Mr. McIldowie. and continuation of the methods adopted for the exploratory measures.

⁂ The reply by Messrs. Bromage and Sethi will be found on p. 542; that by Mr. Kelso will be printed in the next volume of Proceedings.—SEC. INST. C.E.

Correspondence.

Mr. Climie. Mr. H. R. CLIMIE, of Napier, N.Z., observed that it would be interesting to know on what evidence a steel reservoir had been chosen for the Murree water-supply as being better able to withstand earthquakes than a reinforced-concrete structure. When reconstructing the municipal services at Napier, following the disastrous earthquake of February, 1931, he had come to the contrary conclusion. In 1922 he had designed for the neighbouring municipality of Wairoa three reinforced-concrete reservoirs, which withstood the 1931 and subsequent earthquakes without suffering any damage whatever. That was the more remarkable as the reservoirs were founded on alluvial ground about 2 feet below the surface. They consisted of cylindrical tanks 38 feet in diameter and 22 feet deep, the walls, floor and roof being all 6 inches thick and suitably reinforced. The behaviour of those reservoirs was convincing proof of the suitability of reinforced concrete for the purpose, and he had chosen it in preference to steel plates for the new reservoirs in Napier.

The new reservoirs consisted of cylindrical tanks, 75 feet in diameter and 29 feet deep. The walls tapered from 9 to 6 inches in thickness, with a fillet on each side at the base 3 inches wide and 1 foot high. The circumferential reinforcing-rods had a mechanical bond and were simply overlapped 40 diameters. There were two spiral rows suitably spaced to give a hoop-stress of 12,000 lbs. per square inch. The walls had a footing 3 feet wide and 15 inches thick, which was tapered off to give a floor-thickness of 6 inches. The floor was reinforced with radial and circumferential rods, $\frac{5}{8}$ inch in diameter, to give a mesh about 12 inches by 12 inches. The wall was restrained at the floor, and was tied to it with $\frac{3}{4}$-inch vertical rods, of hairpin shape, placed at 8-inch centres close to the face of each fillet to resist a bending moment of 50 per cent. of that given by Hool's formula (which was based on the assumption of an unyielding foundation). To resist the reverse bending moment on the outside of the wall $\frac{5}{8}$-inch vertical rods at 8-inch centres were provided, and the hoop-steel was supported in position by $\frac{5}{8}$-inch

Mr. Climie. rods at 24-inch centres close to the inner face. The roof consisted of a 4-inch reinforced-concrete slab supported on pre-cast radial girders carried on one central column with a flared head 8 feet in diameter. The cost of those reservoirs was about £5 per 1,000 gallons. (Cement cost £6 10*s* per ton, steel £14 10*s*. per ton, and labour 1*s*. 6*d*. to 2*s*. per hour.) Although no plaster or waterproofing material was applied, the reservoirs were quite watertight a fortnight after being filled, that result being achieved simply by careful workmanship. Standpipes 100 feet high with 9-inch walls had been equally satisfactory. The floors were placed in one continuous operation, and immediately before a ring of concrete was added to the wall, 2-to-1 mortar was placed on the old concrete to a depth of 1½ inches.

His experience confirmed the results of the percolation-tests made by Mr. McIldowie. Natural unwashed river-sand gave the best results. In the construction of all the reservoirs described above such sand and shingle was used in the proportion of 1 cubic yard to 500 pounds of cement.

Mr. Furkert. Mr. F. W. FURKERT, of Wellington, N.Z., wished to express his appreciation of the very clear and detailed manner in which Mr. McIldowie had described the works at the Silent Valley, and particularly the difficulties met with in sinking the cut-off trench; the part dealing with the compressed-air work and the statistical information as to the incidence of and remedy for caisson disease was particularly interesting and instructive.

