

The influence of climate on hydro-electric development in Malaya and some design features of the Batang Padang scheme

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Mr K. R. Northgreaves, Freeman, Fox and Partners

I was interested to read in the Paper that difficulty was experienced with iron and sulphate reducing bacteria in water control equipment. In matters of this nature we learn much by the experience of others, and my own limited experience of a similar phenomenon was connected with a thermal power station in Malaysia drawing sea water from a tidal inlet in the coast.

85. In order to combat normal salt-water corrosion the sea water coarse screens were constructed in rust-resisting steel, type EN58B. After 12 months in service they were found to be suffering from severe pitting corrosion. The corrosion was so extensive in parts that reinforcing bars resembled pieces of sponge. It was caused by a strain of bacteria in the sea water which reduced sulphates to H_2S , and this in turn attacked the steel. The tidal range at that part of the coast was small and the inlet, which was about $\frac{3}{4}$ mile wide, received a proportion of local sewage waste. The bacteria flourished in anaerobic conditions and corrosion was particularly evident under bolted connexions and where the screens were coated with mud.

86. The matter was finally resolved by replacing the rust-resisting steel screens with conventional galvanized mild steel screens, but in hindsight epoxy coating on the original screens would probably have been effective had it been applied during manufacture.

87. I should be interested to learn further details of the methods adopted to overcome the problem at Batang Padang and whether rust-resisting steel was used at any time.

Dr D. E. Wright, Research Manager, CIRIA, formerly Lecturer, Department of Civil Engineering, Imperial College

I found the Authors' Paper of great interest, having previously worked on the Cameron Highlands scheme, which developed the power potential in the valleys above the Batang Padang scheme. Two examples from my own experience vividly confirm the points made about weathering and ground topography in §§ 17, 18 and 22.

89. When the $6\frac{1}{2}$ mile long Telom tunnel was 4000 ft from its southern portal with approximately 1200 ft of cover, a weathered region about 400 ft wide was traversed. This material was a soft weathered granite, with quartz as the only hard constituent, and could be gouged out with the fingers. Fortunately the original fissures had been sealed by the clayey nature of the material itself and the arch stood without support during the time required to drive the rest of the tunnel (about two years).

90. The second example concerned the right bank of the Habu weir, a mass concrete structure 112 ft wide and rising some 50 ft above the original river level. The original ground presented the appearance of a solid rock promontory having rock slab sides. Upon excavation these were found to be no more than a façade and a

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large proportion of the promontory had to be replaced by an extension of the weir flank.

91. Regarding § 22, what was the rate of drawdown which caused the rock fall to occur? Could the Authors suggest a safe drawdown rate for tunnels in granite from their experience in Malaya?

92. To my own knowledge, the only other siphon bellmouth spillway with a ski-jump tailwater seal which is in existence is at the Shek Pik reservoir in Hong Kong. There are, of course, more examples of siphons built on to straight crests. Has the spillway been in phase 2 operation yet, and if so have the Authors any comment to make?

93. I know that prototype tests on this siphon bellmouth are out of the question now, but I would like to enter a plea that serious consideration be given at the design stage to the possibility of prototype tests on sophisticated hydraulic structures of this type. This is of particular importance when their operation depends significantly on air/water flow, because then the model:prototype scaling relations are not completely certain.

94. With the co-operation of the Authors I was able to make prototype tests on the Menglang tunnel of the Batang Padang scheme and appreciate the difficulties of site tests; in the case of ungated spillways these are increased, as floods cannot be sent to order. For spillways the minimum provision required is for the measurement of the head over the crest and the flow, and these quantities may need to be determined by the operating staff after the consultant's staff have left site.

95. Could the Authors describe the general characteristics of reservoir and operating situations in which siphon bellmouth spillways would have an advantage over ordinary bellmouth spillways? In § 46, the Authors say that the saving in cost was M\$1 000 000. Is this the actual reduction in capital cost or does it include an assessment of the benefit of increased storage and higher retention level?

96. It should be noted that the cost comparison of the two bellmouths is based on the assumption that the Jor reservoir 'affords no appreciable regulation for major floods' (§ 44). If storage had been significant, the volume of flood water delayed in the reservoir during the operation of the siphon bellmouth would have been less than that delayed by an ordinary bellmouth with its less efficient hydraulic characteristics. Consequently the maximum discharge passed by the former type would have been higher than that passed by the latter. Thus in the usual situation, where storage is significant, the true comparison is between systems giving the same reservoir flood levels and different normal TWL's and having different maximum discharge capacities. This should be borne in mind as the savings in cost may be very much smaller, or even reversed, particularly where outlet tunnel costs are a large proportion of the whole.

97. What is meant by H_s , the 'total head across the siphon' in phase 2 operation (§ 51)?

98. The hydraulic jump device for excluding sediment-laden water at the side-stream intakes has all the elegance of simplicity, and together with the pond upstream and settling tanks downstream should form an effective and reliable means of dealing with the difficult design problems posed by intakes on steep hill catchments.

