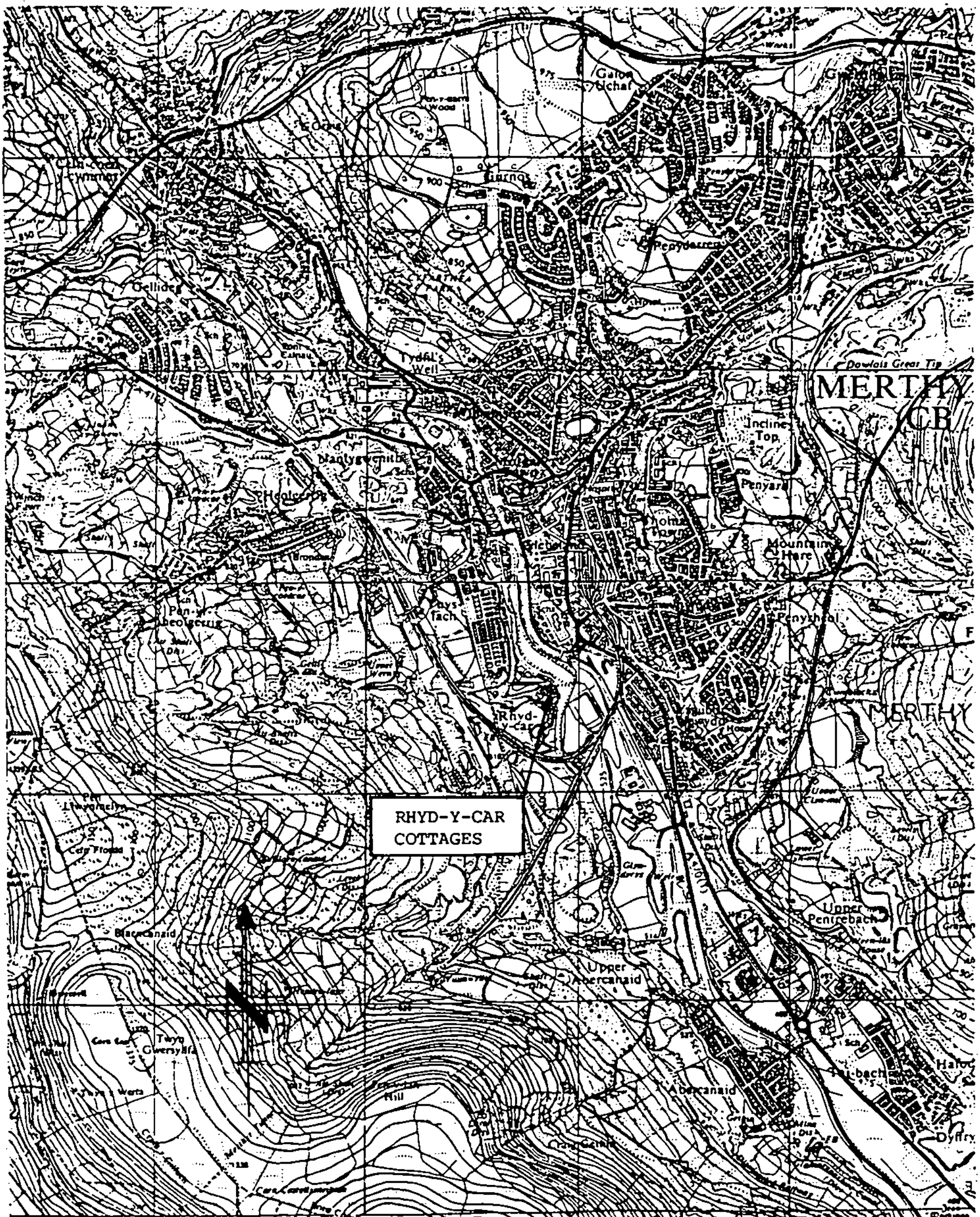
2.3 FLOODING INCIDENT OF 27TH DECEMBER 1979

The flooding incident of 27th December 1979 has been reported upon by Mr. R.A. Criddle, Area Opencast Geologist of the NCB in two reports dated the 2nd January 1980, viz:

(i) Colliers Row Site: Flooding at Ynysfach

(ii) Colliers Row Site: Flooding at Rhyd-y-Car Merthyr Thursday 27th December 1979. Notes on Visits to Site between Friday, 28th December 1979 and Sunday 30th December 1979.

Drawing Nr. 0707555 is an extract from the plan accompanying the latter report in which the various features of the flooding incident have been annotated by means of notes on the plan and letters which are referred to in the text of Mr. Criddle's report.



Scale: 1.25000

LOCATION OF RHYD-Y-CAR COTTAGES

FIGURE 2.1

From Mr. Criddle's report, it appears that the culvert at point J on Drawing Nr. 0707555 became blocked. That particular culvert passed under a road embankment which impounded the water to a depth of about 7.3 metres. There then appeared to be a breaching of the embankment with an outpouring of the water which overtopped culverts and embankments downstream, except the culvert between points E and C shown on Drawing Nr. 0707555.

The water was contained by the embankment between points E and C except for a slight overspill and the discharge of water beyond this culvert was controlled by the capacity of the culvert between points E and C.

Just downstream of the culvert between points E and C, were the Rhyd-y-Car cottages.

The references in this report to points A, C, E and J are those referred to on NCB plan 0707555.

CHAPTER 3

FLOOD HYDROLOGY OF SITE J CATCHMENT, RHYD-Y-CAR

3.1 CATCHMENT DESCRIPTION

The Nant Rhyd-y-Car catchment to site J drains a relatively steep, ENE facing catchment of about 1.43km^2; see Figure 3.1. The catchment ranges in altitude from about 200 to 450m AOD with an estimated average annual rainfall of 1700mm. The natural soils are relatively impermeable. A small portion of the upper catchment is forested with some ditching. The catchment has been subject to extensive drift and deep mining, with widespread tipping.

In estimating the catchment area effective in flood conditions, account has been taken of the many culverts, embankments and other man-made features. For example, the lack of an adjacent effective culvert through the site J embankment means that the catchment drained by the Nant Rhyd-y-Car is somewhat greater than if the entire embankment were removed. Particular examples of the influence of man-made features are highlighted by drainage ambiguities at sites X and Y on Figure 3.1. The effect of incompletely sealed mine shafts and adits on surface water drainage in flood conditions is thought to be slight. Although locally there may be some mid-term and long-term underdrainage through old mine workings, it is estimated that any benefit from this (in terms of reducing flood response) is outweighed by the inferior infiltration capacity of the disturbed ground (compared to the natural condition).

In some parts of the catchment, tips have encroached on water-courses and are then susceptible to erosion. There is visible indication that substantial erosion has occurred in recent history, especially in the 215 to 245m AOD altitude

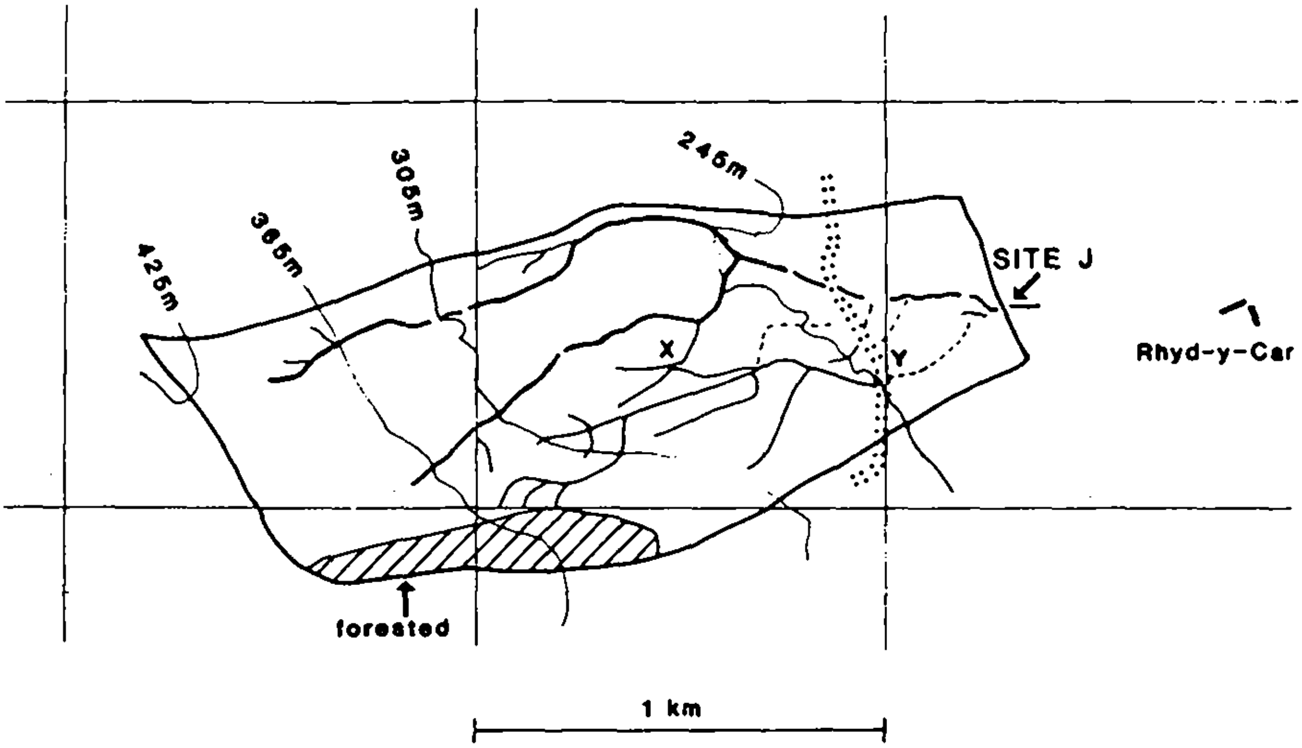


FIGURE 3.1 PLAN OF CATCHMENT TO SITE J, NEAR RHYD-Y-CAR

band, and this process will appreciably accelerate at times of high stream flow such as occurred in the December 1979 flood. The mechanism of erosion is a continuous removal of material in contact with fast flowing water. During high flow periods the depth of flow increases and the bank surface subject to erosion is enlarged. As material is removed the bank steepens or even undercuts locally causing bank slippages which may be large enough to temporarily obstruct the flow. These in turn will be eroded and collapse; the process causing flow fluctuations and short term velocity increases which will accelerate the erosion process.