Could the Author give any particulars of the borings or other exploratory work done before the contract at £983,000 was entered into in 1923, and explain the reasons why the true extent of the work was not disclosed by the original investigations? Although the depth below ordinary ground-water-level to which work had to be carried was very considerable, the total quantity of pumping was not excessive; could not the trench have been excavated with the aid of electric sinking pumps without the prior sinking under compressed air of the very expensive and difficult shafts? The matter could be better judged if equally full details were given of the methods utilized and water experienced in the abortive attempt to sink a timbered sump, also if the actual extent of the glacial silt mentioned on p. 498 as "not extending to any great depth" were given. At Arapuni, N.Z., where a cut-off trench had to be taken down 75 feet in loose, recently-deposited, fragmental rock debris, an average of 1,500,000 gallons of water per day was pumped from a length of 100 feet, wooden shuttering being used; at the Waitaki Dam, inside steel sheet-piling driven through gravel, glacial silt and boulders, over 9,000,000 gallons of water per day was pumped from

Mr. Furkert. deep foundations for long periods, the water carrying a quantity of glacial silt. Mr. Furkert would greatly value a few details of costs, as well as a broad subdivision of the total cost in such a form as :—

Total cost of shafts,
,, ,, trench-excavation,
,, ,, cast-iron trench-lining,
,, ,, pumping,
,, ,, trench-concrete,
,, ,, puddle core,
,, ,, main filling, etc.

He would also like to know the quantity of concrete actually used in the trench, compared with the theoretical 6-foot thickness.

As electrical power was available, electric hoists mounted on and controlled from inside the air-locks would have had certain advantages over the steam cranes outside, apart from the saving in labour. In work under compressed air he had found it difficult to prevent men decompressing too rapidly, and the automatic decompression-valves described should be valuable safeguards. With regard to the first stage, during which the pressure was dropped fairly rapidly, there was a tendency for fog to form in the chamber and for the men to be chilled; in New Zealand, men who had worked under both systems preferred to decompress at a uniform rate of 1 lb. per square inch per minute, which gave practically the same over-all time. Hot coffee and extra clothes were supplied during that period. Under those conditions at Mohaka foundations no case of "bends" occurred up to 29 lbs. per square inch (the maximum pressure), but when the men controlled their own decompression, cases were frequent at much lower pressures. Considering the physiological cause of the disease, he was not inclined to the belief that there was any connection between humidity and "bends," as suggested at the bottom of p. 491. The value of the long break between the two halves of the working day had been proved, and usually, up to 30 lbs. per square inch, the method was to work 4 hours on, 8 hours off, 4 hours on and 8 hours off, any time from entering to leaving the lock being considered as working time.

He would like to know if the Silent Valley country generally had shown any tendency to sink as the result of lowering the ground-water-level by about 70 feet for so long a period. He was impressed by the neatness with which the material in the shafts was excavated, so that even in the worst ground only seven bags of cement were needed to grout a ring, in view of his own experience of 25 per cent. overbreak in bad cases. He would like some explanation of the statement on p. 495 that cavities which formed outside the shaft iron by fine material following the pumped water, were refilled "through the hand-holes or from the surface." Did the latter alternative mean that "runs" reaching the surface occurred? **Mr. Furkert.**

With reference to the vertical-bellmouth overflow, Mr. Furkert had adopted the same method of discharging floods up to 15,000 cusecs past the Manuherekia rock-fill dam (nearing completion), the bellmouth being shaped parabolically and constructed entirely in mass-concrete well reinforced. Prior to the preparation of the final details a model was constructed which showed the necessity of measures to prevent the formation of a vortex which would greatly reduce the discharging capacity. Various numbers and shapes of baffle-ribs were tried, and finally an arrangement of six was selected, the ribs having a height equal to the highest expected flow over the sill, 7 feet 6 inches, and extending from the sill at full height to a point about half-way down the tapered throat. The shuttering presented no difficulty, being much simpler than that necessary for the forming of turbine scroll-cases and draught-tubes in mass-concrete. The reasons for the use by the Author of 4-ton granite sill-blocks would be welcomed. Could some details be given of the operation of the overflow at Silent Valley under various heads and discharges?

