Mr. Stokes. been prepared or the work executed. The early completion of the contract had been rendered possible by a lucky succession of favourable seasons, and by the hearty co-operation of all concerned.

Correspondence.

Mr. Binnie. Mr. W. J. E. BINNIE remarked that in a foot-note to p. 75 it was stated that all reduced levels were referred to heights in metres above mean level of the Mediterranean Sea. At the port of Alexandria a datum existed on the locks of the Mahmudie Canal, which was extreme low-water of the Mediterranean, and was used as a reference for bench-marks in that neighbourhood. This was the datum marked "Ordnance Bench Mark" on the chart of the port dated 1898. It might be of interest to mention that this datum was 0·31 metre below the mean minimum tidal level of the Mediterranean, as shown by the readings of the mareograph established at the end of the inner mole of the port. The datum in question was the only one in existence at the port of Alexandria, and he had recently had to investigate this question in order to establish a high-water level for the new graving-dock constructed for the Khedivial Co. The high-water level had been ultimately fixed at 0·53 metre above the datum, that being the average maximum tide-level throughout the year. The average tidal variation at Alexandria would therefore be 0·22 metre, and the mean level of the Mediterranean would be 0·42 metre above the above-mentioned datum. Apparently some other datum, perhaps taken from levels established for the Suez Canal, must exist, as no mean tidal level at Alexandria had been established; and he thought it would add to the value of Mr. Fitzmaurice's Paper if the origin of the datum used at Assuan were more clearly defined; for if two different datums were in use in Egypt confusion must arise. He would also like to know whether any difficulty had been experienced at Assuan from too rapid setting of the Portland-cement mortar.

Sir R. H. Brown. Sir R. H. BROWN, K.C.M.G., considered that Mr. Fitzmaurice's Paper was so complete and lucid as a technical description of the construction of the work, and the projected method of handling it, as to require nothing but Mr. Stokes's Paper to supplement it. But in the concluding sentence of his Paper, Mr. Fitzmaurice referred to the anticipated effects of the work in words that seemed to encourage a popular delusion. He described the work as "destined to increase the wealth of the country, and to lessen the great anxiety with which the rise of the Nile has been regarded in past years, since on this it depended whether the year was to be one of plenty or one of famine." It was quite correct to say that the work was destined to increase the wealth of the country; but the rest of the sentence gave the reservoir credit for producing effects which had not been contemplated in the project for the construction of the Assuan dam. The uninitiated might conclude from the sentence quoted that the Nile flood in Egypt below the reservoir would be affected by the construction of the dam. It was a common delusion that the dam would give in future the power of moderating high floods, and of improving low floods. It gave no such power, and had no effect on floods in Egypt: its function was to give a better supply than had hitherto been available in summer, so that the cultivation of sugar-cane and cotton might be increased. These were not the food-crops of the people; and, although the expression "plenty" was in a sense connected with them, it was not connected in its special sense as opposed to famine. Famines in Egypt had been out of date before the Assuan dam was made. There had been no famine in 1899, but only local scarcity in unfavourably situated lands; and these lands would be no better off than they had been before the reservoir was made. The only difference the Assuan dam would make to the flood would be that the river immediately above it would be 2 to 3½ metres higher than before: the volume of the flood flowing forward would be unchanged. Mr. Fitzmaurice stated clearly enough what the dam would do; but the misconception about its influence on the flood was so widespread that it seemed necessary to state also what it would *not* do. It might be of interest to mention the following facts regarding the first use made of the dam. The flood of 1902 had been very poor in quantity and quality. Its levels had been low, and the quantity of matter carried in suspension comparatively small; consequently, it had been considered advisable to commence filling the reservoir at an early date. The closing of the first gates had been begun on the 20th October, 1902, with the following water-levels:— Sir R. H. Brown.

Up stream of the dam	R.L. 94·90
Down-stream ,, ...	R.L. 90·30

The first operation of closing had been letting down the fifty sliding gates. The gradual rise of the water-level in the reservoir

Sir R. H. Brown. had followed, and on the 10th December, the date of the inauguration of the dam, the levels had been :—

Up-stream of the dam	R.L. 103·59
Down-stream ,, ...	R.L. 87·15

On 26th January, 1903, the levels had been :—

Up-stream of the dam	R.L. 105·91
Down-stream ,, ...	R.L. 86·06

and the full up-stream level of R.L. 106 would be reached by the end of the month.

