Discussion.

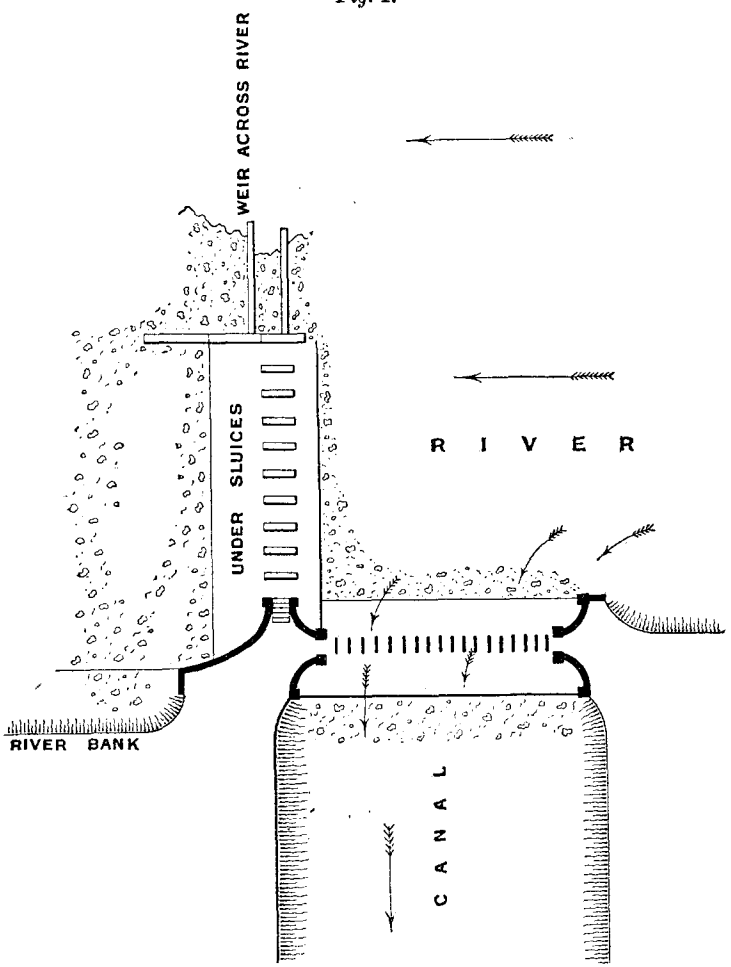
The President remarked that the Papers showed the extreme value of the irrigation work carried out by English engineers abroad, and also called attention to the important administrative duties which they were called upon to undertake, quite apart from ordinary engineering work. He had great pleasure in proposing a vote of thanks to the Authors for their Papers. The President.

Mr. R. B. Buckley thought that those members who were acquainted with Egyptian irrigation would be struck with the great similarity between the Bhadar weir and the Asyut and Zifteh weirs, which had just been completed. But there was one important difference between them, namely, in the shutters. He did not quite understand the arrangement for working the shutters of the Bhadar weir when the floods came, but he presumed the beam on which the upright channel bars rested was removed. He ventured to think the form of shutter described in the Paper was not a suitable one. It was somewhat like the shutters used in some weirs in France, but it was a form which would give rise to a good many difficulties when floods came, and the whole of the shutters had to be cut adrift in the stream. In India, notably on the Sone weir and in Orissa, forms of tumbling shutters had been used in somewhat similar situations, namely, in the under-sluices of the weirs; and there were many situations in which such shutters, which had been described in Papers[1] read before the Institution, were very useful. But the forms of shutter which had been adopted on the Chenab weir in Upper India, and particularly on the weirs in Egypt to which he had referred, had, he believed, superseded those which had been adopted in Bengal, and he thought they were far better than those described in Mr. Benson's Paper. They were plain iron shutters spanning the entire opening, about 3 to 4 feet high, and they were lifted by one, two or three travellers, as the case might be, which traversed the whole length of the weir. They could easily be removed when the occasion demanded, and were extremely simple to work. It would have been better if the plan had been adopted which had now been approved for India, and largely adopted in Egypt. Mr. Buckley.

[1] Minutes of Proceedings Inst. C.E., vol. lx., pp. 24 and 43.

Mr. Buckley. He wished to corroborate Mr. Preston's remarks upon Kutter's formula. It was generally the practice to take N in Kutter's formula for canals as 0·025; but in many canals—notably those

Fig. 1.



which had silted to a certain extent, and therefore had adjusted themselves into the best form of channel—a much higher discharge could be obtained than was indicated by the formula; an increase of 20 per cent. or even 25 per cent. having been obtained in cases

within his knowledge. With regard to silt, all canal engineers knew the great difficulties caused by silt in the canal-head. In the last 10 or 15 years there had been a notable advance in India towards overcoming those difficulties. In some canals the water flowing in from the river caused large deposits, which tended to reduce materially the discharge of the canal, sometimes at critical periods, and necessitated the removal of the silt by fleets of dredgers, at heavy expense. In the Sirhind and Sone canals both expense and difficulty had been entirely obviated by a few simple expedients. The primary use of under-sluices in a weir across a river was to maintain in the river a channel leading to the head-sluice of the canal (*Fig. 1*). In many cases it was thought to be the right practice to keep open as many as possible of the under-sluices, in order to induce scour in front of the head-sluice. No doubt the result was that a channel was kept open; but it had been found that, where the river-bed was of sand, the high velocity which was induced kept the river-bed in front of the head-sluice in a constant state of agitation, and the sand from the bed was caught up by the draught of the head-sluice vents and drawn into the canal, where it was immediately deposited, because the velocity was materially reduced as soon as the water got fairly into the canal. This was especially the case when only a few of the head-sluice vents were open, and the head on them was considerable. There were five main points which experience showed should be observed, in order to reduce the deposition of silt at the head of a canal. The first was to reduce the velocity in the river in front of the canal head-sluice, by keeping the under-sluices next to the canal closed as far as possible, the result of which was that the sand on the bed was not churned up and carried into the canal. Of course when floods came down that could not be done; the under-sluices were opened, or opened automatically, and a high velocity was induced. The head-sluices of the canal were then closed altogether. The second point in connection with the reduction of silt was to draw the water, as far as possible, from the surface of the stream, instead of from the bottom of it, as had been practised at first. That was done, not because the top water of the river had less silt in it than the bottom water, although that was true to a certain extent, but because, by drawing the water from a narrow layer at the top, the disturbance of the water in front of the sluices was stopped, and consequently the churning action which went on did not stir up the bed of the river and carry it into the canal. The deposit which had formerly occurred at the head of the Sone canals had been largely sand from the bed of the stream. It was desirable to reduce the

Mr. Buckley.