Mr. Lacey. Mr. J. M. LACEY, referring firstly to the Paper by Mr. Kelso, observed that the method of increasing the catchment of a tank or reservoir by a contour catchwater channel had been practised by the ancient tank builders of South India, and they had shown considerable ingenuity in their alignment in crossing from one valley into another. A modern instance was the Russellkonda reservoir of the Rushikullia irrigation system, South India, constructed in 1892–94, which consisted of an earthern embankment between two hills intercepting a small tributary of the Rushikullia river. The dam at its deepest portion impounded water to a depth of about 60 feet. It was constructed, according to the then standard practice, of selected material with a puddle core carried down 15 or 20 feet into the soil. The rear slope was provided with dry stone drains, penetrating some distance from the outer slope, and connected to a longitudinal drain which carried away any percolation that might pass through to the outer slope. Since its construction the dam had given no cause for anxiety, the only maintenance required being the preservation of the outer slopes against scour from rain and against rat- and snake-holes. The front slope was heavily pitched with stone not less than 2 feet in thickness. The actual catchment of the reservoir was small, and it was fed by a canal taking off above an anicut built across the upper waters of

Mr. Lacey. the Rushikullia river. The canal was provided with a head-regulator to control the supply entering the reservoir.

The capacity of the Silvan reservoir was given as 8,800 million cubic feet (p. 404) and the maximum capacity of the outlet channel was given as 200 million cubic feet per day (p. 405). If the latter figure was correct the reservoir held only 44 days' supply. The population of Melbourne and its environs was, he supposed, about a million, so that the channel provided for a supply of 200 gallons per day per person. The chief point of interest in the Paper was the description of the novel form of core-wall. The Author had given his reasons for not adopting a plain concrete core (p. 405), but he had given no reason why a puddle core of suitable dimensions had not been employed. From the description given (p. 407) the soil seemed suitable for such a purpose, if mixed with a certain proportion of grit. A clay-puddle wall was capable of adapting itself to any settlement which might take place in the bank; it was hard to believe that a concrete core 2,000 feet long with a maximum height of 130 feet and an average thickness of about 8 feet would not be subject to some movement due to the differential pressures of saturated and dry soil. Another point of interest was the extraordinary depth to which the cut-off wall was carried. Was consideration given to the possibility of carrying the cut-off wall to a depth of some 30 to 40 feet into the soil, and grouting the lower portion by means of bore-holes sunk to hard rock?

The thickness of the stone pitching or revetment seemed small for so large a bank. No wave-breaker wall was provided; with the slope given to the water-face it seemed that waves would be easily carried up and over the top, but possibly the height of waves had been considered. The Paper disclosed the considerable care and forethought taken in the arrangement of all details of the work, particularly in the details of costing. There was no better training for an engineer than to carry out a work by the departmental method.

With reference to the Paper on the water-supply of Murree, the provision of a supply of potable water to small towns in India was very difficult, except in a few favourable localities. Water was often difficult to obtain and funds available for such purposes were not large. The late Mr. J. A. Jones had given an account [1] of the finance of such schemes in South India. In some towns water for a continuous supply was so difficult to obtain that a protected supply of 3 to 4 gallons per head per day would be a boon. Murree

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[1] "Waterworks of the Madras Presidency." Minutes of Proceedings Inst. C.E., vol. cxxxvii (1898–99, Part III), p. 2.

was fortunate in obtaining a source of sufficient yield for its needs, and so situated that the water could be conveyed by gravitation to the service reservoir. **Mr. Lacey.**

Turning to the Paper, he had not been able to ascertain how the consumption-figures of 6,940,000 gallons for May, June and July in the Table on p. 452 had been obtained; also, in the next column there appeared to be a mistake in the figures or in the heading. If the difference between the yield of the springs and the consumption was 4·5 million gallons in June and only 3·875 million gallons in July, there must have been a greater demand from the reserve in June than in July.

The steel reservoir was supported on concrete pillars; details of those pillars were not given, and it was not stated whether they were reinforced. The estimated pressure on a pillar was given as 6·87 tons per square foot. Did that provide for eccentric loading in case the grillage became displaced by earth-movements?