Mr. Carew-Gibson. Mr. H. F. Carew-Gibson observed that the difficulty of estimating what the surface-gradient of the full reservoir would be was no doubt due in a large measure to the prevailing wind, which was a northerly one, and consequently tended to back up the water, as it blew up-stream; but as this was an important matter, affecting as it did in no small degree the capacity of the reservoir, it would be of great interest if Mr. Fitzmaurice would state what the gradient was found to be. The reservoir was now full, or sufficiently so to render it possible to obtain this information. Careful levels had been established for a considerable distance up-stream of the dam. With regard to the setting-out of the work, Mr. Bakewell, who had been chiefly responsible for this, had had a much harder problem to face than might be supposed from a glance at Fig. 3, Plate 1, owing to the climatic conditions and to the fact that it had been impossible in such rough country to find level ground near the cataract on which to measure a long base-line. In spite of this he believed that when the dam had been closed, and it had been possible to get a direct measurement through, there had been found to be only a possible error of 11 centimetres in the 2,000 odd metres; a result which entitled Mr. Bakewell to great credit. With regard to the burnt clay and lime mortar spoken of in the Paper—known locally as "homera" —this, or something like it, seemed to have been used both by the ancient Egyptians and by the Romans in all their large buildings throughout Egypt; and it showed as fresh in some of these at the present day as if it had been placed there only within the last few years, instead of at least 2,000 years ago. This in itself proved that the material had some good qualities. He believed that at Assuan, and in fact all over Upper Egypt, no pure clay existed, and for this reason it had been found difficult to manufacture satisfactory bricks; but, apart from such reasons and those of cost, he thought Mr. Fitzmaurice had been well advised in using Portland-cement mortar, as it appeared to him that when it set "homera" had a tendency to shrink away considerably from any large stones bedded in it, and that it had no great adhesion to granite. It had been found to form a strong mortar for brickwork, and no doubt the same would be the case when it was used with any porous rock, such as sandstone. The great trouble at Assuan had been to keep the granite and green masonry well watered; for under such a fierce sun all moisture had evaporated very rapidly. At first rush mats from Lower Egypt had been used to cover the new work; but it had soon been found that when these had been wetted the water ran off from them much the colour of pea-soup, and it had been feared that this green water might have some harmful action upon the cement: canvas had therefore been substituted, and had answered its purpose well. A temperature-chart added to the Paper would be of interest. Mr. Carew-Gibson.

Mr. W. DYCE CAY pointed out that as the water from the reservoir was conveyed to the irrigated lands of Egypt in the ordinary low-water channel of the River Nile, it would be subject to great loss from evaporation in a dry climate. With a view to appreciate this loss he had prepared the accompanying Table (pp. 144 and 145) from the Egyptian Government Meteorological Reports for 1902. It would be seen that, taking Assuan and Asyut together, the average evaporation at these places was in May 14·9 millimetres and in June 15·35 millimetres per diem; also the reports showed that in the first 7 days of July it was 14·5 millimetres, making an average evaporation of, say, 15 millimetres per diem for the 68 days of the year mentioned in the Paper as the period when, in an ordinary year, the contents of the reservoir would be run off to feed the river. The Table also showed that climatic conditions for a high rate of evaporation, namely, high temperature and low relative humidity, existed up to Khartum and beyond it. Supposing a length of river channel of 2,300 kilometres, with a width of 1,300 metres, and an evaporation of 15 millimetres per diem for 68 days, there would be evaporated in that time, say, 3,050 million cubic metres, or nearly three times the contents of the reservoir, which was stated at 1,065 million cubic metres. Again, taking the distance from the reservoir at Assuan down the river to Asyut at 480 kilometres, and the other data as before, the quantity evaporated between these places would be, say, 636 million cubic metres. While considering the reservoir system to be the best for compensating such losses, he thought it possible that local study might discover advantages to be gained by regulating the low-water channel of the river, so as to reduce the areas on which the evaporation would have most effect, and so Mr. Dyce Cay.

Mr. Dyce Cay.

TABLE OF EXTRACTS FROM METEOROLOGICAL OBSERVATIONS MADE IN THE YEAR 1902 BY THE EGYPTIAN PUBLIC WORKS SURVEY DEPARTMENT.