Mr. Buckley. velocity through the sluices by increasing the water-way, and especially by drawing the water from the top in as shallow a layer as possible, so that the velocity of approach to the head-sluice was as small as it could reasonably be made. The third point was to keep the largest possible flow in the canal, even during the period when the quantity of silt in the river was at a maximum. This might seem to be the reverse of what was desired. But by keeping as large a flow as possible in the canal during the season of silt, the canal would be caused to maintain its section, and the silt would be forced forward on to the fields, where it was required, instead of being allowed to settle in the canal. Of course this could be done only where the sand of the river-bed had been prevented, by the means already mentioned, from entering the canal. The fourth point was the scouring of the canal after the silt season, that was, when the floods in the river had gone down, and the under-sluices were all closed. At that time the water was clear, there was little or no head on the head-sluices of the canal, and the velocity through them was small. It was then possible to open all the sluices down to the bottom: there was no object in taking water from the top, because the water was clear and did not scour, owing to the lower level of the river. During the cold weather the canals had been run to their maximum capacity, in order to keep up a large discharge and carry away the silt; and in that way, in the Sirhind Canal in the Punjab and the Sone Canal in Bengal, enormous quantities of silt had been cleared away and passed forward to the fields or flushed out of escapes. The fifth point was that, in designing new works, one of the most important things was to keep the velocity at the head of the canal as high as possible. Mr. Preston said the velocity should not be above 3 feet per second, otherwise the banks would be scoured away: but in some cases it was better to scour the banks and go to the expense of protecting them by revetments, in order to keep up a higher velocity and thus carry forward the silt. In two important canal systems the five main principles he had mentioned had been quite successful, not only in reducing the working-expenses to a large extent, but also, what was far more important, in ensuring a full supply to the canals for irrigation.

Sir Alexander Binnie. Sir ALEXANDER BINNIE, Vice-President, remarked that the Papers might be considered as, in some measure, a contribution to the knowledge of that great problem—he might almost say miracle—of modern government, by which 200,000 Europeans governed 200 millions of Asiatics. It was by the perusal of such Papers that the important part which the engineering profession was

playing, in the endeavour to govern probably the largest number of people that had been brought under one rule since the time of the Roman Empire, was made clear. The Papers described works which in India would be considered as of no extraordinary magnitude; yet by means of the works described in Mr. Preston's Paper alone, an area of 3,000,000 acres was being brought under cultivation: which meant that an area almost as large as Yorkshire was being raised from a state of utter barrenness to one of luxuriant vegetation. Not only was that the case, but the redundant populations of certain provinces were being afforded an outlet for their labour in the profitable cultivation of an area which previously had been a desert. Looking at those facts from the broad point of view of the province which the engineer in India assumed, of not merely constructing works, but also adding to the civilization and the prosperity of hundreds of thousands of persons, the miracle of Indian government could be appreciated in some small measure. All who had ever served in that country had come away feeling in their inmost hearts that the government was beneficent to the people of the country and to themselves; and it would always remain a difficult thing to explain how and why it had been brought about. The Papers gave some slight inkling of the movements that were at work in securing that good result. From them it was seen that the engineer was not concerned only in the construction of works for bringing under cultivation large barren areas, but that he became the administrator, under Government, of the works which he had himself constructed; and, as Mr. Preston carefully pointed out, it was only by the employment in that capacity of one scientifically trained in the art of distributing water, that a profitable revenue could be realized from the large capital expenditure entailed by works of the kind. It would be a pleasant thing for all engineers if the works constructed in England were managed at a charge of 18·4 per cent. of the receipts for working-expenses, and returned to investors something like 24 per cent. on the capital outlay. When the meaning of those figures in regard to the prosperity of India and its vast population under English sway was realized, it could be understood in a small measure how it was that that population was contented under British dominion.

Sir Alexander Binnie.

Colonel S. L. JACOB thought Mr. Preston might have dwelt even more strongly on the extremely arduous duties of the canal engineer. The assistant engineer was usually the only European in the part of the country in which he lived, so that he had to forgo all the pleasures of ordinary society. Even when he was promoted, and

Colonel Jacob.

Colonel Jacob. became a divisional officer, having his headquarters in a station with a few Europeans, he had to spend the greater part of his time—hot weather, cold weather, rain or fine—in camp, performing unceasingly harassing duties. He had to work at all hours of the day or night, as well as to eat indifferent food and drink bad water, and equally bad milk. But the canal engineer not only had the ordinary engineering work connected with the canal to perform, he had, as stated in the Paper, to carry out the whole of the administration. For that purpose he must be thoroughly acquainted with the language; not only with the language proper, but even with the dialects of the people, so that he could talk on terms of intimacy with the ordinary people of the villages, and thus get "behind the scenes." The worst difficulty that every administrator in India had to face was the extremely corrupt character of the ordinary native establishment; and it was only a really efficient man, whose knowledge of the native enabled him to get behind the scenes, who could keep down the corruption. If an inefficient man was in charge, corrupt practices flourished; such a man might spend 20 or 30 years in India and never know what had been going on under his nose. Again, the engineer had to keep the canal running at all costs, for the life of the country was dependent upon it. If such a canal as the Chenab Canal was closed for 2 months, or even a shorter period, everybody would have to leave the land as quickly as possible; because not only would it be impossible to obtain a harvest, but no water would be available for drinking purposes, the canal being the sole source of supply. The engineer might see his masonry works being scoured, and his bridges likely to tumble down, but the canal must run by hook or by crook. The destruction of half a dozen bridges might mean a matter of £10,000 at most. But a closure of the canal for 3 days to enable urgent temporary repairs to be done might cost £30,000 direct loss, and £300,000 actual loss to the cultivation of the harvest. An appalling state of things would arise if, from any dire calamity, the canal ceased to work. Undoubtedly such a thing had happened in the past, because ruins of old cities were to be met with all over the Rechna Doab country. When aligning the Chenab Canal, on which he had been engaged before Mr. Preston's time, he had found running beside his line the traces of an old canal made years before. That canal had rendered the country fertile, but it had passed away, and with it, of course, the population. Canal engineers had exceedingly onerous duties to perform, and they had been instrumental in bringing in a large revenue to the Government. The Chenab Canal, which was unique in many

ways, produced a larger revenue than most canals, but all canals, in the Punjab at all events, paid excellently. The Chenab Canal produced a profit of about 25 per cent. per annum on a low assessment; if the Government desired, it could increase the assessment with the greatest ease, but it preferred to charge low rates. Further, the land, instead of being given to the settlers, might have been sold to them, in which case double the cost of the canal would have been realized. But Government, very wisely, did not want to do that. In view, however, of the magnificent results obtained by the canal engineers, he wished the Government would take up the matter of the canal establishment in a much more thorough way than it had done; for there was no doubt that the engineering establishment was not in a satisfactory condition. Such remuneration ought to be given as would allow of the best men being obtained. It would pay the Government over and over again; for a good engineer would earn his pay fifty times over, while a bad one would cause loss fifty times greater than his pay. Colonel Jacob.