Erosion from the banks will deposit material ~~in the stream~~ and raise the bed level so that, in time, the culverts will be below the general profile of the stream bed. This in time will substantially increase the possibility of culvert blockage. The process would be accelerated if there is a substantial bank slip adjacent to the upstream end of a culvert.

Gibb contribn /re-wording

3.2 FLOOD ESTIMATES

Peak flood estimates derived by the Flood Studies Report rainfall/runoff method (as updated by Supplementary Report No. 16) are given in Appendix D. The corresponding flood frequency relationship is shown in Figure 3.2. For example the estimated 50-year peak flow is 5.84 cumecs.

Flood estimates made from catchment characteristics (as opposed to gauged flow data) are inevitably uncertain. The true flood frequency relationship might easily be 33 per cent lower or 50 per cent higher. Better estimates can be gained by gauging flow and rainfall for at least five floods, requiring perhaps a 12 month record. To obtain flood estimates reliable to within 10 per cent it is necessary to gauge peak flows for a period of at least 5 years.

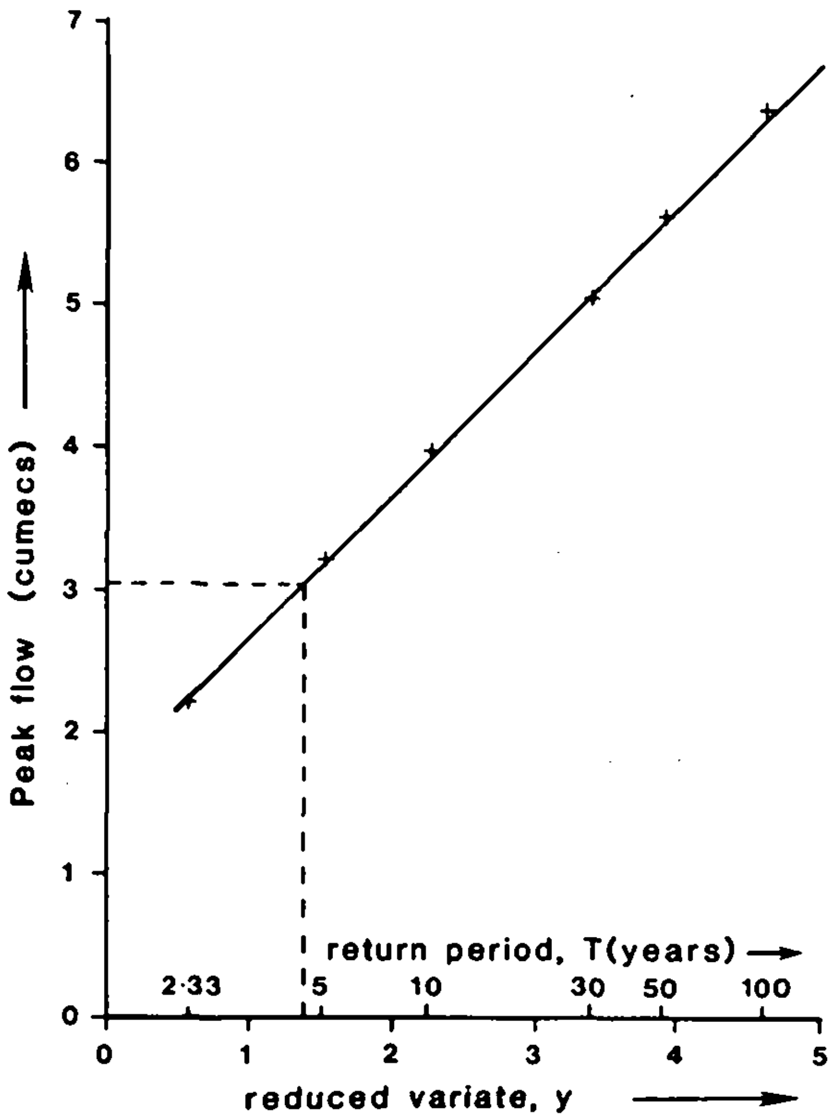


FIGURE 3.2 SITE J FLOOD FREQUENCY RELATIONSHIP (rainfall/runoff method)

The calculations in Appendix D indicate that the highest peak flows from the site J catchment generally result from short intense storms (e.g. of 4.25 - hour duration) rather than from prolonged heavy rainfall events.

3.3 THE DECEMBER 1979 STORM

The storm of 26/27th December 1979 was a prolonged heavy rainfall event which produced severe flooding of major South Wales rivers such as the Rhondda, Taff and Usk.

Close inspection of daily raingauge data indicates that about 144mm fell on the site J catchment in the two-day period 26/27th December 1979. This estimate was obtained as the mean of ten gauges within a 15km radius, the gauges being selected to give good spatial coverage and a representative mean altitude (295m AOD).

Inspection of recording raingauge data for a number of sites - notably the record at Aberdare Filters (5km SW of the catchment centroid) - indicates that about 87 per cent of the two-day depth fell in a 16 hour period commencing 23.00 hr. on 26th December 1979. Table 3.1 shows that the ascribed rarity of the 26/27th December storm depends very much on the duration of rainfall considered. The peak discharge of 3.05 cumecs (calculated from the rainfall figures) resulted from 45mm. rainfall in the wettest period of 4.25 hours and this rainfall (intensity) has a return period of only about 9 years (Figure 3.2). However, the 16 hour rainfall of 125mm has a return period of 155 years. The event was therefore not unusual on the basis of rainfall intensity leading to peak flow, but rare on the basis of its duration.

MOVED DELIBERATELY, BUT COMPLETELY OUT OF PLACE HERE

COULD HAVE GONE TO START OF 3.6.

There are several features of the catchment that it is not practical to represent in the type of rainfall/runoff model available for flood estimation but which nevertheless may be important. The very extensive mining and tipping activities in the past have left a catchment with many surface depressions, embankments and culverts of limited capacity which may delay runoff from the catchment appreciably, making it more sensitive to large volume, long duration storms. The encroachment of tips on watercourses gives particular scope for erosion; if appreciable sediment transport does occur then it will travel further in a long duration event.

As is evidenced by the catastrophic impoundment at the site J culvert, the obstruction or partial obstruction of a culvert further increases the sensitivity to long duration flood events. There are many culverts in the site J catchment and some of these may have temporarily held back water in the December 1979 event. Unfortunately, it is not practical to model the catchment in such detail, nor is it necessarily true that present conditions reflect the state of the catchment at the time of the December 1979 event.

TABLE 3.1

ASSESSED RETURN PERIOD OF MAXIMUM FALLS EXPERIENCED IN 26/27TH DECEMBER 1979 STORM

Duration	Rainfall Depth	M5 depth (from FSR II.3)	Inferred return period (from FSR II.2)
	mm	mm	years
4.25 hr.	45	39	9
16 hr.	125	68	155
2 days	144	100	90

A BIT OUT OF PLACE

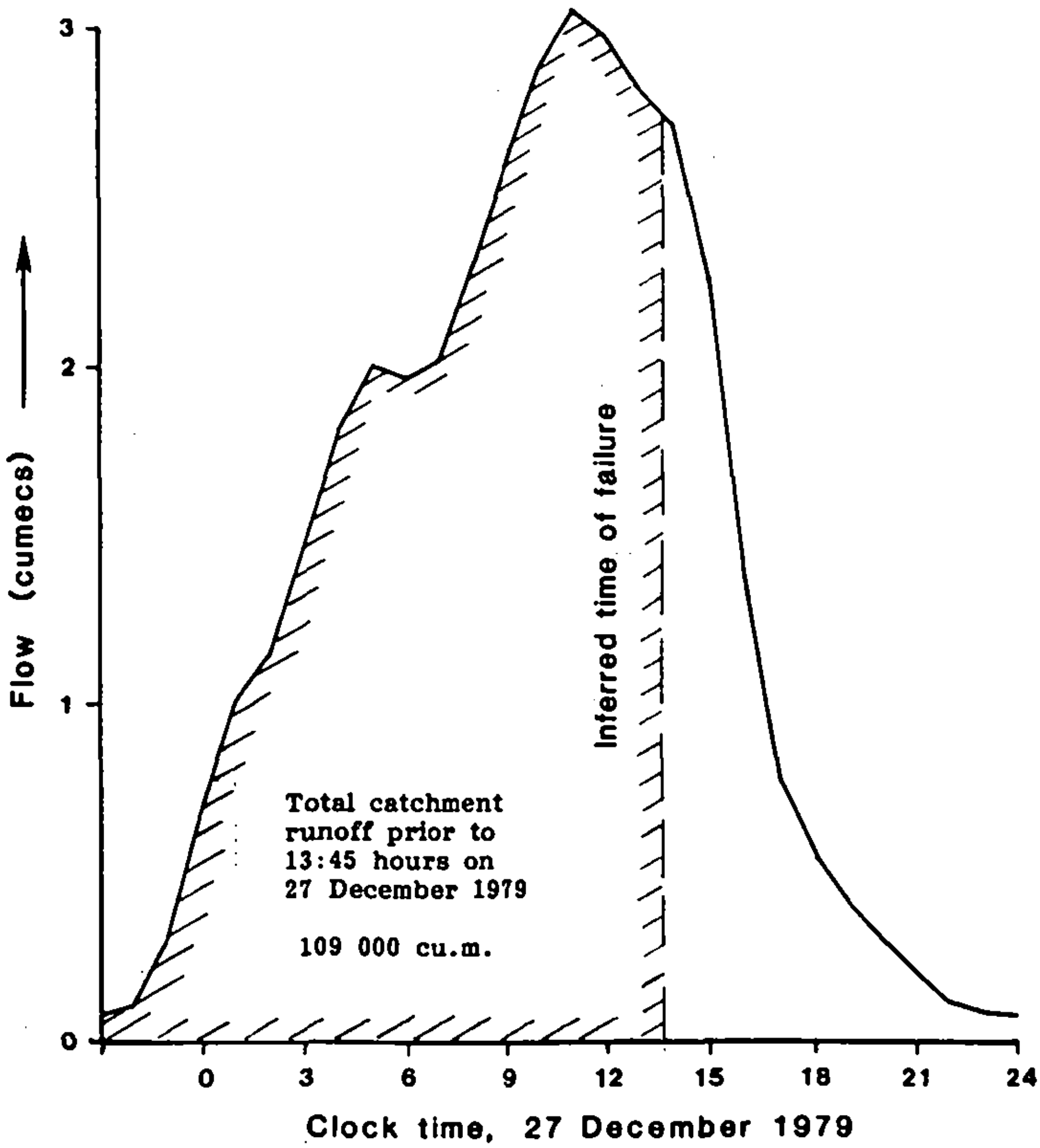


FIGURE 3.3 SYNTHESISED FLOOD HYDROGRAPH TO SITE J FOR 26/27 DECEMBER 1979 EVENT

Direct analysis of daily rainfall records for long-term gauges in the area indicates that the 26/27th December 1979 two-day rainfall depth was not unprecedented. Rainfall totals on 9/10th October 1933 were of similar magnitude and those on 2/3rd November 1931 were perhaps 10 per cent higher. However, information to hand about the temporal profile of rainfall for the November 1931 and October 1933 storms was insufficient to make definitive comparisons.