Mr. Legget. Mr. R. F. Legget, of Montreal, observed that the contrast between the careful attention paid to geology and to geological details in Mr. Kelso's description of the Silvan dam and the complete absence of references to geology in Mr. McIldowie's Paper on the Silent Valley reservoir would intensify the disappointment of all who had hoped for a full description of the latter work. Mr. McIldowie had given most valuable data and careful explanations, particularly of the compressed-air work. In view, however, of the basic importance of the geological structure of the Silent Valley in connection with all the works described, he earnestly hoped that in his reply Mr. McIldowie would give some data thereon, that he would state whether any geological advice was taken when the original boreholes were put down, or since that time, and that he would explain what was the peculiar geological structure which had necessitated the completion of the core-wall for the dam down to rock-level.

Mr. McConnel. Mr. S. McConnel, of Nairobi, observed that there were several unusual features about the small scheme for the water-supply of Murree which invited comment. A low standard of living must exist among both Europeans and Indians if allowances of water averaging about 14 and 10 gallons per diem respectively were sufficient to satisfy their requirements. The use of a siphon with a maximum head of 1,380 feet was uncommon in waterworks practice, but was necessitated by the nature of the topography at Murree. About 400 feet head was the limit for commercial cast-iron pipes, and 600 feet for ordinary lead joints, so that the use of steel or wrought-iron pipes was essential, but the employment of cast-iron flanges was a practice unlikely to be followed to-day. Screwed steel

Mr. McConnel. pipes up to 6 inches in diameter were regularly used with couplings under comparable pressures in oil pipe-lines, and in some work of that description which he had carried out flanged joints had been employed at short intervals to facilitate uncoupling the pipe in the case of damage. The arris between the face and the internal diameter of the flange had been rounded and the end of the pipe after screwing into the flange had been expanded by peening. Joints of the Gibault type could also be used. There seemed to be no advantage in substituting two 5-inch pipes for a single pipe in that portion of the siphon under the greatest head, since it would add considerably to the cost, while there would be no delay in repairing the 6-inch pipe when necessary.

The most interesting feature of the scheme was the substitution—at considerably increased expense, especially when the cost of painting was capitalized—of a large pressed-steel tank in place of the more usual reinforced-concrete structure. It was the largest steel tank founded practically at ground level of which he had knowledge, although there were quite a number of elevated tanks of greater size. It would be of great interest if the Authors would state why the "final sanctioning authority" considered that a reinforced-concrete structure would be less safe than a steel tank. In that connection it was interesting to note that at Napier, New Zealand, when mass-concrete reservoirs had been severely damaged by an earthquake, replacement had been made by circular reinforced-concrete reservoirs.[1] From all accounts of earthquakes, it appeared that properly-designed reinforced-concrete structures soundly constructed had behaved at least as well as those of steel. Was it considered necessary to increase the normal staying of the tank, required on account of the water-pressure, to resist the force of acceleration due to earthquake-shocks? There was also an overturning force on the concrete pillars, to which he presumed attention had been paid in design. The excavation seemed very expensive; it would have been carried out for one-quarter or one-third of the rate given in most parts of Africa. The reservoir had cost about £12,400 per million gallons capacity, but similar reservoirs of reinforced concrete, with roofs capable of carrying a load of 100 lbs. per square foot, had been constructed in England and South Africa for as little as £5,000 per million gallons capacity.

Mr. Manchester. Mr. E. J. T. Manchester, of Brisbane, observed that in June, 1927, he had inspected water-supply and sewage works at Belfast, but discussion and inspection of the Silent Valley appeared to be interdicted. Since then much had been done, and what had then

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[1] Minutes of Proceedings Inst. C.E., vol. 236 (1933), p. 404.

been a nightmare had since become an engineering triumph. As one **Mr. Manchester.** who had had air-lock experience in combating saturated ground in Melbourne, Victoria, and also in Brisbane, Queensland, it seemed to him after reading the Paper that the arrangements for the Silent Valley works were right up to date and ready for any emergency. In fact, the Paper was a classic contribution to the subject of driving back water in saturated ground. Reference was made to the ultimate costs as against those of the original shallower scheme, but the increase was humanly unavoidable, and all concerned should feel proud of a successful consummation which was well worth while from every viewpoint. He congratulated the Commissioners on their courage and vision in proceeding after the first serious setback, and the Engineers and Contractors on their resource in combating very grave, natural and other difficulties with a fidelity that ensured ultimate success.