Colonel JOHN W. OTTLEY remarked that his only excuse for speaking was his intimate acquaintance with the Chenab Canal project, of which he had laid down the first centre line in 1882. For the greater part of 12 years he had been closely associated with it, either as Superintendent or as Chief Engineer of the Punjab. Mr. Preston stated that already nearly 2,000,000 acres had been irrigated, and confidently expected the figure would soon reach 2,500,000 acres. Those were large figures, and difficult to grasp; and they might be brought home better if he gave an idea of what they meant. Recently, in connection with the food-supply enquiry, it had been stated that the whole of the home-grown wheat amounted to 6,000,000 quarters per annum. Taking the canal as it stood, and after allowing ample margin for crops such as rice, sugar-cane, cotton, maize, rape-seed, millets, etc., he found that the district irrigated by the Chenab Canal ought to be able to produce annually quite five-sixths of the amount produced by the whole of England in the year. That fact gave an idea of the magnitude of the project under discussion. On his first visit to the tract of the Chenab River, 21 years ago, it had been an interminable waste, with scarcely a living thing throughout it. There had been no villages, and the engineer had travelled sometimes many miles without seeing a human being. The subsoil-water had been at a depth of 70 feet to 110 feet, and probably more in places; the rainfall of the district was exceedingly small, and the revenue of the country, so far as he could ascertain it, had not been more than 1*d.* per acre, drawn from grazing-dues levied from men Colonel Ottley

Colonel Ottley. who fed their camels on the thorns in the desert, or from the cattle-owners who, after a shower of rain, took their cattle there for fodder. Since 1892, the whole aspect of the place had been changed. Villages were now dotted all over the country, the population being about 140 to 150 per square mile. The Rechna Doab, instead of being a desert was now a garden; the revenue had probably been increased fifty-fold; and the railway was, he believed, earning a good return. The whole of that transformation was due to the application of water to land which was fertile in itself, and simply waited for the water to turn everything into gold. Seeing the magnificent results which had been achieved by the Chenab Canal, as constructed, it might seem a little out of place to enquire whether something better could not have been done. He was inclined to think that, with the knowledge now possessed, it might have been improved upon. The tract irrigated was really only about half the land comprised between the Ravi and Chenab Rivers, the total area of which was about 12,300 square miles. The area commanded by the present canal was about 6,000 square miles; but much of it was land which, owing to the height of the spring-level, it was not desirable to irrigate; and therefore the actual irrigable area had been put down at 4,000 square miles or 2,500,000 acres. Mr. Preston stated that in the near future 2,500,000 acres would be watered each year; that meant that every acre of the tract would be watered every year. He thought all irrigation officers would agree that that was a mistake, and that if possible more land ought to be under control. The only way to get more land would have been to go to the head, where the water came from the hills, and to command the whole tract of 12,000 miles. That scheme had been thought of long before. As far back as 1862 the question had been gone into, and in 1864 the late Mr. T. Login, M. Inst. C.E., had sent in a scheme for a canal from Aknur, or close by. That had been rejected, on the ground that the estimates were based on such imperfect data as to be quite untrustworthy. The project had then been shelved, and nothing more had been heard of it until 1872, when Mr. Palmer had been sent there with a large staff to consider the whole question. The field-work had occupied 2 years, and eventually, in 1876, Mr. Palmer had submitted to the Government of India a project for one perennial canal to water the whole of the uplands, and two inundation canals, one from Ramnagar and the other from Chiniot, to water the low lands bordering the Chenab. That scheme had been rejected in 1877, on the ground that, in view of the problem-

atical nature of the return, and the improbability of even getting a return at all, at least for a great many years, the Governor-General could not embark on a scheme of such magnitude. It had been shelved until 1882, when he had been superintendent of works of the Bari Doab Circle. Towards the end of June, 1882, in the middle of the hot weather, he had received a telegram directing him to send an officer to report on the Ramnagar inundation project. At the time his staff had been very short-handed; and having no officer available, and the matter being exceedingly urgent, he had sent a trusted native subordinate to pick up Mr. Palmer's levels. From his experience on that occasion he had learned the lesson that in a country such as India pegs would not stand for 10 or 12 years; exposed to the weather and white ants they quickly disappeared. Only with the greatest difficulty had a few of the points left by Mr. Palmer been picked up. Near Ramnagar, however, one of Mr. Palmer's lines had been found, and he had been able to go into the question. The proposal had been to take an inundation channel out of a branch of the river known as the Ramnagar Nullah, which, about 1872 or 1874, had been a fairly strong stream. But on his arrival there in 1882, things had changed entirely; the river had taken a set to its right bank, leaving the nullah without water, and rendering it useless to contemplate the construction of any canal to take off from it. Even in the heaviest flood probably not more than a trickle went down. On reporting that fact, he had been instructed to work up the river until he found a point suitable for a canal-head. He had carried out his instructions, at the same time pointing out that the place at which he had arrived, which was some miles above Ramnagar, was absolutely unsuited for the purpose of watering the low lands, and that an inundation canal was entirely out of place for the high lands. He had also asked that he might be allowed to put in a perennial canal, if the project was to be carried through. He had suggested that either Mr. Palmer's project of 1876 should be carried out, or a scheme should be commenced lower down the river, if that were found too high. After considerable discussion, his chief, Colonel Home, had written him a very kind and amusing letter, telling him to drink as much cold water as he liked, but not to pour it over this project; requesting him to do as he was told, and lay out the line; and prophesying that millions yet unborn would bless the day he went there. Of course, that had closed the subject, and he had had to lay out the line. The estimate had been prepared in Colonel Home's office, and had been

Colonel Ottley.

Colonel Ottley. handed over to him to carry out. He had had a terrible time with the inundation canal, on which he had been engaged thenceforward until its opening in 1887. His contention all along had been that it would be impossible to take out from such a river as the Chenab an open channel which would not silt. Colonel Home had had a different opinion, and had thought that if the canal proper were begun about 4 miles down the line, and if a supply channel were made and connected with an escape to run back into the river, with a sharp slope of 1 in 4,000, or about 1·3 foot per mile, that would give a velocity of between 3¼ feet and 3½ feet per second, which would be quite sufficient to keep all the silt moving. He had had doubts about it; and, in the result, Colonel Home's hopes had been falsified, and it had never been possible to keep the canal free from silt. The worst months for silting were July and August. During those months 5,000 cubic yards of silt per day had been deposited in a channel of 109 feet bottom width; the total amount in a season having been something like 300,000 cubic yards, with a depth of 6 feet near the head. Nothing had availed to remedy that state of affairs, although he had tried dredgers, coolies and an alternative head. He had managed to get along in a way, but the canal had been a fearful anxiety and very unsatisfactory; as an instance he might mention that in September, 1886, a silt-clearance by coolies had resulted in the removal of 50,000 cubic yards. He had then re-opened the canal, and a few days later had obtained a discharge of about 750 cubic feet per second; but within a month the canal had silted up again, reducing the discharge to 202 cubic feet per second. Under such conditions it had been impossible to go on, and, therefore, while the canal was building, and in the early days of its working, he had kept hammering away at the question of a weir. The weir had eventually been granted, and in 1892 completed, and his anxieties in regard to silt had then come to an end. The weir had not been built at that site, one strong reason being that he had not seen how it would be possible to keep the canal open during the construction of the head-works. He had thought the best plan would be to go up to the Alexandra railway bridge, about 15 miles higher, which seemed to be an ideal site. But the railway officers had objected to his interfering with their works, and he had been unable to carry out the scheme without doing so. Apart from that, the piers caused such an obstruction of the bed of the river that, in the middle of the cold season, when all the pot-holes had been to a large extent silted up, he had sounded a depth of about 30 feet between the piers.