—	Place of Observations.	Latitude. North.	Distance from Victoria Nyanza.	March. Mean Temp. Dry Bulb.	March. Relative Humidity.	March. Total Rainfall.	April. Mean Temp. Dry Bulb.	April. Relative Humidity.	April. Total Rainfall.	May. Mean Temp. Dry Bulb.	May. Relative Humidity.	May. Total Rainfall.	May. Evaporation per Diem.	June. Mean Temp. Dry Bulb.	June. Relative Humidity.	June. Total Rainfall.	June. Evaporation per Diem.
		° ′ ″	Kilometres.	°C.	Per Cent.	Mm.	°C.	Per Cent.	Mm.	°C.	Per Cent.	Mm.	Mm.	°C.	Per Cent.	Mm.	Mm.
1	Giza, Cairo .	30 01 57	4,790	..	..	..	..	..	..	23·0	56	drops	..	24·5	58	0	..
1a	Abbassia, Cairo	30 4 36	4,790	..	..	..	..	..	..	23·9	47	drops	8·1	25·8	50	0	6·4
2	Asyut . . .	27 11 0	4,430	..	..	..	..	..	..	27·2	26	0	14·1	28·8	26	0	15·5
3	Assuan . .	24 2 25	3,950	..	..	..	..	..	..	32·3	16	0	15·7	32·4	20	0	15·2
4	Wadi Halfa .	21 54 49	3,580	..	..	..	..	..	..	30·6	20	0	..	31·0	23	0	..
5	Berber. . .	18 1 0	2,480	..	..	..	29	12	0	34·8	14	0	..	34·7	18	0	..
6	Khartum . .	15 38 20	2,130	..	..	..	..	..	..	..	..	..	..	..	..	..	..
6a	Omdurman .	15 38 20	2,130	28	14	0	31	13	0	34·1	19	0	..	33·1	27	0	..
7	Wad-Medani .	14 24 0	2,010	..	..	..	..	..	..	33·3	23	5·6	..	31·6	34	53	..
8	Duem . . .	14 0 0	1,970	..	..	..	..	..	..	32·7	25	36·0[1]	..	30·6	36	0	..

NOTE.—The daily mean temperature is deduced from the formula $\frac{8\,h + 14\,h + 20\,h + m}{4}$ in the cases of Giza, Abbassia, Asyut in August, September and October, Assuan, Khartum, Omdurman in May and June; the other daily mean temperatures and all the relative humidities are deduced from the formula $\frac{8\,h + 20\,h}{2}$.

[1] In one day.

Mr. Dyce Cay.

TABLE OF EXTRACTS FROM METEOROLOGICAL OBSERVATIONS MADE IN THE YEAR 1902 BY THE EGYPTIAN PUBLIC WORKS SURVEY DEPARTMENT—*continued*.

—	Place of Observations.	Latitude. North.	Distance from Victoria Nyanza.	July.				August.				September.				October.			
				Mean Temp. Dry Bulb.	Relative Humidity.	Total Rainfall.	Evaporation per Diem.	Mean Temp. Dry Bulb.	Relative Humidity.	Total Rainfall.	Evaporation per Diem.	Mean Temp. Dry Bulb.	Relative Humidity.	Total Rainfall.	Evaporation per Diem.	Mean Temp Dry Bulb.	Relative Humidity.	Total Rainfall.	Evaporation per Diem.
		° ′ ″	Kilometres.	°C.	Per Cent.	Mm.	Mm.	°C.	Per Cent.	Mm.	Mm.	°C.	Per Cent.	Mm.	Mm.	°C.	Per Cent.	Mm.	Mm.
1	Giza, Cairo .	30 01 57	4,790	26·0	61	0	..	25·9	67	0	..	24·6	74	0	..	22·7	75	0	..
1a	Abbassia, Cairo	30 4 36	4,790	27·0	55	0	5·2	26·8	62	0	5·7	24·9	70	0	4·3	22·8	71	drops	4·5
2	Asyut . . .	27 11 0	4,430	28·7	..	0	12·5	29·3	40	0	12·9	27·5	46	0	9·4	24·6	56	0	6·9
3	Assuan . .	24 2 25	3,950	32·5	20	0	13·2	32·5	20	0	13·2	31·6	32	0	12·0	28·5	41	0	8·8
4	Wadi Halfa .	21 54 49	3,580	30·9	27	0	..	30·0	28	0	..	29·3	29	0	..	26·3	39	0	..
5	Berber . .	18 1 0	2,480	32·9	30	0	..	33·7	24	0	..	32·6	28	0	..	29·4	34	0	..
6	Khartum . .	15 38 20	2,130	30·1	47	116·4	..	31·2	46	5·3	..	30·0	41	1·8	.	..	..	..	..
6a	Omdurman .	15 38 20	2,130	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
7	Wad Medani .	14 24 0	2,010	28·2	57	135·0	..	28·4	60	78·0	..	28·4	56	243·3	..	29·8	38	2·4	..
8	Duem . . .	14 0 0	1,970	28·1	59	126·6	..	28·2	61	69·4	..	28·0	61	59·8	..	29·0	36	6·2	..