99. I have a few detailed queries about these intakes:

- (a) to what order of velocity is the stream reduced by the upstream pond?
- (b) what is the longitudinal section of the settling tanks?
- (c) does § 77 (b) refer to the total area of the gaps along both sides of the entire length of the precast concrete covers?
- (d) does § 76 include considerations in addition to that described in § 24? Any data on the relation between machine erosion and particle size would be interesting.

Messrs P. Ackers and A. J. M. Harrison, Hydraulics Research Station, Wallingford

The Paper gives an interesting account of hydro-electric development in Malaya. We are familiar with many of the features of the Batang Padang scheme since the Hydraulics Research Station co-operated with Messrs Binnie and Partners in developing the hydraulic design of several features. These were the siphon spillway, the stilling basin,⁸ the side-stream intakes and the surge shafts.

101. The siphon spillway provided an interesting hydraulic model investigation. As far as we know, this was the first time an air-regulated saddle siphon with a double-curved hood and a flow section contracting in plan had been designed. The hydraulic study has been fully described elsewhere.⁹

102. A novel aspect of the study not mentioned in the Paper was an investigation of 'overrun'. If the water level in the reservoir is well below the siphon crests when a flood occurs it is possible that the water level could be approaching the siphon lip level as the flood inflow approaches its peak. Under these conditions the reservoir level rises very rapidly and an 'overrun' condition occurs, i.e. the water level rises above its equilibrium level for the given inflow discharge (as shown on the stage-discharge curve, Fig. 11) in the time that the siphons take to prime. The siphons then discharge more than the inflow discharge for a few minutes until the reservoir has been drawn down to its equilibrium level.

103. The results from a number of overrun tests showed that the spillway discharge could temporarily exceed the inflow discharge by up to 50%. However, the disadvantages of these characteristics of the siphon spillway should not be overstressed—they are common to all such spillways to some degree—for the chance of a large (and hence infrequent) flood occurring when the water level is such that an overrun condition could occur is probably very small.

104. In § 46 the Authors state that estimates for the siphon spillway showed a saving in cost of M\$1 000 000 over a conventional bellmouth. Is this the actual saving in construction costs or does it allow for the increased value of the higher head and storage volume as a result of the raised crest level?

105. It is not clear how the coefficient of 3.77 in § 51 was obtained. It is usual to express the discharge coefficient for a siphon by the equation $C_d = Q/A\sqrt{2gH_t}$, where H_t is the total head across the siphon, i.e. the difference in level between the upstream water surface and the foot of the siphon hood. At the design discharge the coefficient C_d is 0.47. At the 'black water' discharge of 3700 cusecs the coefficient is 0.63, a typical value for siphons of this type.

106. A comprehensive model investigation of a typical side-stream intake was also carried out at the Hydraulics Research Station. From the studies a logical design method was developed which was used by our clients to determine the geometry of the various intakes. Since these were of different sizes but not geometrically similar it was important to understand the theoretical background to the performance of the intakes.

107. Several alternative methods of achieving the required cutting off of the flow to the drop-shaft at a given discharge were reviewed, and the one selected for study and ultimate use, namely the concept of using the sweep-out of a hydraulic jump to trigger a change of flow, was evolved by Messrs Harrison and Montes, who were responsible for the model investigation. This system does not require the operation of any mechanical device when the discharge reaches the value at which it is to be cut off, a particular advantage in view of the large amount of sediment and trash carried by the streams and the fact that the intakes are not continuously manned. The performance of the model intake was found to be in good agreement with theory developed from the hydraulic jump, total energy and weir equations for the jump channel for values of a/p below 1.5, where a and p are the heights of the gate opening and the weir respectively. It was also shown theoretically, in a paper on this subject,¹⁰ that the water level upstream of the control gate remains almost constant

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for a range of gate settings given by $0.3 < a/p < 1.5$. This gives great flexibility to the operator who can thus adjust the cut-off discharge from time to time to suit the observed sediment characteristics of the stream or changes in the demand for water.

108. The design of the settling tank was based on Camp's sediment removal function¹¹ and tests in the model showed good agreement with this theory. The system for removing sediment from the tank was developed during the investigation from an idea of Indri's.¹² The work is described in the report of the model investigation⁶ and includes a theoretical justification of the experimental finding concerning the size of the gap under the concrete covers (see § 77(b)).

109. We are pleased to learn that the intakes have proved satisfactory with regard to the positive cut-off of flow by the sweep-out of the hydraulic jump, the efficiency of the settling tank and the effectiveness of the scouring system. Such prototype evidence of performance is a desirable follow-up to any hydraulic model investigation, and it is a great satisfaction to the research engineers concerned to know that this is one of the schemes in which their findings have been put into effect and that results have so far satisfactorily confirmed their predictions.