Consequently he would have required a weir about 60 feet high; and, needless to say, the cost would have been so absurdly high that the scheme would have been put out of court altogether. He had therefore abandoned that spot, and had gone to one 2,000 feet lower down. There, on the same day as the 30-foot sounding had been obtained at the bridge, the deepest sounding obtained had been 6 feet. In accordance with instructions from Colonel Fred Home, who had succeeded his brother Robert Home, he had drawn up a complete estimate for a weir at that site, which would have had many advantages: for one thing, it would have commanded much more land than did the existing works. But, after careful consideration, Colonel Home —and he believed everybody else interested in the matter at that time—had thought it would be quite sufficient if a smaller area were commanded; and therefore, as at this site the project would be so much more costly than one lower down the river, he had been directed to choose another site. He had then gone 10 miles lower down the river, and had designed the weir afterwards carried out and completed in 1892. It might be thought rather an extraordinary thing that no one had known what the canal would do. He himself, and Sir Thomas Higham independently, had arrived at the figure of 1,100,000 acres. The most sanguine person had been his old friend Colonel Jacob, whose estimate of the amount of land which it would be possible to water had been 1,435,000 acres. Those opinions had been based on the best information obtainable from the older canals. It would thus be seen that Colonel Jacob's estimate, which had been regarded as absurdly sanguine, was too small by 1 million acres, while that made by Sir Thomas Higham and himself was out by 1½ million acres. It might be asked why that was so; and he thought there were two reasons for it. In the first place, he thought the head-works had been more successful than even he had dared to contemplate; so that much less silt came into the canal, and a larger supply of water was obtained, than had been anticipated. But there was a much more important reason, namely, that the carefulness with which the channels had been laid out and constructed, and the minuteness of the distribution, had resulted in an enormous economy of water. He was not aware whether the fact was generally known that, of every 100 cubic feet of water which came into the heads of the older canals, 70 cubic feet were absolutely wasted, only 30 per cent. of the supply doing any good at all in the way of irrigating crops. Obviously, if even a comparatively small fraction of that 70 per cent. could

Colonel Ottley.

Colonel Ottley. be saved, the irrigated area might be largely increased. He believed that was what had occurred. Up to the time of the construction of the Chenab Canal, engineers had been working on the basis of the older canals; now a new departure must be taken. One great lesson was to be learned from the undertaking, namely, that the question of the saving of water, not on the main canals perhaps, but on the distributaries, must be very carefully gone into; and he was inclined to think that in the future it would be found worth while to make all minor channels absolutely water-tight. In regard to the remainder of the Rechna Doab, probably the day would come when a canal would be started from Mr. Palmer's point somewhere near Aknur, and the whole of the district would be irrigated. In that manner the procedure in the Ganges canals, where the upper canal had been made first, and the lower years afterwards, would be reversed. In the present instance the lower canal had been built first; and he hoped that before many years had passed the upper canal would be built. With regard to cross drainage, it would be observed that till the main ridge was reached the canal quartered the ground. In framing the estimate it had been anticipated that there would be practically no drainage—in fact, it had been stated that there was no drainage worthy of the name; and the total provision in the estimate for drainage had been £400. But before the canal was rendered safe he had put in nine drainage-works in the upper part of the canal, which were calculated to pass about 1,600 cubic feet per second; so that a good deal of drainage had had to be done. The reason was that the rainfall was capricious. When putting in a drainage at Ahmedpur he had determined not to be caught again, and had therefore put a bank across the depression, leaving a 50-foot gap, with gauges for registering what water passed that way. For 3 years the maximum discharge had been 147 cubic feet per second, and he had been actually considering the estimate of his resident engineer for a proposal to pass 400 cubic feet, when fortunately a rain-storm had occurred, during which about 8 inches had fallen in as many hours. Of course, both bank and gauges had been swept away; but it had been calculated that during the storm 3,870 cubic feet per second had passed down that depression, which for 3 whole years had never carried more than 147 cubic feet per second. Considerable difficulty had been experienced in dealing with this matter of drainage; all kinds of formulas had been tested, including one by Mr. Craig, and another by Colonel Dickens, but no satisfactory results had been obtained. It had been found

by actual experiment that allowance had to be made for a discharge of between 28 cubic feet and 35 cubic feet per second per square mile of area, which was thought, as a general rule, to be fairly safe. He had already stated how difficult it had been found to pick up Mr. Palmer's survey: even when picked up it had not been of much use, because the lines had been spaced too far apart, namely, 5 miles. Practically no surveys had been made by Mr. Login in 1864, most of the work having been done without levels. In Mr. Palmer's time, 10 years later, cross sections had been taken 5 miles apart. In the Jhelum Canal survey, on the other side of the Chenab, he himself had spaced them 1 mile apart; Colonel Jacob had reduced it to about ½ mile apart; and now Mr. Preston had gone even further, to 1,000 feet apart. He was sure Mr. Preston was right in following that course, although he did not think it would be done anywhere but in such a tract as the Rechna Doab. The limit, he believed, had now been touched. If there was any truth in the old saying, "nothing succeeds like success," he thought the Chenab Canal had succeeded. Its success had doubtless fostered the revival of interest in irrigation in India, and he hoped other canals which took the Chenab for a model would be as successful. Colonel Ottley.

Mr. MAURICE FITZMAURICE remarked that he was considerably interested in the two Papers, because during 4 years he had had every opportunity of seeing, in Egypt, not only the way in which large areas were administered in regard to the distribution of water, but also the different works required to enable the water to be brought on to the land. He agreed thoroughly with Mr. Buckley's comment on the gates of the Bhadar weir. Steel gates, which were largely used in Egypt, and which were easily managed, were much more effective than those described in the Paper. With reference to the cost of the work in the Appendix, he wished he could imitate in every undertaking the result that the estimated cost of the work had been £20,900, and the actual cost £20,734. Mr. Fitzmaurice.

Turning to Mr. Preston's Paper, to an engineer, especially a young engineer who was keen about organization and administration, he thought there was no more interesting job than to be engaged on a large irrigation work. At the same time, the experience he had gained in Egypt showed that it was work entailing great responsibilities, decisions on important matters often having to be made at short notice. In addition, there were the difficulties arising from climate and dealings with natives. In dealing with natives, particularly where water was invaluable, the engineer must be careful that no partiality was shown towards any

Mr. Fitzmaurice.

individual or village. Such a thing would not occur with any of the engineers; but they had to be careful that it did not happen with any of their subordinates who dealt with the distribution of the water. Several of the perennial irrigation canals in Egypt were much larger than the Chenab Canal, but in Egypt it was impossible to obtain the gradients which had been obtained in the Chenab. As the difference in the water-level of the Nile between Alexandria and Assuan, a distance of 750 miles, was only about 330 feet, it was difficult to get a gradient which would prevent the deposition of silt. In the Chenab Canal there was a gradient of about 1 in 6,000; in Egypt the gradient usually obtained was about 1 in 20,000. It was impossible to get anything like a velocity of 3 feet per second, consequently a large amount of silt was deposited, necessitating a considerable amount of dredging. He presumed that in the Chenab Canal there was a comparatively small amount of silt, which was also got rid of by dredging. He noticed in the Paper a statement that efforts were made to get the silt on to the land. He would like to know whether that land could grow crops with the help of silt and water alone, or whether it had to be helped by manure, or in any other way. Mr. Preston's Paper dealt almost entirely with administration: it was a pity that further information was not given in reference to the actual works needed for dealing with such an enormous tract of land; for he presumed there must be regulators and head-works to the canals and branches. Mr. McLean's Paper[1] did not say much on the subject, and it would have been interesting if more information on those points had been included in the Paper. The maximum duty expected from the canal appeared to be about 3,000,000 acres; already 2,000,000 acres were irrigated, or 66 per cent. of the possible maximum, which was a large and satisfactory percentage. But when, as the Author anticipated would shortly be the case, 2,500,000 acres were served, 80 per cent. of the total possible land would be irrigated. That result seemed to indicate excellent arrangements on the part of the engineers. He did not quite understand what the Author meant by saying (p. 162) that the total area irrigated amounted to 6,722,621 acres. It seemed to be the sum of all the acreage irrigated during about 10 years. A kind of danger-signal was hung out at the end of the Paper, where the rise of the subsoil-water was referred to. The rising of the subsoil-water, and the absence of proper drainage, were serious drawbacks in large irrigated tracts. In the Paper it was stated that it would not be possible to make any escape, because the escape would be so