The antecedent conditions in December 1979 were fairly severe. It had been a very wet and windy month, with a cold snap from 22 to 24 December which left a small amount of snow lying on the upper part of the catchment and semi-frozen ground conditions which probably persisted to 26 December.

Taking these antecedent conditions into account it seems reasonable to assert that the 26/27th December 1979 event was probably the most severe event in the region arising from prolonged heavy rainfall since detailed rainfall records began around 1920. However, in terms of flooding on the Nant Rhyd-y-Car, such a statement is largely irrelevant. The peak flow from the site J catchment is generally due to short intense storms and the December 1979 event was not uncommon in this respect.

3.4 FLOOD SYNTHESIS FOR THE DECEMBER 1979 EVENT

Following the principle outlined in Flood Studies Supplementary Report No. 12, a flood hydrograph has been constructed for the 26/27th December 1979 event. The hydrograph is illustrated in Figure 3.3 and the calculations are given in Appendix E. The flood synthesis estimates that the peak flow to site J was 3.05 cumecs, occurring at about 11.00 hr. on 27th December 1979.

The synthesis is based on a rainfall/runoff model calibrated from catchment characteristics (as opposed to recorded rainfall and flow data) and is therefore inevitably uncertain. Comparison with gauged records for the same event on the Rhondda does however support the broad features of the reconstruction - namely, the progressive rise and the more rapid decay. The one obvious defect is the failure of the model to represent fully the increase in baseflow (i.e. slow response runoff) that is expected in such an event. However, this is of little significance in terms of peak flow.

From Figure 3.2 it is possible to read off the design return period corresponding to a peak flow of 3.05 cumecs; it is seen that this is about a 5-year event compared with the 9-year event for the rainfall causing it. This confirms the interpretation made in Section 3.3 that, in terms of producing high peak flows in rapidly responding catchments such as the Nant Rhyd-y-Car, the 26/27th December 1979 was not a severe event. This theoretical conclusion is qualified in Section 3.5, where particular implications of a long duration event (e.g. for sediment transport) are considered.

3.5 IMPLICATIONS OF THE DECEMBER 1979 FLOOD AT SITE J

Later in this report it is indicated that 20 500cu.m of water was impounded at site J, prior to failure of the embankment at about 13.45 hr. on 27th December 1979. From Section 3.4 and Figure 3.3 it is possible to estimate the volume of runoff to site J up to this time. The calculated volume (Appendix F) is 109 000cu.m. While there is some uncertainty in the estimates of these two volumes - particularly the latter - it is clear that a very considerable proportion of the flood runoff had been discharged from site J prior to the embankment failure.

The impounded volume of 20 500cu. m represents only 14.3mm of runoff from the catchment. Thus, if the culvert at site J became substantially blocked, a relatively common place storm could have led to failure of the embankment. With regard to the December 1979 event the impoundment of 20 500cu. m prior to 13.45 hr. would be explained if the discharge from site J were limited to 1.95 cumecs. On this basis it would take nearly eight hours for this volume of water to be impounded. However, the discharge through a submerged culvert would normally be expected to increase appreciably as the level of impounded water rises. In the absence of any evidence as to the time and manner in which impounding occurred - save only a qualitative account that an appreciable rise in discharge was noted in the Nant Rhyd-y-Car downstream of site J, an hour or so before passage of the "dam-break" flood wave - quantitative analysis of the flood at site J can proceed no further.

3.6 ADDITIONAL REMARKS

Taken out!

In some of the papers studied (e.g. Para. 21 of Paper 10), reference is made to the satisfactory performance of the culvert at site R. Given the generally good internal condition of the culvert, its satisfactory gradient, and the fact that it drains only a portion of the site J catchment, then this appears to be no surprise. Perhaps the chief similarity between the site J and site R culverts is that they both had an appreciable embankment overburden and therefore presented a potential impoundment risk. This aspect of Mr. Perry's proof (Paras. 4.17, 4.22 and 4.23 of Paper 13) appears to be well-founded.

With regard to the safe design of embankments across water-courses, one practice - apparently recommended in the Netherlands - is to position an auxiliary array of simple, smaller diameter pipes at various levels in the embankment. This practice recognizes the implicit danger of relying on a single culvert that might become blocked and lead to water impoundment. [1] However, cost implications are substantial and it is also necessary to protect the downstream face of the embankment below the culvert discharge points.

1. Jansen P.P. (Chief Editor) Principles of river engineering: the non-tidal alluvial river. Pitman 1979.

CHAPTER 4

SAFETY GRILLE

4.1 MR PERRY'S VIEW ON NEED FOR SAFETY GRILLE

Mr M.A. Perry in paragraph 3.20 of his report dated 5th May 1983 states that "none of the culverts .... had grilles on their upstream ends to assist in the prevention of blockage."

Mr Perry then considers the maintenance of grilles in paragraphs 4.20 and 4.21 of his report. He indicates that they should be inspected "at fairly frequent intervals of a few months and in particular at the end of a period of dry weather because they do become blocked more easily than an open entrance" and that the "importance of their use is that they greatly reduce the possibility of a blockage inside a culvert."

4.2 GIBB'S VIEW ON NEED FOR SAFETY GRILLE

In order to give consideration to whether or not safety grilles should be fitted to the upstream end of culverts the characteristics of debris movement and accumulations on the site need to be appreciated.

The Nant Rhyd-y-Car is a steep fast flowing stream which drains a mixed catchment including areas subject to extensive drift and deep mining with widespread tipping infringing on the stream itself. It is relevant to note the comments in Section 3.1 relating to the erosion of the bottoms of the tips and the resulting various degrees of bank slippage. These conditions will result in a gradual migration of material from the riverbanks into the stream and subsequently towards downstream. Downstream movements would be accelerated during periods of high flow. This type of regime is typical of streams subject to bed movement, the faster the flow the larger the material which can be moved. Material migration and variations in bed level are of little consequence in an open stream. Bed profiles frequently change during periods of high flow and generally the effect is only noticed at features such as bridge foundations.

For reasons connected with mining, access embankments were tipped across the stream at intervals. The stream was canalised under these embankments in culverts generally about 1.50m in diameter. These culverts would normally be required to pass water, hard bed material, and debris such as bushes, grass and similar matter stripped from the banks during storms. Although, as stated above, the regime of this type of stream would involve considerable bed material transport, the velocity through the culverts would generally ensure that such material as enters them would be washed through. This is evidenced by the general cleanliness of the culvert between points C and E, even though it is obvious from the conditions of the river bed adjacent to its inlet that appreciable quantities of bed material are washed through.

Bushes and other floating debris less than about 1.5m in diameter would also be washed through. Should a grille be fixed to the upstream ends of culverts then any material larger than the spacing between the rods would collect against them. If the spacing between the rods, was, for example, 150mm then all bed material greater than that size and bushes, pieces of timber etc. would all collect against them. As soon as this happens the smaller material upstream would also accumulate against it and locally raise the stream bed, which would increase the risk of blocking the culverts.

Taken out

Also, illicit dumping of rubbish within the catchment is an important factor. When Gibb visited the site on 12th February 1986, several supermarket trolleys were dumped in the watercourse downstream of the culvert at point C. Mr Richard Miles has indicated in his report dated 19th October 1983 that for the period 1976 to 1981 he had to deal on a regular basis with trespassers on the site "in the shape of gypsies camping on the site, people trying to steal coal out of the heaps on the site and people dumping refuse."

Due to the characteristics of the particular stream in question, any culvert on it should be capable of permitting the following to pass through it.

(i) Water
(ii) Hard bed material
(iii) Debris such as bushes and grass

Any hinderance in permitting the culvert to perform the above functions could result in an impounding of water. Certainly a grille would impede the free passage of hard bed material and debris such as bushes and grass. In this respect Mr Perry's statement that the fitting of grilles at the upstream of the culverts to assist in the prevention of blockage cannot be supported. In fact, Gibb are of the view that the contrary will be the case. This is particularly evidenced by:

(i) The culvert between points C and E not becoming blocked despite carrying a great deal of debris and bed material through it on the flood flow.

(ii) The fact that the debris was caught by the footbridge below point C which acted as an obstruction to the flow of the water and this in effect diverted more water into the Rhyd-y-Car cottages.

Mr Perry's view that culverts fitted with grilles "do become blocked more easily than an open entrance" is accepted and indeed endorsed.

Also Mr Perry's statement that a culvert fitted with a grille at its upstream end will greatly reduce the possibility of blockage inside the culvert is supported but Mr Perry has then not gone on to say that there would be a much greater increase in the risk of blockage at the culvert entrance.

The only instances where Gibb would recommend the fitting of safety grilles are as follows:-

(i) Where it is necessary to prevent access into or through the culvert by unauthorised people or stray animals.

(ii) It is considered a danger to allow access.

(iii) It is essential to prevent people being swept into the culvert during the flood conditions.

(iv) To prevent objects which could damage plant immediately downstream of the culvert being carried through the culvert.

(v) If there was a history of frequent blockages of the culvert.

None of the above cases can be strictly applied to the Rhyd-y-Car situation.

In short, Gibb are of the view that the fitting of grilles to the upstream of the culverts on the Rhyd-y-Car site would increase the risk of blockage.

CHAPTER 5

FLOOD ROUTING

5.1. SCOPE OF THIS CHAPTER

This chapter examines the effect of the outpouring of the impounded water from the blocked culvert at J.