Mr. JAMES MITCHELL remarked that the differences between the **Mr. Mitchell.** cross sections of the Silvan and the Silent Valley dams were noteworthy. The former, with its brittle concrete core-wall, had a much steeper downstream slope than the latter, thus affording a proportionally less resistance to downstream pressure. On the whole, the Silent Valley dam, with its massive core-wall of plastic clay, appeared to be better fitted to resist any general movement affecting the whole body of the dam, such as that due to an earthquake. Attention might also be directed to the fact that, in the one dam, the thickness of the underground portion of the core-wall was 4 feet, while in the other, in what appeared to be a stronger rock-formation, the thickness was 50 per cent. greater.

A particularly valuable portion of Mr. Kelso's Paper was that which dealt with the general layout of the work and the reasons for its separate features, together with the results of the working out, in practice, of the various arrangements. The provision of drainage-wells in the core-wall was ingenious and no doubt effective, but it hardly appeared to justify its cost. In the case of a rubble-stone backing, the washing of the earth-fill into its voids by rain-storms during construction might be prevented by keeping its top-level always well above that of the earth-fill, and interposing a diaphragm of tar-macadam between the rubble and the earth. That diaphragm would also prevent the fill from being forced into the voids of the rubble, while permitting the fill to be thoroughly consolidated at its junction with the rubble. In order to allow the layers of the fill to be sloped downward toward the rubble, the surface-water might be dealt with by drains extending along the ground-surface from the tail of the filling to the tar-macadam diaphragm, and thence vertically upward, pipes being added to the upper ends as the fill

Mr. Mitchell. rose in height. In the description given, on pp. 408 and 434, of tests relating to the consolidation of the earth-fill, no details were supplied of the dimensions of the steel cylinder used for taking samples, and the 3-inch cube mould used in the hammer-test was too small for an approximation to working conditions. Although no doubt trial-borings had been made before designing the works there was no mention of them in the Paper, and it was desirable that some details should be given. The reasons given on p. 428 for the consistency of the concrete were sound. It was probable, however, that the wall as constructed was actually stronger than if it had been attempted to build it with concrete having a consistency such as gave the best results in a laboratory. A 6-inch laboratory cube so made could not be regarded as properly representing the body of concrete in a mass-wall, with its various segregation-defects. In that connection, the "hopper-shoot" arrangement described on p. 429 seemed to have been well adapted for its purpose of preventing the segregation which was so difficult to avoid in the placing of concrete. In discussions on the proper water-content of concrete, the fact was too often overlooked that the water, in addition to supplying a constituent necessary for the setting of the cement, had two other important functions. It acted as a lubricant, and it helped to prevent segregation. The reference to the use of stone-dust, as adding to both the density and the strength of the concrete, might be compared with the reference, in Mr. McIldowie's Paper, to the effect of a proportion of silt in the sand used for concrete. The floating section at the junction of the outlet-conduit with the outlet-tower, described on p. 439, was ingenious, but appeared to be unduly elaborate and expensive. It seemed probable that its purpose would have been equally well served by having a plain butt-joint at the tower, the abutting faces having circular grooves in them, and with a space between them of, say, 2 inches ; the space, including the grooves, would be filled with a properly encased and supported jointing of plastic bitumen. The concrete lining of the dry well, mentioned on p. 436, seemed also to be unnecessarily expensive. A very extensive leakage might have been dealt with by a light timber-lining.