[1] Minutes of Proceedings Inst. C.E., vol. cxiii. p. 314.

close to the head of the canal; but it appeared to him it would be possible to make an escape some distance down, which would be effective in the event of the supply lower down having to be shut off on account of heavy rain or other causes. In any case it was necessary to have efficient drainage. Mr. Fitzmaurice

Mr. J. E. WHITING mentioned that he had had a good deal to do with the Bhadar project in the beginning, and his opinion had been asked as to whether it was a sound work. After going carefully into the matter with Mr. Benson, he had come to the conclusion that the works deserved all the care that could be given to them. On visiting the place he had seen first the weir at Gosa Bara for excluding the sea-water from the Mokul Rann. He had been pleased to see the extraordinary effect it had had in the short time which had elapsed since its construction. The land was improving, the floods were washing out the salt, and it was clear, from what was being done, that it was possible to improve the whole of the Mokul Rann, if water could be provided. He did not know whether the project was clearly understood; it certainly was not easy to understand it from the description given in the Paper. Mr. Whiting.

Having seen a good deal of irrigation work on the Indus, which was one of the rivers drawing from the Himalayas, he could not but feel the immense advantages which the engineers of the Chenab undertaking had had over those engaged on similar work in Sind. Their chief advantage, of which they had made use, lay in being able to cast a weir across the river. That was impossible in Sind; the river was far too large to allow of anything of the kind. All the canals in that part of India were inundation canals, though they had head-works. There were other advantages at the Chenab which had evidently been turned to very good account, judging from the Paper. It seemed to him a remarkable thing that after the canal had been worked for some time the coefficient N in Kutter's formula had been found from the discharge to be really 0·018 or 0·020, instead of the usual 0·025. Instead of making the canal worse as time went on, the deposit of silt seemed to have filled up the crevices and plastered the sides, and thereby to have improved the channels. He did not think that was usual in most parts of India; it was generally found that canals became worse as they grew older. Another remarkable thing was that the enlarged canal, designed to work with a depth of 9½ feet, was actually running 10·8 feet deep, and discharged 10,800 cubic feet per second, giving a velocity of 4 feet per second. The soil must be of splendid character to stand

Mr. Whiting. such a current without being washed away. It was also stated in the Paper that the gradients were such that the velocity could be maintained throughout without any deposition of silt. One of the greatest difficulties experienced in Sind was the silt. The canals had to be cleared out periodically, and the silt, which consisted largely of sand and was of no use whatever on the fields, had to be deposited on the sides. If he understood the Paper correctly, in the Chenab Canal the engineers were able to carry all the silt, which was of a useful kind, on to the fields, where it was distributed: which was a great advantage. He thought there must be some deposits of sand near the heads of canals, and how they were dispersed had not been stated in the Paper, which did not refer to silt-clearances. In Sind, in parts of the canal far away from the head, where the water became clear, the whole canal was choked with weeds. The benefit of having such water as that in the Chenab Canal was that it apparently kept muddy during the whole of its course: because weeds could not grow in muddy water. If it could be arranged, where silting took place, that the silt deposited could be put into the canal at different times of the year, it would be a good thing. The Nira Canal was almost constantly filled with muddy water, or, at all events, water in which weeds did not grow. The canal head-works in that case were situated below a large stretch of land, on the banks of which, during the monsoon, an immense amount of alluvial soil was deposited. During the monsoon all canal water was muddy; and during the fine weather, when, in all other canals in the Deccan, the water became clear, the water in the Nira Canal did not do so; because on a long stretch of water, about 12 miles long and $\frac{1}{2}$ mile wide, the banks were constantly being washed up, with the result that the water which went down the canal was muddy, and the growth of weeds was prevented. Another advantage enjoyed in connection with the Chenab Canal was that the engineers had been able to arrange where the villages should be placed, and where the people should live, so that fewer bridges were necessary. In fact, the engineers had everything under their own management and direction. The question of the distribution of the water was one of the most difficult problems the engineer had to study, especially in such an enormous tract, where water was so keenly sought after. Although the plan finally adopted in the Chenab Canal undertaking, of permitting water to be taken for a certain number of hours instead of restricting the quantity, was admirable, it must be inconvenient for one man to take his water for 4 hours at a stretch, obtaining all he

could within that time, and then for the next man to take it for 4 hours, and so on. It would have been much better if the plan had been adopted of allowing every one to use the water simultaneously. It was not difficult to arrange outlets so as to discharge the share allotted to each man, whatever might be the depth of the water in the canal. Proportional outlets could easily be arranged by means of vertical walls in the canal built in brick. If, for instance, in a canal the ratios of the first, second and third outlets were 5 : 4 : 3, and the width of the canal at the first outlet was 12, then the outlet where the first man's distributary took off would be 5. The outlet would have vertical walls, and to whatever height the water rose, 7 parts would go on and 5 would go out into the distributary. Between that outlet and the next the width of the canal would be 7. The second outlet with vertical walls would take off 4 parts, and the other 3 would go on to the last outlet. Thus, instead of having only 4 hours in which to distribute the water, there would be 12 hours. It was much more convenient for a man with a large holding to have the water distributed slowly over it, and to have ample time for his work. The man could close his outlet altogether when he had had enough water, which would send more on to the next man, if he wished for it. It was possible that cultivators lower down might pay the man above for the water; but there was little harm in a cultivator selling his water to somebody else lower down who obtained the benefit of it, which was quite a different thing from bribing canal peons for the purpose of obtaining water taken from somebody else. So long as the cultivators gave the water to one another, he did not see any harm in it.

Mr. Whiting.

Mr. C. W. ODLING observed that when irrigation had been commenced in Bengal 35 years ago, the great object of the authorities had appeared to be to prevent engineers from participating in the management of the canals. It had been considered that, as they were interested in the success of the canals, they might be rather harsh in their assessments, and might not treat the people with proper consideration. That policy had been bad for the engineers, because they had not been able to follow the water and see what became of it. Further, they had not been brought into intimate and constant communication with the cultivators, whereby they could ascertain what their grievances were. It had been worse still for the cultivators, who had been debarred from access to the persons who, if they had the authority, could prevent many of the grievances from arising. Eventually dissatisfaction had become so general that a Commission, of which he had been a member, had been appointed by the Government of

Mr. Odling.