In particular, an assessment of the capacity of the watercourse downstream of the blocked culvert at J is made so as to determine if it could contain the outpouring water.

5.2. STREAM BETWEEN POINTS J AND E.

The mode of failure of the embankment at J is unknown and it is therefore not possible to evaluate the peak flow resulting from the 'dam break'.

From the reports prepared by Mr. R.A. Criddle it can be concluded that the water outpoured in a very short space of time and completely overwhelmed all that was in its path between points J and E. Some of the outpouring water flowed down an old railway cutting to ultimately enter the River Taff via the Rhyd-y-Car playing fields. The remainder of the water was largely contained by the embankment through which the culvert between points C and E passes. Only a small amount overtopped the embankment. With a knowledge of the probable maximum water level upstream of the culvert, obtained from debris lines and the general topography, an assessment can be made of the maximum discharge through the culvert between points C and E.

5.3 CAPACITY OF CULVERT BETWEEN POINTS C AND E

The capacity of the culvert between points C and E has been evaluated by using Manning's formula.

$$Q = \frac{R^{2/3} \; Sf^{\frac{1}{2}} \; A}{n}$$

Where : Q = discharge (cumecs)
R = hydraulic mean depth
Sf = hydraulic gradient
A = area of flow
n = Manning's coefficient

This culvert is 1.5 metres diameter and is of brick and stone construction. It is considered that an appropriate value of 'n' for the culvert in its present condition is 0.017 but a parametric study has been carried out to note the difference in discharge for 'n' values of 0.015 and 0.012. ? 0.020 The lower the value of 'n', the greater is the discharge since it assumes lower friction. Conversely, the higher the value of 'n', the lower is the discharge. An 'n' value of 0.015 has been selected to evaluate the peak discharge through the culvert since it will produce a more onerous condition downstream of the culvert.

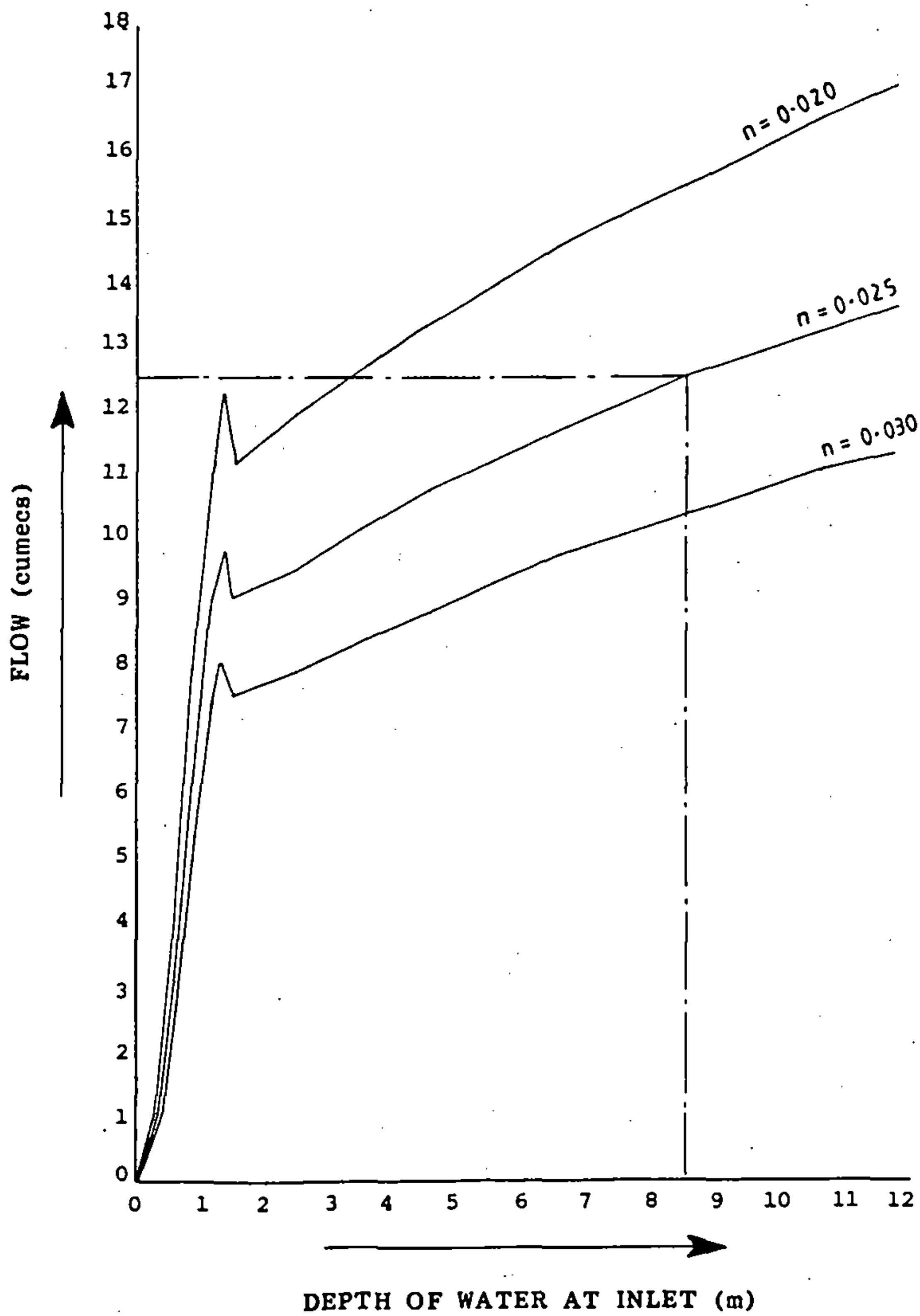
BUT FIG. HASN'T BEEN CHANGED!

Figure 5.1 indicates the discharge capacity of the culvert for different depths of water at inlet and also indicates the effect on the discharge by varying the value of 'n'. The results shown in Figure 5.1 must be regarded as best estimates since it is not possible to verify them by gauging the flow in the culvert. The peak flow through the culvert is estimated to be 20.8 cumecs.

5.4 QUANTITIES OF WATER

From information provided by the NCB from a survey of

NEEDS UPDATING



STATE WHERE

VARIATION OF FLOW RATE WITH DEPTH OF WATER AT INLET

FIGURE 5.1

the site of the flooding incident which was carried out by them within a few weeks of the incident, sufficient information is available to assess the volume of the water impounded at J. This has been calculated to be 20 500cu.m by taking the debris line as the top water level 203.75m. This volume is significantly less than the figure of 28 000cu.m estimated by Mr. Hugh Payne for a top water level of 203.5m. How much of this water was contained by the culvert between points C and E cannot be estimated accurately because of the unknown proportion which flowed down the old railway cutting. Nevertheless, it was noted from Mr. R.A. Criddle's report that the water level in the watercourse downstream of this particular culvert subsided after about 20 minutes. This would suggest that the quantity of water which flowed through the culvert was about 15 000cu.m. In other words about 5 500cu.m flowed down the old railway cutting. However, the exact time is of less significance than the estimated maximum discharge of 20.8 cumecs.

5.5 CAPACITY OF WATERCOURSE DOWNSTREAM OF CULVERT AT POINT C

An assessment of the capacity of the watercourse downstream of the culvert between points C and E has been made. The length of the watercourse examined is illustrated in Figure 5.2.

The details of the watercourse used in the assessment have been taken from the topographical survey carried out by the NCB during the first week of January 1980. The analysis has been carried out using Manning's formula.

On NCB drawing 0707555 are recorded the depths of water in the watercourse between the footbridge over the stream at the West end of Rhyd-y-Car cottages and the culvert outlet at C. These depths provide a self-checking mechanism on the flow

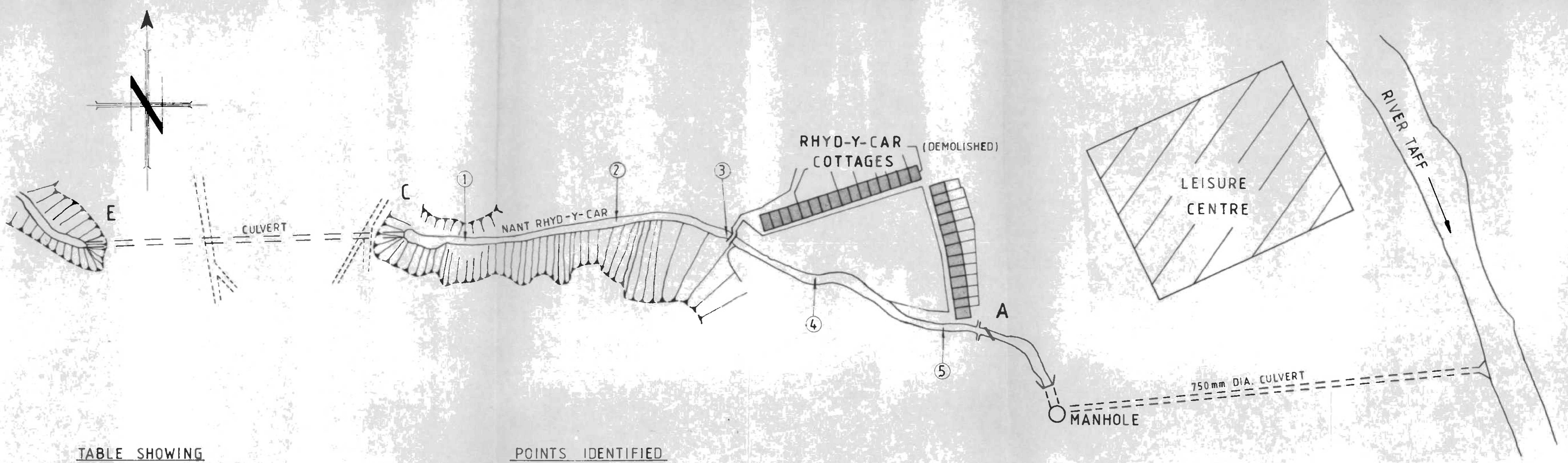


TABLE SHOWING CAPACITY OF WATERCOURSE

1. CAPACITY GREATER THAN 25 CUMECS
2. CAPACITY 23 CUMECS
3. FOOTBRIDGE – CAPACITY 13 CUMECS
4. CAPACITY 10 CUMECS
5. CAPACITY 6 CUMECS