With reference to Mr. McIldowie's Paper, the use of intensive pumping, in conjunction with compressed-air work, for the sinking of the exploratory shafts, and the lining of the core-wall excavation with iron segments, were outstanding features of a very interesting and difficult piece of work. It seemed probable that intensive pumping, continued over a considerable time, as a preliminary to excavation work, might be advantageously adopted more frequently than was the case. It was easy to understand that escaping air would, as mentioned on p. 485, lead to a loss of pumping efficiency, **Mr. Mitchell.** but it did not seem probable that it would have any appreciable effect in raising the ground-water level. With regard to the remarks, on p. 478, as to the difficulty in getting the Eustachian tubes to open on entering compressed air, swallowing was sometimes difficult under such circumstances, owing to dryness of the throat. In such cases, the use of a sweet in the mouth was helpful, by inducing a free flow of saliva. The use of neat cement for grouting behind the iron segments of the shaft and trench linings was to be commended, as producing sounder work than a cement-sand mixture would. Reference was made on p. 486 to "the tracks of numerous cloudbursts." The word "cloudburst" was in common use as applied to cases of torrential rain, but it was apt to be misleading, as it did not correspond to any known meterological phenomenon.

Mr. E. G. RITCHIE, of Melbourne, observed that the features of **Mr. Ritchie.** special interest in the work at Silvan reservoir were the hollow core-wall and the twin outlet-works. The hollow core-wall had, in his judgement, much to commend it for general practice apart from the fact that its use at Silvan was, as pointed out by the Author, specially dictated because of the absence of any free-draining material for use in the downstream embankment. In the first place, all leakages through such a core-wall could be located both vertically and horizontally throughout the whole length of the wall. Then, having been located, they could readily be stopped by caulking from inside the wells. If that method of stopping leaks were found to be ineffective for any particular well, the well could readily be filled with concrete. Neither of those methods was, however, found necessary at Silvan. In that form of wall more information as to the behaviour of the upstream material in resisting water-penetration was available than with the ordinary types of solid core-walls. The upstream embankment at Silvan was composed of red clayey material which should have offered effective resistance to water-penetration. It was thoroughly rolled in layers with the requisite amount of water to make it a very dense mass, causing critical observers who visited the site during construction to suggest that the water would never reach the concrete core-wall because of the large mass of clay it would have to penetrate. Observations of the leakages collected in the wells showed that that was not the case; as water was introduced into the reservoir it very soon entered the wells through numerous minute leakages. He was of opinion that the water probably found its way through open strata or by effecting a junction with spring-water below natural surface-level, and then probably rose on the upstream face of the

Mr. Ritchie. core-wall, finding a passage along the junction between concrete and clay where the latter had shrunk from contact with the wall. However that might be, the water certainly reached the core-wall, and the cellular drainage-system then functioned to carry away percolating water, exactly as had been planned in the designs.

He agreed with the Author's statement that the use of loosely-placed stone immediately on the downstream side of the core-wall was a practice open to much question. His own experience led him to the conclusion that it was undesirable. If a non-monolithic drainage-system were to be used on the downstream side of a concrete core-wall, it would be much better to use hollow pre-cast concrete blocks than open stone, however carefully graded and packed the latter might be. The design as used at Silvan permitted of such measures of consolidation as would develop the fullest possible passive resistance to the downstream thrust of a more or less rigid core-wall of the type employed.

The use of slightly-tapered rigid well-forms with grease or greased hessian covering was a valuable measure in reducing the cost of formwork for the wells. It could, with advantage, be used in many kinds of well or manhole-shaft construction, and was therefore worthy of notice. As pointed out by the Author, the hollow core-wall made available a valuable means for bringing air- and water-pipes up so that they could be used for concrete and earth-work during construction, thus avoiding the use of pipes laid on the embankment or on the outside forms of the concrete wall which would impede the earth-dumping and spreading operations.

The use of twin outlet-works was a special feature at Silvan and was dictated by the fact that the whole supply to a population of more than a million would at an early date pass through the Silvan reservoir. There being only limited accommodation in service-reservoirs at the city end, it was considered advisable to make provision for attention to outlet-valves, renewals of outlet-pipes, and so on, in such a manner as would not affect the continuity of supply to the city. It was his opinion that the provision of alternatives in outlet-works of storage-reservoirs did not commonly receive the attention which it deserved. Such alternatives could be provided at a cost which was not prohibitive at the time of construction, but after the reservoir had been established it was often impossible to provide them except at great cost.