Mr. Odling. Bengal, with a view to apply some remedy. After some time the Government had determined—not exactly in accordance with the recommendations of the Commission—to cast on the engineers the entire responsibility and management of the canals; not only the management, as in the Punjab, but also the collection of the revenue. The result had been entirely successful. Under the old system, the arrears had amounted to £10,000 or £20,000 a year, whereas in the last report he had been able to inspect they amounted to only £2. The objections to assessment had diminished in number, although the complaints had increased, because the cultivators immediately went to the engineers when they had anything to complain of. The revenue was not only punctually collected, but a much smaller amount was collected by coercion. When the cultivators would not pay, some kind of coercive process had to be applied, and before the engineers had undertaken the management it had been applied in a large number of the cases; now the number had been materially diminished. The change had been equally beneficial to the canal officer, who had to realize that only by growing good crops could the cultivator pay the water-rate. The crops depended on a timely and sufficient supply of water being available, which could be ensured only by incessant supervision on the part of the irrigation officer. Unfortunately, so far as Bengal was concerned, that supervision had to be exercised in the worst time of the year. The life of a canal officer had been described as devoid of all social and much domestic enjoyment. The reward he received was the contentment of the people he served; he did not get much recognition from his employers. It was stated that the Chenab Canal gave an amount in excess of the calculated discharge. The same had occurred in the Sone Canal, which gave 20 per cent. to 25 per cent. more than the anticipated quantity. For reasons already given by Mr. Buckley, all difficulty due to silt had disappeared. He had had an opportunity of inspecting the Chenab Canal in November, 1901, and what had struck him most was the fact that the villages looked as if they had been there for centuries. The only difference between them and the surrounding villages was that they had fairly good roads, and that some attempts at conservancy arrangements had been made. Industries of all kinds, including cotton-pressing and ginning, were springing up, and the Government had started a number of horse-breeding establishments. It was sincerely to be hoped that there would never be an accident to the canal. At present there were nearly 1,000,000 people on the land, and in a few years' time he believed there would be 3,000,000· and as they were dependent on the canal for even

their drinking-water, a disastrous calamity would happen if the canal water-supply failed. Mr. Odling.

Colonel JACOB remarked that Mr. Preston spoke of a fair duty for the water being 100 acres of crop per cubic foot per second during the rains, and 200 acres in the cold weather, or 300 acres in all per annum. The difficulty experienced by designers of canals in the past had been that they had never been permitted to allow for more than 200 acres: the authorities had not believed in the capabilities of the water. He was a little doubtful whether, in the old canals, even as much as the 30 per cent. mentioned by Colonel Ottley used to get into the fields—probably 25 or 26 per cent. was nearer the mark. Even now, if 300 acres per cubic foot per second was achieved, which was doubtful, only about 40 per cent. went on to the land, so that about 60 per cent. of the water was absorbed. The evaporation was so trifling in comparison that it might be left out of account; almost the whole of the loss was due to absorption. If it were worth while, the absorption, as Colonel Ottley had pointed out, could be stopped in a large measure. There was not the slightest doubt that the water must increase immensely in value, and for that reason it would be possible to go to far greater expense for the purpose of saving and conserving water than had been possible in the past. In that way vast possibilities were opened up for irrigation. Probably there were many present who did not understand how vital water was to India. It sounded pleasant to hear of a canal paying a dividend of 25 per cent.; but the lives of the people of India were infinitely more important than dividends. There had been a most appalling loss of life from famine during the past few years; he did not think anybody would put it at less than 10 millions, and he had recently seen an estimate which put it at 25 millions, although probably that was an exaggeration. With a growing population, the difficulty of providing the people with food became more and more acute, unless irrigation was possible. Railways were very useful in distributing food; but food could not be brought into India from another country, because the cost and difficulty of distributing it were so great. India must raise its own food, or the people would die; and they could raise their own food only by irrigation. Besides the preventable waste of water in the canals at certain seasons of the year, immense volumes ran to waste, even in the rivers which were most utilized. There were also large volumes of subsoil-water at no considerable depth. On the other hand, immense tracts of land were wholly dependent upon the rainfall, and Colonel Jacob.

Colonel Jacob. were subject to periodical and appalling famines. Any one who had seen famine-stricken people, and the awful suffering entailed by starvation, knew what a serious matter was involved. Colonel Ottley had raised the question whether the existing Chenab Canal was the best canal that could have been made. It was easy to make a project for a scheme here or there which would pay a good return; but that was a different thing from making the best project, and so arranging it that it would not interfere with further projects, in order that the vast stores of water in one district might be applied in the best possible way to the immense dry areas in another. The matter under discussion would tax the utmost energies of the most skilful engineers, and would have to be worked out on far more scientific lines than had been the case in the past. Already tremendous strides had been made. Those who could look back 30 years knew the extraordinary developments which had taken place in the science of irrigation during that period; but the possibilities of the future were far greater. The work undertaken in the Rechna Doab was nothing to what would have to be performed in the future. Water would have to be conveyed far greater distances and over mighty drainages; and possibly it might be necessary to use machinery to lift the water, in a way which had never been contemplated in the past. Water was the life's blood of India, and it must be obtained at all costs; but great difficulties would have to be met and overcome. Mr. Preston's Paper described how some of those difficulties had been surmounted, what a great advance had been made, and how a far better duty was obtained than formerly. That was something to be thankful for, and it might be a stepping-stone to greater achievements in the future. The only way to look at the problem scientifically was to take a map and mark out the vast areas which must be watered, if the people were to be made famine-proof. Railways could distribute food to a certain extent, and were very useful in this way: but they could not produce grain, and their power was limited. People had starved in India a hundred miles from railways, because there was no way of carrying the grain over those 100 miles.

Colonel Pennycuick. Colonel J. PENNYCUICK remarked that Mr. Preston's quotation from Mr. Hawksley's Presidential Address, in regard to the want of knowledge existing in England of the work engineers were doing in India, might be extended; and it might be said that few engineers in India knew what was happening in more than one small part of the country. The two Papers under discussion would go far towards removing some of that ignorance. Personally,

he would often have been exceedingly glad to know what had been done in other parts of India in connection with irrigation works; and he knew of more than one instance in which railway engineers could have saved themselves a great deal of trouble and expense, if they had been able or willing—he was not quite sure which, but he was afraid it was the latter—to take advantage of the experience of their colleagues in the Public Works Department. It might be asked why engineers in India did not communicate with each other more. One reason was that in India they were always extremely busy; another was the difficulty of communication, which was hardly realized at home. For all practical purposes, Madras, Bombay, and Calcutta were farther apart than Vienna, London and St. Petersburg, and often the first news engineers in Madras received of a work like that described in the Paper came from reading the "Proceedings" of the Institution. The work described in Mr. Benson's Paper differed in regard to physical and climatic conditions from that dealt with in Mr. Preston's Paper—a fact which illustrated the wide range of the work that engineers had to perform in India. About 4 years ago he had been present at the reading of a Paper[1] by Mr. Strange on large reservoirs in the west of India, and a year earlier he had the honour of contributing a Paper[2] on another work; so that, including the two Papers under discussion, he recalled four distinct works, which were quite different, and yet all came under the same general head of irrigation engineering. The work described in Mr. Benson's Paper was, so far as he knew, almost unique; the Author had apparently been helping Nature to create a delta. Nature had been trying to form the delta, but had not succeeded, because as fast as the delta had been formed it had passed away. The work carried out by Mr. Benson was an attempt to combine reclamation and irrigation. He was afraid it would be found in the future that the undertaking, like all work which tried to achieve two objects at the same time, would not be perfect for both. The site of the weir had been chosen very properly, with reference to reclamation; but he ventured to predict that in another 20 years, when the work of reclamation was completed, a new weir would have to be built about 8 or 10 miles higher up the river. The details of construction of the weir illustrated what he had already said as to the advantage engineers in India would gain by knowing what was being done in other parts of the country.