POINTS IDENTIFIED IN MR R.A. CRIDDLE'S REPORT

A. 2 Nr 800mm DIAMETER PIPES

C. OUTLET OF 1·5M DIAMETER CULVERT

E. ENTRANCE OF 1·5M DIAMETER CULVERT

SCALE

10 0 20 40 60 80 100 METRES

CAPACITY OF NANT RHYD-Y-CAR WATERCOURSE

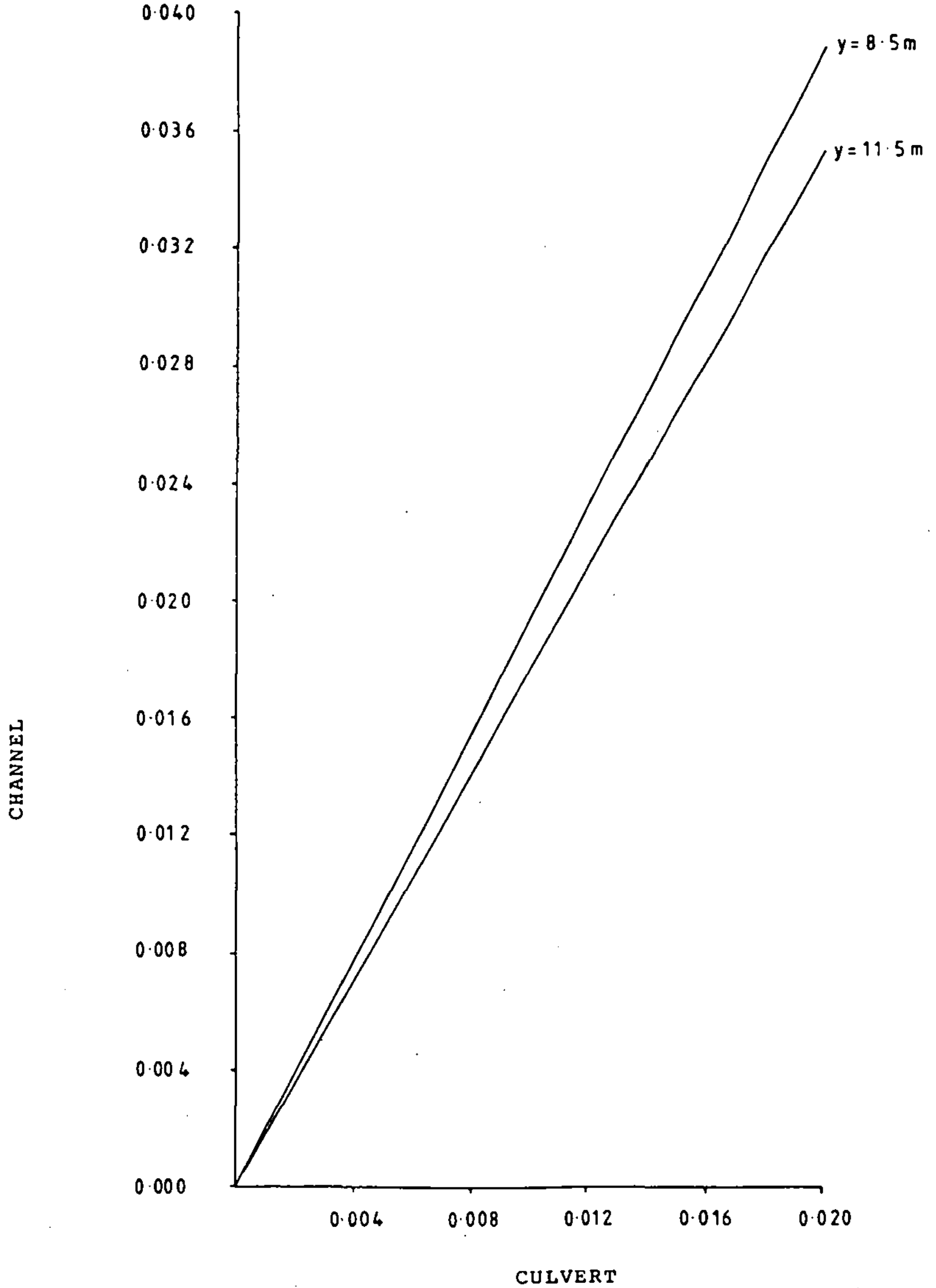
FIGURE 5·2

conditions assumed. Figure 5.3 illustrates the relationship between the n values for the culvert and the stream to produce the measured depth. Variation of the depth of water at the entrance to the culvert and hence the flow rate has little effect on this relationship. It is evident from the analysis that the watercourse upstream of the footbridge was capable of accommodating the peak discharge. The capacity reduced at the footbridge where it is calculated that a maximum of 13.3 cumecs could be safely contained if the waterway was otherwise unobstructed by uprooted bushes and other debris with the rest (7.5 cumecs) overflowing.

Insufficient information survives to check if the overflow discharge of 7.5 cumecs would have caused depths of flows in the passageway adjacent to the cottages of 5'0" (1.525 metres) as reported by Mr. R.A. Criddle. It is evident from photographs taken shortly after the event that debris partially blocked the free flow of water under the footbridge which effectively acted as a dam to divert flow appreciably greater than 7.5 cumecs into Rhyd-y-Car cottages with tragic results. The flooding might have been significantly less if the footbridge had not existed.

Further downstream of the footbridge the capacity of the watercourse has been assessed at 6.0 cumecs and overtopping of the banks of the stream may have occurred here. It is not possible to ascertain the peak flow downstream of the footbridge due to the partial blockage of the watercourse at this point.

Figure 5.2 shows very clearly that the stream carrying capacity upstream of the footbridge is very much greater than its capacity downstream of the footbridge. As far as can be judged this was not always the case. For instance whereas at present the trunk water mains at point A are only a matter of inches above the stream bed, it was apparently possible at one time to walk under them without stooping. Downstream of point A on Figure 5.2 the stream flows in a concrete-lined channel before passing under the playing fields in a 750mm diameter culvert. For reasons connected with the culvert under the



RELATIONSHIP BETWEEN MANNING'S 'n' VALUE FOR CULVERT (POINTS C TO E) AND WATERCOURSE DOWNSTREAM OF POINT C

FIGURE 5.3

playing fields, a weir was constructed in the concrete-lined channel. This weir had the effect of raising the stream bed level upstream of it. The effects of this raising extended well upstream because bed material adopts its natural flow-related gradient. It is the obvious reason for the raised bed under the trunk mains and its effect could have reduced the stream area under the footbridge. This would explain why the stream at the footbridge only had a capacity of 13.3 cumecs compared with at least 23 cumecs upstream as far as the culvert exit at C. If this is the case then the effects of the weir must be considered as contributing to the extent of the flooding.

5.6 EFFECT IF EMBANKMENT AT J DID NOT EXIST

If the embankment at J did not exist at the time of the rainfall event of 26/27th December 1979 there would not have been an impounding of water.

Instead, the watercourse would have had to accommodate a peak flow of 3.05 cumecs.

If this were the case, then such a peak flow would have been safely accommodated in the watercourse except at point A where the trunk water mains obstruct the stream. Here there would have been local flooding.

Taken out

Chapter taken out

CHAPTER 6

RESPONSIBILITY FOR MAINTENANCE OF CULVERT AT J

6.1 INTRODUCTION.

At the meeting held with the NCB in their Aberaman offices on 18th February 1986 it emerged that the NCB had to make an application to the Highway Authority in the 1960's to "stop up" the road which passed over the embankment at J.

If the then Highway Authority had maintanined the roadway, which led to Colliers Row, then it was probably a 'highway, maintainable at the public expense'. If this was the case the Highway Authroity may have also been responsible for the maintenance of the embankment. Any slippage from those embankments could have affected the culvert.

6.2. ENQUIRIES MADE TO DETERMINE THE STATUS OF THE ROAD

The present Highway Authority is Mid Glamorgan County Council but prior to the local government reorganisation in 1974 the former County Borough of Merthyr Tydfil were the Highway Authority.

Gibb made enquiries with Mid Glamorgan County Council which revealed that very few records survived from the County Borough. However, the County Council pursued the matter through internal discussions and concluded that there does seem to be an opinion within the County Council that the highway was maintainable at the public expense.

However, in order to give a definitive response to this matter, the County Council indicated that this be pursued through the County Solicitor.

This matter has not been pursued further by Gibb.

CHAPTER 7.

CONCLUSIONS

The study which has been undertaken to examine the cause and effect of the flooding incident at Rhyd-y-Car has indicated the following;

(i) The prolonged heavy rainfall of 26th and 27th December 1979 gave rise to severe flooding of main rivers in the region. An analysis of rainfall data and comparisons with historical events support the view that the December 1979 floods were possibly the worst this Century. Most of the 2-day rain depth fell in a 16-hour period and, for this duration, the return period of rainfall was assessed at 155 years.

(ii) However, the catchment to site J - where the catastrophic embankment failure occurred - is quickly responding and therefore generally sensitive to short duration, high intensity storms. The 26th and 27th December 1979 storm did not include short duration rainfalls of exceptional severity.

Reconstruction of the flood hydrograph to site J (using a rainfall/runoff model) yielded a peak flow estimate of 3.05 cumecs corresponding to a flood peak return period of about 5 years.

(iii) Given the apparent lack of any regular flooding problem from the Nant Rhyd-y-Car, the December 1979 event would not have been expected to produce problems, either at site J or downstream. It is therefore concluded that the catastrophe arose from a malfunction of the drainage system rather than design exceedance.

(iv) The volume impounded at site J was calculated to be 20 500 cu. m, representing about 20 per cent of the estimated total runoff to site J prior to failure of the embankment. It is therefore concluded that the site J culvert must have functioned adequately during the early part of the event, before becoming substantially or totally blocked. The impounded volume of 20 500 cu.m probably built up over a period of a few hours, the ponding commencing some time between about 05.00 and 11.45. Given the prolonged heavy rainfall and the fairly remote location it is not surprising that the build-up of water was not reported. When the embankment was breached it is estimated that about 5 500cu.m flowed down the old railway cutting and 15 000 cu.m. through the culvert between points C and E.

(v) The peak flow through the culvert between points C and E has been estimated to be 20.8 cumecs.

(vi) The capacity of the watercourse between the outlet of the culvert at point C and the footbridge was adequate to contain the peak flow.