The Author had referred to the cost schedules, and Mr. Ritchie, under whose direction the whole of the works was carried out, desired to record that the excellence of the results was mainly due to the capable management of the Author and to his readiness to adopt mechanical methods wherever possible. The use of gablebottom trucks in particular was an ingenious device, for which the Author was mainly responsible, by means of which lost time in receipt and disposal of earth and despatch of trucks was greatly reduced. **Mr. Ritchie.**

The energy-dissipator works at the outlet-basins from the reservoir, as referred to by the Author, and as shown on Fig. 5, Plate 7, were completely successful. The velocity of the water which passed out of the four regulator-valves shown was so disposed of that there was a most even and steady flow over the two gauging-weirs leading from the twin stilling-basin to the main outlet-channel. Those gauging-weirs were required to measure the quantity of water despatched daily to the city by way of the channel.

Mr. Temple. Mr. F. C. TEMPLE observed that the figures of supply to Murree were interesting, and indicated that there was very little waste. In a cool climate such as that of Murree they were undoubtedly sufficient for necessities, though it was certain that if opportunities for waste were given the consumption would be far greater. In one town in the plains which gave its water-supply only through street stand-posts the average consumption in the cold weather was 3½ gallons per head, and in the hot weather (when the temperature rose sometimes to 115° F.) the consumption went up to about 6 gallons per head. As soon as house-connections were given the consumption went up to 60 gallons per head.

The statement that " Except in rare cases, no Indian contractor maintains an engineering staff " was beginning to require modification. Many contractors in the capital towns of the Provinces had realized the advantage to themselves in employing fully-qualified engineers, and the engineering societies were constantly urging the Government to insist upon contractors employing qualified engineers.

It was suggested that the climate was responsible for the fact that the plates manufactured in England did not fit the grillage manufactured in Bombay. The difference of temperatures might have been sufficient to cause the discrepancy, but it seemed much more likely that there was actual inaccuracy in the manufacture of one or the other. Both should have been set out with steel tapes, and any variation in the length of the steel tape due to difference of temperature which would appear in either finished product should correct itself when the products came to the same temperature.

The remark that the original scour-connections did not permit the tank to be completely emptied should be taken to heart by every maker of a tank, for it was very often found necessary to alter the connections.

Mr. McIldowie. Mr. McILDOWIE, in reply, observed that Mr. Furkert's inquiry

Mr. McIldowie. as to the preliminary borings was to a certain extent answered by Mr. Binnie's remarks (p. 517). The borings put down in 1913 gave satisfactory information as to the rock on the side slopes, but the very large boulders in the glacial deposits in the centre of the valley led to wrong conclusions regarding that area.

He was afraid that Mr. Furkert's suggestion that electrical sinking-pumps might have obviated the necessity for compressed air might not have been feasible. In addition to the silt-beds, which had to be contained and supported until they dried out, all the material excavated was so lubricated with an intermixture of wet silt as to be very difficult to restrain, whilst another factor was the depth, which was about three times that of the Arapuni trench. The compressed air was more certain of success. The special circumstances governing the whole policy of the undertaking should not be forgotten.

The abortive sump was briefly dealt with on p. 468; it was situated near cross section 16 (Fig. 3, Plate 9). The ring of interlocking steel piles was driven within the timbered sump after the latter had proved a failure. There was not a large quantity of water to deal with, but it was impossible to drive the piles sufficiently in advance of the excavation to preclude the material boiling up inside the ring. That pointed to the likelihood of similar trouble if steel piling were used for supporting the sides of the trench, as the piles could not be driven past the large boulders. An indication of the depth of the fine silt was given on p. 498.

Mr. Furkert asked about costs. That information was not available in the form he asked for, but the details in the Table on p. 541 might be of assistance. In every case the contractor's profit was included in the figures given.

The amount of concrete actually placed in the trench approximated very closely to the theoretical quantity. There was, naturally, no excess in the segmentally-lined portion of the trench, and in the timbered portions the excavation was very neat, while in rock the sides and bottom were hand-trimmed and there was little overbreak.