NOTE.—The daily mean temperature is deduced from the formula $\frac{8\,h + 14\,h + 20\,h + m}{4}$ in the cases of Giza, Abbassia, Asyut in August, September and October, Assuan, Khartum, Omdurman in May and June; the other daily mean temperatures and all the relative humidities are deduced from the formula $\frac{8\,h + 20\,h}{2}$.

Mr. Dyce Cay. as to expedite the passage of floods from the upper reaches of the White Nile, which would increase the flow in Egypt in the summer months, before the flood season of the Blue Nile and of the Atbara commenced.

Mr. Ford. Mr. J. T. FORD observed that there seemed to be a slight discrepancy between the statement (p. 98) that five times the amount of excavation provided for in the contract had been made, and that on p. 104 to the effect that the excess was 100 per cent. for the excavation and 45 per cent. for masonry. Inasmuch as the primary object of such Papers was to serve as means of comparing the work described with other great works, cost was an important point; and in this respect Mr. Fitzmaurice's Paper was somewhat vague. At p. 77 the contract was said to have been let for £1,500,000 for the dam, and £500,000 for the weir at Asyut. No further mention was made of the weir, hence, apparently, the total cost given at p. 104, £2,450,000, was for the dam alone. He would like to know whether the latter figure represented the actual cash payments to the contractor, and, if possible, to have an approximate statement of the extras paid for, both in quantities, classification and unit prices, with a statement of daily or piece-work wages paid for different kinds of labour, skilled and unskilled. He would also be glad to know the extra cost to the Egyptian Government of engineering and supervision generally, as well as for the preliminary work of commissions, estimates, etc., so that some idea might be formed of the actual total cost, in view of the financial scheme mentioned on p. 77 for raising the money on 30-year bonds for £4,716,780. If such figures could be given they would add greatly to the completeness and utility of the Paper, both to engineers and contractors.

Mr. Marrian. Mr. A. E. MARRIAN remarked that he would be glad if Mr. Fitzmaurice could give any details as to the amount of work done per man per hour on the sudds, etc., as being an interesting and important consideration in such works executed abroad. In tipping earthen banks for railways in West Africa the natives mostly used baskets on their heads, and would not carry more than about ½ cubic foot at a time. Of course there such labour was very cheap. Referring to the rotten granite in the foundations, it would be interesting to know whether the material quarried for the dam was similar in composition to that of the bed of the river, and whether the deterioration of the latter was due to its composition—for instance, to abundance of felspar or to the presence of iron—or was rather accounted for by its extreme age. It was mentioned in the Paper that a little expenditure on borings would have disclosed the state of the bed; and as at low Nile about 80 per cent. of the bed of the river was dry, it appeared that trial holes at intervals should have given a good approximation to the amount of soft stuff to be excavated. Mr Marrian.

Mr. JAMES PRICE observed that he was interested in the Papers, as they described works similar in some points to those of which he had had charge on Lough Erne, Co. Fermanagh, in 1882–88.[1] The principal work at Lough Erne had been the cutting of Belleek falls and the erection of four Stoney free-roller sluices of 30 feet span at a level of 12 feet below the original crest of the falls. In order to dry the site for the sluices, rock banks had been formed in the stream above the crest, and when the force of the current had been broken, dams of clay in bags had been built behind the rock banks. The diagrams given in Mr. Fitzmaurice's Paper afforded interesting information. If the Author would show in diagram form the discharge of the Nile at different gauge-levels it would be useful in illustrating the discharge in large channels partly controlled by natural weirs. From Fig. 8, Plate 1, between the gauge-heights of 84·25 metres and 86 metres the discharges seemed to increase as the ordinates of a curve; between 86 metres and 90 metres the discharge was proportional to the height of gauge, and between 90 metres and 103 metres the discharge increased again as the ordinates of a curve—the whole, when plotted, giving a distorted hyperbolic curve. A similar diagram of discharge for different heights of Lough Erne with the channels in their natural state had given an approximately hyperbolic curve. The sluices erected at Belleek in 1883 had been the first Stoney sluices erected in the United Kingdom; and a comparison between the Belleek and the Assuan sluices might be of interest, as showing the completeness of the inventor's design 20 years ago. The following Table showed the respective dimensions:— Mr. Price.