(vii) The capacity of the stream channel under the footbridge would have been insufficient to contain the peak flow even if it had been unobstructed by storm-induced debris. Without the further obstruction of the floating debris the flooding of the cottages might have been significantly less.

(viii) It is probable that the level of the stream bed under the footbridge and at all points downstream was raised due to the effects of a weir constructed in the concrete-lined stream channel adjacent to the point at which the stream is culverted under the playing fields.

(ix) The peak flows downstream of the footbridge are uncertain. However, the reduced stream channel capacity, particularly at point 5 on Figure 5.2. and at point A where the trunk water mains crossed the channel would have had a significant effect in causing water to overtop the banks or preventing flows diverted further upstream from returning to the main channel. Either effect could have aggravated flooding.

(x) It has been suggested that the impounding of the water may not have occurred if a safety grille was fitted to the inlet of the culvert at J. It is considered that any grille or other form of obstruction at or immediately upstream of the entrance to a culvert in a stream subject to bed material movement or one which carries floating debris would increase the potential to obstruct the flow into the culvert.

APPENDIX A

NCB letter ref SWAG 352/GW dated
30 August 1985

Gibb letter ref 84712F/M.2407 dated
3 September

When calling or telephoning, please ask for Mr. G. Watkins

NATIONAL COAL BOARD

Legal Department

SOUTH WALES OFFICE

R. WILLIAMS
Solicitor

COAL HOUSE
TY-GLAS AVENUE
LLANISHEN, CARDIFF
CF4 5YS

Telephone: CARDIFF (0222) 753232

Telex: 882161 CBHOB G

Our Ref: SWAG 352/GW

Your Ref:

30th August 1985

Sir Alexander Gibb and Partners,
Consultant Engineers,
124 Cathedral Road,
CARDIFF.

For the attention of Dr. D. W. Reed

Dear Sirs,

**RE: PETER DAVIES AND NICHOLA DAVIES -v- NATIONAL COAL BOARD
FLOODING AT RHYD-Y-CAR, MERTHYR TYDFIL, DECEMBER 1979**

The Board are currently defending an action for personal injuries by the above mentioned Peter Davies and his minor daughter, Nichola Davies. The action arises out of a flooding incident which occured at their home at Rhyd-y-Car, Merthyr Tydfil in December 1979.

Mr. John Roch, QC, has recommended that the Board seek a report from you dealing with certain aspects of the flooding incident with a view to your giving expert evidence at the trial on behalf of the defendents.

Briefly, you will recall the widespread flooding which occured in South Wales in the few days following the Christmas of 1979. The plaintiff in this case lived at Rhyd-y-Car Cottages, which are a row of terraced houses adjacent to the Colliery Row Open Cast site (the term "Open Cast" is something of a misnoma. The land was acquired by the Board's Open Cast Executive with a view to commencing Open Cast operations but in fact permission to work the site was refused following the public enquiry in 1970). There are a large number of culverts on the site and one of these culverts either collapsed, became blocked, or failed to accommodate the volume of water, with the result that an old railway embankment above the culvert was swept away by a build-up of water and the force of water thus released flooded (amongst other things) the plaintiff's house. Neither of the plaintiffs suffered physical injury but they both claim to have suffered psychiatric damage as a result of the traumatic experience.

Mr. Hugh Payne, formerly of Sir Williams Halcrow and Partners, had been engaged by the Board to investigate the security of the old dis-used tips of the Colliery Row site, some months before the flooding incident occured. Subsequently, Mr. Payne was engaged by the Board as an expert witness in relation to this litigation and has prepared a report which has been disclosed to the other side.

Cont'd ....

Counsel is perfectly happy with Mr. Payne's report but for various reasons considers that the expert evidence requires further consideration and strengthening in certain respects - particulartly with regard to the question of whether the culvert should have been fitted with a grill.

I hope that you will be able to undertake this assignment on behalf of the Board. Your investigations will involve the perusal of a considerable quantity of paperwork, including the reports of Mr. Payne and the plaintiff's engineer and the Board's various ~~briefs~~ proofs of evidence. No doubt you would also wish to visit the scene of the incident and possibly to interview the Board's Open Cast officials who were involved with the site.

If you are able to act in this matter I will write to you further with full and detailed instructions and papers.

I look forward to hearing from you as soon as possible.

Yours faithfully,

R. Williams
Solicitor (South Wales)

c.c. Institute of Hydrology f.a.o. Dr. A. Debney

Head Office
File 84712F
Chron

84712F/M.2407

3rd September, 1985

National Coal Board,
Legal Department,
Coal House,
Ty-Glas Avenue,
Llanishen,
CARDIFF.
CF4 5YS

For the attention of Mr. R. Williams

Dear Sir,

P & N DAVIES v. N.C.B.
FLOODING AT RHYD-Y-CAR, MERTHYR TYDFIL, DECEMBER 1979:

Thank you for your letter reference SWAG 352/GW dated 30th August 1985, inviting us to act as an expert witness in the above cause.

We shall be most pleased to assist you in this matter. As discussed between the writer and Mr. Bryn Lloyd, we believe that there are two aspects to the study as follows:

(i) an assessment of run-off from the site i.e. the hydrology of the site

(ii) an analysis of the culverts serving the site i.e. the hydraulics of the culverts

The type of work envisaged appears to be very similar to that done by us in preparation for the forthcoming Garnant Site Public Inquiry. We have contacted the Institute of Hydrology and we were given to understand that Dr. Duncan Reed will be pleased to carry out the work noted in (i) above. It is proposed that M. Ll. Chapman will carry out the work noted in (ii) above.

We look forward to hearing from you in order that a meeting can be arranged to discuss the work and your proposed programme.

Yours faithfully,

MLLC

M. Ll. CHAPMAN
Resident Representative

APPENDIX B

NCB letter ref SWAG 352/GW dated
16 December 1985

When calling or telephoning, please ask for Mr. G. Watkins

NATIONAL COAL BOARD

Legal Department

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Telex: 882161 CBHOB G

Our Ref: SWAG 352/GW

Your Ref: 84712F/M2407

16th December 1985

Sir. Alexander Gibb & Partners,
Consulting Engineers,
124 Cathedral Road,
Cardiff
CF1 9LQ

SIR ALEXANDER GIBB & PARTNERS
CARDIFF
20 DEC 1985

Dear Sirs,

re: P. & N. Davies v. National Coal Boad
Flooding at Rhyd-y-Car, Merthyr Tydfil - December 1979

I refer to your letter dated 3rd September 1985 and I apologise for the delay in replying.

This is quite a complex matter with a lengthy and tortuous history. In the circumstances I think that I can do no better than to enclose a copy of the Instructions which I recently prepared for a conference with Counsel, together with a copy of Counsel's written Opinion. The Instructions and the Opinion do of course refer to other matters other than the liability issues with which you will be dealing, such as Medical Reports and the potential value of the claims. So far as the Instructions are concerned I would refer you to paragraphs 1 - 34 (inclusive) and in the Opinion I would refer you to paragraphs 1 - 56 (inclusive).

You will note that on the front of the Instructions to Counsel there are listed a number of enclosures which were sent with and referred to in the Instructions. I enclose copies of the following item numbers, following the same numbering sequence as used in the Instructions:

Enclosures 1, 9 - 19 (inclusive), 21 - 26 (inclusive) and 29.

There are at present only one set of the photographs at enclosure 7, and I am arranging for the Board's Opencast Executive to have further sets prepared. As soon as these are ready I will let you have a set of these photographs together with a copy of the list of photographs at enclosure 8.

You will see from the enclosures that the Board has already obtained an Expert's Report from Mr. Hugh Payne. Mr. Payne was formerly employed by Sir William Halcrow and Partners and is now employed by the Welsh Office. Mr.Payne's report is favourable to the Board. However Mr.Payne himself is in a somewhat unusual position. In his capacity as an engineer employed by Sir. William Halcrow & Partners he was engaged by the Board to carry out a survey of the tips in question, some months before the flooding occurred. As he personally visited the area sometime before the flooding he is therefore a witness of mixed fact and expertise. Counsel feel that the Board's position will be strengthened if we can produce further expert evidence, from an expert who is not also involved in the case as a witness of fact which supports the findings of Mr. Payne. The first part of your Brief therefore is to cover the ground which has already been covered by Mr. Payne and to come to your own independent conclusion as to whether or not you can support Mr. Payne's findings and opinions, highlighting in particular points of disagreement between yourselves and Mr. Payne. As part of this exercise you will no doubt also be considering and commenting upon the Report of the Plaintiff's Engineer Mr. M.A. Perry.

For the second part of your Brief I would refer you to paragraphs 35, 46 48, 49, 50, 51 and 52 of the Instructions to Counsel. You will see from these paragraphs that in Counsel's view the vital question in the case is whether the culvert in question should have been protected by a grill. I would therefore ask you to consider this question carefully as if the Board are to defend this claim successfully we will have to be in a position to produce convincing expert evidence to the effect that, in all the circumstances, it was not necessary to construct a grill.

Thirdly, there is a proposition of law to the effect that if a landowner interferes with the natural course of a stream then he is liable for any damage to his neighbours land which occurs as a consequence of that interference. In this context the Board may be vulnerable to allegations that the culvert, and the embankment which was built over it (and which originally carried a railway track) amounted to an interference of the natural course of the stream. Counsel advised that as these engineering works took place so long ago there may be a legal argument to the effect that by 1979 the embankment and culvert could be regarded as a 'natural state' of the land. However, in the event that it is held that the embankment and culvert do amount to an interference with the natural state we have to consider what effect the culvert and embankment had on the rain which preceded the flooding. It might be said that on the day of the incident the embankment had the same effect on the free flow of the stream as the artificial dam. In other words but for the existence of the embankment,

(a) There would not have been created a pond with the consequent flooding or

(b) Even if there was a flood it would not have effected the Plaintiff's land to the same effect (for example the water may have escaped in a different direction or with less force).

Finally, therefore I would like you to consider what effect the embankment and the blocked culvert played in the flooding and whether it is necessarily true that there would not have been any flooding or so severe a flooding had the culvert and embankment not been there. The question may seem so obvious as to hardly merit serious consideration, but nevertheless I would like you to specifically deal with the point.

cont'd ......