Colonel Pennycuick.

[1] Minutes of Proceedings Inst. C.E., vol. cxxxii. p. 130.

[2] *Ibid*, vol. cxxviii. p. 140.

Colonel Pennycuick.

He thought the Author would have gained a great deal if he had known how engineers dealt with such works in Madras, where they were common. There they had found by experience that movable shutters on the top of a weir were abominations. They were sometimes necessary, but they were always evils. If used at all, they ought to be much larger than those used in the Bhadar weir. The numerous shutters, 4 feet square, which were liable to be floated up, and had to be held by ropes in order to prevent them from being washed away, were not desirable in such a situation. If he had had to deal with such a river in the south of India, he would have put in a permanent masonry weir for the whole 8 feet which was to be closed, and would have obtained an additional discharge by vents in the body of the weir, certainly not less than 8 feet or 10 feet wide, the shutters being lifted bodily. On two points he had some difficulty in following the Author's reasoning. It was stated that the height of 8 feet which was closed by movable shutters was opened in two halves, because if it were opened all at once, the scour would be excessive. He took it they were intended to be opened at some time or other, and probably when the flood in the river was at its height the whole 8 feet must be opened. Whatever scour was to be feared would be suffered then, and he could not see that it would be any greater if the whole 8 feet were opened at once, than if it were opened in two steps. Another reason given for limiting the discharge was that it would interfere too much with the river's banks, which were so soft that the river might change its position altogether; but apparently every other outlet had been closed, and it was very difficult for the river to change its course during the last 8 miles. Apart from that, it was stated by the Author that only a fraction—an insignificant part, he called it—of the whole discharge was sent through the weir. That was perfectly true, because in such a situation a flood-discharge of 180,000 to 200,000 cubic feet per second must be expected, and from the figures given he did not suppose the weir would discharge more than one quarter of that. Therefore the reduction by making the weir permanent up to 8 feet above the existing sill would certainly not raise the flood-discharge greatly, nor, if the drawings were correct, could it cause any serious difficulty. He hoped it would not be thought he was finding fault with the Paper; he only wished to emphasize the advantage of obtaining information as to what had been done in other works.

Mr. Preston's Paper was a singularly interesting one to him,

because it dealt with a class of work of which he had had no practical experience, but from which engineers in Madras might learn a great deal. The most important parts of the works, from the constructive engineering point of view, were not dealt with in the Paper, the interest of which lay more in the administration and working of the scheme. One of the chief points which struck any one accustomed to work in the south of India was the extreme care with which the distribution had been carried out—a point which was apt to be neglected in Madras. It was only fair to say, however, that in Madras they had not such a clean slate as the engineers had had in the Chenab Canal, and were not able to lay out the village communities precisely to suit their convenience. Existing rights had to be dealt with; but, making every allowance for those, he thought the detail of distribution was far too much neglected in the south. He hoped his friends in Madras would study the work which had been done in the north, and follow it. One point which filled with envy an engineer who had been accustomed to work in the south was the high duty obtained from the water in the Chenab Canal. He thought the difference was not due entirely to the waste of water, as had been stated by Colonel Ottley, because he did not think that in the Madras canals there was anything like that waste; it was really due to climatic and other circumstances. More water was needed for raising crops. As far as he could make out from Mr. Preston's Paper, 1 cubic foot of water per second flowing continuously earned a revenue of something like 900 or 1,000 rupees per annum; in Madras half that revenue would be considered satisfactory, and naturally the figure quoted gave a much more favourable percentage return for the Chenab Canal. Both the works were exceedingly interesting. There was no question whatever of the magnitude of the work connected with the Chenab Canal, but he was not quite sure whether, from the point of view of engineering construction, Mr. Benson's Paper was not the more interesting of the two. Speaking as an old Public Works officer, he wished to express his thanks to Colonel Ottley for the extremely interesting information he had given as to the history of the Chenab project, which supplemented to a large extent that given by Mr. Preston.

Colonel Pennycuick.

Mr. F. R. UPCOTT remarked that one point had not been noticed, namely, the inclusion of a railway in the Chenab scheme of irrigation. That had been rendered easy on account of the embankment thrown up from the canal; and a good deal of the financial success of the project was due to the fact of the railway having been built. He had had a good deal to do with the railway

Mr. Upcott.

Mr. Upcott. when it was first started. As the work had progressed, and as soon as the water had begun to flow and the crops to be cultivated, it had been found that there was an excess of food grain, and immediately a large export of grain had taken place. A few figures relating to irrigation over the whole of India might be of interest. He found from a blue book recently published by Parliament that, in the year 1901, the total area under irrigation in the whole of India had been 30 million acres; of which 13½ million acres had been irrigated by Government canals, leaving 16½ million acres irrigated from other sources. The Government main canals had comprised a length of 13,000 miles, with 31,000 miles of distributaries. Those figures would give some idea of the magnitude of the irrigation works in India. The financial success of the works all over India in 1901 had been such that, after paying 4 per cent. interest on the capital, there had been a surplus profit of 3¾ per cent. That was an extraordinary result, to which railways could not hope to attain for many years.

Mr. Robertson. Mr. F. E. ROBERTSON thought, from the diagram in Mr. Benson's Paper and the statement that on one occasion the mouth of the river had been choked, that there must be a considerable drift of sand to the northward along the coast. As it was stated that there was a lock provided in the weir, and sailing-boats were spoken of, it was to be hoped that the navigation of the river was not important; because it seemed to him that, when so much tidal area had been shut off, the mouth of the Bhadar must deteriorate, if not silt up entirely, except in times of flood. With reference to Mr. Upcott's remarks, as to the service the railway had probably done to the Chenab scheme, it was certainly true that irrigation by itself might keep the people alive in a district, but it was impossible to derive the full benefit from irrigation unless there were means of communication. He believed instances had been known in India of people being unable to pay their taxes because they had such good crops. It might not be immediately apparent why fine crops should be a curse; but it would readily be understood that if a cultivator had no means of selling his surplus crop it was of no use to him. He reaped as much as he could use; he could not sell any to his neighbours, because they all had the same crops; and the rest was left to rot in the fields, with the consequence that the cultivator could not pay his taxes. It therefore seemed that for an extensive plan of irrigation such as that described, some means of communication was a necessity.

Mr. Buckley. Mr. R. B. BUCKLEY wished, on Mr. Preston's behalf, to thank the members for the way in which his Paper had been received,

and for the discussion which had taken place on it. It was undoubtedly the case, as Colonel Ottley had mentioned in his interesting and instructive remarks, that the great loss of water occurred in the distributaries; and if the distributaries and minor channels could be made water-tight, an enormous amount of water would be saved. But he was not able to agree with Colonel Ottley's statement that the losses were as high as 70 per cent. They might be in some cases, but they were not so in general. In that opinion he was confirmed by Colonel Pennycuick's remarks. In Bengal, also, a smaller percentage of loss was obtained. The silt in the canal was generally of an advantageous nature, and did good rather than harm. There was a certain amount of sand, but not much. Mr. Fitzmaurice seemed to think the silt was removed by dredging: that was not so. The velocity was kept at such a pitch that there was no appreciable deposit in the canal. While he agreed with what Colonel Jacob had said as to the excellent return yielded by the canals, he did not altogether agree with that speaker's remarks. No doubt the profit was an important matter; but it was of comparatively small importance compared with the great amount of good done. Colonel Jacob seemed to think that by irrigation alone famines could be prevented. Engineers would never be able to do that. The food which the existing irrigation works of India in the five principal provinces would save in a famine would be sufficient to feed about one-fifth of the population. If more works were constructed, more people might be fed; but sufficient works could never be built to feed the whole of the population. Although a large quantity of grain might be raised in one part, there must be a railway to carry that grain to the place where it was required. The advances made in the past half-century in the irrigation works of India had been very great. In 1856 or 1857 there had been about 3 million acres irrigated by Government works. A quarter of a century later, when Lord Mayo had introduced his system of constructing irrigation works from borrowed capital, about 10 million acres had been under irrigation, and at the present time the area was nearly 20 million acres, a somewhat larger figure than that given by Mr. Upcott. That advance had been of the greatest service to the country. An irrigation engineer had no greater pleasure than to see the good which the works did. It had been his duty 5 or 6 years ago, when a district with which he had been connected was afflicted with famine, to travel over many miles of main canals, and scores of miles of distributaries; and he had there seen luxuriant

Mr. Buckley.