Sluices.	Span.		Height.		Area.	Weight.	Pressure.	——
	Ft.	Ins.	Ft.	Ins.	Sq. Ft.	Tons.	Tons.	
Belleek . . .	29	2	14	6	427	13	100	Rollers.
Assuan, R.L. 87·5	6	6¾	23	0	152	13	210	,,
,, R.L. 92·0	6	6¾	23	0	152	9	150	Sliding.
,, R.L. 96·0	6	6¾	11	6	76	6	60	Rollers.
,, R.L. 100·0	6	6¾	11	6	76	5	30	,,

In details the Assuan sluices were similar to those at Belleek in

[1] Minutes of Proceedings Inst. C.E., vol. ci. p. 73.

Mr. Price. form of rollers, stanching-bars, rocking beam to take roller-pressures, and dimensions of sluice-grooves. The grooves for the Belleek sluices were in the masonry of the piers, with the castings bolted to the masonry. The difficulty of getting the masons to work to exact dimensions had suggested to Mr. Stoney the construction of the grooves in cast iron, and building the masonry round them, as had been done at Assuan. The side walls at Belleek were of limestone set in cement; and the inverts, some limestone in cement and others concrete. The scour from the sluices cut out both forms of invert, though the velocity was not more than 28 feet per second. The cast-iron inverts and linings at Assuan were therefore a necessary improvement. At Belleek the lifting was done by screws at each side of the gates, connecting the gate-rods to the nuts. Under the horizontal gear-wheel on the screw-head, to bear the weight, was a ring of coned rollers, each alternate roller being turned smaller, so as to act as a distance-piece between the other rollers, and thus do away with all sliding friction. The gearing was arranged so that each pair of screws worked together, and was actuated by hand or by a small turbine. In practice it was found that a boy could work any of the Belleek sluices, and there was no perceptible difference when the full pressure or no pressure was on the gates. When the winch-handles were slipped out of gear, the gates, if started, would descend slowly, their weight being just sufficient to overcome the friction of the gear, screw and rollers. This method of lowering was always used until there was sufficient head of water to keep the turbine moving. The great height of dam above the sluice no doubt necessitated the use of wire-ropes for lifting at Assuan, and if the winch-handles could be slipped out of gear the sluices would probably run down of their own weight. The use of sliding sluices at R.L. 92 was somewhat surprising; unforeseen circumstances might arise, requiring that these sluices should be worked under a full head; and then the results might be disappointing. It was not quite clear why such small sluices should be used at Assuan: the resistance to motion arising from water-pressure in roller sluices was so small that it might be neglected; and if the sluices had been doubled in width, the moving weight of each would not have been more than that of a Belleek sluice. The number of sluices might then have been reduced to eighty, which would have led to considerable saving in gearing, sluice-grooves, rollers and culvert-lining; or the top row of sluices might have been made 20 feet wide.

Mr. Siccama. Mr. H. Siccama remarked that the Assuan dam worthily inaugurated the series of wonders of the world which would probably be added to those of old during the twentieth century, as the Forth Bridge had closed the series of the nineteenth century. Though the mass of the structure and its money cost might perhaps be exceeded in other works, it was the energy, thought, and resourcefulness expended on it which would mark this successfully-completed task as a great triumph. Only those who had had to work under similar conditions of distance from the base of supply, quality of local labour, and climate, could appreciate at its full value the grit and courage of the responsible builders. He supposed that, although the rock found in the river-bed was to a large extent untrustworthy for foundations, it was hard enough to permit the omission of an apron on the down-stream side of the dam. Also, the absence of a side weir or safety overflow might have some excellent reason, but it seemed to him that in a region so far removed from civilisation there might at some time or other be the coincidence of an extraordinary flood and the want of proper supervision, so that the flood-level might overtop the dam. In such an event, would there be any danger to the structure? It would also be instructive if the cost of the work, apart from incidental expenses, could be given, or unit prices for excavation and masonry. Some idea as to the cost of housing and feeding the working force would interest him; and he would like to know whether it had been possible to cover some of these charges from the wages paid. Engineers had so often to execute work departmentally in the desert places of the earth, that the experience gained here might be useful on similar occasions. Mr. Siccama.