I am not quite sure how you would wish to approach the task of compiling your report, but no doubt at some stage you will need to undertake site visits and probably also you will wish to meet with some of the Opencast officials who have had some responsibility for this site. I have informed the Opencast Executive that you are being instructed in this matter and I have asked them to let me know with whom you should liaise in order to obtain any further information or assistance which you require. My own contacts in this case have been Reg Criddle and Mr. Harry Coates. Possibly either or both of these gentlemen are known to you from your work on Opencast Public Inquiries. In the meantime if you would like a meeting with either myself or Mr. Watkins of my Department in order to discuss the points arising out of this letter then please do not hesitate to contact me.

Yours faithfully,

R. Williams
Solicitor, South Wales

APPENDIX C

Notes of Meeting held between NCB
and Gibb on 18 February 1986

84712F

NATIONAL COAL BOARD - OPENCAST EXECUTIVE

FLOODING AT RHYD-Y-CAR, MERTHYR TYDFIL

DECEMBER 1979

NOTES OF MEETING

PLACE: Offices of National Coal Board, Aberdare

DATE: 18th February, 1986

PRESENT:

H. Coates R. Criddle G. Watkins * R. Miles	National Coal Board	(NCB)
Dr. D. W. Reed	Institute of Hydrology	
R. Westwell M. Ll. Chapman	Sir Alexander Gibb & Partners	(Gibb)

* Part time

PURPOSE: To lay before the National Coal Board, preliminary findings of study carried out by Gibb and to seek clarification for further work

ACTION

1. INTRODUCTION

1.1 Gibb opened the meeting by saying that they had studied the bundle of papers which had been forwarded to them under cover of the NCB's letter dated 23rd December, 1985.

1.2 Also, Dr. D. W. Reed had visited the site primarily to check the catchment boundary and to view the general area. A separate visit to the site had been made by W. T. Mee, R. Westwell and M. Ll. Chapman of Gibb, in order to look at the culverts and streams which were flooded during the tragic event of December 1979.

1.3 The brief which the NCB had given to Gibb was essentially to examine the following three matters:

(i) To check the report prepared by Mr. Hugh Payne and to highlight any differences of fact and opinion. The report prepared by Mr. Payne is largely concerned with the hydrology of the site.

ACTION

(ii) To consider the need for a safety grille at the inlet to the culvert which was at point J on the plan attached to Mr. Criddle's Report.

(iii) Flood routing and in particular the effect if the embankment at J were not there.

2. HYDROLOGY

2.1 Dr. Reed stated that he had examined Mr. Payne's Report.

2.2 The figure of 140 mm. of rainfall in two days was agreed but there were minor differences in analysis in the way that Mr. Payne had evaluated this but the end result was the same.

2.3 It was agreed that the rainfall was exceptional due to its duration rather than its intensity.

2.4 Because of the long duration of the rainfall it was a rare event for large catchments such as the Taff and for that catchment the return period would be in the range 50 to 100 years.

2.5 In terms of long duration, heavy rainfall events in the area, it was not the worst event this century. A comparable event occurred in October 1946 and a slightly worse one in November 1931.

2.6 However, the special feature of the 1979 event was that it followed a wet period and just prior to the event the ground was frozen which may have contributed to a greater run off.

2.7 However, rainfall intensity was not rare and for a small catchment the return period would be about 5 to 8 years. The critical duration for the catchment in question is about 4 hours.

2.8 In terms of the small catchment, since the return period is relatively small, then there should not have been a problem with the capacity of the culvert.

2.9 Dr. Reed advised that he agreed with Payne's statement about the sensitivity of the catchment.

2.10 Calculations for a 4.25 hour duration storm give peak flows of:

Return Period Years	Discharge cumecs
10	4.1
100	6.6

ACTION

The discharge figures are higher than the capacity of the culvert quoted in Payne's Report.

2.11 However, for the December 1979 event, the peak flow was 3.0 cumecs., about a 5 year flood. The range of accuracy of this figure of peak flow is 2.0 - 4.5 cumecs.

2.12 In carrying out the above assessment the catchment area was evaluated to be 1.43 sq.kms which is larger than the area evaluated by Payne. (viz: 1.03 sq.kms.)

2.13 It was noted in Payne's report that he was of the opinion that the culvert had passed a lot of water safely prior to the blockage.

2.14 It was noted that Payne had evaluated the volume of water retained behind the blocked culvert to be 28 000 cu.m. This figure has not yet been checked and this will be done. Gibb

2.15 However, if the figure of 28 000 cu.m. is accepted and it is known that the blockage occurred towards the end of the storm, there is no doubt that the culvert passed a lot of water safely.

2.16 The evaluation of the cumulative inflow was very much larger than 28 000 cu.m., being in excess of 100 000 cu.m. The actual figure can be assessed. Gibb

2.17 NCB stated that this particular fact was a very important leg of their defence, since it demonstrated that the culvert was functioning adequately prior to the blockage.

2.18 Dr. Reed noted that on page 4 of Mr. Perry's report a reference was made to the statement given by Mr. Glanmor Davies which indicated that there was an increase in flow in the stream 1 hour before failure. Dr. Reed requested the NCB to obtain a copy of the statement made by Mr. Glanmor Davies in order to check exactly what he said as it could prove important. NCB

2.19 It was noted in paragraph 12 of Mr. Payne's report that the long duration rainfall event gives more scope for debris to move and this is accepted.

2.20 Because of the long duration of the storm and the movement of the debris when the culvert had blocked, it could not have happened at a worse event because the duration of the rainfall was sufficiently long enough to cause the filling of a large pond of water.

2.21 In this respect, the event could be considered in terms of a return period of between 50 - 100 years.

ACTION

2.22 The NCB noted the difficulty in trying to indicate the degree of risk by return periods in that it is very important to ensure that all the relative factors are taken into account. The NCB pointed out that Mr. Perry, in his report, had gone along with the idea that the rainfall event in question was a rare occurrence.

2.23 Dr. Reed indicated that Mr. Perry had incorrectly noted the highest level of the catchment as being 900 ft. whereas it is, in fact, 1 400 ft.

2.24 Gibb were of the view that following the blockage of the culvert the embankment then became saturated when the water of the impounded lake rose and failure of the embankment was proposed as a result of the embankment giving way rather than over topping; although the top water level was nearly coincident with the top level of the embankment.

2.25 Mr. Perry in his report raises the question of what would be the consequence if the culvert blocked. NCB agreed that this should be examined. — Gibb

2.26 It was agreed that Dr. Reed should check on the likelihood of 28 000 cu.m. of water collecting behind the blocked culvert. In other words, to evaluate the return periods necessary for such a volume of water to collect. — Gibb

3. SAFETY GRILLES

3.1 Gibb stated that they shared the same opinion about the use of safety grilles as stated in Mr. Payne's report.

3.2 In order to verify this view, a letter had been written to the Welsh Water Authority, Brecon, inviting them to advise what is their policy or recommendations with regard to the fixing of grilles to culverts.

4. FLOOD ROUTING

4.1 Following a visit to the site, Gibb noted that the discharge was controlled by a long culvert up stream of the cottages at Rhyd-y-Car.

4.2 It would be possible to calculate the amount of water which discharged through that culvert and to evaluate the peak flow if survey information was available. The NCB stated that they did have survey information which indicates the required details and this would be forwarded to Gibb. — NCB

4.3 Gibb noted that down stream of the controlling culvert were a number of significant obstructions in the water course.

ACTION

4.4 The first of these was a cill constructed on the inlet to the culvert which passes under the Rhyd-y-Car playing fields. The NCB stated that the cill was, in fact, constructed by Merthyr Borough Council prior to 1974.

4.5 Because of the construction of the cill, siltation had occurred in the water course to such an extent that there was virtually no gap between the stream bed and the underside of the water mains. The NCB advised that they were given to understand that in the past it was possible to walk along the stream bed under the water mains without having to bend down.

4.6 Because of the siltation in the stream, the water mains effectively act as a dam and caused water to back up in the stream.

4.7 It seems likely that this backing up would have occurred up to the footbridge across the stream and because of that, it would have contributed to the stream becoming blocked with floating debris at the footbridge.

4.8 The consequence of this would have been that the water was directed down the back alleyway of the Rhyd-y-Car cottages resulting in the severe and fatal flooding.

4.9 It was noted that the footbridge was constructed by one of the residents living in the Rhyd-y-Car cottages and was of steel and concrete. Although no details survive of its construction it is known that the abutments were constructed in the stream bed and the deck was not a great distance above the invert of the channel. In itself, it was likely that the footbridge acted as a constriction in the stream.

4.10 The NCB stated that they own the stream from the point where the water mains cross it and up stream as far as the outlet of the culvert; but they did not own the banks of the stream.

5. MISCELLANEOUS

5.1 It was noted in Mr. Payne's report that he had examined other culverts within the Merthyr area and Gibb stated that it would be a great deal of work for them to check the statement made by Mr. Payne about these culverts. The NCB stated that there was no need for Gibb to check the other culverts in the area and that Gibb should concentrate on the particular culverts in question on the site.

5.2 It was agreed by the NCB that Gibb should prepare a draft report first of all for comment by the NCB. — Gibb

ACTION

5.3 The draft report should, in fact, be independent and not be inter-meshed with Mr. Payne's report but it should refer to Mr. Perry's report instead.

5.4 It was mentioned during the meeting that the road on top of the embankment from culvert J was " a public vehicular track". The NCB advised that Merthyr County Borough used to maintain the road.

5.5 Gibb stated that if the highway was maintained at public expense then it is probable that the maintenance of the culvert under the highway should also rest with the highway authority.

5.6 Gibb would establish if the road on top of the embankment at culvert J is a highway maintainable at the public expense. This could be done by inspecting the plans which should be maintained for such purposes at the offices of Mid Glamorgan County Council. Gibb

5.7 The NCB stated that when they made an application for opencast activities on the site in the late 1960's they had prepared a draft order for stopping up the highway and because planning consent was not granted the stopping up order was never put into effect.

APPENDIX D

Design Flood Estimates

Design flood estimates

Method used: FSR rainfall/runoff method as updated by Supplementary Report No. 16.

Catchment characteristics

Catchment centroid: grid reference 3033 2053

AREA 1·43 km²
MSL 1·95 km
S1085 86·5 m/km
SAAR 1700 mm
URBAN 0·0

Preliminary calculations:

$$Tp(0) = 283\ S1085^{-0.33}\ (1+URBAN)^{-2.2}\ SAAR^{-0.54}\ MSL^{0.23}$$

$$= 283\ (86.5)^{-0.33}\ (1700)^{-0.54}\ (1.95)^{0.23} = 1.364\ hr$$

Choose data interval, T = 0·25 hr

Then: $Tp(0.25) = 1.364 + 0.125 = 1.489$, say 1·49 hr.