The use of electric hoists would have necessitated additional generating plant, as the power-house was fully taxed by lighting, pumping, and compressed-air requirements. Further, the steam cranes were available at the outset of the exploratory work, and in addition to the work they did in the shafts, they served for trench-excavation and concrete, and were useful at many other points.

It was impossible to say whether or not there was any settlement of the ground near the trench, but some settlement had probably taken place. The surface-levels were always being altered, while unwatering and excavation were going on, by the removal of sand, Mr. McIldowie.

silt, or other materials from the site and from the valley above and below the site, as well as by the depositing of bank-filling or by the peat-covering operations. The cavities mentioned on p. 495 as occurring behind the cast-iron shaft-segments did in some cases extend to the surface of the ground, and were filled from there.

Granite sill-stones were utilized in the overflow, to be in keeping with the granite masonry of the adjoining structures. As far as he was aware, no data were as yet available of any exceptional floods having passed over the sill of the overflow. A depth on the crest of 13 inches (equivalent to approximately 1,100 cusecs) had shown no tendency to cause a vortex, the four baffle-ribs acting quite satisfactorily.

Item of work.	Cost.
Main trench, excavation	£6 15*s*. per cubic yard (including pumping).
,, ,, concrete	53*s*. per cubic yard (including pumping).
Main embankment, general filling . . .	1*s*. 10¾*d*. per cubic yard.
,, ,, selected material . .	4*s*. 6*d*. ,, ,, ,,
,, ,, puddle	13*s*. 6*d*. ,, ,, ,,
,, ,, 12-inch to 18-inch pitching, including broken stone underlayer	25*s*. 3*d*. per superficial yard.
,, ,, soiling and sowing . .	8*d*. ,, ,, ,,
Overflow tunnel, rock excavation . . .	40*s*. ,, cubic yard.
,, ,, soft ,, ...	3*s*. 4½*d*. ,, ,, ,,
,, ,, concrete lining . . .	46*s*. 7½*d*. ,, ,, ,,
,, ,, blue-brickwork lining, 4½ inches thick . . .	£12 13*s*. 7½*d*. ,, ,, ,,
Peat-covering	1*s*. 4*d*. ,, ,, ,, (equivalent to 9½*d*. per superficial yard covered).

In every case the contractor's profit was included in the above figures.

Mr. Legget inquired as to the geology of the Silent Valley. The valley was entirely a granite formation. The whole of the rock disclosed by the trench-excavation (Fig. 3, Plate 9) was granite and was of fairly uniform character, that portion of it lying between cross sections 13 and 15 (Fig. 3, Plate 9) being somewhat soft and decomposed at and near the surface. It would be observed that the depth to which the trench-excavation was carried into the rock between those cross sections was considerably greater than elsewhere. That extra depth was considered advisable for the reason

Mr. McIldowie. just stated. Overlying the rock, and extending to the surface of the ground, the bed of the valley was filled with glacial drift consisting of sands, fine silts, gravel, and boulders. The nature and origin of that drift was referred to by Mr. Binnie in the Discussion, and further reference was made to it by Mr. Hill. The material was not impervious to water, and a water-tight embankment could not have been constructed without extending the core-wall down and into the underlying granite. It was some 23 years since the preliminary borings had been put down, and Mr. McIldowie was not able to say what geological opinions, if any, had been taken at that time; during the operations with which the Paper principally dealt, however, several eminent geologists were consulted.

Messrs. Bromage and Sethi. Messrs. BROMAGE and SETHI, in reply to the Discussion and Correspondence, stated that they were unable to say on what evidence the steel reservoir had been selected for Murree. The concrete pillars were not reinforced, but their design allowed for small eccentricities in loading.

The reason for the greater demand from reserve in June than in July was that the monsoon broke in July and the springs recuperated. In connection with the low consumption of water per head, it had to be remembered that water-flushed sewage-disposal was not installed in Murree.

⁂ Mr. Kelso's reply to the Discussion and Correspondence on his Paper will be printed in the next volume of Proceedings.—SEC. INST. C.E.