He was much interested in the ingenuity displayed in solving the many problems presented by the sluices. He would like to know how the pressure from the turbine in the dam was conveyed to the accumulator-house east of the locks: whether the pipes were carried underneath the lock-bottoms, or whether they must be disconnected each time vessels passed through the locks. Further, he thought a swing-bridge would have been a simpler device than the drawbridge shown in the drawings. No doubt a good reason had existed for adopting a segmental horizontal section for the lock-gates, but would not a rectangular section have been more easily balanced for rolling into recesses? He also inferred that valves in the gates were preferred to culverts in the lock-walls, for fear of such culverts or submerged passages silting up; but if there were any other reason for adopting this construction, it would be interesting if Mr. Stokes would state it.

Mr. Lionel B. Wells remarked that information as to the area of land brought under cultivation, and the area to which a full Mr. Wells.

Mr. Wells. supply of water would now be given where formerly only a partial supply had been available, would be instructive; indeed, a Paper dealing fully with the irrigation work, and its effect on the soil, population and revenue of Egypt, would be a valuable contribution to the "Proceedings," for the importance of these subsidiary works was second only to the great work of dam-construction. The reason for building in rubble masonry instead of concrete was not stated. It was useful to note the fact that cement made in England had proved to be better suited for this work than material found on the ground. It showed plainly the advantage of having an industry organized. He had frequently found sand useful in making temporary dams, using it in a loose state, however, with a view to its being either washed away or removed by dredging. He had constructed a dam of this kind in the main navigation of the River Weaver. The channel was 85 to 90 feet wide at the surface, 30 feet at the bottom, and 11 to 12 feet deep. Sand had been dredged for maintenance and deposited by hoppers to form the bottom of the mound, leaving a navigable depth of 9 feet 6 inches. Sand had also been dredged into lighters and wheeled on to the banks, to form a reserve for replenishing the mound during the stoppage. Traffic having then been suspended, the dam had been raised by emptying hoppers as long as the water remained deep enough, and afterwards by discharging from lighters. The mound had been quickly completed, and easily maintained against the full pond above, during the stoppage, which had lasted for a fortnight. It had then been reduced by loading the sand into lighters, and when the mound had become no longer trustworthy, the water had been allowed to rush through. A dredger had then been set to work upon the wreck of the dam, and had made in a short time a navigable passage, which had been enlarged at leisure. The dam had proved efficient; it had been quickly made and quickly removed; and the whole cost had been small. The advisability of enlarging the entrance to sluice-culverts could be seen readily where the openings were above water. From Fig. 11, Plate 4, it appeared that little rounding was given to the sill of the culverts through the dam, and there was nothing to show whether the sides followed the lines of the top or of the sill. The Dutton sluices,[1] which he had completed in 1881, were eight in number, and were worked by a single crab which travelled overhead from sluice to sluice. The arrangement

[1] Minutes of Proceedings Inst. C.E., vol. ci. p. 114.

generally had been most satisfactory. Up to 1888, when he had ceased to have charge of the River Weaver, no difficulty had arisen in working the sluices, nor had they suffered from floating débris. The sluices and other improvements carried out on the Weaver had had so marked an effect on the discharge of floods that whereas 25 years ago there had been floods of 7 feet and 8 feet, a rise of 2 feet on the navigation-gauge was now commented upon as a high flood-level. The absence of a longitudinal section of the canal and locks was a drawback, and the small scale adopted for the drawings generally rendered it difficult to follow the details. He feared that mud would be deposited in the locks in troublesome quantities, and that side culverts would be found necessary, not only for assisting to clear away mud, but also for distributing the influx of water, and thus lessening the risk of vessels being knocked about in the process of locking. Mr. Wells.