Mr. Buckley. and plentiful crops irrigated by the canal, while a few feet away from the tract which the water had reached the crops were scanty, and were being cut before they were ripe, to be given to the cattle. It was no exaggeration to say that, in that year, up to the line where the water went there had been plenty and prosperity, beyond it dearth and ruin. A result of that kind acted in a double way; because the people who, in such a year, got good crops by irrigation, sold their produce at enormously enhanced rates, and, while they fed their neighbours, made large profits for themselves. He could give more than one instance where the value of the crops saved by an irrigation canal in a year of famine had been equal to one-half or three-quarters of the entire capital cost of constructing the canal. Many references had been made to the size of the scheme described in Mr. Preston's Paper: he would make one more. It commanded about 3 million acres, while the entire cultivable area of Egypt was about 6 million acres. The Chenab Canal had therefore converted from a desert into a garden an area which was about equal to half of the cultivable land of Egypt.

Colonel Jacob. Colonel JACOB explained that he had no wish to decry railways; the engineer could not possibly do without them. He had meant that there must be irrigation to produce the grain in years of drought, as well as railways to carry the grain when produced.

Mr. Benson. Mr. BENSON, in reply, remarked that the simplest form of shutter had been adopted because (1) the weir was not to be worked under skilled supervision; (2) initial cost was low; (3) steel was avoided, as it corroded remarkably on the Kathiawar coast and would require painting twice a year, as had been proved on the railway. After the removal of shutters and guides the beams were raised and laid on the stone brackets shown in the cross section (Figs. 4, Plate 3). With regard to Colonel Pennycuick's remarks, 11 miles up the river was the territory of another chief, who might not consent to the building of a weir. The present weir could be raised, and would have to be lengthened when the flood spill area was much reduced. The alluvial soil between the Bhadar and Ojat rivers was so low and soft that no bank protection would render it safe to close the main channel with a solid weir.

Mr. Preston. Mr. PRESTON observed, in reply, that he was much gratified that so much interest has been evinced in the subject of his Paper, and regretted that absence on duty in India had prevented him from being present to answer the criticisms in person. He had never agreed with Colonel Ottley that it was a pity the larger scheme for the irrigation of the Rechna Doab, proposed by Mr.

Login in 1864, had not been carried out; he thought it was a great mistake to have too many eggs in one basket, and, in his opinion, there was already quite as much irrigation on the Chenab Canal as it was safe to make dependent on a single weir across a river which might discharge in flood as much as 700,000 cubic feet per second. A scheme was now being worked out for a second canal which would take out of the river at or near Aknur, as proposed by Mr. Login, to irrigate the upper portion of the tract not commanded by the present canal; and he considered that the two canals built separately would be more efficient and more easily administered than a single canal. Mr. Fitzmaurice was mistaken in thinking that the amount of silt in the canal was comparatively small. It was so in the six cold-weather months, but directly the snows began to melt in the Himalayas, and floods caused by the monsoon rain came down the river, it was very considerable, the river often looking like pea-soup. An immense amount of warping had been done on the Chenab Canal to strengthen the banks in low ground, and the results showed that for 6 months in the year the quantity of silt averaged about $\frac{1}{200}$ of the volume of the water. He had made a calculation from the statistics maintained of the supply which had entered the canal since its opening in March, 1892, and he estimated that 329,202,428 cubic feet of silt must have passed into the canal in the 10 years ending 31st March, 1902. Yet during that time, as far as he was aware, no silt-clearance had ever been made from the main or branch canals by dredging or otherwise. Some clearance had been made in the distributaries, both major and minor; but the great bulk of the silt had been carried right through the system and deposited on the fields, which it fertilized. With regard to Mr. Whiting's remarks, he thought there were two reasons for the difference between the Chenab and the Sind canals in the matter of silt-deposits: one was that the Sind canals were aligned in the low ground adjacent to the river, in which it was impossible to obtain the bed-slope necessary to generate a high velocity in the canal, which would carry the silt away; the other reason was that, being inundation canals, they had no weir for forcing the low supplies of clear river-water into the canals in the cold weather, which, with good velocities in the channels, removed any silt that might have been deposited. The experience in the Punjab inundation canals was the same as in Sind; the clearance of silt from them by manual labour every year was extremely heavy. Every branch canal, every distributary (whether major or minor), and every village watercourse was provided with a head regulator, and

Mr. Preston.

Mr. Preston. furnished with iron gates and gearing for enabling the supply to be regulated in the channel. Mr. Fitzmaurice had misunderstood the duty anticipated from the canal, which was never likely to reach the 3,000,000 acres mentioned by him. The canal had been designed to irrigate 1,100,000 annually, and had already done 2,000,000; but it was unlikely it would ever exceed 2,500,000 acres. Mr. Whiting's suggestion that every cultivator should use the water simultaneously was impracticable; it was correct for the distribution of the water from the Government distributaries to the village watercourses, and was the practice actually in vogue; but the distribution of the water to the fields from the village watercourses, which was done in the manner described in the Paper, could not be done as Mr. Whiting suggested, as the volume of water would be too small. Such a channel might discharge 2 cubic feet per second, and be kept running for 10 days for the use of one hundred cultivators; it would be quite useless to give every cultivator 0·02 cubic foot for the whole 10 days; it would never reach the fields, and the whole volume would be lost in meandering about innumerable field-channels. Instead of this, the cultivator was given a larger volume for a shorter period, which rushed quickly on to his holding in a single channel; and when he had had his turn the same volume was given to the next irrigator.

Correspondence.

Mr. Arnott. Mr. M. H. ARNOTT thought a brief description of irrigation in Orissa might be of interest. The irrigation system there was altogether settled and scarcely any considerable addition was possible. There were three Divisions which comprised the irrigation portion of the Public Works Circle, and he would describe the working of the division of which he had been in charge, that of the other two divisions being similar. The canals from which the distributaries took off were as a rule used for both navigation and irrigation. One of them, however, the Machgang, in the division described, was used purely for irrigation, the locks at the head of each reach except the first never having been constructed. The head-sluice of the system was served from the Mahanadi River, which was entirely rain-fed, so that the supply was dependent on the rainfall over the catchment-area. As rice constituted fifteen-sixteenths of the crops irrigated by the canals, the scanty discharge available in the cold- and hot-weather months offered no practical