Messrs Shallow, Gerrard and Green

We thank the contributors for their interesting comments and the way in which they have amplified the information given in the Paper.

111. **Mr Northgreaves** experienced much more corrosion at his sea water inlet screens than has been encountered at similar structures on the Batang Padang scheme where the river water frequently became acidic (e.g. pH 5.0) for short periods during floods but has not been particularly corrosive to steel in river and reservoir structures. Steel liners of tunnels were shot-blasted and bitumen painted, intake screens were galvanized and bitumen painted. No special rust-resisting steel was specified.

112. **Dr Wright** has cited some good examples of the uncertainties associated with construction in areas of weathered granite. With regard to § 22, the rate of draw-down during dewatering of the unlined tunnel in which a roof fall occurred was approximately $7\frac{1}{2}$ ft head/h. It is considered that in future, during dewatering, the water level in the tunnel should be lowered at a rate not exceeding 6 ft/h.

113. So far as we are aware, discharges over the Jor siphon spillway have not yet reached the phase 2 stage (Fig. 11). Calibration of large spillways is usually difficult. Firstly, as **Dr Wright** observes, because floods cannot be prearranged and secondly because, in the case of gated spillways, any large discharges usually embarrass or cause damage to riparian owners downstream.

114. After their experience with the Jor siphon spillway the Authors, when studying future schemes, would always examine the complete economics of this type of spillway for comparison with other types. It appears to be particularly suitable in situations where there are compelling reasons for limiting the flood rise above crest level or where, for one reason or another, it is decided to place no reliance on mechanically operated gates. The saving in cost referred to in § 46 was on construction costs only.

115. The reference to discharge coefficient in § 51 was an attempt to compare phase 2 and phase 1 performances regarding both as weir discharges. The Authors now realize that this is, regrettably, misleading. **Messrs Ackers and Harrison** have drawn attention in § 105 to the correct phase 2 stage discharge equation and coefficients, and, incidentally, answer **Dr Wright's** question about the definition of 'total head across the siphon'. The symbol A in the equation is the throat area measured vertically above the crest.

116. With regard to **Dr Wright's** questions about the side-stream intakes, no meaningful figure can be given for the velocity of the stream in the upstream pond as it depends upon the topography of the site, the inflow, and the length of the weir formed by the bed load excluder wall. A typical longitudinal section of a settling tank, requested by **Dr Wright**, appears in Fig. 19 which shows the tank on the Bot

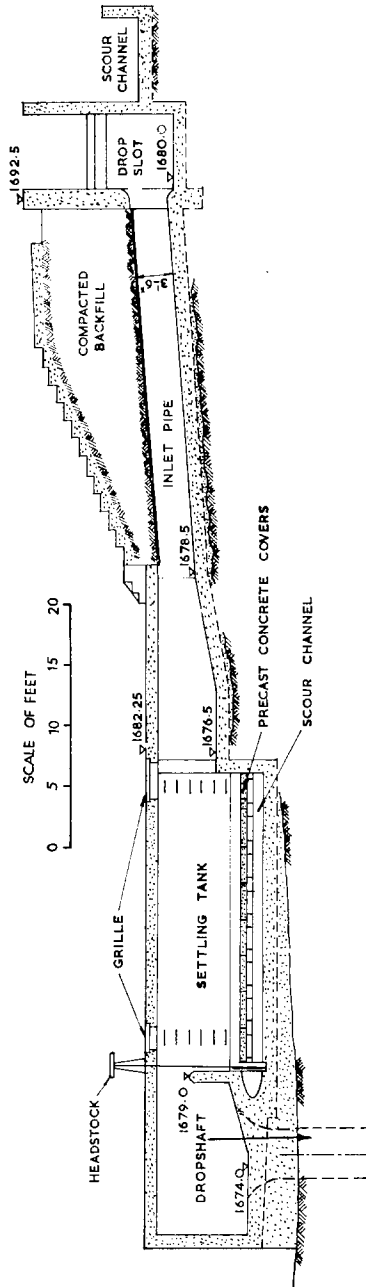


Fig. 19. Bot settling tank : longitudinal section

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sidestream intake. The total area of the gap referred to in § 77(b) is the total area available in the bottom of the tank through which sediment can pass. It is the total of the gaps on both sides of all the precast concrete covers.

117. In answer to Dr Wright, the size of settling tank was determined solely on the criteria stated in § 76.

118. We are grateful to Messrs Ackers and Harrison for mentioning the rare condition of short duration referred to as 'overrun' which formed part of their siphon spillway model investigation.

119. The questions asked by Messrs Ackers and Harrison about saving in spillway cost and about discharge coefficient have been answered in §§ 113 and 114.

120. The Authors fully endorse their remarks about the performance of prototype on the Batang Padang scheme confirming model study predictions. The Hydraulics Research Station's findings and recommendations guided the Consulting Engineers to effective economic solutions for the various hydraulic features.

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