Mr. Fitzmaurice, in reply, observed that he was unable to give the origin of the datum used at Assuan. All levels were referred to the datum in use by the Irrigation Department all over Egypt, which certainly varied little, if at all, from the mean level of the Mediterranean. The too-rapid setting of the cement mortar used had been prevented by keeping all masonry damp for 10 days after building. Referring to Sir R. H. Brown's remarks, he regretted that anything in the Paper tended to encourage the delusion that the Assuan dam would in any way affect the discharge of the Nile while the river was in flood. What he intended to convey was, that a large amount of land now irrigated solely by flood-water would, in the future, be under perennial irrigation; and therefore, in the case of a bad flood, there would not be so much flood-irrigated land to cause anxiety as in the past. He was unable to give the gradient of the water-surface in the full reservoir. This information had not yet been obtained, as the reservoir had only just been filled for the first time. With regard to Mr. Dyce Cay's observations, he did not think that the average evaporation shown by the Egyptian Government Meteorological Reports could be applied to the Nile. The result of measurements on a very small scale did not appear to be applicable to a river of considerable depth and volume. In his book on Egyptian irrigation, Sir William Willcocks, who had studied the subject carefully, gave 7 millimetres per day as the summer evaporation of Upper Egypt. Mr. Dyce Cay's figure for the average width of the Nile in summer, between Assuan and Asyut, was about three times too large. In reply to Mr. Ford, it was stated in the Paper that, during the season of Mr. Fitzmaurice.

Mr. Fitzmaurice. 1900, five times the amount of excavation provided for in the contract had been taken out. Taking the whole length of the dam the amount of excavation had been 100 per cent. in excess of the contract quantities. Both statements in the Paper were correct. The £2,450,000 represented the total cost of the Assuan dam alone, and was the actual cash payment to the contractors. The extras paid had been almost entirely on account of the additional excavation and masonry, necessitated by finding unexpectedly large depths of rotten rock. In answer to Mr. Marrian, where loose sand or earth had been tipped on to sudds it had generally been carried in baskets on the heads of natives. The greater part of the sudds, however, had been made of sand in bags, or of rock, which had been brought on to the sudds in trucks, or by boat. The granite quarried for masonry had been absolutely solid, but of course it had had to be chosen carefully. It had been obtained largely from big boulders, many of which contained 50 to 200 cubic metres. With reference to the composition of the rotten granite he could add nothing to the information given in the Paper. The following Table would give Mr. Price the information he wished for, as to the discharge of the

Assuan Gauge in Metres.	Approximate Corresponding Discharge in Cubic Metres per Second.	Assuan Gauge in Metres.	Approximate Corresponding Discharge in Cubic Metres per Second.
85·00	410	90·00	4,350
85·50	610	90·50	5,100
86·00	830	91·00	5,850
86·50	1,080	91·50	6,600
87·00	1,390	92·00	7,600
87·50	1,720	92·50	8,600
88·00	2,130	93·00	9,800
88·50	2,600	93·50	11,200
89·00	3,100	94·00	12,800
89·50	3,600	..	..

Nile at different gauge-levels. There were many reasons why it was not advisable to have the sluices, particularly the deeper ones, larger than those adopted at Assuan. With a number of small sluices the discharge was delivered at numerous points instead of being concentrated at a few places. This was in accordance with the advice of the International Commission, referred to in the Paper. The distribution of the stresses in the masonry was better dealt with in this way, and there was less chance of cutting out rock down-stream of the dam. It was necessary, as far as possible, to send water down two channels at all times, as there were villages on both channels just below the dam, and as in March and April very little sluiceway was required, it was necessary to have the small amount of water going down well distributed. With larger sluices, the gates, which were unbalanced, would have been much heavier and more difficult to manage. There would also have been difficulty with the sills and lintels of larger sluices. It must be remembered that one hundred and fifty out of the one hundred and eighty sluices were lined with granite, not with cast iron. If larger sluices had been adopted, with masonry lining, the inverts and sills would have had to be arched: this would have taken longer time, which, in view of the shortness of the season for working, would have been a serious matter. Of course, cast iron could have been adopted in larger sluices, but it would have been more expensive. Probably the most satisfactory plan for larger sluices would be to build the side walls in granite ashlar, and to use cast iron for the sills and lintels. In the event of a mishap to one or two of the existing sluices, it would not seriously interfere with the working of the dam if they were closed for a season; while with large sluices this course might be very difficult. The arrangement devised for shutting off a sluice by means of a shield was quite complicated enough for the Assuan sluices, and would have presented great difficulties with any sluices of much larger size. Should a boulder or a large piece of timber prevent one of the deep sluices from being fully closed when the reservoir was being filled, it would be a very serious matter if the sluice could not be shut off by means of a shield or otherwise. When the reservoir was full the water would flow through the sluice under a head of about 18 metres, and with a velocity of about 18 metres per second. With this velocity the lining of the sluices and the granite down-stream of the dam might be affected. He quite agreed with Mr. Price that the resistance arising from water-pressure in free-roller sluices was so small that it might almost be neglected; but this had not been the determining factor in settling the size of the Assuan sluices. The velocity of 28 feet per second at Belleek was very high, and it was not surprising that the limestone and concrete were cut out. In reply to Mr. Siccama, it would probably be necessary to lay a masonry apron below the high-level sluices on the high ground, where there was no water-cushion, in order to lessen the effect on the rock of the discharge from these sluices at low Nile. He thought that, with the large number of sluices, and the practical certainty

Mr. Fitzmaurice.