From soil maps and site inspection: 100% soil type S

∴ SPR = 53 (No explicit allowance made either for manmade improvements - eg. drainage ditching, underdrainage through mine works - or for exacerbations - eg. reduced infiltration capacity of disturbed ground.)

design CWI = 125 mm

design storm duration, D = (1 + SAAR/1000) Tp(T) = 4·02 say 4·25 hr (add multiple of data interval).

Climate characteristics:

M5-2day rainfall 100 mm
Jenkinson 'r' 0·21

Rainfall calculations:

M5-4¼hr = 0·39 × M5-2day = 0·39 × 100 = 39 mm

Flood peak return period (years)	Storm return period (years)	MT/MS growth factor	MT rainfall (mm)	P = MT. ARF storm depth (mm)
2.33	2	0.77	30.0	29.0
5	8	1.11	43.3	41.9
10	17	1.335	52.1	50.4
30	50	1.65	64.4	62.3
50	81	1.82	71.0	68.7
100	140	2.03	79.2	76.6

ARF = areal reduction factor = 0.967 ($1.43\ km^2$, D = 4.25 hr)

Completion of PR calculation:

$$DPR_{CWI} = 0.25\,(CWI - 125) = 0.0$$

$$DPR_{RAIN} = 0.45\,(P - 40)^{0.7} \quad \text{for } P > 40$$

$$PR = PR_{rural} = SPR + DPR_{CWI} + DPR_{RAIN} = 53 + DPR_{RAIN}$$

Short-cut method to peak flow:

$$ANSF = [33\,(CWI - 125) + 3.0\,SAAR + 5.5] \times 10^{-5}$$
$$= (0 + 5100 + 5.5) \times 10^{-5} = 0.0511 \text{ cumecs}/km^2$$

∴ baseflow allowance = 1.43×0.0511 = 0.073 cumecs

$$q = RC\left(\frac{PR}{100}\right) \cdot \frac{P}{D} \cdot AREA$$

where AREA = 1.43
D = 4.25
and RC = 0.416 (D/Tp = 2.85)

$$\therefore q = 0.140 \times \frac{PR}{100} \times P$$

Flood peak return period (years)	P (mm)	PR/100	q (cumecs)	baseflow (cumecs)	Q = q + baseflow (cumecs)
2.33	29.0	0.530	2.152	0.073	2.22
5	41.9	0.537	3.150	0.073	3.22
10	50.4	0.553	3.902	0.073	3.97
30	62.3	0.570	4.972	0.073	5.04
50	68.7	0.577	5.550	0.073	5.62
100	76.6	0.586	6.284	0.073	6.36

Construction of hydrograph for 5-year flood

From Supplementary Report No. 9, Fig. 3:

$D/T_p = 2.85$ ∴ intermediate to curves labelled 2.6 and 3.0

$T_p = 1.49$, $q_p = 3.15$

$\frac{q}{q_p}$	$\frac{t}{T_p}$	q (cumecs)	t (hrs)	Q = q + baseflow (cumecs)
0	0	0	0	0.07
0.2	1.14	0.63	1.70	0.70
0.4	1.48	1.26	2.21	1.33
0.6	1.70	1.89	2.53	1.96
0.8	1.95	2.52	2.91	2.59
1.0	2.45	3.15	3.65	3.22
0.8	2.97	2.52	4.43	2.59
0.6	3.25	1.89	4.84	1.96
0.4	3.56	1.26	5.30	1.33
0.2	3.87	0.63	5.77	0.70
0	5.2	0	7.75	0.07

DWR
9 April 1986

APPENDIX E

December 1979 Flood Synthesis

Dec 79 flood synthesis

Antecedent condition

API5 at 09.00hr on 26Dec79 taken from gauge 489384 (close by and similar altitude).

$$API5_{09.00} = \sqrt{0.5}\,(16.0 + 0.5(0.0 + 0.5(1.1 + 0.5(0.0 + 0.0))))$$
$$= 11.5 \text{ mm}$$

API5 at 21.00hr calculated by recessing 09.00hr value and assuming antecedent rainfall of 10.1 mm centred at 15.00hr:

$$API5_{21.00} = \sqrt{0.5} \times 11.5 + 0.5^{1/4} \times 10.1 = 16.6 \text{ mm}$$

$SMD_{21.00}$ taken to be zero.

$\therefore$ initial CWI = 125 − SMD + API5 = 125 − 0.0 + 16.6 = 141.6 mm

Event rainfall

Event taken to be from 21.00hr on 26Dec79 to 20.00hr on 27Dec79.

$\therefore$ Storm depth, P = 133.6 mm. Profile taken from Aberdare Filters recording raingauge.

Calculation of percentage runoff

SPR = 53 (soil type 5)

$$DPR_{RAIN} = 0.45(P-40)^{0.7} = 0.45(93.6)^{0.7} = 10.8$$

$$DPR_{CWI} = 0.25(CWI-125) = 0.25 \times 16.6 = 4.2$$

$$\therefore PR = PR_{rural} = SPR + DPR_{RAIN} + DPR_{CWI}$$
$$= 53 + 10.8 + 4.2 = 68$$

Calculation of baseflow

$$ANSF = [33(CWI-125) + 3.0\,SAAR + 5.5] \times 10^{-5}$$
$$= [33 \times 16.6 + 3.0 \times 1700 + 5.5] \times 10^{-5}$$
$$= 0.0565 \text{ cumecs/km}^2$$

$\therefore$ baseflow = ANSF × AREA = 0.0565 × 1.43 = 0.08 cumecs.

Unit hydrograph synthesis

From Appendix 1: $T_p(0.25) = 1.49\,hr$

$$Q_p = \frac{220}{T_p} \times \frac{AREA}{100} = \frac{220}{1.49} \times \frac{1.43}{100} = 2.111 \text{ cumecs}$$

$$T_b = \frac{250}{99} T_p = 3.76\,hr$$

$$Q_t = \begin{cases} \frac{t}{T_p} \cdot Q_p & \text{for } 0 < t \le T_p \\ \frac{T_b - t}{T_b - T_p} \cdot Q_p & \text{for } T_p < t \le T_b \end{cases}$$

These are ordinates of $\frac{1}{4}$ hr u.h. ← (Q_t)

Offsetting replicas by $\frac{1}{4}$ hr, and ~~summing~~ averaging, gives equivalent 1 hr u.h. → (last column)

t	Q_t					
0	0	0	0	0	⇒	0
0.25	0.354					
0.5	0.708					
0.75	1.063					
1	1.417	1.063	0.708	0.354	⇒	0.89
1.25	1.771					
1.5	2.102					
1.75	1.869					
2	1.637	1.869	2.102	1.771	⇒	1.84
2.25	1.404					
2.5	1.172					
2.75	0.939					
3	0.707	0.939	1.172	1.404	⇒	1.06
3.25	0.474					
3.5	0.242					
3.75	0.009					
4	0	0.009	0.242	0.474	⇒	0.18
4.25	0					
4.5	0					
4.75	0					
5	0	0	0	0	⇒	0

Convolution

Net rainfall (cm) = 0.068 × Rainfall (mm)

Rainfall (mm)	Net rainfall (cm)	Unit hydrograph ordinates 0.89	1.84	1.06	0.18	Baseflow (cumecs)	Total flow (cumecs)	Time (clockhr.)
						0.08	0.08	21.00
0.4	0.03	0.027				0.08	0.11	22.00
2.8	0.19	0.169	0.055			0.08	0.30	23.00
3.8	0.26	0.231	0.350	0.032		0.08	0.69	24.00
4.3	0.29	0.258	0.478	0.201	0.005	0.08	1.02	1.00
4.9	0.33	0.294	0.534	0.276	0.034	0.08	1.15	2.00
6.9	0.47	0.418	0.607	0.307	0.047	0.08	1.46	3.00
7.7	0.52	0.463	0.865	0.350	0.052	0.08	1.81	4.00
6.7	0.46	0.409	0.957	0.498	0.059	0.08	2.00	5.0
6.7	0.46	0.409	0.846	0.551	0.085	0.08	1.97	6.0
8.5	0.58	0.516	0.846	0.488	0.094	0.08	2.02	7.0
9.7	0.66	0.587	1.067	0.488	0.083	0.08	2.31	8.0
10.3	0.70	0.623	1.214	0.615	0.083	0.08	2.61	9.0
11.7	0.80	0.712	1.288	0.700	0.104	0.08	2.88	10.0
10.6	0.72	0.641	1.472	0.742	0.119	0.08	3.05	11.00
9.9	0.67	0.596	1.325	0.848	0.126	0.08	2.98	12.00
10.1	0.69	0.614	1.233	0.763	0.144	0.08	2.83	13.00
8.7	0.59	0.525	1.270	0.710	0.130	0.08	2.71	14.00
4.0	0.27	0.240	1.086	0.731	0.121	0.08	2.26	15.00
1.6	0.11	0.098	0.497	0.625	0.124	0.08	1.42	16.00
1.9	0.13	0.116	0.202	0.286	0.106	0.08	0.79	17.00
1.1	0.07	0.062	0.239	0.117	0.049	0.08	0.55	18.00
0.9	0.06	0.053	0.129	0.138	0.020	0.08	0.42	19.00
0.4	0.03	0.027	0.110	0.074	0.023	0.08	0.31	20.00
			0.055	0.064	0.013	0.08	0.21	21.00
				0.032	0.011	0.08	0.12	22.00
					0.005	0.08	0.09	23.00
						0.08	0.08	24.0

APPENDIX F

Estimate of Volume of Runoff to Site J between 21.00hrs on 26 December and 13.45hrs on 27 December

Estimate volume of runoff to site J
between 21.00 hr on 26 December and 13.45 hr on 27 December

$$V = \frac{1}{2} \times 0.5 + 0.11 + 0.30 + 0.69 + 1.02 + 1.15 + 1.46 + 1.81 + 2.00$$

$$+ 1.97 + 2.02 + 2.31 + 2.61 + 2.58 + 3.05 + 2.98 + 2.83 + \frac{1}{4} \times 2.71$$

$$= 30.27 \text{ cumec hrs}$$

$$= 109\,000 \text{ m}^3$$