Mr. Fitzmaurice. that at the most only three or four could be out of order at one time, there was not the least necessity for a spill channel. Even in a most exceptional flood of 14,000 cubic metres per second, the water on the up-stream side would not rise within 3 metres of the full-reservoir level. Of course while the reservoir was filling—at which time the discharge of the Nile was small in comparison with the flood-discharge—the level of the water was absolutely under control. He could not conceive any conditions under which the water would top the dam; but should such an event ever happen, any damage done would not extend beyond the parapet. With reference to the absence of culverts in the lock-walls, and to depending on the sluices in the gates, he considered that the working of the locks would be much simplified if culverts had been used, and he would wish to adopt them in any similar work. The principal reason why they had not been used was, that it had been anticipated that solid granite would be met with in the locks, and that masonry facing to the granite would be all that was necessary for the side walls: had that been so, culverts would have necessitated tunnelling through the granite.

Mr. Stokes. Mr. STOKES, in reply, remarked that it was difficult to draw any close analogy between the Belleek sluices and those at Assuan, because at Belleek the larger dimension was horizontal, while at Assuan it was vertical. Also, at Assuan there was a considerable head of water above the sluices, while at Belleek the water never flowed over the top of them. With regard to the sluices at R.L. 92 without rollers, it was difficult to imagine circumstances which would require these to be worked with a full head against them, because the sluices at the same level with rollers, and those at R.L. 87·5, provided more than ample area for discharge. The 25-ton steam-crane could, however, if necessary, assist the lifting-gear of these sluices, so as to open them against a considerable head. In reply to Mr. Siccama, the water from the turbine pumps was taken across to the west of the locks by duplicate copper pipes carried across the bottom of two gate-recesses, the necessary stop-cocks being provided to cut off either pipe should it become damaged. With regard to the lift-bridge, this class of bridge was most common in Egypt, and had some advantages over a swing-bridge, notably the absence of any pit into which people might fall. The bridge was also quickly and easily operated, and there was nothing to get out of order. The principal objection to culverts in the lock-walls in the case of the Assuan locks as originally designed

Mr. Stokes. was that, owing to the head, a considerable pressure would have had to be provided for, which would not have been practicable, as good rock had been anticipated, and this was to have been only faced with dressed masonry. In carrying out the work, however, bad rock had been met with which had rendered necessary the section of wall shown in the illustrations. No doubt, had this been known in the first instance, culverts would have been adopted as suggested by Mr. Siccama. The enlarged entrances to the culverts were apparently ample, because with the water in the reservoir just level with the top of the culvert entrance, the culvert ran full bore on the down-stream face of the dam, which was a satisfactory result. With regard to mud in the locks it had been found that after one season's working and flood, there was remarkably little deposit, and no trouble whatever had resulted from it. With the present arrangement of sluices in the lock-gates, the locks could be filled with little disturbance to the water, much less in fact than with side culverts. This was doubtless due to the sluices being distributed over the lock-gate, and also to the long sluice at the bottom of the gate, the discharge from which tended to counteract any back-water action, which might have been a trouble. Vessels could be locked without any risk of their being knocked about.

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3 February, 1903.

JOHN CLARKE HAWKSHAW, M.A., President, in the Chair.

The President mentioned that the Institution had lost one of its most distinguished Honorary Members, Sir George Gabriel Stokes, Bart. Endowed with the highest mathematical ability, Sir George Stokes, like Sir Isaac Newton, had devoted his life to scientific research at Cambridge, and, like Sir Isaac Newton, he had been President of the Royal Society and had represented his University in Parliament. All civilized nations would feel his loss, as all would benefit by his life's work. At a meeting of the Council held that evening the following resolution had been passed, in which he was sure all present would concur: "That the Council deeply regret the death of Sir George Gabriel Stokes, a distinguished Honorary Member of the Institution, and desire to convey to Lady Stokes an expression of sympathy in her bereavement."